THE FOUNDATION OF A NEW TRANSPORTATION PLANNING MODEL FOR THE MANITOBA CAPITAL REGION

by

Kean Hoe Lew

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

Master of Science

Department of Civil and Geological Engineering
University of Manitoba
Winnipeg, Manitoba
Canada

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
*****
COPYRIGHT PERMISSION PAGE

The Foundation of a New Transportation Planning Model for the Manitoba Capital Region

BY

Kean Hoe Lew

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University

of Manitoba in partial fulfillment of the requirements of the degree

of

Master of Science

ABSTRACT

This thesis develops the foundation of a model to predict P.M. peak vehicle trips for the Manitoba Capital Region. This model, called the Manitoba Capital Region Transportation Planning Model (MCRTPM), is built on a Geographical Information System for Transportation (GIS-T) platform. Components of the model were calibrated using the 1996 Statistics Canada Journey-to-Work database and the matrix adjustment algorithm with newly developed traffic data from the City of Winnipeg and Manitoba Department of Highways and Government Services (MHGS).

The foundation developed in this thesis allows further refinement to be made to the MCRTPM in order to develop a complete model. This model facilitates transportation planning in the Manitoba Capital Region.

ACKNOWLEDGEMENTS

I would like to express my sincerest gratitude to Mr. Kenn Rosin and Mr. Doug Hurl for allowing me the opportunity to work with them.

I would also like to thank Mr. Dave Duncan for his support and encouragement.

I would like to extend my appreciation to the City of Winnipeg Public Works Department for their financial assistance in this research. I would also like to thank the people who has helped me in the course of the completion of this thesis:

Mr. Malcolm Brown

Mr. Alan Brownlee

Mr. David Krieger

Mr. Clark Lim

Dr. Ali Mekky

Mr. Alan Taylor

My deepest gratitude goes out to Jeannette Montufar for inspiring me.

I would like to thank C.K. and S.L. for helping me stand up during the times when I faltered.

My deepest gratitude goes out to V.L.M. for giving me a reason to continually strive to be a better person.

I wish to thank my parents, sister and brother-in-law for their love, support, and understanding.

Finally, I would like to thank my advisor, Professor Alan Clayton, for his wisdom, insight, patience, assistance, encouragement and for believing in me.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This chapter presents the purpose, background, objectives, scope and organization of the thesis.

1.1 Purpose

The thesis develops the foundation of a model to predict P.M. peak vehicle trips for the Manitoba Capital Region. This model, called the Manitoba Capital Region Transportation Planning Model (MCRTPM), is built on a Geographical Information System for Transportation (GIS-T) platform. Components of the model were calibrated using the 1996 Statistics Canada Journey-to-Work database and the matrix adjustment algorithm with newly developed traffic data from the City of Winnipeg and Manitoba Department of Highways and Government Services (MHGS).

1.2 Background and Need

The City of Winnipeg and the surrounding region are termed the "Manitoba Capital Region" (see Figure 1). The 1996 Census of Canada indicates that the Capital Region has a population of approximately 700,000 people with 625,000 of them residing in Winnipeg (Capital Region Review, 1999). Like most North American metropolitan areas, the City of Winnipeg is experiencing urban sprawl characterized by the rise of suburban communities surrounding the older areas. Klassen (1999) documents the urban sprawl pattern in the region. Growth in the ex-urban communities in the Capital Region, and large activity shifts in the City of Winnipeg itself have translated into significant changes in the traffic patterns.

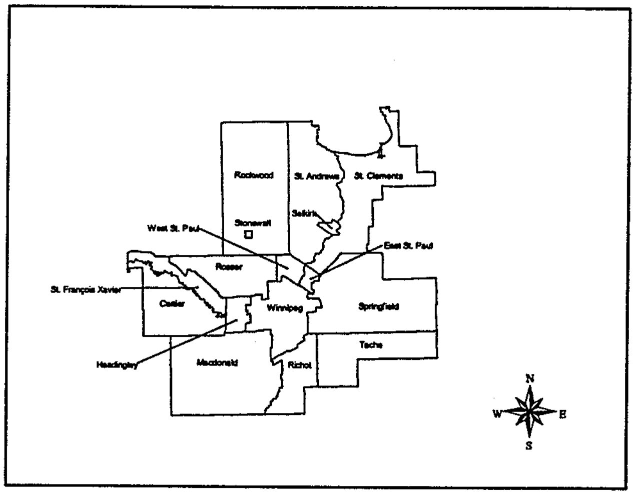

Figure 1: The Manitoba Capital Region

To this day, transportation agencies in the region, like the City of Winnipeg, Manitoba Department of Highways and Government Services (MHGS), Manitoba rural municipalities, Winnipeg Transit, and the Winnipeg Airport Authority perform their own respective transportation planning. The lack of a regional approach to transportation planning has led to a situation in which there is insufficient understanding of the regional traffic characteristics in the region. The Capital Region Review panel highlighted this lack of understanding when they concluded that there is "inadequate information and research for assessing commuting patterns within the region" (1999). In order to increase the effectiveness of transportation planning, there is a need to develop better means to understand, structure, analyze and predict transportation demand (characterized by traffic flows) in the Manitoba Capital Region. This can be achieved through the construction of a model that links the transportation and land-use systems of the region in terms of traffic flows. This linkage provides a capability to better assess and test a variety of transportation planning alternatives. This capability in turn provides decision makers with quantitative information about the consequences of their decisions, thus allowing objective transportation systems analysis and planning in the region (Mekky, 2000).

In the United States, metropolitan areas have their respective Metropolitan Planning Organizations (MPOs). The MPOs are formed for cooperative transportation decision making for the metropolitan planning area (FHWA, 1994). MPOs are required by the Transportation Equity Act for the 21st Century (TEA-21) to develop transportation plans that consider (FHWA, 2000): (1) the preservation of existing transportation facilities; (2) the consistency of transportation planning with applicable Federal, State and local energy conservation programs; (3) the need to relieve congestion and prevent congestion; (4) the likely effect of transportation policy decisions on land use and development; (5) the programming of expenditure on transportation enhancement activities; (6) the effects of all transportation projects to be undertaken within the metropolitan area; (7) international border crossings; and (8) the need for connectivity of roads within a metropolitan area with roads outside of a metropolitan area. As a result of the United States legislative requirement for transportation plans, many MPOs have developed transportation models within their jurisdictions in order to facilitate the development of the required transportation plans.

In Canada, transportation agencies (municipal, provincial, or regional) are not required to produce transportation plans by law. However, many agencies develop, maintain and improve transportation planning models in order to facilitate the development of transportation plans.

As well as important shifts in population and activity systems in the region, several developments in the regional transportation network highlight the need for a regional transportation planning model. The completion of the Highway 101 Northeast extension and the opening of the Charleswood Bridge had significant impact on the traffic flow in the region (see Figure 2).

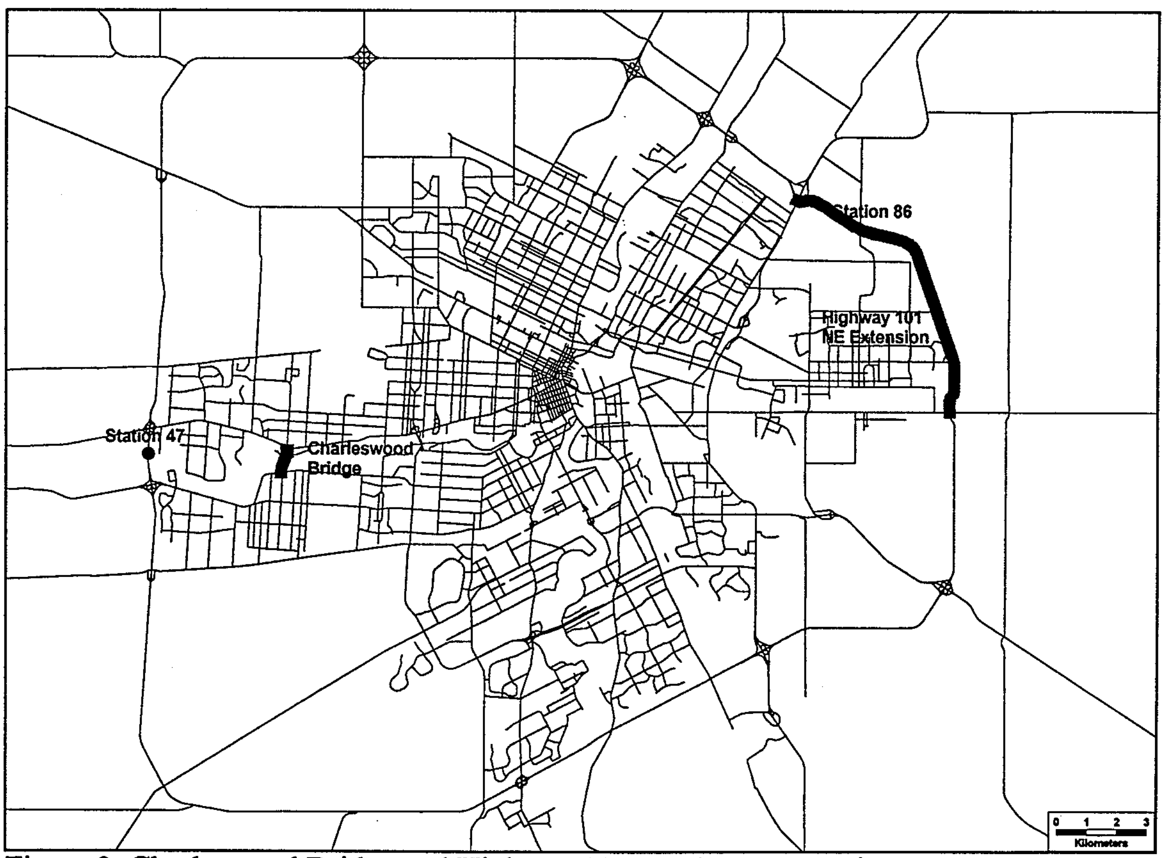

Figure 2: Charleswood Bridge and Highway 101 Northeast Extension

When the Charleswood Bridge was opened in 1996, the Annual Average Daily Traffic (AADT) at Permanent Count Station 47 on Highway 100 decreased from 22,020 (in 1995) to 17,260 (in 1996) (UMTIG, 2000). Figure 3 shows the historical AADT for Station 47. Figure 4 shows a map of the Charleswood Bridge and the location of Station 47.

The Highway 101 northeast extension resulted in an AADT of 3,150 at Station 86 in its first year of operation in 1997. This traffic increased to 3,460 in 1998 and 3,970 in 1999 (UMTIG, 2000). Since the traffic on provincial highways outside of the city has not decreased, this leads to the inference that the traffic on the northeast extension used to be traffic that operated on City streets before the northeast extension was completed.

In the first case, a new transportation facility within the City of Winnipeg led to a substantial decrease (5000 vehicles per day) in traffic flow on a major provincial highway link in the Capital Region. In the second case, a new transportation facility outside of the City of Winnipeg has (presumably) led to a substantial decrease of traffic on certain City streets (3000 vehicles per day).

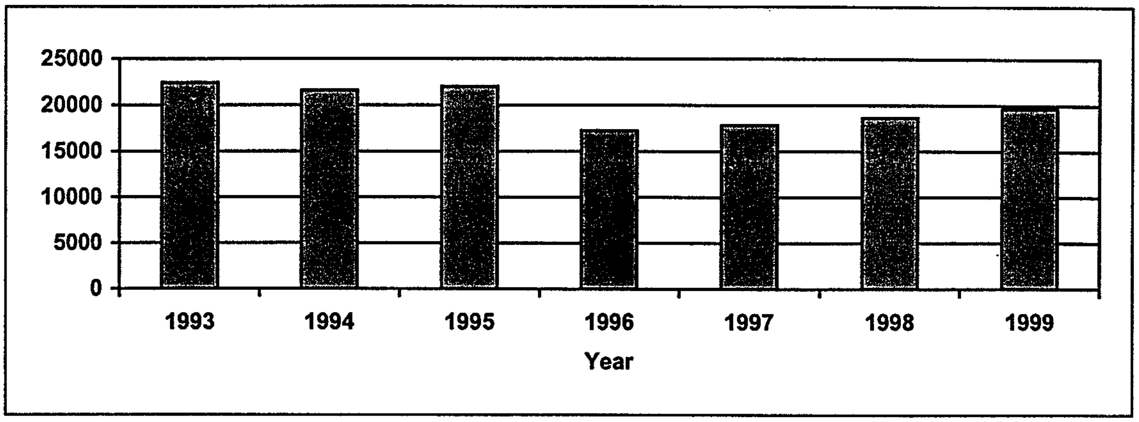

Figure 3: AADT at Station 47 (UMTIG, 1999)

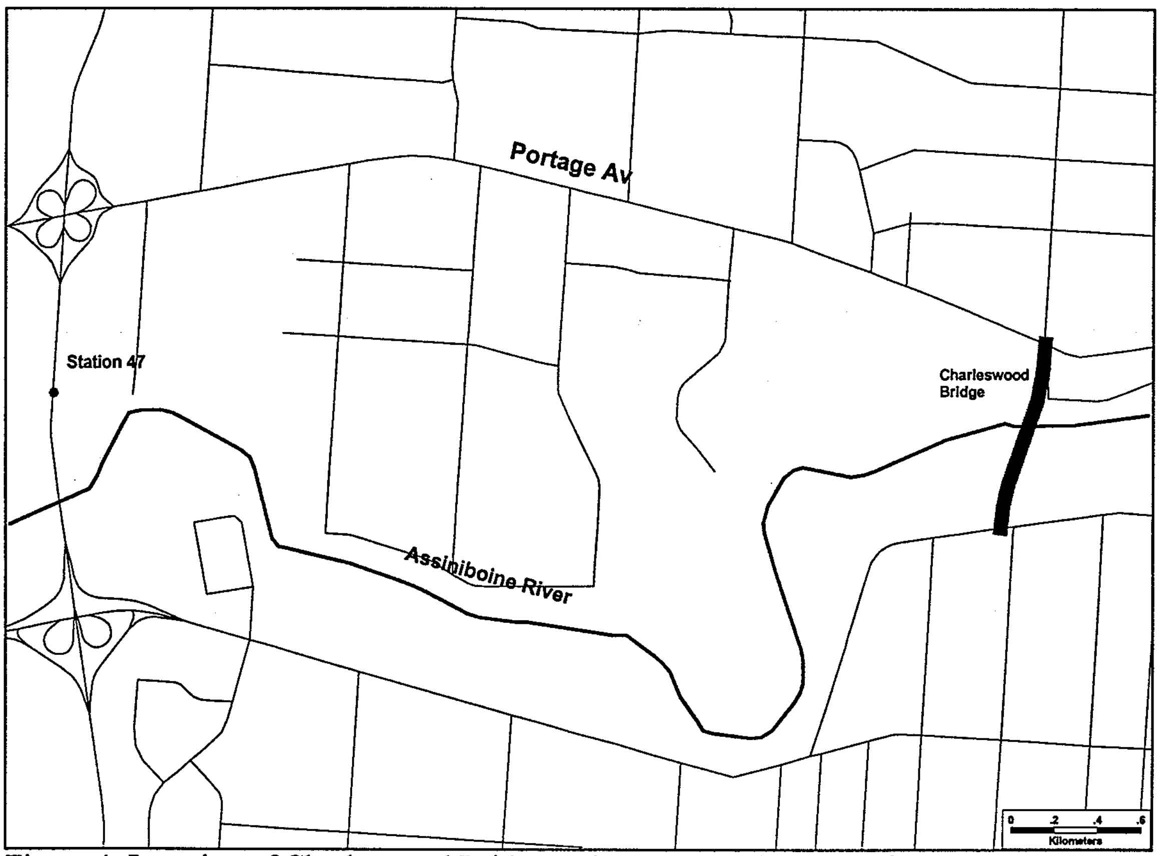

Figure 4: Location of Charleswood Bridge and Permanent Count Station 47

In November 1999, Statistics Canada made available the 1996 Journey-to-Work database for the Manitoba Capital Region. Furthermore, new traffic databases from the Manitoba Highways Traffic Information System (MHTIS) and the City of Winnipeg have also been made available. In addition, Geographic Information Systems for Transportation (GIS-T) technology has evolved to a level where it is readily accessible and offers an efficient means for transportation modeling. The need for a regional approach to transportation planning, the availability of the Statistics Canada database and new traffic databases, and the evolution of GIS-T technology make the development of a transportation planning model for the Manitoba Capital Region feasible.

At the heart of transportation systems analysis and planning is the understanding and prediction of traffic flows under different transportation and land-use scenarios (Manheim, 1984). These flows are key inputs into basic engineering design and evaluation processes. Flows can be quantified through a variety of measurements. For this research, a P.M. peak hour model was developed. The rationale for this decision is: (1) the P.M. peak is critical for system analysis since area wide traffic volumes and congestion are typically higher (NCHRP, 1998); (2) the P.M. peak accounts for a greater number of trips than the A.M. peak in the region (Hurl, 2000 and UMTIG, 1998); and (3) the lack of a P.M. peak model to supplement the current existing A.M. peak model.

1.3 Research Objectives and Scope

1.3.1 Objectives

The objectives of the thesis are:

(1) to review, compare and contrast the current transportation modeling practices in Winnipeg and selected Canadian cities.

(2) to develop the framework and structure for the Manitoba Capital Region Transportation Planning Model (MCRTPM).

(3) to construct and develop a Manitoba Capital Region Transportation Analysis Network (MCRTAN) on a Geographic Information System for Transportation (GIS-T) platform that is compatible and suitable for the development of the MCRTPM.

(4) to develop, analyze and integrate P.M. peak traffic data with the MCRTAN.

(5) to develop an automobile driver work trip (ADWT) matrix from the Statistics Canada 1996 Journey-to-Work database into a form suitable for the MCRTPM development.

(6) to develop components of the MCRTPM:

   (a) trip generation equations for ADWT using the ADWT matrix developed in Objective 5.

   (b) a P.M. peak automobile driver work trip (PMPADWT) matrix using the ADWT matrix developed in Objective 5 and the National Cooperative Highway Research Program (NCHRP) diurnal factor.

   (c) an estimated P.M. peak vehicle total trip (PMPVTT) matrix using the PMADWT matrix developed in (b), traffic data from the City of Winnipeg and MHGS, and TransCAD's matrix adjustment algorithm (which uses Nielsen's (1993) method).

   (d) a P.M. peak vehicle other trip (PMPVOT) matrix using the PMPADWT developed in (b) and the PMPVTT matrix developed in (c).

(e) trip distribution equations for PMPADWT using Statistics Canada 1996 Journey-to-Work data, travel time estimates from MCRTAN, and TransCAD's trip distribution component calibration function.

(f) trip distribution equations for PMPVOT using the PMPVOT matrix developed in (d), travel time estimates from MCRTAN, and TransCAD's trip distribution component calibration function.

(g) the trip assignment component using Bureau of Public Roads (1964) default link performance function parameters.

(7) to recommend further developments for the MCRTPM.

1.3.2 Scope

This thesis is limited to the following:

- The region of analysis is the Manitoba Capital Region with the rest of Manitoba considered as large external zones. This zone system is called the Winnipeg Regional Traffic Zone System (see Figure 5).
- The model predicts P.M. peak automobile driver work trips and P.M. peak vehicle other trips.
- Due to the nature of the available data, the level of analysis of the model is zonal (aggregate analysis).
- Objectives 2, 3, 4, 5, and 6(a), 6(b) and 6(c) were the primary concern. Objectives 6(d), 6(e) and 6(f) are were of secondary concern.

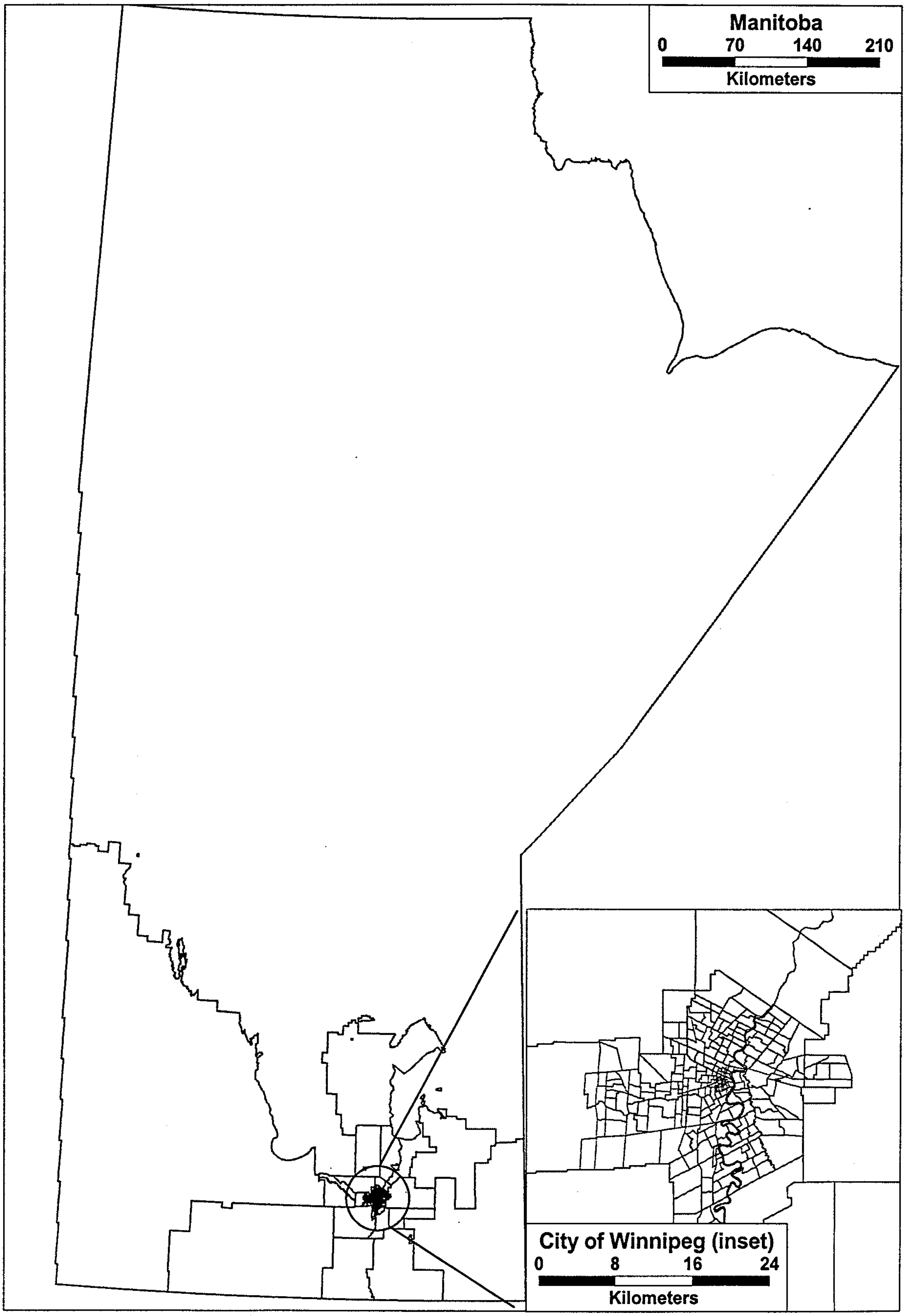

Figure 5: Winnipeg Regional Traffic Zone System
Source: City of Winnipeg Public Works Department
//pc-trans2/d:\users\kean\thesis2\gis\wpg5\countvol.lay

1.4 Thesis Organization

Chapter 1 provides the background and the need for the research.

Chapter 2 examines the generic transportation planning model structure and reviews current transportation planning models in selected Canadian cities

Chapter 3 provides the structure of the Manitoba Capital Region model.

Chapter 4 develops the Manitoba Capital Region Transportation Analysis network (MCRTAN).

Chapter 5 details the development of components of the MCRTPM using the MCRTAN, Statistics Canada 1996 Journey-to-Work database, newly developed traffic databases from the Manitoba Highways Traffic Information System (MHTIS) and the City of Winnipeg.

Chapter 6 provides the conclusions of the research, and proposes work for the further development of the MCRTPM.

Appendix A provides a list of the cartographic, spatial layer and database computer files used in the development of this thesis.

Appendix B shows a sample of the MCRTAN in tabular form.

Appendix C shows the MCRTAN Turn Restriction File in tabular form.

Appendix D shows a sample of Winnipeg Regional Traffic Zone System in tabular form.

Appendix E shows the links in the MCRTAN which contain traffic counts used as input for the matrix adjustment algorithm.

Appendix F shows the different trip production equations for ADWT examined in this research.

Appendix G shows the different trip attraction equations for ADWT examined in this research.

Appendix H shows the different trip production and attraction equations for PMPVOT examined in this research

Appendix I is a report on the Census Place of Work seminar held by the Region of Peel and Statistics Canada on October 20, 2000.

2.0 Transportation Planning Models

This chapter provides an overview of the general transportation planning model structure. Using the structure, transportation planning models from the City of Winnipeg and selected Canadian cities are reviewed, compared and contrasted.

2.1 Transportation Planning Model Structure

A transportation planning model can be classified in terms of its: (1) subsystem components and organization; (2) level of analysis of each subsystem; and (3) technique(s) used in each subsystem.

2.1.1 Subsystem Components and Organization

The four-step sequential modeling method is the most common method for constructing transportation planning models. This method divides the model into four components: (1) trip generation; (2) trip distribution; (3) mode split; and (4) trip assignment. Transportation models can differ between each other in terms of the components present as well the organization of the components within the overall model. Examples of variations in the organization are shown in Figure 6.

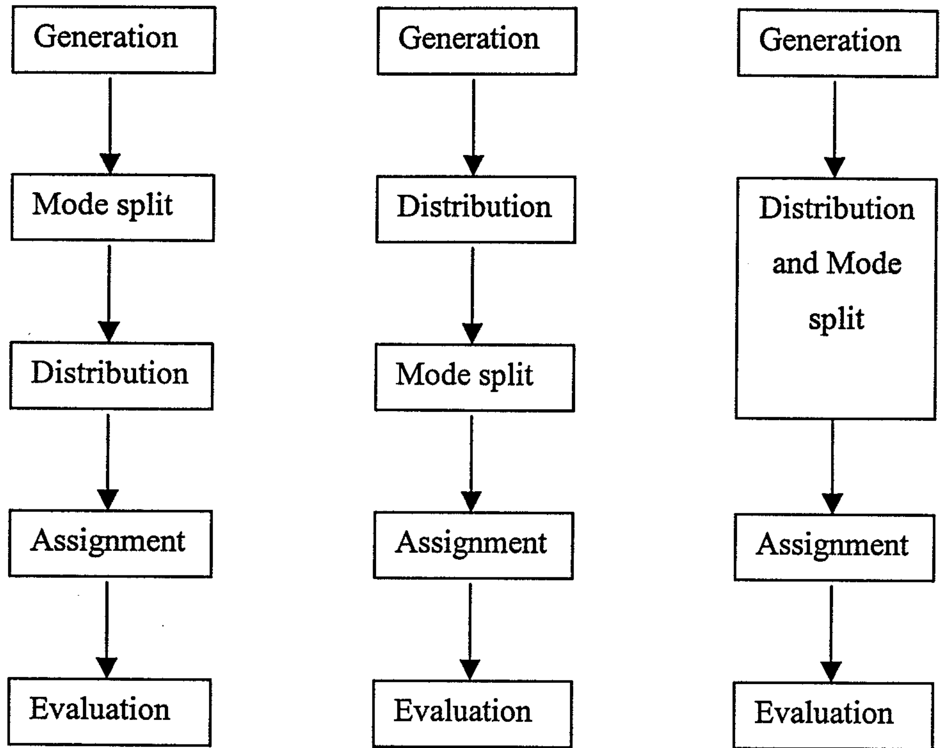

Figure 6: Variations in the Organization of Transportation Models (Mekky, 2000)

The trip generation component predicts the number of trips produced by each zone i (o_i) and the number of trips attracted to each zone j (d_j).

The trip distribution component predicts the number of trips that originate from zone i destined for zone j (t_{ij}). This is can be expressed in a matrix form with the origins as rows and the destinations as columns.

The mode split component divides the t_{ij} matrix into several matrices by mode of travel.

The trip assignment component assigns the t_{ij} matrices to travel routes in order to produce the volume (traffic) on each link in the analysis network.

2.1.2 Level of Analysis of Each Subsystem

The level of analysis of each subsystem defines the input data requirements and the accuracy of the results which can be obtained from the model. There are typically three analysis units: (1) zonal; (2) household; and (3) individual.

The zonal analysis unit assumes that all individuals in a zone have identical characteristics. The zone is assumed to have homogeneous land-use within its boundaries. Furthermore, it is assumed that trips begin and end at the centroid of each zone.

The household analysis unit assumes that households with identical characteristics such as income, vehicle ownership or household size have the same travel behaviour. Essentially, this type of aggregation means grouping system elements which are different and assuming that they are identical (Mekky, 2000).

The individual analysis unit uses characteristics of each individual, such as age, sex, income, occupation and vehicle availability, in order to model the travel behaviour of the individual.

Analysis units of households and individuals are often aggregated to the zonal level at one point or another.

2.1.3 Methods Used by Each Subsystem

Mekky (2000) classifies the methods used in each subsystem into three types: (1) mathematical or algorithimic; (2) probabilistic or deterministic; and (3) discrete or continuous variables.

Mathematical methods exist in the form of mathematical equations. Algorithmic methods contain logical instructions. Probabilistic methods describe the probability of an individual using a facility. Deterministic methods predict the number of people using a transportation facility. Discrete variables answer the question in terms of "which one?" (e.g. which mode, which destination, which route). Continuous variables answer the question of "how much?" (e.g. how many trips destined to a zone) (Mekky, 2000).

2.2 **Winnipeg Transportation Model** (Winnipeg (1992a), Winnipeg (1992b) and Winnipeg (1996))

The Winnipeg Transportation Model is based on the model developed by the University of Montreal as part of the EMME/2 package. Since the development of the model, the City of Winnipeg has conducted travel surveys every five years and used the data to recalibrate and enhance the model. The latest calibration data are based on 1992 City of Winnipeg Travel survey. In 1996, the travel survey was not performed because of budget constraints. Instead, the City of Winnipeg obtained the 1996 Journey-to-Work database from Statistics Canada.

The Winnipeg Transportation Model is maintained on the EMME/2 software. The model predicts the A.M. peak hour traffic divided into two trip purposes: (1) work (which includes post-secondary school); and (2) non-work. The structure of the model is shown in Figure 7. The model is based on the City of Winnipeg Zone System (see Figure 8).

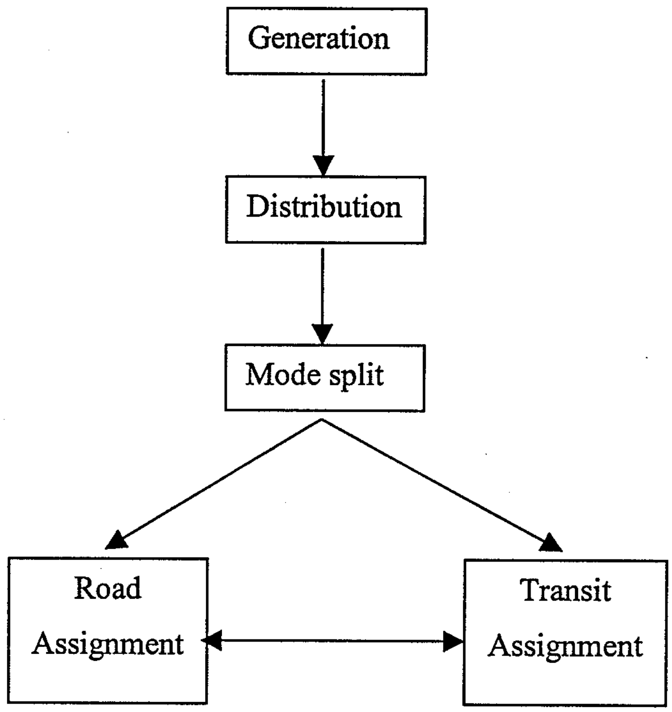

Figure 7: Structure of Winnipeg Model

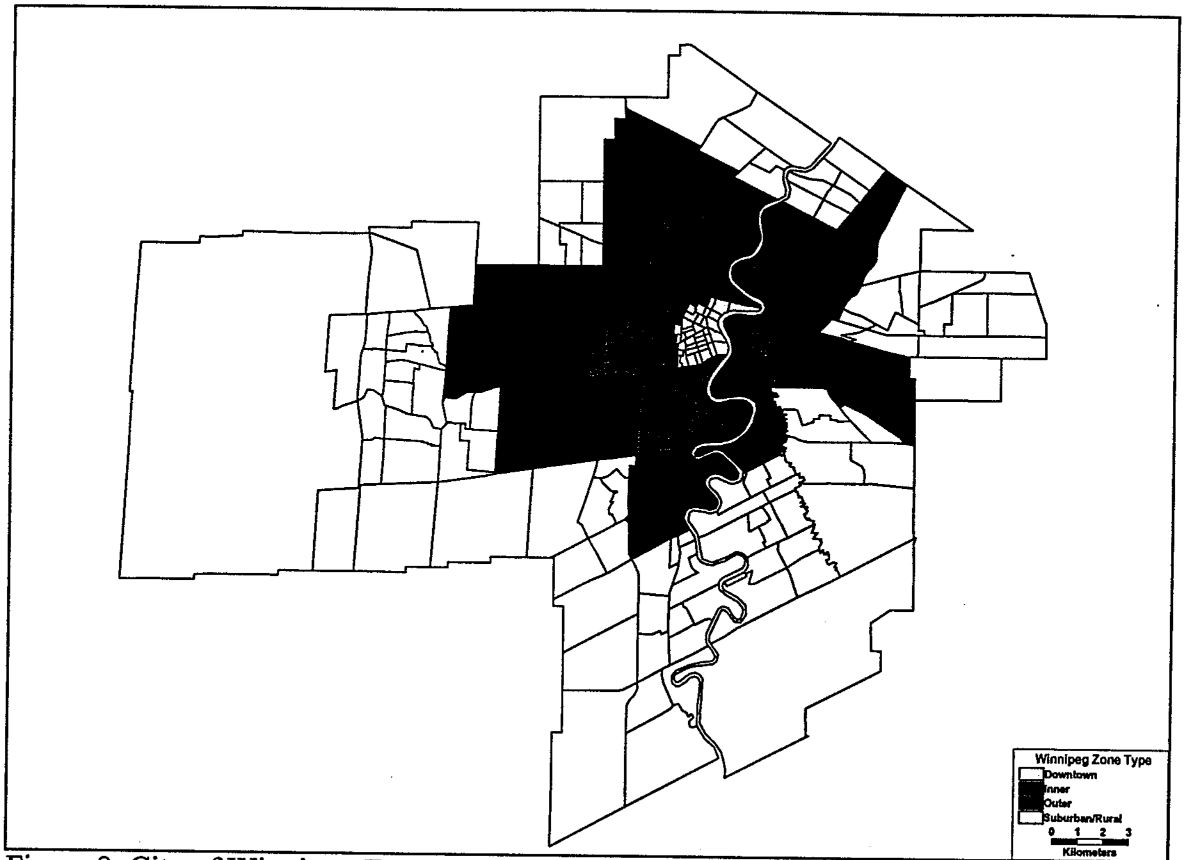

Figure 8: City of Winnipeg Zone Types

There are two types of trip generation equations: (1) trip production; and (2) trip attraction. The trip generation equations were developed using the multiple regression method.

The dependent variable for the trip production equations is the number of person trips produced. The trip production equations are a function of: (1) type of zone (downtown, inner, outer, suburban/rural) (see Figure 8); (2) trip purpose (work, non-work, and total trips); and (3) number of single family residential units and multiple family residential units.

The dependent variable for the trip attraction equations is the number of person trips attracted by each zone. The trip attraction equations are a function of: (1) area of the city (downtown, inner, outer, suburban/rural); (2) trip purpose (work, non-work, and total trips); and (3) number of office employment, retail employment, industrial employment and other employment.

The trip distribution component uses the doubly-constrained gravity model with and exponential friction factor equation. Mathematically, this is written as:

$$t_{ij} = o_i \, d_j \, F_{ij}$$

where

t_{ij} is the number of person trips produced in zone i and attracted to zone j

o_i is the number of person trips produced in zone i

d_j is the number of person trips attracted to zone j

F_{ij} is the friction factor matrix expressed as:

$$F_{ij} = EXP\,(-\gamma_k \, c_{ij} + CONST_k), \text{ for all } K$$

where

c_{ij} is the travel impedance from zone i to zone j (the travel time in minutes)

K is the index of the time intervals

γ is the exponent associated with interval K

$CONST_k$ is a constant added to the exponent on interval K in order to obtain a smooth curve.

The mode split component is formulated as a zonal aggregate logit type model. Mathematically, this is expressed as:

$$AP = TP / [1 + EXP (CONST - x_1 * TT + x_2 * AT - x_3 * A/DU)]$$

where

AP is the number of persons traveling by automobile
TP is the total number of persons
TT is the transit time matrix
AT is the auto time matrix
A/DU is the autos per dwelling unit
CONST, x_1, x_2, x_3 are calibrated parameters

The mode split component was improved separately in March 1996 using data from the 1992 O-D survey. The mode split component predicts the proportion of transit trips to automobile trips. The resulting mode split equation is a function of: (1) the difference between total transit travel time and total auto travel time; (2) the average walk time to transit from the transit stop at the origin end; (3) the average number of automobiles per dwelling unit at the origin zone; (4) the average parking cost at the destination zone; and (5) the total waiting time for transfers between bus routes.

The number of automobile drivers is obtained by dividing the AP matrix with the number of persons per vehicle matrix (obtained from 1992 O-D survey). The number of transit passengers is obtained by subtracting the AP matrix from the TP matrix.

The traffic assignment component uses the user equilibrium method (also known as the capacity constraint method). Volume-delay curves for this component were developed by the University of Montreal and included as part of the EMME/2 package.

ND-Lea Consultants (2000) produced a Winnipeg downtown model in order to evaluate the different roadway alternatives connecting the Provencher Bridge and Main Street. The network for the downtown model is shown in Figure 9. The Downtown Model is constructed using the TransCAD software based on traffic data from the City of Winnipeg. The report for this model is unpublished.

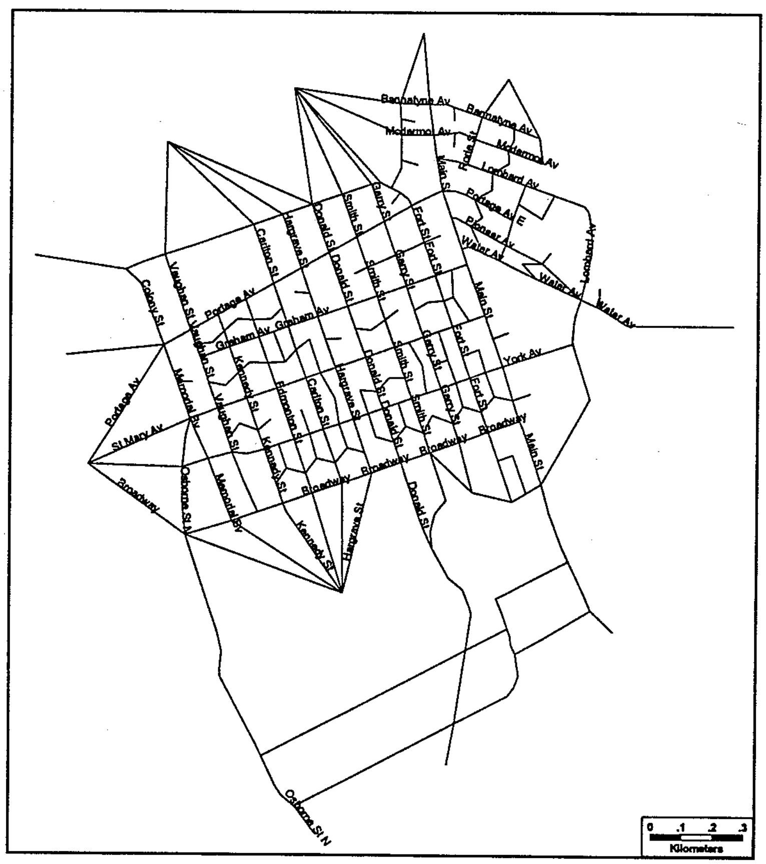

Figure 9: ND-Lea Winnipeg Downtown Model