THE UNIVERSITY OF MANITOBA

POTENTIAL ECONOMIC IMPACTS OF AN AREA TRANSPORTATION PROGRAM

by

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ABSTRACT

The objective of this project is to design a model capable of specifying the impact on area employment and income attributable to an improvement in the quality of the highway system. Essential components of the model include estimates of agricultural production, manufacturers and service dollars trade flows. The analytical framework will be based on a regional input-output model. Thus the impacts of changes in final demands associated with highway capacity investment can be estimated and projected. A secondary objective will be an assessment of the adequacy of the transportation system to meet projected final demand requirements.

The model developed for this study provides a basis for integrating engineering transportation planning concepts with those of regional economic development. The first submodel, dealing with the economic system, estimates area business sales and incomes and allocates them to towns within the region. The highway sub-model relate economic variables to traffic flows, highway design criteria and capacity requirements. The impact sub-model is formulated to measure the impacts of highway investment expenditures on area economic growth evaluated by area business sales, regional income and local employment, using a regional input-output table. The transportation capacity costs that are

not offest with increases in levels of variables evaluating area economic development measure the cost of attaining certain social goals through the highway transportation programs. For example, in rural Manitoba, it is a goal of the government to provide relatively easy access to community centers, villages, etc., and highways are the major instrument used to achieve this goal. The economic issue concerns the ratio of economic impacts derived from the model, i.e. the change in income and employment associated with a dollar of highway investment. The simplest case is when economic impacts are negligible; then highway construction expenditures should be entirely allocated to the achievement of non-economic goals.

The results obtained indicate that business sales and incomes only increase by a fraction of highway construction expenditures, even after allowing for multiplier effects.

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

The ARDA-FRED Interlake development plan, spanning the years 1967-68 to 1976-77, called for expenditures of $85 million "to promote its (Interlake's) economic development, to increase income and employment opportunities and to raise standards of living".[1] More than ten percent of the planned expenditures were allocated to the road program, which was formulated to facilitate school consolidation and to upgrade east-west access to the adult training centre. The road program was to provide a means to increase productivity in the area by providing more skilled workers, and to contribute in this way to achieving the plan objective of greater income.

The Interlake development plan was formulated under federal-provincial agreement as a means to achieving a "better" distribution of income among regions in Canada. Two sets of arguments have been used to promote the lessening of regional disparities. It has been argued that the loss due to regional re-distribution of income might be more than offset by the gains in poorer areas.[2] In essence, this is the

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[1] Interlake of Manitoba Federal-Provincial Rural Development Agreement of 1967, (Ottawa: Department of Forestry and Rural Development, 1967), p. 7.

[2] The opposite argument, that regional re-distribution of incomes might retard national growth, has been put forward as well. See T.N. Brewis, Regional Economic Policies in Canada, (Toronto: MacMillan, 1969), pp. 90-92.

argument for a more egalitarian personal distribution of income applied to regions. The lessening of regional income disparities has also been argued for on political grounds, such as, to preserve national unity.[3]

This distributive approach has succeeded to a policy of encouraging high-growth regions. It has been argued that greater gains can be made by promoting high-growth regions than by equalizing the regional distribution of income. The debate surrounding these two policy alternatives is beyond the scope of this study. The choice between the two policies has numerous implications for individual countries where there are regional disparities. The problem even presents itself, although in much more complex form, at the world level, where attention has been focussed on the gap between richer and poorer countries.

In Canada, a recent study found that the regional distribution of income did not change significantly between the mid 1920's and the mid 1960's.[4] Apart from equalization grants, no governmental action was taken to reduce the problem until the enactment of the Agricultural and Rural Development Act (ARDA) and the creation of the Fund for Rural Economic Development (FRED) by the federal government.

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[3] P.E. Trudeau, Federalism and the French-Canadians, (Toronto: MacMillan, 1967), pp. 21-45.

[4] S.E. Chernick, Interregional Disparities in Income, (Ottawa: Economic Council of Canada, Staff Study no. 14, 1966), p. 65.

Subsequently, interest in regional problems developed to the point where the federal Department of Regional Economic Expansion was created to coordinate and administer the regional programs of the federal government. One of the results of this activity was the formulation and implementation of the Interlake development plan and of its constituent programs, of which the road program is one of the largest.

PROBLEM STATEMENT

A total of some $8.85 million was allocated to the road program, of which $2.47 million was earmarked for highways, on the basis of planners' judgements as to the region's needs and the economic impact of these programs expenditures. Regardless of the question of soundness of these judgements, it is necessary to have an objective method to assess these needs. Such a method would have several advantages. First, it would provide quantitative estimates of needs and of economic impacts, and thus bring more information into the decision-making process. Second, it would bring out implicit assumptions made about relevant variables and their growth paths, and so clarify what is being decided. Finally, the development of an objective method leads to criticism of that method, to its improvement and to better decision-making. The purpose of this study is to take the initial step in constructing an objective method for the evaluation of highway needs and of the impact of highway construction expenditures.

OBJECTIVES AND CONTRIBUTIONS

The objectives of this study are: to construct a model to evaluate the need for, and impact of, highway construction expenditures on a regional economy; to estimate the coefficients of the model for Manitoba's Interlake area and to compute the highway investment needs and their impacts on the Interlake economy; and, finally, to conduct a sensitivity analysis so that the effect of different assumptions may be computed.

The development of the model constitutes the major contribution of this study. Although the model will certainly lack many refinements, it will represent a step in the development of an objective planning method for assessing highway needs and impacts in the context of a regional economy. Moreover, the specific application of the model to the Interlake area will allow planners for that region to gain wider insights into the functioning of the regional economy and to obtain some estimates of the effect of the highway program on the development of the region.

OUTLINE OF THE STUDY

The region is the focus of this study. The literature review in the following chapter discusses objectives of transportation programs in a regional framework. The choice of planning procedure is discussed in the light of the objectives selected. Some elements of the chosen planning procedure are then selected and problems involved in their use are raised. The theoretical model is elaborated in Chapter 3. The model consists of three sub-models which are interlinked. The economic sub-model computes business sales and incomes. These are used in the highway sub-model to estimate traffic flows, highway needs and required investment. The impact sub-model is used to quantify the effect of highway investment on the economic and highway systems. Chapter 4 discusses the application of the theoretical model to the Interlake area. Data sources and utilization of the data are briefly discussed. Modifications to the theoretical model are required because of empirical problems which are explained at length. The limitations of the model are presented in Chapter 5. In Chapter 6, the results of the empirical model are presented for the Interlake area. Chapter 7 concludes with a summary of the study.

Chapter 2

LITERATURE REVIEW

The objectives of the ARDA-FRED highway program were to facilitate school consolidation by improving bussing possibilities and to upgrade ease of access to the adult training centre by bettering east-west routes. The achievement of these objectives contributes to increasing productivity and thus attaining the plan objective of raising incomes. Highway investment programs can have a wide range of other objectives, which the literature has distinguished. The choice among objectives can influence the planning procedure best suited to the problem at hand. Alternative planning procedures thus need to be evaluated for their relevance to the problem. Once the choice of planning procedure is settled, there remains a choice among alternative methods of effecting the chosen procedure. These matters of methods can best be resolved by seeking through the literature for options, and then choosing the best possibility.

CHOICE OF OBJECTIVES

As indicated above, highway investment programs can have numerous objectives. These can be grouped into two categories: economic, and social. The economic objectives can be further classified under the heading of efficiency and of development.[1] The efficiency criterion can be stated alternatively as minimizing costs for a given level of traffic, or as maximizing the benefit-cost ratio, given the level of traffic to be satisfied.[2] Two types of development criteria have been proposed. One defines development in terms of additional traffic volumes using a highway because of reduced transportation costs.[3] This definition in effect considers only traffic development. On the other hand, one can choose to focus on the economic impacts of highway investment. Thus the development criterion is defined as the level of increases in local business sales, employment and income, subject to budgetary constraints and the achievement of social goals.[4] The definition of social objectives of highway investment programs is quite difficult. Broadly speaking, the social objectives are those goals which society deems desirable, and which might be achieved by the highway program. For example, although the ARDA-FRED plan proposes the highway program as a means to increasing productivity by

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[1] H. G. van der Tak and A. Ray, The Economic Benefits of Road Transport Projects, Report no. EC-160, (Washington: International Bank for Reconstruction and Development Association, 1968), pp. 1-4. See also J. A. MacMillan, "Evaluation of Regional Development Programs: Application of Planning, Programming and Budgeting, Benefit-Cost and Systems Analysis Methodology" (paper presented to the Engineers and Resource Management Conference, October 1970, Winnipeg, Manitoba), pp. 15-17.

[2] H. G. van der Tak and A. Ray, loc. cit.

[3] Ibid.

[4] J. A. MacMillan, "Evaluation of Regional Development Programs: ...", pp. 15-17.

encourating education, and it thus has implications for economic development; however, in terms of the highway investment program per se, encouraging better education constitutes a social goal. Other examples of social goals include improved access to major centres, accident reduction, encouragement of tourism, etc. An economic evaluation of a highway program in terms of these social objectives is very difficult, because of the difficulty in obtaining economic criteria for units of intangible achievement (e.g. the valuation of the saving due to a person's death being prevented), or even of measuring the intangibles themselves (e.g. quantifying, in economic terms, accessibility). Thus a highway investment program is effective, to a varying extent, in promoting various economic and social objectives.

Inevitably, some of the objectives must conflict. For example, the accident-reduction objective must be traded off against cost-minimization. So must economic development be traded off against cost-minimization. Thus a scale of preference among objectives is required in order to evaluate a highway investment program. Given the primary objective, the evaluation procedure considers other goals as limits on the extent to which the first objective is pursued.

Since this is an economic study, it considers the economic goals to be most important. In particular, the highway program's effect on the economic well-being of an area's residents are of greatest concern. This effect is measured in terms of business sales, employment and income. The pursuit of the development criterion is subject to available funds for regional development purposes, and to the requirements for highway investment due to highway capacity deficiencies. It will be assumed that the cost-minimization problem has been solved before investment is committed, i.e. that the most efficient combination of resources is known and used to provide increased capacity.

CHOICE OF PLANNING PROCEDURES

As mentioned earlier, the choice of objectives has implications for the choice of a planning procedure. For example, the efficiency criterion would require a different planning method from that required by the development criterion, as will become clear in this section. Many alternative procedures were examined, and the one that seemed the best for purposes of this study was selected. The review of procedures considers first the planning method currently in use in the Manitoba Department of Highways. The theoretical analyses of planning-programming-budgeting, benefit-cost analysis and systems analysis are then briefly outlined.

Current practice in Manitoba is to begin by an assessment of the sufficiency of the highway systems to meet present needs.[5]

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[5] Bryan K. Johnston, "The Total Highway Programming Process in the Province of Manitoba", (paper presented at the Highway Programming Workshop, December, 1969, Denver, Colorado), pp. 1-5.

Determination of need is based on twelve factors, including the condition of the road, shoulder and sightlines, the accident rate and traffic service. Highway sections are either found to be currently deficient or their time of deficiency is computed. All sections presently deficient or which will become so in the next five years are noted. For these sections, detailed estimates of required investments are computed. They are then noted for priority on the basis of

1. Condition of roadway
2. Ratio of current design hours volume to limiting service volumes
3. Geometrics
4. Cost to improve relative to vehicle miles of travel.[6]

These projects, which form the "priority pool", are then scheduled after the "assigned pool" projects have been deducted from available funds for a given year. The "assigned pool" is made up of projects such as the construction of a new highway, completion of previously started work, commitments undertaken with other agencies.

The resultant schedule may then be modified to take into account equity in the distribution of work across the province,

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[6] Ibid., p. 5.

continuity of route development, requirements for greater lead time by the Districts, and so on. In other words, funds are allocated almost exclusively on the basis of engineering needs. The procedure does not consider the problem as one of economic optimization.

In essence, the approach used is that of Planning-Programming-Budgeting. It consists of determining the objectives which a program is to meet, along with a priority rating among objectives, determining a program designed to meet these goals, and estimating the program expenditures for several years in the future, or until the program is terminated. This approach relates expenditures to objectives, and assumes that the most efficient means possible are used to achieve the objectives. But it does not present any analysis of the program's effects on the economy.

The scope of cost-benefit analysis is less than that of Planning-Programming-Budgeting in that it is designed primarily for use with single projects rather than with programs. Its purpose is to determine the most efficient -- yielding the greatest benefits over costs, all discounted to the present -- way of doing something. It can determine the best way of several of accomplishing a project, or the best project among several possibilities for a program. As has been pointed out, it is a widely used planning tool,[7] but it

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[7] A. R. Prest and H. Turvey, "Theories of Cost-Benefit Analysis", American Economic Association and Royal Economic Society (ed.), Surveys of Economic Theory, Volume III, (New York: MacMillan, 1967), pp. 155-156.

has serious limitations. For instance, it fails to consider changes in the economic system caused by relatively large projects. It has been modified to some extent to consider changes in demand conditions for highway projects, by developing a method to synthesize a market for highway services.[8] Treating benefits as cost changes allows the derivation of a supply curve. The demand function for the highway's services is then estimated, and an equilibrium defined. But, in fact, there is more than one demand curve, as there are different demands at different times of the day. This yields a number of optimal solutions, varying with time of day, season, and so on. And no criterion for choosing among the many equilibrium points is supplied. Thus even a more sophisticated approach using cost-benefit analysis shows itself to have limitations in the analysis of highway projects. Although it does provide an economically quantifiable estimate of the effect of the project, the limitations of cost-benefit analysis greatly reduce its utility.

The systems analysis methodology consists in constructing an abstract model of the major features of the system being studied.

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[8] David M. Winch, The Economics of Highway Planning, (Toronto: University of Toronto Press, 1962).

Various events are then assumed, and their effect on the system is evaluated in terms of critical variables. For example, a model of the Northern Manitoba transportation system was attempted recently.[9] Although it did not achieve its goals, because its data requirements were too great, it has been helpful to this study in showing some of the pitfalls to be avoided. While the Northern Manitoba model was based on transport costs, the current model uses distance as an index of cost, thus implicitly assuming that cost per unit of distance is constant.[10] Moreover, the present model includes the determinants of highway travel, as well as a congestion function, highway requirements, investment, and the interaction between these variables. Although the data requirements are larger than for other planning procedures, it is only the systems analysis methodology which can consider income and employment impacts on the local economy. Thus it is the most relevant methodology for the investigation of the current problem.

MAJOR ELEMENTS OF THE MODEL

The task remains to choose the elements of the model. As mentioned above, two systems and their interactions are being

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[9] Province of Manitoba Royal Commission Report on Northern Transportation, (Winnipeg: Queen's Printer, 1969), Appendix G, pp. 546-575.

[10] While this assumption may not hold exactly for all classes of traffic, it is probably sufficient for household travel. Moreover, it might be argued that it can also apply to commercial traffic if the distances involved are fairly short.

modeled: the economic system and the highway system. The economic system may be represented by a Keynesian-type model such as was developed by Dhuvarajan and others.[11] Alternatively, a more disaggregated model can be chosen. Assuming that the same data are required for both types of models, the disaggregated model would be preferred as it can yield more information about the economy. Thus the model chosen was a disaggregated one, namely, an input-output model.

Input-Output Analysis

The fundamental ideas underlying the use of the input-output technique are quite simple, and have been reviewed in several textbooks.[12] The input-output model to be used could be one of several types: regional (describing only the trading patterns within a region) or interregional (describing the trading patterns between regions and within each of the areas). The latter can be of the "dog-leg" type, in which both exports and imports are disaggregated by purchasing and selling sectors. A full interregional model also includes inter-industry sales within all regions.[13]

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[11] P.S. Dhuvarajan, C. A. Nicolaou and J. I. Vorst, "A Multiplier Model for Northern Manitoba", in Province of Manitoba Royal Commission Report on Northern Transportation, (Winnipeg: Queen's Printer, 1969), Appendix G, pp. 546-575.

[12] For example see W.H. Miernyk, Elements of Input-Output Analysis, (New York: Random House, 1965).

[13] Ibid., Ch. 4; See also W. Isard, Methods of Regional Analysis, (Cambridge: the M.I.T. Press, 1960), ch. 8.

These models assume constant technologies and trading patterns, and are thus quite restrictive.[14] The difficulties relating to fixed production coefficients can be overcome by using data from "better" firms.[15] However, the definition of "better" firms makes the procedure arbitrary, particularly for service industries where the definition of capacity in empirical terms is even more difficult to determine than in manufacturing. The constancy of trading patterns has been held to require constant costs in both regions.[16] But, in fact, constant relative costs suffice to maintain the stability of trading patterns. However, even this less restraining version implies constancy in the relationship between regions. To the extent that the ARDA-FRED Interlake plan is successful, the Interlake - "rest of Manitoba" relationships will change, thus raising questions as to the appropriateness of using this model. Nevertheless, the model represents the best of the alternatives.

Traffic Prediction Models

Studies attempting to predict traffic flows often use one

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[14] W. Isard, loc. cit.; see also C. M. Tiebout, "Regional and Interregional Input-Output Models: an Appraisal", in L. Needleman (ed.), Regional Analysis, (Baltimore: Penguin Books, 1968), ch. 3, pp. 86-96.

[15] W. H. Miernyk, op. cit., pp. 117-125.

[16] L. Moses, "Interregional Input-Output Analysis", American Economic Review, XLV(1955), pp. 810, as quoted by C. M. Tiebout, op. cit., p. 92.

of three types of models: the gravity model, the intervening opportunities model, or the abstract mode model. The gravity model originated as an attempt to explain social phenomena by the use of physical models. It has been used quite widely with varying degrees of success.[17] This type of model has been justified at the intuitive level[18], and shown to be consistent with the theory of consumer behaviour.[19] However, it is deficient in theoretical terms, as it does not explain the causes of travel formally, but resorts to explanations in terms of attractiveness of masses for each other, whether such masses be represented by populations, business sales, or whatever. The intervening opportunities model is used primarily to allocate a given number of trips departing from an origin to several destinations. In a later formulation, it was combined with a gravity-type model to predict traffic flows between origin-destination pairs.[20]

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[17] For instance, M. Helvig, Chicago's External Truck Movements, (Chicago: University of Chicago Press, 1964). Also R. J. Wolfe, "Parameters of Recreational Travel in Ontario", Proceedings of the 1965 Canadian Good Roads Association Convention, (September, 1965, Saskatoon, Saskatchewan), pp. 235-261.

[18] W. Isard, op. cit., ch. 11.

[19] J. H. Niedercorn and B. V. Bechdolt, "An Economic Derivation of the 'Gravity Law' of Spatial Interaction," Journal of Regional Science, IX (1969), 273-282.

[20] A. N. Duggal, "A Formula for Predicting Inter-City Traffic Generation", Proceedings of the 1967 Canadian Good Roads Association Convention, (September, 1967, Vancouver, British Columbia), pp. 440-449.

But, like the gravity model, it fails to explain motivations for travelling beyond the usual appeal to masses attracting each other.

The abstract mode model represents an improvement over the gravity and intervening opportunities models in that it attempts to predict travel demand on the basis of the reasons for which travel between two points is desired and of the characteristics of the mode being considered (e.g. automobile, train, airplane, etc.) as they relate to inconvenience and cost.[21] Numerous specifications have been given to the model. But none of these different forms has emerged as the best for general use because of insufficient testing of the model.[22] However, a recent comparison of gravity and abstract mode models established that predictions based on a gravity model tended to be more accurate than those derived from the abstract mode model.[23] But neither model was clearly superior, and it was decided to formulate a composite model for this study, inspired by these discussions.

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[21] R. E. Quandt, and W. J. Baumol, "The Demand for Abstract Transport Modes: Theory and Measurement", Journal of Regional Science, VI (1966), 13-26.

[22] R. E. Quandt and K. H. Young, "Cross-Sectional Travel Demand Models: Estimates and Tests", Journal of Regional Science, IX (1969) 201-214.

[23] E. P. Howrey, "On the Choice of Forecasting Models for Air Travel", Journal of Regional Science, IX (1969), 215-224.

SUMMARY

The review of objectives outlined some of the possible criteria in the economic and social spheres. The criterion of economic development was chosen, as it reflects the highway program's impacts on the local community. The planning procedures considered included planning-programming-budgeting, benefit-cost and system analysis. Because of the scope and complexity of the analysis to be undertaken, the latter methodology was chosen. The problems associated with input-output analysis were discussed as was that of choosing an appropriate traffic forecasting model.

Chapter 3

THE THEORETICAL MODEL

Highway construction or renovation programs can be used to attain economic and social objectives. Economic objectives are exemplified by economic development. Improved accessibility to other places constitutes one of the many social goals. The ARDA-FRED highway program was designed primarily to facilitate access to educational institutions. But, along with conventional highway investments, the program expenditures have impacts on the regional economy as well as on traffic flows. The model is designed to evaluate these impacts resulting both from the ARDA-FRED projects and from conventional highway investments committed on the basis of capacity requirements. The impacts have two major aspects, namely, the multiplier processes set off by the increased government expenditures on highways and the improvement of highway conditions in the region. Thus the model represents interactions between the economic and highway systems as well as the relationships between units within each system.

The economic system is composed of two economies linked through a matrix of inter-industry as well as household transactions. These transactions are facilitated by the communications networks available to residents of the area. The highway system is a critical element in the process. Without it, goods could not easily be transferred from one locality to another within the region, nor imported or exported. Improvements, involving increased expenditure of government funds, relieve undesirable highway conditions. Assuming that highway surfaces and geometrics meet design standards, the only reason for additional investment in terms of the model is lack of capacity. The investment causes changes in the economic system through the multiplier processes, and thus generate further changes in traffic conditions. Thus the model includes the following components: outline of a town-centred transaction system of an area economy, a representation of the mechanism by which the economic system generates traffic requirements and, potentially at least, highway construction or renovation expenditures, and analysis of the impact of changes in the highway system on the economic system. These components and their links are presented graphically in Figure 3.1 on the following page.

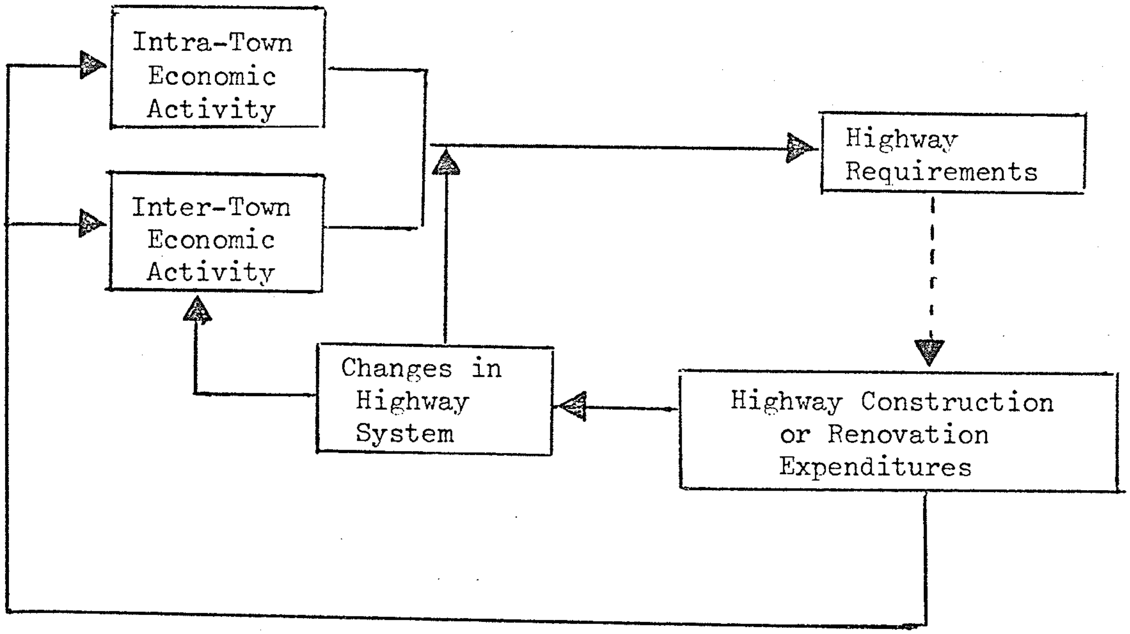

Figure 3.1

Interactions between Major Components of the Model

Broken lines indicate potential interactions

THE ECONOMIC SUB-MODEL

By economic sub-model is meant the description of the economic relationships within and between towns. But before considering individual towns, it is preferable to start from the region as a whole.

Business Sales

Given the levels of final demands for the output of each industry in the region--i.e. expenditures on consumption, investment, government services and exports--and given the structure of the area economy as depicted by an input-output table, it is possible to estimate total business sales in the area for each industry,

$$AS = (I - X)^{-1} FD \qquad (3.1)$$

since

$$X \cdot AS + FD = AS$$

where AS is a column vector of N elements, the value of yearly business sales by the N industries in the region, in thousands of dollars;

I is the identity matrix of conformable order, i.e. N x N;

X is a matrix of N x N elements, the input-output technical coefficients;

FD is a column vector of N elements, the value of yearly final demands for the output of the region's N industries, in thousands of dollars.

Equation (3.1) is the formal expression of the input-output "direct and indirect effect" multiplier. If the household sector is defined as one of the N industries, say the Nth one, an alternative expression to equation (3.1) is

$$AS = (I - X)^{-1} (G + IN + EX) \qquad (3.2)$$

where G, IN and EX are each column vectors of N elements, the value of yearly final demands for the output of the region's N industries (including households), by the government, investment and export sectors respectively, in thousands of dollars; and the other variables are as defined previously.

Equation (3.2) is the formal expression of the input-output "direct, indirect and induced effect" multiplier. It assumes that household expenditures and sales are endogenously determined. This form of the input-output multiplier has been adopted for two reasons. First, the household sector was assumed not to possess any dynamism of its own, but to progress only as a consequence of the impulses which export, government and investment final demands give to the regional economy. Second, considering the household sector as exogenous would understate the income effects of highway expenditures. The implications of the latter statement will be discussed within the framework of the impact sub-model. But defining households as the Nth industry requires that the interpretation of the vector AS be altered slightly. Henceforth, the first N - 1 elements of AS represent "area business sales", and the whole vector AS represents "area business and household sales". Unless otherwise specified, the expression "business sales", "area business sales", "town business sales", or variants thereof, exclude sales by the household sector.

Given the area business sales by sector, the total area business sales can be computed by

$$ATS = (RIV)\,(AS) - AS_N \qquad (3.3)$$

where

ATS is a scalar, the value of total yearly business sales for the region, in thousands of dollars;

RIV is a row vector of N elements, all 1;

AS_N is the value of household sales in thousands of dollars, the Nth element of the vector AS.

Equation (3.3) thus defines total yearly business sales for the region.

From the area business sales, estimated by equations (3.3) above, the model computes business sales for the M area towns. Two methods are available for estimating town business sales. The first is to construct input-output tables for each town, and to use relationship (3.2) above, to provide the required estimates. The second method is to allocate regional business sales according to some criterion such as population. The first method, the construction of town-specific input-output tables, appears preferable theoretically. However, town-specific input-output tables embody the current patterns of industrialization and urbanization. To the extent that long term growth modifies these patterns, the town-specific tables provide incorrect projections. This is also true of the area-wide table. But the area, having a greater variety of industries than any town, is less likely to see its whole industrial structure deeply altered than is a town. Moreover, the changing urbanization pattern is less likely to affect the regional estimates than those for a single centre. For these reasons, the second method was chosen and area sales are allocated to towns.

The criterion for this allocation remains to be chosen. Should population be used, or should some other factor? And if so, which one? The use of population as an allocator requires the assumption that business sales per capita do not vary between towns. This assumption does not appear to be realistic in a case where some towns are little more than fringe suburbs to a major city outside of the region whereas other towns are centres of attraction in their own right. Although population might be satisfactory for areas not dominated by a large centre it is not so for a region strongly influenced by a metropolis. However, local employment, i.e. employment within the town itself, might be better. It requires the assumption that town business sales and local employment vary together. Two reasons support this contention. First, the greater the volume of business sales in a town, the more people are employed, assuming (as has been done) linear technologies. Second, business sales are likely to fluctuate with local employment since people, not travelling to other centres for work, have less opportunity to spend their incomes in other centres, all other things being equal. Thus,

$$TS = (ATS)\ (1/AN)\ (TNU) \qquad (3.4)$$

where TS is a column vector of M elements, the value of yearly business sales in each of the M towns, in thousands of dollars;

ATS is a scalar, the value of yearly area business sales, in thousands of dollars;

TNU is a column vector of M elements, the number of people locally employed in non-agricultural industries, for each of the M towns;

AN is a scalar, the number of people employed in the area in non-agricultural industries.

Equation (3.4) allocates area business sales to towns on the basis of each town's share of area non-agricultural employment. It is assumed that the volume of business sales per locally-employed person is constant in the region. This average is multiplied by the volume of local employment in each town to obtain that town's yearly value of business sales. It should be noted that the allocation of sales to each town is done on the basis of local employment, rather than total employment. This implies that employees who commute regularly to other centres tend to spend their income in other centres as well. The out-of-town expenditure has two aspects: errand-running on the way home from work, and more importantly, increased out-of-town expenditures because of the breakdown of the time and distance barriers which result from regular commuting. In other words, regular commuting makes the route seem shorter, and it is thus less of a bother than otherwise to shop out of town.

The ratios TN / AN (one for each town might have been utilized to allocate the business sales of each sector to each town. Thus,

$$\left.\begin{aligned} TSS &= (AS)(TNU')\,(1/AN) \\ TS &= (TSS)\,(CIV) \end{aligned}\right\} \quad (3.4A)$$

where TSS is a matrix of $M \times (N - 1)$ elements, the yearly value of business sales by sector by town, in thousands of dollars;

TNU' is the transpose of the column vector TNU,

CIV is a column vector of conformable order, all elements being unity;

and all other variables are as previously defined. However, to use this procedure implies that the business sales of an industry make up the same proportion of the total business sales within the town. It requires that each industry have a constant share of each town's business sales and of the whole area's business sales. In addition to the assumptions implied by equation (3.4) this assumption implies that all industries in each town grow at the same rate. But, as mentioned in the discussion of town-specific input-output tables, to do so is to embody the current pattern of industrialization, and thus make projections more restrictive.

Incomes

It is possible to compute regional income on the basis of information contained in the input-output table and to allocate regional income to towns, as was done for business sales. Thus,

$$AY = AS_N - EX_N - GT + (BR)(AS) \tag{3.5}$$

where AY is a scalar, the yearly value of gross regional income, in thousands of dollars;

AS_N is the Nth element of the vector AS, the yearly value of household incomes, in thousands of dollars;

EX_N is the Nth element of the vector EX, the yearly value of household incomes from outside of the region, in thousands of dollars;

BR is a row vector of N elements, the proportion of yearly business sales used in business taxes, depreciation, retained earnings, business gifts, and payments to non-resident factor owners for each of the sectors, with the Nth element (for households) being zero;

GT is the yearly value of government transfer payments, in thousands of dollars;

and the other variables are as defined previously.

Equation (3.5) computes gross regional income from the information contained in the input-output table. The income concept used[1] above is defined to include all factor payments arising out of activity in the region, thus excluding non-local earnings of households and government transfer payments. A more relevant income concept for the purpose at hand should include non-local household earnings (EX_N) and government transfer payments.

Thus,

$$EY = AY + EX_N + GT \qquad (3.6)$$

where EY is a scalar, the yearly value of income available for expenditure within the region, or "spendable income", in thousands of dollars

and the other variables are as defined previously.

Equation (3.6) defines the concept of "spendable income", which is regional income added to non-local household earnings and government transfer payments. These variables are included so that the income concept can include all funds available to area residents for making purchases, and thus for travelling. In a national accounting framework, the inclusion of transfer payments constitutes double-counting and is avoided. However, by assuming that all transfer payments originate from outside of the region, and that

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[1] J.A. MacMillan and C. M. Lu, "Regional Development Planning and Evaluation: An Impact Analysis of Manitoba's Interlake Area Development Plan", unpublished manuscript, p. 63.

the region forms a minor part of the taxation jurisdiction from which the transfer payments originate (i.e. that the region pays a negligible share of its own transfer payments), the inclusion of transfer payments is equivalent to including factor payments from outside the region.

However, the inclusion of non-locally earned income raises the problem of how to allocate "spendable income" to the different towns. Clearly the use of local employment as in relationship (3.4) is not warranted, since income does not depend only on local employment. However, total employment can be used as an allocator of regional income to towns. Total employment is defined as the total level of employment within the community, regardless of whether workers are employed in the town or elsewhere.

Thus,

$$TY = EY\,(1 \;/\; AE)\,(TE) \tag{3.7}$$

where TY is the column vector of M elements, the value of yearly "spendable income" for each town, in thousands of dollars;

TE is a column vector of M elements, the total number of residents of each town who are employed, regardless of where their place of work is;

AE is a scalar, the total number of residents of the region who are employed, whether they be employed within or outside of the region;

EY is a scalar, the yearly value of regional "spendable income" (see equation (3.6) above).

Equation (3.7) allocates regional "spendable income" (as defined by equation (3.6) above) to specific towns on the basis of the ratio between total employment in each town to total employment in the region. Since regional "spendable income" and total employment are constants in the equation, the equation (3.7) can also be interpreted as stating that the average income per employed person in the region multiplied by the number of people in each town estimates the income of people residing in that town.

Summary of the Economic Sub-Model

The economic sub-model estimates yearly business sales and "spendable incomes" for the region and for each town on the basis of exogenous final demands. Equation (3.2) estimates yearly business sales by sector for the whole region. The total yearly business sales for the region, i.e. the sum over sectors of sectoral business sales, are then allocated to towns on the basis of exogenous local employment in the town and in the region, by equation (3.4). The area sales are also used in equation (3.5), in order to compute regional income as it is normally defined. Equation (3.6) then defines the concept of "spendable income", which includes more than regional income. Equation (3.7) then allocates "spendable income" for the region to each town on the basis of exogenous total (local and non-local) employment. These relationships are illustrated in Figure 3.2 on the following page.

THE HIGHWAY SUB-MODEL

Given town incomes, yearly business sales by town and town employment, the highway sub-model calculates yearly vehicle flows between towns and over highway sectors, as well as peak hour highway requirements. The sub-model then evaluates the need for investment and, if investment is required, estimates the appropriate level of expenditures.

These expenditures benefit three groups of highway users, each with its own set of motivating factors. The user groups are, (1) commercial traffic, i.e. the movement of goods between communities by truck transport; (2) errand-running traffic, i.e. household and farm business travel into first-order, as well as higher-order, centres; and (3) residual traffic, i.e. transportation that does not fall into either of the other two categories, such as recreational travel, school bus traffic, etc. The motivations of these different highway user groups are discussed below, and behavioural equations hypothesized.

Commercial Traffic

If the only method of commercially transporting commodities between towns is by truck, the volume of commercial traffic is a

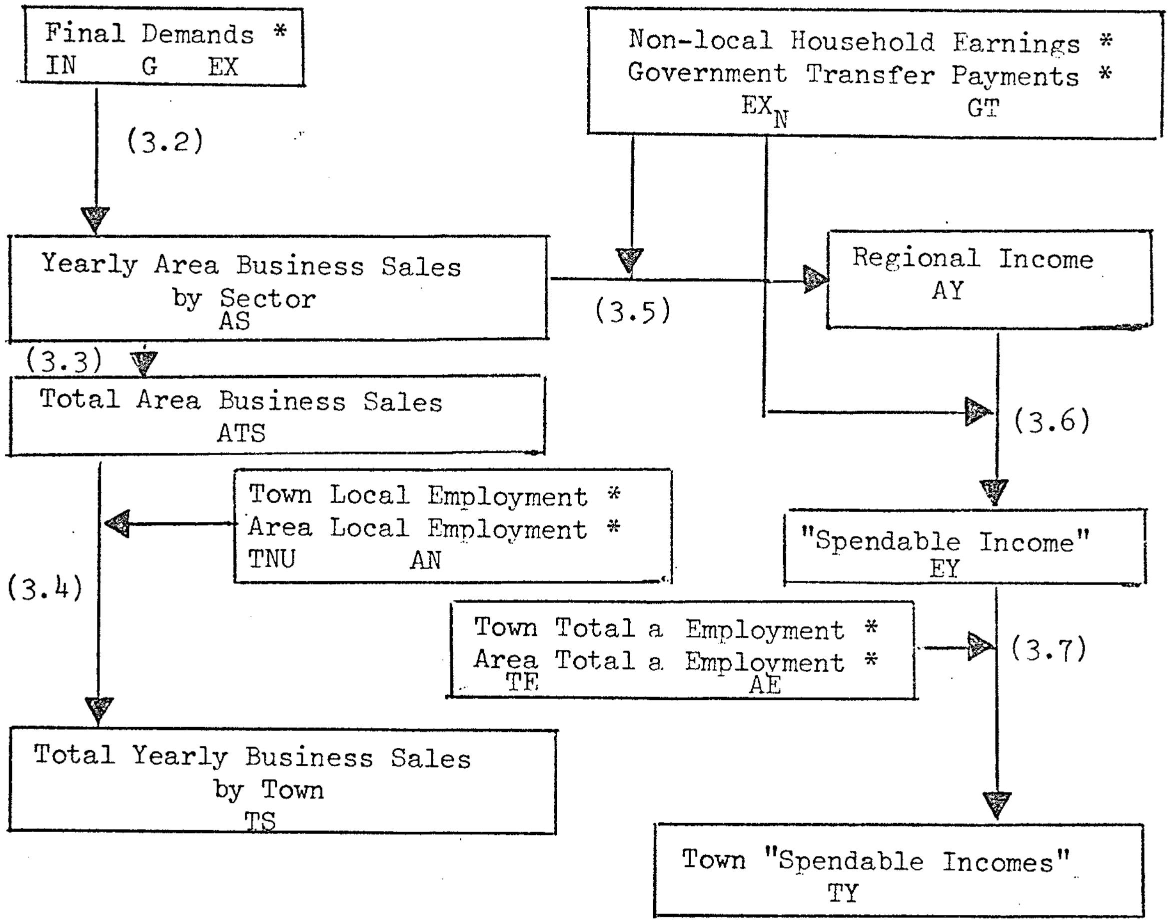

Figure 3.2

The Economic Sub-Model

a Includes local and non-local employment.

* denotes exogenous variable.
Numbers refer to equations discussed in text above.
Lower halves of boxes contain symbols of the variables.

function of the value of inter-town transactions. If exports from a town represent a constant proportion of that town's business sales, the value of town business sales can be used to determine the volume of commercial traffic. Similarly, if imports into a town represent a constant proportion of the income available to residents of that town, town incomes should also enter the relationship determining the volume of commercial traffic between towns. Finally, transport costs inhibit the shipment of goods between towns. If transport costs are a function of distance alone, the latter can be used in the determination of the volume of inter-town commercial traffic. Thus,

$$CT_{ij} = A_1\ (TS_i)^{at}\ (TY_j)^{bt}\ (D_{ij})^{ct} \tag{3.8}$$

where CT_{ij} is the yearly volume of truck traffic from town i to town j, measured in number of trucks;

A_1 is an empirical constant;

D_{ij} is the distance in miles from town i to town j;

at is an empirical constant, the elasticity of truck traffic with respect to origin-town sales;

bt is an empirical constant, the elasticity of truck traffic with respect to destination-town incomes;

ct is an empirical constant, the elasticity of truck traffic with respect to distance between towns;

and where the other variables are as defined in Figure 3.2, page 33.

Equation (3.8) estimates inter-town truck traffic as a function of yearly business sales in the origin town, yearly incomes in the destination towns, and distances between origins and destinations. Although equation (3.8) is similar to conventional gravity models[2], it differs in two ways that make comparisons with demand equations seem more appropriate than to gravity models. First, gravity models are usually discussed in terms of similar "homogeneous masses" that attract each other, such as population, or business sales. Thus the conventional model would have expressed the volume of truck traffic as a function of incomes in both towns, or of business sales in both towns, etc., the underlying idea being that like masses attract each other. Second, gravity models do not compute empirical constants for factors other than distance. This means that they do not provide estimates of elasticities of travel with respect to determining factors and thus say less about the effect of these factors on trip generation than does equation (3.8).

The relationship is based on the fact that every town's economy is quite open. Attempts at self-sufficiency would impose too many restrictions on the quality and range of available consumer commodities. Every town imports some of the goods sold within its limits, and most export at least some of their production.

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[2] Cf. the discussion of traffic prediction models in the previous chapter, as well as the review of gravity models in the Isard reference, ...n. 18, p. 16.

The volume of inter-town trade is directly related to town sales and incomes, and inversely related to the distance separating the towns. Commercial traffic is proportional to the volume of inter-town trade. The exponents attached to the town business sales, town incomes and distance factors indicate by how much truck traffic will change in percentage terms if one of the factors changes by one percent. Thus a one percent increase in business sales in the origin town leads to an $\underline{at}$ percent increase in truck traffic. Similarly, a one percent increase in town incomes bring about a $\underline{bt}$ percent increase in truck traffic. But an increase of one percent in distance between towns leads to a decrease of $\underline{ct}$ percent in truck traffic, since the greater distance between towns implies greater transport costs and thus less traffic volume.

Errand-Running Traffic

There are two major components of errand-running travel. The first is the travel of urban households to other urban centres for the purchase of goods and services not available in their own town. The second is the movement of rural people, both from farm and non-farm households, to urban centres for farm business as well as for household purposes. The principles underlying the two sub-sets of errand-running travel are the same, although there are differences in the treatment of rural origins, which are discussed later.

In general, errand-running is the result of two effects. The supply effect alludes to travel generated by the availability of a wider range of goods and services in higher-order[3] centres. The income effect denotes people's capacity to afford travel as well as to purchase higher-order goods and services, i.e. goods and services available only in higher-order centres. As with commercial traffic, distance tends to cancel out at least some of the demand and income effects by imposing additional costs and thus raising the real cost of higher-order commodities. Thus.

$$ET_{ij} = A_2\ (TY_i)^{ac}\ (1-TN_i/TE_i)^{bc}\ (TS_j)^{cc}\ (D_{ij})^{-dc} \qquad (3.9)$$

$$\text{if} \quad TS_i \leq TS_j$$

$$\text{and } ET_{ij} = 0 \qquad \text{if} \quad TS_i > TS_j \qquad (3.10)$$

where ET_{ij} is the annual volume of errand-running travel from i to j, measured in number of cars;[4]

A_2 is an empirical constant;

ac is an empirical constant, the elasticity of errand-running travel with respect to town incomes in the origin;

bc is an empirical constant, the elasticity of

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[3] Order of towns is here defined in terms of yearly business sales, rather than the conventional use of population. For it is the greater variety of goods and services, usually associated with greater sales volumes, which attracts people from lower-order, i.e. smaller, centres.

[4] Cars are defined to include light trucks, pick-ups, etc.

errand-running travel with respect to the ratio of non-local employment to total employment, at the origin;

cc is the empirical constant, the elasticity of errand-running travel with respect to town business sales in the destination town;

dc is an empirical constant, the elasticity of errand-running travel with respect to the distance between origin and destination

and the other variables are as defined in Figure 3.2, page 33.

Equations (3.9) estimates errand-running travel to higher-order centres on the basis of town incomes at the origin, the ratio of non-local employment to total employment at the origin, the value of business sales at the destination, and the distance separating origin from destination. Equation (3.10) implies the assumption that there is no errand-running travel to lower-order centres.[5] The volume of errand-running traffic to higher-order centres depends on the amount of income available in a town -- the income effect mentioned previously. The income estimate is not sufficient in itself however. The proportion of employed labour force that works in other centres is relevant, because of the assumed

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[5] In other words, it is assumed that any centre of order N has available in it all goods available in any centre of order N-1, as well as some additional goods. Errand-running travel to lower order centre is thus redundant.

propensity of those working outside of their own town of residence to spend more in other centres. This propensity comes partly from the breakdown of the psychological barriers of time and distance due to frequent commuting, and partly to greater opportunities of spending income non-locally due to the very fact of being employed non-locally.[6] The volume of errand-running traffic is also influenced by the varlue of business sales at the destination, i.e. by the order of the destination town, -- the demand effect mentioned previously. As noted above, distance tends to reduce the volume of errand-running traffic by imposing greater travel costs. The exponents of these factors just mentioned indicate how responsive errand-running traffic is to given changes in the factors themselves. Their precise interpretation is analogous to that of the at, bt and ct exponents of equation (3.8).

Equation (3.9) can be used in rural settings by creating "demand points", i.e. fictitious towns without any local employment and whose incomes are the total incomes of rural households in a given area. The geographical location of these towns does not pose a problem. All that is required is the distance between origin and destination. This distance can be computed as a

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[6] For example, this is the situation of residents of Stonewall who commute to Winnipeg.

weighted average of distances travelled to a particular destination from a particular set of rural households or a particular rural area, the weights being the number of times each household travels to that centre. Using such pairings of rural area origins to different destinations results in several "demand points" being linked to only one destination. Thus, equation (3.9) estimates errand-running traffic for urban and rural households to higher-order centres.

Residual and Total Traffic

The greatest part of residual traffic is probably recreational traffic, which could be explained largely by measures of usage of regional recreational facilities. But this information is not currently available. As an alternative, it could be assumed that recreational traffic responds mostly to income changes, despite containing a large arbitrary volume.[7] Thus,

$$RT_{ij} = A_3 + (ar)(TY_i) \qquad (3.11)$$

where RT_{ij} is the annual volume of residual (mostly recreational) traffic from i to j, measured in number of cars;

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[7] In fact, however, "residual traffic" made up more than half of the traffic flows over the area highways.

A_3 is an empirical constant, the basic volume of residual traffic volume;

ar is an empirical constant, the amount by which residual traffic increases when town incomes increase by $1.;

TY is the value yearly incomes in the origin town, in thousand of dollars.

Equation (3.11) estimates the volume of residual traffic as a function of town incomes. It is an expedient in view of the lack of information about recreational facility usage.

The volume of total traffic can now be computed from the estimates of truck, errand-running, and residual traffic volumes derived above. But simple addition of these different types of traffic is not permissible, as they are measured in different units. The volume of commercial traffic is measured in number of trucks, whereas the errand-running and residual volumes are measured in number of cars. Thus a definition of equivalence between trucks and cars is required. Such an equivalence has been computed by engineers.[8]

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[8] Estimate obtained during conversation with Mr. B. K. Johnston, Planning Engineer, Highways Branch, Manitoba Department of Public Works and Highways.

In flat terrain, one truck is equivalent to two cars in terms of effects on highway capacities, which is our only concern. The ratio differs for wear and tear on the highway surface, but this model only considers highway investment due to lack of capacity. Thus,

$$TT_{ij} = 2 \cdot CT_{ij} + ET_{ij} + RT_{ij} \qquad (3.12)$$

where TT_{ij} is the yearly volume of total traffic between i and j,

and the other variables are as defined previously.

Equation (3.12) defines the total yearly flow of traffic between origins and destinations. This total flow is on an origin-destination basis.

Highway Requirements

The estimate of total traffic derived above is on an origin-destination basis. To compute traffic requirements, it is necessary to convert those traffic estimates to estimates of traffic volumes over specific highway sections. To do so requires that the routes used by the total traffic on the origin-destination basis be known, as well as the proportion of total traffic on the origin-destination basis which uses each possible alternative route.

If there are Z origin-destination pairs and W highway sections, and if the routings mentioned above are shown as the percentage of the total traffic volume between an origin-destination pair using a given specific section of highway, a matrix of Z by W factors can be compiled. Each row of the matrix shows the routing of the total traffic volume between a given origin-destination pair over all W highway sections, most sections having a zero percent share of any given origin-destination pair. By multiplying the matrix by the vector of Z origin-destination pair total traffic volumes and summing over the columns of the product, the annual volume of traffic over highway sections is estimated. In formal terms,

$$YVT_a = \underset{b=1}{\overset{Z}{}} (TT_b \cdot FAC_{ba})$$

or in matrix notation

$$YVT = (TT)\ (FAC) \tag{3.13}$$

where YVT is a row vector of W elements, the annual traffic volumes over each highway section, measured in number of cars;

TT is a row vector[9] of Z elements, the total traffic volumes on an origin-destination basis, measured in number of cars;

FAC is a matrix of Z x W elements, the percentage distribution of origin-destination traffic volumes over highway sections.

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[9] It is a row vector for notational simplicity. The vector is derived from the equations (3.11) for all origin-destination pairs where total traffic volume is non-zero. These pairs are identified by an index number ranging from 1 to Z.

Equation (3.13) computes yearly traffic volumes over highway sections from total traffic volumes on an origin-destination basis.

The distribution of yearly traffic volumes is not even over the whole year. Highway planning manuals emphasize that this distribution is of critical importance.[10] Thus, it is not sufficient to know the yearly volume of traffic in order to estimate highway requirements. To do this requires knowledge of the distribution of peak traffic demands, and of the intensity of the peaks.

A graphical representation of the hourly variation of traffic flows for a fictitious highway for one day is given in Figure 3.3 below. Similar curves can be drawn for each day of the year. It is then possible to determine the traffic volume at the first, second, third, and so on, hours of heaviest traffic during the year. By plotting the hourly traffic volumes against the rank of the hours, a graph of the distribution of peak hours is obtained. An illustrative example of such a graph is presented in Figure 3.4 for two different types of highways -- one used primarily for access to recreational facilities, and one used mostly for commercial purposes. It has been observed that curves similar to those depicted in Figure 3.4 tend to indicate steep declines in traffic volumes during the top peak hours,

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[10] For instance, B.V. Martin, F. W. Memmott III, and A. J. Bone, <u>Principles and Techniques of Predicting Future Demand for Urban Area Transportation</u>, (Cambridge: M.I.T. Press, Report no. 3, 1965)

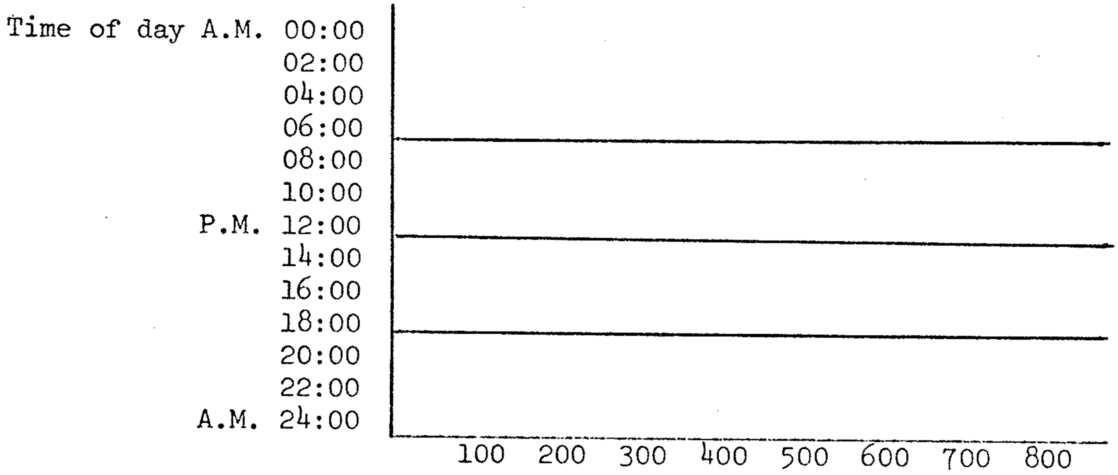

Figure 3.3
Hourly Variation of Traffic During a Day
(Illustrative Example)

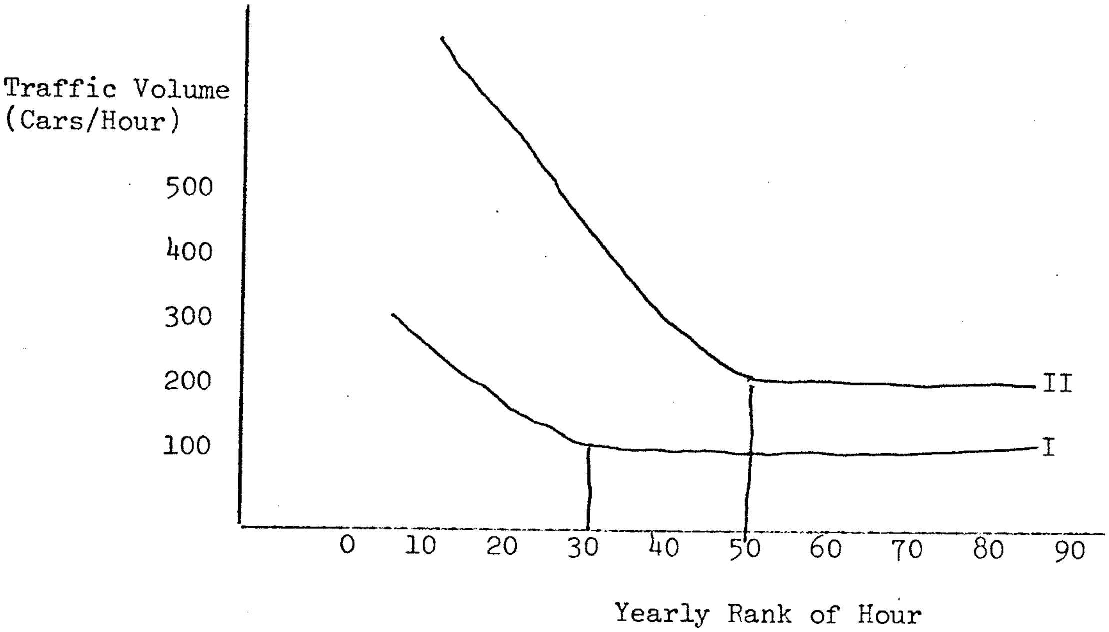

Figure 3.4
Peak Hourly Traffic Volumes by Yearly Rank of Hour
(Illustrative Example)

I denotes primarily commercial highway
II denotes primarily recreational highway

but that, at some point they tend to level out. This turning point usually comes after less peak hours for commercial highways than for recreational highways, as the latter are more subject to very intense, but short-lived rushes to and from recreational resources. The relevance of these turning points is considered to be high by highway planners. They feel that the added cost needed to provide sufficient capacity to satisfy the traffic volumes at the next-lowest ranking hours far outweighs the added benefits to road-users, whereas above the turning point the opposite is deemed to hold.

The traffic volumes of Figure 3.4 can also be expressed as a percentage of annual average daily traffic volumes. Thus if the annual average daily traffic volume on the fictitious highway of Figure 3.4 were 1000 cars, the vertical axis could be re-labeled "Percentage of annual average daily traffic" and marked at 10%, 20%, 30%, 40%, 50% without changing any aspect of the curve. Given this distribution, and the rank of the hour to serve as a criterion for planning -- the turning-point hour referred to above -- the proportion of annual average daily traffic for which sufficient highway capacity must be planned is determined. Formally,

$$CHT = (1/365)\ (YVT)\ (I)\ (CHP) \qquad (3.14)$$

where CHT is a column vector of W elements, the volume of traffic at the planning criterion hour, measured in number of cars;

CHP is a column vector of W elements, the proportion of average daily traffic using each highway section at the peak hour;

I is the identity matrix of conformable order, i.e. W x W;

YVT is as defined on page 43.

Equation (3.14) computes the volume of traffic at the planning criterion hour on the basis of yearly traffic volumes and of the proportion of average daily traffic using the highway during the criterion hour. The volume of traffic computed to be using the highway at the criterion hour is, by definition, the requirement for highway capacity, i.e.

$$HR \equiv CHT \qquad (3.15)$$

where HR is a column vector of W elements, the requirements for highway capacity, measured in number of cars;

and where the other variables is as previously defined.

Equation (3.15) defines highway requirements as identical to the volume of traffic at the criterion hour.

Investment Decision

Before making any investment decision, it is necessary to know whether the highway requirements exceed the service volume, i.e. the capacity, of the highway. The determination of the service volume of a highway requires quantifying the ability of a road to accommodate traffic. The estimate is based on the highway's geometrics (e.g. sight lines, sharpness of curves, etc.), the number and width of traffic lanes, the shoulder width, the level of service to be provided, and many other variables. Only the level of service variable needs further explanation. It indicates average highway speeds and ease of manoeuvre which are desirable. From these variables, an estimate of a highway's service volume is computed. Given the highway requirements estimated above, and the service volumes of highway sections, the congestion over highway sections can be computed.

$$CO = HR - SV \tag{3.16}$$

where CO is a column vector of W elements, the amount of congestion on each highway section, measured in number of cars per hour, at the criterion hour;

SV is a column vector of W elements, the service volume, i.e. capacity, of a highway section, measured in number of cars per hour;

HR is defined on page 48, as the highway requirements.

Equation (3.16) defines congestion for each highway section as the number of vehicles per hour (at the criterion hour) by which highway requirements exceed the service volume. If there is no congestion of ir congestion is negative, which implies excess capacity, there is no need for investment for reasons of capacity. But this does not preclude investment for other purposes, such as the economic development of the region. If there is congestion, investment is required to eliminate the bottle-neck.

The volume of capacity-based investment then remains to be decided. If the service volume deficiency is the only reason for highway investment, and if an empirical link exists between increases in service volume and the value of investment, then

$$RHI_a = CO_a / DSV \qquad \text{if } CO_a > 0 \tag{3.17}$$

$$RHI_a = 0 \qquad \text{if } CO_a \leq 0 \tag{3.18}$$

where RHI_a is an element of a column vector of RHI of W elements, the value of required highway investment for the $_a$-th highway section, in thousands of dollars;

CO_a is the $_a$-th element in the column vector CO, the level of congestion;

DSV is an empirical constant, the increase in service volume per thousand dollars of investment, in cars per hour.

Equation (3.17) defines required highway investment for a highway section as a function of congestion (if it exists) and of the increase in service volume per thousand dollars of investment. Equation (3.18) defines required highway investment as nil if there is no congestion.

However, highway investment is not planned solely on the basis of deficiencies in service volumes. It might be undertaken for a variety of other reasons, such as poor surface conditions, the desire to provide improved access to an area, the encouragement of the economic development of an area, and so on. The term discretionary highway investment will be used in this text to refer to these non-capacity based highway investments.

If, for a given highway section, both discretionary highway investment and required highway investment are implemented, they are considered as complementary but no additive. Thus the total amount of investment for that section is the larger of the required or discretionary investments. If the discretionary investment is considered the larger, only the difference between it and the required investment is considered as being truly discretionary. If the required investment is the larger, truly discretionary investment is deemed to be nil. Formally,

$$THI_a = DHI_a \qquad \text{if } DHI_a > RHI_a \geq 0 \qquad (3.19)$$

$$THI_a = RHI_a \qquad \text{if } RHI_a \geq DHI_a \geq 0 \qquad (3.20)$$

where THI_a is the a-th element of a column vector of W elements, the value of total highway investment for the a-th highway section, in thousands of dollars;

DHI_a is the a-th element of a column vector of W elements, the value of discretionary highway investment for the a-th highway section, in thousands of dollrs;

RHI_a is required investment as defined on page 49.

Equations (3.19) and (3.20)define total highway investment for a section as the larger of discretionary or required highway investments. The required investments are those needed to provide sufficient service volumes for the anticipated peak hour traffic volumes. The discretionary investments are those made for any other reason. In the operation of this model, they will be restricted to investment for purposes of regional development in order to maintain simplicity.

Summary of the Sub-Model

To summarize the highway sub-model, Figure 3.5 on the following page illustrates the relationships just discussed. From the sales and income estimates computed by the economic sub-model, and using exogenous distance, commercial traffic between origin-destination pairs is estimated. Those variables, as well as exogenous employment variables determine errand-running traffic, also on an origin-destination basis. Residual traffic volumes on an origin-destination basis are then estimated as a function of incomes in originating centres. Total traffic is then computed on an origin-destination basis, and this estimate converted to yearly traffic volumes over highway sections. The criterion hour traffic volume is then estimated and the highway requirements thus defined.

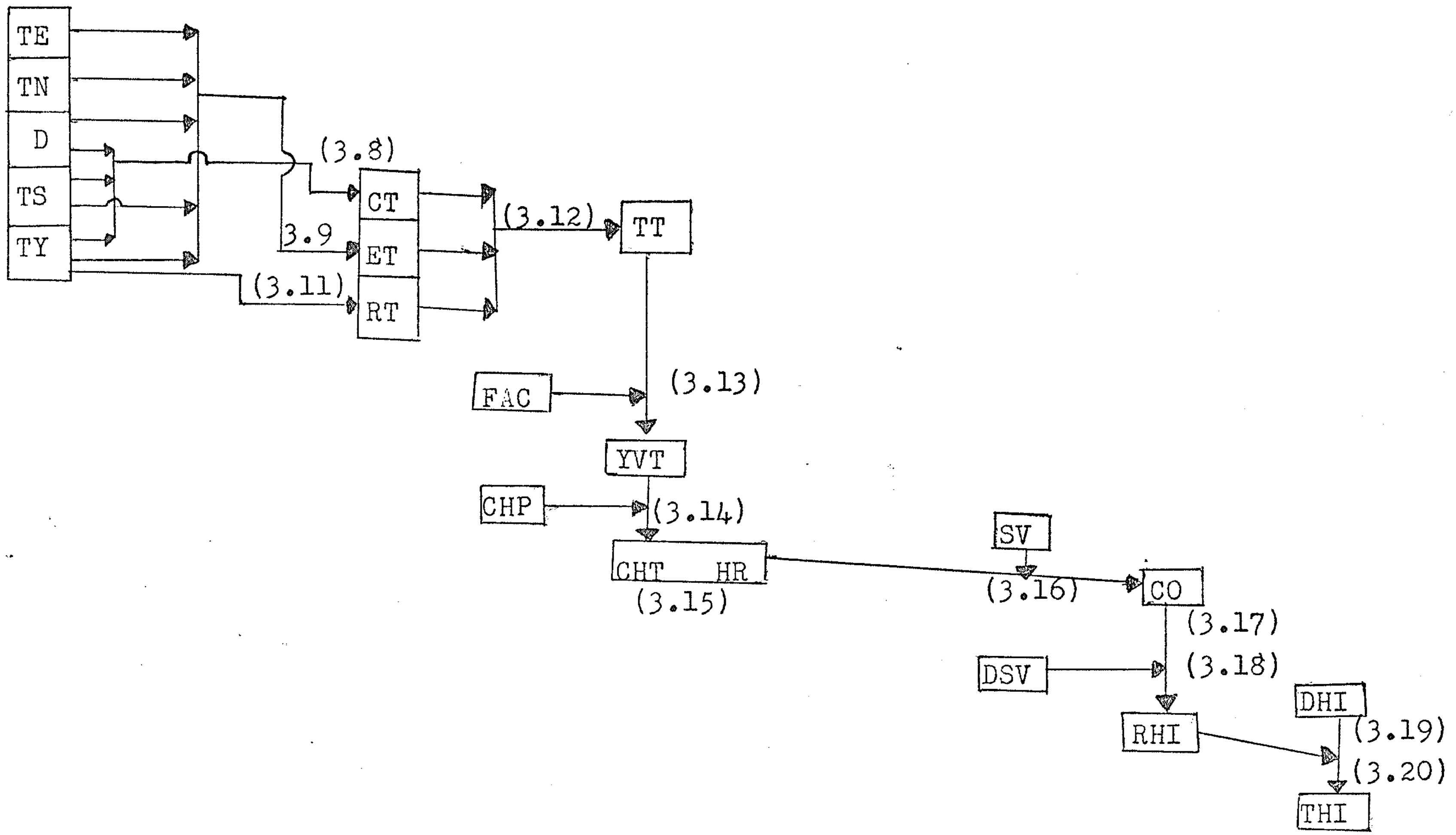

Figure 3.5

The Highway Sub-Model

Variables are as defined on the following page.

Numbers refer to relationships discussed in the text.

TABLE 3.1

GLOSSARY OF SYMBOLS USED IN FIGURE 3.5 IN ORDER OF APPEARANCE

Symbol	Variable
TE	Town total (local and non-local) employment
TN	Town local employment
D	Distance between origin-destination pairs
TS	Town yearly business sales
TY	Town yearly incomes
CT	Volume of commercial traffic on origin-destination basis.
ET	Volume of errand-running traffic on origin-destination basis.
RT	Volume of residual traffic on origin-destination basis.
TT	Volume of total traffic on origin-destination basis
FAC	Matrix of routings assigned to origin-destination basis.
YVT	Yarly volume of total traffic on highway section basis.
CHP	Proportion of average daily traffic using highway at criterion hour, by section.
CHP	Volume of traffic using highway at criterion on hour, by section.
HR	Requirement for highway capacity, by section
SV	Service volume of highway, by section
CO	Level of congestion, by highway section
DSV	Change in highway service volume per $1000 highway investment.
RHI	Required highway investment, by highway section.
DHI	Discretionary highway investment, by highway section
THI	Total highway investment, by highway section

If the service volume, or capacity, is not sufficient to meet these requirements, highway investment is estimated as a function of the level of congestion. Discretionary highway investment complements required highway investment. Total highway investment for a given section is defined as the larger of the discretionary (exogenous) or required (endogenous) highway investments.

THE IMPACT SUB-MODEL

This investment of resources in highways has several effects on both the highway and the economic systems. Thus, highway service volumes, travel times and distances are altered by the investment. And these expenditures have multiplier effects on business sales, incomes and employment levels. These changes in both systems are discussed formally in the following sections.

Highway Service Impacts

Investment in a highway increases the service volume of that highway. If a constant relationship exists between the value of highway expenditures and increases in service volumes, then

$$NSV = (DSV)\ (THI) \qquad (3.21)$$

where NSV is a column vector, the additional service volume created on each highway section measured in cars per hour,

and the other variables are defined in Table 3.1 page 53.

Equation (3.21) computes the change in the service volume of a highway section on the basis of the value of investment. If similar relationships exist between highway investment on the one hand and travel times and lengths of highway sections on the other, then

$$NTT = (DTT)(THI) \qquad (3.22)$$

$$NHL = (DHL)(THI) \qquad (3.23)$$

where NTT is a column vector, the percentage change in travel times over each highway section;

DTT is the percentage change in travel time over a highway section per thousand dollars of investment;

NHL is a column vector the percentage change in the length of each highway section;

DHL is the percentage change in the length of highway sections per thousand dollars of investment;

THI is total highway investment, a column vector of W elements.

Equations (3.22) and (3.23) compute the percentage changes in travel times and lengths of highway sections on the basis of the value of investment on those sections.

The change in lengths and travel times of highway sections has some implications for the traffic generation functions of the highway model. Those functions use distance as an index of resistance to the other factors which encourage travel. But clearly the distance factor should be modified for changes in travel time. For it can be assumed that the effect of a ten percent reduction in distance, namely that it is ten percent easier to travel. This is what is meant by the term "effective distance", or "change in effective distance". In formal terms, this change can be identified with the percentage reduction of the length of a highway section. Thus

$$PRL_a = NHL_a \qquad \text{if } NHL_a \geq NTT_a \tag{3.24}$$

$$PRL_a = NTT_a \qquad \text{if } NTT_a > NHL_a \tag{3.25}$$

where PRL_a is the percentage change in the length of the a-th highway section as measured in distance or time, i.e. in "effective distance" as defined above, the a-th element of the column vector PRL:

and the other variables are as defined on the previous page.

Equations (3.24) and (3.25) define the percentage reduction in the "effective distance" of a highway section as the greater of the percentage change in mileage or the percentage change in travel time. And the value of the change in "effective distance" in terms of miles is given by

$$CHL = (HL)\,(I)\,(PRL) \tag{3.26}$$

where CHL is a column vector, the change of the "effective distance" of each highway section, in miles;

HL is a column vector, the length of the "effective distance" of each highway section, in miles;

and the other variable is as defined above.

Equation (3.26) translates the change in "effective distance" into terms of miles from percentages.

The "effective distances" just discussed referred to highway sections. But the change in "effective distances" on an origin-destination basis must also be computed. It will be recalled that the distances used in the traffic generation functions were weighted averages. They represented the sum of the distances of each highway section on a route multiplied by the volume of traffic using that route, for each route between a given origin and destination, and all divided by the total volume of traffic between the origin and destination. Formally,

$$D_b = \frac{\sum_{k=1}^{W} (VT_{bk}) \quad (HL_k)}{\sum_{k=1}^{W} VT_{bk}} = \frac{\sum_{k=1}^{W} (TT_b)\ (FAC_{b\ k})\ (HL_k)}{TT_b} \qquad (3.27)$$

or, by simplifying,

$$D_b = \sum_{k=1}^{W} (FAC_{b\ k})\ (HL_k) \qquad (3.28)$$

and, in matrix notation, $D = (FAC)\ (HL)$

where b, as a subscript, denotes the origin-destination pair ij;

k, as a subscript, denotes any highway section;

VT_{bk} is the total volume of traffic between origin-destination pair b using highway section k;

and the other variables are as previously defined.

Equation (3.27) is used implicitly in calculating the distance between the origin-destination pair b. It is the sum of the distances of each highway section weighted by the proportion of traffic between origin-destination pair b which uses that section. If the "effective distance" of any given highway section should change, the weighted average must necessarily be altered. Thus,

$$ND = (FAC)\ (HL - CHL) \qquad (3.29)$$

where ND_b is a column vector, the new "effective distance" between origin-destination pair b, in miles;

and the other variables are as previously defined.

Equation (3.29) computes the new "effective distances" on an origin-destination basis from the changes in the length of the "effective distances" of the highway sections affected by investment. These changes in "effective distances" combined with the changes in the service volumes of highway sections are the impacts on the highway system of the required and discretionary highway investments.

Economic Impacts

These investments also have effects on the economic system, as has already been noted. The first perceivable economic impact is the increase in final demands due to highway investment. Given a highway construction technology and the level of highway investment, the change in final demands for the output of each industry can be estimated by

$$\mathrm{AHI} = (\mathrm{RIV})\,(\mathrm{THI}) \tag{3.30}$$

$$\mathrm{DFD} = \mathrm{AHI}\ (\mathrm{HCT}) \tag{3.31}$$

where DFD is a column vector of N elements, the value of the change in final demands due to highway investment for each sector of the regional economy, in thousands of dollars;

AHI is a scalar, the value of all highway investment in a year, in thousands of dollars; it is the sum of highway investments over all highway sections;

HCT is a column vector of N elements the proportion of each dollar of highway investment which is spent on each sector of the regional economy.

RIV is a row vector of conformable length, all elements being unity;

THI is defined previously as the value of highway investment for each highway section.

Equation (3.31) computes the changes in final demands resulting from all highway investment through the use of the highway construction technology vector. Substituting the changes in final demands for the original values in equation (3.1) provides an estimate of the increase in area business sales. This increase includes the direct, indirect and induced requirements of each industry for the output of every other industry. The direct effect is simply the increase required in a sector's inputs due to a change in that sector's final demands. The indirect effect is the added increase in every sector of the economy because of an increase in the final demands of one sector's output. In other words, if the final demands for the output of, say the food and beverage manufacturing sector, increase by a given amount, the food and beverage manufacturing sector will require more inputs from various sectors, such as agriculture. In order to increase its output, the agricultural sector requires more inputs from other sectors, and so on. These are the indirect effects. The induced effects, or income effects, result from including households as an endogenous sector in the system. They represent the increase in consumption expenditures due to the increased incomes generated by the added investment expenditures. The importance of including the income effects is quite clear. Without them, the impacts of any investment would be sriously understated. Thus all three effects are included in the computation of the increase in business sales. Equations (3.4) and (3.5) can then be used to compute the increases in regional incomes and in "spendable incomes". Thus,

$$DAS = (I - X)^{-1} (DFD) \qquad (3.1)'$$

$$DAY = DAS_N - EX_N - GT + (BR)(DAS) \qquad (3.5)'$$

$$DATS = (RIV)(DAS) - DAS_N \qquad (3.3)'$$

$$DEY = DAY + EX + GT \qquad (3.6)'$$

where D, as a prefix, denotes the increase in the value of the variable to which it is attached;

and the other variables are as defined in Figure 3.2, page 33.

These equations estimate the increases in area business sales, regional income and area "spendable income". By assuming that the distribution of business sales and of incomes is constant, it is possible to compute the change in town business sales and town incomes. Thus,

$$DTS = (DATS)(1/AN)(TNU) \qquad (3.4)'$$

$$DTY = DEY (1/AE)(TE) \qquad (3.7)'$$

where all variables are defined in Figure 3.2, page 33. These equations estimate the sales and income impacts of highway investment on each town in the region. Moreover, if there is a constant relationship between town business sales and local employment, the employment impact of the investment can also be computed. If

$$TEPS = (I \cdot TS)(I \cdot TN)^{-1} \qquad (3.32)$$

where TEPS is matrix of M x M elements; the value of town sales per locally employed worker, or output per employee, for each town are the diagonal elements, and off-cliagonal elements are zero,

and the other variables are defined in Figure 3.2, page 33.

and if the output/employee ratio remains constant in each town (although not necessarily the same from town to town),

then

$$DTNU = (DTS)\,(TEPS)^{-1} \qquad (3.33)$$

where D, as a prefix, denotes changes in the values, and the other variables are as previously defined.

Equations (3.32) defines the output/employee ratio for each of the towns in the region. Equation (3.33) uses this ratio (assumed constant) to estimate local employment impacts of highway investment.

The economic impacts have thus been estimated. They include the increase in area business sales and incomes, as well as in town business sales, incomes and local employments. This concludes the analysis of the impact sub-model _per se_. But, as will be seen in the following section, this does not represent the end of all the marifications of the original highway investment.

Further Investment

The original investment in highways lead to increases in service volumes, reductions in "effective distances", increases in area and town business sales, incomes and local employment levels. These increases lead in their turn to greater volumes of traffic, for the volume of traffic depends on the new levels of the variables just named. In order to estimate these new traffic levels, the total values of the variables must be used. Thus,

$$\begin{aligned}
SV' &= SV + NSV \\
HL' &= HL - CHL \\
D' &= ND \\
AS' &= AS + DAS \\
TS' &= TS + DTS \\
AY' &= AY + DAY \\
EY' &= EY + DEY \\
TY' &= TY + DTY \\
ATS' &= ATS + DATS \\
TNU' &= TNU + DTNU \qquad (3.34)
\end{aligned}$$

where ' denotes new values of the variables;

and all other variables are as previously defined.

The set of equations (3.34) define the new levels of the economic variables to be used in a further round of estimating traffic volumes. These new values are then used as inputs into the highway sub-model. If congestion is found to exist again, new additional investment is required and its impacts estimated. The highway sub-model is then used a third time. The procedure continues until congestion no longer exists.[11]

Summary of the Impact Sub-Model

Given the level of highway investments, as determined by the highway sub-model, the impact sub-model estimates the resultant changes in final demands by sector. The increases in area business sales, regional income and area "spendable income" resulting from the direct, indirect and induced input-output multiplier effects are then computed. The town business sales and incomes are then computed by assuming that the distribution of sales and incomes between towns remains constant. The increases are added to the original values and used as inputs into the highway sub-model. The procedure continues until congestion disappears. The sub-model is presented graphically in Figure 3.6 on the following page.

THE TIME DIMENSION

The impact sub-model, as with the economic and highway sub-models discussed before it, is static, i.e. timeless. Implicit in such an approach is the assumption that investment in implemented in the same time period as when the capacity increase is required.

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[11] This assumes that investment does more to reduce congestion by improving highways than to increase congestion by inducing additional traffic.

It also means assuming that the impacts of the investment all work themselves out instantly, or at best in the same time period, and this even if there are several rounds of incrementing investment. These assumptions are clearly unrealistic.

However, various attempts at developing a dynamic model failed because of difficulties associated with the dating of the variables and with the distribution of the multiplier effects over time. Another version of the model, which assumed that investment was implemented in the year before which it would be required, also proved to be too complex. Moreover, the model sought was to be analytically, and not necessarily historically, predictive. Given the acceptability of the concepts of static Keynesian multipliers, the lack of an appropriate dynamic formulation does not appear critical.[12]

SUMMARY

The theoretical model is a static one, composed of three sub-models. The economic sub-model estimates the value of business sales and incomes, both for the region and for individual towns. These estimates are then used in the highway sub-model, which

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[12] The empircial model was modified to compute the effects of various assumptions as to the growth of final demands and of populations, as will be explained in the following chapter.

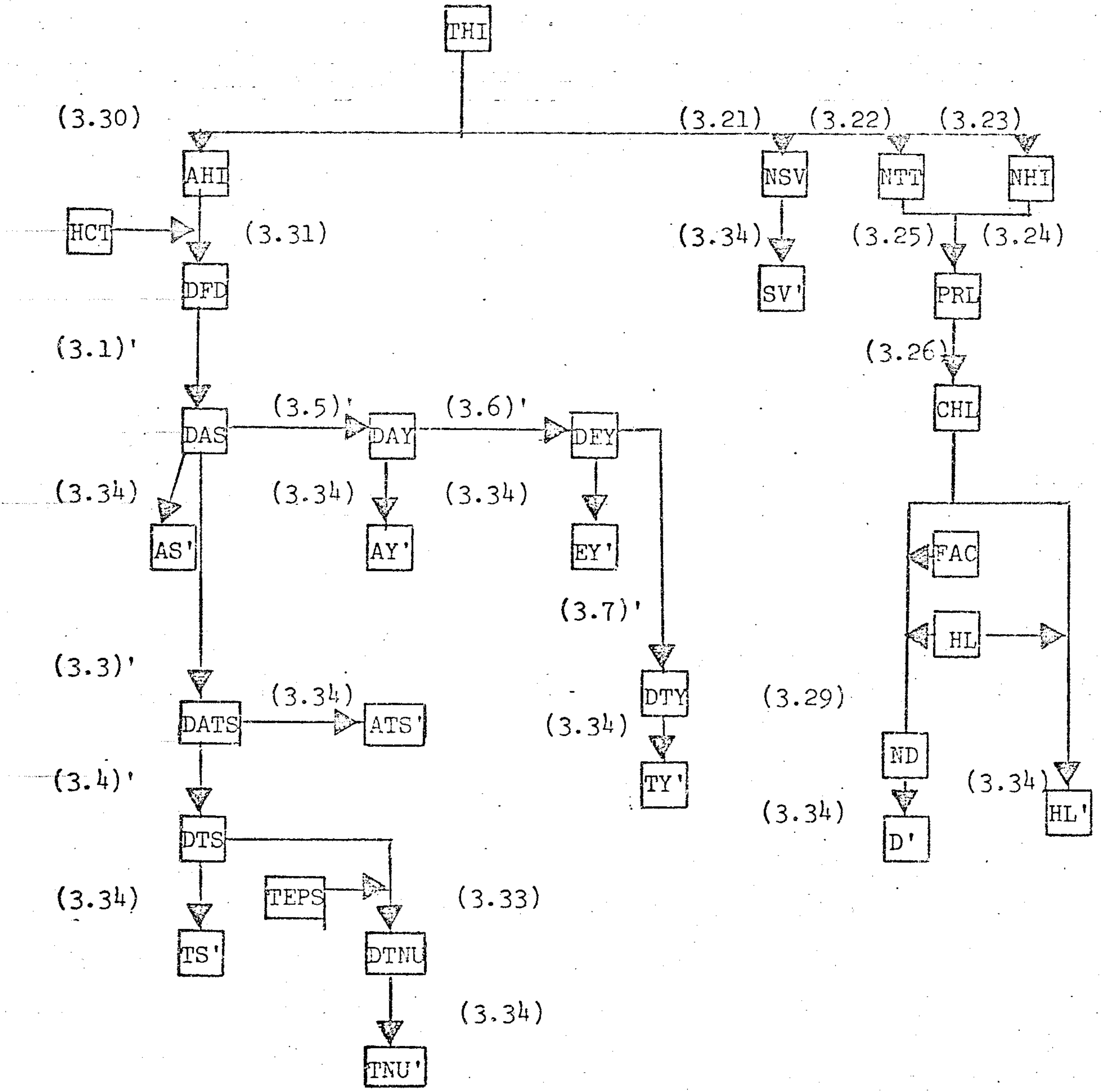

Figure 3.6

THE IMPACT SUB-MODEL

Variables are as defined on the following page.
Numbers refer to relationships discussed in the text.

TABLE 3.2

GLOSSARY OF SYMBOLS USED IN FIGURE 3.6 IN ORDER OF APPEARANCE

Symbol	Meaning
THI	Value of highway investment by highway section
AHI	Total value of highway investment during
HCT	Highway construction technology vector
DFD	Change in final demands of sector
DAS	Change in area business sales by sector
DAY	Change in area incomes
DEY	Change in area "spendable incomes"
DTY	Change in town incomes
DATS	Change in total area business sales
DTS	Change in town business sales
TEPS	Output-employment ratio by town
DTN	Change in town local employment levels
NSV	Change in service volume by highway section
NTT	Percentage change in travel time by highway section
NHL	Percentage change in length of highway section
CHL	Change in "effective distances" by highway section
HL	Length of "effective distances" in miles, by highway section
FAC	Matrix of routings of origin-destination traffic
ND	New "effective distances" in miles, on origin-destination basis
'	Defines new values of variables

Other symbols: see Figure 3.2, page 33
Figure 3.5 and Table 3.1, pages 52, 53

computes traffic flows on an origin-destination basis as well as on a highway section basis. The traffic flows are inputs in the computation of highway requirements. The latter, when compared with existing facilities, are used to decide whether or not highway investment is required as well as the amount of any required investment. The impact sub-model evaluates the effect of highway investment on the service volumes (i.e. capacities) and "effective distances" of the highway system. The impact of highway investment expenditures on area business ales, incomes and local employment levels is also assessed. The results are entered as inputs into the highway sub-model and new impacts computed, until congestion disappears from the highway system.

Chapter 4

THE EMPIRICAL MODEL

The theoretical model described in the previous chapter was designed with a minimum consideration of the availability and suitability of data. In applying the model to Manitoba's Interlake area, some modifications in the model were required because of gaps in data. The sources of the data and the changes that they required are discussed in the first part of this chapter. The modifications made to the model because of data problems are then explained. The third part of the chapter presents the estimates of the model coefficients.

THE DATA

The model required considerable data. These data came from three major sources. First, the Department of Agricultural Economics of the University of Manitoba conducted two surveys in the Interlake area from which considerable economic and demographic information was made available. Second, the Planning Division, Highways Branch, Manitoba Department of Public Works and Highways, provided information about the highway system. These data will be referred to as the Highway Planning Data. Third, the office of the District Engineer, District Number 11, Highways Branch, Manitoba Department of Public Works and Highways, at Arborg, provided the information about the highway construction technology. These data will be referred to as the Arborg Data. In addition, some estimates of ARDA-FRED expenditures on highways were provided by the accounting offices of the Department of Public Works and Highways and the ARDA-FRED Provincial Co-ordinator. Moreover, some constractors supplied information about their expenditures related to ARDA-FRED highway projects.

Information Obtained

The University of Manitoba's Department of Agricultural Economics conducted two Interlake surveys in 1969. The household survey sampled urban, rural non-farm and rural farm dwellers to collect extensive information about the relationships of households and farm businesses with other economic units within and outside of the region for the calendar year 1968. This survey also collected demographic information and data about available resources. The business survey obtained information about the purchase and sale of goods by Interlake firms, their operating expenses, investments and incomes for the calendar year 1968.[1] These data were used to compute the estimates published recently of the state of the Interlake economy.[2] The

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[1] For a description of the design of the business and household questionnaires, see J.A. MacMillan, "Household and Business Questionnaire Design", in J.A. MacMillan and C.F. Framingham (ed.), Seminar on the Evaluation of the Manitoba Interlake Area Development Plan, (Winnipeg: June 26-27, 1969), ch. VII, pp. 44-54.

[2] C.F. Framingham, J.A. MacMillan and D.J. Sandell, The Interlake Fact, and The Interlake Fact Digest (Winnipeg: Queen's Printer, 1970). Reference to page and table numbers are to the Digest only.

published estimates which were used in this study are for size of the labour force by town or municipality[3] as well as the trading pattern behaviour of urban rural non-farm and rural farm households by municipality.[4] The latter includes the identification of origin-destination pairs, the number of round trips on an origin-destination basis and the weighted average of round-trip distances between origin-destination pairs. Altough a six sector input-output table was published with these other estimates,[5] it was not the table used in this study. The table used here was computed on the basis of 18 sectors (including households) from the results of the business survey.[6] The estimates of final demands used in this study were obtained in the same nanner. The method used to compute regional income, as well as the estimates of that variable,[7] the value of town business sales, and the information used to compute town local employment levels all resulted from processing of the business survey results.[8]

The Highway Planning Data described the Interlake Provincial Trunk Highway system in terms of service volumes (i.e. capacities), annual average daily traffic for 1968, percentage of trucks in that volume estimate for 1968, and length of highway sections. The

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[3] C.F. Framingham, et al., the Digest, table no. 6; pp. 17-19, 85-90.

[4] Ibid., table no. 16, pp. 173-185.

[5] Ibid., table no. 15, p. 43.

[6] J.A. MacMillan and C.M. Lu, "Regional Development Planning and Evaluation: an Impact Analysis of Manitoba's Interlake Area Development Plan", mimeographed draft report; table 13, pp. 55 et seq.

[7] Ibid., table 15, page 63.

[8] Unbublished information supplied by J.A. MacMillan and C.M. Lu.

sections used were those normally employed by the Highways Branch for administrative purposes. They include all Provincial Trunk Highways north of P.T.H. 101[9] in the Interlake area up to the latitude of Steep Rock.[10] Because the 52 highway sections did not correspond to suitable intervals for purposes of this model, some modifications were made. These will be discussed in the next section.

The Arborg Data related to the ARDA-FRED highway program expenditures for the fiscal year 1968-1969 and their impact on the area's highway system. Information was collected on the breakdown of expenditures on each ARDA-FRED project relating to a Provincial Trunk Highway in the District by items of work. These items of work were disaggregated further on the basis of engineers' judgements about the major components of the item. For example, if a project such as shoulder widening required additional land to the sides of the highway, one of the items might be replacing of fencing. A specific amount would be allocated to that item. Judgements then would be made about the proportion of materials, labour and equipment costs in the total. It should be noted that these data were based on the Work Order forms on file at the Arborg Office. The Work Orders are authorizations for

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[9] The North Perimeter Highway near Winnipeg

[10] These data are presented in Appendix A.

expenditures, and not a record of payments made. These data were used to estimate the coefficients of the highway construction technology vector.[11] Because of confidentiality requirements, data for specific projects or contracts are not presented. In addition to the economic information, engineers' judgements as to the effect of a contract on travel time, capacity and distance were made available. However, estimates of direct employment on ARDA-FRED projects were unavailable.

Additional data about ARDA-FRED highway program expenditures were obtained for fiscal years after 1968-1969. These estimates only contained the total value of the work to be done and the location of the work. These values were used as discretionary highway investments[12] in the application of the model to the Interlake area.

Interviews with contractors provided some information about the sectoral allocation of their expenditures related to specific ARDA-FRED contracts. The data obtained were used in conjunction with the Arborg Data to estimate the coefficients of the highway construction technology vector, as discussed in Appendix B.

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[11] The estimation procedure is defined in Appendix B.

[12] As defined in Chapter 3.

Data Changes

The changes in the data related to highways and their utilization. The first modification that was necessary was to convert the Highway Planning Data from the basis of 52 sections to a set of more meaningful sections. It was found that some of the origin-destination traffic data had to be omitted for various reasons.

The Highway Planning Data were not based on sections suitable to their use in the model, since town-to-town intervals are required. Thus the original data were combined into a new set of sections. These sections begin and end either in towns or cities or at major intersections. The determination of the end-points of new sections was thus quite easy. But converting the other variables of this data set posed some problems, since old and new sections did not exactly overlap, as illustrated in Figure 4.1

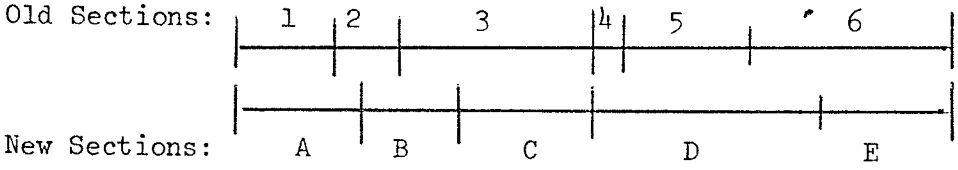

Figure 4.1

Overlapping of Old and New Highway Sections
(Illustrative Example)

Three types of situations can occur. First, the new section is entirely contained in one of the old sections, such as C in 3 or E in 6. In these cases, all the values of variables, except distance, will be the same for the new section as for the old section which contained it.

Thus the annual average daily traffic, service volume and percentage of trucks in the daily volume is the same for sections 6 and E, in the example. The same applies of course to sections 3 and C. As for the length of the sections, they were determined from a road map.[13] Second, the case of simple overlap arises where a new section corresponds to all or part of each of two old sections. This is illustrated in Figure 4.1 by the correspondence between new Section A and old sections 1 and (partially) 2, as well as by new section B and old sections (partially) 2 and (partially) 3. As in the previous case, distance is computed from a road map. But, in addition to the length of the whole new section, it was also necessary to know how much of each old section was included in the new section. These latter distances were then used to compute a weighted (by distance) average daily traffic volume over the new section. The same weights were used in the computation of the truck volumes, after having multiplied the (old section) truck percentages by the (old section) average daily traffic to obtain the (old section) average daily truck volume. In formal terms

$$\frac{VNS = (d_1)\ (VOS_1)\ +\ (d_2)\ (VOS_2)}{d_1 + d_2} \qquad (4.1)$$

where VNS is the value of the variable for the new section;

d_i is the length of the i-th section which is included in the section;

VOS_i is the value of the variable for the i-th old section.

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[13] Manitoba Road Map, (Winnipeg: Manitoba Department of Public Works and Highways, 1970).

Equation (4.1) computes the value of average daily traffic volume and of average daily truck volume for a new section on the basis of the values for the old sections which are included in the new one. For service volumes (i.e. capacities), the lower value of the service volumes of the old sections was used as the value for the new section. This was done on the grounds that the old section with the smaller capacity acted as a bottleneck. The combination of data into new sections does not contribute to the removal of any bottlenecks, so the bottlenecks were not removed. Third, a new section might overlap all or part of each of three or more sections, as illustrated by the relationship between new section D and old sections 4, 5, and 6. In this case, the computations are the same as for the two-section case, with the exception that more sections are involved. Equation (4.1) thus becomes

$$\frac{VSN = \sum_{i=1}^{N} (d_i)\ (VOS_i)}{\sum_{i=1}^{N} d_i} \qquad (4.2)$$

where N is the total number of old sections which are being used in whole or in part to form the new section,

and the other variables are as previously defined.

Equation (4.2) computes new section traffic volumes on the basis of those observed on old sections. It is a generalization of equation

(4.1), when more than two old sections are included in a new section.[14] The highway sections were placed on a town-to-town basis so that it would be possible to reconcile them with the origin-destination data obtained from the Interlake household survey as published. However, two problems arose with this origin-destination based travel data. First, some origin-destination pairs had to be omitted for one of two reasons. The first reason for omission (this applied to 33 origin-destination pairs) was that the destinations were such small localities that some or all of the economic data required for the traffic generation functions were not available for these localities.[15] The second reason for omissions (this applied to only 5 origin-destination pairs) was that the traffic to destinations did not appear to require using the Provincial Trunk Highway system, since the Provincial Road system provided easier access.[16] Thus the data from these 38 origin-destination pairs were not used in the model. The second problem arose because of the form of the data, which were given only by urbanization types for each municipality. This only posed a problem in municipalities where there was more than one urban locality - Rockwood, St. Andres and Bifrost. In these municipalities, traffic volumes originating in urban localities to a

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[14] A list of locations of the new sections is in Appendix C, along with the length of each section and traffic volumes as estimated by the model for the first and tenth years.

[15] A list of these omitted origin-destination pairs is included in Appendix D. The 13 destinations were Argyle, Arnes, Balmoral, Camper, Camp Morton, Chatefield, Clandeboye, Gordon, Grosse Isle, Gypsumville, Moosehorn and Rosser.

[16] A list of these omitted origin-destination pairs is included in Appendix D. The destination of all 5 pairs was Inwood.

given destination were allocated to each town on the basis of population. The only exception to this rule was when there could be no doubt as to the town of origin. For example, travel to Arborg by residents of urban areas in Bifrost could only originate in Riverton. Except in these special cases, the general rule just stated was applied. The end result of these manipulations to the origin-destination data was that 110 pairs of origins and destinations remained for utilization with the model.

EMPIRICAL RELATIONSHIPS

In preparation for the application of the model to the Interlake area, the empirical values of some variables and coefficients had to be determined, such as the coefficients of the traffic equations, the highway construction technology vector and the factors used to compute the effect of investment on the highway system. The procedures used for deriving these estimats are described in the following sections.

Traffic Equations: Origin-Destination Basis

The origin-destination traffic data relate only to errand-running traffic. As far as can be ascertained, the only way of obtaining truck movement data on an origin-destination basis for the Interlake area is to conduct a survey of trucking companies operating in the Interlake area, whether based within or outside of the area. To do this within the constraints of time and money placed on this study was impossible. Thus the commercial traffic equation on an origin-destination basis was abandoned. However, a method was found to circumvent the difficulties which the lack of such an equation raised as will be explained in the next section. Similar problems arose for the estimation of residual traffic on an origin-destination basis. But in this case, it was not even possible to determine precisely who should be surveyed. Once again it was necessary to abandon an equation of the theoretical model. But here too, a solution to the problem was found, as will be discussed in the next section.

As for the errand-running traffic equation, the estimation of its coefficients required some preliminary work. The equation, it will be recalled, was assumed to be

$$ET_{ij} = A_2 \, (TY_i)^{ac} \, (1 - TN_i/TE_i)^{bc} \, (TS_j)^{cc} \, (D_{ij})^{dc} \qquad (3.9)$$

$$\text{if } TS_i \leq TS_j$$

To estimate the value of the constant A_2 and of the elasticities ac, bc, cc and do requires that data be available for the volume of errand-running traffic from i to j (ET_{ij}), incomes in the origin (TY_i), town business sales at the destination (TS_j), distance between origin-destination pairs (D_{ij}), town local employment at the origin (TN_i) and town total -- local and non-local -- employment at the origin (TE_i). All but the last two were available.[17]

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[17] Except for the value of town sales for Winnipeg. This was assumed to be 10 times as large as the total Interlake area business sales, on the basis of population ratios.

The local employment estimates were derived from town business sales. For some towns, the area employment/output ratio was multiplied by the value of town business sales.[18] But for most towns, local employment was estimated by sectoral employment-output functions applied to sectoral business sales in each town. The summation of the value of these functions over sectors provided the town local employment estimates. These values, presented in Table 4.1 on the following page, were used in the estimation of the coefficients of equation (3.9). For rural areas, it was assumed that local employment had the value of 1. The value 0 could have been used. But the form of the equation was changed so local employment could not be zero. Since local non-agricultural employment was used as a measure of negative incentive to travel, the equation implies that rural people are much more likely to travel to make purchase than are town-dwellers.[19] Before exploiting the change in the form of the equation, it should be mentioned that estimates of town total employment were not available. Nor were estimates of non-local employment by town. The total employment variable was thus replaced by the size of the labour force in each town or rural area, since this was the best available substitute.[20] Substituting labour force size for total employment required the implicit assumption that the rate was constant among towns.

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[18] This ratio, as well as the sectoral employment - output functions and the estimates of town business sales on a sectoral basis mentioned in the test were all obtained from computations made by J.A. MacMillan and C.M. Lu.

[19] The value of 1 was used to minimize the negative incentive, although some non-agricultural jobs were located in rural areas.

[20] These estimates were obtained from the Interlake Fact Digest, table 6, pp. 88-90.

TABLE 4.1

ESTIMATED TOWN LOCAL EMPLOYMENT LEVELS - 1968.

Town	Estimated Local Employment	Method of Estimation
Selkirk	2,752	Average
Gimli	583	Average
Stonewall	525	Average
Winnipeg Beach	247	Average
Lundar	191	Average
Arborg	172	Functions
Ashern	157	Functions
Fisher Branch	145	Functions
Teulon	138	Functions
Riverton	97	Functions
Steep Rock	78	Average
Stony Mountain	73	Functions
Warren	44	Functions
St. Laurent	43	Functions
Eriksdale	34	Functions
Petersfield	28	Functions
Fraserwood	27	Functions
Poplarfield	27	Functions
TOTAL URBAN INTERLAKE	5,361	
RURAL AREAS	1	Assumption

Source: See text, previous page

Equation (3.9) was modified in order to facilitate the estimation of the coefficients. Thus the expression $(1-TN_i/TE_i)$ was replaced by (TL_i/TN_i), to simplify calculations and the equation became:

$$ET_{ij} = A_2\ (TY_i)^{ac}\ (TL_i/TN_i)^{bc}\ (TS_j)^{cc}\ (D_{ij})^{dc} \quad (4.3)$$

where TL_i is the size of the labour force in origin-town i, and the other variables are as defined on the previous page. The equation was then converted to logarithmic form, and an attempt made to estimate its coefficients by Ordinary Least Squares. Unfortunately, the matrix of cross-products was found to be singular and no estimate could be obtained in this form. However, by re-writing equation (4.3) as .

$$ET_{ij} = A_2\ (TY_i)^{ac}\ (TL_i)^{bc}\ (TN_i)^{ec}\ (TS_j)^{cc}\ (D_{ij})^{dc} \quad (4.4)$$

hypothesizing that the exponent ec is negative, and converting the equation into logarithmic form, the results shown in Table 4.2 were obtained. The column titled Equation I gives the statistical results for the errand-running traffic equation as it is written in (4.4). However, the coefficient of town "spendable incomes" does not differ significantly from zero at the 5 percent level. This result was due to multi-collinearity, the simple correlation between TY_i and TL_i being quite high at 0.878. TY_i was therefore dropped from the equation and new regression coefficients were computed. The results are presented in the Equation II column of Table 4.2

The equation used in the model for estimation of errand-running traffic volumes on the origin-destination basis was thus,

$$ET_{ij} = \frac{e^{1.1597} (TL_i)^{1.2499} (TS_j)^{0.3697}}{(TN_i)^{0.2156} (D_{ij})^{1.0366}} \qquad (4.5)$$

TABLE 4.2

RESULTS OF REGRESSIONS FOR ERRAND-RUNNING TRAFFIC ON ORIGIN-DESTINATION BASIS

COEFFICIENT	EQUATION I	EQUATION II
$TY_i(t)$	0.2569 (0.73)[a]	
$TL_i(t)$	1.0063 (2.77)[b]	1.2499 (8.62)[b]
$TN_i(t)$	-0.2297 (4.19)[b]	-0.2156 (4.20)[b]
$TS_j(t)$	0.3544 (5.61)[b]	0.3697 (6.22)[b]
$D_{ij}(t)$	-0.9948 (5.52)[b]	-1.0366 (6.08)[b]
$A_2(t)$	0.7969 (0.23)[a]	1.1598 (0.92)[a]
R^2	0.605	0.603
F	31.92	39.95
Number of Observations	110	110

a Not significantly different from zero at the 5% level.

b Significantly different from zero at the 1% level.

Equation (4.5) is the empirically-determined traffic generation function for origin-destination based errand-running travel. All coefficients are of the expected sign. Thus the theoretical considerations developed in the previous chapter appear to be correct, at least for the Interlake area. The coefficients provide a measure of the sensitivity of errand-running traffic to changes in the variables. Thus a rise of 1% in labour force size at the origin causes a 1.25% increase in errand-running travel, all other things being equal. Similarly, an increase of 1% in local employment in the origin town leads to a decrease of 0.22% in errand-running travel. A gain of 1% in town sales at the destination increases errand-running traffic by 0.37%. Finally, a reduction in the "effective distance" of 1% between origin and destination leads to a 1.04% increase in errand-running traffic volume. Thus errand-running traffic is proportionally more responsive to changes in labour force size at the origin and in distance separating origin and destination than to town sales at the destination and local employment at the origin.

Traffic Equations: Highway Sections Basis

The data gaps mentioned in the previous section made it impossible to estimate the coefficients of the commercial traffic and residual traffic equations on an origin-destination basis. Because of this, estimates of commercial traffic, as well as of total non-commercial traffic, were required on the basis of highway sections.

The estimate of non-commercial traffic was computed for each highway section by subracting the average daily truck volume from the volume of average daily traffic. Multiplying that estimate by 365 yielded yearly non-commercial traffic volume by highway section. It was assumed that there is a relationship between the errand-running traffic volume and the yearly non-commercial traffic volume. The regression of the latter on the former provides a function which could be used in the model.

The errand-running traffic volumes had to be converted to the highway section basis from the origin-destination basis. Figure 4.2 on the following page illustrates the difference between traffic flows on the two bases. In the absence of factual information, the routes used by errand-running travellers were assumed. In terms of the theoretical model, it meant that all the elements of the matrix of the matrix FAC, of order 110 x 34, were determined by judgement. And the regression thus became a measure of the extent to which the routing judgements were "sound", i.e. in harmony with the assumption of a relationship between errand-running traffic and non-commercial traffic. An initial attempt at assuming the routings was arbitrary, and the correlation was correspondingly low. A second attempt yielded an excellent result, i.e. high correlation, and that routing matrix was adopted. Appendix E presents the routings that were assumed in the form of the proportion of origin-destination traffic volumes travelling over a given highway section.

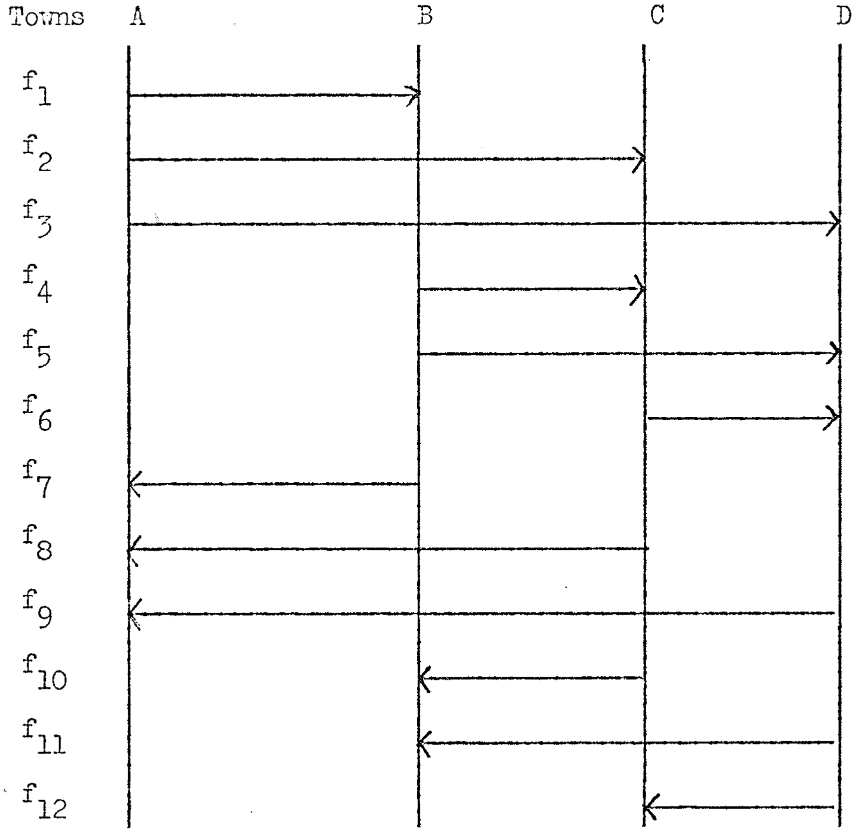

Figure 4.2

Conciliation of Origin-Destination Based and Highway Section Based Traffic Flows.

A,B,C,D are origins and destinations.
f_1 - f_{12} are traffic flows on origin-destination basis
Traffic flows on highway section basis are defined as
1. - Section A - B: $f_1 + f_2 + f_3 + f_7 + f_8 + f_9$
2. - Section B - C: $f_2 + f_3 + f_4 + f_5 + f_8 + f_9 + f_{10} + f_{11}$
3. - Section C - D: $f_3 + f_5 + f_6 + f_9 + f_{11} + f_{12}$

The Figure depicts the case where only one routing is possible between origins and destinations. When there is more than one possibility, the correspondence between highway section volumes and origin-destination volumes becomes correspondingly more complex.

The non-commercial traffic volumes were then regressed against the commercial traffic volumes. Both logarithmic and linear forms of relationships were tested. In both cases, the logarithmic forms provided better fits. The results of these regressions are given in Table 4.3 on the following page. Both these relationships were found to be statistically significant, as were the values of the regression coefficients. Expressed in the usual form,

$$NCT = e^{-1.6105} (RET)^{1.2519} \qquad (4.6)$$

and

$$RCT = e^{-2.1760} (NCT)^{0.9873} \qquad (4.7)$$

where

$$RET = (ET)\ (FAC) \qquad (4.8)$$

NCT_a is a row vector of 34 elements, the volume of non-commercial traffic over each highway section, in cars per year;

RET is a row vector of 34 elements, the volume of errand-running traffic over each highway section, in cars per year;

RCT_a is a row vector of 34 elements, the volume of truck traffic over each highway section, in trucks per year;

ET is a row vector of 110 elements, the yearly volume of errand-running traffic on an origin-destination basis between each origin-destination pair, in cars per year.

Equations (4.6), (4.7) and (4.8), along with equation (4.5) combine to determine the traffic flows over the Interlake Provincial Trunk Highway system.

TABLE 4.3

RESULTS OF REGRESSIONS FOR TOTAL NON-COMMERCIAL AND FOR COMMERCIAL TRAFFIC ON HIGHWAY SECTION BASIS

	Equation I	Equation II
Dependent Variable	Total Non-Commercial Traffic Volume	Commercial Traffic Volume
Independent Variable	Errand-Running Traffic Volume	Total Non-Commercial Traffic Volume
Value of Coefficient (t- value of estimate)	1.2519 (16.83)[b]	0.9873 (13.91)[b]
Constant Term (t- value of estimate	-1.6105 (-1.70)[a]	-2.1760 (-2.16)[a]
Coefficient of Determination	0.8984	0.8580
F Ratio	283.08	193.39
Number of Observations	34	34

[a] Significantly different from zero at 5% level.

[b] Significantly different from zero at 1% level.

Highway Construction Technology Vector

In order to use the input-output multipliers, the value of highway investment must be converted into terms of changes in final demands for the output of each sector of the economy. To affect this conversion, it was assumed that the share of highway investment spent on each sector was constant. The estimates of sectoral shares were derived from the Arborg Data and from some questionnaires obtained from a construction firm. The estimation procedure is discussed in detail in Appendix B. In brief, it consisted in breaking out items of expenditure from the Arborg Data into their major components on the basis of engineers' judgements. These components were then further disaggregated -- to the sectoral level -- on the basis either of the construction questionnaires just mentioned, or of personal judgement. The resulting estimates of the highway construction technology vector -- i.e. of the vector showing the share of each sector's inputs into the construction of highways -- is presented in Table 4.4 below. The large share of imports may appear surprising at first. But it must be remembered that this includes, among other things, imports of paving asphalt from Winnipeg.

TABLE 4.4

HIGHWAY CONSTRUCTION TECHNOLOGY VECTOR

Sector	Share of Total Expenditures
1. - Agriculture - Livestock	.019
2. - Agriculture - Crops (including Agric. Services)	.022
3. - Mining and Quarrying	.093
6. - Construction	.010
7. - Transportation	.009
8. - Petroleum Wholesale	.099
9. - Farm Equipment	.020
10. - Food STores	.002
12. - Automotive Sales and Service	.017
15. - Insurance	.018
17. - Other Services (Non-Personal)	.243
18. - Households	.169
TOTAL INTERLAKE	.720[a]
TOTAL IMPORTS	.280
TOTAL EXPENDITURES	1.000

[a] Figures may not add due to rounding.
Source: Appendix B

The sectors omitted from Table 4.4 did not benefit directly from the highway investments. However, they obtained some benefits from the indirect and induced effects as these worked themselves through the system.

Highway Effects of Investment

Apart from the economic effects, the investment in highways also had direct impacts on the road system itself. The three major potential effects, as discussed in the previous chapter, were changes in the length of highway sections, changes in service volumes and changes in travel time. Estimates of the values of these coefficients were derived from the Arborg Data, which contained engineers' judgements as to the magnitudes of the effects for specific projects. The first effect, changes in the length of highway sections, was found to be non-existent for all projects. Thus,

$$DHL = 0 \qquad (4.9)$$

The second effect, that on service volumes, was positive for six of eight projects. The estimated average change in service volume per $1000 of investment was computed and used to quantify the affect of investment on service volumes. The method used[21] yielded the estimate

$$DSV = .244 \qquad (4.10)$$

Thus additional capacity of 1 car/hour was created by an investment of, on the average, a little more than $4000. The third effect, the

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[21] Cf. Appendix B.

change in travel times, occurred as a result of only five projects. And, even then, they only related to truck traffic. Nevertheless, it was possible to use the Arborg Data to compute an average overall effect by weighing the travel time changes by truck volumes. The resultant average effect was

$$\mathrm{DDT} = .00012 \qquad (4.11)$$

that is to say, investment of $100,000 resulted, on the average in a travel time saving of one percent.[22]

MODEL ALTERATIONS

Given the estimates, of the coefficients, the model could then be applied to the Interlake area. But a first attempt fell short because some changes were required to make the model completely operational. Alterations were made to each of the economic, highway and impact sub-models. These changes, and their significance, are discussed in the following sections.

Economic Sub-Model

Three changes were brought to the economic sub-model. First, the "spendable income" concept was dropped. This was done because "spendable income" was not a significant variable in the traffic

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[22] Cf. Appendix B.

generation functions. Moreover, the conventional regional income concept was preferable for measuring income impacts of investment. Thus equation (3.6)[23] was deleted. Second, the computation of town incomes was changed, partly because of the adoption of the conventional regional income concept, and partly because of the unavailability of the total employment estimates. Thus, it became,

$$TY = AY\ (1/AL)\ (TL) \tag{4.12}$$

where TL is a column vector of M elements, the size of the labour force in

each of the M towns (origins); AL is a scalar, the size of the area labour force; and the other variables are defined in Figure 3.2, page 32.

Equation (4.12) now allocates regional income to towns on the basis of the size of labour force instead of total local and non-local employment, since estimates of the latter were not available. Finally, the model was latered to compute the yearly value of business sales in Winnipeg, since this was the destination most often travelled to although it was outside of the region. It was assumed that the value of business sales in Winnipeg were 10 times the value of total area business sales in the Interlake region. The factor 10 was used on the basis of approximate population ratios. Thus

$$TSX = 10 \cdot ATS \tag{4.13}$$

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[23] Cf. Fig. 3.2, p. 33.

where TXS is a scalar, the value of the yearly town business sales in Winnipeg.

ATS is defined in Figure 3.2.

Equation (4.13) computes estimates of town business sales in Winnipeg, the most often travelled to city in the system.

Highway Sub-Model

Changes required in the highway sub-model were much more extensive. They related primarily, but not exclusively, to the traffic generation equations. First, as mentioned above, equations (3.8) and (3.11) -- commercial traffic and residual traffic -- were not used because there were no data available to estimate their coefficients. Thus equation (3.12) also had to be cast aside since total traffic could not be computed when two of its components were not available. As previously mentioned, equation (3.10) was also omitted so that all valid data could be used. Thus, the system became

$$RET = (ET)\,(FAC) \qquad (4.14)$$

$$NCT = A_4 \quad RET^{nct} \qquad (4.15)$$

$$RCT = A_5 \quad NCT^{ct} \qquad (4.16)$$

and

$$YVT = 2 \cdot CT + NCT \qquad (4.17)$$

where YVT is the total traffic volume in a year over highway section, as noted on page 42 and the other variables are defined on page 87.

Equation (4.14) computes errand-running traffic volumes on a highway section basis from origin-destination errand-running volumes and the assumed routings. (Equation (4.15) estimates non-commercial traffic volumes on a highway section basis from the highway section errand-running traffic volumes. Equation (4.16) computes commercial traffic over highway sections as a function of non-commercial traffic volumes. Equation (4.17) computes the total traffic volume over a highway section on the basis of the estimated volumes of commercial and non-commercial traffic volumes. The use of equations (4.14) to (4.17) eliminated the need for equation (3.13) which computed highway section traffic volumes from origin-destination total traffic volumes.

The implications of these changes caused by the data are quite important. For, as the system is currently represented, all traffic volumes are a function of the assumed routings that were mentioned previously. Thus all the results of this study are contingent upon the routings being correct. While the regression results indicate that this was true for the base year data, there are no guarantees that such routings will remain constant. Nevertheless, the problem may not be as critical as it appears at first, since there are rather limited opportunities for changing routes between origins and destinations. However, the system also depends on constant relationships between the different types of traffic over highway sections. This constitutes a major weakness of the model as applied to the Interlake.

Two further changes were made to the highway sub-model. The first change was made after a first trial of the model. Equation (3.17) was altered so that sufficient investment would be provided to eliminate congestion and provide a small amount of excess service volume. This excess often disappeared after computing the effects of the investment on traffic volumes. It was provided for in order to speed computation and to diminish the number of smaller investment increments by anticipating their traffic-generation effects. Thus equation (3.17) was changed to

$$RHI_a = (CO_a + 5)/DSV \qquad (4.18)$$

where all variables are defined on page 48.

The second change was also made after a trial run of the model. It was found that the model could become explosive, i.e. that the increases in investment caused greater increases in traffic volumes than in service volumes. This occurred only when high exogenous growth rates in population and final demands were assumed. To counter the problem, a limit of $35,000 per mile of highway section was placed on the increments in investment.[24] The number of incremental rounds in one year was also restricted to 5. These two measures were effective in eliminating endless iterations. Thus, a new equation was added to the sub-model.

$$THI_a = 35 \cdot HL_a \quad \text{if } THI_a > 35\ HL_a \qquad (4.19)$$

Equation (4.19) restricts the value of investment on one highway section to $35,000 per mile.

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[24] On the basis of discussions with highway engineers, this appeared to be a reasonable upper limit for this area.

Impact Sub-Model

The explosiveness of the model also caused the imposing of some restrictions on the values of variables computed by the impact sub-model. Thus the change in travel time over a highway section was restricted to a maximum of 1 percent. This restriction only applied to investment increments of more than $83,000. Formally,

$$NTT_a = 0.01 \quad \text{if } NTT_a > 0.01 \tag{4.20}$$

Similarly, the absolute value of the change in the length of highway sections was constrained to a maximum of .1 mile. The application of this restriction was superimposed on the travel time change constraint, and was not effective save on very long highway sections. It was, in formal terms,

$$CHL_a = 0.1 \quad \text{if } CHL_a > 0.1 \tag{4.21}$$

The other set of changes to the impact sub-model was the omission of equations (3.23), (3.24) and (3.25). These were omitted because the factor DHL was found to be zero. Thus the factor PRL could be omitted and it was possible to replace (3.26) by

$$CHL = (HL)''(I)\ (NTT) \tag{4.22}$$

Finally, the calculation of economic impacts was altered because of the changes involved in equations (4.12) and (4.13) above. Thus

$$DTY = DAY\ (1/AL)\ (TL) \tag*{(4.12)'}$$

$$DTSX = 10 \cdot DATS \tag*{(4.13)'}$$

and

$$TSX' = TSX + DTSX \tag{4.23}$$

were added to the impact sub-model.

Yearly Incrementation

In applying the model to the Interlake area, it was assumed that exogenous growth was occurring in the economic and demographic areas. The growth mechanism used by this model was the simplest available - assumed growth at a constant rate. More complex models could probably have been used. But since the model was analytically rather than historically predictive, the addition would not have been significant. Moreover, it would have unduly complicated the analysis. The effect of assuming yearly exogenous growth was to add on several equations:

$$TP_{t+1} = TP_t \quad (1 + DPO) \qquad (4.24)$$

$$TL_{t+1} = TL_t \quad (1 + DPO) \qquad (4.25)$$

$$G_{t+1} = G_t \quad (1 + DEC) \qquad (4.26)$$

$$IN_{t+1} = IN_t \quad (1 + DEC) \qquad (4.27)$$

$$EX_{t+1} = EX_t \quad (1 + DEC) \qquad (4.28)$$

For the basic application of the model to the Interlake area, it was assumed that

$$DPO = 0.02 \qquad (4.29)$$

and

$$DEC = 0.05 \qquad (4.30)$$

However, these assumptions were changed and the effect of the changes computed as will be discussed shortly.

SUMMARY

The major data sources were the University of Manitoba Department of Agricultural Economics surveys of the Interlake area for 1968 and the Manitoba Department of Public Works and Highways. From these sources information was obtained about demographic and economic variables in the Interlake area, as well as trip-making behaviour of area residents and characteristics of the highway system. The data were screened for non-useable information. Useable data were inputs into the estimation of coefficients for the region. Because data were not always available, some changes were made to all three sub-models. In addition, yearly growth rates were applied to exogenous variables. The resultant model, as applied to the Interlake economy is summarized in Appendix F.

Chapter 5

LIMITATIONS OF THE MODEL

The model developed and modified in the previous three chapters has a number of deficiencies which must be discussed before the results of the application to the Interlake are mentioned. These limitations affect all three sub-models. There are also some limits imposed by the treatment of time in the model.

THE ECONOMIC SUB-MODEL

The limitations of the economic sub-model stem both from the theoretical framework adopted and from data gaps. The model computes the values of regional variables such as business sales and incomes and allocates these to towns on the basis of demographic variables. Although this procedure is the only one available, it is quite restrictive, particularly when it is considered that each town's share is assumed to remain constant. However, the alternative would require tremendous amounts of data. It would compute town sales from exogenous final demands for each town. A growth model could then be used for each town. Thus the area totals would be built up from town estimates rather than being allocated to towns. Nevertheless, this procedure would still be severely limited by the assumed constancy or input-output coefficients. The latter problem is also present in the model formulated in the previous chapters. It thus limits the validity of conclusions drawn, expecially for the later time periods.

The application of the model to the Interlake area was constrained by the absence of employment data suitable for use in the model. Although it was possible to calculate estimates of town local employment, it would have been preferable to have sounder estimates. The fact that the average method[1] yielded higher results for all towns than the functional method makes one suspicious of the validity of both. The lack of information about total town employment levels prevented what was felt to be the best allocator of regional incomes from being used.

THE HIGHWAY SUB-MODEL

In its theoretical formulation, the highway sub-model has two gaps of some significance. First, there is no mechanism provided for diversion of traffic to alternate routes when congestion occurs. This is not as serious as it could otherwise be, since the model assumes investment as soon as congestion occurs. This will be elaborated later. Moreover, in the Interlake region, diversions over the Provincial Trunk Highway system are probably quite rare because of the location of highways and of trading pattersn. Second, the sub-model assumes homogeneous sections, whereas this is obviously not the case. Thus estimated congestion could be caused by one point, although it would be assumed to occur over the whole section. However, if a map of the

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[1] Cf. Chapter 4, p. 80 , for an explanation of the two methods used.

highway system, along with indications of bottlenecks and potential bottlenecks were integrated into the model, it would provide the model with greater flexibility in determining investment needs. One could visualize computing deterioration of highway surfaces on the basis of traffic volumes, and including deterioration-based investment in the model.

Several empirical problems are also associated with the highway sub-model. These relate to limitations imposed by the routings that were assumed for errand-running traffic and the exclusion of Provincial Roads. To reiterate what has already been said, all the results derived from the model depend on the routings that were assumed. A different set of routings could -- and probably would -- have resulted in an entirely different set of results.

The exclusion of Provincial Roads was based on several factors. Most important was the added complexity that would have been introduced into the model and the near-impossibility of dealing with a network many times more involved than the Provincial Trunk Highway system. Nevertheless, the absence of the Provincial Road system influenced the routings assumed, and it must be taken into account.

THE IMPACT SUB-MODEL

One of the gaps in the impact sub-model is related to the economic sub-model. Because it was not realistic to formulate the economic sub-model in terms of a series of town economies, it was not possible to relate changes in final demands to specific towns but only to the area as a whole.

Empirically, it was not possible to obtain estimates of the employment impacts of highway construction projects. The employment impacts specified, which include changes in employment levels due to the indirect and induced as well as direct multiplier effects, were computed from estimated employment-output ratios.

THE TIME DIMENSION

The model's deficiency in this respect has already been discussed at the conclusion of Chapter 3. It will be recalled that the static formulation of the model imposes serious limitations on the validity of the results derived from it. The assumptions of instantaneous in investment without administrative or perceptive lags and of instantaneous multiplier effects, are certainly very restrictive. However, attempts to overcome these problems did not succeed because of the complexity involved.

SUMMARY

There are severe limitations to the application of the model. The economic sub-model allocates incomes and business ales to towns rather than estimating them for each town. It is also constrained by lack of employment data. The highway sub-model uses homogenous sections rather than maps of sections with their bottlenecks. It also lacks provisions for investment on the basis of roadway deteriortation. In addition, it is based on assumed routings which exclude Provincial Roads. The impact sub-model specifies regional impacts rather than effects on given towns. Finally, the model is essentially static.

Chapter 6

RESULTS

The model computed estimates of business sales, incomes, population, labour force and local employment for ten years under the assumption that highway investment would not occur. It also yielded predictions of highway investment for the ten one-year periods under the assumptions that multiplier effects were instantaneous and that highway investment is of the pump-priming type, i.e. one-shot expenditures. The impacts of these investments on the economic and highway systems were then estimated.

ASSUMED GROWTH

Before discussing the investment results of the model, it would be useful to know the growth conditions assumed and the magnitude of their effects. Table 6.1 presents the exogenous levels of some economic and demographic variables for the first and tenth years. The assumed growth rates were 2% per year for the human resource variables (except local employment), and 5% per year for the economic variables. Local employment was computed as a function of town sales and was not assumed to grow, but expanded as a consequence of the increase in town sales. The growth rates used imply very rapid growth of the economic system and of population and labour force sizes.

INVESTMENT

The very high growth rates assumed were associated with quite high levels of investment for capacity reasons. Capacity-based investment was computed to be about $7 million over the ten years, whereas the ARDA-FRED

TABLE 6.1

EXOGENOUSLY CAUSED GROWTH IN SELECTED VARIABLES, TEN YEAR SUMMARY

Variable	First Year	Tenth Year	Percentage Change
Area Business Sales[a]	151,558	235,117	55.1
Area Income	75,054	116,433	53.8
Area Population[b]	50,468	60,314	19.5
Area Labour Force[c]	21,345	25,509	19.5
Area Local Employment[c]	5,361	7,962	48.5
Local Employment as a Percentage of Labour Force (excluding Agriculture)	25.1	31.2	24.3

[a] Thousands of dollars, except for last column

[b] Number of people, except for last column

[c] Number of man-years, except for last column

Source: Computed from the model.

development expenditures amounted to almost $2.5 million, or just over one quarter of the total ten year outlays. These investments were concentrated on a few of the highway sections. Development investment was limited to 6 highway sections, all in the Northern part of the region. Capacity-based investment was required on only 4 highway sections, all in the Southern part of the region. The two types of investment also differed in the average expenditure per highway section, as Table 6.2 shows. Capacity-based investment averaged more than 4 times as much expenditures per highway section as did development investment.

TABLE 6.2

HIGHWAY INVESTMENT BY CATEGORY
TEN-YEAR SUMMARY

Category	Expenditure[a]	Number of Highway Sections Affected	Average Expenditure per Section[a]
Capacity	6,903	4	1726
Development	2,473	6	412
Total	9,376	10	938

[a] Thousands of dollars

Source: Computed from the model.

Even within this small number of affected sections, the concentration of investments was very high, for each type of investment. Close to 40% of the development expenditures was spent on one of the six affected highway sections. As can be seen from Table 6.3, the two sections which had the greatest development investments together accounted for nearly 70% of total development outlays on highways.

The concentration of capacity-based investment was also very high. Investment was only required on four highway sections for capacity reasons. Of these four, the section with the largest investment accounted for nearly 46% of total capacity-based investment., while the least-invested in section only used up 8% of those funds as can be seen from Table 6.4 below.

These investments were spread out over a number of years. The time path of highway investment is plotted in Figure 6.1. The capacity-based investments increased steadily from $0.25 million in the first year to $1.6

TABLE 6.3

DEVELOPMENT INVESTMENT BY HIGHWAY SECTION, TEN-YEAR SUMMARY

Section	Location	Expenditure[a]	Percentage of Total
34	P.T.H.68: Eriksdale to Poplarfield	928	37.5
6	P.T.H. 6: Ashern to Junction of P.R. 239	783	31.7
5	P.T.H. 6: Eriksdale to Ashern	356	14.4
32	P.T.H.68: P.T.H.7 to P.T.H. 16	203	8.2
31	P.T.H.68: P.T.H.8 to P.T.H. 7	197	8.0
33	P.T.H.68: P.T.H. 16 to Poplarfield	6	0.2
TOTAL		2,473	100.0

[a] Thousands of dollars

Source: Computed from the model.

TABLE 6.4

CAPACITY-BASED INVESTMENT BY HIGHWAY SECTION, TEN-YEAR SUMMARY

Section	Location	Expenditure[a]	Percentage of Total
14	P.T.H. 8: Perimeter to P.T.H. 27	3,143	45.5
25	P.T.H. 9: Petersfield to Winnipeg Beach	1,867	27.0
15	P.T.H. 8: P.T.H. 27 to P.R. 231 (Gimli)	1,356	19.6
8	P.T.H. 7: Jct. Stony Mountain Rd to P.T.H. 67	538	7.8
TOTAL		6,904	100.0

[a] Thousands of dollars

Source: Computed from the model.

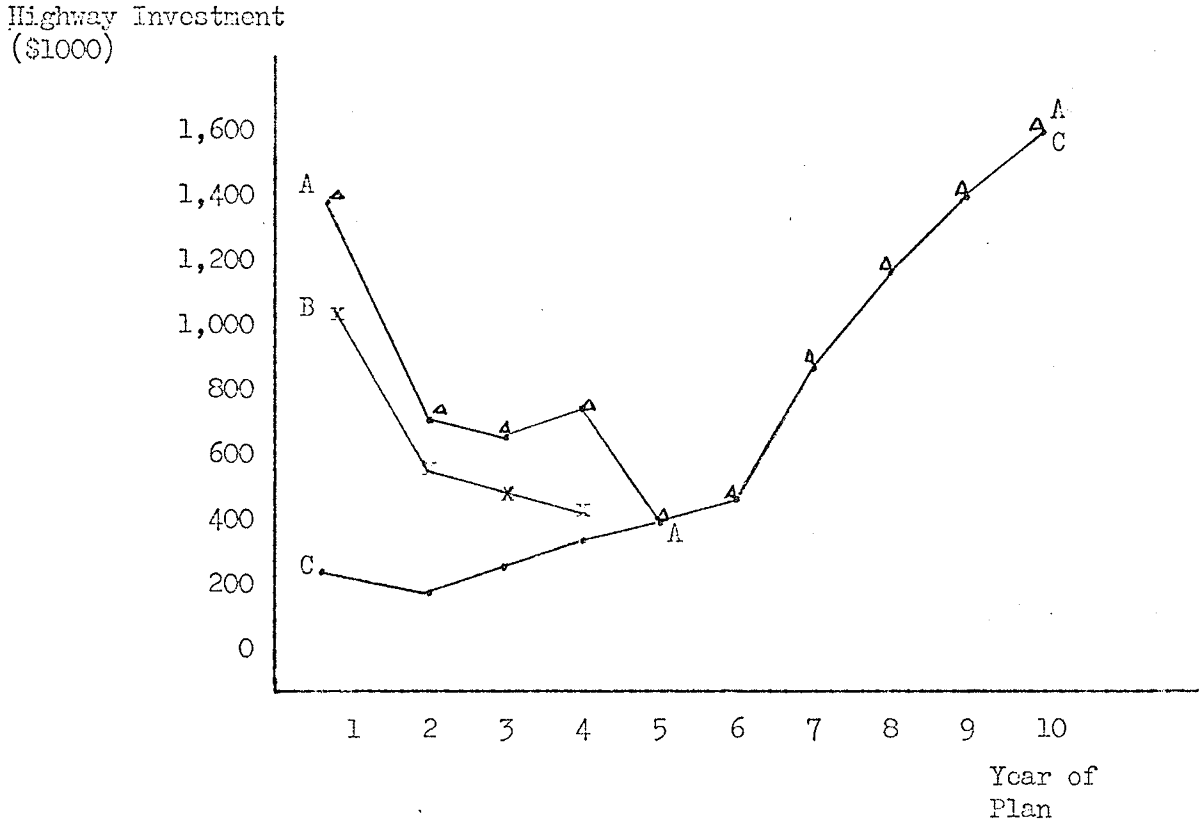

Figure 6.1

TIME PATH OF HIGHWAY INVESTMENT

A - Total Investment - △

B - ARDA-FRED highway program expenditure - X

C - Highway investment for capacity reasons - •

Source: Computed from the model.

million in the tenth year. At the same time, the development investment in highways declined from $1.1 million in the first year to $0.4 million in the fourth and to nothing in the fifth and following years. The combination of both types of investment resulted in a more or less steady decline from the first year high of $1.3 million to a low of $0.4 million in the fifth year. Then investment increased steadily to attain a new peak in the tenth year, at $1.6 million.

IMPACTS

These investments had some impacts on the Interlake economic and highway systems. The direct, indirect and induced effects of highway investment on area business sales were in the range of 0.86. The income and employment multipliers were substantially smaller. They averaged out to approximately 0.50 for incomes and 0.00003 for employment.[1] These impacts are summarized in Table 6.5 which presents estimates of the changes in area business sales, area incomes and local non-agricultural employment resulting from the highway investments.

The small values for the income impacts are manifested again in Table 6.6 which gives per capita incomes with and without the highway investment. The effect of investment is to increase per capita incomes by 0.2 to 0.9 of 1%. Thus for a "typical" family of four, incomes would have increased by $52 to $6,000 in the first year, or by $56 to $7,720 in the tenth year. It seems safe to conclude that income effects of the highway investment are not particularly significant.

The investments also had some effects on the highway system. Table 6.7 summarizes these effects on "effective distances" and service volumes of highway sections where investment occurred. There were also impacts

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[1] Thus an investment of $1 million would lead to an increase in area business sales of $860 thousand, a rise of $500 thousand in incomes and to the creation of new employment of 30 man-years.

TABLE 6.5

ECONOMIC IMPACTS OF HIGHWAY INVESTMENT, BY YEAR

Year	Investment	Impact on: Area Business Sales[a]	Area Incomes[a]	Local Industrial Employment[b]
1	1,338	1,152	664	41
2	712	613	354	22
3	667	574	331	21
4	695	599	345	21
5	402	346	200	13
6	493	425	245	15
7	931	801	462	29
8	1,172	1,010	582	36
9	1,374	1,183	682	41
10	1,590	1,370	790	48

[a] Thousands of dollars

[b] Number of man-years, excluding Agriculture

Source: Computed from the model.

TABLE 6.6

PER CAPITA INCOMES WITH AND WITHOUT HIGHWAY INVESTMENT, BY YEAR

Year	Per Capita Incomes Without Investment[a]	Per Capita Incomes With Investment[a]	Percentage Change Due to Investment
1	1,487	1,500	0.9%
2	1,531	1,538	0.5%
3	1,567	1,582	0.4%
4	1,622	1,629	0.4%
5	1,670	1,674	0.2%
6	1,719	1,724	0.3%
7	1,770	1,778	0.5%
8	1,822	1,832	0.5%
9	1,875	1,887	0.6%
10	1,930	1.944	0.7%

[a] Rounded to nearest dollar

Source: Computed from the model.

on traffic flows over all highway sections.

TABLE 6.7

INVESTMENT IMPACTS ON HIGHWAY SECTIONS

Section[a]	"Effective Distances"[b]		Service Volumes[c]	
	Before	After	Before	After
14	5.10	4.02	481	1,577
25	13.30	11.35	573	1,029
15	41.50	37.40	753	1,084
34	23.60	22.90	200	426
6	18.60	18.05	200	391
8	4.00	3.82	605	736
5	26.00	25.48	200	287
32	17.10	16.92	792	842
31	9.30	9.19	810	858
33	0.70	0.70	729	730

[a] By order of decreasing volume of investment per section

[b] Measured in miles; for a discussion of the concept, cf. p.

[c] Measured in cars/hour.

Source: Computed from the model.

Table 6.8 presents the changes in total traffic volumes for the 10 highway sections on which investment occurred. The effects of investments on traffic volumes over a specific section depend on a number of factors such as, whether the investment occurred on that section or the increased traffic volumes are just the result of the general rise in economic conditions due to the investment, the magnitude of the multiplier effects, the assumed routings, and so on.

ALTERNATIVE ASSUMPTIONS

The results just discussed assumed growth rates of 2% per year for human resource variables and 5% per year for exogenous increases in final demands. These rates are certainly quite high. By assuming lower rates of

TABLE 6.8

TOTAL TRAFFIC VOLUMES FOR SELECTED HIGHWAY SECTIONS DURING FIRST AND TENTH YEARS, BEFORE AND AFTER INVESTMENT

Section[a]	First Year		Tenth Year	
	Before Investment[b]	After Investment[b]	Before Investment[b]	After Investment[b]
14	1,529	1,537	2,685	2,799
25	982	986	1,906	2,053
15	1,008	1,015	1,832	1,923
34	73	75	124	124
6	196	205	360	361
8	888	891	1,446	1,454
5	11	12	19	19
32	180	182	295	296
31	15	15	24	24
33	185	189	313	314

[a] By order of decreasing volume of investment per section.

[b] Total traffic volumes rounded to nearest thousand cars.

Source: Computed from the model.

growth, the results changed considerably. Table 6.9 presents the total volume of investment and number of highway sections invested in under alternative growth assumptions. It emphasizes again that the original growth assumptions were quite high. Not only were there more highway sections invested in, but the volume of investment per section differed tremendously according to the assumptions used.

These results are based on capacity being defined as 18.4% of annual average daily traffic, except for Provincial Trunk Highway 8 for which the ratio was 20.6%. These were the ratios at the 30th and 50th peak hours for these highways in 1968. These ratios were raised to 20.2% and 22.4% respectively. Table 6.10 presents a summary of the results obtained when greater highway capacity requirements were assumed. Comparing the results of Tables 6.10 and 6.9, it can be seen that changing the peak criterion hour proportion

TABLE 6.9

SUMMARY OF ALTERNATIVE RESULTS UNDER SELECTED RATES OF EXOGENOUS GROWTH

Rate of Growth Assumptions	Highway Investment[a] Capacity-based	Highway Investment[a] Development	Number of Sections Affected	Average Expenditure per Section[a]
0% per year for final demands and for population	252	2,473	7	389
3% per year for final demands; 0% per year for population	687	2,473	7	451
5% per year for final demands; 2% per year for population	6,903	2,473	10	938

[a] Thousands of dollars

Source: Computed from the model.

of annual average daily traffic has very sizeable impacts on capacity-based investment, regardless of the growth assumptions made. An increase of approximately 10% in that proportion brought about corresponding increases in capacity-based investment in the range of 60% - 125%. Thus the system appears to be very sensitive to changes in the peak criterion hour proportion of annual average daily traffic, at least over the range tested.

SUMMARY

The assumed growth levels in the basic computation of the model were quite high. This led to considerable capacity-based highway investment to accompany the pre-determined levels of development-based investment.

TABLE 6.10

SUMMARY OF ALTERNATIVE RESULTS UNDER SELECTED RATES OF EXOGENOUS GROWTH WITH GREATER PEAK CRITERION HOUR RATIOS

Rate of Growth Assumptions	Highway Investment[a] Capacity-Based	Highway Investment[a] Development	Number of Sections Affected	Average Expenditure per Section[a]
0% per year for final demands and for population	576	2,473	7	436
3% per year for final demands; 0% per year for population	1,357	2,473	8	479
3% per year for final demand; 2% per year for population	11,061	2,473	11	1,230

[a] Thousands of dollars

Source: Computed from the model.

Regardless of the basis for investment, it was concentrated on only a few sections, although distributed widely over time. The economic impacts of the investment were fairly small. The multiplier effects of investment averaged out to roughly 0.86 for business sales, 0.50 for incomes and 0.03 for employment. In terms of per capita incomes, the investment meant an increase of a fraction of 1%. There were also considerable effects on "effective distances" and service volumes of highway sections. Traffic volumes also increased because of the investment. The system was quite sensitive to different assumptions about exogenous growth in some key variables. It was found to be very sensitive to changes in the peak criterion hour proportion of annual average daily traffic over the range tested.

Chapter 7

SUMMARY AND CONCLUSIONS

The study developed a method to evaluate the effect of -- and need for -- investment in highways within the framework of a regional economy. The effect of investment was measured in terms of the criterion of economic development. A simulation model was chosen as the best way to estimate that effect and to compute the need for investment, in preference to benefit-cost and planning-programming-budgeting approaches.

A theoretical model, consisting of three sub-models, was then formulated. The economic sub-model utilized input-output techniques to estimate area business sales and incomes on the basis of exogenous final demands. Sales and incomes were then allocated to towns in the area in proportion to the values of human resource variables. The highway sub-model used town incomes, business sales and human resource variables to estimate the volumes of the different types of traffic flows between origins and destinations. These flows were converted to traffic volumes over highway sections, and then to estimates of highway requirements. The latter, along with service volumes of the highway sections, served to estimate whether investment was required and, if so, the value of required expenditures. The impact sub-model computed the effects of highway investment on area and town business sales, incomes and local employment levels. It also assessed the changes to the highway system, in terms of additional service volumes created, reduced travel times and reduced "effective distances".

The empirical model which was used to analyze the Interlake area Provincial Trunk Highway system used data from several sources. Major data suppliers were the University of Manitoba Department of Agricultural Economics and the Manitoba Department of Public Works and Highways. The data included extensive economic and demographic information about the Interlake area, as well as descriptions of the highway system and estimates of construction expenditures. These data were used to estimate the model coefficients, particularly the traffic equations and the highway construction technology vector. However, not all of the model's data requirements could be met. Because of these gaps, alterations were made to all three sub-models. The most significant changes were to the highway sub-model. The latter was reformulated so that all traffic flows were a function of errand-running traffic on an origin-destination basis.

This reformulation was one of the several major limitations of the model. The revised model was so formulated that all results depended on the routings assumed for the origin-destination pairs. Moreover, impacts could not be estimated for different towns, but were computed for the area and allocated to towns. This necessity to allocate regional variables to towns rather than to compute town estimates constituted an additional limitation. Finally, the use of long highway sections rather than a mapping of the highway system placed further limits on the model.

Despite these limitations the model was applied to the Interlake area. It was found that the multiplier effects of highway investment on business sales was approximately 0.86. The effect on incomes was about 0.50. The local employment multiplier was in the neighborhood of 0.00003. Thus, for $1 million of highway investment, area business sales increased by $860 thousand, regional income by $500 thousand and local employment by 30 man-years. The ten-year total for capacity-based highway investment varied between $0.25 and $11.06 million depending on the assumptions made about exogenous growth and the definition of highway capacity requirements.

On the basis of these results, it is not possible to assess the ARDA-FRED highway program expenditures in terms of the long term impact on area productivity through improved educational facilities to area residents. Moreover, the relative magnitude of the development and the capacity-based investments depends solely on the growth rates assumed. The results indicate that highway investment for capacity reasons will only be required in large volume if tremendously rapid growth rates are maintained in the area. The attainment of such rates appears very unlikely. Thus it appears that over capacity in the region's highway system will be maintained for some time.

These conclusions must be tempered by knowledge of the limitations discussed in Chapter 5. One of the major gaps mentioned there was the use of quite long highway sections. Research is required to determine the effect on the model of using different sets of sections and of using route mappings rather than highway sections. Further research could also explore the sensitivity of the model to changes in the magnitude of the limits on investment and on travel time changes due to investment.

APPENDICES

APPENDIX A

HIGHWAY PLANNING DATA

TABLE A.1

DATA SUPPLIED BY THE PLANNING DIVISION, HIGHWAYS BRANCH, MANITOBA DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

P.T.H. No.	Location	Mileage	Capacity (Cars/Hour)	A.D.T.[a] 1968	Percent Trucks
6	P.T.H. 101 to P.T.H. 67	13.9	810	1338	8
	P.T.H. 67 to Northern Boundary of R.M. of Woodlands	20.3	658	1034	11
	N. Bdry. R.M. of Woodlands to P.T.H. 68	40.3	756	658	13
	P.T.H. 68 to 5.4 miles North of P.R. 235	12.0	765	526	11
	5.4 miles North of P.R. 235 to South Junction with P.R. 325	12.5	*	500	8
	S. Jct. P.R. 325 to P.R. 237	9.0	*	478	10
	P.R. 237 to P.R. 239	11.1	*	421	13
	P.R. 239 to P.R. 513	23.3	*	312	13
7	P.T.H. 101 to South Junction with P.R. 321	5.0	605	3590	13
	S. Jct. P.R. 321 to P.T.H. 67	5.8	605	3226	12
	P.T.H. 67 to P.R. 228	17.4	481	1899	13
	P.R. 228 to P.R. 229	8.8	517	802	10
	P.R. 229 to P.T.H. 16	11.1	518	659	10
	P.T.H. 16 to 8.5 miles North	8.5	621	638	11

Table A.1 continued

P.T.H. No.	Location	Mileage	Capacity (Cars/Hour)	A.D.T.[a] 1968	Percent Trucks
7	8.5 miles N. of P.T.H. 16 to 3.2 miles S. of P.T.H. 68	4.6	639	789	10
	3.2 miles S. of P.T.H. 68 to P.T.H. 68	3.2	613	879	10
8	P.T.H. 101 to P.T.H. 27	5.1	810	2533	7
	P.T.H. 27 to 0.8 miles North	0.8	791	2004	6
	0.8 miles N. of P.T.H. 27 to P.R. 515	12.4	794	1715	6
	P.R. 515 to P.R. 225	14.3	803	1489	5
	P.R. 225 to P.R. 229	4.8	786	1159	5
	P.R. 229 to P.R. 231	9.2	753	1015	7
	P.R. 231 to P.R. 324	5.1	634	961	10
	P.R. 324 to P.R. 611 (Arnes)	6.2	712	848	9
	P.R. 611 (Arnes) to P.T.H. 68	7.0	734	716	9
	P.T.H. 68 to P.R. 234	6.5	765	602	9
	P.R. 234 to N.E. 19-23-4E	0.7	*	361	9
9	P.T.H. 101 to P.T.H. 27	5.3	2286	4962	6
	P.T.H. 27 to P.T.H. 44	4.8	2714	7000	6
	P.T.H. 44 to S. Jct. with P.T.H. 9A	28	3572	7000	6
	S. Jct. P.T.H. 9A to 0.4 miles S. of N. Jct. with P.T.H. 9A	4.4	895	900	4
	0.4 miles S. of N. Jct. P.T.H. 9A to N. Jct. P.T.H. 9A	0.4	826	900	4
	N. Jct. P.T.H. 9A to P.R. 515	6.0	828	1644	5
	P.R. 515 to Netley	8.1	828	1270	6
	Netley to P.R. 225	6.2	573	890	6

Table A.1 continued

P.T.H. No.	Location	Mileage	Capacity (Cars/Hour)	A.D.T.[a] 1968	Percent Trucks
9	P.R. 225 to P.R. 601	3.1	573	786	7
	P.R. 601 to N. Bdry. of Winnipeg Beach	2.5	480	895	7
	N. Bdry Wpg. Beach to P.R. 231	8.0	463	1066	8
9A	S. Jct. with P.T.H. 9 to Strathnaver Ave. (Selkirk)	1.8	3348	6133	7
	Strathnaver Ave. to E. Jct. Manitoba Ave.	1.0	**	8586	7
	E. Jct. Manitoba Ave. to W. Jct. Manitoba Ave.	0.6	**	2836	7
	W. Jct. Manitoba Ave to N. Jct. with P.T.H. 9	1.4	737	1902	7
16	P.T.H. 7 to P.T.H. 68	29.2	*	171	9
	P.T.H. 68 to P.R. 611 (Broad Valley)	6.2	768	452	9
	P.R. 611 (Broad Valley) to P.R. 233	7.1	768	548	9
67	P.T.H. to N. Jct. with P.R. 236	3.0	573	2402	7
	N. Jct. with P.R. 236 to S. Jct. with P.R. 236	1.1	619	774	10
	S. Jct. with P.R. 236 to P.T.H. 6	9.2	766	645	10
68	P.T.H. 8 to P.T.H. 7	9.3	810	408	9
	P.T.H. 7 to P.T.H. 16	17.1	792	543	9
	P.T.H. 16 to Railway Crossing (Poplarfield)	0.7	729	197	6
	Railway Crossing (Poplarfield) to P.T.H. 6	23.6	*	118	6

[a] A.D.T. 1968 is defined as the annual average daily traffic during the year 1968.

*Unpaved road; no capacity estimate available. For purposes of the model, capacity was assumed to be 200 vehicles/hour on such highway sections.

**Urban area; no capacity estimate available. For purposes of the model, these highway sections were ignored.

APPENDIX B

UTILIZATION OF DATA SUPPLIED BY THE OFFICE OF THE DISTRICT ENGINEER, HIGHWAYS BRANCH, ARBORG, MANITOBA

The purpose of this appendix is to discuss the procedure used to estimate the highway construction technology vector, and the average change in highway section characteristics (length, service volume and travel time) due to investment.

HIGHWAY CONSTRUCTION TECHNOLOGY

There were two sources of data used for the estimation of the highway construction technology vector. First, a limited amount of data was obtained from an interview with one contractor who executed three separate contracts on major highway projects during the year 1968. Second, a considerable amount of data was provided by the Manitoba Department of Highways District Engineer's Office at Arborg, Manitoba. For both these groups of data, the contract or piece of work done constituted the sampling unit.

The Department of Highways data were taken from Work Order records for the fiscal year 1968-1969 which related to ARDA-FRED projects on Provincial Trunk Highways in the study area. It should be noted that these are authorizations for expenditures, and are thus likely to overstate by a small amount the sums actually expended. However, the data have been reported to be quite accurate. Because of confidentiality requirements, only the computations based upon the data are presented here.

The Work Orders were generally divided into two sections: "contract items" and "other items", the latter being expenditures mostly for work done by the Department itself. The discussion of the handling of the contract items will be delayed until after the presentation of the use made of Department items.

Non-Contract Items

An estimate of Department of Highways expenditures on ARDA-FRED programs was required on a sectoral basis. However, the Work Orders only provide data on the basis of work items, e.g. "laying cover coat aggregate", and any sectoral breakdown on the basis of the records kept would not have been possible given the time limits imposed on this phase of the project. The expenditures on each item were discussed with engineering staff from the Department, and an allocation made as to the proprtion of material costs, labour costs and expenditures for equipment on the basis of working experience. The engineers whose assistance was provided had the advantage of having worked personally on most if not all of the projects in question, and thus their estimates are bound to be quite accurate. Moreover, an estimate of the proportion of expenditures on each item which were made outside of the Interlake region was requested, where the allocation was not obvious. Thus an estimate of Departmental expenditures on materials (these could be classified by producing sector), labour costs and equipment costs was derived. The labour costs were assumed to include an allocation for office supplies, and thus 5 percent of Departmental labour costs were assigned to purchase office supplies. Equipment costs were allocated by assuming that one-half of the cost of running equipment was made up of the purchase of gas, oil and minor repairs. These were allocated equally to the "automotive sales and service" and to the "farm equipment" sectors. The other half of equipment costs was assumed to be the manpower required for normal maintenance as well as for operating the equipment. All these expenditures were assumed to be made in the Interlake except for materials obviously purchased in Winnipeg (e.g. paving asphalt, etc.) and for 2 percent of wages which were estimated to have been paid to residents outside the region. The resulting sectoral allocation for Departmental non-contract items is shown below.

TABLE B.1

PLANNED HIGHWAYS DEPARTMENT EXPENDITURES ON ARDA-FRED PROJECTS — 1968-1969 WORK ORDER DATA, BY SECTOR

Sector	Value ($1000)	Percent of Total
Agriculture-Livestock	23	6.0
Agriculture-Crops (incl. Ag. Services)	27	7.0
Mining and Quarrying	1	0.2
Petroleum Wholesale	34	9.0
Farm Equipment	10	2.7
Automotive Sales and Service	7	1.8
Other Services	5	1.2
Households	103	27.4
TOTAL INTERLAKE	209[a]	55.3[a]
TOTAL IMPORTS	168	44.7
TOTAL NON-CONTRACT EXPENDITURES	377[a]	100.0[a]

[a] Figures may not add due to Rounding.

Source: Computed from original data.

It will be noted that large payments have been made to the agricultural sectors. These represent, to a large extent, payment for land required for shoulder widening projects. That particular sum was allocated evenly between the crop and livestock sectors. The additional $4000 paid to the crop sector were for the supply of seed and fertilizer for the side of highways which otherwise would have been left bare after construction work.

Thus the largest part of Departmental non-contract items were spent on imports from outside the region and these were mostly non-competitive imports such as paving asphalt - and on payments to Interlake residents in the form of wages. This allocation differs considerably from that of the contract items, i.e. of contractor's expenditures on FRED projects, which will now be discussed.

Contract Items

The Work Orders at the Arborg office of the Department of Highways provided some basic data about the expenditures of contractors on FRED projects in the Interlake for the fiscal year 1968-1969. The engineering staff provided estimates of the breakdown between material costs, labour and equipment expenses. However, they felt much less certain of their estimates than when they dealt with non-contract items. They seemed to think that their best estimates concerned material purchases, with the other two categores being "guesstimates". Thus, apart from material expenditures, these data were lacking.

A survey of contractors yielded only three useable questionnaires and all from the same contractor. Nevertheless, these questionnaires were judged to be reliable and it was decided to use them to allocate the Work Order data relevant to contract items.

The first step was to compute total expenditures from the Questionnaires, being careful to omit expenditures on construction materials. Then, the proportion of expenditures going to each sector was computed. These ratios are presented in Table B.2, below. It is only possible to present the ratios, and not the value of expenditures, because of confidentiality requirements, as these data only relate to three contracts and all were executed by the same firm.

From the Work Orders, the total contract expenditures were computed,

TABLE B.2

SECTORAL ALLOCATION OF CONTRACTOR EXPENDITURES

Sector	Percentage of Total Expenditures, Excluding Purchases of Materials
Construction	1.7
Transportation	1.5
Petroleum Wholesale	12.0
Farm Equipment	1.9
Food Stores	0.4
Automotive Sales and Service	1.9
Finance, Insurance	3.0
Other Services	40.2
Households	14.1
TOTAL INTERLAKE	76.4[a]
TOTAL IMPORTS	23.6
TOTAL EXPENDITURES EXCLUDING MATERIALS	100.0[a]

[a] Figures may not add due to rounding.

Source: Computed from original data.

as were the contract item expenditures on materials. Then the materials expenditures were deducted from the total to provide an estimate of Non-Material Contract Item Expenditures. The latter were then multiplied through by the percentages presented in Table B.2, and thus allocated to sectors. Then the material expenditures were added in, and an estimate of contractor expenditures on FRED highway projects was obtained, as presented in Table B.3 below.

The Technology Vector

The final step in constructing the highway construction technology vector is the obvious one of adding together, on a sectoral basis, the

TABLE B.3

ESTIMATED CONTRACTOR EXPENDITURES ON 1968-1969 ARDA-FRED PROJECTS, BY SECTOR

Sector	Value ($1000)
Mining and Quarrying	112
Construction	12
Transport	11
Petroleum Wholesale	86
Farm Equipment	13
Food Stores	3
Automotive Sales and Service	13
Finance, Insurance	21
Other Services	290
Households	102
TOTAL INTERLAKE	663[a]
TOTAL IMPORTS	171
TOTAL CONTRACTOR EXPENDITURES	834[a]

[a] Figures may not add due to rounding.

Source: Computed from original data.

estimates of contract and of non-contract expenditures, and to compute the resulting coefficients, as presented in Table B.4. The technology vector is simply the last column of Table B.4 divided by 100. In other words, it represents how much of each dollar spent on highway construction is spent on every sector of the economy. Another way of looking at it is to say that the vector indicates the demands which will be placed upon each sector if an additional dollar is spent on highway construction.

TABLE B.4

HIGHWAY CONSTRUCTION EXPENDITURES AND TECHNOLOGY VECTOR

Sector	Value ($1000)	Percentage of Total
Agriculture-Livestock	23	1.9
Agriculture-Crops (incl. Ag. Services)	27	2.2
Mining and Quarrying	113	9.3
Construction	12	1.0
Transportation	11	0.9
Petroleum Wholesale	120	9.9
Farm Equipment	24	2.0
Food Stores	3	0.2
Automotive Sales and Service	20	1.7
Finance, Insurance	21	1.8
Other Services	295	24.3
Households	205	16.9
TOTAL INTERLAKE	872[a]	72.0[a]
TOTAL IMPORTS	339	28.0
TOTAL EXPENDITURES	1,211[a]	100.0[a]

[a] Figures may not add due to rounding.

Source: Computed from original data.

HIGHWAY SECTION CHARACTERISTICS

The data obtained at Arborg included engineers' judgements as to the effect of highway investment on length of highway sections, changes in service volume and changes in travel time.

Changes in Length

There were no changes in the length of any highway section due to the 8 projects for which data were obtained.

Changes in Service Volume

The original data included the location of the project and the engineers' judgements about the percentage increase in service volume (i.e. capactity) due to the project, as well as the value of the project. From these data, Table B.5 was constructed.

As can be seen from Table B.5, the percentage change in highway service volumes was multiplied by the original service volume for the given section. In cases where more than one section was involved, a weighted average of the service volumes was used, the weights being the length of the project over each section. A weighted average was used here rather than the smallest of the two, as the improvement was assumed to bring benefits to both sections. The change in service volume due to a project was divided by the expenditures on that project in thousands of dollars. The changes in serivce volume per $1000 expenditure were the summed over all projects and divided by the number of projects. The average change in service volume per $1000 expenditure on highway projects was thus computed. Rounding off the last digit, the result was, in terms of the formal model

$$DSV = 0.244 \tag{B.1}$$

where DSV is measured in cars per $1000 expenditure.

Changes in Travel Time

Engineers' judgements were obtained about the effect on travel time of highway investment. The judgements were stated in terms of increases in average speeds. But these increases were said to apply only to truck traffic. From these data, the percentage change in travel time for trucks was computed by

$$PCTTT = 1 - (TS/TS') \tag{B.2}$$

since $$PCTTT = \frac{TTT - TTT'}{TTT} = \frac{TD/TS - TD/TS'}{TD/TS}$$

TABLE B.5

CALCULATION OF AVERAGE CHANGE IN SERVICE VOLUME PER $1000 OF EXPENDITURE ON HIGHWAY PROJECTS

Project[a]	Sections Affected[b]	Percentage Change in Service Volume	Service Volume[c]	Change in Service Volume	Expenditure[d]	Change in Service Volume Per $1000 Expenditure
1	34	20	200	40	308	.1299
2	5	15	200	30	275	.1091
3	31,32	15	804	120.6	246	.4902
4	6	8	200	16	191	.0838
5	6	0	200	0	59	.0000
6	34	0	200	0	55	.0000
7	32	5	792	39.6	50	.7920
8	5,6	5	200	10	27	.3444
TOTAL					1,211	1.9494
AVERAGE CHANGE IN SERVICE VOLUME PER $1000 EXPENDITURE =						0.2436

[a] These are not ARDA-FRED project numbers, but only the rank of projects by decreasing order of expenditure.

[b] 34 Section basis. When more than one section was involved, a weighted average of the sections was used, the weights being the length of the project in each section.

[c] Cars per hour

[d] Thousands of dollars

Source: Original data.

where PCTTT is the percentage change in truck travel time;

TS is the average truck speed;

TTT is the truck travel time;

TD is the distance to be travelled;

' denotes new values of the variables.

Multiplying the percentage travel time reduction for trucks by the proportion of trucks using the highway gives an estimate of the over-all percentage change in travel time for the highway. Dividing this result by the expenditure on the highway project in thousands of dollars provided the percentage change in travel time per $1000 expenditure for each project. Summing those results over projects and dividing by the number of projects produced the average percentage change in travel time per $1000 expenditure on highways. Rounding off the last digit, the result was

$$DTT = 0.00012 \qquad (B.3)$$

where DTT is the average percentage change in travel time per $1000 expenditure. These calculations are presented in Table B.6.

It would have been possible to use in the model an estimate of the average percentage change in truck travel time, and apply it only to commercial traffic. But to do this is to overlook that trucks and cars are intermingled in the traffic flow. Thus the change in average truck speeds has some effect on all highway users' travel times, although the effect on cars might be quite small. In order to include such effect the change in travel time was computed for all traffic over the highway.

TABLE B.6

CALCULATION OF AVERAGE PERCENTAGE CHANGE IN TRAVEL TIME PER $1000 EXPENDITURE ON HIGHWAY PROJECTS

Project[a]	Sections Affected[b]	Average Truck Speeds		Percentage Change in Truck Travel Time	Percentage Trucks	Over-all Percentage Change in Travel Time	Expenditure ($1000)	Percentage Change in Travel Time Per $1000
		Before	After					
1	34	50	60	-16.7	6	-1.002	308	-0.0033
2	5	40	55	-27.4	9.5	-2.603	275	-0.0095
3	31,32	45	60	-25.0	9	-2.250	246	-0.0092
4	6			0.0	11.7	0.0	191	0.0
5	6			0.0	11.7	0.0	59	0.0
6	34			0.0	6	0.0	55	0.0
7	32	45	55	-18.2	9	-1.638	50	-0.0328
8	5,6	40	45	-11.1	9.9	-1.099	27	-0.0407
TOTAL							1,211	-0.0955

TOTAL PERCENTAGE CHANGE IN TRAVEL TIME PER $1000 EXPENDITURE = -0.0119% = -0.000119

[a] These are not ARDA-FRED project numbers, but only the rank of projects by decreasing order of expenditures.

[b] 34 section basis. When more than one section was involved, a weighted average of the sections was used, the weights being the length of the project over each section.

Source: Original data.

APPENDIX C

TRAFFIC VOLUMES ON HIGHWAY SECTION BASIS

TABLE C.1

YEARLY TRAFFIC VOLUMES FOR FIRST AND TENTH YEARS ON HIGHWAY SECTION BASIS

Section No.	P.T.H. No.	Location	Mileage	Total Traffic Volume[a]	
				First Year	Tenth Year
1	6	Perimeter to Warren	13.9	621	998
2		Warren to St. Laurent	26.3	77	124
3		St. Laurent to Lundar	20.6	76	122
4		Lundar to Eriksdale	13.7	43	70
5		Eriksdale to Ashern	26.0	12	19
6		Ashern to P.R. 239 (Steep Rock)	18.6	205	361
7	7	Perimeter to Jct. Stony Mountain	6.8	348	569
8		Jct. Stony Mountain to P.T.H. 67	4.0	891	1,454
9		P.T.H. 67 to Teulon	17.4	455	745
10		Teulon to Fraserwood	17.8	156	256
11		Fraserwood to P.T.H. 16	2.1	160	263
12		P.T.H. 16 to P.R. 324	8.5	115	189
13		P.R. 324 to P.T.H. 68 (Arborg)	7.8	119	196
14	8	Perimeter to P.T.H. 27	5.1	1,537	2,799
15		P.T.H. 27 to P.R. 231 (Gimli)	41.5	1,015	1,923
16		P.R. 231 to P.R. 324	5.1	139	243
17		P.R. 324 to P.T.H. 68	13.2	140	241
18		P.T.H. 68 to Riverton	7.2	128	210
19	9 & 9A	Perimeter to P.T.H. 27	5.3	1,926	3,189
20		P.T.H. 27 to S. Jct. 9 & 9A	7.6	1,001	1,877
21		S. Jct 9 & 9A to Selkirk (Strathnaver Ave.)	1.8	512	948
22		Selkirk (W. Jct. Manitoba Ave.) to N. Jct. 9 & 9A	1.4	204	361
23		S. Jct. 9 & 9A to N. Jct 9 & 9A (By-pass)	4.8	370	697

Table C.1 continued

Section No.	P.T.H. No.	Location	Mileage	Total Traffic Volume[a] First Year	Total Traffic Volume[a] Tenth Year
24	9 & 9A	N. Jct. 9 & 9A to Petersfield	10.1	760	1,475
25		Petersfield to Winnipeg Beach	13.3	986	2,053
26		Winnipeg Beach to Gimli	10.5	63	104
27	16	P.T.H. 7 to P.T.H. 68	29.2	98	158
28		P.T.H. 68 to Fisher Branch	13.3	137	223
29	67	P.T.H. 7 to Stonewall	4.0	474	771
30		Stonewall to Warren	9.2	231	375
31	68	P.T.H. 8 to P.T.H. 7 (Arborg)	9.3	15	24
32		P.T.H. 7 to P.T.H. 16	17.1	182	296
33		P.T.H. 16 to Poplarfield	0.7	189	314
34		Poplarfield to Eriksdale	23.6	75	124

[a] Rounded to nearest thousand cars.

Source: Computed from the model.

APPENDIX D

TRAFFIC VOLUMES AND DISTANCES ON ORIGIN-DESTINATION BASIS

TABLE D.1

FIRST AND TENTH YEAR "EFFECTIVE DISTANCES" AND ERRAND-RUNNING TRAFFIC VOLUMES ON ORIGIN-DESTINATION BASIS

Destinations and Origins[a]	"Effective Distances"[b]		Errand-Running Traffic[c]	
	First Year	Tenth Year	First Year	Tenth Year
TO: WINNIPEG				
FROM: Bifrost RF	70.50	67.82	25	38
Bifrost NF	75.00	72.32	6	9
Arborg	64.00	64.00	3	4
Riverton	71.00	70.95	2	3
Coldwell RF	85.00	84.98	13	19
Coldwell NF	60.00	59.98	5	7
Lundar	77.50	77.48	3	4
Eriksdale RF	100.50	100.38	9	13
Eriksdale NF	94.50	94.38	1	2
Eriksdale UR	89.50	89.48	2	3
Fisher RF	96.00	95.84	48	71
Fisher NF	102.50	102.43	8	11
Fisher Branch	99.50	99.50	2	3
Gimli RF	61.00	56.63	13	21
Gimli NF	68.50	64.13	9	14
Gimli UR	41.50	38.74	12	17
Rockwood RF	26.50	26.34	86	128
Rockwood NF	20.00	19.84	22	33
Stonewall	14.00	14.00	34	46
Stony Mountain	8.00	8.00	32	43
Teulon	28.00	28.00	9	12
Rosser RF	15.50	15.50	54	79
Rosser NF	12.50	12.50	16	23
St. Andrews RF	21.50	18.41	205	352
St. Andrews NF	28.00	25.11	112	185
Selkirk	14.00	13.78	213	289
Winnipeg Beach	38.00	36.81	6	8
St. Laurent RF	57.50	57.48	4	6
St. Laurent NF	56.50	56.48	7	11
St. Laurent UR	57.50	57.48	3	3
Siglunes RF	126.00	125.95	5	8
Siglunes NF	119.50	119.45	3	5
Ashern	137.50	137.48	1	2
Woodlands RF	23.50	23.41	62	91
Woodlands NF	30.00	29.91	20	29

Table D.1 continued

Destinations and Origins[a]	"Effective Distances"[b]		Errand-Running Traffic[c]	
	First Year	Tenth Year	First Year	Tenth Year
TO: GIMLI (UR)				
FROM: Armstrong RF	17.00	17.00	28	40
Armstrong NF	20.00	20.00	10	15
Bifrost RF	24.00	24.00	9	13
Bifrost NF	18.00	18.00	3	4
Arborg	29.00	29.00	1	1
Riverton	28.00	28.00	1	1
Gimli RF	9.50	7.86	11	19
Gimli NF	7.00	7.00	11	17
TO: STONEWALL				
FROM: Rockwood RF	14.00	13.93	20	30
Rockwood NF	6.00	5.93	9	14
Stony Mountain	8.00	8.00	4	5
Teulon	20.00	20.00	1	2
Rosser RF	8.00	7.93	13	19
Rosser NF	13.50	13.43	2	3
Woodlands RF	11.00	11.00	16	24
Woodlands NF	12.50	12.50	6	9
TO: ARBORG				
FROM: Armstrong RF	15.00	15.00	21	31
Armstrong NF	21.00	21.00	6	9
Bifrost RF	10.00	9.98	15	22
Bifrost NF	8.50	8.48	4	6
Riverton	14.00	14.00	1	1
Fisher RF	21.00	20.73	19	28
Fisher NF	27.00	26.91	2	4
Fisher Branch	29.50	29.50	1	1
TO: ASHERN				
FROM: Eriksdale RF	30.50	30.49	2	4
Eriksdale NF	27.50	27.49	---	---
Eriksdale UR	27.50	27.49	1	1
Grahamdale RF	23.50	23.22	11	17
Grahamdale NF	31.50	31.22	4	7
Siglunes RF	12.00	11.92	5	7
Siglunes NF	21.50	21.42	2	2
TO: LUNDAR				
FROM: Coldwell RF	8.00	8.00	13	19
Coldwell NF	7.00	7.00	4	6
Eriksdale RF	16.00	16.00	5	7
Eriksdale NF	11.00	11.00	1	1
Eriksdale UR	13.50	13.50	1	2
St. Laurent RF	18.00	18.00	1	2
St. Laurent NF	13.50	13.50	3	4
St. Laurent UR	17.50	17.50	1	1

Table D.1 continued

Destinations and Origins[a]	"Effective Distances"[b]		Errand-Running Traffic[c]	
	First Year	Tenth Year	First Year	Tenth Year
TO: ERIKSDALE (UR)				
FROM: Coldwell RF	24.50	24.50	3	5
Coldwell NF	20.00	20.00	1	2
Lundar	20.00	20.00	1	1
Eriksdale RF	7.50	7.33	9	14
Eriksdale NF	2.00	1.83	4	7
Siglunes RF	27.00	26.99	2	3
Ashern	18.50	18.49	1	1
TO: WINNIPEG BEACH				
FROM: Gimli RF	6.50	6.50	11	16
Gimli UR	5.00	5.00	8	11
St. Andrews RF	6.50	4.74	56	114
St. Andrews NF	8.50	7.04	31	55
TO: ST. LAURENT (UR)				
FROM: Coldwell RF	7.50	7.50	13	20
Coldwell NF	8.00	8.00	3	5
St. Laurent RF	7.00	7.00	3	4
St. Laurent NF	3.50	3.50	11	16
TO: SELKIRK				
FROM: St. Andrews RF	26.50	26.00	38	57
St. Andrews NF	24.50	24.00	30	45
Winnipeg Beach	26.00	25.98	2	3
TO: TEULON				
FROM: Rockwood RF	10.50	10.50	22	33
Rockwood NF	9.00	9.00	5	7
Stony Mountain	22.00	22.00	1	2
TO: FISHER BRANCH				
FROM: Fisher RF	14.00	13.98	24	42
Fisher NF	12.00	12.00	6	9
TO: RIVERTON				
FROM: Bifrost RF	7.50	7.49	22	33
Bifrost NF	6.50	6.49	6	9
TO: STEEP ROCK				
FROM: Grahamdale RF	2.50	2.22	92	147
TO: FRASERWOOD				
FROM: Armstrong RF	3.00	3.00	59	87
TO: POPLARFIELD				
FROM: Fisher RF	5.00	4.75	45	69
Fisher NF	4.50	4.50	9	12
Fisher Branch	15.00	15.00	1	1

Table D.1 continued

Destinations and Origins[a]	"Effective Distances"[b]		Errand-Running Traffic[c]	
	First Year	Tenth Year	First Year	Tenth Year
TO: PETERSFIELD				
FROM: St. Andrews RF	5.50	4.52	37	66
St. Andrews NF	4.00	3.02	37	72
TO: WARREN				
FROM: St. Laurent RF	28.00	28.00	--	1
St. Laurent NF	34.00	34.00	1	1
Woodlands RF	5.50	5.50	14	21
Woodlands NF	3.00	3.00	11	16

[a] For list of abbreviations used, see Table D.4

[b] Measured in miles. The concept is explained on p.

[c] Thousands of cars/year.

Sources: Origin-Destination pairs and first year "effective distances": C.F. Framingham, J.A. MacMillan and D.J. Sandell, The Interlake Fact Digest, (Winnipeg: Queen's Printer, 1970), table 16, pp. 173-185.

All other columns: Computed from the model.

TABLE D.2

LIST OF ORIGIN-DESTINATION PAIRS OMITTED BECAUSE OF INSUFFICIENT ECONOMIC INFORMATION

Destinations[a]	Origins[a]
Argyle	Rockwood RF, Woodlands RF, Woodlands NF
Arnes	Bifrost RF, Gimli RF, Gimli NF
Balmoral	Rockwood RF, Rockwood NF
Camper	Ashern, Grahamdale RF, Grahamdale NF, Siglunes RF, Siglunes NF
Camp Morton	Gimli RF, Gimli NF
Chatfield	Armstrong RF, Armstrong NF
Clandeboye	St. Andrews RF, St. Andrews NF
Gordon	Rosser RF
Grosse Isle	Rosser RF
Gypsumville	Eriksdale RF, Grahamdale RF, Grahamdale NF
Hodgson	Fisher Branch, Fisher RF, Fisher NF
Moosehorn	Ashern, Grahamdale RF, Grahamdale NF, Siglunes RF, Siglunes NF
Rosser	Rosser RF

[a] For a list of abbreviations used, see Table D.4, p. 133.

TABLE D.3

LIST OF ORIGIN-DESTINATION PAIRS OMITTED BECAUSE OF EXCLUSION OF PROVINCIAL ROAD SYSTEM

Destinations[a]	Origins[a]
Inwood	Armstrong RF, Armstrong NF, Coldwell RF, St. Laurent RF, St. Laurent UR.

[a] For a list of abbreviations used, see Table D.4.

TABLE D.4

ABBREVIATIONS USED IN LISTING ORIGINS AND DESTINATIONS

Abbreviation	Meaning
a)- General	
NF	Rural Non-farm households
RF	Rural farm households
UR	Urban households
b)- Place Names	
Armstrong	Local Government District of Armstrong
Bifrost	Rural Municipality of Bifrost
Coldwell	Rural Municipality of Coldwell
Eriksdale	Rural Municipality of Eriksdale
Fisher	Local Government District of Fisher
Gimli	Rural Municipality of Gimli
Grahamdale	Local Government District of Grahamdale
Rockwood	Rural Municipality of Rockwood
Rosser	Rural Municipality of Rosser
St. Andrews	Rural Municipality of St. Andrews
St. Laurent	Rural Municipality of St. Laurent
Siglunes	Rural Municipality of Siglunes
Woodlands	Rural Municipality of Woodlands

All other place names refer to villages, towns or cities.

APPENDIX E

ASSUMED ROUTINGS

TABLE E.1

ASSUMED ROUTING OF ERRAND-RUNNING TRAFFIC OVER HIGHWAY SECTIONS

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
1	6	Perimeter-Warren	Coldwell RF-Winnipeg	90
			Coldwell NF-Winnipeg	90
			Lundar-Winnipeg	90
			Eriksdale RF-Winnipeg	90
			Eriksdale NF-Winnipeg	90
			Eriksdale UR-Winnipeg	90
			Rosser RF-Winnipeg	60
			Rosser NF-Winnipeg	90
			St. Laurent RF-Winnipeg	90
			St. Laurent NF-Winnipeg	90
			St. Laurent UR-Winnipeg	90
			Siglunes RF-Winnipeg	50
			Siglunes NF-Winnipeg	50
2	6	Warren-St. Laurent	Coldwell RF-Winnipeg	100
			Coldwell NF-Winnipeg	100
			Lundar-Winnipeg	100
			Eriksdale RF-Winnipeg	100
			Eriksdale NF-Winnipeg	100
			Eriksdale UR-Winnipeg	100
			St. Laurent RF-Winnipeg	100
			St. Laurent NF-Winnipeg	100
			St. Laurent UR-Winnipeg	100
			Siglunes RF-Winnipeg	100
			Siglunes NF-Winnipeg	100
			Ashern-Winnipeg	100
			Woodlands RF-Stonewall	40
			Woodlands NF-Stonewall	40
			St. Laurent RF-St. Laurent UR	20
			St. Laurent NF-St. Laurent UR	20
			St. Laurent RF-Warren	100
			St. Laurent NF-Warren	100
			Woodlands RF-Warren	50
			Woodlands NF-Warren	50

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
3	6	St. Laurent-Lundar	Coldwell RF-Winnipeg	100
			Coldwell NF-Winnipeg	100
			Lundar-Winnipeg	100
			Eriksdale RF-Winnipeg	100
			Eriksdale NF-Winnipeg	100
			Eriksdale UR-Winnipeg	100
			St. Laurent RF-Winnipeg	10
			St. Laurent NF-Winnipeg	10
			Siglunes RF-Winnipeg	100
			Siglunes NF-Winnipeg	100
			Ashern-Winnipeg	100
			Coldwell RF-Lundar	20
			Coldwell NF-Lundar	20
			St. Laurent RF-Lundar	90
			St. Laurent NF-Lundar	90
			St. Laurent UR-Lundar	100
			Coldwell RF-St. Laurent UR	80
			Coldwell NF-St. Laurent UR	80
			St. Laurent RF-St. Laurent UR	20
			St. Laurent NF-St. Laurent UR	20
			St. Laurent RF-Warren	10
			St. Laurent NF-Warren	10
4	6	Lundar-Eriksdale	Coldwell RF-Winnipeg	10
			Coldwell NF-Winnipeg	10
			Eriksdale RF-Winnipeg	100
			Eriksdale NF-Winnipeg	100
			Eriksdale UR-Winnipeg	100
			Siglunes RF-Winnipeg	100
			Siglunes NF-Winnipeg	100
			Ashern-Winnipeg	100
			Coldwell RF-Lundar	10
			Coldwell NF-Lundar	10
			Eriksdale RF-Lundar	90
			Eriksdale NF-Lundar	90
			Eriksdale UR-Lundar	100
			Coldwell RF-Eriksdale UR	90
			Coldwell NF-Eriksdale UR	90
			Lundar-Eriksdale UR	100
			Eriksdale RF-Eriksdale UR	20
			Eriksdale NF-Eriksdale UR	20
5	6	Eriksdale-Ashern	Eriksdale RF-Winnipeg	20
			Eriksdale NF-Winnipeg	20
			Siglunes RF-Winnipeg	100
			Siglunes NF-Winnipeg	100

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
5 (cont.)	6	Eriksdale-Ashern	Ashern-Winnipeg	100
			Eriksdale RF-Ashern	100
			Eriksdale NF-Ashern	100
			Eriksdale UR-Ashern	100
			Siglunes RF-Ashern	10
			Siglunes NF-Ashern	10
			Eriksdale RF-Eriksdale UR	20
			Eriksdale NF-Eriksdale UR	20
			Siglunes RF-Eriksdale UR	100
			Ashern-Eriksdale UR	100
6	6	Ashern-Junction P.R. 239	Siglunes RF-Winnipeg	5
			Siglunes NF-Winnipeg	5
			Grahamdale RF-Steep Rock	50
7	7	Perimeter-Jct. Stony Mountain RD.	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Coldwell RF-Winnipeg	10
			Coldwell NF-Winnipeg	10
			Lundar-Winnipeg	10
			Eriksdale RF-Winnipeg	10
			Eriksdale NF-Winnipeg	10
			Eriksdale UR-Winnipeg	10
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Rockwood RF-Winnipeg	100
			Rockwood NF-Winnipeg	100
			Stonewall-Winnipeg	100
			Stony Mountain-Winnipeg	100
			Teulon-Winnipeg	100
			Rosser RF-Winnipeg	20
			Rosser NF-Winnipeg	20
			St. Laurent RF-Winnipeg	10
			St. Laurent NF-Winnipeg	10
			St. Laurent UR-Winnipeg	10
			Siglunes UR-Winnipeg	10
			Siglunes NF-Winnipeg	10
			Ashern-Winnipeg	10
			Woodlands RF-Winnipeg	50
			Woodlands NF-Winnipeg	50
			Rockwood RF-Stonewall	10
			Rockwood NF-Stonewall	10
			Rosser RF-Stonewall	20
			Rosser NF-Stonewall	20

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
8	7	Jct. Stony Mountain Rd.-Jct. P.T.H. no. 67	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Coldwell RF-Winnipeg	10
			Coldwell NF-Winnipeg	10
			Lundar-Winnipeg	10
			Eriksdale RF-Winnipeg	10
			Eriksdale NF-Winnipeg	10
			Eriksdale UR-Winnipeg	10
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Rockwood RF-Winnipeg	90
			Rockwood NF-Winnipeg	90
			Stonewall-Winnipeg	100
			Teulon-Winnipeg	100
			St. Laurent RF-Winnipeg	10
			St. Laurent NF-Winnipeg	10
			St. Laurent UR-Winnipeg	10
			Siglunes RF-Winnipeg	10
			Siglunes NF-Winnipeg	10
			Ashern-Winnipeg	10
			Woodlands RF-Winnipeg	50
			Woodlands NF-Winnipeg	50
			Rockwood RF-Stonewall	40
			Rockwood NF-Stonewall	40
			Stony Mountain-Stonewall	100
			Rosser RF-Stonewall	40
			Rosser NF-Stonewall	40
9	7	Jct. P.T.H. 67-Teulon	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Rockwood RF-Winnipeg	60
			Rockwood NF-Winnipeg	60
			Teulon-Winnipeg	100
			Rockwood RF-Stonewall	50
			Rockwood NF-Stonewall	50
			Teulon-Stonewall	100
			Rockwood RF-Teulon	30
			Rockwood NF-Teulon	30
			Stony Mountain-Teulon	100

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
10	7	Teulon-Fraserwood	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Rockwood RF-Winnipeg	10
			Rockwood NF-Winnipeg	10
			Rockwood RF-Teulon	20
			Rockwood NF-Teulon	20
			Armstrong RF-Fraserwood	20
11	7	Fraserwood-P.T.H. 16	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Armstrong RF-Arborg	20
			Armstrong NF-Arborg	20
			Armstrong RF-Fraserwood	40
12	7	P.T.H. 16-P.R. 324	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Armstrong RF-Arborg	25
			Armstrong NF-Arborg	25
			Armstrong RF-Fraserwood	20
13	7	P.R. 324-P.T.H. no. 68 (Arborg)	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Arborg-Winnipeg	100
			Fisher RF-Winnipeg	100
			Fisher NF-Winnipeg	100
			Fisher Branch-Winnipeg	100
			Bifrost RF-Gimli UR	50
			Bifrost NF-Gimli UR	50
			Arborg-Gimli UR	100
			Armstrong RF-Arborg	50
			Armstrong NF-Arborg	50
14	8	Perimeter-P.T.H. no. 27	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
14 (cont.)	8	Perimeter-P.T.H. no.27	Riverton-Winnipeg	100
			Gimli RF-Winnipeg	75
			Gimli NF-Winnipeg	75
			Gimli UR-Winnipeg	25
			St. Andrews RF-Winnipeg	60
			St. Andrews NF-Winnipeg	60
			Selkirk-Winnipeg	20
			Winnipeg Beach-Winnipeg	20
			St. Andrews RF-Selkirk	10
			St. Andrews NF-Selkirk	10
15	8	P.T.H. 27-P.R. no. 231 (Gimli UR)	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Riverton-Winnipeg	100
			Gimli RF-Winnipeg	75
			Gimli NF-Winnipeg	75
			Gimli UR-Winnipeg	25
			St. Andrews RF-Winnipeg	50
			St. Andrews NF-Winnipeg	50
			Gimli RF-Gimli UR	40
16	8	P.R. 231 (Gimli UR)-P.R. 324	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Riverton-Winnipeg	100
			Gimli RF-Winnipeg	50
			Gimli NF-Winnipeg	50
			Armstrong RF-Gimli UR	10
			Bifrost RF-Gimli UR	100
			Bifrost NF-Gimli UR	100
			Riverton-Gimli UR	100
			Arborg-Gimli UR	100
			Gimli RF-Gimli UR	50
			Gimli NF-Gimli UR	50
17	8	P.R. 324-P.T.H. no.68	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Riverton-Winnipeg	100
			Gimli RF-Winnipeg	40
			Gimli NF-Winnipeg	40
			Armstrong RF-Gimli UR	5
			Bifrost RF-Gimli UR	50
			Bifrost NF-Gimli UR	50
			Riverton-Gimli UR	100
			Gimli RF-Gimli UR	40
			Gimli NF-Gimli UR	40

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
18	8	P.T.H. 68-Riverton	Bifrost RF-Winnipeg	50
			Bifrost NF-Winnipeg	50
			Riverton-Winnipeg	100
			Bifrost RF-Gimli UR	50
			Bifrost NF-Gimli UR	50
			Riverton-Gimli UR	100
			Bifrost RF-Arborg	10
			Bifrost NF-Arborg	10
			Riverton-Arborg	100
			Bifrost RF-Riverton	50
			Bifrost NF-Riverton	50
19	9	Perimeter-P.T.H. 27	Gimli RF-Winnipeg	25
			Gimli NF-Winnipeg	25
			Gimli UR-Winnipeg	75
			St. Andrews RF-Winnipeg	40
			St. Andrews NF-Winnipeg	40
			Selkirk-Winnipeg	80
			Winnipeg Beach-Winnipeg	80
			St. Andrews RF-Selkirk	20
			St. Andrews NF-Selkirk	20
20	9	P.T.H. 27-South Jct. with P.T.H. 9A	Gimli RF-Winnipeg	25
			Gimli NF-Winnipeg	25
			Gimli UR-Winnipeg	75
			St. Andrews RF-Winnipeg	50
			St. Andrews NF-Winnipeg	50
			Selkirk-Winnipeg	100
			Winnipeg Beach-Winnipeg	100
			St. Andrews RF-Selkirk	30
			St. Andrews NF-Selkirk	30
21	9A	South Jct. with P.T.H. no. 9- Selkirk (south)	St. Andrews RF-Winnipeg	25
			St. Andrews NF-Winnipeg	30
			Selkirk-Winnipeg	100
			St. Andrews RF-Selkirk	40
			St. Andrews NF-Selkirk	40
22	9A	Selkirk (north)-North Jct. with P.T.H. 9	St. Andrews RF-Winnipeg	10
			St. Andrews RF-Selkirk	50
			St. Andrews NF-Selkirk	50
			Winnipeg Beach-Selkirk	100

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
23	9	South Jct. with P.T.H. no. 9A-North Jct. with P.T.H. 9A (Selkirk by-pass)	Gimli RF-Winnipeg	25
			Gimli NF-Winnipeg	25
			Gimli UR-Winnipeg	75
			St. Andrews RF-Winnipeg	25
			St. Andrews NF-Winnipeg	20
			Winnipeg Beach-Winnipeg	100
24	9	North Jct. with P.T.H. 9-Petersfield	Gimli RF-Winnipeg	25
			Gimli NF-Winnipeg	25
			Gimli UR-Winnipeg	75
			St. Andrews RF-Winnipeg	30
			St. Andrews NF-Winnipeg	20
			Winnipeg Beach-Winnipeg	100
			St. Andrews RF-Winnipeg	10
			St. Andrews NF-Winnipeg	10
			St. Andrews RF-Selkirk	30
			St. Andrews NF-Selkirk	30
			Winnipeg Beach-Selkirk	100
			St. Andrews RF-Petersfield	40
			St. Andrews NF-Petersfield	40
25	9	Petersfield-Winnipeg Beach	Gimli RF-Winnipeg	25
			Gimli NF-Winnipeg	25
			Gimli UR-Winnipeg	75
			St. Andrews RF-Winnipeg	20
			St. Andrews NF-Winnipeg	10
			Winnipeg Beach-Winnipeg	50
			St. Andrews RF-Winnipeg Beach	90
			St. Andrews NF-Winnipeg Beach	75
			St. Andrews RF-Selkirk	20
			St. Andrews NF-Selkirk	20
			Winnipeg Beach-Selkirk	100
			St. Andrews RF-Petersfield	50
			St. Andrews NF-Petersfield	50
26	9	Winnipeg Beach-Gimli UR	Gimli RF-Winnipeg	25
			Gimli NF-Winnipeg	25
			Gimli UR-Winnipeg	75
			Gimli RF-Gimli UR	10
			Gimli NF-Gimli UR	50
			Gimli RF-Winnipeg Beach	100
			Gimli UR-Winnipeg Beach	100
27	16	P.T.H. 7-P.T.H. no. 68	Armstrong RF-Gimli UR	50
			Armstrong NF-Gimli UR	50

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
27 (cont.)	16	P.T.H. 7-P.T.H. no. 68	Armstrong RF-Arborg	10
			Armstrong NF-Arborg	10
			Armstrong RF-Fraserwood	15
28	16	P.T.H. 68-Fisher Branch	Fisher RF-Winnipeg	25
			Fisher NF-Winnipeg	20
			Fisher Branch-Winnipeg	100
			Fisher RF-Arborg	20
			Fisher NF-Arborg	10
			Fisher Branch-Arborg	75
			Fisher RF-Fisher Branch	25
			Fisher NF-Fisher Branch	20
			Fisher RF-Poplarfield	20
			Fisher NF-Poplarfield	50
			Fisher Branch-Poplarfield	100
29	67	P.T.H. 7-Stonewall	Coldwell RF-Winnipeg	10
			Coldwell NF-Winnipeg	10
			Lundar-Winnipeg	10
			Eriksdale RF-Winnipeg	10
			Eriksdale NF-Winnipeg	10
			Eriksdale UR-Winnipeg	10
			Rockwood RF-Winnipeg	20
			Rockwood NF-Winnipeg	50
			Stonewall-Winnipeg	100
			St. Laurent RF-Winnipeg	10
			St. Laurent NF-Winnipeg	10
			St. Laurent UR-Winnipeg	10
			Siglunes RF-Winnipeg	10
			Siglunes NF-Winnipeg	10
			Ashern-Winnipeg	10
			Woodlands RF-Winnipeg	50
			Woodlands NF-Winnipeg	50
			Rockwood RF-Stonewall	90
			Rockwood NF-Stonewall	90
			Stony Mountain-Stonewall	100
			Teulon-Stonewall	100
			Rosser RF-Stonewall	40
			Rosser NF-Stonewall	40
30	67	Stonewall-Warren	Coldwell RF-Winnipeg	10
			Coldwell NF-Winnipeg	10
			Lundar-Winnipeg	10
			Eriksdale RF-Winnipeg	10
			Eriksdale NF-Winnipeg	10
			Eriksdale UR-Winnipeg	10

Table E.1 continued

Highway Section	P.T.H. No.	Location	Origins and Destinations[a]	Percentage of Volume Using Section[b]
30 (cont.)	67	Stonewall-Warren	Rockwood UR-Winnipeg	10
			Rockwood NF-Winnipeg	10
			St. Laurent RF-Winnipeg	10
			St. Laurent NF-Winnipeg	10
			St. Laurent UR-Winnipeg	10
			Siglunes RF-Winnipeg	10
			Siglunes NF-Winnipeg	10
			Ashern-Winnipeg	10
			Woodlands RF-Winnipeg	50
			Woodlands NF-Winnipeg	50
			Rockwood RF-Stonewall	10
			Rockwood NF-Stonewall	10
			Woodlands RF-Stonewall	100
			Woodlands NF-Stonewall	100
31	68	P.T.H. 8-P.T.H. no. 7 (Arborg)	Bifrost RF-Arborg	20
			Bifrost NF-Arborg	20
			Riverton-Arborg	100
			Bifrost RF-Riverton	10
			Bifrost NF-Riverton	10
32	68	P.T.H. 7 (Arborg)-P.T.H. 16	Fisher RF-Winnipeg	50
			Fisher NF-Winnipeg	40
			Fisher Branch-Winnipeg	100
			Fisher RF-Arborg	50
			Fisher NF-Arborg	50
			Fisher Branch-Arborg	100
			Fisher RF-Fisher Branch	10
			Fisher RF-Poplarfield	20
33	68	P.T.H. 16-Poplarfield	Fisher RF-Winnipeg	20
			Fisher NF-Winnipeg	20
			Fisher RF-Arborg	40
			Fisher NF-Arborg	40
			Fisher RF-Poplarfield	70
			Fisher NF-Poplarfield	100
			Fisher Branch-Poplarfield	100
34	68	Poplarfield-Eriksdale	Fisher RF-Winnipeg	10
			Fisher RF-Arborg	25
			Eriksdale RF-Eriksdale UR	10
			Eriksdale NF-Eriksdale UR	10
			Fisher RF-Poplarfield	30

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[a] For a list of abbreviations used, see Table D.4, p. 133.

[b] "Percentage of Volume Using Section" means the proportion of errand-running traffic between a given origin and destination which uses the highway section listed.

APPENDIX F

FORMAL SUMMARY OF THE MODEL

The symbols used in the model equations are the following.

AHI - a scalar, the value of annual highway investment for all sections, in thousands of dollars.

AL - a scalar, the size of the labour force for towns, rural farm areas and rural non-farm areas.

AN - a scalar, the level of local employment in non-agricultural sectors for all towns, in man-years.

AS - a column vector of 18 elements, the yearly value of area business sales for each sector, in thousands of dollars.

AS_N - a scalar, the last element of the vector AS, the yearly value of sales by households, i.e. household incomes.

ATS - a scalar, the yearly value of area business sales for all sectors, in thousands of dollars.

AY - a scalar, the yearly value of regional income, in thousands of dollars.

BR - a row vector of 18 elements, the proportion of each sector's business sales allocated to depreciation, retained earnings, business taxes, gifts and contributions, and payments to non-resident owners of factors of production.

CHL - a column vector of 34 elements, the change in the "effective distance" of each highway section due to investment, in miles.

CHL_a - the value of the a-th element of the vector CHL, the change in "effective distance" of the a-th highway section.

CHP - a column vector of 34 elements, the proportion of annual average daily traffic using each highway section at the criterion hour.

CHT - a column vector of 34 elements, the volume of traffic using each highway section at the criterion hour, in number of cars.

CO - a column vector of 34 elements, the volume of congestion(i.e. the excess of highway requirements over the service volume) for each highway section, in number of cars.

CO_a - the a-th element of the vector CO, the volume of congestion on the a-th highway section.

D - a column vector of 110 elements, the "effective distance" between each origin-destination pair, in miles.

DAS - a column vector of 18 elements, the change in yearly area business sales due to highway investment for each sector, in thousands of dollars.

DAS_N - the last element of the vector DAS, the change in the value of yearly household incomes, in thousands of dollars.

DATS - a scalar, the change in total area business sales for a year due to highway investment, in thousands of dollars.

DAY - a scalar, the change in the value of regional income due to highway investment, in thousands of dollars.

DEC - a scalar, the assumed exogenous rate of growth of area final demands.

DFD - a column vector of 18 elements, the change in the value of final demands by sector due to highway investment, in thousands of dollars.

DHI - a column vector of 34 elements, the value of discretionary highway investment for each highway section, in thousands of dollars.

DHI_a - the a-th element of the vector DHI, discretionary highway investment for the a-th highway section.

DPO - a scalar, the assumed rate of exogenous growth of population and of labour force.

DSV - a scalar, the average increase in highway service volumes per thousand dollars of highway investment.

DTNU - a column vector of 18 elements, the change in local employment in non-agricultural sectors in each of the region's urban areas due to highway investment, in man-years.

DTS - a column vector of 18 elements, the change in yearly town business sales for each town due to highway investment, in thousands of dollars.

DTSX - a scalar, the change in the yearly business sales of Winnipeg (the region's metropolis) due to highway investment, in thousands of dollars.

DTT - a scalar, the average percentage change in travel time per thousand dollars of highway investment.

DTY - a column vector of 44 elements, the change in incomes of each town, rural farm area and rural non-farm area in the region due to highway investment, in thousands of dollars.

e - the limit of $(1 + 1/x)^x$ as x tends to infinity.

ET_{ij} - the yearly volume of errand-running traffic from origin i to destination j, in number of cars.

ET - a new vector of 110 elements, the non-zero values of ET_{ij}.

EX - a column vector of 18 elements, the value of yearly export final demands for each sector, in thousands of dollars.

EX_N - the last element of the vector EX, the value of household earnings from outside of the region, in thousands of dollars.

FAC - a matrix of order 110 x 34, the proportion of each errand-running flow on an origin-destination basis using each highway section.

G - a column vector of 18 elements, the value of yearly government final demands for each sector, in thousands of dollars.

GT - a scalar, the value of government transfer payments for a year, in thousands of dollars.

HCT - a column vector of 18 elements, the proportion of highway investment spent on each sector, i.e. the highway construction technology.

HL - a column vector of 34 elements, the "effective distance" of each highway section, in miles.

HL_a - the a-th element of the vector HL, the "effective distance" of the a-th highway section.

HR - a column vector of 34 elements, the requirement for highway capacity for each section, in cars per hour.

I - the unit matrix, where the all elements of the main diagonal are unity and all other elements zero.

IN - a column vector of 18 elements, the value of yearly investment final demands for each sector, in thousands of dollars.

NCT - a row vector of 34 elements, the yearly volume of non-commercial traffic for each highway section, in cars.

ND - a column vector of 110 elements, the "effective distance" for each origin-destination pair after highway investment, in miles.

NSV - a column vector of 34 elements, the change in service volume for each highway section due to highway investment, in cars per hour.

NTT - a column vector of 34 elements, the percentage change in travel time over each highway section due to highway investment.

NTT_a - the a-th element of the vector NTT, the percentage change in travel time over the a-th highway section.

RCT - a row vector of 34 elements, the yearly volume of commercial traffic over each highway section, in trucks.

RET - a row vector of 34 elements, the yearly volume of errand-running traffic over each highway section, in cars.

RHI – a column vector of 34 elements, the value of highway investment required for alleviation of congestion, for each highway section, in thousands of dollars.

RHI_a – the a-th element of the vector RHI, required highway investment for the a-th section.

RIU – a row vector of which the elements are all unity.

SV – a column vector of 34 elements, the service volumes for each highway section, in cars per hour.

t, t+1 – subscripts denoting discrete time periods of one year.

TEPS – a diagonal matrix of order 18 x 18, the elements of the main diagonal being the output/employee ratios for each town, and all other elements being zero.

THI – a column vector of 34 elements, the total investment in each highway section in a year, in thousands of dollars.

THI_a – the a-th element of the vector THI, total yearly investment for the a-th highway section.

TL – a column vector of 44 elements, the size of the labour force for each town, rural farm area and rural non-farm area in the region.

TN – a column vector of 44 elements, the level of local non-agricultural employment in each town, rural farm area and rural non-farm area in the region.

TNU – a column vector of 18 elements, the level of local non-agricultural employment in each town in the region, a subset of the vector TN.

TP – a column vector of 44 elements, the population of each town, rural farm area and rural non-farm area in the region.

TS – a column vector of 18 elements, the value of yearly business sales for each town in the region, in thousands of dollars.

TSW – a scalar, the yearly value of business sales in Winnipeg, in thousands of dollars.

TY – a column vector of 44 elements, the yearly value of incomes for each town, rural farm area and rural non-farm area in thousands of dollars.

X – a matrix of order 18 x 18, the input-output technical coefficients.

YVT – a row vector of 34 elements, the yearly volume of total traffic over each highway section, in cars.

' – defines a new value of the variable to which it is attached.

" – used to indicate the transpose of a vector or matrix.

The equations of the model used to derive the results for the Interlake area are the following.

$$AS = (I - X)^{-1} (G + IN + EX) \qquad (3.2)$$

$$ATS = (RIV) (AS) - AS_N \qquad (3.3)$$

$$TS = ATS \cdot (1/AN) (TNU) \qquad (3.4)$$

$$TSX = 10 \cdot ATS \qquad (4.13)$$

$$AY = AS_N - EX_N - GT + (BR) (AS) \qquad (3.5)$$

$$TY = AY (1/AL) (TL) \qquad (4.12)$$

$$ET_{ij} = \frac{e^{1.1597} \quad (TL_i)^{1.2499} \quad (TS_j)^{0.3697}}{(TN_i)^{0.2156} \quad (D_{ij})^{1.0366}} \qquad (4.5)$$

$$RET = (ET) (FAC) \qquad (4.8)$$

$$NCT = e^{-1.6105} (RET)^{1.2519} \qquad (4.6)$$

$$RCT = e^{-2.1760} (NCT)^{0.9873} \qquad (4.7)$$

$$YVT = 2 \cdot CT + NCT \qquad (4.17)$$

$$CHT = (1/365) (YVT) (I) (CHP) \qquad (3.14)$$

$$HR \equiv CHT \qquad (3.15)$$

$$CO = HR - SV \qquad (3.16)$$

$$RHI_a = (CO_a + 5)/DSV \qquad (4.18)$$

$$DSV = .244 \qquad (4.10)$$

$RHI_a = 0 \qquad \text{if } CO_a \leq 0$ (3.18)

$THI_a = DHI_a \qquad \text{if } DHI_a > RHI_a \geq 0$ (3.19)

$THI_a = RHI_a \qquad \text{if } RHI_a \geq DHI_a \geq 0$ (3.20)

$THI_a = 35 \cdot HL_a \qquad \text{if } THI_a > 35 \cdot HL_a$ (4.19)

$NSV = (DSV)\ (THI)$ (3.21)

$NTT = (DTT)\ (THI)$ (3.22)

$DTT = .00012$ (4.11)

$NTT_a = 0.01 \qquad \text{if } NTT_a > 0.01$ (4.20)

$CHL = (HL)''\ (I)\ (NTT)$ (4.22)

$CHL_a = 0.1 \qquad \text{if } CHL_a > 0.1$ (4.21)

$ND = (FAC)\ (HL - CHL)$ (3.29)

$AHI = (RIV)\ (THI)$ (3.30)

$DFD = AHI\ (HCT)$ (3.31)

$DAS = (I - X)^{-1}\ (DFD)$ (3.1)'

$DATS = (RIV)\ (DAS) - DAS_N$ (3.3)'

$DTS = DATS\ (1/AN)\ (TNU)$ (3.4)'

$DTSX = 10 \cdot DATS$ (4.13)'

$DAY = DAS_N - EX_N - GT + (BR)\ (DAS)$ (3.5)'

$$DTY = DAY\ (1/AL)\ (TL) \qquad (4.12)'$$

$$TEPS = (I \cdot TS)\ (I \cdot TNU)^{-1} \qquad (3.32)$$

$$DTNU = (TEPS)^{-1}\ (DTS) \qquad (3.33)$$

$$SV' = SV + NSV$$

$$HL' = HL - CHL$$

$$D' = ND$$

$$AS' = AS + DAS$$

$$TS' = TS + DTS$$

$$AY' = AY + DAY$$

$$EY' = EY + DEY$$

$$TY' = TY + DTY$$

$$ATS' = ATS + DATS$$

$$TNU' = TNU + DTNU \qquad (3.34)$$

$$TSX' = TSX + DTSX \qquad (4.23)$$

$$TP_{t+1} = TP_t\ (1 + DPO) \qquad (4.24)$$

$$TL_{t+1} = TL_t\ (1 + DPO) \qquad (4.25)$$

$$G_{t+1} = G_t\ (1 + DEC) \qquad (4.26)$$

$$IN_{t+1} = IN_t\ (1 + DEC) \qquad (4.27)$$

$$EX_{t+1} = EX_t \, (1 + DEC) \tag{4.28}$$

$$DPO = 0.02 \tag{4.29}$$

$$DEC = 0.05 \tag{4.30}$$

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