ANALYSIS OF OPERATIONAL DATA FROM THE LETHBRIDGE TRANSIT SYSTEM WITH RESPECT TO THE ENVIRONMENT, POPULATION, AND SPATIAL CONTEXT

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Dedication

In memory of one of the strongest, most determined, funniest Rad Grad Girls, Cathy (Catherine) Kloppenburg. Though cancer won the battle, you won the war. Your strength, determination, humor, and brilliance continue to live on through your friends, family, and work. Luv ya, chicka! Rad Grad Girls forever!

Abstract

I completed two research projects for this thesis. The first research project examined fuel efficiency and vehicle emission differences between Lethbridge Transit's hybrid and diesel buses. The second research project examined the actual vs potential utilization of the Lethbridge Transit system.

I compared the City of Lethbridge hybrid buses against their diesel counterparts, as well as to the STURAA standards to assess fuel efficiency and vehicle emissions. The results were comparable with STURAA and the hybrid did perform better than the diesel.

The key factors affecting utilization of the transit system are identifying the users, their location, and improving transit efficiency across large areas with low density. Lethbridge user qualities and quantities were not well known until the implementation of the Breeze Card data system. By conducting a hot spot analysis using the Breeze Card data, along with city age demographics, areas of high or low efficiency were identified.

Preface

“Science, for me, gives a partial explanation for life. In so far as it goes, it is based on fact, experience and experiment.”

− Rosalind Franklin, Letter to Father taken from The Dark Lady of DNA

“The more that you read, the more things you will know. The more that you learn, the more places you’ll go.”

− Dr. Seuss, *I Can Read With My Eyes Shut!*

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A huge thank you to my family and friends, all of who thought I was crazy to pursue more school but supported me anyways with late night phone calls and going out to let off some steam. It was an adventure that I was glad to take! I am also thankful for the new friends and family that I found along the way. My life is richer for all of you being in it.

Finally, I thank my dog. He is the Sherlock to my Watson, and I could not have it through this experience without him!

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ANOVA	Analysis of Variance
ATU	Amalgamated Transit Union
CO	Carbon Oxide
CO_2	Carbon Dioxide
CUTA	Canadian Urban Transit Association
CV	Coefficient of Variation
DEA	Data Envelope Analysis
ESRI	GIS Mapping software
GIS	Geographic Information System
GM	General Motors
GPS	Geographical Positioning System
HC	Hydrocarbon
ID	Identification
LA	Lethbridge Area
MCI	Motor Coach Industries
MRTOM	Multiple-Route Transit Optimization Method
NMHC	Non-methane Hydrocarbons
NO_X	Nitrogen Oxides
PM	Particulate Matter
STURAA	Surface Transportation and Uniform Relocation Assistance Act
THC	Total Hydrocarbon
UDDS	Urban Dynamometer Driving Schedule
UPass	University Transit Bus Passes
US	United States
UTM	Universal Transverse Mercator
XD	New Flyer of America diesel bus model type
XDE	New Flyer of America hybrid diesel bus model type
XY	Coordinate data

Chapter 1: Introduction

Public transportation is a complex issue requiring multiple viewpoints. Economic, social, and environmental concerns all must be considered. Finding the balance point between economic, social, and environmental is one the larger challenges facing researchers, businesses, and governments. Every city has unique public transportation challenges. This is due to many influences, including population size, demographics, social biases, economics, history, and topography.

Transportation research generally focuses on economic, social, and environmental considerations. Due to political and business pressures, most transit studies focus on social or economic factors. Only in the recent decade has published research for transit planning and policy started examining environmental factors alongside social and economic factors. Previous research traditionally studied work commuting, but transportation use is now for leisure and shopping (Banister & Banister, 1995; Banister, Watson, & Wood, 1997). These activities are less structured and more diverse than work activities, causing transit analysis to become more difficult in meeting efficiency targets.

With more knowledge from decades of research and large amounts of data available, researchers need to identify relationships and create cumulative analysis from different disciplines on big picture issues, such as transportation. New ways of approaching planning need to be investigated and reported in comprehensive ways that are usable and understandable to policy makers, practitioners, and public (Meyer, 2010; U.S. Transportation Research Board, 2009). Identified gap areas of transit research are the need for new tools and methods that help reduce transportation greenhouse gas emissions (Meyer, 2010).

To examine public transportation efficiency, several factors are considered: system accessibility, travel time, trustworthiness (i.e. reliability and safety), frequency, maximum load, vehicle characteristics, adequate information and support vehicles, and mobility in accordance with necessities (Murray, Davis, Stimson, & Ferreira, 1998; Sampaio, Neto, & Sampaio, 2008; Tomazinis, 1977).

The first component of this thesis will examine the carbon output of diesel buses versus the hybrid diesel buses in the Lethbridge Transit system. The second component will examine, through statistical relationships in time and space, the differences between Lethbridge demographics and current transit ridership. The data will then be used to assess the efficiency of the system for transit riders.

1.1 The Importance of Studying Public Transit

The environmental analysis of Lethbridge Transit regarding efficiency, emissions, and use should be conducted with global environmental implications in mind. Transit is a potential method to reduce urban impact on the environment by decreasing vehicle emissions through increasing ridership and decreasing personal vehicle usage (Banister et al., 1997; Taylor & Morris, 2015; Tomazinis, 1977). To accomplish this, the efficiency and use of transit systems must be understood and refined where possible. Efficiency and use can be examined through detailed summaries and comparisons of use between routes, stops, data, and times, as well as, comparison of transit use to city districts and characteristics. This task is too large and complex to complete in a single study, and this study focuses on the possible value of individual rider data, summarized and examined in a statistical and spatial context. The resulting efficiency and use studies can then be used to improve the system to allow for rider retention and ridership increase, thus reducing environmental impact.

The other component of the thesis, regarding the hybrid and diesel emissions comparison, will examine the differences in carbon dioxide emission output through comparing test results and analyzing kilometers traveled. Analysis of emissions identifies areas of improvement and areas of difference.

1.2 The Main Areas of Transit Research

1.2.1 Environment and transit. Environmental science is based on science and social science. Transit analysis and objectives combine science, engineering and social sciences, with a focus on environment and socio-economic situations (Dodson, Gleeson, & Sipe, 2004; Meyer, 2010). This type of multi-disciplinary work and focus is why environmental science research supports transit planning and projected future studies being undertaken for the triple bottom line management style (environment, economic and social considerations when planning) that transit planners are incorporating (Sampaio et al., 2008; Zahabi, Miranda-Moreno, Patterson, Barla, & Harding, 2012).

Many transit studies are conducted on metropolis-sized cities. However, many of Canada's cities are not metropolis-sized; therefore using the transit planning structures of a metropolis on a small city does not create the most effective planning nor does it consider the differences of usership between ridership demographics of small cities and metropolis areas. Fricker and Shanteau (1986) are some of the earliest researchers to acknowledge the need to improve strategies for small city transit.

Lethbridge has grown in the past years, with several new subdivisions being developed on the north, south, and west sides of the city. This has placed demands on Lethbridge's public transportation system and has affected the form and development of the transit system. Two key factors affecting transit system development and future operation are the questions of who

the users are and where are they located related to services. This information is crucial to designing an efficient system and increasing transit system use. User qualities and quantities are poorly known for Lethbridge. This thesis compares the emission performance of hybrid and diesel Lethbridge Transit buses, as well as investigates and characterizes user data of the Lethbridge public transportation system. This information can help determine whether the system could be designed to be not only more efficient but also more successful in contributing to local and global environmental goals.

1.2.2 Usership. Usership is a main focus of transit research. Transit managers in cities of all sizes attempt to attract more riders to their transit system and convince vehicle owners to switch to public transportation. They, therefore, need to base their actions on evidence regarding the characteristics of the actual user population and the potential user population. The key is identifying the barriers and motivators that influence people's decisions (Hung Wei & Yuan Kao, 2010; Popuri, Proussaloglou, & Ayvalik, 2011). Many variables affect people choosing transit as a main mode of transportation, including individual perceptions, reliability, frequency, pricing, speed, access, comfort, convenience, driver kindness, cleanliness, and occupancy (dell'Olio, Ibeas, & Cecin, 2011; Redman, Friman, Gärling, & Hartig, 2013). In the absence of details regarding decision makers, planners, and user motivation, characteristics of the general population and user population can be compared.

1.2.3 Post-secondary & transit. In many communities, post-secondary institutions and public transit have a mutually beneficial relationship. Since students constitute a large proportion of transit users, many post-secondary institutions' studies analyze the relationships between students and public modes of transportation. Shannon et al. (2006) examined the commuting habits of staff and students and the barriers that affect their choices. The motivation behind this study was to examine reducing parking demand, improving student health, reducing

traffic congestion issues, and reducing the environmental impact of the post-secondary institute. The study used a staff and student survey that studied travel patterns, stage of behaviour change, self-efficacy, barriers, motivators, and interventions. The results of the survey were then analyzed with t-test and ANOVA statistical analysis. The results from this study identified trip generation, potential for change, motivators, and interventions as barriers. The authors then considered ways to reduce these barriers, ways to increase convenience and cost-effectiveness, and the potential for change.

Miralles-Guasch and Domene (2010), Stasiskiene and Makarskiene (2013), and Villanueva (2008) researched universities and public transportation. They explored motivations, barriers, user preferences, lack of adequate infrastructure, sustainability of public transportation, and how public transportation can improve the health of students. Their main topics were motivators, barriers, infrastructure, and cost. Miralles-Guasch and Domene, as well as Villanueva, used user surveys to collect data. Stasiskiene and Makarskiene used quantitative data for their analysis, and their primary focus was comparing traffic emissions during times of congestion and non-congestion.

1.2.4 Socioeconomics and transit. With the increase of personal vehicle use, transit has become an important public service for those who cannot operate personal vehicles (Banister et al., 1997). Literature identifies that the main users of transit are low-mobility individuals, post-secondary students, seniors, lower income individuals, and school-aged youth (Jansuwan, Christensen, & Chen, 2013; Taylor & Morris, 2015). These people are generally referred to as transit-dependent, as they rely on public transit to provide access to economic opportunities, school, medical care, family and friends, and social and community services (Dodson et al., 2004; Garrett & Taylor, 1999). Banister et al. (1997) identify that newer data sets need to be created in

such a way that social-economic and physical data requirements can be related to census data so that comprehensive analysis can be conducted at various scales for transit analysis.

Research papers that examine transit use tend to use qualitative analysis. Some authors have noted that more quantitative studies would be beneficial because evidence and statistical information help policymakers make decisions with more detail and confidence than does qualitative information (Del Castillo & Benitez, 2012). This type of research has been conducted mostly in large metropolitan areas. Studies in smaller cities are generally lacking. The results and design of many of the research projects described could be applied to an analysis of the Lethbridge system. This study will analyze the quantitative composition of usership information from the Lethbridge Transit Breeze Cards and city census data. This study will also consider the kilometers traveled, liters of fuel used, and comparisons of carbon dioxide production between the hybrid and diesel buses to examine emissions and fuel efficiency.

1.3 Thesis Objectives

The purpose of this thesis is twofold. The first objective is to use City of Lethbridge's database on bus types and kilometers traveled to compare emission outputs. The second, and major, objective is to examine detailed ride data of the Lethbridge Public Transit system, characterize some usage patterns, and assess system efficiency compared to the city demographics through time and space. Together these objectives help assess environmental sustainability of some aspects of the system.

Chapter 2 provides the background and context of transit from a social, environmental, and economic perspective. A description and overview of the City of Lethbridge, which is the location being used for this study, is provided, along with the history of Lethbridge Transit.

Chapter 3 reviews the available research on transit from an environmental science perspective. The literature that is available on small city and public transit studies is reviewed, as well as the studies that have examined environmental analysis of hybrid and diesel emissions.

In Chapter 4, the methodologies used for this study is listed and explained. An explanation of how the data was gathered, where it came from, how it was managed and what will be done with it after the study is provided.

In Chapter 5, an analysis of the results for both the hybrid/diesel analysis and the spatial usership analysis is provided in sections in this chapter.

In Chapter 6, a summary of the research and findings is discussed, as well as the challenges of the study and opportunities for research.

Chapter 2: Background

2.1 Introduction

Many aspects need to be considered when planning a public transportation system, such as operational considerations, system management, staffing, vehicle management, revenue collection and security, financial management, customer interface, and system evaluation and monitoring. This section presents an overview of public transit from a social, environmental, and economic perspective, as well as an overview of the City of Lethbridge and the history of Lethbridge Transit.

2.2 Overview of Bus Public Transportation

Transit plays a key role in connecting communities, while allowing the daily transportation of people from one part of a town or city to another. People who primarily use public transit in smaller communities include significant numbers of those with disabilities, who do not have access to personal transportation, or who are too young to drive. Public transportation systems are also seen as having broader positive environmental value (i.e. by reducing traffic congestion, greenhouse gas emissions, and the need for parking). With increasing concerns for these issues, both from the public and from city managers and planners, the promotion and use of public transportation as an alternative to driving continues to increase (City of Toronto, 2011).

Description and analysis of the structure and dynamics of public transportation requires multiple viewpoints and must refer to economic, social, and environmental concerns. Every city has unique public transportation challenges because of the influences of population size, demographics, social biases, and economics. What works for large, commuter-based

metropolitan cities will not necessarily work for small cities, where part of the value of a transit system is seen as fulfilling a social need.

2.2.1 Social. The general users of public transportation in Canada are seniors, post-secondary school students, low mobility individuals, lower income individuals, and school-aged youth (Jansuwan et al., 2013; Masterton Planning Group, 2006; Taylor & Morris, 2015). Public transit provides access to economic opportunities, school, medical care, family and friends, and social and community services (Dodson et al., 2004; Garrett & Taylor, 1999). Due to increased personal vehicle usage, transit usage has changed in most Canadian cities to being primarily used by the transit dependent population (Banister et al., 1997; Garrett & Taylor, 1999). Since these people tend to be lower income and do not have positions of power in our society, the barriers to accessing the transit system have increased, as it is seen as a social service (Taylor & Morris, 2015). The same barriers listed in studies from the 1980s, such as the need to increasing hours of service, lowering cost of riding passes and making more direct routes to make transit more usable, are still the same issues listed in current transit usership literature (Hung Wei & Yuan Kao, 2010; Intergroup Advertising Ltd., n.d.; Popuri et al., 2011).

2.2.2 Economic Details. City development layouts are classified as scattered, town centers, or linear (Masterton Planning Group, 2006). Many Canadian cities fall into the scattered category, as the cities are spread over large areas of land. Scattered cities are the most difficult to develop a sustainable transportation system for. Scattered cities are expensive, require a greater number of buses due to the road structure being non-discernible and the scattering of shopping centers, schools, and work locations (Masterton Planning Group, 2006; Murray et al., 1998). This results in the movement of a lower number of people over a greater distance and low levels of service with a high cost, making it faster and cheaper to drive than to take the bus (Masterton Planning Group, 2006; Taylor & Morris, 2015). Public transit needs to attract the

population that already owns private vehicles, especially families and households with multiple people.

The less talked about side of economics and transit is the economic development that transit provides, as well as the access needed for people getting to jobs, revitalization of neighbourhoods (especially downtowns), and the economic costs of traffic congestion (Garrett & Taylor, 1999; Taylor & Morris, 2015). There is not a lot of qualitative research on this subject, but it has been highlighted as an area that needs to be researched.

2.2.3 Environment. Transit and environment are closely-linked words, and the research around them endeavors to improve sustainable methods of moving people on a daily basis. Many communities have looked to public transit as a way to reduce air pollutants, increase their green image, and meet global environmental objectives (Harford, 2006; Shen, Sakata, & Hashimoto, 2009). Environmental conditions, such as temperature and weather, affect user choices (Chunming & Kangli, 2012). Environmental life-cycles of transit buses with alternative fuels have been studied by McKenzie and Durango-Cohen (2012). Land-use and transit relationships have been analyzed for planning strategies and environmental costs related to land loss (Camagni, Gibelli, & Rigamonti, 2002; Chakraborty & Mishra, 2013; Rastogi & Rao, 2003). These types of studies will be reviewed in more detail in the literature review in chapter three.

2.3 Overview of Lethbridge Transit

The time frame for the data used in this study is from years 2012 to 2014. The City of Lethbridge had a population of approximately 89,000 in 2012 (City of Lethbridge, 2012b). The city covered an area of 122.4 km^2 with a population density of 683 people/km^2. The Lethbridge population distribution had a high percentage of 20–24 year-olds and 50–54 year-olds (S. Canada, 2013; City of Lethbridge, 2012b) (Figure 2-1).

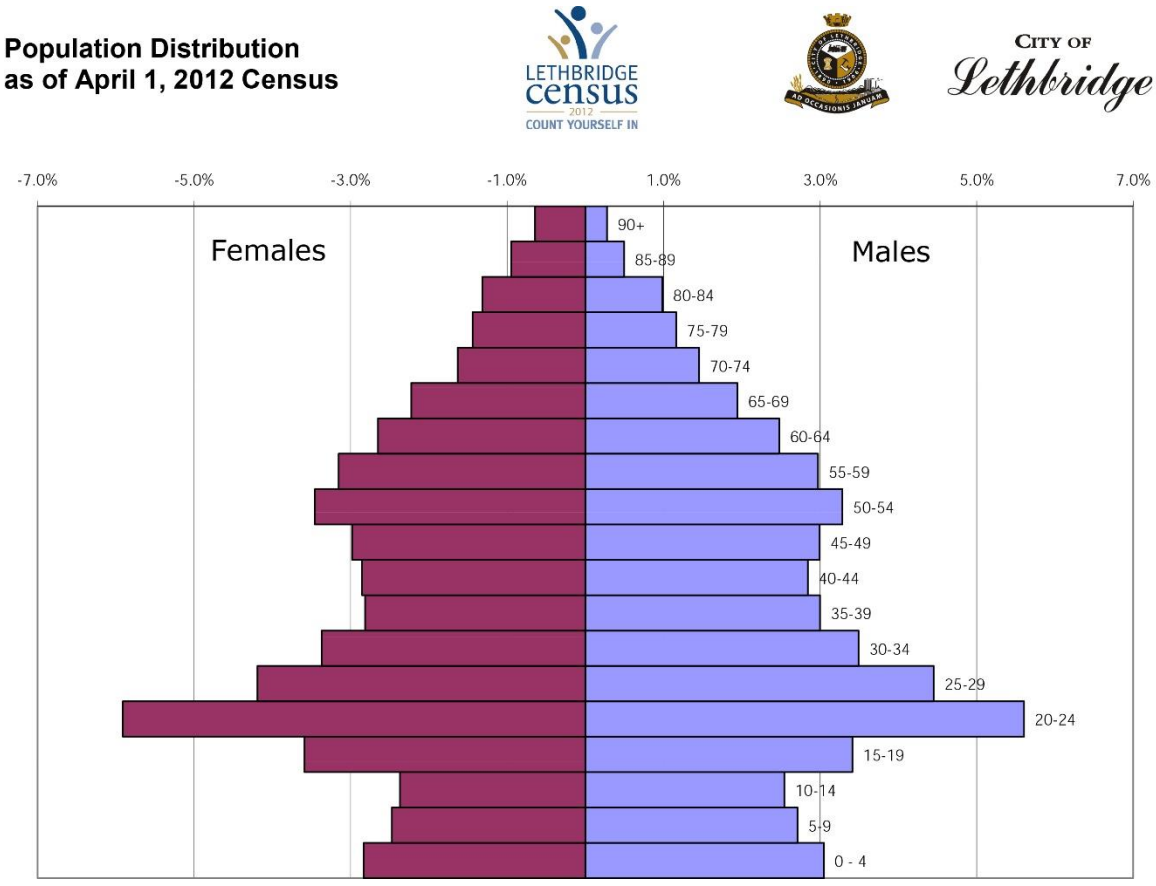

Figure 2-1: City of Lethbridge population distribution (City of Lethbridge, 2012b).

At the time the data used for this study was collected, the City of Lethbridge transit system consisted of 11 routes (City of Lethbridge, 2013) (Figure 2-2). It included diesel and hybrid buses with hydraulic systems to allow for wheelchair and easy access onto the buses. The transit system also provided an Access-A-Ride program and helped manage school buses. This research study focused on the main Lethbridge Transit public buses and excluded the school buses and Access-A-Ride buses.

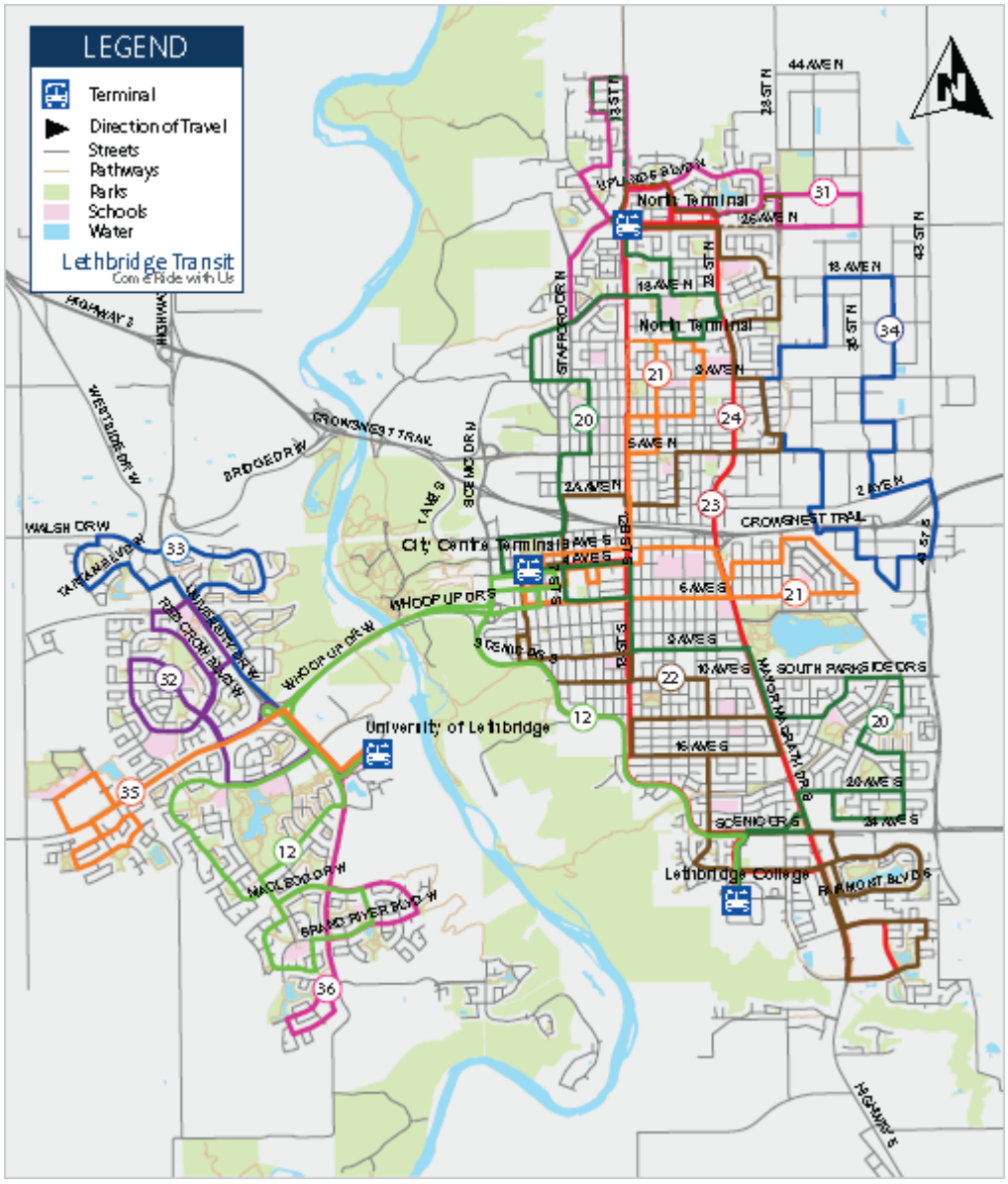

Figure 2-2: City of Lethbridge public transit routes (City of Lethbridge, 2013).

2.4 History of Lethbridge Transit

Lethbridge Transit (also referred to as LA Transit) was first implemented by Mayor George Hatch on August 16, 1912 (City of Lethbridge, 2002, 2012b). It consisted of a streetcar

rail system on 11 miles of track. Two buses were introduced into the system in 1939. In 1947, streetcars were retired, and the city relied fully on buses for public transportation. School buses were added to the system in 1974. Between 1977 and 1985, the types of buses used were GM classics. From 1985 to 1992, the types of buses used were MCI classics, and this is when the turbocharged engines for increased power were introduced (City of Lethbridge, 2012a). In 1993, the New Flyer model was introduced because it was a low-floor, improved accessibility bus. In 2000, university and college were added as satellite terminals (City of Lethbridge, 2012a). In 2005–2006, the first wheelchair accessible community bus with air conditioning was added to the transit service, the new north terminal was created, and route frequency went from 20 minute service to 30 minute service (City of Lethbridge, 2012a).

According to the 2003–2005 business plan (City of Lethbridge, 2002), the transit business plan in place for 2002 had an operating system that ran 18 hours a day; would carry approximately 3.1 million passengers a year; traveled 2 million km per year; and used approximately 1 million L of diesel a year. Between 2003 and 2005, the plan was to create a routing system based on the beltline model: loop routes supplied by feeder routes. The mission for this Lethbridge Transit business plan was to provide a safe and affordable transportation option that improves access to the social, economic, educational, leisure and health institutions and services. Their vision during this time was to meet community needs, improve operating efficiencies, and make transit a viable alternative to personal vehicle usage. The values of LA Transit are listed as awareness and sensitivity, respect for individual differences and human dignity, competence and positive work ethic, honesty and integrity, equity and fairness, and initiative and innovation. At the time of this business plan, the LA Transit fleet was 34 buses. In 2001, the cost of operating Lethbridge Transit was $6.3 million; in 2002, the budget was $6.5 million. In this budget, they were also considering the addition of a smartcard program. A

customer profile was created based off of passenger accounts, open houses, and surveys. The information collected involved walking distance to routes, distance between stops, coverage area, timing and frequency of buses, transfers, direct service, shares, and customer values of both user and nonuser. Students comprised 57% of the ridership; were considered to be under the age of 25; ridership frequency was all hours of the day; were considered to have no vehicle; and were part-time employed with half earning less than $20,000 a year and half earning less than $10,000 a year. Parents of children and/or strollers comprised of 17% of the ridership; travel frequency was all hours of the day; income was listed as may or may not work, half earn less than $30,000 a year and half earn less than $20,000 a year; parents of children and/or strollers under the age of 25; may or may not have access to a vehicle; prefer not to walk long distances with toddlers; and need shelter. Seniors comprised 8% of the ridership; travel frequency was mid-day; half earn less than $20,000 a year and half earn less than $10,000 a year; the average age was over 65 years; may or may not have access to a vehicle; are very weather dependent; need shelter; and prefer not to walk long distances. For 18% of the ridership, there were no definable characteristics, classifying them as 'other'. Challenges listed in this plan included incorporating new development areas; the expansion of transit service areas; customer needs, particularly at the University of Lethbridge and Lethbridge Community College; development operations model for beltline; new school site impact on busing; accessibility model requirements; fleet management support for the beltline and accessible services; complying with environmental legislation changes; being seen as unattractive environmental alternative for transportation; demographic related; age structure; and increase in population.

In the Lethbridge Transit Business Plan for 2006–2008 (City of Lethbridge, 2006), the mission was similar to that of the 2003 to 2005 business plan; however it also includes reliability, economical, and environmental statements. The vision for this plan was to provide

transportation services that are accessible, deliver a high level of service, increase environmental stewardship, remain cost-effective, and raise public awareness about these services. The customer profile for this service does not provide any numbers, only the needs and expectations for each group of customers. These included such things as being safe, having friendly and responsive drivers, service timing, affordability, environmental responsibility, and economic considerations.

"On the road to sustainability" is the theme of the LA Transit Business Plan for 2009–2011 (City of Lethbridge, 2009). This reporting acknowledges that as the city has grown, transit has not kept pace. It acknowledges that the 2006 plan was to improve the services, attract the customers, and grow within the community. This report says that the community sees transit as a real transportation alternative. This report does not provide a detailed documentation of numbers like what was provided in the 2003 – 2005 business plan. This business plan acknowledges the opening of the new transit terminal in North Lethbridge that occurred in 2006, with its goal to provide express transit service connecting North Lethbridge with downtown, the University of Lethbridge, and Lethbridge College. This report states that in 2006 and 2007, LA Transit expanded its programs to provide full service to all areas of the community with more consistent routing, less transferring, weekday express services, more frequent service on higher ridership routes, and a new, improved, and user-friendly guide. In August 2007, LA Transit assumed the full responsibility for Access-A-Ride from the Lethbridge Handi-bus Association. In September 2010, one new route was would be added to West Lethbridge, and routes 12 and 32 operated on 15-minute frequencies during morning and afternoon weekday peak periods from September to April, commencing in September 2009. One point made in this plan is to develop the smartcard fare media technology for the transit system. It was expected

that in 2009, it would cost $8.6 million to operate transit, $9.2 million 2010, and $9.7 million in 2011.

Lethbridge Transit business plan 2012 – 2014 (2012a) includes the 100th anniversary of Lethbridge Transit in 2012. This 2012 – 2014 plan is based on the Canadian Urban Transit Association's (CUTA) long-range vision, Transit Vision 2040. CUTA were tasked with revolutionizing service through expanding and innovating and focusing on customers, greening transits, and ensuring financial health and strength, using the knowledge and practices of transit systems to respond to future opportunities and challenges. In 2011, the new electronic fare collection system called smartcard was implemented. This business plan reported that there were 13 routes providing 115,000 hours of annual service with a fleet of 43 buses. This plan's mission returned to discussing just safety and efficiency of public transportation, and the vision changed focus to providing the best customer-focused public transportation system. According to the 2012 – 2014 business plan, the cost of running Lethbridge Transit in 2007 was $7.3 million, 2008 was $7.7 million, 2009 was $8.8 million, 2010 was $9.8 million, and 2011 was $10.7 million. Transit ridership was 2,268,468 in 2006, 2,257,175 in 2007, 2,309,852 in 2008, 2,215,062 in 2009, and 2,252,616 in 2010. This plan also states that the 400m walking distance service standard be incorporated for all routes and stops.

2.5 Transit Legislation

The legislation that affects Lethbridge Transit includes human rights legislation, occupational health and safety legislation, commercial vehicle safety, environmental legislation, professions and occupations legislation, and general legislation (City of Lethbridge, 2002). The Human Rights, Citizenship and Multiculturalism Act's purpose is to promote equality and protect individuals from discrimination. To comply with this legislation, LA Transit is developing an

accessibility transportation policy. The purpose of the Occupational Health & Safety Act is to promote the well-being of employees and employers through regulations covering safe working practices, making sure a certain level of training for employees is met and that equipment and workplace hazards are reduced and mitigated for (City of Lethbridge, 2002). LA Transit must also follow the Highway Traffic Act and Motor Transport Act regarding maintaining proper inspections and certifications (City of Lethbridge, 2002). Transit must adhere to the Environmental Protection and Enhancement Act to address climate change and waste management (City of Lethbridge, 2002). To promote professional and workplace standards, LA Transit follows the legislation set out for self-regulating professional associations. They also follow the City Transportation Act and the Freedom of Information and Protection of Privacy Act (City of Lethbridge, 2002).

2.6 Conclusion

As seen in the information above, Lethbridge Transit has discussed ridership, transit efficiency, and green initiatives. However, the plans never outlined how they would achieve these goals and did not establish measurables. Part of this could be due to a lack of quantitative, peer-reviewed studies available for small cities or for topics such as environment and transit, social and transit, and economics and transit. It could also be from insufficient quality data, funds, and qualified personnel within Lethbridge Transit to be able to complete such studies for a small municipal transit system. Beginning around 2011, the City of Lethbridge started implementing technology and hiring professionals to fill these gaps. Due to this technology and the professionals hired, it is possible for this research project to take place. This research project aims to help contribute to the peer-reviewed literature and testing of methodologies to fill the gaps highlighted in the previous sections and in the literature review in Chapter 3.

Chapter 3: Literature Review

3.1 Introduction

This section presents the general information concerning previous research on transit from an environmental science perspective, as well as on small city and public transit studies. This section also summarizes key studies concerning environmental analysis of hybrid and diesel emissions.

3.2 Efficiency Analysis of Transit

One of the main goals of public transportation is efficiency of transit services provided. Areas that are studied with respect to efficiency and sustainability of a transit system include system accessibility, travel time, trustworthiness, frequency, maximum load, vehicle characteristics, adequate information and support facilities, and mobility in accordance to necessities (Sampaio et al., 2008). These are considered in relation to two factors (Walker, 2008):

a) Patronage, when a transit plan focuses on high ridership
b) Coverage, when a plan focuses more on providing the service no matter the ridership so that there is an emphasis on social needs being met

To measure the efficiency of a transport system, data envelope analysis (DEA) is used to determine decision-making units (DMUs) (Sampaio et al., 2008). This helps policy makers determine what they want their transit system to do and whether this is achieved. The required data for completing the DEA include an assessment of efficiency, effectiveness, and overall performance of the transit system.

Hassan, Hawas, and Ahmed (2013) use a multi-dimensional method to evaluate efficiency that examines subjective and objective measurements of service quality by using fuzzy logic analysis. Mishra, Welch, and Jha (2012) use a graph theoretical approach to analyze transit service coverage, integration of routes, schedules, socio-economic situations, demographic patterns and spatial activity patterns. In another approach, Holmgren (2013) uses stochastic frontier analysis to evaluate the efficiency of public transportation between several countries that have different operating conditions.

Looking at the efficiency of Lethbridge Transit would be useful for understanding transit user barriers. Combined with spatial analysis, this would informatively investigate hypothesized problem areas, efficient areas, and possible causes, generating results that could be used to improve the system.

3.3 Spatial Analysis of Transit

Spatial analysis of public transit is becoming a primary tool for providing quantitative data needed to improve public transportation delivery (Currie, 2010). This includes description statistical analysis and hypothesis testing. This type of research identifies service time gaps, transportation quality related to social needs, accessibility, network model development, and user behavior (Beltran, Carrese, Cipriani, & Petrelli, 2009; Currie, 2010; Dodson et al., 2004; Jaramillo, Lizárraga, & Grindlay, 2012; Salonen & Toivonen, 2013; Tribby & Zandbergen, 2012). These studies used various methods.

Some studies used GIS software to measure service frequency, ridership forecasts, and pedestrian accessibility (Aultman-Hall, Roorda, & Baetz, 1997; Azar & Ferreira, 1995; Currie, 2010; Jaramillo et al., 2012). However, to use these methods, thresholds were created, data assumptions was made, and access to high volumes of information was needed. For the studies

that required thresholds, the thresholds were based on information from the census, social data from statistical groups, distance buses traveled (km), and high-use areas (e.g., hospitals, doctors, and schools) (Currie, 2010; Dodson et al., 2004). The results examined the spatial disparity between social needs and transportation (Currie, 2010; Jaramillo et al., 2012). Dodson et al. (2004) identified an important point that weighting and creation of thresholds can cause a bias in the outcomes due to researcher motivation. For example, road engineers will focus more on road and automobile outcomes, whereas transit managers will focus more on transit routes. Therefore, more multi-disciplinary studies with high integrity data that can reduce the need of weighting are required.

Another method used was computational models (Figure 3-1) that measured road congestion, parking, and transit schedules (Salonen & Toivonen, 2013). The study looked at travel time by private car, travel time by public transportation, and door to door approach. By studying the results from these models, analysis of accessibility disparity is possible (Salonen & Toivonen, 2013).

Tribby and Zandbergen (2012) used a multimodal model similar to the computational models used by Salonen and Toivonen (2013). Páez, Trépanier, and Morency (2012) also used a computational model. However, these studies focused on bus routes, income proportion, walking networks, and age of users. The examined results included the spatial disparity between social needs, costs, and transportation (Currie, 2010; Jaramillo et al., 2012; Salonen & Toivonen, 2013; Tribby & Zandbergen, 2012).

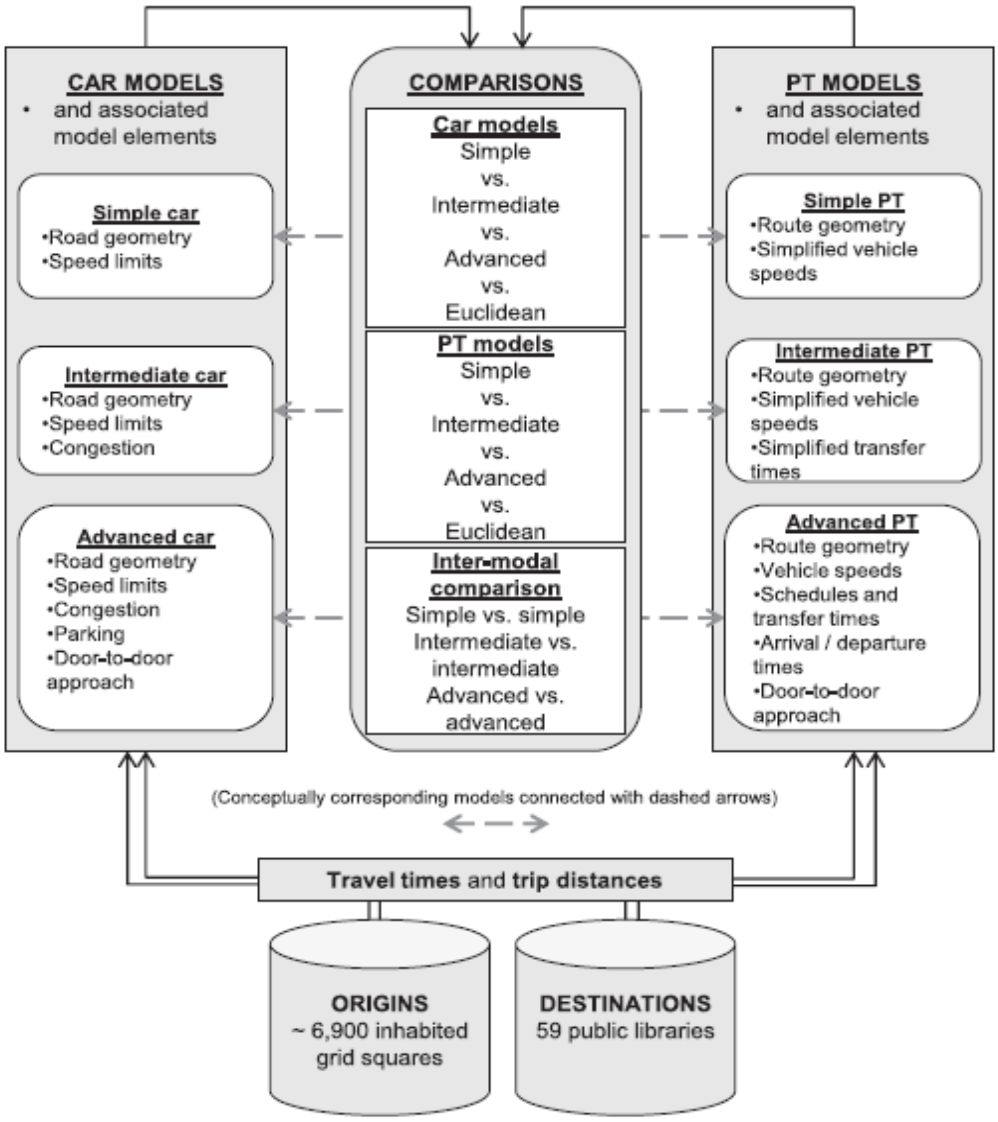

Figure 3-1: Salonen & Toivonen (2013) workflow of modelling travel time.

3.4 Small Cities and Public Transportation

City development layouts are classified as scattered, town centers, or linear (Masterton Planning Group, 2006). Scattered cities are the most difficult to develop a sustainable transportation system for because they require a greater number of buses due to the road

structure being non-discernible, a result of the scattering of shopping centers, schools, and work locations (Masterton Planning Group, 2006). The City of Lethbridge is classified as a scattered city with a low density. This results in an expensive system with low efficiency (Karlaftis & McCarthy, 1999).

In 1986, Fricker and Shanteau developed a route planning model for small city transit. It was called the Multiple-Route Transit Optimization Method (MRTOM). Fricker and Shanteau (1986) MRTOM was one of the first multi-objective approaches created, as it considers many variables, such as route length, ridership, and fare costs. Other models have been created and updated from this one; however they have been adjusted to larger cities (Israeli & Ceder, 1995).

Studies in smaller cities, specifically Canadian cities, are generally lacking. Most peer-reviewed literature on transit studies is done on larger metropolitan cities in other countries, as is seen through the literature reviewed in this chapter. Though there are many reports and work that individual transit groups do, that knowledge is not accessible through peer-reviewed sources or not easily accessible to other groups or researchers. This causes issues for small city transit planning, as the requirements, costs, and ridership differ from that of larger cities, yet the available information and research is all based on large city studies.

During the literature research, an old report called *Marketing of Small Transit Properties in Alberta* (Intergroup Advertising Ltd., n.d.) was located. It was a joint report for smaller transit cities, including Fort McMurray, Grande Prairie, Lethbridge, Medicine Hat, and Red Deer. It refers to using census data from 1983, so we can assume this report was created in the 1980s. This report was one of the few grey literature items found that researched small transit systems in Alberta. It looked at the marketing of the systems, their usership and citizen demographics, and what riders were interested in. The report found that for Lethbridge Transit 71% of riders

were considered captive riders and had no other forms of transportation. For the 29% who have alternative transportation, the report found that they used transit 34% of the time to go to work, 32% to get to school, 26% for shopping and 25% for other purposes. There is no mention as to how these numbers were found or if the user could choose more than one option for use. The areas identified for improvement to increase ridership were

a) Provide more direct routing
b) Increase buses during school hours
c) More later evening buses so people can get home from work
d) Make schedules more available
e) Run bus to westside Lethbridge
f) Lower fare rates of monthly passes
g) Run services earlier and later
h) Provide services to satellite communities

The City of Lethbridge recently commissioned Stantec to create a Lethbridge Transit Master Plan. In the executive summary that was provided to the City of Lethbridge in July of 2017, many of the issues brought up by the marketing report mentioned above from the 1980s were still large issues identified within the surveys conducted (Intergroup Advertising Ltd., n.d.; Stantec, 2017). Stantec's identified issues are as listed:

a) Shorter trip times
b) Improved connections
c) More frequent stops
d) Fewer transfers
e) More services on evening and weekends

f) Increased ridership

g) Reduction of fare costs

h) Increase the directness of routing

i) Try new ideas

j) Make it easier to use and understand

k) Create expansion opportunities

l) Increase trip frequencies

m) Make fundamental changes to meet growth and improve services

That these two reports span approximately 30 years shows that the concerns and issues are still the same, highlighting the need for better planning, monitoring, and evaluating the effectiveness of transit services.

3.5 General Environmental Science on Public Transportation

Vehicle CO_2 emissions account for 20–25% of the global CO_2 emissions (Tao & Hung, 2003). This has led to the need for international agreements, such as the current Paris Agreement, and older accords, such as the Copenhagen and Kyoto Accords, to reduce transportation emissions. The way to meet these international agreements can be accomplished through several different ways. The first is reducing emissions of transportation through alternative fuel and engine designs (Bivona & Montemaggiore, 2010; Wang & González, 2013; Zahabi et al., 2012). Secondly, there is increasing the efficiency of travel routes and public transit (Azar & Ferreira, 1995; Gaur, Mudgal, & Singh, 2013; Murray et al., 1998; Sampaio et al., 2008).Another measure being taken is increasing the use of alternative transportation, such as pedestrian, cycling, and public transportation (Aultman-Hall et al., 1997; Hsiao, Lu, Sterling, & Weatherford, 1997). The goal to reducing emissions has increased multidisciplinary research in the area of public transportation to be able to create quantitative and spatial analysis of how to

understand the data and make recommendations that are usable to policymakers (Banister et al., 1997; Meyer, 2010; Meyer & Miller, 1984; Tao & Hung, 2003).

3.5.1 Transportation through alternative fuel and engine designs. Alternative fuel and engines being considered in the literature as options for reducing emissions are electric, hybrid, and gas. Wang and González (2013) assess electric bus usage in communities as an environmentally friendly option that would reduce emissions, noise, and energy consumption. Larsen, Kofoed-Wiuff, and Karlsson (2010) raise the point that though electrical transportation does not have tail emissions, they still produce emissions indirectly through their parts and sources of energy generation. Therefore, researchers are investigating life cycle analysis and cradle-to-grave analysis on green technologies to be able to objectively compare the environmental footprints of green technology and conventional technology and create benchmarks that can be used to reduce greenhouse gas emissions (Chester & Horvath, 2008; Karman, 2006; McKenzie & Durango-Cohen, 2012; Meyer, 2010; Ou, Zhang, & Chang, 2010; Wang & González, 2013). Wang and González (2013) found that electric buses produced 34,198 kg/year of CO_2, hybrid diesel buses produced 45,054 kg/year of CO_2, compressed natural gas produced 56,600 kg/year of CO_2, and diesel buses produced 65,124 kg/year of CO_2.

Another research area with engines includes maintenance schedules. Ben-Daya, Ait-Kadi, Duffuaa, Knezevic, and Raouf (2009) have highlighted that the benefits of preventative maintenance are that the components and people are available when needed, unlike an unplanned breakdown, and it reduces the additional damage that occurs when something breaks down from not having regular maintenance. Chan, Mui, and Woo (1997) highlight that a disadvantage of preventative maintenance is the waste of resources due to the replacing of components when they are still in good operational condition. Dodson et al. (2004) examine the complex task of assessing and creating a model for short and long-term sustainable strategies

for maintenance of transit fleets. They found that the model was effective in communicating and keeping maintenance up for the fleet through the transit company, as well as allowing for the flow of communication between transit company and the different stakeholders including government, financial groups, and citizens. However, this model considers only financial and customer satisfaction for sustainability. This highlights that even though environmental considerations were discussed in the paper, they are not accounted for in the outcomes or analysis.

3.5.2 Efficiency and emissions of public transit. For a comprehensive understanding of efficiency and emissions, studies need to be conducted over the lifespan of transit fleet vehicles, as many studies are conducted in labs, on specific testing grounds, and under specific set conditions. Demir, Bektaş, and Laporte (2011) make the important point that fuel consumption is affected by various factors, which differ in various locations, and must be considered in research projects. These include but are not limited to the age of the vehicle, distances travelled, weight of the vehicle, vehicle speed, road inclination, aerodynamic drag, and traffic congestion.

Efficiency of public transportation can be defined by several characteristics, according to Santos (as cited in Sampaio et al., 2008):

(a) System accessibility: the distance between the users' original location, transfer locations, and final destination
(b) Travel time: the length and layout of the routes
(c) Trustworthiness: the punctuality of the transit services
(d) Frequency: the time intervals of each trip
(e) Maximum load: number of passengers related to vehicle capacity

(f) Vehicle characteristics: the age of the vehicle, ambiance and environment of the vehicle, technology, and adaptations for special needs

(g) Adequate information and support facilities: identification of stations and fleet, protection from the elements at stops, and availability of schedules and timetables

(h) Mobility related to necessities: route coverage of the city that allows flexibility and adapts to passengers with mobility restrictions

Access barriers can reduce the accessibility and efficiency of the transit systems. According to Murray et al., (1998), if the barriers are too great at the origin or end, transit time is too long or cost is too high, and use of the system will reduce to only those who are transit dependant. Even the transit dependent ridership can be reduced if ridership costs are too high.

Zahabi et al. (2012) assessed the most efficient strategies in Montreal for reducing greenhouse gas emissions for transportation related to urban design, transit accessibility, and green technologies. They found that improvements to fuel efficiency for private vehicles and increased public transit accessibility were the two strategies most effective for reducing greenhouse gas emissions at the regional and household level.

3.5.3 Quantitative and spatial analysis. Azar and Ferreira (1995) identified the need to use geographical information system (GIS) tools to identify and measure factors needed for transit planning. The added bonus is that the GIS tools can be used to display the information in spatial and graphical ways that improve the ability to identify and address needs and services of public transit. Murray et al. (1998) identify that an issue with spatial analysis is the need for more precise data that is not always available at the residential level for all communities. This is an area that policy makers can contribute to, as census data “specifically city census data” is generally the best low-scale data available (Banister et al., 1997). But not every municipality has

the same level of detail to their data, and national level census data quality in Canada depends on the political will at the time of collection. For example: the Canadian long form census data was cancelled in 2010 and reinstated in 2016.

Hsiao et al. (1997) identified the gap in analytical method research to measure pedestrian walking distance to transit access, regarding local conditions. Aultman-Hall et al. (1997) and Hsiao et al. (1997) showed the benefits of using GIS to spatially analyze relationships between pedestrian accessibility and transit. Hsiao et al. (1997) highlighted the importance of needing transit operational data collected continuously at the transit stop level, as well as needing further study into additional ways to interface transit data to allow for in-depth analysis as a disaggregated level.

3.6 Diesel Hybrid and Environmental Impact studies

With the goal of reducing transportation emissions, many studies have tested the efficiency of reducing emissions via alternative forms of bus engine systems, including hybrid, conventional diesel, and liquefied natural gas systems (Wayne, Clark, Nine, & Elefante, 2004).

Wayne, Clark, Nine, and Elefante's (2004) comparison study of hybrid electric, conventional diesel, and liquified natural gas systems found that hybrid electric systems have reduced emissions of nitrogen oxides (NO_X) by 50% from the conventional system, while liquified natural gas systems reduced NO_X emissions by 10%. They also found that the particulate matter emissions (PM) were reduced by 90% from the liquified natural gas systems. For carbon dioxide (CO_2) emissions, they found that hybrid electric systems reduced emissions by 70% from the conventional system and hydrocarbon (HC) emissions were reduced by 98%.

Cook and Straten (2001) highlight that emission testing is affected by things like vehicle maintenance, bus age, and routes, which cannot be accounted for in lab tests or the original

manufacturers' emissions stated in their manuals. This creates a need to collect data over the life of the transit fleets and run comparisons over long periods to account and track true emission reductions. Their study examined the projected emission estimate scenarios for 2009. They found that with 1999 emissions baseline created to compare the estimated emissions for the 2009 scenarios, NO_X would increase by 10.1%, PM would reduce by 68.7 %, HC would increase by 66.9%, and CO would increase by 66.9%. They found that if 50% of the fleet was replaced with hybrid electric vehicles, NO_X would reduce to 405.8 imperial tons, PM would reduce to 5.5 imperial tons, HC would reduce to 138.35 imperial tons, and CO would reduce to 414.2 imperial tons. Their results showed that if 50% of the fleet was replaced with natural gas vehicles, NO_X would reduce to 401.3 imperial tons, PM would reduce to 5.3 imperial tons, HC would reduce to 137.7 imperial tons, and CO would reduce to 406.1 imperial tons. Their research found that if the fleet was replaced with clean diesel vehicles, NO_X would reduce to 405.8 imperial tons, PM would reduce to 5.7 imperial tons, HC would reduce to 145.7 imperial tons, and CO would reduce to 414.2 imperial tons. Wayne *et al*. (2009) predicted that changing 15% of the US transit system to hybrid-diesel buses could reduce CO by 1800 imperial tons, NMHC by 400 imperial tons, NO_X by 4400 imperial tons, PM by 200 imperial tons, and CO_2 by 400 imperial tons.

Chandler et al. (2002) collected New York City Transit emission data from 1999 to 2001 for their hybrids and conventional buses. They ran three different driving cycles: in the central business district, New York bus cycle, and the Manhattan cycle. For the central business district, hybrid emissions were lower by 97% for CO, 36% for NO_X, 43% for HC, 50% for PM, and 19% for CO_2. For the New York bus cycle, hybrid emissions were lower by 56% for CO, 44% for NO_X, 77% for PM, and 40% for CO_2. But HC emissions increased by 88% for the hybrids. For the Manhattan

bus cycle, hybrid emissions were lower by 98% for CO, 44% for NO_X, 28% for HC, 99% for PM, and 33% for CO_2.

Chandler et al. (2006) point out in their technical report that research needs to be conducted from data collected all year round to make season comparisons, as fuel economy can be affected by air conditioning use during higher temperatures. Without including the summer months in the analysis, Chandler et al. (2006) found that compressed natural gas had 25% lower fuel economy than diesel, while the hybrids had 45% higher fuel economy than the diesels.

3.7 Conclusion

The greatest issue with transit planning and evaluation of emissions and services, especially for small cities, is having good quality, continuous data and planning how to effectively monitor and evaluate the success of implementing changes to transit systems. Since the research is generally completed by municipalities or consultants, it is rarely published, which makes it difficult to locate when you are an outside researcher or planner. Sometimes it is not researched at all, due to the lack of funds, technology, ability to collect the data needed, and the personnel required to complete the necessary in-depth analysis. Peer-reviewed journal articles on quantitative analysis are limited and tend to be conducted on large cities in the US, Europe, or China, leaving a large gap in the literature for Canadian cities, especially those that are not a metropolis size.

Regarding efficiency and spatial studies, understanding transit user barriers and demographics, along with the demographics and challenges of the cities, would be useful, as combining it with spatial analysis would allow for a more comprehensive analysis and understanding of transit systems and the needs of those systems. As many of these topics have been researched independent of each other, combining this information was recent in the

literature (as seen above) and is a large, complex task due to the volume of data and the need for multidisciplinary research teams to accurately deal with the data in a comprehensive and useful manner.

This research project will provide data analysis, description, and testing of methodologies that will help create better planning, monitoring, and evaluating the implemented plans to the desired outcomes of transit services.

Chapter 4: Methodology

4.1 Introduction

Environmental science is interdisciplinary: it draws upon the physical sciences, the social sciences, and economics (Adger et al., 2003). The research environmental scientists conduct typically investigates variables in these areas and may significantly affect policy changes (Kriebel et al., 2001). Environmental scientists use the scientific method in creating methodology that accounts for effects and application of the results on society to assist policy developers with using data and research (McNeill, 1999). This contextualization of research and data collection is important as we realize the complexity of the problems that our policymakers deal with and the balance needed between economic, social, and environmental requirements. Policy makers need methods and results that will allow them to make informed decisions that consider economic efficiency, environmental effectiveness, equity, and political legitimacy (Adger et al., 2003). This includes applying characterization and description of large databases resulting from environmental monitoring systems.

Interdisciplinary research allows developing new questions that may not have otherwise been considered due to the various backgrounds and methodologies available to environmental science research (McNeill, 1999). This research is generally policy-oriented but will have a quantitative approach. A quantitative approach helps remove the need for assumptions regarding policy development when considering environmental decision-making and economic benefits (Adger et al., 2003).

One major hurdle of interdisciplinary research is that paradigms vary between disciplines: what is considered to be a common term in one field will mean something else in

another field (McNeill, 1999). To eliminate this confusion within this thesis, all terms, methodologies, and tools used will be described with the purpose they are used for.

In creating the methodology for this project, I considered the precautionary principle. As explained by Kriebel et al. (2001), the precautionary principle causes environmental scientists to consider potential harm to human health and the environment under occurrences such as climate change when conducting research. The precautionary principle encourages research for alternatives and encourages to explore new areas of research, as there is a tendency for research to continue to re-analyze well researched problems instead of taking a risk on exploring newer problems. It is important to follow the scientific method to reduce uncertainty for policymakers and others outside of scientific disciplines. The scientific method includes a statement of the problem, formulation of the hypothesis, the design of the experiment, collection of data, interpretation the data, and conclusion of the results (Dowdy & Wearden, 1991). This section will focus on the design of the analysis, how the data was collected, and what programs and processes I used to interpret the data.

4.2 Analysis Design, Data Collection and Processing

This thesis is based on compilation and analysis of two data sets, which represented two distinct sides to environmental variables in assessing transportation systems. The first part compares the carbon dioxide (CO_2) emissions and fuel consumption of the hybrid buses and the diesel buses the City of Lethbridge operates. The second part compares the City of Lethbridge spatial variables and age demographics and the various bus ridership groups.

4.2.1 Hybrid and Diesel Analysis Design, Data Collection and Processing. The City of Lethbridge, in a management experiment intended to yield data regarding fuel use and sustainability, purchased five 2010 New Flyer of America XD40 diesel-powered, 36-seat, 81-

passenger, 40-foot buses and five 2010 New Flyer of America XDE40 diesel-powered hybrid electric, 42-seat, 76-passenger, 40-foot buses (The Thomas D Larson Pennsylvania Transportation Institute Bus Testing and Research Center, 2011, 2012). The city of Lethbridge provided the data for the kilometers traveled from the first time the XD and XDE 40 buses were on the road in 2011 through to 2015, as well as the fuel that was used for years 2014 to 2015.

The fuel data could be obtained only for years 2014–2015, so for this thesis summary, the CO_2 emission comparison was limited to years 2014 and 2015. I completed a basic descriptive statistical analysis to compare CO_2 and fuel consumption between the two models that the City of Lethbridge Transit department operates, as well as how it compares to the STURAA tests results. The United States Federal Department of Transportation requires testing of public-purchased fleet vehicles under the Surface Transportation and Uniform Relocation Assistance Act (STURAA) (United States Department of Transportation, 2017). These tests examine the emissions of the transit buses at different years and miles traveled. These tests are recommended by the New Flyer of America group to show the efficiency of their transit fleet buses. The emissions test results from the STURAA test (The Thomas D Larson Pennsylvania Transportation Institute Bus Testing and Research Center, 2012) for the Manhattan, Orange County Bus, and UDDS can be seen in Table 4-1. The STURAA test results for fuel consumption and CO_2 emissions will be used to compare how the average Lethbridge fleet 2010 New Flyer of America XD and XDE 40 perform.

Table 4-1: STURAA (Institute & Center, 2011, 2012) Emission test results for bus models XD and XDE 40

Driving cycle	Manhattan		Orange County Bus		UDDS	
Bus model	**XD40**	**XDE40**	**XD40**	**XDE40**	**XD40**	**XDE40**
CO_2, gm/mi	2830	1960	1950	1431	1256	1254
CO, gm/mi	0.2	0.25	0.02	0.15	0.05	0.11
THC, gm/mi	0.08	0.01	0.04	0.003	0.02	0.006
NOx, gm/mi	1.69	2.63	0.92	0.82	1.17	1.09
Particulates, gm/mi	0.009	0.002	0.016	0.001	0.002	0.002
Fuel consumption mpg	3.59	4.72	5.22	6.45	8.1	7.37

4.2.2 Population Demographics and Bus Ridership Analysis Design, Data Collection and Processing. The City of Lethbridge provided detailed Breeze Card ridership information that has been collected for each individual ride during 2012–2014. A Breeze Card is an electronic card used to pay fare on the transit system. It is reloadable and can carry 30-day passes, tickets, and e-cash (City of Lethbridge, 2017a). Each Breeze Card has a unique ID set to each rider. Each time a Breeze Card is used, the data of the transit stop, GPS coordinates, and whether it is a transfer or new ride is recorded. The types of Breeze Cards available are Adult (ages 18–64), Senior (65+), Youth (ages 6–17), Post-Secondary Semester passes, and Grad Student Semester passes. For this study I combined Post-Secondary and Grad Student pass numbers and called them Post-Secondary. The Breeze Card terminals on the buses also allow for cash collection and electronically record each time a user uses cash instead of a card. For this study, cash transactions are called Cash. Bus drivers manually record through the system blind patron users, postal workers, assistance personnel, youth under the age of 5, strollers, and bikes. To be able to compare usership against demographics, youth under the age of 5 are kept in their own category and for this study are called Child. Blind patron users, postal workers, assistance personnel,

strollers, and bikes were summed together into a group called Other. This allows for data collection on who the ridership is and where and how they ride the bus from get on points.

The census information for years 2012–2014 were downloaded from the City of Lethbridge (City of Lethbridge, 2017b). The census data the City of Lethbridge collects is classified by age and gender. For this study, the age information was grouped into age categories similar to the Breeze Card categories: Census ages 6 to 17, Census ages 18 to 64, Census ages 65+, Census Under age 5, and Census Total (includes all ages).

The Lethbridge Transit Breeze Card ridership data and Lethbridge census data were summarized in descriptive statistics using JMP 13 statistical software and Microsoft Excel 2016. I used JMP and Excel to create pie charts, summary tables, and bar graphs. The descriptive statistics calculated are sample size (N), mean, min, max, median, standard deviation, standard error, variance, and coefficient of variation (CV) (Appendixes A–C).

I used spatial analysis software available in ArcGIS for this Lethbridge Transit study. The focus of the spatial analysis is intended to provide quantitative analysis and parameter estimation regarding user-ship efficiency using Hot Spot Analysis. Though we found no published articles about using Hot Spot Analysis for transit usership and demographic comparisons, there is literature about using it as a tool for identifying hot spots of other municipal information, such as criminal activity, pedestrian–vehicle crashes, and identifying areas of high traffic for various activities (e.g., shopping centers and new firehouse locations) (Aultman-Hall et al., 1997; Lao & Liu, 2009; Lyon, 2001; Truong & Somenahalli, 2011), which provides a base for this research to be analyzed with this tool. Hot Spot Analysis (Getis-Ord Gi*) is the ArcGIS tool I used (Esri, 2016). It calculates the Getis-Ord Gi* statistic for each feature and provides a z-score and p-value to indicate which features contain values that are high or low spatially clustered (Esri, 2016). These

results then allow for the tool to identify in map format the statistically significant hot spots and cold spots. The calculations used in this hot spot analysis are taken from the ESRI website directly (Esri, 2016) and seen below in Figure 4-1. A high z-score and associated low p-value indicate spatial clustering of high values and result in a hot spot. A low p-value indicates that the observed clustering is unlikely to be due to chance arrangement. A low negative z-score and low p-value equal spatial clustering of low values and result in a cold spot. The closer to the extreme high or low z-scores, the greater the spatial clustering, but if the z-score is near zero (with p-value, closer to 1.0), then there is no spatial clustering (Esri, 2016).

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}$$

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$

Figure 4- 1: ArcGIS Hot Spot Getis-Ord Gi* calculations from Esri (Esri, 2016). xj is the attribute value for j. wi,j is the spatial weight between feature i and j. n is the total number of features.

Spatial relationships can be modeled and parameterized to estimate the strength of co-incidence or to forecast the consequences of mechanisms linked in space. In this analysis, the concept of the Zone of Indifference was chosen because it combines the Inverse Distance and Fixed Distance band models, does not initially exclude potentially important variables or geographical features from the analysis, and does not impose sharp boundaries (Esri, 2017b).

For this “hot spot” tool, an initial estimate of a threshold distance parameter is selected to help determine the neighbouring features’ influence. To determine the threshold parameter value, which indicates degree of spatial autocorrelation, I used the ArcGIS tool “Global Moran’s I”. The Global Moran’s I measures the spatial autocorrelation based on the feature locations and attribute values and provides estimated values and test statistics: the Moran’s I index, expected index, variance, z-score, and p-value, the probability of the z-value if spatial autocorrelation is not significant from zero (Esri, 2017c). It also evaluates the pattern of the data as clustered, dispersed or random (Esri, 2017a). The calculations used in the Global Moran’s I are taken from the ESRI documentation (Figure 4-2).

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2}$$

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}$$

$$z_I = \frac{I - \mathrm{E}[I]}{\sqrt{\mathrm{V}[I]}}$$

$$\begin{aligned} \mathrm{E}[I] &= -1/(n-1) \\ \mathrm{V}[I] &= \mathrm{E}[I^2] - \mathrm{E}[I]^2 \end{aligned}$$

Figure 4-2: The ArcGIS Global Moran's I calculation (Esri, 2017a). zi is the deviation of an attribute for feature i from its mean (xi- $\bar{X}$). wi,j is the spatial weight between i and j. n equals the total number of features and S0 is the aggregate of all the spatial weights.

ArcGIS 10.5 student licence is the version that I used for this study. In ArcGIS, the shape files from the City of Lethbridge were imported and xy data points were created from the

latitude and longitude readings of the Breeze Card data. The shape files and data points were projected into UTM 12 N (N. R. Canada, 2016). Spatial drawing was then used to place the XY data points into the polygon shapes of the census data areas. This was done so that frequency analysis could be created, allowing the breeze point data to be analyzed using the hot spot analysis tool. Prior to running the hot spot analysis tool (Getisi-Ord Gi*), the Global Moran's Index tool was run on the census data and the breeze data to determine which thresholds should be used in the hotspot analysis. With these tools, a quantitative, visual spatial analysis of Lethbridge Transit efficiency and user-ship was identified and evaluated through creating maps that display the hotspot analysis outcomes.

As explained, the design of the analysis, how the data were collected, and what programs and processes were used to interpret the data were tailored to the two types of environmental data: fuel use and transit geography. The first study compares the CO_2 emissions and fuel consumption of the hybrid buses and the diesel buses the City of Lethbridge operates to the STURAA tests results. The second study compares the City of Lethbridge's age demographics and the various bus ridership groups with descriptive statistics and spatial analysis using JMP, Excel, and ArcGIS. Chapter 5 will review the results derived from both studies.

4.3 Data Management and Retention

All the Transit Breeze Card data provided by the City of Lethbridge were provided on a confidential research basis and are being kept by myself and my supervisor on backup hard drives and our computers. The unique identifying numbers associated with the Breeze Cards were changed by Lethbridge Transit prior to the data being given to us to protect ridership privacy. In developing a program to put the Breeze Card data into a usable format for analysis, a computer scientist was hired to create code that would compress the data into useable file sizes

that stopped overpowering the software. They received a sample of the Breeze data with no traceable information to create the program under my supervision. All files that the computer scientist had were deleted after the creation of the program, and confidentiality was maintained during this thesis project.

Chapter 5: Results

5.1 Introduction

This section focuses on the analysis results of the two studies. The first study compares the CO_2 emissions and fuel consumption of the City of Lethbridge hybrid buses and diesel buses to the STURAA (Surface Transportation and Uniform Relocation Assistance Act) test results. The second study analyzes and compares the City of Lethbridge age demographics to that of the various bus ridership groups through time and space using descriptive statistics (software used: JMP and Excel) and spatial analysis with ArcGIS.

5.2 Summary of Methodology

I completed a basic, descriptive statistical analysis on 2014 and 2015 data from the City of Lethbridge XD and XDE 40 buses. The analysis compared CO_2 emissions and fuel consumption STURAA test results to determine how the average Lethbridge fleet of 2010 New Flyer of America XD and XDE 40 perform.

The City of Lethbridge provided detailed Breeze Card ridership information collected for each individual ride from 2012 to 2014. Each time a Breeze Card is used, the data is recorded; it was possible to identify how many times Adult (Ages 18–64), Senior (65+), Youth (ages 6–17), Post-Secondary Semester passes were used. The Breeze Card terminals on the buses allowed for cash collection and electronically recorded when a passenger used cash. Through the Breeze Card terminal, bus drivers manually record children getting on the bus who are under the age of 5.

I downloaded the census information for 2012–2014 from the City of Lethbridge and grouped it into age categories that aligned with the Breeze Card age groups. They are broken

into the following groups: Census ages 6 to 17 (Youth), Census ages 18 to 64 (Adult), Census ages 65+ (Senior), Census Under age 5 (Child), and Census Total (Total Population).

I used spatial analysis software available in ArcGIS to analyze the Lethbridge Transit rider information. Spatial analysis focuses on providing quantitative analysis and parameter estimation regarding usership efficiency through ArcGIS Hot Spot analysis. These results then allow for the tool to identify in map format the statistically significant hot spots and cold spots. The z-scores and p-values are found in Appendixes D – F. The spatial relationship parameter used for this research project was the zone of indifference, and the threshold distance parameter was determined by using the ArcGIS tool Global Moran's, the results of which are found in Appendix G. These tools created the quantitative and visual spatial analysis results of this chapter.

5.3 Hybrid and Diesel Bus Emission and Fuel Consumption Comparison

Table 5-1 summarizes the liters used and kilometers traveled for the Lethbridge Transit 2010 Flyer XD40 (Diesel) and XDE40 (Hybrid) bus models. I calculated the percent difference to compare years. Though the differences in liters used between 2014 and 2015 ranged from -4.1% to 30.8% for the hybrid buses; on average, the percent difference of liters used between 2014 and 2015 increased by 6.1%. The percent differences in liters used between 2014 and 2015 range from -21.5% to 18.4% for the diesel buses, while the averaged percent difference of liters used between 2014 and 2015 increased by 2.5%.

The differences of kilometers traveled between 2014 and 2015 were small, ranging from -14.8% to 21.0% for the hybrid buses, averaging only a 0.3% increase in percent difference of kilometers traveled between 2014 and 2015. The differences of kilometers traveled between

2014 and 2015 range from -22.3% in 2014 to 20.1% in 2015 for the diesel buses; on average, the percent difference of kilometers traveled between 2014 and 2015 increased by 1.9%.

Table 5-1: Summary of liters used and km traveled for the Lethbridge Transit 2010 Flyer XD40 and XDE40 bus models for years 2014 and 2015. H=Hybrid (XDE40) D=Diesel (XD40)

Bus ID	Liters used 2014	Liters used 2015	% difference liters used	Km traveled 2014	Km traveled 2015	% difference Km traveled
Bus 170-H	23214.2	22270.6	-4.1	62328	61837	-0.8
Bus 171-H	24849.4	20787.1	-16.3	64511	54953	-14.8
Bus 172-H	21629.2	26454.5	22.3	53461	64669	21.0
Bus 173-H	18350.6	23996.8	30.8	71675	67349	-6.0
Bus 174-H	23927.6	25313.8	5.8	62494	66637	6.6
Bus 175-D	30803.9	29548.8	-4.1	64755	62577	-3.4
Bus 176-D	25395.6	30058	18.4	57832	65074	12.5
Bus 177-D	30381.9	23836	-21.5	63024	48985	-22.3
Bus 178-D	22194.3	26108.9	17.6	47341	56865	20.1
Bus 179-D	25556	28163.5	10.2	54965	59791	8.8

Since each bus ran on different routes and was used for different amounts of time, making an unbiased comparison between the individual buses was not possible. Therefore, I summed the number of liters used by the 5 hybrids and the 5 diesel buses, so I could analyze total emissions and liters used, comparing the hybrid and diesel buses. The results of the emissions analysis are seen in Table 5-2. In 2014, the hybrid buses had 13.9% fewer CO_2 emissions than the diesels, while in 2015, the hybrid buses had 16.8 % fewer CO_2 emissions than the diesels. Table 5-3 also provides the results of CO_2 emissions by g/km and shows the fuel economy differences between the hybrid and diesel buses. For the hybrid buses, the CO_2 emissions worked out to 948.2 g/km in 2014 and 1003.1 g/km in 2015, while the diesel buses were 1242.5 g/km in 2014 and 1250.4 g/km in 2015. The hybrids produced 23.7% less emissions in 2014 and 19.8% less emissions in 2015 than the diesel buses. The fuel economy values of

hybrid buses were at 6.61 mpg for 2014 and 6.24 mpg for 2015, while the diesel buses had fuel use of 5.04 mpg in 2014 and 5.01 mpg in 2015. The hybrids were 31.2% more fuel-efficient in 2014 and 24.6% more fuel-efficient in 2015 than the diesel buses.

As was mentioned in Chapter 4, the Surface Transportation and Uniform Relocation Assistance Act (STURAA) tests examine transit bus emissions at different years and miles traveled. The New Flyer of America Group recommends these tests to show a measure of the efficiency of their transit fleet buses. As seen in Table 5-4, I compared the Lethbridge results from 2014 and 2015 to the STURAA results for the XD 40 and XDE40 New Flyer of America bus models.

Regarding CO_2 emissions, for both years in Lethbridge, the hybrid and diesel emission results were higher than the Orange County and UDDS but lower than Manhattan. The Lethbridge results are comparable to the combined average of the STURAA tests.

Diesel fuel efficiency results for both years for Lethbridge were less than that of Orange County and UDDS, but greater than that of Manhattan. The fuel efficiency was less than the combined average of the STURAA tests. The hybrid fuel efficiency results for both years in Lethbridge were less than that of UDDS, comparable to the Orange County bus, but greater than that of Manhattan, and the fuel efficiency was less than the combined average of the STURAA tests.

Table 5-2: Summary of the combined liters used by the hybrid buses and the diesel buses to calculate the CO_2 emissions from 2014 and 2015. Conversions to several units represented for comparison to other existing standards.

Bus ID	Liters used 2014	US gallons 2014	Liters used 2015	US gallons 2015	CO_2 emissions factor (g/L)	CO_2 emissions (g) 2014	CO_2 emissions (tonnes) 2014	CO_2 emissions (Imperial tons) 2014	CO_2 emissions (g) 2015	CO_2 emissions (tonnes) 2015	CO_2 emissions (Imperial tons) 2015
Total hybrid	111971	29580	118823	31390	2663	298178773	298	329	316425116	316	349
Total diesel	134332	35487	137715	36380	2663	357725317	358	394	366735578	367	404

Table 5-3: Summary of the combined kilometers (Km) traveled by the hybrid buses and the diesel buses to calculate the CO_2 emissions and fuel economy for 2014 and 2015. Conversions to several units represented for comparison to other existing standards.

Bus ID	Km traveled 2014	Miles 2014	Km traveled 2015	Miles 2015	2014 CO_2 emissions g/km	2015 CO_2 emissions g/km	2014 CO_2 emissions gm/miles	2015 CO_2 emissions gm/miles	2014 Fuel economy mpg	2015 Fuel economy mpg
Total hybrid	314469.00	195401.92	315445.00	196008.38	948.20	1003.11	1525.98	1614.34	6.61	6.24
Total diesel	287917.00	178903.27	293292.00	182243.14	1242.46	1250.41	1999.55	2012.34	5.04	5.01

Table 5-4: STURAA Results compared to Lethbridge outcomes from 2014 and 2015.

Driving cycle	Manhattan		Orange County bus		UDDS		Combined average		Lethbridge 2014		Lethbridge 2015	
Bus model	**XD40**	**XDE40**	**XD40**	**XDE40**	**XD40**	**XDE40**	**XD40**	**XDE40**	**XD40**	**XDE40**	**XD40**	**XDE40**
CO_2 emissions gm/mi	2830	1960	1950	1431	1256	1254	2012	1548	2000	1526	2012	1614
Fuel consumption mpg	3.59	4.72	5.22	6.45	8.1	7.37	5.637	6.180	5.04	6.61	5.01	6.24

5.4 Age Demographics and Bus Ridership Comparison

I completed descriptive statistics and yearly comparisons using the data provided by the City of Lethbridge, from the Lethbridge Transit Breeze Cards and the census data (Appendixes A–C and H). Table 5-5 breaks down the bus passes sold and the city population for 2012 to 2014. On average, about 20% of the population purchased the bus passes assuming no repeat purchases. Between 2012 and 2013, bus pass sales increased by 14%, then decreased by 9% between 2013 and 2014; although pass sales for 2014 were still higher than 2012. Between 2012 and 2013, the population grew by 1.5%, and from 2013 through 2014, the population grew by 2.9%. To better understand these numbers, I further broke down the bus pass user and city census data at a census tract level.

Table 5-5: Data analysis of Lethbridge Transit bus passes called Breeze Cards and city demographics by city census data.

	Data analysis by year		
	2012	**2013**	**2014**
Total bus passes sold	17515	20017	18183
City population	89074	90417	93004
% bus passes sold to population	19.7	22.1	19.6
Growth rate for bus passes sold between years (%)		14.3	-9.2
Growth rate for population between years (%)		1.5	2.9

5.4.1 Lethbridge demographics analysis. As seen in Tables 5-6 and 5-7 and Figures 5-1 – 5-3, the percentages of children, youth, adults, and seniors in bus rider records have not changed greatly during 2012 – 2014. Children comprised 7% of the Lethbridge population, Youth 12%, Adults 66%, and Seniors 15%.

Table 5-6: Lethbridge demographics by age group as per the city census data for years 2012 and 2014.

	Lethbridge demographics		
Lethbridge demographic by age group as per city census	**2012**	**2013**	**2014**
Child (5 and under)	6105	6198	6315
Youth (6 - 17)	10634	10839	11216
Adult (18 - 64)	58005	58394	59702
Senior (65 and up)	12750	13114	13480
All Ages	87494	88545	90713

Table 5-7: Lethbridge demographics by age group as a percentage breakdown for the City of Lethbridge.

	Lethbridge demographics		
Lethbridge demographic by age group by percentage	**2012**	**2013**	**2014**
Child	6.98	7.00	6.96
Youth	12.15	12.24	12.36
Adult	66.30	65.95	65.81
Senior	14.57	14.81	14.86

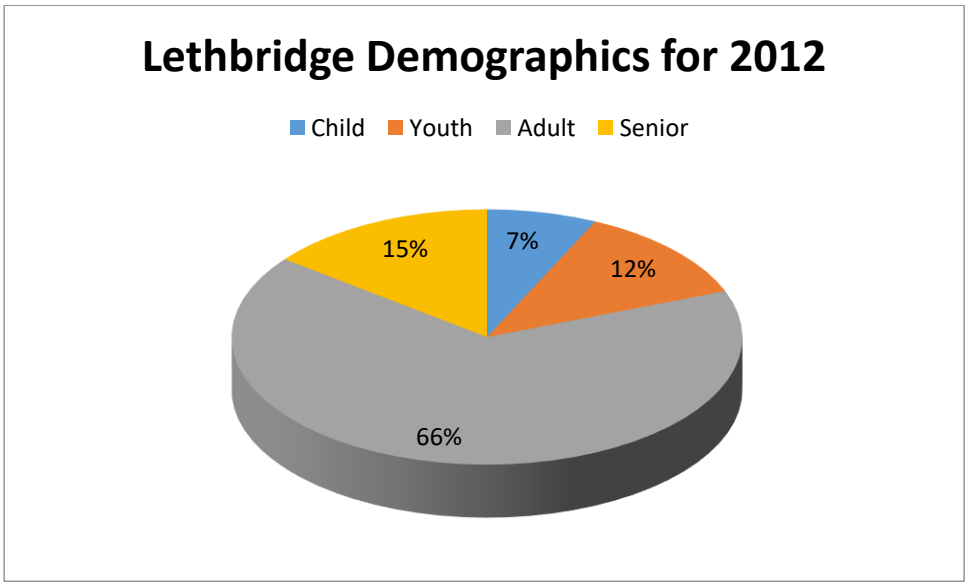

Figure 5-1: Lethbridge demographics of different age groups for 2012

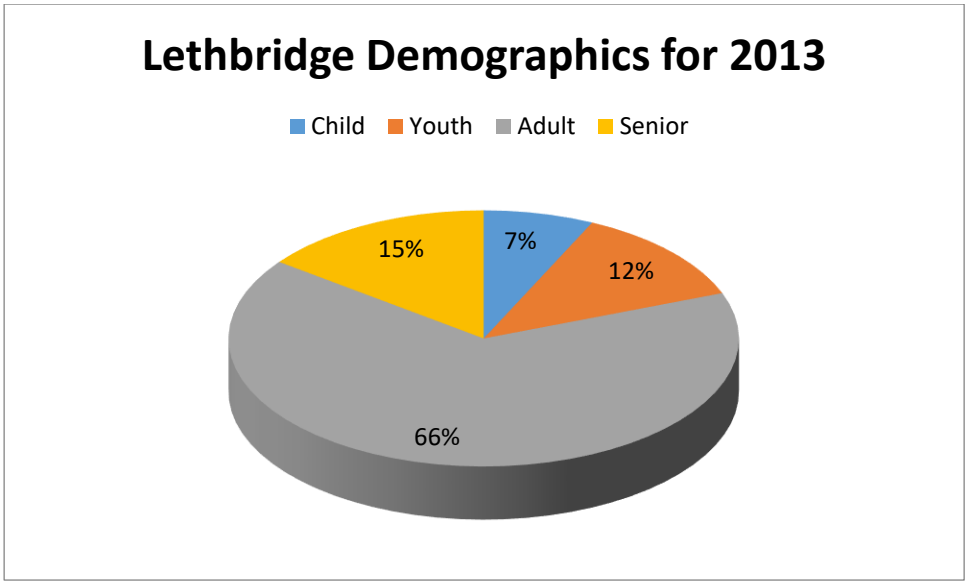

Figure 5-2: Lethbridge demographics of different age groups for 2013

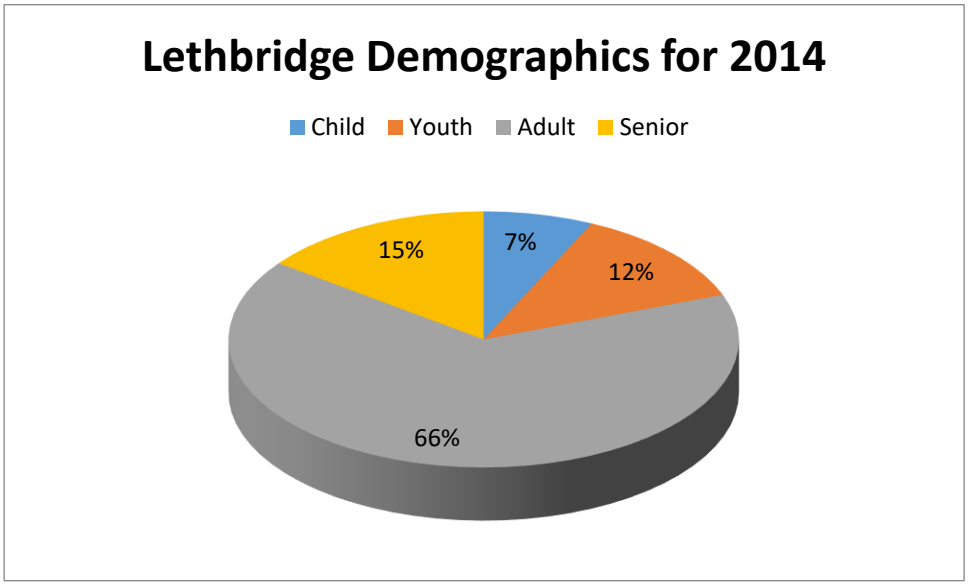

Figure 5-3: Lethbridge demographics of different age groups for 2014

5.4.2 Lethbridge transit bus user analysis. As seen in Tables 5-8 and 5-9 as well as Figures 5-4 to 5-6 the percentage of post-secondary, children, youth, and adult bus pass users slightly increased from 2012 through 2014. Post-secondary users increased from 17% to 18%, children increased from 1% to 2%, youth increased from 6% to 7%, and adults increased from 35% to 39%. Seniors stayed at 6%, and others stayed at 2%. Cash users decreased from 33% to 26%.

Table 5-8: How many times bus passes were used for Lethbridge Transit users by Breeze Pass type

	Total times passes were used		
Transit users by breeze pass type	**2012**	**2013**	**2014**
Adult (18 – 64)	648523	658157	736199
Cash (unknown users who pay cash)	602195	532773	494945
Child (5 and under)	26428	34193	32069
Post-secondary (unknown age)	301482	311621	341751
Senior (65 and up)	114612	114924	122681
Youth (6 – 17)	109306	127469	140252
Other (Riders who do not fall in other categories)	27862	32950	34534
Total bus users	1830408	1812084	1902431

Table 5-9: How many times bus passes were used for Lethbridge Transit users by Breeze Pass type by %

	Total times passes were used		
Transit users by pass group	**2012**	**2013**	**2014**
Adult	35.4	36.3	38.7
Cash	32.9	29.4	26.02
Child	1.4	1.9	1.7
Post-secondary	16.5	17.2	18.0
Senior	6.3	6.3	6.5
Youth	6.0	7.03	7.4
Other	1.5	1.8	1.8

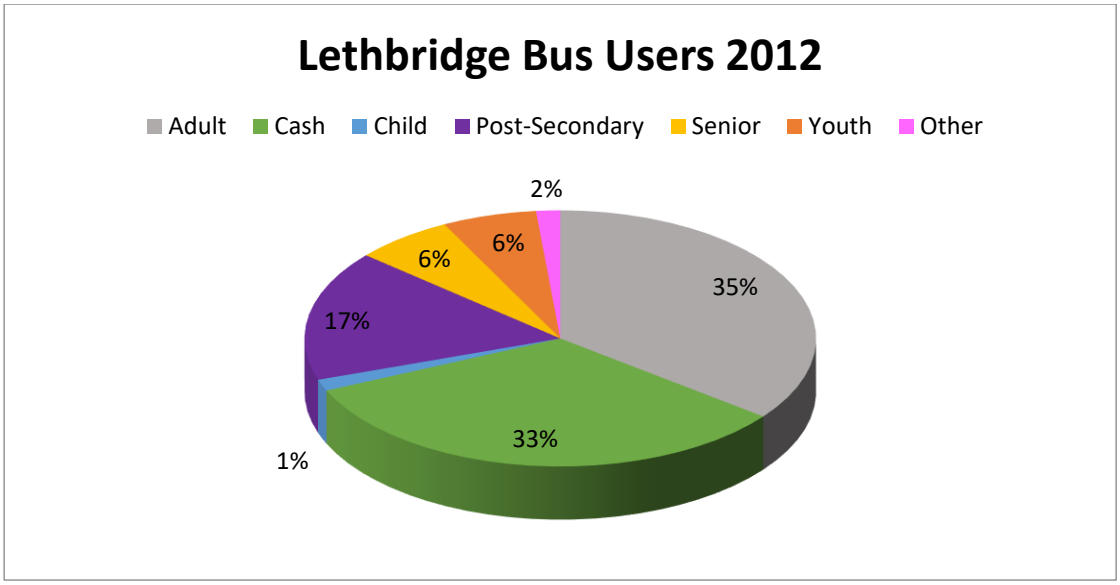

Figure 5-4: Lethbridge bus users based off Lethbridge Transit data for 2012

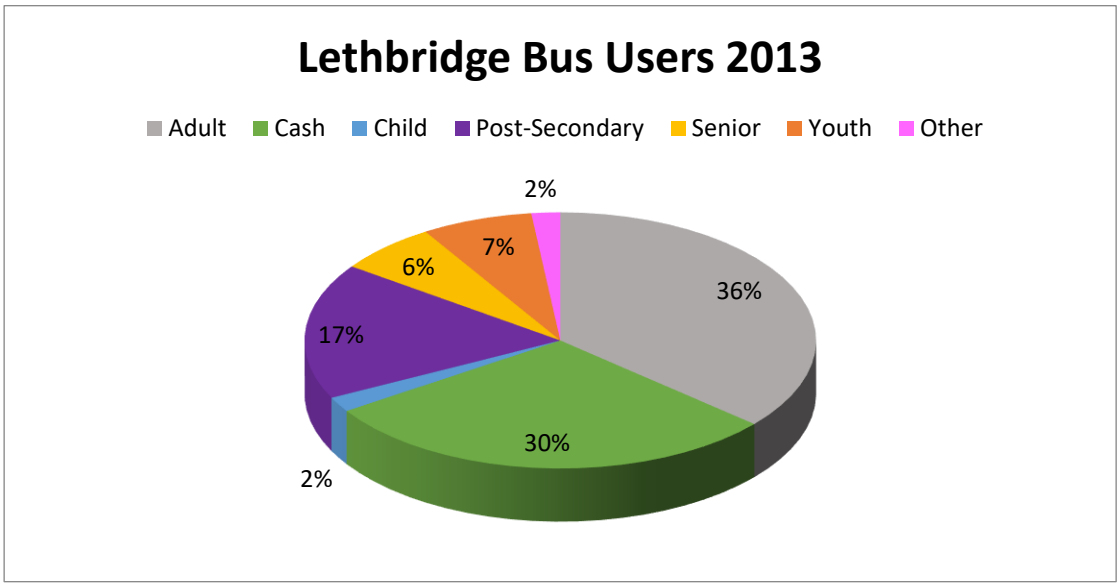

Figure 5-5: Lethbridge bus users based off Lethbridge Transit data for 2013

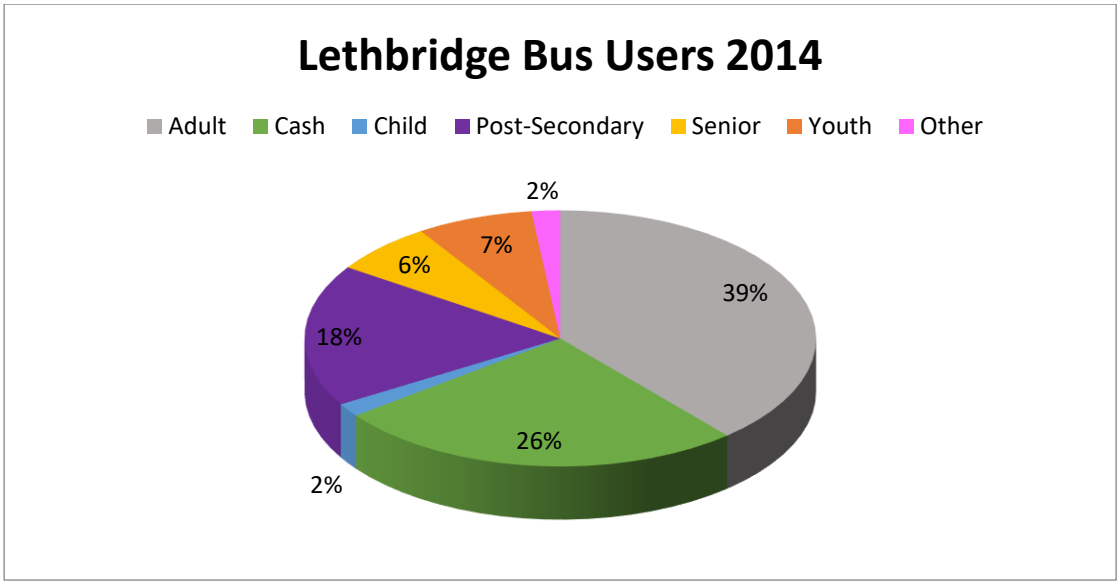

Figure 5-6: Lethbridge bus users based off Lethbridge Transit data for 2014

5.4.3 Lethbridge demographic and transit bus user hot spot analysis. The hot spot analysis identifies significant spatial clustering of high values (hot spots) and low values (cold spots) using z-score and p-values to determine if the data is more than just random distribution of the clustering. The clustering is binned into statistically significant confidence levels of 99, 95 and 90 percent that identify high clustering of high or low values by assigning -/+ 3, 2 or 1 (Appendix D – F). To achieve the best fitting results for the hot spot analysis, the parameter chosen was the Zone of Indifference, as it does not initially exclude variables or geographical features from the analysis and does not impose sharp boundaries. The threshold distance parameter is also selected to help with neighboring feature influences. To select the best fitting threshold distance, the results from the Moran's I (Appendix G) was used. The threshold best fitted for the demographic data was 750m and for the transit usage data, 4000m. Due to the large amount of results, this section combines the three years of each category for the maps, resulting in 12 figures, followed by the five hot spot results comparison tables.

Figure 5-7 maps out the hot spot analysis for the population of Lethbridge from years 2012 to 2014. Table 5-10 provides the census tract ID for the population hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also in Table 5-10 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values; and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 33 hot spots, 12 of which are a #3 ranking, 16 are #2, and 5 are #1. In 2013, there were 33 hot spots, 14 of which are a #3 ranking, 11 are #2, and 8 are #1. In 2014, there were 33 hot spots, 11 of which are a #3 ranking, 16 are a #2, and 6 are #1. Between 2012 and 2014, 16 hot spots stayed the same, 8 of which are a #3 ranking, 7 are #2, and 1 are #1. I identified no shared hot spots between 2013 and 2014. Four hot spots were the same for years 2012 and 2014, 1 of which is a #3 ranking, 2 are #2, and 1 is #1. Seven hot spots were the same for 2012 and 2013, 2 of which are a #3 ranking, 3 are #2, and 2 are #1.

The cold spot ratings are also provided in Table 5-10 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 shows how these cold spots change between 2012 and 2014. In 2012, there were 51 cold spots, 23 of which are a -3 ranking, 14 are -2, and 14 are -1. In 2013, there were 50 cold spots, 26 of which are a -3 ranking, 16 are -2, and 8 are -1. In 2014, there were 50 cold spots, 24 of which are a -3 ranking, 16 are -2, and 10 are -1. During the same period, 37 cold spots stayed the same, 22 of which are a -3 ranking, 11 are -2, and 4 are -1. Three were the same during 2013 and 2014: 2 of which are a -3 ranking, 1 is -2, and none are a -

1. Five cold spots were the same for 2012 and 2014: 1 is -2 ranking and 4 are -1. Four cold spots were the same for 2012 and 2013, 1 of which is a -3 ranking and 3 are -1.

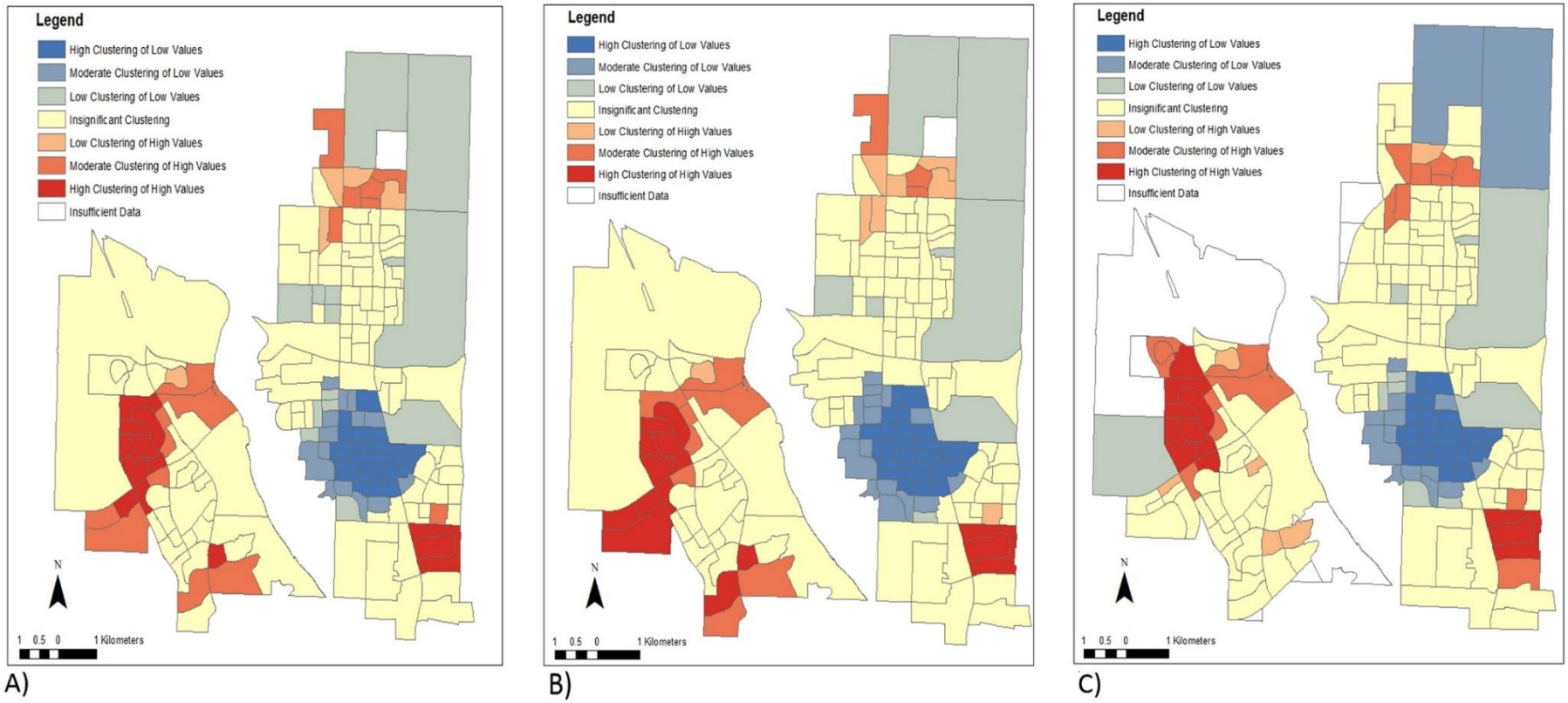

Figure 5-7: Hot spot analysis results for total population demographics. A) 2012 B) 2013 C) 2014

Table 5-10: Hot spot analysis results for total population demographics

Total population, 2012				Total population, 2013				Total population, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
138	1	101	St. Edwards	138	1	101	St. Edwards	138	2	101	St. Edwards
2	-1	106	Senator Buchanan	124	-1	108	Senator Buchanan	19	-1	109	Senator Buchanan
124	-1	108	Senator Buchanan	19	-1	109	Senator Buchanan	136	2	112	St. Edwards
19	-1	109	Senator Buchanan	136	1	112	St. Edwards	156	2	116	Legacy Ridge/ Hardieville
125	-1	111	Senator Buchanan	163	2	113	Legacy Ridge/ Hardvieville/Royal View Future Development	8	-1	203	Park Meadows
136	2	112	St. Edwards	158	1	116	Legacy Ridge/ Hardvieville	126	1	215	Uplands
163	2	113	Legacy Ridge/ Hardieville/Royal View Future Development Area	8	-1	203	Park Meadows	133	2	216	Uplands
158	1	116	Legacy Ridge/ Hardieville	133	1	216	Uplands	77	2	217	Uplands
8	-1	203	Park Meadows	77	2	217	Uplands	146	2	218	Uplands
126	1	215	Uplands	146	2	218	Uplands	147	2	220	Uplands
133	2	216	Uplands	162	1	219	Uplands	63	-2	403	London Road
77	2	217	Uplands	147	1	220	Uplands	65	-1	404	London Road
146	2	218	Uplands	63	-2	403	London Road	66	-2	405	London Road
162	2	219	Uplands	65	-2	404	London Road	67	-1	406	London Road
147	1	220	Uplands	66	-2	405	London Road	120	-2	409	Fleetwood
63	-2	403	London Road	67	-2	406	London Road	69	-2	410	Fleetwood
65	-1	404	London Road	120	-2	409	Fleetwood	131	-3	411	Fleetwood
66	-2	405	London Road	69	-3	410	Fleetwood	130	-2	412	Fleetwood
67	-1	406	London Road	131	-3	411	Fleetwood	132	-2	413	Fleetwood
120	-1	409	Fleetwood	130	-2	412	Fleetwood	64	-1	414	London Road
69	-2	410	Fleetwood	132	-2	413	Fleetwood	145	-2	417	Scenic Heights

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

131	-3	411	Fleetwood	64	-2	414	London Road	21	-2	504	Victoria Park
130	-2	412	Fleetwood	145	-2	417	Scenic Heights	22	-3	505	Victoria Park
132	-2	413	Fleetwood	21	-2	504	Victoria Park	23	-3	506	Victoria Park
64	-1	414	London Road	22	-3	505	Victoria Park	114	-1	509	Henderson Lake
145	-2	417	Scenic Heights	23	-3	506	Victoria Park	24	-3	510	Victoria Park
21	-2	504	Victoria Park	114	-1	509	Henderson Lake	25	-3	511	Victoria Park
22	-2	505	Victoria Park	24	-3	510	Victoria Park	71	-2	512	Victoria Park
23	-3	506	Victoria Park	25	-3	511	Victoria Park	26	-3	513	Victoria Park
114	-1	509	Henderson Lake	71	-2	512	Victoria Park	27	-3	514	Victoria Park
24	-3	510	Victoria Park	26	-3	513	Victoria Park	30	-3	515	Victoria Park
25	-2	511	Victoria Park	27	-3	514	Victoria Park	31	-3	605	Victoria Park
71	-2	512	Victoria Park	30	-3	515	Victoria Park	32	-3	606	Victoria Park
26	-3	513	Victoria Park	31	-3	605	Victoria Park	90	-3	607	Victoria Park
27	-3	514	Victoria Park	32	-3	606	Victoria Park	33	-3	608	Victoria Park
30	-3	515	Victoria Park	90	-3	607	Victoria Park	91	-3	609	Victoria Park
31	-3	605	Victoria Park	33	-3	608	Victoria Park	34	-3	610	Agnes Davidson
32	-3	606	Victoria Park	91	-3	609	Victoria Park	36	-3	611	Agnes Davidson
90	-3	607	Victoria Park	34	-3	610	Agnes Davidson	40	-3	612	Agnes Davidson
33	-3	608	Victoria Park	36	-3	611	Agnes Davidson	35	-3	613	Agnes Davidson
91	-3	609	Victoria Park	40	-3	612	Agnes Davidson	37	-3	614	Agnes Davidson
34	-3	610	Agnes Davidson	35	-3	613	Agnes Davidson	38	-2	615	Agnes Davidson
36	-3	611	Agnes Davidson	37	-3	614	Agnes Davidson	39	-2	616	Agnes Davidson
40	-3	612	Agnes Davidson	38	-2	615	Agnes Davidson	41	-3	617	Agnes Davidson
35	-3	613	Agnes Davidson	39	-3	616	Agnes Davidson	42	-3	618	Agnes Davidson
37	-3	614	Agnes Davidson	41	-3	617	Agnes Davidson	62	-2	619	Agnes Davidson
38	-2	615	Agnes Davidson	42	-3	618	Agnes Davidson	43	-2	620	Agnes Davidson
39	-3	616	Agnes Davidson	62	-2	619	Agnes Davidson	52	-1	622	Agnes Davidson
41	-3	617	Agnes Davidson	43	-2	620	Agnes Davidson	121	-1	623	Royal Chinook Heights
42	-3	618	Agnes Davidson	52	-1	622	Agnes Davidson	44	-3	701	Lakeview

62	-2	619	Agnes Davidson	121	-2	623	Royal Chinook Heights	46	-3	702	Lakeview
43	-2	620	Agnes Davidson	44	-3	701	Lakeview	47	-3	703	Lakeview
121	-1	623	Park Royal/ Chinook Heights	46	-3	702	Lakeview	45	-3	706	Lakeview
44	-3	701	Lakeview	47	-3	703	Lakeview	50	-2	709	Lakeview
46	-3	702	Lakeview	45	-3	706	Lakeview	93	2	714	Redwood
47	-3	703	Lakeview	50	-2	709	Lakeview	92	3	718	Fairmont
45	-3	706	Lakeview	93	1	714	Redwood	148	3	719	Fairmont
50	-2	709	Lakeview	92	3	718	Fairmont	157	2	720	Southgate
93	2	714	Redwood	148	3	719	Fairmont	96	3	801	Indian Battle Heights
92	3	718	Fairmont	96	3	801	Indian Battle Heights	59	2	802	Indian Battle Heights
148	3	719	Fairmont	59	2	802	Indian Battle Heights	101	2	805	Indian Battle Heights
96	3	801	Indian Battle Heights	101	2	805	Indian Battle Heights	144	3	806	Indian Battle Heights
59	2	802	Indian Battle Heights	144	2	806	Indian Battle Heights	97	3	807	Indian Battle Heights
101	2	805	Indian Battle Heights	97	3	807	Indian Battle Heights	98	3	808	Indian Battle Heights
144	3	806	Indian Battle Heights	98	3	808	Indian Battle Heights	95	3	809	Indian Battle Heights
97	3	807	Indian Battle Heights	95	3	809	Indian Battle Heights	128	3	810	Indian Battle Heights
98	3	808	Indian Battle Heights	128	3	810	Indian Battle Heights	143	3	811	West Highlands
95	3	809	Indian Battle Heights	129	3	812	Indian Battle Heights	129	3	812	Indian Battle Heights
128	3	810	Indian Battle Heights	170	3	904	Sunridge	185	2	813	West Highlands
129	3	812	Indian Battle Heights	153	2	906	Heritage Heights	150	2	814	West Highlands
170	2	904	Mountain Heights/ Sunridge	105	2	908	Ridgewood	152	2	906	Heritage Heights
153	2	906	Heritage Heights	156	2	910	Riverstone	105	2	908	Ridgewood
105	2	908	Ridgewood	137	1	911	Heritage Heights	137	1	911	Heritage Heights
156	2	910	Riverstone	174	3	914	Riverstone	172	1	914	Riverstone
137	1	911	Heritage Heights	169	2	915	Sunridge	171	1	916	Riverstone

174	3	914	Riverstone	94	2	1008	Varsity Village	94	3	1008	Varsity Village
94	2	1008	Varsity Village	165	3	1012	Varsity Village	164	2	1012	Varsity Village
165	3	1012	Varsity Village	172	3	1015	Copperwood	104	1	1014	Varsity Village
172	2	1015	Copperwood	171	3	1016	Copperwood	182	1	1016	Copperwood
171	3	1016	Copperwood	168	3	1017	Copperwood	112	-1	2002	Churchill/ Shackleford/ Anderson Industrial
168	2	1017	Copperwood	112	-1	2002	Anderson/ Shackleford/ Churchill Industrial Park	174	-2	2003	Sherring Industrial Park
112	-1	2002	Churchill/ Shackleford/ Anderson Industrial Parks	178	-1	2003	Sherring Industrial Park/North Sherring Future Development	175	-2	2004	Blackwolf 2
178	-1	2003	North Sherring Future Development Area/Sherring Industrial Park	179	-1	2004	Blackwolf 2/ Burbridge Farms Future Development	184	-1	2009	The Piers/ The Crossing
179	-1	2004	Blackwolf 2/ Burbridge Farms Future Development								

Table 5-11: Yearly totals comparison of hot spot results

Hot spot confidence level	Number of hot spots for Breeze Card user categories for each year							Number of hot spots for census demographic categories for each year				
	Post-secondary	Cash	Child	Youth	Adult	Senior	All card users	Child	Youth	Adult	Senior	Total population
High clustering of high values in 2012	12	3	-	-	2	-	2	12	18	11	9	12
Moderate clustering of high values in 2012	12	8	9	5	4	14	10	11	9	16	2	16
Low clustering of high values in 2012	14	6	13	14	9	18	7	5	8	10	3	5
Total hot spots for 2012	38	17	22	19	15	32	19	28	35	37	14	33
High clustering of high values in 2013	14	3	-	-	1	-	3	14	20	13	2	14
Moderate clustering of high values in 2013	9	8	8	5	5	10	9	6	6	13	2	11
Low clustering of high values in 2013	15	7	15	12	6	19	7	4	8	6	9	8
Total hot spots for 2013	38	18	23	17	12	29	19	24	34	32	13	33
High clustering of high values in 2014	12	4	-	-	2	-	2	14	17	13	9	11
Moderate clustering of high values in 2014	11	7	24	4	5	14	10	12	12	12	3	16
Low clustering of high values in 2014	7	7	37	12	9	33	7	5	2	7	1	6
Total hot spots for 2014	30	18	61	16	16	47	19	31	31	32	13	33

Table 5-12: Yearly totals comparison of cold spot results

Cold spot confidence level	Number of cold spots for Breeze Card user categories for each year							Number of cold spots for census demographic categories for each year				
	Post-secondary	Cash	Child	Youth	Adult	Senior	All card users	Child	Youth	Adult	Senior	Total population
High clustering of low values in 2012	-	-	-	-	-	-	-	3	13	21	-	23
Moderate clustering of low values in 2012	1	-	-	2	-	-	-	26	26	14	-	14
Low clustering of low values in 2012	1	3	8	11	-	-	1	10	8	12	-	14
Total cold spot for 2012	2	3	8	13	-	-	1	39	47	47	-	51
High clustering of low values in 2013	-	-	-	-	-	-	-	-	14	22	-	26
Moderate clustering of low values in 2013	-	-	-	1	-	-	-	23	28	15	-	16
Low clustering of low values in 2013	2	6	6	12	-	-	3	15	7	13	-	8
Total cold spot for 2013	2	6	6	13	-	-	3	38	49	50	-	50
High clustering of low values in 2014	-	-	-	-	-	-	-	5	20	20	-	24
Moderate clustering of low values in 2014	-	-	-	-	-	-	-	27	21	14	1	16
Low clustering of low values in 2014	1	-	-	7	-	-	-	9	9	13	3	10
Total cold spot for 2014	1	-	-	7	-	-	-	41	50	47	4	50

Table 5-83: Comparison between years of hot spot results

Hot spot confidence level	Number of shared hot spots over the years for Breeze Card user categories							Number of shared hot spots over the years for census demographic categories				
	Post-secondary	Cash	Child	Youth	Adult	Senior	All card users	Child	Youth	Adult	Senior	Total population
Shared hot spots across years 2012-2014												
High clustering of high values	12	3	-	-	1	-	2	6	13	9	9	8
Moderate clustering of high values	8	7	-	4	4	9	9	3	4	7	2	7
Low clustering of high values	5	5	-	6	5	9	7	-	-	5	1	1
Total hot spots	25	15	-	10	10	18	18	9	17	21	12	16
Shared hot spots across years 2013 & 2014												
High clustering of high values	-	-	-	-	-	-	-	1	-	-	-	-
Moderate clustering of high values	-	-	10	-	-	-	-	-	1	2	-	-
Low clustering of high values	-	1	5	1	-	1	-	-	2	-	-	-
Total hot spots	-	1	15	1	-	1	-	1	3	2	-	-
Shared hot spots across years 2012 & 2014												
High clustering of high values	-	-	-	-	1	-	-	1	-	-	-	1
Moderate clustering of high values	2	-	-	-	-	4	-	3	2	2	-	2
Low clustering of high values	-	-	-	4	3	6	-	-	-	2	-	1
Total hot spots	2	-	-	4	4	10	-	4	2	4	-	4
Shared hot spots across years 2012 & 2013												
High clustering of high values	-	-	-	-	-	-	-	5	4	1	-	2
Moderate clustering of high values	1	1	1	-	-	-	-	1	1	4	-	3
Low clustering of high values	9	1	-	4	1	1	-	2	3	2	1	2
Total hot spots	10	2	1	4	1	1	-	8	8	7	1	7

Table 5-94: Comparison between years of cold spot results

Cold spot confidence level	Number of shared cold spots over the years for Breeze Card user categories							Number of shared cold spots over the years for census demographic categories				
	Post-secondary	Cash	Child	Youth	Adult	Senior	All card users	Child	Youth	Adult	Senior	Total population
Share cold spots across years 2012-2014												
High clustering of low values	-	-	-	-	-	-	-	-	12	18	-	22
Moderate clustering of low values	-	-	-	-	-	-	-	17	18	11	-	11
Low clustering of low values	-	-	-	4	-	-	-	2	2	6	-	4
Total cold spots	-	-	-	4	-	-	-	19	32	35	-	37
Share cold spots across years 2013 & 2014												
High clustering of low values	-	-	-	-	-	-	-	-	2	-	-	2
Moderate clustering of low values	-	-	-	-	-	-	-	1	1	-	-	1
Low clustering of low values	1	-	-	1	-	-	-	-	2	-	-	-
Total cold spots	1	-	-	1	-	-	-	1	5	-	-	3
Share cold spots across years 2012 & 2014												
High clustering of low values	-	-	-	-	-	-	-	2	1	-	-	-
Moderate clustering of low values	-	-	-	-	-	-	-	5	-	1	-	1
Low clustering of low values	-	-	-	-	-	-	-	1	2	2	-	4
Total cold spots	-	-	-	-	-	-	-	8	3	3	-	5
Share cold spots across years 2012 & 2013												
High clustering of low values	-	-	-	-	-	-	-	-	-	3	-	1
Moderate clustering of low values	-	-	-	1	-	-	-	3	6	2	-	-
Low clustering of low values	-	3	-	5	-	-	1	6	2	1	-	3
Total cold spots	-	3	-	6	-	-	1	9	8	6	-	4

Figure 5-8 maps out the hot spot analysis for all bus card uses from Lethbridge Transit Breeze Cards from 2012 to 2014. Table 5-15 provides the census tract ID for all bus card uses hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-15 and are ranked as 1, 2, or 3 where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 19 hot spots, 2 of which are a #3 ranking, 10 are #2, and 7 are #1. In 2013, there were 19 hot spots, 3 of which are a #3 ranking, 9 are #2, and 7 are #1. In 2014, there are a total of 19 hot spots, 2 of which are a #3 ranking, 10 are #2, and 7 are #1. During 2012 – 2014, 18 hot spots stayed the same, 2 are a #3 ranking, 9 are #2, and 7 are #1. No shared hot spots occurred from 2013 to 2014, none occurred between 2012 and 2014, and none occurred between 2012 and 2013.

The cold spot ratings are also provided in Table 5-15 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots change during 2012 – 2014. In 2012, there was 1 cold spot, and it was a -1 ranking. In 2013, there were 3 cold spots, and they were a -1 ranking. In 2014, there were no cold spots. Only 1 cold spot occurred in the same place for 2012 and 2013 and had a #3 ranking. There were no other cold spot locations shared between any combination of the research years.

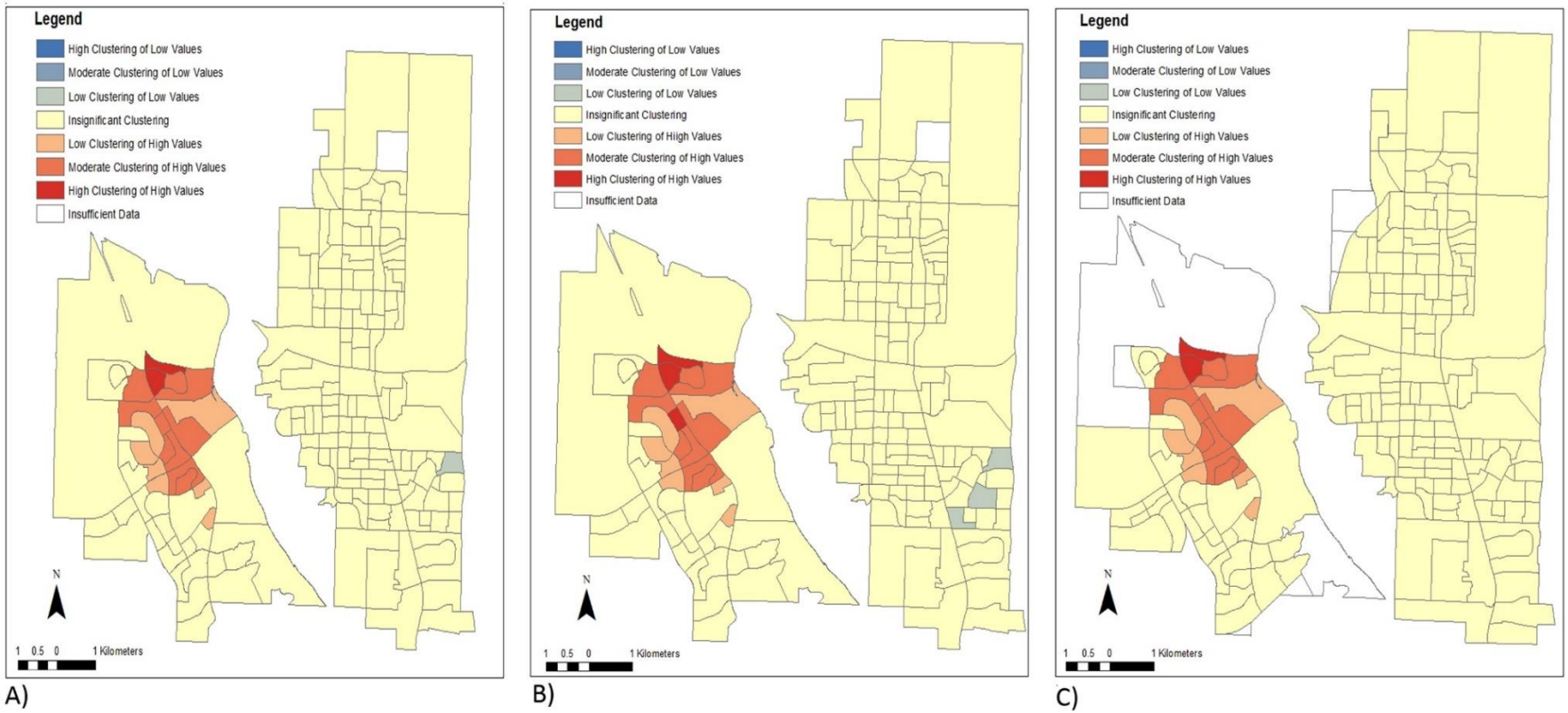

Figure 5-8: Hot spot analysis results for all bus pass uses. A) 2012 B) 2013 C) 2014

Table 5-15: Hot spot analysis results for all bus pass uses

All bus pass uses, 2012				All bus pass uses, 2013				All bus pass uses, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
54	-1	705	Lakeview	54	-1	705	Lakeview	96	1	801	Indian Battle Heights
96	1	801	Indian Battle Heights	49	-1	711	Redwood	59	2	802	Indian Battle Heights
59	2	802	Indian Battle Heights	75	-1	712	Redwood	100	2	804	Indian Battle Heights
100	2	804	Indian Battle Heights	96	1	801	Indian Battle Heights	101	2	805	Indian Battle Heights
101	2	805	Indian Battle Heights	59	2	802	Indian Battle Heights	144	2	806	Indian Battle Heights
144	2	806	Indian Battle Heights	100	2	804	Indian Battle Heights	97	1	807	Indian Battle Heights
97	1	807	Indian Battle Heights	101	3	805	Indian Battle Heights	98	1	808	Indian Battle Heights
98	1	808	Indian Battle Heights	144	2	806	Indian Battle Heights	143	2	811	West Highlands
143	2	811	West Highlands	97	1	807	Indian Battle Heights	102	2	905	Ridgewood
102	2	905	Ridgewood	98	1	808	Indian Battle Heights	152	2	906	Heritage Heights
153	2	906	Heritage Heights	143	2	811	West Highlands	127	3	907	Heritage Heights
127	3	907	Heritage Heights	102	2	905	Ridgewood	105	1	908	Ridgewood
105	1	908	Ridgewood	153	2	906	Heritage Heights	151	3	909	Heritage Heights
152	3	909	Heritage Heights	127	3	907	Heritage Heights	137	2	911	Heritage Heights
137	2	911	Heritage Heights	105	1	908	Ridgewood	58	2	1006	Varsity Village
58	2	1006	Varsity Village	152	3	909	Heritage Heights	103	1	1007	Varsity Village
103	1	1007	Varsity Village	137	2	911	Heritage Heights	94	1	1008	Varsity Village
94	1	1008	Varsity Village	58	2	1006	Varsity Village	99	2	1013	Varsity Village
99	2	1013	Varsity Village	103	1	1007	Varsity Village	104	1	1014	Varsity Village
104	1	1014	Varsity Village	94	1	1008	Varsity Village				
				99	2	1013	Varsity Village				
				104	1	1014	Varsity Village				

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

Figure 5-9 maps out the hot spot analysis for adult demographics in Lethbridge from 2012 to 2014. Table 5-16 provides the census tract ID for the adult hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-16 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots change during 2012 – 2014. In 2012, there were 37 hot spots, 11 of which were a #3 ranking, 16 are #2, and 10 were #1. In 2013, there were 32 hot spots, 13 of which were a #3 ranking, 13 were #2, and 6 were #1. In 2014, there are 32 hot spots, 13 of which were a #3 ranking, 12 were #2, and 7 were #1. During 2012 – 2014, 21 hot spots stayed the same, 9 of which were a #3 ranking, 7 were #2, and 5 were #1. From 2013 to 2014, 2 hot spots stayed the same, with a #2 ranking. During 2012 and 2014, 4 hot spots were the same; 2 were a #2 ranking, and 2 were #1. During 2012 and 2013, 7 hot spots were the same, 1 of which were a #3 ranking, 4 were #2, and 2 were #1.

The cold spot ratings are also provided in Table 5-16 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots change during 2012 – 2014. In 2012, there were 47 cold spots, 21 of which were a -3 ranking, 14 were -2, and 12 are -1. In 2013, there were 50 cold spots, 22 of which were a -3 ranking, 15 were -2, and 13 were -1. In 2014, there were 47 cold spots, 20 of which were a -3 ranking, 14 were -2, and 13 were -1. From 2012 to 2014, 35 of the cold spots stayed the same, 18 of which were a -3 ranking, 11 were -2, and 6 were -1. No hot spots stayed the same between 2013 and 2014. For years

2012 and 2014, 3 cold spots were the same; 1 had a -2 ranking and 2 had -2. During 2012 and 2013, 6 cold spots were the same, 3 of which were a -3 ranking, 2 were -2, and 1 were -1.

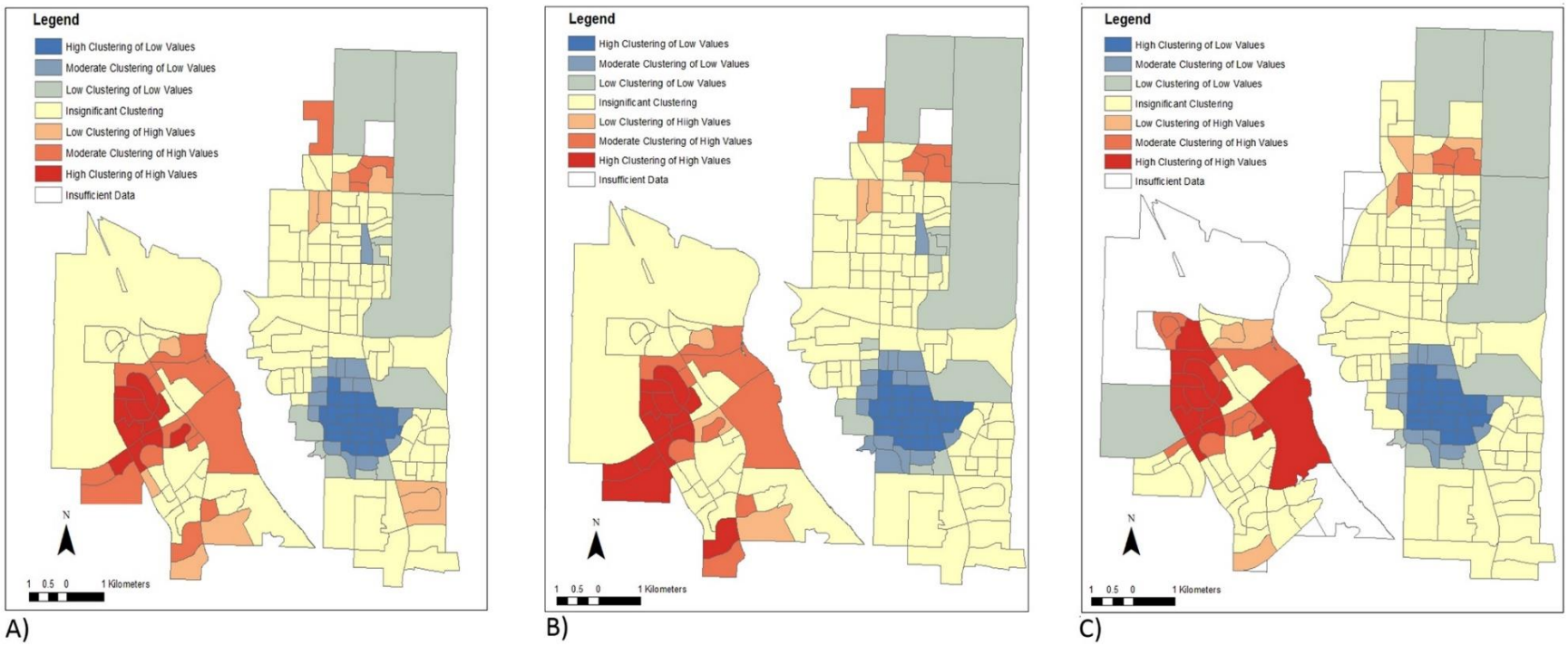

Figure 5-9: Hot spot analysis results for adult demographics. A) 2012 B) 2013 C) 2014

Table 5-16: Hot spot analysis results for adult demographics

Adult demographics, 2012				Adult demographics, 2013				Adult demographics, 2014				Matching hotspot areas
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	All 3 years
138	1	101	St. Edwards	138	1	101	St. Edwards	138	1	101	St. Edwards	2014 – 2013
136	1	112	St. Edwards	136	1	112	St. Edwards	136	2	112	St. Edwards	2014 – 2012
163	2	113	Legacy Ridge/ Hardieville/ Royal View Future Development Area	163	2	113	Legacy Ridge/ Hardvieville/ Royal View Future Development	156	1	116	Legacy Ridge/ Hardieville	2013 – 2012
8	-1	203	Park Meadows	8	-1	203	Park Meadows	8	-1	203	Park Meadows	
9	-1	205	Park Meadows	9	-1	205	Park Meadows	9	-1	205	Park Meadows	
85	-2	206	Winston Churchill	85	-2	206	Winston Churchill	85	-1	206	Winston Churchill	
133	1	216	Uplands	10	-1	213	Park Meadows	133	1	216	Uplands	
77	2	217	Uplands	77	1	217	Uplands	77	2	217	Uplands	
146	2	218	Uplands	146	2	218	Uplands	146	2	218	Uplands	
162	2	219	Uplands	162	2	219	Uplands	161	1	219	Uplands	
147	1	220	Uplands	147	2	220	Uplands	147	2	220	Uplands	
65	-1	404	London Road	12	-1	306	Majestic Place	65	-1	404	London Road	
66	-2	405	London Road	63	-1	403	London Road	66	-2	405	London Road	
69	-2	410	Fleetwood	65	-1	404	London Road	69	-2	410	Fleetwood	
131	-3	411	Fleetwood	66	-2	405	London Road	131	-2	411	Fleetwood	
130	-2	412	Fleetwood	69	-2	410	Fleetwood	130	-2	412	Fleetwood	
132	-1	413	Fleetwood	131	-3	411	Fleetwood	145	-1	417	Scenic Heights	
145	-1	417	Scenic Heights	130	-2	412	Fleetwood	21	-2	504	Victoria Park	
21	-2	504	Victoria Park	132	-1	413	Fleetwood	22	-2	505	Victoria Park	
22	-2	505	Victoria Park	145	-2	417	Scenic Heights	23	-2	506	Victoria Park	
23	-2	506	Victoria Park	21	-2	504	Victoria Park	114	-1	509	Henderson Lake	
114	-1	509	Henderson Lake	22	-2	505	Victoria Park	24	-3	510	Victoria Park	
24	-3	510	Victoria Park	23	-2	506	Victoria Park	25	-3	511	Victoria Park	
25	-2	511	Victoria Park	114	-1	509	Henderson Lake	71	-2	512	Victoria Park	
71	-2	512	Victoria Park	24	-3	510	Victoria Park	26	-3	513	Victoria Park	
26	-3	513	Victoria Park	25	-2	511	Victoria Park	27	-3	514	Victoria Park	
27	-3	514	Victoria Park	71	-2	512	Victoria Park	30	-3	515	Victoria Park	
30	-3	515	Victoria Park	26	-3	513	Victoria Park	31	-3	605	Victoria Park	
31	-3	605	Victoria Park	27	-3	514	Victoria Park	32	-3	606	Victoria Park	
32	-3	606	Victoria Park	30	-3	515	Victoria Park	90	-3	607	Victoria Park	
90	-3	607	Victoria Park	31	-3	605	Victoria Park	33	-3	608	Victoria Park	
33	-3	608	Victoria Park	32	-3	606	Victoria Park	91	-3	609	Victoria Park	
91	-3	609	Victoria Park	90	-3	607	Victoria Park	34	-3	610	Agnes Davidson	

34	-3	610	Agnes Davidson	33	-3	608	Victoria Park	36	-3	611	Agnes Davidson
36	-3	611	Agnes Davidson	91	-3	609	Victoria Park	40	-3	612	Agnes Davidson
40	-3	612	Agnes Davidson	34	-3	610	Agnes Davidson	35	-3	613	Agnes Davidson
35	-3	613	Agnes Davidson	36	-3	611	Agnes Davidson	37	-3	614	Agnes Davidson
37	-3	614	Agnes Davidson	40	-3	612	Agnes Davidson	38	-2	615	Agnes Davidson
38	-2	615	Agnes Davidson	35	-3	613	Agnes Davidson	39	-2	616	Agnes Davidson
39	-3	616	Agnes Davidson	37	-3	614	Agnes Davidson	41	-3	617	Agnes Davidson
41	-3	617	Agnes Davidson	38	-2	615	Agnes Davidson	42	-3	618	Agnes Davidson
42	-3	618	Agnes Davidson	39	-3	616	Agnes Davidson	62	-2	619	Agnes Davidson
62	-2	619	Agnes Davidson	41	-3	617	Agnes Davidson	43	-2	620	Agnes Davidson
43	-2	620	Agnes Davidson	42	-3	618	Agnes Davidson	74	-1	621	Agnes Davidson
74	-1	621	Agnes Davidson	62	-2	619	Agnes Davidson	52	-1	622	Agnes Davidson
52	-1	622	Agnes Davidson	43	-2	620	Agnes Davidson	121	-1	623	Royal Chinook Heights
121	-1	623	Park Royal/ Chinook Heights	74	-1	621	Agnes Davidson	44	-3	701	Lakeview
44	-3	701	Lakeview	52	-1	622	Agnes Davidson	46	-3	702	Lakeview
46	-3	702	Lakeview	121	-2	623	Royal Chinook Heights	47	-2	703	Lakeview
47	-2	703	Lakeview	44	-3	701	Lakeview	45	-3	706	Lakeview
45	-3	706	Lakeview	46	-3	702	Lakeview	50	-2	709	Lakeview
50	-2	709	Lakeview	47	-3	703	Lakeview	96	3	801	Indian Battle Heights
92	1	718	Fairmont	45	-3	706	Lakeview	59	3	802	Indian Battle Heights
148	1	719	Fairmont	50	-2	709	Lakeview	101	2	805	Indian Battle Heights
96	3	801	Indian Battle Heights	96	3	801	Indian Battle Heights	144	3	806	Indian Battle Heights
59	3	802	Indian Battle Heights	59	3	802	Indian Battle Heights	97	3	807	Indian Battle Heights
101	2	805	Indian Battle Heights	101	2	805	Indian Battle Heights	98	3	808	Indian Battle Heights
144	2	806	Indian Battle Heights	144	2	806	Indian Battle Heights	95	3	809	Indian Battle Heights
97	3	807	Indian Battle Heights	97	3	807	Indian Battle Heights	128	3	810	Indian Battle Heights
98	3	808	Indian Battle Heights	98	3	808	Indian Battle Heights	143	3	811	West Highlands
95	3	809	Indian Battle Heights	95	3	809	Indian Battle Heights	129	3	812	Indian Battle Heights
128	3	810	Indian Battle Heights	128	3	810	Indian Battle Heights	185	2	813	West Highlands
129	3	812	Indian Battle Heights	129	3	812	Indian Battle Heights	150	2	814	West Highlands
106	2	901	University	106	2	901	University	106	3	901	University
170	2	904	Mountain Heights/Sunridge	170	3	904	Sunridge	152	1	906	Heritage Heights

153	2	906	Heritage Heights	153	2	906	Heritage Heights	105	2	908	Ridgewood
105	2	908	Ridgewood	105	2	908	Ridgewood	137	1	911	Heritage Heights
156	1	910	Riverstone	156	1	910	Riverstone	167	1	915	Sunridge
137	1	911	Heritage Heights	137	1	911	Heritage Heights	165	2	1005	Varsity Village
174	2	914	Riverstone	174	2	914	Riverstone	58	2	1006	Varsity Village
169	1	915	Sunridge	169	2	915	Sunridge	94	3	1008	Varsity Village
166	2	1005	Varsity Village	166	2	1005	Varsity Village	164	3	1012	Varsity Village
58	3	1006	Varsity Village	58	2	1006	Varsity Village	99	2	1013	Varsity Village
94	3	1008	Varsity Village	94	3	1008	Varsity Village	104	3	1014	Varsity Village
164	1	1011	Varsity Village	165	3	1012	Varsity Village	182	2	1016	Copperwood
165	3	1012	Varsity Village	99	1	1013	Varsity Village	112	-1	2002	Churchill/ Shackleford/ Anderson Industrial
99	2	1013	Varsity Village	172	3	1015	Copperwood	174	-1	2003	Sherring Industrial Park
104	2	1014	Varsity Village	171	3	1016	Copperwood	175	-1	2004	Blackwolf 2
172	2	1015	Copperwood	168	3	1017	Copperwood	184	-1	2009	The Piers/ The Crossing
171	3	1016	Copperwood	112	-1	2002	Anderson/ Shackleford/ Churchill Industrial Park				
168	2	1017	Copperwood	178	-1	2003	Sherring Industrial Park/ North Sherring Future Development				
112	-1	2002	Churchill/ Shackleford/ Anderson Industrial Parks	179	-1	2004	Blackwolf 2/ Burbridge Farms Future Development				
178	-1	2003	North Sherring Future Development Area/ Sherring Industrial Park								
179	-1	2004	Blackwolf 2/ Burbridge Farms Future Development								

Figure 5-10 maps out the hot spot analysis for adult bus card uses from the Lethbridge Transit Breeze Cards during 2012 to 2014. Table 5-17 provides the census tract ID for the adult hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-17 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 15 hot spots, 2 of which were a #3 ranking, 4 were #2, and 9 were #1. In 2013, there were 12 hot spots, 1 of which were a #3 ranking, 5 were #2, and 6 were #1. In 2014, there were 16 hot spots, 2 of which were a #3 ranking, 5 were #2, and 9 were #1. Between 2012 – 2014, 10 of the hot spots stayed the same, 1 of which was a #3 ranking, 4 were #2, and 5 were #1. From 2013 to 2014, no shared hot spots occurred. However, in 2012 and 2014, 4 hot spots were the same, 1 of which was a #3 ranking and 3 were #1. For 2012 and 2013, 1 hot spot was the same and had a ranking of #1.

The cold spot ratings are also provided in Table 5-17 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show that there were no cold spots between 2012 – 2014.

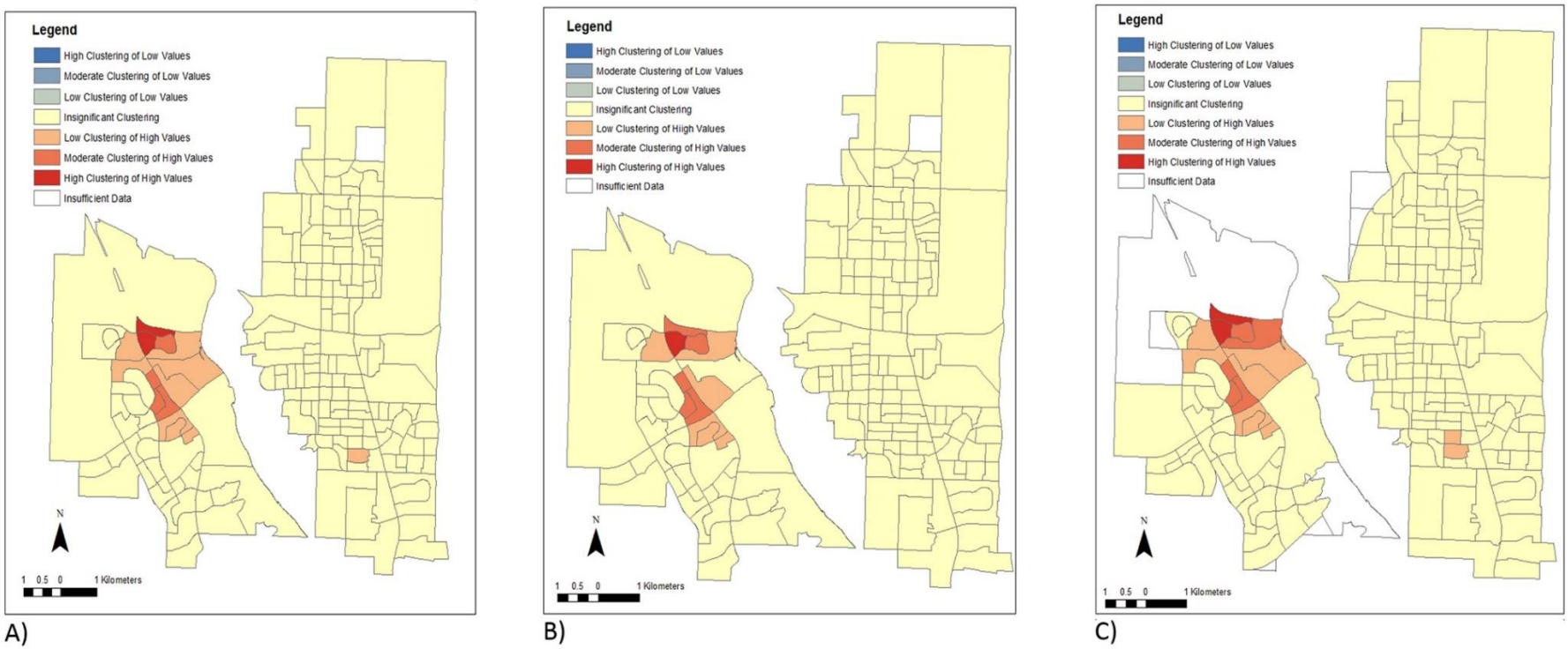

Figure 5-10: Hot spot analysis results for adult bus pass usage. A) 2012 B) 2013 C) 2014

Table 5-17: Hot spot analysis results for adult bus pass usage.

Adult bus pass usage, 2012				Adult bus pass usage, 2013				Adult bus pass usage, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
43	1	620	Agnes Davidson	59	2	802	Indian Battle Heights	41	1	617	Agnes Davidson
59	2	802	Indian Battle Heights	100	2	804	Indian Battle Heights	43	1	620	Agnes Davidson
100	2	804	Indian Battle Heights	101	2	805	Indian Battle Heights	59	2	802	Indian Battle Heights
101	2	805	Indian Battle Heights	143	1	811	West Highlands	100	2	804	Indian Battle Heights
144	1	806	Indian Battle Heights	102	1	905	Ridgewood	101	2	805	Indian Battle Heights
143	1	811	West Highlands	153	1	906	Heritage Heights	144	1	806	Indian Battle Heights
102	1	905	Ridgewood	127	3	907	Heritage Heights	143	1	811	West Highlands
153	1	906	Heritage Heights	152	2	909	Heritage Heights	102	1	905	Ridgewood
127	3	907	Heritage Heights	137	2	911	Heritage Heights	152	2	906	Heritage Heights
105	1	908	Ridgewood	58	1	1006	Varsity Village	127	3	907	Heritage Heights
152	3	909	Heritage Heights	99	1	1013	Varsity Village	105	1	908	Ridgewood
137	2	911	Heritage Heights	104	1	1014	Varsity Village	151	3	909	Heritage Heights
58	1	1006	Varsity Village					137	2	911	Heritage Heights
99	1	1013	Varsity Village					58	1	1006	Varsity Village
104	1	1014	Varsity Village					99	1	1013	Varsity Village
								104	1	1014	Varsity Village

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

Figure 5-11 maps out the hot spot analysis for Lethbridge child demographics from 2012 to 2014. Table 5-18 provides the census tract ID for the child hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-18 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 28 hot spots, 12 of which were a #3 ranking, 11 were #2, and 5 were #1. In 2013, there were 24 hot spots, 14 of which were a #3 ranking, 6 are #2, and 4 were #1. In 2014, there were 31 hot spots, 14 of which are a #3 ranking, 12 were #2, and 5 were #1. During 2012 – 2014, 9 of hot spots stayed the same, 6 of which were a #3 ranking and 3 were #2. During 2013 – 2014, 1 hot spot stayed the same with a #3 ranking. For 2012 and 2014, 4 hot spots were the same; 1 was a #3 ranking and 3 were #2. During 2012 and 2013, 8 hot spots were the same, 5 of which were a #3 ranking, 1 was #2, and 2 were #1.

The cold spot ratings are also provided in Table 5-18 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots changed during 2012 – 2014. In 2012, there were 39 cold spots, 3 of which were a -3 ranking, 26 were -2, and 10 were -1. In 2013, there were 38 cold spots, 23 were -2 ranking and 15 were -1. In 2014, there were 41 cold spots, 5 of which were a -3 ranking, 27 were -2, and 9 were -1. During 2012 – 2014, 19 cold spots stayed the same; 17 were a #2 ranking and 2 were -1. During 2013 – 2014, 1 cold spot was the same, with a -2 ranking. During 2012 and 2014, 8 cold spots remained the same; 2

were a -3 ranking, 5 were -2 ranking, and 1 was -1. During 2012 and 2013, 9 cold spots were the same; 3 were a -2 ranking and 6 were -1 ranking.

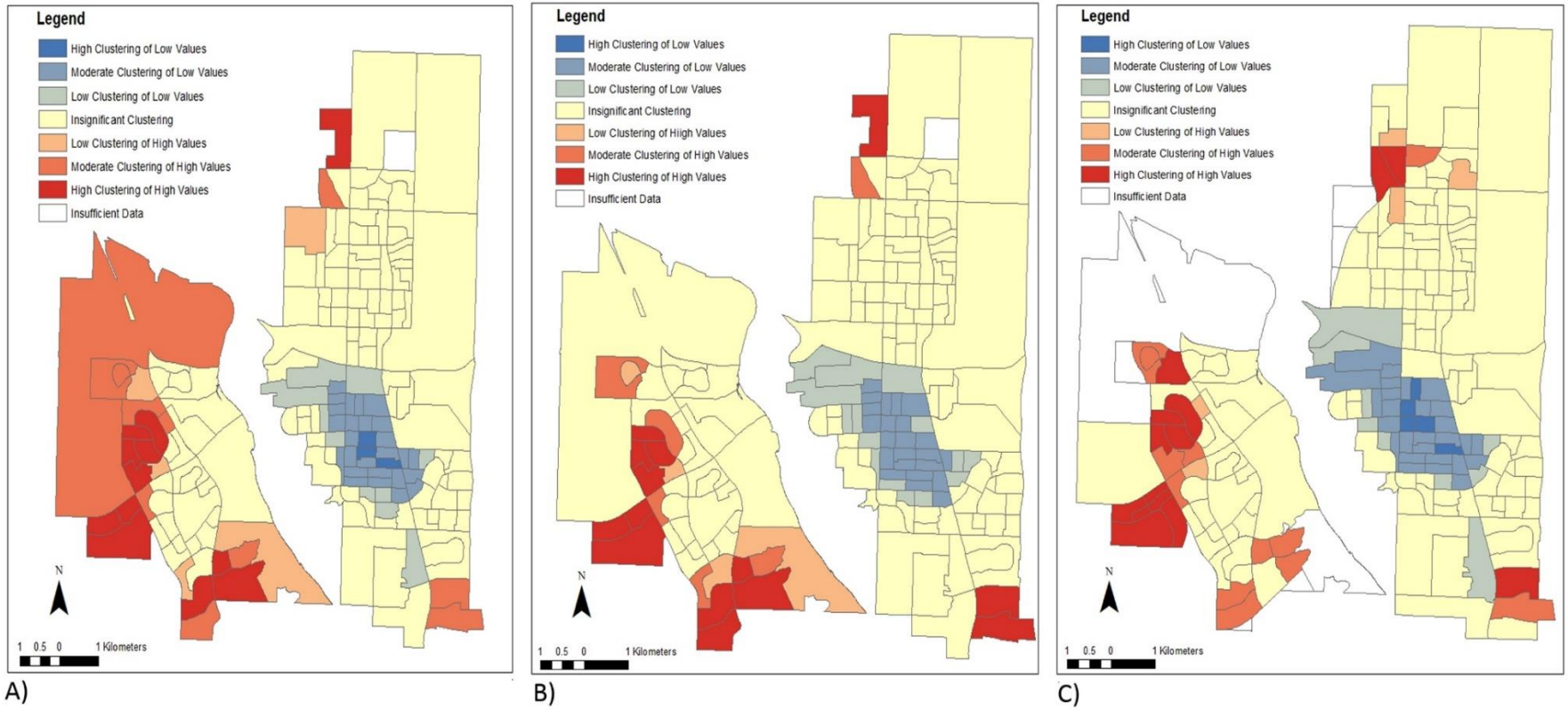

Figure 5-41: Hot spot analysis results for child demographics. A) 2012 B) 2013 C) 2014

Table 5-18: Hot spot analysis results for child demographics.

Child demographics, 2012				Child demographics, 2013				Child demographics, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
163	3	113	Legacy Ridge/ Hardieville/ Royal View Future Development Area	163	3	113	Legacy Ridge/ Hardieville/ Royal View Future Development Area	123	-1	110	Senator Buchanan
154	1	114	Stafford Manor	157	2	115	Legacy Ridge/Hardieville	136	1	112	St. Edwards
157	2	115	Legacy Ridge/Hardieville	115	-1	401	Upper Eastside/ Downtown	155	3	115	Legacy Ridge/ Hardieville
115	-1	401	Upper Eastside/ Downtown	116	-1	402	Downtown/Upper Eastside	156	3	116	Legacy Ridge/ Hardieville
116	-1	402	Downtown/Upper Eastside	63	-2	403	London Road	177	1	117	Legacy Ridge/ Hardieville
63	-2	403	London Road	65	-2	404	London Road	126	2	215	Uplands
65	-2	404	London Road	66	-2	405	London Road	147	1	220	Uplands
66	-2	405	London Road	67	-1	406	London Road	115	-2	401	Downtown
67	-1	406	London Road	69	-1	410	Fleetwood	116	-2	402	Downtown
69	-1	410	Fleetwood	131	-1	411	Fleetwood	63	-2	403	London Road
131	-2	411	Fleetwood	64	-2	414	London Road	65	-2	404	London Road
64	-2	414	London Road	117	-1	415	London Road	66	-2	405	London Road
20	-1	501	Upper Eastside	175	-1	418	Downtown	67	-2	406	London Road
21	-2	504	Victoria Park	20	-1	501	Upper Eastside	120	-1	409	Fleetwood
22	-2	505	Victoria Park	21	-2	504	Victoria Park	69	-2	410	Fleetwood
23	-2	506	Victoria Park	22	-2	505	Victoria Park	131	-2	411	Fleetwood
24	-2	510	Victoria Park	23	-2	506	Victoria Park	130	-1	412	Fleetwood
25	-2	511	Victoria Park	24	-2	510	Victoria Park	64	-2	414	London Road
71	-2	512	Victoria Park	25	-2	511	Victoria Park	117	-1	415	London Road
26	-2	513	Victoria Park	71	-1	512	Victoria Park	173	-1	418	Downtown
27	-3	514	Victoria Park	26	-2	513	Victoria Park	21	-2	504	Victoria Park
30	-2	515	Victoria Park	27	-2	514	Victoria Park	22	-3	505	Victoria Park
149	-1	603	West Mayor Magrath Dr	30	-2	515	Victoria Park	23	-2	506	Victoria Park

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

31	-2	605	Victoria Park	31	-2	605	Victoria Park	24	-3	510	Victoria Park
32	-3	606	Victoria Park	32	-2	606	Victoria Park	25	-2	511	Victoria Park
90	-2	607	Victoria Park	90	-2	607	Victoria Park	71	-2	512	Victoria Park
33	-2	608	Victoria Park	33	-2	608	Victoria Park	26	-3	513	Victoria Park
91	-3	609	Victoria Park	91	-2	609	Victoria Park	27	-3	514	Victoria Park
34	-2	610	Agnes Davidson	34	-2	610	Agnes Davidson	30	-2	515	Victoria Park
36	-2	611	Agnes Davidson	36	-2	611	Agnes Davidson	149	-1	603	West Mayor Magrath Dr
40	-2	612	Agnes Davidson	40	-2	612	Agnes Davidson	31	-2	605	Victoria Park
35	-2	613	Agnes Davidson	35	-1	613	Agnes Davidson	32	-2	606	Victoria Park
37	-2	614	Agnes Davidson	37	-2	614	Agnes Davidson	90	-2	607	Victoria Park
39	-1	616	Agnes Davidson	39	-1	616	Agnes Davidson	33	-2	608	Victoria Park
41	-1	617	Agnes Davidson	41	-1	617	Agnes Davidson	91	-3	609	Victoria Park
42	-2	618	Agnes Davidson	42	-2	618	Agnes Davidson	34	-2	610	Agnes Davidson
43	-1	620	Agnes Davidson	44	-2	701	Lakeview	36	-2	611	Agnes Davidson
44	-2	701	Lakeview	46	-1	702	Lakeview	40	-2	612	Agnes Davidson
46	-2	702	Lakeview	47	-1	703	Lakeview	35	-2	613	Agnes Davidson
47	-1	703	Lakeview	45	-1	706	Lakeview	37	-2	614	Agnes Davidson
45	-2	706	Lakeview	159	3	720	Southgate	41	-1	617	Agnes Davidson
50	-2	709	Lakeview	160	3	721	Southgate	42	-2	618	Agnes Davidson
159	2	720	Southgate	96	2	801	Indian Battle Heights	44	-2	701	Lakeview
160	2	721	Southgate	97	1	807	Indian Battle Heights	46	-2	702	Lakeview
96	3	801	Indian Battle Heights	98	3	808	Indian Battle Heights	47	-1	703	Lakeview
101	2	805	Indian Battle Heights	95	3	809	Indian Battle Heights	45	-2	706	Lakeview
144	2	806	Indian Battle Heights	128	3	810	Indian Battle Heights	50	-1	709	Lakeview
97	1	807	Indian Battle Heights	129	3	812	Indian Battle Heights	157	3	720	Southgate
98	3	808	Indian Battle Heights	151	2	813	West Highlands	158	2	721	Southgate
95	3	809	Indian Battle Heights	150	1	814	West Highlands	96	3	801	Indian Battle Heights

128	3	810	Indian Battle Heights	107	2	902	Mountain Heights	101	1	805	Indian Battle Heights
143	1	811	West Highlands	139	1	903	Mountain Heights	97	2	807	Indian Battle Heights
129	3	812	Indian Battle Heights	170	3	904	Mountain Heights/Sunridge	98	3	808	Indian Battle Heights
151	2	813	West Highlands	156	3	910	Riverstone	95	3	809	Indian Battle Heights
150	2	814	West Highlands	174	3	914	Riverstone	128	3	810	Indian Battle Heights
107	1	902	Mountain Heights	169	3	915	Sunridge	143	3	811	West Highlands
170	3	904	Mountain Heights/Sunridge	173	2	916	Riverstone	129	2	812	Indian Battle Heights
156	3	910	Riverstone	165	2	1012	Varsity Village	185	2	813	West Highlands
174	3	914	Riverstone	172	3	1015	Copperwood	150	2	814	West Highlands
169	2	915	Sunridge	171	3	1016	Copperwood	172	2	914	Riverstone
173	2	916	Riverstone	168	3	1017	Copperwood	167	2	915	Sunridge
165	2	1012	Varsity Village	167	1	2008	University/River Valley West	171	2	916	Riverstone
172	3	1015	Copperwood					168	2	917	Sunridge
171	3	1016	Copperwood					179	2	918	Riverstone
168	3	1017	Copperwood					94	1	1008	Varsity Village
167	1	2008	University/River Valley West					164	2	1012	Varsity Village
177	2	2009	The Piers/ The Crossings/ Garry Station/ Country Meadows/ West Lethbridge Employment Center					170	3	1015	Copperwood
								182	3	1016	Copperwood
								166	3	1017	Copperwood
								183	3	1018	Copperwood
								169	3	1019	Copperwood
								181	3	1020	Copperwood

Figure 5-12 maps out the hot spot analysis for child bus card uses from the Lethbridge Transit Breeze Cards from 2012 to 2014. Table 5-19 provides the census tract ID for the child hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-19 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 22 hot spots; 9 were a #2 ranking and 13 were #1. In 2013, there were 23 hot spots, 8 were a #2 ranking, and 15 were #1. In 2014, there were 61 hot spots, 24 were a #2 ranking and 37 were #1. During 2013 and 2014, 15 hot spots stayed the same; 10 were a #2 ranking and 5 were #1. One hot spot was the same for 2012 and 2013 and had a #2 ranking.

The cold spot ratings are also provided in Table 5-19 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 shows how these cold spots changed during 2012 – 2014. In 2012, there were 8 cold spots with a #1 ranking, and in 2013, there were 6 cold spots with a #1 ranking. Table 5-14 shows that there were no shared cold spots during 2012 – 2014.

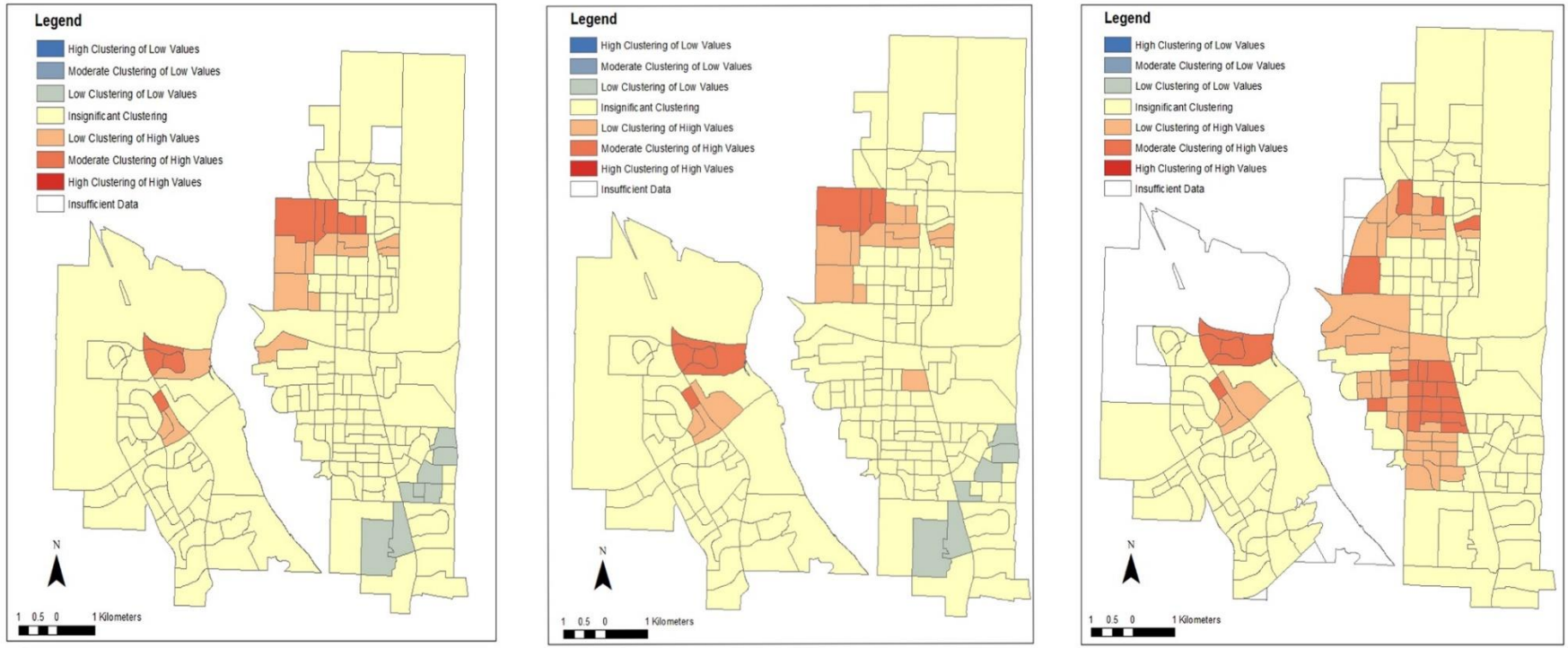

Figure 5-52: Hot spot analysis results for child bus pass usage. A) 2012 B) 2013 C) 2014

Table 5-19: Hot spot analysis results for child bus pass usage.

Child bus pass usage, 2012				Child bus pass usage, 2013				Child bus pass usage, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
3	1	3	Winston Churchill	138	2	101	St. Edwards	138	1	101	St. Edwards
8	1	8	Park Meadows	135	1	102	St. Edwards	135	1	102	St. Edwards
49	-1	49	Redwood	155	1	104	Staffordville	153	1	104	Staffordville
54	-1	54	Lakeview	122	1	105	Staffordville	122	1	105	Staffordville
56	-1	56	Redwood	70	1	107	Senator Buchanan	124	2	108	Senator Buchanan
59	1	59	Indian Battle Heights	124	1	108	Senator Buchanan	123	1	110	Senator Buchanan
70	1	70	Senator Buchanan	136	2	112	St. Edwards	136	2	112	St. Edwards
75	-1	75	Redwood	154	2	114	Stafford Manor	178	1	114	Stafford Manor
76	-1	76	Redwood	134	1	201	Winston Churchill	134	1	201	Winston Churchill
80	2	80	Winston Churchill	81	1	202	Winston Churchill	81	1	202	Winston Churchill
81	1	81	Winston Churchill	8	1	203	Park Meadows	8	1	203	Park Meadows
86	1	86	Park Meadows	80	1	209	Winston Churchill	80	2	209	Winston Churchill
93	-1	93	Redwood	86	1	212	Park Meadows	86	2	212	Park Meadows
100	1	100	Indian Battle Heights	3	1	214	Winston Churchill	3	1	214	Winston Churchill
101	2	101	Indian Battle Heights	23	1	506	Victoria Park	115	1	401	Downtown
122	1	122	Staffordville	141	-1	601	Lethbridge College	63	1	403	London Road
124	1	124	Senator Buchanan	149	-1	603	West Mayor Magrath Dr	65	2	404	London Road
127	2	127	Heritage Heights	54	-1	705	Lakeview	66	1	405	London Road
134	2	134	Winston Churchill	56	-1	708	Redwood	67	1	406	London Road
135	1	135	St. Edwards	49	-1	711	Redwood	118	1	407	London Road
136	2	136	St. Edwards	75	-1	712	Redwood	120	2	409	Fleetwood
137	2	137	Heritage Heights	59	1	802	Indian Battle Heights	69	1	410	Fleetwood
138	2	138	St. Edwards	100	1	804	Indian Battle Heights	131	1	411	Fleetwood
141	-1	142	Lethbridge College	101	2	805	Indian Battle Heights	130	1	412	Fleetwood
149	-1	152	West Mayor Magrath Dr	102	1	905	Ridgewood	64	1	414	London Road
152	2	155	Heritage Heights	153	2	906	Heritage Heights	117	1	415	London Road

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

153	1	156	Heritage Heights	127	2	907	Heritage Heights	68	1	416	London Road
154	2	157	Stafford Manor	152	2	909	Heritage Heights	173	1	418	Downtown
155	1	158	Staffordville	137	2	911	Heritage Heights	20	1	501	Upper Eastside
175	1	186	Downtown					21	2	504	Victoria Park
								22	2	505	Victoria Park
								23	2	506	Victoria Park
								24	2	510	Victoria Park
								25	2	511	Victoria Park
								71	2	512	Victoria Park
								26	2	513	Victoria Park
								27	2	514	Victoria Park
								30	2	515	Victoria Park
								31	2	605	Victoria Park
								32	2	606	Victoria Park
								90	2	607	Victoria Park
								33	1	608	Victoria Park
								91	2	609	Victoria Park
								34	1	610	Agnes Davidson
								36	1	611	Agnes Davidson
								35	1	613	Agnes Davidson
								37	1	614	Agnes Davidson
								38	1	615	Agnes Davidson
								39	1	616	Agnes Davidson
								41	1	617	Agnes Davidson
								62	1	619	Agnes Davidson
								43	1	620	Agnes Davidson
								121	1	623	Royal Chinook Heights
								59	1	802	Indian Battle Heights
								100	1	804	Indian Battle Heights
								101	2	805	Indian Battle Heights
								102	1	905	Ridgewood
								152	2	906	Heritage Heights
								127	2	907	Heritage Heights
								151	2	909	Heritage Heights
								137	2	911	Heritage Heights

Figure 5-13 maps out the hot spot analysis for youth demographics for Lethbridge from 2012 to 2014. Table 5-20 provides the census tract ID for the youth hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-20 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 shows how these hot spots changed during 2012 – 2014. In 2012, there were 35 hot spots, 18 of which were a #3 ranking, 9 were #2, and 8 were #1. In 2013, there were 34 hot spots, 20 of which are a #3 ranking, 6 were #2, and 8 were #1. In 2014, there were 31 hot spots, 17 of which were a #3 ranking, 12 were #2, and 2 were #1. During 2012 – 2014, 17 hot spots stayed the same, 13 of which were a #3 ranking and 4 were #2. From 2013 – 2014, 3 hots spots stayed the same; with 1 having a #3 ranking and 2 having #2. For 2012 and 2014, 2 were the same and had a #2 ranking. Eight hot spots were the same for 2012 and 2013, 4 of which were a #3 ranking, 1 was #2, and 3 were #1.

The cold spot ratings are also provided in Table 5-20 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots changed during 2012 – 2014. In 2012, there were 47 cold spots, 13 of which were a -3 ranking, 26 were -2, and 8 were -1. In 2013, there were 49 cold spots; 14 were a -3 ranking, 28 were -2, and 7 were -1. In 2014, there were 50 cold spots, 20 of which were a -3 ranking, 21 were -2, and 9 were -1. During 2012 – 2014, 32 cold spots stayed the same; 12 were a -3 ranking, 18 were -2, and 2 were -1. Five cold spots were the same during 2013 – 2014; 2 were a -3 ranking, 1 were -2, and 2 were -1.

Three cold spots were the same for 2012 and 2014; 1 was a -3 ranking and 2 were -1. Eight cold spots were the same for 2012 and 2013; 6 were a #2 ranking and 2 were #1.

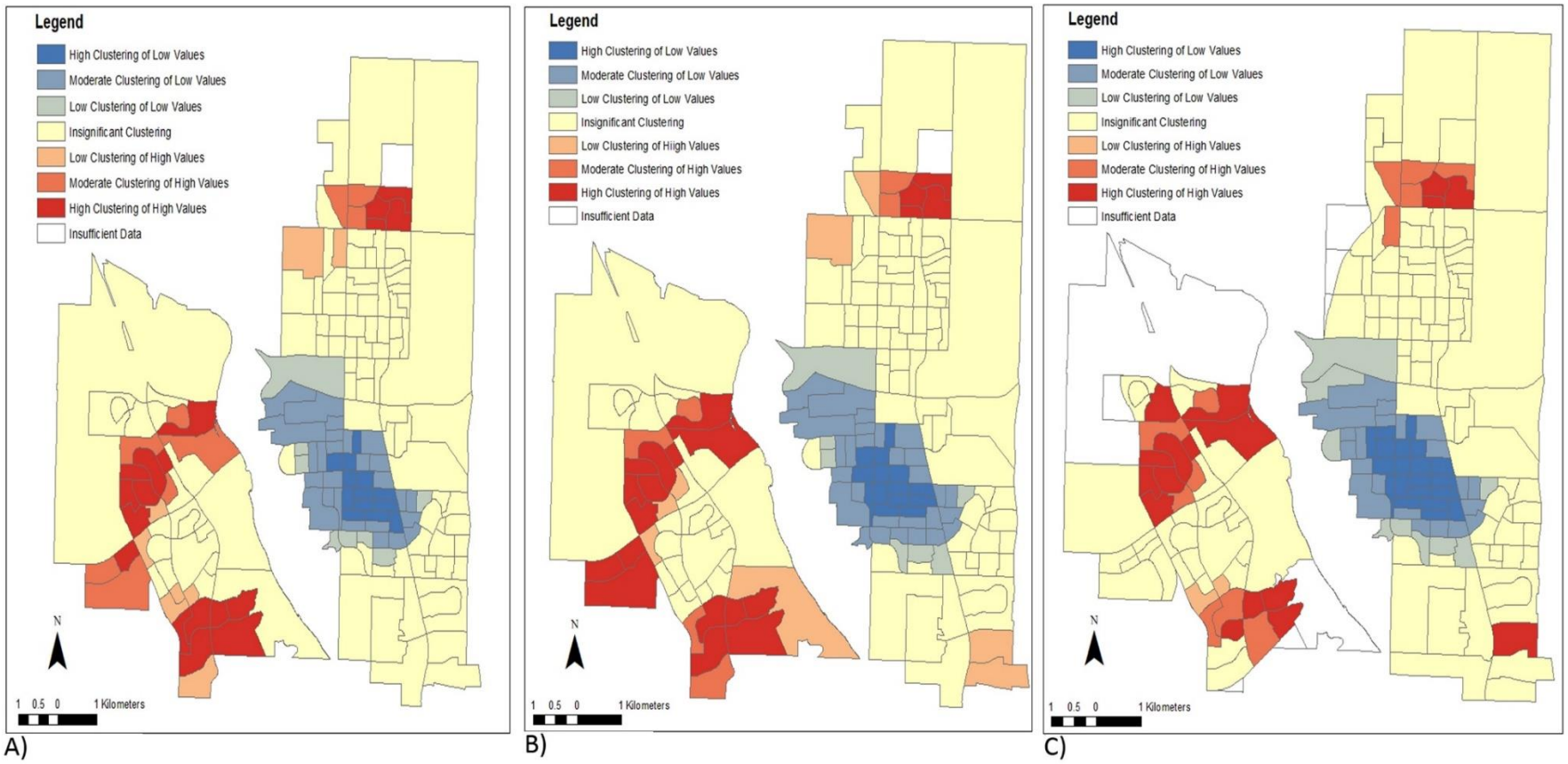

Figure 5-13: Hot spot analysis results for youth demographics. A) 2012 B) 2013 C) 2014

Table 5-20: Hot spot analysis results for youth demographics.

Youth demographics, 2012				Youth demographics, 2013				Youth demographics, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
123	-1	110	Senator Buchanan	123	-1	110	Senator Buchanan	123	-1	110	Senator Buchanan
136	1	112	St. Edwards	154	1	114	Stafford Manor	136	2	112	St. Edwards
154	1	114	Stafford Manor	158	1	116	Legacy Ridge/Hardvieville	156	2	116	Legacy Ridge/ Hardieville
158	2	116	Legacy Ridge/Hardieville	126	2	215	Uplands	126	2	215	Uplands
126	2	215	Uplands	133	2	216	Uplands	133	2	216	Uplands
133	2	216	Uplands	77	3	217	Uplands	77	3	217	Uplands
77	3	217	Uplands	146	3	218	Uplands	146	3	218	Uplands
146	3	218	Uplands	162	3	219	Uplands	161	2	219	Uplands
162	3	219	Uplands	147	3	220	Uplands	147	3	220	Uplands
147	3	220	Uplands	115	-2	401	Upper Eastside/Downtown	115	-2	401	Downtown
115	-2	401	Upper Eastside/ Downtown	116	-2	402	Upper Eastside/Downtown	116	-2	402	Downtown
116	-2	402	Downtown/Upper Eastside	63	-2	403	London Road	63	-2	403	London Road
63	-2	403	London Road	65	-2	404	London Road	65	-3	404	London Road
65	-2	404	London Road	66	-3	405	London Road	66	-3	405	London Road
66	-3	405	London Road	67	-2	406	London Road	67	-3	406	London Road
67	-2	406	London Road	118	-1	407	London Road	118	-2	407	London Road
118	-1	407	London Road	120	-2	409	Fleetwood	119	-1	408	London Road
120	-2	409	Fleetwood	69	-3	410	Fleetwood	120	-2	409	Fleetwood
69	-2	410	Fleetwood	131	-3	411	Fleetwood	69	-3	410	Fleetwood
131	-2	411	Fleetwood	130	-2	412	Fleetwood	131	-3	411	Fleetwood
130	-2	412	Fleetwood	132	-2	413	Fleetwood	130	-2	412	Fleetwood
132	-2	413	Fleetwood	64	-2	414	London Road	132	-2	413	Fleetwood
64	-2	414	London Road	117	-2	415	London Road	64	-2	414	London Road
117	-2	415	London Road	68	-1	416	London Road	117	-2	415	London Road
68	-1	416	London Road	145	-2	417	Scenic Heights	68	-2	416	London Road
145	-1	417	Scenic Heights	175	-2	418	Downtown	145	-1	417	Scenic Heights
175	-2	418	Downtown	21	-2	504	Victoria Park	173	-1	418	Downtown
21	-2	504	Victoria Park	22	-3	505	Victoria Park	21	-2	504	Victoria Park
22	-3	505	Victoria Park	23	-2	506	Victoria Park	22	-3	505	Victoria Park
23	-2	506	Victoria Park	24	-3	510	Victoria Park	23	-2	506	Victoria Park
24	-3	510	Victoria Park	25	-2	511	Victoria Park	24	-3	510	Victoria Park

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

25	-2	511	Victoria Park	71	-2	512	Victoria Park	25	-3	511	Victoria Park
71	-2	512	Victoria Park	26	-3	513	Victoria Park	71	-2	512	Victoria Park
26	-3	513	Victoria Park	27	-3	514	Victoria Park	26	-3	513	Victoria Park
27	-3	514	Victoria Park	30	-2	515	Victoria Park	27	-3	514	Victoria Park
30	-2	515	Victoria Park	31	-3	605	Victoria Park	30	-3	515	Victoria Park
31	-3	605	Victoria Park	32	-3	606	Victoria Park	31	-3	605	Victoria Park
32	-3	606	Victoria Park	90	-3	607	Victoria Park	32	-3	606	Victoria Park
90	-3	607	Victoria Park	33	-3	608	Victoria Park	90	-3	607	Victoria Park
33	-3	608	Victoria Park	91	-3	609	Victoria Park	33	-3	608	Victoria Park
91	-3	609	Victoria Park	34	-3	610	Agnes Davidson	91	-3	609	Victoria Park
34	-3	610	Agnes Davidson	36	-3	611	Agnes Davidson	34	-3	610	Agnes Davidson
36	-3	611	Agnes Davidson	40	-2	612	Agnes Davidson	36	-3	611	Agnes Davidson
40	-3	612	Agnes Davidson	35	-2	613	Agnes Davidson	40	-3	612	Agnes Davidson
35	-2	613	Agnes Davidson	37	-2	614	Agnes Davidson	35	-2	613	Agnes Davidson
37	-2	614	Agnes Davidson	38	-2	615	Agnes Davidson	37	-3	614	Agnes Davidson
38	-1	615	Agnes Davidson	39	-2	616	Agnes Davidson	38	-1	615	Agnes Davidson
39	-1	616	Agnes Davidson	41	-2	617	Agnes Davidson	39	-2	616	Agnes Davidson
41	-2	617	Agnes Davidson	42	-2	618	Agnes Davidson	41	-2	617	Agnes Davidson
42	-2	618	Agnes Davidson	62	-1	619	Agnes Davidson	42	-2	618	Agnes Davidson
43	-1	620	Agnes Davidson	43	-1	620	Agnes Davidson	62	-1	619	Agnes Davidson
44	-2	701	Lakeview	74	-1	621	Agnes Davidson	43	-1	620	Agnes Davidson
46	-2	702	Lakeview	44	-2	701	Lakeview	74	-1	621	Agnes Davidson
47	-1	703	Lakeview	46	-2	702	Lakeview	44	-2	701	Lakeview
45	-2	706	Lakeview	47	-1	703	Lakeview	46	-2	702	Lakeview
50	-2	709	Lakeview	45	-2	706	Lakeview	47	-1	703	Lakeview
96	3	801	Indian Battle Heights	50	-2	709	Lakeview	45	-2	706	Lakeview
59	2	802	Indian Battle Heights	159	1	720	Southgate	50	-2	709	Lakeview
101	3	805	Indian Battle Heights	160	1	721	Southgate	157	3	720	Southgate
144	2	806	Indian Battle Heights	96	3	801	Indian Battle Heights	96	3	801	Indian Battle Heights
97	1	807	Indian Battle Heights	59	1	802	Indian Battle Heights	59	2	802	Indian Battle Heights
98	3	808	Indian Battle Heights	101	3	805	Indian Battle Heights	101	3	805	Indian Battle Heights
95	3	809	Indian Battle Heights	144	2	806	Indian Battle Heights	144	2	806	Indian Battle Heights
128	3	810	Indian Battle Heights	97	1	807	Indian Battle Heights	97	2	807	Indian Battle Heights
129	3	812	Indian Battle Heights	98	3	808	Indian Battle Heights	98	3	808	Indian Battle Heights

107	3	902	Mountain Heights	95	3	809	Indian Battle Heights	95	3	809	Indian Battle Heights
139	3	903	Mountain Heights	128	3	810	Indian Battle Heights	128	3	810	Indian Battle Heights
170	3	904	Mountain Heights/Sunridge	129	3	812	Indian Battle Heights	143	3	811	West Highlands
153	3	906	Heritage Heights	107	2	902	Mountain Heights	129	3	812	Indian Battle Heights
105	2	908	Ridgewood	139	3	903	Mountain Heights	107	2	902	Mountain Heights
156	3	910	Riverstone	170	3	904	Sunridge	139	2	903	Mountain Heights
137	2	911	Heritage Heights	153	3	906	Heritage Heights	180	3	904	Mountain Heights
174	3	914	Riverstone	105	3	908	Ridgewood	152	3	906	Heritage Heights
169	1	915	Sunridge	156	3	910	Riverstone	105	3	908	Ridgewood
173	3	916	Riverstone	137	2	911	Heritage Heights	154	2	910	Riverstone
108	1	1003	Varsity Village	174	3	914	Riverstone	137	2	911	Heritage Heights
72	1	1009	Varsity Village	169	2	915	Sunridge	172	3	914	Riverstone
60	1	1010	Varsity Village	173	3	916	Riverstone	171	3	916	Riverstone
165	1	1012	Varsity Village	165	1	1012	Varsity Village	179	3	918	Riverstone
172	2	1015	Copperwood	172	3	1015	Copperwood	108	1	1003	Varsity Village
171	3	1016	Copperwood	171	3	1016	Copperwood	72	1	1009	Varsity Village
168	2	1017	Copperwood	168	3	1017	Copperwood				
				167	1	2008	University/River Valley				

Figure 5-14 maps out the hot spot analysis for youth bus card uses from the Lethbridge Transit Breeze Cards from 2012 to 2014. Table 5-21 provides the census tract ID for the youth hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-21 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 19 hot spots, 5 were a #2 ranking, and 14 were #1. In 2013, there were 17 hot spots, 5 were a #2 ranking and 12 were #1. In 2014, there were 16 hot spots, 4 were a #2 ranking and 12 were #1. During 2012 – 2014, 10 hot spots stayed the same; 4 were a #2 ranking and 6 were #1. One hot spot was the same for 2013 and 2014 and had a #1 ranking. Four hot spots remained the same for 2012 and 2014 and had a #1 ranking. Four hot spots remained the same for 2012 and 2013 and had a #1 ranking.

The cold spot ratings are also provided in Table 5-21 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots changed during 2012 – 2014. In 2012, there were 13 cold spots, 2 with a -2 ranking and 11 with -1. In 2013, there were 13 cold spots, 1 with a -2 ranking and 12 with a -1 ranking. In 2014, there were 7 cold spots with a -1 ranking. During 2012 – 2014, 4 of the cold spots stayed the same, with a -1 ranking. One of the cold spots was the same in years 2013 – 2014 with a -1 ranking. Six of the cold spots were the same for 2012 and 2013; 1 had a -2 ranking and 5 were -1.

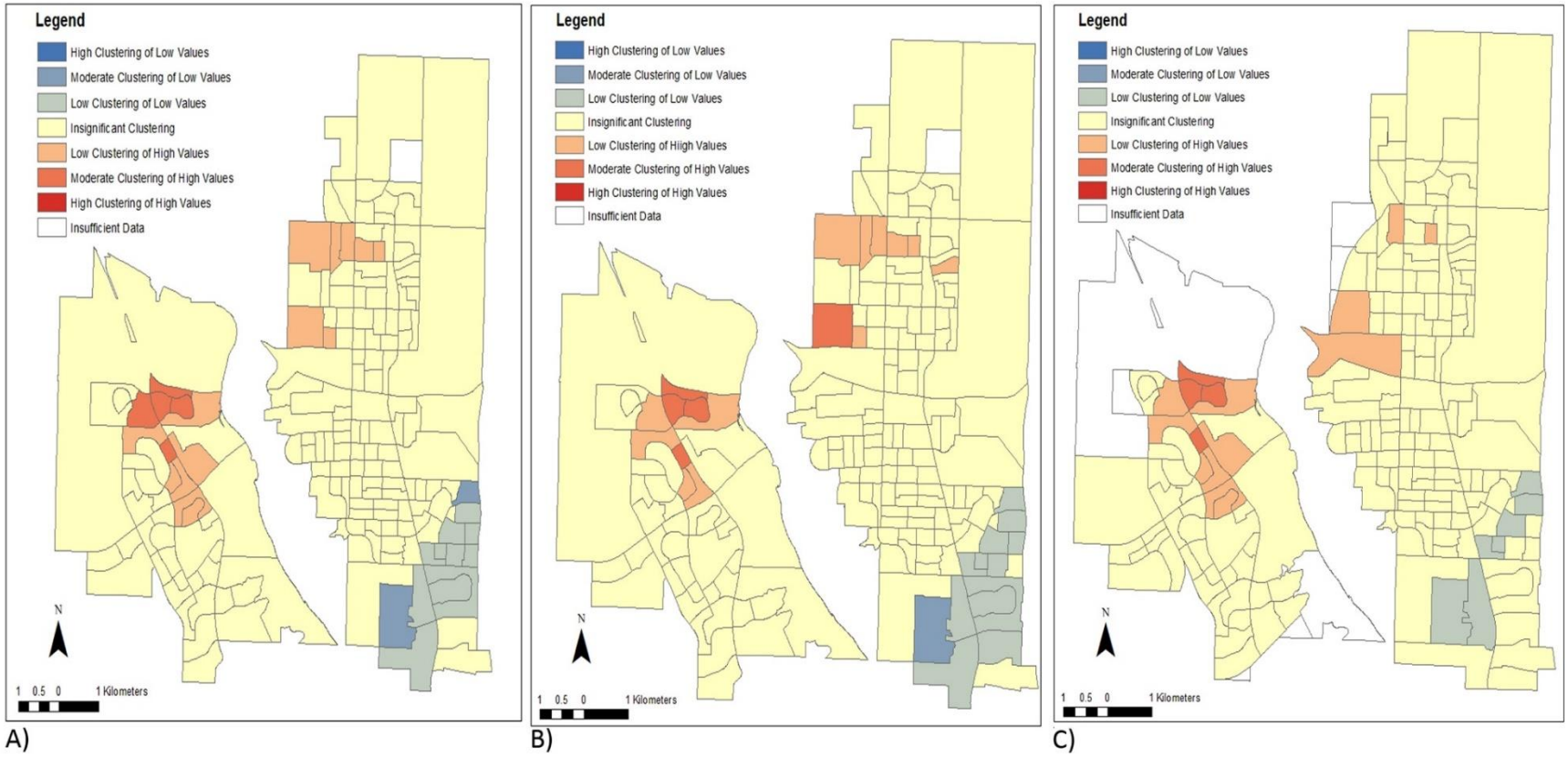

Figure 5-64: Hot spot analysis results for youth bus pass usage. A) 2012 B) 2013 C) 2014

Table 5-21: Hot spot analysis results for youth bus pass usage.

Youth bus pass usage, 2012				Youth bus pass usage, 2013				Youth bus pass usage, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
138	1	101	St. Edwards	138	1	101	St. Edwards	124	1	108	Senator Buchanan
70	1	107	Senator Buchanan	70	1	107	Senator Buchanan	123	1	110	Senator Buchanan
124	1	108	Senator Buchanan	124	2	108	Senator Buchanan	136	1	112	St. Edwards
136	1	112	St. Edwards	136	1	112	St. Edwards	80	1	209	Winston Churchill
154	1	114	Stafford Manor	154	1	114	Stafford Manor	141	-1	601	Lethbridge College
134	1	201	Winston Churchill	134	1	201	Winston Churchill	149	-1	603	West Mayor Magrath Dr
80	1	209	Winston Churchill	80	1	209	Winston Churchill	54	-1	705	Lakeview
141	-2	601	Lethbridge College	86	1	212	Park Meadows	56	-1	708	Redwood
149	-1	603	West Mayor Magrath Dr	141	-2	601	Lethbridge College	49	-1	711	Redwood
161	-1	604	Southridge/West Mayor Magrath Dr	149	-1	603	West Mayor Magrath	75	-1	712	Redwood
54	-2	705	Lakeview	161	-1	604	Southridge/West Mayor Magrath Dr	76	-1	713	Redwood
56	-1	708	Redwood	54	-1	705	Lakeview	59	1	802	Indian Battle Heights
49	-1	711	Redwood	56	-1	708	Redwood	100	1	804	Indian Battle Heights
75	-1	712	Redwood	49	-1	711	Redwood	101	2	805	Indian Battle Heights
76	-1	713	Redwood	75	-1	712	Redwood	144	1	806	Indian Battle Heights
93	-1	714	Redwood	76	-1	713	Redwood	143	1	811	West Highlands
57	-1	716	Redwood	93	-1	714	Redwood	102	1	905	Ridgewood
73	-1	717	Redwood	57	-1	716	Redwood	152	1	906	Heritage Heights
92	-1	718	Fairmont	92	-1	718	Fairmont	127	2	907	Heritage Heights
148	-1	719	Fairmont	148	-1	719	Fairmont	151	2	909	Heritage Heights
59	1	802	Indian Battle Heights	159	-1	720	Southgate	137	2	911	Heritage Heights
100	1	804	Indian Battle Heights	59	1	802	Indian Battle Heights	58	1	1006	Varsity Village

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

101	2	805	Indian Battle Heights	100	1	804	Indian Battle Heights	99	1	1013	Varsity Village
144	1	806	Indian Battle Heights	101	2	805	Indian Battle Heights				
143	2	811	West Highlands	144	1	806	Indian Battle Heights				
102	1	905	Ridgewood	143	1	811	West Highlands				
153	1	906	Heritage Heights	153	1	906	Heritage Heights				
127	2	907	Heritage Heights	127	2	907	Heritage Heights				
152	2	909	Heritage Heights	152	2	909	Heritage Heights				
137	2	911	Heritage Heights	137	2	911	Heritage Heights				
58	1	1006	Varsity Village								
99	1	1013	Varsity Village								

Figure 5-15 maps out the hot spot analysis for senior demographics for Lethbridge from 2012 to 2014. Table 5-22 provides the census tract ID for the senior hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-22 and are ranked as 1, 2, and 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 14 hot spots, 9 of which were a #3 ranking, 2 were #2, and 3 were #1. In 2013, there were 13 hot spots, 2 of which were a #3 ranking, 2 were #2, and 9 were #1. In 2014, there were 13 hot spots, 9 of which were a #3 ranking, 3 were #2, and 1 was #1. During 2012 – 2014, 12 hot spots stayed the same, 9 of which were a #3 ranking, 2 were #2, and 1 were #3. One hot spot remained the same for 2012 and 2013, with a #1 ranking.

The cold spot ratings are also provided in Table 5-22 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots changed during 2012 – 2014. There were no cold spots for 2012 and 2013. In 2014, there were 4 cold spots, 1 had a -2 ranking and 3 were -1. No cold spots remained the same across the years of 2012 – 2014.

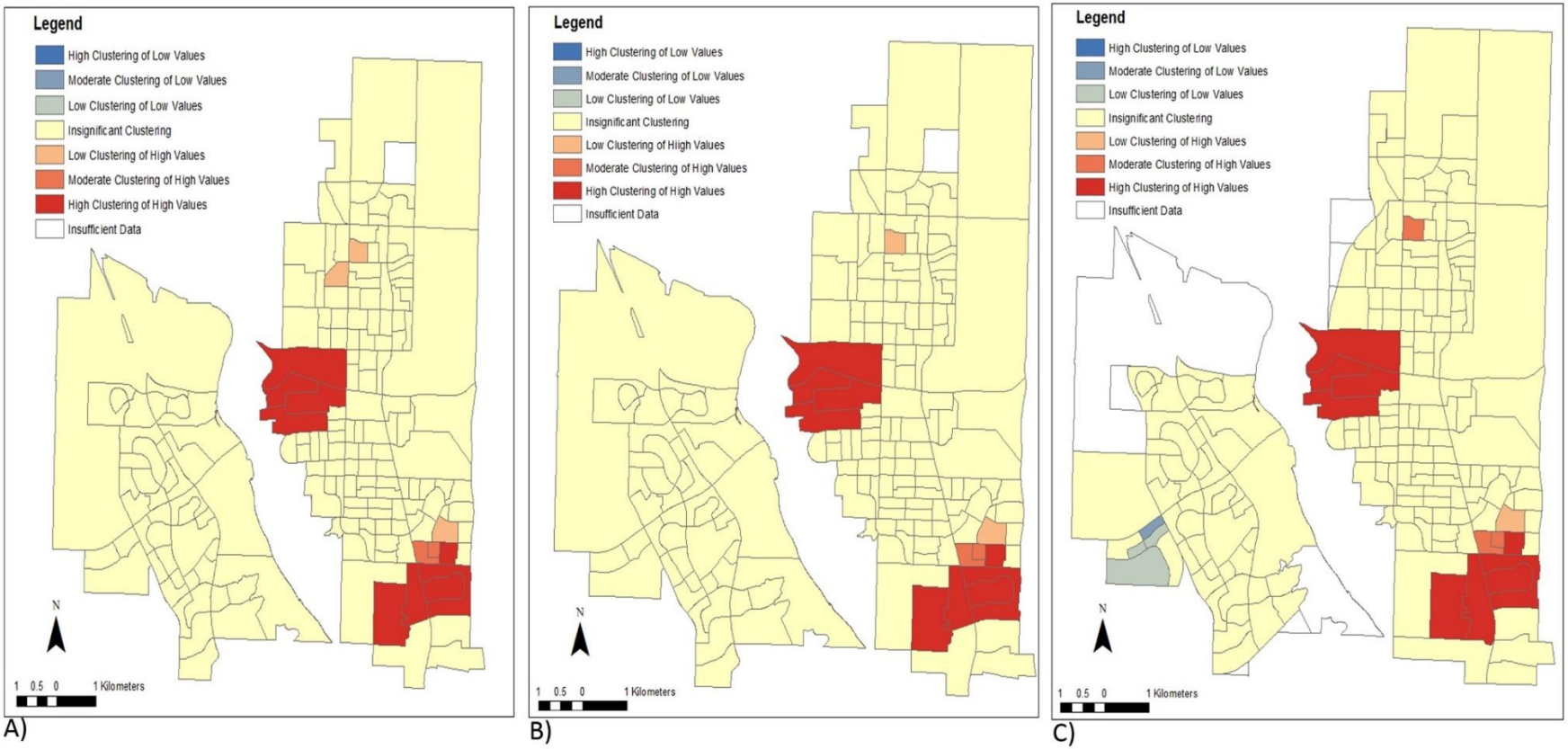

Figure 5-75: Hot spot analysis results for senior demographics. A) 2012 B) 2013 C) 2014

Table 5-22: Hot spot analysis results for senior demographics.

Senior demographics, 2012				Senior demographics, 2013				Senior demographics, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
135	1	102	St. Edwards	123	3	110	Senator Buchanan	123	3	110	Senator Buchanan
123	3	110	Senator Buchanan	134	1	201	Winston Churchill	134	2	201	Winston Churchill
134	1	201	Winston Churchill	115	3	401	Upper Eastside/Downtown	115	3	401	Downtown
115	3	401	Upper Eastside/ Downtown	116	3	402	Upper Eastside/Downtown	116	3	402	Downtown
116	3	402	Downtown/Upper Eastside	175	3	418	Downtown	173	3	418	Downtown
175	3	418	Downtown	141	3	601	Lethbridge College	141	3	601	Lethbridge College
141	3	601	Lethbridge College	149	3	603	West Mayor Magrath	149	3	603	West Mayor Magrath Dr
149	3	603	West Mayor Magrath Dr	49	1	711	Redwood	49	1	711	Redwood
49	1	711	Redwood	75	2	712	Redwood	75	2	712	Redwood
75	2	712	Redwood	76	2	713	Redwood	76	2	713	Redwood
76	2	713	Redwood	93	3	714	Redwood	93	3	714	Redwood
93	3	714	Redwood	92	3	718	Fairmont	92	3	718	Fairmont
92	3	718	Fairmont	148	3	719	Fairmont	148	3	719	Fairmont
148	3	719	Fairmont					182	-2	1016	Copperwood
								166	-1	1017	Copperwood
								183	-1	1018	Copperwood
								169	-1	1019	Copperwood

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

Figure 5-16 maps out the hot spot analysis for senior bus card uses from the Lethbridge Transit Breeze Cards from 2012 to 2014. Table 5-23 provides the census tract ID for the senior hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-23 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 shows how these hot spots changed during 2012 – 2014. In 2012, there were 32 hot spots; 14 were a #2 ranking and 18 were #1. In 2013, there were 29 hot spots; 10 were a #2 ranking and 19 were #1. In 2014, there were 47 hot spots; 14 were a #2 ranking and 33 were #1. During 2012 – 2014, 18 of the hot spots stayed the same; 9 were a #2 ranking and 9 were #1. One hot spot remained the same for 2013 and 2014 and had a #1 ranking. Ten hot spots remained the same for 2012 and 2014; 4 were a #2 ranking and 6 were #1. One hot spot remained the same for 2012 and 2013 and had a #1 ranking. The cold spot ratings are also provided in Table 24. Tables 5-12 and 5-14 show that there were no cold spots during 2012 – 2014.

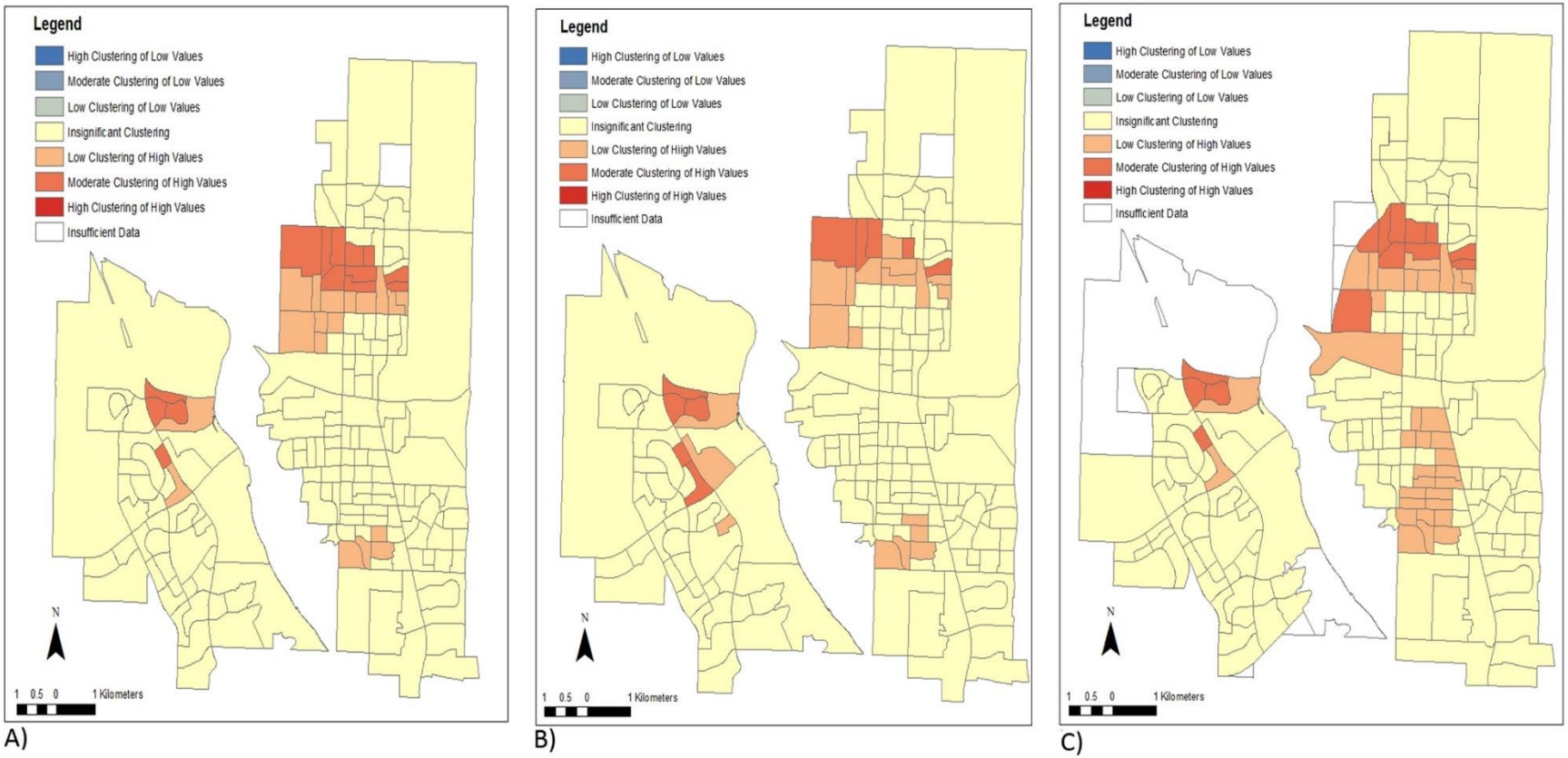

Figure 5-86: Hot spot analysis results for senior bus pass usage. A) 2012 B) 2013 C) 2014

Table 5-23: Hot spot analysis results for senior bus pass usage.

Senior bus pass usage, 2012				Senior bus pass usage, 2013				Senior bus pass usage, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
138	2	101	St. Edwards	138	2	101	St. Edwards	138	2	101	St. Edwards
135	2	102	St. Edwards	135	1	102	St. Edwards	135	2	102	St. Edwards
1	1	103	St. Edwards	155	1	104	Staffordville	1	1	103	St. Edwards
155	1	104	Staffordville	122	1	105	Staffordville	153	1	104	Staffordville
122	1	105	Staffordville	70	1	107	Senator Buchanan	122	1	105	Staffordville
2	1	106	Senator Buchanan	124	1	108	Senator Buchanan	124	2	108	Senator Buchanan
70	1	107	Senator Buchanan	136	2	112	St. Edwards	123	1	110	Senator Buchanan
124	1	108	Senator Buchanan	154	2	114	Stafford Manor	125	1	111	Senator Buchanan
125	1	111	Senator Buchanan	134	1	201	Winston Churchill	136	2	112	St. Edwards
136	2	112	St. Edwards	81	1	202	Winston Churchill	178	2	114	Stafford Manor
154	2	114	Stafford Manor	8	1	203	Park Meadows	134	2	201	Winston Churchill
134	2	201	Winston Churchill	85	1	206	Winston Churchill	81	2	202	Winston Churchill
81	2	202	Winston Churchill	80	2	209	Winston Churchill	8	2	203	Park Meadows
8	2	203	Park Meadows	86	2	212	Park Meadows	9	1	205	Park Meadows
9	1	205	Park Meadows	10	1	213	Park Meadows	85	1	206	Winston Churchill
85	1	206	Winston Churchill	3	1	214	Winston Churchill	80	2	209	Winston Churchill
80	2	209	Winston Churchill	37	1	614	Agnes Davidson	86	2	212	Park Meadows
86	2	212	Park Meadows	41	1	617	Agnes Davidson	10	1	213	Park Meadows
10	1	213	Park Meadows	62	1	619	Agnes Davidson	3	1	214	Winston Churchill
3	2	214	Winston Churchill	43	1	620	Agnes Davidson	82	1	301	Winston Churchill
82	1	301	Winston Churchill	121	1	623	Royal Chinook Heights	4	1	302	Winston Churchill
4	1	302	Winston Churchill	100	2	804	Indian Battle Heights	22	1	505	Victoria Park
41	1	617	Agnes Davidson	101	2	805	Indian Battle Heights	23	1	506	Victoria Park
62	1	619	Agnes Davidson	102	1	905	Ridgewood	24	1	510	Victoria Park
43	1	620	Agnes Davidson	153	1	906	Heritage Heights	25	1	511	Victoria Park
121	1	623	Park Royal/Chinook Heights	127	2	907	Heritage Heights	71	1	512	Victoria Park
100	1	804	Indian Battle Heights	152	2	909	Heritage Heights	30	1	515	Victoria Park
101	2	805	Indian Battle Heights	137	2	911	Heritage Heights	32	1	606	Victoria Park
153	1	906	Heritage Heights	104	1	1014	Varsity Village	90	1	607	Victoria Park

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

127	2	907	Heritage Heights
152	2	909	Heritage Heights
137	2	911	Heritage Heights

33	1	608	Victoria Park
91	1	609	Victoria Park
34	1	610	Agnes Davidson
36	1	611	Agnes Davidson
35	1	613	Agnes Davidson
37	1	614	Agnes Davidson
38	1	615	Agnes Davidson
39	1	616	Agnes Davidson
41	1	617	Agnes Davidson
62	1	619	Agnes Davidson
43	1	620	Agnes Davidson
121	1	623	Royal Chinook Heights
100	1	804	Indian Battle Heights
101	2	805	Indian Battle Heights
152	1	906	Heritage Heights
127	2	907	Heritage Heights
151	2	909	Heritage Heights
137	2	911	Heritage Heights

Figure 5-17 maps out the hot spot analysis for cash bus rider usage from the Lethbridge Transit Breeze Cards from 2012 to 2014. Table 5-24 provides the census tract ID for the cash hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-24 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 shows how these hot spots changed during 2012 – 2014. In 2012, there were 17 hot spots; 3 were a #3 ranking, 8 were #2, and 6 were #1. In 2013, there were 18 hot spots; 3 were a #3 ranking, 8 were #2, and 7 were #1. In 2014, there were 18 hot spots; 4 were a #3 ranking, 7 were #2, and 7 were #1. During 2012 – 2014, 15 hot spots stayed the same; 3 were a #3 ranking, 7 were #2, and 5 were #1. One hot spot remained the same for 2013 and 2014 and had a #1 ranking. Two hot spots remained the same for 2012 and 2013; 1 had a #2 ranking and 1 had #1.

The cold spot ratings are also provided in Table 5-24 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots changed during 2012 – 2014. In 2012, there were 3 cold spots, all of which had a -1 ranking. In 2013, there were 6 cold spots, all of which had a -1 ranking. In 2014, there were no cold spots. Three cold spots remained the same for 2012 and 2013 with a -1 ranking. No other years shared cold spots.

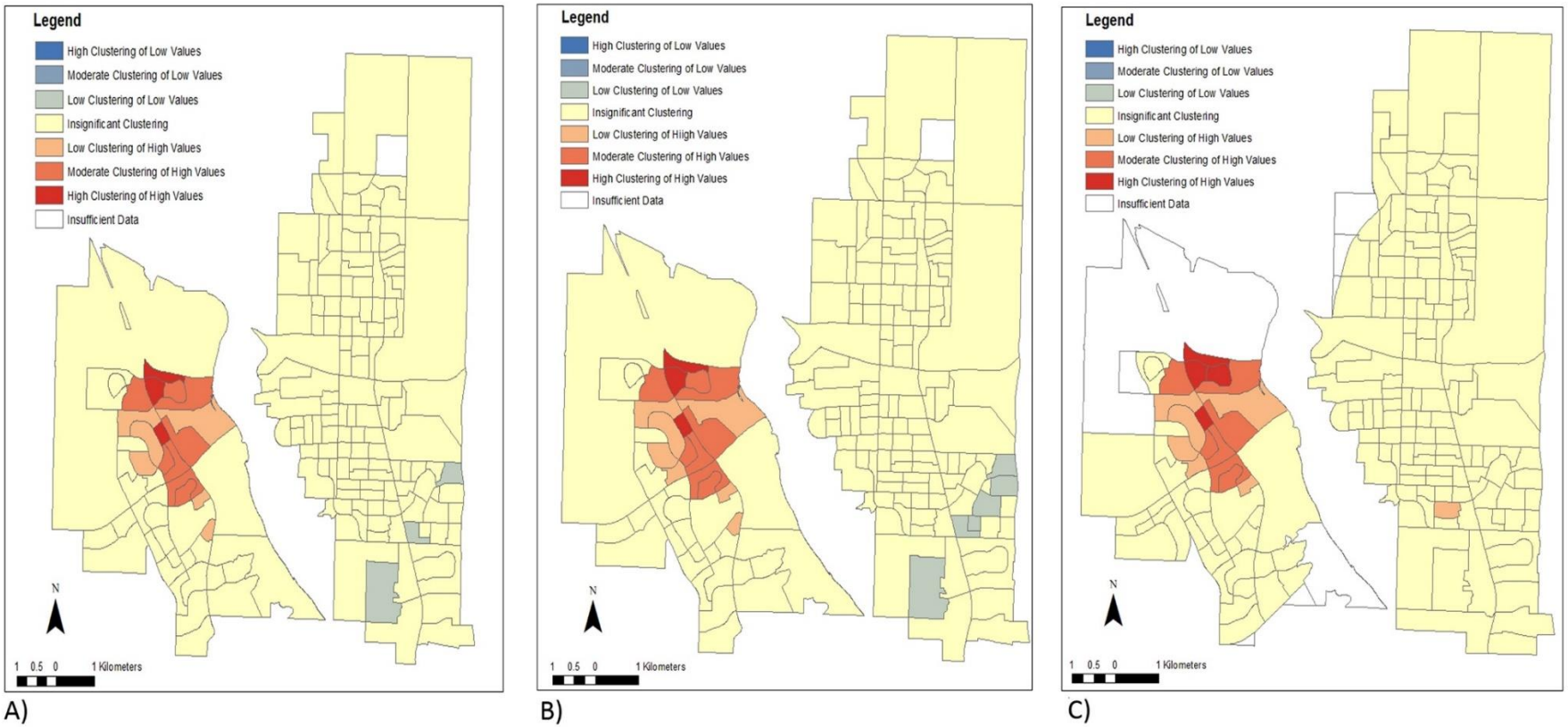

Figure 5-17: Hot spot analysis results for cash bus rider usage. A) 2012 B) 2013 C) 2014

Table 5-24: Hot spot analysis results for cash bus rider usage.

Cash bus rider usage, 2012				Cash bus rider usage, 2013				Cash bus rider usage, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
141	-1	601	Lethbridge College	141	-1	601	Lethbridge College	43	1	620	Agnes Davidson
54	-1	705	Lakeview	54	-1	705	Lakeview	96	1	801	Indian Battle Heights
75	-1	712	Redwood	56	-1	708	Redwood	59	2	802	Indian Battle Heights
96	1	801	Indian Battle Heights	49	-1	711	Redwood	100	2	804	Indian Battle Heights
59	2	802	Indian Battle Heights	75	-1	712	Redwood	101	3	805	Indian Battle Heights
100	2	804	Indian Battle Heights	76	-1	713	Redwood	144	1	806	Indian Battle Heights
101	3	805	Indian Battle Heights	96	1	801	Indian Battle Heights	97	1	807	Indian Battle Heights
144	1	806	Indian Battle Heights	59	2	802	Indian Battle Heights	98	1	808	Indian Battle Heights
98	1	808	Indian Battle Heights	100	2	804	Indian Battle Heights	143	2	811	West Highlands
143	2	811	West Highlands	101	3	805	Indian Battle Heights	102	2	905	Ridgewood
102	2	905	Ridgewood	144	1	806	Indian Battle Heights	152	2	906	Heritage Heights
153	2	906	Heritage Heights	97	1	807	Indian Battle Heights	127	3	907	Heritage Heights
127	3	907	Heritage Heights	98	1	808	Indian Battle Heights	105	1	908	Ridgewood
105	1	908	Ridgewood	143	2	811	West Highlands	151	3	909	Heritage Heights
152	3	909	Heritage Heights	102	2	905	Ridgewood	137	3	911	Heritage Heights
137	2	911	Heritage Heights	153	2	906	Heritage Heights	58	2	1006	Varsity Village
58	2	1006	Varsity Village	127	3	907	Heritage Heights	99	2	1013	Varsity Village
103	1	1007	Varsity Village	105	1	908	Ridgewood	104	1	1014	Varsity Village
99	2	1013	Varsity Village	152	3	909	Heritage Heights				
104	1	1014	Varsity Village	137	2	911	Heritage Heights				
				58	2	1006	Varsity Village				
				103	1	1007	Varsity Village				
				99	2	1013	Varsity Village				
				104	1	1014	Varsity Village				

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

Figure 5-18 maps out the hot spot analysis for post-secondary bus pass usage from the Lethbridge Transit Breeze Cards from years 2012 to 2014. Table 5-25 provides the census tract ID for the post-secondary hot spots. The associated neighborhoods for the census tract ID are listed as well. The hot spot ratings are also provided in Table 5-25 and are ranked as 1, 2, or 3, where 1 is the low clustering of high values, 2 is the moderate clustering of high values, and 3 is the high clustering of high values, signalling that those areas have the highest clustering of people compared to the other areas. Tables 5-11 and 5-13 show how these hot spots changed during 2012 – 2014. In 2012, there were 38 hot spots; 12 were a #3 ranking, 12 were #2, and 14 were #1. In 2013, there were 38 hot spots; 14 were a #3 ranking, 9 were #2, and 15 were #1. In 2014, there were 30 hot spots; 12 were a #3 ranking, 11 were #2, and 7 were #1. During 2012 – 2014, 25 hot spots stayed the same; 12 were a #3 ranking, 8 were #2, and 5 were #1. Two hot spots remained the same for 2012 and 2014 and had a #1 ranking. Ten hot spots remained the same for 2012 and 2013; 1 had a #2 ranking and 9 had #1.

The cold spot ratings are also provided in Table 5-25 and are ranked as -1, -2, or -3, where -1 is the low clustering of low values, -2 is the moderate clustering of low values, and -3 is the high clustering of low values, signalling that those areas have the lowest clustering of people compared to the other areas. Tables 5-12 and 5-14 show how these cold spots changed during 2012 – 2014. In 2012, there were 2 cold spots; 1 of which had a -2 ranking and 1 which had -1. In 2013, there were 2 cold spots, both of which had a -1 ranking. In 2014, there was 1 cold spot with a -1 ranking. One cold spot was the same for 2013 and 2014 with a -1 ranking. No other years shared cold spots.

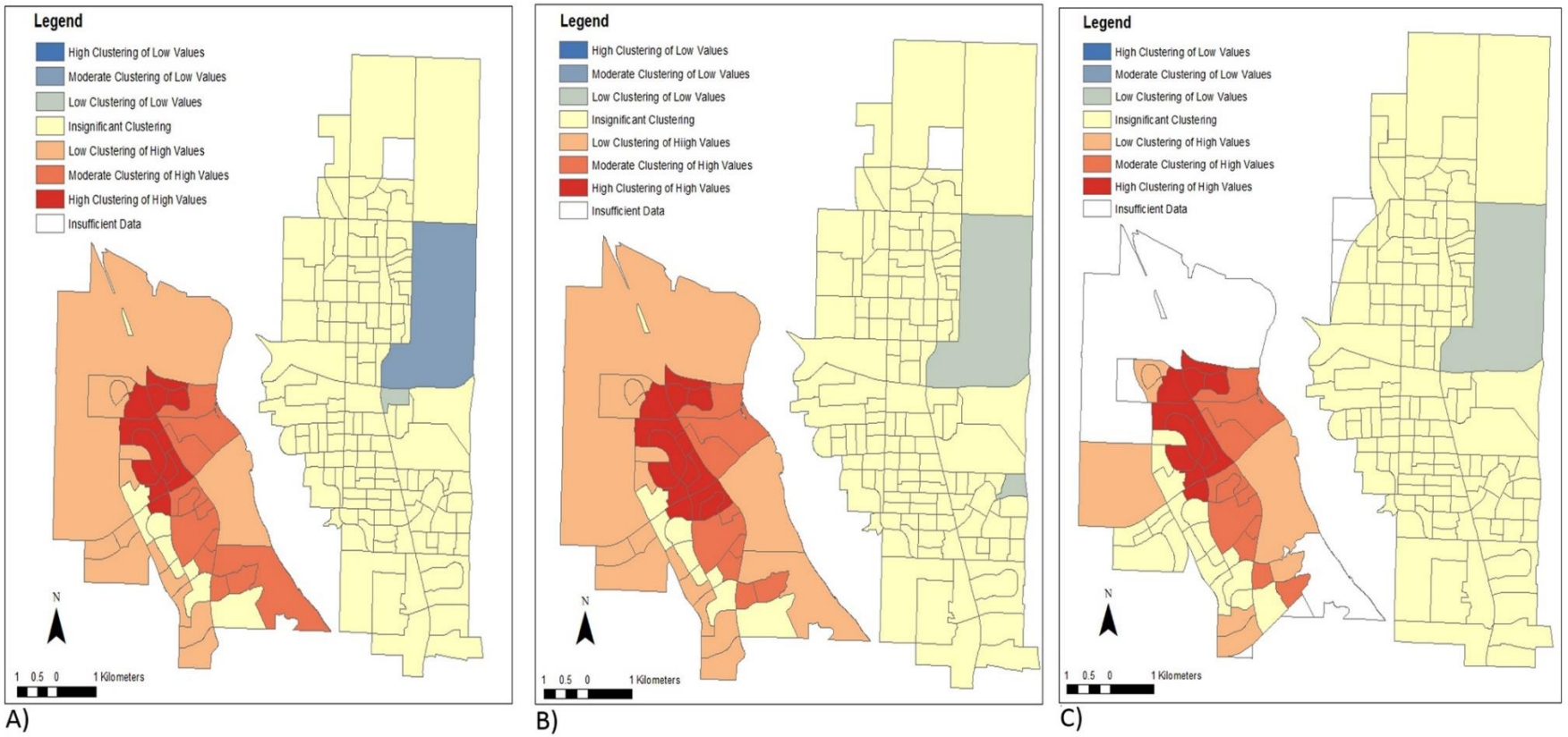

Figure 5-98: Hot spot analysis results for post-secondary bus pass usage. A) 2012 B) 2013 C) 2014

Table 5-25: Hot spot analysis results for post-secondary bus pass usage.

Post Secondary bus pass usage, 2012				Post Secondary bus pass usage, 2013				Post Secondary bus pass usage, 2014			
Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood	Object ID	Hotspot rating	Tract ID	Neighborhood
29	-1	502	Glendale	54	-1	705	Lakeview	96	3	801	Indian Battle Heights
96	3	801	Indian Battle Heights	96	3	801	Indian Battle Heights	59	3	802	Indian Battle Heights
59	3	802	Indian Battle Heights	59	3	802	Indian Battle Heights	100	3	804	Indian Battle Heights
100	3	804	Indian Battle Heights	100	3	804	Indian Battle Heights	101	3	805	Indian Battle Heights
101	3	805	Indian Battle Heights	101	3	805	Indian Battle Heights	144	3	806	Indian Battle Heights
144	3	806	Indian Battle Heights	144	3	806	Indian Battle Heights	97	3	807	Indian Battle Heights
97	3	807	Indian Battle Heights	97	3	807	Indian Battle Heights	98	3	808	Indian Battle Heights
98	3	808	Indian Battle Heights	98	3	808	Indian Battle Heights	143	3	811	West Highlands
95	1	809	Indian Battle Heights	95	1	809	Indian Battle Heights	185	1	813	West Highlands
128	1	810	Indian Battle Heights	128	1	810	Indian Battle Heights	150	1	814	West Highlands
143	3	811	West Highlands	143	3	811	West Highlands	106	1	901	University
151	1	813	West Highlands	151	1	813	West Highlands	102	2	905	Ridgewood
150	1	814	West Highlands	150	1	814	West Highlands	152	2	906	Heritage Heights
106	1	901	University	106	1	901	University	127	3	907	Heritage Heights
107	1	902	Mountain Heights	107	1	902	Mountain Heights	105	2	908	Ridgewood
170	1	904	Mountain Heights /Sunridge	170	1	904	Sunridge	151	3	909	Heritage Heights
102	2	905	Ridgewood	102	2	905	Ridgewood	137	3	911	Heritage Heights
153	2	906	Heritage Heights	153	2	906	Heritage Heights	172	2	914	Riverstone
127	3	907	Heritage Heights	127	3	907	Heritage Heights	167	1	915	Sunridge
105	2	908	Ridgewood	105	2	908	Ridgewood	171	1	916	Riverstone
152	3	909	Heritage Heights	152	3	909	Heritage Heights	168	1	917	Sunridge
137	3	911	Heritage Heights	137	3	911	Heritage Heights	179	2	918	Riverstone
174	2	914	Riverstone	174	2	914	Riverstone	109	2	1001	Varsity Village
169	1	915	Sunridge	169	1	915	Sunridge	140	2	1002	Varsity Village
173	2	916	Riverstone	173	2	916	Riverstone	58	2	1006	Varsity Village
109	2	1001	Varsity Village	109	2	1001	Varsity Village	103	2	1007	Varsity Village
140	2	1002	Varsity Village	140	2	1002	Varsity Village	94	3	1008	Varsity Village
108	1	1003	Varsity Village	108	1	1003	Varsity Village	99	2	1013	Varsity Village

Matching hotspot areas
All 3 years
2014 – 2013
2014 – 2012
2013 – 2012

58	2	1006	Varsity Village	58	3	1006	Varsity Village	104	2	1014	Varsity Village
103	2	1007	Varsity Village	103	2	1007	Varsity Village	112	-1	2002	Churchill/ Shackleford/ Anderson Industrial
94	3	1008	Varsity Village	94	3	1008	Varsity Village	184	1	2009	The Piers/The Crossing
164	1	1011	Varsity Village	164	1	1011	Varsity Village				
99	2	1013	Varsity Village	99	3	1013	Varsity Village				
104	2	1014	Varsity Village	104	2	1014	Varsity Village				
172	1	1015	Copperwood	172	1	1015	Copperwood				
171	1	1016	Copperwood	171	1	1016	Copperwood				
168	1	1017	Copperwood	168	1	1017	Copperwood				
112	-2	2002	Churchill/ Shackleford/ Anderson Industrial Parks	112	-1	2002	Anderson/ Shackleford/ Churchill Industrial Park				
167	2	2008	University/ River Valley West	167	1	2008	University/ River Valley				
177	1	2009	The Piers/ The Crossings/ Garry Station/ Country Meadows/ West Lethbridge Employment Center	177	1	2009	West Lethbridge Employment Center/ Country Meadows/ Garry Station/ The Piers/ The Crossings				

After comparing the bus usage and the demographic census hot spot results individually between 2012 and 2014, I compared the bus usage and the demographic census hot spot and cold spot results. The results of overlapping hot spots and cold spots are in Table 5-26, and the in-depth results written about here are in appendixes D – F. The results are only for Child, Youth, Adult, Senior and All bus passes. Census demographic categories were the only ones compared, as there were no comparable data to compare for cash and post-secondary bus usage.

For 2012, there were no shared hot spots for the Child and Senior categories. For Youth, there are 3 shared hot spots: 1 #2 ranking hot spot (census tract ID 911, which was in Heritage Heights) and 2 #1 ranking hots spots (census tracts 112 and 114, which are in neighborhoods St. Edwards and Stafford Manor). For Adult, there was 1 shared hot spot, with a #2 ranking hot spot (census tract ID 805, which is in Indian Battle Heights). For All bus passes/census demographics, there were 3 shared hot spots, all #2 ranking hot spots (census tracts 802, 805 and 906, which are in neighborhoods Indian Battle Heights and Heritage Heights).

For 2013, there were no shared hot spots for the Child category. For Youth, there were 3 shared hot spots: 1 #2 ranking hot spot (census tract ID 911, which is in Heritage Heights) and 2 #1 ranking hots spots (census tracts 114 and 802, which are in neighborhoods Stafford Manor and Indian Battle Heights). For Adult, there were 2 shared hot spots: 1 #2 ranking hot spot (census tract ID 805, which is in Indian Battle Heights) and 1 #1 ranking hot spot (census tract ID 1013, which is in Varsity Village). For Senior, there was 1 shared hot spot: 1 #1 ranking hot spot (census tract ID 201, which is in Winston Churchill). For All bus passes/census demographics, there were 2 shared hot spots, both of which were #2 ranking hot spots (census tracts 806 and 906, which are in neighborhoods Indian Battle Heights and Heritage Heights).

For 2014, there were no shared hot spots for the Child category. For Youth, there was 1 shared hot spot, a #2 ranking hot spot (census tract ID 911, which is in Heritage Heights). For Adult, there was 1 shared #2 ranking hot spot (census tract ID 805, which is in Indian Battle Heights). For Senior, there was 1 shared #2 ranking hot spot (census tract ID 201, which is in Winston Churchill). For All bus passes/census demographics category, there were 4 shared hot spots, 3 of which were #2 ranking hot spots (census tracts 802, 805 and 906, which are in neighborhoods Indian Battle Heights and Heritage Heights), and the other hot spot was a #1 ranking hot spot (census tract 1014, which is in neighborhood Varsity Village).

Shared hot spots between the categories and between 2012 and 2013 are as follows. For the Youth category, 1 hot spot was shared across the years, with the #1 ranking for hot spots (census tract 114, which is in neighborhood Stafford Manor). Shared hot spots between the categories and between 2012 and 2014: for the All bus passes/census demographics category, 2 hot spots were shared, with the #2 ranking for hot spots (census tracts 802 and 805, which is in neighborhood Indian Battle Heights). There were no shared hot spots between years 2013 and 2014.

Table 5-26: Bus usage and census hot spot and cold spot comparison results

Hot spot confidence level	Number of shared hot spots between census and bus usage 2012					Number of shared hot spots between census and bus usage 2013					Number of shared hot spots between census and bus usage 2014				
	Child	Youth	Adult	Senior	All users and ages	Child	Youth	Adult	Senior	All Users and Ages	Child	Youth	Adult	Senior	All users and ages
High clustering of high values	-	-	0	-	0	-	-	0	-	0	-	-	0	-	0
Moderate clustering of high values	0	1	1	0	3	0	1	1	0	2	0	1	1	1	3
Low clustering of high values	0	2	0	0	0	0	2	1	1	0	0	0	0	0	1

Cold spot confidence level	Number of shared cold spots between census and bus usage 2012					Number of shared cold spots between census and bus usage 2013					Number of shared cold spots between census and bus usage 2014				
	Child	Youth	Adult	Senior	All users and ages	Child	Youth	Adult	Senior	All Users and Ages	Child	Youth	Adult	Senior	All users and ages
High clustering of low values	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moderate clustering of low values	-	0	-	-	-	-	0	-	-	-	-	-	-	-	-
Low clustering of low values	0	0	-	-	0	0	0	-	-	0	-	0	-	-	-

5.5 Conclusion

This section focused on the analysis results of the two studies. The first objective is comparing the CO_2 emissions and fuel consumption of the hybrid and diesel buses that the City of Lethbridge operates with the STURAA (Surface Transportation and Uniform Relocation Assistance Act) tests results, which showed that the Lethbridge hybrid buses were more fuel efficient and were consistently producing less CO_2 emissions than the diesel buses. Compared to the STURAA tests, the diesel fuel efficiency results for both years for Lethbridge were less than that of the Orange County and UDDS but greater than that of Manhattan. It worked out that the fuel efficiency was less than the combined average of the STURAA tests. The hybrid fuel efficiency results for both years for Lethbridge were less than that of UDDS, comparable to than that of Orange County bus but greater than that of Manhattan, and the fuel efficiency was less than the combined average of the STURAA tests. A discussion about the results, problems, and future studies will be in Chapter 6.

The second objective is analyzing and comparing the City of Lethbridge age demographics to the Lethbridge Transit ridership data. The results found showed that there were more differences in the hot spot locations than similarities between the bus usage and city demographics. A discussion about the results, data problems, and future studies will be in Chapter 6.

Chapter 6: Conclusion

6.1 Introduction

This thesis analyzes the data to separate the signal from the noise to help direct future research and planning resources for transit systems to stop the continuous cycle of not improving transit. Chapter 3 highlighted the inability to move transit past certain issues, specifically with the paper from the 1980s titled *Marketing of Small Transit Properties in Alberta: Fort McMurray Transit, Grande Prairie Transit, Lethbridge Transit, Medicine Hat Transit, Red Deer Transit* and the City of Lethbridge 2017 proposed Transit Master Plan (Intergroup Advertising Ltd., n.d.; Stantec, 2017), where the same issues highlighted in the 1980s report were highlighted in the 2017 report. These issues revolved around topics, such as timing of the buses, hours of operation, efficiency, and cost. By identifying utilization patterns through hot spot analysis within the city population, this study extracted information from the overload of data that may be of use to small city transit planning.

This research examined emissions and transit usership, which have been a problem for transit groups, through two research objectives. The first objective was to analyze the emission performance of hybrid and diesel Lethbridge Transit buses. The second objective was to examine how to improve the efficiency of transit use through a spatial analysis of transit ridership and city demographics from the City of Lethbridge.

6.2 Hybrid and Diesel Bus Emission and Fuel Consumption Comparison

This section summarizes the hybrid and diesel bus emission and fuel consumption comparison for the Lethbridge Transit buses. I will review how this information will help add to the current information and research in this area.

6.2.1 Summary of findings: I found that the Lethbridge Transit hybrid buses (XDE40) produced 23.68% less emissions for 2014 and 19.78% less emissions for 2015 than the Lethbridge Transit diesel buses (XD40) when comparing the emissions calculated from the kilometers traveled and fuel used. I also calculated the fuel-efficiency and I found that the Lethbridge Transit hybrids (XDE40) were 31.2% more fuel-efficient for 2014 and 24.6% more fuel-efficient for 2015 than the Lethbridge transit diesel buses (XD40).

The Lethbridge hybrid and diesel CO_2 emissions and fuel consumption were compared against the STURAA test standards, which are known as Orange County, UDDS, and Manhattan. Regarding the hybrid CO_2 emission results (Table 6-1), I found that Lethbridge bus emissions output was 6.2% greater in 2014 and 11.3% greater in 2015 than that of Orange County and 17.8% greater in 2014 and 22.3% greater in 2015 than that of that of UDDS. However, when compared against the Manhattan standard, the Lethbridge hybrid buses had 22.1% less emissions in 2014 and 17.7% less emissions in 2015. I average the three STURAA tests and compared them against the Lethbridge results, I found that Lethbridge emissions were 1.4% greater than the STURAA results in 2014 but 4.1% less than the STURAA results in 2015.

For the diesel CO_2 emission results (Table 6-1), I found that the Lethbridge buses emissions output was 2.5% greater in 2014 and 3.1% greater in 2015 than that of Orange County and 37.2% greater in 2014 and 37.6% greater in 2015 than that of UDDS. However, when compared against the Manhattan standard, the Lethbridge diesel buses had 29.3% less emissions in 2014 and 28.9% less emissions in 2015. I averaged the three STURAA tests and compared them against the Lethbridge results, I found that Lethbridge emissions were 0.5% greater than the STURAA results in 2014 but were the same in 2015.

Table 6-1: CO_2 emissions percent difference comparison between the STURAA and Lethbridge transit buses XD40 and XDE40 for 2014 – 2015.

	Manhattan	Orange County Bus	UDDS	Combined average
Lethbridge XD40 2014	29.3	-2.5	-37.2	0.5
Lethbridge XD40 2015	28.9	-3.1	-37.6	0
Lethbridge XDE40 2014	22.1	-6.2	-17.8	1.4
Lethbridge XDE40 2015	17.7	-11.3	-22.3	-4.1

Diesel fuel efficiency results (Table 6-2) for the hybrids found that Lethbridge bus (XDE40) fuel consumption was 2.4% greater in 2014 and 3.3% less in 2015 than that of Orange County and 10.3% less in 2014 and 15.3% less in 2015 than that of UDDS. However, when compared against the Manhattan standard, the Lethbridge hybrid buses had 28.6% greater fuel consumption in 2014 and 24.4% greater fuel consumption in 2015. I averaged the three STURAA tests and compared them against the Lethbridge results, I found that Lethbridge fuel consumption was 6.5% greater than the STURAA results in 2014 and 1% greater than the STURAA results in 2015.

The diesel fuel efficiency results (Table 6-2) for the diesels found that Lethbridge bus (XD40) fuel consumption was 3.4% less in 2014 and 4.0% less in 2015 than that of Orange County and 37.8% less in 2014 and 38.1% less in 2015 than that of UDDS. However, when compared against the Manhattan standard, the Lethbridge diesel buses had 28.8% greater fuel consumption in 2014 and 28.3% greater fuel consumption in 2015. I averaged the three STURAA tests and compared them against the Lethbridge results, I found that Lethbridge fuel

consumption was 10.6% less than the STURAA results in 2014 and 11.1% less than the STURAA results in 2015.

Table 6- 2: Fuel consumption percent difference comparison between the STURAA and Lethbridge transit buses XD40 and XDE40 for 2014 - 2015.

	Manhattan	Orange County Bus	UDDS	Combined average
Lethbridge XD40 2014	-28.8	3.4	37.8	10.6
Lethbridge XD40 2015	-28.3	4	38.1	11.1
Lethbridge XDE40 2014	-28.6	-2.4	10.3	-6.5
Lethbridge XDE40 2015	-24.4	3.3	15.3	-1

The results from this in-use analysis confirm that the hybrids perform better than their diesel counterparts for both CO_2 emission reduction and decreased fuel consumption. When compared with the STURAA standards, they performed comparably to what was expected, as they fell within the set spectrum of the 3 standards.

6.2.2 Research limitations, contributions and future applications. In summary, vehicle CO_2 emissions account for 20–25% of global CO_2 emissions (Tao & Hung, 2003), which is why there are international agreements, such as the Paris Agreement, to meet targets to reduce transportation emissions. To meet some of these requirements, we need to properly analyze what our in-use emissions and fuel consumption are for public transit outside of the studies conducted in labs, on testing grounds, or in specific conditions, as this information impacts recommendations to policymakers and managers (Banister et al., 1997; Demir et al., 2011; Meyer, 2010; Meyer & Miller, 1984; Tao & Hung, 2003). Since each bus runs different routes, varying topography, and different weather and seasons, it is important to see how these factors influence efficiency and emissions. Knowing this information will allow for policy and purchasing decisions and technology to continuously improve and effectively meet the emission and fuel

consumption reduction goals at all levels of government (Demir et al., 2011; Hallmark, Wang, & Sperry, 2013).

By calculating the CO_2 emissions and fuel consumption of the Lethbridge Transit XDE40 and XD buses, this research contributes to in-use data and results needed to meet emission and fuel consumption reduction targets. This information could be given to managers, planners and researchers to improve transit fleet green technology, as well as to those managers and researchers in charge of collecting efficiency and emission data.

The available study information and data did not allow a full lifecycle analysis, beyond the fuel and kilometer comparison and emissions analysis. Even a precise accounting of the amount of fuel and kilometers traveled for these buses was not always available. This is due in part to the natural change of personnel and technology, the movement of data responsibility between different groups, and insufficient funds for maintaining documentation and data collection occurring in government organizations. If this kind of study is considered for further comparisons, more consideration needs to be given to how data and information is collected and maintained within the government organization, especially when it deals with more than one department or group.

During this study's duration, Lethbridge Transit stopped purchasing hybrid technology. According to ATU Local 987 Union President Travis Oberg via an email conversation on November 19, 2017, these were the following reasons:

1. *The hybrid components cost more to the department then clean diesel buses.*
2. *The hybrid bus is a safety concern in winter driving conditions. This is a result of the electric propulsion.*

   A normal bus has a 6 gear transmission which is complemented with a torque converter. Meaning when you step on the throttle the torque to the tires to begin moving is not immediate. Also if the tires break traction from the road you only let of the throttle lightly and reapply to regain traction.

In a hybrid bus the electric propulsion transmission which applies immediate torque to the tires. If the tires break traction from the road the propulsion has to reset prior to reapplying the throttle (3-5seconds). This causes a safety issue when trying to cross and intersection or turning left or right from a yield or stop sign.

Expenses and costs are generally important when considering the incorporation of green technologies, but it is rare to see seasonal and safety information being considered when doing an environmental analysis or critiquing developing green technology. This shows that interdisciplinary studies are needed, that take into account various perspectives and backgrounds.

6.3 Age Demographics and Bus Ridership Comparison

This section summarizes the Lethbridge age demographic and Lethbridge Transit bus ridership comparison. Review of how this information will add to the current information and research in this area of study, as well as considerations and future studies that could be of interest will occur in this section.

6.3.1 Summary of findings. For the study period of this research project, 2012 – 2014, the results found that Lethbridge age demographics stayed consistent. The categorises of the demographics are Child, Youth, Adult, and Senior. The results of the demographics analysis show that Children make up 7% of the population, Youth composed 12% of the population, Adults made up the majority at 66%, and Seniors the remaining 15%. Growth rate from 2012 to 2013 was 1.5% and from 2013 to 2014 was 2.9%. Bus pass growth rates for these same periods were 14% and 9% respectively. Alberta was in an economic slump during this period, which could have influenced the bus pass fluctuations. Rider composition fluctuated from 2012 to 2014. Senior passes stayed constant at 6%, Post-secondary and Youth passes increased by 1%, and Child usage increased by 1%. The largest change was seen among Adult bus passes and Cash users;

Adult bus passes increased by 4%, and Cash decreased by 7%. The decrease in cash users may be attributed to people switching to the new Breeze Card bus passes, which were introduced late 2011, as the combined increase of Post-secondary, Youth, Child, and Adult is equivalent to the 7% change. Over the 3 years of this study, I found that the percentage of bus passes sold compared to the city population was around 20% for each year. This shows that the transit usage stayed relatively stable with no growth.

The hot spot analysis highlighted the similarities and differences in the clustering of people within the city and in transit usage. For this discussion, I will discuss only the hot spots, as we are interested in where the people are for this study. Identifying cold spot locations is also of value, as discussed in the results section. The results showed that for the total population demographics (Figure 5-7), most people-living locations are clustered on the west side of Lethbridge, with a couple of far north and south locations, while the downtown and north industrial park areas have tiny clusters of people residing in them. In comparison, when analyzing Lethbridge Transit users and their usage (Figure 5-8), we see that most of the use shows clustering on the west side of Lethbridge. The results showed that the Adult population demographics (Figure 5-9) are clustered, although distributed unevenly, on the west side of Lethbridge, with a couple in the far north. When analyzing the Adults and their usage (Figure 5-10), we see that most of the use shows clustering in the central to northern part of the west side of Lethbridge, with a small area occurring on the south side of Lethbridge. For the Child demographics (Figure 5-11), most people-living locations are clustered sporadically on the west side of Lethbridge, with a few spots in the far north and far south parts of Lethbridge. When analyzing the Children users and their usage (Figure 5-12), we see clustering on the central to northeast part of the east side of Lethbridge, with a couple of spots on the west side. For the Youth demographics (Figure 5-13), most people-living locations are clustered on the edges of the

west side, with a couple on the far north and south sides of Lethbridge. When comparing Youth and their usage (Figure 5-14), we see that clustering happens in the central to northwest part of the west side of Lethbridge, as well as the northeast side of Lethbridge. For the Senior demographics (Figure 5-15), most people-living locations are clustered in the central-east and southeast side of Lethbridge with a couple small spots in the northeast side of Lethbridge. When analyzing the Senior users and their usage (Figure 5-16), we see clustering happens in the north and southeast parts of the east side of Lethbridge with a couple of spots on the west side of Lethbridge. The Cash usage (Figure 5-17) was in the central and north part of the west side of Lethbridge, and the Post-secondary usage (Figure 5-18) occurred the most in the west side census areas.

The number of hot spots for the demographic groups stayed consistent to the clustering. This was expected since people can live only in certain parts of the city and cities tend to plan group clusters. However, the number of hot spots overall fluctuated with some groups, like Post-secondary, Child, and Senior, yet stayed consistent for others, like the Cash, Youth, Adult, and All user groups. To understand why this occurred would require further study at the individual bus-stop and street level instead of at the census tract level. Some influences may be the adding of new census tracts, better tracking of child use by drivers, and the adding of high-density housing to neighborhoods on the west side, so post-secondary students are more concentrated there than in previous years.

The number of hot spots, depending on the group and year, varies from 12 to 47 identified clusters. Though we have these large numbers of hot spots, only 9 – 25 of the hotspots (dependent on group and year) share identified areas of clustering within their identified groups for all 3 years. These are the areas managers and planners should pay attention to as they show consistency in these areas. The areas not showing consistency but occurring in 2 of the 3 years

should also be considered, as it would benefit the city to explore these areas and see what barriers or other variables may be causing these differences.

When comparing the hot spot clustering between the demographic groups and the bus usage groups, we see very little hot spot sharing. A large number of areas appear to overlap on the maps; however, the levels of clustering differ. Most hot spots are not shared when comparing the same levels of clustering between demographic groups and bus usage groups. None of the high clustering hot spots are shared. The Youth and Adult share only 1 common moderate clustering hot spot for years 2012, 2013, and 2014. Three were shared for the all users and ages groups in 2012 and 2014, but only 2 were shared in 2013. Seniors shared 1 hot spot in 2014 and none in 2012 or 2013. Youth shared 2 low clustering hot spots in 2012 and 2013, but none in 2014. Seniors and Adults shared 1 common low clustering hot spot in 2013, and All users and ages shared 1 low clustering hot spot in 2014.

The majority of clusters for the majority of the groups had common areas for different levels of clusters but not for the same level of clustering. This means that there is reason to believe that there are potential barriers that prevent people from using transit in those areas. This would be an area where planners and managers should focus resources to see if they can identify those barriers or conduct a more targeted analysis to get clarity on patterns showing. It would be valuable to do a stop and street level analysis for these areas to see if there are underlying factors or if there is opportunity to improve the transit service in the areas highlighted, as clusters are not yet shared between the demographics and the bus usership. The Senior demographics and bus usage hot spots did not overlap for their major areas. This may explain why Senior bus usage stays the same. To improve the service for seniors, planners should survey this group to see why the hot spot results are so different. The Post-secondary group has no demographic data that could be compared against it. It may be in the city's interest

to note where the majority of the usage is and compare that against student surveys that have been taken about the barriers to students using the bus, as they use it on the west side but not significantly anywhere else. Cash users mostly being on the west side could indicate that several cash users are students, as the hot spots are in the same area as the adult passes and the post-secondary passes. This would require a more in-depth study to determine through a mixture of questionnaires and data analysis. The youth hot spots show that the bus usage is in the census tracts neighbouring the demographic hotspots. This could be explored by planners to see if routing is a factor or if routes can be modified for situations like this to make them more effective. The adult hotspots show a similar pattern to the youth, where the hot spots neighbour each other. Some of the usage hotspot is happening in a demographical cold spot. This could be due to work locations or some other factor that could be revealed through a targeted study. The Child hot spots do not align between the demographics and the bus usage. This could be because of influence of the adults, as they determine where children use the bus, and these two groups are linked. However, this may be lost in the census level and could potentially be sussed out through a stop/street analysis.

6.3.2 Research limitations, contributions and future applications. Azar and Ferreira (1995) identified the need to use geographical information system (GIS) tools to identify and measure factors needed for transit planning, and Hsiao et al. (1997) highlighted the need for further study to investigate additional ways to interface transit data to allow for in-depth analysis at a disaggregated level. This research contributes to the gap in the literature for in-depth analysis at a disaggregated level. This was accomplished by using GIS, which is an effective tool that provides valuable spatial auto correlations and effectively shows spatial patterns that are valuable to planning an efficient transit system. This research also contributes to the less published research areas of transit analysis on small cities and contributes information about

Canadian transit by providing a quantitative, visual spatial analysis of Lethbridge Transit efficiency and user-ship.

Zahabi et al. (2012) found that increased public transit accessibility was one of the most effective ways to reduce greenhouse gas emissions. By understanding the complexities of our city demographics and transit usership, we can reduce barriers and create a more accessible transit system.

Data quality and ability to analyze large amounts of data were some of the largest issues with this project. Finding programs and code that can compress the data into meaningful groups of information and verifying the quality of data were the largest challenges. Having access to large sets of raw data was great. However, it was difficult to get it into a usable and comparable format, as the collection of the data was predetermined for this project. Having access to a programmer to overcome the challenges of dealing with these data sets was great and showed that collaboration needs to occur between disciplines, as the programmer did not have the background to understand the purpose or the context of the data to be able to catch errors. Combining both talents improves the best data and work availability.

Specifically, regarding the hot spot analysis, it would be great to see future studies take this methodology of analyzing city demographics that include age, income levels, and ridership data at a neighborhood and bus stop level. It would also be beneficial to examine this information seasonally to find emerging patterns influenced by weather and school. Error issues that appeared in the Breeze data have since been sorted out at the city. The long form census at the federal level has been reinstated. With these two issues being resolved, it is possible for a future study to be done at the bus stop and street level. By conducting a study at this level using

the methodology from this study, some of the complexities that are hinted at in the hot spot analysis could be investigated more thoroughly.

6.4 Future combined studies

It would be of value to the Canadian transit community, as well as our local transit group, to have an all-inclusive study done on the following topics:

(a) System accessibility

(b) Travel time

(c) Frequency

(d) Costs

(e) Maximum load

(f) Vehicle characteristics

(g) Adequate information and support facilities

(h) Mobility related to necessities

(i) Seasonal emissions analysis

(j) Seasonal driving issues

(k) Vehicle engine technology

(l) Season fuel efficiency

(m) User analysis

(n) City demographics

Although there is a large amount of information on these topics individually, it is very rarely combined into a quantitative all-encompassing analysis, which would provide a stronger basis for decision making to efficiently and effectively green our transit systems by reducing emissions and increasing ridership in Canadian small to mid-sized cities.

6.5 Conclusion

Transportation is one of the largest influencers on regional patterns, economic viability, quality of life, and environmental impacts (Murray et al., 1998). How transportation is used determines if the influence is positive or negative. With Canada recovering from a recession and the increasing negative environmental impacts, understanding the various influences that affect and feed into transit from research fields involving economic, social, and environmental areas is a growing need. However, one of the largest issues (aside from lack of funding), especially for small municipalities like Lethbridge, is collecting high quality, continuous data with proper monitoring and evaluation over decades. Because of limitations with the data available, this study could not do a bus stop and individual comparison. However, the outcomes of the analysis ran at the census tract level and show the usefulness and functionality of having a high-quality data set and the planning benefits that can be achieved from analyzing large volumes of data in a quantifiable format.

This research focused on analyzing the data that would help improve public transportation, as that has been a key item identified in reducing CO_2 emissions and a large component of climate change mitigation plans. To successfully achieve the goals to mitigate emissions and climate change, proper data analysis that considers all aspects is important, as is having access to high quality data and methodology that can be assessed, monitored, and replicated. This study is a small sample of what can be done and provides a base that future

studies can build upon to improve the efficiency and effectiveness of small city public transportation in its efforts to decrease emissions through green vehicle technology and increased ridership. I hope this thesis will add to the literature that encourages researchers, managers, and policy makers to increase the scope of studies that include analyzing the relationships between environmental, social, and economic and their complexities, so we can move our decision making and policies into more sustainable, long-term solutions that fix the decades-old problems that are worsening over time.

Peer-reviewed journal articles on transit quantitative analysis are limited and tend to be conducted on large cities in the US, Europe, or China, leaving a large gap in the literature for Canadian cities, especially those that are not a metropolis size. This research will help fill this research gap and will hopefully encourage further research into this complex but highly beneficial area of research.

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Appendix A

Descriptive statistics for 2012 transit use data

This appendix section can be found at http://hdl.handle.net/10133/5091. It provides the descriptive statistic results for transit use by user type by neighbourhood census tract. The descriptive stats ran were sample size, mean, min, max, median, standard deviation, standard error, variance and coefficient variation.

Appendix B

Descriptive statistics for 2013 demographics data

This appendix section can be found at http://hdl.handle.net/10133/5091. It provides the descriptive statistic results for transit use by user type by neighbourhood census tract. The descriptive stats ran were sample size, mean, min, max, median, standard deviation, standard error, variance and coefficient variation.

Appendix C

Descriptive statistics for 2014 transit use data

This appendix section can be found at http://hdl.handle.net/10133/5091. It provides the descriptive statistic results for transit use by user type by neighbourhood census tract. The descriptive stats ran were sample size, mean, min, max, median, standard deviation, standard error, variance and coefficient variation.

Appendix D

All hot spot results for 2012

This appendix section can be found at http://hdl.handle.net/10133/5091. It provides all the hot spot analysis result output tables for the hot spot maps generated.

Appendix E

All hot spot results for 2013

This appendix section can be found at http://hdl.handle.net/10133/5091. It provides all the hot spot analysis result output tables for the hot spot maps generated.

Appendix F

All hot spot results for 2014

This appendix section can be found at http://hdl.handle.net/10133/5091. It provides all the hot spot analysis result output tables for the hot spot maps generated.

Appendix G

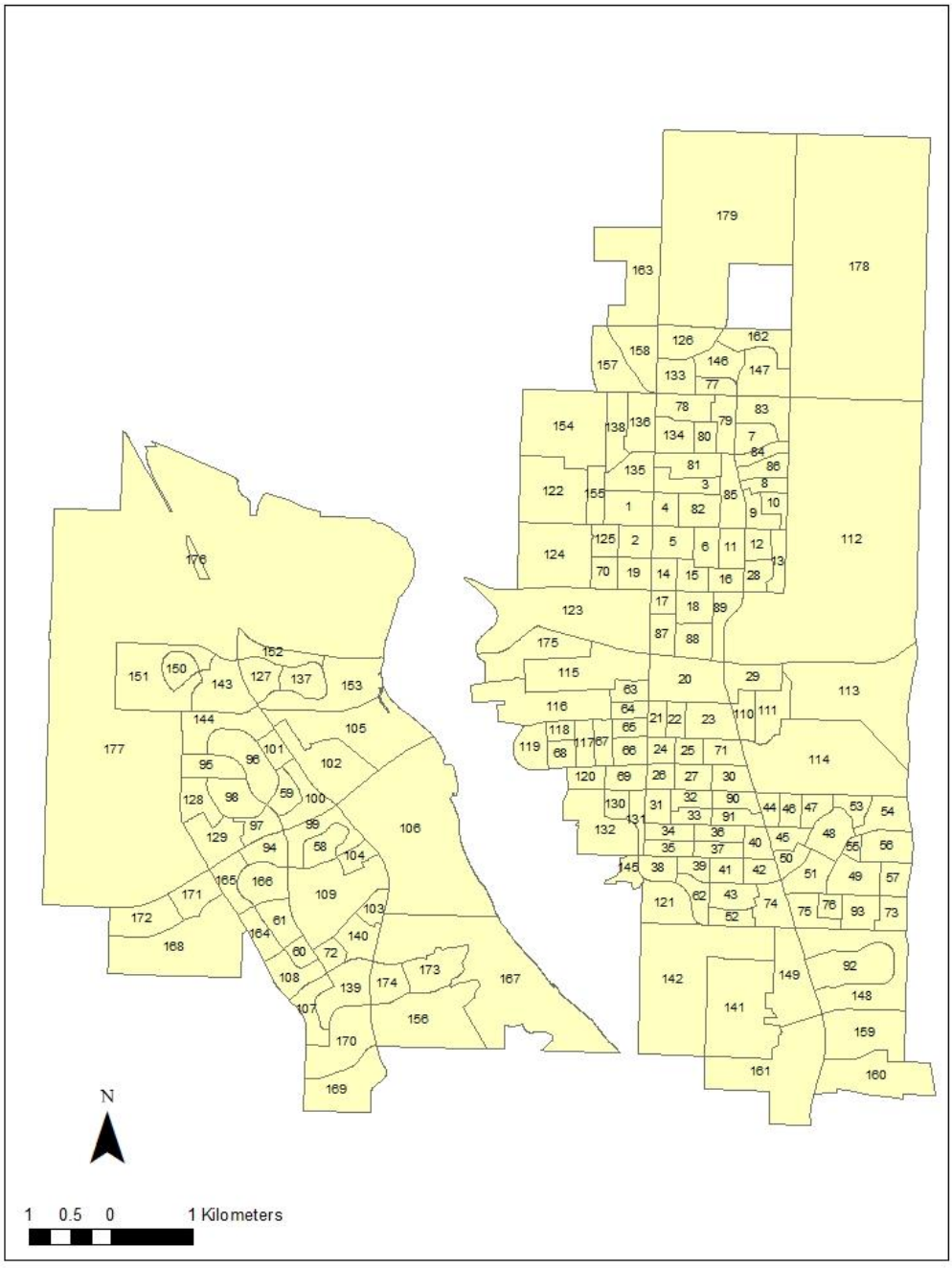
Moran's I analysis

This appendix section can be found at http://hdl.handle.net/10133/5091. It contains all the Moran's I ArcGIS analysis results for determining the threshold distance for the hot spot analysis.

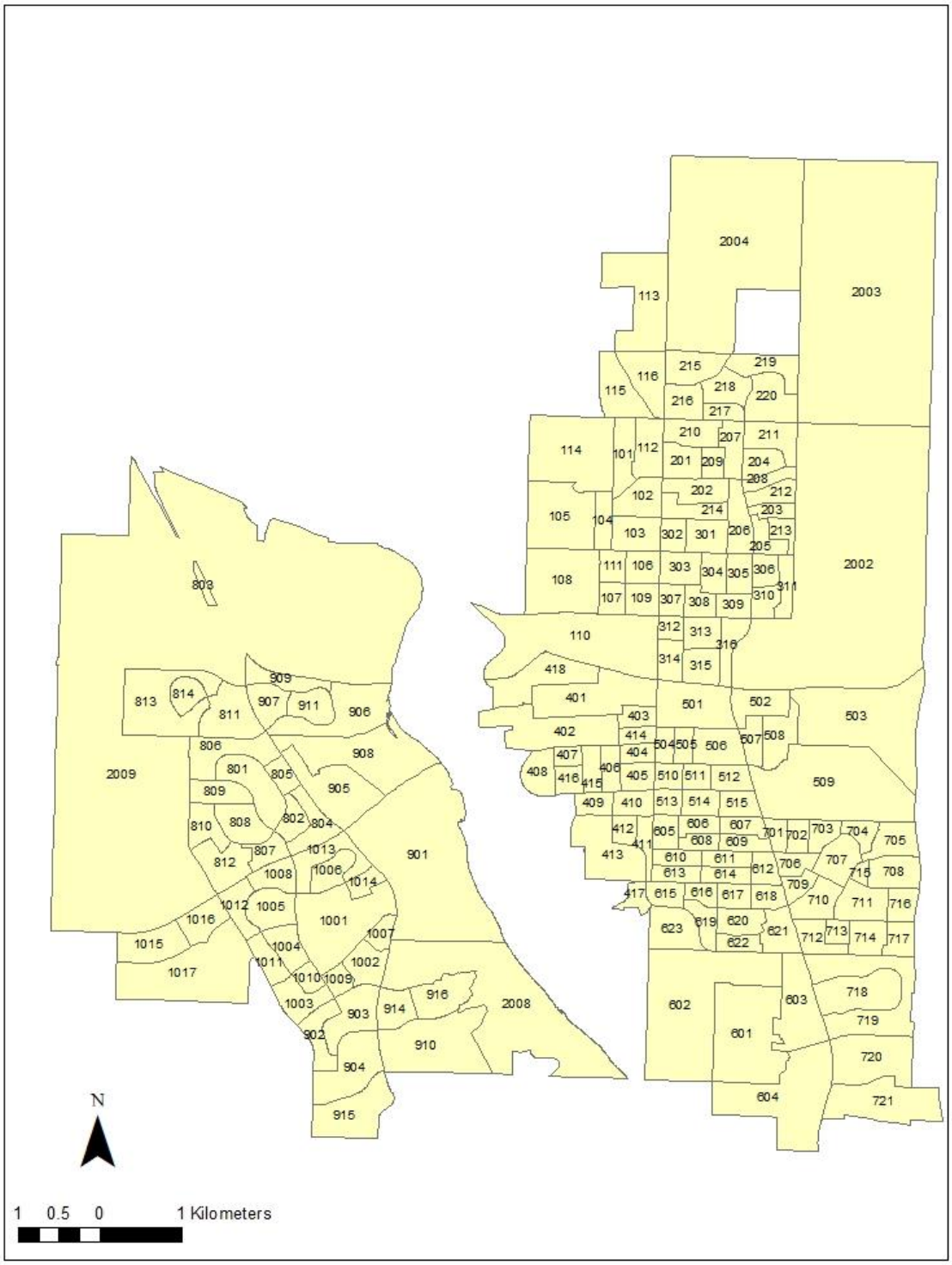
Appendix H

Maps that Identify the Census Tracts from 2012 – 2014

City of Lethbridge census tracts 2012



City of Lethbridge census tracts 2013



City of Lethbridge census tracts 2014