THE UNIVERSITY OF MANITOBA

THE IMPACT OF BRANCH LINE AND ELEVATOR RATIONALIZATION ON THE RURAL ROAD NETWORK

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF AGRICULTURAL ECONOMICS

WINNIPEG, MANITOBA

October, 1978

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ABSTRACT

THE IMPACT OF BRANCH LINE AND ELEVATOR RATIONALIZATION ON THE RURAL ROAD NETWORK

by Henry Kent Magarrell

Major Advisor: Dr. E. W. Tyrchniewicz

The impact upon the rural road network from changes in the grain handling and transportation system has been studied over the past ten years. The magnitude of the road impact has varied greatly depending upon the assumptions in each analysis.

The general objective of this study was to develop a framework in which rationalization of the grain transportation system in Western Canada could be analyzed with respect to the impact upon road costs. The specific objects were: (1) to review the public positions of the principals in the rationalization process with respect to its impact upon road costs along with a critique of the methodology used, (2) to isolate the relevant criteria which should be considered in objectively assessing the road cost effects of a rationalization scenario, and (3) to utilize these criteria in the calculation of the road cost component of an available conceptual model for rationalizing the collection, handling and distribution of grain in Western Canada at a regional level.

The conceptual model that was extended to include the road cost component of rationalization was developed by Robert Tosterud. His CHAD (collection, handling and distribution) model was designed to minimize the total cost of collecting, handling and distributing grain for a specified, bounded production region.

The study concentrated upon the separate road degradation factors of traffic load and volume. Traffic loads were transformed via an engineering formula that related varying traffic loads through an equivalent application basis. The incremental road costs with respect to reconstruction, upgrading, road maintenance and seal coating were presented for the region under study.

A manual simulation was performed that abandons twelve grain delivery points and four rail branch lines. The volumes of grain displaced and the alternate points receiving this displaced grain were provided by the CHAD model. Traffic routes were developed for the displaced grain and the road impact calculated for three separate truck sizes: (1) 250 bushel, single-rear axle, (2) 490 bushel, tandem rear axle, and (3) 890 bushel five axle semi-trailer. These incremental road load factors, when combined with base traffic statistics, provided separate post-rationalization loads for the three truck sizes over the grain route network on a road segment-by-segment basis. Comparison of this post-rationalization traffic load on the grain route network with previously determined threshold values indicated the road segments which would require upgrading. The appropriate upgrading unit costs were applied to determine the incremental road costs of the rationalization scenario being simulated for each of the three truck sizes. Sensitivity analysis was applied to important traffic components to determine the stability of the costs being generated.

The road cost impact upon the selected region was minor in comparison to the CHAD cost reductions of the rationalization scenario that underwent analysis. The effect of the 250 bushel, single rear axle truck size that generated the largest annual incremental road cost of $16,800 was small compared with the annual saving of $168,000 to the local grain collection, handling and distribution system.

The study region has a very well-developed road network and, as such, the study conclusions may not apply to other Prairie regions.

ACKNOWLEDGEMENTS

My appreciation is extended foremost to Dr. E. W. Tyrchniewicz, my major advisor, whose patience and candour contributed immensely to this study as well as to my graduate program. I also acknowledge and thank my committee members Dr. C. F. Framingham and Professor R. F. Harris. The Manitoba Department of Highways was most helpful in the provision of data and interpretive guidance while Transport Development Agency funding was gratefully received. My appreciation is extended to Mr. B. H. Russell for the graphics and Mrs. Hiebert for the typing.

Finally, I dedicate this thesis to two people: my mother for encouraging all her children to expand their horizons and my wife Barbara for the inspiration she provides.

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CHAPTER I

INTRODUCTION

The Problem

The Canadian grain industry is heavily export oriented. Due to the inland location of the main grain producing region of Canada compared with its export competitors, the grain handling and transportation facilities are crucial to the successful marketing of Canadian grain. These facilities must be high volume, flexible and cost minimizing: high volume to deliver all that is committed for export, flexible to move the required varieties and grades of grain and cost minimizing to maximize producer returns.

The effectiveness of the grain transportation and handling system of Canada has been seriously questioned by the various components of that industry. Each places its emphasis upon different reasons for system ineffectiveness. The railways focus upon their losses on the transportation of grain to the virtual exclusion of all else: "the statutory rate is the key."[1] In their view, rail

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[1]Fred S. Burbidge, President, Canadian Pacific Limited, in a submission to the Grain Handling and Transportation Commission, Regina, October 20, 1975, p. 11.

deterioration and an inefficient grain gathering system have followed inexorably from the low level of the statutory rate. On the other hand, primary elevator companies, while acknowledging a variety of industry problems, stress the deterioration of an overbuilt branchline network: "the resulting system of branchlines is better described as a patchwork than a network."[2]

Farmers are upset by reports of lost sales due to an unresponsive grain handling and transportation system. They lay the majority of the responsibility for their lost sales upon the railways because of an admitted lack of investment in branchline maintenance and rolling stock. The prairie provincial governments have been quick to condemn the railways for concentrating on profits and not fulfilling their historic service obligations.

All of the above have called upon the Federal Government to uphold its responsibility to develop policies which would allow each of the industry participants to function effectively and to fulfill its objectives. The Federal Government, in turn, has been unable to discern a consensus among these participants upon the direction that the industry should move. Indeed, there is disagreement

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[2]Ted K. Turner, President, Saskatchewan Wheat Pool, in a submission to the Grain Handling and Transportation Commission, Regina, October 22, 1975, p. 3.

between individual companies of the same sector of the industry (such as primary elevator companies) as to which approach should be taken.

The major source of the conflict was the legislation of rail rates by Parliament. This legislation had the result of isolating the grain transportation system from market pressures and, as such, changes did not occur in response to them. With rates below costs, railways did not offer incentives for elevator companies to consolidate low volume points that were costly to serve. This situation of costs exceeding revenues resulted in a lack of railway investment and the continued use of low volume elevators. Railway attempts to have their legislated rates raised have been strongly opposed by most producers whose incomes would initially decrease by the amount of a rate increase. Given the relative political strength of the participants, legislation to increase rates has not been proposed. The deferral of rail freight rate increases has led to the present stage: one of tremendous pressure under which the grain handling and transportation system is unable to function properly and is beginning to collapse.

One response to this increasing pressure for change has been the commission of studies into the rationalization of the present grain handling and transportation system. Three organizations which have done extensive research into this area over the past ten years are: the Grains Group, the Canada Grains Council and the University of Manitoba. In addition, the Federal Government in 1975 appointed two Commissions of Inquiry: the Commission on the Costs of Transporting Grain by Rail (the Snavely Commission) and the Grain Handling and Transportation Commission (the Hall Commission).

The Grains Group was established in 1969 by the Federal Government to develop policies that would improve the efficiency of the Canadian grain handling, transportation and storage system. A summary report of the research of the Grains Group was made public in the summer of 1972.[3] This report estimated the individual cost components and the total system cost from the farm to the seaboard terminal for five "benchmark" systems. Not one of the thirteen studies commissioned by the Grains Group addressed the factor of additional road costs resulting from increased trucking of grain. In addition, the implications of replacing storage capacity lost through rationalization were ignored by the Grains Group. These two major shortcomings of the Grains Group report weakened the validity of its conclusions that a totally new system would be an improvement over the present one.

The Canada Grains Council undertook the task of evaluating the Grains Group report and of bringing forward

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[3]Grain Handling and Transportation Costs in Canada, prepared for Grains Group, Office of the Minister, The Honourable Otto E. Lang, (Ottawa: The Queen's Printer, August, 1971).

recommendations to improve the system. A number of broadly-based industry committees were established with an increased emphasis upon producer participation. An initial weakness was the dependence of the Canada Grains Council upon the Grains Group report as a basis for evaluation and research. The Council subsequently moved beyond the Grains Group report to propose specific philosophical avenues of approach to rationalization[4] and to develop its own methodology to evaluate the effects of various rationalization scenarios upon all affected parties.[5] The major weakness of this broadly-based industry committee approach is that each participant has a virtual veto power over the recommendations of the committee. The process of compromise may result in a report of generalities with little hope of stimulating action.

The University of Manitoba is actively carrying on research relative to the rationalization of the grain handling and transportation system. As well as some involvement with the Grains Group report and the Grain Handling and Transportation Commission, the Department of Agricultural Economics is active in the development of a

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[4]The Canada Grains Council, State of the Industry (Winnipeg: The Grain Handling and Transportation Committee, 1973).

[5]The Canada Grains Council, The Grain Handling and Transportation System in the Brandon Area (Winnipeg: Brandon Area Study Committee, 1974).

model for the rationalization of the grain handling and transportation system in Canada to be used in evaluating alternative rationalization proposals. A computer simulation model which is a modification of the Stollsteimer plant location model has been developed by Tosterud.[6] This simulation model utilizes previous cost studies carried on at the University of Manitoba and applies them to a specified bounded region. Further research is ongoing and extensions are being incorporated into the simulation model.

The Snavely Commission had two basic tasks: (1) to establish the total costs and revenues to the railways in transporting grain under contemporary conditions, and (2) to evaluate railway costing practices as outlined in Canadian Transport Commission Costing Order R6313, and to identify and review any related grain costing issues. Volume I of the report was released in December, 1976 and established that for the three railways (Canadian National, CP Rail and the Northern Alberta Railway) costs exceeded revenues by $89.4 million in 1974 on the movement of grain at statutory rates.[7] This figure of $89.4 million counted

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[6] E. W. Tyrchniewicz and R. J. Tosterud, "A Model for Rationalizing the Canadian Grain Transportation and Handling System on a Regional Basis," American Journal of Agricultural Economics, Vol. 55, No. 5 (December, 1973).

[7] The Commission on the Costs of Transporting Grain by Rail, Report: Volume I (by Carl M. Snavely) (Ottawa: October, 1976).

the branchline subsidy payments as revenue. The results of this Commission added much validity to railway demands for increased compensation for the transportation of statutory grain.

The Hall Commission conducted a comprehensive evaluation of regional transportation requirements in the territory served by the 6,283 miles of railway branch lines which came under its purview. The Commission considered the implications of adjustments to the total grain handling and transportation system as related to: grain producers, the elevator system, local community viability, railways and general economic development opportunities. Volume I of the Hall Commission Report[8] contained a number of recommendations ranging from the disposition of branch lines through to its conclusions on the socio-economic effects of abandonment. In the context of this study, four findings are significant: (1) railways must be compensated for the cost of moving grain, (2) off-line elevators may perform a useful role in the future grain handling and transportation system, (3) rail service is not necessarily a prerequisite for a viable rural community, and (4) the abandonment of branch lines would cause a minor increase in road maintenance costs, depending upon the type of road (oil surface roads being the most susceptible to major

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[8]The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: April, 1977).

cost increases.) These and other conclusions added impetus to the rationalization of the grain handling and transportation system.

Largely overlooked in most studies are the effects that any re-organization would have upon closely-related sectors of the economy. The Grains Group report on the economic effect of rationalization upon Prairie communities[9] focused on the relationship between the presence of an elevator and the resultant viability of that community as a service center. Zimmerman and Moneo[10] described the pattern of settlement on the Prairies and the development of the hierarchy of service centers. These two studies, by concentrating on the service center function of communities, neglected other economic aspects of community survival. The Prairie Regional Studies in Economic Geography[11] have concentrated on data collection about the economic sector of Prairie regions but "have refrained from

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[9] _Economic Effect of Rationalization of the Grain Handling and Transportation System on Prairie Communities_, prepared for Grains Group, Office of the Minister, The Honourable Otto E. Lang (Ottawa: The Queen's Printer, March, 1972).

[10] Carle C. Zimmerman and Garry W. Moneo, _The Prairie Community System_ (Ottawa: Agricultural Economics Research Council of Canada, 1970).

[11] _Prairie Regional Studies in Economic Geography_ (Ottawa: Economics Branch, Canada Department of Agriculture).

drawing reference, arriving at conclusions and making recommendations."[12] Snavely concentrates strictly upon the costs of grain transportation by rail to the exclusion of all other economic factors of the grains industry.[13] The Hall Commission took a more comprehensive approach and attempted to weigh both economic and social factors in its analysis.[14] Due to its heavy emphasis on social and political considerations, its methodological approach appears inconsistant and its analysis lacks rigour from a purely economic standpoint.

All of the above studies are weakened by their inability to utilize the systems approach to economic analysis. Cost-minimizing changes in the handling and transportation sphere may have an effect in other spheres: direct local employment changes, local government property and business tax receipt changes, loss of rail service with a subsequent loss of present and potential rail-dependent industry, changes in road costs due to changes in truck traffic (whether grain related or not), and so on. These other local costs and benefits should be estimated

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[12] Ibid., p. ii.

[13] The Commission on the Costs of Transporting Grain by Rail, Report: Volume I (by Carl M. Snavely) (Ottawa: October, 1976).

[14] The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: April, 1977).

and included in the decision-making process before an overall benefit-cost relationship can be constructed to determine the "best" rationalization plan.

The broad goal of the present research is to increase the scope of current rationalization studies by isolating the relevant factors that cause changes in road costs due to changes in truck traffic as a result of rationalization. Past studies often have approached this problem in two ways: (1) by ignoring the impact on road costs by assuming no effect at all, or (2) by exaggerating the impact on road costs to such an extent that almost any rationalization scenario is shown to be more costly than the present system.

Public Positions on Road Costs

The positions of the major organizations towards the impact of the rationalization process upon road costs were contained in submissions to the Grain Handling and Transportation Commission final hearings convened in Saskatoon during the months of August and September, 1976. Of all the participants, only the Provincial Governments advanced a quantitative opinion of the incremental road costs. This was to be expected since only the Provincial Governments possessed the expertise to quantify their position.

The three submissions of the Provincial Governments of Alberta, Manitoba and Saskatchewan stated that rail line abandonment is a cost transference from the railways and the Federal Government to the Provincial Governments, municipalities and farmers. The Province of Alberta estimated an incremental present worth cost over twenty years of $37.0 million from the abandonment of all Category "B" lines in Alberta.[15] The Province of Manitoba calculated incremental road costs of between $41.8 million and $93.7 million from the abandonment of 727 miles of rail line in Manitoba.[16] The Province of Saskatchewan considered a variety of abandonment scenarios to claim additional road costs ranging from $62 million to approximately $2.25 billion over fifteen years.[17]

The submissions of the two railways minimized the incremental road costs resulting from rail line abandonment. Neither railway attempted to quantify the effect nor undertook research into the area of road costs. This is understandable since the Provincial Departments of Highways possess far more expertise in this field than do the railways. Canadian National declared that "the expansion and upgrading of highway networks will continue

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[15]Province of Alberta, Submission to the Grain Handling and Transportation Commission, Saskatoon, September 2, 1976, p. 17.

[16]Province of Manitoba, Submission to the Grain Handling and Transportation Commission, Saskatoon, September 7, 1976, pp. 22-29.

[17]Province of Saskatchewan, Submission to the Grain Handling and Transportation Commission, Saskatoon, September 3, 1976, pp. 24-26.

whether rail lines are abandoned or not."[18] CP Rail stated that road costs would be "somewhat higher."[19]

The line elevator companies did not take a position upon rural road costs, in fact, some did not even comment upon the need to include such costs in the Commission's deliberations. With the primary elevator companies undergoing their own system contraction, they were careful not to become embroiled in the incremental road cost controversy. Elevator closures result in longer farm hauling distances and a subsequent increase in rural road traffic. The Provincial positions on incremental road costs resulting from rail line abandonment can be readily modified to apply to primary elevator closures.

The Hall Commission took a moderate stance on the impact of abandonment upon road costs. Although its research indicated that the provincial estimates were high, in general the Hall Commission accepted the provincial data.[20] When matched with the specific rail lines

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[18] Canadian National Railways, Final Submission to the Grain Handling and Transportation Commission, Saskatoon, August 30, 1976, p. 14.

[19] CP Rail, Submission to the Grain Handling and Transportation Commission, Saskatoon, August 31, 1976, p.1.

[20] The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: April, 1977), p. 515.

recommended for abandonment, the Hall Commission estimated increased annual road maintenance and amortized construction costs amounted to "approximately $300 thousand for Alberta, $600 thousand for Saskatchewan, and $150 thousand for Manitoba."[21] It was additionally recommended that the Federal Government should assist the provinces and municipalities for the anticipated increase in road costs. When compared to total system costs, however, the Hall Commission stated its findings that these additional road costs would not form a large portion of the total cost of handling and transporting grain.[22]

Objectives and Scope of This Study

The general objective of this study is to develop a framework in which rationalization of the grain transportation system in Western Canada can be analyzed with respect to the impact upon road costs.

The specific objectives are: (1) to review the public positions of the principals in the rationalization process with respect to its impact upon road costs along with a critique of the methodology used, (2) to isolate the relevant criteria which should be considered in objectively assessing the road cost effects of a rationalization scenario, and (3) to utilize these criteria in the

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[21]Ibid., p. 516.

[22]Ibid.

calculation of the road cost component of an available conceptual model for rationalizing the collection, handling and distribution of grain in Western Canada at a regional level. Literature review and a critique of that literature comprises a major component of this study.

The scope of this analysis views the road component of a rationalization scenario in an agrarian region to be affected primarily by grain truck traffic. While non-grain truck traffic is excluded from this calculation, the conceptual model can be readily employed to include the effect of non-grain truck traffic in a scenario where such traffic is a significant factor.

The conceptual model to be extended to include the road cost component of rationalization was developed by Robert Tosterud. His CHAD (collection, handling and distribution) model is designed to minimize the total cost of collecting, handling and distributing grain, subject to certain specified constraints. The analysis is constrained in two ways: (1) it considers only that grain which moves directly from farms to country elevators and (2) it examines grain handling and transportation rationalization in the context of a specified, bounded production region.

The bounded production region under analysis in this study is the Boissevain grain growing area of southwestern Manitoba. This region is approximately 3,000 square miles in size and, in 1971, contained about 2,200 farmers and sixty-seven country elevators. During the last several crop years, grain production in the region has averaged around 10 to 11 million bushels.

Organization of the Remainder of the Thesis

Chapter II describes the factors that have led to the present situation of an overbuilt Prairie rail network and the attendant rural road system. Problems associated with developing road costs are reviewed along with the impact of road surface upon farm trucking costs. In addition, a critique is made of previous area study approaches to road costs. Chapter III presents a conceptual model for road costing as well as the development of significant road wear factors for use in the analysis of the impacts of rationalization upon the road network. Rural road needs and data requirements are also discussed. The area study application of the conceptual model comprises Chapter IV. It argues the need for the simulation approach, where feasible, and the CHAD model is described. The data needs are specified, developed and presented in the analysis of one CHAD simulation to determine the impact upon road costs. Finally, Chapter V presents the results of the analysis and discusses the limitation of the present approach. A more sophisticated avenue which could be constructed to enable greater precision is then tendered.

CHAPTER II

BACKGROUND FOR THE ANALYSIS

The objective of this chapter is to provide four kinds of information: (1) a brief description of the development of the rail branch line structure and the rural road network in Western Canada, (2) a selective review of problems associated with road cost studies, (3) the impact of road surface upon trucking costs, and (4) a critique of the methodology utilized to calculate the road cost component of some previous road impact studies. This background information provides a basis for understanding the conceptual model and the analysis presented further along in the study.

The Development of the Rail Branch Line Structure and the Rural Road Network in Western Canada

No situation can be fully understood unless its history is known. The development of the Prairie transport infrastructure is presented in three sections: (1) the maturation of the Prairie branch line network, (2) the evolution of the rural road system, and (3) the changes in rail branch line and rural road traffic.

Maturation of the Prairie Branchline Network.

Before the advent of railways, the only means of bulk inland transportation was via navigable waterways. The Canadian West had only labour intensive, low volume water traffic--with the exception of commercial steamboats on the Red River--due to the lack of an interlocking river system. With the short duration of the navigation season precluding any incentive for the construction of connecting canals, the West, therefore, was limited in population and economic growth by the constraint of animal-powered land and human-powered water transportation. Railways first became established in the West during the last quarter of the 19th century and brought a tremendous advance in transport services. Depending upon distance, volume, weight and time requirements, the railways virtually had no competition on the Prairies.

Canadian railway construction proceeded at a tremendous pace until the beginning of the Depression in 1929. The numerous competitive railways constructed a network of main, secondary and branch lines throughout all areas that had agricultural or other resources potential. This expansion in the rail network was the result of a number of factors:

1. Railways were the only economical form of inland transportation at that time. The process of economic expansion and population growth was expected to mean increased rail traffic.

2. The long-term economic outlook was one of optimism and growth so that, although present traffic potential did not often justify construction of a rail line in an area, it was generally believed that traffic would follow rail construction into a previously undeveloped area.

3. Each railway was determined to capture as great a percentage of total traffic as possible. This led to the construction of branchlines into areas already served by another railway, or to discourage another railway from building in a particular area.

   In many instances, construction standards were quite low. The emphasis was on gaining location advantages within a limited time, and construction quality was a secondary consideration.

4. There was political desire for the formation of competitive railway systems. Railway construction was often greatly aided by incentives of cash, security guarantees and land grants.

Even after the formation of the Canadian National Railway from an assortment of bankrupt and federally-owned lines (the Intercolonial, the National Transcontinental, the Hudson Bay, the Grand Trunk, Grand Trunk Pacific, Canadian Northern and other lesser lines) in 1923, branch line construction continued until the onset of the Depression of the 1930's.

Evolution of the Rural Road System.

The Prairies are surveyed in a grid pattern which has the section as its primary element. A section is a parcel of land one square mile in area consisting of 640 acres. Separating each section from its neighbour is a 99 foot strip of land called the road allowance. Road allowances are reserved for public use primarily, as the term suggests, for roads. The survey pattern of the sections and the attendant road allowances is such that a grid of public lands in 99 foot strips one mile apart covers the Prairies. The construction of roads on all of the road allowances would result in a network of roads running north-south only one mile apart, being intersected by an east-west road every mile.

As settlement commenced in an area, some of the road allowances began to be utilized for local roads. Local transport was animal powered with the result that rural roads were rough trails suitable for wagons. Railways were the sole means of transport over any distance and rural roads served only as feeder routes to the nearest rail point.

The advent of technology changed transportation on the Prairies. As cars and trucks became widely affordable, the use of rural roads altered. Country roads were no longer merely local trails to the nearest rail point: road trunk routes were constructed--many right alongside of rail lines. Automobiles and trucks require higher standards of road construction than do horse-drawn wagons. Road construction proceeded at a rapid pace right to the present and is still continuing. The populated areas of the Prairies are served by an excellent network of all-weather local and trunk roads. This network is being constantly maintained and upgraded by Provincial and Municipal road forces. Table 1 illustrates the growth in vehicle population on the Prairies since 1915.[23]

Changes in Rail Branch Line and Rural Road Traffic.

The railway branch lines had been constructed in an era when railways served most, if not all, of an area's transportation needs. During the first three decades of this century, there was little alternative to railways for moving the bulk of goods, raw materials, livestock and people that were transported between different parts of the country. While various railway companies competed vigourously for this traffic, there was little, if any, competition from other modes of transportation. The number of rural motorized vehicles was minimal and the road network was not suitably developed.

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[23] In the absence of accurate road investment statistics, vehicle population statistics are used as a proxy.

Table 1

Registration of Motor Vehicles, Prairie Provinces
1915 to 1975

Year	Manitoba	Saskatchewan	Alberta	Total
1915	9,937	10,225	5,832	25,994
1920	38,257	60,325	38,015	136,597
1925	50,884	77,940	54,538	183,362
1930	78,850	127,193	101,119	307,162
1935	70,660	94,792	93,870	259,322
1940	90,932	126,970	120,514	338,416
1945	92,758	140,257	130,153	363,168
1950	157,546	199,866	230,624	588,036
1955	222,474	274,950	356,839	854,263
1960	285,689	335,148	486,370	1,107,207
1965	342,335	418,606	606,754	1,367,695
1970	403,181	464,405	768,759	1,636,345
1975	535,808	613,269	1,073,020	2,222,097

SOURCE:

Statistics Canada, The Motor Vehicle, Part III: Registrations, 53-219 (Ottawa), pp. 11-12.

At first, that situation changed gradually. The economic Depression put a brake on vehicle population growth during the Thirties, and the Second World War produced shortages of manpower and materials during the early Forties. Even though there was a resurgence of demand for transport services during World War II, the wartime shortages of materials prevented further expansion of facilities.

After the war ended, provincial and municipal governments began a period of massive construction of all-weather roads. This kind of activity is still continuing. Use of the private car and, to a lesser extent, buses, drew away many of the railways' passengers. At the same time, cars, buses, and trucks began carrying much of what once would have been railway freight traffic.

The erosion of rail traffic was particularly pronounced on Prairie branch lines. These lines served local traffic carrying supplies and people to and from small towns and regional distribution centres. An improved regional road network now permits cars and trucks to perform these services faster and more conveniently than trains. The result is that many Prairie branchlines have little traffic except grain.[24] For some branchlines even

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[24]The Commission on the Costs of Transporting Grain by Rail, Report: Volume I (by Carl M. Snavely) (Ottawa: October, 1976, Appendix H).

grain traffic has been lost. With the improved rural road systems, farmers are trucking grain greater distances to deliver to the grain elevator of their choice. Some farmers prefer to deliver to elevators at competitive points where, they believe, service and sometimes even grades are better than at the local single elevator point. Economies of size have also "forced" the contraction of the primary elevator system through the closure of low volume elevators. An extreme example of this process is the CP Rail Boissevain subdivision. In 1974, Manitoba Pool Elevators closed its remaining elevators at Croll, Dand and Regent leaving the subdivision with no traffic. The result was the abandonment of the subdivision in 1976.

A Selective Review of Problems Associated with Road Cost Analysis

The usual procedure for analyzing large numbers of observations is to group the date into categories which, through ease of handling and clarity of thought, make major relationships more readily apparent. Inherent in this approach is the problem of choosing that classification system which best retains important features necessary for the analysis while eliminating irrelevant details that would confuse. Roads generally are classified by their surface type although other criteria such as weight capacity and width of road surface are used. Such broad categories, however, are rarely utilized by highway engineers who, in formulating their detailed maintenance and reconstruction schedules, treat each road as physically unique, not only from other roads but also internally--on a section by section basis. This heterogeneity of roads is only one of the problems associated with the analysis of road costs. Other problems that hamper the accurate measurement of road wear are variations in traffic components: traffic mix, distance, volume from year to year and season to season. These variations have separate effects upon road wear and, thus, upon road costs.

Heterogeneity of Roads.

Every road section has unique characteristics, a function of, for example, its soil base, method and quality of construction, local topography and drainage patterns. With these unique characteristics each road section responds to the same traffic differently so that maintenance and reconstruction costs are not easily predictable. Any road classification system must guard against being too broad, thus losing important facts or too detailed, becoming impossible to grasp easily. Any attempt to construct a schedule of road costs quickly encounters these problems.

Most provincial road classification systems are too broad for use in accurate costing of road wear. The Province of Manitoba has two categories of roads in Southern Manitoba: (1) Provincial Trunk Highways (P.T.H.) and (2) Provincial Roads. P.T.H. have several different surface treatments ranging from cement to an asphalt composite while Provincial Roads are usually gravel surfaced although the use of asphalt surfaces is growing. The range within these two categories with respect to quality of construction, width, ability to carry large weights and general condition is very large. The Manitoba Highways Department uses a system of five classes of road, each class corresponding to a range of traffic volumes, for internal maintenance cost projections. For use in an analysis where traffic increments must be accurately costed, however, such broad classes, while helpful, do not comprise the necessary detail.

There are also local gravel and dirt roads which are the responsibility of the local municipality. While all have lower construction standards than Provincial Roads, the municipal roads have wide variations in carrying ability and general condition.

To be representative, road cost studies should take into account the heterogeneity of roads and determine the response of each road to various traffic loads. Through this approach, a road cost study can reach a high degree of realism.

Traffic Mix.

There is a great diversity of vehicles travelling on the Prairie road network. While a large proportion of the traffic upon major East-West highways consists of inter-urban freight and passenger traffic, the traffic mix on the Prairie road system away from major inter-urban routes is regional in nature, concerned with the marketing of local products and the consumption of pleasure travel. The local network carries consumption goods from urban areas to rural households while the reciprocal traffic consists of raw materials and local commodities undergoing transport to market centers.

Road wear is not a linear function of the traffic volume but is an exponential function of the weight resting on each axle.[25] Thus the damage attributable to truck traffic is greater than the simple proportion of truck traffic volume to road traffic volume would indicate. The farm truck traffic inherent in a grain producing and exporting region contributes an important percentage of total truck traffic and, therefore, of total local road wear. Measuring this farm truck traffic is necessary in any attempt to analyze road costs in the grain-producing regions of the Prairies.

A major difficulty in this measurement of farm truck traffic is the great diversity in truck size. Prairie farm trucks used for hauling grain are a large number of sizes and this range of sizes presents a calculation problem. Table 2 illustrates the diversity of farm

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[25] See Chapter III for a more specific treatment of the axle load measurement function.

Table 2

Average Size of Truck, Number of Trucks, Average Bushels Transported and Average Year of Truck for Farmers Owning Trucks, Boissevain Region 1970-1971

	Size of Truck (Gross Vehicle Weight)						
	6,000 and less	6,001-9,000	9,001-12,000	12,001-16,000	16,001-22,000	22,001 and over	Total all trucks
Average size of truck	5,755	7,878	10,262	14,863	19,686	26,581	11,355
Number in stratum	364	466	303	293	244	61	1,731
Average bushels transported	2,976	3,217	3,937	4,598	6,005	8,548	4,108
Average year of truck	1962	1955	1960	1955	1961	1964	1959

SOURCE: R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis" (unpublished Doctor's dissertation, University of Manitoba, 1973), p. 110.

truck sizes in the Boissevain region for 1970-71.[26] Farm trucks have a wide range of capacities and gross vehicle weights (G.V.W.) as well as the possibility of a different number of axles and wheels. All of these factors must be considered before reckoning the effect that each truck has upon the road surface. In addition, each road reponds in a unique manner to the same equivalent weight application. These variables suggest that the systems approach be used to include all of these factors when an attempt is made to allocate a road wear cost as a consequence of farm truck traffic.

Distance.

Distance is another of the traffic components whose variation causes difficulties in measuring road wear. The relationship between distance and road wear is one of truck size. What effect does farm to elevator distance have upon truck size? Intuitively one expects that as distance increases, *ceteris paribus*, so should the average size of trucks. It is assumed that as truck size increases, per bushel collection costs decrease. In the Boissevain region, for 1970-71, as shown by Table 3, this hypothesis linking

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[26] R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis (unpublished Doctor's dissertation, University of Manitoba, 1973), p. 110.

Table 3

Average One-Way Distance, Number of Trucks and Size of Truck for Farmers Owning Trucks and Farmers Using Custom Truckers, Boissevain Region 1970-1971

	One-Way Distance to Elevator					
	0.0-3.0	3.1-6.0	6.1-9.0	9.1-12.0	12.1 and over	Total all trucks
Farmers owning trucks:						
Avg. one-way distance to elevator	2.01	4.55	7.28	10.16	15.13	5.25
Number in stratum	406	752	406	126	41	1,731
Average size of truck (GVW)	11,166	11,572	11,184	10,417	13,829	11,355
Farmers using custom truckers:						
Avg. one-way distance to elevator	1.86	4.49	7.31	10.10	14.48	5.33
Number in stratum	107	188	106	42	13	456

SOURCE: R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis" (unpublished Doctor's dissertation, University of Manitoba, 1973), p. 107.

distance and truck size is supported for one-way distances greater than 12.1 miles while for lesser distances there is no discernable trend.[27]

The acceptance of this hypothesis has implications for any rationalization scheme in which collection points would be spaced further and further apart. Given a constant volume of grain, which causes the greater wear on roads: large but fewer trucks or small but more trucks? Shurson and Sparks suggest that, given a constant quantity of grain to be hauled, 750 bushel capacity trucks will do half the road damage of 200 bushel capacity trucks.[28] With these conclusions, any rationalization scheme which induces farms to use large trucks may have a beneficial effect upon road wear.

The effect that distance has upon truck size and ultimately road wear is difficult to determine. It is necessary, however, to determine the effect before any rationalization model is chosen as "the" one for implementation.

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[27] Ibid., p. 107.

[28] G. W. Shurson and G. A. Sparks, "Centralization of Country Elevator Operations and Its Impact Upon the Rural Road Network," The Logistics and Transportation Review, Vol. 9, No. 2 (1973), p. 147.

Volume.

Primary farm marketings through the licensed elevator system in Western Canada fluctuate from year to year depending upon weather, world market demand and other conditions. In the design of any rationalization scheme, the range of these oscillating marketings must be recognized. For example, the Prairie primary farm marketing in the 1972-73 crop year was 992.7 million bushels while in the 1974-75 crop year it was 734.1 million bushels.[29] Should the base volume for a newly-designed grain handling and transportation system be too small, then in peak volume years the system would not be able to handle the flow. Similarly, in the use of the systems approach to rationalization that included road costs, choosing a base volume that was not realistic may indicate that a scheme with a certain distribution of elevator points which was cost minimizing with respect to road wear is no longer cost minimizing. A major shift in truck traffic volume may greatly increase road costs and this increase in costs could change the cost-minimizing aspect of the entire model.

Volume fluctuation and the subsequent effect on the cost-minimization aspect of the entire rationalization scheme is a prime example of the need for sensitivity testing. Should traffic volume be a very sensitive

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[29] Based on correspondence with George McLaughlin, Statistics Division, Canadian Grain Commission, Winnipeg.

component of the total cost of the system, then the scheme chosen must be one that can optimally handle large shifts in traffic volume. The search for the "optimum" solution must be tempered by the need for flexibility.

Estimating the volume that may flow through the system is difficult but, considering the effect that increases in traffic load may have upon road costs, it is necessary that the volume estimation be made which is realistic for the region.

Seasonal.

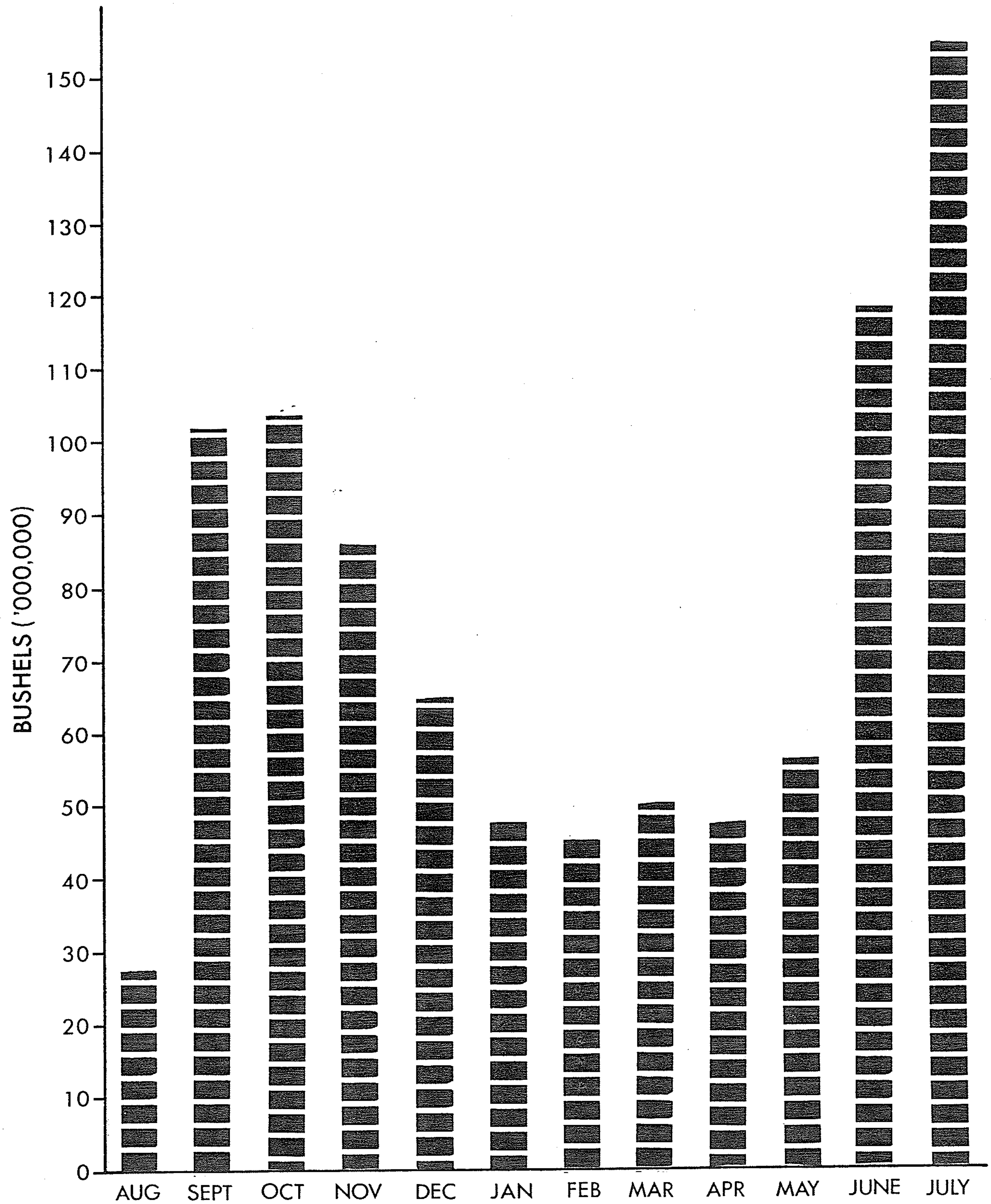
Primary farm grain marketings do not only fluctuate from year to year but they also fluctuate seasonally. Figure 1 illustrates the five year average seasonal marketings for the Canadian Grain Commission's Western Division from 1971-72 to 1975-76. Deliveries are highest just before the end of the crop year and after the harvest while winter months and the month of August are periods of lowest delivery of grain.

Farm grain hauling is not only seasonal in nature but is concentrated on days within each period. Weather, quotas and general economic conditions all contribute to the "peaking" of farm trucking on certain days. When Sundays, other holidays and seasonal weight restriction periods are considered, there may be only 200 days a year in which grain is hauled in the average Prairie region. This point brings up the problem of averaging. Any analysis

FIGURE 1

WESTERN DIVISION PRIMARY FARM MARKETINGS THROUGH LICENSED ELEVATORS, 5 YEAR AVERAGE

1971-72 TO 1975-76



in which total farm deliveries are averaged over the year introduces error into the research. Once the seasonal traffic peaks are included, the wear on a road may be greatly increased and the road costs may be greater than otherwise would be expected. Roads, which under no peaking problems can easily handle the traffic, may be found to break up under the intensified use caused by seasonal traffic variation.

The time of the year affects road wear. Traffic carried in the winter months when the road beds are frozen causes little, if any, road wear. Under frozen conditions, roads can carry a much greater volume and weight of traffic than at any other time of the year. In spring when road beds are soft, weight restrictions are usually in force. Under spring conditions, any increase in traffic could have a major effect upon road wear and eventual collapse. One overloaded truck may, by itself, damage a road bed enough to necessitate heavy reconstruction. Both summer and autumn haulage affect road wear to a different degree. This factor of seasonal traffic changes and different road response is a major one that presents problems to the researcher. Often it is unrealistic to attempt to include all of these variables in a system approach so the challenge becomes one of choosing those variables which are most necessary to the research.

The Impact of Road Surface Upon Trucking Costs

Road surface has an effect upon trucking costs. Studies performed at the University of Manitoba dealing with farm trucking costs[30] and custom trucking costs[31] for grain demonstrate that the type of road surface has an influence upon trucking costs.

Farm Trucking Costs.

Based upon a random sample of 128 farm trucks in Manitoba and Eastern Saskatchewan for the 1967-68 crop year, one of the aims of this study was to determine the impact upon grain transportation costs of variations in the proportion of grain miles on treated surface roads.[32] Treated and gravel surfaces were the two categories of road surface in the study. The relationship between the proportion of grain miles on treated surface roads and average cost per

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[30]E. W. Tyrchniewicz, A. H. Butler and O. P. Tangri, The Cost of Transporting Grain by Farm Truck, Research Report No. 8 (Winnipeg: Center for Transportation Studies, University of Manitoba, July, 1971).

[31]E. W. Tyrchniewicz, G. W. Moore and O. P. Tangri, The Cost of Transporting Grain by Custom and Commercial Trucks, Research Report No. 16 (Winnipeg: Center for Transportation Studies, University of Manitoba, August, 1974).

[32]Grain miles refer to the annual truck miles in grain transportation, which is equal to the annual number of trips to the various sales outlets multiplied by the appropriate round-trip distance to that sales outlet.

bushel-mile was negative.[33] That is, as the proportion of grain miles on treated surfaces roads increases, the average cost per bushel-mile decreases.[34]

Custom Trucking Costs.

As with the farm trucking cost study, 1967-68 crop year data were used in the custom trucking study. The study region encompassed Western Manitoba and Eastern Saskatchewan from which 45 usable questionnaires were obtained. One of the aims of this study was to determine the impact that the proportion of grain miles on treated surface roads has upon grain trucking costs. Treated surface and gravel roads were the two surface categories in the analysis. As was demonstrated in the farm trucking cost study, the relationships between the proportion of grain miles on treated surface roads and average cost per bushel-mile was negative.[35] The analysis also revealed that the proportion of grain miles on treated surface roads is greater for larger trucks, as well as for trucks travelling

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[33]A bushel-mile is defined as the movement of one bushel of grain a distance of one mile.

[34]Tyrchniewicz, Butler and Tangri, op. cit., pp. 53-54.

[35]Tyrchniewicz, Moore and Tangri, op. cit., p. 42.

a greater distance to the sales outlet.[36] These relationships are an important influence upon some of the problems associated with road cost studies.

Both reports stated that the type of road surface affects truck average costs. This conclusion has implications for the rationalization of the grain handling and transportation system. Should rationalization result in elevators being located further and further apart from each other, as most proposed schemes suggest, then there would be an increase in the trucking of grain. Treated surfaces would cause lower average trucking costs than would occur on roads with a gravel surface. The relationship between the savings on trucking costs compared with the increased expenditure on road construction and maintenance will determine the economic feasibility of this approach. The systems approach could be used to analyze the region under study to determine which roads should undergo surface treatment and which should be left as gravel to minimize total system costs.

A Critique of Some Previous Road Impact Studies

There are a number of studies which have attempted to estimate the impact of additional grain trucking upon the Prairie road network. The six following studies have all been completed since 1973 and each concentrates upon

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[36] Ibid., pp. 42-44.

different areas of the Prairies. Of the six studies, five provide a road cost related to the abandonment of various rail branchlines while the remaining study gives a general description of the intensity of road impact as the distance between collection points increases. The studies are discussed in chronological order, starting with the Platts Study of 1973.

The Platts Study.

The Platts Study[37] was initiated to provide a Saskatchewan Government input into the discussion and controversy that followed the release of the Grains Group report.[38] The particular rationalization scheme examined by the Platts Study is the reduction of the Prairie elevator system to 3,600 elevators in 1969. The Platts Study separately estimated the capital and maintenance cost implications of this scheme over a twenty-year design period (1972-91) for the road system of two regions: The Kerrobert Region and the Medstead Region. The Kerrobert Region scenario abandoned 308 miles of rail line while the Medstead

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[37] J. B. Platts, "The Impact of a Rationalized Country Elevator System on Rural Roads and Highways in two regions of the Province of Saskatchewan" (Planning Branch, Saskatchewan Department of Highways and Transportation, 1973) (Mimeographed).

[38] Grain Handling and Transportation Costs in Canada, prepared for the Grains Group, Office of the Minister, the Honourable Otto E. Lang (Ottawa: The Queen's Printer, August, 1971).

Region scenario abandoned 227 miles. These two regions are heavily affected by abandonment and Platts warned that should the study conclusions be extended for use over the entire Province, "caution would be required in expanding the figures in order to prevent over-estimation of impact."[39]

The Platts Study has five weaknesses that detract from its modest aim of estimating only an "order of magnitude" of the impact of rationalization. These shortcomings are: (1) the assumption of a standard truck size for calculating road wear, (2) the procedure for selecting alternate delivery points, (3) the routes utilized, (4) the capital cost equations, and (5) the lack of base traffic statistics.

The assumption of a 250 bushel capacity farm truck for the twenty-year design period (1972-91) weakens the credibility of the study. A standard truck size was created for several reasons, among which are: ease of computation, the diversity of farm truck sizes and the unknown impact that rationalization will have upon the farm truck population. Platts utilized two 1971 sources of data: the Canada Department of Agriculture and the Saskatchewan Department of Highways. These two sources supported the assumption of a 250 bushel capacity single rear axle truck as the basic farm truck in 1971. These two sources of data

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[39] Platts, op. cit., p. 19.

do not support the assumption of this "standard" farm truck to 1991.

The magnitude of road cost bias introduced by the assumption of constant average farm truck capacity is affected by the type of larger farm truck assumed: single rear axle or dual (tandem or tag) rear axle. Road wear is an exponential function of the weight resting on each axle. Single rear axle trucks which have a capacity greater than 250 bushels will inflict greater wear to the rural road system.[40] In the event that the rationalization scenario analyzed by Platts results in a trend to single rear axle trucks with a larger capacity, then the Platt's road costs will be low. Should farmers react to longer haul distance by the purchase of dual rear axle trucks, then the opposite would occur: Platts' road cost estimates would be high. Shurson and Sparks suggest, that for a given amount of grain to be transported, dual rear axle trucks cause less road damage than do single rear axle trucks.[41] The assumption of a standard capacity farm truck for any one year is, in itself, a loss of realism. The utilization of an

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[40]Table 4 in the critique of the Province of Alberta submission further along in this chapter illustrates this concept.

[41]G. W. Shurson and G. A. Sparks, "Centralization of Country Elevator Operations and Its Impact Upon the Rural Road Network," The Logistics and Transportation Review, Vol. 9, No. 2 (1973), p. 147.

unrealistically small standard truck for a twenty year period compounds this loss of realism and affects the credibility of the Platts study.

The second shortcoming of the Platts Study is the selection of alternate delivery points. Of the fifty-four delivery points abandoned in this scenario, it was decided that, except for three points, all farmers delivering to any one closed point would unanimously choose the same alternate point. The post-rationalization elevator point identification was a judgement process based "largely upon shortest haul distance with minor adjustments for road surface type.."[42] It is extremely doubtful that there would be such unanimity of opinion among farmers. Even for the three points where grain was assigned to more than one alternate point, the grain was evenly shared between two alternate points. One suspects that the procedure of manually calculating road impact was a significant factor in this unrealistic allocation of farm grain to alternate points.

Route selection is another weakness of the study. A series of "inter-elevator links" was plotted along the shortest feasible route between a closed point and the point receiving the re-assigned grain. Feasibility was attempted by charting the route over roads best able to withstand the

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[42] Platts, op. cit., p. 8.

additional traffic. If possible, provincial highways were utilized. The Decreasing Correction Factor Method[43] assigned traffic loads over the one route (composed of inter-elevator links) between the closed point and its alternate. The traffic load decreased from its maximum value at the alternate point to zero at the closed point. The decrease occurred in stages coinciding with the junction of feeder routes. The traffic load cannot be greater than that generated by the total diverted grain carried in 250 bushel capacity trucks. It was assumed that feeder roads into the inter-elevator route are not adversely affected by increased truck traffic and, therefore, incur no additional costs.

The effect of this "funneling" of grain traffic along one route is to over-estimate the road cost impact of this rationalization scenario. Many provincial highways in rural areas are oil treatment highways. Oil treatment highways are very sensitive to increased truck traffic: the oil surface will break down under heavy vehicle loads. The arbitrary funneling of the displaced grain traffic along provincial highways, many of which are oil treatment highways, will bias the road costs upward. The results of the Platt's Study support this proposal: 80 percent of the capital impact figure calculated for the Kerrobert Region and 95 percent of that figure calculated for the Medstead

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[43] Ibid., p. 51.

Region were attributable to the reconstruction and upgrading of existing oil treatment highways to paved standards.[44] In the area of maintenance, 65 percent and 73 percent of the maintenance cost increases for the Kerrobert Region and the Medstead Region were allotted to oil treatment highways.[45] The significance of these percentages is realized when compared with the fact that oil treatment highways comprise only 25 percent and 35 percent, respectively, of the total link mileage.

The capital cost equations are the fourth shortcoming of the Platts Study. Whereas maintenance costs were determined in advance by formula for various incremental traffic loads for each road type, capital improvements were based upon judgement. Increased annual equivalent 18 kip single axle loads were calculated for each "inter-elevator line." Highway engineers then estimated the number of years that a capital improvement to that "inter-elevator link" would be advanced due to the increased traffic load. Costs were allocated accordingly. The degree of advancement for each "inter-elevator line" was judged from such factors as "highway subsystem, design standard, year of subgrade construction, surface type and

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[44]Ibid., p. 17.

[45]Ibid., p. 18.

width."[46] This process is analogous to the one followed in the Brandon Study.[47] The inflexibility of this manual approach not only precludes the ready testing of different rationalization scenarios but also precludes the assumption of different "inter-elevator links."

The final weakness of the Platts Study is the lack of base traffic statistics for all but Provincial highways. The use of a "best guess" to set standard base traffic loads for grid, main farm access and gravel roads casts suspicion upon the incremental maintenance cost figures. A standard base traffic load for each of these three road types removes the realism that area studies require. The incremental maintenance cost equations in this Study are sensitive to minor variations in traffic loads. The lack of realistic base traffic statistics casts doubt upon the conclusions of this study that, over a twenty year period, maintenance costs for the Kerrobert Region would increase by $870,000 while those for the Medstead Region would increase by $1,380,000.[48] Increments cannot be accurate unless the base figures are known.

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[46]Ibid., p. 11.

[47]The Canada Grains Council, The Grain Handling and Transportation System in the Brandon Area (Winnipeg, Brandon Area Study Committee, 1974).

[48]Ibid., p. 17.

Shurson and Sparks.

Shurson and Sparks[49] attempted to estimated the impact that changes in truck traffic would have upon the rural road network as a result of varying degrees of centralization of the country elevator system. A uniform agricultural plane was assumed with the collection points located on a square matrix with major routes between centers and a grid of secondary routes. It follows that total truck traffic destined to each collection point is proportional to the square of the distance between collection points.[50] The result is that total truck traffic observed at a collection point is relatively insensitive to small changes in the spacing between collection points but is highly sensitive to large scale changes in collection point spacing.

The analysis next quantified the expected truck volumes into equivalent 18 kip axle loads in order to assess the effect upon the rural road system. Shurson and Sparks made the following significant statement:

> "...from the point of view of impact upon
> the road network, it is twice as desirable
> to use the 750 bushel tandem axle truck

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[49] G. W. Shurson and G. A. Sparks, "Centralization of Country Elevator Operations and Its Impact Upon the Rural Road Network," The Logistics and Transportation Review, Vol. 9, No. 2 (1973).

[50] Ibid., p. 143.

> rather than the 200 bushel single axle truck."[51]

The main conclusion of the study was that major elevator centralization would have its greatest impact upon oil treatment and, to a lesser extent, gravel surface roads. Small scale consolidation, up to a spacing of 20 miles, would have a minor effect upon roads.[52]

The Shurson and Sparks analysis contained three features that weaken the study: (1) the assumption of either 200 bushel capacity single-rear axle trucks or 750 bushel capacity tandem rear axle trucks, (2) the lack of road cost data, and (3) the emphasis upon the effects of large scale centralization.

The exclusion of the broad diversity of Saskatchewan farm truck sizes, while not a major weakness in a theoretical analysis such as this, would preclude the easy application of the Shurson and Sparks methodology to the calculation of a quantitative cost result. As the major aim of analysis should be to provide a quantitative response to aid in decision-making, the Shurson and Sparks approach, while a useful tool, is not adequate. Farm

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[51]Ibid., p. 147.

[52]Ibid., p. 158. It is interesting to note that increasing the collection point spacing to 20 miles would reduce the number of Saskatchewan grain collection points to 520. This contrasts with the Platts study where it was assumed that Saskatchewan would have over twice that number of collection points.

trucks cannot be considered to be one of two sizes as such an assumption will bias the road wear effect. As an example, the study assumes that large scale centralization would result in the use of 750 bushel tandem rear axle trucks. This assumption neglects the fact that producers living close to a collection point will still be able economically to utilize smaller trucks. Such simplifications such as these remove much realism for an analysis.

The Shurson and Sparks study does not attempt to attach costs to any one centralization scenario; what it does is to provide a general measure of the road wear implications as the distance increases between collection points. It points out that oil surface roads and gravel surface roads bear the brunt of road degradation. In addition, the study demonstrates that the secondary routes near the extremities, rather than those near the center of a shed area, have the greatest increase in traffic load of all secondary roads.[53] While interesting, these study results are not helpful in the construction of a total least-cost grain handling and transportation system. Neither reconstruction nor maintenance costs are provided. What would be useful is the estimation of an approximate annual road cost of different distances between collection

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[53] Ibid., p. 150. This viewpoint is different from the Platts Study where it was assumed that these were no significant effects upon secondary roads.

points, for example, ten miles, fifteen miles, twenty miles and so on.

Even though such costs would be, at best, "ball-park" numbers, they would be more useful than the Shurson and Sparks qualitative approach with respect to costs.

The emphasis upon the effects of large scale and centralization debilitates the study. After stating that a spacing of collection points under twenty miles would have only a minor effect on road maintenance, the study goes on in greater length upon the more significant road effect of spacing collection points up to and beyond 60 miles apart. While an interesting exercise, such emphasis is misplaced. The upper distances considered between collection points are not germane to the analysis of the 1970's and 1980's. The authors should have explored the road impact of spacing collection points 30 miles apart and less. As the authors mentioned in an aside, centralization with spacing between points of twenty miles would reduce the number of collection points in Saskatchewan to approximately 520 while a spacing of 50 miles would reduce the number of Saskatchewan collection points to approximately 85.[54] The need is to concentrate upon the practical and not to concentrate upon the unrealistic.

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[54] Ibid., p. 156.

Aside from the aforementioned weaknesses, the Shurson and Sparks study is an interesting conceptual look at the road impact of grain collection point centralization.

The Brandon Area Study.

This study[55] is the only Prairie in-depth grain handling and transportation area analysis completed by a committee of producers, elevator, railway and provincial government personnel.[56] It "...describes in some detail producer trucking, farm storage, elevator and railway operations and cost experiences in 1971-72 within the area."[57]

Three basic alternative grain collection systems were analyzed for the Brandon Area of Manitoba. Alternative Number One upgraded all the light density rail lines to a gross carrying capacity of 263,000 pounds with the elevator system remaining in place. Alternative Number Two

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[55]The Canada Grains Council, The Grain Handling and Transportation System in the Brandon Area (Winnipeg, Brandon Area Study Committee, 1974).

[56]The Canada Grains Council initiated a second study titled The Area Eleven Study to apply the methodology developed for the Brandon Area Study to a region in Saskatchewan. The Area Eleven Study--roughly encompassing the territory between Lloydminster, Saskatoon, Kyle and Coronation--was adjourned with the announcement of the formation of the Grain Handling and Transportation Commission.

[57]The Canada Grains Council, op. cit., p. 2.

abandoned the light density rail lines with all the elevators remaining in operation. Commercial trucks were employed to transport grain from the now, off-track elevators to elevators on the basic rail network. The abandonment of the light density rail lines along with the elevators located on these rail lines comprised Alternative Number Three.

No incremental road costs were assumed for Alternative Number One since the grain handling system was not altered. Alternative Number Two--which employed homogeneous commercial trucks--readily allowed the Manitoba Department of Highways engineers to calculate road degradation of the trucking routes and to generate incremental road cost estimates. The increased farm trucking of Alternative Number Three entailed too great an investment of time by the Department of Highways engineers to calculate the incremental road damage and a "ballpark" cost per bushel was therefore assigned.

The study has two road cost weaknesses: (1) the inability to incorporate the heterogenous Prairie farm truck population into the calculations of road wear, and (2) the inflexibility inherent in the method utilized to estimate the effect of incremental truck traffic upon road costs.

The inability to incorporate the diversity of local farm trucks used to haul grain is a major weakness of the Brandon Area Study. Of the three scenarios analyzed, only Alternative Number Three envisaged an increased farm trucking distance. The Brandon Area Study Committee, however, did not investigate the road costs of this additional farm trucking distance. Citing the many unknowns in the Brandon Area farm truck population, the Study Committee "..decided to arbitrarily allocate an extra cost to the highways for maintenance of 1¢ per bushel."[58] The Study Committee did not state whether this cost is a net road cost or a gross road cost. If it is a gross cost, then a saving must be included to reach a net cost since, as truck patterns change, some roads will have less traffic, and presumably lower maintenance costs, than before. The accuracy of this approach is, at best, questionable. One suspects that the method used to estimate incremental road costs--to be discussed next--was an important factor in this allocation of 1¢ per bushel for road costs.

Alternative Number Two utilized commercial trucks to transport grain from the off-track elevators, caused by the abandonment of the light-density rail lines, to the elevators on the basic rail network. All commercial trucks were assumed to carry 800 bushels with a gross vehicle weight of 74,000 pounds. The routes followed by these trucks were derived by "plotting the shortest distance over

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[58]Ibid., p. 19.

the rural road network from a branch line delivery point to a main line delivery point."[59] Once the increased stress on each affected road segment was calculated, Department of Highways engineers made a "rough estimate... as to the potential damage..."[60] The engineers considered present road condition, present traffic volume and the absolute increase in traffic volume in making their "rough" estimates. This approach, while presumably as accurate as possible, is time-consuming and inflexible. Should incremental traffic volumes change, then the entire road cost study would have to be re-estimated by the Department of Highways engineers.

The Brandon Area Study was a prototype analysis of rail rationalization and its effects upon the cost structures of each participant in the process. As with any prototype, improvements can be made. In the area of road costs, the need is to add flexibility and mechanization to future analyses: flexibility to consider a diversity of truck gross vehicle weights and mechanization to enable the road wear component of many scenarios to be rapidly estimated. The use of Department of Highways engineers to assess the effect of each scenario upon each road segment

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[59]Ibid., p. 17.

[60]Ibid., p. 38.

was too limiting and costly an exercise to permit easy expansion of the Brandon Area Study methodology.

Province of Alberta.

The Province of Alberta estimated the incremental road costs from the abandonment of rail branch lines at two separate hearings before the Hall Commission. At Stettler[61] the Province submitted its methodology while at Saskatoon,[62] total incremental costs for the abandonment of thirty-one rail subdivisions were exhibited. Two methods of post-abandonment grain transportation were considered: (1) semi-trailer units from off-track elevators to rail head elevators, and (2) direct producer hauling from farm to rail head elevators.

Preliminary studies of engineering literature indicated that, for a given amount of grain to be transported, high capacity semi-trailer trucks have less total load effect upon the road structure than smaller capacity trucks. Upon further analysis, however, the Province of Alberta decided that the above case does not necessarily apply:

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[61] Alberta Transportation, in a submission to the Grain Handling and Transportation Commission, Stettler, Alberta, June 14, 1976.

[62] Alberta Transportation, in a submission to the Grain Handling and Transportation Commission on Behalf of the Government of Alberta, Saskatoon, Saskatchewan, August 30, 1976.

"In most cases individual producers in the production area of a delivery point that may be closed have more than one rail head elevator option, and consequently disperse the loadings on more than one route to railhead elevators. Whereas the large trucks would tend to use one single route from a satellite elevator to the nearest rail head."[63]

This approach of the Province of Alberta differs from that of both the Platts Study and the Province of Saskatchewan,[64] which assume that farm trucks would follow one route consisting of a series of "inter-elevator links."

The Province of Alberta projected the loadings upon the road system over the next twenty years and the basic road management program that would likely have been followed. The increased loadings as a result of elevator closure were then estimated along with a modified road management program. The difference between the two programs was defined as the incremental road cost attributable to rail line abandonment. Both capital and maintenance expenditures were included in the incremental road costs. In addition to rural road costs, street improvements in communities which would receive the concentrated grain truck traffic were also calculated. Costs were based over a twenty year period in 1975 costs. If

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[63]Alberta Transportation, Stettler, op. cit., p. 2.

[64]Province of Saskatchewan, in a submission to the Grain Handling and Transportation Commission, Saskatoon, Saskatchewan, September 3, 1976.

all thirty-one subdivisions were totally abandoned the incremental road cost would be $44.8 million.[65]

The methodology described by the Province of Alberta appears realistic but, as no supporting data was presented, it is impossible to comment upon the accuracy of the conclusions. One interesting factor does stand out: that the relationship between rail rationalization and the attendant incremental road costs need not always be positive. Indeed, of two rationalization scenarios with equal farm trucking dispersal patterns, the one which entails <u>greater</u> average farm trucking distances may generate <u>less</u> incremental road costs than the other scenario. This is due to the use of larger farm trucks. It is generally assumed that, as haul distance increases, farmers will replace their present farm trucks over time with larger ones. As Table 4 illustrates for a given grain volume to be transported, three axle "tandem" trucks would have a lesser road impact than the use of the current farm population mix of two axle trucks. Depending upon the effect upon the farm truck population, therefore, one cannot always assume that incremental road costs will increase in some direct relationship with incremental truck miles.

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[65] Alberta Transportation, Saskatoon, op. cit., p. 17.

Table 4

Road Effect of Various Truck Types
To Move 300,000 Bushels per Year

Truck type	Bushels	E.S.A.L.[1]	Trucks per Year	Trucks per Day: Average full Year[2]	Trucks per Day: Peak month July[3]	E.S.A.L. per year
Average Farm truck	225	.76	1,330	5	12	1,010
2 Axle "3 ton"	286	1.61	1,050	4	10	1,690
3 Axle "tandem"	535	1.21	560	2	5	680
4 Axle "semi"	768	2.82	390	1	4	1,100
5 Axle "semi"	964	2.42	310	1	3	750

SOURCE:
Alberta Transportation, in a submission to the Grain Handling and Transportation Commission, Stettler, Alberta, June 14, 1976.

1. Equivalent Single Axle loads
2. 5 days a week, 52 weeks
3. 18 percent in July, 5 days a week, 4 weeks.

The policy implications of this conclusion are large. The assumption can no longer be made that, *ceteris paribus*, the greater the degree of rail rationalization, the greater will be road costs. It may well be that the incremental road cost savings of an enlarged rationalization scenario would be sufficient to enable the governments concerned to compensate farmers for part, or all, of the additional costs of purchasing "tandem" trucks rather than larger two axle trucks. The extent of this approach would, of course, depend upon the expected incremental road cost savings, if any, of one rationalization scenario versus another.

Province of Manitoba.

The Province of Manitoba[66] submitted a range of road costs estimates which could result from the abandonment of 727 miles of rail branch line in the province. The realism of the methodology used to calculate the expected range of road costs is, at best, questionable.

Manitoba contains approximately 4,500 miles of rail line and approximately 47,500 miles of road. This provides a ratio of 10.5 miles of road for each mile of rail line. The abandonment of 727 miles of rail line, therefore, would

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[66]Province of Manitoba, in a submission to the Grain Handling and Transportation Commission, Saskatoon, Saskatchewan, September, 1976.

affect 7,600 miles of road.[67] The Provincial road network is constituted as follows: 8.4 percent Provincial Trunk Highway, 15.8 percent Provincial Roads and 75.8 percent municipal roads.[68] It was assumed that the 7,600 miles of road affected by rail abandonment would have the same composition. Both Provincial Trunk Highway and Provincial Road unit repair costs were established. Two estimates of per mile repair costs were assigned to municipal roads: one submitted by the municipalities and the other introduced by the Province. The total estimated road costs resulting from rail line abandonment were $41.8 million and $93.7 million respectively.[69]

The Province of Manitoba submission has two main weaknesses: (1) the simplistic use of a ratio and (2) the supposition that each one of the 7,600 miles of road assumed to be affected by rail line abandonment would require extensive expenditures.

The use of a Provincial ratio to ascertain the miles of road affected by rail line abandonment is simplistic. Rail line abandonment will not occur in relation to the miles of road in an area. Some of the rail

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[67] 727 x 10.5 = 7,600.

[68] Ibid., p. 26.

[69] Ibid., p. 29.

branch lines, which are candidates for abandonment, are concentrated in a small region and as such, may have an intense effect upon the local traffic.[70] In other areas, very few miles of rail line are being considered for abandonment and, thus, would cause little disruption in traffic patterns.[71] Some other factors which will have an influence upon the road impact are: traffic volumes on lines being abandoned, number of producers affected, the number of alternate delivery points within reasonable distance, and so on. The calculation and utilization of this ratio appears to be based upon convenience and not upon objective analysis. The resultant lack of realism detracts from the credibility of the study.

The Province of Manitoba supposition that each of the 7,600 miles of road affected by rail line abandonment would require extensive work is questionable. Incremental truck traffic was assumed to necessitate the sealcoating of all Provincial Trunk Highways while all Provincial Roads would require regravelling. Municipal roads would require upgrading as well, although at two different costs. The

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[70]The Lenore, Miniota, Neepawa, Rapid City and Varcoe Subdivisions which total 288 miles of rail branch line are candidates for abandonment. They are located in an area 80 by 35 miles.

[71]The Wakopa Subdivision is an example of a rail line which is bounded on both sides by permanent network rail lines.

Municipal estimates of upgrading were judged "extremely conservative" by the Province and a figure of two and one half times as much was deemed a "minimum."[72] It was the presence of these two municipal road upgrading costs which resulted in the estimation of two total road costs from rail line abandonment.

The costs assigned to each of the three road types by the Province of Manitoba do not appear to be based on any in-depth research. If incremental truck traffic was not calculated, then any estimate of incremental road impact costs was merely an exercise. Neither the per mile costs assigned to each road type, the incremental traffic on each road segment nor the number of miles of road affected by rail line abandonment seem to have resulted from more than a simplistic analysis. In comparison to the Province of Alberta study,[73] the Province of Manitoba submission lacks depth.

Province of Saskatchewan.

The Province of Saskatchewan[74] estimated the incremental road costs from the abandonment of 2,418 miles of

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[72]Province of Manitoba, op. cit., p. 25.

[73]Alberta Transportation, in a submission to the Grain Handling and Transportation Commission, Stettler, Alberta, June 14, 1976.

[74]Government of Saskatchewan, in a submission to the Grain Handling and Transportation Commission, Saskatoon, Saskatchewan, September 3, 1976.

rail branch line. The displaced grain was assumed transported in 250 bushel capacity trucks with a 200 day hauling year. The total estimated additional road costs was calculated at $61.9 million over 15 years.[75]

The submission did not explain the methodology utilized to determine the truck routes. From the assumption of a 250 bushel capacity farm truck and the road cost results where oil treatment roads have the greatest cost share,[76] however, the study bears a resemblance to the Platts Study.[77] The comments presented about the Platts Study regarding: the assumption of a standard 250 bushel capacity truck size, the procedure for selecting alternate delivery points and the routes utilized--all apply to the Province of Saskatchewan submission. Aside from the above, little comment can be made about the methodology.

The Province of Saskatchewan also provided incremental road cost estimates of two more rail line abandonment scenarios. The first estimated a cost of $500 million

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[75] Ibid., p. 24.

[76] Ibid., p. 22.

[77] J. B. Platts, "The Impact of a Rationalized Country Elevator System on Rural Roads and Highways in Two Regions of the Province of Saskatchewan" (Planning Branch, Saskatchewan Department of Highways and Transportation, 1973), (Mimeographed).

to asphalt the gravel roads and to pave the oil treatment roads affected by the abandonment of 2,418 miles of rail branch line.[78] The second estimated a road cost of more than $2.25 billion for an inland terminal grain handling system.[79] Two-thirds of the oil treated roads and half of the gravel roads in the Province of Saskatchewan would be paved. Both of the above scenarios cannot be commented upon except to mention that little, if any, analysis appears to have gone into the evolution of these incremental road costs.

Summary of Literature Review.

The preceding six studies attempted to estimate the road impact of changes in the rural elevator network. None had the ability to: (1) incorporate the heterogenity of the farm truck fleet--thereby necessitating the assumption of one or two standard truck sizes, and (2) evaluate grain trucking at the fundamental level--on a farm to elevator basis. All of the five studies that endeavoured to calculate incremental road capital and maintenance costs[80] suffered from requiring individual engineering

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[78]Government of Saskatchewan, op. cit., p. 25.

[79]Ibid., p. 26.

[80]Shurson and Sparks did not attach costs to any one centralization scenario but provided only a general measure of road wear implications.

analysis. None developed a cost formula based upon actual traffic statistics and actual engineering costs.[81] The subsequent lack of flexibility ensured that any sensitivity analysis on the impact of variations in such variables as truck size, total bushels transported and route selection would require the labour intensive, time consuming and subjective exercise of individual study by highway engineers. The consequent result is the lack of any sensitivity analysis.

Two important factors affecting Provincial policy were high-lighted by the preceding studies: (1) that oil surface roads are most susceptible to damage from increased traffic loads, and (2) that truck size and number of axles are key, if not the key, factors influencing road costs.

The susceptibility of oil surface roads to damage from truck traffic suggests an intriguing policy question: Should trucks be allowed to travel upon oil surface roads? A road capital and maintenance cost minimizing policy may well be that trucks should be restricted to gravel, dirt

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[81]One example of the result due to the absence of a cost formula is the variation in provincial road cost estimates submitted to the Hall Commission. The Province of Alberta estimated a 20 year cost of $30,200 per mile of rail branch line abandoned; Manitoba estimated between $57,500 and $128,900 per mile of rail branch line abandoned (no time period was given) while Saskatchewan submitted a 15 year cost of $25,600 per mile of rail branch line abandoned.

or paved roads, leaving oil-surfaced roads accessible only to car traffic. Adoption of this policy, while it may be politically unpalatable, could aid in reducing the road cost impact of rail line abandonment and elevator consolidation.

The knowledge that truck size and number of axles greatly influences the amount of road degradation also has important policy implications. Provincial governments may discover that the potential savings in road reconstruction and maintenance costs are such that it would be worthwhile encouraging farmers to purchase three or four axle trucks for hauling grain. Tangible encouragement could be shown through lower licence fees, accelerated depreciation rates for tax purposes and direct grants. The current Province of Saskatchewan policy of restricting grain transport truck sizes to below 58,000 pounds gross vehicle weight regardless of the number of axles is a movement in the exact opposite direction to that suggested by the preceding review. Perhaps other than highway degradation factors influenced Provincial policy in this area.

CHAPTER III

CONCEPTUAL MODEL

The purpose of this chapter is to identify the four important components in the framework of road cost analysis: (1) the provision of rural road services, (2) road design and traffic factors, (3) incremental road cost sources, and (4) data requirements. All of these constituents need to be grasped before the investigation in Chapter IV is undertaken.

Provision of Rural Road Services

In a commercial industry, a good is sold in known quantities to known consumers. A pricing structure is present which has, among others, the following two functions: (1) the rationing of scarce resources among the consumers of that service or product, and (2) the attraction of additional investment to that activity. Roads do not have a pricing structure. Everyone in a community uses roads to some degree, but the degree of usage varies greatly so that the utilization of any one road by each person is impossible to determine. The absence of a market in which users and the extent of their use are identifiable thus poses problems in the planning of road investment.

The vital nature of roads to communities has dictated that control be invested in public hands. This is re-inforced by the absence of a market which precludes management by the commercial system. The various levels of government charged with the provision of roads have had to devise techniques of allocating road investments based upon other than market criteria. This planning process is complicated by the multiple use of roads. A road that carries local community vehicle traffic may also be used by local commercial traffic, through commercial traffic and through pleasure traffic. Each type of traffic has its own needs for road service qualities such as: surface type, width, maximum weight carrying capacity, maximum speed, allowable curvature, gradients and so forth.

The process of road investment planning is further entangled by the allocation of road responsibilities between Provincial and Municipal governments. Rural roads are maintained by the local government authority and are primarily utilized by local residents. As a benefit to the entire community, the roads are financed out of the local real estate tax revenues. Provincial roads are the trunk routes patronized by private and commercial traffic. Funds for provincial roads spring from a variety of sources: direct such as vehicle registration, licencing fees, fuel taxes and indirect such as general Provincial revenues. Direct sources of road revenues may or may not cover provincial road expenditures. The extensive road network on the Prairies in comparison to the population level leads one to assume that in total, the provincial roads are in a net direct revenue shortfall position.

A benefit-cost analysis would appear to offer a guide to the allocation of resources among the components of the road network. This approach, however, is complicated by the fact that roads do not have utility in themselves but are used in the production of goods and services which do have utility.[82] A grain handling and transportation benefit-cost analysis would attempt to treat each road segment as the product and would compare the costs of road work with the benefits derived to the system through a reduction in total cost from the farm gate to the unloading of grain at the port. In order to assess the benefits, current traffic loads on each road segment would first have to be known. This process is complicated by the fact that present traffic loads are themselves a function of the current benefits and costs of road use to the system. In any analysis, therefore, it is impossible to start from a neutral base; current road utilization patterns are a reflection of current benefits and costs as perceived by the consumers of the road resource. Resource

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[82] David M. Winch, The Economics of Highway Planning, Canadian Studies in Economics, No. 16 (Toronto: University of Toronto Press, 1963), p. 12.

allocation in roads is, therefore, a process which must start from an already imperfect system.

Rural road investment is guided by many factors--the primary one being traffic volume. Starting with the basic rural road grid system, those with larger traffic volumes receive additional investment in the form of widening and better surface treatments. In this approach, investment follows traffic patterns. To some extent this process may be self-generating in that better roads attract traffic from other local roads thus raising total traffic on that road, which may attract further road improvement investment, more traffic, and so on. Other considerations, however, can enter into the road investment decision criteria of government. It may be a Provincial policy, for example, that in general rural residents should be no more than a certain number of miles from a treated surface road. A policy may be that all Provincial roads should have, at a minimum, a gravel surface. Recreation areas may be connected to urban centers by major highways even though they carry large volumes of traffic only on Friday evening and Sunday evening. Roads are also heavily influenced by political considerations as roads are a very visible proof of Provincial government expenditures in an area. The enlightened agility of a region's population in voting for the party forming the government may result in that region receiving more than its "fair" share of good roads while the opposite may occur to those regions who were unfortunate enough to vote for the losing party.

The sum total of the factors--some economic and some not--which combine to shape the present rural road network are not evenly applied throughout rural areas. Two areas of equal road requirements may have quite major differences in road network quality. This has a bearing upon modifications in the grain handling and transportation industry. Changes in grain hauling patterns may have little or no effect upon areas with an "overbuilt" road network, while the same changes in an area with an "under built" road network may cause severe road degradation. Each region must be analyzed separately.

Road Design and Traffic Factors

Road design is a function of traffic volume and load. These two concepts have separate design requirements. Traffic volume refers to the number of vehicles utilizing a road section during a given time period and has design demands for features necessary to facilitate the safe movement of traffic. Load relates to the stress put upon the physical road bed structure by the variety of vehicles operating over a road section and has its own engineering needs.

Expected traffic volume will influence such road design features as: lane width, number of lanes, shoulder size, allowable curvature, cross slope, maximum gradient and, to a large degree, surface type. The greater the volume of traffic using a road, the more that road safety and quality of ride will be stressed. In many cases these are relatively subjective factors and each road authority will establish its own guidelines. As a general principle, however, the following process holds as traffic levels increase. Lane width may be increased, additional lanes may be added and shoulders widened to carry increased traffic safely. The road may undergo reconstruction to accommodate higher average speeds with some curves eliminated and the remaining curves super-elevated and re-aligned. The cross slope may be reduced to provide a flatter road surface and the maximum gradient reduced.[83]

The greater the traffic volume, the greater the requirement for a smooth and dust-free road surface such as asphalt or concrete. Gravel roads may be unsafe when subject to large traffic volumes which cause surface pitting, the formation of transverse corrugations and dust.[84] Should the road surface have many loose stones, corrugations and "potholes", then the result of high speed travel could be a loss of vehicle control and an accident. In addition, loose stones can be thrown into the air causing damage to other vehicles. In general then, the

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[83]Clarkson H. Oglesly and Laurence I. Hewes, Highway Engineering (2nd ed.: New York: John Wiley & Sons, Inc., 1963), pp. 241-255.

[84]Ibid., p. 505.

larger the expected traffic volume, the greater the tendency for roads to be widened, designed with reduced curves and gradients and to have a treated surface applied.

Traffic load influences the structural design requirements of a road. Road stress is a function of the axle load of the vehicles utilizing the road. Traffic stress affects the road sub-grade, sub-base, base and surface structures. The effect of traffic loads upon the physical road structure is that part of road design and costs which are central to this analysis.

It is a fairly simple operation for a highway engineer to design pavement structures to withstand a certain number of applications of a load of a given magnitude. The problem is in designing a structure where the pavement is subjected to applications of a large variety of loads ranging from less than 2,000 pounds on a single rear axle to more than 50,000 pounds on a set of tandem axles. This problem is apparent when endeavouring to measure the road damage caused by a complicated mixture of traffic. The usual approach is to use an equivalent axle load concept. A base or reference load is chosen to relate other loads to the base load by the equivalent number of applications required to produce an equal amount of damage.[85]

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[85]J. F. Shook and F. N. Finn, "Thickness Design Relationships for Asphalt Pavements," _International Conference on the Structural Design of Asphalt Pavements_

The effects of loads of other magnitudes are given in terms of equivalent 18-kip (each kip equals 1,000 pounds) single-axle loads. Each load of a given magnitude is identified with an equivalency factor. A load with an equivalency factor of two will do in one application as much damage as two applications of the basic 18-kip single-axle load. An axle load having an equivalency factor of 0.01 will do as much damage in 100 applications as would occur after one application of an 18-kip single-axle load. Thus load equivalency factors are defined as ratios of applications. The load factor is the ratio determined by dividing the expected number of 18-kip applications by the expected number of applications of the load for which the factor is to be determined.[86]

$$\text{Load Factor} = \frac{W_{18}}{W_L} \text{ for a given load L}$$

To combine applications of different loads for a mixed traffic design, the total effect is:

$$W_{18} = W_L F_L$$

Proceedings, August 20 to August 24, 1962 (Ann Arbor: University of Michigan, 1963), p. 79.

[86] Ibid.

where:

W_{18} = equivalent 18-kip single-axle applications

W_L = applications of load L

F_L = load factor for load L.

The formula used in calculation of axle factors is that constructed by Shook and Finn.

$$\text{Axle factor} = 10^{.12088(L - 18)}$$

where:

L = axle weight in kips (thousand pounds).

Single-axle load or .571 times the tandem axle load.[87]

An example calculation is provided. The fully loaded single rear axle truck weighs a total of 26,000 pounds, of which 18,000 pounds rests on the rear axle and the remaining 8,000 pounds rest on the front axle.

Front axle load factor: $10^{.12088(8 - 18)} = 0.06183$

Rear axle load factor: $10^{.12088(18 - 18)} = 1.00000$

The total load factor for one application of that fully loaded truck is 1.06183. Table 5 presents a general summary of axle weights and their equivalent axle factor while Figure 2 gives the visual impact. As is apparent, the growth in the axle factor is exponential so that the

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[87] Ibid., p. 80.

Table 5

Road Load Factors, Single and Tandem Axle

Single Axles		Tandem Axles*	
Axle Load in Kips	Factor+	Axle Load in Kips	Factor+
2	0.01164	4	0.0126
3	0.01538	8	0.0237
4	0.02030	12	0.0448
6	0.03545	16	0.0843
7	0.04681	20	0.1590
8	0.06183	24	0.3005
10	0.1080	28	0.5650
12	0.1882	32	1.069
14	0.3285	36	2.017
16	0.5731	40	3.814
18	1.000	44	7.175
20	1.745	48	13.45
22	3.045	52	25.34
24	5.312		
26	9.269		
28	16.17		
30	28.22		

SOURCE:

J. F. Shook and F. N. Finn, "Thickness Design Relationships for Asphalt Pavements," International Conference in the Structural Design of Asphalt Pavements Proceedings, August 20 to August 24, 1962

(Continued)

Table 5 (Continued)

SOURCE: (continued)

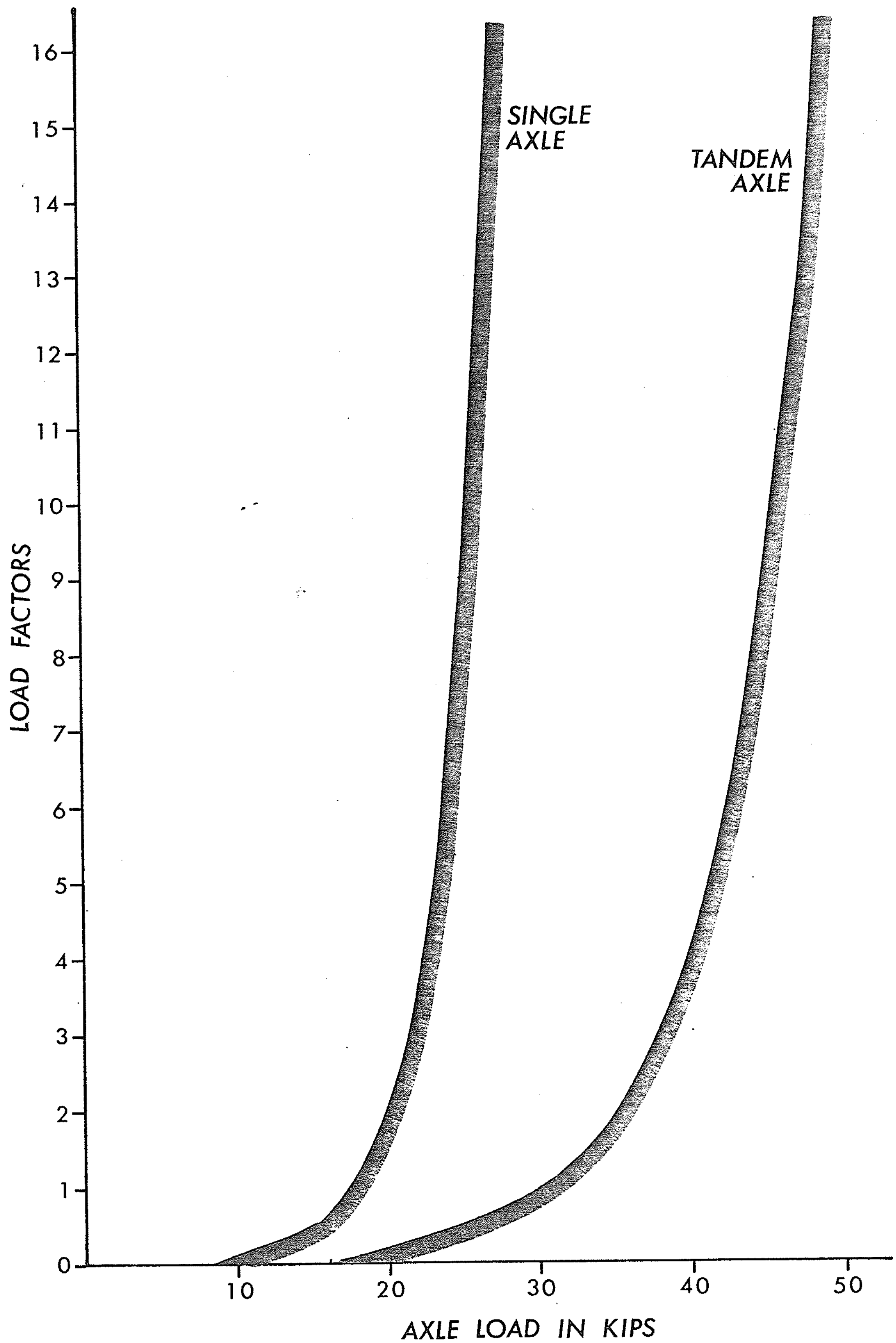
(Ann Arbor: University of Michigan, 1963), p. 80.

*Gross load on a set of tandem axles spaced approximately 40 inches apart.

+Load factor = $10^{.12088\,(L-18)}$; L = single-axle load or .571 times the tandem axle load.

FIGURE 2

AXLE LOAD AND LOAD FACTORS, SINGLE AND TANDAM AXLES



general effect of heavy trucks upon road wear is easily ascertained.

Incremental Road Cost Sources

Incremental road costs that result from changes in the grain handling and transportation system are a function of the two traffic factors--volume and load--discussed previously in this chapter. Incremental road costs are reflected by changes in: road reconstruction programs, road upgrading agendas, road maintenance costs and seal-coat schedules.

Road Reconstruction Programs.

Each Provincial Highways Department estimates the expected life of each section of highway by the quality of construction, present traffic load and future projected traffic loads. Barring unforeseen traffic changes, each Highways Department can predict the year that each road should undergo major reconstruction to regain its original design standards. These road renewals are an ongoing part of each Highway Department's activities.

Changes in the expected traffic load utilizing a road may affect that road's reconstruction schedule. Should traffic loads increase, then the reconstruction year may be advanced while, if the traffic load decreases, the reconstruction date may be postponed. In either case, road capital costs are affected to some degree. The degree of advancement (postponement) of the reconstruction year should be calculated, the incremental cost (saving) derived and allocated to the proper source. In the case of changes in grain truck volume and load resulting from changes in the grain handling and transportation system, the appropriate road reconstruction cost (saving) should be included in any total cost calculations.

Road Upgrading Agendas.

Traffic volume and load are the prime factors that determine the construction quality requirements of each road. As traffic factors change over time so do the necessary road design standards. When traffic factors change to the extent that the road design standards are no longer sufficient, then the Provincial Departments of Highways will upgrade the road to the standard commensurate with the present and expected future traffic volumes and loads. Upgrading of roads is a costly process. When changes in the grain handling and transportation system develop sufficient incremental truck traffic to "trigger" the upgrading of a road, then the upgrading cost should be allocated to grain.

Road Maintenance Costs.

Road maintenance "...is the act of preserving the roadway, roadside, structures, and other facilities as nearly as possible in their as-constructed or subsequently improved condition..."[88] Road maintenance costs are a function of traffic volume and load. As traffic increases, so should road maintenance costs in some manner. As traffic load approaches the upper bounds of the road design parameters, each increment of traffic should cause a higher marginal road maintenance cost than the one before it. The approach of traffic loads to the upper design parameters would cause the road to suffer greater damage, thus necessitating increased road maintenance effort. Each type or class of road should also have its own maintenance cost equation. With different design standards, each class of road should respond to the same traffic load differently. The incremental road maintenance costs generated by increased grain truck loads on some rural roads are costs that should be included in the total costs for the grain handling and transportation system. At the same time, some roads may show a decrease in their maintenance costs as a result of changes in the grain handling and transportation system.[89] These savings should be

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[88]Roy Jorgensen Associates, Gaithersberg, Maryland, Performance Budgeting System for Highway Maintenance Management, National Cooperative Highway Research Program Report, No. 131 (Washington, National Academy of Sciences, 1972).

[89]A load decrease could result from either a reduction in the number of bushels transported over a road or a switch to three axle trucks from the present standard two axle truck.

accommodated in the total cost algorithm to reflect accurately the benefits and costs.

Better quality roads should have fewer maintenance costs than should lower quality roads for the same traffic load. This is to be expected since roads are upgraded so that each road can better carry the expected traffic load. Higher construction costs are compensated for, to an extent, by reduced maintenance expenditures. Changes in the grain handling and transportation system significant enough to cause the upgrading of some roads may have the effect of reducing maintenance costs on the following two types of roads: (1) upgraded roads and (2) roads with reduced grain truck traffic. Changes in the grain transport network may result, therefore, in a reduction of total road maintenance costs.

Seal Coat Schedules.

A seal coat consists of applying a bituminous material upon an existing bituminous surface--asphalt surface treatments and road mixes--and immediately placing a single layer of cover aggregate on the bituminous material. Rolling embeds the cover aggregate in the bituminous surface. Seal coats lengthen the service life of an existing facility by waterproofing it, slightly increasing the surface strength and improving the surface texture.[90]

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[90]American Association of State Highway Officials, Construction Manual for Highway Construction (Washington, D.C.: American Association of State Highway Officials, 1968), p. 95.

Seal coat degradation is a function of time and traffic levels. On prairie roads, a seal coat application will last a maximum of five years. Regardless of traffic levels, after the five year exposure to the prairie climate, a further seal coat application will be necessary.

Traffic also has an effect upon seal coat wear. Traffic volumes in excess of 220,000 vehicles per year (based on two axles per vehicle) will shorten the life span of a sealcoat. Seal coat wear is a linear function of the number of tires which contact the road surface, not the weight carried by each tire as in the case of road wear. A car has the same effect as does a fully loaded single rear axle truck. A tandem truck would have the same impact as 1.5 cars.[91]

The separate seal coat wear factors of time and traffic volumes are important to remember when quantifying the impact of elevator consolidation upon the rural road system (Figure 3 illustrates this concept in graph form). The additional traffic may or may not cause a seal coat cost to be included in the analysis. Should the incremental grain traffic raise the total number of vehicles utilizing a road to above 220,000 vehicles per year, then the appropriate cost must be derived and entered into the

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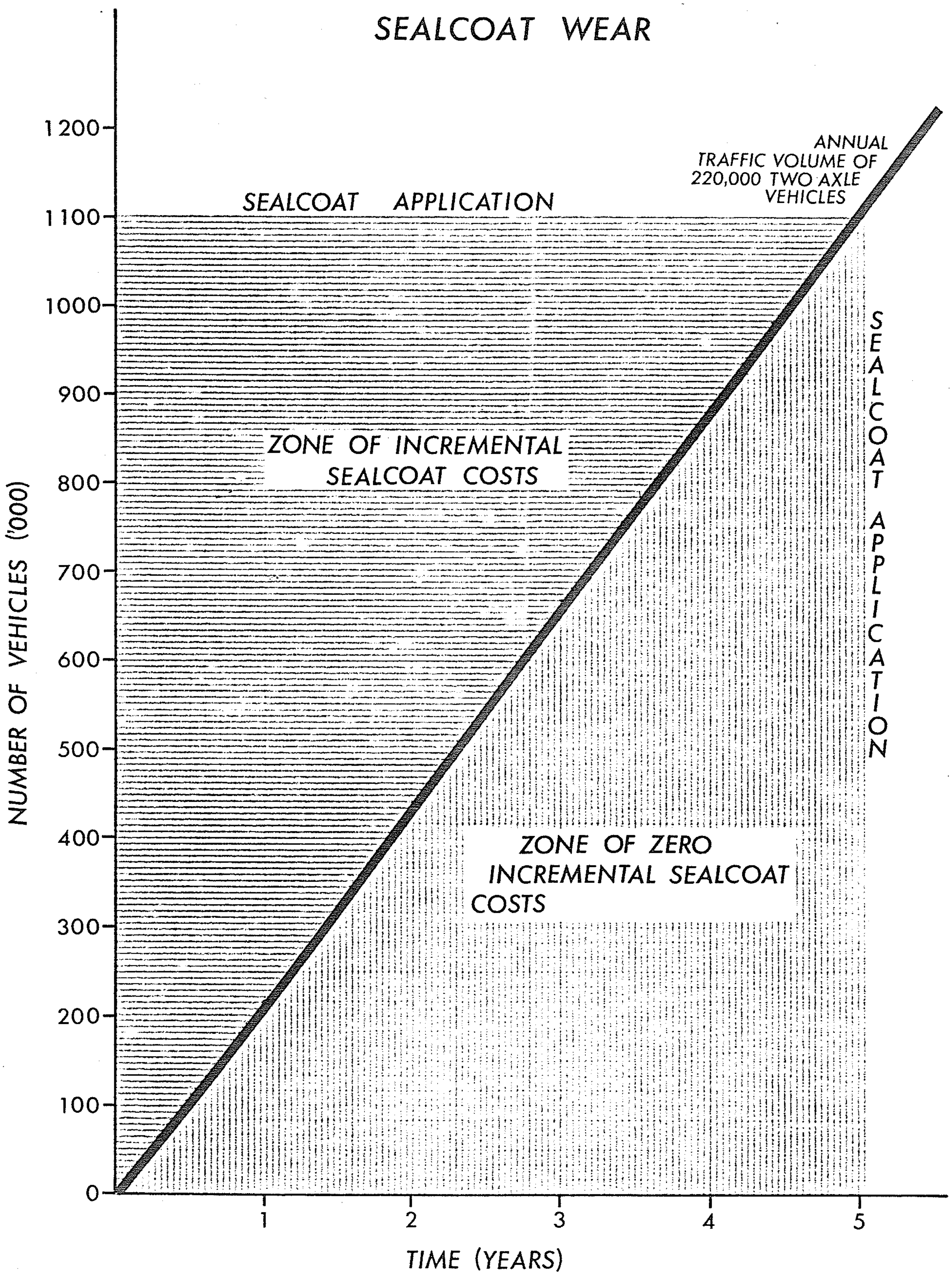
[91] Mr. Alex Livingston, Materials Section, Manitoba Department of Highways was most helpful in several interviews in Winnipeg, May, 1974.

FIGURE 3


SEALCOAT WEAR
NUMBER OF VEHICLES ('000)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
TIME (YEARS)
1
2
3
4
5
SEALCOAT APPLICATION
ANNUAL TRAFFIC VOLUME OF 220,000 TWO AXLE VEHICLES
ZONE OF INCREMENTAL SEALCOAT COSTS
ZONE OF ZERO INCREMENTAL SEALCOAT COSTS
SEALCOAT APPLICATION

total cost equation. Should this benchmark traffic volume of 220,000 vehicles per year not be reached, then no incremental seal coat costs need be considered. In like fashion, should changes in the grain delivery pattern result in the reduction of traffic levels on roads presently carrying in excess of 220,000 vehicles per year, then the appropriate saving must be recognized.

Data Requirements

The estimation of incremental road costs (savings) that may result from changes in the grain transportation pattern requires quantitative information. The four general sets of information required are: (1) base traffic statistics for each road, (2) maintenance cost equations for each class of road, (3) capital costs of reconstruction and upgrading, and (4) seal coat costs. In addition, three criteria must be established to aid in the analysis: (1) road class traffic boundaries, (2) selection of alternate delivery points and (3) routing factors.

Base Traffic Statistics.

Base traffic statistics for each road are an essential prerequisite. Unless the base traffic load can be determined, then any attempt to estimate the costs of the incremental grain truck traffic has little validity. The base traffic load for both cars and trucks is necessary to calculate the traffic load. Cars are a relatively homogeous vehicle: once the volume is found then the total load is readily derived. Trucks, on the other hand, are present in a wide variety of sizes. Tallying the number of trucks is the easier part of the task. Gathering and utilizing information on the gross vehicle weight and number of axles is much more difficult. As is illustrated in Tables 2 and 5, the diversity of truck gross vehicle weights, number of axles and the exponential nature of the equivalent load formula results in a total traffic load that is very sensitive to variations in truck characteristics. Thus it is important to have an accurate truck population data base.

Of the two types of rural vehicles in this study--cars and trucks--trucks are the more important vehicle in terms of road impact. Data gathering efforts should be concentrated in the area of truck statistics rather than car statistics.

Maintenance Cost Equations.

The derivation of a maintenance cost equation for each class of road would be a useful tool. Each maintenance cost equation, primarily dependent upon construction quality and traffic load, would allow the calculation of incremental maintenance costs--or savings--as a result of minor changes in the grain truck traffic loads. It may not be possible, however, to derive a maintenance cost equation for each class or road. All that may be achievable is to arrive at an average maintenance cost for each class of road. While this approach introduces some error into the analysis, this error would be minor. Road maintenance costs are not a major item when compared with road capital costs. As will be discussed in Chapter IV, even the difference in maintenance costs between road classes is small when compared with other road costs.

Road maintenance costs are very sensitive to levels of traffic loads near the upper design limits of each road. The establishment of traffic load upper bounds to "trigger" upgrading in a simulation at a level which forestalls destructive traffic loads will ensure that major road damage, and, therefore, high road maintenance costs, does not occur. The upgrading "trigger" values chosen, if realistic, can allow the use of an average per mile maintenance cost for each class of road with little loss of realism.

Capital Costs.

Each Provincial Department of Highways should be an excellent source of road capital costs. Historical data and expert opinion from the highways departments would allow the calculation of the average per mile costs of reconstruction and upgrading. Once the road quality standards are set, road engineers would have little difficulty in providing the capital costs.

Bridges and other special road structures may require additional investment as a result of increased grain truck traffic loads. Average costs may not suffice in these cases but specific costs may need to be generated. In all cases, once the load requirements are known, road engineers should be able to provide accurate cost information.

Seal Coat Costs.

Annual traffic volumes of less than 220,000 vehicles--based on a two-axle vehicle--indicate that a seal coat will be applied every five years. The projected seal coat replacement year may be advanced or deferred as a result of changes in grain truck traffic volume. In such instances, the appropriate value must be recognized and included in the total cost for the grain handling and transportation system. Each Provincial Department of Highways should be able to provide the per mile seal coat cost. Since truck traffic volume is a small percentage of total vehicle traffic, and given the seal coat cost formula discussed in Appendix B, incremental seal coat cost should be minimal.

Road Class Traffic Boundaries.

A road cannot continue to carry increasing traffic loads without occurring major road damage and breakdown. Each road class is designed to carry the expected traffic load with little road damage. Once the upper expected traffic load is reached, the design limits of the road structure are being tested. At such times, the road must be upgraded to be able to handle the increased traffic. The requirement is to set an upper traffic load boundary that will act as a "trigger" to signal road improvement needs. Since it is expected that road upgrading capital costs may form a large portion of the incremental costs from changes in the grain handling and transportation system, great care must be taken to ensure that realistic "trigger" traffic loads are chosen. It would be best to look to design criteria of each Provincial Department of Highways to aid in the setting of the "trigger" loads. Since traffic load and not traffic volume is the key to this exercise, the need is to establish traffic boundaries in 18-kip equivalent applications per mile per year.

Alternate Delivery Points.

In a study such as this one, the selection of the alternate delivery point as a result of grain elevator closure is necessarily an arbitrary one. A farmer may be influenced in his choice of a new delivery point by a variety of subjective factors: the belief that a competitive point may "give" better grades, the agent and level of services, other services available at one town versus another, historical congestion times of one point versus another, and so on. No researcher can realistically weigh all of these factors and predict one hundred percent of the time where a farmer will deliver. The usual approach is to choose the nearest alternative delivery point primarily on the basis that this represents the minimum trucking cost to the farmer. This assumption, however, would only hold true if all road surfaces were homogenous, i.e. of the same surface type. Different road surfaces affect trucking costs differently with the result that the nearest elevator may not be the lowest cost one with respect to the costs of grain trucking. Each of the three road surface types has a relative trucking cost factor. Treated surface roads are the least costly to operate over with dirt roads raising costs by ten percent and gravel roads raising trucking costs by twenty percent.[92] Thus the shortest distance may not always be the minimum cost route. Even if it is, other non-trucking cost factors may influence a farmer to deliver to another point.

Routing Factors.

The route selected by a farmer is part and parcel of the alternate point selection process previously discussed. The two criteria are integrally related functions. There may be, for example, only one obvious route from a farm to each of three potential delivery points. The best route will direct the alternate point decision process. Where more than one potential route exists to any one point, obvious impracticalities should be excluded: steep

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[92] Conversation with Mr. Dan Davis, Director of Costs and Controls, CP Transport, Vancouver in September, 1974 and Mr. England of Swan River-The Pas Transfer in October, 1974.

gradients in the loaded direction, use of very soft or narrow local roads, roads where the truck gross vehicle weight exceeds the maximum weight limit on bridges, and so on.

In all cases, the optimum is to isolate each farmer's grain delivery route so that accurate incremental loadings--and costs--can be derived. The greater the emphasis upon accuracy and realism in this process, the more representative will be the total cost result.

Summary of the Conceptual Model.

The absence of a market allows non-economic forces to direct the allocation of regional road investment. Two regions of similar traffic characteristics may have dissimilar road network capacities, that is the road network of one region may be "overbuilt" in comparison to that of the other region. The result is that equal changes in traffic loads and volume may generate significantly different incremental road costs from one region to the next.

Of the two traffic factors discussed, traffic load is the more critical. Traffic load influences reconstruction year, upgrading requirements and maintenance costs. Traffic volume is a lesser factor that governs seal coat life. Whereas the traffic load cost components are relatively time independent--traffic load reductions can result in road cost savings--the traffic volume cost component is constrained by time. Cost savings expected from reductions in traffic volume may not be fully recoverable due to the seal coat maximum life expectancy of five years.

In order to calculate the road cost impact of changes in traffic load and volume resulting from rationalization, specific attention must be directed towards the collection of accurate statistics: base traffic volume, truck traffic percentage and truck population size distribution. In addition, the appropriate maintenance, capital and seal coat cost schedules need to be developed in tandem with realistic road classification traffic boundaries. Finally the impact of road surface type upon trucking costs must be recognized so that the low cost route, as perceived by the grain trucker, is discovered. This allows both the alternate delivery point and the trucking route to be estimated with a high degree of precision. These steps are important in ensuring that the analysis accurately simulates reality.

CHAPTER IV

APPLICATION TO A REGION

The preceding chapters have defined the problem, outlined background information, examined critical components and proposed a conceptual framework. The present task is to apply these endeavours by testing the model against the exigencies of the "real world". This testing process is facilitated by the existence of a regional grain handling and transportation model which can be readily extended to include a road cost component.

This chapter will: (1) briefly define simulations and argue their usefulness, (2) discuss the rationale for a manual approach, (3) present the CHAD model, (4) select an appropriate CHAD simulation for analysis, (5) outline the steps in the investigative procedure, and (6) state the road cost component results.

Simulations

Many of the weaknesses of previous studies into the regional effects of changes in the grain handling and transportation sector can be attributed to the neglect of the systems approach to analysis. The systems approach is being increasingly applied to areas of complex interrelationships as computer technology and availability improves. Computer technology allows the simulation of highly interrelated systems for many fields of study.

For the physical and behavioural sciences, simulation has come to have a specific meaning such as one provided by Maisel and Gnugnoli:

> Simulation is a numerical technique for conducting experiments...this technique involves certain types of mathematical and logical models that describe the behavior of business, economic, social, biological, physical or chemical systems (or some component thereof) over periods of time.[93]

The above definition of simulation explicitly states that simulation is applied to systems. Maisel and Gnugnoli have defined a system as:

> ...a collection of regularly interacting or interdependent components (such as machines, people, information and communications) acting as a unit in carrying out an implicitly or explicitly defined mission.[94]

A system may be an entity unto itself or it may form a subsystem of a more complex system. Systems have three major characteristics: discrete or continuous, deterministic or stochastic, and static or dynamic. These three characteristics illustrate the diversity between various systems and indicate that simulation can apply the systems approach to a large number of problems.

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[93] Herbert Maisel and Guiliano Gnugnoli, Simulation of Discrete Stochastic Systems (Chicago: Science Research Associates, Inc., 1972), p. 4.

[94] Ibid., p. 8.

Systems analysis requires that the _ceteris paribus_ condition be minimized thus demanding a thorough understanding of the system under analysis. This requirement of understanding is both an advantage and a disadvantage. It is advantageous in that the act of designing the simulation can itself result in an increased perception of the system under study as often previously unrecognized relationships or deficiencies are discovered. Cost is the disadvantage in the requirement of understanding. The amount of man-hours consumed in minimizing the _ceteris paribus_ condition is large and usually outweighs the not inconsiderable computer expenditure.

Tosterud has stated some of the contributions of the systems approach to grain transportation rationalization:

> (1) a co-ordinated and objective treatment of the many and diverse facets of the problem, (2) the means of locating and identifying bottle-necks in the flow of grain from the farm to export and domestic markets, (3) induced or simulated changes of either a technical or political nature which may be made in one transportation component or subsystem and their resultant effects on other stages and the general performance of the entire system measured, and (4) the means of identifying existing policy conflicts which may be used as an aid in formulating a general policy of grain transportation.[95]

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[95] R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis" (unpublished Doctor's dissertation; University of Manitoba, 1973).

These contributions enable the simulation of proposed rationalization models resulting in the isolation of that model which best corresponds to the objective function: all without modification of the real system in any way.

A Manual Approach

It was the original intention to simulate the road cost model at a micro-level, selecting a trucking route from each farm centroid to the delivery point. This approach, however, demanded the design of a computer program that was beyond the resources of the study. It became necessary, therefore, to conduct the analysis at a more aggregate level: that of the country elevator. Each country elevator that closes is treated as the origin point for "its" displaced grain.[96] This aggregate level of analysis, with twelve origins and nineteen potential destinations, permits a manual simulation.

The chosen aggregate level of analysis requires that two assumptions, which weaken the power of this study, be made: (1) the assumption that diverted grain will follow one route to each alternate delivery point, and (2) the assumption that all the diverted grain will move over the entire route rather than building in volume as the alternate delivery point is approached. The consolidation of traffic

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[96]The process of selecting the alternate point(s), the volume of grain trucked and the route followed are described further along in this chapter.

upon one route is unrealistic and will inflate the road impact. In such an analysis, it is difficult to draw the distinction between "acceptable" and "not acceptable" deviations from reality. Both the Brandon Study and the Province of Alberta submission (discussed in Chapter II) allocate a lower road impact to producers trucking from farms than to trucking from off-track elevators. This lower impact is due to the dispersal of producer truck traffic over the rural road network whereas traffic from off-track elevators is concentrated on one or two routes.

The approach of this study must weaken the analysis to a degree. This is regrettable but no other procedure available improves the situation. In that a major purpose of this study is to calculate the impact of rationalization upon road costs, the upward bias of this resulting traffic concentration should have the dubious benefit of ensuring that the costs are not understated.

The CHAD Model

The Stollsteimer plant location model[97] was the basis of the CHAD model developed by Tosterud.[98,99]

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[97] J. F. Stollsteimer, "A Working Model for Plant Numbers and Locations," Journal of Farm Economics, Vol. 45, No. 3 (August, 1963), pp. 631-45.

[98] Tosterud, op. cit.

[99] Appendix A contains a detailed description and critique of both the Stollsteimer model and the Tosterud model.

The CHAD model,

> was designed: (1) to analyze grain handling and transportation rationalization at the regional level, and (2) as a simulation model capable of measuring the economic impact of country elevator and delivery point closures and rail line abandonment on grain producers, country elevators and the railways.[100]

The various simulations that were utilized in the CHAD study are separable into four definable sets. The first set is composed of two parts: (1) the CHAD model was constrained to consider farmer preferences in the choice of their grain delivery point as provided under quota regulations, and (2) the model was adapted to the classic location assumption of minimum cost-distance.

Once the approach of either revealed preference or minimum cost/distance was chosen,[101] the system proceeded through the simulated abandonment of individual or combinations of (1) country elevators, (2) delivery points, and/or (3) rail lines. At each abandonment step the following information was provided: (1) an estimate of grain collection costs, (2) an estimate of country elevator operating costs, (3) an estimate of rail distribution costs,

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[100] Tosterud, op. cit., p. 1.

[101] The revealed preference approach mirrors reality in that farm deliveries are credited to the elevator to which the farmer actually delivered his grain in 1970-71, as shown in each permit book. The minimum cost/distance path allocates farm deliveries to the closest elevator to the farm centroid.

(4) an estimate of aggregate system cost, (5) the number of grain producers and amount of bushels diverted due to abandonment, and (6) the effect of abandonment on average one-way distance.[102]

The second set of simulations incorporated custom trucking of grain. Given a variety of farm truck characteristics, simulations were performed requiring that all grain producers, who owned and operated a truck with one of the given characteristics, switch to the custom trucking of their grain. The third set of simulations used the objective function of minimizing grain producer collection costs to determine the optimal location for the construction of new elevators in the study region. The final simulation set involved increasing the grain output of that regional system by 35 percent.

Simulation Selection

Of the many CHAD simulations undertaken by Tosterud, one was selected for extension via the inclusion of the road impact component. The simulation chosen best represented reality in light of the 1977 grain elevator system and the recommendations of the Grain Handling and Transportation Commission.[103]

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[102] Tosterud, op. cit., p. 2.

[103] The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: April, 1977).

The scenario elected was the one which closed the delivery points of Belleview, Broomhill, Coulter, Cranmer, Croll, Dalny, Dand, Goodlands, Lyleton, Regent, Tilston and Waskada. Figure 4 is a map of the area. At the beginning of 1970-71, all of these delivery points were open but by the end of the 1976-77 crop year, the delivery points of Belleview, Broomhill, Cranmer, Coulter, Croll, and Regent were closed. Tilston is on the CP Rail Alida Subdivision which was recommended for abandonment on June 30, 1977 by the Grain Handling and Transportation Commission[104] and subsequently abandoned on March 13, 1978. The remaining points of Dalny, Goodlands, Lyleton and Waskada are on the CP Rail Lyleton Subdivision. The Grain Handling and Transportation Commission recommended the abandonment of part of the subdivision on June 30, 1977 which would affect only the delivery point of Lyleton.[105] Lyleton was subsequently abandoned on December 7, 1977. Since the CHAD model was applied to analyze on a rail subdivision basis, the choice was between retaining all the delivery points on the Lyleton Subdivision or closing all the delivery points. It was decided that it was better to err on the "high side" rather than on the "low side" and, as a result, the simulation selected was the one which assumed that all delivery points on the Lyleton Subdivision were closed.

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[104]Ibid., p. 348.

[105]Ibid., p. 349.

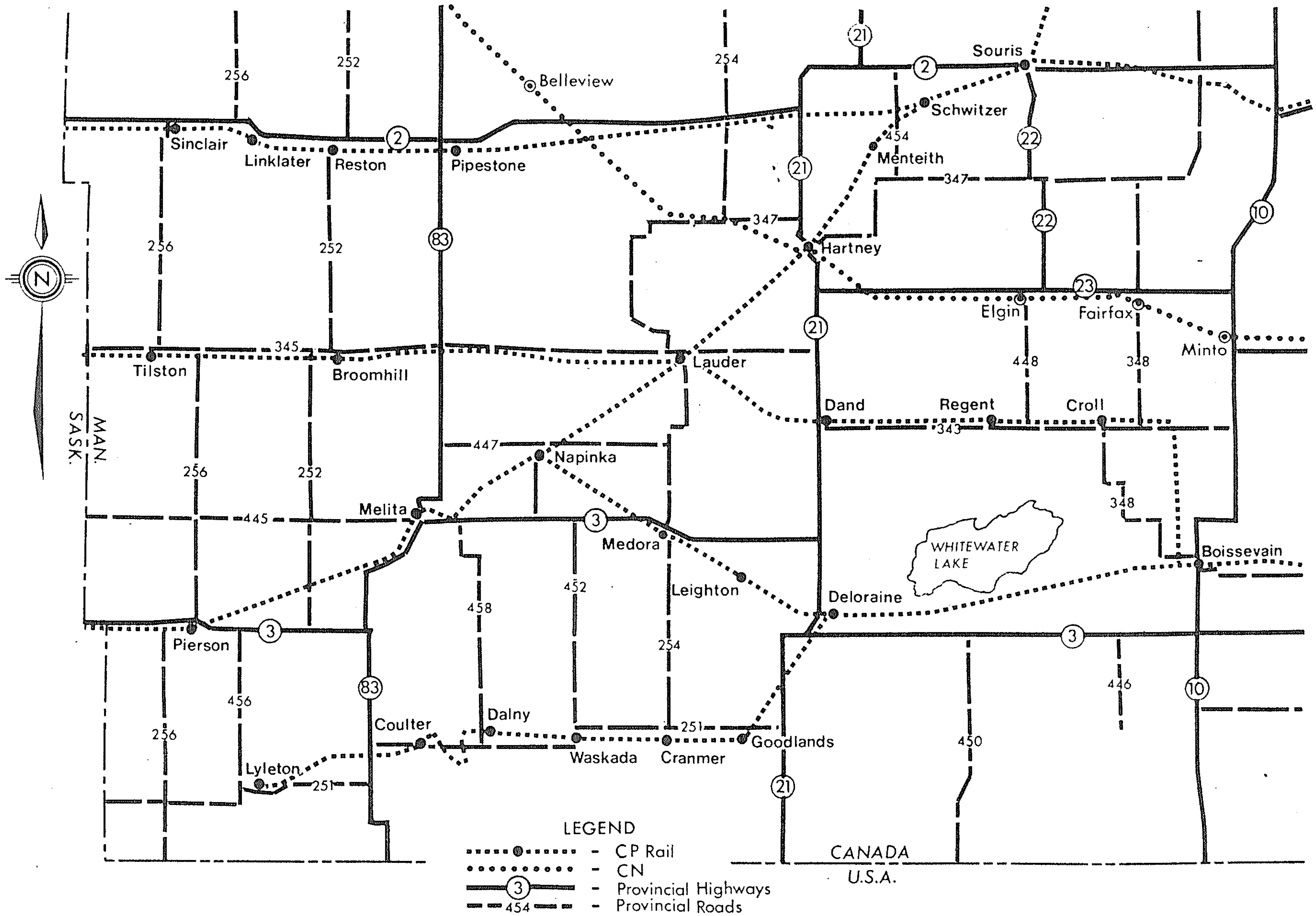

Figure 4 Boissevain Area

The revealed preference assumption was elected over the minimum cost/distance assumption. Revealed preference recognizes that a farmer may transport his grain to a delivery point other than the closest one whereas the minimum cost-distance procedure assumes that grain is delivered to the nearest elevator. The revealed preference procedure assigns grain deliveries on the basis of permit book records and, therefore, better represents reality. Once a delivery point is closed, however, the displaced grain is assigned, for each farmer, to the operating delivery point nearest the farm centroid. This was deemed the best course of action in light of the lack of supportative data for any alternate process.

Investigative Procedure

The section discusses the steps of the investigation procedure in the following sequence: (1) the selection of alternate delivery points, (2) route selection, (3) truck size determination, (4) the development of capital, maintenance and seal coat costs, and (5) upgrading criteria. Appendix B is utilized in support of this discussion.

Alternate Point.

The CHAD revealed preference simulation allocates grain deliveries to each delivery point in the Boissevain study region on an individual, farm by farm basis, using a farm centroid to delivery point distance. The CHAD simulations progressively close elevators and assign the displaced grain to alternate points using the farm centroid to delivery point data bank. In other words, grain is reassigned on a micro level; the shortest farm centroid to delivery point road distance is the sole criterion used in determining the alternate delivery point for each farmer's grain.

For those simulations closing only one delivery point, the volume of displaced grain is readily followed to the alternate point(s). Some simulations, however, close as many as six adjacent delivery points. This simultaneous closure of neighbouring delivery points does create some difficulty tracing the dispersal pattern of grain as calculated by CHAD from each newly closed delivery point. In order to quantify the road cost impact resulting from rail line abandonment, it is necessary to determine the volume of grain diverted to each alternate point. Therefore a manual sort is made of the diverted grain by calculating the incremental receipts of open delivery points and assigning the appropriate amount as determined by CHAD to the nearly closing delivery point. This approach contains an element of judgment but should introduce minimal error given the two constraints that: (1) grain is confined to the study region and (2) the minimum cost/distance criterion of the CHAD model is observed. The fact that the abandoned rail lines are separated from each other by functioning rail lines aids in the minimization of error. This fortunate separation means that grain is diverted only once and is, therefore, more readily traceable.[106] Table 6 presents the shift in grain volumes resulting from elevator closure.

CHAD does recognize that the closure of a delivery point may result in the diversion of grain to more than one or two other delivery points. Table 7 shows the diverse pattern and the grain volumes involved. Grain from one closed point is delivered to as many as five alternate points. This approach contains, therefore, a greater degree of reality than the other studies mentioned in Chapter II which diverted grain to a maximum of two alternate points.

Route Selection.

The CHAD simulations divert grain from closing delivery points to operating delivery points. The volume of grain affected is calculated by CHAD for each closing point. The amount transferred to each alternate point is also calculated by CHAD.

The manual nature of this analysis precludes the derivation of each farmer's route in the transport of grain to the alternate delivery point. It is necessary to make the assumption that diverted grain from the closed point to each alternate delivery point receiving that grain would follow one route to each alternate delivery point. These routes were selected by judgment based upon the shortest

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[106] Only Broomhill received diverted grain (6,717 bushels) before its own closure. This grain eventually is delivered to Lauder.

Table 6

Bushels Collected, Handled and Distributed by Delivery Point for CHAD System 1970-71, Revealed Preference Assumption, Boissevain Area, 1970-71

("A" denotes abandoned in simulation)

Delivery Point	Simulation 1	Simulation 2
Belleview	35,986	A
Boissevain	879,817	889,415
Broomhill	87,127	A
Coulter	45,357	A
Cranmer	69,855	A
Croll	103,813	A
Dalny	108,181	A
Dand	132,886	A
Deloraine	509,215	668,605
Elgin	415,803	549,465
Fairfax	313,687	377,236
Goodlands	307,134	A
Hartney	357,618	358,347
Lauder	118,069	168,237
Leighton	93,631	341,367
Linklater	179,183	251,933
Lyleton	247,505	A
Medora	524,017	758,600
Melita	473,438	618,527
Mentieth	117,820	117,820
Minto	360,556	360,556
Napinka	118,636	250,348
Newstead	174,077	174,077
Pierson	502,918	833,010
Pipestone	214,278	253,561
Regent	111,819	A
Reston	424,838	476,655
Sinclair	275,377	441,021
Souris	488,912	488,912
Tilston	323,172	A
Waskada	262,967	A

SOURCE: R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis" (unpublished Doctor's dissertation, Winnipeg: University of Manitoba, 1973), pp. 247-248.

Table 7

Grain Diversion by Closed Delivery Point, Alternate Point and Bushels Diverted, Boissevain Area, 1970-71

Closed Delivery Point	Alternate Point	Diverted Grain (bushels)
Belleview	Pipestone	35,986
Croll	Boissevain	9,598
	Elgin	30,666
	Fairfax	63,549
Dand	Deloraine	61,515
	Hartney	729
	Lauder	50,168
	Leighton	20,474
Regent	Deloraine	8,823
	Elgin	102,996
Broomhill	Linklater	21,683
	Melita	6,198
	Napinka	4,132
	Pipestone	3,297
	Reston	51,817
Tilston	Linklater	51,067
	Pierson	106,461
	Sinclair	165,644
Cranmer	Leighton	9,180
	Medora	60,675
Coulter	Melita	45,357
Dalny	Melita	69,660
	Napinka	38,521
Goodlands	Deloraine	89,052
	Leighton	218,082
Lyleton	Melita	23,874
	Pierson	223,631

(continued)

Table 7 (Continued)

Closed Delivery Point	Alternate Point	Diverted Grain (bushels)
Waskada	Medora	173,908
	Napinka	89,059

SOURCE:

R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis" (unpublished Doctor's dissertation, Winnipeg: University of Manitoba, 1973), pp. 247-248.

distance and a good quality road surface.[107] Treated surface roads were chosen wherever feasible. This process is supported by the conclusions of two University of Manitoba studies which found that as the proportion of grain miles on treated surface roads increases, the average cost per bushel-mile decreases.[108] From the point of view of a trucker, therefore, a treated surface road is preferred over gravel. Dirt roads were not included in the route structure as their soft roadbed is not suitable for sustained use by heavy trucks.

Truck Size.

The six road impact studies discussed in Chapter II are weakened by the assumption of one or both of the following truck sizes: (1) a 200 to 250 bushel capacity single rear axle farm truck, and/or (2) a five axle semi-trailer outfit in the 700 to 800 bushel capacity range. A major weakness of these studies is the surprising lack of a

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[107] Appendix B-1 lists the route, length of each road segment and the bushels of grain divested.

[108] E. W. Tyrchniewicz, A. H. Butler and O. P. Tangri, The Cost of Transporting Grain by Farm Truck, Research Report No. 8 (Winnipeg: Center for Transportation Studies, University of Manitoba, July, 1971).

E. W. Tyrchniewicz, G. W. Moore and O. P. Tangri, The Cost of Transporting Grain by Custom and Commercial Trucks, Research Report No. 16 (Winnipeg: Center for Transportation Studies, University of Manitoba, August, 1974).

middle ground: either farmers will continue to use single rear axle trucks or else increasing haul distances will necessitate the utilization of semi-trailer trucks.

While both of the above truck models will undoubtably be a factor in the continually evolving grain gathering system, the vast middle ground is being ignored. Many farmers will have an increased hauling distance as a result of elevator and rail line consolidation but the additional distances will not be so large as to compel the utilization of semi-trailer trucks. The majority of farmers will not be able to employ semi-trailer trucks in an economical manner as they will not have such necessary prerequisites as: a long distance to market, a large quota base,[109] a proper bin arrangement and sturdy farm yard roads. The best candidate for the "average" farm truck of the next few decades is the tandem truck.

Should average farm size increase to the stage where semi-trailer trucks are economical for the purpose of marketing grain, a need would still exist for a general purpose farm truck. A general purpose farm truck will still be necessary to perform such chores as hauling grain from the combine to the bin and assisting in seeding. The demand for such a vehicle will culminate in many farmers

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[109] A two bushel terminating quota would require 445 assigned acres in order to fill a 890 bushel capacity semi-trailer truck.

purchasing a dual purpose vehicle: able to drive into the field to assist in seeding and harvest operations while also being an economic size for transporting grain twenty, thirty or even forty miles to the delivery point. This dual purpose farm truck is the tandem.

The analysis measures the road impact of moving the displaced grain in three types of trucks: (1) a single rear-axle truck with an average capacity of 250 bushels and a load factor of 0.839, (2) a tandem rear axle truck with an average capacity of 490 bushels and a load factor of 1.257, and (3) a five axle semi-trailer truck with an average capacity of 890 bushels and a load factor of 2.246. Table 8 presents the pertinent data.[110] The measurement of the road impact from three different truck types adds more realism than the studies previously discussed. This should aid in the discovery of the direction road costs move as truck sizes vary.

Capital Costs.

Road construction costs for the study area were procured from the Manitoba Department of Highways.[111] All road bases are expected to have a life of forty years.

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[110]Appendix B-2 presents more information on the truck types in the study.

[111]Mr. Barry Prentice, District 4 Highway Engineer was most helpful in an interview in Boissevain on June 6, 1974.

Table 8

Truck Gross Vehicle Weight and Load Factor, by Truck Type

Truck	G.V.W.	Tare Weight	Load	Capacity* (bushels)	Load Factor
	(...........'000 pounds.........)				
Single Rear Axle	26	12	14	250**	0.839
Tandem Rear Axle	44	17	27	490	1.257
5-Axle Semi	74***	25	49	890	2.246

*Based on 55 pounds per bushel.

**The actual value is 255 bushels but 250 bushels was selected so that it would be comparable to other road impact studies.

***Some Provincial Highways allow G.V.W.'s in excess of 74,000 pounds but Provincial Roads and some Provincial Highways have this value as a maximum. The common denominator was selected.

Gravel roads are classified as a road base and therefore are expected to last forty years. Treated surface roads have an expected surface life of fifteen years.[112] There are no Provincial bridges in the study region that have a carrying capacity of less than 74,000 pounds G.V.W. and, as a result, there are no bridge construction costs to be considered. Table 9 presents the 1971 upgrading costs per mile for each of the road surfaces that are in the study area.[113]

The construction costs are summable, that is to say, if increased traffic volume is sufficient to cause the upgrading of a road from a 24 foot wide gravel surface to a 6 inch thick A.S.T., the total cost would be the cost of upgrading from a 24 foot wide gravel surface road to a 34 foot wide gravel surface road plus the cost of upgrading from a 34 foot wide gravel surface road to a 6 inch thick A.S.T. The cost per mile for this example would be $16,000 to upgrade from 24 foot wide gravel road to a 34 foot wide gravel road plus $15,000 to upgrade from a 34 foot wide gravel surface road to a 6 inch thick A.S.T. The total cost per mile would be $31,000.

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[112] Appendix B-3 lists the 1971 road surfaces affected by grain diversion.

[113] The 9" A.S.T. road surface is not in the study area but is present in other areas of Manitoba. It is an intermediate stage between the 6" A.S.T. and the bituminous surfaces and is slightly more durable than a 6" A.S.T. It would be applied in the upper ranges of the 6" A.S.T. traffic load.

Table 9

Road Upgrading Costs, by Road Surface Type, per Mile Basis, Boissevain Area, 1971

Road Surface		Cost Per Mile
From	To	($)
24' gravel	34' gravel	16,000
34' gravel	6" A.S.T.*	15,000
6" A.S.T.	Bituminous	34,000

*Asphalt surface treatment.

The Grain Handling and Transportation Commission compared the road upgrading cost estimates of the three prairie provincial governments.[114] The Province of Manitoba provided little detail while the other two provinces were more specific. Each province had its own road construction specifications but they are roughly comparable. The capital costs presented in Table 9 are lower than those of the provincial submissions primarily due to the different base year. The Table 9 capital costs are for 1971 while the provincial costs are for 1975.

Once placed upon the same basis, the study costs and the provincial costs are roughly equivalent. For example, the Province of Saskatchewan estimated the 1975 costs of upgrading a 24 foot wide gravel road to a 28 foot wide bituminous (plant mix) surface standard to range from $74,000 to $174,000 per mile.[115] The 1971 study costs presented in Table 9 total $65,000 per mile to upgrade a 24 foot wide gravel road to a 34 foot wide bituminous surface road. Using an index value of 153[116] to bring the study costs to a 1975 basis, the road upgrading cost would be

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[114]The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: April, 1977), pp. 75-77.

[115]Ibid., p. 77.

[116]Statistics Canada, Industry Price Indexes, 62-011 (Ottawa), p. 64.

approximately $99,400 per mile--certainly in the range of the Province of Saskatchewan costs. The Province of Alberta cost submission for about the same work (a 28 foot wide gravel road upgraded to one with a plant mix surface) ranged from $90,000 to $214,000 per mile.

Maintenance Costs.

Maintenance costs are a function of many variables such as traffic volume, traffic mix, road surface treatment and road base strength. In general, as traffic volume and load increase, maintenance costs should rise. There are a large number of unquantified factors that influence road maintenance costs. Attaching specific relationships to maintenance costs--as in the construction of a maintenance cost formula--was not considered appropriate for this study. After discussion with the Manitoba Department of Highways,[117] it was decided that an annual maintenance cost could be allocated per mile for each road surface type. It was assumed that intra-surface type maintenance costs are not affected by traffic volume and thus each mile of road of the same surface type has the same maintenance cost. Increases in traffic sufficient to precipitate upgrading results in the new surface type's maintenance costs being used.

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[117] Mr. Barry Prentice, op. cit.

Table 10 presents the 1971 maintenance costs per mile of each of the five road surface types. Appendix B-4 auguments this presentation by listing the maintenance cost components.

Seal Coat Costs.

Seal coats are applied to both 6" A.S.T. and bituminous surfaces. As previously discussed, seal coat degradation is a function of time and traffic volume. Unless traffic volume exceeds 220,000 vehicles per year (based on two axles per vehicle), the seal coat will last approximately five years. Only when annual traffic volume is greater than 220,000 two-axle vehicles, will incremental traffic influence seal coat life and, therefore, road costs resulting from rationalization. Seal coat response to traffic is a function of the number of times a tire passes over the surface, not the weight upon each tire as in the case of road surface wear. Appendix B discusses seal coat wear and presents the formula which estimates the seal coat costs, if any, attributable to the rationalization scenario being analyzed.

Upgrading Criteria.

Knowledge of the incremental traffic without knowledge of the base or pre-rationalization traffic is not sufficient to enable an assessment of the costs of rationalization. The base values must be known so that the impact of incremental traffic can be calculated. The

Table 10

Maintenance Costs per Mile, by Surface Type,
Boissevain Area, 1971

Surface Type	Cost per Mile $
24' gravel	338.30
34' gravel	417.90
6" A.S.T.*	291.90
Bituminous	138.60

*Asphalt surface treatment.

Manitoba Department of Highways conducts traffic counts of Provincial Highways at four different periods during the year.[118] While some of the traffic counts also record the percentage of truck traffic, this information was not released by the Manitoba Department of Highways. The withholding of available truck statistics necessitated the use of the Brandon Study mean value of truck traffic comprising ten percent of total vehicle traffic.

The assignment of traffic volume boundaries to each road type is not a precise operation. Traffic volumes do not necessarily correlate closely with the road surface type. A gravel road may or may not have greater traffic volumes than a treated surface road. In spite of this variation, however, the general trend is to construct roads with a better surface as traffic volumes increase. In a study such as this, it may be necessary to group information to facilitate analysis. As in the Manitoba Department of Highways' classification system, daily vehicle traffic volumes are used to segregate road surface types. Using the assumption of ten percent truck traffic, these traffic volumes are transformed into equivalent applications per mile per year. Differences in average truck size are recognized for various road types. Table 11 summarizes

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[118] Released in correspondence with Mr. Angus MacLeod, P. Eng., Continuing Studies Engineer, Manitoba Department of Highways, January 30, 1975.

Table 11

Daily Traffic and Annual Load Factor Boundaries, by Road Type

Road Type	Vehicles/Day	Equivalent Applications/ Mile/Year
24' gravel	0 to 75	0 to 1,464
34' gravel	76 to 250	1,465 to 4,880
6" A.S.T.*	251 to 600	4,881 to 13,768
Bituminous	601 to 2,000	13,769 to 64,437

*Asphalt surface treatment.

both the daily traffic and the annual load factors for each road type as calculated in Appendix B.

Increasing traffic loads will shorten the expected life of a road surface and base. It is important that the cost of the decreased road life be included in any road impact study. The problem that road impact studies face is not so much one of measuring the incremental traffic load carried by each road segment--which is accurately derived from traffic surveys and accepted engineering formulae--but is one of estimating the extent of the resultant road damage. Since each road segment has unique physical characteristics, the degree of road damage inflicted by any given incremental load cannot be accurately quantified. This necessitates highway engineers estimating the impact of a traffic load increase upon the life and, therefore, the reconstruction schedule of each segment of road. Thus the appropriate incremental cost applicable to any one scenario of elevator and branch line closure is obtained via a subjective process.

As stated in Chapter I, one of the aims of this study is the objective assessment of road cost effects of a rationalization scenario. Whereas the studies discussed in Chapter II required highway engineers to estimate the reduction in road life resulting from each abandonment scenario, it is an objective of this study to provide incremental road costs without the labour intensive and subjective requirement of utilizing highway engineers for each scenario.

Discussion with Manitoba Department of Highways engineers produced the traffic boundaries shown in Table 11. These traffic boundaries were set at a sufficiently low level to insure that traffic levels could not exceed the design parameters of the roads without "triggering" an upgrading. These boundaries also allowed the use of an annual road maintenance cost per mile for each road type rather than the design of a road maintenance equation. It was decided that the setting of road traffic boundaries was sufficient to ensure that severe road life reduction would not occur. An incremental road load increase that would markedly reduce road life would also cause upgrading. Thus the costs of reduced road life are included in the upgrading costs because the upper load boundaries for each road type are set at a sufficiently low level to remove significant road life reduction as a cost component. Minor road life reduction on roads that are not upgraded will occur, however, and no costs will be allocated. These costs should be minor and as is shown by the sensitivity analysis in Chapter V, the study conclusions will not be weakened by their absence.

In summary, the incremental traffic which causes a road segment to exceed the upper bound of its category, thus "triggering" upgrading, will be assessed the pertinent upgrading costs. The companion maintenance cost of the upgraded road is also recognized and its net value is included in the analysis. Road life reduction costs are a component of the upgrading costs.

Results of the Road Cost Analysis

Prior to the calculation of the incremental road impact caused by the diverted grain, traffic statistics, cost units and upgrading decision criteria were established. Statistics on traffic volumes, the truck percentage of that traffic volume and average truck size by road type were gathered and transformed into equivalent 18-kip applications. Cost units for road construction, maintenance and seal coats were developed at 1971 levels. Upper and lower load factor boundaries were established for each road type. A seal coat formula was also developed.

The CHAD simulation allocated farm grain deliveries from the twelve closed delivery points to nineteen potential alternate points. A total of 1,835,802 bushels comprising 22 percent of the study area deliveries in 1971-72 was diverted. The diverted grain was assumed to follow one route from the closed delivery point to each alternate point. Each route was selected on the basis of shortest distance along a good quality road surface.

The road impact of transporting the diverted grain over each route is calculated three times--once for each of the three truck sizes under analysis: (1) a 250 bushel capacity, single rear axle truck, (2) a 490 bushel capacity, tandem rear axle truck, and (3) an 890 bushel capacity, five axle semi-trailer truck. It is assumed that the legal weight restrictions are observed, that overloads do not occur. Given the exponential load factor equation, overloads would have a large impact upon the incremental traffic figure. The incremental traffic load for each truck size over each segment of road is added to the base traffic load and tested against the annual load factor boundary for that segment of road. Should the boundary be exceeded, the incremental traffic is assigned the appropriate capital and maintenance costs as per the previously developed cost tables.

The same approach is followed for seal coat wear. Incremental vehicle traffic is transformed into two-axle equivalents--for example, a five axle semi-trailer is counted as two and one half vehicles. The road segment totals are tested against the previously constructed boundary and, if exceeded, the appropriate cost is applied.

The effect of the elevator closures upon road costs is surprisingly small. This section will discuss the incremental road costs under three categories of: (1) upgrading, (2) maintenance and (3) seal coats.

Upgrading Costs.

Only one segment of road is "triggered" for upgrading as a result of changes in elevator configuration. As shown in Appendix C-4, an eight mile section of 24 foot wide gravel road south of the town of Leighton exceeds its load limit. This section of road is upgraded to the standards of a 34 foot wide gravel road at a cost of $16,000 per mile for a total cost of $128,000.

The upgrading cost of $128,000 is solely assignable to the single rear axle truck with its capacity of 250 bushels. The two other truck sizes do not create a large enough load factor to "trigger" the upgrading process.

Maintenance Costs.

Under the assumptions of this study, a change in road surface type is necessary to vary annual maintenance costs per mile. Minor traffic variations, therefore, have no impact unless a road segment's base traffic load is large enough that little additional traffic is needed to "trigger" an upgrading. The upgrading of an eight mile section of 24 foot gravel road to a 34 foot gravel road is the only change in the road network resulting from the assumptions and conditions of this study. The net maintenance effect is an increase in the annual per mile maintenance cost for that eight mile road segment by $79.60. The total net maintenance cost increase is $636.80 per year.

Seal Coat Costs.

Seal coat degradation is a function of time until annual traffic volume exceeds 220,000 two-axle vehicles. As shown in Appendix C-5, the incremental traffic on treated surface roads did not cause any road segment to surpass the

220,000 vehicle factor. There were two road segments, however, which had a base traffic volume in excess of the critical value. As such, the additional traffic volumes resulting from changes in grain delivery patterns have the impact of accelerating the reapplication of the seal coat. In both cases the incremental seal coat cost is negligible.

Both of the road segments affected have a bituminous surface: (1) a five mile section of Provincial Highway #83 between Provincial Roads #345 and #447, and (2) the six mile section of joint Provincial Highways #3 and #83. The additional annual cost for Provincial Highway #83 is $0.17 per mile for a total cost of $0.85 while the additional annual cost for the joint Provincial Highways #3 and #83 is $2.82 per mile or a total of $16.92. These fractional costs total $17.77 and are a result of the slightly accelerated seal coat wear caused by the additional traffic volumes. Such minor cost increases are not significant, therefore, the additional traffic should have no impact upon current Manitoba Department of Highways seal coat schedules.

A summary of the three incremental cost categories of upgrading, maintenance and seal coats is presented in Table 12. It is important to remember that these three costs are incurred over different time periods. The upgrading cost is present during the first year but the road is expected to last for a 40 year period. The maintenance cost is an annual expenditure throughout the expected life

Table 12

Incremental Road Costs, by Category and Time Period
Boissevain Area, 1971

Cost Category	Time Period (Years)	Cost ($)
Upgrading	40	128,000
Maintenance	1	637
Seal Coat	4 to 5	-

of the gravel road. The seal coat cost is negligible and is treated as zero.

When transformed into a Present Value, using a ten percent interest rate over a 40 year life, the 1971 incremental road cost becomes $134,200. The Present Value approach, however, is neither particularly representative nor accurate since over $128,000 or 95 percent of the costs occur in the first year. In order to derive an annual cost per diverted bushel, it is better to calculate an annual cost based upon the cost of money, depreciation, and the annual maintenance charge. Using a 10 percent annual interest charge upon the $128,000 upgrading cost plus a 2.5 percent depreciation rate--the road has an anticipated 40 year life--plus the $637 annual maintenance cost, the annual incremental road cost comes to $16,637. This annual 1971 incremental road cost when restated on a bushel basis, becomes .91¢ per diverted bushel.

The Hall Commission accepted the provincial submissions that incremental annual road costs, at the 1975 level would average 3¢ per diverted bushel.[119] Bringing the 1971 study costs to 1975 levels would place the incremental road cost at 1.4¢ per diverted bushel.[120] Thus the

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[119] The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: April, 1977) pp. 515-16.

[120] Using an index value of 153, Statistics Canada, Industry Price Indexes, 62-011 (Ottawa), p. 64.

Hall Commission cost estimates are slightly greater than double the study results and, granting the expertise of the provincial highway engineers, this would at first appear to place either the study methodology or data base in doubt.

There are two reasons why this study would be expected to yield a lower per diverted bushel incremental road cost than that of the Hall Commission. Firstly, the Provinces were presenting their viewpoint that rationalization includes a cost transfer to the road system. As such, the Provincial submissions would be conservative--overstating the road cost. Secondly, the rural road network in the Boissevain area is superior to that of the Prairie average due to the absence of oil surface roads. The Provinces of Alberta and Saskatchewan have a large number of oil surface roads and, as discussed in Chapter II, there roads are the most susceptible to damage from truck traffic. It is to be expected that areas with oil surface roads would have a higher average road cost per diverted bushel than areas, such as the Boissevain study region, without this road surface type.

The effect of these two factors upon incremental road costs is unknown. The gap between the per diverted bushel costs of the Hall Commission and this study should, however, be significantly narrowed and potentially even eliminated.

CHAPTER V

SUMMARY AND CONCLUSIONS

The preceding chapters have introduced the problem, identified background issues, isolated difficulties, devised a conceptual model and undertaken analysis. This chapter will: (1) summarize the results of the analysis, (2) test the sensitivity of the solution, (3) present conclusions and policy implications, and (4) suggest areas of future research.

Summary of the Analysis

The general objective of this study was to develop a framework in which rationalization of the grain transportation system in Western Canada could be analyzed with respect to the impact upon road costs. The specific objects were: (1) to review the public positions of the principals in the rationalization process with respect to its impact upon road costs along with a critique of the methodology used, (2) to isolate the relevant criteria which should be considered in objectively assessing the road cost effects of a rationalization scenario, and (3) to utilize these criteria in the calculation of the road cost component of an available conceptual model for rationalizing the collection, handling and distribution of grain in Western Canada at a regional level.

The six studies that were reviewed attempted to estimate the road impact of changes in the rural elevator network. None had the ability to: (1) incorporate the heterogeneity of the farm truck fleet--thereby necessitating the assumption of one or two standard truck sizes, and (2) evaluate grain trucking at the fundamental level--on a farm to elevator basis. All of the five studies that endeavoured to calculate incremental road capital and maintenance costs suffered from requiring individual engineering analysis. None developed a cost formula based upon actual traffic statistics and actual engineering costs. Sensitivity analysis was precluded by the necessity of individual study by highway engineers.

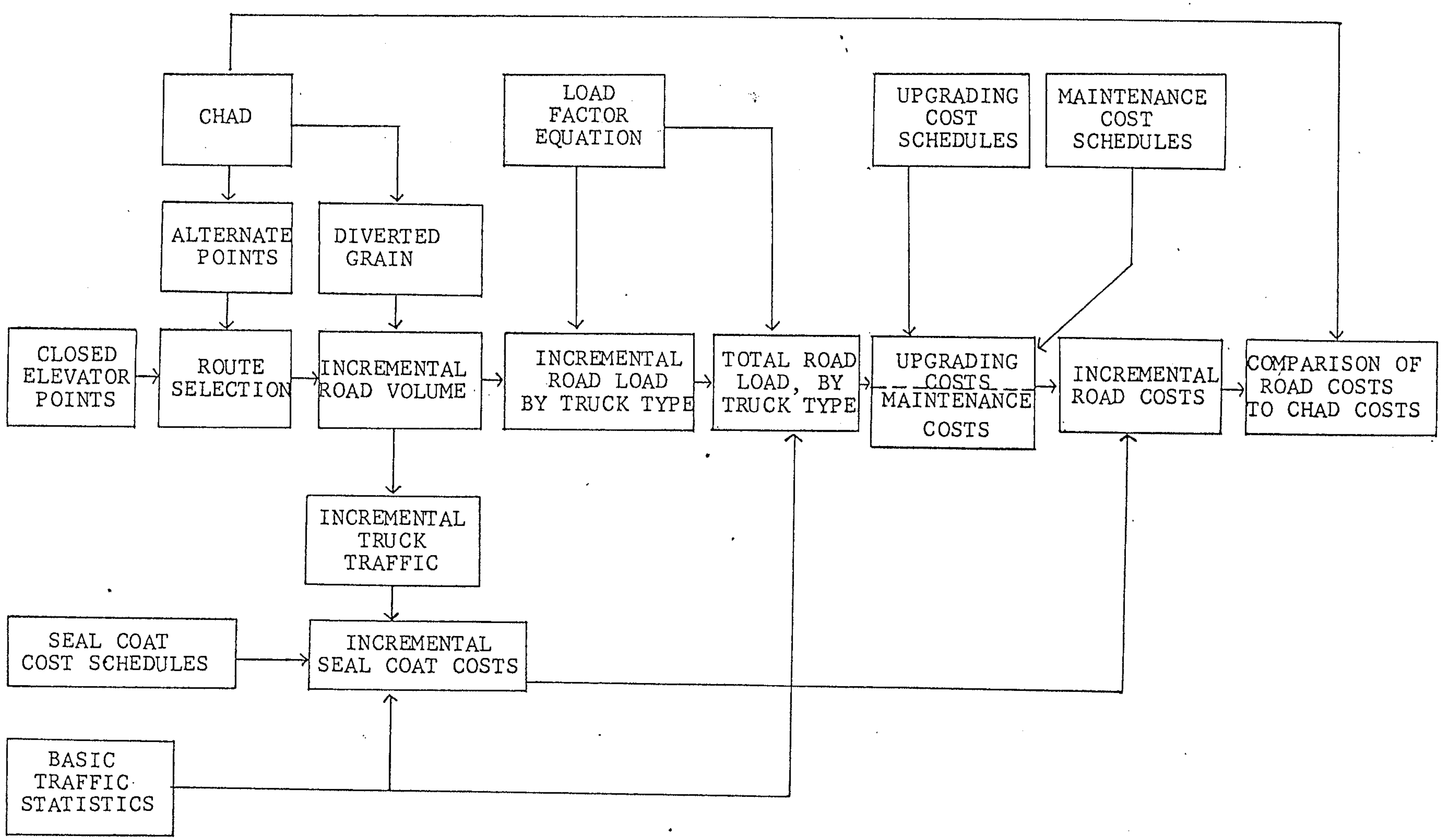
This analysis consisted of constructing maintenance, capital and seal coat cost schedules that enabled variations in the traffic load and volume of the study region. These schedules constitute a major step beyond the six studies previously reviewed.

Two important factors affecting Provincial policy were highlighted by the preceeding studies: (1) that oil surface roads are most susceptible to damage from increased traffic loads, and (2) that truck size and number of axles are key factors influencing road costs.

The CHAD elevator configuration, grain volume and grain delivery pattern results were utilized along with Manitoba Department of Highways cost and traffic statistics to develop an annual incremental road cost for three truck

FIGURE 5

Road Cost Methodology
Flow-Chart



types. Figure 5 presents the methodology in chart form. The analysis shows that the road impact from proposed changes in the grain gathering system of the Boissevain study area is minor. The annual incremental road cost is less than $16,700 which is not a significant amount when compared with the costs of other participants in the system. Table 13 illustrates the magnitude of these other costs.

As is readily apparent, the annual road cost increase of $16,700 is only ten percent of the CHAD total cost reduction. In addition, this minor road expense is assignable to only the single rear axle truck scenario and not to the other two truck size scenarios. The movement of grain in tandem or semi-trailer trucks would have an impact solely upon seal coat wear with a negligible annual cost.

The results of this analysis suggest that, at least for the Boissevain study area, rail line abandonment and elevator closure have little adverse road impact. This study's modest "pruning" of an area's grain gathering system had a negligible effect upon provincial and municipal road investment commitments. A greater contraction of delivery points would undoubtably have had a greater road impact than the study simulation. Other regions would be affected differently according to such conditions as: the road network quality and distribution, presence of oil surface roads, the amount of grain displaced, distance to alternate delivery points, base traffic volume and

Table 13

Collection, Handling and Distribution Costs, CHAD System, Revealed Preference Assumption, Abandonment Simulations 1 and 2, Boissevain Area, 1970-71

Simulation[1]	Collection Costs $	Handling Costs $	Distribution Costs $	CHAD Total Costs $
1	242,521	667,934	1,934,756	2,845,211
2	267,619	538,328	1,877,248	2,683,195

SOURCE:

R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis," (unpublished Doctor's dissertation, University of Manitoba, 1973).

[1] Simulation 1 is the system as it existed for crop year 1970-71 in the Boissevain region, Simulation 2 closes the delivery points of Belleview, Broomhill, Coulter, Cranmer, Croll, Dalny, Dand, Goodlands, Lyleton, Regent, Tilston and Waskada.

composition, and so forth. Each region must be studied separately to provide an estimate of costs. The results of the Boissevain analysis, however, leads to the conclusion that the road impact of selective elevator and rail line closure may not be as severe as other studies have claimed. It also lends support to the conclusions of the Hall Commission on road impact.

Sensitivity of the Solution

The assumptions and suppositions inherent in any research study influence the conclusions. The influence of each factor may vary greatly and this determines the stability of the conclusions. The following five factors will be discussed to ascertain their power upon the conclusions of the study: (1) traffic boundaries, (2) route selection, (3) annual traffic base, (4) base traffic truck percentage and (5) base traffic truck load factor.

Traffic Boundaries.

In the analysis, traffic boundaries for each road type were taken from the Manitoba Department of Highways classification system. The overlapping nature of road types, however, made it necessary to assign arbitrarily one road type to each traffic volume class. This arbitrary assignment of necessity abstracted from reality to some degree in that the "real life" classification system used in Manitoba is not as rigid and "compartmentalized."

In order to estimate the impact of the traffic boundaries upon the road impact, the upper bound of each road type is reduced by ten and twenty percent respectively.[122] The lower bounds are adjusted accordingly. All of the other assumptions discussed in Appendix B are retained.

Table 14 exhibits the ten percent reduction of the upper traffic boundary for each road type. The only additional road impact that results is the upgrading of eleven miles of 34 foot gravel road to a 6 inch asphalt surface treatment.[123] The upgrading cost of $15,000 per mile is slightly reduced by a maintenance saving of $126 per mile. The upgrading applies for all three truck sizes.

Reducing the upper traffic bound for each road type by ten percent slightly more than doubles the annual incremental road cost per diverted bushel.

There is no real road impact from reducing the upper bounds by twenty percent. The eight mile section of 24 foot gravel road, which was upgraded to a 34 foot gravel surface for the single rear axle scenario in the original solution, is now upgraded for tandem and five axle semi-trailer trucks. If one of these two scenarios is being analyzed,

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[122]Raising the traffic bounds would eliminate upgrading costs completely.

[123]Provincial Road #452 between Provincial Highways #251 and #3.

Table 14

Daily Traffic and Annual Load Factors by Road Type, Ten Percent Reduction of the Upper Bound

Road Type	Vehicles/Day	Equivalent Applications/ Mile/Year
24' gravel	0 to 68	0 to 1,327
34' gravel	69 to 225	1,328 to 4,391
6" A.S.T.	226 to 540	4,392 to 12,391
Bituminous	541 to 1,800	12,392 to 57,993

then an upgrading cost is applicable. For the single rear axle truck scenario, no additional upgrading costs are generated as a result of reducing the upper traffic bounds by twenty percent.

The above analysis indicates that the "solution" is relatively stable for reductions in traffic bounds by ten and twenty percent. At some stage, a reduction in upper traffic boundaries will cause massive amounts of upgrading but for as much as a twenty percent reduction, the solution is stable.

Route Selection.

The CHAD analysis assumes that grain is moved from the farm centroid to the nearest alternate delivery point. Due to a lack of resources, it was not possible to duplicate this process for an investigation into the road impact. This study assumes that diverted grain to each alternate delivery point follows only one route. This concentration of truck traffic should bias the road impact upwards. The analysis shows, however, that the road impact is both minor and relatively insensitive to changes in the upgrading "trigger" values.

The above factors lead to the conclusion that an analysis measuring the road impact of grain hauled directly from the farm centroid to the alternate delivery point would develop a relatively minor incremental road cost. It may be that there would be no road impact at all--at least within the parameters and assumptions of this model.

Annual Traffic Base.

Manitoba Department of Highways traffic statistics are used for all road types except 24 foot gravel surfaces. For this road type, due to a lack of statistics, the class median is utilized. The base traffic load is allocated for all road types based on equal traffic moving on each of the 365 days of the year. In other words, weekend traffic is assumed to be the same as weekday traffic. It may be argued that Sunday and perhaps Saturday traffic loads are different in that there would be less truck traffic. It was decided, however, that the traffic statistics would apply equally for all days of the year.

The study conclusions are not influenced by this decision. While the assumption of consistent daily traffic may inflate the yearly traffic base load, the traffic boundaries for each road type are also inflated to the same degree as both statistics are derived via the same formula. There is a slight comparative reduction, however, of the incremental traffic load from any upward bias in the base traffic load and traffic boundaries. The incremental traffic load is calculated directly and is not affected by the assumption of constant traffic for each day of the year. To the extent that the base traffic load and the road load boundaries are inflated, then the incremental traffic load from the diverted grain forms a smaller percentage than it otherwise might. Given the low sensitivity of the solution to a lowering of the traffic load boundaries previously demonstrated, the effect of assuming constant daily traffic upon the solution would be minimal.

Base Traffic Truck Percentage.

The lack of truck traffic statistics made it necessary to assume an average truck traffic percentage for the study area's traffic counts. This is an important assumption as the road impact of each truck is many times that of a car. The selection of that truck percentage does have an impact upon the study results. The ten percent truck percentage was chosen due to its use in the Brandon Study[124] as the Brandon study area is adjacent to the Boissevain study area.

The selection of a truck percentage larger than ten percent for both the base traffic load and the road boundaries would reduce the incremental upgrading costs. As just discussed in the previous section on the annual traffic base, inflated base traffic loads and road boundaries have the effect of reducing the relative impact of the incremental grain traffic. Reduction of the truck percentage, conversely, would enhance the relative importance of the

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[124]The Canada Grains Council, The Grain Handling and Transportation System in the Brandon Area (Winnipeg: Brandon Area Study Committee, 1974).

incremental grain traffic and may cause additional upgrading costs.

In the absence of local truck traffic counts, the ten percent figure is the best one to utilize in the analysis. The relative insensitivity of the solution to reductions in the traffic boundaries re-inforces the accuracy of the study results in spite of the variability implicit in the truck percentage assumption.

Base Traffic Truck Load Factors.

The methodology of the Brandon Study[125] is followed in applying separate truck load factors to the base traffic truck volume for each surface type. The average truck factor increases as the road surfaces "improve" i.e. gravel to 6" A.S.T. to bituminous. These separate truck load factors recognize that major routes have a better type of road surface and carry a different mix of truck traffic. These load factors also incorporate the appropriate empty return ratios and the effect upon the total base truck load factor.

The increasing truck load factors have the effect of reducing the impact of each incremental grain load upon the treated surface roads. This reduction in impact is due to the raising of the base traffic loads and the traffic

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[125]Ibid., background working papers.

boundaries for bituminous roads and, to a lesser degree, the 6" A.S.T. roads.

The reduction of the base traffic truck load to a common value equal to that used on gravel roads, however, has no effect. As shown in Appendix C the re-statement of 6" A.S.T. and bituminous base traffic loads and upper boundaries to incorporate a smaller truck load does not lead to the upgrading of any treated surface road. The only result is to lower the gap between the post-diversion road traffic and the upper boundaries. The study results do not change.

Conclusions and Policy Implications

The impact upon the rural road network from changes in the grain handling and transportation system has been studied over the past ten years. The magnitude of the road impact has varied greatly depending upon the assumptions in each analysis. This study utilizes an available conceptual model of grain collection, handling and distribution costs and extends it to the road cost component. The study results lead to the conclusion that, at least for the region under analysis with its current grain production volumes and patterns, the road impact of rationalization is not a major cost component. Changes in grain volumes and types may, however, have an effect upon the road impact. While the manual nature of the analysis reduces the accuracy of the model, it does have the effect of further re-inforcing the conclusions that the incremental road cost component is not a significant factor in total system costs. As was previously discussed, the manual application of the model would bias the incremental road impact upward. The use of a computer to generate a route for each farmer should, therefore, result in a lower incremental road cost.

The report of the Grain Handling and Transportation Commission[126] lends credence to the conclusions of this study. The Commission discusses the "wide array of assumptions"[127] that have to be made in assessing road costs. While cognizant of the wide variety of assumptions that can be made, the Commission stated that:

> "...additional highway costs resulting from rail abandonment and 'foreseeable' rationalization will not form a large portion of the cost of handling and transporting grain."[128]

The magnitude of the road impact will vary from region to region as a result of such factors as: degree of rationalization, condition of road network, base traffic loads, size of grain trucks utilized, and so forth. Nevertheless the general conclusion of this study should hold true: that while a cost factor, road impact is not as major an item as is sometimes stated.

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[126] The Grain Handling and Transportation Commission, Grain and Rail in Western Canada (Ottawa: Government of Canada, May, 1977).

[127] Ibid., p. 513.

[128] Ibid., p. 516.

The policy implications of the study results are germane to the current debate between the federal and provincial levels of government. Provincial governments have argued that rationalization implies a cost transfer with the share of total grain handling and transportation system costs borne by the railways, grain elevator companies and the Federal Government[129] being reduced. The farmers and Provincial Governments, in contrast, will assume a greater portion of the total costs. The provinces will have to endure increased road capital and maintenance costs resulting from expanded grain trucking.[130] The general conclusion of this study, that road impact is not as great a cost factor as is sometimes stated, may reduce provincial objections to rationalization.

The study results also pertain to present provincial vehicle licensing policy. The Province of Saskatchewan has limited the maximum gross vehicle weight of road transport

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[129]The Federal Government would have reduced Branch Line Subsidy expenditures with the abandonment of many low-density grain dependent branch lines.

[130]Alberta Transportation, in a submission to the Grain Handling and Transportation Commission in Behalf of the Government of Alberta, Saskatoon, Saskatchewan, August 30, 1976, p. 5.

Province of Saskatchewan, in a submission to the Grain Handling and Transportation Commission, Saskatoon, Saskatchewan, September 3, 1976, pp. 15-19.

Province of Manitoba, in a submission to the Grain Handling and Transportation Commission, Saskatoon, Saskatchewan, September 7, 1976, pp. 1-5.

allowed to move grain to 58,000 pounds. Under this policy, four and five axle trucks may carry only partial loads of grain, thus making the utilization of these trucks an uneconomic proposition. This regulation, implemented with the stated objective of reducing road damage, is not in harmony with the conclusions of this study. It may well be that a road cost minimizing policy would be to promote the use of large multi-axle trucks in grain service. Table 4 presented the findings of Alberta Transportation which support the conclusions of this study.

Provincial and municipal achievable road savings resulting from a switch away from the current two-axle "standard" farm truck may be significant enough to encourage the creation of public programs designed to invite farmers to purchase or to hire multi-axle trucks to transport grain from the farm to rail head position. Potential program avenues to encourage this shift in truck transport run the gambit from changes in vehicle licence and registration fees, reductions in fuel taxation,[131] accelerated vehicle depreciation rates, to capital grants to facilitate the purchase of larger trucks. The achievable road savings resulting from a shift in farm truck size will determine the appropriate program.

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[131]Tax free gasoline for farm vehicles could be authorized for use in private and commercial multi-axle grain trucks.

Suggestions for Further Research

The power and realism of the road cost model would be improved by the addition of accurate truck statistics and by a computer simulation. Each will be briefly discussed.

Before provincial governments can quantify the road cost implications of program alternatives, accurate truck traffic statistics are required. During the study year, only a few major highways in the Boissevain region had even the most elementary truck surveys, and these surveys were only vehicle counts. While vehicle counts are useful in influencing such volume-related road features as lane width, surface treatment and number of lanes, truck statistics emphasizing gross vehicle weight and the number of axles are necessary to calculate the load carried by the road structure. Load is the crucial factor that determines maintenance costs and reconstruction schedules. Load, through its effect upon oil surface roads, can also affect the surface treatment of a road. Truck statistics are, therefore, a necessary component in quantifying the expected road budget requirements and in subsequently influencing policy and program design. Provincial highways departments should expend more effort in gathering such truck statistics as gross vehicle weight and the number of axles; allowing a more accurate estimation of current road degradation patterns.

A computer simulation of the road cost model would enable the selection of a route from each farm centroid to the delivery point. This route generation process would facilitate: (1) improved accuracy in the calculation of road impacts from changes in the grain handling and distribution system, (2) a more realistic selection of the alternate delivery point, and (3) an enhanced and modified CHAD system cost structure.

As delivery points are closed in various scenarios, the computer simulation would allow the development of new farm delivery patterns to the alternate points with each scenario calculating the traffic volumes and loads. The availability of pre-scenario and post-scenario delivery patterns and road impacts would enable the ready derivation of incremental road costs (and savings). The route generation procedure would be more realistic than the assumption that the diverted grain moves over one route to the alternate delivery point.

Computer generated delivery routes may result in the selection of a different alternate elevator than that assumed by the CHAD analysis which used data provided by the Canadian Transport Commission. The Commission generated the road distance from each farm centroid to each elevator in the study area. These distances were obtained from latitude and longitude information with the result that local road surface types were not a factor. As previously discussed, farm trucking costs are influenced by the road surface so that minimum distance does not necessarily result in minimum cost. The various road surfaces in an area may induce a farmer to transport his grain to a more distant elevator than that allocated in CHAD. The minimum cost criterion is still being obeyed, only the minimum distance assumption is invalidated.

A computer simulation could incorporate a trucking cost function. Recognizing various surface types, this trucking cost function would generate a more realistic delivery pattern than that assumed by CHAD. This would change the diversion pattern of grain and have further ramifications on the CHAD cost structure. As farm delivery patterns are altered, so are farm trucking costs, elevator handling costs and, to a lesser extent, rail costs.

Analysis such as the one just completed is only a first step. The methodology needs refining so that it can be readily applied to a variety of situations. More accurate truck statistics and computerization would add accuracy and flexibility to the model. Once calculated, the incremental costs (and savings) are useful components in the formulation of policy. Those adversely affected by change are now more readily reached once accurate costs are generated. As such, this model has a place in the present debate about grain handling and transportation rationalization.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alberta Transportation. Submission to the Grain Handling and Transportation Commission. Stettler, Alberta: Province of Alberta, June 14, 1976. (Mimeographed.)

________. Submission to the Grain Handling and Transportation Commission on Behalf of the Government of Alberta. Saskatoon: Province of Alberta, August 30, 1976. (Mimeographed.)

American Association of State Highway Officials. Construction Manual for Highway Construction. Washington, D.C.: American Association of State Highway Officials, 1968.

Canada Grains Council. The Grain Handling and Transportation System in the Brandon Area. Winnipeg: Canada Grains Council, 1974.

________. State of the Industry. Winnipeg: Canada Grains Council, 1973.

Canadian Grain Commission. Internal statistical review 454.32.

Canadian National Railways. Final Submission of Canadian National Railways to the Grain Handling and Transportation Commission. Saskatoon, August 30, 1976.

Canadian Pacific Railway. Submission by F. S. Burbidge, President, Canadian Pacific Limited to the Grain Handling and Transportation Commission, Regina: October 20, 1975.

________. Submission to the Grain Handling and Transportation Commission. Saskatoon, August 31, 1976.

Channon, John W., D. Zasada, and R. T. Miller. The Boissevain Region of Manitoba. Prairie Regional Studies in Economic Geography No. 2, Economics Branch, Canada Department of Agriculture, Ottawa, 1968.

Chern, W. and L. Polopolus, "Discontinuous Plant Cost Functions and a Modification of the Stollsteimer Model," American Journal of Agricultural Economics, Vol. 52, No. 4, November, 1970.

The Commission on the Costs of Transporting Grain by Rail (Carl M. Snavely). Report: Volume I. Ottawa: Queen's Printer, 1976.

Dalvi, M. Q. "Highway Costs and Expenditures in Canada," Canadian Journal of Economics, Vol. 2, No. 4, November, 1969.

The Grain Handling and Transportation Commission. Grain and Rail in Western Canada: Volume I and II. Ottawa: Queen's Printer, 1977.

Grains Group. Grain Handling and Transportation Costs in Canada. Ottawa: Queen's Printer, 1971.

________. Economic Effects of Rationalization of the Grain Handling and Transportation System on Prairie Communities. Ottawa: Queen's Printer, 1972.

Maisel, Herbert and Guiliano Gnugnoli. Simulation of Discrete Stochastic Systems. Chicago: Science Research Associates, Inc., 1972.

Manitoba Department of Highways. Personal interviews with Mr. Alex Livingston and Mr. Barry Prentice, May and June, 1974.

Oglesly, Clarkson H. and Laurence I. Hewes. Highway Engineering. 2nd ed. New York: John Wiley and Sons Ltd., 1963.

Platts, J. B. "The Impact of a Rationalized Country Elevator System on Rural Roads and Highways in two regions of the Province of Saskatchewan." Regina: Planning Branch, Saskatchewan Department of Highways and Transportation, 1973. (Mimeographed.)

Province of Manitoba. Submission to the Grain Handling and Transportation Commission. Saskatoon: Province of Manitoba, September 7, 1976. (Mimeographed.)

Province of Saskatchewan. Submission to the Grain Handling and Transportation Commission. Saskatoon: Province of Saskatchewan, September 3, 1976. (Mimeographed.)

Roy Jorgenson Associates. Performance Budgeting System for Highway Maintenance Management. National Cooperative Highway Research Program Report, No. 131. Washington: National Academy of Sciences, 1972.

Saskatchewan Wheat Pool. Submission by Saskatchewan Wheat Pool to the Commission on Grain Handling and Transportation. Regina, October 22, 1975.

Shook, James F. and Fred N. Finn. "Thickness Design Relationships for Asphalt Pavements," International Conference on the Structural Design of Asphalt Pavements Proceedings, August 20 through 24, 1962. Ann Arbor: University of Michigan Press, 1963.

Sparks, Gordon A. Moving Grain in the 70's. Publication RP-6, Transportation and Geotechnical Group, Department of Civil Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, October, 1973.

Shurson, Gordon W. and Gordon A. Sparks. "Centralization of Country Elevator Operations and its Impact Upon the Rural Road Network," The Logistics and Transportation Review, Vol. 9, No. 2, 1973.

Statistics Canada. The Motor Vehicle, Part III: Registrations. 53-219, Ottawa: Queen's Printer, 1975.

________. Industry Price Indexes. 62-011, Ottawa: Queen's Printer, 1977.

Stollsteimer, J. F. "A Working Model for Plant Numbers and Locations," Journal of Farm Economics, Vol. 45, No. 3, August, 1963.

Straszheim, Mahlon R. "Researching the Role of Transportation in Regional Development," Land Economics, Vol. XLVIII, No. 3, August, 1972.

Tangri, O. P., D. Zasada, and E. W. Tychrniewicz. Country Grain Elevator Closures: Implications for Grain Companies. Research Report No. 10, Center for Transportation Studies, University of Manitoba, Winnipeg, Manitoba, January, 1973.

Tosterud, Robert J. "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis." Unpublished Doctor's dissertation, University of Manitoba, 1973.

Tyrchniewicz, E. W., A. H. Butler, and O. P. Tangri. The Cost of Transporting Grain by Farm Truck. Research Report No. 8, Center for Transportation Studies, University of Manitoba, Winnipeg, Manitoba, July, 1971.

Tyrchniewicz, E. W., G. W. Moore, and O. P. Tangri. The Cost of Transporting Grain by Custom and Commercial Trucks. Research Report No. 16, Center for Transportation Studies, University of Manitoba, Winnipeg, Manitoba, August, 1974.

Tyrchniewicz, E. W. and Robert J. Tosterud. "A Model for Rationalizing the Canadian Grain Transportation and Handling System on a Regional Basis," American Journal of Agricultural Economics, Vol. 55, No. 5, December, 1973.

Winch, David M. The Economics of Highway Planning. Canadian Studies in Economics, No. 16. Toronto: University of Toronto Press, 1963.

Zimmerman, Carle C. and Garry W. Moneo. The Prairie Community System. Ottawa: Agricultural Economics Research Council of Canada, 1970.

APPENDIX A

APPENDIX A

THE STOLLSTEIMER MODEL AND TOSTERUD'S MODIFICATIONS

The Stollsteimer model,

> considers the problem of simultaneously determining the number, size and location of plants that minimize the combined transportation and processing costs involved in assembling and processing any given quantity of raw material produced in varying amounts at scattered production points.[1]

The data requirements of the Stollsteimer model are:[2] (1) Estimated or actual amount of raw material to be assembled for each point or origin (raw material site). (2) A transportation-cost matrix which specifies the cost of transporting a unit of material between each point of origin and each potential plant site. (3) A plant-cost function (or functions) which permits the determination of the cost of processing any fixed total quantity of material in a varying number of plants. (4) Specification of potential plant locations.

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[1]J. F. Stollsteimer, "A Working Model for Plant Numbers and Locations," Journal of Farm Economics, Vol. 45, No. 3 (August, 1963), pp. 631-45.

[2]R. J. Tosterud, "A Simulation Model for Rationalizing the Grain Transportation and Handling System in Western Canada on a Regional Basis," (unpublished Doctor's dissertation, University of Manitoba, 1973).

Algebraically, the model may be stated as follows:[3]

$$\text{Min TC} = \sum_{j=1}^{J} P_j X_j / L_k + \sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} C_{ij} / L_k$$

where:

i = origin,

j = plant,

TC = total processing and assembly cost,

P_j = unit processing costs in plant j: (j=1...J L) located at L_j,

X_j = amount of raw material processed at plant j,

X_{ij} = quantity of raw material shipped from origin i to plant j located at L_j,

C_{ij} = unit cost of shipping material from origin i to plant j located with respect to L_j,

L_k = one locational pattern for J plants amount the $\binom{L}{J}$ possible combinations of locations for J plants given L possible locations, and

L_j = a specific location for an individual plant (j=1...J).

All potential plant sites (L) are selected by the location analyst; from these possible sites the analyst arbitrarily chooses J sites $\left[\binom{L}{J};\ J \leq L\right]$. The processing

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[3]The first term of this equation represents total processing costs and the second term, total transfer costs with a specified number of plants (J) located in a specified pattern (L_k).

costs for the J plants are summed and added to the summation of all material collection costs from I raw material sites to the J plants. The variable portion of transportation costs are rather straight forward, being a function of distance and volume, that is, simply $X_{ij}C_{ij}$. Plant processing costs can be a function of size of plant and location of plant, while the presence or absence of economies of scale will influence plant cost variations with respect to plant size. The Stollsteimer model also considers variations in per unit plant costs when plant factor costs vary with location, for example, labor costs.

Criticisms of the Stollsteimer Model

There have been five areas of criticism about the Stollsteimer model as previously presented. These areas deal with the determination of plant size, the empirical problems, the assumption of only one raw material, the assumption of no institutional restraints, and the partial equilibrium approach.[4]

In the Stollsteimer model, plant size is determined after optimal plant numbers and locations are determined. The volume of production at each plant site represents plant size, thus assuming that excess capacity cannot exist. The plant function is assumed to be linear and continuous in the sense that plant segmentation does

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[4]For a more detailed review, see Tosterud, op. cit., pp. 49-54.

not exist. All factors are completely divisible and there is no discontinuity in the rate of output.

In agricultural handling and processing operations, continuous plant cost functions are often unrealistic. The nature of a linear plant cost function precludes economies of scale in an industry's total plant cost. The assumption of a long-run total plant cost that goes through the origin is not realistic, in that, some intercept value would normally be expected. These arguments, among others, leads the Stollsteimer model to under-estimate total plant costs for the industry.[5]

The Stollsteimer model requires large data inputs for calculation of optimal results. Perhaps more serious than the amount of data required is the computational problems in terms of the number of calculations needed. Even on modern computers, the time, and therefore the expense, of calculation is very large for all but small problems.

The Stollsteimer model only considers minimizing combined transportation and processing costs for one raw material. If there is more than one raw material to be processed in a single plant, the locational problems become

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[5]W. Chern and L. Polopolus, "Discontinuous Plant Cost Function and a Modification of the Stollsteimer Model," American Journal of Agricultural Economics, Vol. 52, No. 4 (November, 1970), p. 581.

complicated. The basic Stollsteimer model lacks the ability to handle easily more than one raw material.

Another assumption of the Stollsteimer model is that of no restrictions either institutional or structural affecting the least-cost optimal location pattern of plants. In practice, this assumption means a spatial monopoly which runs counter to many laws designed to foster competition. Such laws may make the least-cost optimal solution unattainable. The model should first incorporate institutional constraints before determining the optimal number, size and locational pattern of plants.

The fifth area of weakness of the Stollsteimer model is that it represents a partial equilibrium approach. Only those elements which directly influence production at the plant site are considered. This approach is based upon four assumptions: (1) all costs are fixed or stable, (2) market demands are given and constant, (3) all other forces are exogenous variables and considered fixed, and (4) the locational decisions of other firms are not allowed to constrain the analysis.

Tosterud used the Stollsteimer model as a theoretical basis for the development of a mathematical model to represent the grain collection, handling and distribution (CHAD) system in Western Canada at a regional level. The Stollsteimer model required some modification before it could be applied to the grain transportation and handling system in Western Canada. These modifications included:[6]

1. Application to the collection, handling and distribution of grain in Western Canada. This application is unique compared to other applications of this type of model.

2. Introduction of a grain collection cost function. Rather than use a constant unit collection cost with distance being the only variable, a collection cost function is introduced where unit collection costs are dependent upon a number of variables whose values change under different conditions of grain collection.

3. Inclusion of a grain distribution activity where the estimated rail costs of movement from country elevators to export terminals are included in the model.

4. Consideration of existing processing plants (country elevators). Existing country elevators were considered in two ways: as a restraint in the model where some or all of those elevators would be forced into the final location pattern, or as possible locations for the construction of new elevators.

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[6] E. W. Tyrchniewicz and R. J. Tosterud, "A Model for Rationalizing the Canadian Grain Transportation and Handling System on a Regional Basis," American Journal of Agricultural Economics, Vol. 55, No. 5 (December, 1973), p. 806.

5. Introduction of institutional constraints such as the "freeze" on branch line abandonment, the Crowsnest Pass rail rates, and the negotiated handling rates at country elevators, compared to no constraints, was measured by the CHAD model.

In summary, the conceptual model was based upon the principal of minimizing the total cost of collecting, handling and distributing grain, subject to certain specified constraints.

Mathematically, the model may be expressed as:[7]

For given $L_k M$

$$\text{Min } TC = \sum_{i=1}^{I} C_{ij} X_{ij} + \sum_{j=1}^{J} P_j K_j + \sum_{t=1}^{T} R_{jt} X_{jt}$$

where:

TC = total collection, handling and distribution costs,

C_{ij} = cost per bushel of transporting grain from farm i to elevator j,

X_{ij} = bushels of grain transported from farm i to elevator j,

L_k = a locational pattern for J elevators among the $\binom{L}{J}$ possible combinations of locations for J elevators given L possible locations, $J \leq L$,

M = institutional constraints,

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[7]Ibid.

P_j = cost per bushel of handling grain at elevator j,

X_j = bushels of grain handled at elevator j,

R_{jt} = cost per bushel of transporting grain by rail from elevator j to terminal t, and

X_{jt} = bushels of grain transported from elevator j to terminal t.

Some Critical Limitations of the CHAD Model

In any simulation, assumptions and simplifications are made in the attempt to obtain a solution. The CHAD model contains a number of limitations as a result of simplifying assumptions.[8]

The use of a bounded production region presents many problems. After any abandonment, the farmers' alternate delivery points must lie within the region while, in reality, a delivery point outside the region might be chosen. No artificial boundaries represent actual situations and, thus, inaccuracies enter the solution. Where the advantages of a bounded region for analysis outweighs the disadvantages, then bounded regions will still be used for analysis. Hopefully, as simulation models such as CHAD become more sophisticated, then a macro analysis can be attempted that would eliminate the problems occasioned by defining a bounded region.

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[8]Ibid., p. 812.

The manner in which elevator operating costs were handled was a major limitation of the CHAD model. Since it was impossible to determine, in the case of multiple elevator delivery points, the elevator to which a farmer actually delivered his grain, elevator operating costs were estimated on a delivery point rather than an individual elevator basis. This use of delivery point costs restricted the accuracy of the elevator cost figures to some extent since elevator size stratas were used for costing.

There were other data-related problems in the CHAD model. Elevator costs were somewhat biased due to the exclusion of all non-Wheat Board grains from farmers' deliveries. Inclusion of all grains handled by the elevators should have the effect of lowering the per bushel costs on CHAD grain as some economies of scale are realized. Tosterud did run a simulation which increased system throughput to account for excluded non-Wheat Board grains but this did not remove all the inaccuracies occasioned by the exclusion of non-Wheat Board grains.

The information on the characteristics of custom trucks used in hauling grain was insufficient for a high degree of accuracy. Much of the data that was needed to accurately portray custom trucking costs was not available so that the regression equations lost much of their power. This was not a crucial flaw in the study but it, like the others, added a degree of error to the CHAD model.

Cost functions were based on different time periods than the crop year to which they were applied in the CHAD model. The cost functions of farmer-owned trucks for grain movement from the farm to the elevator were based upon a 1967-68 study.[9] Similarly the cost functions for estimating custom trucking grain hauling costs were based upon a 1967-68 study.[10] The elevator size stratas and their relative cost functions were derived from a 1968-69 based study.[11] The rail cost data which composed the distribution process were taken from previous Grains Group results which in themselves were supplied by the two major railroads. This was a potential source of error.[12] All of these data studies of different years do add some inaccuracy to the CHAD results although, hopefully, not to a major extent.

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[9]E. W. Tyrchniewicz, A. H. Butler, and O. P. Tangri, The Cost of Transporting Grain by Farm Truck, Research Report No. 8 (Winnipeg: Center for Transportation Studies, University of Manitoba, July, 1971).

[10]E. W. Tyrchniewicz, G. W. Moore and O. P. Tangri, The Cost of Transporting Grain by Custom and Commercial Trucks, Research Report No. 16 (Winnipeg: Center for Transportation Studies, University of Manitoba, August, 1974).

[11]O. P. Tangri, D. Zasada and E. W. Tyrchniewicz, Country Grain Elevator Closures: Implications for Grain Elevator Companies, Research Report No. 10 (Winnipeg: Transportation Studies, University of Manitoba, January, 1973).

[12]Grains Group, Grain Handling and Transportation Costs in Canada (Queen's Printer, Ottawa, August, 1972).

The CHAD model simulation abstracts from the effects of certain institutional constrains such as the Canadian Wheat Board quota system and block shipping system on collection, handling and distribution costs. In addition, the introduction of the alternate delivery point system makes less tenable the assumption that farmers choose their nearest delivery point when their preferred delivery point is closed due to abandonment. This makes it extremely difficult to measure the impact of rationalization on farmers' collection costs.

A further limitation of the CHAD model is its emphasis on the economic implications of rationalization. There are political and social consideration, as well as economic, to any changes in the grain collection and handling system. However, it is not possible to incorporate these changes into a simulation of this nature so that the CHAD economic emphasis, while a weakness, does not undermine the results. Once the scope of a study is defined then excluded considerations cannot be used to erode the results of that study.

APPENDIX B

APPENDIX B

BASIC DATA SERIES

The simulation of elevator closures in order to estimate the road cost impact involves a number of steps preparatory to the tracing of diverted grain traffic. A data base must first be developed so that the characteristics of the system being simulated are then specified. Finally the decision or test criteria are defined. Only after these preliminary stages are developed can a simulation commence.

Chapter IV applies the conceptual model to a regional road cost analysis. It develops the characteristics of the system being simulated and presents much of the appropriate data. This Appendix contains a variety of background information for the summary tables in Chapter IV. The following information is: (1) grain diversion routes and volumes, (2) truck load factors, (3) the road surface carrying the diverted grain traffic, (4) 1971 road maintenance cost components, (5) seal coat costs and (6) road traffic boundaries.

Grain Diversion Routes and Volume

The manual allocation procedure requires judgment to select routes from each closed delivery point to each alternate delivery point that receives diverted grain.

The routes are selected for the shortest distance along good quality gravel or surface treated roads.

Truck Load Factors

The exponential nature of the load equivalency formula requires the researcher to provide accurate and representative truck specifications. It is not possible, however, to supply definitive statistics as gross vehicle weights and tare weights vary among brands. It was decided to select representative truck models for the three truck sizes in the analysis. Discussing with dealers of trucks and trailers yielded the gross vehicle weight and tare weight data.

The Shook and Finn formula described in Chapter III is used to derive the load factor. The percentage of weight resting on each axle was furnished by the Manitoba Department of Highways and Alberta Transportation.[1]

Maintenance Cost Components

The maintenance cost components for each type of road were received from the Manitoba Department of Highways.[2] It is assumed that intra-road type maintenance costs are not affected by traffic volume or load.

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[1]Alberta Transportation, in a submission to the Grain Handling and Transportation Commission, Stettler, Alberta, June 14, 1976, p. 16.

[2]Mr. Barry Prentice, District 4 Highway Engineer, an interview in Boissevain on June 6, 1974.

APPENDIX B-1

Grain Diversion, Alternate Point,
Route, Distance and Volume,
Boissevain Study Area, 1971

Closed Point	Alternate Point	Route	Distance (miles)	Volume (bushels)
Belleview	Pipestone	Local gravel road	2	
		#2	5	
			7	35,986
Broomhill	Linklater	#345	4	
		Local gravel road	11	
			15	21,683
	Melita	#252	9	
		#445	5	
			14	6,198
	Napinka	#345	5	
		#83	5	
		#447	5	
			15	4,132
	Pipestone	#345	5	
			11	
			16	3,297
	Reston	#252	11	51,817
Coulter	Melita	#251	3	
		#83	6	
		Joint #83 & #3	6	
			15	45,357

(continued)

APPENDIX B-1 (continued)

Closed Point	Alternate Point	Route	Distance (miles)	Volume (bushels)
Cranmer	Leighton	#251 Local gravel road	4 8	
			12	9,180
	Medora	#254	10	60,675
Croll	Boissevain	#348	12	9,598
	Elgin	#343 #448	4 7	
			11	30,666
	Fairfax	#348	8	63,549
Dalny	Melita	#458 #3	13 2	
			15	69,660
	Napinka	#458 #251 #452 #3 #452	1 5 11 2 4	
			23	38,521
Dand	Deloraine	#343 #21 #3	1 6 4	
			11	61,515
	Hartney	#343 #21	1 9	
			10	729

(continued)

APPENDIX B-1 (continued)

Closed Point	Alternate Point	Route	Distance (miles)	Volume (bushels)
	Lauder	#343	1	
		#21	4	
		#345	7	
			12	50,168
	Leighton	#343	1	
		#21	6	
		#3	4	
		Local gravel road	2	
			13	20,474
Goodlands	Deloraine	#251	2	
		#21	7	
			9	89,052
	Leighton	Local gravel road	8	218,082
Lyleton	Melita	#251	6	
		#83	8	
		Joint #83 & #3	6	
			20	23,874
	Pierson	#251	3	
		#256	8	
			11	223,631
Regent	Deloraine	#343	9	
		#21	6	
		#3	4	
			19	8,823
	Elgin	#343	2	
		#448	7	
			9	102,996

(continued)

APPENDIX B-1 (continued)

Closed Point	Alternate Point	Route	Distance (miles)	Volume (bushels)
Tilston	Linklater	#345	5	
		Local gravel road	11	
			16	51,067
	Pierson	#345	2	
		#256	15	
			17	106,461
	Sinclair	#256	12	165,644
Waskada	Medora	#251	5	
		#254	10	
			15	173,908
	Napinka	#452	11	
		#3	2	
		#452	4	
			17	89,059

APPENDIX B-2

Axle Load Factors, Loaded Movement, by Truck Type

Type of Truck	Gross Vehicle Weight (lbs.)	Front Axle		Rear Axles(s)		Other Axle(s)		Total Load Factor
		Weight (lbs.)	Factor	Weight (lbs.)	Factor	Weight (lbs.)	Factor	
Single Rear Axle	26,000	9,000	0.082	17,000	0.757			0.839
Tandem Rear Axle	44,000	12,000	0.188	32,000	1.069			1.257
5-Axle Semi	74,000	10,000	0.108	32,000	1.069	32,000	1.069	2.246

SOURCE: Canada Grains Council, The Grain Handling and Transportation System in the Brandon Area (Winnipeg: Brandon Area Study Committee, 1974)--background working papers.

Alberta Transportation, in a submission to the Grain Handling and Transportation Commission, Stettler, Alberta, June 14, 1976, p. 16.

APPENDIX B-3

Road Surfaces Carrying Grain Diversion Traffic, Boissevain Study Area, 1971

Road Type	Highway Number
Bituminous	#2, #3, #83
6" A.S.T.	#21, #251 (Between #21 and #83), #452 (Between #3 and Napinka)
34' gravel	#251 (#83 west), #252, #254, #256, #343, #345, #348, #445, #447, #448, #452, #458

APPENDIX B-4

Road Maintenance Cost Components, by Road Type, Boissevain Study Area, 1971

1. 24' Gravel Surface

28 pass miles @ $2.37 per pass mile	$ 66.36
.5 reshaping @ $23.75 per reshaping	11.88
75 cubic yards of gravel @ $2 per yard	150.00
.5 sites per mile @ $64 per site (Dust control)	32.00
Subtotal	$260.24
30% overhead expenses	78.07
Total	$338.31

rounded off to $338.30 per mile

2. 34' Gravel Surface

40 pass miles @ $2.37 per pass mile	$ 94.80
.5 reshaping @ $23.75 per reshaping	11.88
85 cubic yards of gravel @ $2 per yard	170.00
.7 sites per mile @ $64 per site (dust control)	44.80
Subtotal	$321.48
30% overhead expenses	96.44
Total	$417.92 per mile

rounded off to $417.90 per mile

3. 6" A.S.T. Surface

4 premix patching @ $25.50 per patch	$102.00
Spray patching 50 gal. per mile @ $1.04 per gallon	52.00
Resurfacing 4 yards @ $14 per yard	56.00

(continued)

APPENDIX B-4 (continued)

2 pass miles @ \$4.50 per pass mile*	\$ 9.00
2 cubic yards of gravel (shoulders) @ \$2.76 per yard**	5.52
Subtotal	\$224.52
30% overhead expenses	67.36
Total	\$291.88
rounded off to \$291.90 per mile	
4. Bituminous Surface	
3 premix patching @ \$25.50 per patch	\$ 76.50
Spray patching 15 gal. per mile @ \$1.04 per mile	15.60
2 pass miles @ \$4.50 per pass mile	9.00
2 cubic yards of gravel (shoulders) @ \$2.76 per yard	5.52
Subtotal	\$106.62
30% overhead expenses	31.99
Total	\$138.61
rounded off to \$138.60 per mile	

*It costs more per pass mile to work treated surface road shoulders than to work a gravel surface road.

**A better quality gravel is used for shoulders than for gravel surfacing.

Seal Coat Costs

Seal coat applications are applied on all Manitoba surface treated roads. 1971 seal coating costs are approximately $2,250 per mile and an application will last for a maximum of five years. Regardless of traffic levels, the Manitoba climate will force a further application after that period of time. Traffic levels above the minimum volume of 220,000 vehicles per year will shorten the life span of a seal coat.[3]

Seal coat wear is a function of the number of tires which contact the road surface, not the weight carried by each tire as is the case of road surface wear. A car has the same effect upon seal coat wear as does a fully loaded single rear axle truck. A tandem truck would have the same wear effect as 1.5 single rear axle trucks while a semi-trailer truck would have the impact of 2.5 single rear-axle trucks.

Increased traffic due to rationalization which does not cause total traffic on a treated surface road to exceed 220,000 vehicles per year is assumed to have no affect upon seal coat wear. When traffic exceeds 220,000 vehicles per year, the following formula is used to calculate additional seal coat costs allowable to rationalization:

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[3]Mr. Alex Livingston, Materials Section, Manitoba Department of Highways was most helpful in several interviews in Winnipeg, May 1974.

[4]Ibid.

$$\frac{\text{Total annual vehicle traffic} - 220{,}000}{220{,}000} \times \$2{,}250$$

The assumption is that the effect of traffic volume greater than 220,000 vehicles--car or single rear-axle trucks--per year upon seal coat costs is linear.

In the event that a road has an annual base traffic volume in excess of 220,000 vehicles, then the cost for each of the two traffic volumes--"before" and "after" is calculated. The net cost is then determined by subtraction and is the incremental road cost resulting from the increased or decreased traffic.

Road Traffic Boundaries

The Manitoba Department of Highways road classification scheme forms the basis of the traffic boundaries used in the study. This schedule has five classes of roads based upon the average daily traffic of each road. As the classification system is based solely on traffic, a road surface type may be represented in more than one road class. For this analysis it is necessary to restrict each surface type to only one road class. The resulting rigidity does result in the loss of some realism but is deemed necessary to enable the consistent application of the upgrading criterion.

The base truck traffic on a road varies in composition. Major routes connecting regional centres carry a rich mixture of truck traffic while local gravel roads' truck traffic is predominantly grain. The assumption of the Brandon Study that ten percent of the traffic on each road is composed of trucks is adopted for this analysis.[5] The Brandon Study also recognizes that the average truck size on major roads exceeds that on local roads. The average truck load factor in the following calculations acknowledges this difference and is a function of both of the average of the loaded movement and the empty return.[6]

The method of calculating the traffic boundaries for each type of road is presented below. The upper bound traffic load on each road type is the "trigger value" that, when exceeded, causes a road to be upgraded.

<u>24' Gravel Surface</u> 0⟶75 vehicles per day

The lower boundary is 0; the upper boundary is:

total vehicle traffic = 75 x 365 = 27,375

10% Truck:	2,738 x .325	=	890
90% Car:	24,637 x .0233	=	574
	27,375		1,464

The load range of the 24' gravel surface road is from 0⟶1,464 equivalent 18 kip applications per mile per year.

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[5] Canada Grains Council, <u>The Grain Handling and Transportation System in the Brandon Area</u> (Winnipeg: Brandon Area Study Committee, 1974)--percentage used when a truck count was not available.

[6] Ibid.--background working papers.

<u>34' Gravel Surface</u> 76→250 vehicles per day

The lower boundary is 1,465; the upper boundary is:

total vehicle traffic = 250 x 365 = 91,250

10% Truck:	9,125	x .325 =	2,966
90% Car:	82,125	x .0233 =	1,914
	91,250		4,880

The load range of the 24' gravel surface road is from 1,465→4,880 equivalent 18 kip applications per mile per year.

<u>6" Asphalt Surface Treatment</u> 251→600 vehicles per day

The lower boundary is 4,881; the upper boundary is:

total vehicle traffic = 600 x 365 = 219,000

10% Truck:	21,900	x .419 =	9,176
90% Car:	197,100	x .0233 =	4,592
	219,000		13,768

The load range of the 6" A.S.T. road is from 4,881→13,768 equivalent 18 kip applications per mile per year.

<u>Bituminous Surface</u> 601→2,000 vehicles per day

The lower boundary is 13,769; the upper boundary is:

total vehicle traffic = 2,000 x 365 = 730,000

10% Truck:	73,000 x .673 =	49,129
90% Car:	657,000 x .0233 =	15,308
	730,000	64,437

The load range of the bituminous surface road is from 13,769 → 64,437 equivalent 18 kip applications per mile per year.

Pavement Surface > 2,000 vehicles per day

There are no paved roads in the study area.

The lower boundary is 64,438; there is no upper boundary.

APPENDIX C

APPENDIX C

DETAILED RESULTS

The manual allocation procedure selects the route from each closing delivery point to each alternate point to which the CHAD simulation has allocated grain deliveries. The Manitoba Department of Highways provided the 1971 traffic survey results for roads in the study region. These survey statistics are integrated with the truck traffic percentage and the truck load factor information provided from the Brandon Study to produce the base traffic load factor for each road segment over which the diverted grain is transported. This base load factor is the pre-rationalization traffic load.

The amount of grain transported over each road segment is converted into an incremental load factor for three different truck types: (1) a 250 bushel capacity single rear axle truck (the current "standard" farm truck), (2) a 490 bushel capacity tandem rear axle truck, and (3) an 890 bushel five axle semi-trailer truck. Each of the three truck types inflicts a different total incremental road impact when transporting the same total volume of diverted grain. The first series of tables C-1 through C-4 presents the road impact for each of the three truck types. Each table--one for all the road segments of each road surface--contains the base load factor, the three potential incremental load factors and the three total load factors.

The seal coat incremental traffic information is presented in Table C-5. The base, incremental and total number of two-axle vehicles moving over each treated surface road segment is listed. The table utilizes only the 250 bushel capacity truck as that truck size develops the largest number of incremental axles for any given volume of grain being transported.

The last three tables relate to the sensitivity analysis of restating the average base truck traffic load factor. Whereas the study utilizes the Brandon Study data of increasing average truck size in the base vehicle population as truck surface "improves", the sensitivity analysis restates the average truck load factor for all road surfaces to be the same as that for gravel roads. These tables support the conclusion in Chapter V that the restatement of base traffic loads and upper boundaries to incorporate a smaller base truck load does not lead to the upgrading of any treated surface road.

APPENDIX C-1

Bituminous Surface Base, Incremental and Total Load Factors, by Truck Type, Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle		Tandem Rear Axle		5-Axle Semi	
						Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor
2	Pipestone East	5	Belleview	Pipestone	16,786	120.8	16,906.8	91.8	16,877.8	89.8	16,875.8
3	Melita East	2	Dalny	Melita	14,917	234.1	15,151.1	178.5	15,095.5	175.2	15,092.2
3	Deloraine North	4	Dand	Deloraine	19,041	206.4		158.4		155.0	
			Regent	Deloraine	19,041	29.4		22.6		22.5	
						235.8	19,276.8	181.0	19,222.0	177.5	19,218.5
3	Jct. #21 West	4	Dand	Leighton	12,823	68.8	12,891.8	52.8	12,875.8	51.7	12,874.7
3	Joint #3 & #452	2	Dalny	Napinka	14,853	129.2		99.3		96.6	
			Waskada	Napinka	14,853	298.7		228.8		224.6	
						427.9	15,280.9	328.1	15,181.1	321.2	15,174.2
83	#345⟷#447	5	Broomhill	Napinka	20,362	14.3	20,376.3	10.1	20,372.1	11.2	20,373.2
83	Pipestone South	11	Broomhill	Pipestone	18,203	10.9	18,213.9	8.8	18,211.8	9.0	18,212.0
83	Jct. #3 South	6	Coulter	Melita	9,118	151.9		116.9		114.5	
			Lyleton	Melita	9,118	79.7		61.6		60.6	
						231.6	9,349.6	178.5	9,296.5	175.1	9,293.1
83	Joint #83 & #251	2	Lyleton	Melita	9,118	79.7	9,197.7	61.6	9,179.6	60.6	9,178.6
3, 83		6	Coulter	Melita	22,456	151.9		116.9		114.5	
			Lyleton	Melita	22,456	79.7		61.6		60.6	
						231.6	22,687.6	178.5	22,634.5	175.1	22,631.1

APPENDIX C-2

Six Inch Asphalt Surface Treatment Base, Incremental and Total Load Factors by Truck Type, Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle: Incremental Load Factor	Single Rear Axle: Total Load Factor	Tandmen Rear Axle: Incremental Load Factor	Tandmen Rear Axle: Total Load Factor	5-Axle Semi: Incremental Load Factor	5-Axle Semi: Total Load Factor
21	#343↔#345	4	Dand	Hartney	8,491	2.5		1.3		2.2	
				Lauder	8,491	168.6		128.2		125.8	
						171.1	8,662.1	129.5	8,620.5	128.0	8,619.0
21	#345↔Hartney	5	Dand	Hartney	8,491	2.5	8,493.5	1.3	8,492.3	2.2	8,493.2
21	#343↔#3	6	Dand	Deloraine	8,192	206.4		158.4		155.0	
				Leighton	8,192	68.8		52.8		51.7	
			Regent	Deloraine	8,192	29.4		22.6		22.5	
						304.6	8,496.6	233.8	8,425.8	229.2	8,421.2
21	#251↔#3	7	Goodlands	Deloraine	6,999	298.7	7,297.7	228.8	7,227.8	224.6	7,223.6
251	Coulter West	3	Coulter	Melita	2,318	151.9	2,469.9	116.9	2,434.9	114.5	2,432.5
251	Cranmer East	4	Cranmer	Leighton	6,678	31.0	6,709.0	23.9	6,701.9	22.5	6,700.5
251	Dalny East	5	Dalny	Napinka	3,924	129.2	4,053.2	99.3	4,023.3	96.6	4,020.6
251	Goodlands East	2	Goodlands	Deloraine	6,678	298.7	6,976.7	228.8	6,906.8	224.6	6,902.6
251	Waskada East	5	Waskada	Medora	4,750	583.9	5,333.9	446.2	5,196.2	438.0	5,188.0
452	#3↔Napinka	4	Dalny	Napinka	3,695	129.2		99.3		96.6	
			Waskada	Napinka	3,695	298.7		228.8		224.6	
						427.9	4,122.9	328.1	4,023.1	321.2	4,016.2

APPENDIX C-3

34 Feet Wide Gravel Surface Road Base, Incremental and Total Load Factors by Truck Type, Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle		Tandem Rear Axle		5-Axle Semi	
						Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor
251	Lyleton East	6	Lyleton	Melita	1,717	79.7	1,796.7	61.6	1,778.6	60.6	1,777.6
251	Lyleton West	3	Lyleton	Pierson	1,093	750.9	1,843.9	573.2	1,666.2	563.7	1,656.7
252	#345⟷#445	9	Broomhill	Melita	351	21.0	372.0	16.3	367.3	15.7	366.7
252	#345⟷#2	11	Broomhill	Reston	725	173.7	898.7	133.2	858.2	130.3	855.3
254	#251⟷#3	10	Cranmer	Medora	2,401	203.9		155.9		152.7	
			Waskada	Medora	2,401	583.9		446.2		438.0	
						787.8	3,188.8	602.1	3,003.1	590.7	2,991.7
256	#251⟷#3	8	Lyleton	Pierson	2,030	750.9	2,780.9	573.2	2,603.2	563.7	2,593.7
256	#345⟷#3	15	Tilston	Pierson	2,264	357.4	2,621.4	272.8	2,536.8	269.5	2,533.5
256	#345⟷#2	12	Tilston	Sinclair	1,815	556.3	2,371.3	424.9	2,239.9	417.8	2,232.8
343	Croll West	4	Croll	Elgin	742	103.2	845.2	79.2	821.2	76.4	818.4
343	Dand West	1	Dand	Deloraine	2,791	206.4		158.4		155.0	
				Hartney	2,791	2.5		1.3		2.2	
				Lauder	2,791	168.6		128.2		125.8	
				Leighton	2,791	68.8		52.8		51.7	
			Regent	Deloraine	2,791	29.4		22.6		22.5	
						475.7	3,266.7	363.3	3,154.3	357.2	3,148.2
343	Regent West	8	Regent	Deloraine	2,791	29.4	2,820.4	22,6	2,813.6	22.5	2,813.5
343	Regent East	2	Regent	Elgin	2,791	345.7	3,136.7	264.0	3,055.0	260.5	3,051.5
345	Broomhill⟷ #83	5	Broomhill	Napinka	1,483	14.3		10.1		11.2	
				Pipestone	1,483	10.9		8.8		9.0	
						25.2	1,508.2	18.9	1,501.9	20.2	1,503.2
345	Broomhill West	4	Broomhill	Linklater	1,737	73.0	1,810.0	55.3	1,792.3	53.9	1,790.9
345	Lauder⟷#21	7	Dand	Lauder	2,674	168.6	2,842.6	128.2	2,802.2	125.8	2,799.8

(continued)

APPENDIX C-3 (continued)

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle		Tandem Rear Axle		5-Axle Semi	
						Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor
345	Joint #345 & #256	2	Tilston	Linklater	1,737	171.2		130.7		128.0	
				Pierson	1,737	357.4		272.8		269.5	
						528.6	2,265.6	403.5	2,140.5	397.5	2,134.5
345	Tilston East	3	Tilston	Linklater	1,737	171.2	1,908.2	130.7	1,867.7	128.0	1,865.0
348	Croll South	12	Croll	Boissevain	1,386	31.9	1,417.9	25.1	1,411.1	24.7	1,410.7
348	Croll North	8	Croll	Fairfax	468	213.1	681.1	163.4	631.4	159.5	627.5
445	#252⟷#3	5	Broomhill	Melita	3,025	21.0	3,046.0	16.3	3,041.3	15.7	3,040.7
447	#83⟷#452	5	Broomhill	Napinka	1,151	14.3	1,165.3	10.1	1,161.1	11.2	1,162.2
448	#343⟷#23	7	Croll	Elgin	625	103.2		79.2		76.4	
			Regent	Elgin	625	345.7		264.0		260.5	
						448.9	1,073.9	343.2	968.2	336.9	961.9
452	#251⟷#3	11	Dalny	Napinka	4,138	129.2		99.3		96.6	
			Waskada	Napinka	4,138	298.7		228.8		224.6	
						427.9	4,565.9	328.1	4,466.1	321.2	4,459.2
458	#251⟷#3	13	Dalny	Melita	1,522	234.1	1,756.1	178.5	1,700.5	175.2	1,697.2
458	Dalny South	1	Dalny	Napinka	1,132	129.2	1,261.2	99.3	1,231.3	96.6	1,228.6

APPENDIX C-4

24 Feet Wide Gravel Surface Base, Incremental and Total Load Factors by Truck Type, Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor*	Single Rear Axle		Tandem Rear Axle		5-Axle Semi	
						Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor	Incremental Load Factor	Total Load Factor
Nil	Belleview South	2	Belleview	Pipestone	742	120.8	862.8	91.8	833.8	89.8	831.8
Nil	Linklater South	11	Broomhill	Linklater	742	73.0	815.0	55.3	797.3	53.9	795.9
Nil	Leighton South	8	Cranmer	Leighton	742	31.0		23.9		22.5	
			Goodlands	Leighton	742	731.6		559.4		550.3	
						762.6	1,504.6	583.6	1,325.6	572.8	1,314.8
Nil	Leighton North	2	Dand	Leighton	742	68.8	810.8	52.8	794.8	51.7	793.7
Nil	Linklater South	11	Tilston	Linklater	742	171.2	913.2	130.7	872.7	128.0	870.0

*Due to a lack of traffic statistics, the average for this road type of 38 vehicles per day was assigned as the base traffic volume.

APPENDIX C-5

Base and Incremental Two-Axle Traffic, Treated Surface Roads, Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Traffic (Vehicles)	Incremental Traffic* (Vehicles)	Total Traffic (Vehicles)
2	Pipestone East	5	Belleview	Pipestone	190,165	144	190,309
3	Melita East	2	Dalny	Melita	168,995	279	169,274
3	Deloraine North	4	Dand Regent	Deloraine) Deloraine)	215,715	246 35 281	215,996
3	Jct. #21 West	4	Dand	Leighton	145,270	82	145,352
3	Joint #3 & #452	2	Dalny Waskada	Napinka) Napinka)	168,630	154 356 510	169,140
83	#345⟷#447	5	Broomhill	Napinka	230,680	17	230,697
83	Pipestone South	11	Broomhill	Pipestone	206,225	13	206,238
83	Jct. #3 South	6	Coulter Lyleton	Melita) Melita)	103,295	181 95 276	103,571
83	Joint #83 & #251	2	Lyleton	Melita	103,295	95	103,390
3, 83		6	Coulter Lyleton	Melita) Melita)	254,405	181 95 276	254,681
21	#343⟷#345	4	Dand	Hartney) Lauder)	135,050	3 201 204	135,254

(continued)

APPENDIX C-5 (continued)

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Traffic (Vehicles)	Incremental Traffic* (Vehicles)	Total Traffic (Vehicles)
21	#345⟷Hartney	5	Dand	Hartney	135,050	3	135,053
21	#343⟷#3	6	Dand	Deloraine)		246	
				Leighton)	132,130	82	
			Regent	Deloraine)		35	
						363	132,493
21	#251⟷#3	7	Goodlands	Deloraine	111,325	356	111,681
251	Coulter West	3	Coulter	Melita	36,865	181	37,046
251	Cranmer East	4	Cranmer	Leighton	106,215	37	106,252
251	Dalny East	5	Dalny	Napinka	62,415	154	62,569
251	Goodlands East	2	Goodlands	Deloraine	106,215	356	106,571
251	Waskada East	5	Waskada	Medora	75,555	696	76,251
452	#3⟷Napinka	4	Dalny	Napinka)	58,765	154	
			Waskada	Napinka)		356	
						510	59,275

*Single rear axle trucks as this vehicle uses the greatest total number of axles to transport the diverted grain.

APPENDIX C-6

Traffic and Load Factors, by Road Type
Base Truck Size Restated,*
Boissevain Study Area, 1971

Road Type	Vehicle/Day	Equivalent Applications/ Mile/Year
24' gravel	0 to 75	0 to 1,464
34' gravel	76 to 250	1,465 to 4,880
6" A.S.T.	251 to 600	4,881 to 11,710
Bituminous	601 to 2,000	11,711 to 39,033

*Base truck load factor is .325 for all road surfaces.

APPENDIX C-7

Bituminous Surface, Base and Incremental Load Factors, Base Truck Size Restated,* Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle**	
						Incremental Load Factor	Total Load Factor
2	Pipestone East	5	Belleview	Pipestone	10,168	120.8	10,288.8
3	Melita East	2	Dalny	Melita	9,036	234.1	9.270.1
3	Deloraine North	4	Dand	Deloraine	11,534	206.4	
			Regent	Deloraine	11,534	29.4	
						235.8	11,769.8
3	Jct. #21 West	4	Dand	Leighton	7,768	68.8	7,836.8
3	Joint #3 & #452	2	Dalny	Napinka	9,017	129.2	
			Waskada	Napinka	9,017	298.7	
						427.9	9,444.9
83	#345⟷#447	5	Broomhill	Napinka	12,334	14.3	12,348.3
83	Pipestone South	11	Broomhill	Pipestone	11,027	10.9	11,037.9

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APPENDIX C-7 (continued)

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle**	
						Incremental Load Factor	Total Load Factor
83	Jct. #3 South	6	Coulter	Melita	5,523	151.9	
			Lyleton	Melita	5,523	79.7	
						231.6	5,754.6
83	Joint #83 & #251	2	Lyleton	Melita	5,523	79.7	5,602.7
3, 83		6	Coulter	Melita	13,603	151.9	
			Lyleton	Melita	13,603	79.7	
						231.6	13,834.6

*Load factor is .325, same as for the gravel surface roads.

**Only single rear axle trucks are shown as this type has the largest incremental road impact.

APPENDIX C-8

Six Inch Asphalt Surface Treatment,
Base and Incremental Load Factors,
Base Truck Size Restated,*
Boissevain Study Area, 1971

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle**	
						Incremental Load Factor	Total Load Factor
21	#343⟷#345	4	Dand	Hartney	7,221	2.5	
				Lauder	7,221	168.6	
						171.1	7,392.1
21	#345⟷Hartney	5	Dand	Hartney	7,221	2.5	7,223.5
21	#343⟷#3	6	Dand	Deloraine	7,065	206.4	
				Leighton	7,065	68.8	
			Regent	Deloraine	7,065	29.4	
						304.6	7,369.6
21	#251⟷#3	7	Goodlands	Deloraine	5,953	298.7	6,251.7
251	Coulter West	3	Coulter	Melita	1,971	151.9	2,122.9
251	Cranmer East	4	Cranmer	Leighton	5,679	31.0	5,710

(continued)

APPENDIX C-8 (continued)

Highway Number	Location	Distance (miles)	Closed Point	Alternate Point	Base Load Factor	Single Rear Axle**	
						Incremental Load Factor	Total Load Factor
251	Dalny East	5	Dalny	Napinka	3,337	129.2	3,466.2
251	Goodlands East	2	Goodlands	Deloraine	5,679	298.7	5,977.7
251	Waskada East	5	Waskada	Medora	4,040	583.9	4,623.9
452	#3⟷Napinka	4	Dalny	Napinka	3,142	129.2	
			Waskada	Napinka	3,142	298.7	
						427.9	3,569.9

*Load factor is .325, same as for the gravel surface road.

**Only single rear axle trucks are shown as this type has the largest incremental road impact.