BUILT ENVIRONMENT CORRELATES OF ASTHMA IN THE REGION OF PEEL

by

Fatima Alhaan

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Fatima Alhaan

ABSTRACT

Asthma is one of the most common respiratory illnesses. In Canada, about 3 million people suffer from chronic asthma. Studies have demonstrated association of asthma with built environment, socio-economic, and environmental factors. Land use planning can play an important role in shaping the built environment and consequently decrease asthma incidence. This research investigates the relationship of asthma outcome and its key determinants: built environment, socio-economic, and environmental factors in the Region of Peel between 2007 and 2011, and reviews the existing planning provisions concerning the disease. The primary research question that was addressed in this study is "what is the asthma pattern in the Region of Peel and what are the probable factors affecting it?" In order to address the research question, three sub questions were devised: 1) what is the pattern of asthma over space and time in the Region of Peel?; 2) what are the relevant factors that may explain asthma patterns?; and 3) what are the relevant policies that shape these factors?

A retrospective, quantitative approach was taken to address the questions using secondary data from open sources. To assess the spatiotemporal patterns, Geographic Information System (GIS) and descriptive statistics were used. The relationships between asthma and its key determinants were evaluated using correlation analysis. The policies concerning asthma and land use planning were also reviewed.

The research showed decreasing trends in asthma between 2007 and 2011 by 7.2%.

The correlation analysis showed moderate relationships between asthma outcomes and average annual daily traffic, industrial emission, percentage of population using vehicles, percentage of population using transit, population at risk, prevalent low income population, and educated population. The study demonstrated importance of asthma awareness programs to ensure improved health in the Region of Peel. In addition, the importance of accessible health care facilities to reduce asthma outcome has been realized. Moreover, the study revealed that proper land use planning can result in improved health outcomes.

However, data was a limiting factor for this research. The data used were at aggregate levels and more observations could have increased accuracy of the study. Nevertheless, this study is the first of its kind as it attempts to investigate asthma outcomes in the built environment with explicit policy review at a regional scale.

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DEDICATION

To my Mother for her unconditional love and teaching me great lessons of life,
my sister Naureen, for always showing me the brighter side
and
my son Shehzad

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LIST OF ABBREVIATIONS

AQI	Air Quality Index
AQHI	Air Quality Health Index
AADT	Average Annual Daily Traffic
CCOHS	Canadian Center for Occupational Health and Safety
GIS	Geographical Information System
GHGs	Green House Gases
GPGGH	Growth Plan for Greater Golden Horseshoe, 2006
ICES	Institute of Clinical Evaluative Science
LHINs	Local Health Integration Networks
OASIS	Ontario Asthma Surveillance Information System
OPHS	Ontario Public Health Standards
PPS	Provincial Planning Statement

LIST OF SYMBOLS

NOx	Oxides of Nitrogen (Nitrogen Monoxide, Nitrogen dioxide, Dinitrogen oxide)
SOx	Oxides of Sulphur (Sulphur dioxide, Sulphur trioxide)
$PM \leq 2.5 \mu m/cm^3$	Particulate Matter of less than2.5 micronmeter ($PM_{2.5}$)
$PM > 10 \mu m/cm^3$	Particulate Matter of more than 10 micronmeter (PM_{10})
VOC	Volatile Organic Compound

CHAPTER 1: Introduction

Since the second half of the 20th century, chronic diseases such as cardiovascular diseases, diabetes and respiratory illness are on the rise. Respiratory illness can range from (occasional) breathing problems to lung cancers. Asthma is one of the most common respiratory diseases and is characterized by the World Health Organization (2012) as shortness of breath, coughing, wheezing, chest tightness. Studies have identified asthma as the fifth most probable cause visits to emergency departments (OASIS, 2012; Creighton et., al. 2012). About 235 million people suffer from asthma worldwide (WHO, 2012). In Canada, as of 2010, about 8.5% of the population (aged 12 and over) have been diagnosed as asthmatic (Statistics Canada, 2010). In Ontario, the number of individuals estimated to suffer from asthma is 1.6 million (Creighton et al 012). It is projected that in 2022 there will be about 71,000 new cases of asthma, elevating the total to about 1.9 million people living with asthma in Ontario alone. (Teresa To et al., 2013; ICES, 2013).

There is a close relationship between asthma and the built environment (Frank, L., & Engelke, P., 2005). The built environment consist of the nature of physical structures such as houses, schools and commercial centers, industrial areas, parks, public spaces and transport structures including streets, highways, paths, sidewalks, transit systems, and neighborhood that have been correlated with public health issues (Frank, L., & Engelke, P., 2005; Lopez, R., 2012). Studies indicate associations between the built environment and health outcomes such as obesity, asthma, diabetes, mental health, and injuries (Frank, L., & Engelke, P., 2005). Asthma can be developed from exposure to hazardous substances such as dust, pollen, fume, and particle matter that originates from the built environments (Frank, L., &

Engelke, P., 2005; Juhn, Y. J., 2005; Patel et al, 2009). In the past decade, there has been a growing interest to study impacts of the built environment, particularly land use planning and transportation, on the levels of air pollution and asthma incidence (Lopez, R., 2012). Public health researchers are emphasizing prevention strategies as well as community-based intervention in order to reduce the incidence of asthma. However if current anthropogenic activities in the built environments remain unchanged, asthma will continue to rise (Public Health Agency Canada, 2007). Therefore planning strategies must consider all components of the built environment in order to provide better air quality to reduce asthma.

In Ontario land use planning, along with public health sectors and health care systems, can create important links between the built environment and healthy communities (Ministry of Health, 2008). Public health units are adapting policies through the Ontario Public Health Standards and new land use planning initiatives developed in accordance to the *Provincial Planning Statement* (2014) and the *Places to Grow Act* (2005) to incorporate the built environment into their Chronic Disease Prevention and Environmental Health Hazard Programming (OPHS, 2012; PPS, 2014). Although asthma is regarded as an illness that can be reduced, very little work has been done to see how the regions within Ontario are administering the air quality standards, built environment and asthma outcomes.

1.1 State of Asthma

Asthma is a common respiratory illness that can be acute or chronic by nature. The severity of the disease varies from person to person. During an asthma attack, the lining of the bronchial tubes swells, causing the airways to narrow and reducing the flow of air into and out of the lungs (WHO, 2013).

The fundamental causes of asthma are not completely understood. However, the strongest risk factors for developing asthma include: tobacco smoke; indoor allergens (such as house dust mites in bedding, carpets and stuffed furniture and pet dander); and air pollution. Other triggers of asthma can include cold air, extreme emotional arousal such as anger or fear, physical exercise, and reactions to medication (Public Health Agency Canada, 2012). Although asthma cannot be cured, appropriate management can control the disease and allow people to live a fairly normal life.

Public Health Agency (PHA) Canada has categorised asthma as a chronic respiratory disease under the broader category of chronic diseases and injuries. The organization has established a good source of data at both federal and provincial levels that are openly accessible. PHA has developed a chronic disease indicator where socio-economic factor and environmental factors are considered to provide information on contextual factors and equity measures that influence health. Other public health strategies for asthma prevention are initiatives of Health Canada Tobacco Control, awareness programs of Health Canada Air Quality, and research and development of the Canadian Lung Association

1.2 Conceptual Framework

Human health and wellbeing are affected by a wide range of factors. The factors that have most influence are known as the "determinants of health". Figure 1.1 represents the rainbow of "determinants of health" model developed by Dahlgren and Whitehead (1991). There is a broad range of determinants of health at individual and societal levels, as improved population health involves a holistic approach. This research is rooted in broad determinants of health framework that recognizes factors beyond the improvement in population health, with particular emphasis on the built environment.

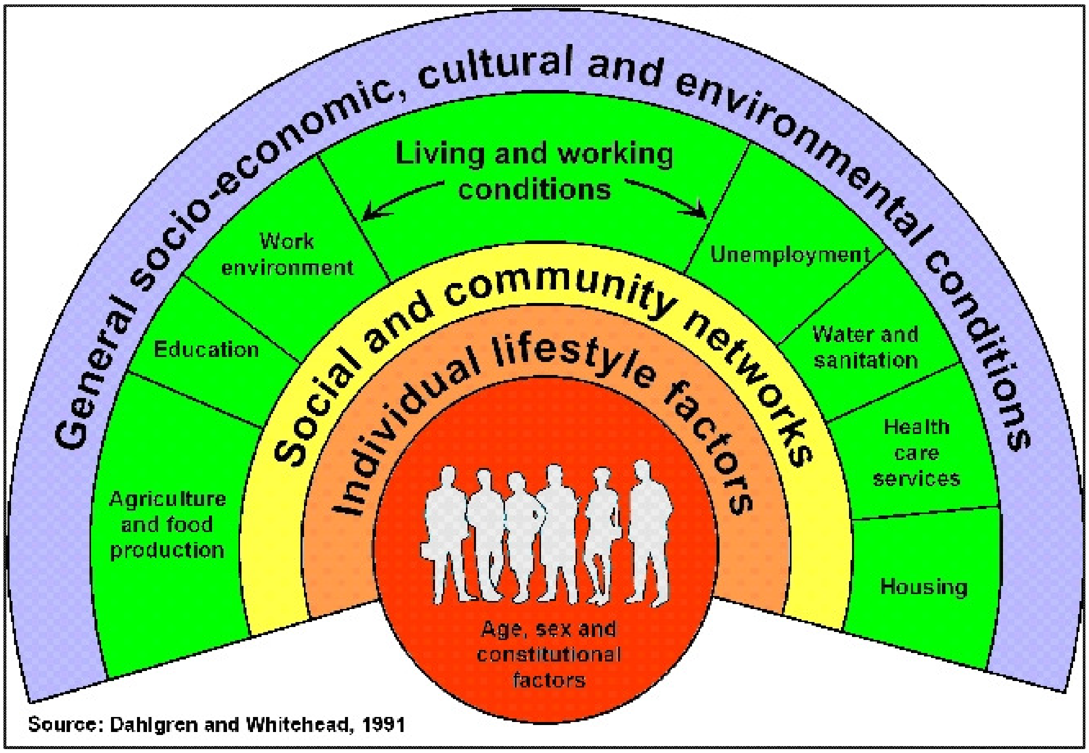

Figure 1 Determinants of Health
(Source:http://www.scattergoodfoundation.org/activity/applicant/green-space-tool-improve-individuals-health#.U7F5QvldXNk)

Figure 1 Determinants of Health

1.3 Determinants of air pollution

Environment Canada considers land use as the determinant factor for air pollution. Land use is interrelated to the functionality of land with physical, environmental and social aspects. Therefore, by incorporating all these aspects to gain a holistic perspective, the term built environment can be used. Built Environment essentially means everything in and around the community. Health Canada's definition of the built environment provides a framework for the discussion of this paper (Health Canada, 2003):

The built environment includes our homes, schools, workplaces, parks/recreation areas, business areas and roads. It extends overhead in the form of electric transmission lines, underground in the form of waste disposal sites and subway trains, and across the country in the form of highways. The built environment encompasses all buildings, spaces and products that are created or modified by people. It impacts indoor and outdoor physical environments (e.g., climatic conditions and indoor/outdoor air quality), as well as social environments (e.g., civic participation, community capacity and investment) and subsequently our health and quality of life.

The concept of the importance of considering the built environment has been developing over the last fifty years.A broad array of literature has identified evidence relating the impacts of built environment on health (Frank, Engelke 2005, Srinivasan et al 2005; Crigheton, 2012; Stone, 2010; Lopez, et al, 2012). In addition, most of the studies have shown strong association between built environment and air pollution.

Air pollution can be a by-product of the built environment and it directly impacts the people living in it. Poor, degraded air quality possesses a number of health risks to human life and raises public health concerns (Frank Engle, 2005; Stone et al, 2007; Lopez 2012). These conclusions are remarkably similar across studies conducted worldwide (Hester et al, 1998; McEnntee, Y., & Himmelberg, O., 2008; Kalaiarasan. M et al, 2009; YangZong et, al, 2012). The key determinants of air pollution in the built environment are discussed in the following sections.

1.3.1 Land Use Patterns

Land uses are commonly categorized as residential, commercial, industrial, transportation, institutional and open spaces (Hodge, Gordon, 2008). Land use planning determines the facilities, activities and functions of the communities such as the location of houses, schools, parks, institution, and businesses (Hodge, Gordon, 2008). It plays an important role in the evolving land use patterns in a built environment. Land use patterns refer to the spatial distribution of human activities including land use mix and density.

The aim of land use planning is to provide the population with amenities that would improve health; examples of community amenities may include more advanced sanitation systems, public open spaces, and access to safe drinking water (Lopez G., 2012). Historically, land use planning tools such as housing laws and zoning codes facilitated urban and suburban developments resulting in urban sprawl (Verderber, S, 2011). Urban sprawl has been criticised for its unsustainable patterns of land use and high automobile dependence. In order to control sprawl in Ontario, regulatory frameworks started implementing greenbelt strategies to restrict urban growth, and protect agricultural land and natural environment (Taylor, 1995; Hodge, Gorden, 2008; Verderber, S, 2012).This lead to mixed use of land theory, which was able to make health a priority (Lopez, 2012. Verderber, S, 2012).

However, there is no model land use pattern that can be attributed to ensuring that air pollution is controlled. However, Borrega et al. (2006) emphasized that air quality is typically better in compact cities than in dispersed and corridor cities. However, even though urban centres such as New York, Los Angeles, Chicago, Toronto, Montreal and London have reasonably compact urban forms with good transit systems, amenities at close proximity, and elevated levels of active transportation, air pollution remains a concern (Handy, 2005, Stone et al, 2007, Lopez 2012). On the other hand, many studies have identified suburban communities and rural areas to have better air quality than compact urban forms (Schweitzer, L. & Zhou, J., 2010; Coghill, C, 2012). Nevertheless, sprawling communities can have significantly less breathable air due to extensive use of automobile, fright transportation and offsite location of industries (Borrega et al, 2006; Handy,S et al, 2007; Schweitzer, L. & Zhou, J., 2010; Verderber, S. 2012; Verderber, S. 2012).

1.3.2 Transportation Systems

Transportation system includes all types of automobile use, roads, highways, transport corridors, transits, rail, airways and all infrastructures related to transportation. Transportation, over the last century had direct effects on the air quality, GHG emission, and smog, and indirect impacts on human health (Lopez, 2012; Zeman F, 2012).

Transit oriented development has been encouraged in cities to reduce air pollution by reducing automobile use (Handy S., 2005; Frank, L., Engelke, 2005; Lopez, R., 2012, Marshall, et al, 2007). Research shows that cities that have focused on the reduction of automobile use and the improvement of public transit systems have improved air quality (Wach, M., 1993; Frank L., 2003). In addition, people living in high density areas are found more likely to use active transportation over automobiles (Handy S, 2005; Marshall, et al, 2007; Lopez, 2012, Barette et al, 2012).

Built environments are inherently related to transportation corridors, as land use development is driven by new transportation developments (Lopez, 2012). The literature shows two important aspects with regards to transportation corridors. First, cities develop as transportation corridors expand, as was the case in the East-West expansion of the highway system in Southern Ontario and the North-South expansion of freeways in Los Angeles (Wach,1993; Kenedy, 2002; Lopez, 2012; Zemen, 2012). Second, emissions from transportation corridors are responsible for poor air quality (McEntee, Himmelberg, 2008; Rioux, et al., 2010). An increase in the average number of vehicles can increase air pollution (Ministry of Transport, 2012). Hitchins et al.(2000) found that concentrations of air pollutants decrease by 65% to 75% from transport corridors at a distance of 375 meter from the roads.

Transportation systems also include features such as airports. Cohen B. S. et al (2007) showed increased indoor and outdoor air pollution in the neighbouring areas of the LaGaurdia Airport in NY, NY and substantial deterioration in the respiratory health of the people. A myriad of research has correlated airports with poor air quality, noise pollution, and vibrations that can have detrimental impacts on human health (Swan, P. R., Lee, I. Y., 1980; Moussiopoulos, N., et al 1997; Otto V., Joop W. V., Van L. F., 2004; Cohen, B. S., et al, 2007; Picker, L., 2012).

1.3.3 Green Spaces

Another important part of the built environment is green space. This includes street trees, open space, urban greenery and parks. Studies show a negative association of green space with air pollution (Juhn et al., 2005; Lovasi, 2006; Zandbergen , 2007; Nowak et al, 2008; Stone et al., 2012; Villeneuve et al., 2012). However, more research is needed to investigate the potential of open spaces and urban greenery in compact cities to mitigate air pollution.

1.3.4 Collaboration of Built Environment, Planning and Public Health

Historically, public health practitioners and planners collaborated in the 19th century to address public health concerns such as infectious diseases associated with overcrowding and poor living conditions (Frank & Engelke, 2005). Urban and regional planning emerged as the result of the established relationships among planning, land use, and public health (Frank & Engelke, 2005). The land use planning and development that resulted from the 19th century, such as low density development, the separation of residential, commercial and industrial land uses, and suburban sprawl, are now thought to contribute to a more car dependent, sedentary lifestyle, which is a risk factor for many chronic illnesses.

Chronic disease and associated risk factors, including asthma, have renewed the public health practitioners' interests in the built environment as a key determinant of controlling health risk factors (Frank & Engelke, 2005). Many researchers and policy makers have called on public health officials to reconnect and work with land-use planners and engineers to design healthy built environments (Frank & Engelke, 2005; Giles, et al. 2009). According to the visions of Ontario Professional Planning Institute (OPPI) and the Ontario Public Health Association (OPHA), public health and planning professionals need to work more closely through land use planning initiatives such as Official Plans, Secondary Plans, Transportation Master Plans, Pedestrian and Cycling Plans and Sustainability Plans (OPHA, 2012). For instance, the Region of Peel's Public Health Department work with different planning initiatives such as *Healthy Peel by Designs* (2011); transportation planning; Clean Air Peel; working with paramedic service providers; waste management and recycle enterprises (Region of Peel, 2012).

1.3 Purpose of the Study

The purpose of this study is to explore the status of asthma in the Region of Peel over time and space and determine the factors that may contribute to the asthma patterns. This is a retrospective quantitative study, where all the data collected are from secondary sources. The data will be used to study the pattern of changes over time using Geographic Information Systems (GIS). Statistical analysis is performed to investigate the correlations between dependent variable, asthma outcome, and independent variables such as transportation, industry, park area and socio-economic factors. The key question that has been addressed in this research is:

What is the asthma pattern in the Region of Peel and what are the probable factors affecting it?

A few sub-questions have been addressed to answer this question.

1. **What is the pattern of asthma in the Region of Peel over time and space?**

2. **What are the relevant factors that may explain asthma patterns?**

1.4 Structure of the thesis

This thesis is divided into four chapters. Chapter 2 provides a detailed literature review related to asthma, air pollution and the built environment. It will identify the gaps in literature and it will also specify the aspects that this study will cover in an attempt to bridge the missing links in research on asthma and its determinants.

Chapter 3 describes the methodology for this research. The rationale for selecting the Region of Peel in Ontario as the study area is outlined in the chapter. A detailed description of data collection, data management, and the use of data in GIS and statistical analysis are also explained.

Chapter 4 presents the results from the GIS-based pattern analysis and statistical analysis of correlation. Finally, chapter 5 discuss the findings from the results and provides recommendations. The chapter concludes by identify the limitation of the research and suggests future research trajectories.

CHAPTER 2 Literature Review

The literature review is a comprehensive and critical compilation of research on built environments, air pollution, respiratory illness such as asthma, public health, and planning. The literature reviews are based on systematic literatures collected from text books, peer reviewed articles, journal articles and government documents closely related to the focus statement and non-systematic literature reviews from internet websites, academic notes and experiences, and news articles.

The literature review is divided into four distinct parts. The first part deals with air pollution and will include the definition of air pollution, a brief history of the issue, and a discussion of the different types of air pollution. The second part of the literature review consists of the built environment, and air pollution as it relates to asthma. In the third part, policies and practices are outlined, relating them to land use planning, human health, air pollution, and collaboration of planning and public health. The final part will address the gaps in literatures and identify the specific gaps that this study will attempt to enlighten.

2.1 Air Pollution and its Determinants

2.1.1 What is Air Pollution?

Air is a mixture of gases in the atmosphere. Air pollution occurs whenever the compositions of these gases are affected by contamination (Brunekreef, B. 2002). According to World Health Organization (2013), air pollution is defined as:

... *Contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.*

The World Health Organization categorizes air pollution as outdoor pollution and indoor pollution. According to WHO, US Environmental Protection Agency (USEPA) and Environment Canada, sources of outdoor air pollution are due to combustion of fuels for transport, power generation and other human activities such as home heating and cooking. According to WHO, urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year 2013.

Health Canada has adapted the use of health effects pyramids of air pollution, as shown in Figure 3 (Ayres, 2006). The pyramid shows that a large number of people are affected by

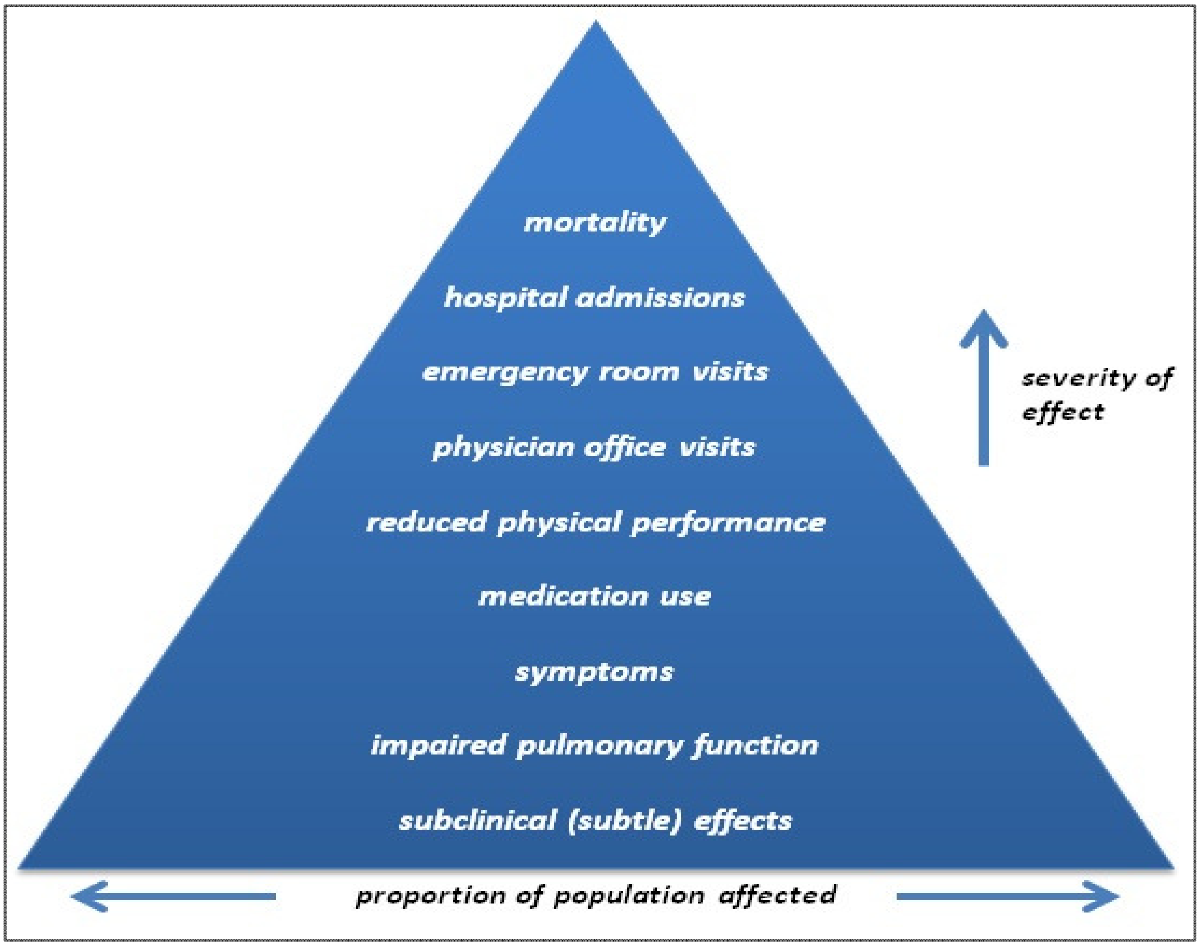

Figure 2 Pyramid of Health Effects of Air Pollution

(Source:http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/health-sante/index-eng.php) minor problems related to air pollution, while the severe impacts affect a much smaller number of people.

2.1.2. Importance of Air Pollution

An average person breaths approximately 3000 gallons of air a day. It is the only necessity that is more important than food and water. If the quality of air is compromised it will affect human health. Literature shows air pollution can have devastating effects on the environment, wildlife, ecosystems, water bodies, human health, the ozone layer, and economy (Dales, 1995; Cohen, et al, 2007; Kessel, 2007; Patel & Miller, 2007; Lee, et al., 2009; Chen et. Al., 2012; Health Canada, 2012; Laumbach & Kipen, 2012). Air pollution can also result in lost days at work and school due to increased (USEPA, 2013). Air pollution also reduces agricultural crop and commercial forest yields by billions of dollars each year (USEPA, 2014). Air pollution is one of the leading causes of cancer, cataracts, respiratory diseases and asthma. In the United States alone, 30 million adults and children suffer with asthma. In Canada, 3 million people suffer chronic respiratory diseases. Every year, statistics indicate 20 children and 500 adults' die of their asthma - a shocking stastic considering 80% of all asthma deaths can be prevented (Asthma Society of Canada, 2010). According to 2010 estimates, chronic lung diseases (including asthma) cost \$12 billion including \$3.4 billion in direct health care costs and \$8.6 billion in indirect costs (Asthma Society of Canada, 2010). The city of Toronto spends \$2.2 billion every year to combat health effects due to air pollution (McKeown, 2007). Due to the high social and financial costs of lung disease, it is important to assess potential sources and determinants of air pollution that degrade the air quality.

2.1.3 History of Air Pollution

Industrialization was rapidly taking place in North America in 1850s. Most of industries were placed near waterways, ports and rail ways in order to increase accessibility (Goklany, 1999). Thankfully, the importance of public health was recognized during the 1890s, when workers health began to deteriorate and there were loss of productivity. The first Public Health Service Act was passed in 1944. In October of 1948, The Donora Smog in Philadelphia, killed 20 people and made thousands ill from emissions from the zinc plant. It was a devastating environmental disaster in the United States. Eventually United States enacted The Clean Air Act in 1970, with major amendments in 1977 and 1990 under the United States Environmental Protection Agency. With regards to air pollution, US Congress has emphasized the importance of managing hazardous and toxic air pollutants, acid rain and its damage to aquatic life, chemical emission that are damaging to the health, and regional haze that cause visual impairment in open spaces (Goklany, 1999). In a Canadian context, air pollution combat was initiated by the *Department of Environment Act* of 1971. The role of Environment Canada is to assess, monitor and protect the environment and provide weather and meteorological information (Environment Canada, 2013). The Canadian Environmental Protection Act was passed in 1999 and included pollution prevention measures (CEPA, 1999; Snider & Smith, 2013). By 2010 air pollutants had significantly reduced in Canadian air (2010 Air Pollutant Emission Summaries and Historical Trends, 2010).

2.1.3 Composition of Air Pollution

In this section the different types of air pollutants, and their effects on human health, will be discussed. Most of the information in this section was sourced from a systematic literature review which considered text books, peer reviewed articles and government documents.

Outdoor air pollutants are derived from natural and human resources. Small portions of released natural air pollutants originate from forest fires, dust from bacteria and fungi, and chemicals from plant and animals (Ayres, 2006). Conversely, more air pollutants are from human activity such as vehicular use, industrial use and burning fossil fuel. The most common pollutants according to Canadian ground measurements are Ozone, Particulate matters, Carbon monoxides, Sulphur oxides (SOx), Nitrogen oxides (NOx) and Volatile Organic Compounds (VOC) (Kessel, 2007). The interaction of these air pollutants with the atmosphere is shown Figure 2.2. Carbon dioxide (CO_2) and carbon monoxides (CO) are the main components of GHGs and reduction of these gases is crucial to combat climate change. The largest source of these gases in Ontario is transportation, which accounts for 68% of the total emission (Environment Canada, 2012). Ozone is produced as intermediate molecules from NOx and VOC reaction near the ground level. Over the last 30 years the ozone layer is seen to be depleting near the Australian and Antarctica continents, increasing the overall temperature of the world by 1.3° Celsius (IPCC, 2012). SOx and NOx are produced from the burning of fuels from vehicles, and heating and industrial processes, which accounts for 94% of all emission in Ontario (Laumbach & Kipen, 2012; Environment Canada, 2012).

Particulate matter are of different sizes, $PM_{2.5}$ ($PM \leq 2.5 \mu m/cm^3$) means smaller particulates of size 2.5 microns in diameter and PM_{10} ($PM > 10 \mu m/cm^3$) means particles of size 10 micros meter (Kessel, 2007). These particles can be SOx, NOx, VOC, dust, pollen, radon etc. Research shows the health impacts of inhaling particle matter can range from breathing problems, asthma, bronchitis, lung cancer and cardiovascular diseases, fatigues and depression (Patel & Miller, 2007; McEntee & Ogneva-Himmelberger, 2008; Rioux et al, 2009). Air pollution can shorten life expectancy by 2 years in adults (Brunekreef, 2002). It is estimated 50% of particulate matter comes into Ontario from the United States, resulting in transboundary pollution (Environment Canada, 2012). Particle matter is the key pollutant that causes asthma (Lin et al., 2002; Villeneuve et al., 2007; McEntee & Ogneva-Himmelberger, 2008; Lavigne et al., 2012).

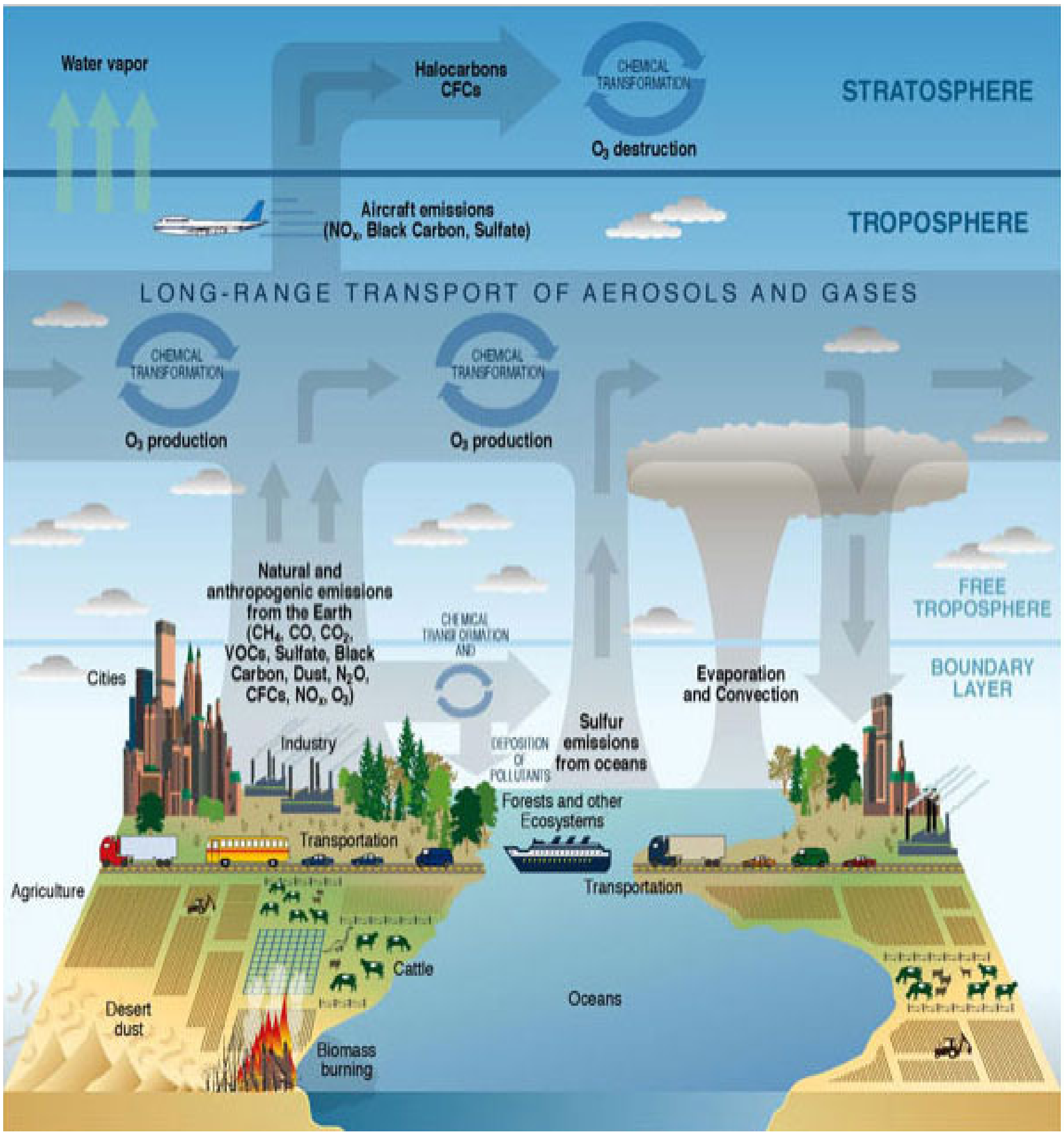

Figure 3Atmospheric Composition (Source:http://www.learner.org/courses/envsci/unit/pdfs/unit11.pdf)

Indoor air pollution has become an important stream of research, with concerns to exposure type, sources, and the impact on health. WHO has concluded that 4.3 million deaths are caused by household indoor air pollution (WHO, 2012). The Canadian Center for Occupational Health and Safety (CCOHS), have related indoor air pollutants to commonly encountered occupational hazards and household hazards (CCOHS, 2012). According to researches, PM≤2.5µm/cm^3 are linearly related to indoor pollutants and linearly related to asthma (Dales, 1995; Cohen et al, 2007; Kessel, 2007; Patel & Miller, 2007; Lee et al, 2009; Chen et al., 2012; Health Canada, 2012; Laumbach & Kipen, 2012). Studies also show housing type like apartments trap more indoor pollution than free-standing houses (Chapter 10, *Clearing the air: asthma and indoor, air exposure*, 2000). Often, the type and condition of housing people dwell in can be representative of their low income status, and therefore their socio-economic status (Chapter 9, *Clearing the air: asthma and indoor, air exposure*, 2000, Brunekreef & Holgate, 2002; Mendall et. al., 2011). While indoor air quality is important to look at when considering asthma incidence, it is beyond the scope of the study.

2.1.5 Who is Impacted by Air Pollution

Some social factors that show association between asthma and air pollution include: socio-demographic variables such as age, income, and education; cultural and personal variables; community isolation; and health disparity. Many systematic literature shows socio-economic status and income often lead people to live in isolated communities with exposure to air pollution and a poor built environment, therefore increasing health disparity (Marshall, 2007; Frank & Engelke, 2005; Northridge et al., 2003; Srinivasan et al., 2003; Landrigan et. al., 2010; Schweitzer & Zhou, 2010; Lopez, 2012; McEntee & Himmelberg, 2008; Sallis et al., 2011). The issue of age is addressed in various studies, highlighting that children are more susceptible to air pollutants due to their small size and increased exposure to outdoor and indoor pollution (Frank & Engelke, 2005; Landrigan et al., 2010; Barrett, 2011; Amram, 2011). Conversely, elderly people are also more vulnerable due to their sedentary lifestyle, complex relations to chronic illnesses like cardiovascular, obesity, mental illness and degeneration due to aging (Schwartz, 1994; Devlin et.al., 2003; Schweitzer & Zhou, 2010; Sallis et.al., 2011; Lopez, 2012). The literature also emphasizes that other SES factors can often increase exposure and further endanger the health of vulnerable populations.

Another body of research suggests that exposure of pollutants can make a big impact on people's general health. According to a systematic literature review of place-based effects on health, it is seen that social disparity, SES factors such as education, employment, household income, affordable housing, ownership of property and assets, and being a visible minority, can often cluster vulnerable population into weak communities and lack of awareness and motivation, can make these population more susceptible to air pollution exposure (Macintyre et al., 1993; Roux, 2003; Sallis et al., 2011). In the future, more research should be directed to investigating the literature gap that exists in revealing the relationship between social factors and the built environment.

2.2 Built Environment, Air Pollution and Asthma

The literature suggests that the built environments produces air pollution. When ambient air quality deteriorates it has the potential to cause asthma. The following section explains the relation between asthma, air pollution, and the built environment.

2.2.1 Measure of air quality

Studies suggest that air quality measures are related to asthma outbreaks. Measures such as the Air Quality Index (AQI) are useful indicators to identify the level of pollutants in the air. The USEPA database suggests days with higher AQI are considered to cause respiratory outbreaks, especially asthma. According to To (2012), a study from the Institute of Clinical Evaluative Sciences correlated different Air Quality Health Index (AQHI) with hospitalization due to asthma in different local health networks in Ontario. Designated "Smog days" are an alternative measure, as it accounts for all types of air pollutants (Brunekreef & Holgate, 2002; Public Health Agency Canada, 2007; Environment Canada Publication Report, 2012). The aforementioned studies show that on days that are recorded as having poor air quality, the potential for asthma-related emergency room visits increases.

2.2.2 Asthma and Transportation Systems

Evidence suggests asthma incidences correlate strongly with transportation emissions. According to clinical findings, traffic related air pollutants such as fine particulate matter of $PM \leq 2.5 \mu m/cm^3$, $PM > 10 \mu m/cm^3$ and black carbon particles can potentially trigger asthma outbreaks (Patel & Miller, 2009).

Proximity to highways and major arteriole roads play an important part in exposure to pollutants (Finkelstein et al., 2004; McEntee & Himmelberg, 2008). As mentioned earlier, Hitchins et al., (2000) dispersion models of particulate matter suggest $PM \leq 2.5 \mu m/cm^3$ and $PM > 10 \mu m/cm^3$ diffuse in 375 m away from transport corridors. Another study identifies that local pollution exposure, coupled with long term effects of living near transport corridors, can result in the development of asthma (Barett, 2012). In addition, the number of vehicles moving through corridors have the potential to effect the concentrations of particulate matter (Patel & Miller, 2009). Therefore, transportation corridors and vehicular traffic can be considered asthma triggers (Srinivasan et al, 2003; Finkelstein et al., 2004; Stone et al, 2007;

Schweitzer & Zhou, 2010; Rioux, 2010; Lopez, 2012).

2.2.3 Asthma and Hazardous Sites

A study by Sahsuvaroglu et al. (2010) in Hamilton explains that exposure to airborne pollutants (from hazardous materials such as crude oil) may aggravate the respiratory symptoms of asthma (Sahsuvarogluet al, 2009). Hazardous sites can release complex chemicals, like particulate matter, that are potential triggers for asthma (Seinfield & Pandis, 2006; Patel & Miller, 2007). Another study by McEntee & Himmelberg (2008) found a strong correlation between asthma and proximity to industrial areas. Landrigan et al. (2010), present a troubling human element to this reality, as their study determined that people living in or near industrial areas often have a low socio-economical status.

2.2.4 Asthma and Green Spaces

There are ample findings that support asthma triggers can be neutralized and asthma can be mitigated with open spaces and urban greenery (Beckett et al., 1997; Frank & Engelke, 2005; Juhn et al., 2005; Stone et al., 2012; Villeneuve et al., 2012). Other studies suggest street trees and small patches of greenery are beneficial even if the provision of urban woodland is not possible (Nowak et al, 2005; Zanderberg, 2009). In another study by Juhn et al. (2005) suggests neighborhoods with open spaces and parks are seen to have fewer people suffering asthmatic disorders. Open spaces and parks are places where children can get adequate physical activity and increase their breathing capacities, therefore better equipping them to fight asthmatic symptoms (Frank & Engelke, 2005). It can be concluded that open spaces are good for asthma prevention, as well as general physical health.

2.3 Addressing Literature Gaps

- Knowledge from scientific research, policy review and health research will be integrated to investigate the status of asthma due to air pollution and the built environment, and evaluate policies on air pollution and land use planning.
- This study will look into a specific regional municipality of Ontario. Most of the work relating the built environment to chronic disease pertains to cardiovascular diseases, respiratory diseases, obesity and others; research linking the built environment to asthma specifically is lacking. This study will look into asthma and its probable relation to the built environment.
- The study will try to find a relationship between the built environment and asthma outcomes. The built environment will be categorised by transportation, industrial, green space and socio-economic factors that were identified in the literature. In order to understand the present status of asthma, retrospective studies will help in identifying the practices of the past and present.

2.4 Re-iterating the Research

The intent of this observational retrospective study, is to relate built environment factors such as transportation, industrial emission, park area and socio-economical factors to asthma. In the study, spatiotemporal methods and statistical analysis will be used to establish a relationship between asthma and the determinants mentioned, based on empirical evidence. At the same time, literature review of policies, guidelines, governance and practice will be explored that are related to determinants of asthma, land use planning and public health.

CHAPTER 3: Research Design and Method

In order to best investigate the research questions, the research method selected was quantitative analysis based on secondary data. As mentioned in the literature gap, no study had conducted empirical research that can relate the changing trends of asthma with the determinants of built environment at a regional level. This is a retrospective study and the scale of analysis is at a regional level, therefore a quantitative method was more appropriate. The data used in this research was considered classified, but due to open access policies at the Region of Peel, secondary data was accessed and used. This is a spatiotemporal study observing the changes over a period of 2007 to 2011.

3.1 Research Design

This is a non-experimental, observational, retrospective, longitudinal, quantitative study using spatial pattern analysis. Being an observational quantitative study, the identified dependent variable is asthma emergency department visits and the independent variables are transportation factors, industrial factors, park areas, environmental factors and socio-economic factors. The study will measure the association between the dependent and independent variables using statistical analysis.

The research design was established based on literature reviews of different methods. According to Creswell (2003), quantitative studies are deductive in nature. Therefore, any quantitative research design has measureable variable (Morgenstern, 1995). Quantitative study specifies the dependent and independent variables, attempting to bridge these variables, which may be related but may not be causation relation (Creswell, 2003). According to Mann (2008), retrospective studies are based on available data and can be used to study a single outcome of health. This is an advantage, as retrospective studies lack bias. Time trend designs are longitudinal studies and can provide essential elements of population's health status (Morgenstern,1995). These kind of study facilitates the observation of changes in health outcome patterns compared to health outcomes in a specific geographic area, and compares health status following interventions across a period of time.

In this study both independent (transportation factors, industrial factors, park areas, environmental factors and socio-economic factors) and dependent variables asthma emergency department visits (asthma ED visits) are measurable and identified. The study is based on single health outcome over a specific geographic area of Region of Peel and time period of 2007 to 2011.

3.2 Research Approach

In order to address the research question, this study employs a quantitative research method, as mentioned. The primary research question as established in Chapter 1 is: ***What is the asthma pattern in the Region of Peel and what are the probable factors affecting it?*** To answer this question, three specific research objectives will also be addressed:

1. To assess the pattern of asthma in the Region of Peel over time and space.
2. Investigate the relevant factors that may explain asthma patterns.

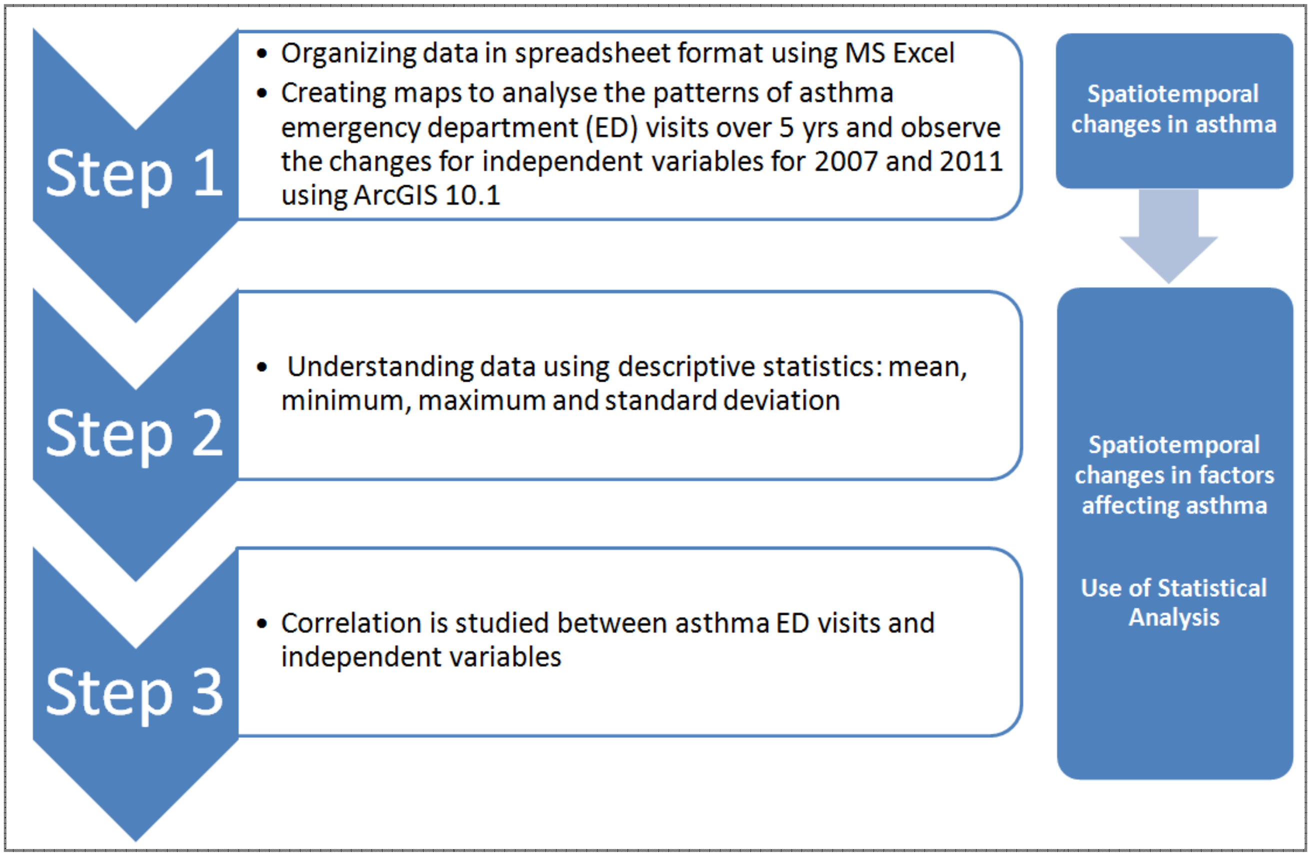

Figure 4 Research Approach

In order to address all the research objectives, the research design indicates the methods by which the available data was used to address the research objective (Figure 3.1).

3.3 Study Area

The Region of Peel was the selected study area for high Ontario Health Insurance Plan (OHIP) claims due to asthma, high AQHI records (OASIS, 2012) and asthma data available over time. As of 2011, the Region of Peel has a population of 1.3 million, showing an increase of 8% from 2006 (Statistics Canada, 2013). The region consists of three major urban growth centers, identified under the Growth Plan: Mississauga, Brampton, and the town of

Caledon (Places to Grow, 2006).

The Public Health Department at the Region of Peel provides open access to the Peel Data Center, where certain data are available for different health issues and diseases. The health data is divided into 15 data zones as shown in Figure 3.2. Data zones are defined as geographic areas within the Region of Peel that are smaller and more manageable. Based on 2011 municipal data, data zones are home to average 25,000 to 105,000 people (Dracley et al., 2011; Region of Peel, 2012). Caledon's data zones are less populated and are home to about 22,000 to 35,000 people, while data zones in Brampton and Mississauga have a larger population range from 75,000 to 105,000 (Dracley et al., 2011; Region of Peel, 2012). The data zones were contiguous, followed census tract boundaries, and avoided cases where zones were encircled by other zones. The data zone allocation respected natural and man-made boundaries such as rivers, highways and municipal boundaries (i.e. data zones are entirely within municipalities) (Dracley et al., 2011).

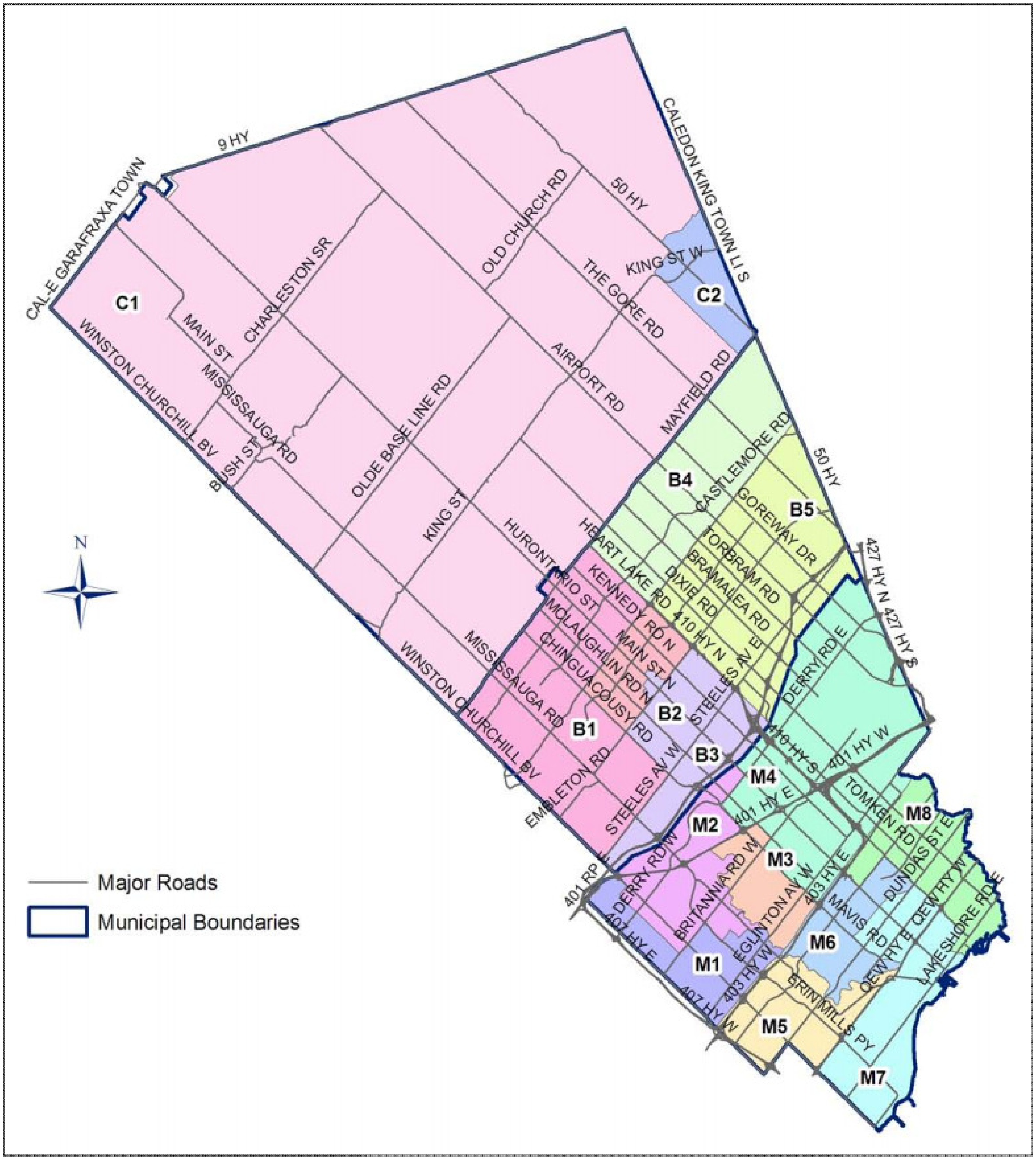

Figure 5 Map of Region of Peel (Source: Peel Data Centre, Region of Peel)

3.4 Data Collection

3.4.1 Asthma Data

The data for this particular region was obtained from Peel Data Centre. Under the Public Health Department website, respiratory diseases are categorised as lower respiratory illness and asthma. The dependent variable of this study was selected as asthma Emergency Department visits (ED visits). The Region's Public Health Department has acknowledged that all asthma data were sourced from Intellihealth Ontario and Canadian Community Health Survey, collected from the National Ambulatory Care Reporting System Data for the year 2007 to 2011; the Intellihealth Ontario, Ministry of Health and Long-Term Care Population 2007-2011; Tax files data, and Statistics Canada. Data were available for all 15 data zones of the Region of Peel, categorized by years, age and sex.

In order to reduce the impacts in the differences in the number of population at the data zones, the asthma ED visits was calculated per 1000 population. Figure 6 shows how the raw data was processed into the required form. These data were from 2007 to 2011.

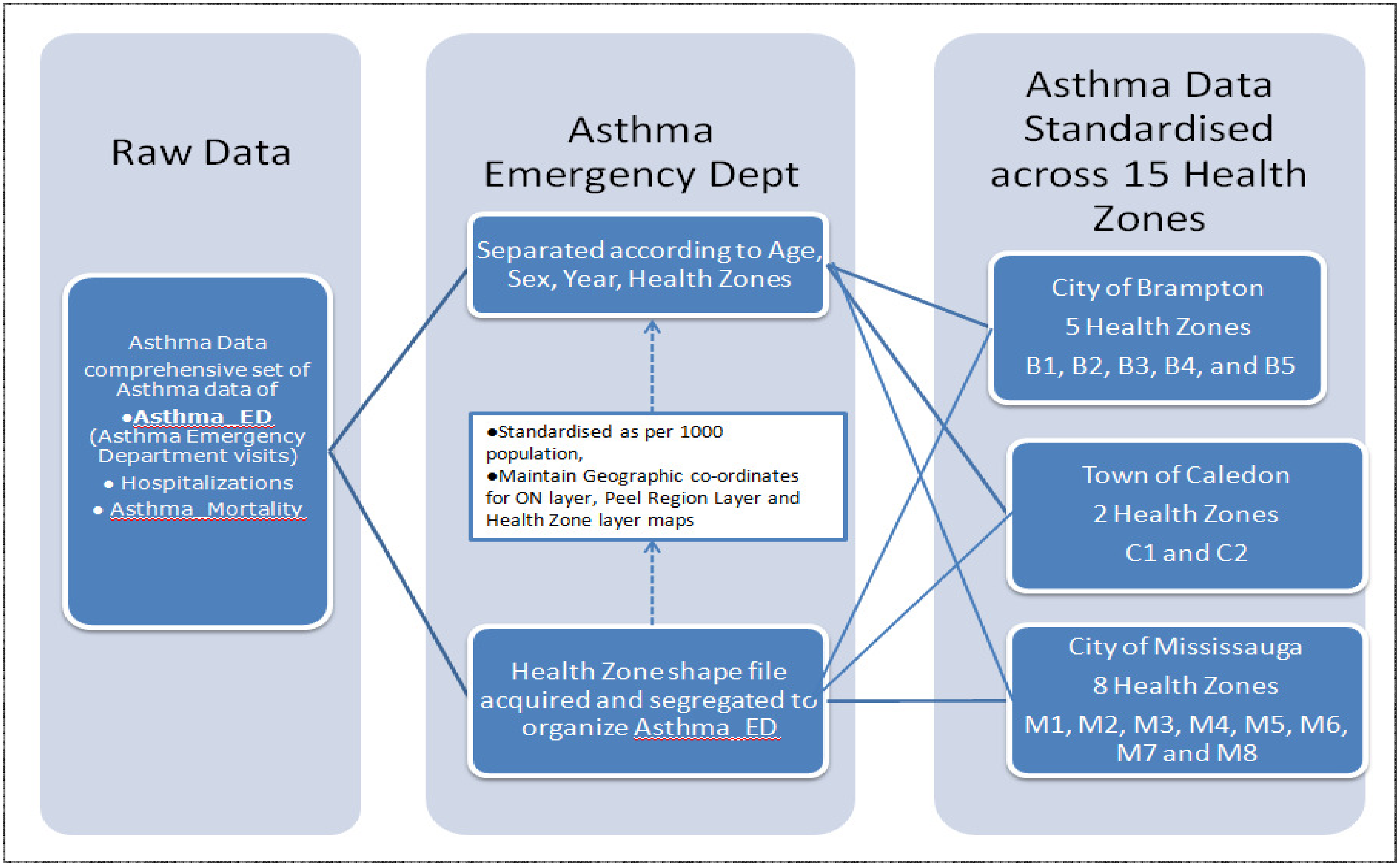

Figure 6 Dependent Variable Asthma Emergency Department Visits and Data organization

3.4.2 Independent Variables

The independent variables are transportation, industrial, environmental factors, parks area and socio-economical variables. All these variables originate from open source data retrieved from the Peel Data Center. The raw data were acquired, arranged and categorized into tables using MS-Excel in Comma-Separated-Values or CSV format.

Data Land Use Data: The Land Use data for the Region of Peel were acquired from the Geospatial Library of the University of Waterloo for the years 2007 and 2011. These data sets are available in UTM co-ordinates; horizontal datum is NAD 83 UTM zone 17.

Transportation data: The transportation data were secondary data collected from several different sources.

1. Data was obtained from Peel Data Center, in spreadsheets and shape files format. It contained Annual Average Daily Traffic (AADT) information from 2001 to 2012 that included geographic co-ordinates, related road names and intersections. (See Appendices A and B).
2. The second source of data was from the open source iCorridors from the Ministry of Transportation, Ontario. This source was specifically used to get AADT data for highways. The highways that goes through Region of Peel are 401 (EW), 410 (NS), 427, 409 (extension to Airport), 407 (EW) and Queens Elizabeth Way (EW) (Appendix C shows a sample of the interactive map and data management from iCorridors, MTO).

All the records of AADT across Ontario in iCorridors are available in 10 year intervals, from 1988 to 2008. The data for 2009-2011 was extrapolated by seeing the previous trend and the growth of the region. Comparing the trend over five years shows that AADT increased on an average of 2500 vehicles. From this AADT increase, the data was extrapolated for 2009 to 2011 by the researcher.   Figure 7 shows how data were retrieved for 2007 and 2011, layered into maps and then calculated for each health zones.

In order to gather the total number of vehicles used in AADT, the traffic count stations were located for each of the data zones. For example, B4 had 58 traffic count station IDs for both highway and road intersections. The AADT for all the 58 traffic counts stations were averaged. Also the traffic count stations at the borders between two adjacent data zones were also considered, in order to reduce the underestimation of AADT in each zone. This was done for all 15 data zones.

According to the literature, airports can produce air pollutants like particulate matters of 2.5µm and less, (Swan & Lee, 1980; Moussiopoulos et al., 1997; Otto et al., 2004; Cohen et al., 2007; Picker, 2012). According to Cohen et al., (2007), neighbourhoods near airports can have poor air quality, and proved a negative relation of health outcomes to the distance from airport. Distance of data zones away from the airport was used as a variable for this research. The airport data zone is M4, and centre point or centroid was located for all the data zones. Figure 3.5 presents how the distance from airport data zones centroid were calculated to other data zone centroid.

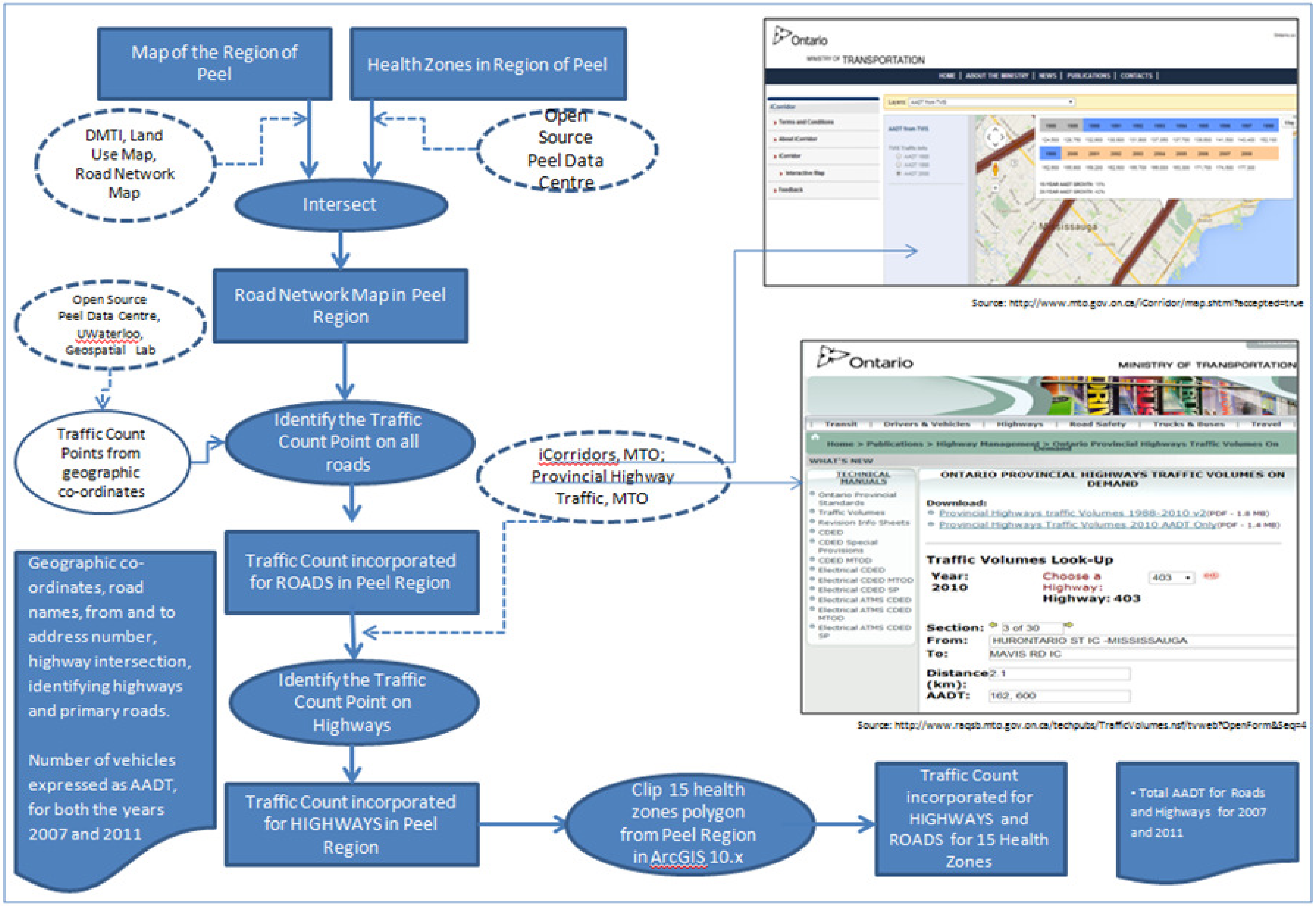

Figure 7 Organizing Average Annual Daily Traffic Data

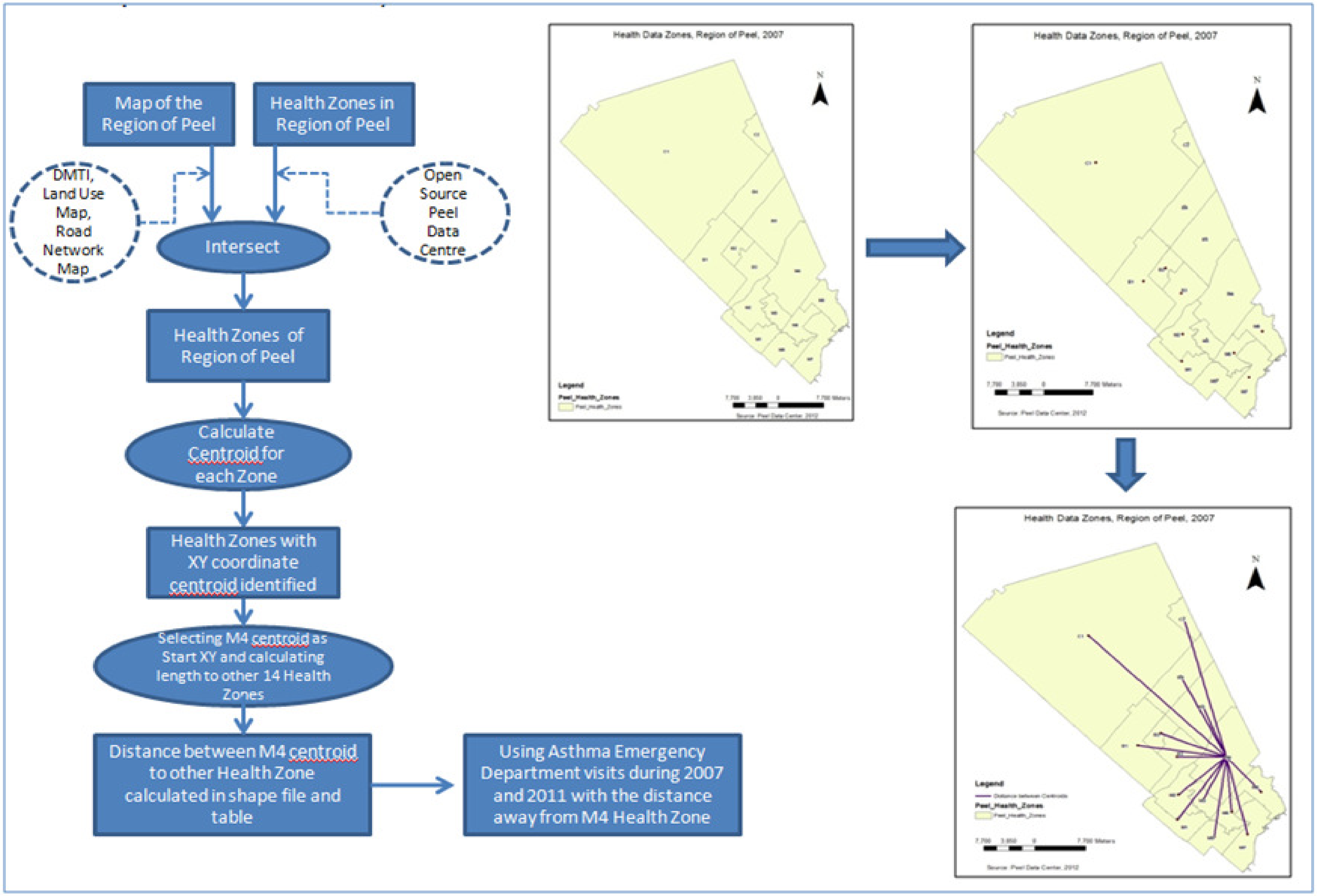

Figure 8 Calculating Distance from the Airport Data Zone to other Data Zone

Industrial Data: Industrial data were collected from the National Pollutants Release Inventory (NPRI), a gazetteer under the Environment Canada, by tracking pollutions from all sources. NPRI provides interactive screening option to find information on types of pollutant, emission category, and industry. The pollutants considered for this study are particulate matter of 2.5μm and less diameter (PM$\leq 2.5\ \mu m$); as the literature suggests, PM$\leq 2.5\ \mu m$ are considered as potential triggers in asthma (Kessel, 2006). Particulates can be of biological nature (like pollen), vehicular emission, intermediate pollutants etc, however, studies have revealed that particulates from vehicular emission have greater potential to cause asthma than other allergens (Seinfield & Pandis, 2006; Kessel, 2006; Patel & Miller, 2007; Rioux et al., 2009).

The data collected were according to the City of Brampton, City of Mississauga and Town of Caledon. It consisted of geographic co-ordinates, emission quality and quantity and industry name and type. For instance, Mississauga has 33 units of industries whereas Brampton has 25 units of industries and Caledon has 2 units of industries, as of October, 2013 (NPRI, 2013). A sample of NPRI open source data of different industries producing air pollutants of PM$\leq$ $2.5\ \mu m/$cm3 is shown in Appendix D).

Figure 9 demonstrates how the industrial emissions, industrial names, addresses of the industries were located and how they are mapped and classified into 15 data zones. It also calculated the industrial land use area per data zones. Industrial emission was not average as its cumulative emission was calculated for each of the data zones.

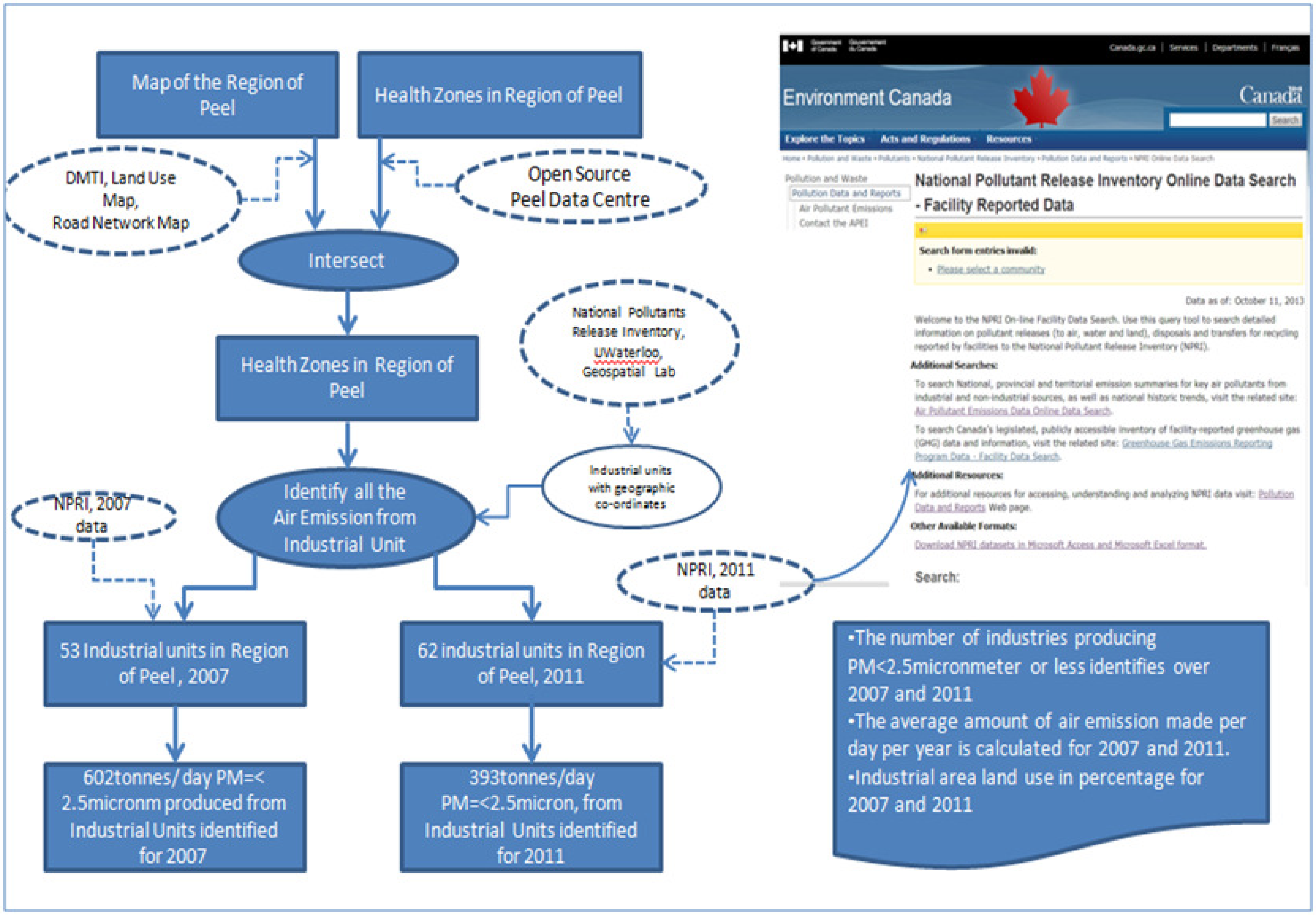

Figure 9 Collection of Industrial Pollutants Record from National Pollutants Release Inventory

3.4.3 Parks and Recreation Data: Parks and Recreation data were accessed from the Geospatial Library at the University of Waterloo. The researcher was able to obtain archived data on parks, open spaces, recreation centers, and conservatory areas in the region of Peel for 2007 and 2011. Since the category of parks and recreation comprises of broad spectrum of land uses, only parks and conservatory areas were considered; open spaces, agricultural areas, water bodies and greenbelts were excluded from the study (Beckett et al., 1997; Frank & Engelke, 2005; Juhn et al., 2005; Stone et al., 2012; Villeneuve et al., 2012). Figure 10 illustrates how the parks and recreation land use areas were calculated.

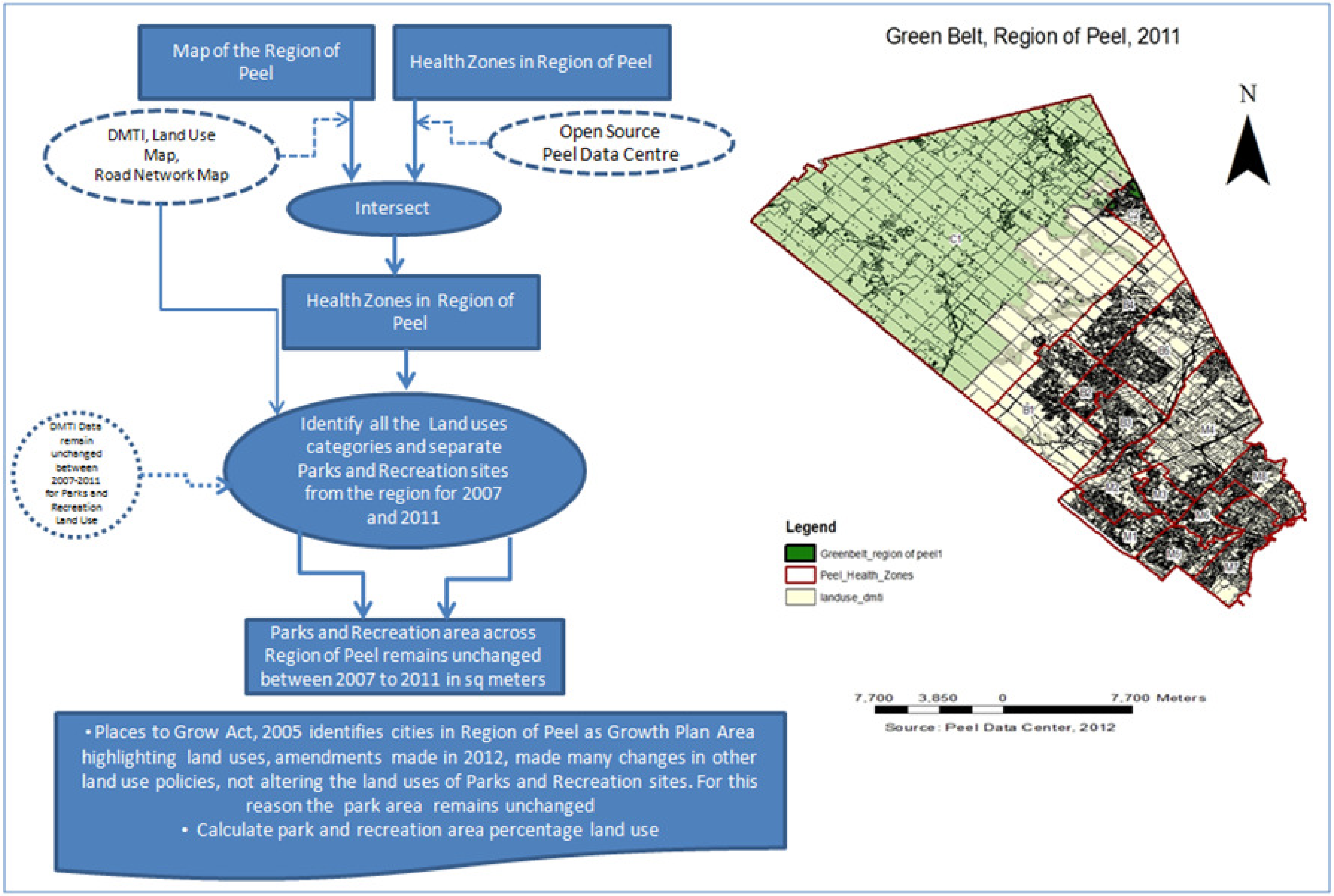

Figure 10 Calculation of Park and Recreation Area

3.4.4 Demographic and Socio-Economic data: The demographic data and socio-economic data were gathered from the open access Peel Data Center and the Region of Peel's Socio-demographic data sources. The data were originally sourced from Statistics Canada and distributed by the Ontario Ministry of Health and Long-term Care. The data were originally collected from the Census 2006 Census 2011. All data covers for the 15 data zones for the Region of Peel.

Demographic information and socio-economic data are important, as they provide a basis for profiling areas according to the people living in the region (Cohen, 2007). While demographics provide information on gender, age, population at risk, employment, ethnicity and location, socio-economic data is the social position of an individual's (or family's) economical situation based on education, employment, household income, access to health care, access to amenities, affordable housing, ownership of property and assets, and visible minority (Eisner, 2000; Macintyre et al., 2002; Giles-Corti, 2006; Pearce et al., 2007; Asanin, & Wilson, 2008; Macintyre et al., 2008; Pickett &Wilkinson, 2008; Adler & Stewart , 2010; Ballas & Tranmer, 2012; McMahon, 2012). Therefore, based on these investigations and the available information from the Region of Peel, the factors selected for socio-economic demographics study are population at risk, income after taxes, and prevalence of low-income population, education and employment. Figure 11 shows how the other socio-economic variables and environmental factors were retrieved from the Region of Peel open source data for the year 2007 and 2011.

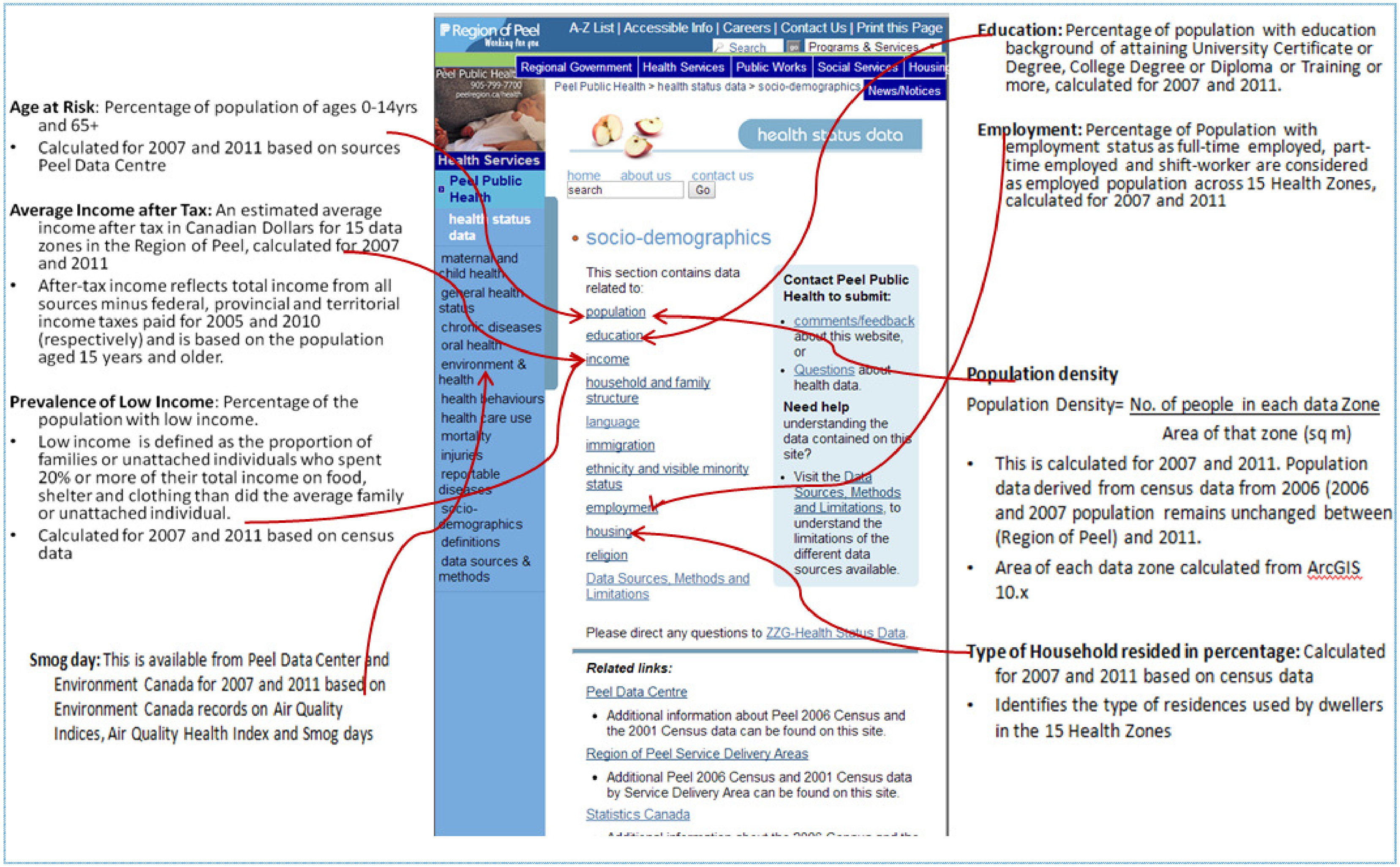

Figure 11 Data retrieved from Region of Peel Open Data Centre

3.4.5 Environmental Data: Environmental data includes outdoor air quality and indoor air quality. The quality of outdoor air plays a vital role in triggering asthma outcome (Cohen et al., 2007; Lavigne et al., 2012). In order to assess outdoor air quality, smog days can be considered a potential indicator. However, smog day data is only available at the city level and not for the individual health data zones. In addition, indoor air quality can be further deteriorated if the household inhabitants are cigarette smokers, which increases the chances of respiratory diseases ranging from asthma to lung cancer (Chapter 7, *Clearing the air: asthma and indoor, air exposure*, 2000; Bernstein, 2009; Lee et. al., 2009; Patrick, 2013). According to Cohen B. S et al. (2007) indoor air pollution can get trapped in internal housing ventilations, especially in cold seasons, which can increase allergens and pollutants to incite respiratory illnesses like asthma, a fact also supported by other studies (Kessel, 2007; Patel & Miller, 2007; Laumbach & Kipen, 2012; Chen et al., 2012). Other studies have also shown that housing type such as apartments trap more indoor pollution than free-standing houses (Chapter 10, *Clearing the air: asthma and indoor, air exposure*, 2000). Often, the type of housing people dwell in can be representative of their prevalent low income status (Chapter 9, *Clearing the air: asthma and indoor, air exposure*, 2000, Brunekreef, B., & Holgate, S. T., 2002; Mendall M. J., et. al., 2011;). For this reason, the type of housing can be determined from the prevalence of low income, like a collinear factor.

3.5 Analysis

The focus of the analysis was dependent on the research objectives.

3.5.1 Spatiotemporal Analysis:

The first research objective sought to ***"assess the pattern of asthma outcomes across the Region of Peel over time"***. This is Step 1 of the research design. There were two purposes in this research objective:

1. Investigate the trend of asthma ED visits from 2007 to 2011

2. Investigate the difference between asthma ED visits in 2007 and 2011.

In this step, all the data on asthma ED visits and population over the five years, across the 15 health zones were calculated in MSExcel to get asthma ED visits per 1000 population.

Spatiotemporal analysis was done by observing the spatiotemporal changes, using geographic information system (GIS). The use of Geographic Information System (GIS) in planning and health research cannot be over emphasized, as the literature has already addressed (Hitchen, J., 2000; Ardal, S., *Health Planner's* Toolkit, 2006; McEntee, J. C., & Ogneva-Himmelberger, Y., 2008; Darcley et, al., 2011; Lopez, R., 2012; Davis, P., & Scott, A., Chapter 9, 2013). ArcGIS 10.1 version was used for creating choropleth maps for the temporal study of asthma ED visits per 1000 population pattern across 15 health zones for five years between 2007 to 2011. The shape file of Health Data zones can be accessed upon request from the Peel Data Center.

3.5.2 Statistical Analysis

The second research objective was to ***"investigate the relevant factors that may explain the asthma ED visits trend".*** Step 2 and 3 of the research design were used to address the second research objective. The relevant factors are the independent variable of the study. Based on relevant literature, three categories of independent variables were identified. These categories are: the built environment, socio-economic variables and environmental conditions, as shown in Figure 12.

- It has been identified that the built environment can have probable effects on asthma outcome due to transportation factors, industrial emission, and total areas of parks and recreations.
- Socio-economical variables, such as populations at risk, average income after taxes, population with employment, education, and prevalence of low-income population, as identified in the literature, shows significant effect on asthma outcomes.
- Environmental factors are due to exposure in the outdoor air. Smog days are better representative for outdoor pollution; however, data is not available for health zone level.

In addressing the changes in relevant factors, spatiotemporal analysis was employed, using GIS. This will enable the illustration of the temporal changes in all the independent variable in 2007 and 2011.

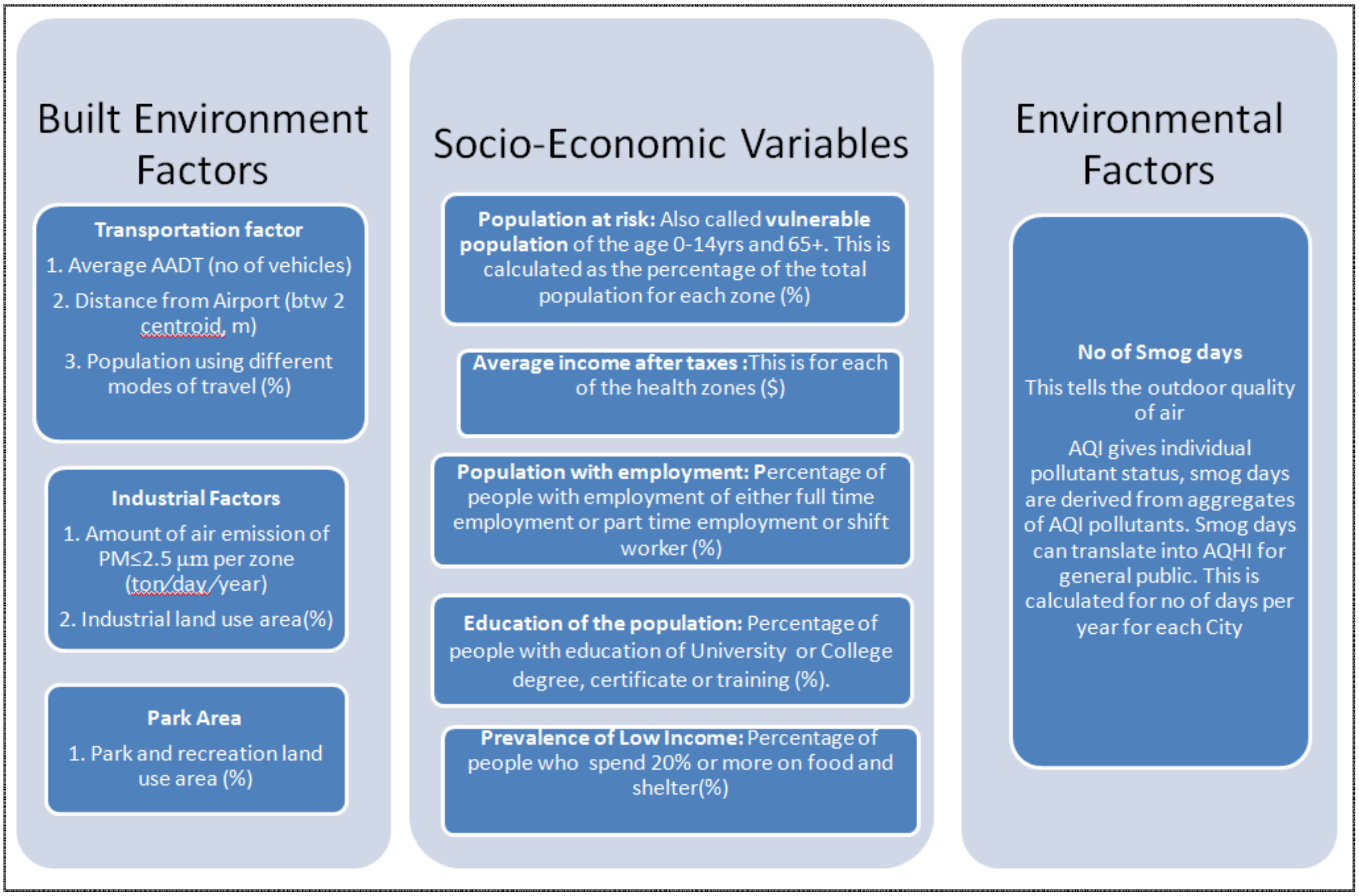

Figure 12 Independent Variable Categories

Statistical analysis is commonly used in health researches. Health research is an interdisciplinary area of study, as it often requires qualitative and quantitative methods to fully understand health implications. The literature suggests that while qualitative methods of research gives exploratory facts, the basis of health research centres around quantitative analysis (Finkelstein et al., 2005; Argyrous, 2013). Quantitative methods look for statistical relationship between patterns of health and population. Statistical analysis has enabled researches to better represent, assess, evaluate, implement and manage data sets in order to generalize trends and explain new incidences in all genres of health related studies, as referred by the Association of Faculties of Medicine of Canada (2012). For the purpose of this study, which is not an epidemiology study, statistical tools are used to see the relation between asthma emergency department (ED) visits and other independent variables. The statistical analysis is divided into two distinct parts.

Descriptive Statistics: Descriptive Statistics gives a general summary of the sample of data. Descriptive statistics are the average, minimum, maximum and the standard deviation. It will give a synopsis of the changes of variables between 2007 and 2011. Many studies use descriptive statistics to provide basic information on the population of the study or the study area (Finkelstein et., al., 2005; Cohen, 2007; De Veaux, 2008; Lee et al., 2009; Lavigne, 2012; Argyrous, 2013). These statistics were calculated in MS-Excel for all the variables.

Correlation Analysis: To assess possibility of associations between the dependent variable (asthma ED visits in per 1000 population) and independent variables, correlation analysis was conducted. It Correlation was calculated in data analysis function of correlation in MS-Excel. This function enabled a series of numbers that provides two important factors: first how strong the correlation is (if number was towards 1) and second the direction of the correlation (directly related or inversely related). Correlation Coefficient was used to represent correlation between dependent variable and independent variables. These statistical analysis tools were used to address the second research objective of the research.

3.6 Summary

This chapter has discussed the research methodology and data collection methods used in the study. First, the research design was explained along with the research question and objectives, and the use of a retrospective and longitudinal, quantitative research method was justified. Second, the most suitable research approach to the research question were discussed. Third, the data collection and data organization methods were elaborated and secondary sources of data were identified. Finally, the data analysis themes of spatiotemporal analysis, statistical analysis and policy review analysis were briefly discussed.

CHAPTER 4: Research Findings

This chapter presents the research findings using the methodology discussed in the previous chapter. This chapter provides an overview of the data zones and the relationship of different variables' spatial pattern of asthma outcomes from 2007 to 2011. To identify the factors that were closely related to the asthma, emergency department visits were further analysed through correlation analysis. Key policies were reviewed and commented upon. A summary is provided on the interpretation of the results to analyze the relationship of built environment to its effects on asthma health on the population.

4.1. Pattern of Asthma Across Data Zones

In order to meet the first research objective, the spatiotemporal changes in the asthma emergency department (ED) visits per 1000 population per year for the 15 data zones from 2007 to 2011 were examined. The results are shown in Figure 13, where the areas in dark orange represent high emergency visits and the areas in lighter shades of orange represent lower incidences of visits. For the entire Region of Peel, a 6% decrease in asthma emergency visits was noted. An increasing trend in emergency visits was observed in health zones B4, and M3 and B5 remained relatively unchanged. A decrease in the number of visits was observed in all the remaining health zones.

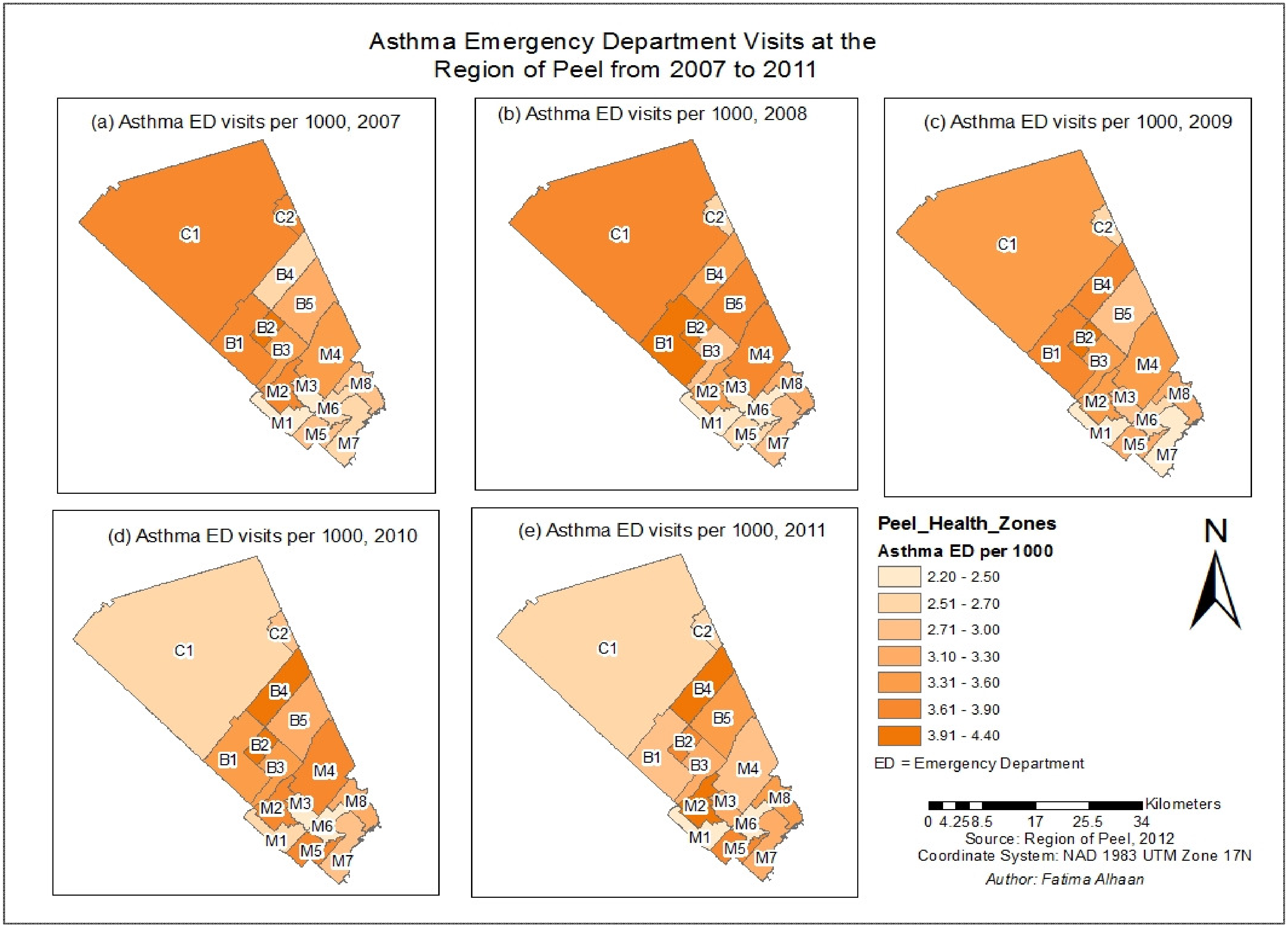

Figure 13 Asthma Emergency Department visit over the period of time 2007 to 2011

To quantify the changes in asthma emergency department visits between 2007 and 2011, the difference in the number of emergency department visits was calculated. The results are presented in Figure 14, where the count of the asthma emergency visits for 2007 and 2011 (14a and 14b), changes in the number of visits (increase or decrease) between the years (14c), and the percentage changes (14d) are shown. From Figure 14c, a major increase in the number of visits in zone B4 was observed as the number of visits increased from 2.7 and 4.3 per 1000 population between 2007 and 2011 and a relatively small increase in zone M3 was identified. However, health zones C1, B2 and M4 have shown a decrease in the number of visits by 2 per 1000 population. An insignificant decrease of 1 visit per 1000 population was observed in zones M1, M2, M5, M6, M7, M8, B3 and B5 between 2007 and 2011. The percentage of changes in the number of visits were calculated; 9% increase in zone B4, 6% increase in zone M3 and 15% decrease in zones C1, C2 and B1 were identified. Small increase of 3% in the number of emergency visit was observed in the remaining of the health zones.

Therefore the first research objective was identified, where the pattern of asthma ED visits per 1000 population showed a decrease in emergency visits by 7.2% from 2007 to 2011. The data zones that showed an increase in asthma ED visits per 1000 population were B4 and M3. The Data Zones that showed most decrease in asthma ED visits per 1000 population were B1, M4, C1 and C2.

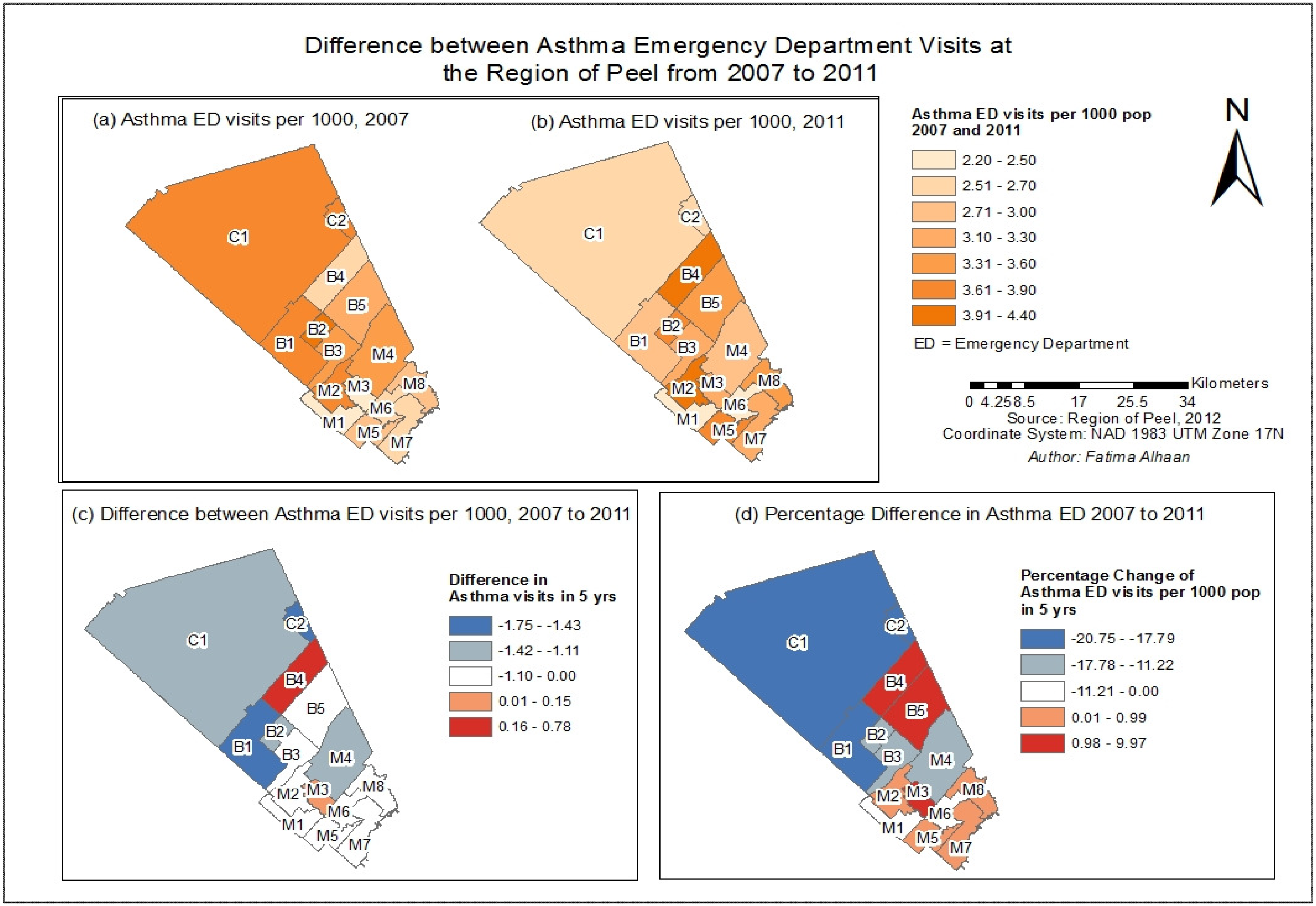

Figure 14 Asthma Emergency Department visit per 1000 of population between 2007 and 2011

In order to answer the second research objective, further spatiotemporal analysis was conducted, as explained from section 4.2 to 4.6.

4.2 Transportation Factors and Asthma Outcomes Results

After patterns of asthma were analyzed over the five year period (2007-2011), the selected transportation variables with the potential to influence asthma emergency visits were examined. The transportation variables that were analyzed are:

- Average Annual Daily Traffic, AADT
- Distance from the Airport
- Percentage of population using different modes of transport

4.2.1 Average Annual Daily Traffic (AADT)

For the year 2007, high values of AADT was identified in health zones M1, M4, M5 and M6 with the highest daily traffic of more than 45000 to 75000 vehicles per day. Low values of AADT were found in zones C1 and C2. The remaining health zones ranged from moderate to high AADT values of 35000 vehicles (as shown in figure 4.3).

An increase in the average AADT was observed in the Region of Peel in 2011. On average, there has been an increase of approximately 20,000 vehicles across all the health zones, however, a major reduction in the average AADT in M3 and M6 was identified as shown in Figure 4.3. No change was observed for the health zone C2 (as shown in figure 4.3).

Table 4.1 and Figure 4.3(c) depict the average changes for AADT over the five years study period. Table 4.1 also provides information on percentage changes in the asthma emergency department visits in order to understand the relationships between the changes in average AADT and emergency department visits. A negative percentage change indicates a decrease in AADT and emergency visits, and a positive percentage change indicates an increase in average AADT and emergency visits. Looking at the percentages in AADT from Table 4.1 and the Figure 4.3(c), it can be concluded that M1, B4, B5 and C2 have shown a major decrease in average AADT, and the other health zones have particularly in M3 and M6 a major increase in average AADT.

Table 1 Percentage Changes in Average AADT

Health Zones	Avg AADT 2007	Avg AADT 2011	Change	Percentage change in AADT 2007-2011	Percentage change in Asthma ED Visit 2007-2011
M1	55323	44502	-10821	-24.32	-6.50
M2	31021	29598	-1423	-4.81	0.11
M3	37685	56787	19102	33.64	6.09
M4	48527	56570	8044	14.22	-15.34
M5	52439	60780	8341	13.72	0.68
M6	34426	71229	36803	51.67	-12.92
M7	30259	30220	-38	-0.13	0.97
M8	32720	36408	3688	10.13	0.99
B1	20622	20565	-57	-0.28	-17.79
B2	38942	47252	8311	17.59	-12.48
B3	36606	33273	-3333	-10.02	-11.22
B4	28833	24504	-4329	-17.67	9.97
B5	45878	34376	-11502	-33.46	4.37
C1	8396	7321	-1075	-14.68	-20.75
C2	19463	13070	-6392	-48.91	-20.46

After comparing Figure 15 and Table 1, AADT increased in percentage in M4, M6, M8 and B2 and there was a decrease in asthma emergency department visits. In zones M3 and M5, the daily traffic percentage increased and an increase in asthma emergency department visits were identified. However, zones M2 and B4 showed a decreased percentage in daily traffic values with an increase in asthma emergency department visits. Nevertheless, a decreased percentage of daily traffic and decreased percentage of asthma emergency department visits were identified for zones M7, B1, B3, B5, C1 and C2. As a result, some relationships between the variables were anticipated; however, further statistical analysis was required to confirm its validity.

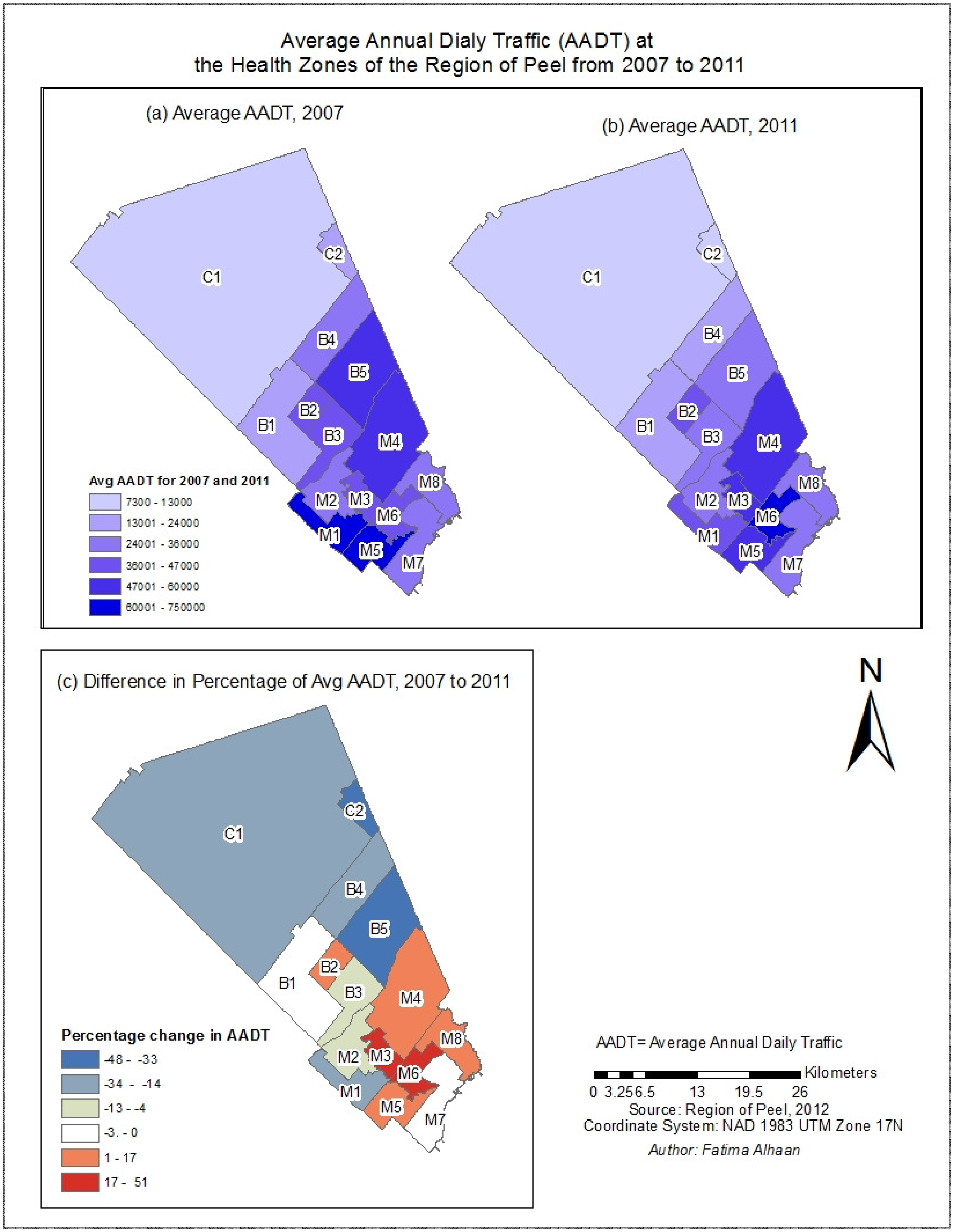

Figure 15 Average AADT over 2007-2011 and the difference

4.2.2 Distance from the airport

Located within the Region of Peel, Pearson International Airport, also known as Greater Toronto Area Airport, GTAA, facilitates 400,000 regional and international flights a year (City of Mississauga, 2012). According to the report on 'Air Pollution from Airport' by the Toronto Public Health, airport services are identified as a key contributor to the degrading neighbourhoods' air quality adjacent to airports (Toronto Official Plan, 2009). Thus, distance to airport is an important factor to consider. The distance from the airport located in zone M4 to the other health zones are shown in Figure 16.

From 2007 to 2011, the total area of the Region of Peel and the health zones had not been changed which retains the distance from airport to the health zones constant in both 2007 and 2011. In Figure 16, the emergency visits and the distance from airport to the health zones were compared for relationships, however no specific patterns emerged. Theoretically, areas in close proximity to the airport should have high values of emergency visits (Cohen, 2007). However, in data zone M4, where the airport is located, the emergency visits have decreased from 2007 to 2011. On the contrary, zone B4, which is located further away from M4, shows an increase in emergency visits between 2007 and 2011. Therefore, no apparent patterns can be identified from this analysis.

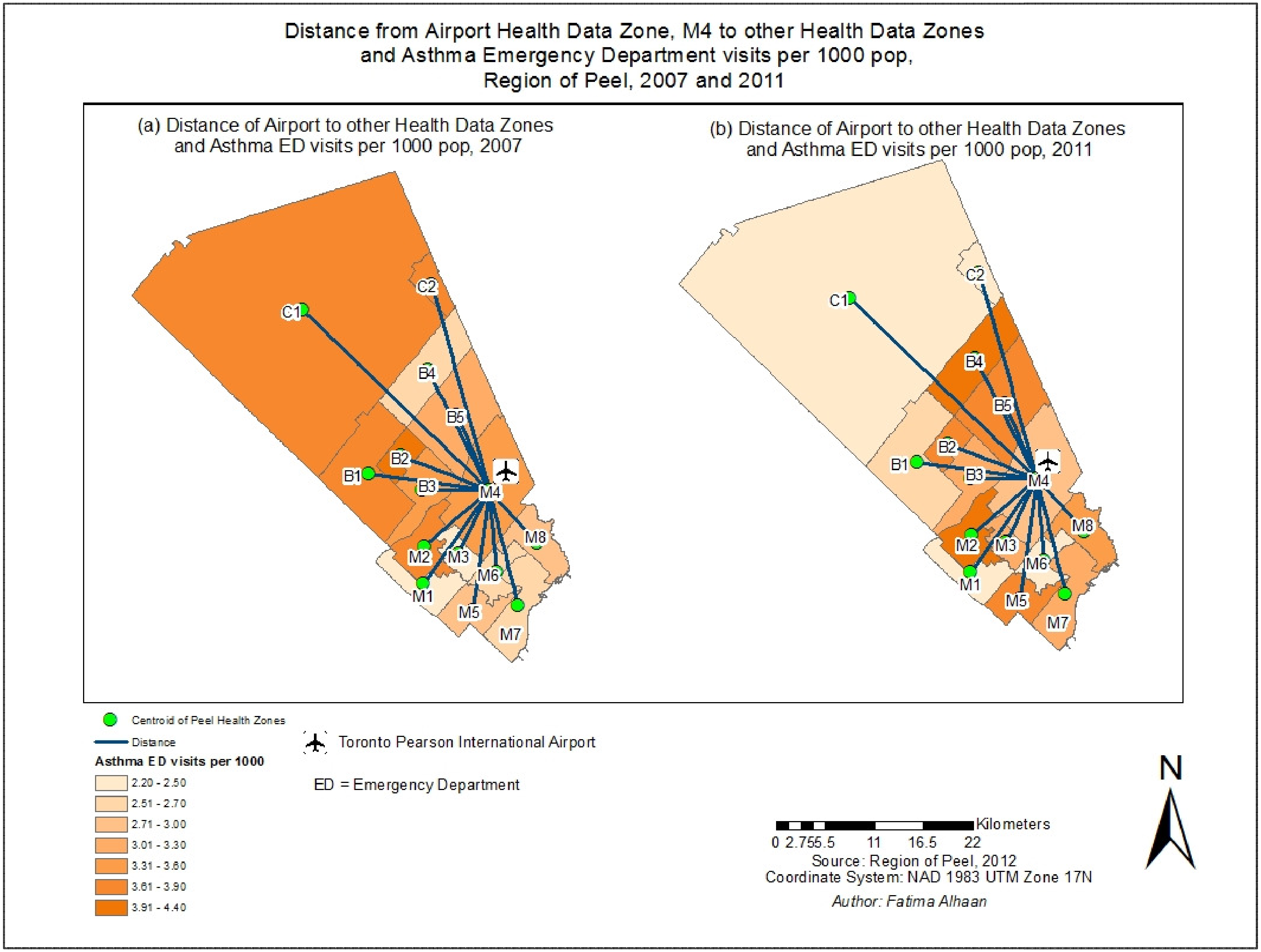

Figure 16 Asthma emergency department visit with distance from airport

4.2.3 Mode of Transportation

The types of transportation used in the region were analyzed for 2007 and 2011, as displayed in Figure 17. The types of transportation identified for the analysis were: vehicles user (van/car/truck user that could be a driver or a passenger), public transit users (bus, trains etc), and others (walking, biking etc).

An overall increase in the percentage of vehicle users and public transit users was observed over the 5 years. It was found that the use of personal vehicles have decreased by 8.9% while the asthma emergency department visits have decreased. However, the use of public transit has also increased by 12%, with decreased asthma ED visits. This increase was also stated by the Region of Peel (Region of Peel, 2011).

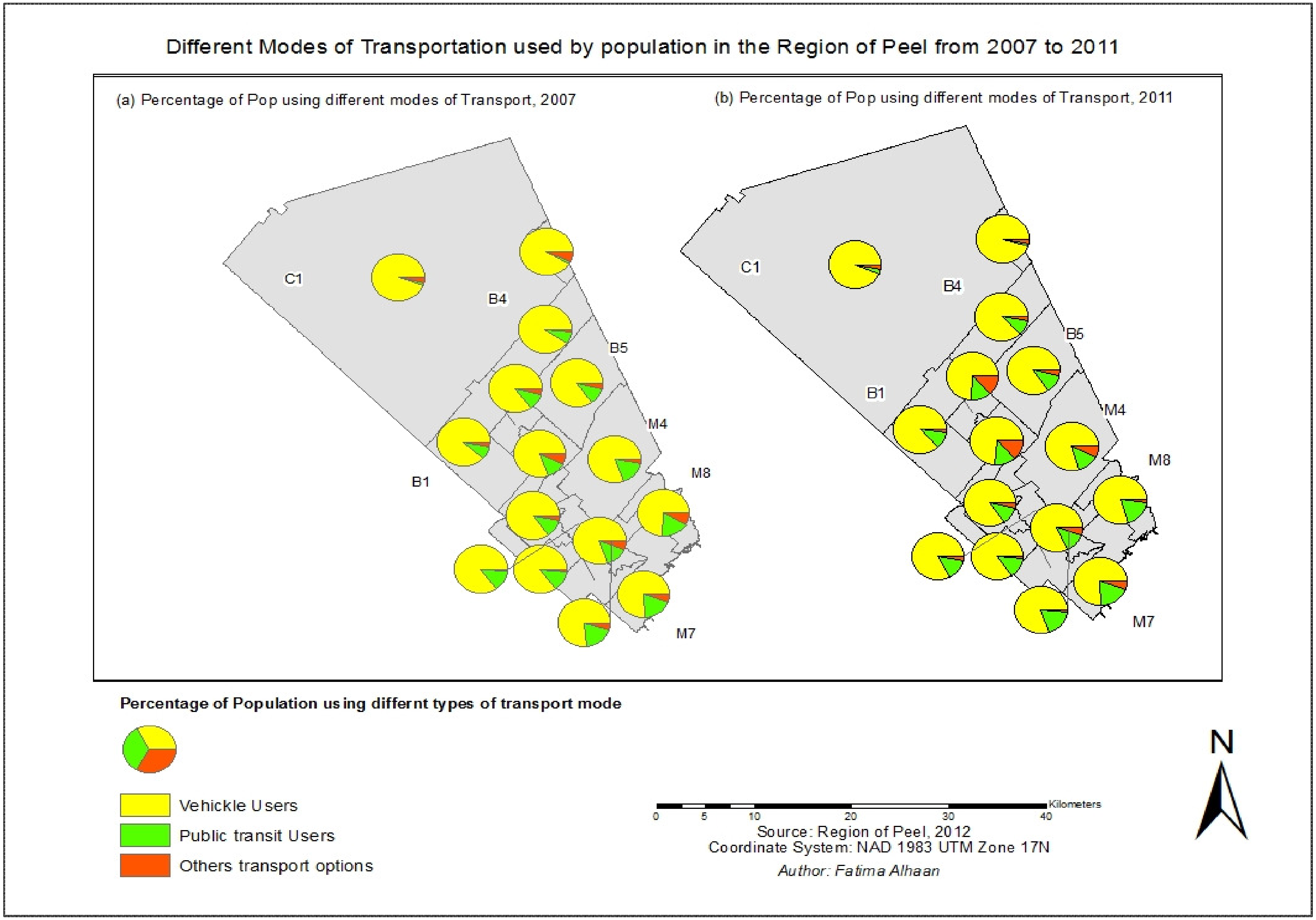

Figure 17 Pie Chart comparison of percentage of population using different modes of transport

4.3 Industries and Asthma ED Visits Results

As identified in the literature, the two industry-related factors considered in this study are industrial emissions and industrial area land use.

4.3.1 Industrial Emission

Figure 18 and Table 2 illustrate the industrial emission for PM≤2.5µm⁄cm^3 tonnes per day per year for 15 health zones. Over the period of five years, the overall emission of $PM_{2.5}$ has increased in M2, M3 and B2, and has decreased in other health zones. This indicates a potential relationship between industrial emission and asthma emergency department visits. However, zones B4 and C2 were excluded from this analysis because of the absence of industries in the respective zones. In Figure 18(c), the difference in industrial emission with negative numbers are showing a decrease in pollutant emissions. This is to note that despite the increase in the number of industries, the number of emergency visits have decreased. This may have occurred because of strict emission standards imposed by the Region of Peel.

Table 2 Difference in Industrial Emission in percentage and Asthma ED

Health Zones	Industrial Emission 2007	Industrial Emission 2011	Difference in Industrial Emission	Percentage in Industrial Emission	Percentage change in Asthma ED Visit
M1	11.900	11.795	0.1052	-0.89	-6.50
M2	9.094	10.845	-1.7513	16.15	0.11
M3	13.130	19.401	-6.2708	32.32	6.09
M4	90.933	75.855	15.0782	-19.88	-15.34
M5	1.600	1.165	0.435	-37.34	0.68
M6	0.531	0.364	0.1675	-46.08	-12.92
M7	87.996	47.793	40.2033	-84.12	0.97
M8	12.374	7.456	4.918	-65.96	0.99
B1	56.700	30.810	25.89	-84.03	-17.79
B2	1.900	2.220	-0.32	14.41	-12.48
B3	39.148	28.933	10.2153	-35.31	-11.22
B4	0.000	0.000	0	NA	9.97
B5	257.031	97.956	159.0751	-162.39	4.37
C1	20.000	4.975	15.0254	-302.04	-20.75
C2	1.900	0.000	1.9	NA	-20.46

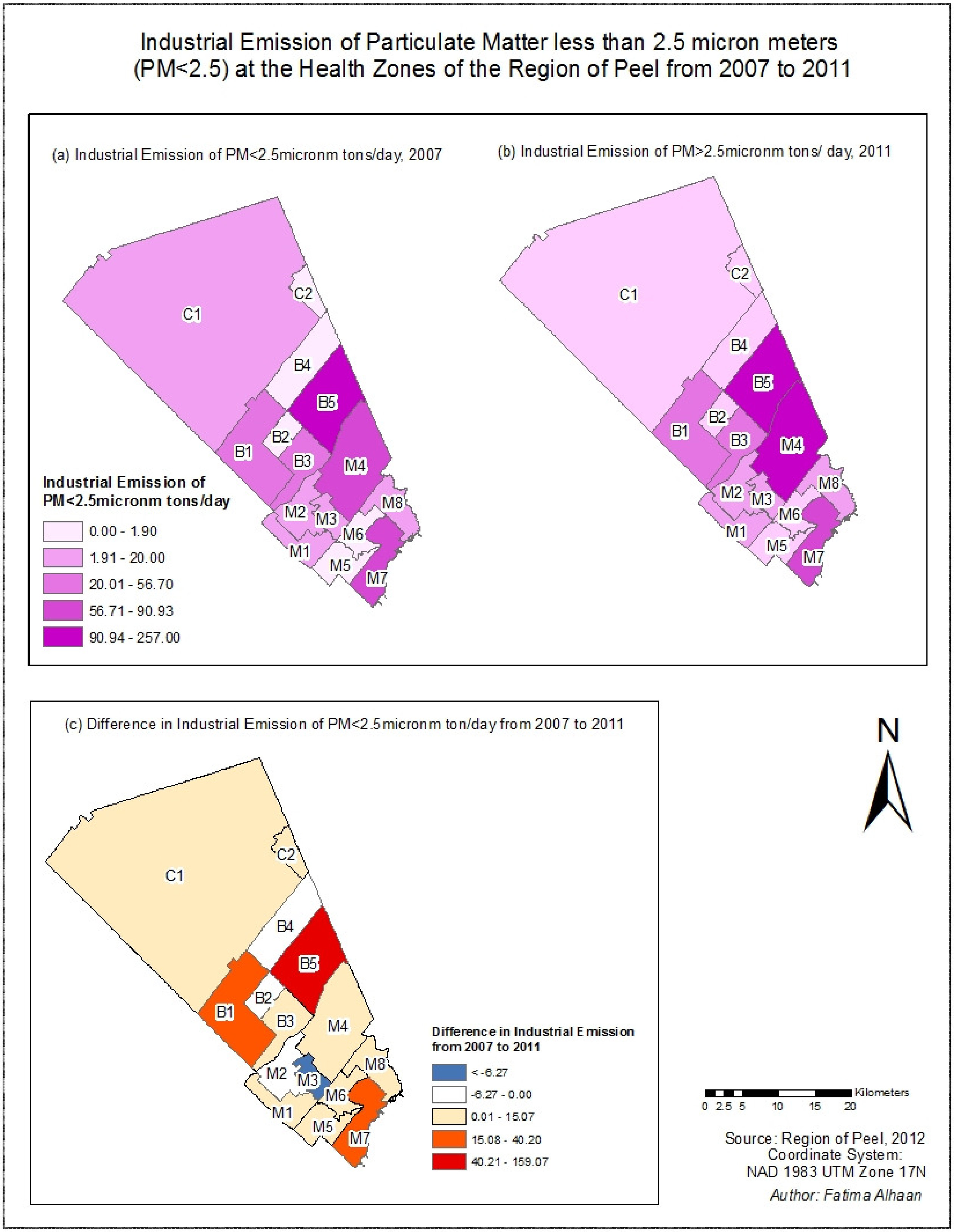

Figure 18 Industrial Emission and Asthma Emergency Department Visits, 2007 and 2011

4.3.2 Industrial Area Land Use

The industrial land coverage was calculated in percentages, as shown in Figure 19. It is important to note that over the 5 years there has been no change in the percentage of industrial land use across the 15 health zones. This may have been influenced by the Official Plan laid out in accordance to the Growth Plan of 2006 from the Region of Peel (Region of Peel, 2006). However, asthma outcomes have shown decreasing trend over the five years. Whether it has a potential to become a compromising influence on the asthma emergency department visit or not, it can be a subject for investigation.

The pattern identified for industrial factors are decreased industrial emission by 20% can be associated with decreased asthma ED visits. Whereas, industrial land area shows no association to the asthma ED visits.

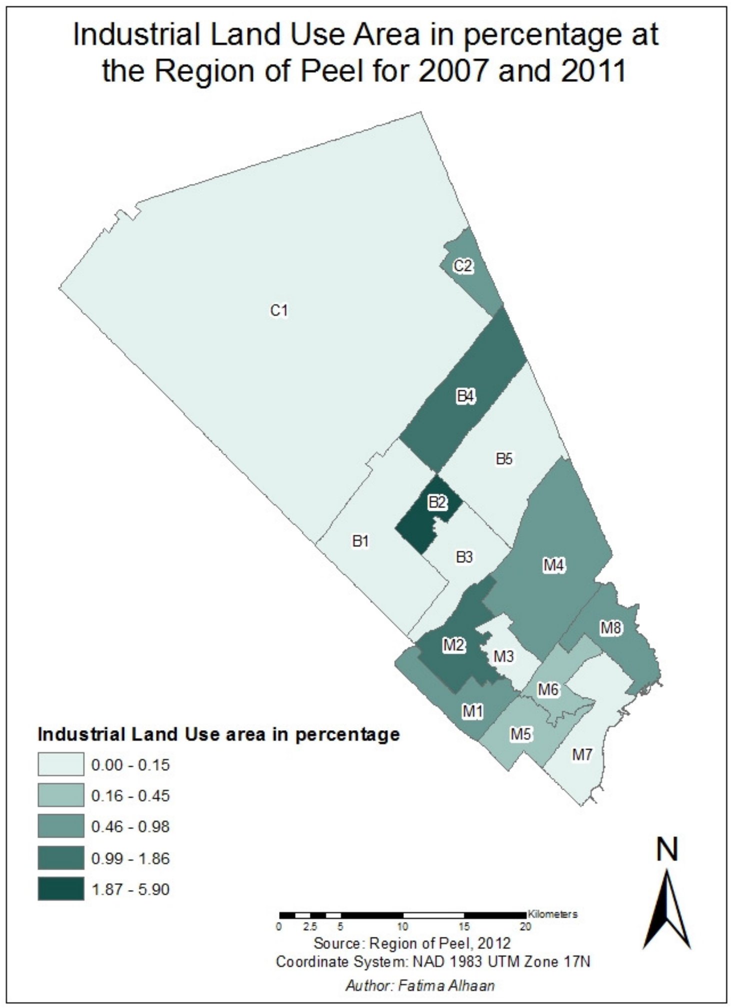

Figure 19 Industrial Land Use area coverage in percentage

4.4 Parks and Recreation with Asthma Emergency Department visits

Park land coverage was also calculated in percentages, as shown in Figure 20. Similar to the areas of industrial land use, over the 5 years, no change in the percentage of parks and recreation land use was observed. However, about 12% of the park and recreational land was located in zone B4, making it the zone with highest park land area. Nevertheless, asthma emergency department visits increased mostly in zone B4 from 2007 to 2011.

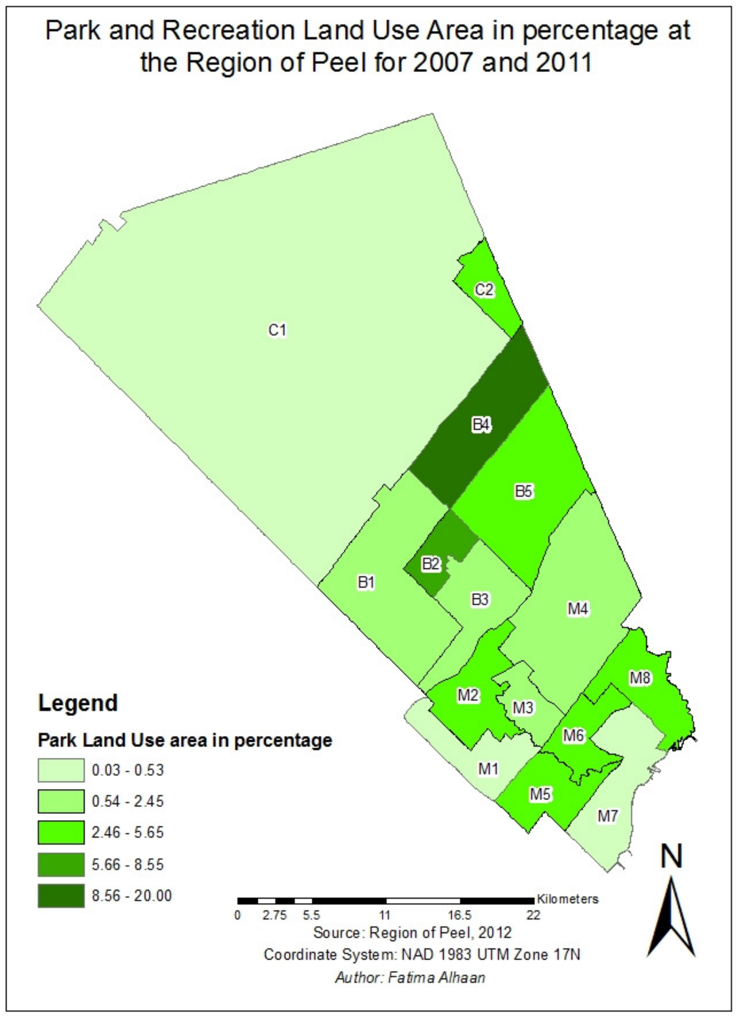

Figure 20 Parks and Recreation Land Use area coverage in percentage

4.5 Socio-economical Variables and Asthma emergency department visits

The five major socio-economic variables that were analyzed against asthma ED visits are discussed in the following sections.

4.5.1 Populations at Risk

Residents below 14 years of age and above 65 years of age are commonly defined as the population most at risk (Cowie et Al., 2001; Eisner et al., 2001; Ren et al., 2011; Lavigne et al., 2012; Stone et al., 2012; Yangzong et al., 2012). These population at risk were categorized, tabulated and mapped for the years 2007 and 2011 as shown in Figure 21. Over the five year study period, an 8.5% increase in both age groups was observed. In the region, zone M8 experienced the highest increase of the population at risk (21%), whereas zones M7 and B5 increased by 12% and zone M6 increased by 10%. Zones M1, M2 and M5, had a decrease in population at risk by 5%. All other data zones had an increase by 9% or less.

While comparing the regional statistics with the Province of Ontario, the Region of Peel demonstrated higher population at risk. A 14% decrease in the population at risk was observed at the provincial level, whereas the number increased by about 20% in the region.

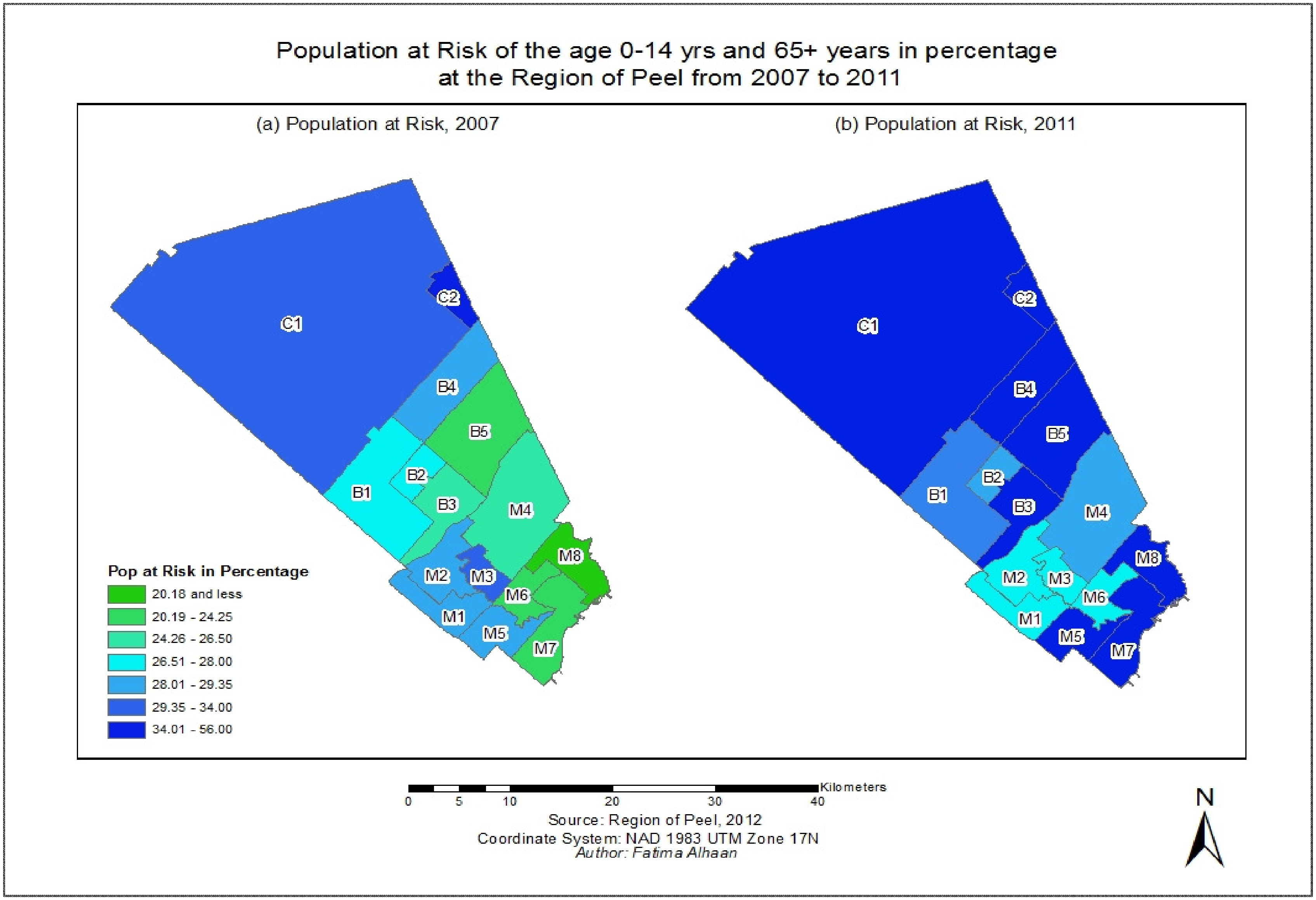

Figure 21 Population at Risk in percentages

4.5.2 Average Income After Tax and Prevalence of Low Income Population

The next two indicators for socio-economic variables, average income after taxes and prevalence of low income population percentage, have also demonstrated similarities. As per Figure 22, over the five year period, the average income after taxes increased by 5.5% in the Region of Peel. At health zone levels, a 4% increase in income was seen for M2, M4 and B3 and a 3.4% increase was observed for M6, M8 and B4, whereas the rest of the zones remained unchanged. The average increase in income after taxes in the Region of Peel shows similarity to the average increase in income after taxes in Ontario, for instance, $26000 to $36000 between 2007 and 2011.

As shown in Figure 23, the low income population increased by 2% across the region. Zones such as M2, M8, B1, B2, B3 and B5 were observed to have an increase of low income citizens by 9% or more, whereas M1, M4, M5, M6, M7, B4, C1, and C2 showed an increase by 6% or less, with an exception of zone M2 that decreased by 12%. When compared with Ontario as a whole, the percentage of prevalence of low income populations increased from 19% to 23% or by 3%, which was similar to all the 15 health zones.

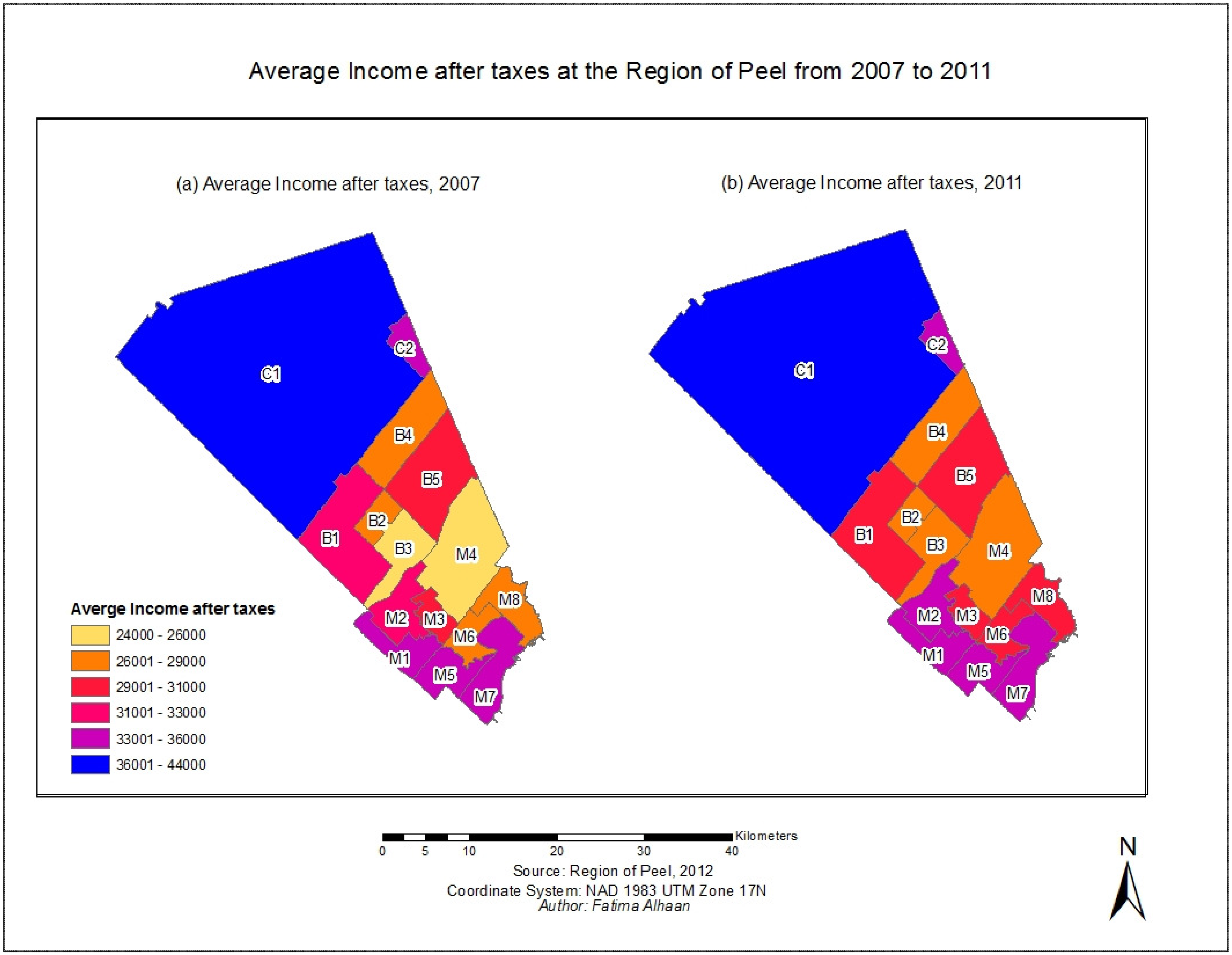

Figure 22 Average income after taxes for 2007 and 2011

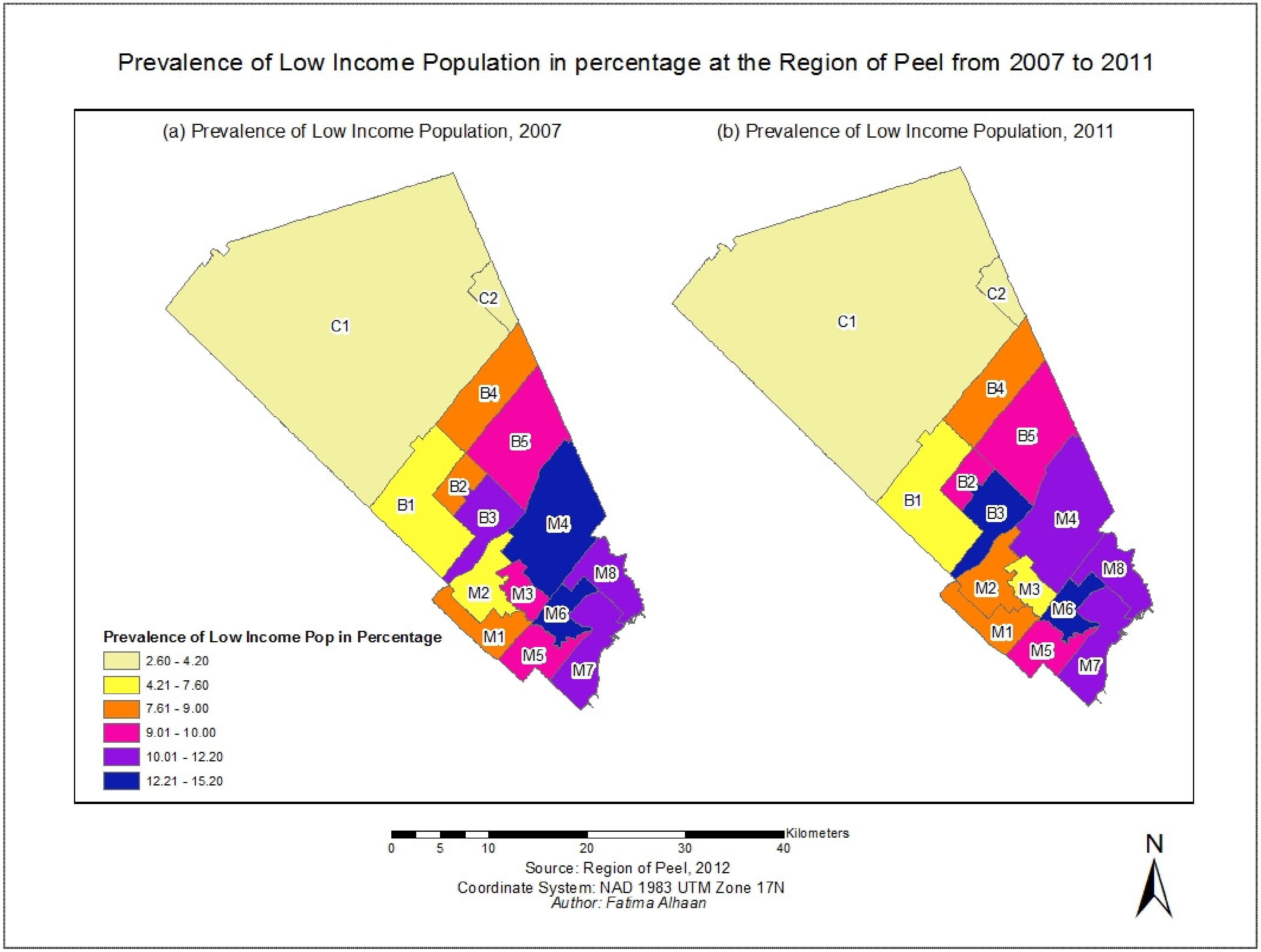

Figure 23 Prevalence of Low Income Population in percentage

4.5.3 Percentage of Employed Population and Percentage of Educated Population

The employed population and educated population demonstrated a significant correlation to asthma outcome in previous studies (Wu, 2011, Bianchi, 2011, Baum, & Flores, 2011). Data collected on percentage of employed population and percentage of educated population were tabulated, standardized and mapped as shown in Figure 24 and Figure 25.

Figure 4.12 examines the percentage of employment across the 15 health zones in 2007 and 2011. On average, the percentage of employed population in the zones B1, B2, B3, B4, B5 increased by 2.5% and in zones M1, M2, M5, M6, C2 employment levels increased by 7%. On the other hand, the percentage of employed population decreased by 5% in zones M3, M4, M7, M8 and C1. However, compared to the percentage of employed population of Ontario (39%), health zones such as, B1, B2, B3, B5, M1, M2, M5 and M6 have greater percentage of employed population with an average of 43% (Region of Peel, 2012).

The educated population in this study was defined as the population with a university or college degree, certificate or training. The maps in Figure 4.13 shows an increase in the percentage of educated population by 40% in zones M1, M2, M3, B1, B2 and B4; 30% in zones M4, M5, M6, M8, B3, B5 and C1; and 10% in zones M7 and C2. On average, over the five year study period, the educated population increased by 30% all across the Region of Peel. However, the increase in the educated population in Ontario was 28%, which indicates a higher proportion of educated citizens in the health zones of Region of Peel compared to the province as a whole.

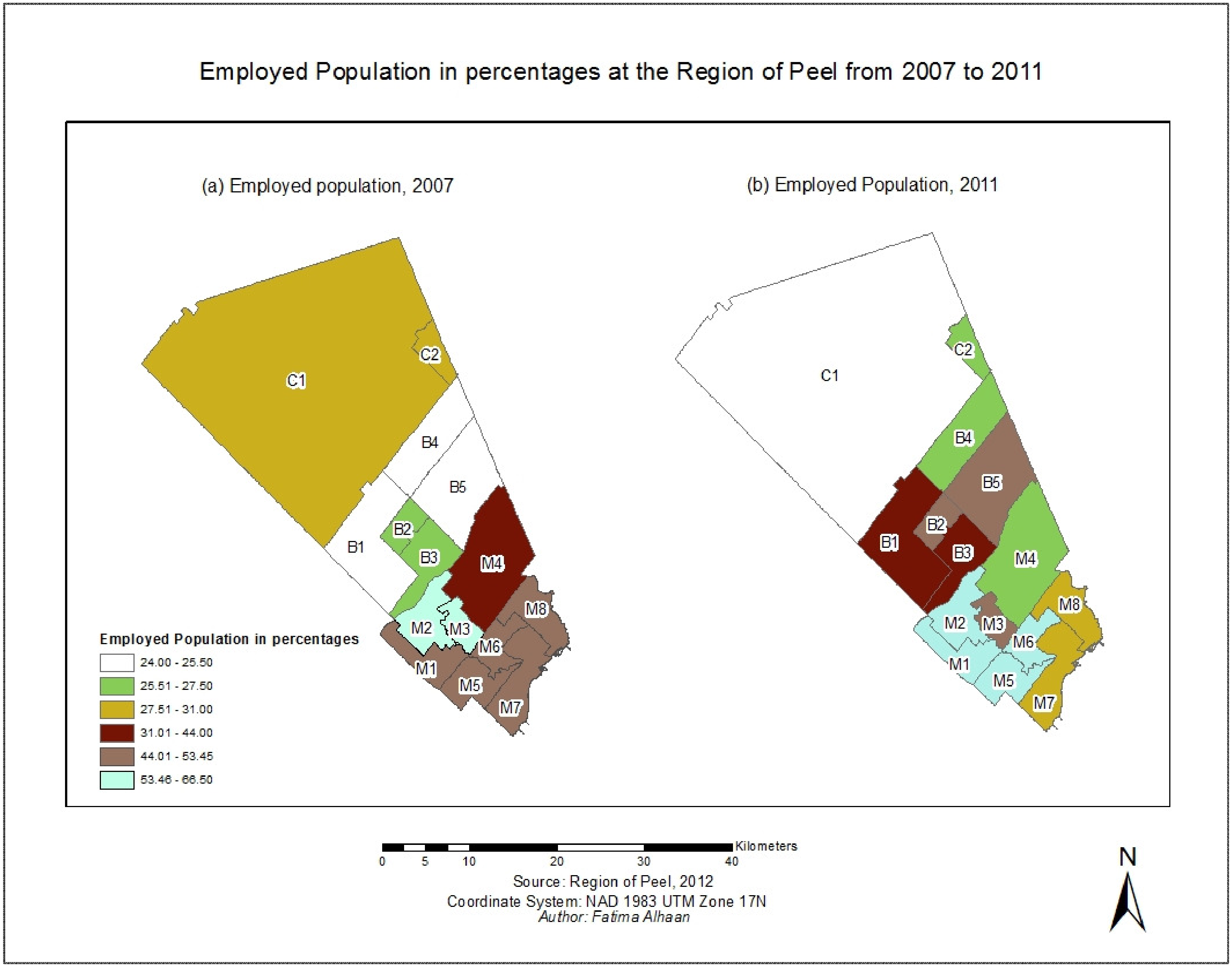

Figure 24 Percentage of Employed population 2007 and 2011

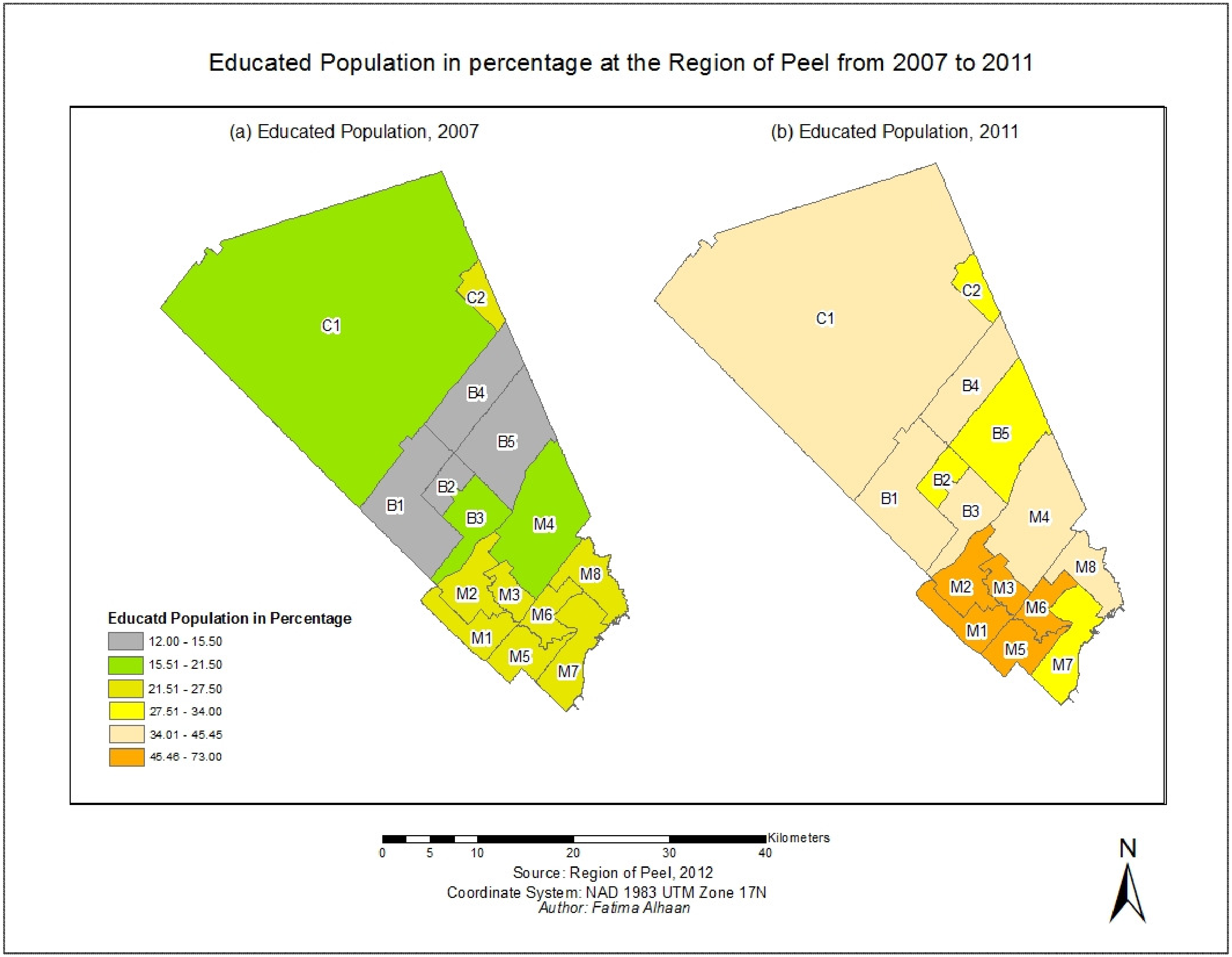

Figure 25 Educated population percentage in 2007 and 2011

4.6 Environmental Factors

The built environment is comprised of the population and the surrounding biotic and abiotic environment. Thus, air quality was examined in relation to the asthma outcomes as part of this research.

Air Quality

The number of recorded smog days was selected as the measure of air quality. Figure 26 displays the spatial pattern of the number of smog days for 2007 and 2011. There has been fewer smog days in 2011 compared to 2007. This means, the number of days with poor air quality, potentially responsible for asthma, were more in 2007 than in 2011. The asthma emergency department visit maps show similar trends, where 2007 has more emergency visits than 2011. This is important to note that due to limited data, the number of smog days were only considered at a city-wide level and was excluded from further analysis.

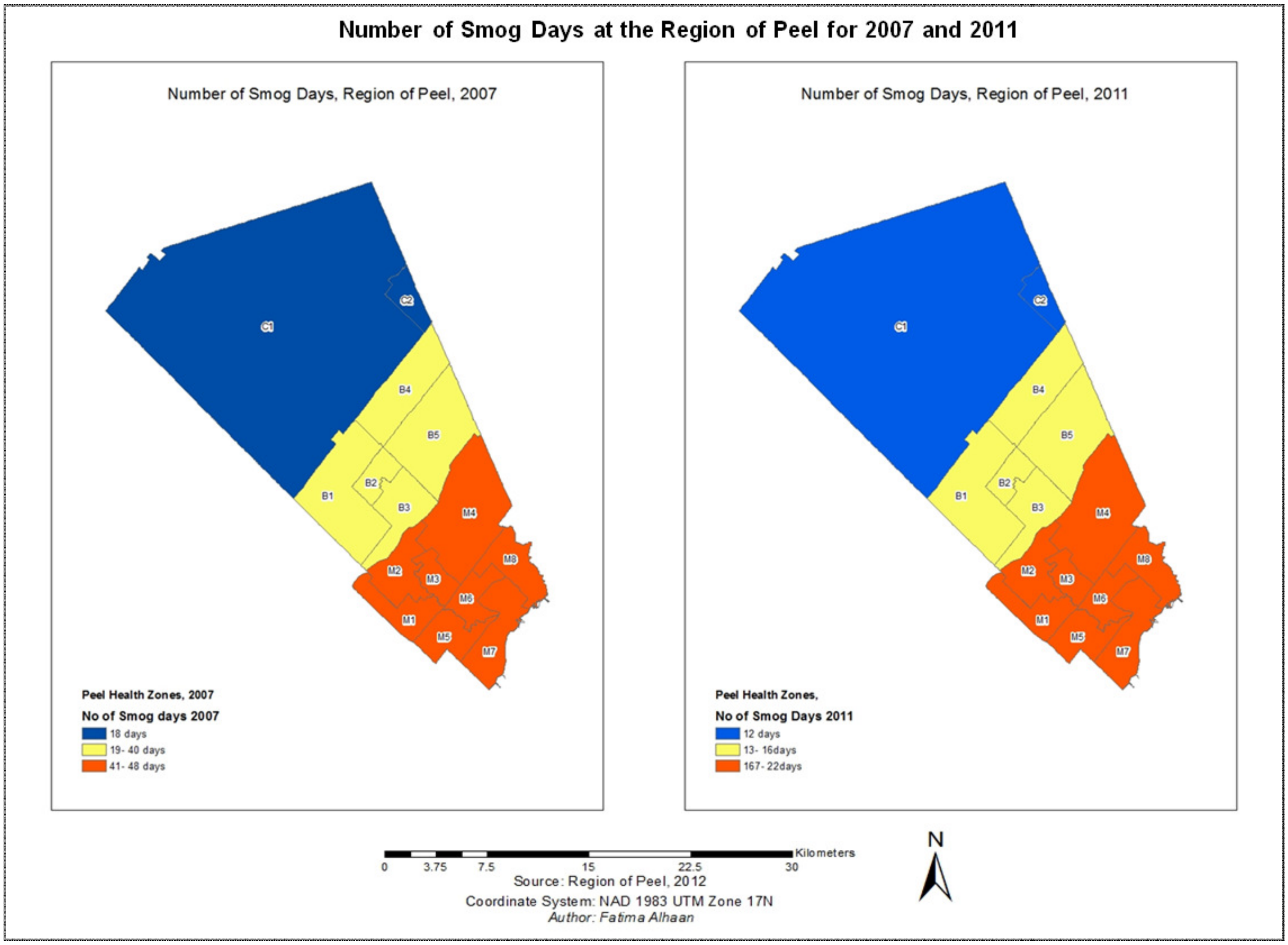

Figure 26 Number of Smog Days for 2007 and 2011

Housing Type

Housing type was categorized as single detached housing, semi-detached housing, row housing, apartments, moving housing, and others, as defined by the Region of Peel. Figure 27 shows the distribution of population living in different housing types for the year 2007 and 2011.

The literature suggests that there is a close relation between housing type and air quality. For example, detached houses have better air quality compared to apartments that evidently foster poor indoor air (Chau et al., 2008; Nazir & Colbeck, 2013). From the analysis of the housing types, it was found that between 2007 and 2011, there was an overall increase in all types of housing by 13%. An increase in detached housing was observed in few health zones such as, C2, B2, B3 and B4. More apartment building complexes were constructed in zones M3, M7, and M8. In the other health zones there were an increase in both townhouses and apartments. However, the percentage of people, living in movable housing was seen to decrease in small amounts over the five year period. Although the trend shows an increase in housing, it may or may not have a relation to the decreasing trend in asthma emergency department visits.

Household types and prevalence of low income population can potentially have co-linearity as studies show people of low income population tend to live in poor quality housing. Thus, prevalence of low income population was only selected for further analysis.

The result findings addressing the second research objectives are partially elaborated here. Among these independent variables the factors that showed similar trends to asthma ED visits were:

- Increased AADT, increased vehicle users, and transit users
- Industrial emission
- Percentage of population at risk
- Percentage of educated populations
- Percentage of prevalent low income population

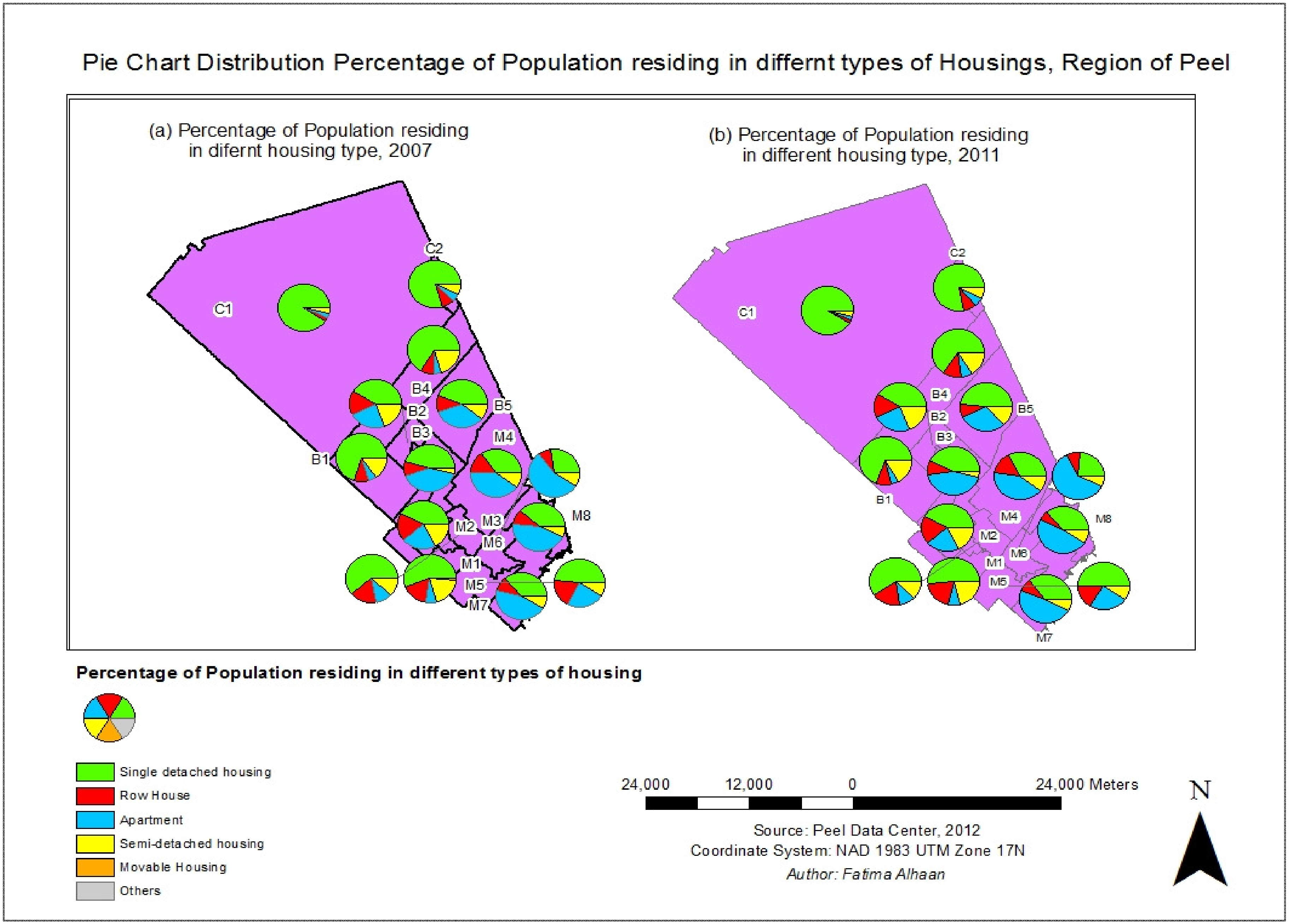

Figure 27 Pie Chart distribution of types of housing and asthma emergency department visits, 2007 and 2011

4.7 Statistical Analysis Result

Descriptive statistics (maximum, minimum, mean and standard deviation) were calculated to understand the nature of the independent and dependent variables for this study. Table 3 summarizes the results for the built form, land use, and socioeconomic variables for 2007 and 2011. No changes in the land use categories such as, parks area, industrial area, and the distance from the airport zone at M4 to other health zones were observed. The independent variables that increased over the five year study period are average AADT (2%), use of public transit (12%), average income after taxes (4%), prevalent low income population (6%), employed population (6%), and educated population (30%). The only independent variables that showed decrease over time is industrial emissions (20%). The dependent variable, asthma emergency department visits per 1000 population has decreased by 7%.

Table 3 Descriptive Statistics for 2007 and 2011 for built form and land use

	Average 2007	**Minimum 2007**	**Maximum 2007**	**Std Dev 2007**	**Average 2011**	**Minimum 2011**	**Maximum 2011**	**Std Dev 2011**
Asthma ED per 1000	3.310	2.475	4.088	0.502	2.86	2.20	3.76	0.43
Average AADT	34743	8396	55323	12763	37764	7321	71229	18256
Industrial Emission	40.282	0	257.031	67.318	22.64	0	97.96	29.82
Parks/Rec Area%	4.15	0	20.07	4.96	4.15	0	20.07	4.96
Industrial Area%	0.88	0	5.90	1.49	0.88	0	5.90	1.49
Vehicle users (cars/van/truck) Driver or Passenger %	83.79	74	94.80	6.03	82.9	74	95	6.24
Public transit %	11.83	1.40	19.40	5.40	12.47	2	18.9	2
Others %	4.37	1.40	8.30	2.16	4.63	1.6	13.2	3.74
Distance from M4	12394	0	29343	7026	12394	0	29343	7026
Population at Risk %	29.6	20.18	56.26	8.41	30.20	27.22	32.48	1.58
Average after Tax Income	31015	26073	41290	4313	33598	28451.63	440565	4733
Employed Pop %	41.43	24.82	66.26	14.49	47.53	29	64	9.46
Prevalent Low Income Pop %	9.15	2.60	13.80	3.09	10.33	2.9	15.2	3.537
Educated Pop %	21.63	12.73	27.65	5.37	45.56	30.54	73.94	13.26

4.7.1 Correlation

In order to identify relationships between the dependent variables and other independent variables, correlation analysis was performed for both 2007 and 2011. The correlation coefficient, *r*, was interpreted as follows: $0.35<r<0.67$ indicated **moderately correlation**; $0.68<r<1.00$ indicated **high correlation**; and any value less than 0.35 was indicated to have **low correlation** (Taylor, 1990). The results are shown in Table 4 and Appendices C and D.

For 2007, asthma emergency department visits was **negatively moderately correlated** with percentage of population using public transit, which may indicate when more people used public transit, the number of asthma emergency department visits may decrease. The percentage of employed population and percentage of educated population had a **negative moderate correlation** with the asthma emergency department visits, indicating that people with higher education may have a better understanding of illness associated with asthma and may be more cautious to try and prevent triggers to the illness. It may also indicate, these people may use other options to seek asthma treatment, other than emergency department visits. On the other hand, **negative moderate correlation** of asthma emergency department visits with the employed population can be interpreted as employed people are may be more healthy or may not want to give away working hours to seek treatment. A **positive moderate correlation** was observed for industrial emission and population using personal vehicle. This can be interpreted as increase in industrial emission can potentially increase asthma ED visits. It can also be interpreted that an increase in the use of personal vehicle users can potentially increase asthma ED visits. All other variables had *r* values less than 0.3, indicating low correlation with asthma.

For the year 2011, it was observed that asthma emergency department visits had positive moderate correlation to the population at risk. This can potentially mean that an increased population at risk can possibly increase the number of asthma emergency department visits. Seasonal factors during data collection can partly be responsible for this type of observed relationships. All other variables for 2011 had *r* values less than 0.3, which indicate low correlation.

Table 4 Correlation Coefficient for asthma emergency department vs. independent variables

	Correlation Coefficient *r*	Strength of Correlation
2007 Dataset for asthma emergency department visits vs.		
Average AADT	-0.40249	Negative moderate correlation
Industrial Emission	0.57071	Positive moderate correlations
Personal vehicle use in %	0.39782	Positive Moderate correlation
Public transit in %	-0.52907	Negative moderate correlation
Employed Pop %	-0.54523	Negative moderate correlation
Prevalence of Low Income Pop %	-0.45673	Negative moderate correlation
Educated Pop %	-0.50972	Negative moderate correlation
2011 Dataset for asthma emergency department visits vs.		
	Correlation Coefficient *r*	Strength of Correlation
Population at Risk in %	0.4452	Positive moderate correlation

From this correlation analysis, the variables that demonstrated strong correlations to asthma Emergency Department Visits are:

- Average AADT
- Industrial emission
- Percentage of population using vehicles
- Percentage of population using public transit
- Percentage of population at risk

- Percentage of educated populations
- Percentage of prevalent low income population

4.9 Summary of the Results

- Asthma emergency department visits have decreased all across the Region of Peel by 7.2 %; however zones M2, M3, B4, and B5 showed increases in asthma emergency departments.
- There was an increase in average AADT across the Region of Peel by 2%. Some health zones showed strong trends between decreased daily traffic to decreased asthma ED visits, such as M7, B1, B3, B5, C1 and C2. Also increased daily traffic in M3 and M5 shows increased asthma ED visits.
- The airport is located in M4 which has shown to decrease asthma ED, but the immediate health zones show mixed results, where there were increased visits for B3, M2, M5 M7 and M8 and decreased visits for B2 and B5.
- The use of public transit (12%) and personal vehicles travel (8%) has increased across the region. B4, M4, C2 shows the most increase in vehicle users whereas M3, M6, M7, M8 have seen increased public transit users.
- Industrial emission has reduced by 20% across the region.
- The percentage of industrial area land use has not changed over time
- No changes in the percentage of parks and recreation area was noted across the 15 health zones. Noteworthy result was the park area in percentage is seen most in B4, however asthma emergency department visits increased most in B4 in the five years.

- The population at risk has increased for zones B5 and M8, and has decreased in zones M1, M2 and M3.
- There was an overall increase in income after taxes across the 15 health data zones, though the most significant increase in income was seen in zones B2, B4, M2 and M3. This variable was observed to be similar to the prevalence of low income population where it was seen to have increased low income prevalent population in B3 and M2 and no changes in this category for B2, B4, M1 and M5.
- The number of smog days was the nearest possible variable to air quality, which showed over time as number of smog days decreased the average asthma emergency department visits decreased. Due to lack of accurate data for smog days within the health zones, it was not considered for further analysis.
- Correlation was found for asthma emergency department visits with independent variables that had moderate correlation coefficient, *r* values. Asthma emergency department visits were **negatively moderately correlated** with average AADT, percentage of population using public transit, percentage of employed population, percentage of educated populations and percentage of prevalent low income population. Asthma emergency department visits were **positively moderately correlated** with industrial emission, percentage of population using vehicles and percentage of population at risk.

CHAPTER 5: Discussion and Recommendation

5.1 Introduction

This chapter draws conclusions from the analysis results discussed in the previous chapter. A series of recommendations and scopes for future research will be identified.

5.2 Key Findings

Over the five year study period, 2007 to 2011, a decrease by 7.2% in asthma emergency department visits was observed; however, two data zones, B4 and M3, showed an increase in asthma emergency department visits. A decrease in industrial emissions and an increase in the average annual daily vehicular traffic were observed in the region. Factors such as industrial land area, park area, and the distance from the airport to health zones remained unchanged. In addition, in the region of Peel, overall population increased by 3.8%, the population who are at risk increased by 2%, the average income after taxes increased by 4%, the prevalent low income population increased by 8%, employment increased by 6.8%, and educated population increased by 35%. Moreover, other aspects such as the quality of air has improved over time, as there were fewer observed smog days. The correlation analysis demonstrated that asthma emergency department visits increased with increased average annual daily traffic (AADT), increased industrial emission, greater park area, increased prevalent low income population, and decreased educated population.

5.3 Limitations

Data Limitation: Secondary sources were used to collect data and was standardized for the analysis. Three major limitations were identified for the data. Firstly, the data available for asthma emergency department visits did not address the impact of occupational exposure. Secondly, the data was available for the data zones with aggregate values. However, local scale data with more observations would have facilitated the statistical analysis. The census tract level data as used by the Diabetes Atlas, Region of Peel, 2013 would have been a better option. Nevertheless, the census tract data was not accessible. Finally, the Canadian censuses take place at 5 years' interval. The census data of 2006 was used as 2007 data and the census data of 2011 was used for that year. The 2011 data was collected through volunteer participation of the residents and have concerns with bias. However, the Peel Data Centre claims to have controlled the dataset for bias.

Operationalising Air Pollution Data: The number of smog days was used to represent air quality. However smog day data were available at the city level for only Mississauga and Brampton. The information cannot be generalized to all other health zones because of their differences in the population, acreage, and geography. The air quality information is acquired from 4 monitoring stations in the Peel Region as shown in Figure 5.3. However, there is no air monitoring station in the Town of Caledon. All the air quality information was gathered from the neighbouring Town of New Market. There was no way that the information could have been segregated as two regions, therefore creating a potential source of error.

5.4 Population and Risk of Asthma

In this section, the first research question, **"what are the patterns of asthma in the Region of**

Peel over time and space?" will be discussed. Part of the second research question, **"what are the relevant factors that may explain asthma patterns?"** will be discussed in the section regarding health care services.

5.4.1 Location of emergency hospital

Three trends of asthma ED visits were observed from the research findings. There was an overall decrease in the asthma ED visits by 7.2% from 2007 to 2011. The data zones that experienced most decrease were M4, B1, C1, and C2. B4 and M3 experienced increase in asthma ED visits. Data zone B4 is situated in the north-east side of the City of Brampton. Brampton Civic Hospital is conveniently located at the south-west boundary of the zone (Brampton Secondary Plan, 2011). Data zone M3 is relatively small, situated near the core of the City of Mississauga. The Credit Valley Hospital is located at the periphery of the zone M3, within a distance of 3.5 kilometres. A decreasing trend of asthma ED visits were observed for M4, B1, C1, and C2. These zones are further away from hospitals (as shown in Figure 5.1). Zone M4 is the airport zone and zone B1 is a developing zone, where the Brampton Secondary Plan (2011) targets extension of the residential land use. Zones C1 and C2 falls within the Greenbelt Plan area that restricts development (see Figure 5.2).

The identified common factor among data zones B4 and M3 was the accessibility of emergency health care units, explaining the increasing asthma ED visit trend. In the region of Peel, Credit Valley Hospital and the Brampton Civic Hospital are the only two emergency health care facilities that have been operating for more than 20 years (City of Brampton, 2012). Based on this fact, it is possible for patients encountering asthma attacks to easily access nearby emergency services, therefore resulting in an increased number of asthma visits in data zones M3 and B4. The decrease in number of asthma emergency department visits in M4, B1, C1 and C2 can possibly be due to a lack of emergency departments within accessible distance. Peel residents also use healthcare facilities in Toronto, Etobicoke, Vaughan, North York and Oakville. Therefore, access to health care service need to be accounted for in future research.

The arrangement of LHINs and municipality are of different scales. West Central LHINs include parts of Mississauga (Zone M4 and parts of M2), Etobicoke, Rexdale and Dufferin. The other parts of Mississauga (Zone M3, M5, M6, M7 and M8) and the Region of Halton make up Mississauga-Halton LHIN.

In case of a medical emergency, people living in other zones opt to go to the nearest emergency departments. However LHINs coordinates all health services, family doctors, and health care services according to their administrative boundaries. This is a major geographic discrepancy between land use planning and health care planning. LHINs are criticised for its monopoly on health care and expensive operating cost of $68 million (Born & Sullivan, 2012).

Recommendations: There is a need for better communication between different key players of health care providers. To improve the functionality of the LHINs, more responsibilities can be added to organizations' mandate, such as working to prevent chronic diseases. LHINs can partner with public health departments and land use planners to address issues such as disease outbreaks, air quality and transportation. The number of LHIN employers can be increased from 30 to better manage the work load (Born & Sullivan, 2012). Another option can be to further breakdown LHINs according to cities and municipalities depending on the population density. This will potentially reduce cost and provide equal opportunity to get health services for all types of people.

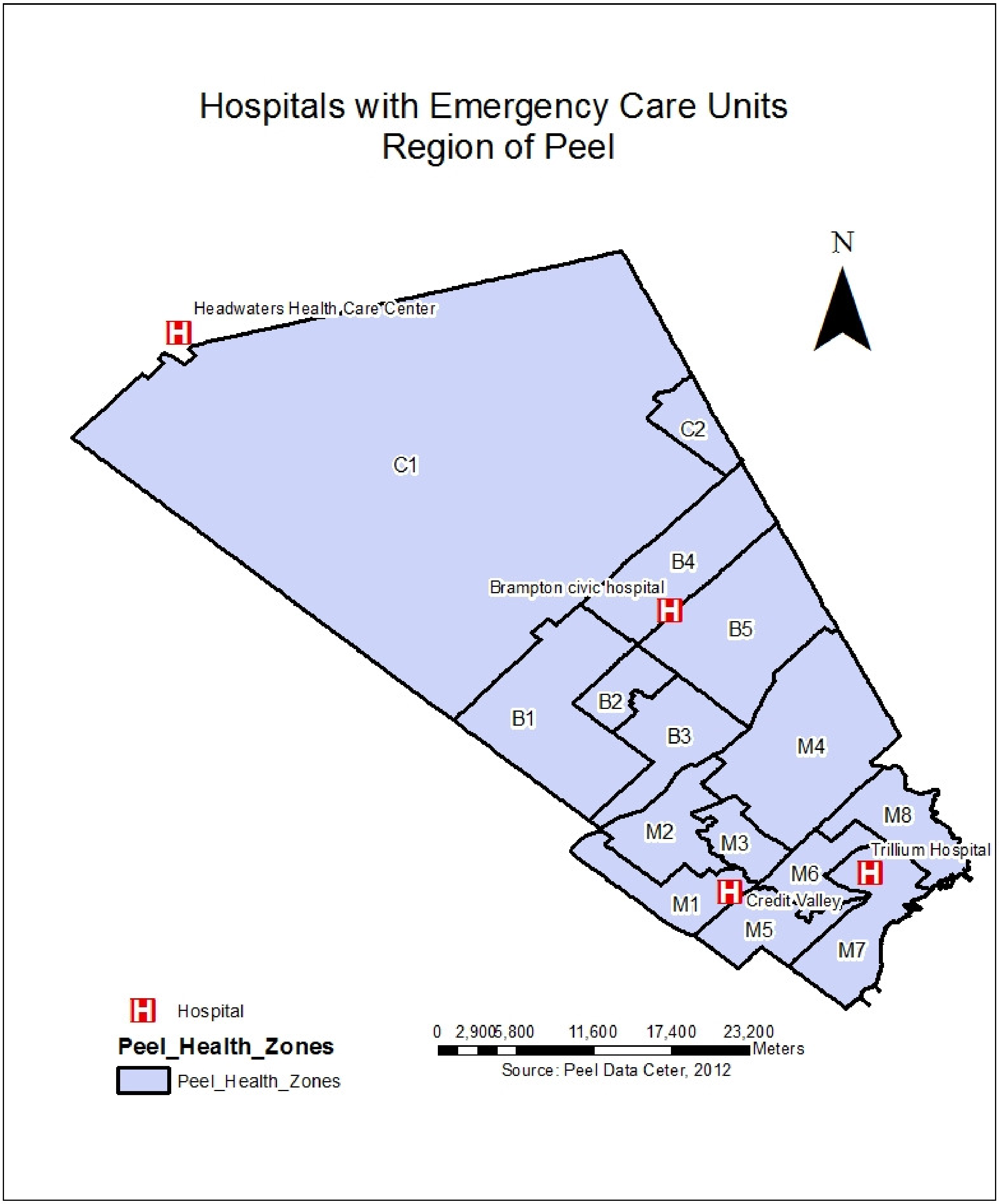

Figure 28 Location of Emergency Department Hospital in the Region of Peel

Telephone based interventions such as the *Telehealth Ontario* (2009) system proved to be effective for remote and rural areas and follow-ups on chronic diseases, such as asthma (Polisena et al., 2009). Another way of improving asthma ED visits can be to seperate severe and milder cases in the emergency departments (Dale et al., 1995; Eisner et al., 2001; Cowie et al., 2001; American Academy for Paediatrics, 2006). If specialized clinics and community health providers can have immediate treatment options located in the neighbourhood for minor respiratory illness including asthma, the number of emergency visits can be reduced (Asthma Association Ontario, 2011).

Future Research Opportunities: Future research can use data based on census tract and postal code level to avoid inconsistencies of geographic boundaries (McEntee & Ogneva-Himmelberger, 2008; Peel Diabetes Atlas, 2013). More research is needed related to wait time, access to health care, access to family physicians, and elderly care services. Future studies should also investigate the emergency department performances in managing issues such as asthma.

From this study it can be concluded that the comprehensive effect of health care initiatives has brought about a positive change in the asthma ED visits in the Region of Peel.

The spatiotemporal changes in the population at the data zones were evaluated and then compared with the asthma ED visits using a correlation analysis. This section is divided into three sub-sections: population pattern analysis, relationship of the population attributes to asthma, policies concerning the population and asthma incidence.

5.4.2 Population Patterns in The Data Zones

The population at risk was found to increase on an average by 2% in the region; however few data zones demonstrated increase above the average value. Data zones C1 and C2 showed about 10% increase in the elderly population and data zone B4 showed increase in children population by 24%. The results indicate high family residence in B4 and more elderly residents in C1 and C2. In case of prevalent low income population, M4 demonstrated the highest increase between 2007 and 2011, potentially because of the airport and nearby commercial establishments. For the educated population, data zone B4 showed the highest increase that can be potentially explained by the highest self employment rate in the area.

5.4.3 Population and their relation to Asthma

Generally, the asthma ED visits showed a decreasing trend, where as the population at risk and prevalent low income increased over time. This situation is different from the conventional perception of increased asthma with increased population at risk and prevalent low income population. However, since the air quality was observed to improve in the region, the asthma incidence has potentially decreased. It is also likely that this population may lack awareness on asthma protocol, leading to a misrepresentation of asthama incidences and, subsequently, ED visits. Although the Region of Peel has asthma awareness programs, the initiatives may not been effective enough. The data zones such as B4, M5, and M1 with a highly educated and employed population demonstrated high asthma ED visits. This increase may have resulted because of the self awareness of the patients and caregivers. On the contrary, data zone M4 has high prevalent low income population and low educated and employed population, but demonstrates low asthma incidence, despite being located in the airport and commercial zone. This phenomenon supports the argument of the effectiveness of the awareness program previously discussed.

5.4.4 Planning Provisions Concerning Population and Asthma

The Region of Peel has taken matters of employment areas and growth seriously. The Peel's Regional Strategic Plan (2011-2014) and the Official Plan (2013) have emphasised social development and community health by improving the quality of life for all, and investing in policies for preventive disease and provide better health facilities. Mississauga Official Plan (2013) has new policies to include neighbourhood and employment area together, provide better housing options. The City of Brampton has adopted their Secondary Plan (2013) and it emphasizes the importance of identifying employment land uses, residential infill, and intensification. However, all Official Plans, Strategy Paper and Growth and development policies are limited to the use of land, and resources are allocation. The Peel Poverty Reduction Strategy has been developed for 2012 to 2015 to reduce poverty and its related causes. A task force combining efforts of the Social Planning Council of Peel and Public Health Department of Peel Region, and the City of Mississauga and Brampton have plans to encourage low income population to get employment, but implementation is slow (Kotacka, 2012).

Recommendations: More creative and multi-disciplinary approaches are needed in order to address issues of socio-economic factors with asthma ED visits. As population at risk due to their age or prevalent low income population are less likely to get help for health issues, more elaborate preventive initiatives need to be taken. The focus needs to be on integrating primary public health, social housing, and employment. New strategies for education and assistance in relocating can be provided for the prevalent low income population, while reducing the feelings of being stigmatised. Social planners have a role to play in creating services and collaborating with other sectors of the community. Local employment opportunities may also be created through economic development plans.

Future Research Opportunities: There need to be more retrospective and longitudinal research seeking to investigate how presently implemented polices will shape the future and effect the social status of the population and health services provided. There remains a need for future research on the evaluation of the asthma awareness programs in the region.

This is how population at risk and prevalent low income population can affect the asthma emergency department visits, as observed from the research findings.

5.5 Built Environment Factors

The research has found that emergency department visits were moderately correlated to the average annual daily traffic, industrial emission, use of vehicles, use of transit. In discussing these aspects the second research questions will be addressed.

5.5.1 Transportation Factors

Results suggest that a decrease in the asthma ED visits by 7.2% can potentially be related to the increase in AADT by 2%. According to the Ministry of Transportation Ontario, the increase of AADT across the Region of Peel was 18% over the last five years, particularly in the highway corridors that consists of the 400 series highways and Queen Elizabeth Way, (QEW). These highways are the most important transportation nodes and connect various parts of the Greater Toronto Area (GTA). Therefore the increased mobility of vehicles would potentially increase air pollution (Finkelstein et al., 2004). All existing land developments are located more than 1000 meters away from the major corridors that is above the pollution diffusion distance discussed in Hitchins et al., (2000). The transport corridors and increased AADT might not have direct effects on the asthma emergency department visits; however, over time, continual exposure to pollutants can probably result in asthma (Finkelstein et al., 2004).

Over time, the Ministry of Transportation Ontario (MTO) has become more stringent with standards of vehicular emission. An air pollution regulation of 419/05 identifies particulate matter (PM_{10} and $PM_{2.5}$) as pollutant, even though the federal government has declared these to be toxic substances. The need to abide by regular vehicle screening, emission tests, are being implemented as part of the *Canadian Environmental Protection Act*, 1999 (CEPA). In recent amendments to the *Provincial Planning Statement* (2005), the Region of Peel has insisted on working with transportation demand management, multi-modal transportation facilities and active transportation and better communication with Ministry of Transportations and local transport planners (Amendment to PPS, 2014).

The results reveal that the proportion of transit users increased by 12% and the asthma ED visits decreased by 7.2%. The results are identically reflected in the measures by the MTO. For instance, the City of Mississauga had established *miWAY* transit in 1973 and since then public transit services have grown almost by 45% (Mississauga Transit, 2012). On the other hand, the City of Brampton's transit, *Züm,* went into operation in 2010. GO train and GO bus services have increased with the growing demand for frequent and fast transport to Toronto and other areas of the GTA. This can mean that transit oriented development can potentially improve air quality and consequently decrease asthma.

Recommendation: There is need for implementing strategies to build high rise residential building as further away from highway corridors. Local actions such as regular road cleaning, closing certain roads to automobile traffic, elimination of idling, routing heavy trucks away from residential areas, and increased use of alternative modes of transportation are all important. The promotion of cleaner vehicles at the federal level is also encouraged (*Sustainable Communities*, OPPI, 2010). Adaption of new technologies, like Road Dust Study in Hamilton, Ontario can prove to be innovative means of measuring particulate matter air pollutants and keeping records for future research (Perotta, 2010). The Region of Peel need to address the changing trends of transportations, residential development and population growth to adapt better techniques in monitoring, update data and establish customised solutions for the region or adapt from best practices.

Future Research Opportunities: More research is needed to understand residential need with transport demand and policy planning. For transportation planning, it is necessary to forecast the demands of transportation in the future, predict the increase in vehicles over the years to come and anticipate the impact on the air quality and its detrimental effects on human health and environment.

5.5.2. Industrial Emissions

From the correlation analysis it was found that a decrease in asthma emergency department is positively moderately correlated to decreased decrease in industrial emissions. Industrial emissions are stationary sources of air pollutants. According to the Peel Region Official Plan, heavy industries and the airport are focal polluters to $PM \leq 2.5 \mu m/cm^3$ (*Air Quality,* Peel Region Official Plan Review, 2007). The types of industries in the region are storage, packaging, food industries, and petroleum industries. Ontario air pollution regulation, Regulation 419/05, has replaced the previous regulatory framework with stricter standards for many contaminants including particulate matters. The implementation and continuous audit may contribute to reduce the emission of pollutants by 20% in the Region of Peel.

Regulation 419/05 has also manifested the use of airshed monitoring that gives context to the modeling and health risk analyses. The success story of airshed monitoring was observed in Ottawa, Hamilton, Halton Region and Greater Sudbury. However the Region of Peel did not act in accordance to the requirement of airshed monitoring as the region argued their industries to be less polluting compared to other cities and municipalities (Perotta, K., 2010).

Recommendations: All land uses must be within specified distances from facilities with potential industrial emissions. Area wide air-quality monitoring is also required, together with regulatory and policy mechanisms to enable governments at all levels to address local airsheds and non-point sources.

Future Research Opportunities: There is no other study that shows the improved air quality in Peel, neither are there any studies showing improved health outcomes due to reduced pollution. Future research can potentially address these issues.

5.5.3 Role of Planner in reducing asthma

Asthma is a complex chronic disease with determinants at both the individual and environmental levels. Planners may not have direct role to play in reducing asthma but can contribute to reductions in incidence through land use planning that improves air quality, and through social and community development that limits social inequalities in health. Based on the findings of this research, it is recommended that planners focus on changing AADT and promote transit use to limit emissions from vehicles. Planners can also advocate for policies, regulatory standards and land use allocation of industries to continue to contribute to the observed decreased emission of particulate matter from industries. Planners can advocate for engaged communities that seek to attain social and health equity by means of public involvement, awareness programs, and strong advocacy by community members. Finally, in terms of asthma, planners are one important piece of the complex puzzle and therefore need to continue to work collaboratively with other municipal and regional departments such as public health and engineering to create healthy built environment.

5.6 Reiterating the Research to the Conceptual Framework

The motivation of the research was based on the Dahlgren & Whitehead (1991) "determinants of health". The model categorized key components such as socio-economic and built environment factors. In a Canadian perspective, Raphael (2009) identified the key socio-economic factors such as income, employment, education, lifestyle and housing, as determinants of health. All these parameters were addressed in this research.

This study specifically observed relationships among asthma ED visits, the built environment, and socio-economic factors. The study also confirmed potential evidence that the air quality had improved over time possibly due to the initiatives from governments, public health agencies, and environmental organizations.

The key findings from the study are:

1) improved built environments can possibly reduce asthma ED visits;

2) accessibility to health care is potentially the key to improved health; and

3) effective asthma awareness programs can potentially improve health.

5.7 Conclusion

The purpose of the study was to investigate the changes in asthma illness in the Region of Peel between 2007 and 2011. The literature review narrowed the determinants of the study. This was a retrospective, quantitative analysis. The dependent variables were asthma emergency department visits, and the independent variables were the built environment and socioeconomic status. The quantitative methods used were spatiotemporal analysis and statistical correlation. It was observed that asthma ED visits reduced in 5 years. Changes in transportation, industrial emission and socio-economic variables were observed. Using statistical tool of correlation, it was observed that strong correlations exists between to asthma ED visits and average AADT, industrial emissions, percentage of population using vehicles, percentage of population using public transit, percentage of population at risk, percentage of educated populations, and percentage of prevalent low income population. The discussion highlighted the key relations between health care system, public health departments, regional changes and land use planning. Recommendations were suggested and opportunities for future research were proposed.

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APPENDICES

APPENDIX A Differences between AQI and AQHI

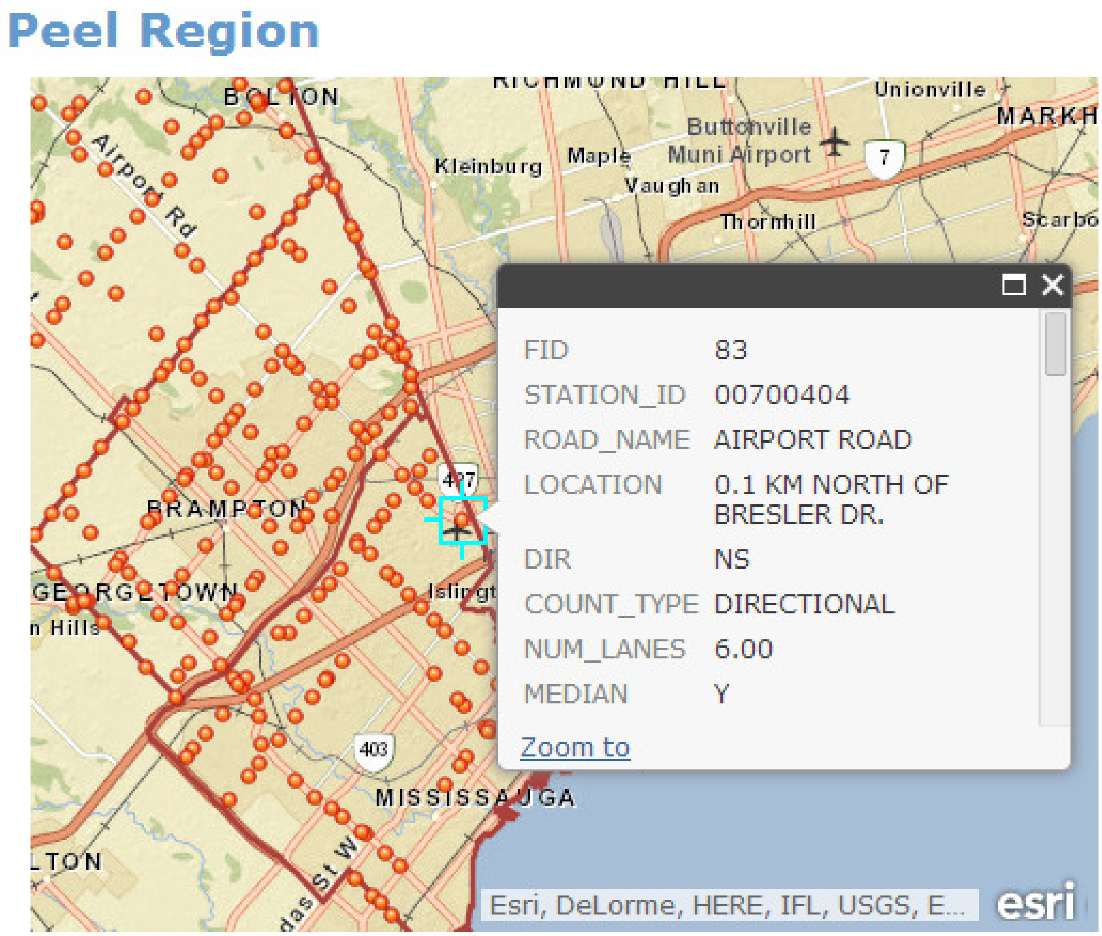
Air Quality Index		Air Quality Health Index	
Strengths	**Limitations**	**Strengths**	**Limitations**
- Includes five pollutants (O_3, $PM_{2.5}$, NO_2, SO_2, and TRS) with flexibility for easily adding more air pollutants	- The formula fails to capture effects from simultaneous exposure to the mix of air pollutants	- Includes three pollutants (O_3, $PM_{2.5}$, and NO_2) that have the best-established scientific grounds with respect to human health effects according to a daily time-series study conducted in Canada	- It remains uncertain whether the coefficient of NO_2 in the statistical relationship between air pollution and mortality reflects a direct causal effect, or more likely, is due to NO_2 acting as a proxy for other unmeasured air pollutants
- More responsive to transient change of O_3 and $PM_{2.5}$ (due to forest fire smoke)	- AQI is based on air quality standards/ guidelines; , existing air quality standards/guidelines are not linked to health effects in a consistent quantitative manner	- Reflects combined effects of air pollution as a mixture rather than a single pollutant and the index value has an interpretation that is directly related to the risk of mortality	- Knowledge regarding how multiple pollutants interact and impact on human health has not yet been fully established
- Pollutant-specific health messaging recognizes the fact that exposure reduction is not the same for all pollutants	- Pollutant-specific health messaging may lead to confusion and misunderstanding regarding the overall health impact of air pollution as a mixture	- Correlations with multiple air pollutants are stronger for the AQHI than the AQI	- Limited generalizability between urban and rural settings
	- A lack of evidence supporting any quantitative relationship between the AQI and known health effects	- More responsive to rapidly changing air quality due to NO_2, a marker for traffic-related air pollution	- Fails to recognize the public-health importance of chronic exposure to ambient air pollution
	- Fails to recognize the public-health importance of chronic exposure to ambient air pollution	- Based on a statistical relationship between air pollution and mortality. There is also preliminary evidence showing possible association between the AQHI and asthma- and cardiac-related hospitalizations	- Fails to recognize the importance of spatial locations on increasing individual's risk to ambient air pollution
	- Fails to recognize the importance of spatial locations on increasing individual's risk to ambient air pollution	- Includes a communication and education program developed through a national process that provides health messaging for individuals	- It is uncertain whether the coefficients currently used in the AQHI formula are still valid
	- Little evidence to support the effectiveness of advisories in reducing exposure to pollutants	- Consistent health messaging	-Little evidence to support effectiveness of advisories in reducing exposure to pollutants

APPENDIX B Ontario Chronic Disease Prevention and Management Framework

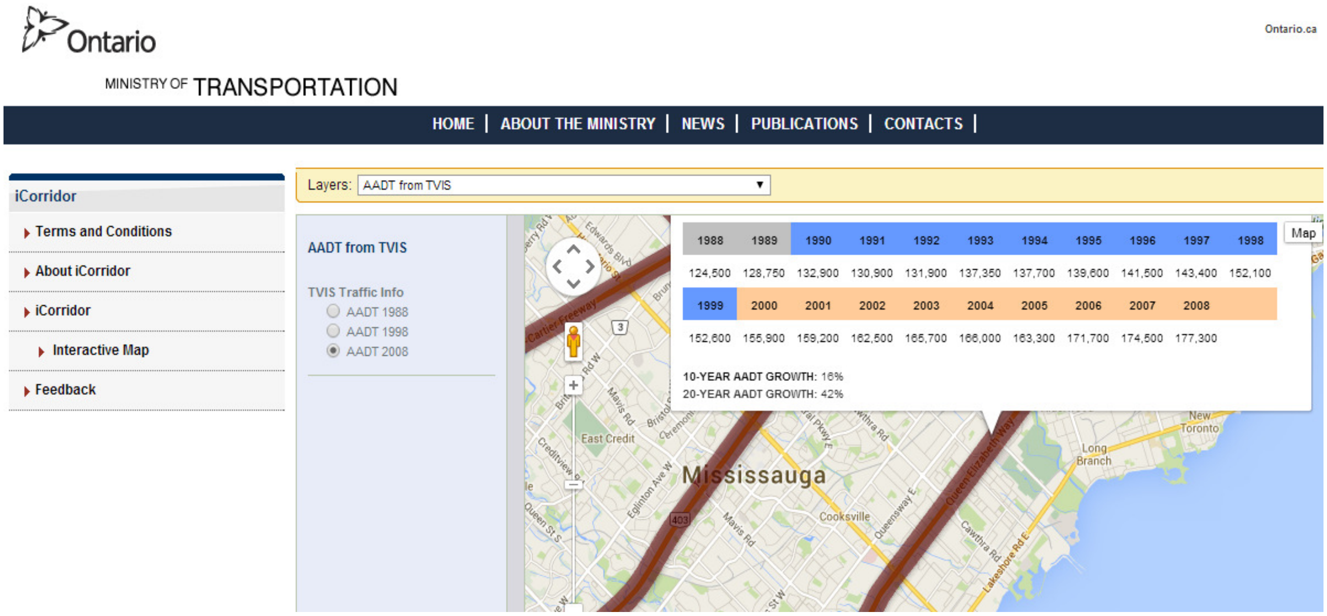
Logic Model for Ontario's Chronic Disease Prevention and Management Framework

Vision	An integrated, coordinated system for the prevention and management of chronic diseases, with productive interactions and relationships among individuals/families, communities, and health care organizations/providers, that are proactive, individual and family-centred, and that provides access to quality care by the right provider at the right time in the right place		
Inputs	Policy, Legislation/Regulations, Guidelines, Fiscal and Human Resources, Information Systems		
Components	Activated Communities and Prepared, Proactive Partners	Informed, engaged individuals and families	Prepared, proactive practice teams
Outputs	▪ Communities collaborating with HCOs to identify and prioritize issues affecting the health of the population. ▪ Communities championing activities for healthy public policy, and supportive environments. ▪ Community collaboration with HCOs to develop, link and coordinate services and information for individuals and families. ▪ Community information and programs integrated with health care services.	▪ Education, counselling, behaviour modification programs, and information for individuals and families to build skills for healthy living and coping with disease. ▪ Tools for individuals and families to become daily self-managers and communicate with providers. ▪ Care teams with individuals and families at the centre, and engaged in decision making and care planning. ▪ Self-management information and resources accessible and tailored to meet the needs of individuals and families. ▪ Community programs and resources integrated into care.	▪ Health promotion, primary, secondary, and tertiary prevention incorporated into care. ▪ Visible leadership, aligned incentives, policies, resources, measurement, and accountability for CDPM system changes. ▪ Interdisciplinary team practices, with links to specialists, where health care providers collaboratively provide patient-centred care in a seamless and coordinated manner. ▪ Integrated electronic information systems with comprehensive, accurate information for providers and individuals to share information & make the best decisions. ▪ Evidence-based tools for prevention, assessment and management incorporating planned interactions, and prompts for follow-up.
Short-term outcomes	▪ Increased community collaboration with HCOs to identify and prioritize issues affecting health. ▪ Increased community action for healthy public policy, supportive environments to meet the needs of their population. ▪ Increased awareness, linkages and referral to community programs, information, and resources.	▪ Individuals and families have increased skills and knowledge for healthy behaviours. ▪ Individuals, families and providers have improved understanding of their roles as partners on care teams, and consumers are involved in care planning. ▪ More individuals and families have increased knowledge of their disease processes and role as daily self-manager. ▪ Increased knowledge and skills of consumers in self-management. ▪ More individuals and families are aware of and linked to community programs and resources.	▪ Providers have increased knowledge, skills and tools to incorporate prevention into their practices. ▪ More HCOs promote system change and provide incentives, align policies, resources, measurement, and accountability. ▪ Increased number of interdisciplinary teams, with links to specialists working collaboratively and providing coordinated, patient-centred care. ▪ More providers using electronic information systems and sharing information among team members, their clients, other health providers and settings. ▪ More providers using evidence-based tools, and quality improvement approaches for prevention, assessment and management.
Intermediate outcomes	▪ Improved healthy public policies and supportive environments. ▪ More community information and programs integrated with health care services.	▪ More people exhibiting healthy behaviours ▪ Individuals and families at the centre of the care team, actively engaged in decision-making, and daily managers of their health. ▪ More individuals and families gaining benefits through involvement in self-management ▪ Increased participation in community programs and resources ▪ Increased overall satisfaction of individuals and families with the responsiveness of the health care system to meet their needs	▪ Health promotion and prevention integrated across continuum of care. ▪ Health care coordinated across the continuum of care, providers and settings. ▪ The appropriate type and number of health care providers working in collaboration to meet the needs of the individual and family. ▪ Care is evidence based and meets the diverse needs of consumers. ▪ Care is proactive, and provides for complex and continuing care, with follow-up and ease of navigation. ▪ Integrated information systems with consumer, decision support and community information.
Long-term outcomes	Improved Clinical Outcomes	Reduced burden of Chronic Disease	Improved sustainability of the health system

APPENDIX C Traffic Count Points in Interactive Mapping, the Region of Peel (Source: Region of Peel)



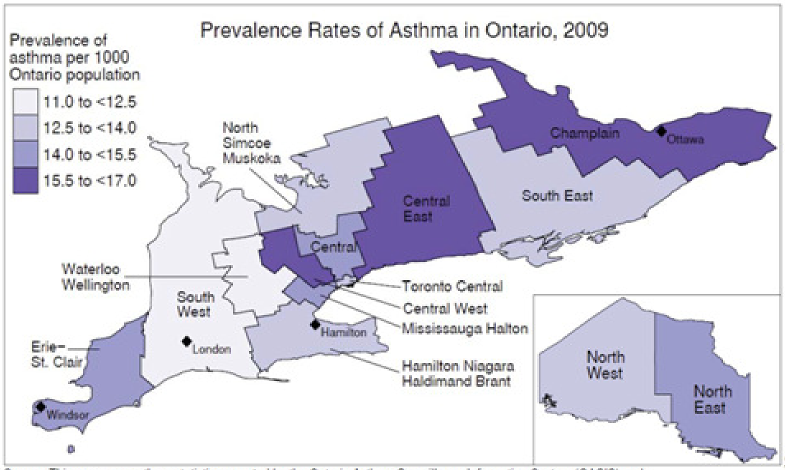
APPENDIX D Sample of iCorridor AADT Interactive Map, Ministry of Transportations, Ontario (Source: Ministry of Transportations, Ontario, 2014)



APPENDIX E Sample of NPRI Emissions (Source: NPRI, 2013)

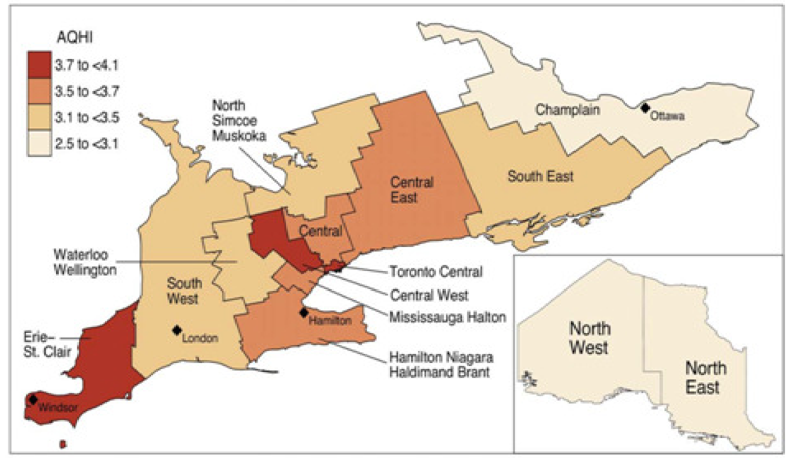
1	Inventaire national des rejets de polluants 2012 / National Pollutant Release Inventory 2012					
2	Facility Information / Renseignements sur l'installation					
3	Année	ID INRP	Raison Sociale	Nom de l'installation	Ville	SDR
4	Year	NPRI ID	Company Name	Facility Name	City	CSD
1386	2012	566	Acorn Packaging Inc.	Acorn Packaging Inc.	Mississauga	Mississauga
2996	2012	1260	Fielding Chemical Technologies Inc.	Fielding Chemical Technologies Inc.	Mississauga	Mississauga
5364	2012	2182	Holcim (Canada) inc.	Mississauga Cement Plant	Mississauga	Mississauga
5653	2012	2256	Tonolli Canada	TONOLLI CANADA LIMITED	Mississauga	Mississauga
9758	2012	3889	Samuel Strapping Systems	Mississauga Location	Mississauga	Mississauga
9870	2012	3899	Petro-Canada Lubricants Inc.	Mississauga Lubricants Centre	Mississauga	Mississauga
10262	2012	3983	Stackpole Powertrain International ULC	Stackpole PMDM	Mississauga	Mississauga
11446	2012	4451	Greater Toronto Airports Authority	Toronto Pearson International Airport	Mississauga	Mississauga
11524	2012	4507	Magellan Aerospace, Mississauga	Magellan Aerospace, Mississauga	Mississauga	Mississauga
11785	2012	4618	A&M SurfTech Ltd.	A&M SurfTech Ltd.	Mississauga	Mississauga
12529	2012	4873	TransAlta Generation Partnership	Mississauga Cogeneration Plant	Mississauga	Mississauga
15876	2012	5732	Aleris Specification Alloy Products	Aleris Mississauga	Mississauga	Mississauga
15879	2012	5733	Lincoln Electric Co. of Canada LP	INDALCO ALLOYS	Mississauga	Mississauga
16227	2012	5890	Nestle Purina Petcare	Mississauga Plant	Mississauga	Mississauga
16289	2012	5912	Frendel Kitchens Limited	FRENDEL KITCHENS LIMITED	Mississauga	Mississauga
16471	2012	5989	Region of Peel	Britannia Sanitary Landfill Site	Mississauga	Mississauga
17028	2012	6163	Pratt & Whitney Canada Inc.	Plant 22	Mississauga	Mississauga
20185	2012	7070	Booth Centennial Healthcare Linen Services	BOOTH CENTENNIAL HEALTHCARE LINEN SERVICES	Mississauga	Mississauga
20345	2012	7148	Mondelez Canada Inc	Mississauga Mill	Mississauga	Mississauga

APPENDIX F LHINs across Ontario with High Prevalence of Asthma, High OHIP Claims, High distribution of AQHI and Particulate Matter

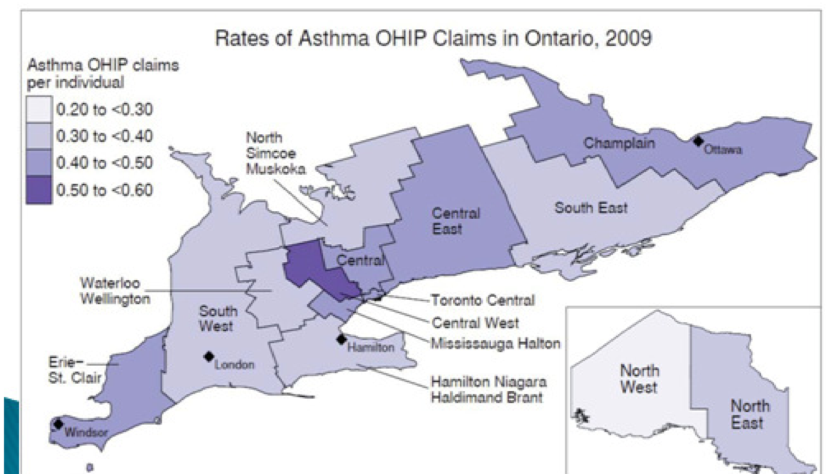


Source: This map uses asthma statistics reported by the Ontario Asthma Surveillance Information System (OASIS) and data provided by the Institute for Clinical Evaluative Sciences (ICES), Ontario.

Distribution of AQHI in Ontario, 2003-2010

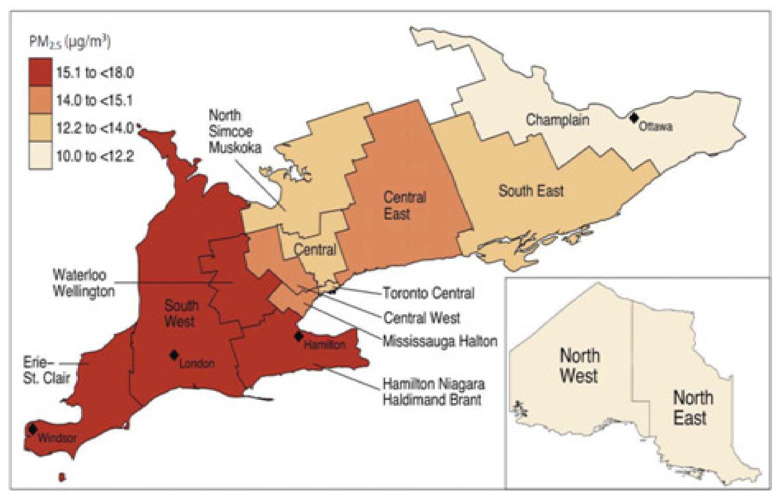


Source: Ontario's Ministry of the Environment (MOE)



Source: This map uses asthma statistics reported by the Ontario Asthma Surveillance Information System (OASIS) and data provided by the Institute for Clinical Evaluative Sciences (ICES), Ontario.

Distribution of $PM_{2.5}$ in Ontario, 2003-2010



Source: Ontario's Ministry of the Environment (MOE)

APPENDIX G Descriptive Statistical Result of Built Environment factors for 2007

HEALTH ZONES	CITY	**ASTHMA ED PER 1000_2007**	AVERAGE AADT 2007	INDUSTRIAL EMISSION 2007	PARKS/REC %2007	IND %2007	Car/Truck/Van DP2007	Public transit 2007	Others2007	Distance from M4
M1	Mississauga	**2.60**	55323	11.900	0.31	0.84	84.7	13.1	2.2	13049
M2	Mississauga	**3.75**	31021	9.094	3.86	1.87	85.1	11.6	3.3	9680
M3	Mississauga	**2.47**	37685	13.130	2.31	0.00	85	13.6	1.4	9480
M4	Mississauga	**3.60**	48527	90.933	1.13	0.99	80.8	16	3.2	0
M5	Mississauga	**3.16**	52439	1.600	4.23	0.41	80.3	13.8	5.9	13854
M6	Mississauga	**2.85**	34426	0.531	3.37	0.34	76.1	18.8	5.1	8054
M7	Mississauga	**2.90**	30259	87.996	0.00	0.00	75.6	19.4	5	13663
M8	Mississauga	**3.09**	32720	12.374	4.27	0.66	74	17.7	8.3	8026
B1	Brampton	**3.87**	20622	56.700	1.16	0.02	88.6	8.6	2.8	13511
B2	Brampton	**4.09**	38942	1.900	8.52	5.90	85.3	10.7	4	10673
B3	Brampton	**3.49**	36606	39.148	2.48	0.08	80.3	11.7	8	7421
B4	Brampton	**2.87**	28833	0.000	20.07	1.27	90.3	8.1	1.6	15348
B5	Brampton	**3.33**	45878	257.031	4.37	0.19	84.5	11.5	4	9358
C1	Caledon	**3.78**	8396	20.000	0.53	0.00	94.8	1.4	3.8	29343
C2	Caledon	**3.79**	19463	1.900	5.64	0.64	91.5	1.5	7	24453
Average		**3.310**	34743	40.282	4.15	0.88	83.79	11.83	4.37	12394
Max		**4.088**	55323	257.031	20.07	5.90	94.80	19.40	8.30	29343
Min		**2.475**	8396	0.000	0.00	0.00	74.00	1.40	1.40	0
Std devi		**0.502**	12763	67.318	4.96	1.49	6.03	5.40	2.16	7026
Skewness		**-0.14675**	-0.264125	2.707929	2.616088	3.073753	0.048761991	-0.663891	0.53344	1.04192458

APPENDIX H Descriptive Statistical Result of Socio-economic factors for 2007

HEALTH ZONES	CITY	ASTHMA ED PER 1000_2007	Pop Risk % 2007	Avg After Tax Income 2007 $	Employed % pop 2007	Prevalence of Low Income_2007 in %	Educatd Pop % 2007
M1	Mississauga	**2.60**	29.32	34024	50.07	8.7	26.13
M2	Mississauga	**3.75**	29.04	32354	60.96	7.6	24.00
M3	Mississauga	**2.47**	34.08	29377	66.26	9.8	26.46
M4	Mississauga	**3.60**	25.00	26073	44.16	12.6	21.66
M5	Mississauga	**3.16**	28.51	36065	53.46	9.8	27.38
M6	Mississauga	**2.85**	22.88	27674	50.98	13.8	27.38
M7	Mississauga	**2.90**	24.26	35168	50.62	11.2	25.84
M8	Mississauga	**3.09**	20.18	28157	52.87	11.2	23.48
B1	Brampton	**3.87**	27.66	31063	24.82	6.6	14.72
B2	Brampton	**4.09**	28.02	27484	27.76	8.9	12.73
B3	Brampton	**3.49**	26.50	26778	27.16	12.2	18.64
B4	Brampton	**2.87**	28.99	27577	25.13	8.7	15.08
B5	Brampton	**3.33**	23.01	28555	25.47	9.7	15.47
C1	Caledon	**3.78**	33.75	41290	30.81	2.6	17.86
C2	Caledon	**3.79**	56.26	33588	30.96	3.8	27.65
Mean		**3.31**	29.16	31015.13	41.43	9.15	21.63
Min		**2.47**	20.18	26073.00	24.82	2.60	12.73
Max		**4.09**	56.26	41290.00	66.26	13.80	27.65
Std Dev		**0.50**	8.41	4313.80	14.49	3.09	5.37
Skewness		**-0.15**	2.59	1.00	0.20	-0.74	-0.39

APPENDIX I Descriptive Statistical Result of Built Environment factors for 2011

HEALTH ZONES	CITY	**ASTHMA ED PER 1000_2011**	AVERAGE AADT 2011	INDUSTRIAL EMISSION 2011	PARKS/REC %2011	IND %2011	CTV 2011	Public Transit 2011	Others 2011	Distance from M4
M1	Mississauga	**2.28**	44502	11.79	0.31	0.84	84.5	13.9	1.6	13049
M2	Mississauga	**3.76**	29598	10.85	3.86	1.87	84.3	12.4	3.3	9680
M3	Mississauga	**2.80**	56787	19.40	2.31	0.00	82.6	14.5	2.9	9480
M4	Mississauga	**2.65**	56570	75.85	1.13	0.99	79.2	13.4	7.4	0
M5	Mississauga	**3.20**	60780	1.17	4.23	0.41	81.9	13.4	4.7	13854
M6	Mississauga	**2.20**	71229	0.36	3.37	0.34	80.2	18.2	1.6	8054
M7	Mississauga	**2.84**	30220	47.79	0.00	0.00	75.5	18.9	5.6	13663
M8	Mississauga	**3.03**	36408	7.46	4.27	0.66	80.2	17.6	2.2	8026
B1	Brampton	**2.70**	20565	30.81	1.16	0.02	87.1	10.7	2.2	13511
B2	Brampton	**3.18**	47252	2.22	8.52	5.90	74	12.8	13.2	10673
B3	Brampton	**2.79**	33273	28.93	2.48	0.08	74	13.2	12.8	7421
B4	Brampton	**3.51**	24504	0.00	20.07	1.27	87.3	10.4	2.3	15348
B5	Brampton	**3.05**	34376	97.96	4.37	0.19	84.2	12.2	3.6	9358
C1	Caledon	**2.48**	7321	4.97	0.53	0.00	93.5	3.5	3	29343
C2	Caledon	**2.50**	13070	0.00	5.64	0.64	95	2	3	24453
Average		**2.86**	37764	22.64	4.15	0.88	82.9	12.47	4.63	12394
Max		**3.76**	71229	97.96	20.07	5.90	95	18.9	13.2	29343
Min		**2.20**	7321	0.00	0.00	0.00	74	2	1.6	0
Std Dev		**0.43**	18256	29.82	4.96	1.49	6.24	4.68	3.74	7026
Skewness		**0.09377**	0.17031	1.64683	2.6160	3.0737	0.4161	-1.03304	1.7123	1.041925

APPENDIX J Descriptive Statistical Result of Socio-economic factors for 2011

HEALTH ZONES	CITY	**ASTHMA ED PER 1000_2011**	Pop Risk % 2011	Avg After Tax Income 2011	Employed % pop 2011	Prevelance of Low Income 2011 %	Educated pop 2011 %
M1	Mississauga	**2.28**	28.60	37426.40	59	9.8	65.11
M2	Mississauga	**3.76**	27.89	35589.40	64	9.5	58.09
M3	Mississauga	**2.80**	27.22	32314.70	49	7.6	73.94
M4	Mississauga	**2.65**	29.56	28680.30	39	13.2	40.61
M5	Mississauga	**3.20**	31.10	39671.50	59	10.5	52.44
M6	Mississauga	**2.20**	28.45	30441.40	59	15.2	59.33
M7	Mississauga	**2.84**	31.09	38684.80	44	12.9	32.86
M8	Mississauga	**3.03**	31.42	30972.70	42	13.5	45.45
B1	Brampton	**2.70**	30.24	33004.44	45	8.6	39.62
B2	Brampton	**3.18**	29.66	29201.75	48	10.8	30.54
B3	Brampton	**2.79**	31.61	28451.63	47	14.8	39.64
B4	Brampton	**3.51**	31.88	29300.56	41	9.8	40.72
B5	Brampton	**3.05**	30.93	30339.69	49	11.7	34.18
C1	Caledon	**2.48**	30.97	44056.43	29	2.9	39.95
C2	Caledon	**2.50**	32.48	35838.40	39	4.2	30.88
mean		**2.86**	30.20	33598.27	47.53	10.33	45.56
min		**2.20**	27.22	28451.63	29	2.9	30.54
max		**3.76**	32.48	44056.43	64	15.2	73.94
std dev		**0.43**	1.58	4733.76	9.46	3.537	13.265
Skewness		**0.46128996**	-0.54463	0.8302328	0.0854908	-0.723683815	0.8601344

APPENDIX K Correlation Coefficient Table for 2007

	ASTHMA ED PER 1000_2007	AVERAGE AADT 2007	INDUSTRIAL EMISSION 2007	PARKS/REC% 2007	IND %2007	Car/Truck/Van DP2007	Public transit 2007	Others2007	Distance from M4
ASTHMA ED PER 1000_2007	1								
AVERAGE AADT 2007	-0.402496214	1							
INDUSTRIAL EMISSION 2007	0.057712383	0.22430573	1						
PARKS/REC%2007	-0.036183577	-0.07499505	-0.203078655	1					
IND %2007	0.432232185	0.146993242	-0.243064171	0.38534398	1				
Car/Truck/Van DP2007	0.397829771	-0.49515421	-0.093407977	0.27458878	0.0940259	1			
Public transit 2007	-0.529072306	0.58923971	0.128919428	-0.2369022	-0.057249	-0.9340535	1		
Others2007	0.211473057	-0.09052971	-0.061361156	-0.1738257	-0.119035	-0.4552841	0.10728772	1	
Distance from M4	0.203958298	-0.66894599	-0.253361151	0.0804474	-0.136478	0.68836922	-0.77464762	0.014865	1

	Asthma ED per 1000	pop at risk%	Avg Income after tax	Employed pop %	Prevalence of Low Income %	Educated Pop %
Asthma ED per 1000	1					
Pop at Risk %	0.24370	1.00000				
Avg Income after Tax	0.06778	0.36175	1.00000			
Employed Pop %	-0.54523	-0.15157	0.11361	1.00000		
Prevalence of Low Income Pop %	-0.45673	-0.69239	-0.66641	0.33914	1.00000	
Educated Pop %	-0.50972	0.25360	0.27390	0.78049	0.18631	1

APPENDIX L Correlation Coefficient for 2011

	ASTHMA ED PER 1000_2011	AVERAGE AADT 2012	INDUSTRIAL EMISSION 2011	PARKS/REC% 2011	IND %2011	CTV 2011	Public Transit 2011	Others 2011	Distance from M4
ASTHMA ED PER 1000_2011	1								
AVERAGE AADT 2012	-0.121834544	1							
INDUSTRIAL EMISSION 2011	-0.027952127	0.043664602	1						
PARKS/REC%2011	0.548416665	-0.115455677	-0.307773787	1					
IND %2011	0.383192338	0.133224901	-0.247616664	0.385344	1				
CTV 2011	-0.154873554	0.583945363	-0.228939576	0.1177626	-0.3248602	1			
Public Transit 2011	0.07600137	0.680795446	0.189292006	-0.1634187	0.0020163	-0.802225	1		
Others 2011	0.163270883	0.121956678	0.145005457	0.0081179	0.5395701	-0.664177	0.086500	1	
Distance from M4	-0.167921537	-0.686671903	-0.448796655	0.0804474	-0.1364777	0.742566	-0.746930	-0.30383	1

	Asthma ED visits 2011	Pop at Risk %	Avg Income after TAX	Employed pop %	Prevalence of Low Income pop %	Educated pop %
Asthma ED visits	1					
Pop at Risk %	0.068406938	1				
Avg Income after Tax	-0.166355572	0.0686387	1			
Employed pop %	0.211701214	-0.5742781	-0.064915929	1		
Prevalence of Low Income Pop %	0.069098153	-0.0865818	-0.603787722	0.385729807	1	
Educated Pop %	-0.107531015	-0.7712776	0.100183051	0.599083004	0.027639052	1

APPENDIX M Correlation Coefficient

Asthma ED visits	2007 data set Correlation Coefficient r	Strength of Correlation	2011 data set Correlation Coefficient r	Strength of Correlation
AVERAGE AADT	-0.40249	Negative moderate correlation	-0.1218	Negative low correlation
INDUSTRIAL EMISSION	0.57071	Positive moderate correlation	-0.0279	Negative weak correlation
PARKS/REC%	-0.03618	Negative weak correlation	0.03841	Positive Low correlation
IND %	0.04223	Positive Moderate correlation	0.38319	Positive Moderate correlation
Personal use vehicle	0.59782	Positive Moderate correlation	-0.15487	Negative low correlation
Public transit	-0.52907	Negative moderate correlation	0.07600	Positive weak correlation
Other transport modes	0.21147	Positive weak correlation	0.16327	Positive low correlation
Pop at Risk %	0.44370	Positive weak correlation	-0.4452	Negative moderate correlation
Avg Income after Tax	0.06778	Positive weak correlation	0.06840	Positive weak correlation
Employed Pop %	-0.54523	Negative moderate correlation	-0.16635	Negative low correlation
Prevalence of Low Income Pop %	-0.65673	Negative moderate correlation	0.21170	Positive low correlation
Educated Pop %	-0.50972	Negative moderate correlation	0.06909	Positive weak correlation

APPENDIX N Profiling Data Zone

	Increased Asthma ED		Decreased Asthma ED			
	M3	**B4**	**M4**	**B1**	**C1**	**C2**
Asthma ED VISIT per 1000	0.32	0.64	-0.95	-1.16	-1.30	-1.29
Probable number of asthma ED visits	17.92	65.36	-124.00	-135.33	-47.12	-29.87
Asthma ED visit change in %	6.09	9.97	-15.34	-17.79	-20.74	-20.46
Change in AADT %	20	-8.31	14.22	-0.28	-14.68	-48.91
Change in Industrial Emission %	19	0	-9.04	-29.58	-60.00	0
Area of Industries %	2	0	0.98	0.02	0.00	0.64
Distance from M4 in meters	9480.49	15347.63	0.00	13511.00	29342.00	24452.00
Area of Park %	2.3	15	1.13	1.50	1.50	5.64
Change in Vehicle use %	-1.6	-1.8	7.90	-0.89	-0.69	1.89
Change in Transit Use %	3.2	12.4	13.40	-8.80	42.50	14.80
Population change %	-11	5.4	9.10	6.02	1.90	1.60
0-19yrs	29.1	34.2	28.8	31.9	26	30.8
20-64 yrs	61.3	53.9	62	57.1	57	59.4
65+yrs	9.6	11.9	9.2	10.2	17	9.8
Male	49.3	49.1	49.1	48.9	49.9	49.3
Female	50.7	50.9	50.9	51.1	50.1	50.7
Pop at Risk change %	-11.4	4.7	8.36	4.46	-4.30	-26.80
Income change in %	3.03	4.76	3.50	4.20	3.20	3.50
Prevalent Low income pop %	-12.64	5.95	2.33	13.10	5.45	5.00
Change in educated pop %	45	47	30.00	45.00	38.21	5.51
Change in employed pop %	-14.98	24	-6.20	28.90	-3.02	11.49