Developing Expansion Factors to Estimate Cyclist Seasonal Average Daily Traffic in Winnipeg, MB

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

This research examines travel characteristics of cyclists on active transportation (AT) paths in the City of Winnipeg and develops expansion factors to be applied to short duration cyclist volume counts conducted in Winnipeg, MB. The expansion factors will be applied to short duration counts to estimate seasonal average daily traffic (SADT) volumes in Winnipeg and normalize counts taken on different days with different conditions that could affect levels of cycling in a jurisdiction. This will help answer critical questions regarding cycling in a jurisdiction and allow transportation professionals promote the safe and equitable accommodation of cyclists in our transportation system. This thesis (1) determines which months should be included in the SADT calculation for Winnipeg and selects a method of expansion based on ten years of historical weather data and one year of cyclist volume data; and (2) develops expansion factors which can be applied to short duration counts in order to estimate SADT.

ACKNOWLEDGEMENTS

I want to express my sincere gratitude to my advisor, Dr. Jeannette Montufar, P.Eng., for her help, guidance, and encouragement during the process of completing this thesis. Through the duration of my graduate studies she has provided me with numerous experiences which have helped me to develop my own skills further and transform me into the engineer I have become.

I am extremely thankful to Mr. Kevin Nixon from the City of Winnipeg for providing funding towards this research and supplying me with valuable insight throughout this thesis. I would also like to express my deepest thanks to Mr. Jean-Francois Rheault and the staff at Eco-Counter for their continuous technical support. My sincere thanks to other individuals who also provided continuous support throughout this thesis – Dr. Orly Linovski from the Department of City Planning, and Dr. Jonathan Regehr, P.Eng., from the Department of Civil Engineering.

I am also grateful to my fellow graduate students at the University of Manitoba Transport Information Group for all of their support, especially Rob Roy Poapst, EIT, Mark Vogt, EIT, Maryam Moshiri, EIT, and Karen Wiens.

I would also like to acknowledge the financial assistance provided by the Canadian Institute of Transportation Engineers, and the Transportation Association of Canada.

Finally, I am grateful for the patience, support, and encouragement of my family and friends over the past two years – specifically my mother and father whose love for their children is rivalled by many – but matched by none. I also wish to express my greatest thanks to Rebecca Peterniak, EIT. Rebecca not only introduced me to the world of transportation engineering, but also provided me with support and advice throughout my graduate studies as both a colleague and as my best friend of 26 years.

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1 INTRODUCTION

1.1 PURPOSE

The research examines travel characteristics of cyclists on active transportation (AT) paths in the City of Winnipeg and develops expansion factors to be applied to short duration cyclist counts conducted in Winnipeg, MB. Ten automated cyclist counters were installed at various locations on five AT paths in Winnipeg. Each counter collected data at the same location for a one year period. These data were analyzed to determine daily cyclist traffic patterns and create expansion factors for cyclist data to estimate annual statistics. The expansion factors can then be used to expand short duration counts at multiple sites across Winnipeg in an effort to quantify cycling across the entire city. This will be one of the first steps in implementing a formal cyclist travel monitoring program.

1.2 BACKGROUND AND NEED

Cycling provides a wide range of benefits to a community such as improving the overall health of a population, decreasing congestion on roadways, and reducing carbon emissions (Pucher et al., 2010) (WHO, 2008). These benefits have justified an increase in funding opportunities for AT projects over the past 20 years (McCann et al., 2009). It is transportation professionals who are responsible for these AT projects that promote the safe and equitable accommodation of cyclists. This task requires a comprehensive understanding of the travel characteristics of these users to ensure they are properly accommodated in our transportation system. Although there have been improvements to the frequency and quality of cyclist traffic data collection, it is still nowhere near the level to which motorized traffic is monitored (FHWA, 2013).

It is imperative that travel patterns of cyclists be monitored in order to understand their travel characteristics (Schneider, Patton, Toole, & Raborn, 2005). The collection of cyclist data yields several benefits, including:

- Determining expansion factors that can be used to estimate cyclist volumes;
- Documenting changes in cyclist activity, safety, and facilities over time;
- Identifying locations for cyclist facility improvements; and
- Using data in cyclist planning documents.

However, the lack of cyclist count data is one of the greatest impairments to completely understanding travel characteristics of cyclists (Alta Planning & Design, 2015). Most jurisdictions currently have no formal cyclist monitoring program in place. This lack of data can cause problems when determining how to allocate funding for new projects and answer critical questions about the impacts of completed work. Many jurisdictions, including Winnipeg, perform short duration counts in order to determine cyclist volumes. The majority of these counts are hourly volume counts taken on different days for different durations of time, and cannot accurately quantify cyclist traffic across an entire jurisdiction due to the amount of volatility associated with cyclist volumes from day to day. Daily (24-hour) cyclist volume counts are sometimes conducted, but not necessarily on the same date. Given the variability associated with cyclist traffic, comparing daily volumes taken on different dates between different locations does not allow for an appropriate comparison.

A common practice in traffic monitoring is to develop expansion factors based on data collected at continuous count stations (sites where data is collected 24 hours a day, generally for at least a one year period) in order to improve data quality. Expansion factors help to normalize daily volume data to average daily volume estimates over a season or year to allow for better comparisons to be made between sites where cyclist data is collected. According to the Traffic Monitoring Guide, in order to effectively apply expansion factors to hourly or daily volume counts it is essential to use data from continuous count stations to establish temporal patterns (FHWA, 2013).

This research develops and implements a methodology to collect and analyze cyclist volume data on AT pathways in Winnipeg over all seasons. Ten continuous cyclist counting devices were installed to generate data which could be used to create expansion factors. Expansion factors were created which can be applied to daily volume counts in order to estimate seasonal average daily traffic (SADT). The results of this research provide information on the temporal patterns of cyclists on AT pathways. This will improve the knowledge and understanding of cyclist traffic in Winnipeg and allow transportation professionals to develop new concepts in the planning, design, operation, and maintenance of these facilities.

1.3 OBJECTIVES AND SCOPE

Specific objectives of this research are to:

(1) Understand current practices regarding the collection and expansion of cyclist traffic data including what other jurisdictions in Canada and the U.S. have done or are doing regarding cyclist traffic monitoring.

(2) Identify the leading technologies currently available for continuous cyclist traffic monitoring and select the most appropriate technology to be used in Winnipeg.

(3) Design a method to collect and analyze cycling traffic data, including the selection of a continuous cyclist traffic monitoring technology, selection of sites, data collection system, and equipment calibration.

(4) Design methods to expand cyclist traffic data in Winnipeg, MB, taking into consideration location, weather and temporal variations such as time-of-day, and day-of- season.

(5) Determine appropriate times and durations of short duration counts which are intended to be expanded to SADT.

The scope of this research is limited to AT paths. The expansion factors created in this research apply only to short duration counts which are collected on AT pathways and are 1-day in duration or longer. However, these expansion factors may be applicable to other types of cyclist facilities as well. The research takes place in Winnipeg, a city characterised by long harsh winters, short hot summers, and home to an estimated 699,300 citizens as of the year 2013 (Statistics Canada, 2014). The data analyzed in this research was collected over the one year period beginning November 1st, 2013 and ending October 31st, 2014.

1.4 THESIS ORGANIZATION

This thesis is divided into six chapters. Chapter 2 summarizes findings from the environmental scan regarding cyclist traffic data collection. The environmental scan is comprised of a literature review and a jurisdictional survey including Canada and the U.S. This chapter addresses the following:

- Technologies currently available to collect cyclist traffic data; and
- Current practices regarding the collection and expansion of cyclist traffic data.

Chapter 3 outlines the methodology developed for this research to collect and analyze cyclist traffic data. The methodology includes:

- Selection of technology to continuously monitor cyclist traffic;
- Selection of sites to continuously monitor cyclist traffic;

- The data collection system;
- Equipment calibration; and
- Special issues associated with the equipment chosen to monitor cyclist traffic.

Chapter 4 analyzes the data collected in Winnipeg to:

- Determine which months should be consistently included in the SADT calculation for Winnipeg, MB; and
- Determine which expansion method will be most appropriate to use for data collected in Winnipeg, MB;

Chapter 5 uses the analysis from Chapter 4 to create expansion factors for Winnipeg, MB, which can be applied to daily volume data to estimate SADT. The accuracy of the expansion factors are then tested and conclusions are drawn with regards to how long, and during which months short duration counts should be conducted.

Chapter 6 discusses research findings and conclusions, and opportunities for future research.

1.5 TERMINOLOGY

The following terms are used throughout the thesis.

Continuous Count Station (CCS) – a site where volume data is collected 24 hours a day for a one year period.

Cyclist Annual Average Daily Traffic (AADT) – the average daily number of cyclists observed passing a point for a one year period.

Cyclist Seasonal Average Daily Traffic (SADT) – the average daily number of cyclists observed passing a point during months which contain 80% of the annual traffic.

Expansion Factors – factors applied to short duration counts in order to estimate volumes at either a different time or a longer time than was counted. For example, expansion factors can be applied to hourly volume counts to estimate daily volume estimates, or to daily volume counts to estimate average annual daily volume estimates. The term “expansion” does not necessarily mean that the volume will be increased. For the purpose of this research, the term “expansion” is used as the period of time for which an average daily volume is applicable is being expanded.

Short Duration Count (SDC) – a count performed at a site which can last anywhere from 15 minutes to two weeks.

Traffic Pattern – the regular or repeated way which traffic behaves at a site. Many different types of traffic patterns exist, for example, time of day (hourly), day of week, month of season, and day of season.

Traffic Pattern Group (TPG) – a group of sites which exhibit similar traffic patterns.

2 ENVIRONMENTAL SCAN

This chapter summarizes findings from the environmental scan regarding cyclist traffic data collection. The environmental scan is comprised of a literature review and a jurisdictional survey including Canada and the United States. The scan addresses the following:

(1) Statistics to report on cyclist volume data;

(2) Current practices regarding the collection of cyclist volume data;

(3) Technologies currently available to automatically collect cyclist volume data; and

(4) Current practices regarding the expansion of cyclist volume data

2.1 LITERATURE REVIEW

A comprehensive literature review was conducted of research published in the last 15 years. The literature search included a variety of data and information sources including research periodicals, journals, readily available papers, conference proceedings, special government reports, and documents on the World Wide Web. Two documents were used for primary guidance:

- The Traffic Monitoring Guide - 2013 (Federal Highway Administration); and
- AASHTO Guidelines for Traffic Data Programs (American Association of State Highway and Transportation Officials).

Together, these documents provide strategies and methodologies to be used when implementing a traffic monitoring program, or analyzing traffic data in North America. Although both of these are American documents, they are used across Canadian jurisdictions.

2.1.1 Statistics to Report for Permanent Cyclist Volume Counting Sites

Most traffic engineering and planning applications require annual traffic statistics. The Traffic Monitoring Guide (TMG) provides guidance for traffic monitoring programs in North America and released a new edition in 2013 which includes a chapter dedicated to “Traffic Monitoring for Non-Motorized Modes”. The TMG recommends several summary statistics to report for cyclist traffic modes. In particular, two statistics were identified which pertained specifically to this research (FHWA, 2013):

- Annual Average Daily Traffic (AADT); and
- Seasonal Average Daily Traffic (SADT).

Average Annual Daily Traffic (AADT)

AADT is defined as the average daily number of cyclists observed at a location for a one year period. It is the most commonly used statistic in motor vehicle traffic monitoring. Typically, the primary goal of vehicle traffic monitoring programs is to expand short duration counts to AADT estimates in order to standardize sites and ensure that fair comparisons are made when analyzing traffic volume data (FHWA, 2013). The formula for calculating AADT was developed by AASHTO and adopted by the TMG. This formula can be seen below:

$$AADT = \frac{1}{7}\sum_{i=1}^{7}\frac{1}{12}\sum_{j=1}^{12}\frac{1}{n}\sum_{k=1}^{n} VOL\,(i)(j)\,(k)$$

Where:

VOL	=	daily traffic for day (k), of DOW (i), and month (j)
(i)	=	day of week
(j)	=	month of 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 in a month
n	=	the number of days of that day of the week during that month

This formula first averages the same days – for example, Tuesdays – within each month to create monthly average day of week traffic volumes. These volumes are then averaged across the year in order to create annual average day of week traffic volumes for each type of day. Finally, the annual average daily traffic volumes from each day of the week are averaged to create an AADT volume. This formula uses the following two assumptions regarding daily traffic volumes:

(1) Daily traffic volumes are influenced by the month of year and relatively consistent within the same month; and
(2) Daily traffic volumes are influenced by the day of week, and days of the same week within the same month will have similar proportions of weekly traffic.

By using these assumptions, AADT estimates can still be made for incomplete data sets, as the formula only requires one of each day of the week (Monday to Sunday) for each month. These assumptions have proven to be true for vehicle traffic, but no research was identified which tested either of these assumptions with regards to cyclist volume data.

Seasonal Average Daily Traffic (SADT)

SADT is defined as the average daily number of cyclists observed at a CCS in months that contain at least 80% of the annual traffic. This statistic is typically used in recreational areas with very high seasonal peaking such as a National Park. The formula for SADT is almost the same as the formula for AADT, but the number of months included in the calculation is reduced (FHWA, 2013).

2.1.2 Cyclist Volume Data Collection

In order to develop statistics for a given location data must be collected. This can be done using both continuous counts from continuous count stations (CCS) and short duration counts (SDC). Both types of counts are used frequently in traffic monitoring programs and are described in detail below.

Continuous Counts

In most jurisdictions, the continuous counts form the basis of the overall traffic monitoring program. Continuous counts are taken from continuous count stations which collect traffic volume data 24 hours a day, 7 days a week, generally over the entire year. The data from these locations are used to generate traffic statistics such as AADT or SADT and can also be used to expand SDC data to these statistics (FHWA, 2013). Data is usually collected in 15-minute, 1-hour, or 2-hour bins, which allows for the creation of hourly TOD profiles at CCS. Data are collected using automated technologies, as it would be impossible to collect continuous data using manual counters. Types of automated technologies for collecting cyclist volume data are further discussed in Section 2.1.3.

Short Duration Counts (SDC)

Since it would not be feasible or practical to deploy a CCS at every location where cyclist volume data was needed, SDC are often taken to help monitor cyclist traffic. Typically, the duration of a SDC can be as short as 15 minutes, and can last up to two weeks. Hourly data can usually be collected by one or more manual observers, but for durations of 12 hours or more automated counting technologies are used. Using automated counting technologies requires capital investment that many jurisdictions do not have access to. As a result, many jurisdictions still collect data in the hourly form. A study which surveyed 11 jurisdictions in the United States found that six used automated counting devices to collect data for durations of more than 24 hours. The recurring issue facing most jurisdictions in this study was a lack of resources, but many indicated they have experienced successes with recruiting large amounts of volunteers to conduct manual hourly SDC (Hudson, Qu, & Turner, 2010).

2.1.3 Automated Cyclist Volume Count Technologies

The literature identified multiple automated cyclist counting technologies and four technologies emerged for practical use in Winnipeg, MB:

- Inductive loops;
- Active infrared;
- Video imaging; and
- Pneumatic tubes.

Findings regarding each of the technologies are summarized below. The summarized findings include how each technology works, pros and cons associated with each technology, and how each technology performed in other research studies.

Inductive Loops

Inductive loop technology is commonly used to count motorized traffic and detect the presence of motor vehicles at stoplights. Recently, inductive loops have become a popular way to count cyclists. Inductive loop counters operate by generating an electromagnetic field around wire coiling wound in a loop formation and embedded in the pavement. When a conductive object passes over the field, such as a bicycle, it induces eddy currents in the circuit, which changes the circuit's inductance. The change in inductance is recorded by a device and the device then records a count. They are unable to detect pedestrians as inductive loops only detect conductive objects containing ferrous metal (L. Klein, 2006).

Some inductive loops can distinguish the direction of travel of a cyclist, depending on the configuration of the loops. This can be done by installing two inductive loops in series along the facility where cyclists are intending to be counted. The counter determines the direction of travel based on which loops electromagnetic field was disrupted first. The wiring for an inductive loop counter is embedded in the pavement making them difficult to remove.

Inductive loops can also be installed in soft soils (i.e. gravel pathways) by burying pre-formed wiring under the path. Inductive loops can be installed on any type of facility, but when installed on-street they must be calibrated and the settings must be adjusted in order to prevent them from counting motorized traffic (Nordback, Piatkowski, Janson, Marshall, Krizek, & Main, 2011). Research has proven that if they are installed and maintained correctly, inductive loop counters have very high accuracy. In Boulder, CO, researchers found that loops in their jurisdiction had a mean absolute percent error (MAPE) of 19 percent, based on 9.5 hours of count data (Nordback & Janson, 2010). The National Cooperative Highway Research Program (NCHRP) recently published a study which tested various types of automated pedestrian and cyclist counting technologies, titled NCHRP 07-19: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection. NCHRP 07-19 had similar findings to Nordback and Janson, recording a MAPE of 18 percent based on 273 hours of count data (NCHRP, 2015).

Active Infrared

Active infrared detectors send a series of infrared pulses in a beam from a transmitter across a sidewalk or pathway to a receiver. When the beam is broken by a pedestrian or cyclist a count is recorded. Because an active infrared device will only record a count if the beam is broken, active infrared units do not typically distinguish between cyclists and pedestrians. Active infrared detectors also have problems detecting users travelling side by side in platoons. This effect, known as “occlusion” can have a significant effect on the accuracy of the devices as each group of cyclists riding side-by-side may only get counted once.

The Massachusetts Highway Department tested the capabilities of an overhead mounted active infrared device to evaluate its capabilities of counting and classifying cyclists properly.

The device was able to record the user height, vertical profile, width, length, and speed in order to count and classify cyclists. This study found that while 97 percent of cyclists were counted, only 77 percent were properly classified as cyclists (FHWA, 2005). Users that were improperly classified as cyclists were classified as motorcyclists. This technology performed well when tested in NCHRP 07-19, with a MAPE of 12 percent based on 30 hours of count data. However, in this study the devices ability to detect pedestrians and cyclist separately was not analyzed (NCHRP, 2015).

Video Image Processing

Video imaging applies complex visual pattern recognition algorithms to pre-recorded video data in order to identify cyclists. Few recognition algorithms have been developed for cyclists specifically. Rogers and Papanikolopoulos (2000) found that using video imaging to count cyclists on an AT path trail yielded a 70 percent accuracy rate for a variety of weather conditions. Dukesherer and Smith (2001) developed a hybrid algorithm which accurately counted 95 percent of cyclists in “clean” imagery conditions. However, the performance of the algorithm did not extend to “natural” imagery, which may have had snow, rain, fog or varying amounts of sunlight. These factors can influence the accuracy of video imaging significantly, with the highest accuracy being observed on clear, sunny days (MnDOT, 2010). Video imaging requires large capital spending to obtain proper video cameras. The additional fees for processing data prevent this method from being economically feasible as a continuous counting device. However, jurisdictions already using video cameras to analyze vehicle traffic can easily request that the recorded data be analyzed for both vehicle and cyclists volumes. The NCHRP 07-19 report did not test video image processing for its ability to detect and count cyclists (NCHRP, 2015).

Pneumatic Tubes

Pneumatic tube counters consist of rubber road tube(s) connected to a data logger. When a cyclist goes over the set of tubes, it generates an air pulse which travels to the data logger to be recorded as a count. The rubber road tubes are thinner and smaller than traditional road tubes for counting motorized traffic, as cyclists may not have enough force to generate a pulse when travelling over regular road tubes. Pneumatic tubes are typically for SDC, as they are a more invasive technology; the tubes can become a tripping hazard for pedestrians and rollerbladers on paths and can easily become damaged and require replacement tubing. These counting devices are relatively easy to transport and set-up, and have been proven to have perfect accuracy (100 percent) when counting cyclists at off-street locations and high accuracy (86 perfect) when counting cyclists at on-street locations (Macbeth & Weeds, 2002). NCHRP 07-19 found that pneumatic tubes had a MAPE of 19 percent, based on 160 hours of count data (NCHRP, 2015).

2.1.4 Data Expansion

Since it would not be practical or cost effective to install permanent counting devices at all locations where cyclist volume data is needed jurisdictions will often conduct and expand SDC to annual statistics (for example, expanding a daily cyclist volume to an AADT volume). This helps to normalize data which may have been collected on different dates or for different durations. The TMG cautions the use of short duration counts which are less than 24 hours in duration to estimate annual or seasonal statistics for cyclists (FHWA, 2013). If SDC which are less than 24 hours in duration are used to estimate SADT or AADT, there is “the potential to produce skewed interpretations of the level of cycling and or walking in a community” (USDOT, 2011). Research from Boulder, CO supports these findings and has suggested that the optimum duration for a SDC which is to be expanded to an AADT estimate is 7 days (Nordback, Marshall, Janson, & Stolz, 2013).

Expanding volume data is generally done using the following process:

(1) Analyze data from CCS and create traffic pattern groups (TPG) based on spatial or temporal characteristics;

(2) Compute expansion factors to apply to short duration counts for each TPG; and

(3) Assign short duration count sites to TPG apply expansion factors to short duration count data.

Establishing TPG for motor vehicles is discussed in depth in the TMG. However, the TMG acknowledges that there is no consensus on how to properly create TPG for non-motorized traffic (FHWA, 2013). Recently, cyclist traffic patterns in five North American cities were used to develop a methodology for grouping CCS based on their temporal characteristics. However, no analysis was performed which tested this method's ability to expand cyclist traffic volume data (Miranda-Moreno, Nosal, Schneider, & Proulx, 2014).

Three methodologies for expanding cyclist volume data were identified in this research:

- Traditional Factor Method;
- Day-by-Month Factor Method; and
- Disaggregate Factor Method.

It is worth noting that each of these three methods has previously been examined in Minneapolis, MN, for its ability to predict AADT in a mixed mode environment (pedestrians and cyclists) based on twelve-hour short duration counts (Hankey, Lindsey, & Marshall, 2015). These methods were also tested in Montreal, QC, and Ottawa, ON for their ability to predict cyclist AADT based on SDC which were 1-day in duration (Nosal, Miranda-Moreno, & Krstulic, 2014). The Disaggregated Factor Method performed best in all three cities.

Traditional Factor Method

This method applies individual day of week (DOW) factors averaged over the entire season for each day of the week, and month of year (MOY) factors averaged over the entire season for each month. Each factor (DOW and MOY) are generated using data from CCS. This method has been frequently used to annualize motor vehicle traffic. The formulae for estimating AADT and computing expansion factors can be seen below:

$$AADT(estimate)(i)(j) = DailyVolume(i)(j) * \frac{1}{DOW(d,k)} * \frac{1}{MOY(m,k)}$$

And:

$$DOW(d,k) = \frac{1}{n}\sum_{x=1}^{n} \frac{AverageDaily\,Traffic(d,y)}{AADT(y)}$$

$$MOY(m,k) = \frac{1}{n}\sum_{x=1}^{n} \frac{AverageDaily\,Traffic(m,y)}{AADT(y)}$$

Where:

DOW	=	the day-of-week factor for TPG *(k)*
MOY	=	the month-of-year factor for TPG *(k)*
(i)	=	the short-duration count site
(j)	=	the day of season
(k)	=	traffic pattern group
(d)	=	the day of the week of *(j),* Monday to Sunday
(m)	=	the month of the season of *(j),* May to October
(n)	=	the number of stations in traffic pattern group *(k)*
(y)	=	the continuous count station(s) within TPG *(k)*

Day-by-Month Factor Method

The Day-by-Month Factor Method is similar to the Traditional Method, but instead of averaging data from the entire year to create day-of-week factors, this method uses only data from that month. The formula for estimating AADT using this method can be seen below along with the formula for computing expansion factors:

$$AADT(estimate)(i)(j) = DailyVolume(i)(j) * \frac{1}{DMF(d,m,k)}$$

And:

$$DMF(d,m,k) = \frac{1}{n}\sum_{x=1}^{n}\frac{AverageDaily\ Traffic(d,m,y)}{AADT(y)}$$

Where:

DMF	=	the day-by-month factor for TPG (k)
(i)	=	the short-duration count site
(j)	=	the day of season
(k)	=	traffic pattern group
(d)	=	the day of the week of *(j),* Monday to Sunday
(m)	=	the month of the season of *(j),* May to October
(n)	=	the number of stations in traffic pattern group *(k)*
(y)	=	the continuous count station(s) within TPG *(k)*

Just like the Traditional Method, this method generates factors based on data from CCS. It is worth noting that both methods use the same assumptions discussed earlier surrounding the AADT formula; traffic volumes are influenced by the month of the year and day of the week.

Disaggregated Factor Method

This Disaggregated Factor Method applies individual day-of-year factors which are developed by calculating the ratio of daily volume to AADT for CCS within the same TPG and averaging them. These factors can then be applied to SDC taken at sites in the same TPG in order to expand them to AADT estimates. The formulae for both the estimation method and computing day-of-year factors are shown below:

$$AADT(estimate)(i)(j) = DailyVolume(i)(j) * \frac{1}{DAG(j,k)}$$

And:

$$DAG(j,k) = \frac{1}{n}\sum_{x=1}^{n}\frac{VOL(j,y)}{AADT(y)}$$

Where:

DAG	=	the disaggregated factor for TPG (k), on day (j)
(i)	=	the short-duration count site
(j)	=	the day of season
(k)	=	traffic pattern group

(n) = the number of stations in traffic pattern group *(k)*
(y) = the continuous count station(s) within TPG *(k)*

Unlike the Traditional Method or the Day-by-Month, this method does not use the assumption that traffic volumes will be influenced by the day of the week, or the month of the year. Instead, this method assumes that traffic is influenced by the individual date within the year or seasonal period. This may help account for the changes in cyclist volumes which could be caused by weather. Research has shown that weather variables such as temperature or rainfall can have a significant effect on cyclist volumes (Ahmed, Rose, Figliozzi, & Jacob, 2012). The successes experienced in other cities with Northern climates when applying the Disaggregated Factor Method could stem from the fact that this is the only method of the three which accounts for weather in some form. By assigning each day of the period a unique expansion factor based on CCS data, the expansion factors actually do take into account the weather experienced on that day, as the weather experienced on that day would have an effect on the CCS data used to create the expansion factors.

2.2 JURISDICTIONAL SURVEY

This section presents the findings from the jurisdictional survey given to major cities in Canadian and the U.S. The survey's design provided insight as to the current practice of North American cities in regards to cyclist traffic collection.

The survey targeted Canadian provincial and territorial capitals as well as major cities in U.S. states that border Canada. If a province contained another major city other than the capital, two cities were contacted. Only one U.S. city was selected from each border state. In addition to these cities, any U.S. cities which were identified as leaders in the cyclist monitoring field by responding survey participants were also contacted. Eighteen Canadian jurisdictions were contacted to represent the major urban centers of the country; 15 of the

18 Canadian jurisdictions responded. Eighteen U.S. jurisdictions were contacted; 17 of the 18 U.S. jurisdictions responded. Table 2-1 shows the responding jurisdictions from each country.

Table 2-1: Jurisdictions which responded to survey.

15 CND jurisdictions		17 U.S. jurisdictions	
Calgary, AB	**1,096,833**	**Ann Arbor, MI**	**117,025**
Charlottetown, PEI	**34,562**	**Anchorage, AK**	**300,950**
Edmonton, AB	**812,201**	**Billings, MT**	**109,059**
Fredericton, NB	**56,224**	**Boise, ID**	**214,237**
Halifax, NS	**390,096**	**Chittenden, VT**	**159,515**
Montreal, QU	**1,649,519**	**Columbus, OH**	**822,553**
Moncton, NB	**69,074**	**Fargo, ND**	**113,658**
Ottawa, ON	**883,391**	**Denver, CO**	**649,495**
Quebec City, QU	**516,622**	**Manchester, NH**	**110,378**
Toronto, ON	**2,615,060**	**Milwaukee, WI**	**599,164**
Saskatoon, SK	**222,189**	**Minneapolis, MN**	**400,070**
Vancouver, BC	**603,502**	**Portland, ME**	**66,318**
Victoria, BC	**80,017**	**Portland, OR**	**609,456**
Whitehorse, YT	23,276	**Philadelphia, PA**	**1,560,297**
Yellowknife, NWT	19,234	**Raleigh, NC**	**431,746**
		Rochester, NY	**210,358**
		Seattle, WA	**652,405**

Canadian Populations: (Statistics Canada, 2011)
U.S. Populations: (United States Census Bureau, 2013)

2.2.1 Extent of Cyclist Volume Data Collection

For Canadian jurisdictions, 12 of the 15 respondents indicated that they collect cyclist traffic data. The three jurisdictions that replied ‘no’ were jurisdictions with smaller populations less than 40 000. All of the U.S. jurisdictions surveyed indicated that they collect cyclist volume data to some extent. Jurisdictions who indicated they collected cyclist volume data are highlighted in bold text in Table 2-1. Eleven of the twelve Canadian jurisdictions and 14 of the 17 U.S. jurisdictions indicated that they collect cyclist volume data on a regular basis and have some form of cyclist monitoring program in place.

2.2.2 Methods for Collecting Cyclist Volume Data

Table 2-2 shows the methods that jurisdictions use to collect cyclist volume data. Most jurisdictions (83% and 70% of Canadian and U.S. jurisdictions respectively) which collect cyclist volume data reported using some sort of automated technology to help with the data collection process. The types of technologies used varied across jurisdictions. The most common types of technologies in use were inductive loops and pneumatic tubes. Several jurisdictions indicated using video classifiers, passive infrared and active infrared technologies to count cyclists. It is worth noting that jurisdictions using either active or passive infrared do not have the capability to distinguish between pedestrians and cyclists when conducting counts. These types of counting devices are generally suitable for counting on either sidewalk or AT paths where only combined data is needed.

Table 2-2: Response Summary:
Do you collect cyclist volume data using automated technologies or manually?

Response	12 CND Jurisdictions		17 U.S. Jurisdictions	
	Total	Percent	Total	Percent
Manual Only	2	17%	5	29%
Automated Only	4	33%	6	35%
Manual and Automated	6	50%	6	35%
If you use automated technologies, what types of technology do you use?				
Inductive Loops	5	50%	9	75%
Pneumatic Tubes	4	40%	7	58%
Video	4	40%	0	0%
Passive Infrared**	0	0%	4	33%
Active Infrared**	0	0%	1	8%

** Jurisdictions that indicated using these technologies as a primary mean of counting cyclists do not separate cyclists and pedestrians when collecting volume data.

2.2.3 Count Frequency and Duration

Almost half of Canadian jurisdictions surveyed (5 of 12) and over 60% of U.S. jurisdictions surveyed (11 of 17) continuously monitor cyclist volume data as shown in Table 2-3. The majority of jurisdictions also indicated that they will collect cyclist volume data on an “as needed" basis.

Table 2-3: Response Summary:
How often do you collect cyclist volume data?

Response	12 CND jurisdictions		17 U.S. jurisdictions	
	Total	Percent	Total	Percent
Continuously	5	42%	11	65%
Seasonally	6	50%	7	41%
As needed	9	75%	7	41%

Table 2-4 and Table 2-5 reveals the periods that jurisdictions repeat counts at locations while using manual and automated counts. Manually, the majority of both Canadian and U.S. jurisdictions conduct counts for three hours or less. When using automated technologies, most Canadian jurisdiction indicated they will count for either 12 or 24 hours, with three indicating they conduct continuous cyclist monitoring. Most U.S. jurisdictions count either continuously only, or for one week.

Table 2-4: Response Summary:
What are your typical count durations when manually collecting cyclist volume data?

Response	8 CND jurisdictions		11 U.S. jurisdictions	
	Total	Percent	Total	Percent
12 Hours	2	25%	0	0%
4 Hours	0	0%	1	9%
3 Hours	2	25%	0	0%
2 Hours	4	50%	10	91%

Table 2-5: Response Summary:
What are your typical count durations when using automated technologies to collect cyclist volume data?

Response	10 CND jurisdictions		12 U.S. jurisdictions	
	Total	Percent	Total	Percent
Continuously Only	3	30%	5	42%
One Week	1	10%	6	50%
48 Hours	0	0%	1	8%
24 Hours	2	20%	0	0%
12 Hours	4	40%	0	0%

2.2.4 Selection of Counting Sites

Canadian respondents indicate, in Table 2-6, that cyclist traffic counting sites are primarily selected either as part of a screenline count program, or to inform current projects. Many jurisdictions also indicated that sites are selected to satisfy requests or complaints, or on an as needs basis. U.S. respondents had similar responses and generally select count sites for similar reasons.

**Table 2-6: Response Summary:
How are counting sites selected?**

Responses	12 CND jurisdictions		17 U.S. jurisdictions	
	Total	Percent	Total	Percent
Part of Screenline Count Program	9	75%	12	71%
Project Based	9	75%	11	65%
Request Based (professional)	5	42%	11	65%
Request Based (citizen)	3	25%	2	12%
With Vehicle Count Sites	6	50%	3	18%

2.2.5 Expansion Methods for Cyclist Volume Data

Table 2-7 shows that one Canadian jurisdiction and five U.S. jurisdictions use factors to expand the raw cyclist volume data. Given the number of respondents who indicated they collect data continuously and as part of a screenline count program, this number was considered low. The fact that many jurisdictions collect data in this manner, but do not expand volume counts further reveals the absence of a structured methodology for monitoring cyclists, and the need for this methodology to be further developed. This is also supported by the lack of consistent types of expansion factors used between jurisdictions.

**Table 2-7: Response Summary:
Do you use temporal expansion factors to expand short term counts?**

Response	12 CND Jurisdictions		17 U.S. Jurisdictions	
	Total	Percent	Total	Percent
Yes	1	8%	5	29%
No	11	92%	12	71%
If you temporal expansion factors, what types do you use?				
NBPD Factors	0	0%	3	60%
Disaggregated Factors	0	0%	1	20%
Vehicle Factors	0	0%	1	20%
O-D Survey Factors	1	100%	0	0%

2.2.6 Issues with Implementing Cyclist Counting Programs

As a supplementary question to this survey, jurisdictions were asked to identify any issues which were or had prevented them from implementing a cyclist counting program. The findings are summarized in Table 2-8. Many jurisdictions were concerned with the accuracy of automated counters and the amount of difficulty associated with counting cyclists due to their unpredictable movements. The most common issue revealed across all jurisdictions was the lack of available resources to implement count programs for cyclists and purchase counting equipment, while having an available lack of guidance was not cited as a main impediment to implementing a count program. This may suggest that many jurisdictions are still in the preliminary stages of developing a cyclist monitoring program and are focusing most of their efforts on obtaining raw data.

Table 2-8: Response Summary:
What are the major issues and challenges you have experienced when collecting cyclist volume data?

Responses	12 CND jurisdictions		17 U.S. jurisdictions	
	Total	Percent	Total	Percent
Lack of resources available	4	33%	8	47%
Too difficult to count cyclists	4	33%	3	18%
Concerns with counter accuracy	3	25%	3	18%
Lack of available guidance	0	0%	2	12%
No Response	1	9%	1	5%

2.3 ENVIRONMENTAL SCAN SUMMARY

The literature revealed the following surrounding cyclist traffic monitoring and cyclist volume data collection:

(1) AADT and SADT are common statistics to report for cyclists. The formulae for these statistics are taken from vehicle traffic monitoring.

(2) Four automated technologies emerged for counting cyclists including inductive loops, pneumatic tubes, video imaging, and active infrared.

(3) When expanding data to average daily volume estimates, such as AADT or SADT, it is not advised to use hourly volume data. It is best practice to use seven consecutive days of volume data as a SDC.

(4) Three methods for expanding daily volume data to SADT estimates were identified. Each will be explored further in Chapter 4.

Major results from the jurisdictional survey are the following:

(1) Although many jurisdictions indicated they collect cyclist volume data using automated technologies, many rely heavily on two or three hour manual counts to provide information regarding cycling in their communities.

(2) Inductive loops and pneumatic tubes were the most frequently used automated technologies for collecting cyclist volume data.

(3) Count sites are usually selected as part of a screenline count program, are project-based, or are selected by professional request.

(4) Most jurisdictions do not expand cyclist counts. Among those who do, no consistent types of expansion factors were identified.

(5) Jurisdictions are interested in counting cyclists, but many find that they lack the resources required to do so.

3 METHODOLOGY

This chapter discusses the methodology applied in this research for cyclist data collection, continuous *pedestrian* and *cyclist* count station selection, equipment calibration and the analysis of traffic characteristics. Although this research pertains only to cyclists, the site selection process was part of a larger project for the City of Winnipeg which aims to collect both cyclist and pedestrian data on active transportation (AT) paths. The chapter presents the following:

(1) Selection of the cyclist count technology for data collection;

(2) Selection of locations for cyclist and pedestrian continuous count stations (CCS);

(3) The methodology applied to collect, process, and analyze the cyclist traffic data;

(4) Accuracy and calibration processes for the selected cyclist count technology; and

(5) Special issues surrounding the equipment used to count cyclists which were identified during the course of this research.

Cyclist volume data was collected from November 1st, 2013 to October 31st, 2014. These data will be used to develop and test the applicability of cyclist volume expansion factors, which are discussed further in Chapter 4 and Chapter 5.

3.1 SELECTION OF COUNTING TECHNOLOGY FOR ANALYSIS

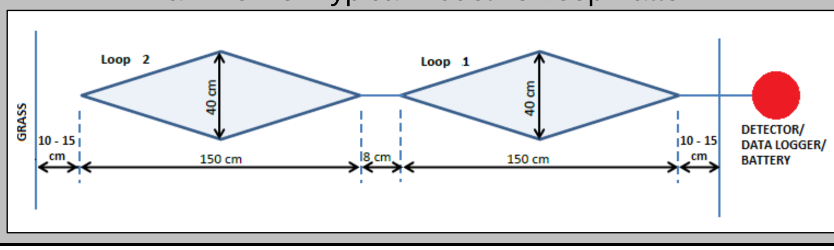
Viable counting technologies were selected based on a comprehensive literature review. Four types of technology were identified to be capable of continuously counting cyclists:

- Inductive Loops
- Active Infrared
- Pneumatic Tubes; and
- Video Imaging.

However, only one technology was identified to be practical for use in Winnipeg, MB. The available technologies were evaluated based on factors such as performance in variable outdoor conditions, and ease of installation and maintenance. Active infrared units and video image processing were eliminated as options because of their issues with accurately detecting and differentiating cyclist and pedestrians in all weather conditions. Because of the harsh winters in Winnipeg, pneumatic tubes were not selected as no literature was identified which tested this technology in a winter climate similar to Winnipeg's. In addition to this, the pneumatic tubing could be easily damaged by snow clearing equipment which is frequently used in Winnipeg from November to March. Inductive loops were selected as they were the only appropriate continuous counting technology to collect cyclist volume data in Winnipeg. Inductive loops can be installed permanently without becoming a hazard to pathway users, require little maintenance, and have been shown to perform accurately when tested in other jurisdictions.

The Eco-Counter Dual Inductive Loop Zelt has been chosen because of its accuracy, data storage capabilities, wireless connectivity, and longer battery life. This manufacturer's counter has already been tested in research literature and calibration has been proven effective which is preferable for this research. The technical specifications of the Eco-Counter Dual Inductive Loop Zelts are given in Table 3-1.

Table 3-1: Eco-Counter Dual Inductive Loop Zelt technical specifications.

	Asphalt	Gravel
Dimensions	2 x 1.5 m (8 units)	2 x 1.5m (1 unit) 2 x 1.1m (1 unit)
Battery Life	10 years	
Operating Temperature	-40°C to 50°C (-40°F to 140°F)	
Data Collection Interval	15 minute	
Waterproof	IP 68	
Data Transmittal	GSM Connection	
Plan View of Typical Inductive Loop Pattern 		

3.2 SELECTION OF STATIONS FOR CONTINUOUS DATA COLLECTION

The University of Manitoba Transport Information Group (UMTIG) worked with the City of Winnipeg to identify five multi-use pathways within the City. These five pathways are shown in Figure 3-1 as follows:

(1) Harte Trail;

(2) Yellow Ribbon Greenway;

(3) Bishop Grandin Greenway;

(4) Northeast Pioneer’s Greenway; and

(5) Transcona Trail.

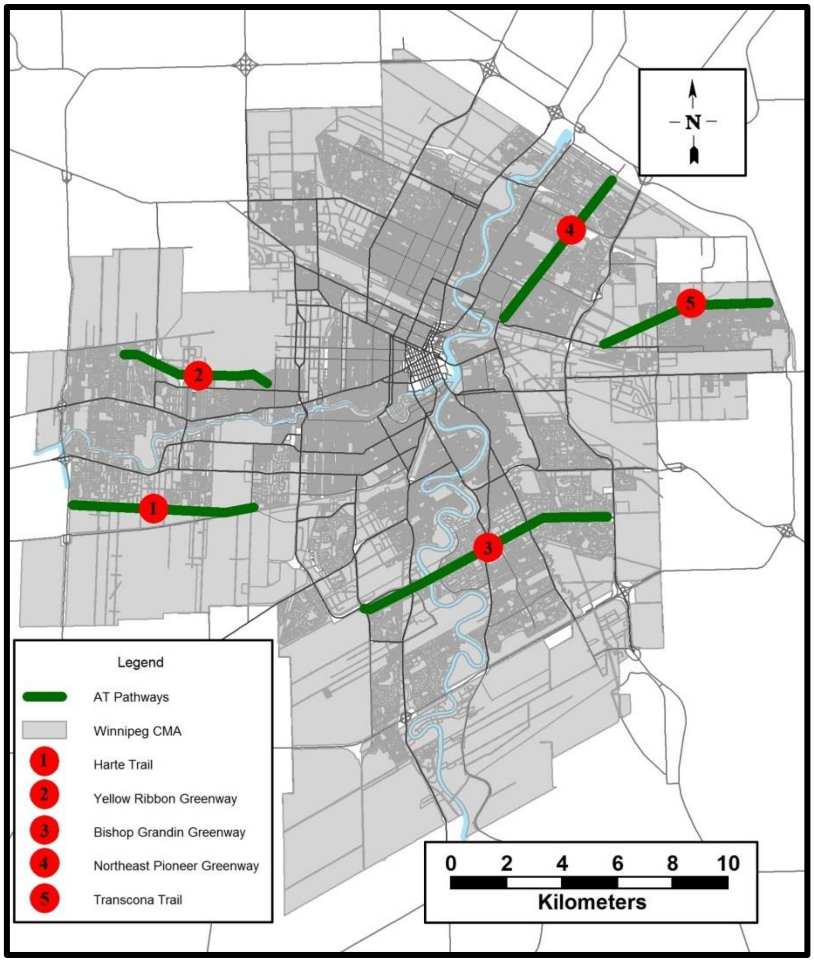


Figure 3-1: Active transportation paths in Winnipeg, MB, selected for pedestrian and cyclist monitoring.

At each trail, manual preliminary counts were conducted at to identify pedestrian and cyclist traffic patterns, site accessibility requirements, and to select the continuous count stations (CCS). The research team narrowed the number of data collection sites to 10 locations in total across the 5 recreational trails.

The U.S. Traffic Monitoring Guide recommends installing CCS at locations that are located on straight, level sections of trails with smooth, flat surfaces and portions of the path where the traveled way is delineated and deviation is uncommon. Focus should be given to locations with moderate to high cyclist volumes, but it is more important to choose a location which will be representative of the prevailing traffic pattern (FHWA, 2013). Additionally, sections of pathway which showed signs of cracking, or that had cracked and been repaired with tar were avoided in order to prevent the wiring in the inductive loops from being damaged; Winnipeg's large temperature differentials between summer and winter can cause pavement cracking which could expose or tear wiring in the inductive loop systems.

In order to obtain a better understanding of the activity on each pathway site visits were conducted at each facility to identify potential locations to install CCS. Every site visit included a bike ride over the entire path to look for suitable locations. Areas that were heavily wooded, or had hills or parts of the built environment around them were often chosen as these barriers help to funnel traffic past a point which would allow the counting device to record the largest number of users.

After conducting site visits, 16 locations were identified on the five pathways. On each pathway three to four potential locations were identified, with the exception of Transcona Trail which only had one potential location. Six locations were to be eliminated as only ten continuous counting devices were able to be purchased. To help determine which locations should have continuous counting devices installed, seven or eight hour manual preliminary counts were conducted at 15 of the locations. This duration was chosen as it would develop knowledge of travel patterns during at least one peak commuter period and throughout the middle of the day. All counts were done in teams of three or four to ensure that cyclist and pedestrian volumes were being collected at the same time for locations on the same path. To reduce the chance of human error occurring counts were performed in shifts of two or three hours. No preliminary count was conducted at the one location on Transcona Trail. This location was automatically selected as a site for a CCS as it was the only preliminary location identified on this path. When selecting final CCS locations from the preliminary count data, preference was given to sites with higher volumes of pedestrians and cyclists.

Additionally, if two sites on the same path exhibited similar hourly travel patterns only one of the sites would be considered to have a CCS installed. A summary of the preliminary counts and CCS locations are shown in Table 3-2 and the details of the preliminary counts for each pathway are explained in the following sections.

Table 3-2: Number of preliminary count sites and final sites for continuous cyclist and pedestrian count stations.

Pathway	Preliminary Count Sites	CCS Locations	Paved/Gravel
Harte Trail	4	2	Gravel
Yellow Ribbon Greenway	3	1	Paved
Bishop Grandin Greenway	4	3	Paved
Transcona Trail	1	1	Paved
Northeast Pioneer's Greenway	4	3	Paved

3.2.1 Harte Trail

Harte Trail is a gravel path running over an abandoned rail right-of-way located in the southwest region of the city. The residential neighbourhood of Charleswood is north of the path, while the land south of the path is presently undeveloped. Four locations were selected on Harte Trail as preliminary count sites, as shown in

Figure 3-2 on the following page. Location 1 is just west of Charleswood Road, close to the west end of the path. Location 2 is between Community Row and Harstone Road. Location 3 is found between Faimont Road and Oakdale Drive, while Location 4 is west of Elmhurst Road, adjacent to the west edge of Assiniboine Forest. Preliminary counts were conducted at four locations on Monday August 19th, 2013, from 11:00 – 13:00 and 15:00 – 17:00. Additional preliminary counts were conducted at each of the four locations on Tuesday, August 20th, 2013, from 13:00 – 15:00 and 17:00 – 19:00. The data from each of these counts can be seen in

Figure 3-2.

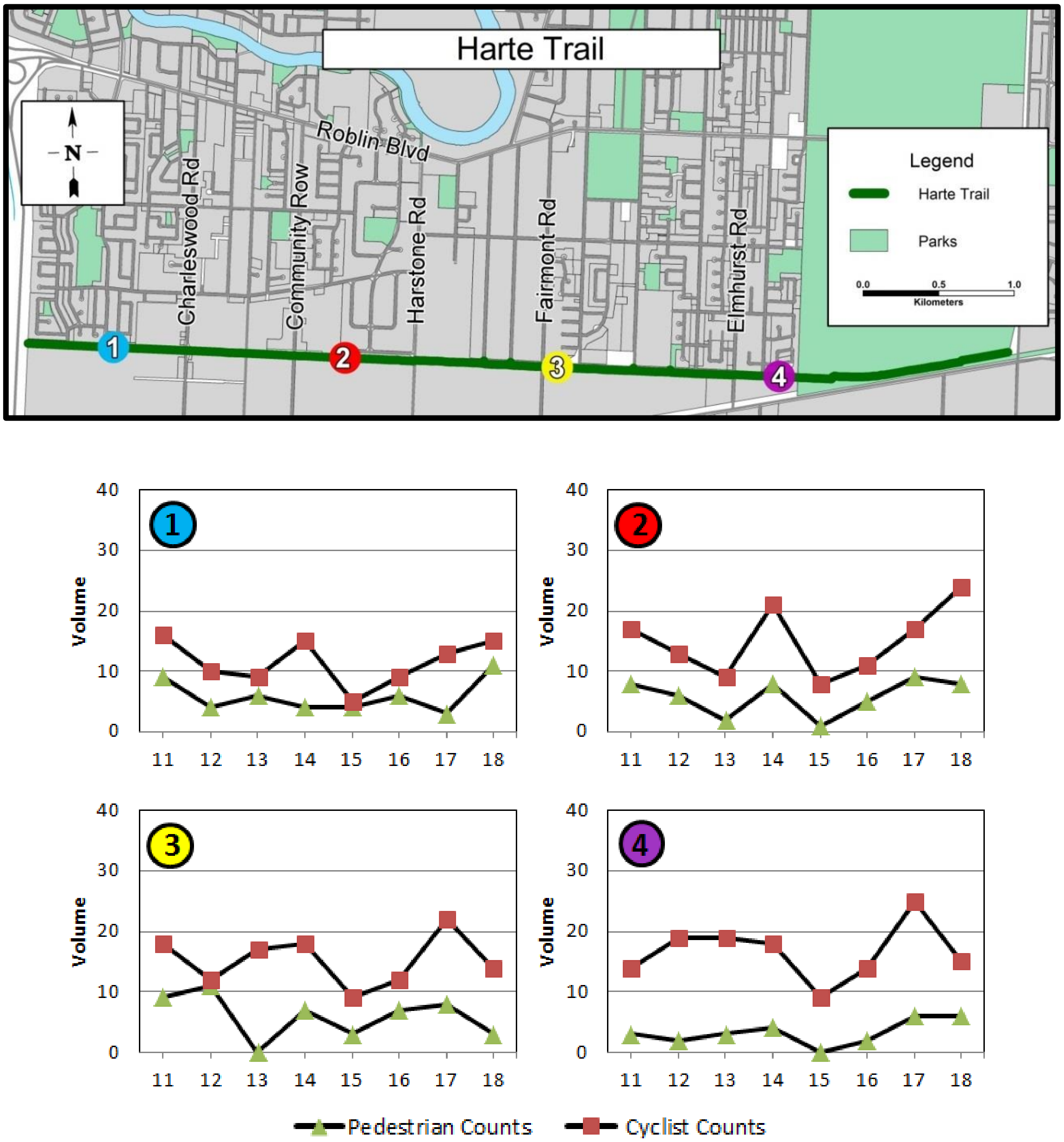


Figure 3-2: Preliminary count locations and volumes of cyclists and pedestrians, Harte Trail.

Two locations were selected for continuous cyclist and pedestrian monitoring: Location 2 and Location 4. Location 1 and Location 2 show similar travel patterns, with similar volumes throughout the day and peaks from 14:00 – 16:00 and again from 17:00 – 19:00. Location 2 was selected over Location 1 as this location experienced higher volumes of pedestrians and cyclists. Location 3 and Location 4 also had similar travel patterns with moderate volumes throughout the day and a peak in traffic from 17:00 – 18:00. Although higher volumes were observed at Location 3, Location 4 was selected for continuous monitoring because it was thought that this site would capture larger amounts of commuter cyclists, and may also capture larger amounts of recreational pedestrian and cyclist traffic travelling to the Assiniboine Forrest. Once Location 2 and Location 4 were selected as continuous sites they were renamed as stations "HT1" and "HT2", respectively.

3.2.2 Yellow Ribbon Greenway

Yellow Ribbon Greenway runs east-west and extends from Saskatchewan Avenue to Ferry Road, past the Winnipeg James Armstrong Richardson International Airport. Three locations were selected on the Yellow Ribbon Greenway as a preliminary count sites, as shown in Figure 3-3. Location 1 is adjacent to the Living Prairie Museum and Park, near the west end of the path. Location 2 is just east of the AT path's intersection with Whytewold Road and Location 3 is near the corner of Silver Avenue and Winchester Street on the south side of the cyclist and pedestrian bridge. Preliminary counts were conducted at each of the three locations on Wednesday, August 21st, 2013, from 8:00 – 12:00 and Thursday, August 22nd, 2013, from 12:00 – 16:00. The data obtained from each preliminary count can be seen in Figure 3-3.

One location was selected for continuous cyclist and pedestrian monitoring: Location 2. Location 1 and Location 2 each had similar travel patterns. Location 2 experienced slightly higher numbers of both pedestrians and cyclists, which eliminated Location 1 as an option. Location 3 varied slightly from these two sites, however was not considered unique enough to warrant its own continuous counter. Only Location 2 was selected and was renamed as "YRG".

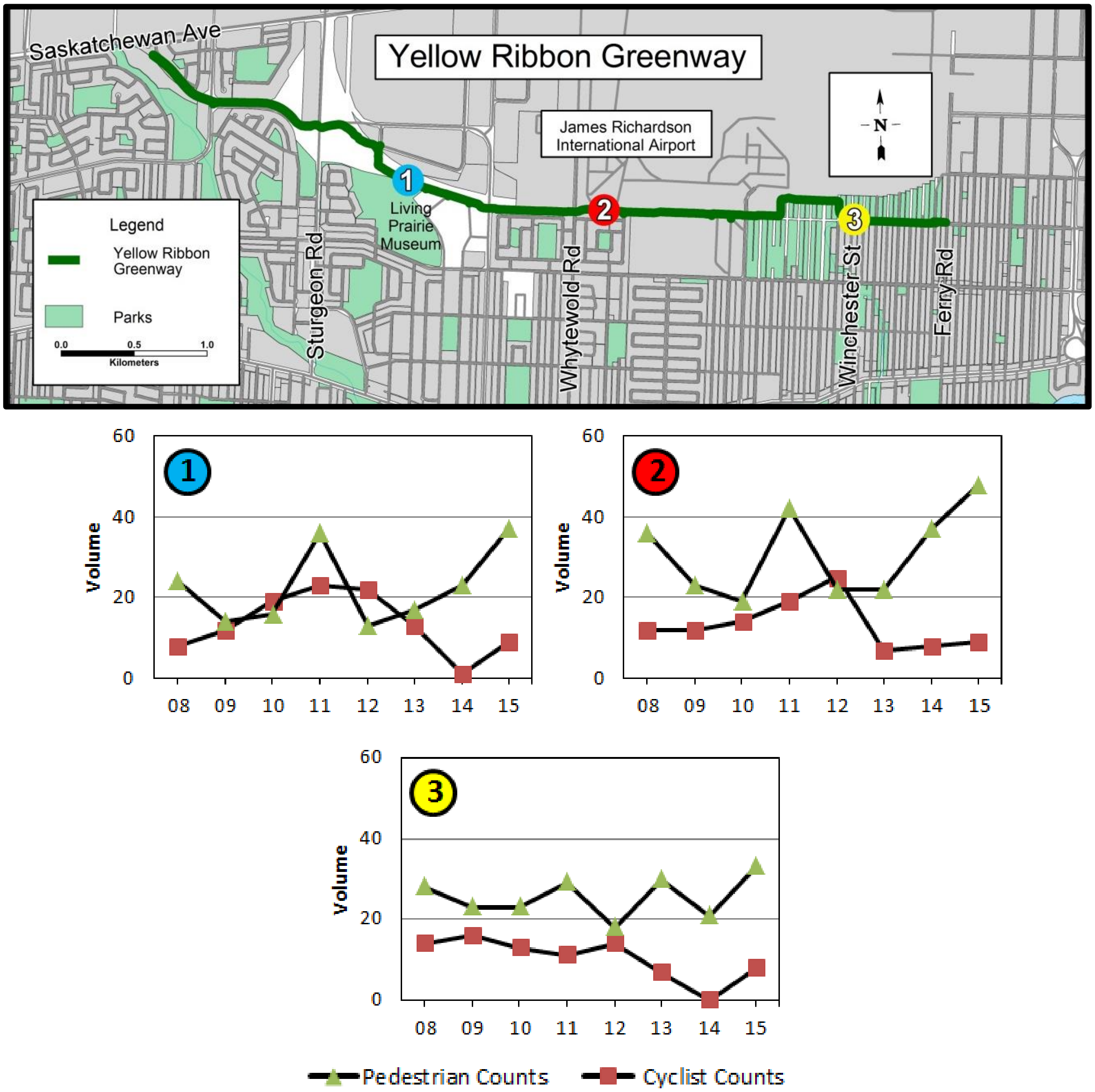


Figure 3-3: Preliminary count locations and volumes of cyclists and pedestrians, Yellow Ribbon Greenway.

3.2.3 Bishop Grandin Greenway

The Bishop Grandin Greenway runs parallel to Bishop Grandin Boulevard and extends from

Waverley Street to Lagimodière Boulevard. Four locations were selected on the Bishop Grandin Greenway as preliminary count sites, as shown in Figure 3-4 on the following page. Location 1 is at the west end of the Fort Garry Bridge over the Red River. This site was expected to have high volumes of both pedestrians and cyclists given its close proximity to the University of Manitoba. Location 2 is at the 1 km trail mark between River Road and St. Mary's Road. Location 3 is between St. Mary's Road and Dakota Street, located adjacent to St. Vital Centre, while Location 4 is just east of St. Anne's Road where the path traverses over the Seine River. Preliminary counts were conducted at each of the four locations on Monday, August 19th, 2013, from 11:00 – 13:00, and 15:00 – 17:00 and on Tuesday, August 20th, 2013, from 9:00 – 11:00 and 13:00 – 15:00. The results of the preliminary data collection are illustrated in Figure 3-4, which shows cyclist and pedestrian volumes recorded for each hour of data collection.

Three locations were selected for continuous cyclist and pedestrian monitoring on Bishop Grandin Greenway; Location 1, Location 2, and Location 4. Location 1 was selected because high volumes of pedestrians and cyclists were observed which did not occur at any other location. The traffic pattern experienced at Location 1 was also distinctly different from all other sites on this path. Location 4 saw lower traffic volumes, but also experienced a different traffic pattern from the other preliminary locations on this path. Traffic patterns at Location 2 and Location 3 were observed to be similar. However, slightly higher volumes were recorded at Location 2 which resulted in Location 3 being eliminated as a potential location for continuous monitoring. Location 1, Location 2, and Location 4 were renamed as "BG1", "BG2", and "BG3", respectively.

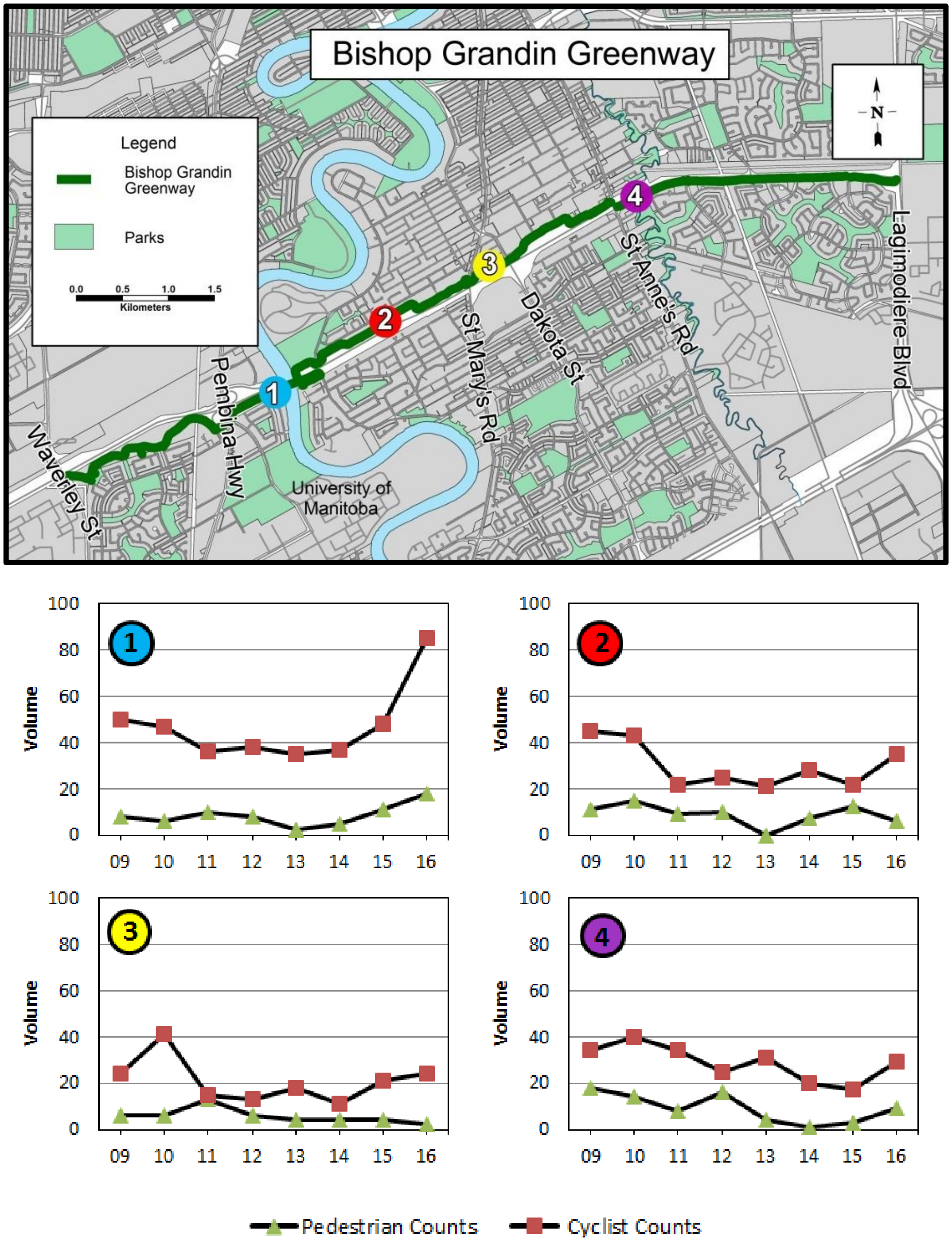


Figure 3-4: Preliminary count locations and volumes of cyclists and pedestrians, Bishop Grandin Greenway

3.2.4 Northeast Pioneer's Greeenway

Northeast Pioneer's Greenway is located between Raleigh Street and Gateway Road, and runs parallel to each from Talbot Avenue to Glenway Avenue. Four locations were selected on the Northeast Pioneer's Greenway as potential count sites, as shown in Figure 3-5. Location 1 is just south of the path's intersection with Munroe Avenue, while Location 2 is adjacent to Andersen Park about halfway between Kimberly Avenue and Mcleod Avenue. Location 3 is south of the AT path's bridge over Chief Peguis Trail, while Location 4 is on the north side. Preliminary counts on Northeast Pioneer Greenway were performed at each location on Tuesday, August 27th, 2013, from 8:00 – 12:00, and on Wednesday, August 28th, 2013, from 14:00 – 17:00. No data was collected between the hours of 12:00 – 14:00 on either day. Pedestrian counts are missing from the last three hours of data collection at Location 1 and Location 3. Cyclist volumes were used to inform site selection in the absence of pedestrian data for these hours at these locations. The results of the preliminary data collection are shown in Figure 3-5.

Three locations were selected for continuous cyclist and pedestrian monitoring: Location 1, Location 2, and Loaction 3. As shown in Figure 3-5, all preliminary locations demonstrate AM and PM peaks. Location 1 was selected because a smaller AM peak than the other locations, which occurred earlier in the morning. Location 2 was also selected given that the largest amounts volumes of both pedestrians and cyclists were observed at this site. At Location 3 and Location 4 similar volumes were observed. However, Location 4 was eliminated as it was expected that much of the traffic travelling along Northeast Pioneer's Greenway may turn off the path to travel along Chief Peguis Greenway, which runs parallel to Chief Peguis Trail. After selecting Location 1, Location 2, and Location 3 as continuous sites, they were renamed as "NEP1", "NEP2", and "NEP3", respectively.

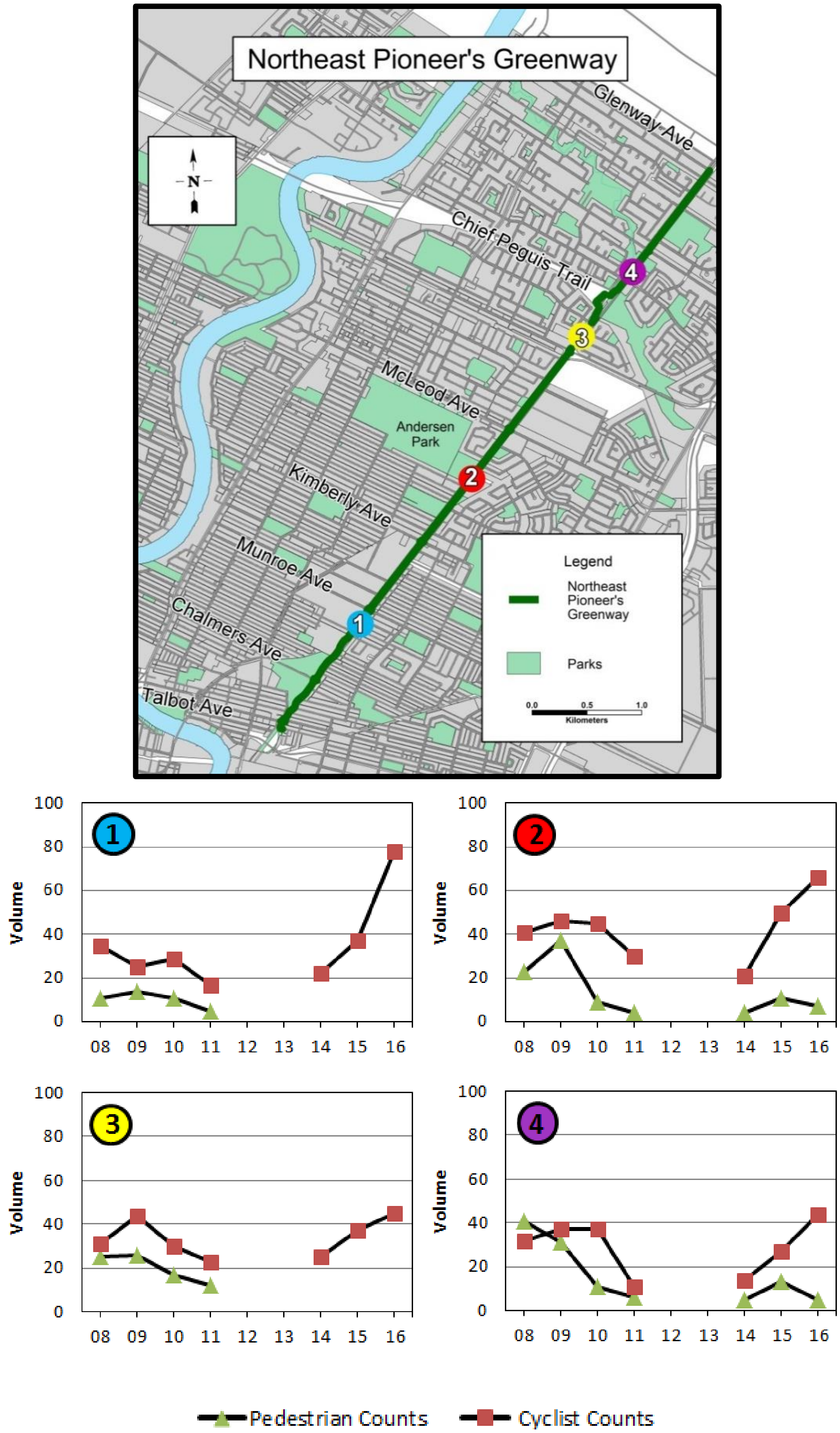


Figure 3-5: Preliminary count locations and volumes of cyclists and pedestrians, Northeast Pioneer's Greenway

3.2.5 Transcona Trail

Transcona Trail runs east-west through the neighbourhood of Transcona from the path's intersection with Regent Avenue to just before the Perimeter Highway, through the neighbourhood of Transcona. No preliminary counts were conducted on Transcona Trail and only one possible count site was identified, as shown in Figure 3-6. Location 1, which will now be referred to as "TT", is located east of the path's intersection with Plesis Road, a few meters east of the fork in the trail which provides access to Kiwanis Park.

Figure 3-6: Location selected for continuous cyclist and pedestrian monitoring, Transcona Trail.

3.3 DATA COLLECTION SYSTEM

The field equipment setup, field data collection and weather data collection make up the data collection system.

3.3.1 Field Equipment Setup

All cyclist counting units were installed near the beginning of October, 2013, and began collecting data immediately after installation. Each Zelt (cyclist counting unit) was comprised of a battery (red cylinder), a GSM transmitting device (green cylinder), and a counting unit (yellow cylinder) which were housed in a buried manhole, along with wiring to form the loops, which can be seen in Figure 3-7. Installation was done according to Eco Counter's installation guidelines (Eco-Counter, 2012).

Figure 3-7: Zelt counting unit.

Installation of Zelts on Asphalt Pathways

This installation process was performed for the eight automated cyclist counters installed on the Bishop Grandin Greenway, the Northeast Pioneer Greenway, Transcona Trail, and the Yellow Ribbon Greenway. All pathways were approximately 3.5 m wide with a painted yellow centreline. Figure 3-8 illustrates the typical loop configuration for Zelts installed in Winnipeg.

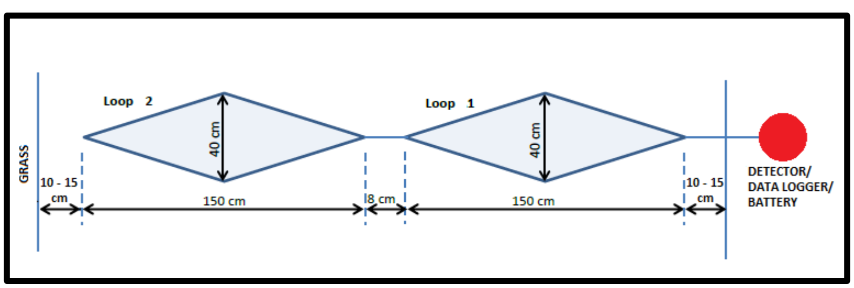


Figure 3-8: Zelt inductive loop wiring configuration.

In order to achieve the desired configuration, a wooden stencil was made with two 1.5 m diamond cut outs separated by an 8 cm space. This was placed onto the pathway in the desired location and then the outline was spray-painted. A diamond saw blade was then used to cut out the pavement where the wiring was to be laid, which can be seen in Figure 3-9. Each loop was laid separately by attaching a 15-gauge wire to the counting unit in the manhole and running it around each of the loop patterns eight times. The other end of the wire was then attached to the counting device to complete the circuit.

Figure 3-9: Pavement saw cutting traced loop pattern on asphalt path.

Once each loop was laid and connected to the counting device each loop was tested to ensure it would detect a cyclist. In order to do so, the counter was first “woken up” by waving a magnetic key over the translucent circle in the centre of the manhole, as seen in Figure 3-10. If the counter was correctly woken up, a blue LED light would flash. Following this, someone from the research team would ride a bike over each loop while another person watched the counting device to see if it would pick up the cyclist. A proper detection was indicated by an additional green flashing LED light on top of the counting unit (yellow disc in Figure 3-7, centre circle in Figure 3-10).

Figure 3-10: Manhole covering of a Zelt with magnetic key.

Installation of Zelts on Gravel Pathways

This installation process was performed for the two Zelts installed on the Harte Trail. The layout of the inductive loops was the same as those installed on asphalt pathways, but the dimensions varied depending on the width of the gravel pathway at the location. Location 1 on this pathway had a width of 2.2 m (2 x 1.1 m loops) while the width at location 2 was 3.0 m (2 x 1.5m loops). Because the inductive loops were being installed in a soft soil, they were required to be pre-formed to prevent them from shifting. Inductive loops are pre-formed by the manufacturer to ensure the dimensions are correct. In order to place the pre-formed loops, diamond cut-outs were dug which can be seen in Figure 3-11. Each of the loops were then placed in the cut-outs, connected to the counting device, tested to ensure they were properly working, and then buried.

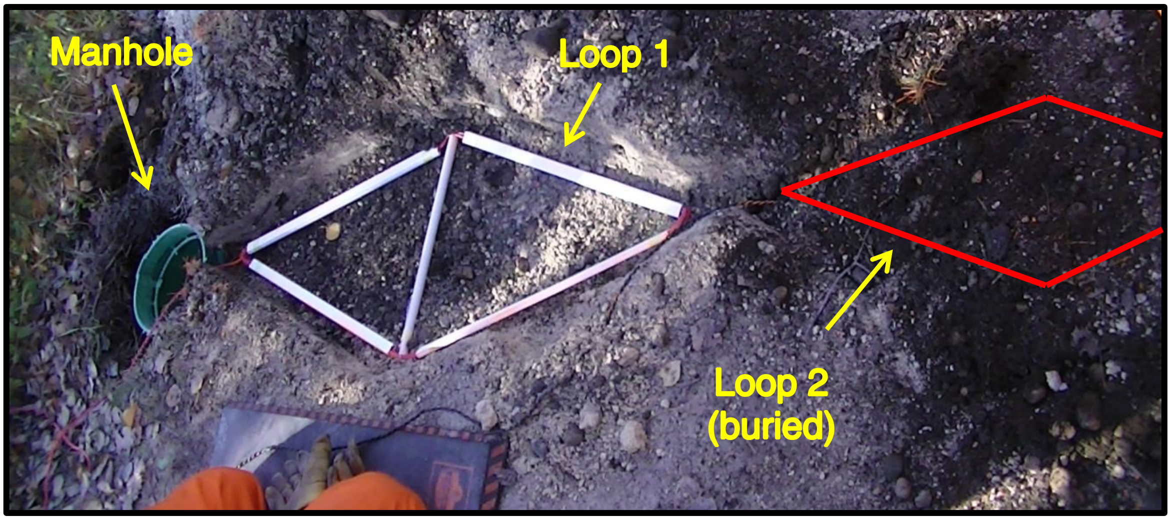


Figure 3-11: Installation of inductive loops on gravel path.

3.3.2 Field Data Collection

The installed Zelts monitor cyclist volumes 24 hours a day, seven days a week. The devices used in this research have a Global System for Mobile (GSM) communication connection which enables them to transfer data remotely via cellular network. At 3:00 a.m. every morning, the data is uploaded to Eco-Counter's online software called Eco-Visio and can be accessed at any time. With daily data updates the software is able to alert the user if a count is unusual based on user inputs like minimum expected daily volume or minimum percent variation of daily volume. This service requires an annual licence to be purchased for each counter from Eco-Counter.

Data can also be uploaded on site by using a laptop computer which has Eco-Link software installed and Bluetooth capabilities. The counter must first be woken up by using the same procedure that was used to verify that the Zelts were detecting cyclists. By using the Eco-Link program, a connection can be established between the counter and the laptop. This allows the user to download any data which has been stored on the counter, as well as view the real-time performance of the counting devices. This is helpful when trying to decipher the source of false calls or other disturbances. The data is viewed daily in the Eco-Visio software; Figure 3-12 shows one of the figures that can be queried to visually inspect cyclist and pedestrian counting device performance.

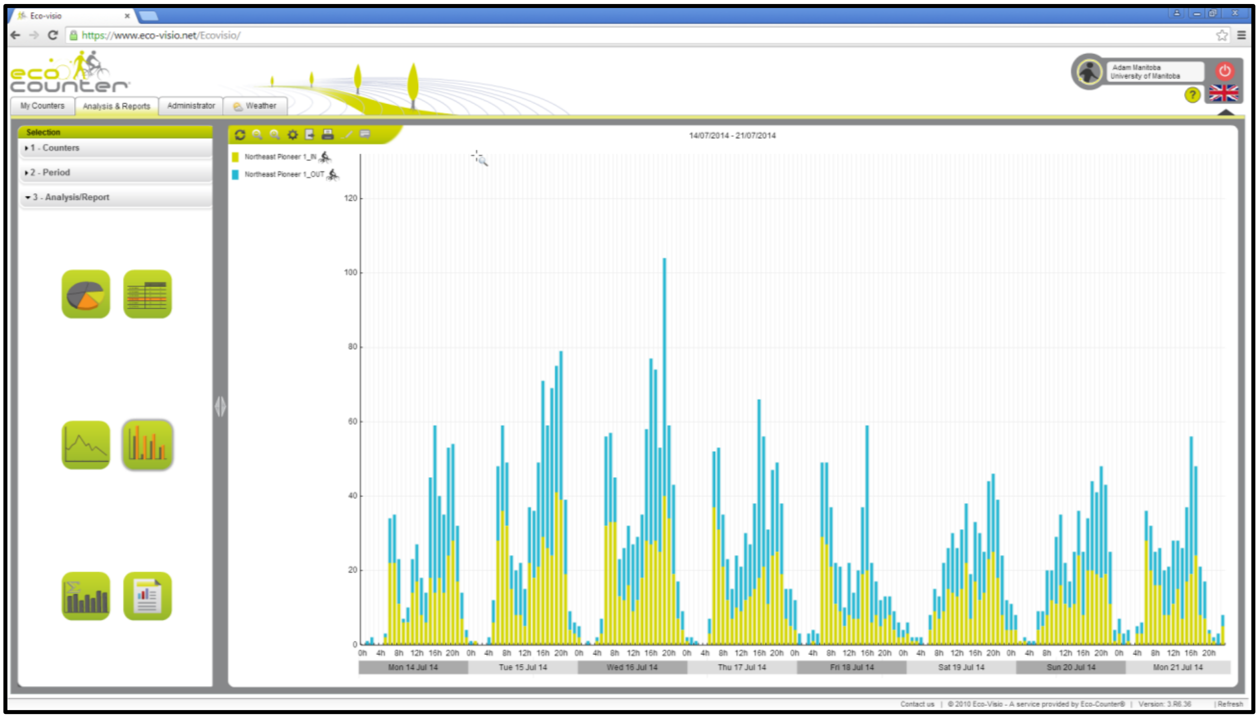


Figure 3-12: Analysis of cyclist count data by hour from Eco-Visio software

3.3.3 Weather Data Collection

Hourly data for Winnipeg was collected monthly from the Environment Canada website (http://www.weatheroffice.gc.ca) at a weather station located at the James Armstrong Richardson International Airport. The weather data collected for this research were temperature and cumulative snow on ground.

3.4 COUNTER VERIFICATION

There has been minimal research conducted on proper verification techniques for inductive loop cyclist counters. Because the devices were installed so late in the year, user volumes on the pathway were too low to conduct proper verification counts. Immediately after the counting units were installed the accuracy of each was verified by cycling over the counters 50 to 100 times on a bicycle. All counting devices performed adequately, and a proper verification process was undertaken in May, 2014.

Manual verification counts, which were from two to four hours in duration, were conducted at each site in order to verify each device's accuracy. Manual verification counts involved an observer at the site recording the number of cyclists passing the automated counters. The ground truth data gathered by the manual counters were then compared to the data generated by the devices in order to assess the accuracy of each device. Manual calibration counts involved three counts per site which were conducted at varying times throughout the day. Two of the verification counts at each location were conducted on weekdays and one was collected on a weekend day. All counts were conducted in May and June 2014, after the devices had been in place for one complete winter season. Constraints on the number of manual observers available to count at any one time prevented all 10 locations from having verification counts at the same time. However, manual counts were conducted simultaneously on paths with more than one site. In total, 97.75 hours of verification were conducted. Table 3-3 shows the details of verification counts conducted for each site and Figure 3-13 depicts the results graphically. The accuracy of each device was evaluated using the following formula:

$$Percent\ Error = \frac{Volume(Zelt) - Volume\ (Observed)}{Volume(Observed)}$$

Table 3-3: Calibration counts for Zelts in Winnipeg, MB.

Location	Dates	Day of Week	Duration	Number of Hours	Percent Error
BG1	09-May-14	Fri	13:00 - 17:00	4	1.3%
	24-May-14	Sat	14:00 - 16:30	2.5	0.9%
	16-Jun-14	Mon	14:15 - 17:00	2.75	-4.5%
BG2	09-May-14	Fri	13:00 - 17:00	4	-7.1%
	24-May-14	Sat	14:00 - 16:30	2.5	-9.0%
	16-Jun-14	Mon	14:15 - 17:00	2.75	-5.9%
BG3	09-May-14	Fri	13:00 - 17:00	4	-9.0%
	24-May-14	Sat	14:00 - 16:30	2.5	-3.4%
	16-Jun-14	Mon	14:15 - 17:00	2.75	-2.7%
HT1	22-May-14	Thu	13:15 - 17:15	4	6.2%
	31-May-14	Sat	9:15 - 12:15	3	5.7%
	17-Jun-14	Tue	14:00 - 17:30	3.5	2.3%
HT2	22-May-14	Thu	13:15 - 17:15	4	-10.0%
	31-May-14	Sat	9:15 - 12:15	3	1.8%
	17-Jun-14	Tue	14:00 - 17:30	3.5	7.5%
NEP1	15-May-14	Thu	13:00 - 17:00	4	-1.0%
	24-May-14	Sat	10:00 - 13:00	3	-7.7%
	18-Jun-14	Wed	14:00 - 17:00	3	-4.2%
NEP2	15-May-14	Thu	13:00 - 17:00	4	2.7%
	24-May-14	Sat	10:00 - 13:00	3	-4.5%
	18-Jun-14	Wed	14:00 - 17:00	3	-4.0%
NEP3	15-May-14	Thu	13:00 - 17:00	4	2.3%
	24-May-14	Sat	10:00 - 13:00	3	-3.7%
	18-Jun-14	Wed	14:00 - 17:00	3	-5.0%
TT	09-May-14	Fri	13:00 - 17:00	4	10.6%
	24-May-14	Sat	10:00 - 13:00	3	-15.0%
	17-Jun-14	Tue	14:00 - 17:00	3	-20.3%
	10-Jul-14**	Thu	N/A	N/A	-5.0%
YRG	09-May-14	Fri	13:00 - 17:00	4	-4.0%
	17-Jun-14	Tue	14:00 - 17:00	3	-2.3%
	21-Jun-14	Sat	11:00 - 13:00	2	-2.8%

**verification was performed by one researcher passing over the counter 20 times

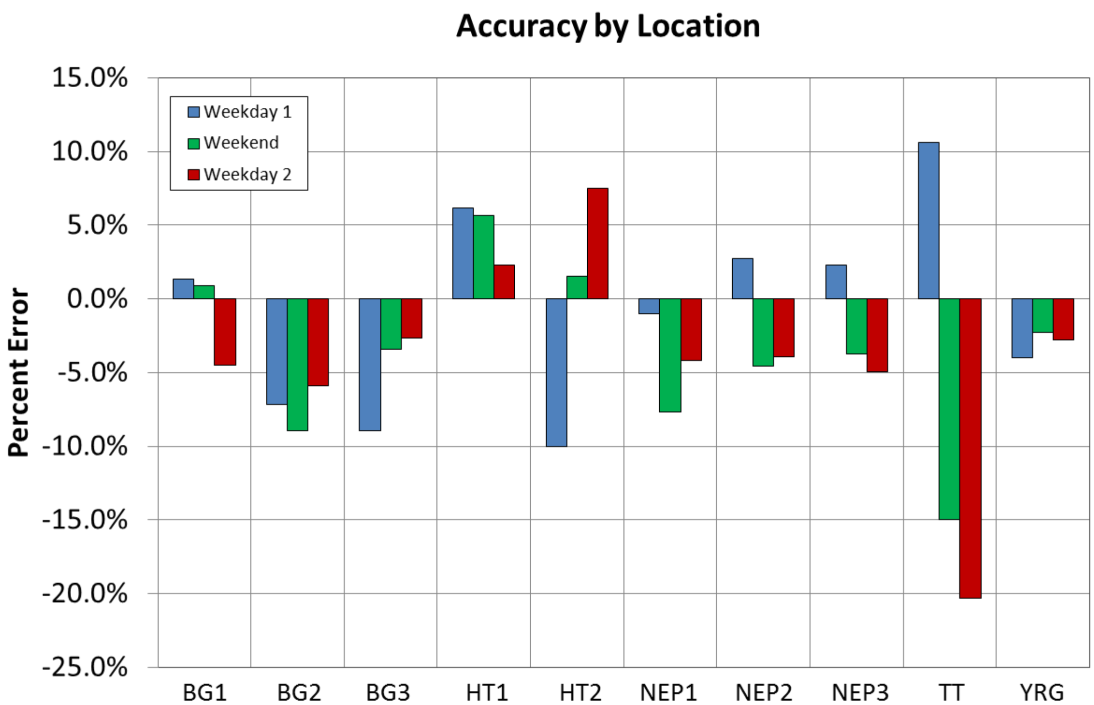


Figure 3-13: Accuracy of Zelts in Winnipeg, MB by location.

With the exception of the Zelt on Transcona Trail, all observed errors were between negative 10 percent (under counting) and positive 8 percent (over counting). Cyclists were observed to be over counted on gravel pathways more often than they were under counted, while on asphalt pathways the opposite was the case. The observed errors were low and random. For instance, many of the stations, such as BG1, HT2, NEP2 and NEP3 experienced both over counting and under counting. Because the observed absolute errors at each station were low (< 10 %), and inconsistent (over counting or under counting) no calibration factors were assigned to any of these counting devices.

After the first two counts were conducted at TT, it was suspected that there was a problem with this station. When data from the third verification count was analyzed these suspicions were confirmed; not only did TT experience the largest error, but this station also had the largest range in error, ranging from negative 20 percent to positive 11 percent. The manufacturer, Eco-Counter, was contacted in order to resolve this issue. A site visit was required and through talking with the manufacturer while at the site the problem was determined to be from something known as interference. This occurs when there are a number of utilities present such as overhead power lines. While at the site the manufacturer was able to remotely adjust the settings of the Zelt. Zelts have a number of different settings which can be adjusted depending on the amount of interference experienced by a particular station. Interference is described in detail in Section 3.5. After the settings had been adjusted the device was tested by having a member of the research team ride over the counter 20 times. The device performed well, detecting 19 of the 20 passes and was determined to be in working order.

3.5 SPECIAL ISSUES

A number of special issues were identified throughout the process of installing and monitoring these devices. The following section highlights issues which were discovered during the course of this research. These issues should be kept in mind when installing Zelts in Winnipeg in the future. The following issues were identified surrounding ZELT inductive loop cyclist counters in Winnipeg:

- Inductive loop spacing;
- Interference caused by utilities; and
- Time drift on internal clock.

3.5.1 Inductive Loop Spacing

Figure 3-14, shows the typical inductive loop pattern used for Zelts on AT paths in Winnipeg. This diagram also shows two areas which can affect the Zelt's ability to properly count cyclists:

- “A”: If the spaces on the outer edges of the path are too large, cyclists riding on the outer edges of the path may not be counted. This issue only affects stations on paved paths. At these locations loops cannot cover the entire path as it is likely that the integrity of the wiring could become jeopardized if pavement deterioration occurs and causes the wiring to become exposed.
- “B”: If the space between the two loops is too large, cyclists riding in the middle of the path may not be counted. Similarly, if the distance is too small, cyclists riding in the middle of the path may be double counted (once by each loop).

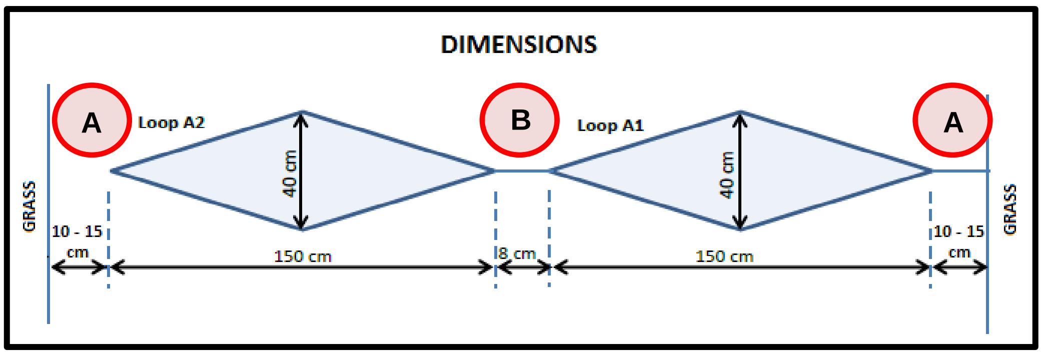


Figure 3-14: Problematic areas for Zelts installed in Winnipeg.

Distance “B” between the loops was easier to control on paved AT paths as the outline of the loop pattern was made from a wooden stencil which was cut to the exact dimensions of the loops. On gravel paths, the loops are buried, and could move while being buried or over time due to heaving and settling during spring and fall. Distance “A” was not an issue on gravel paths; the pre-formed loops were designed to extend 10cm past the path edges.

3.5.2 Interference Caused by Utilities

Inductive loops generate an electromagnetic field in order to detect cyclists. Sometimes the presence either overhead utilities such as power lines, or buried utilities such as cables and electrical wiring can cause something known as “interference”. The utilities in the area disrupt the electromagnetic field created by the Zelt, and impair the devices ability to count cyclists. This was the cause of the issues experienced at the Transcona Trail station. Eco-Counter has developed a number of different settings for their Zelts depending on where the Zelt is located, for example, counting in a mixed traffic environment, or counting in an area with higher amounts of interference. Typically these settings can be adjusted to counteract the effects of interference, which was the case at Transcona Trail.

3.5.3 Time Drift on Internal Clock

When connecting to counting devices using a laptop while at the count station via Eco-Link it was noticed that the time shown on the Zelts had a natural tendency to drift from the actual time. The amount of deviation observed at each location varied. The maximum deviation experienced by any counter was 8-minutes, and the largest rate of deviation was less than 1.5-minutes per month. This was not viewed as a major problem, as the data for this research was collected in hourly bins, however, if left unchecked, the time drift could create problems. It is recommended that the time on the counters be resynched at least once every year. This is done by connecting to the counter via Eco-Link when onsite, using the procedure described in Section 3.3.2. Once connected, the user simply clicks on the button labelled “Sync Logger Clock”.

4 DATA ANALYSIS

This chapter analyzes one year of cyclist count data collected between November 1st, 2013, and October 31st, 2014 from ten continuous count sites (CCS) to determine:

(1) the months which should be included when calculating SADT in Winnipeg;

(2) the SADT formula which should be used in Winnipeg; and

(3) the expansion method which will be used to expand short duration counts (SDC) to SADT estimates.

Expansion factors which can be applied to daily volume counts in order to forecast SADT volumes will be created and tested for their ability to accurately estimate SADT in Chapter 5.

Although AADT is generally preferred as a report statistic as it provides a representation of traffic over the entire year, the data collected during the winter season (from November, 2013 to April, 2014), were considered questionable. This was because the equipment performance was called into question on days where there was a strong presence of wind and snow. Snow and wind can cover up the counting unit and impair its ability to properly count cyclists. Site visits to each continuous count station (CCS) were conducted approximately once every month in winter to monitor the snowpack conditions at each CCS. With the exception of CCS-BG1, the rest of the stations had too much snow to accurately count cyclists during at least one of the site visits in winter. Seven out of the ten CCS reported at least one week or more daily volumes which were consistently zero, which was determined to be a result of too much snow covering the counting unit. Applying expansion factors to days where the volume of cyclists was zero would complicate the estimation process, and calculating AADT was impossible at every station except BG1. As a result, the focus of this research shifted to SADT.

4.1 MONTHS INCLUDED IN SADT CALCULATION

SADT is defined by the Traffic Monitoring Guide (TMG) as the average volume of traffic for a one day (24 hour) period during the data reporting season where over 80 percent of the yearly traffic is observed. Apart from stating that the period for which SADT is calculated should contain 80 percent of the annual traffic, limited guidance is provided on determining exactly which months should be selected for this calculation, as this could change from jurisdiction to jurisdiction. Selecting the months to be included in the SADT calculation for Winnipeg, MB was done by analyzing historical weather data in conjunction with the cyclist volume data collected from November 1st, 2013 to October 31st, 2014. Two weather variables which were expected to have a significant impact on cyclist volumes were analyzed: 1) daily high temperature, and 2) cumulative snow on ground.

4.1.1 Effects of Daily High Temperature on Daily Cyclist Volumes

The effects of daily high temperature on daily cyclist volumes were tested by establishing 5°C temperature bins and calculating the average daily traffic (ADT) that was observed on all days with the daily high temperature falling within a given temperature bin from the past year. Figure 4-1 shows the effects of daily high temperature on ADT by CCS in Winnipeg, MB as temperatures approach 0°C. As daily high temperatures fall below freezing, the average number of daily cyclists decreases. Once temperatures drop below 0°C, volumes stabilize, but the ADT at most stations dropped below 20 cyclists per day. It was decided that months during which the daily high temperatures are expected to fall below 0°C should not be included in the SADT calculation as volumes during these months would be too low to include in the SADT calculation.

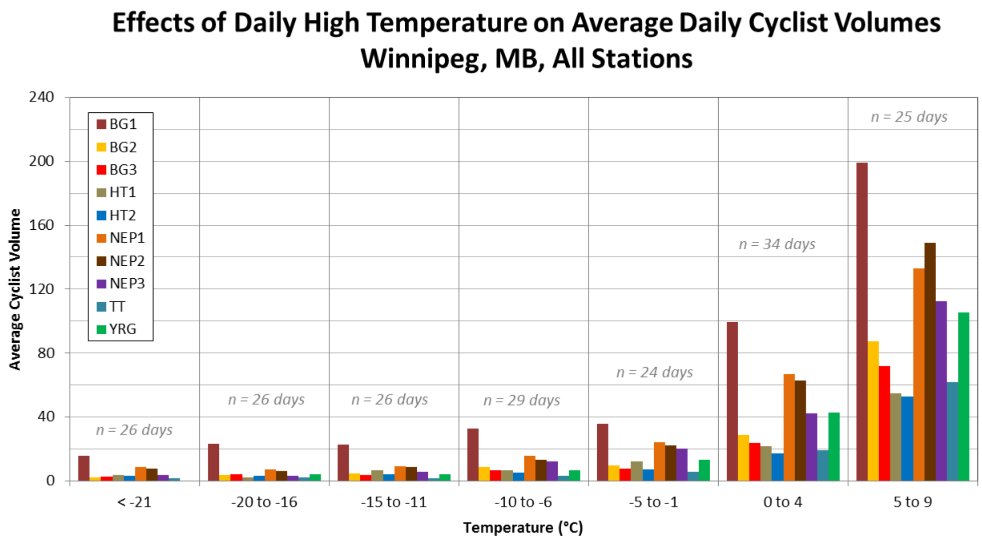


Figure 4-1: Influence of daily high temperature on average daily cyclist volumes.

Daily high temperatures from the past 10 years (2005 – 2014) were analyzed to determine the months when daily high temperatures typically fall below freezing. Figure 4-2 shows the minimum daily high temperatures observed in the last ten years for Winnipeg, MB for each date of the year. This represents the *lowest* temperature which would be expected to occur on any given day of the year based on ten years of historical data. From December to March, minimum daily high temperatures were consistently below 0°C. During the months of April and November the minimum daily high temperatures frequently fell below 0°C, which suggests that based on daily high temperature, the period for which SADT should be calculated between May and October.

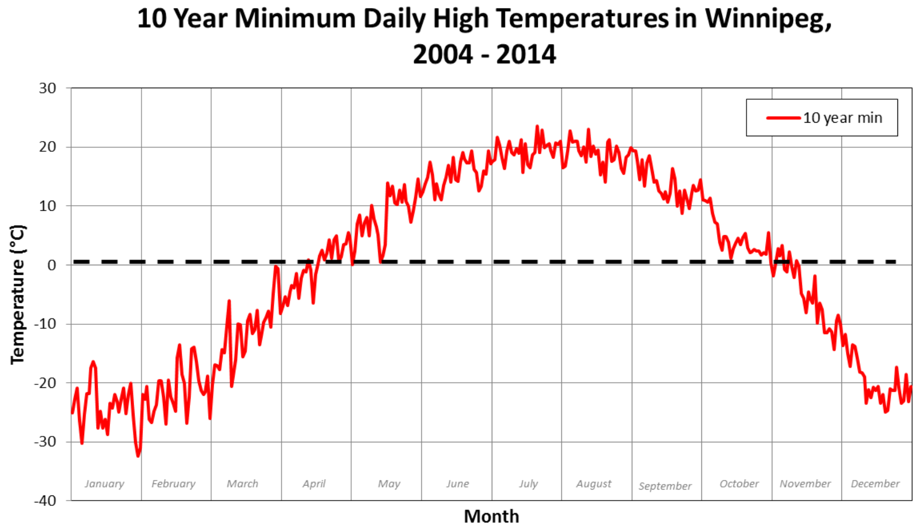


Figure 4-2: Minimum and Maximum Recorded Daily High Temperatures Winnipeg, MB, 2005 – 2014.

4.1.2 Effects of Cumulative Snow on Ground on Daily Cyclist Volumes

The effects of "cumulative snow on ground" on ADT were tested by establishing 5 cm snow bins and calculating the ADT that was observed on all days where the recorded cumulative snow on ground was within a given depth from November 1st, 2013 to October 31st, 2014. "Cumulative snow on ground" was selected over "precipitation (snowfall in winter)" because unlike rain, snow will have a longer lasting effect on pathway conditions. Although there could be better indicators to use, such as "cumulative snow on pathway", "cumulative snow on ground" was the only statistic available which showed the lasting effects of a snowfall. The ADT for each snow bin would be expected to be smaller if "cumulative snow on pathway" was used as this would remove the bias created by volumes recorded on days when the pathway had been cleared, but there was still large amounts of "cumulative snow on ground" recorded by Environment Canada.

Figure 4-3 and Figure 4-4 show the effects of the cumulative amount of snow on the ground on ADT by CCS in Winnipeg, MB. The ADT volumes observed when there was any snow on the ground were substantially less than days with no snow on the ground. Minimal fluctuation in daily volumes was observed as the amount of cumulative snow increased. From these data, it was determined that months which usually have any presence of cumulative snow on the ground should not be included in the SADT calculation.

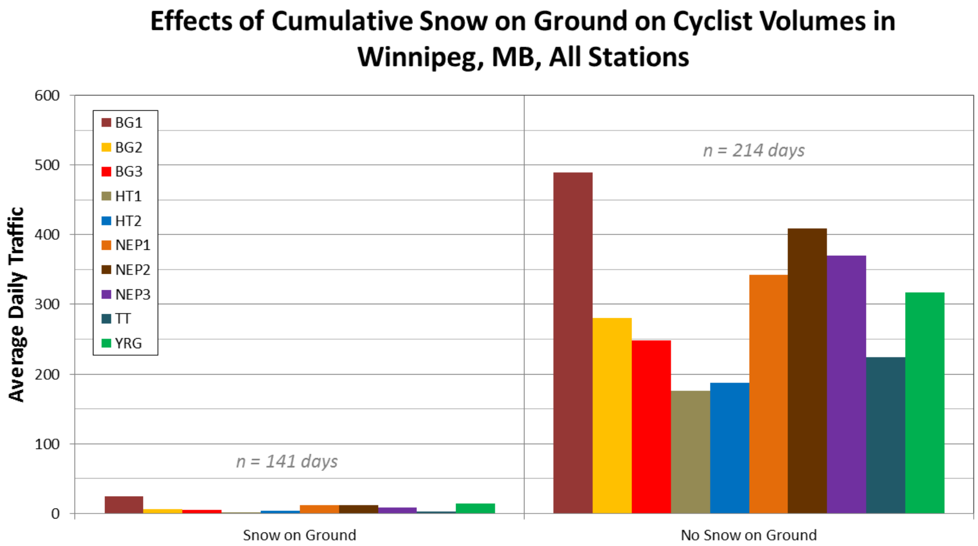


Figure 4-3: Comparison of average daily traffic volumes with and without the presence of "cumulative snow on ground".

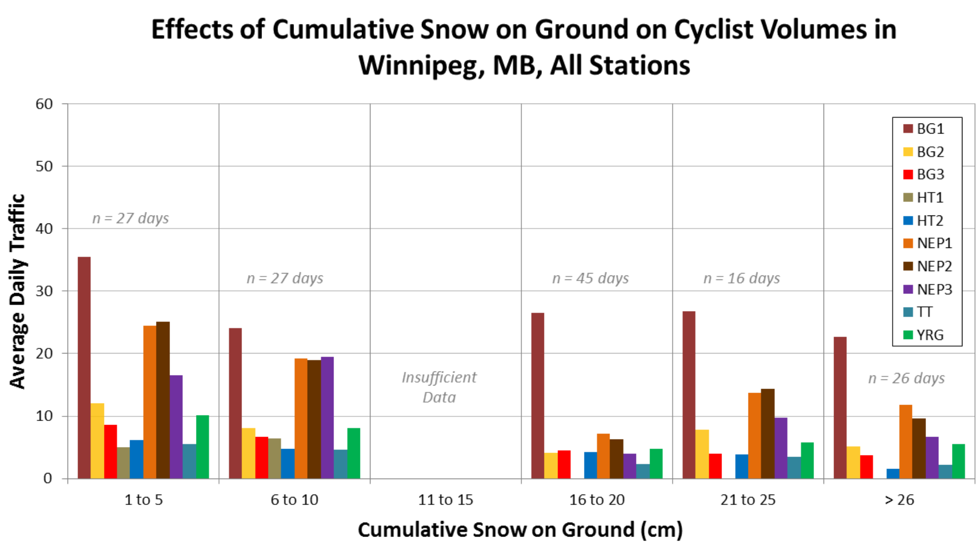


Figure 4-4: Comparison of average daily traffic volumes by amount of "cumulative snow on ground".

Ten years of cumulative snow on ground data were analyzed in order to determine which months typically have cumulative snow on the ground. Figure 4-5 shows the cumulative snow on ground data for Winnipeg over the past ten years. With the exception of a small snowfall in September, 2010, and October, 2009, snow usually falls and stays on the ground by November. It should be noted that after both of these events snow did not remain on the ground and melted very quickly. In spring, snow is typically present in April, and has usually melted entirely by May. Similar to the daily high temperature data, these data suggest that SADT should be calculated from May to October, inclusively.

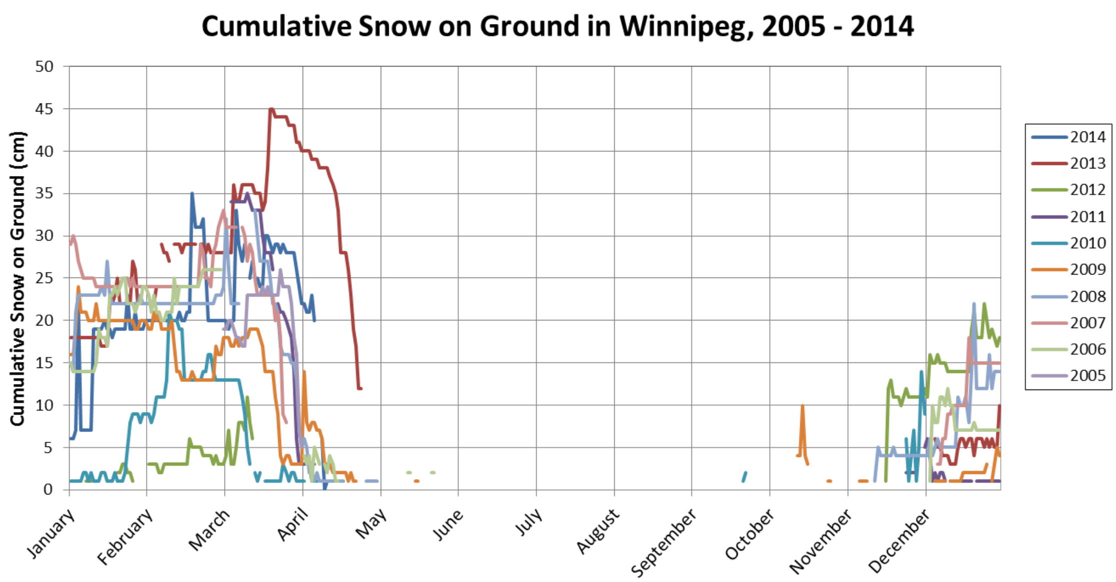


Figure 4-5: Historical daily high temperatures in Winnipeg, MB.

To verify that over 80 percent of traffic occurred during these six months, as stated in the TMG, the ratio of total traffic occurring from May to October to total annual traffic was compared at each station. Table 4-1 shows these ratios for each cyclist CCS in Winnipeg. At each station, the ratio was much higher than 80 percent, exceeding 90 percent at all stations.

Table 4-1: Ratios of seasonal total cyclist traffic to annual total cyclist traffic.

BG1	BG2	BG3	HT1	HT2	NEP1	NEP2	NEP3	TT	YRG
92%	94%	94%	97%	95%	92%	93%	94%	95%	94%

Given that both weather variables supported the SADT calculation including only the months of May to October, and the condition outlined in the TMG was met, the period during which SADT should be calculated in Winnipeg, MB was determined to be from May to October which should be kept consistent. This will allow for better comparisons to be made between cycling seasons year after year.

4.2 SADT FORMULA

Recall from Section 2.1.1 the assumptions made by the AADT and SADT estimation formulae:

(1) Daily traffic volumes are influenced by the month of year and relatively consistent within the same month; and

(2) Daily traffic volumes are influenced by the day of week, and days of the same week within the same month will have similar proportions of traffic.

However, no literature was identified which tested either of these assumptions for cyclist traffic data. Each of these assumptions was tested using cyclist data collected in Winnipeg to determine the applicability of this equation in a northern climate for cyclists. To establish if cyclist ADT volumes were influenced by the month of the year, monthly average daily traffic (MADT) volumes were calculated using the formula from the TMG. The MADT volumes were then summed and each month's MADT was expressed as a percentage of the total summation. Figure 4-6 shows the monthly distribution of cyclist volumes based on the data collected from November 1st, 2013 to October 31st, 2014. This graph shows that cyclist volumes differ based on the month of year, suggesting that month of the year has some impact on cyclist volumes. As a result, the assumptions regarding the influence of month of year on cyclist volumes in the AADT calculation were considered to be true.

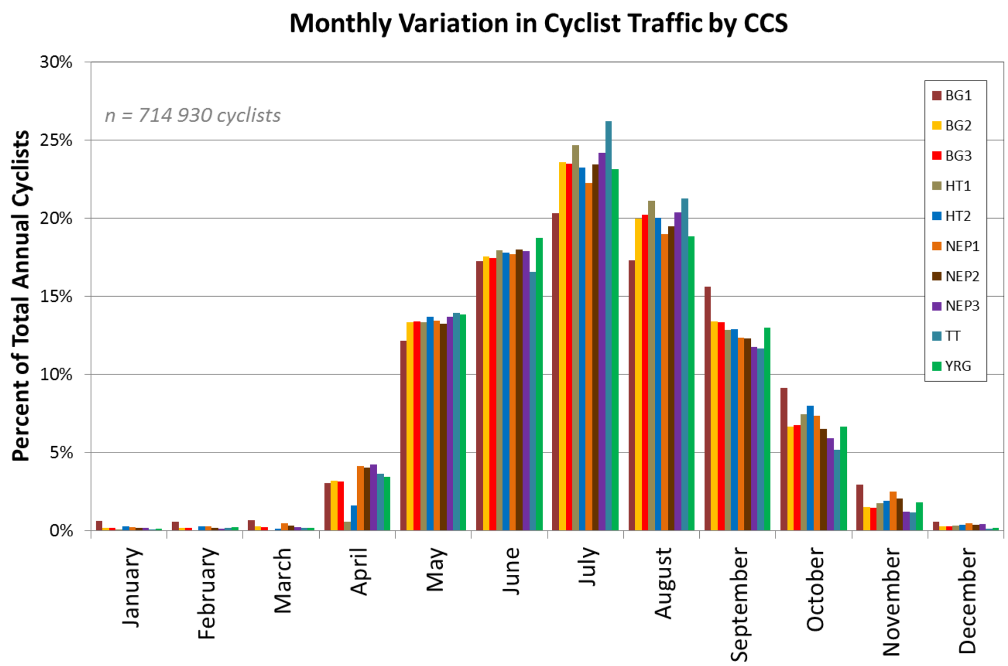


Figure 4-6: Monthly variation in cyclist traffic in Winnipeg, MB, November 1st, 2013 to October 31st, 2014.

Data from each cyclist CCS were also used to determine if the day of the week influenced cyclist traffic volumes. To test this assumption, day of week (DOW) patterns were created separately for each week of the year at each station. Day of week patterns show each day of the week, expressed as a percentage of total weekly traffic for that week. Weeks which contained a holiday were not considered for this analysis. Figure 4-7 shows what practitioners would typically expect to find with motorized traffic when analyzing DOW patterns at a CCS. Each day of the week within a month – for example, Mondays – would be expected to have approximately the same proportions of weekly traffic from week to week – approximately 11 percent for Mondays in June. However, Figure 4-8 shows the typical DOW patterns at a cyclist CCS in Winnipeg. Unlike vehicle DOW patterns, cyclist DOW patterns are inconsistent – days of the week within the same month do not yield similar proportions of weekly traffic. This process was repeated at each cyclist CCS station in Winnipeg with no relationship found between DOW and expected daily traffic volumes. From week to week, no patterns appeared that suggest day of week has no consistent influence on the volume daily of cyclists observed at a station for that day.

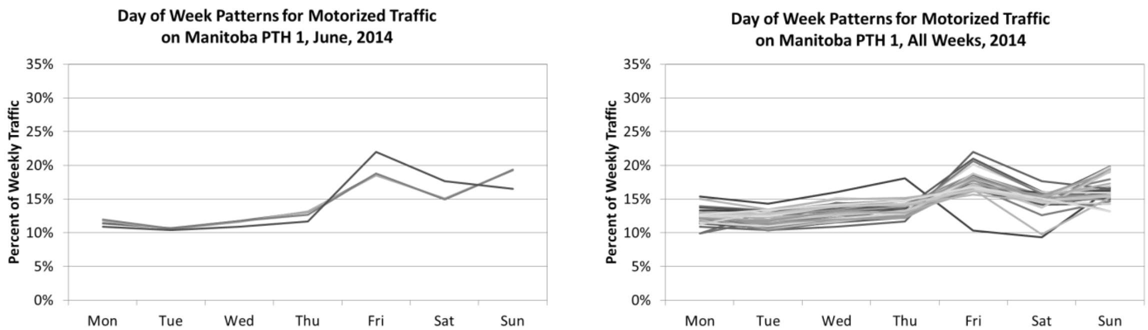


Figure 4-7: Day-of-week variations at motorized CCS on Manitoba highways for June, 2014 only (left) and November, 2013 to October, 2014 (right).

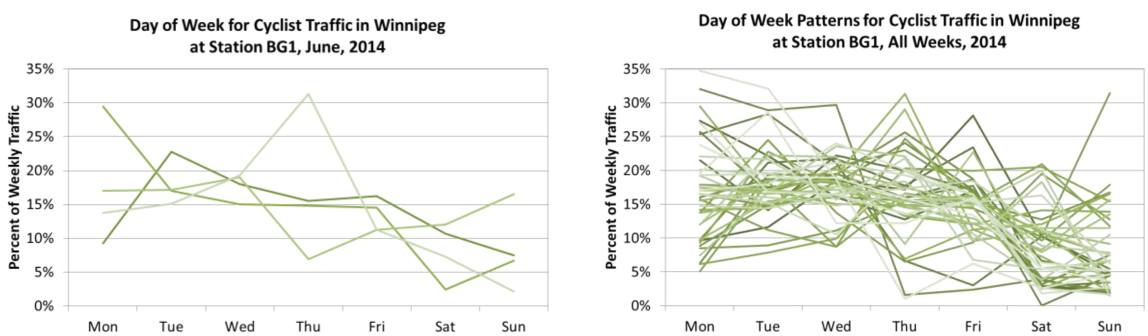


Figure 4-8: Day of week variations at cyclist station BG1 in Winnipeg, MB for June, 2014 only (left), and November, 2013 to October, 2014 (right).

This analysis demonstrates why it is necessary to use caution when applying formulae used in motorized traffic monitoring to non-motorized traffic monitoring. The SADT formula used in this research was changed to acknowledge these findings:

$$SADT = \frac{1}{m}\sum_{j=1}^{m}\frac{1}{n}\sum_{i=1}^{n} DailyVolume\,(i)(j)$$

Where:

(i) = day of month

(j) = month of year
m = number of months included in SADT calculation
n = the number of days within a month

This version of the formula is simple; all days within the same month are averaged to create monthly average daily traffic (MADT) volumes, then the MADT volumes are averaged across the entire period. Technically, only one day from each month is required to make an SADT calculation. Future research will be required to determine the effects of missing data on this formula, and determine an appropriate amount of data to be required in order to use this formula. In this research, there were cyclist volume data available for each day at each station.

4.3 METHODS FOR SADT EXPANSION

Three methods which have the capability of expanding short duration counts (SDC) which are 1-day in duration or longer to SADT estimates were identified in the literature review:

- Traditional Method;
- Day-by-Month Method; and
- Disaggregated Factor Method.

Each of the following methods have previously been examined in Minneapolis, MN, for their ability to predict AADT in a mixed mode (pedestrians and cyclists) environment based on SDC (Hankey, Lindsey, & Marshall, 2015). These methods were also tested in Montreal, QU, and Ottawa, ON for their ability to predict cyclist AADT based on 1-day SDC (Nosal, Miranda-Moreno, & Krstulic, 2014). The Disaggregated Factor Method performed best in all three cities. Both the Traditional Method and the Day-by-Month Method rely on the assumption that that DOW traffic proportions will be relatively consistent from week to week which has already been shown to be false for cyclist traffic in Winnipeg. Because the assumptions surrounding each of these methods were proven to be false, and each was shown to perform poorly when applies in other jurisdictions with similar climates as Winnipeg, neither will be analyzed as a practical method to forecast SADT from SDC in Winnipeg. Only the Disaggregated Factor Method will be explored further for its ability to forecast SADT estimates based on SDC.

4.4 CHAPTER SUMMARY

After analyzing the data, the following was revealed surrounding the expansion of SDC for cyclists in Winnipeg, MB:

(1) SADT should be calculated using the months between May and October, which was proven using 10 years of historical weather data. This period should be kept consistent which will allow for better comparisons to be made between cycling seasons year after year.

(2) When calculating SADT in Winnipeg, a different formula should be used than for motor vehicle SADT. However, further research will be needed to develop this formula and identify what should be done with incomplete datasets.

(3) When estimating SADT from daily volume counts in Winnipeg, the Disaggregated Factor Method of expansion should be used, as the assumptions regarding temporal influences on daily cyclist volumes used by other methods of expansion were shown to be false.

5 ESTIMATING SADT IN WINNIPEG, MB

This chapter develops expansion factors which can be applied to daily volume counts in order to estimate SADT in Winnipeg, MB and tests the accuracy of the newly created expansion factors. This will be useful when trying to normalize short duration counts (SDC) to a consistent metric and will allow for fair comparisons to be made between sites where only SDC data are available. Based on the findings in Chapter 4 regarding the relationship between the day of the week and the proportion of weekly traffic, the Disaggregated Factor Method was selected to produce SADT expansion factors for Winnipeg. The period for SADT to be calculated is from May 1st to October 31st, which should be kept consistent year after year.

This chapter develops and tests SADT expansion factors using the following procedure:

(1) Develop traffic patterns for each continuous count stations (CCS) and sort stations into traffic pattern groups (TPG);

(2) Generate average expansion factors for each TPG by averaging expansion factors from the CCS within the TPG;

(3) Identify practical durations for short duration counting; and

(4) Test the accuracy of each expansion method and duration for each station by removing CCS from the pool of data one by one and treating them as SDC sites. This will provide insights into when, and how long short duration counts should be completed for each type of expansion.

5.1 TRAFFIC PATTERN GROUPS

As mentioned in the literature review, there is no consensus on how to properly create TPG for non-motorized traffic. In this research, TPG were formed by comparing the day of season

(DOS) profiles for each CCS. DOS profiles were created for each CCS by creating individual DOS factors for each day within the SADT season from the formula seen below:

$$DOSFactor(i) = \frac{DailyVolume(i)}{SADT}$$

Where:

(i) = day of season (from 1 to 184)

A clustering procedure was used to help group stations together with similar DOS profiles. The analysis focused on comparing DOS factors between CCS on the same day in order to draw conclusions about the similarities between different CCS locations. The cluster procedure used in this analysis uses Ward's minimum-variance method, which finds the closest squared Euclidean distance between two data objects and then clusters, or groups these sets together (Ward, 1963). The procedure will continue grouping sites together until only one cluster remains. The results of the cluster procedure provide guidance for grouping stations with similar characteristics together, but the final decision on how groups should be formed is based on the analyst's judgment. This method of clustering months was chosen as it provides statistical guidance from the cluster procedure, and allows for the input of expert judgment. It is the same method which was used to cluster vehicle classification data on Manitoba highways by Reimer and Regehr (Reimer & Regehr, 2013).

Two traffic pattern groups were identified from the ten stations whose average DOS variations can be seen in Figure 5-1:

- Winnipeg (CCS: BG2, BG3, HT1, HT2, NEP1, NEP2, NEP3, TT, YRG); and
- Winnipeg Post-Secondary (CCS: BG1).

Average DOS profiles were created by averaging DOS factors on the same day for stations within the same TPG. Both TPG are similar which can be expected due to the uniform impacts of weather across the jurisdiction. However, the "Winnipeg" TPG has larger proportions of traffic being observed during summer months (July and August). Alternatively the “Winnipeg Post-Secondary” TPG shows more consistent proportions of traffic occurring throughout the period, with large spikes which are associated with special event days at the University of Manitoba and Investor’s Group Stadium. When analyzing the DOS factors on each day of the season, the DOS factors at the CCS-BG1 were consistently the lowest out of all ten CCS for days in July and August, and the highest for days in September and October. Figure 5-2 highlights the differences between these two TPG by showing the DOS profiles for each CCS.

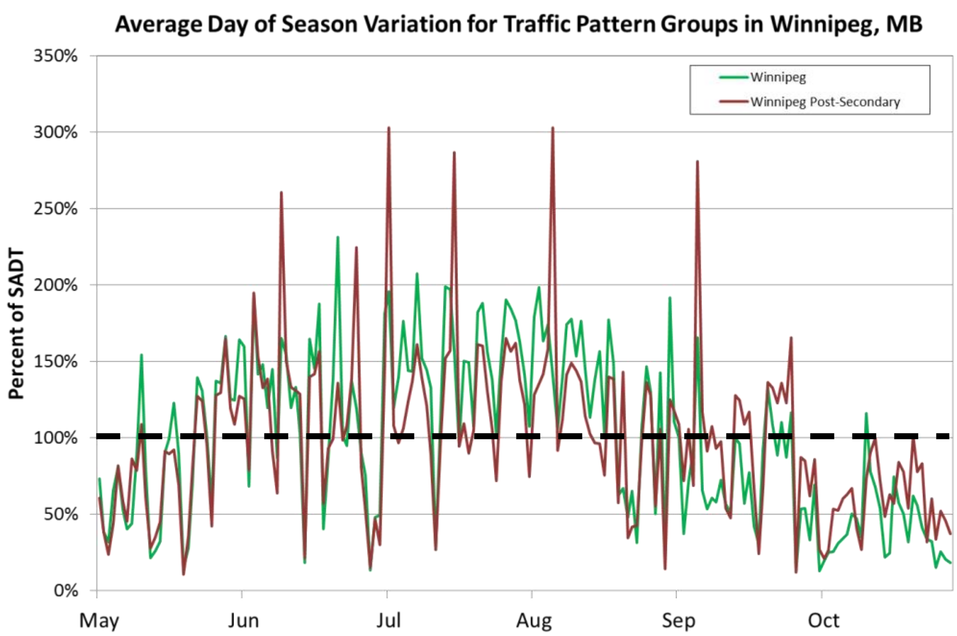
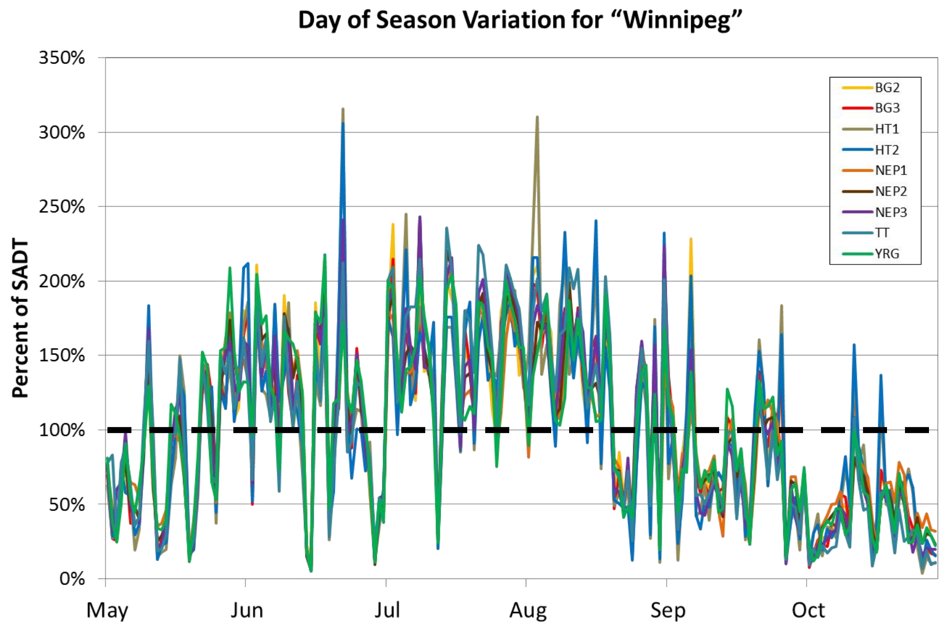


Figure 5-1: Average day of season variations of the two traffic pattern groups identified in Winnipeg, MB, November 1st, 2013 to October 31st, 2014.



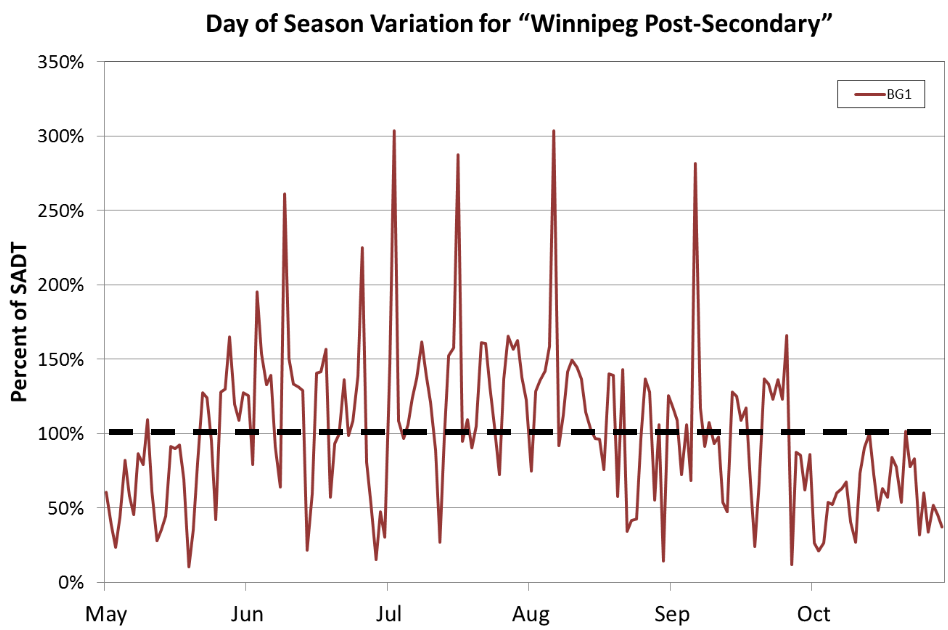


Figure 5-2: Day of season variations for stations of the two traffic pattern groups identified in Winnipeg, MB, November 1st, 2013 to October 31st, 2014.

5.2 SADT EXPANSION FACTORS FOR TRAFFIC PATTERN GROUPS

Individual SADT expansion factors were created for each TPG from May to October by averaging DOS factors for stations within the same TPG. A complete list of SADT expansion factors for both TPG can be found in Appendix A.

5.3 SAMPLING DURATIONS

Sampling durations were selected based on information collected in the Environmental Scan. In total, six durations were selected to expand daily volumes to SADT estimates:

- One Day (Any Day);
- One Day (Tue, Wed, or Thu);
- Two Days (Tue-Wed or Wed-Thu);
- Three Days (Tue-Thu);
- Seven Days (Consecutive); and
- Fourteen Days (Consecutive).

One day was used as a reference value as it was expected to produce a SADT estimate with the largest error. Emphasis was placed on volume data collected on Tuesday, Wednesday, or Thursday as jurisdictions will typically employ count staff on a Monday to Friday schedule, making it difficult to obtain all 24 hours of volume data on a Monday or Friday. Seven days was chosen as this has been proven to be the optimal duration for a SDC to be expanded to an SADT (Nordback, Marshall, Janson, & Stolz, 2013). Although seven days was shown to be the optimal duration in Boulder, CO, fourteen days was selected as the longest duration to determine if any added value could be gained from extending the length of SDC.

5.4 EXPANSION AND ACCURACY

In order to expand SDC to SADT estimates the following formula was used:

$$SADT\ Estimate(i) = \frac{DailyVolume(i)}{DOSFactor(i,k)}$$

Where:

(i) = day of the six-month season
(k) = traffic pattern group

When calculating DOS Factors, CCS were removed from the data set one by one and treated as SDC sites. DOS expansion factors by TPG were then recalculated to reflect the removal of one of the stations from the TPG, and daily volumes at the SDC site were used to predict SADT. The predicted SADT for each day(s) was calculated and compared to the observed SADT. This process was repeated for each station using each of the sampling durations previously identified. For durations greater than one day, SADT estimates were calculated for each day and averaged together. Because the “Winnipeg Post-Secondary” TPG only had one station – BG1 – the SADT estimation method could not be properly tested at this station. For this station, expansion factors were calculated using pooled data from the other nine CCS stations in Winnipeg, because the day of season profiles were determined to be similar enough to do so.

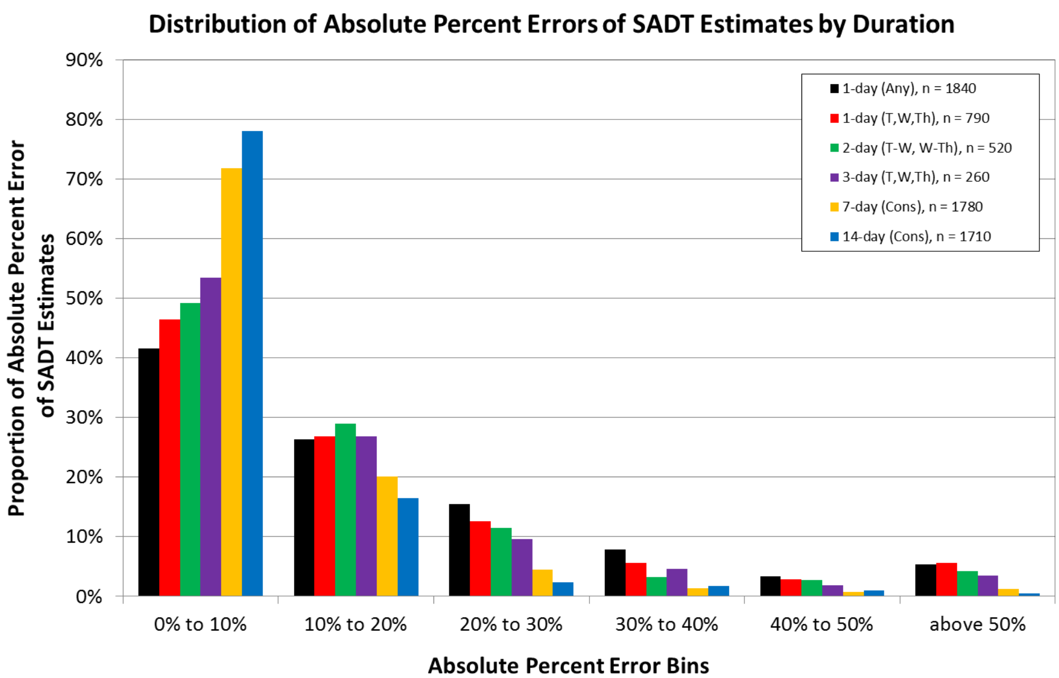
The accuracy of the Disaggregated Factor Method was evaluated by calculating the absolute percent error (APE) of each SADT estimation at each station. The formula for APE can be seen below:

$$|APE(i)| = \frac{|SADT(estimate)(i) - SADT(observed)|}{SADT(observed)}$$

Where:
(*i*) = day of data SADT estimation is determined from

The APE of SADT estimates were used to help determine which duration should be used for SDC conducted in Winnipeg. Figure 5-3 shows a histogram which represents what proportion of the APE fell within a given bin for each duration. For example, for the 7-day (consecutive) duration, approximately 72 percent of the SADT estimation errors were in the

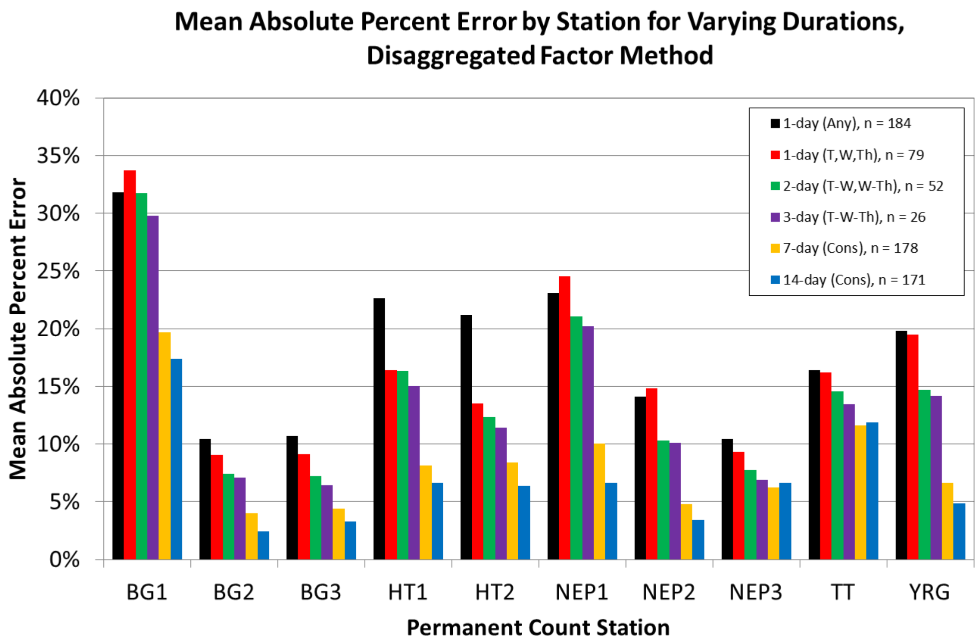
"0% to 10%" APE bin. The 14-day (consecutive) duration performed the best; this duration had the largest proportion of APE errors in the "0% to 10%" bin and the smallest proportion of APE errors which were in the "above 50%" bin. The 7-day (consecutive) duration also performed well; over 70 percent of APE were in the "0% to 10%" bin and few APE were over 30 percent (approximately 3 percent). Durations of 3-days or less did not perform as well as the 7-day and 14-day durations, but still had a significant proportion of APE which were less than 20 percent – at least 65 percent for each duration.



Error Bins	1-day (Any)	1-day (T,W,Th)	2-day (TW,WTh)	3-day (TWTh)	7-day (Cons)	14-day (Cons)
0% to 10%	42%	46%	49%	53%	72%	78%
10% to 20%	26%	27%	29%	27%	20%	16%
20% to 30%	15%	13%	12%	10%	5%	2%
30% to 40%	8%	6%	3%	5%	1%	2%
40% to 50%	3%	3%	3%	2%	1%	1%
Above 50%	5%	6%	4%	3%	1%	1%

Figure 5-3: Histogram: Distribution of absolute percent errors of SADT estimates by duration.

In addition to analyzing the distribution of APE the mean absolute percent error (MAPE) was calculated at each CCS by duration. Figure 5-4 shows the MAPE for each sampling duration at each CCS. The largest MAPE were observed at CCS-BG1, which could be a result of using pooled data from the "Winnipeg" TPG to expand volumes and estimate SADT values. All other stations showed relatively low MAPE, and were below 25 percent for all durations. The 1-day (any), 1-day (T,W,Th), 2-day (TW,WTh), and 3-day (TWTh) durations had similar MAPE values, ranging from 6 percent to 25 percent for stations in the "Winnipeg" TPG and 30 percent to 34 percent when estimating SADT values for BG1, the only station in the "Winnipeg Post-Secondary" TPG. The 7-day (consecutive) and 14-day (consecutive) also had similar MAPE values to each other, ranging from 2 percent to 12 percent for stations in the "Winnipeg" TPG and 17 percent to 20 percent when estimating SADT values for BG1. The MAPE generally decreased as the count duration was extended. At the majority of stations, the largest decrease occurred when the count duration was increased from 3-days to 7-days.



	1-day (Any)	1-day (T,W,Th)	2-day (TW,WTh)	3-day (TWTh)	7-day (Cons)	14-day (Cons)
BG1	32%	34%	32%	30%	20%	17%
BG2	10%	9%	7%	7%	4%	2%
BG3	11%	9%	7%	6%	4%	3%
HT1	23%	16%	16%	15%	8%	7%
HT2	21%	13%	12%	11%	8%	6%
NEP1	23%	25%	21%	20%	10%	7%
NEP2	14%	15%	10%	10%	5%	3%
NEP3	10%	9%	8%	7%	6%	7%
TT	16%	16%	15%	13%	12%	12%
YRG	20%	19%	15%	14%	7%	5%

Figure 5-4: Mean absolute percent error for calculating SADT when using the Disaggregated Factor Method for CCS in Winnipeg, MB, May to October, 2014.

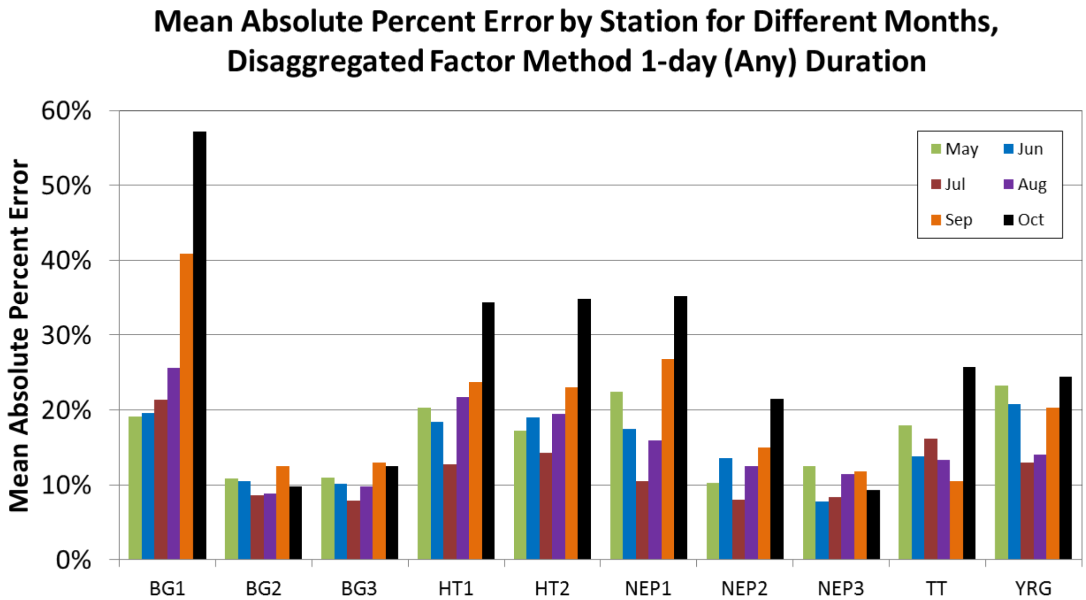
Current research suggests that the optimal duration for a SDC which is intended to be expanded to a seasonal or annual average daily traffic estimate to be 7-days (Nordback, Marshall, Janson, & Stolz, 2013). However, in that research the MAPE were between 15 percent and 30 percent. This research was able to achieve results with similar errors by using a 1-day duration – the shortest duration which was tested. It is recommended that the length of the SDC be determined based on the purpose for which the estimate is needed, and the level of error which a practitioner would be comfortable with. Table 5-1 shows the range of MAPE values, proportion of absolute errors which are less than 20 percent, and the number of SADT estimates which were developed. This table is intended to help guide a practitioner when selecting a SDC length as they provide insight into the expected levels of error. SADT estimates from the CCS-BG1 were not used to calculate values in this table as this station used expansion factors from a different TPG to produce SADT estimates.

Table 5-1: Accuracy of selected durations.

Duration	Range of MAPE**	Proportion of Errors < 20%**	Number of SADT Estimates Produced
1-day (Any)	9% - 23%	68%	1840
1-day (T,W,Th)	9% - 25%	73%	790
2-day (TW,WTh)	7% - 21%	78%	520
3-day (TWTh)	6% - 20%	80%	260
7-day (Cons)	4% - 12%	92%	1780
14-day (Cons)	2% - 12%	94%	1710

**SADT estimates from CCS-BG1 not used in calculation.

MAPE values for each count duration were also analyzed by month to determine if there would be an optimal month during which to conduct and expand a SDC to a SADT estimate. Figure 5-5 shows each station's MAPE by month for the 1-day (Any) duration. Only the 1-day duration was used to draw conclusions regarding which months to count in. This duration was not expected to perform as well as the others and would be expected to yield MAPE errors which would be the highest that a practitioner would expect. MAPE by month for all durations can be seen in Appendix B.



	May	June	July	August	September	October
BG1	19%	20%	21%	26%	41%	57%
BG2	11%	11%	9%	9%	12%	10%
BG3	11%	10%	8%	10%	13%	13%
HT1	20%	18%	13%	22%	24%	34%
HT2	17%	19%	14%	19%	23%	35%
NEP1	22%	17%	10%	16%	27%	35%
NEP2	10%	14%	8%	12%	15%	21%
NEP3	13%	8%	8%	11%	12%	9%
TT	18%	14%	16%	13%	11%	26%
YRG	23%	21%	13%	14%	20%	24%

Figure 5-5: Mean absolute percent error for expanding a short duration count (7-day consecutive) to a SADT estimate using the Disaggregated Factor Method for CCS in Winnipeg, MB, May to October, 2014.

The best months to conduct a SDC which will be expanded to an SADT estimate would be from May to August, as low MAPE values were observed across all stations during this time. If a count was conducted in September or October, the estimates produced would be expected to have larger errors than those estimates produced from counts taken between May and August. Caution should be used when expanding counts from October, as this month was shown to produce the least accurate SADT estimates at eight of the ten continuous count stations.

The SADT estimates for BG1 were low for months from May to August, despite the fact that BG1 SADT estimates were produced using DOS expansion factors from a different TPG. However, during the months of September and October the MAPE for SADT estimates at BG1 rose significantly to 41 percent and 57 percent, respectively. For the stations in the "Winnipeg" TPG, MAPE values were low at each station from May to August. MAPE values were typically 20 percent or less for this period, suggesting that these months would be optimal months to conduct an SDC. During the month of September, MAPE values increased, but were less than 30 percent at all stations. In general, most stations observed a relatively large increase in MAPE in October. However, each station's MAPE in the "Winnipeg" TPG remained less than 40 percent, which could be an acceptable amount of error for an SADT estimate, depending on the application it will be used for.

5.5 POTENTIAL ISSUES WITH EXPANSION METHODOLOGY

This chapter has shown that the Disaggregated Factor Method can be used to accurately predict cyclist SADT in Winnipeg from daily cyclist volumes if localized data are used to produce expansion factors. However, traffic pattern groups were formed using continuous count data, and short duration count sites could not be grouped using the same methodology as data from the entire SADT season would not be available. Nine of ten CCS fell within the same TPG – "Winnipeg", and when the one station which appeared to be in a different TPG ("Winnipeg Post-Secondary") was forced to use expansion factors from the other TPG the SADT estimates which were produced were accurate. This could suggest the following:

(1) Only one TPG may be necessary for all CCS in Winnipeg. Any CCS deployed in Winnipeg would yield similar DOS profiles.

(2) Only one TPG may be necessary for all CCS on *AT pathways* in Winnipeg. Any CCS deployed on an AT pathway in Winnipeg would yield similar DOS profiles.
(3) Multiple TPG exist for cyclist traffic in Winnipeg, but the locations selected for continuous cyclist monitoring in this research happened to be a part of the same TPG.

Continuous count data would be needed from different facility types across Winnipeg to verify these statements. Continuous count data would also be needed from locations close to other post-secondary institutions within Winnipeg to help strengthen the expansion factors in the “Winnipeg Post-Secondary” TPG. If either of these were the case, developing a methodology to determine the TPG of SDC sites would not be needed, as TPG would be assigned based on facility type or location. Future research will be needed to help determine how to properly classify the TPG of a site when only limited data are available. Based on findings from this research, SDC sites should be automatically classified in the “Winnipeg” TPG unless there is sufficient evidence to suggest otherwise – for example – if the location is close to a post-secondary institution.

5.6 CHAPTER SUMMARY

The following was revealed surrounding the expansion of short duration counts for cyclists in Winnipeg, MB:

(1) Two traffic pattern groups were identified: “Winnipeg”, and “Winnipeg Post-Secondary”. The “Winnipeg” TPG had a higher proportion of traffic throughout July and August, and lower proportions of traffic in September, and October, when compared to the “Winnipeg Post-Secondary” TPG.

(2) Short duration counts which are intended to be expanded to SADT estimates could be from 1-day to 14-days in duration. The duration of the SDC should be determined based on the level of error which a jurisdictions would be comfortable with. Caution should be used when applying expansion factors to short duration counts collected in October, as higher errors were observed for SADT estimates calculated from counts conducted in this month.

(3) Expansion factors were created using data from only AT pathways in Winnipeg. Future research will be needed to determine if these factors are also applicable to SDC data collected on different facility types. These factors were shown to be effective on AT pathways only in this research. If necessary, these factors could be applied to data collected on different facilities in Winnipeg, but caution should be used.

6 CONCLUSIONS AND RECOMMENDATIONS

This Chapter provides conclusions and recommendations for future research in this field.

6.1 CONCLUSIONS

The following conclusions are drawn from this research.

6.1.1 Cyclist Volume Data Collection

Current best practices for cyclist traffic monitoring have been developed using current best practices for motor vehicle traffic monitoring as a guide. Cyclist volume data can be collected either manually or using automated technologies. Counts are either considered to be short duration counts (SDC) or continuous counts taken at a continuous count station (CCS). SDC can are typically 15-minutes to 2-weeks in duration, while continuous counts generally last for one year or more. In cyclist traffic monitoring, seasonal average daily traffic (SADT) and annual average daily traffic (AADT) are important statistics; the primary goal of most traffic monitoring programs is to use data from CCS to expand SDC into SADT or AADT estimates.

Many jurisdictions collect cyclist volume data. About half of those surveyed indicated they used automated counting devices to monitor cyclist traffic for periods of time longer than one year. The most common types of technologies used were inductive loops and pneumatic tubes. Most jurisdictions rely heavily on manual hourly counts to provide information regarding cyclist activity in their community. This could be a result of many jurisdictions indicating that they lack the available resources to purchase, install, and monitor counting equipment. Although many jurisdictions collect cyclist volume data, few apply expansion factors to the short duration counts they collect. Among those that do there was no clear consensus on which method of expansion to use.

6.1.2 Selecting a Period for SADT in Winnipeg, MB

Ten years of historical weather data were used in conjunction with one year of cyclist volume data to draw conclusions regarding what months should be included in the SADT calculation and which method should be used to expand SDC to SADT estimates. The SADT period should be calculated using data from May to October, inclusive. This should be kept consistent in order for proper comparisons to be made regarding cyclist activity in Winnipeg from year to year. When expanding SDC in Winnipeg to SADT estimates the Disaggregated Factor Method should be used, as all other methods make assumptions regarding temporal effects on cyclist activity which were shown to be false in Winnipeg. Additionally, a new SADT formula was proposed to take into consideration the fact that the day of the week has little to no effect on cyclist volumes. More research is needed to develop this formula further and determine what should be done if a dataset is incomplete.

6.1.3 Application of Expansion Factors for Cyclist Volume data in Winnipeg

The accuracy of each type of expansion factor was computed by removing CCS from the pool of data and using the expansion factors to forecast SADT estimates. The estimates were then compared to the observed volumes experienced at each location and the absolute percent error APE of each estimate was calculated. For SADT expansion, two traffic pattern groups (TPG) were identified: 1) “Winnipeg”, and, 2) “Winnipeg Post-Secondary”. Nine stations were determined to be in the Winnipeg TPG while only one was classified as Winnipeg Post-Secondary.

When applying SADT expansion factors to SDC data collected in Winnipeg, SDC which are between 1-day and 14-days in duration will yield SADT estimates with acceptable error. The duration of the count should be determined based on the application of the SADT estimate. When attempting to expand SDC to SADT estimates, SDC data should be collected between May and September, inclusive, but not during October. Although this month is included in the SADT period, it was proven that using expansion factors and data collected in October will yield SADT estimates with high error.

Future research will be needed to determine how to determine the TPG of a site where only a SDC is available. Given that nine out of ten CCS were grouped into the "Winnipeg" TPG and only one station was grouped into the "Winnipeg Post-Secondary" TPG, locations where SDC are performed should be automatically classified into the "Winnipeg" TPG unless there is sufficient evidence to suggest otherwise.

6.2 RECOMMENDATIONS FOR FUTURE RESEARCH

The research has resulted in the following recommendations regarding research opportunities in the future:

- Expansion factors were tested and proven effective using ten continuous counting devices, but were not applied to any short duration counts. Future research should consider developing a methodology for creating a formal count program in Winnipeg by applying these factors to short duration counts in an effort to quantify cyclist activity across the entire city.
- Continuous counting devices collected data on active transportation paths only. In this research, two different traffic pattern groups emerged which suggests that traffic is not influenced by facility type. Future research should collect cyclist volume data

from other facility types in Winnipeg in order to determine if facility type would have any effects on observed traffic patterns.

- Traffic pattern groups were formed by analyzing day of season profiles. Day of season profiles were formed by analyzing continuous count site data, making it easy to determine which traffic pattern group they should fall into. When applying expansion factors at sites where data is collected for the first time identifying the location's traffic pattern group would be difficult. Considerations should be given to determine how to properly identify the traffic pattern group of a site.
- This research examined the statistic of SADT as it was perceived to be an important tool when analyzing cyclist activity in a jurisdiction. SADT is one of two frequently used statistics in traffic monitoring (motorized and non-motorized) – the other being AADT. Both have been adopted in non-motorized traffic monitoring from motorized traffic monitoring. Future research should consider additional statistics which could be useful to cyclist monitoring – for example, a "fair weather" SADT statistic could be used to identify the amount of users which would be expected to use a facility on an average day with favourable weather conditions. This would allow practitioners to ensure facilities are designed based on cyclist volumes which better represent peak flow.

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APPENDIX A:

Day of Season Expansion Factors by Traffic Pattern Group

Date	Traffic Pattern Group	
	Winnipeg Post-Secondary	Winnipeg
01/05/2014	61%	74%
02/05/2014	39%	39%
03/05/2014	24%	32%
04/05/2014	44%	66%
05/05/2014	82%	81%
06/05/2014	58%	53%
07/05/2014	45%	41%
08/05/2014	87%	44%
09/05/2014	79%	89%
10/05/2014	109%	155%
11/05/2014	61%	81%
12/05/2014	28%	22%
13/05/2014	35%	26%
14/05/2014	45%	33%
15/05/2014	92%	91%
16/05/2014	90%	100%
17/05/2014	92%	124%
18/05/2014	69%	91%
19/05/2014	10%	15%
20/05/2014	35%	28%
21/05/2014	81%	71%
22/05/2014	128%	140%
23/05/2014	124%	132%
24/05/2014	95%	101%
25/05/2014	42%	55%
26/05/2014	128%	138%
27/05/2014	130%	137%
28/05/2014	165%	167%
29/05/2014	120%	126%
30/05/2014	109%	125%
31/05/2014	128%	165%
01/06/2014	126%	160%
02/06/2014	79%	69%
03/06/2014	195%	195%
04/06/2014	154%	142%
05/06/2014	133%	149%
06/06/2014	139%	120%
07/06/2014	92%	146%
08/06/2014	64%	87%

09/06/2014	261%	166%
10/06/2014	151%	155%
11/06/2014	133%	120%
12/06/2014	131%	134%
13/06/2014	129%	103%
14/06/2014	21%	18%
15/06/2014	60%	8%
16/06/2014	140%	166%
17/06/2014	142%	146%
18/06/2014	157%	189%
19/06/2014	57%	41%
20/06/2014	93%	87%
21/06/2014	100%	139%
22/06/2014	136%	232%
23/06/2014	99%	102%
24/06/2014	108%	95%
25/06/2014	139%	138%
26/06/2014	225%	120%
27/06/2014	81%	90%
28/06/2014	52%	76%
29/06/2014	15%	13%
30/06/2014	47%	48%
01/07/2014	30%	49%
02/07/2014	147%	182%
03/07/2014	304%	197%
04/07/2014	108%	120%
05/07/2014	97%	140%
06/07/2014	106%	177%
07/07/2014	124%	145%
08/07/2014	137%	144%
09/07/2014	162%	208%
10/07/2014	140%	153%
11/07/2014	121%	145%
12/07/2014	89%	133%
13/07/2014	27%	27%
14/07/2014	97%	112%
15/07/2014	152%	200%
16/07/2014	158%	198%
17/07/2014	287%	157%
18/07/2014	95%	95%
19/07/2014	110%	151%
20/07/2014	90%	150%

21/07/2014	105%	108%
22/07/2014	161%	183%
23/07/2014	160%	189%
24/07/2014	131%	157%
25/07/2014	106%	139%
26/07/2014	72%	103%
27/07/2014	137%	154%
28/07/2014	165%	191%
29/07/2014	157%	185%
30/07/2014	162%	178%
31/07/2014	138%	164%
01/08/2014	122%	142%
02/08/2014	75%	108%
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15/08/2014	103%	114%
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17/08/2014	96%	158%
18/08/2014	76%	102%
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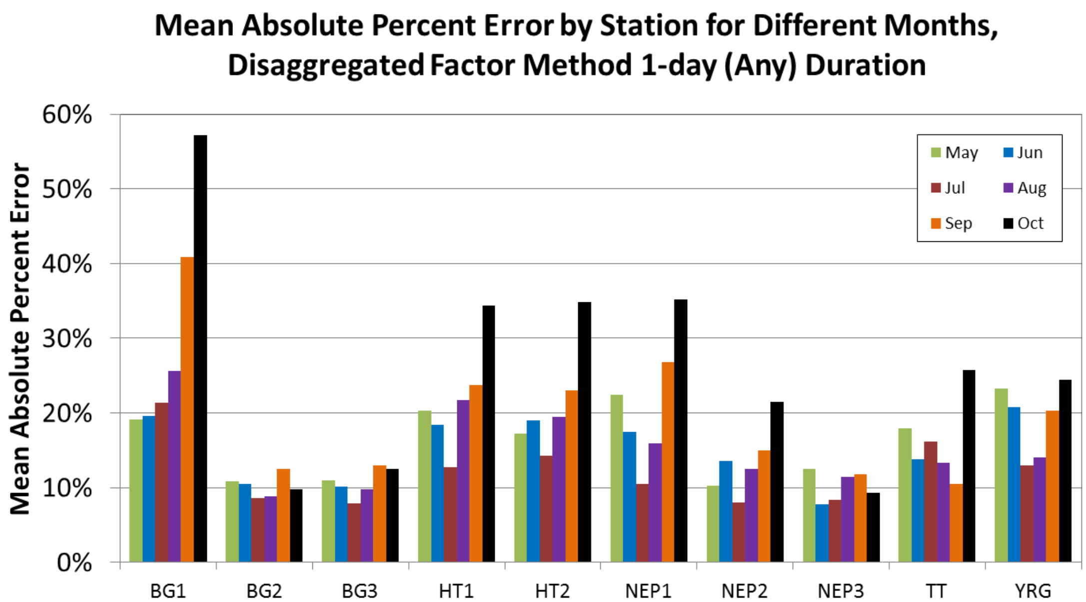
20/08/2014	139%	150%
21/08/2014	58%	63%
22/08/2014	143%	67%
23/08/2014	35%	48%
24/08/2014	42%	66%
25/08/2014	43%	31%
26/08/2014	97%	106%
27/08/2014	137%	147%
28/08/2014	128%	131%
29/08/2014	55%	51%
30/08/2014	106%	143%
31/08/2014	14%	20%

01/09/2014	125%	193%
02/09/2014	118%	111%
03/09/2014	109%	101%
04/09/2014	72%	37%
05/09/2014	106%	71%
06/09/2014	69%	94%
07/09/2014	282%	166%
08/09/2014	117%	66%
09/09/2014	92%	54%
10/09/2014	108%	61%
11/09/2014	94%	58%
12/09/2014	98%	73%
13/09/2014	54%	57%
14/09/2014	48%	51%
15/09/2014	128%	100%
16/09/2014	125%	97%
17/09/2014	109%	57%
18/09/2014	117%	78%
19/09/2014	68%	42%
20/09/2014	24%	31%
21/09/2014	67%	92%
22/09/2014	137%	133%
23/09/2014	133%	109%
24/09/2014	123%	89%
25/09/2014	136%	111%
26/09/2014	123%	88%
27/09/2014	166%	117%
28/09/2014	12%	12%
29/09/2014	87%	54%
30/09/2014	85%	54%
01/10/2014	62%	33%
02/10/2014	86%	70%
03/10/2014	27%	13%
04/10/2014	21%	20%
05/10/2014	26%	25%
06/10/2014	54%	26%
07/10/2014	52%	31%
08/10/2014	60%	34%
09/10/2014	63%	37%
10/10/2014	67%	51%
11/10/2014	41%	47%
12/10/2014	27%	35%

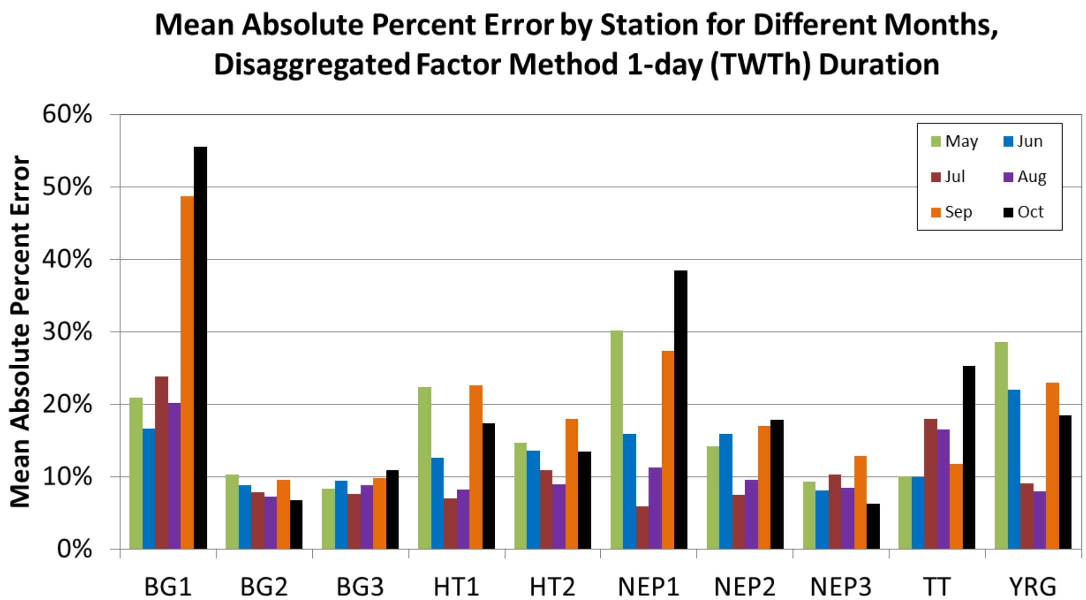
13/10/2014	73%	117%
14/10/2014	91%	78%
15/10/2014	100%	68%
16/10/2014	72%	54%
17/10/2014	49%	22%
18/10/2014	63%	25%
19/10/2014	57%	75%
20/10/2014	84%	58%
21/10/2014	78%	50%
22/10/2014	54%	32%
23/10/2014	102%	62%
24/10/2014	78%	56%
25/10/2014	83%	42%
26/10/2014	32%	34%
27/10/2014	60%	32%
28/10/2014	34%	15%
29/10/2014	52%	26%
30/10/2014	46%	20%
31/10/2014	37%	18%

APPENDIX B:

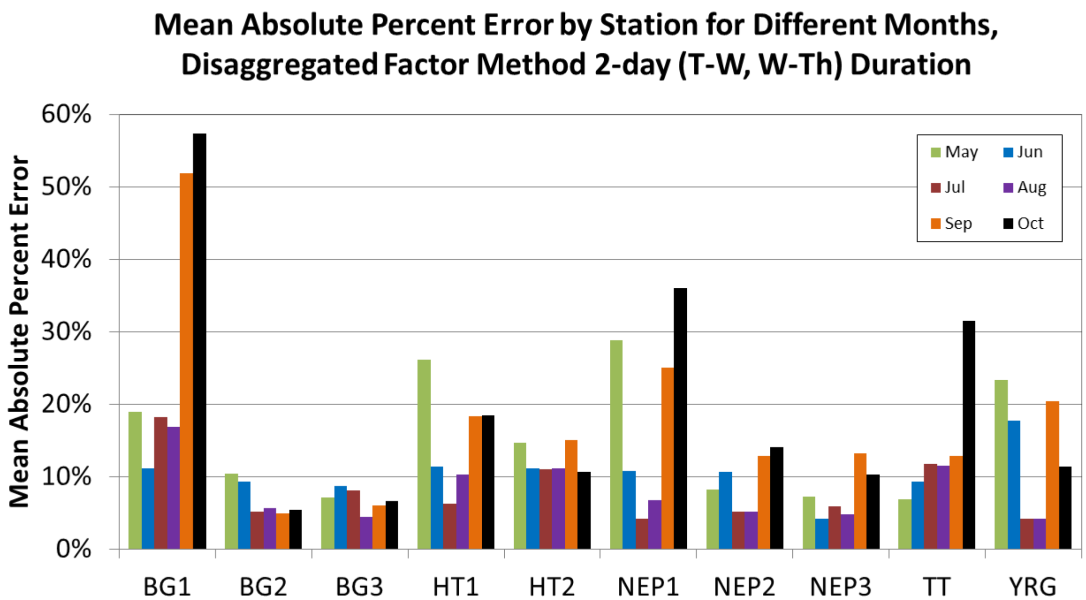
Mean Absolute Percent Error for Each Duration by Month



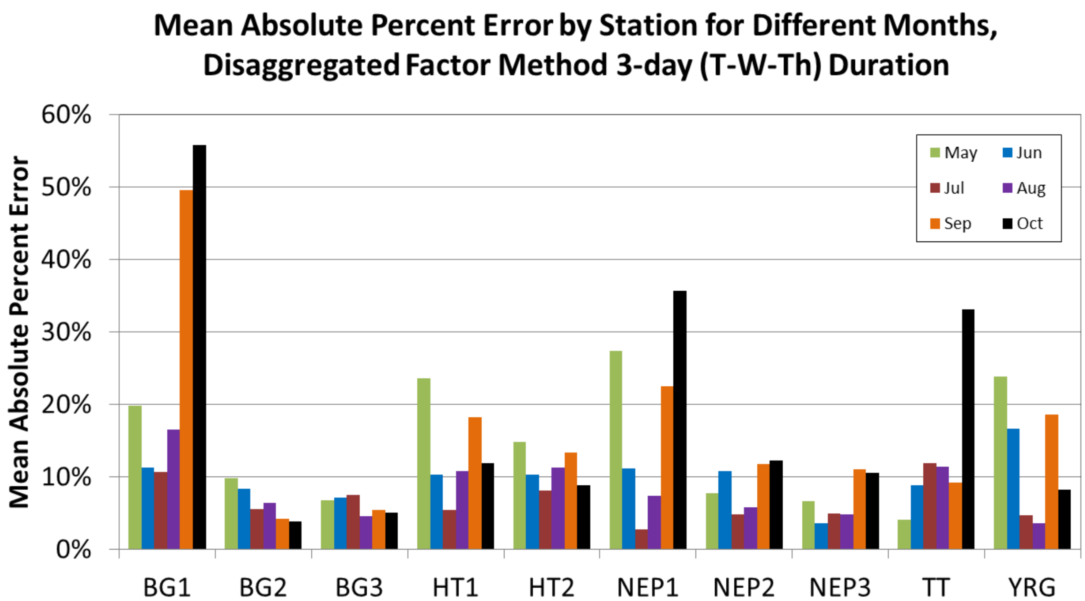
	May	June	July	August	September	October
BG1	19%	20%	21%	26%	41%	57%
BG2	11%	11%	9%	9%	12%	10%
BG3	11%	10%	8%	10%	13%	13%
HT1	20%	18%	13%	22%	24%	34%
HT2	17%	19%	14%	19%	23%	35%
NEP1	22%	17%	10%	16%	27%	35%
NEP2	10%	14%	8%	12%	15%	21%
NEP3	13%	8%	8%	11%	12%	9%
TT	18%	14%	16%	13%	11%	26%
YRG	23%	21%	13%	14%	20%	24%



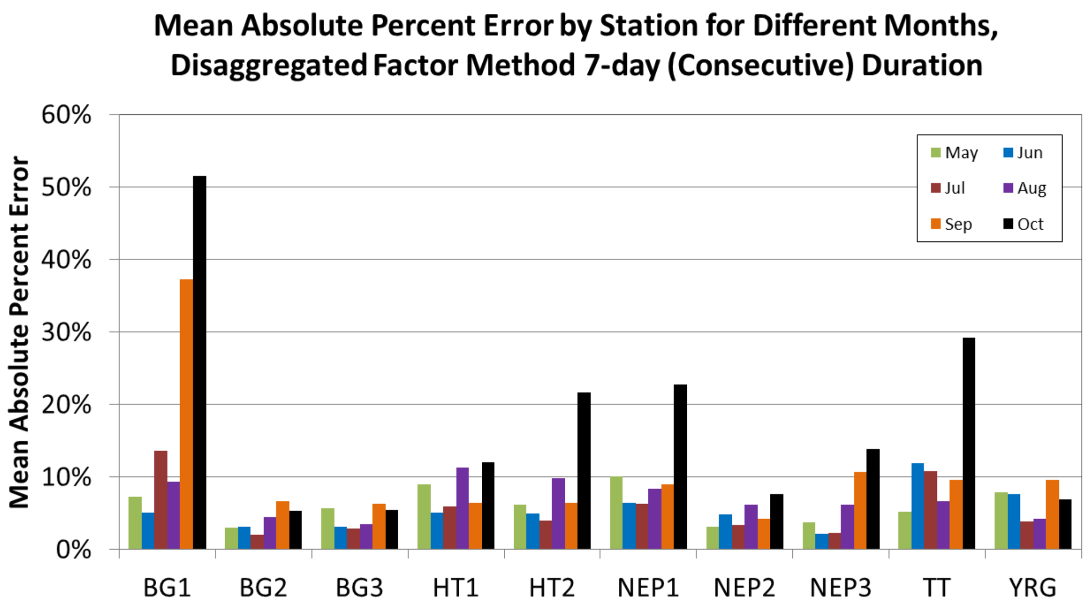
	May	June	July	August	September	October
BG1	21%	17%	24%	20%	49%	56%
BG2	10%	9%	8%	7%	10%	7%
BG3	8%	9%	8%	9%	10%	11%
HT1	22%	13%	7%	8%	23%	17%
HT2	15%	14%	11%	9%	18%	14%
NEP1	30%	16%	6%	11%	27%	38%
NEP2	14%	16%	8%	10%	17%	18%
NEP3	9%	8%	10%	8%	13%	6%
TT	10%	10%	18%	16%	12%	25%
YRG	29%	22%	9%	8%	23%	18%



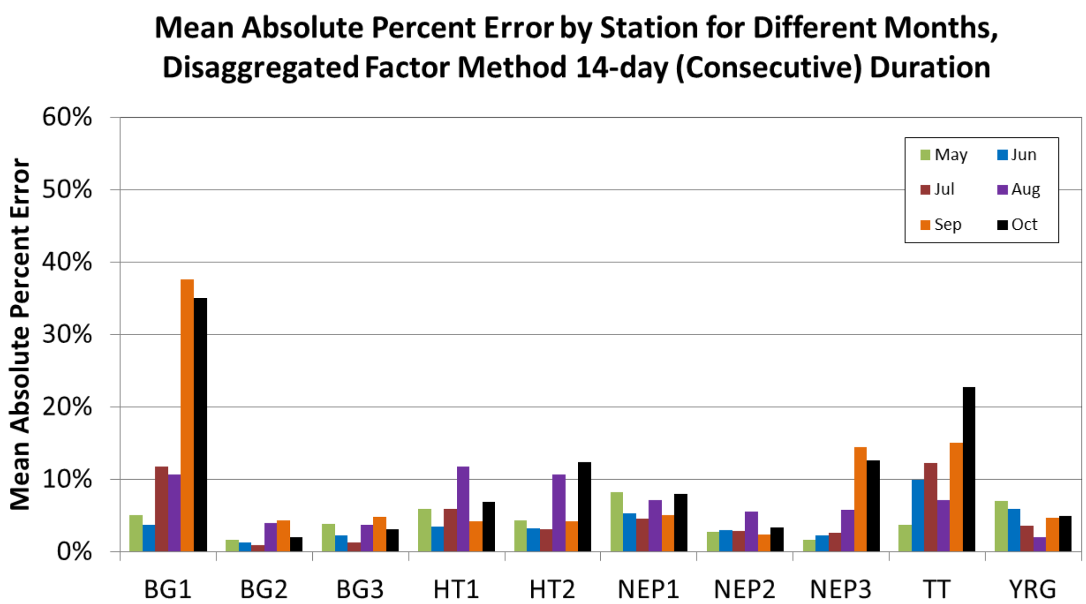
	May	June	July	August	September	October
BG1	19%	11%	18%	17%	52%	57%
BG2	10%	9%	5%	6%	5%	5%
BG3	7%	9%	8%	4%	6%	7%
HT1	26%	11%	6%	10%	18%	18%
HT2	15%	11%	11%	11%	15%	11%
NEP1	29%	11%	4%	7%	25%	36%
NEP2	8%	11%	5%	5%	13%	14%
NEP3	7%	4%	6%	5%	13%	10%
TT	7%	9%	12%	11%	13%	31%
YRG	23%	18%	4%	4%	20%	11%



	May	June	July	August	September	October
BG1	20%	11%	11%	16%	50%	56%
BG2	10%	8%	5%	6%	4%	4%
BG3	7%	7%	7%	5%	5%	5%
HT1	24%	10%	5%	11%	18%	12%
HT2	15%	10%	8%	11%	13%	9%
NEP1	27%	11%	3%	7%	23%	36%
NEP2	8%	11%	5%	6%	12%	12%
NEP3	7%	4%	5%	5%	11%	10%
TT	4%	9%	12%	11%	9%	33%
YRG	24%	17%	5%	4%	19%	8%



	May	June	July	August	September	October
BG1	7%	5%	14%	9%	37%	52%
BG2	3%	3%	2%	4%	7%	5%
BG3	6%	3%	3%	3%	6%	5%
HT1	9%	5%	6%	11%	6%	12%
HT2	6%	5%	4%	10%	6%	22%
NEP1	10%	6%	6%	8%	9%	23%
NEP2	3%	5%	3%	6%	4%	8%
NEP3	4%	2%	2%	6%	11%	14%
TT	5%	12%	11%	7%	9%	29%
YRG	8%	8%	4%	4%	10%	7%



	May	June	July	August	September	October
BG1	5%	4%	12%	11%	38%	35%
BG2	2%	1%	1%	4%	4%	2%
BG3	4%	2%	1%	4%	5%	3%
HT1	6%	3%	6%	12%	4%	7%
HT2	4%	3%	3%	11%	4%	12%
NEP1	8%	5%	5%	7%	5%	8%
NEP2	3%	3%	3%	5%	2%	3%
NEP3	2%	2%	3%	6%	14%	13%
TT	4%	10%	12%	7%	15%	23%
YRG	7%	6%	4%	2%	5%	5%