TEMPORAL VARIATIONS FOR MONITORING TRAFFIC IN URBAN AREAS

By

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

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ABSTRACT

The research designs, develops, and applies a methodology to characterize hourly traffic variations in urban areas. The research documents current traffic monitoring practices in urban areas and assesses the need to understand hourly variations using the city of Winnipeg, Manitoba as a case study.

The methodology applied to develop temporal variations for traffic patterns in urban areas uses a hybrid approach that compares the results from the statistical analysis with variables that explain hourly temporal variations, including road class, traffic volume, and land use.

The research specifically identifies: arterial and non-arterial roads, low and high volume roads, and residential, industrial, and commercial zones as variables that explain hourly temporal variations. Six traffic pattern groups in Winnipeg are developed and characterized based on this approach. These variables are used to develop decision flow charts to assign road segments to TPGs.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my advisors Dr. Jeannette Montufar, P. Eng., and Dr. Jonathan Regehr, P.Eng. for their invaluable support for my research and their encouragement throughout my Master's program. I would also like to thank Prof. Alan Clayton, P.Eng. for his insight and advice during the last three years.

I would like to thank the members of the University of Manitoba Transport Information Group (UMTIG) for their support and friendship. I especially want to thank Mr. Craig Milligan, EIT, Mr. Tom Baumgartner, EIT, Ms. Rebecca Peterniak, EIT, Mr. Mark Reimer, EIT, and Ms. Danielle Salem for their support and contributions to this research.

Sincere thanks to the Public Works Department of the City of Winnipeg, specifically Mr. David Tang, P.Eng. for providing data and support for the research. I would like to acknowledge the financial assistance received from the Transport Association of Canada (TAC) Foundation.

I would like to thank my family, especially my wife, Kattia, for her support, understanding, love and patience; and my children, Santiago and Sofia, for being an inspiration every time I look in their eyes.

DEDICATION

To Kattia, Santiago and Sofia

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GLOSARY OF ACRONYMS

AADT: Annual Average Daily Traffic

AADTT: Annual Average Daily Truck Traffic

AASHTO: American Association of State Highway and Transportation Officials

ATR: Automatic Traffic Recorder

AWDT: Average Weekday Daily Traffic

CBD: Central Business District

DOW: Day of Week

ITE: Institute of Transportation Engineers

FHWA: Federal Highways Administration

GIS: Geographic Information Systems

LCV: Long Combination Vehicle

NCHRP: National Cooperative Highway Research Program

PHF: Peak Hour Factor

PR: Provincial Road

PTH: Provincial Trunk Highway

QA/QC: Quality Assurance/Quality Control

TAC: Transport Association of Canada

TMC: Turning Movement Count

TMG: Traffic Monitoring Guide

TPG: Traffic Pattern Group

TOD: Time of Day

UMTIG: University of Manitoba Transport Information Group

VKT: Vehicle Kilometres Travelled

VPD: Vehicles per Day

1 INTRODUCTION

1.1 PURPOSE

The purpose of the research is to design, develop, and apply a methodology to characterize hourly traffic variations in urban areas. The research documents current traffic monitoring practices in urban areas and assesses the need to understand hourly variations using the city of Winnipeg, Manitoba as a case study.

1.2 BACKGROUND AND NEED

Traffic volume is the most important measure used in transportation engineering (Albright, 1991; FHWA, 2001). According to the *Traffic Monitoring Guide* (FHWA, 2001), traffic data are fundamental to roadway network performance analysis. The data collected are used for a variety of applications including, but not limited to, road safety analysis, signal timing, road maintenance activities programming, pavement design, air quality analysis, and the planning of new road facilities. Additionally, traffic volume is used as a statistic to analyze traffic growth patterns and performance of a transport system, to design road geometry, to perform functional analysis for current and planned road networks (AASHTO, 2009), and to calibrate transportation models (ITE, 2008a).

Trends in historical data are used to estimate future traffic (Zhong & Liu, 2007). The data "support recommendations and decision-making" in transportation (ITE, 2008a). Adequate collection of quality traffic data is essential to facilitate informed decision making (FHWA, 2001). However, the significance of traffic monitoring is usually undervalued (Koonce, et al., 2008).

Inaccuracies and imprecise measures and estimates in traffic data impact decisions made by public agencies (Zhong & Liu, 2007). Inexact or non-representative estimates could lead to decisions that do not reflect future traffic demand requirements. Therefore, accurate traffic estimates are necessary (FHWA, 2001).

The quality of the data collected in urban areas varies among jurisdictions in the United States (Mergel, 1997). Similarly, in Canada data collection practices in urban areas vary among jurisdictions, and achieving uniformity in the reporting of numerous transportation-related indicators is a challenge (TAC, 2010).

In North America, the practices related to traffic monitoring vary between agencies with respect to the amount and type of equipment used, the duration of the short term counts, and the estimation of traffic statistics. This is due to the specific characteristics of each jurisdiction, and different budget and staff constraints. Traffic statistics from different jurisdictions cannot be compared due to inconsistencies in sampling and estimation of traffic data (Zhong & Liu, 2007, p. 26).

The current major reference text regarding traffic monitoring in North America is the *Traffic Monitoring Guide* (TMG) (FHWA, 2001). However, the document focuses on the development of traffic monitoring programs for highway agencies (FHWA, 2001; AASHTO, 2009). The TMG recommends the use of short-term and continuous counts. Short-term counts provide geographical coverage, while continuous counts allow for the adjustment of short-term counts in order to have an understanding of temporal variations of traffic and avoid temporal bias when annual traffic estimates are calculated (FHWA, 2001, p. E-1).

While continuous traffic monitoring in rural settings is very common, the traffic monitoring programs in many urban areas do not include continuous traffic monitoring sites. This situation can be explained because historically, the technology for these sites has not been well suited for higher density and the stop-and-go traffic conditions, which are characteristic of urban areas.

Nonetheless, recent developments in technology have allowed urban jurisdictions to begin continuous monitoring programs. In Winnipeg, budget constraints and questions regarding the effectiveness of developing urban expansion factors from continuous counts have thus far prevented the development of a continuous traffic monitoring program.

Traffic varies by hour of the day, day of the week, and month of the year. Knowledge of these variations is necessary to plan traffic counts and to estimate the accuracy of the traffic counts (Garber & Hoel, 1997; Kim, Park, & Sang, 2008). Characterization of temporal and geographical distributions of traffic allows agencies to identify capacity restrictions, improving mobility in the transport system (Weijermars, 2007).

Land use has a direct impact on the temporal and spatial distribution of trips in urban areas. The hourly variations of traffic define the periods with major congestion. Hourly variations of traffic in North America present a typical double peaking. This double peaking on travel demand is related to the start or end of urban activities including work and school trips. Land use policies affect performance of transportation systems in urban areas. Consequently, urban planners require a good understanding of travel patterns in urban areas (Meyer & Miller, 2001).

Weijermans (2007) indicates that most literature related to time of day (TOD) variations in urban areas addresses the difference on TOD variations by day of the week. Weijermans also finds a lack of literature regarding typical TOD traffic patterns in urban road networks.

This research is relevant to civil engineering because it identifies variables that explain hourly temporal variations in urban areas. The research also develops a methodology that can be applied to analyze traffic data in urban areas. Additionally, the traffic patterns developed can be used for traffic monitoring and management in order to identify anomalies or non-recurrent events. Finally, practitioners can improve traffic estimates from short-term counts, using the suggested time of day ratios.

1.3 APPROACH

This research develops time of day traffic pattern groups (TPGs) using traffic TOD variations of short-term counts in Winnipeg. The research uses a hybrid approach to develop the TPGs. The approach is based on three major elements: a) statistical analysis, b) use of variables that explain hourly temporal variations (road class, traffic volume, and land use), and c) application of engineering judgement. These elements interact jointly to develop and refine traffic pattern groups. The combined use of these elements develops pragmatic meaning from statistical results.

The intention of the research is to consider, from a practical perspective, the hypothesis that variables that explain hourly temporal variations have a relationship with TPGs created from the statistical analysis.

1.4 OBJECTIVES AND SCOPE

Specific objectives of this research are to:

1. Obtain an understanding of the trends, gaps, and issues related to traffic monitoring programs and traffic data in urban areas by conducting a literature review and jurisdictional survey.

2. Identify current traffic monitoring procedures, data needs and available data in Winnipeg by characterizing the current traffic monitoring program of the city.

3. Develop a methodology to create traffic pattern groups based on the temporal traffic variation of short-term counts.

4. Apply the methodology to develop traffic pattern groups based on the temporal traffic variation in the City of Winnipeg.

The characterization of the current traffic monitoring program of the City of Winnipeg considered information regarding traffic counts taken by the Transportation Division between 2001 and 2010.

The development of the traffic pattern groups used data from road tube counts taken by the Transportation Division between 2007 and 2011. Furthermore, only vehicular traffic volumes were considered. The research focuses on hourly variation of traffic and does not develop pattern groups based on seasonal traffic variation due to the lack of continuous counters. The research does not include specifications for counting equipment.

1.5 THESIS ORGANIZATION

This thesis consists of six chapters. Chapter 2 summarizes the findings from the environmental scan regarding trends, gaps, opportunities, and issues related to traffic monitoring programs and traffic data in urban areas, temporal variations of traffic in urban areas, and the analysis of temporal variations using cluster methodologies. The environmental scan includes a literature review and a jurisdictional survey.

Chapter 3 presents a detailed characterization of traffic monitoring in Winnipeg including resources allocated specifically to traffic monitoring, taking into account staff, budget and equipment. The chapter describes automatic link counts, turning movement counts, traffic databases, statistics and maps created by the City of Winnipeg. The chapter also documents traffic data needs in Winnipeg and analyzes how these needs are being met.

Chapter 4 describes the methodology applied to develop temporal variations for traffic patterns in urban areas. The methodology includes the necessary elements to allow for the reproducibility of the proposed analysis.

Chapter 5 applies the methodology to develop temporal traffic variations for traffic patterns in the City of Winnipeg using a hybrid approach that includes three major elements: a) statistical analysis, b) use of variables that explain hourly temporal variations, and c) application of engineering judgement.

Chapter 6 summarizes research results and conclusions, as well as opportunities for future research.

1.6 TERMINOLOGY

The following terms are used in this thesis:

Annual Average Daily Traffic (AADT) is defined as the number of vehicles passing a point on an average day of the year. There are two methods to calculate AADT. The first one is the "simple average of all 365 days in a given year" (FHWA, 2001, p. 2-42i). The second method calculates the average of averages (AASHTO method). The TMG recommends the use of the AASHTO procedure which "first computes average monthly days of the week. These 84 values (12 months by 7 days) are then averaged to yield the seven average annual days of the week. These seven values are then averaged to yield the AADT" (FHWA, 2001, p. 2-42i). The AASHTO formulation is the following (FHWA, 2001, p. 3-37):

$$AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} VOL_{ijk}\right)\right]$$

"where: VOL = daily traffic for day k, of day-of-week i, and month j

i = day of the week

j = month of the year

k = 1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth day of the week.

n = the number of days of that day of the week during that month (usually between 1 and 5, depending on the number of missing data)."

Average Daily Traffic (ADT): "Total traffic volume in a given period of time between one day and one year divided by the number of days in that period of time." (AASHTO, 2009, p. D3).

Automatic Traffic Recorder (ATR): This device is used to monitor traffic at a specific location. At a minimum an ATR collects traffic volume, but it also can collect speed, classification and weight data (AASHTO, 2009). An ATR also "records the distribution and variation of traffic flow by hour of day, day of week, and/or month of the year" (Cambridge Systematics, 2012).

Coverage Count: "A traffic count taken as part of the requirement for system-level estimates of traffic. The count may be obtained from a continuous counter or as a short-term count, and it may measure volume, vehicle class, weight, or speed." (AASHTO, 2009, p. D4).

Engineering judgement: is the application of engineering principles and experience within the practice of professional engineering. The ""practice of professional engineering" means any act of planning, designing, composing, measuring, evaluating, inspecting, advising, reporting, directing or supervising, or managing any of the foregoing, that requires the application of engineering principles and that concerns the safeguarding of life, health, property, economic interests, the public interest or the environment" (The Engineering and Geoscientific Profesions Act of Manitoba, 1998). "Engineering judgement shall be exercised by an engineer or by an individual working under the supervision of an engineer" (FHWA, 2009), where the ultimate responsibility rests with the engineer. It is recognized that the application of engineering judgement is difficult to apply when the impacts of its application are not fully certain (FHWA, 2001).

Explanatory Variables: Factors or elements that influence the hourly variation of traffic. In this research the explanatory variables are: arterial and non-arterial roads, low and high volume roads, schools, and residential, industrial, and commercial zones as variables that explain hourly temporal variations.

Time-of-Day (TOD) Traffic Ratios: "A set of 24 ratios representing the estimated percentages of daily volume for a given set of vehicle classes that occurs during each hour of the day. Used to convert manual classification counts to estimates of daily traffic by vehicle class." (AASHTO, 2009, p. D8).

Traffic Monitoring Program: "The collection, editing, summarization, analysis, and reporting of traffic volume, classification, weight and speed data." (AASHTO, 2009, p. D8).

2 TRAFFIC MONITORING IN URBAN AREAS

This chapter summarizes the findings from the environmental scan regarding trends, gaps, opportunities, and issues related to traffic monitoring programs and traffic data in urban areas. The environmental scan includes a literature review and a jurisdictional survey.

2.1 LITERATURE REVIEW

The elements covered in the literature review include traffic monitoring in urban areas, temporal variations of traffic in urban areas, and the analysis of temporal variations using cluster methodologies.

2.1.1 Traffic Monitoring Programs in Urban Areas

Urban transport systems are intricate and affected by a great number of factors (Transport Canada, 2005) including a variety of transportation modes and travel purposes, and a dense road network (Weijermars, 2007). Urban traffic counting programs differ from rural traffic counting programs due to the dissimilarities in traffic patterns, as traffic volumes are more concentrated during peak hours in urban areas. Traffic data collected during peak hours are essential for traffic operations in urban areas. Trip purpose defines the directionality of traffic. The volume characteristics are affected by type of street, land use, and composition and temporal variations of traffic (Homburger, et al., 2007).

Mergel (1997) found a lack of literature that documents and describes traffic monitoring practices in urban areas, indicating that the latest FHWA guidance related to traffic monitoring in urban areas was from the previous decade.

Transport Canada (2005) indicates that lack of guidance related to traffic monitoring at the national level affects the consistency of data collected and reported in urban areas. Additionally, Transport Canada specifies that budget limitations affect the capabilities of traffic monitoring efforts in urban areas.

Traffic monitoring in urban areas is crucial to following the performance of policies in transportation master plans (Transport Canada, 2005; Milligan, et al., 2012). Generally, transportation agencies dedicate significant effort to the collection of data for transportation planning applications and for performance indicators (ITE, 2008b). Jurisdictions have, over time increased, their traffic monitoring efforts with respect to performance measures (AASHTO, 2009; Margiotta, et al., 2006).

The *Traffic Monitoring Guide* indicates that a count program should have permanent and coverage count stations (FHWA, 2001) complemented with special counts to cover additional data requests. However, the guide does not provide specific guidance related to urban areas. Homburger, et al. (2007) and ITE (2008b) recommend an urban count program that includes the following elements:

a) classification of the street system which separates major and minor streets;

b) control short-term counts (including major control stations, and minor control stations) and key control stations used to obtain variation factors;

c) coverage counts to estimate average daily traffic (ADT), including 24-hour coverage counts every four years in every control section, and 24-hours coverage counts taken as needed in every mile of minor streets;

d) central business district (CBD) cordon counts; and

e) screen line counts.

Monitoring traffic conditions using traditional traffic monitoring equipment and practices provides limited and expensive coverage in complex road networks (Alvarez, Hadi, & Zhan, 2010; Bar-Gera, 2007) and has been a challenge to many jurisdictions (Hellinga, et al., 2008). New technologies allow jurisdictions to collect extensive amounts of information at reduced costs (Alvarez, Hadi, & Zhan, 2010; Chrobok, et al., 2004; Izadpanah, et al., 2012; Soriguera & Rosas, 2012).

There are two main types of counts in urban areas; segment counts and intersection counts. Segment counts are performed at mid-block locations or locations between intersections. Intersection counts usually include the count of the volume by movement at intersections (ITE, 2008a). Additional types of volume data by location include cordon counts, and screen line counts (Homburger, et al., 2007).

Cordon counts provide information on vehicles and people leaving and entering a specific area defined by a cordon (Homburger, et al., 2007; McCartney, et al., 2012). Consequently, cordon counts provide information regarding vehicle accumulation in an area defined by an imaginary loop. The location of the counting stations is defined by the intersection of each street and the imaginary loop. Usually, the area corresponds to a central business district (CBD) of a city. Cordon counts can be used to compare results from transportation models (Gao, Balmer, & Miller, 2010). Cordon counts are used to plan and evaluate transportation infrastructure, policies, operations, and regulations

(Garber & Hoel, 1997; ITE, 2008b; Markose, et al., 2007).

Screen line counts include all the traffic data that cross an imaginary line within an area and are used to calibrate traffic models and to establish traffic trends (Gao, Balmer, & Miller, 2010; Homburger, et al., 2007). Historical screen line counts are required to calibrate/verify origin-destination estimates, and provide information regarding the variation of traffic due to changes in activities in certain areas. The location of the counting stations is defined by the intersection of each street and an imaginary line or lines that divide the study area into large sectors (Garber & Hoel, 1997; ITE, 2008b).

The research divides traffic counts in four categories: vehicular traffic volume data, vehicular traffic variation and distribution, vehicle classification, and people movement.

2.1.1.1 Vehicular Traffic Volume Data

Traffic volumes are the most important data used by traffic engineers (ITE, 2008a), and provides information related to the movement of vehicles (Homburger, et al., 2007). Volume counts can be performed manually or using automatic traffic recorders (ITE, 2008a). The number of vehicles that arrive at a facility during a given period of time describes demand, which is the principal measure of a facility's use (TRB, 2000). Additionally, traffic volumes are requirements for road classification (TAC, 1999). Traffic volumes are essential to perform crash analysis (AASHTO, 2010).

Daily traffic is also required in transportation planning for the economic analysis of infrastructure projects, maintenance programs, estimation of travel demand, infrastructure planning, road classification, development of traffic historical trends, and to indicate vehicular use (Garber & Hoel, 1997; ITE, 2008b). However, annual average daily traffic (AADT) is not sufficient to characterize traffic (Soriguera & Rosas, 2012).

Traffic volume and vehicle classification in terms of AADT or hourly volumes are main inputs in the design of road features and are used to justify the requirement for the upgrading of current facilities (AASHTO, 2004; TAC, 1999). Average daily traffic (ADT) is used in traffic management and in traffic demand analysis (Garber & Hoel, 1997). ADT should not be used directly in geometric design – except for low volume facilities like local and collector roads – because it does not take into consideration temporal variation of traffic (seasonal, day-of-week, hourly) (AASHTO, 2004).

Jurisdictions use vehicles kilometres travelled (VKT) to determine travel and volume trends, evaluate road safety, pavement design, and to define the resource allocation in a road network. VKT reflects the usage of a road network and is employed to estimate congestion, economic activity, and emissions. Additionally, VKT can provide a measure of the relationship between land use and transportation. VKT has been used as an indicator at different government levels from municipalities to national governments (City of Calgary, 2010; EPA, 2012; Garber & Hoel, 1997; Hankey & Marshall, 2010; Huo, et al., 2012; Pirdavani, et al, 2012; Tiwari, Cervero, & Schipper, 2011; Transport Canada, 2009). Annual traffic in vehicles kilometers per year is used to determine travel and volume trends, compute accident rates, and pavement design (Homburger, et al., 2007).

2.1.1.2 Vehicular Traffic Variation and Distribution

The proportion of AADT during the peak hour is defined as the K-factor and usually decreases as AADT and development density increases (TRB, 2000). K-factor is an essential statistic in transportation design and planning (Dykstra, McLeod, & Piszczatoski, 2011).

Peak hour volume is used to classify highways and to define the major characteristics required on a facility, including number of lanes of a highway, number of turning lanes on an intersection, type of intersection. It is used in highway and intersection capacity analysis and is used to establish regulations and programs related to traffic operation procedures (Garber & Hoel, 1997). Traffic management systems need profiles of peak periods (Weijermans & Van Berkum, 2005).

Analyses of level of service are focused on peak hours and should consider temporal variations of traffic (seasonal, day-of week, hour-of-day) to properly accommodate peak traffic demands, as the peak hour is not constant (TRB, 2000). Estimates of emissions also require temporal variations of traffic (EPA, 2012). Hourly traffic volumes are necessary to calibrate transportation models (ITE, 2008b).

Turning movement counts are used for capacity analysis, optimization of traffic signals (Garber & Hoel, 1997; TRB, 2000), and analysis of safety at intersections (Homburger, Hall, Reilly, & Sullivan, 2007). Additionally, intersection turning movement counts are required to warrant traffic signals, and are required for traffic impact studies (ITE, 2008a).

One of the limitations of intersection turning movement counts is that frequently only the departing traffic is recorded. Under congested situations, the count only reflects the capacity of the intersection and does not reflect the traffic demand at the intersection. The arrival traffic has to be counted when this situation is present (ITE, 2008a). Additionally, turning movement counts collected manually have the following shortcomings: they are not suitable for long periods of time, are labour intensive (therefore expensive), and the accuracy is limited to human capabilities (Garber & Hoel, 1997; ITE, 2008a).

Counts in intervals shorter than one hour are necessary to identify maximum flow rates (ITE, 2008b). Peak flow rate is fundamental because it reflects peak traffic conditions for intervals less than an hour (TRB, 2000) and reveals capacity constraints (ITE, 2008b).

Directional and lane distribution of traffic should be included to adjust base conditions for capacity analysis (TRB, 2000). They are also requirements for pavement design (NCHRP, 2005).

Traffic growth factors are necessary to forecast traffic for the design life of the facility which usually varies between 10 and 20 years (AASHTO, 2004; NCHRP, 2005). The 30th highest hour is recommended as the design hourly volume (AASHTO, 2004).

2.1.1.3 Vehicle Classification

Vehicle classification data are required for pavement (NCHRP, 2005) and bridge design (Chotickai & Bowman, 2006; CSA, 2006), emissions estimates (EPA, 2012; IBI Group, 2011; Patmore, 2012; Transport Canada, 2009), freight planning, transportation and resource allocation policies, and truck size and weight regulations (ITE, 2008b). Additionally, vehicle classification data are used to define turning radii, grades, lane widths, to obtain axle adjustments factors for counts from road tubes, and to obtain conversion factors used in capacity analyses (Garber & Hoel, 1997).

Classification counts are necessary to understand truck traffic flows in a road network (AASHTO, 2009). In North America, traffic monitoring efforts related to truck traffic data collection have increased over time (Zhong & Liu, 2007). However, not all agencies have enough resources to collect the required data for pavement design (NCHRP, 2005), and vehicular classification data are still scarce due to physical and budget restrictions (AASHTO, 2009).

2.1.1.4 People Movement

The need for pedestrian and bicycle counts has gained importance in the last few years due to an increased interest in sustainable transportation, the need to understand these modes of transportation, and an increase in infrastructure related to pedestrians and bicycles. Additionally, new technologies are available to automatically record pedestrian and bicycles volumes (ITE, 2008a).

Bicycle volume, speed, directional distribution, and number of pedestrians are required to determine the level of service on active transportation facilities and at locations where pedestrians and cyclists interact with motorized traffic. Pedestrians are essential elements in the design and operation of urban facilities (TRB, 2000). Annual estimates of pedestrian volume are required for pedestrian safety analysis (Milligan, Poapst, & Montufar, 2012).

Additionally, pedestrian volumes are necessary to evaluate existing and future facilities for pedestrians (Garber & Hoel, 1997). Pedestrian counts are also required for pedestrian demand models, for the design of pedestrian facilities (Poapst & Montufar, 2012), and for the analysis of public transportation terminals and adjacent areas (Wang, Chen, He, & Gao, 2006). In North America, vehicle and pedestrian volumes for specific periods of time are required for several warrants for uniform traffic control devices (FHWA, 2009; TAC, 1998). However, there is a deficiency on pedestrian traffic monitoring (Milligan, Poapst, & Montufar, 2012; Miranda-Moreno, Morency, & El-Geneidy, 2011). Furthermore, temporal factors are necessary to expand short-term pedestrian counts (Milligan, Poapst, & Montufar, 2012).

2.1.2 Temporal Variation of Traffic in Urban Areas

Land use is one of the key factors for trip generation. Land use and transportation networks define travel patterns (Khisty & Lall, 1998). Travel patterns in urban areas experience temporal and geographical differences (Kim, Park, & Sang, 2008). For example, land use, population density, number of schools and jobs, and transportation infrastructure have a strong link with pedestrian activity in urban areas (Miranda-Moreno, Morency, & El-Geneidy, 2011).

At a macro level, human activity defines regular traffic patterns (Soriguera & Rosas, 2012). Consequently, temporal variations of traffic can be explained by the distribution of trip purpose (Sharma, 1983). The temporal variations on traffic volumes reflect variations on travel demand (Weijermars, 2007).

Traffic patterns are used to describe recurrent characteristics of traffic (Soriguera & Rosas, 2012). In urban areas, travel patterns of traffic are directly influenced by work, school, business, shopping and leisure activities (Ortuzar & Willumsem, 1994; Weijermars, 2007). Unusual temporal traffic variations are explained by specific trip generators (FHWA, 2001). However, knowledge with respect to temporal traffic variations in different urban roads is inadequate (Weijermars, 2007).

2.1.3 Cluster Analysis

The literature provides several examples of the application of cluster analysis to characterize traffic data based on temporal variations of traffic. Cluster analyisis is a tool to group traffic data variations in order to develop traffic patterns (Alvarez, Hadi, & Zhan, 2010; Capparuccini, Faghri, & Polus, 2008; FHWA, 2001; Flaherty, 1993; Sharma, 1983;

Soriguera & Rosas, 2012; Weijermans & Van Berkum, 2005; Wyatt & Sharma, 1986). Zhong and Liu (2007) indicate that cluster analysis provides logical results for the development of traffic pattern groups. Furthermore, traffic pattern groups produced by cluster analysis provide better mathermatical results when compared with groups developed using only road functional class grouping technique (FHWA, 2001).

Cluster analysis is also used to characterize truck traffic for pavement design including vehicle class distributions (Papagiannakis, Bracher, & Jackson, 2006; Sayyady, et al., 2010; Regehr, 2011), truck axle load distributions, and truck traffic temporal variations (Haider, et al., 2011; Papagiannakis, Bracher, & Jackson, 2006; Sayyady, et al., 2010; Wang, et al, 2011).

Applications of cluster analysis include: grouping locations with similar hourly profiles to determine data sampling for an air quality study (Niemeier, Utts, & Fay, 2002); grouping traffic conditions for signal timing plans (Wang, Cottrel, & Sichun, 2005); and characterization of public transportation facilities (Scherer & Weidmann, 2011). Additionally, traffic patterns developed using cluster analysis can be compared with real time data to detect traffic incidents. Cluster analysis can be used to identify unusual patterns or non-recurrent events (Soriguera & Rosas, 2012; Weijermars, 2007). Characterizations of hourly traffic variations by direction are useful in managing reversible lanes (Weijermars, 2007).

Refinements to the cluster results are necessary to ensure reasonable and logical results. These adjustments are based on previous knowledge, experience and judgement (Flaherty, 1993; Regehr, 2011; Sayyady, et al., 2010; Soriguera & Rosas, 2012; Wang, et al, 2011; Wyatt & Sharma, 1986). Additionally, traffic patterns should respond to explanatory variables (Soriguera, 2012). Weijermars (2007) uses a Geographic Information System (GIS) to determine variables that explain temporal variations based on the spatial distribution of the temporal pattern groups.

Regehr (2011) adjusts the cluster based on type of route, geographical distribution of industry and urban centers, and origin-destination patterns to characterize truck traffic patterns in Manitoba. Wang, et al. (2011) combines the knowledge of truck traffic on specific roads with the geographical distribution of manufacturing, commercial, and farming areas to develop truck traffic patterns in Arkansas.

2.2 JURISDICTIONAL SURVEY

This section presents the findings of a survey conducted to document current traffic monitoring practices in North American urban areas by identifying up-to-date methodologies and procedures of these programs. Appendix A provides a copy of the actual survey form used during telephone and email interviews.

2.2.1 Survey Objectives and Scope

The objective of this survey is to document traffic monitoring practice in urban areas of North America similar to Winnipeg with respect to data collection, traffic data required by major planning documents, and data management and dissemination.

The jurisdictions were selected in consultation with the Transportation Division of the City of Winnipeg based on three criteria: geographical proximity to Winnipeg, cities with similar characteristics to Winnipeg, and cities with leading traffic monitoring programs. The selected jurisdictions are Calgary, Alberta; Edmonton, Alberta; Minneapolis, Minnesota; Ottawa, Ontario; Saskatoon, Saskatchewan; Seattle, Washington; Toronto, Ontario; Vancouver, British Columbia; Waterloo, Ontario; and Winnipeg, Manitoba (for comparison purposes).

2.2.2 Survey Methodology

A total of 10 cities in Canada and the United States were contacted using telephone and email communications between the months of November and December 2011.

The survey questions were developed based on the literature and the objectives and scope previously defined. The survey structure consists of the four sections described below.

2.2.2.1 Data Users

This section addresses the purpose and primary users of the traffic monitoring data. Data users are divided into the public sector and the private sector.

Public sector users include traffic engineering, signals, and city planning departments/branches. Private sector users include consultants, realtors, and researchers.

2.2.2.2 Data Collection

This section describes data collection, including permanent (continuous) counts, short-term (sample) counts, and turning movement counts. For each of these count types, the survey asks about the quantity, frequency, and scheduling of counts, what kind of data are collected (e.g. volume, classification, speed), whether the counts are request-based or part of a core program, and on what road types the counts are done.

2.2.2.3 Traffic Data and Transportation Master Plans

This section covers data requirements for Transportation Master Plans or Long Range Transportation Plans. The survey determines if the traffic monitoring program is required to collect specific data for creating these plans or for performance measurement efforts related to these plans.

2.2.2.4 Traffic Statistics and Quality Assurance

This section aims to determine the traffic statistics produced by the traffic monitoring programs and current practices on traffic data quality assurance.

2.2.3 Synthesis of Findings

This section presents an analysis of the survey results. The results obtained from the jurisdictional survey are organized in the following four categories according to the survey structure: a) data users, b) data collection, c) traffic data and transportation master plans, and d) traffic statistics and quality assurance.

2.2.3.1 Data Users

The most common users of traffic data are traffic signals (10 of 10 jurisdictions), and traffic engineering (nine of 10 jurisdictions) branches/departments, consulting companies (nine of 10 jurisdictions), city planners (eight of 10 jurisdictions), and realtors (seven of 10 jurisdictions). The results reveal that the main users of traffic monitoring data in urban areas are related to traffic operations (traffic signals and traffic engineering) and city planning.

Traffic signals departments need turning movement counts, traffic volumes during peak hours, hourly variation of traffic, vehicle classification, pedestrian and bike volumes for signal warrants and optimization of signal timings.

Similarly, traffic engineering departments require turning movement counts, hourly variation of traffic, temporal factors, directional distribution of pedestrian and bike volumes for road safety analysis, warrants for traffic control devices, capacity analysis and traffic management. City planning data requirements include AADT, ADT, hourly volumes, five and 15 minute volumes, VKT, and classification counts.

Consulting companies that responded to the traffic data needs in the Winnipeg survey (see Chapter 3) indicate that they require a variety of traffic data for different projects mainly for traffic impact studies and for city projects.

The data requirements for traffic impact studies and city projects are similar to the requirements for traffic signals and traffic engineering departments. Additionally, consulting companies require daily volumes and traffic growth factors. AASHTO (2009) indicates that realtors need AADT at specific locations.

2.2.3.2 Data Collection

Data collection for traffic monitoring falls under four different types: a) permanent/continuous counts, b) automatic link/short-term counts, c) turning movement counts and d) classification counts.

<u>Permanent/Continuous Counts</u>

Table 1 shows a summary of count types regarding continuous count stations, road classification, typical count data interval in minutes, and types of information collected from continuous counts for each of the 10 jurisdictions.

Table 1 Continuous Count Stations by Jurisdiction

City	No. of Stations	Freeways [a]	Arterial	Collector	Local	Volume	Classification	Weight	Speed	Bicycles	Pedestrians	Count Interval
		Location				Information Collected						(min)
Calgary	32	✓	✓	✓	×	✓	✓	×	✓	×	×	15
Edmonton	6 [b]	✓	✓	×	×	✓	×	×	×	×	×	60 [c]
Minneapolis	0	-	-	-	-	-	-	-	-	-	-	-
Ottawa	0	-	-	-	-	-	-	-	-	-	-	-
Saskatoon	7	✓	✓	×	×	✓	×	×	×	×	×	15
Seattle	0	-	-	-	-	-	-	-	-	-	-	-
Toronto	225	✓	✓	✓	×	✓	×	×	✓	×	×	15
Vancouver	30	×	✓	×	×	✓	×	×	×	×	×	60[c]
Waterloo Region	17	×	✓	×	×	✓	×	×	×	×	×	15
Winnipeg	0	-	-	-	-	-	-	-	-	-	-	-

[a] While some jurisdictions may have freeways as part of their road network, counting at these locations is not part of their practice.
[b] In Edmonton, only one of the six continuous stations is currently working.
[c] In Edmonton, the newer stations collect traffic in intervals of five minutes. In Vancouver the devices have the ability to retrieve the data in smaller intervals such as five minutes if necessary.
✓: Affirmative response. ×: Negative response. -; Not applicable.
Source: developed by H. Hernandez as part of this research

This table reveals that six of the 10 jurisdictions operate continuous count locations. Responses from the six jurisdictions with continuous count stations reveal that continuous count stations are mainly located on freeways and arterials.

The most common count interval is 15 minutes (15 minutes intervals are related to traffic operations because they are required to develop peak hour factors).

Traffic volume is collected on all the continuous count stations and only one jurisdiction (City of Calgary) collects classification data. None of the jurisdictions collect bicycles, pedestrians or vehicle weight data from continuous counts.

Automatic Link Counts

Table 2 shows the number of automatic link (short-term) counts as well as the approximate split between core program and request-based counts.

Table 2 Automatic Link (Short-Term) Counts by Jurisdiction

City	Counts per year	Core Program (%)	Request-Based (%)
Calgary	2850	84	16
Edmonton	700	14	86
Minneapolis	300	67	33
Ottawa	300	0	100
Saskatoon	230	65	35
Seattle	1400	57	43
Toronto	3500	55	45
Vancouver	700	57	43
Waterloo Region	125	80	20
Winnipeg	491	19	81

Source: developed by H. Hernandez as part of this research

Based on this table, all respondents perform automatic link (short-term) counts in their jurisdictions. Seven of the 10 responding jurisdictions have a core automatic link count program that accounts for more than one half of the total locations counted each year. This finding is in accordance with the recommendations of the *Traffic Monitoring Guide* that indicates that traffic monitoring programs should rely in coverage counts supplemented by special (request-based) counts. However, request-based counts take more than one-third of the traffic monitoring efforts related to automatic count locations in most jurisdictions.

The differences on the percentage of request-based counts are consistent with *Traffic Monitoring Guide* statements that indicate that diverse methods to respond to special needs in different jurisdictions cause dissimilarities among traffic monitoring programs (FHWA, 2001).

Table 3 shows the typical count data interval in minutes, the typical count frequency in years, and the typical count duration in hours.

Table 3 Interval, Frequency and Duration of Short Term (Link) Counts by Jurisdiction

City	Count Interval (minutes)	Frequency (years)	Duration (days)
Calgary	15	1	1
Edmonton	5	3	2 - 22
Minneapolis	15	4	2
Ottawa	15	0.5 - 1	1 – 2
Saskatoon	15	Variable	2 and 7
Seattle	15	1 [a]	7
Toronto	15	4	3 [b]
Vancouver	60	1 - 2	2
Waterloo Region	15	NR	1
Winnipeg	15	1	2 and 7

[a] The frequency at 20 locations is once a month in order to have temporal variation factors.
[b] 3 days for counts in the core program, and 24 hours to 160 hours for request-based counts.
NR: no response.
Source: developed by H. Hernandez as part of this research

This table reveals that eight of the 10 jurisdictions with short-term count stations collect data in intervals of 15 minutes. This result is consistent with the results from continuous count stations.

Additionally, there is a variation (from twice a year to once every four years) on the typical count frequency for recurrent counts, with once a year being the most common (four of 10 jurisdictions). The most common count durations are two days (six of 10 jurisdictions), one day (three of 10 jurisdictions), and seven days (three of 10 jurisdictions). The table indicates that some jurisdictions do not follow the *Traffic Monitoring Guide* recommendation of 48 hours as minimum count duration (FHWA, 2001).

Table 4 shows count location (freeways, arterials, collectors and local roads); and information collected (volume, vehicle classification, speed, bicycles, and pedestrians) by jurisdiction.

Table 4 Count Location and Information Collected on Short-Term (Link) Counts by Jurisdiction

City	Location				Information Collected					
	Freeways [a]	Arterial	Collector	Local	Volume	Weight	Classification	Speed	Bicycles	Pedestrians
Calgary	✓	✓	✓	✓	✓	×	✓	✓	×	×
Edmonton	✓	✓	✓	✓	✓	×	✓	✓	✓ [b]	✓ [b]
Minneapolis	×	✓	✓	✓	✓	×	✓	✓	×	×
Ottawa	✓	✓	✓	✓	✓	×	✓	✓	×	×
Saskatoon	✓	✓	×	×	✓	×	×	✓	×	×
Seattle	×	✓	✓	✓	✓	×	✓	✓	×	×
Toronto	×	✓	✓	✓	✓	×	×	✓	×	×
Vancouver	×	✓	✓	✓	✓	×	✓	✓	✓ [b]	×
Waterloo Region	×	✓	✓	✓	✓	×	✓	✓	×	×
Winnipeg	✓	✓	✓	✓	✓	×	×	✓ [c]	×	×

[a] While some jurisdictions may have freeways as part of their road network, counting at these locations is not part of their practice.
[b] Collected only if special equipment is used.
[c] Collected upon request.
✓: Affirmative response. ×: Negative response.
Source: developed by H. Hernandez as part of this research

The table reveals that five of 10 jurisdictions collect traffic data on freeways. All the jurisdictions collect traffic on arterial roads. Only Saskatoon does not collect traffic data from short-term counts on collectors and local roads.

All jurisdictions collect traffic volume and speed data. Seven of 10 jurisdictions collect classification data. Weight data are not collected in any of the surveyed jurisdictions.

Only Edmonton and Vancouver collect bicycle volumes at some short-term (link) counts using special equipment.

Turning Movement Counts (TMCs)

Table 5 shows the number of TMCs broken down into core program and request-based counts.

Table 5 Turning Movement Counts by Jurisdiction

City	Counts per year	Core Program (%)	Request-Based (%)
Calgary	500	20	80
Edmonton	360	22	78
Minneapolis	100	75	25
Ottawa	1000	0	100
Saskatoon	120	0	100
Seattle	200	0	100
Toronto	1000	50	50
Vancouver	100	0	100
Waterloo Region	335	90	10
Winnipeg	148 [a]	0	100

[a] Including 60 pedestrian-only counts.
Source: developed by H. Hernandez as part of this research

The table reveals that all respondent jurisdictions perform TMCs. Only two of 10 jurisdictions have a core-program that accounts for more than a half of the total TMC locations, and five of 10 jurisdictions do not have a TMC core program (their TMCs are 100 percent request-based). These responses indicate that TMCs in urban areas are mainly directed towards special requests.

Table 6 shows the typical count data interval in minutes; the typical count frequency in years, and the typical count duration in hours.

Table 6 Interval, Frequency and Duration of Turning Movement Counts by Jurisdiction

City	Count Interval (minutes)	Frequency (years)	Duration (hours)
Calgary	15	1	6
Edmonton	5	4	12
Minneapolis	15	4	12
Ottawa	15	1[a]	8[b]
Saskatoon	15	NA	6
Seattle	15	3 to 6	5[b]
Toronto	15	4	8
Vancouver	5	NA	4[c]
Waterloo Region	15	NR	8
Winnipeg	15	NA	8 to 12

[a] Key intersections.
[b] The count covers the a.m. and p.m. peak and midday periods.
[c] The count covers the a.m. and p.m. peak periods.
NR: no response. NA: Not Applicable
Source: developed by H. Hernandez as part of this research

The table reveals that:

- Eight of 10 jurisdictions collect data in intervals of 15 minutes. Two jurisdictions report traffic data in intervals of five minutes. This reflects the importance of tracking variations within short periods of time in urban areas. Additionally, it reflects the link between TMCs and traffic operations. For example, the design hour volume for signal timing represents the maximum 15-minute period during the peak hour (Wang, Cottrel, & Sichun, 2005).
- TMCs are performed in periods shorter than 24 hours. Some typical count durations are six, eight and 12 hours.
- There is a variation on the typical count frequency being once a year and once every four years, with once a year being the most common.

Table 7 shows count location (freeways, arterials, collectors and local roads); and information collected (volume, vehicle classification, speed, bicycles, and pedestrians).

Table 7 Location and Information Collected on Turning Movement Counts by Jurisdiction

City	Freeways [a]	Arterial	Collector	Local	Volume	Classification	Bicycles	Pedestrians
	Location				Information Collected			
Calgary	✓	✓	✓	✓	✓	✓	✓	✓
Edmonton	✓	✓	✓	✓	✓	✓	✓	✓
Minneapolis	✓	✓	✓	✓	✓	✓	✓	✓
Ottawa	×	✓	✓	✓	✓	×	✓	✓
Saskatoon	✓	✓	✓	✓	✓	×	✓	✓
Seattle	×	✓	✓	✓	✓	✓	✓	✓
Toronto	×	✓	✓	✓	✓	✓	✓	✓
Vancouver	×	✓	×	×	✓	✓	×	×
Waterloo Region	×	✓	✓	✓	✓	✓	✓	✓
Winnipeg	✓	✓	✓	✓	✓	✓	✓	✓

[a] While some jurisdictions may have freeways as part of their road network, counting at these locations is not part of their practice.
Source: developed by H. Hernandez as part of this research

The table reveals the following:

- Generally, jurisdictions perform TMCs on arterial, collector and local roads. On the contrary only four of 10 jurisdictions collect data on freeways.
- All jurisdictions collect traffic volume. Additionally, jurisdictions also collect classification, bicycle and pedestrian data.
- The findings reflect that urban jurisdictions rely on TMCs (probably manual or video counts) to collect bicycle and pedestrian data.

Vehicle Classification Scheme

Table 8 shows the classification schemes used by the different respondent jurisdictions.

Table 8 Vehicle Classification Scheme Used by Jurisdiction

City	Classification Scheme	
	13-Class FHWA Scheme	Simplified classification scheme (i.e. passenger car, bus, truck)
Calgary	✓	×
Edmonton	×	✓
Minneapolis	✓	×
Ottawa	✓	×
Saskatoon	×	✓
Seattle	✓	✓
Toronto	✓	✓
Vancouver	✓	×
Waterloo Region	×	✓
Winnipeg	×	✓

Source: developed by H. Hernandez as part of this research

The table reveals that jurisdictions use mainly two classification schemes in urban areas:

a) a simplified classification scheme (i.e., passenger car, bus, and truck), and

b) the 13-class FHWA vehicle classification scheme. Additionally, Seattle and Toronto use both classification schemes.

Scheduling of counts (Temporal Restrictions)

Table 9 shows preferred count periods for short-term and turning movement counts broken down by season, day of week and hour.

Table 9 Preferred Count Periods for Automatic Link (Short-Term) Counts and Turning Movement Counts by Jurisdiction

City	Season	Day of the Week	Hour
Calgary	Not during winter [a]	Weekdays	-
Edmonton	-	Monday - Thursday	-
Minneapolis	May to November	Weekdays	-
Ottawa	May - August [c]	-	7:00-10:00 11:30-13:30 15:00 – 18:00 [a]
Saskatoon	May to October	Weekdays	
Seattle	All year long	Tuesday to Thursday [a]	
Toronto	Summer months	Monday to Thursday [a] Tuesday to Thursday [b]	7:30 - 18:00
Vancouver	University of British Columbia academic year	Weekdays	-
Waterloo Region	-	Weekdays	-
Winnipeg	Fall and spring	Tuesday to Thursday [a]	7:00 – 11:00 14:00 – 18:00 [a]

[a] For turning movement counts
[b] For automatic link (short-term) counts
[c] Automatic link (short-term) counts cease for the season around the first snow fall.
Source: developed by H. Hernandez as part of this research

The table reveals the following:

- Nine of 10 jurisdictions do not count regularly on weekends, and five of 10 jurisdictions do not count on Fridays. Additionally, some jurisdictions count only on periods between peak hours.
- Seven of 10 jurisdictions do not perform counts for at least one season, mostly during winter.
- These restrictions reflect the link in some jurisdictions between traffic operations and traffic monitoring program because traffic collection is oriented to peak periods during typical weekdays.

2.2.3.3 Traffic Data and Transportation Master Plans

Six of nine respondent jurisdictions are required to collect traffic data for their transportation master plans. Six jurisdictions include mode split as a related performance indicator. Other related indicators include: goods travel time, vehicle occupancy, off peak period road congestion, peak period factor for transit, percentage of trips during peak hours, traffic volume, vehicle kilometers traveled, and growth in automobile traffic.

Common collected data include cordon counts (four of six jurisdictions), and screen line counts (three of six jurisdictions). Other data collected include TMCs, pedestrian counts and bicycle counts, traffic volume, truck travel time, flow map, and speed data. Milligan, et al. (2012) presents detailed information with respect to the data collected and the related indicators for transportation master plans by jurisdiction.

2.2.3.4 Traffic Statistics and Quality Assurance

Table 10 provides a summary of the traffic statistics estimated.

Table 10 Traffic Statistics Estimates by Road Type on Surveyed Jurisdictions

Traffic Statistic	No. of Responses	Freeways	Arterial	Collector	Local
Peak Hour Factors (PHFs)	9	4	8	7	7
Annual Average Daily Traffic (AADT)	6	2	5	2	2
Average Weekday Daily Traffic (AWDT)	6	2	6	5	3
Average Daily Traffic (ADT)	4	1	3	2	2
Temporal Factors	2	1	2	1	0
Vehicle-Kilometres Travelled (VKT)	2	1	2	0	0
Annual Average Daily Truck Traffic (AADTT)	1	0	1	0	0

Source: developed by H. Hernandez as part of this research

The table reveals that the highest number of responses is related to peak hour factors, indicating the influence of traffic operations requirements have on the data collected and provided by traffic monitoring programs in urban areas.

Additionally, most jurisdictions (nine of 10) provide daily volumes in the form of AADT (six of 10 jurisdictions), AWDT (six of 10 jurisdictions), and ADT (four of 10 jurisdictions). Some jurisdictions provide more than one daily volume statistic. The table also reveals that traffic statistics are mainly estimated on arterials.

Table 11 summarizes data quality assurance/quality control (QA/QC) and data screening procedures used by the different jurisdictions.

Table 11 Quality Assurance/Quality Control Procedures by Jurisdiction

City	Quality Assurance//Quality Control Procedures
Calgary	• Collector checks the data. • Input/analyzer verifies the data. • No special software is used for data screening.
Edmonton	• PTV`s Traffic Count Management Software screens the data. The software compares the data retrieved with historical data. • The city checks field sheets for anomalies.
Minneapolis	• The city double-checks any count that is 20% greater or lesser from previous counts, and recounts if necessary.
Ottawa	• The city compares all manual counts with historical counts to address any potential cases of significant under or over counting. • The city is developing a system of spot-checking counts, for counts undertaken by summer students.
Saskatoon	• FHWA *Traffic Monitoring Guide* procedures. • The city has planned to enhance the QA/QC in 2012, creating additional customized tools for increase automation during the data processing process.
Seattle	• Manual comparison of the data with historical data. • The city screens every 15 minutes of data. • Petra software indicates if there is some kind of anomalies for turning movement counts, and the in-house program screens the rest of data.
Toronto	• The traffic database software (FLOW) flags errors using historical data and different criteria. The city manually reviews the flagged errors.
Vancouver	• The city verifies the data collected by ATRs using manual counts during peak hours. • The signals department has a system that flags suspect data from the permanent count stations.
Waterloo Region	• Information not provided
Winnipeg	• In-house software imports the data, screens the data for errors, and computes the key traffic statistics based on the data. Flagged data are manually reviewed.

Source: developed by H. Hernandez as part of this research

The table reveals that all the respondent jurisdictions have QA/QC procedures in place for traffic monitoring. The most common methods to screen the data include comparison with historical data (five of nine jurisdictions) and the use of software (four of nine jurisdictions).

2.3 SUMMARY

2.3.1.1 Literature Review

The literature review reveals the following:

- Transport systems in urban areas are more complex than rural transport systems due to more diverse transportation modes, a denser road network, and a greater variety of trip purposes generating different trip patterns in urban areas.

- The literature that documents current traffic monitoring practices in urban areas is limited. Additionally, there is a lack of guiding documents and manuals specifically directed towards traffic monitoring in urban areas.

- New technologies have reduced the cost and have increased the capabilities of traffic monitoring programs in urban areas.

- In urban areas, counts are usually performed at intersections and at mid-block locations. Cordon and screen line counts are used for planning purposes.

- Traffic data are used in a variety of applications including but not limited to: environmental analysis, road safety, traffic engineering, road geometric design, pavement design, resource allocation, bridge design, transportation planning, economic analysis of transportation projects, traffic management, and transportation policies and regulations.

- Flow patterns are defined by travel demand. In urban areas travel demand is characterized by work, school, business, shopping, social, and leisure activities. The temporal variation of patterns can be explained by the distribution of trip purposes. The temporal variation of trips differs by purpose. Since activity patterns change on weekends, traffic variations on weekdays differ from traffic variations on weekends.

- Cluster analysis combined with engineering judgement provides logical results for traffic pattern groups. Traffic pattern groups should respond to variables that explain traffic variations. Furthermore, these variables give meaning to the group.

2.3.1.2 Jurisdictional Survey

The jurisdictional survey reveals the following:

- The main users of traffic data in urban areas include traffic signals departments, traffic engineering departments, consulting companies, city planners, and realtors. The main interest of traffic signal and engineering departments is the analysis of the peak hours when the transportation system experiences the highest demands. While planners are interested in peak hours, they also need indicators to evaluate the transportation system performance.

- The traffic monitoring efforts in urban areas are focused on arterials. Many jurisdictions have permanent/continuous count stations collecting traffic volume data.

- All jurisdictions have automatic link (short-term) count programs collecting volume and speed data. Additionally, most of the jurisdictions collect vehicle classification data. The most frequent count durations are 24 and 48 hours.

- Similarly, all jurisdictions have turning movement count (TMC) programs collecting traffic volume. Additionally, most of the jurisdictions collect vehicle classification, bicycle and pedestrian data.

- The responses reveal that generally the percentage of short-term (link) counts that are part of the core program is greater than the percentage of the TMCs that are part of the core programs. TMCs tend to be request-based counts.

- Regarding counting intervals, the survey responses reveal that the most common data interval for all counts is 15 minutes. The result is in accordance with the recommendations for urban areas of the *Traffic Monitoring Guide* (FHWA, 2001). The most common estimates in urban areas are peak hour factors and daily volumes.

- Traffic monitoring programs are focused on peak hours on typical weekdays. Winter season and weekends are often excluded from traffic monitoring efforts in urban areas.

- Responses related to data requirements for transportation master plans reveal that the most common data collected include cordon counts, and screen line counts. The most frequent related performance indicator for transportation master plans is mode split.

- Quality assurance is usually done by comparing counts with historical data or by screening the data using software.

3 TRAFFIC MONITORING IN WINNIPEG

This chapter presents a detailed characterization of traffic monitoring in Winnipeg. Section 3.1 describes the resources allocated specifically to traffic monitoring, taking into account staff, budget, and equipment. Section 3.2 characterizes the data collection program, including the automatic link counts and turning movement counts. Section 3.3 covers data management including traffic databases. Section 3.4 describes statistics and maps created by the *Traffic Studies Section*. Section 3.5 documents traffic data needs in Winnipeg and analyzes how these needs are being met. Section 3.6 presents a summary of traffic monitoring in Winnipeg.

3.1 TRAFFIC MONITORING PROGRAM RESOURCES

The *Traffic Studies Section* of the City of Winnipeg is responsible for implementing the traffic monitoring program and performing additional traffic studies. The *Traffic Studies Section* falls under the Transportation Systems Planning Branch of the Transportation Division in the Public Works Department (see Figure 1). The section also performs travel time and delay studies, classification counts, speed studies, pedestrian counts, queue studies, traffic noise studies, and maintains a collision database.

There are six data collection personnel within the *Traffic Studies Section*. All of whom have the training to perform all the duties of the group, resulting in better program reliability. Two of these six people act as supervisors. Additionally, the branch head and one engineer dedicate part of their time to manage the section's program delivery and to the analysis of traffic data.

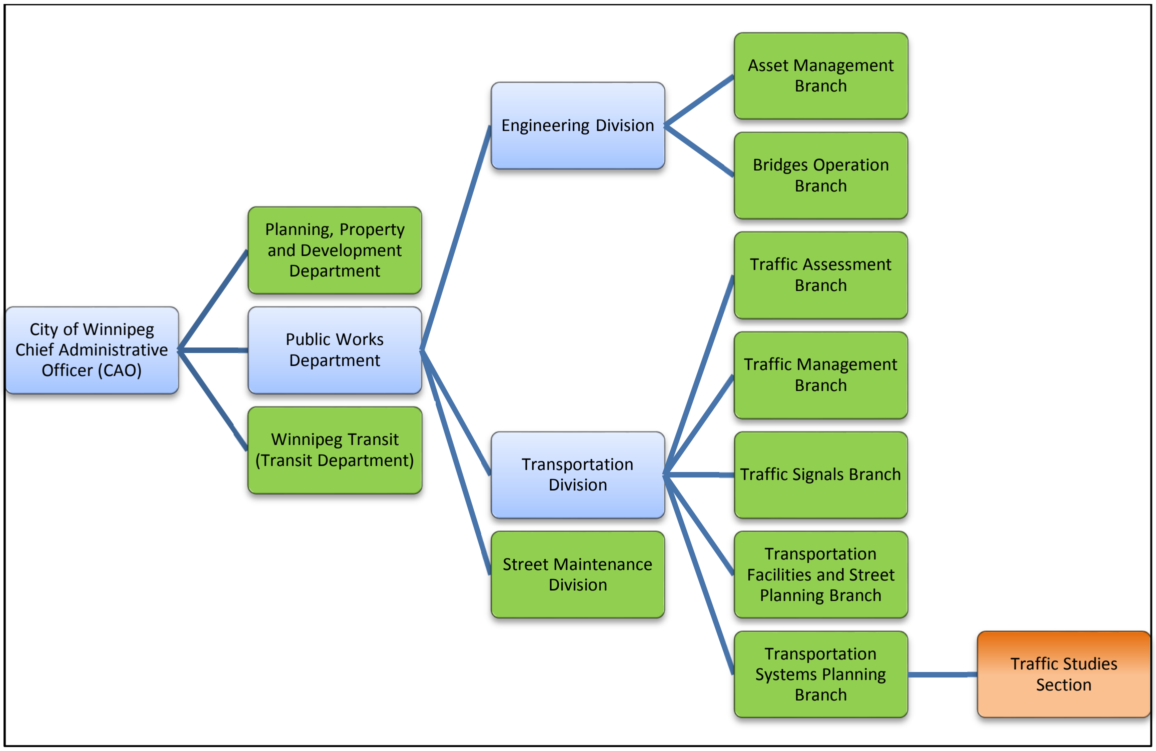


Figure 1 Departments, Divisions, and Branches Directly Contacted in the Survey and Localization of the Traffic Studies Section in the Organizational Structure of the City of Winnipeg

The goal of the city's traffic monitoring program is to support and provide information that is responsive to users' needs in regards to traffic engineering analyses and transportation planning initiatives.

The City of Winnipeg traffic monitoring program collects traffic-related data on the regional, collector, and local streets that comprise the road network of the city, as well as on the provincial roads and highways in the adjacent areas.

The staff requirement for data collection varies according to the nature of the demanded data. For example, a manual turning movement count requires one to four staff members based on intersection volume and complexity, whereas pneumatic tube count equipment can be set up in about 15 minutes by two staff members.

Staff data collection time is divided between planned traffic monitoring (30 percent) and addressing requests for specific counts or studies (70 percent).

The Transportation Systems Planning Branch has its own core budget. This budget is not solely designated for the *Traffic Studies Section*. It includes funds for staff, equipment, maintenance, and vehicles dedicated to traffic monitoring. Most traffic data processing software are purchased for a one-time fee and require no annual maintenance fee.

The equipment resources of the *Traffic Studies Section* relevant to the traffic monitoring program include the following:

- Two Video Collection Units manufactured by Miovision, along with associated equipment, are used to capture turning movements at intersections and can collect traffic counts at midblock locations. Data collected are processed in one of two ways. The first method involves a manual count by staff by replaying the video in the office. Under low volume conditions, the video is replayed at higher speeds to save resources. The second method involves sending the video to Miovision for vehicle counting and classification with their proprietary software. The classification scheme is described further in Section 3.3.
- Thirty-seven pneumatic tube count data collectors are able to count traffic, classify vehicles, and collect speed data. The data are stored in the device and can be transferred electronically to a computer. The specific characteristics of these tube counters are described in Table 12.

Table 12 Types of Data Loggers and Types of Data Provided by Device

Manufacturer (Model)	Quantity	Data Collection		
		Volume Counter	Vehicle Classification	Vehicle Speed
Jamar (Trax)	12	YES	NO	NO
Jamar (Trax mite)	21	YES	YES	YES
Jamar (Apollyon)	4	YES	YES	YES

Source: Based on data provided by Traffic Studies Section, City of Winnipeg (2011)

- Four JAMAR TDC-12 counting boards are used for manual turning movement counts. They have 16 directional buttons (four for each direction) and a second set of 14 buttons for vehicle classification. The data are stored in the device and can be transferred electronically to a computer.
- Four IRD Traffic ACE 2 LP Counter data loggers are used for loop sensors. This device is able to collect volume, collect speed and classify vehicles.
- Two trailers provide shelter from weather and are marked as City of Winnipeg equipment, so that citizens can identify the trailer while staff perform manual counts (see Figure 2).

Figure 2 Manual Count Trailer on Pembina Highway
Source: UMTIG, 2011 by H. Hernandez

- Two trucks are dedicated to transport the personnel and equipment.
- One automated GPS logger is used for travel time studies. This logger consists of one netbook and a GPS receiver connected to it.

Additionally, the Transportation Division is analyzing the operating performance of three vehicle detectors (one microwave, and two video devices) at the intersection of Bishop Grandin and St Mary's Road. The Transportation Division will use the detector selected at signalized intersections to count, classify, and detect vehicles. The automatic traffic recorders will allow for the implementation of an adaptive traffic signal system. The use of these detectors will improve traffic data collection in Winnipeg.

3.2 DATA COLLECTION

While continuous traffic monitoring in rural settings is very common, the City of Winnipeg traffic monitoring program does not have continuous traffic monitoring sites because historically, the technology for these sites was not well suited for the higher density and stop-and-go traffic conditions characteristic of urban areas.

Nonetheless, recent developments in technology have allowed some urban jurisdictions to begin continuous monitoring programs. In Winnipeg, however, budget constraints and outstanding questions regarding the effectiveness of developing urban expansion factors from continuous counts have thus far prevented the development of a continuous traffic monitoring program.

The short-term count traffic data are collected for either planned recurring counts or request-initiated studies. The request-initiated studies are made from three sources: a) internal, b) private, or c) public. These are described as follows:

- *Internal requests:* Requests by other departments, divisions, and branches within the City of Winnipeg. The requests are prompted by data needs related to planning, forecasting, traffic modeling, and before-after studies of new facilities.

For example, the Traffic Signals Branch requires a significant amount of information every year and provides a list of intersections that must be counted.

- *Private requests:* Requests from consultants working on transportation projects, other roadway authorities, commercial real estate, business organizations, universities, and research groups.
- *Public requests:* Requests processed through the City's 311 customer service. These are primarily related to traffic speed, noise, and volume concerns on residential roads.

Counts are performed all year round. The information is collected mainly during the fall/winter and the spring in order to avoid construction and the off-school season. The traffic is counted either manually, by video camera, or with road tubes. Automatic link counts are collected at midblock locations, while turning movement counts are collected at intersection locations.

3.2.1 Automatic Link Counts

Automatic link counts are collected at midblock locations, usually with pneumatic road tubes. Currently, vehicle classification data (e.g., car, medium truck, heavy truck) are not collected on automatic link counts. While some tube counters can collect classification data, this type of data is not routinely collected during automatic link counts. The City of Winnipeg tube count data estimates one vehicle record for every two axle impulses (the factor does not take into account vehicles with more than two axles). The program collects speed data with automatic link counts using pneumatic tubes upon request.

Automatic link counts with tubes collect 48 hours of data on weekdays between Tuesday and Thursday unless a specific request requires weekend data or a full week of data.

Between 2001 and 2010 inclusive, the *Traffic Studies Section* has performed 4911 counts. The 4911 counts were conducted at 2582 unique locations. The 4911 counts are divided between the core automatic link count program (25 percent) and request-based counts (75 percent). This section describes the core automatic link count program, and the location and the frequency of automatic link counts.

3.2.1.1 Core Automatic Link Count Program

The annual core automatic link count program includes 96 locations covering, in order of priority, the central business district (CBD) cordon line (10 locations, seven-day counts), river crossings (17 locations, seven-day counts), radial highways (17 locations, 48-hour counts), external highways (20 locations, 48-hour counts), and other fill-in locations outside downtown (32 locations, 48-hour counts). Some of the river crossing counts also serve to complete the CBD cordon line count, but are classified as river crossing counts. Preference is given to fall and spring for normal traffic and driving conditions, because the traffic during these two periods is expected to be close to the annual average traffic. Figure 3 shows the locations of the automatic link count core program.

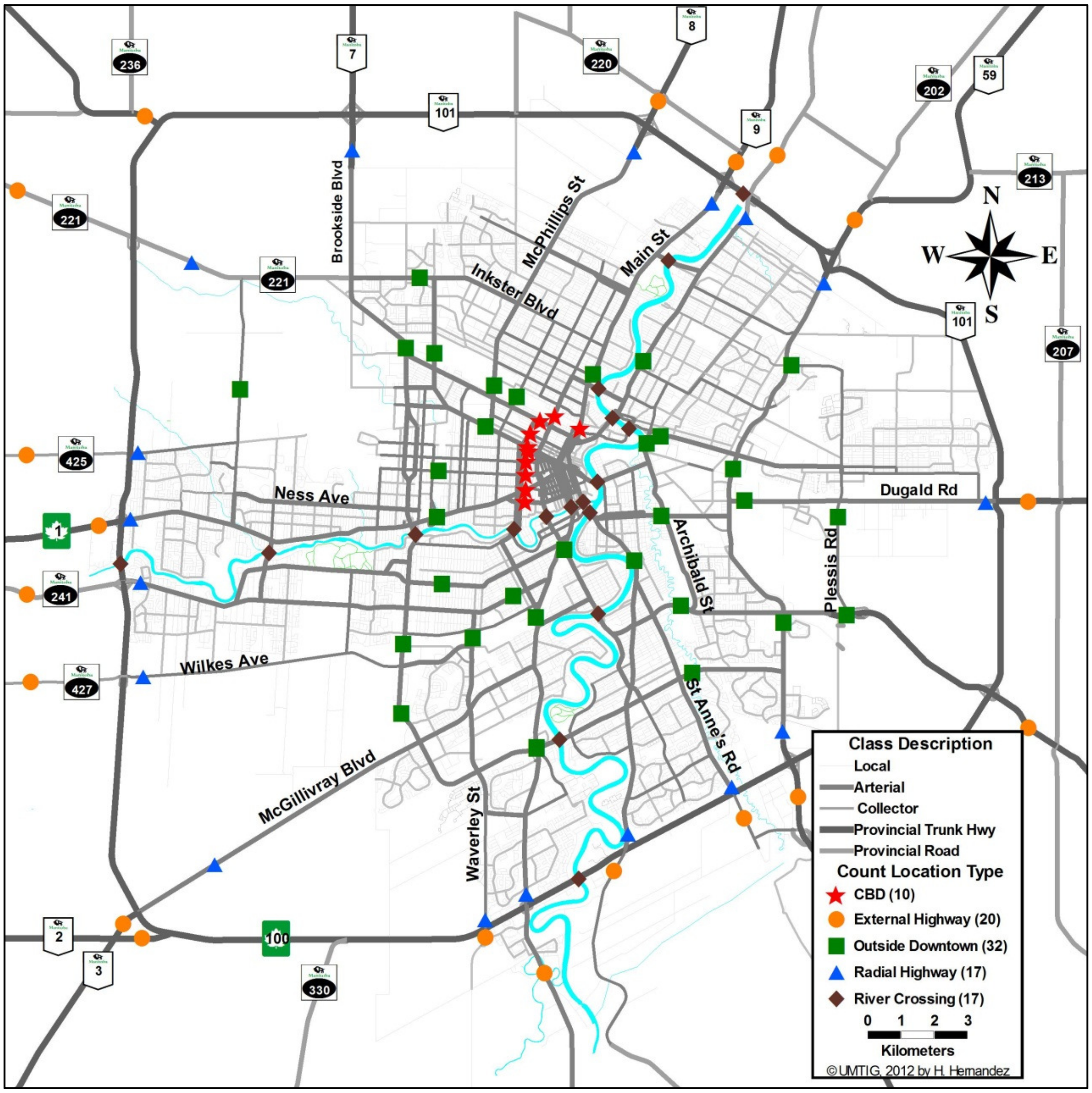


Figure 3 Automatic Link Count Core Program
Source: Based on data provided by Traffic Studies Section, City of Winnipeg (2011)

The rationale in selecting these locations is described below by location type:

- **Central Business District (CBD)** locations were selected to establish a cordon line to capture information on traffic entering and leaving downtown.
- **River Crossing** locations were selected to monitor traffic trends crossing from the East side to the West side of the city (Red River) and vice versa, and from the Southwest to the Northwest (Assiniboine River) and vice versa.

- **Radial Highway** locations were selected to monitor traffic trends on major arterial streets just inside the city edges, providing information about travel between Winnipeg and the rest of the capital region
- **External Highway** locations were selected to monitor traffic trends on external highways just outside the Perimeter Highway (most of which connect to radial highways inside the Perimeter Highway), providing information about travel between Winnipeg and the rest of the capital region.
- **Outside Downtown** locations were selected to fill in the voids in the rest of the city, covering major traffic arterials and providing information on overall traffic growth trends.

3.2.1.2 Location and Frequency of Automatic Link Counts

Table 13 shows a breakdown of the number of unique locations by counting frequency.

Table 13 Frequency of Automatic Link Counts (2001-2010)

Number of Times Counted	Number of locations
1 to 5	2477
6 to 10	54
11 to 15	45
16 to 20	5
21 to 25	1

Source: Based on data provided by Traffic Studies Section, City of Winnipeg

Table 13 reveals that during the ten-year period, the majority of the 2582 locations were counted between one and five times, while 105 of the locations were counted six or more times. Ninety-nine of the 105 locations with more than five counts correspond to the automatic count core program.

Table 14 presents the six locations with more than 15 studies. The six locations are part of the automatic link count core program.

Table 14 Locations with the Highest Number of Counts (2001-2010)

Segment ID	Road Name	Number of Times Counted
s10427	Main Street Bridge	21
s91101	PTH 59 between PR 202 and PTH 101	20
s10223	Osborne Bridge	18
s9605	Slaw Rebchuk Bridge (Salter St)	16
s10395	Midtown Bridge(Donald St)	16
s90006	Pembina Underpass	16

Source: Based on data provided by Traffic Studies Section, City of Winnipeg

Table 15 shows the distribution of counts by road class.

Table 15 Automatic Link Counts by Road Class (2001-2010)

Road Class	Centreline Km [a]	No. of Counts	Percentage
Arterials	451	2223	48
Collectors	512	996	22
Local	1877	869	19
Manitoba Highways	-	290	6
Ramps	56	229	5
Other [b]	21	5	<1

[a] **Does not include Manitoba Highways.**
[b] **Include: Private Collectors, Transit Only Facilities and Roads in Parks.**
Source: Based on data provided by Traffic Studies Section, City of Winnipeg

Table 15 reveals that the *Traffic Studies Section* performs half of the counts on arterial roads. Additionally, collectors and local roads each account for one-fifth of the counts.

Figure 4 shows the 11 routes with more than 60 counts. These 11 routes account for more than 1000 counts and more than one-fifth of the total automatic link counts performed in the period 2001-2010. Furthermore, routes 42, 52, 62 and 90 comprise more than 550 counts and one quarter of the counts performed on arterials between 2001 and 2010. *Appendix B: Traffic Monitoring in* Winnipeg contains the number of counts for each of the 11 routes.

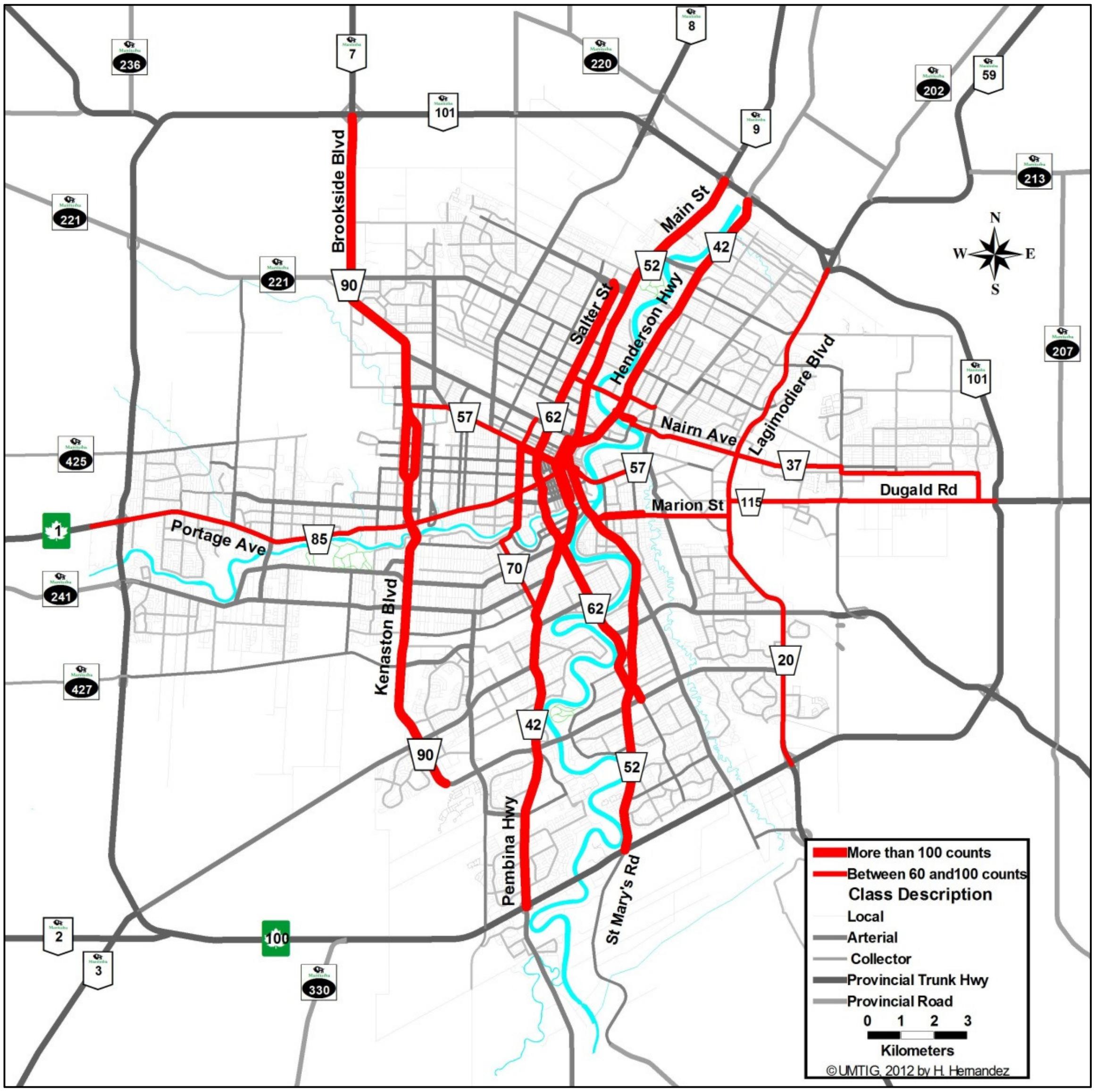


Figure 4 Routes with more than 60 Counts (2001-2010)
Source: Based on data provided by Traffic Studies Section, City of Winnipeg (2011)

3.2.2 Turning Movement Counts (TMCs)

TMCs are collected at intersections either manually using counting boards or with a video camera. The program conducts approximately 90 TMCs per year. All TMCs are request-based. The program does not include a core program for TMCs. Since 2010, the program has started to bring counts at signalized intersections with outdated information up-to-date when there are not pending traffic requests.

TMCs use a 15-minute interval and consist of eight to 11 hours of data collection spread over two days. A typical eight-hour turning movement count includes the 7:00 a.m. to 11:00 a.m. period for one day and the 2:00 p.m. to 6:00 p.m. period for another day. The program uses a factor of 1.45 to expand a typical eight-hour count volume during the periods indicated to a 12-hour volume estimate. Additionally, the program uses a factor of 1.33 to expand the 12-hour volume estimate to a 24-hour volume estimate. Between 2001 and 2010, the program conducted 884 counts at 717 unique locations.

Table 16 lists the roads with 20 or more counts (across multiple intersections). Approximately one quarter of the total counts take place on these major roads.

Table 16 Roads with 20 or more Turning Movement Counts (2001-2010)

Road	No. of Counts
Main St	35
Lagimodiere Blvd	35
Kenaston Blvd	27
McGillivray Blvd	24
Portage Ave	23
Grant Ave	23
Pembina Hwy	23

Source: Based on data provided by Traffic Studies Section, City of Winnipeg

Classification information is collected from the intersection TMCs. The City's classification scheme has recently been changed to be consistent with the Miovision scheme. Consequently, both count types (manual and Miovision) provide data in a consistent format. Table 17 shows the previous classification scheme and the current classification scheme. In the current scheme, truck categories have been consolidated.

In the current vehicle classification scheme, the Medium Vehicle class comprises any single-unit vehicle having at least six tires except buses and tractors without trailers. The

Heavy Vehicle class includes articulated trucks and large school and tourist buses, but not transit buses. The Bus class is exclusive to Winnipeg Transit regular buses. The Car class includes light vehicles such as cars, pickup trucks, SUVs, vans, and motorcycles.

Table 17 Winnipeg's Previous and Current Vehicle Classification Schemes

Previous Vehicle Classification Scheme	Current Vehicle Classification Scheme	13 Classes FHWA Vehicle Classification Scheme
Pedestrian (occasionally included)	Pedestrian (regularly included)	NA
Bicycle (occasionally included)	Bicycle (regularly included)	NA
Single Unit Truck	Medium Vehicle	5, 6 and 7
Semitrailer Truck	Heavy Vehicle (Articulated Trucks and large buses)	4, 8, 9 and 10
Multiple Trailer Truck		11, 12 and 13
Bus	Bus (Winnipeg Transit only)	4
Light Vehicle	Cars	1, 2 and 3

Source: Based on data provided by Traffic Studies Section, City of Winnipeg

The major change between the previous and current classification scheme related to motorized vehicles is the combination of the single and multiple trailer trucks into the heavy vehicle class. After confirmation from Public Works staff, the decision was made to remove the breakdown of heavy truck class by number of trailers from their analyses.

The change of regularly including bicycles and pedestrians in classification and intersection counts is mainly due to the improved capabilities of the new TDC-12 count boards. All the classes are collected in the field during counting.

Pedestrian and bicycles are now counted in consideration of future data needs in response to the city's active transportation policy. The traffic monitoring program is still in the process of examining the initiative to regularly count active transportation modes to see if the change will impact any of the manual counting operations. Initial results indicate that it is no problem for the crew to collect the additional information in the field. So far, the active transportation data are collected but not reviewed. The data are instead stored for potential future use.

In addition to the new initiative to count active transportation modes at turning movement counts, the program also conducts dedicated pedestrian counts based on requests.

3.3 DATA MANAGEMENT

The *Traffic Studies Section* has traffic count databases designed in-house using Oracle® and Excel® to meet the City's operational requirements. The main purpose of the databases is to centralize information collected historically into a format that is easy to understand and readily available when required.

The *Traffic Studies Section* uses two main databases: the automatic link count database and the turning movement count database, which are described in more detail as follows:

a) Automatic Link Count Database (in-house traffic flow program)

The raw data taken from tube counters are processed using this application. The software imports the data, screens the data for errors, and computes the key traffic statistics based on the data.

The database is able to produce standard reports for each automatic link count showing the count date and location, 15-minute and one-hour peak volumes, non-peak volumes, eight-hour summaries, 12-hour estimates, 24-hour estimates, and weekend information if applicable. The report presents information by direction and in combined-direction format. *Appendix B: Traffic Monitoring in* Winnipeg contains an example report.

Each study is assigned a "segment ID" that represents a street segment on the road network. This is used to link the data to a GIS platform that is used to plot the traffic flow and for modeling purposes.

b) Turning Movement Count Database

The turning movement count data collected using the JAMAR TDC-12 counting boards are retrieved and stored on spreadsheet files. One spreadsheet is created for each count. Customized reports can be created using a macro embedded in these spreadsheet files. The report produced shows 15-minute volumes for each movement for each approach throughout the counting period in tabular format. The report also presents other information such as the peak hour, the peak 15 minutes, the peak hour factor, directional splits, date, and weather information. *Appendix B: Traffic Monitoring in* Winnipeg shows an example report from this database. The spreadsheet data is also manually transferred once per year to the transportation model of the city.

The Transportation System Planning Branch is the owner of the traffic databases and has full administrative rights. Read-only access to the databases is granted to everyone within the Public Works Department. The read-only restriction is in place to maintain the integrity of the database.

3.4 STATISTICS PRODUCED BY THE TRAFFIC MONITORING PROGRAM

This section describes the statistics currently created by the *Traffic Studies Section*.

The program produces average weekday daily traffic (AWDT) estimates as the 24-hour average of automatic link counts taken on weekdays, and these estimates are used to create a traffic flow map. Since the traffic monitoring program does not include continuous counting sites, the program does not produce AADT values or estimates.

The AWDT values provide information only on the days that the counts were taken. Since other days of the week and months of the year may have different traffic volumes, the AWDT value does not necessarily represent conditions throughout the year like AADT does. In an effort to obtain AWDT values that are representative of the whole year, the counts are taken during the spring and fall when traffic is thought to be closer to the annual average. Traffic during weekends is not reflected in AWDT calculations.

Since AWDT is not estimated every year for every link, the flow map contains AWDT estimates from several years. The flow map is available on the City of Winnipeg website in portable document format.

Since the City does not estimate AADT, it also does not estimate annual vehicle kilometers traveled (VKT) for the network. Instead, it estimates average weekday daily VKT for the regional street network (for internal use) based on automatic link counts. These estimates, like the AWDT values, represent only the days that the count was taken and not conditions throughout the year.

3.5 TRAFFIC DATA NEEDS IN WINNIPEG

This section documents traffic data needs in Winnipeg and analyzes how these needs are being met. The survey results contribute to the analysis of the traffic monitoring program by identifying what gaps exist with respect to information provided by the program and the users' needs.

The last survey of traffic data users' needs for the City of Winnipeg's traffic monitoring program was performed in 1997 (UMTIG, 1997). It is necessary to update the last survey to document the current needs, in order to determine whether of not the current traffic monitoring program satisfies those needs. The research identifies opportunities for improvement in the current system that tailor the system to the current traffic data needs in Winnipeg.

3.5.1 Survey Objectives and Scope

The objectives of this survey are to:

- Update 1997 survey of traffic data users' needs for the City of Winnipeg's traffic monitoring program (UMTIG, 1997).
- Document the traffic data needs in Winnipeg.
- Determine how these needs are being met.

The survey documents the user needs for key data types that are identified through guidelines, literature, and research experience in traffic monitoring.

3.5.2 Survey Methodology

The survey was conducted during the months of February, March and April 2012, and includes the following City of Winnipeg departments/divisions/branches identified by the Transportation Division as data users of the traffic monitoring program:

1. Asset Management Branch
2. Bridges Operation Branch
3. Planning, Property and Development Department

4. Street Maintenance Division
5. Traffic Assessment Branch
6. Traffic Management Branch
7. Transportation Facilities and Street Planning Branch
8. Transportation System Planning Branch
9. Traffic Signals Branch
10. Winnipeg Transit (Transit Department)

Figure 1 shows the organizational structure of the City of Winnipeg with the location of the surveyed departments, divisions and branches in green. Seven branches, one division and two departments were contacted directly. The survey also includes four Winnipeg transportation consulting companies.

The data requirements were assessed using four criteria: a) data type, b) data need, c) street classification for which data are required, and d) whether or not the data need is being met.

3.5.2.1 Data Type

The traffic data types included in the survey are divided into three categories:

a) *Traffic Volume Data:* This includes annual average daily traffic (AADT), average week day traffic (AWDT), average daily traffic (ADT), morning and afternoon peak hour traffic, and vehicle-kilometers travelled (VKT).
b) *Traffic Variation and Distribution Data:* This includes hourly variation of traffic (including peak hour and off-peak traffic), day-of-week variation of traffic, seasonal variation of traffic, temporal factors, directional distribution of traffic,

lane distribution of traffic, turning movements at intersections, vehicle speeds and traffic growth factors.

c) *Vehicle Classification Data:* This includes annual average daily truck traffic (AADTT), truck percentages, axle correction factors, truck trailer body type (e.g., dry van, container, refrigerated van, hopper, flat bed, etc.), and long combination vehicles (Turnpike Doubles, Rocky Mountain Doubles, or Triple Trailer Combinations).

3.5.2.2 Data Need

The data need criterion identifies the importance of a data type to a user's operation. Data needs are documented as follows:

a) *Essential:* The data type is required for the user's operations. The data type could be essential in the future for the user's operations if the data type becomes available.
b) *Useful:* The data type is practical, but not essential for the user's operations. The data type could be useful in the future for the group's operations if the data type becomes available.
c) *Not Needed:* The data type is not used or needed for the user's operations.

3.5.2.3 Street Classification for which Data Are Required

Street Classification: Street classification identifies the type of routes where the data are needed for a user's operations. The Winnipeg streets are categorized as either:

a) *Regional:* All major routes including arterials and expressways.
b) *Collector:* Streets providing a combination of through movements and local access.

c) *Local:* Residential streets providing access.

The survey also includes the *"all streets"* option. This option applies when the data need is not restricted or required for a specific type of route.

3.5.2.4 Whether or not the Data Need is Being Met

The question of whether or not need is being met aims to ascertain how well the current monitoring program meets the expressed needs for each data type (responses may be either "yes", "no", or "partly"). The question also contains a request for elaborating comments by the respondent on appropriateness of data format, data availability, and other issues.

3.5.3 Survey Summary

This section presents aggregate results and summary findings from the survey results. The goal is to determine opportunities to achieve efficiencies and/or enhance the quality and value for a new traffic monitoring program with respect to users' needs.

Table 18 summarizes the traffic volume data needs.

Table 18 Traffic Volume Data Needs

Traffic Volume Category	Data Need			
	Essential	Useful	Not Needed	TOTAL
1.1 Annual Average Daily Traffic (AADT)	4	5	5	14
1.2 Average Week Day Daily Traffic (AWDT)	8	4	2	14
1.3 Average Daily Traffic (ADT)	3	7	4	14
1.4 Morning/Afternoon Peak Hour	11	1	2	14
1.5 Vehicle-Kilometres of Travel (VKT)	1	7	5	13

Source: developed by H. Hernandez as part of this research

- Table 18 reveals that traffic volumes during peak hours are the most essential traffic volume statistic in the City of Winnipeg (11 of 14 responses received).

Additionally, the results show that the second traffic volume statistic in order of importance is average week day traffic (AWDT) because it is essential to eight of 14 of respondent users.

- All users surveyed in the Transportation Division (see Figure 1 for the list of branches in the Transportation Division), the Bridges Operation Branch, Winnipeg Transit, and consulting companies consider peak hour data to be essential. Alternatively, the Asset Management Branch and Street Maintenance Division do not need peak hour volumes. The respondents indicate that peak hour data are needed to determine schedules, detours and configurations for road/lane closures and work zones, determine signal timing, calibrate transportation models, and perform capacity analysis.
- All users except the Traffic Signal Branch require daily traffic volume data (AADT, AWDT or ADT). The respondents indicate that daily traffic is needed to prioritize infrastructure interventions, correlate traffic information with maintenance costs, determine upgrades on gravel roads, determine street classification, prioritize road's widening, warrant additional lanes, and create traffic flow maps.

Users require traffic volume data mainly on arterials and collectors. Only the Traffic Assessment Branch requires data specifically on local roads. Traffic volume needs are mainly met. However, one-third of the responses from the surveyed users indicate that their traffic volume needs are partly met.

Table 19 condenses traffic variation and distribution data needs.

Table 19 Traffic Variation and Distribution Data Needs

Traffic Variation and Distribution	Data Need			
Data Type	Essential	Useful	Not Needed	TOTAL
2.1 Hourly Variation of Traffic	5	3	5	13
2.2 Day-of-Week Variation of Traffic	5	1	7	13
2.3 Seasonal Variation of Traffic	3	4	6	13
2.4 Temporal Factors	2	4	6	12
2.5 Directional Distribution of Traffic	8	2	2	12
2.6 Lane Distribution of Traffic	1	6	7	14
2.7 Turning Movements at Intersections	8	5	1	14
2.8 Vehicle Speeds	2	7	5	14
2.9 Traffic Growth Factors	7	7	0	14

Source: developed by H. Hernandez as part of this research

- Table 19 reveals that the most essential traffic variation and distribution statistics are turning movement counts at intersections, directional distribution of traffic, and traffic growth factors.
- The table also reveals that 13 of 14 respondent users consider turning movement counts essential or useful.
- All respondents indicate that traffic growth factors are essential or useful. However, the Transportation Division only can provide estimates of traffic growth factors from transportation models because the City of Winnipeg does not have continuous count stations installed (Transportation System Plannign Branch, 2012).
- Eight of 13 users consider hourly variation of traffic essential or useful. Hourly variation of traffic is used to define peak hours and is essential for branches linked to traffic operations. These branches are the Traffic Assessment Branch,

Traffic Management Branch, and Traffic Signals Branch. It is also considered essential by two consulting users.

- The respondents indicate that hourly variation of traffic is needed to determine schedules, detours and configurations for road/lane closures and work zones, determine schedules to permits for use of streets.
- In addition, hourly variation of traffic is required to determine the following operational characteristics of traffic signals: a) flash mode schedules, b) number of timing plans, and c) traffic counting periods required.
- Users require traffic variation and distribution data mainly on arterials and collectors. Only the Traffic Assessment Branch requires data specifically on local roads.
- Each of the three possible responses ("Yes", "No" and "Partly") account for one-third for the traffic variation and distribution data responses.

Additionally, the Traffic Signals Branch plans to hire three traffic analysts in the following two years. Consequently, in order to achieve the goal of the traffic signals operation standards, the number of requested turning movement counts by the Traffic Signals Branch will increase from 30 to 100 counts per year (Traffic Signals Branch, 2012). According to the *Traffic Signal Timing Manual* (Koonce, et al., 2008), the timing in every signalized intersection should be reviewed at least every three to five years.

Table 20 shows the vehicle classification data requirements.

Table 20 Vehicle Classification Data Requirements

Vehicle Classification	Data Need			
Data Type	Essential	Useful	Not Needed	TOTAL
3.1 Annual Average Daily Truck Traffic (AADTT)	4	6	3	13
3.2 Truck Percent	10	2	1	13
3.3 Axle Correction Factors	0	3	8	11
3.4 Truck Trailer Body Type (van, dump, container,...)	0	4	9	13
3.5 Long Combination Vehicles (LCVs)	2	1	8	11

Source: developed by H. Hernandez as part of this research

The table reveals the following:

- Truck percent is the most important statistic related to vehicle classification data, with 12 of 13 respondent users considering truck percent as essential or useful.
- The traffic monitoring program should systematically collect truck traffic information because 10 of 13 respondent users find Annual Average Daily Truck Traffic (AADTT) essential or useful.
- Truck trailer body type or axle correction factors are not considered as essential traffic statistics in Winnipeg.

Additionally, the research identifies the following

- Users require vehicle classification data mainly on arterials and collectors. Only the Traffic Assessment Branch requires truck percent data specifically on local roads.
- Vehicle classification data needs are not being met.
- Vehicle classification data are fundamental to the provision of daily truck volumes and truck percent data.

3.6 SUMMARY OF TRAFFIC MONITORING IN WINNIPEG

The current traffic monitoring program employs short-term counts on links and at intersections to provide traffic data to a wide range of users. The program includes annually recurring traffic counts at some predetermined locations as well as counts conducted to address specific requests. The program produces a flow map available on the website showing estimates of average weekday daily traffic (AWDT) on the regional street network. Further details on turning movements, volumes at 15-minute intervals and classification are available upon request from the *Traffic Studies Section* and are also available to internal users with permission to access the traffic database. The *Traffic Studies Section,* which has six staff members, implements the traffic monitoring program in addition to carrying out other duties.

The most essential traffic variation and distribution statistics are turning movement counts at intersections, directional distribution of traffic, and traffic growth factors. As previously indicated, the Traffic Signals Branch plans to increase the number of requested turning movement counts from 30 to 100 counts per year.

The Transportation Division can only provide estimates of traffic growth factors from transportation models because the City of Winnipeg does not have continuous count stations installed.

Since the current traffic monitoring program does not include continuous counting sites, the current system does not produce AADT values or estimates. It also does not estimate annual vehicle kilometres travelled (VKT) for the network. Alternatively, the system estimates AWDT VKT for the regional street network.

Usually, the system does not collect classification data from automatic link counts. The main source of classification data are the turning movement counts at intersections that generally only cover eight or 11 hours including traffic during the peak hours.

4 METHODOLOGY TO ANALYZE TEMPORAL TRAFFIC VARIATIONS IN URBAN AREAS

This chapter documents the methodology applied to analyze temporal variations for traffic patterns in urban areas using a hybrid approach that includes three major elements: a) statistical analysis, b) use of variables that explain hourly temporal variations, and c) application of engineering judgement. The combined use of these elements develops pragmatic meaning from statistical results.

The methodology compares the results from the statistical analysis with possible variables that explain hourly temporal variations, including road class, traffic volume, and land use. This provides a characterization of each traffic pattern group (TPG). The research uses these variables to develop decision flow charts to assign road segments to TPGs.

Since critical peak hours are present on weekdays, the research focuses on hourly variations for those. The average hourly traffic variation for each day of the week from each study (count) is calculated and the average variations are then compared to determine which days of the week are included in the analysis.

4.1.1 Vector of Temporal Ratios

The *Traffic Monitoring Guide (TMG)* indicates that hourly volumes improve the understanding of peaks during the day. The TMG recommends collecting traffic data in hourly intervals (FHWA, 2001); therefore, the research aggregates the data in hourly intervals.

The use of proportions is appropriate for cluster analysis (Soriguera, 2012; Weijermars, 2007). The average hourly traffic pattern for weekdays at location j is defined as a vector of temporal ratios. The vector is described as follows:

$$P_j = (x_{0j}, \ldots, x_{ij}, \ldots x_{23j})$$

where x_{ij} is the ratio of the specific average hourly volume to the average weekday hourly traffic volume at location j.

The vector indicates the shape of the average temporal variation and characterizes peak hours with respect to the average weekday traffic volume. The analysis does not include data flagged as problematic by the traffic monitoring program. Additionally, days having less than 24 hours of data are rejected from the database.

The research characterizes peak hours because it is at this time that the major traffic demands on the road network occur. One vector is developed for every study (short-term count) performed in the jurisdiction.

4.1.2 Development of Traffic Pattern Groups

The *Traffic Monitoring Guide* (TMG) recommends three methods to develop factor groups based on traffic pattern groups (TPGs) (FHWA, 2001):

- Cluster analysis,
- Geographic/functional assignment of roads to groups, and
- Same road factor application.

The research develops a hybrid approach based on three major elements: a) statistical analysis, b) use of variables that explain hourly temporal variations (which includes geographical/functional assignment of roads to groups and same road application), and c) application of engineering judgement (see Figure 5). These elements interact to develop and refine traffic pattern groups, and provide pragmatic meaning from the statistical results.

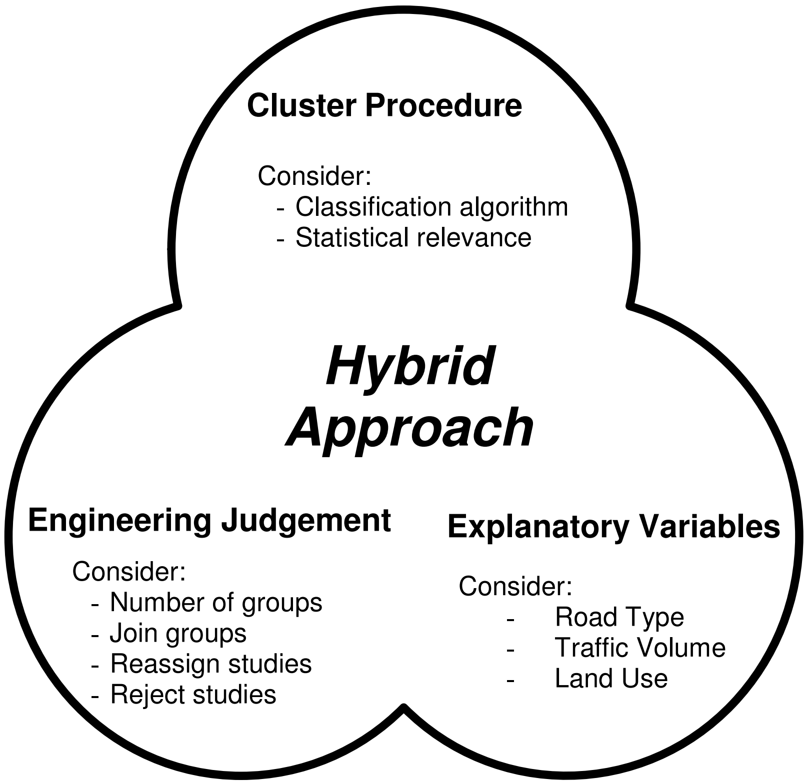


Figure 5 Hybrid Approach for the Development of Traffic Pattern Groups
Source: Adapted from (Reimer & Regehr, 2012). Adapted with permission.

Every group requires a clear and meaningful characterization. This characterization is required to develop procedures to assign road segments to TPGs. The assignment procedure includes the development of decision flow charts that use the variables that explain hourly temporal variations as inputs.

The most similar traffic patterns are clustered applying the hierarchical Ward's Method (Weijermans & Van Berkum, 2005). Several authors have used this method to develop homogeneous groups (FHWA, 2001; Papagiannakis, Bracher, & Jackson, 2006; Regehr, 2011; Wang, et al., 2011; Weijermars, 2007; Weijermans & Van Berkum, 2005).

The Ward's Method is based on a least-squares minimum distance algorithm to hierarchically group the objects with the most similar temporal variations. The method starts by considering every object (in this case every traffic count) as a group. Then the method evaluates all possible unions between two objects, selects the union of the two objects that has the lowest sum of the squared deviations about the group mean, and averages the two objects to create a new group (cluster). The process is repeated until all objects are clustered into one group (Ward, 1963). Ward (1963) presents detailed information with respect to the error sum of squares and the hierarchical method.

There is no one solid statistical method to determine the most appropriate number of clusters (Aunet, 2000; FHWA, 2001; Sharma, 1983). However, graphs of semi-partial R square versus the number of groups visualises the change of variance when two clusters are put together. The optimal number of groups is achieved by obtaining "a low semi-partial R^2 values with as few clusters as possible" (Regehr, 2011).

The cluster analysis defines the preliminary traffic pattern groups. Traffic pattern groups need to have characteristic elements that make them easy to identify (FHWA, 2001). Regehr (2011) indicates that engineering judgement is required to determine the appropriate number of groups and to determine if the groups have adequate explanatory variables that provide significance to the groups.

The TMG recommends the combination of statistical analysis and judgement to develop traffic pattern groups (FHWA, 2001). This combination is applied to: a) determine the number of groups, b) join groups, c) reassign stations, and d) reject stations.

The initial possible variables that explain hourly temporal variations included in the analysis are road class, traffic volume, and land use. The number of locations by TPG in each road type determines the predominant road type for each group.

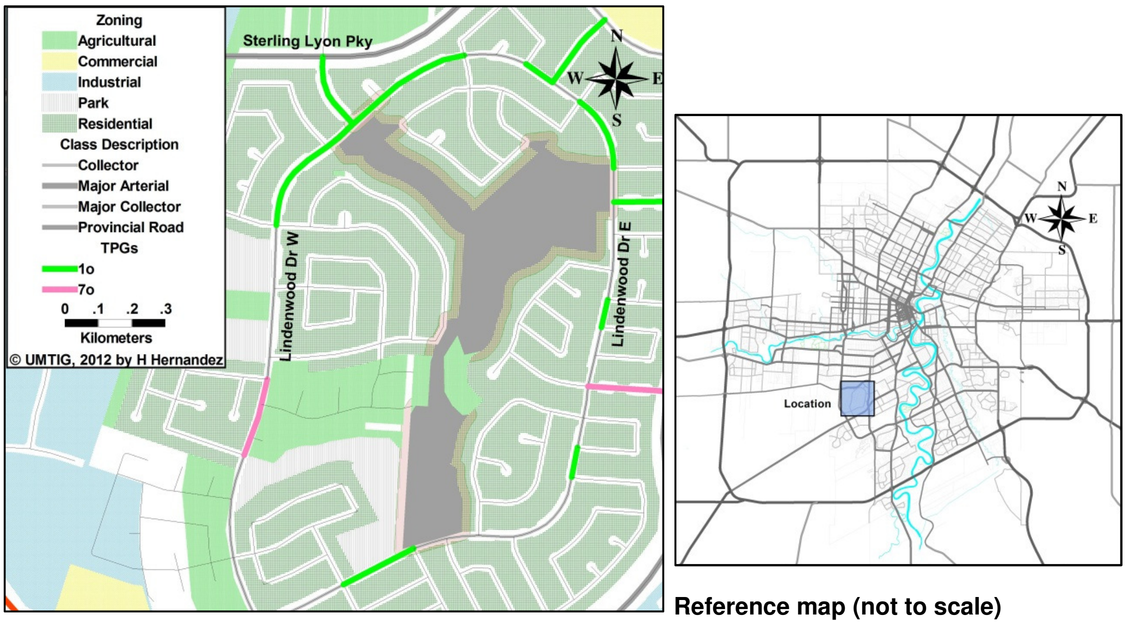
The research studies the relationship between the TPGs and traffic volume to validate the results from the road class analysis. Additionally, the traffic volume analysis provides customized information to the analyst, because the analyst is not restricted by predefined road classes.

The methodology developed in this research proposes a land use analysis to determine the predominant land use for each pattern group. The following paragraphs explain the land use analysis.

Since the research uses segment counts that are performed at mid-block locations or locations between intersections, each study is assigned a “segment ID” representing a street segment on the road network. The segment ID is used to link the data to a street centreline Geographic Information System (GIS) platform.

The geographical analysis performs an overlay analysis using a GIS. The research uses a buffer area of 25 metres for each land zone. Additionally, buffer areas of 10 and 50 metres are used to confirm the results. The research assigns the land zone to a TPG when the buffer area touches road segments assigned to the same TPG.

For example, Figure 6 shows the overlay analysis for one park zone (highlighted in gray) in the residential housing development Linden Woods. The analysis links the park zone with TPG 1_0 because the park's buffer area of 25 metres touches only TPG 1_0 segments. The research uses a subscript of zero ($_0$) to refer to the *initial* traffic pattern groups. For instance TPG 1_0 is the *unrefined* or *initial* TPG 1.



Reference map (not to scale)

Figure 6 Example of an Overlay Analysis for a Park Zone in Linden Woods, Winnipeg

Finally, the number of land zones by land use in each TPG determines the predominant land use for each group.

The characterization of each group is defined by the average hourly traffic variation, and a combination of variables that explain the hourly temporal variation. Each group should present a unique combination of hourly variation and variables that explain hourly temporal variations. Consequently, it is necessary to determine additional variables when two groups share the same initial variables and present different average hourly traffic variations.

To determine additional variables that explain hourly temporal variations for the group with dissimilar hourly traffic variations, the methodology suggests a geographical review and characterization of the surrounding areas for each location within the group. These additional variables that explain hourly temporal variations might be trip generators in the surrounding areas that significantly affect the traffic on the road segment being analyzed. Trip generators include, but are not limited to, schools, leisure centers, and recreational parks. If an additional explanatory variable is determined, the group is refined with the locations that are influenced by this additional explanatory variable. Locations that do not share the additional variable are rejected.

The research also defines a group average weekday hourly traffic pattern as:

$$\overline{P} = (\overline{x}_0, \dots, \overline{x}_i, \dots \overline{x}_{23})$$

where $\overline{x}_i$ is the average of the x_{ij} for all studies in the TPG.

Peak hours are defined as the hours before and after noon that present maximum volumes assuming that hourly variation of traffic presents a typical double peak.

The standard deviation of the group average hourly traffic pattern is defined as:

$$SD = (s_0, \dots, s_i, \dots s_{23})$$

where s_i is the standard deviation of the ratio x for the hour i. s_i is calculated using the following equation:

$$s_i = \sqrt{\frac{\sum\left(x_{ij} - \overline{x}_i\right)^2}{n-1}}$$

where x_{ij} is the ratio of the specific average hourly volume to the average weekday hourly traffic volume at location j.

The research assumes a normal distribution of the average hourly ratios for each group. The Traffic Monitoring Guide recommends an accuracy of 10% with 95% confidence level for temporal factors to calculate annual traffic estimates (FHWA, 2001).

The Traffic Monitoring Guide (Cambridge Systematics, 2012; FHWA, 2001) recommends the following equation to estimate the absolute precision interval:

$$D_a = t_{\left(1-\frac{d}{2}, n-1\right)} \frac{s}{\sqrt{n}}$$

Where:

D_a is the precision interval

s is the standard deviation

$t_{\left(1-\frac{d}{2}, n-1\right)}$ is the t-student value with $1 - {}^{d}/_{2}$ level of confidence and $n-1$ degrees of freedom.

The precision interval as a proportion (or percentage) of the mean is given as follows (Cambridge Systematics, 2012; FHWA, 2001):

$$D_p = t_{\left(1-\frac{d}{2}, n-1\right)} \frac{c}{\sqrt{n}}$$

Where:

D_p is the precision interval as proportion of the mean

c is the coefficient of variation

Consequently, one analysis for each hour is necessary for each TPG. The accuracy of the ratios and the standard deviation of each ratio have to be reported.

The final step consists of the development of a procedure to assign a segment to a specific time of day traffic pattern group. The assignment procedure should include the variables that explain hourly temporal variations found as inputs for the decision algorithm.

Figure 23 shows the group assignment algorithm for collector and local roads in Winnipeg. Figure 24 shows the group assignment algorithm for trunk highways and arterial roads. These assignment procedures are discussed in Section 5.3.

5 TEMPORAL TRAFFIC VARIATION IN WINNIPEG

This chapter analyzes temporal traffic variations for traffic patterns in the city using the methodology discussed in Chapter 4.

The purpose of this chapter is to develop traffic patterns based on the traffic temporal variation of short-term counts in the city in order to have a better understanding of peak periods and traffic variation.

Table 21 presents a summary of hourly variation of traffic and peak hour applications from the literature review and traffic data needs in Winnipeg.

Table 21 Summary of Hourly Variation of Traffic and Peak Hours Applications

Traffic Statistic	Application
Hourly Variation of Traffic	• Determination of schedules, detours and configurations for road/lane closures and work zones • Determination of adequate schedules to permits for use of streets • Determination of flash mode schedules for traffic signals • Determination of the number of timing plans required at signalized intersections • Definition of counting periods required for traffic signals • Geometric design • Traffic operations • Transportation planning
Peak Hour Volumes	• Capacity analysis • Calibration of transportation models • Definition of major characteristics required on a facility (e.g. number of lanes of a highway, number of turning lanes on an intersection) • Geometric design • Traffic operations • Road classification

5.1 ANALYSIS

The research utilizes automatic link count (raw road-tube) data provided by the City of Winnipeg. The research develops time-of-day (TOD) ratios to expand short term counts. The research does not develop seasonal (monthly) ratios due to a lack of continuous counters. Continuous count data would allow a more robust analysis; however, continuous count data are not available in Winnipeg.

The database comprises 1608 road tube counts taken between 2007 and 2011 at 1180 locations and includes 840,562 records of traffic volume in 15-minutes intervals. To develop traffic pattern groups (TPGs) for weekdays, the research selects locations that have volume data for at least one full weekday. These are 1152 of 1608 studies at 897 segments (locations) that meet this requirement. *Appendix D: Temporal Traffic Variation in* Winnipeg provides additional information related to the data cleaning process.

The jurisdictional survey indicates that some jurisdictions do not collect data on Mondays and Fridays. The (TMG) indicates that every jurisdiction should determine whether or not to include Mondays and Fridays in the weekday factor (FHWA, 2001, p. 2-44i). To explore this issue, the research develops a characterization of time of day (TOD) by day of the week.

5.1.1 Characterization of Time of Day Traffic Variation by Day of the Week

Studies that have data for every day of the week are selected for the characterization of the TOD traffic variation for every day of week (DOW). Eighty-nine studies at 81 locations meet the criteria for time-of-day characterization.

The research analyzes TOD variations based on TOD factors as the ratio of the specific hour of the day to average traffic of the seven days of the week. The research calculates the average hourly traffic variation for each day of the week from each station.

Figure 7 reveals that Mondays and Fridays present an average hourly traffic variation similar to other weekdays. Therefore, the research includes Mondays and Fridays in the

TOD analysis for weekdays.

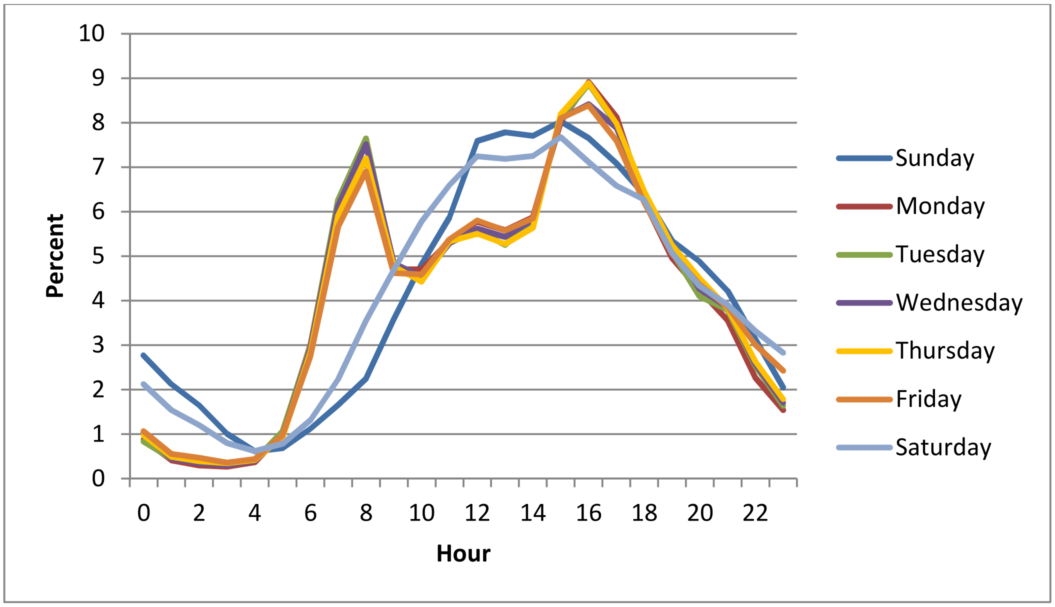


Figure 7 Average Hourly Variations by Day of Week, City of Winnipeg

The differences in hourly traffic variations between weekdays and weekends are consistent with the literature (Festin, 1996; Kim, Park, & Sang, 2008; Soriguera & Rosas, 2012; Weijermans & Van Berkum, 2005).

5.1.2 Statistical Analysis

TPGs for weekdays only are developed by applying the Ward's minimum variance method (sum of squares error) to hierarchically cluster the observations. Graphs of semi-partial R^2 versus the number of groups illustrate the change of variance when two clusters are joined. Figure 8 shows the graph of semi-partial R^2 versus the number of groups (from 1152 groups to one group) for the TOD analysis.

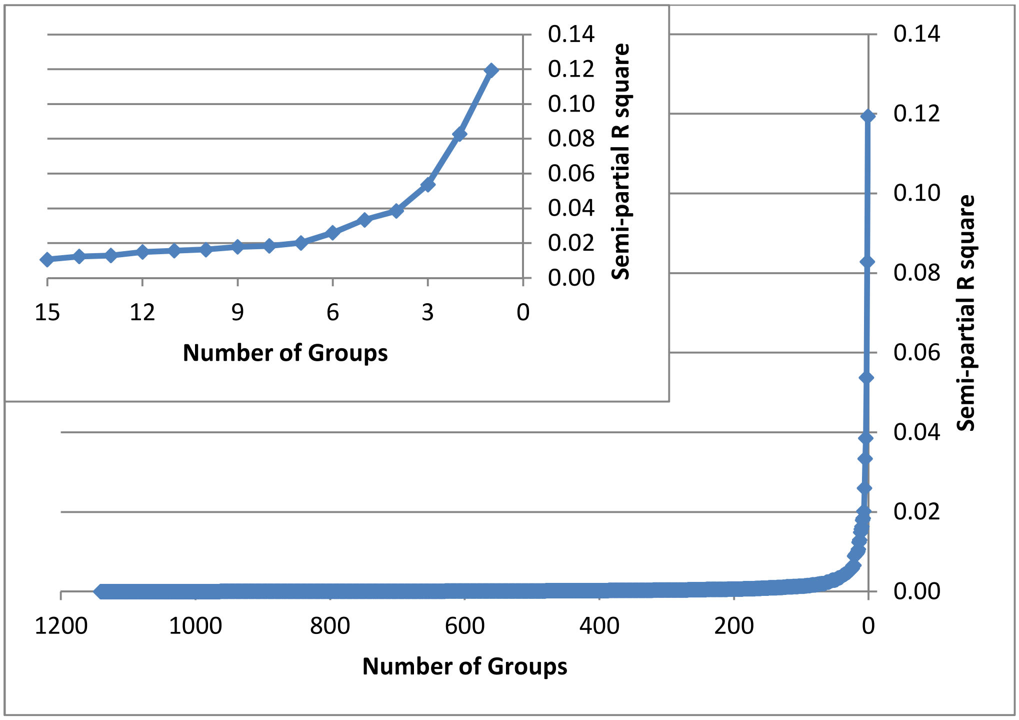


Figure 8 Semi-Partial R Square versus Number of Groups with magnification.

The figure reveals that there are significant semi-partial R^2 changes between one and seven groups and that the slope in the graph does not change significantly when the number of groups exceeds eight. Therefore, based on engineering judgement, the 1152 studies can be approximately considered in terms of eight groups.

5.1.3 Initial Groups

Figure 9 shows the *initial* average TOD variations for the weekday TPGs. The research uses a subscript of zero ($_0$) to refer to the *initial* traffic pattern groups. For instance TPG 1_0 is the *unrefined* or *initial* TPG 1.

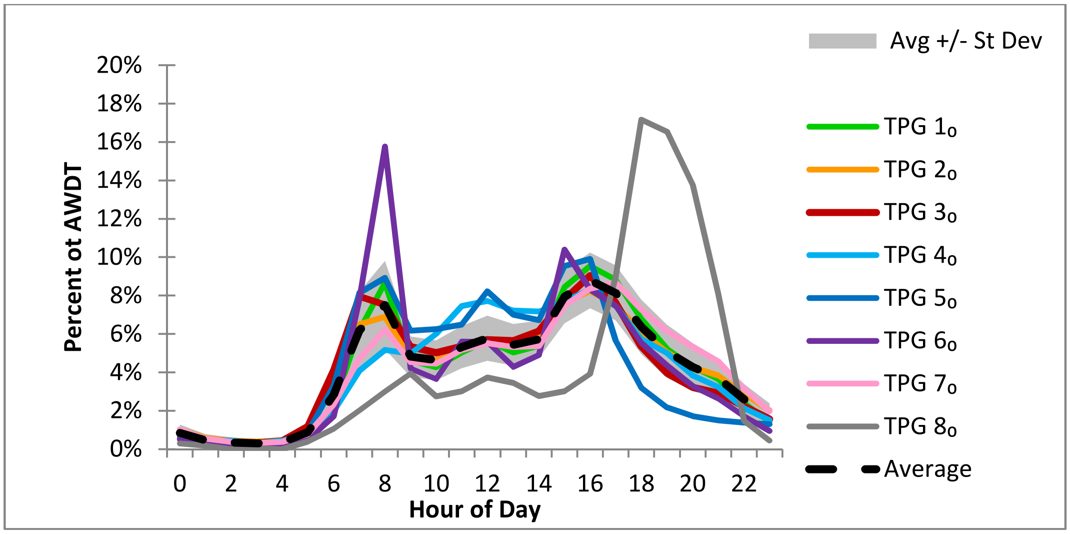


Figure 9 Initial Hourly Traffic Variations, City of Winnipeg

Figure 9 shows the average hourly traffic variation for each group and the general average for all studies. The general average has one peak at 8:00 a.m. (7.5% of AWDT) and another peak at 4:00 p.m. (8.8% of AWDT).

The figure reveals that average values for groups 1_0, 2_0, 3_0, and 7_0 fall within the band of the general average plus or minus one standard deviation. Ninety percent (1041 of 1152) of the studies are in TPGs 1_0, 2_0, 3_0 and 7_0 (see Table 22). The TPGs that do not fall in this band (general average ± 1 SD) are described as having the following distinctive characteristics:

- TPG 4_0 does not present a morning peak.
- TPG 5_0 presents an increase of traffic during lunch time and traffic volume decreases rapidly after four in the afternoon.
- TPG 6_0 presents very high morning peak.
- TPG 8_0 presents a very high afternoon peak.

Table 22 Number of Studies by TPG

TPG 1_0	TPG 2_0	TPG 3_0	TPG 4_0	TPG 5_0	TPG 6_0	TPG 7_0	TPG 8_0	Total
286	213	222	45	31	33	320	2	1152

The two locations in TPG 8_0 are roads that access Maple Grove Park and Buhler Recreation Park. Tournaments and other social activities take place at these locations. These two locations present a very unusual pattern with a very high afternoon peak related to tournaments and special events. The TMG recommends at least six stations per group (FHWA, 2001, p. 3-39). This group does not meet this recommendation. Therefore, the research rejects this group.

5.1.4 Road Type and Traffic Volume Analysis

The first explanatory variable considered is road type validated with a traffic volume analysis. The research studies the TPGs by road type including the following main road types: major arterials, minor arterials, collectors, local, provincial trunk highways and provincial roads. The analysis includes 856 road segments. Table 23 shows TPGs by road type.

Table 23 Time-of-Day TPG by Road Type, City of Winnipeg

TPG	Major Arterial	Minor Arterial	Collector	Local	PTH	PR	Other [a]	Total
TPG 1_0	11	17	99	103	0	2	1	233
TPG 2_0	55	19	31	36	0	0	0	141
TPG 3_0	56	22	14	14	11	3	1	121
TPG 4_0	4	11	6	17	0	0	0	38
TPG 5_0	0	0	7	11	0	2	0	20
TPG 6_0	0	0	3	26	0	0	0	29
TPG 7_0	13	13	75	172	0	0	0	273
Total	139	82	235	380	11	7	2	856

[a] Include ramps and transit facilities.

The table reveals the following:

- Studies on arterial roads tend to be TPGs 2_0 and 3_0 because 69% (152 of 221) of the studies on arterials are classified as TPGs 2_0 or 3_0. Additionally, TPG 3_0 locations account for all studies on provincial trunk highways (PTH).
- Locations on local and collector are more likely to be TPGs 1_0 and 7_0 because 72% (275 of 380) of the studies on local roads correspond to TPGs 1_0 and 7_0 and 74% (174 of 235) of the studies on collectors correspond to TPGs 1_0 and 7_0.
- TPGs 5_0 and 6_0 can be characterized as locations on collector and local roads, because all studies classified as TPGs 5_0 and 6_0 are on collectors or local roads.

In Winnipeg, the road classification system uses traffic volume to separate roads. (City of Winnipeg, 1991). Therefore, there is a correlation between road class and traffic volume. The research studies the relationship between the TPGs and traffic volume to validate the results from the functional class analysis. Additionally, the traffic volume analysis provides customized information to the analyst, because the analyst is not restricted by predefined road classes. Table 24 presents the distribution of studies for clusters 1_0 to 7_0 by average weekday daily traffic (AWDT) volume.

Table 24 Time-of-Day TPG by AWDT, City of Winnipeg

AWDT	TPG 1_0	TPG 2_0	TPG 3_0	TPG 4_0	TPG 5_0	TPG 6_0	TPG 7_0	Total
0 – 5,000	201	69	30	26	29	33	251	639
5,000 – 10,000	51	11	32	5	1	0	37	137
10,000 - 20,000	26	38	50	11	1	0	14	140
> 20,000	8	95	110	3	0	0	18	234
Total	286	213	222	45	31	33	320	1150

The analysis characterizes low volume groups and high volume locations.

Low volume (< 10,000 vehicles per day) groups:

- All TPG 6_0 locations have AWDTs lower than 5,000 vehicles per day (vpd).
- 94% (29 of 31) of TPG 5_0 locations have AWDTs lower than 5000 vpd.
- 90% (288 of 320) of TPG 7_0 locations have AWDT lower than 10,000. Additionally, 78% (251 0f 320) of TPG 7_0 locations have an AWDT lower than 5000.
- 88% (252 of 286) of TPG1_0 locations have AWDT lower than 10,000. Additionally, 70% (201 of 286) of TPG 1_0 locations have an AWDT lower than 5000.

High volume (≥ 20,000 vehicles per day) locations:

- The cluster analysis classifies 205 of 234 (88%) locations with AWDT higher than 20,000 vpd are classified as TPG 2_0 and 3_0.

The results from both analyses are consistent, and the research concludes that locations with high volume (arterial roads and provincial trunk highways) tend to be classified as TPGs 2_0 and 3_0 by the cluster analysis.

The research also concludes that TPG 1_0 and TPG 7_0 are located mainly on low volume facilities (local and collector roads). Additionally, TPGs 5_0 and 6_0 are mainly concentrated in low volume facilities.

5.1.5 Land Use Analysis

The methodology for land use analysis includes the development of buffer areas for each land zone in the City of Winnipeg. Land zones are assigned to a TPG only when the land buffer area touches road segments of the same TPG. Chapter 4 explains the methodology.

The research performs an overlay analysis using buffer zones for 15,719 land zones in the city, of which 2722 buffer areas touch segment(s) with the same TOD TPG. Figure 10 shows the distribution of TPGs by land use results for the 2722 buffer areas.

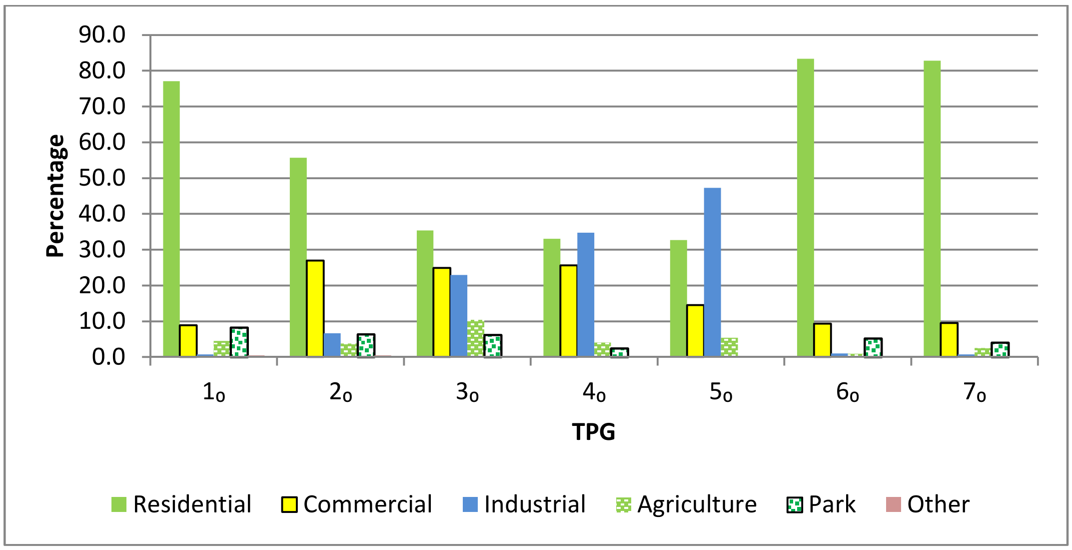


Figure 10 Distribution of TPGs by Land Use

Figure 10 reveals the following:

- TPGs 1_0, 6_0 and 7_0 locations are strongly linked with residential land use. The proportion of residential zones related to these groups varies from 77% to 83%.
- TPG 2_0 can be linked with residential and commercial land uses. 56% of the zones related to group 2_0 are residential zones and 27% are commercial zones.
- TPG 5_0 presents the highest proportion of industrial land zones: 47%.
- TPGs 3_0 and 4_0 present a mixed land use distributions.

5.1.6 Application of Engineering Judgement

Engineering judgement is applied to refine the original groups (the *final* or *refined* groups do not have the subscript of zero). The refinement processes are described as follows:

- TPGs 1_0 and 7_0 are merged into TPG 1 because they have similar characteristics.
- TPG 2_0 locations on collector and local roads are reassigned to TPG 1, given that there is no clear reason to distinguish them from TPG 1 locations. Additionally, they present similar hourly (see Figure 11) and land use distributions.

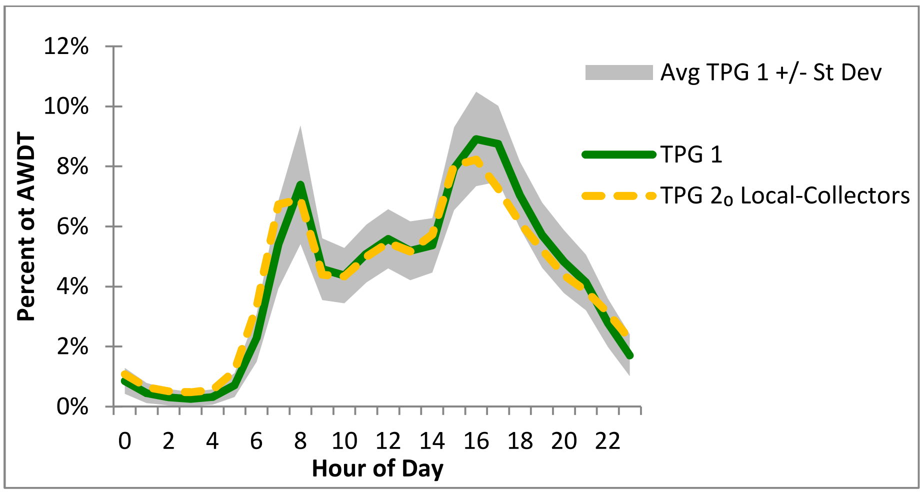


Figure 11 Hourly Traffic Variation of TPG 2_0 in Local and Collectors, and Variation of TPG 1

Additionally, individual locations in a TPG are scrutinized to separate the locations that share a predominant variable that explain hourly temporal variations or to determine additional variables.

For practical reasons, groups with less than 50 locations are refined. This approach is labor intensive because it requires a review of all locations within the group to search for a predominant variable or additional variables that explain hourly temporal variations. The review reveals the following:

- TPG 3 locations on collector and local roads are rejected because no variables that explain hourly temporal variations were found to characterize them.
- 20 of 45 studies at 17 locations classified in TPG 4_0 are strongly influenced by commercial facilities including shopping malls, theaters and supermarkets; *Appendix D: Temporal Traffic Variation in* Winnipeg lists these locations and nearby facilities. The research rejects the locations in this group that are not heavily influenced by commercial zones. This is the only group that does not present a morning peak.
- 16 of 31 studies classified in TPG 5_0 are in industrial zones or at the boundary of industrial zones; *Appendix D: Temporal Traffic Variation in* Winnipeg lists these locations and nearby facilities.
- 25 of 31 locations classified in TPG 6_0 are in the vicinity of a school or a college on residential roads. *Appendix D: Temporal Traffic Variation in* Winnipeg lists these locations and nearby schools. The research rejects the locations in this group that are not heavily influenced by schools.

5.2 TIME OF DAY TRAFFIC PATTERN GROUPS

This section presents the results from the analysis of hourly variation using the hybrid approach. The *refined* groups are defined in terms of road type, traffic volume, land use and hourly traffic variations.

Table 25 shows the refined TPGs by road type and reveals the following:

- 93% (539 of 580) of the studies on local and collectors are TPG 1.
- TPG 3 locations account for all studies on provincial trunk highways (PTH).
- 81% (113 of 140) of the studies on major arterials correspond to TPGs 2 and 3.

Table 25 Refined TPG by Road Type, City of Winnipeg

TPG	Major Arterial	Minor Arterial	Collector	Local	PTH	PR	Other [a]	Total
TPG 1	24	30	218	321	0	2	1	596
TPG 2	55	19	0	0	0	0	0	74
TPG 3	58	22	0	0	11	3	0	94
TPG 4	3	10	1	3	0	0	0	17
TPG 5	0	0	6	6	0	2	0	14
TPG 6	0	0	2	23	0	0	0	25
Total	140	81	227	353	11	7	1	820

[a] Include ramps.

The TMG recommends at least six stations per group (FHWA, 2001, p. 3-39). Refined groups meet this recommendation.

Table 26 presents the distribution of studies for clusters 1 to 6 by average weekday daily traffic (AWDT) volume. Engineering judgement is used to define the ranges of traffic volume. The analysis characterizes low volume groups and high volume locations.

Table 26 Refined TPG by AWDT, City of Winnipeg

AWDT	TPG 1	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	Total
0 – 5,000	519	2	6	4	14	26	571
5,000 – 10,000	97	2	25	4	1	0	129
10,000 - 20,000	43	35	48	10	1	0	137
> 20,000	27	94	110	2	0	0	233
Total	686	133	189	20	16	26	1070

Locations with high volume (arterial roads and provincial trunk highways) tend to be classified as TPGs 2 and 3.

TPG 1 locations correspond to low volume facilities (local and collector roads). Additionally, TPGs 5 and 6 are mainly concentrated in low volume facilities.

Figure 12 shows the distribution of TPGs by land use results for the 2,936 buffer areas that overlay segments with the same TPG assigned.

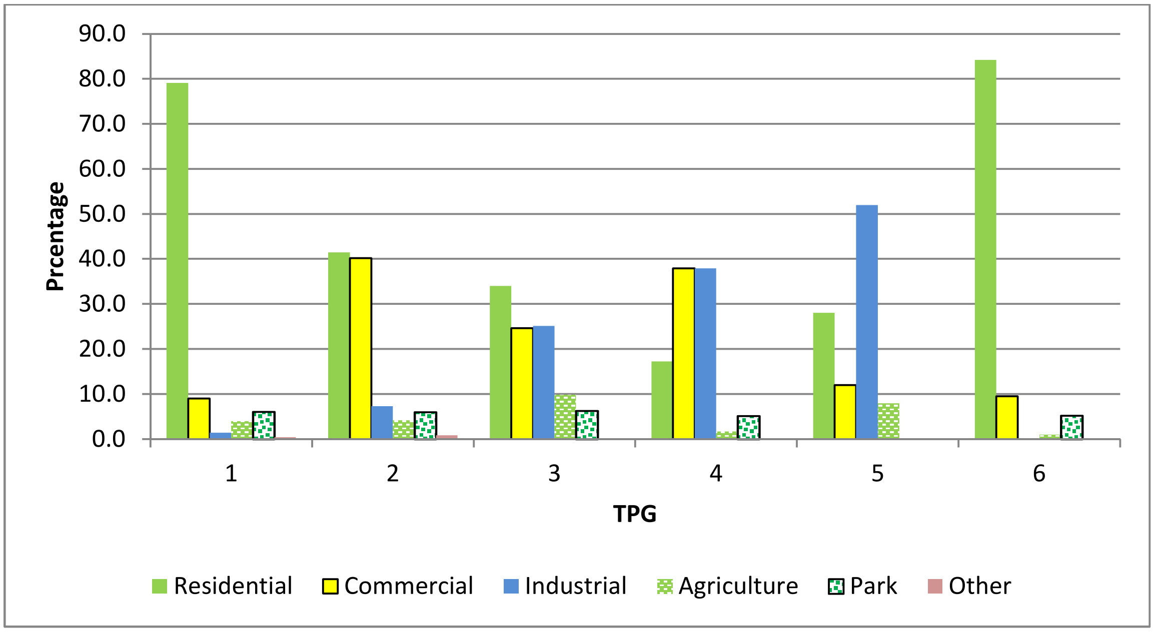


Figure 12 Distribution of Refined TPGs by Land Use

The proportion of residential land use decreases for TPG 2 locations due to the refinement process. Furthermore, the proportion of commercial land use increases for TPG 2 locations.

The process reassigns local and collector roads in TPG 2_0 to TPG 1. The refinement process does not produce major changes in the land use distribution for the other groups.

Table 27 presents a summary of results from the analysis.

Table 27 Characterization of Time-of-Day TPGs, City of Winnipeg

Group	General Shape of TPG Hourly Traffic Variation	Predominant Road Type	Predominant Traffic Volume [a]	Predominant Land Use
TPG 1	Morning and Afternoon Peaks	Local - Collector	Low	Strongly Residential
TPG 2	Morning and Afternoon Peaks	Arterials	High	Residential – Commercial
TPG 3	Morning and Afternoon Peaks	Arterials – PTH	High	Mixed Land Use
TPG 4	Plateau between noon and 4:00 p.m.	Not on Major Arterials	Moderate	Commercial - Industrial
TPG 5	High Morning and Afternoon Peaks	Local – Collector	Low	Industrial
TPG 6	Very High Morning Peak	Local	Low	Strongly Residential (Schools)

[a] Low volume: AWDT < 10,000. High Volume: AWDT > 20,000

The research categorizes the groups as follows:

- Residential roads TPG 1
- Arterial roads TPGs 2 and 3
- Commercial roads TPG 4
- Industrial local roads TPG 5
- School roads TPG 6

Table 28 contains the percent of traffic by hour by group. Hourly traffic variation for each group is defined as:

$$\overline{P} = (\overline{x}_0, \ldots, \overline{x}_i, \ldots \overline{x}_{23})$$

where $\overline{x}_i$ is the average of the x_{ij} for all studies in the TPG.

Table 28 Percent of Traffic by hour by TPG

Hour	Residential Roads	Average Arterial Roads	Arterial Roads	Arterial Roads	Commercial Roads	Industrial Roads	School Areas	General Average
TPG	TPG 1	TPGs 2 and 3	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	Average
0	0.9	0.9	1.0	0.8	0.8	0.7	0.5	0.9
1	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.5
2	0.3	0.4	0.4	0.3	0.3	0.2	0.2	0.3
3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.3
4	0.3	0.4	0.4	0.4	0.3	0.4	0.2	0.4
5	0.8	1.2	1.1	1.2	0.7	1.0	0.5	0.9
6	2.4	3.8	3.3	4.3	2.0	4.5	1.4	2.8
7	5.6	7.3	6.4	8.0	4.1	10.5	6.6	6.2
8	7.3	7.2	6.9	7.4	4.9	8.1	16.5	7.5
9	4.6	5.2	5.1	5.3	5.0	5.3	4.0	4.8
10	4.4	4.9	4.8	5.0	5.6	5.3	3.3	4.6
11	5.1	5.4	5.4	5.3	6.8	6.3	5.6	5.3
12	5.6	5.7	5.8	5.6	8.1	7.6	5.7	5.8
13	5.2	5.6	5.6	5.6	7.6	6.7	4.3	5.4
14	5.4	6.1	6.1	6.1	7.4	6.7	5.0	5.7
15	7.9	7.6	7.4	7.7	7.8	9.8	11.1	7.9
16	8.8	8.7	8.3	9.0	8.3	10.8	8.4	8.8
17	8.6	7.7	7.6	7.7	7.3	6.0	7.6	8.1
18	6.9	5.7	6.2	5.4	6.0	2.7	5.7	6.4
19	5.7	4.3	4.9	3.9	5.3	1.7	4.4	5.1
20	4.8	3.6	4.2	3.3	4.2	1.6	3.5	4.3
21	4.1	3.3	3.8	2.9	3.2	1.3	2.7	3.7
22	2.8	2.5	2.7	2.3	2.1	1.2	1.7	2.6
23	1.8	1.7	1.9	1.6	1.5	1.0	0.9	1.7

Table 29 contains the standard deviation of each hourly factor. The standard deviation indicates the spread of the values used to develop the factors. *Appendix D: Temporal Traffic Variation in* Winnipeg contains the level of precision of each hourly factor. A range defined by the sample average plus or minus the absolute precision interval has a 95% probability of containing the true average factor for a TPG.

Table 29 Standard Deviations by TPG

Hour	Residential Roads	Average Arterial Roads	Arterial Roads	Arterial Roads	Commercial Roads	Industrial Roads	School Areas	General Average
TPG	TPG 1	TPGs 2 and 3	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	Average
0	0.5	0.3	0.3	0.2	0.2	0.5	0.3	0.4
1	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.3
2	0.3	0.2	0.2	0.1	0.3	0.2	0.1	0.3
3	0.3	0.2	0.2	0.1	0.2	0.2	0.1	0.2
4	0.3	0.2	0.2	0.2	0.2	0.3	0.1	0.3
5	0.5	0.4	0.4	0.3	0.3	0.5	0.4	0.5
6	0.9	1.0	0.8	0.9	0.7	2.1	0.5	1.2
7	1.6	1.3	1.0	1.1	1.1	2.1	2.9	2.0
8	1.9	0.9	0.8	0.8	0.8	1.5	3.7	2.3
9	1.0	0.5	0.6	0.4	0.6	1.6	1.2	1.0
10	0.9	0.5	0.4	0.5	0.5	1.6	0.8	1.0
11	1.0	0.5	0.5	0.5	0.7	1.5	1.3	1.1
12	1.0	0.6	0.5	0.6	1.0	1.2	1.3	1.2
13	1.0	0.5	0.5	0.5	0.8	1.5	0.9	1.1
14	0.9	0.4	0.4	0.4	0.6	1.3	1.1	1.0
15	1.3	0.6	0.4	0.6	0.7	2.0	2.9	1.4
16	1.6	0.9	0.7	0.9	0.6	1.9	1.7	1.4
17	1.4	0.8	0.8	0.8	0.9	1.8	1.5	1.4
18	1.2	0.7	0.5	0.6	0.9	1.1	1.3	1.4
19	1.1	0.7	0.4	0.5	1.5	0.8	1.1	1.4
20	1.0	0.6	0.3	0.4	0.8	0.8	1.2	1.2
21	0.9	0.6	0.3	0.4	0.6	0.8	0.9	1.0
22	0.8	0.5	0.4	0.4	0.5	0.7	0.5	0.8
23	0.7	0.4	0.4	0.4	0.6	0.7	0.4	0.7

The research assumes a normal distribution of the average hourly ratios for each group. The Traffic Monitoring Guide recommends an accuracy of 10% with 95% confidence level for temporal factors to calculate annual traffic estimates (FHWA, 2001).

5.2.1 Residential Roads (TPG 1)

The research classifies TPG 1 as residential roads, because 90% (321 of 356) of local streets are classified as TPG 1. Additionally, the geographical analysis shows that more than 79% of land use zones related to TPG 1 are residential zones.

Figure 13 shows average hourly traffic variations for TPG 1, and reveals the following:

- An increase of traffic after 5:00 a.m. in the morning,
- An average morning peak that represents 7.3% of AWDT at 8:00 in the morning,
- A valley between 9:00 a.m. and 2:00 p.m.,
- An average afternoon peak that represents 8.8% of AWDT at 4:00 p.m., and
- A constant traffic decrease after 5:00 p.m.

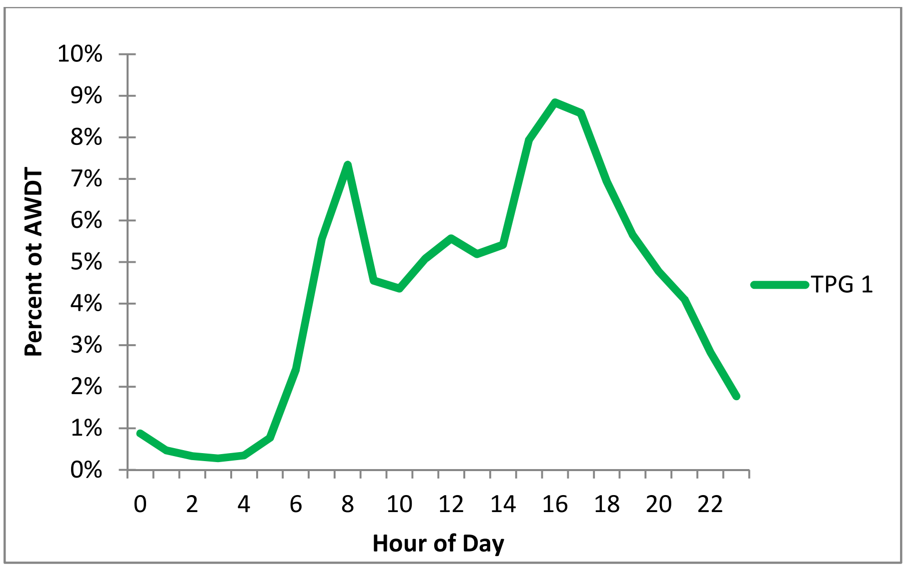


Figure 13 Hourly Traffic Variations for TPG 1

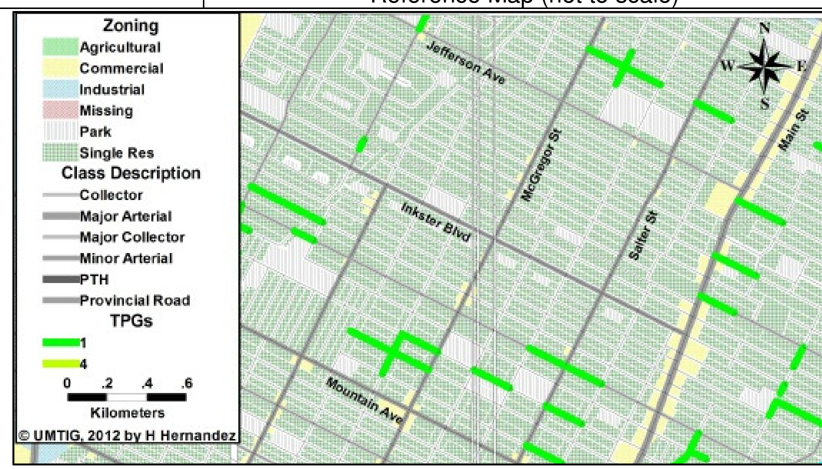
Figure 14 shows examples of TPG 1 segments in the following residential communities: St. Vital South, Linden Woods, and Point Douglas North.

The research determines that 13 of 24 segments on major arterials classified by the cluster analysis as TPG 1 are located on St. Anne's Rd and St. Mary's Rd south of Bishop Grandin Blvd, or Roblin Blvd, which are corridors strongly influenced by surrounding residential zones.

a) St Vital South Communities

Reference Map (not to scale)

b) Linden Woods Community



c) Point Douglas North Communities

Figure 14 Examples of TPG 1 Locations in Residential Communities

5.2.2 Arterial Roads (TPGs 2 and 3)

The cluster analysis classifies 81% (113 of 140) of major arterials as TPGs 2 or 3. Additionally, the traffic volume analysis indicates that 88% (204 of 233) of high volume (AWDT > 20,000) locations are included as TPGs 2 or 3. Figure 15 shows average hourly traffic variations for TPGs 2 and 3.

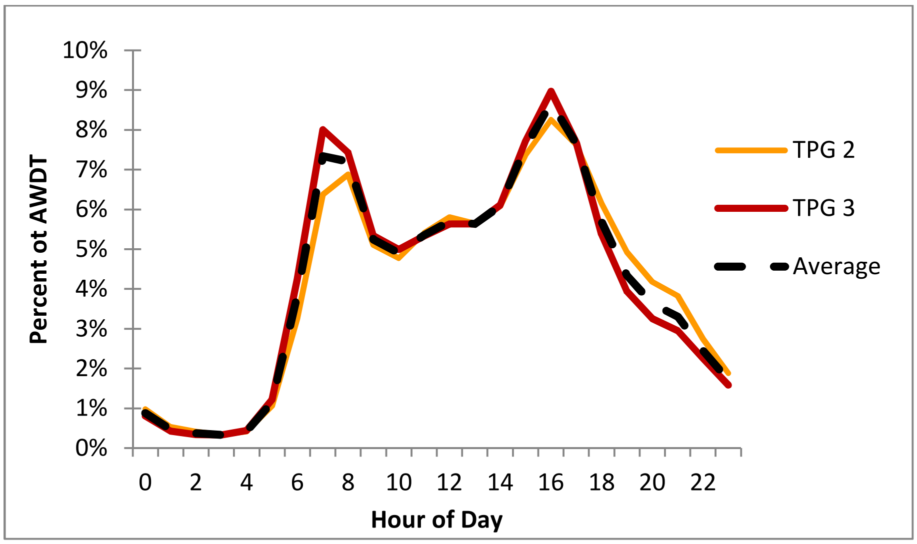


Figure 15 Hourly Traffic Variations for TPGs 2 and 3

Figure 15 reveals the following:

- An increase of traffic after 5:00 a.m. in the morning;
- The morning peak for TPG 2 represents 6.9% of AWDT at 8:00 a.m. while the TPG 3 peak represents 8.0% of AWDT at 7:00 a.m.;
- A valley between 9:00 a.m. and 2:00 p.m.;
- The afternoon peak at 4:00 p.m. represents 8.3% of AWDT for TPG 2 and 9.0% of AWDT for TPG 3; and
- A constant traffic decrease after 4:00 p.m.

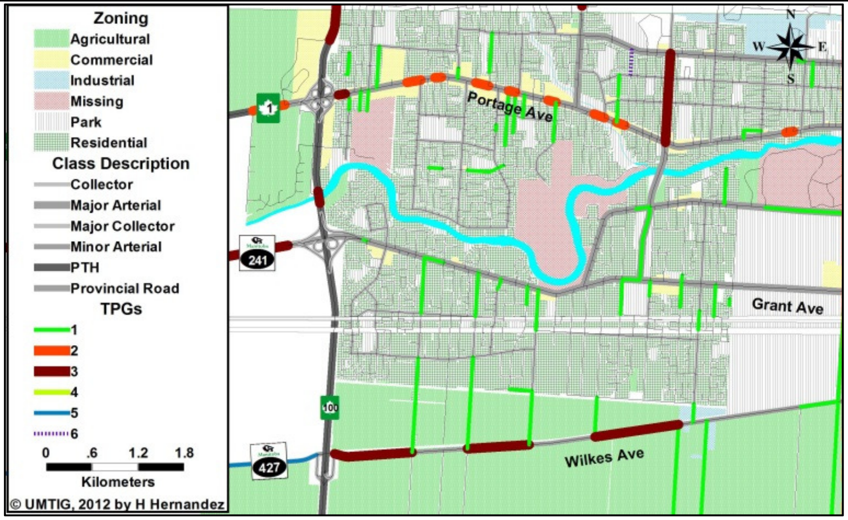
Figure 16 shows TPG 2 segments in the following arterials: Bishop Grandin Blvd, Jubilee Ave, Osborne St, and Portage Ave. TPG 2 also include locations on Grant Ave, University Cres, and Bison Dr.

Additionally, Figure 16 shows TPG 3 segments in the following arterials: Dugald Rd, Kenaston Blvd, Lagimodiere Blvd, Perimeter Hwy, Waverley St, and Wilkes Ave. TPG 3 also include segments on McGillivray Blvd.

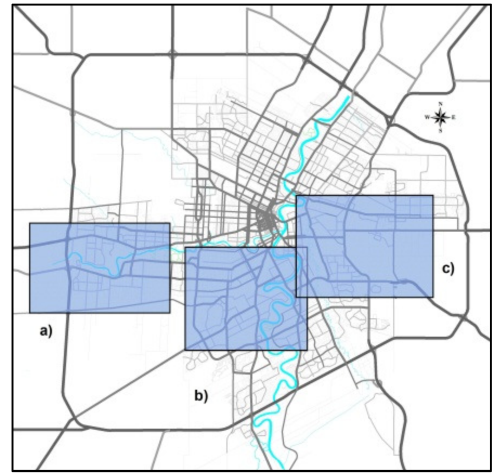
Some arterials present segments in both groups like Route 30 (Archibald St) which has TPG 2 segments south of Mission Industrial and TPG 3 segments east of Mission Industrial. Similarly, Plessis Rd present TPG 2 segments in the residential zone and TPG 3 in the industrial area (see Winnipeg East on Figure 16).

Industrial zones tend to influence more TPG 3 segments, while residential zones influence more TPG 2 segments. The influence of industrial zones combined with a lack of commercial, leisure and social activities (which tend to occur in the evenings) in industrial areas might explain the higher peaks and faster decrease on traffic after 4:00 p.m. during the evenings on TPG 3 segments (see Figure 15).

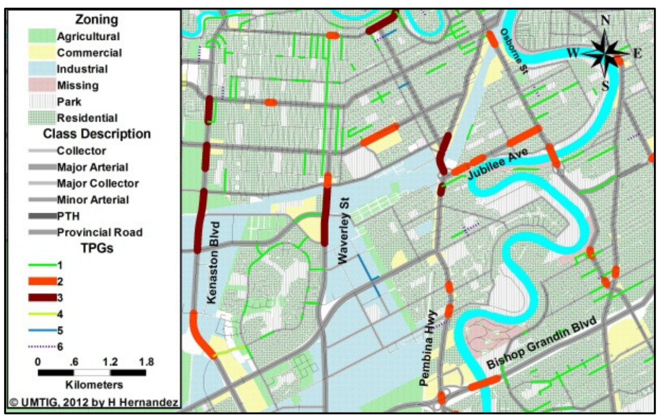
The research separates these groups because they do not share the same land use characteristics. Additionally, this separation would be used as an input to define the location of future permanent traffic monitoring stations on arterials in Winnipeg.



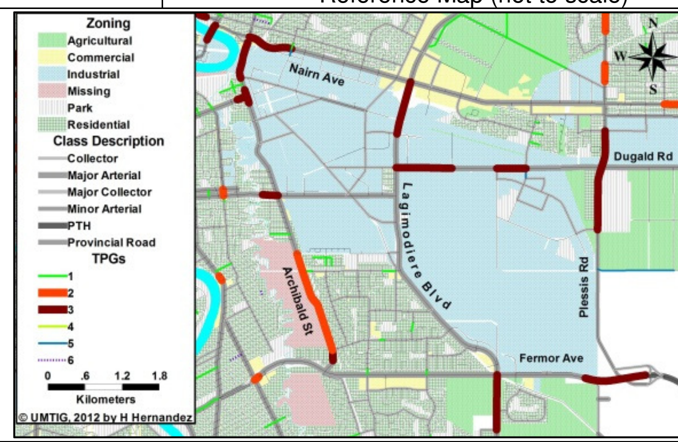
a) Winnipeg West



Reference Map (not to scale)



b) Winnipeg South



c) Winnipeg East

Figure 16 Examples of TPG 2 and TPG 3 Segments

5.2.3 Commercial Roads (TPG 4)

The traffic volume and land use analyses indicate that most studies in this group have an AWDT lower than 20,000 vpd and do not present a predominant land use. Figure 17 shows average hourly traffic variations for TPG 4 locations that are located close to entertainment facilities.

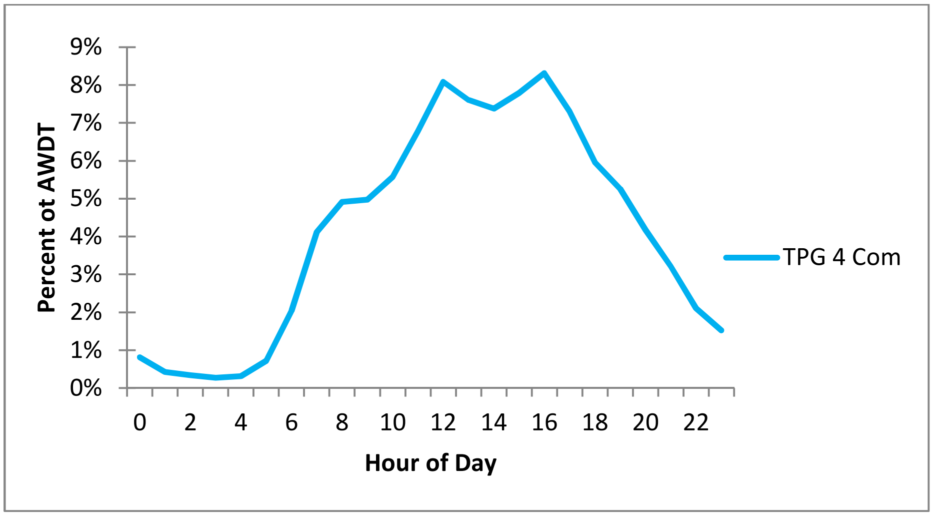


Figure 17 Hourly Traffic Variations for TPG 4 Segments Influenced by Commercial Zones

Figure 17 reveals the following:

- An increase of traffic after 5:00 a.m. in the morning
- Locations in this group do not present morning peak traffic.
- A plateau between noon and 4:00 p.m. that varies between 7% and 8%.
- A constant traffic decrease after 4:00 p.m.

Figure 18 shows TPG 4 segments in the vicinity of Polo Park Shopping Centre; most of them are located on Empress St.

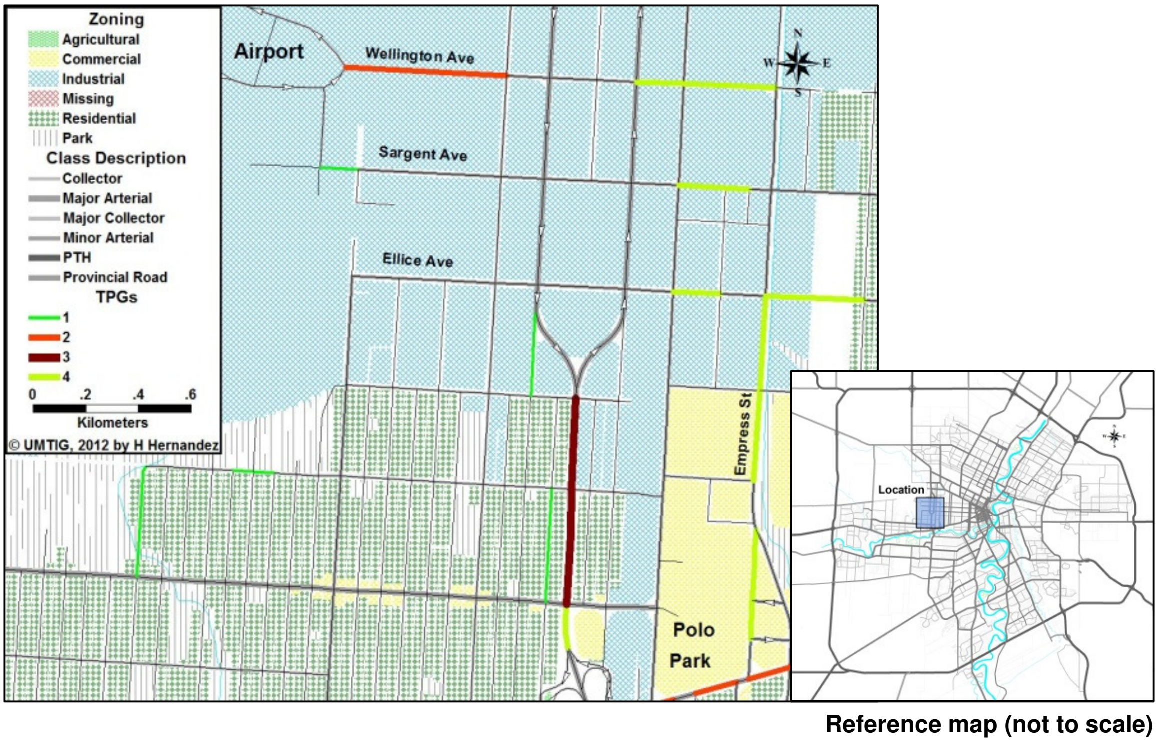


Figure 18 Examples of TPG 4 Segments Influenced by Commercial Zone

5.2.4 Industrial Local Roads (TPG 5)

All segments in this group are collector or local roads. Fourteen of 16 studies have AWDT lower than 5000 vehicles per day. From the land use analysis, TPGs 5 presents the highest proportion of industrial land zones.

Figure 19 shows average hourly traffic variations for TPG 5 locations; and reveals the following:

- An increase of traffic after 5:00 a.m. in the morning
- Locations present high morning (10.4% of AWDT at 7:00 a.m.) and afternoon (10.8% of AWDT at 4:00 p.m.) traffic peaks
- A valley between 9:00 a.m. and 2:00 p.m.
- A constant and rapid traffic decrease between 4:00 p.m. and 6:00 p.m.

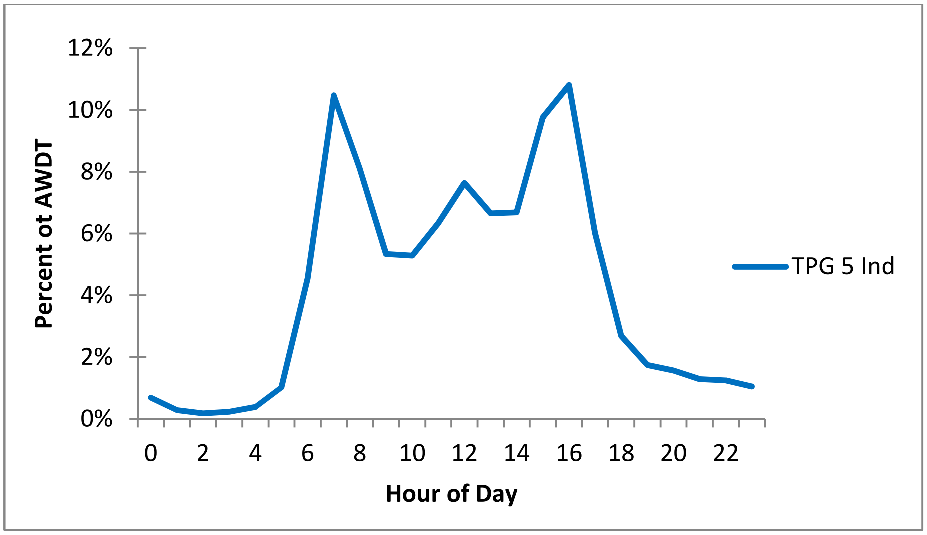
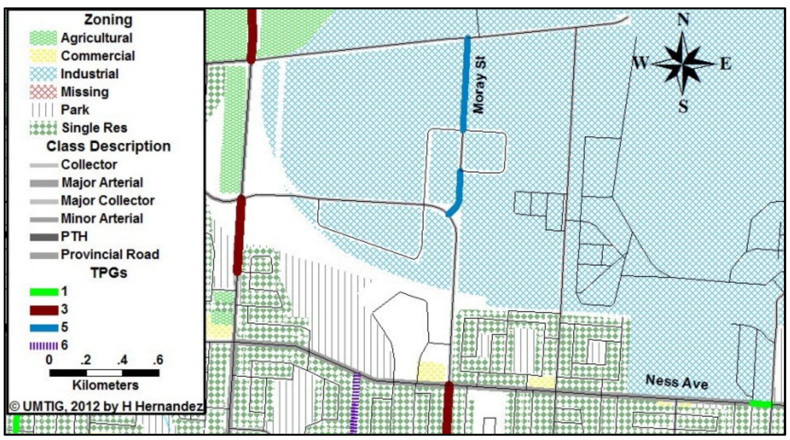
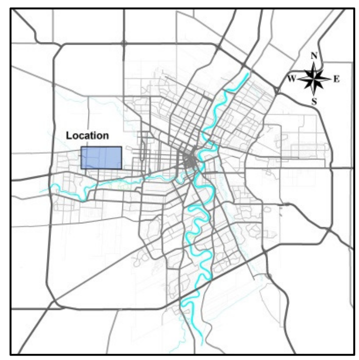


Figure 19 Hourly Traffic Variations for TPG 5 Segments in Industrial Zones





Reference map (not to scale)

Figure 20 Example of TPG 5 In an Industrial Area

Figure 20 shows a TPG 6 segments in Moray Industrial Park in West Winnipeg.

5.2.5 School Roads (TPG 6)

All roads in TPG 6 are located on collector or local roads mainly in residential areas and share these characteristics with TPG 1. However, the average TOD variation differs from TPG 1 because TPG 6 locations present a very high morning peak. Figure 21 shows average hourly traffic variations for TPG 6 locations located close to academic centres.

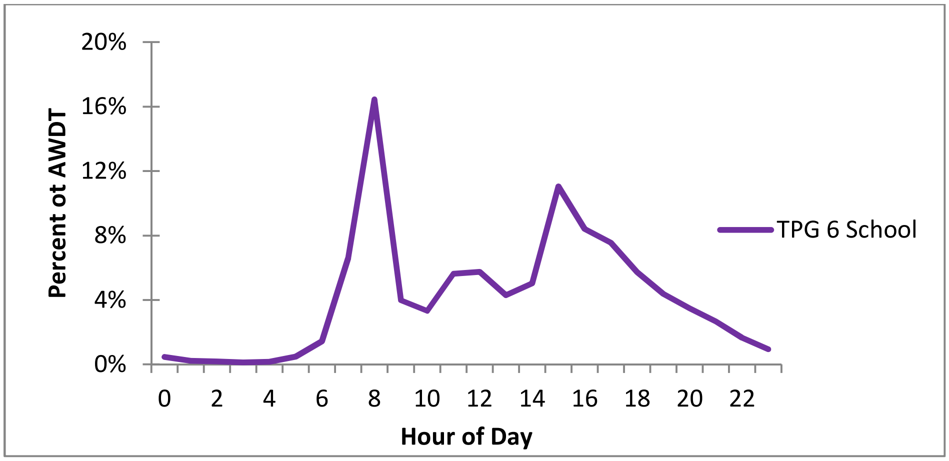


Figure 21 Time-of-Day Traffic Variations for TPG 6 Segments in School Areas

Figure 21 reveals the following:

- An increase of traffic after 6:00 a.m. in the morning
- A very high morning peak (16.5% of AWDT) at 8:00 a.m.
- An afternoon peak (11.1 % of AWDT) at 3:00 p.m.
- A decrease of traffic after 3:00 p.m.

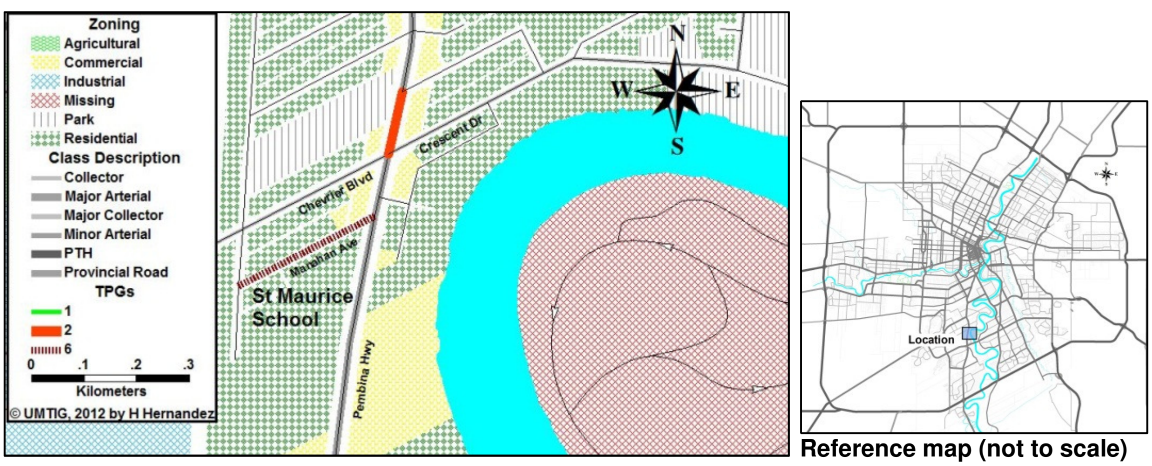


Figure 22 Example of TPG 6 Segment in the Vicinity of a School

Figure 22 shows a TPG 6 segment in the vicinity of St Maurice School in South Winnipeg.

5.3 TRAFFIC PATTERN GROUP SEGMENT ASSIGMENT

This section contains the procedure to assign a segment to a specific time of day traffic pattern group. The assignment procedure includes the findings from the hybrid approach to characterize and define the TPGs.

The procedure includes two initial steps. The first step is to determine whether the road is a minor road (local or collector) or a major road (provincial trunk highway or arterial). The second step is to consider the surrounding land use for minor roads and to determine the main use of the major road in the case of arterials.

The procedure for assigning segments to a TPG includes two decision algorithms (flow charts) to assign segments to TPGs. The first decision algorithm applies to local and collector roads (see Figure 23). The second decision algorithm applies to provincial trunk highways and arterial roads (see Figure 24).

The main shortcoming is that judgement and local knowledge have to be applied to use the decision algorithm for arterials. The flow chart does not define how to estimate or calculate the effect of a specific land use on arterial roads. It can be cumbersome to identify a TPG 2 from a TPG 3 location. However, the research recommends using an average of these groups when the flow chart does not provide a clear answer.

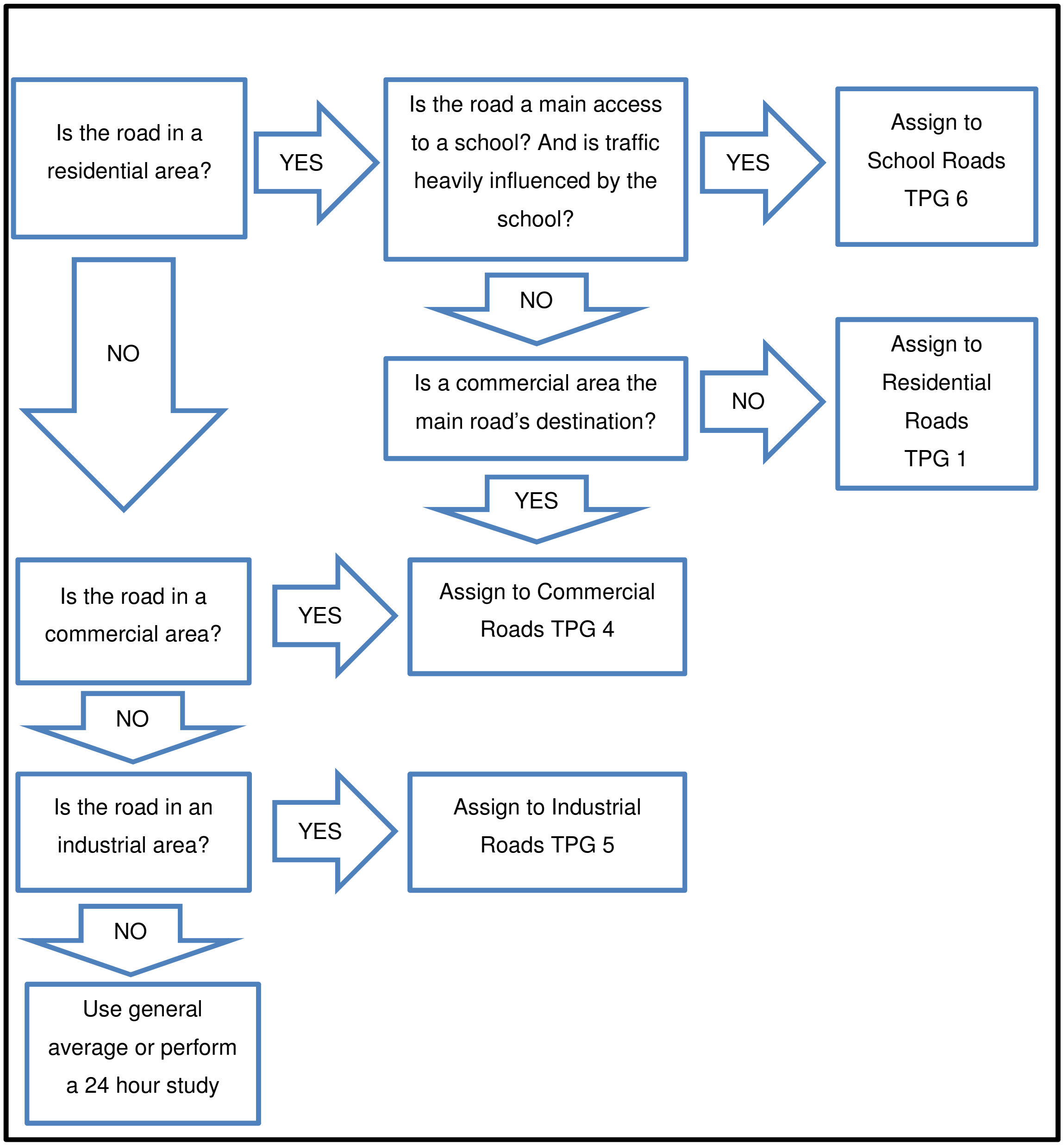


Figure 23 Group Assignment Algorithm for Local and Collector Roads

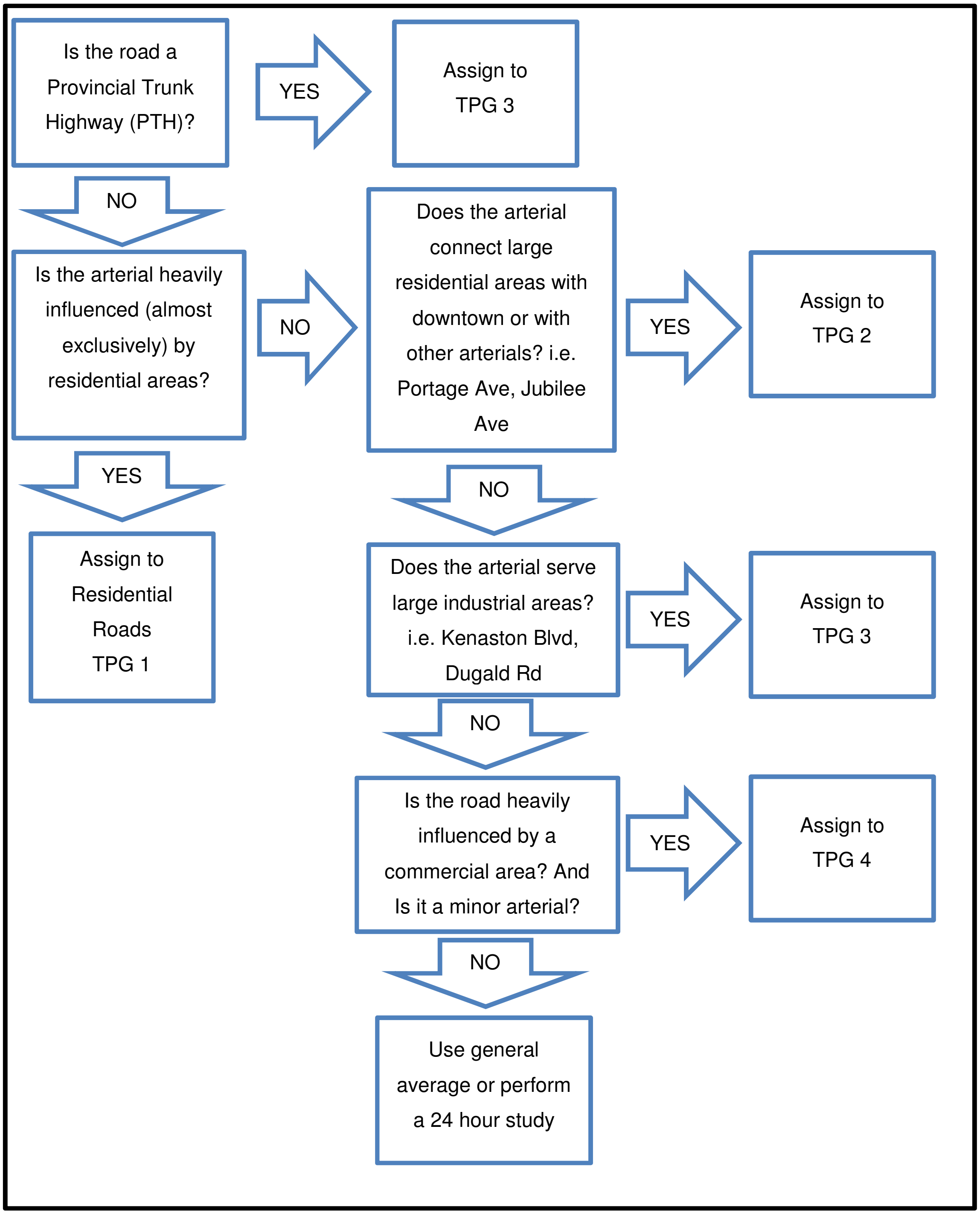
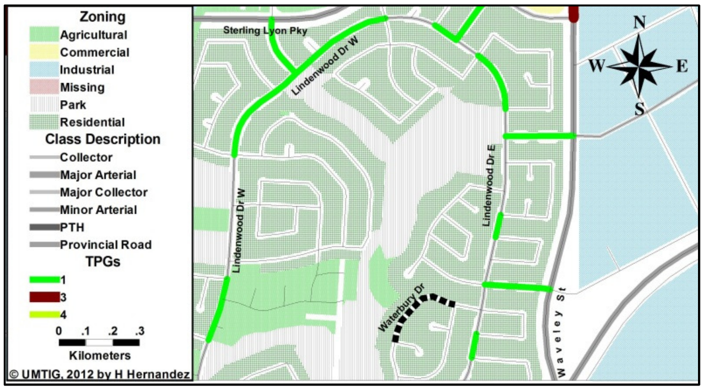
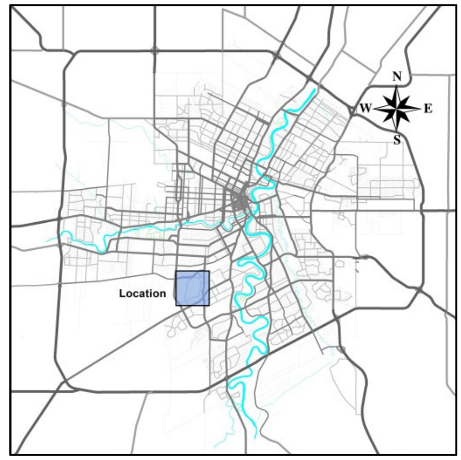


Figure 24 Group Assignment Algorithm for Arterials and Provincial Trunk Highways

The following provides an example of how to apply the assignment algorithm for a count taken on Waterbury Dr. (dashed line on Figure 25).





Reference map (not to scale)

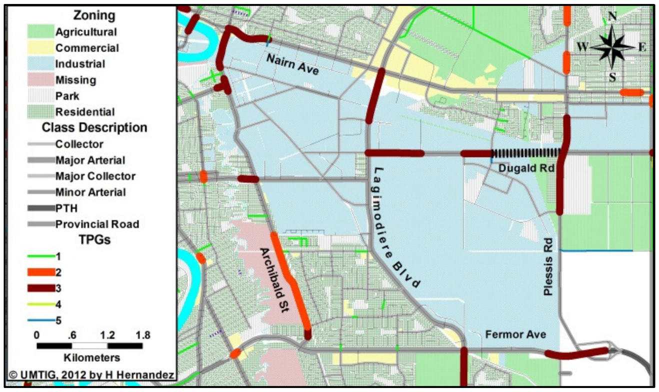
Figure 25 Example of Group Assignment Algorithm for Residential Roads

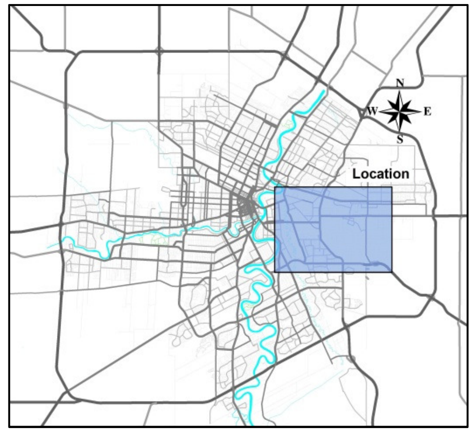
1. **Is the road in a residential area?** Yes

2. **Is the road a main access to a school? And is traffic heavily influenced by the school?** No, the road is not a main access to a school.

3. **Is a commercial area the main road's destination?** No, therefore assign Waterbury Dr. to Residential Roads TPG 1.

The following provides an example of how to apply the assignment algorithm for a count taken on Dugald Rd. (dashed line on Figure 26).





Reference map (not to scale)

Figure 26 Example of Group Assignment Algorithm for Arterials

1. **Is the road a Provincial Trunk Highway?** No

2. **Is the arterial influenced (almost exclusively) by residential areas?** No, the road is not heavily influenced by residential areas.

3. **Does the arterial connect large residential areas with downtown or with other arterials? e.g. Portage Ave, Jubilee Ave.** No.

4. **Does the arterial serve large industrial areas?** Yes, therefore assign the segment to TPG 3.

6 CONCLUSIONS

This chapter summarizes the results and presents the conclusions. Opportunities for enhancing current traffic monitoring programs are identified. Possibilities for future research are also addressed.

The conclusions related to the jurisdictional survey and the characterization of the City of Winnipeg's current traffic monitoring program are as follows:

- The jurisdictional survey yields results that determine that continuous stations are becoming common in urban areas. Additionally, all jurisdictions perform automatic link (short-term) counts at mid-block locations and turning movement counts at intersections. Core count programs rely more on link counts than counts at intersections.

- A lack of continuous count stations limits the data available to study seasonal and historical traffic variations.

The conclusions related to the methodology and analysis of traffic variations in urban areas are as follows:

- The hybrid approach developed in this research is appropriate to develop and refine TPGs. The hybrid approach is based on three major elements: a) statistical analysis, b) use of variables that explain hourly temporal variations, and c) application of engineering judgement.

- The research develops six traffic pattern groups (TPGs) based on the hourly variation of automatic link (short-term) counts. The groups are described as follows:

  a) **TPG 1 Residential Roads:** this group presents morning and afternoon traffic peaks. Local roads, collectors and low traffic volumes are predominant. These locations are heavily influenced by residential zones.

  b) **TPG 2 Arterial Roads:** this group presents morning and afternoon traffic peaks. Arterials and high traffic volumes are predominant. These locations are heavily influenced by residential and commercial zones.

  c) **TPG 3 Arterial Roads:** this group presents morning and afternoon traffic peaks. The morning peak is at 7:00 a.m., which is both earlier and higher than TPG 2 locations. Arterials, provincial trunk highways and high traffic volumes are predominant. Compared to TPG 2, Industrial zones tend to influence more TPG 3 segments.

  d) **TPG 4 Commercial Roads:** this group does not present a morning traffic peak. These locations present moderate traffic volumes, and are heavily influenced by commercial zones.

  e) **TPG 5 Industrial Local Roads:** this group presents high morning and afternoon traffic peaks. Local roads and low traffic volumes are predominant. These locations are heavily influenced by industrial zones.

f) **TPG 6 School Roads:** this group presents a very high morning traffic peak. Local roads and low traffic volumes are predominant. These locations are heavily influenced by schools in residential zones.

- Road classification, traffic volume, and land use are variables that explain hourly temporal variations for hourly traffic pattern groups. This verifies the hypothesis that variables that explain hourly temporal variations have a relationship with TPGs created from the statistical analysis. Specifically, the research identifies: a) arterial and non-arterial roads, b) low, moderate and high volume roads, and c) residential, industrial, commercial zones, and school areas as variables that explain hourly temporal variations.

- Every TPG presents a clear and meaningful characterization. The developed factors on peak hours (8:00 a.m. and 4:00 p.m.) met the accuracy of 10% at the 95% confidence level as recommended by the *Traffic Monitoring Guide*. The absolute precision presents low values during off peak periods (a maximum value of 0.3 for the period between 0:00 and 5:00 a.m. and a value of 0.7 for the period between 5:00 and 12:00 p.m.). However, the relative precision decreases because the proportion of traffic is low during these periods of time compared to peak hours.

- The assignment of segments to TPGs can be accomplished with a decision algorithm that uses the variables that explain hourly temporal variations as inputs. Practitioners can improve traffic estimates from short-term counts by applying the assignment procedure.

- Some jurisdictions do not count at intersections between peak periods and potentially miss high traffic volume periods in commercial zones.

The research makes the following recommendations regarding future research:

- Other tools such as transportation demand models should be used to validate or to find new variables that explain hourly temporal variations. For example, a transportation model should estimate the proportion of traffic in a segment that is influenced by a particular zone.

- The research recommends the exploration of the use of the hybrid approach to study hourly variations of traffic on weekends, day of week variations of traffic, and monthly variations of traffic if continuous counts are available.

- Additional research is necessary to determine the applicability of the developed methodology to study temporal variations of non-motorized traffic.

- Since the temporal distribution of truck traffic is different from the temporal distribution of total traffic, the addition of vehicle classification data would lead to a more comprehensive analysis and understanding of temporal traffic patterns.

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APPENDIX A: ENVIRONMENTAL SCAN

Jurisdictional Survey Form

General Information

Jurisdiction:	Road Network Length (centreline km):
Respondent's Name:	Number of Intersections:
Position:	Signalized Intersections:
Department/Branch:	Population:
Phone:	
Email:	

Introduction

1. What is the purpose of traffic monitoring in your jurisdiction?

2. Who are the primary users of the traffic monitoring program in your jurisdiction?

Public Sector	Private Sector
☐ traffic engineering	☐ consultant companies
☐ signals	☐ realtors
☐ city planning	☐ researchers
☐ other (specify):	☐ other (specify):

Data Collection

3. Please describe the permanent, coverage, and turning movement counting programs according to the table below.

	Continuous Counts	Short-Term (Sample) Counts (link)	Turning Movement Counts
Network portion where this type of count is used			
None	☐	☐	☐
All	☐	☐	☐
Freeway	☐	☐	☐
Arterial	☐	☐	☐
Collector	☐	☐	☐
Local	☐	☐	☐
Data elements collected by type of count			
Volume	☐	☐	☐
Classification	☐	☐	☐
Weight	☐	☐	
Speed	☐	☐	
Bicycles	☐	☐	☐
Pedestrians	☐	☐	☐
Other			
Typical count frequency			
Typical count duration			
Typical count data interval (e.g., 1 hour, 15 minutes)			
Locations/yr (core program)			
Locations/yr (request-based)			
Location selection rationale			

4. If classification data is collected, what classification scheme is used?

5. Who typically triggers request-based traffic studies (select all that apply)?

☐ Other departments ☐ Realtors ☐ Consultants

☐ Public complaints ☐ Researchers ☐ Others:

6. Are short-term counts restricted to particular seasons, weekdays, or hours? If yes, please explain.

Traffic Data and Major Planning Documents

7. Is the traffic monitoring program in your jurisdiction required to collect any traffic data specifically to assist with measuring the successful performance of a Transportation Master Plan (TMP) or Long Range Transportation Plan (LRTP)?

☐ Yes ☐ No

8. If yes to question 10, what types of traffic data are collected to measure plan performance?

Traffic Data Collected	Frequency of Data Collection	Geographical Scope of Data Collection (e.g. all network, key routes)	Related Plan Performance Indicators

9. If yes to question 10, approximately how much funding (if any) is provided through the planning process for these specific data collection requirements?

☐ Amount: $ ☐ No specific funding provided through the planning process

10. What are the primary goals in your jurisdiction's transportation master plan or long range transportation plan?(Alternatively, send the plan)

Data management and dissemination

11. lease describe the quality assurance/quality control procedures.
12. Is any software used for data screening? If yes, please specify.
13. Please indicate which traffic statistics are produced for each portion of the network in your jurisdiction in the table below:

Traffic Statistic	Network Portion for Which Traffic Statistic is Estimated					
	None	All	Freeway	Arterial	Collector	Local
AADT[1]	☐	☐	☐	☐	☐	☐
ADT[2]	☐	☐	☐	☐	☐	☐
AWDT[3]	☐	☐	☐	☐	☐	☐
AADTT[4]	☐	☐	☐	☐	☐	☐
Temporal Factors	☐	☐	☐	☐	☐	☐
Peak Hour Factors	☐	☐	☐	☐	☐	☐
VKT/VMT[5]	☐	☐	☐	☐	☐	☐
Other:	☐	☐	☐	☐	☐	☐

[1] Annual Average Daily Traffic
[2] Average Daily Traffic
[3] Average Weekday Daily Traffic
[4] Annual Average Daily Truck Traffic
[5] Vehicle Kilometres (or miles) Traveled

Additional comments

14. Please provide any additional comments.

APPENDIX B: TRAFFIC MONITORING IN WINNIPEG

Pedestrian Count Example

The City of Winnipeg
Public Works Department

PEDESTRIAN COUNT

15 HOUR RECORD ANALYSIS

Start Time 07:00 / END TIME	CROSSING ON THE WEST SIDE OF Arlington St					CROSSING ON THE EAST SIDE OF Arlington St					CROSSING ON THE NORTH SIDE OF McDermot Ave					CROSSING ON THE SOUTH SIDE OF McDermot Ave					TOTAL
	ADULT	CHILD	OTHER	ELDER	TOTAL	ADULT	CHILD	OTHER	ELDER	TOTAL	ADULT	CHILD	OTHER	ELDER	TOTAL	ADULT	CHILD	OTHER	ELDER	TOTAL	
07:15	1				1	1				1				1	1						3
07:30						1				1											1
07:45	1				1	2				2	2				2			1		1	6
08:00	2				2	1				1	1				1	1				1	5
08:15	2				2	2				2	1				1	2				2	7
08:30			2		2	2		1		3	1				1			1		1	7
08:45	1				1	1				1			1		1	1				1	4
09:00	1				1	1				1	1	1			2						4
10:00	2		2		4	5		2	2	9	2	2		1	5	1		1	1	3	21
11:00	1		4		5	1			1	2	2		1		3	1		2	1	4	14
12:00	3		3		6	5		2		7	3		1		4	4			1	5	22
13:00	6	1	2		9	13	2	6		21	3				3			2	1	3	36
14:00	16				16	18				18	6	2	2		10	6		2		8	52
15:00	7	2	10		19	19	4	9	3	35	14		3	1	18	10	2	4	1	17	89
15:15	2	2	1	1	6	1	1	1		3	2		1		3	1	1	2		4	16
15:30	2	2	1	1	6	3	1	1		5	2	1			3	2	2	1		5	19
15:45	6	4		1	11	2	2	1		5	1	2			3	1		1		2	21
16:00	2	1			3	4	2	2		8	2	1			3	1				1	15
16:15	2				2	2				2	1				1	1				1	6
16:30	1	2	1		4	4	4	5		13	1	1			2	2				2	21
16:45	2				2	2	2			4	3	2			5	1				1	12
17:00	1	2	1		4	2	1	1		4			2		2	1				1	11
17:15	1				1	2				2	2				2			1		1	6
17:30	1				1	1				1				1	1						3
17:45	2		1		3	2	3			5	2	3			5	1				1	14
18:00	3				3	5				5	4				4	3				3	15
19:00	8				8	8				8	23				23	7				7	46
20:00	7				7	3		4		7	16				16	13				13	43
21:00																					
22:00																					
15 HR. TOTAL	83	16	28	3	130	113	22	35	6	176	95	15	11	4	125	60	5	18	5	88	519

WEATHER	Clear	TEMPERATURE	
COUNTED BY	RA (Mio-Vision)	DATE	20100107
COMPILED BY	RA	DATE	20101007

LOCATION	DAY	MONTH	YEAR
Arlington & McDermot	07	10	2010

Automatic Link Count Database Report Example

Winnipeg

The City Of Winnipeg
Public Works Department

Transportation Division
Summary for Study 8344

Count Start: Mon, Jun 06, 2005 01:15 PM
Count End: Fri, Jun 10, 2005 11:15 AM

Location:
University Cr btw Dysart Rd and Chancellor Matheson Rd

Observations:
U OF M SUMMER CLASSES,(COUNT LOW)

Northbound

AM Peak (7:00 AM - 9:00 AM)

15 Minute	170	8:15 AM to 8:30 AM
1 Hour	539	8:00 AM to 9:00 AM
Total	819	7:00 AM to 9:00 AM

PM Peak (3:30 PM - 5:30 PM)

15 Minute	174	4:30 PM to 4:45 PM
1 Hour	588	4:00 PM to 5:00 PM
Total	992	3:30 PM to 5:30 PM

Non Peak (9:00 AM - 3:30 PM & 5:30 PM - 7:00AM)

15 Minute	126	10:30 AM to 10:45 AM
1 Hour	352	1:45 PM to 2:45 PM

Average Weekday Totals

8 Hour:	3,210	7:00 AM to 11:00 AM & 2:00 PM to 6:00 PM
12 Hour:	4,652	7:00 AM to 7:00 PM
24 Hour:	5,903	

Average Daily Totals (Including Weekends)

8 Hour:	N/A	7:00 AM to 11:00 AM & 2:00 PM to 6:00 PM
12 Hour:	N/A	7:00 AM to 7:00 PM
24 Hour:	N/A	

Southbound

AM Peak (7:00 AM - 9:00 AM)

15 Minute	164	8:15 AM to 8:30 AM
1 Hour	518	8:00 AM to 9:00 AM
Total	815	7:00 AM to 9:00 AM

PM Peak (3:30 PM - 5:30 PM)

15 Minute	126	4:30 PM to 4:45 PM
1 Hour	481	4:30 PM to 5:30 PM
Total	873	3:30 PM to 5:30 PM

Non Peak (9:00 AM - 3:30 PM & 5:30 PM - 7:00AM)

15 Minute	120	10:30 AM to 10:45 AM
1 Hour	310	1:45 PM to 2:45 PM

Average Weekday Totals

8 Hour:	2,997	7:00 AM to 11:00 AM & 2:00 PM to 6:00 PM
12 Hour:	4,237	7:00 AM to 7:00 PM
24 Hour:	5,464	

Average Daily Totals (Including Weekends)

8 Hour:	N/A	7:00 AM to 11:00 AM & 2:00 PM to 6:00 PM
12 Hour:	N/A	7:00 AM to 7:00 PM
24 Hour:	N/A	

Combined Average Weekday Totals

8 Hour:	6,207	7:00 AM to 11:00 AM & 2:00 PM to 6:00 PM
12 Hour:	8,889	7:00 AM to 7:00 PM
24 Hour:	11,367	

Processed Date: 12 Jul, 2005
Printed Date: 29 Sep, 2011

Turning Movement Count Database Report Example

THE CITY OF WINNIPEG						**8 Hour Manual Vehicle Count**									**Traffic Studies**		
PUBLIC WORKS DEPARTMENT						**Intersection Turning Movement**									**Phone: 986-5034**		
Time	**NORTHBOUND ON**				**SOUTHBOUND ON**				**EASTBOUND ON**				**WESTBOUND ON**				Previous Count
Start **7:00**	**Arlington St**				**Arlington St**				**Notre Dame Ave**				**Notre Dame Ave**				2000
Time Ending	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	**TOTAL**
7:15		2	84	8		6	74	23		6	210	26		4	240	20	703
7:30			122	10		1	96	27		9	264	23	1	3	327	26	909
7:45		1	117	10		3	128	27		9	291	30		1	333	23	973
8:00		3	168	8		1	162	31		11	364	35		6	368	23	1180
8:15			183	23		1	135	26		13	291	36		4	315	26	1053
8:30		1	163	8			150	32		9	369	37		7	312	29	1117
8:45			163	13		3	157	29		18	331	44		9	313	25	1105
9:00		6	160	12		2	137	30		24	305	40		12	278	27	1033
10:00		51	427	40		34	290	74		44	932	125		27	947	102	3093
11:00	1	42	287	23		51	242	54		47	800	110		19	844	85	2605
12:00																	
13:00																	
14:00																	
15:00		62	347	45		51	319	75	7	43	891	205	1	43	1017	112	3218
15:15		9	129	12		5	129	16	1	13	296	64		10	275	40	999
15:30		17	119	6		8	140	18	4	11	255	94		11	271	51	1005
15:45		5	142	16		1	123	16		17	307	71		8	276	29	1011
16:00		2	191	12			162	15		12	363	48		10	300	44	1159
16:15		4	165	8		2	153	21		22	368	36		14	309	26	1128
16:30		1	169	5		1	179	22		26	361	48		13	377	39	1241
16:45		3	175	8			140	18		16	340	69		13	308	45	1135
17:00		1	210	10		1	147	14	4	11	277	78		15	381	31	1180
17:15		2	158	6		4	133	18		16	272	52		12	313	35	1021
17:30		3	130	3		2	135	15		22	320	52		21	299	43	1045
17:45		22	113	8		9	98	20	1	15	222	29		7	248	41	833
18:00		22	116	7		7	87	15		19	218	47		18	226	21	803
19:00																	
20:00																	
21:00																	
22:00																	
8 hr.	1	259	4038	301		193	3516	636	17	433	8647	1399	2	287	8877	943	29549
TOTAL	4599				4345				10496				10109				
12 hr.est	1	376	5855	436		280	5098	922	25	628	12538	2029	3	416	12872	1367	42846
1.45	6668				6300				15220				14658				
24 hr. Est	1	500	7787	580		372	6780	1226	33	835	16676	2699	4	553	17120	1818	56984
1.33	8868				8378				20243				19495				
AM Peak Hour	**AM Peak Hour (between 7:00 and 9:00), based on total volume, is from:**												**7:45 - 8:45**				4531
		4	677	52		5	604	118		51	1355	152		26	1308	103	4455
Off-Peak Hour	**Highest Off-Peak Hour (between 9:00 and 15:00) is from:**												**14:00 - 15:00**				3339
		62	347	45		51	319	75	7	43	891	205	1	43	1017	112	3218
PM Peak Hour	**PM Peak Hour (between 15:00 and 18:00), based on total volume, is from:**												**16:00 - 17:00**				4938
		9	719	31		4	619	75	4	75	1346	231		55	1375	141	4684
Peak 15 Minute Time & PHF	**8:00 - 8:15**				**7:45 - 8:00**				**8:15 - 8:30**				**7:45 - 8:00**				**A.M. Peak**
		0.29	0.92	0.61		0.46	0.93	0.92		0.67	0.92	0.89		0.67	0.91	0.92	**PHF**
	14:00 - 14:15				**9:15 - 9:30**				**9:15 - 9:30**				**14:45 - 15:00**				**Average**
		0.57	0.81	0.59		0.75	0.76	0.78		0.83	0.86	0.66		0.92	0.97	0.78	**PHF**
	16:45 - 17:00				**16:15 - 16:30**				**16:15 - 16:30**				**16:15 - 16:30**				**P.M. Peak**
		0.56	0.86	0.72		0.61	0.89	0.86		0.76	0.97	0.74		0.73	0.90	0.80	**PHF**

Ratio: E/W to N/S =	2.30	**Shift**	**AM**	**PM**	EVE
E/W =	69.7%	Weather:	Cloudy	Cloudy	
N/S =	30.3%	Temperature:	-8	-4	
		Counted/Compiled By:	RA-DL/RA		
Location:		Count Date:	20100119	20100118	
Arlington St & Notre Dame Ave		Requested By:	David Tang		
Notes:					

Table 30 Routes with more than 60 Counts (2001-2010)

Route	Route's description	Number of Counts
42	Henderson Hwy – Pembina Hwy	193
52	Main St – St Mary's Rd	145
62	Salter St – Osborne St – Dakota St	110
90	Brookside Blvd – King Edward St – Kenaston Hwy	106
85	Portage Ave	97
57	Dublin Ave – Notre Dame Ave – Provencher Blvd	94
20	Lagimodiere Blvd (including sections of PTH 59)	87
37	Redwood Avenue – Nairn Ave – Regent Ave – Pandora Ave W – Pandora Ave E	71
115	Marion St – Dugald Rd	66
70	Sherbrook St – Maryland St – Stafford St	61

Source: Based on data provided by Traffic Studies Section, City of Winnipeg

Data Users Survey Form

Branch/Group: ____________________ Contact Person: ____________________ Phone: __

Type of Data	Data Need			Street Classification				Is Need Being Met?			
	Essential	Useful	Not Needed	Regional	Collector	Local	All Streets	Yes	No	Partly	Comments
1. Traffic Volume Data											
1.1 Annual Average Daily Traffic (AADT)											
1.2 Average Week Day Traffic (AWDT)											
1.3 Average Daily Traffic (ADT)											
1.4 AM/PM Peak Hour											
1.5 Vehicle-Kilometres of Travel (VKT)											
1.6 Other											
2. Traffic Variation & Distribution											
2.1 Hourly Variation of Traffic											
2.2 Day-of-Week Variation of Traffic											
2.3 Seasonal Variation of Traffic											
2.4 Temporal Factors											
2.5 Directional Distribution of Traffic											
2.6 Lane Distribution of Traffic											
2.7 Turning Movements at Intersections											
2.8 Vehicle Speeds											
2.9 Traffic Growth Factors											
2.10 Other											
3. Vehicle Classification											
3.1 Annual Average Daily Truck Traffic (AADTT)											
3.2 Truck Percent											
3.3 Axle Correction Factors											
3.4 Truck Trailer Body Type (van, dump, container,...)											
3.5 Long Combination Vehicles (LCVs)											
3.6 Other											

APPENDIX C: METHODOLOGY

The data cleaning process includes the following steps:

a) Convert data in the proper format from text format including: dates, times and count data.
b) Reject days with less than 24 consecutive hours.
c) Obtain the combined traffic adding both directions of traffic.
d) Delete duplicate records
e) Join the data that is collected in the same location at the same tame in two different studies (one study per direction).
f) Delete values showing “N” inside “USE A” or “USE B” column.
g) Combine studies from the same segment ID and same date and hours for control stations with one direction configuration where there are NO “Count B” data.
h) Reject days with less than 24 hours of data.
i) Group 15-minutes counts into 1-hour counts.
j) Use counts that have data for every day of the week for the day of week traffic variation analysis and for the initial hourly variation analysis.

November 21, 2012

Mark Reimer, EIT
Department of Civil Engineering
University of Manitoba

RE: Copyright Permission

Dear Mr. Reimer

I am requesting permission to include in my graduate thesis, entitled *Temporal Variations for Monitoring Traffic in Urban Areas,* an adaptation of the following material:

> **FIGURE 1 Components and considerations of the hybrid approach**
> Obtained from an electronic copy of the original manuscript:
> Reimer, M., & Regehr, J. (2012). A Hybrid Approach for Clustering Vehicle Classification Data to Support Regional Implementation of the Mechanistic-Empirical Pavement Design Guide (Paper Accepted for Presentation). *Transportation Research Board Annual Meeting 2013.* Washington, D.C.: Transportation Research Board.

My thesis will be microfiched and although it may be reproduced and made available in various formats by University Microfilms International (UMI)/ProQuest. My thesis will also be available in paper format from the University of Manitoba Libraries. It will also be posted electronically and will be accessible for free to a worldwide audience from the University of Manitoba's digital repository called MSpace (http://mspace.lib.umanitoba.ca/index.jsp), and from the Library and Archives Canada's Theses Portal (http://www.collectionscanada.gc.ca/thesescanada).

Access to the thesis in digital format is free of charge and therefore, no profit will be realized from the work. Please respond in writing to confirm whether or not you will grant permission for the above-mentioned work to be included in my thesis, as well as any stipulations that you request.

Thank you very much for your consideration of this request.

Henry Hernandez, P. Eng.
Department of Civil Engineering
University of Manitoba
Winnipeg, MB
Tel: (204) 474-7367
Fax: (204) 474-7549
umhernah@cc.umanitoba.ca

Henry Hernandez
Subject: FW: Copyright Permission
Attachments: Reimer_Copyright_Permission Request.docx; Hybrid Approach for the Development of Traffic Pattern Groups - Adapted from Reimer & Regehr 2012.docx
From: Henry Hernandez [mailto:umhernah@cc.umanitoba.ca]
Sent: November-21-12 9:27 PM
To: XXXXXXX@XXXXXX.com
Subject: Copyright Permission

On Wed, Nov 21, 2012 at 9:26 PM, Henry Hernandez <umhernah@cc.umanitoba.ca> wrote:

Hi Mark

I am completing my Master of Science in Civil Engineering on "Temporal Variations for Monitoring Traffic in Urban Areas". I would like to adapt the figure 1 on page 6 of the document

Reimer, M., & Regehr, J. (2012). A Hybrid Approach for Clustering Vehicle Classification Data to Support Regional Implementation of the Mechanistic-Empirical Pavement Design Guide (Paper Accepted for Presentation). Transportation Research Board Annual Meeting 2013. Washington, D.C.: Transportation Research Board.

I have attached the adapted figure and a letter requesting permission to include in my thesis the adaptation of your figure. You don't need to sign the letter; your email response will suffice. I will PDF the email and add it in an appendix next to the permission letter.

Thank you for your consideration. If you require further information, please don’t hesitate to contact me

Henry Hernandez, P.Eng.
Engineering Research Associate
University of Manitoba Transport Information Group (UMTIG)
Department of Civil Engineering

From: Mark Reimer [mailto:XXXXXXXX@XXXXXX.com]

Sent: November-22-12 11:28 AM

To: Henry Hernandez

Subject: Re: Copyright Permission

Hi Henry,

I would be honored to have an adaptation of my Figure 1 from the noted paper included in your thesis - I give you full permission to use it.

Best of luck as you move on from this stage of your education!

--

Mark Reimer

APPENDIX D: TEMPORAL TRAFFIC VARIATION IN WINNIPEG

Traffic Database Field's Description

Table 31 Traffic Database Field's Description

Field	Description
ID1	Unique value for every record
STUDYID	Study ID number
DESCRIPTION	Indicates if the study includes one or two directions, or is on a divided or undivided facility
LOCATION DESCRIPTIONS	Describes the study's location; generally includes the road in which the study is performed and the two roads that intersect the specific segment.
ID	Indicates the control segment ID used by the City of Winnipeg (The research uses this field to link the count locations with the City of Winnipeg's GIS map).
DESCRIPTION	Provides the traffic direction (Eastbound, Westbound, Northbound and Southbound) of the data located in the "A" field.
OBSERVATIONS	Contains the following information: person who requested the count, clarifications related to count location, anomalies in the count, and special conditions in the surrounding areas like road construction, detours, etc.
BEGINDATETIME	Provides study's begin date and time
BEGINDATE	Provides study's begin date
BEGINTIME	Provides study's begin time
ENDDATETIME	Provides study's end date and time
ENDDATE	Provides study's end date
ENDTIME	Provides study's end time
SERIALNUMBER	Indicates counter's serial number
UNITTYPE	Indicates counter's type employed.
COUNTDATEANDTIME	Provides date and time of each record in 15-min intervals.
COUNTA	Provides traffic volume in "A" (same as DESCRIPTION) direction.
USEA	Indicates if the record's includes traffic volume in the "A" direction.
COUNTB	Provides traffic volume in "B" (opposite to DESCRIPTION) direction.
USEB	Indicates if the record's includes traffic volume in the "B" direction.

Cluster Analysis Code

The research uses following code to develop the time of day cluster analyses.

```
title 'Time of Day Cluster Analysis - City of Winnipeg';
proc print data=TOD1;
proc cluster data=TOD1 method=ward outtree=tree
       ccc psuedo;
       id STUDYID;
proc print data=tree;
proc tree data=tree Horizontal;
       height _NCL_;
       id STUDYID;
run;
proc tree data=tree lineprinter;
       id STUDYID;
run;
proc tree data=tree lineprinter;
       height _NCL_;
       id STUDYID;
run;
proc tree noprint data=tree out=part nclusters=8;
id STUDYID;
proc sort;
       by cluster;
proc print label uniform;
id STUDYID;
by cluster;
run;
```

Absolute Precision Intervals (D_a) by TPG (95% Confidence Level)

Table 32 Absolute Precision Intervals by TPG

Hour	Residential Roads	Average Arterial Roads	Arterial Roads	Arterial Roads	Commercial Roads	Industrial Roads	School Areas	General Average
TPG	TPG 1	TPGs 2 and 3	TPG 2	TPG 3	TPG 4	TPG 5	TPG 6	Average
0	0.0	0.0	0.1	0.0	0.1	0.3	0.1	0.0
1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
2	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0
3	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
4	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0
5	0.0	0.0	0.1	0.0	0.1	0.3	0.1	0.0
6	0.1	0.1	0.1	0.1	0.3	1.1	0.2	0.1
7	0.1	0.1	0.2	0.2	0.5	1.1	1.2	0.1
8	0.1	0.1	0.1	0.1	0.4	0.8	1.5	0.1
9	0.1	0.1	0.1	0.1	0.3	0.9	0.5	0.1
10	0.1	0.1	0.1	0.1	0.2	0.9	0.3	0.1
11	0.1	0.1	0.1	0.1	0.3	0.8	0.5	0.1
12	0.1	0.1	0.1	0.1	0.5	0.7	0.5	0.1
13	0.1	0.1	0.1	0.1	0.4	0.8	0.4	0.1
14	0.1	0.0	0.1	0.1	0.3	0.7	0.5	0.1
15	0.1	0.1	0.1	0.1	0.3	1.1	1.2	0.1
16	0.1	0.1	0.1	0.1	0.3	1.0	0.7	0.1
17	0.1	0.1	0.1	0.1	0.4	1.0	0.6	0.1
18	0.1	0.1	0.1	0.1	0.4	0.6	0.5	0.1
19	0.1	0.1	0.1	0.1	0.7	0.4	0.5	0.1
20	0.1	0.1	0.1	0.1	0.4	0.4	0.5	0.1
21	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.1
22	0.1	0.1	0.1	0.1	0.2	0.4	0.2	0.0
23	0.1	0.0	0.1	0.1	0.3	0.4	0.1	0.0

Land Zones by Refined TPG

Table 33 Number of Land Zones by Refined TPG. Overlay Analysis, City of Winnipeg

TPG	Total	Residential	Commercial	Industrial	Agriculture	Park	Other
TPG 1	2308	1826	208	32	93	140	9
TPG 2	234	97	94	17	10	14	2
TPG 3	191	65	47	48	19	12	0
TPG 4	58	10	22	22	1	3	0
TPG 5	50	14	6	26	4	0	0
TPG 6	95	80	9	0	1	5	0
Total	2936	2092	386	145	128	174	11

Commercial TPG 4 Segments

Table 34 TPG 4 Commercial Segments

ID	Road Class	Road Class Name	Road Name	Nearby Facilities
s90037	A	Major Arterial	Century St	Polo Park
s6346	A	Major Arterial	Corydon Ave	Tuxedo Park
s6560	A1	Minor Arterial	Ellice Ave	Polo Park
s6593	A1	Minor Arterial	Ellice Ave	Polo Park
s6578	A1	Minor Arterial	Empress St	Polo Park
s6520	A1	Minor Arterial	Empress St	Polo Park
s6519	A1	Minor Arterial	Empress St	Polo Park
s6581	A1	Minor Arterial	Empress St	Polo Park
s90873	Coll2	Collector	Lindenwood Dr E	Kenaston and McGillivray Area (Wal-Mart, Canadian Tire, Cinema City, Costco, Safeway, Sobeys, etc.)
s5487	A	Major Arterial	McPhillips St	Safeway, Canada Ins. South of McPhillips and Leila Area
s1000	L	Local	Murdock Rd	Buhler Recreation Park
s6574	A1	Minor Arterial	Sargent Ave	Polo Park
s6596	A1	Minor Arterial	Sargent Ave	Polo Park
s12120	L	Local	Webster Ave	South Transcona Community Club
s6597	A1	Minor Arterial	Wellington Ave	Polo Park
s6572	A1	Minor Arterial	Wellington Ave	Polo Park
s8612	L	Local	Wilton St	Grant Park

TPG 5 Industrial Segments

Table 35 TPG 5 Industrial Segments

ID	Road Class	Road Class Name	Road Name	In Industrial Zone of at the boundary?	Comments
s2049	Coll2	Collector	Moray St	In industrial area	
s2056	Coll2	Collector	Moray St	In industrial area	
s7900	Coll2	Collector	Notre Dame Ave	At the border of an industrial area	
s95	Coll2	Collector	Fennell St	In industrial area	
s8257	Coll2	Collector	Irene St	In industrial area	
s10082	L	Local	Pacific Ave	In industrial area	
s14054	L	Local	Chelsea Ave	Access to an industrial area	
s13813	L	Local	Grey St	In industrial area	
s12336	L	Local	St Boniface Rd	Access to an industrial area	
s12350	Coll2	Collector	Beghin Ave	In industrial area	
s12124	L	Local	McFadden Ave	At the border of an industrial area	South of Transcona yards
S12146	L	Local	Ham St	Access to an industrial area	
s91034	PR1	Minor PR	PR 427	Out of City Borders	Industry and Farms (Wilkes Ave)
s90161	PR1	Minor PR	PR 425	Out of City Borders	Farms

TPG 6 School Segments

Table 36 TPG 6 School Segments

ID	Road Class	Road Class Name	Road Name	School Name	Land Use
s12866	L	Local	Ashworth St S	HS Paul School	Residential
s14403	L	Local	Cobourg Ave	Glenem School	Residential
s5932	L	Local	Darwin St	Darwin School	Residential
s6365	L	Local	Doncaster St	Gray Academy of Jewish Education	Residential
s11667	L	Local	Egerton Rd	Glenwood School	Residential
s3335	L	Local	Harcourt St	College Sturgeon	Residential
s12662	L	Local	Hastings Blvd	École Marie-Anne-Gaboury	Residential
s4042	L	Local	Hay St	Churchill High School	Residential
s4040	L	Local	Hay St	Churchill High School	Residential
s529	Coll2	Collector	Highbury Rd	Highbury School	Residential
s7403	L	Local	Kingsway	Kelvin High	Residential
s7533	L	Local	Laidlaw Blvd	Laidlaw School	Residential
s1183	L	Local	Leach St	École Saint Avila	Residential
s7756	L	Local	Lockwood St	Carpathia School	Residential
s9398	L	Local	Machray Ave	Robertson School	Residential
s8796	L	Local	Manahan Ave	St Maurice School	Residential
s6733	L	Local	Middle Gate	Westgate Mennonite Collegiate	Residential
s1182	L	Local	Patricia Ave	École Saint Avila	Residential
s15230	L	Local	Ridgecrest Ave	West Kildonan Collegiate	Residential
s13865	L	Local	Riverton Ave	River Elm School	Residential
s8450	L	Local	Riverwood Ave	École Viscount Alexander	Residential
s772	Coll2	Collector	Scurfield Blvd	Henry G Izatt Middle School	Residential
s11764	L	Local	Varennes Ave	École Varennes	Residential
s8247	L	Local	Wicklow St	École Viscount Alexander	Residential
s8252	L	Local	Wicklow St	École Viscount Alexander	Residential