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**Development of a Methodology to Use Geographical Information Systems and Administrative Data to
Measure and Improve Inequity in Health Service Distribution**

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**Development of a Methodology to Use Geographical Information
Systems and Administrative Data to Measure and Improve Inequity in
Health Service Distribution**

By

Bruce Libman

Thesis submitted to the Faculty of Graduate and Postdoctoral Studies
In partial fulfillment of the requirements for the M.Sc. degree in Epidemiology and
Community Medicine

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ABSTRACT

A geographic information system was used to measure geographical access to general surgical services in the Champlain Local Health Integration Network. An origin-destination matrix approach was used with discharge data for Champlain residents using the Ontario Road Network file and OC Transpo trip planner for public transportation trips within the city of Ottawa. GIS showed that adding surgical services to the Renfrew Victoria Hospital would be the best location to achieve the goal of reduced drive times for Champlain LHIN residents. However, this hospital was ill suited to take on additional surgeries due to high occupancy rates, a lack of space and surgeons. Differences in neighbourhoods' geographical access (drive and transit time) to the General Campus of the Ottawa Hospital were found. However, it was the more affluent neighbourhoods and neighbourhoods with lower percent of recent immigrants that had longer drive times and transit times.

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Chapter 1

Introduction

Access to health services is a key determinant of health^{1,2}. Unfortunately, the term access is “nebulous and obscure”³, and as such, several competing frameworks⁴ have been developed over the years to bring researchers closer to a common understanding of what access means (reviewed by Higgs (2004)⁵. Perhaps the best way to understand access is to use Penchansky and Thomas’ (1981)⁶ grouping of access into five different dimensions, namely: availability, accommodation, affordability, acceptability and geographic accessibility.

Availability is the total number or types of services available in a given area relative to demand. Affordability relates to the ability to pay for services relative to income. Acceptability refers to cultural or social norms of service providers. Services may be effectively unavailable if they are culturally inappropriate to a certain group. Similarly, if a cultural group perceives unfair treatment, it is possible for this perception to hinder access to health services (Johnson et al. 2004⁷). Accommodation refers to the convenience or efforts made to remove barriers to health services for some segments of society, for example, those who work night shifts. Finally, geographic accessibility refers to the physical location of a healthcare services and the ability of the client to get to that location. Differences in geographical access arise for many reasons, but are most commonly related to the distance between services and residents. Rural residents experience diminished access to services either because they are too far from the service or the cost of transportation is too expensive.

Theoretical understanding of geographical access problems has its roots in location science. Location science is the discipline that examines where to locate facilities “so as to minimize the cost of satisfying some set of demands subject to some set of constraints”⁸. Problems are usually solved in terms of minimizing total system travel time between facilities and clients (p-median problem) or by minimizing the maximum distance any one client has to travel (minimax problem)⁸. Modes of travel used in travel location science include straight-line distances (Euclidean, Manhattan Distances) and distances on a network of arcs and nodes. Finally, the set of facilities can be located anywhere in the service area or they can be chosen from an already existing set of facilities⁸.

The theory of location science is now implemented with Geographical Information Systems (GIS). GIS, as the name implies, is a software tool that has been used to study geographic access issues in settings ranging from water supply access to high-end retail store location. Geographical access in the context of healthcare services is itself a broad area of research and GIS has played a critical role in measuring access and as tool for optimally locating services to meet demands.

Goals and Objectives

The general problem of geographical access to healthcare services is the main focus of this thesis. The first goal of the thesis is to develop a GIS methodology that will allow one to measure geographic access to health services using drive times of patients to services. The second part of the thesis will illustrate how to use both drive time and transit time (by public transportation) to measure inequity in geographic access to a single health service provider for all residents of a city. Inequity will be measured by

linking the geographic accessibility data to neighbourhood income and immigration measures.

Data for both parts of the thesis will be derived from inpatient general surgeries performed on residents of the Champlain Local Health Integration Network (LHIN) at hospitals within the Champlain LHIN. General surgery was chosen because, other than gynaecology and orthopaedics, it is the largest surgical program in most Champlain LHIN hospitals (unpublished data). More information on the hospitals and types of surgeries is listed below.

Objectives

- 1) Review the use of GIS in measuring geographical access to health care services (Chapter 2)
- 2) Develop a GIS based methodology to measure geographical access to health care services as measured by drive time (personal vehicle) (Chapter 3 part A).
- 3) Develop methods to extract transit time data (travel by bus) to a single hospital for all neighbourhoods in the city of Ottawa and link this data to neighbourhood income and immigration data (Chapter 3 part B).
- 4) Illustrate the drive time methodology using general surgery data for the population of the Champlain LHIN (Chapter 4).
- 5) Illustrate the utility of the methodology by determining where surgical services would need to be added to reduce overall drive time (Chapter 4).
- 6) Illustrate the utility of the methodology by determining changes in geographical access that would occur based on a scenario where all primary and secondary level of care surgeries are moved from teaching hospitals to community hospitals (Chapter 4).
- 7) Illustrate the utility of the public transportation methodology by measuring differences in equity (based on income and immigration status) between neighbourhoods to a hospital in the city of Ottawa. (Chapter 4).
- 8) Discuss strengths, weakness, assumptions and possible additions to the methodologies presented (Chapter 5).

The work presented in this thesis will be an important contribution to the access to health services literature in that it will combine several different data sources (health service use, geography (roads), transit routes and social-demographics) to present a picture of geographical access at both small scale (Champlain LHIN wide) and large scale (city of Ottawa). The methodology will provide health system planners the ability to test different configurations of hospital services to determine how it will affect geographic access prior to making changes. The methodology developed can be used throughout Canada by any researcher with access to the PCCF+, SAS and ArcGIS. Further, much of the SAS code is written in SQL, so it can be used directly by any SQL compliant database.

Background on the Champlain Local Health Integration Network

The methodology being developed in this thesis will be piloted using data on surgical services provided within the borders of the Champlain Local Health Integration Network (LHIN) (Figure 1). The Champlain LHIN is one of 14 regional local health planning areas within Ontario. The LHINs were created in 2006 by the Ontario Ministry of Health and Long-Term Care to focus on integration of health services with a focus on public consultation. The Champlain LHIN is 18,000 km² in area and 390 km long east to west. It administers an annual budget of nearly 2 billion dollars. The 2006 Canadian census reported 1.2 million people^{9,10} in the Champlain LHIN, with a growth rate of 4.7 % between 2001 and 2006, most of which was due to immigration to the Ottawa area¹⁰. The administrative boundaries of the LHINs in Ontario were chosen based on the historic boundaries of Ontario District Health Units, current Public Health Units and to minimize cross travel between LHINs with respect to hospital inpatient services.

The Champlain LHIN has been further subdivided into six “Communities of Care” for planning purposes (taken from west to east: Renfrew County, North Lanark / North Grenville, Ottawa West, Ottawa Centre, Ottawa East and Eastern Counties, Figure 1). These Communities of Care are based on entire census subdivisions or census tracts (for the Ottawa Communities of Care).

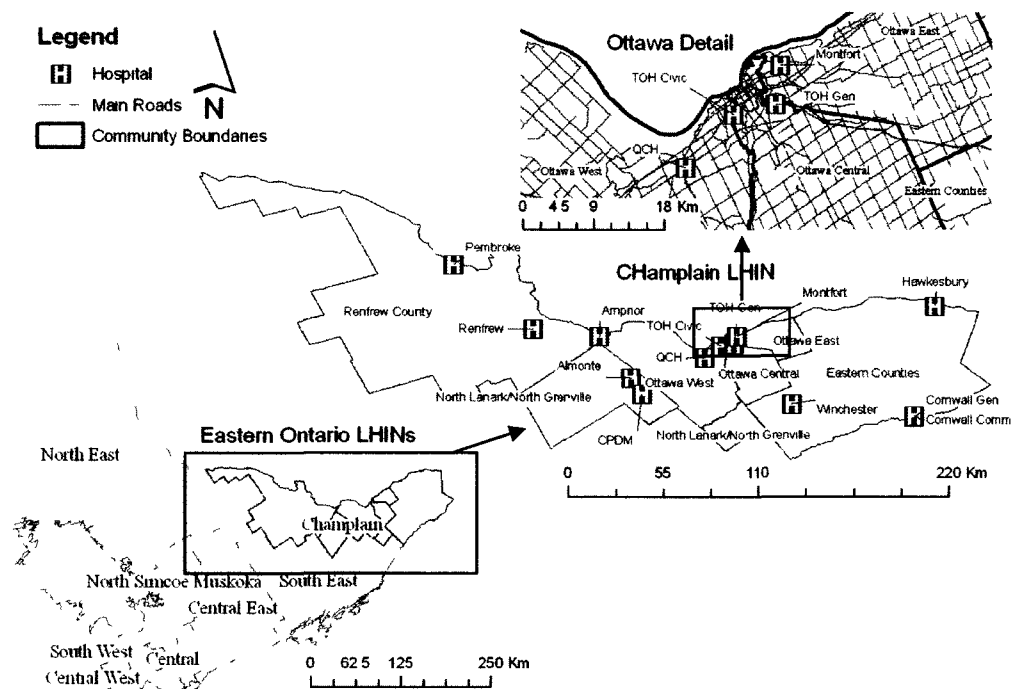


Figure 1. Map of the Champlain Local Health Integration Network showing inpatient hospitals.

The Champlain Local Health Integration Network is an ideal regional health planning organisation to develop and pilot the geographic access tool because of 1) its mandate to improve access in many areas, including surgeries, long-term care wait times;

and in general to move care “closer to home”¹¹ and 2) because of its diverse geography containing urban and rural communities. Further, 95% of residents of the Champlain LHIN receive their health care within the LHIN boundaries. The Champlain LHIN’s goal of moving care closer to home will not only improve geographic access, but may also have the added benefit of decreasing crowding at urban tertiary care hospitals that have higher case costs than community hospitals and could help with reducing alternative level of care days at tertiary care hospitals.

Background on the Champlain LHIN’s Hospitals and Human Health Resources

The Champlain LHIN hospitals that had at least 5 general surgeries performed in fiscal year 2006/07 are listed in Table 1. There are six small community hospitals, four large community hospitals and one teaching hospital situated on two distinct campuses. Occupancy is higher in the community hospitals compared to the small community hospitals, except for the Renfrew Victoria Hospital which reported 103% occupancy in 2009. Most of the hospitals in the Champlain LHIN experience significant bed shortages due the inability to discharge elderly patients to more appropriate settings such as long-term care or assisted living.

Background on the Surgeries Being Considered

The five most frequently performed general surgeries (classified by case mix groups) at Champlain hospitals are found in Appendix A. A summary of Appendix A is found in Table 2 which shows the overlap of case mix groups between hospitals relative to the five most common case mix groups found at the Ottawa Hospital (General and Civic campuses). There is a great deal of overlap in case mix between hospitals. The two most common case mixes are done at 10 of 12 of the hospitals. Further eight of 12

hospitals perform four or more of the most common case mix groups. Overall, the five most common case mixes account for 68% of all the general surgeries considered in this study.

Table 1. Basic statistics for Champlain LHIN Surgical Hospitals in 2009.

Hospital	Hospital Type ⁺	Total Beds	Bed Occupancy	general surgeries per year ^δ	Operating rooms	Operating rooms in operation	# General Surgeons [^]
Queensway-Carleton Hospital	LC	262	90	1,041	9	7	13
Montfort Hospital	LC	185	90	707	8	5	5
Cornwall Community Hospital	LC	157	95	556	7	5	8
Pembroke Regional Hospital	LC	178	88	304	3	3	9
Hawkesbury Hospital	SC	69	80	225	2	2 [§]	3
Renfrew Victoria Hospital	SC	58	103	111	2	2	1
Almonte General Hospital	SC	52	67	78	2	2 [*]	1
Winchester Hospital	SC	55	82	68	3	2	4
Arnprior Hospital	SC	44	83	65	2	2	3
Carleton Place Hospital	SC	16	70	38	1	1	2
The Ottawa Hospital - General Campus	T	994 [†]	88 [†]	1,967	17	14	35
The Ottawa Hospital- Civic Campus	T	994 [†]	88 [†]	1,668	16	15	33

+ SC: Small Community Hospital; LC: Large Community Hospital; T: Teaching/ Academic Hospital.
Source: Internal Champlain LHIN documentation.

* Second operating room is rarely used, but staff is available.

§ may be only one, second is scheduled to be used. Source: Internal Champlain LHIN documentation.

δ elective or urgent classification, three year average. Source: Provincial Data Warehouse

^ General surgeons may have privileges at multiple hospitals. There is double counting in the list.

Source: College of Physicians and Surgeons of Ontario, <http://www.cpso.on.ca/docsearch/> accessed on March 12, 2010.

† Ottawa Hospital Campuses not distinguished in this data set for bed occupancy percentage. Source: Internal Champlain LHIN documentation.

Table 2 Distribution of General Surgeries performed at Champlain LHIN Hospitals in 2006/07. Reading across columns indicates the number of hospitals that perform a given case mix; reading down the columns indicates which case mix group a given hospital performs.

Case Mix Group	Hospital												# of Hospitals performing Case Mix Group
	Ottawa Hospital Civic Site	Ottawa Hospital General Site	Pembroke Hospital	Winchester Hospital	Queen's Carleton Hospital	Arnprior Hosp	Cornwall Community Hospital	Hawkesbury Hospital	Renfrew Victoria Hospital	Hopital Montfort	Almonte General Hospital	Carleton Place Hospital	
Bilateral Hernia Procedures	1	1	1	0	1	1	1	1	1	1	1	0	10
Major Intestinal and Rectal Procedures	1	1	1	1	1	1	1	1	1	1	0	0	10
Total Mastectomy for Breast Malignancy	1	0	1	1	1	0	1	1	0	1	0	1	8
Subtotal Mastectomy and Other Breast Procedures for Malignancy	0	1	1	1	1	1	1	1	0	0	0	0	7
Less Extensive Esophageal, Stomach and Duodenum Procedures	1	1	1	1	0	0	0	0	1	0	0	0	5
Thyroid Procedures	1	1	0	1	0	1	0	0	0	0	0	0	4
Procedure per Hospital	5	5	5	5	4	4	4	4	3	3	1	1	

Chapter 2

Use of GIS to Allocate Health Services

In this chapter I will examine how GIS has been used to study the allocation of health services. Location is important because the underlying assumption is that better location leads to better uptake of interventions and therefore better health outcomes (reviewed by McLafferty¹²). To illustrate this point, I will first look at the literature concerning the location of screening clinics. I will next examine how GIS is used in the planning of emergency services and the routing of ambulances a situation where location is paramount to survival. I will next examine how GIS is being used to tackle human resource issues, namely the availability of general practice physicians. I will end the chapter with a discussion of how GIS has been used to measure the effects of regionalization health services for tertiary care such as cancer and cardiac care. This last section will provide the rationale for the need to develop the GIS methodology presented in this thesis.

Screening Clinics

Screening for disease is an important health service in that it can reduce mortality and morbidity for many different diseases. Screening is a poorly funded health service compared to other health services such as primary and secondary care or research. When funding is available for screening, it is of utmost importance that screening clinics be located such a way to prevent distance from being a barrier to access^{13,14}. As such, the literature is full of examples that have used GIS to examine the effect of distance on screening rates, retrospectively. It is ironic to note that the literature seems devoid of

methodologies that could be used to choose the best locations prior to opening screening clinics. It also interesting, that the best practice for screening high risk populations such as HIV/AIDs advocate the use of mobile screening clinics^{15,16} where the power of GIS could be best put to use. I will now review some of the literature that used GIS to examine the effects of distance on breast cancer screening uptake rates.

Breast cancer is seemingly a good candidate for screening because it affects a large number of a specific population (women age 50 to 70), and early detection has more treatment options, and better outcomes¹⁷. These attributes may, however, be outweighed by recent research showing that mammography is a poor diagnostic test that has a high rate of false positives and it is also possible that better outcomes are a result of better treatments and not early detection¹⁸.

Aside from the above caveats, what does the literature have to say about the effects of distance to a screening center? Maheswaran et al. (2006)¹⁹ examined the effects of distance on breast cancer screening uptake in North Derbyshire, UK by calculating the travel distance from the patient's location to the clinic where screening was received over a three year period. The results showed that 87% of the patients lived within 8 km of a screening location. The odds ratio of receiving screening was 0.87 (95%CI 0.79 to 0.95) for every 10 km increase in distance, suggesting a small negative effect of distance on screening. Socioeconomic deprivation had the largest effect on uptake rate (odds ratio = 0.64 (95% CI 0.59 to 0.70)). In Kansas, USA, Engelman et al. (2002)²⁰ showed that after correcting for age, race and county level of education, distance played a small role in determining whether or not older women attended mammography screening clinics. There was a significant decrease of 6% for attendance at permanent

clinics for every 8 km of distance. These results are open to criticism as they used county wide measures to assign education values and used straight line distances between ZIP codes to estimate distance.

The relationship between low socioeconomic status and late detection of breast cancer is well documented in the United States²¹⁻²³. Zenk et al. (2006)²⁴ used GIS to delve more deeply into the relationship between uptake rate and distance to screening in Chicago, IL. They showed that low cost or free mammography clinics were well placed in that they were located close to low socioeconomic status neighbourhoods both in terms of drive time and bus transit time. However, on closer examination of the data, the poorest neighbourhoods with the greatest percentage of African Americans had longer drive times and bus transit times than other less poor neighbourhoods. In an interesting follow-up study, Tarlov et al. (2006)²⁵ showed that the most important factor in predicting the stage of cancer at diagnosis was the annual number of homicides in a residents neighbourhood.

A set of papers published by Hyndman et al. 2000^{13,14} used GIS to model uptake rates of breast cancer screening under different spatial configurations of the clinics in Perth, Australia. The results showed that moving clinics closer to lower socioeconomic status neighbourhoods (less than 3 km) improved the uptake rate for these neighbourhoods. Unfortunately, and predictably, the gains in uptake were offset by losses in other neighbourhoods that would, by default, have to be further away from the relocated clinics. In a follow-up study, they used the power of GIS to test different constraints on clinic placement. The population-distance, (i.e., the total distance travelled by all the clients) was chosen as the factor to minimize for each of the models. The

different models were evaluated on the amount of travel time reduced and the reduction in travel for neighbourhoods with different socioeconomic status. In the first model, only one clinic was moved and this clinic was one with its lease about to expire. In the second model, all six clinics under consideration are allowed to move. And the third model allowed all the clinics to move, but constrained the maximum travel distance for any client to 15 km. The results were as expected in that moving one clinic had a smaller effect on population travel distance than moving all six clinics. When all the clinics were allowed to move, women from the least socioeconomically disadvantaged areas had their travel time reduced by the greatest amount, indicating that the clinic's original configuration was supportive to low socioeconomic class neighbourhoods. Constraining the movement of the clinics so that no one had to travel greater than 15 km, reduced the skew in travel times between all neighbourhoods and the clinics by the greatest amount. In summary the results show that there are always trade-offs in moving locations. That is, an increase in access to one area will result in lower access to other areas. These trade-offs require *a priori* knowledge of the desired health outcomes for the groups of interest and what might have to be sacrificed to achieve it.

Health Human Resource Issues: Primary Health Care

The importance of primary health care to social development is recognized by several major health policy bodies^{26,27}. In spite of the importance of access to health services, little attention has been paid to the methodology being used to most accurately determine access to these resources²⁸. Measuring access to primary health care has traditionally been done by areal density. To measure areal density, an arbitrary geography is chosen, e.g., a county, and the number of health care professionals is counted and the

density per population or area is calculated and compared to a benchmark. The problem with this methodology is several fold. First the area chosen is usually arbitrary and results in the density being dependent on the size of the area chosen. For example, when the city of Ottawa amalgamated a number of low density communities into its city boundaries, by definition, there were was a shortage of primary health care providers. Areal benchmarking also does not account for differences in accessibility within the area. Using the same example, people in more rural parts of the amalgamated city, would have the same “accessibility” as people living next to the Ottawa Hospital.

To solve the areal problem, GIS can be used to calculate accessibility based on drive times or transit times (as will be demonstrated in Chapter 3). With drive times, GIS is used to calculate the average (or median) drive time for each neighbourhood in a city. From there, one could standardize all the drive times and examine how each neighbourhood fares relative to the mean. One could then further analyze the data by looking for correlations between neighbourhood SES and travel time to determine if there is inequity (See Chapter 3, part 2).

Other than drive time analysis, GIS offers three additional methods to deal with the areal problem: The gravity model, two-point floating catchment area (a special case of the gravity model) and kernel density methods. The gravity model is well-named in that it assumes that demand for a resource is a function of its size and the distance between the supply and the demand. The term “size” can mean many different things, but basically refers to the “attractiveness” of the supply. Attractiveness has been measured in terms of size (e.g., number of doctors, beds, square footage), newness of the facility or perceived quality. Rosero-Bixby (2004)²⁹ calculated the attractiveness of several different

primary health care services in Costa-Rica based on the number of doctors in the facility and date of construction. He showed that larger facilities were 30% more likely to be visited (at the same distance) than smaller facilities, and sites with medical outreach teams were more likely to be chosen over traditional clinics.

The two step floating catchment methodology³⁰ is another methodology used to deal with the areal problem. This methodology uses a predefined catchment around a service provider (e.g., 10 km) and computes the demand for provider and then computes the supply per patient within the catchment. This method does not rely on artificial administrative boundaries, takes into account that multiple providers may be serving the same catchment and allows patients to members of multiple catchments. Because there is a fixed total number of providers, one can make quantitative statements about residents' accessibility to health care (i.e., resident in area A has twice the accessibility than resident in area B)³¹. The drawback to the floating catchment area, is that at some point the researcher will run out of data at the periphery of the study area (e.g., along borders between provinces or countries) and areas along the periphery will experience lower accessibility.

Several studies have used the two step floating catchment area method to examine accessibility to health cares services, most notably for primary care physicians in the USA. The reason for the research is based on the 1998 Bureau of Primary Health Care policy of "100% Access and Zero Health Disparities" reviewed by Juarez (2003)³². In this policy, additional federal funding to Medicare patients was made available for 'regions' that were either underserved with respect to primary care or had over utilization of services or had excessive distances to travel for care.

Wang and Luo (2005)³¹ used the two step floating catchment area method to find regions within Illinois with physician shortages. They also incorporated into the methodology the ability to account for non-geographic factors such as SES and health needs based on census data. The results were very interesting in that using geography only, rural areas would be identified as needing physicians, but when the non-geographic components were added, shortages were largely found in the inner cities³³.

Two dimensions of accessibility, acceptability and geographic access were used by Wang (2007)³⁴ to study Chinese immigrants access to Chinese speaking family physicians. Using the two step floating catchment area methodology, Wang showed that while accessibility to Chinese speaking doctors was as high as access to doctors for the general population, the results were skewed by small populations of Chinese speaking citizens (within high density census tracts) having very good access while less dense populations of Chinese had poorer access. The results also showed that Mandarin speaking Chinese had better access to Mandarin speaking doctors than the Cantonese population had to Cantonese speaking doctors.

The two step floating catchment area method was adapted by Langford et al. (2008)³⁵ to use raster imagery and postal code data to better align population density within census tracts. Areas of no population could easily be determined by the imagery, however the built up urban areas could represent areas of industry / commerce where few people lived. They used the postal code information to determine if the built up areas were commercial or residential. The results of their data rich model showed more variation and generally lower accessibility to physicians (and other social services) compared to the standard (even population distribution throughout a census tract).

While Langford et al. (2008)³⁵ focused on better spatial distribution of populations to use with the two step floating catchment area method, McGrail and Humphires (2009)³⁶ incorporated more accessibility and health data into their model. They estimated mobility based on the percent of households without a car, individuals of low personal mobility and public transport availability from census data (Australia.) They also estimated health needs based on disability adjusted life years. Their results showed heterogeneity in access in large rural areas that were previously undetected.

Kernel density is another method used to estimate disparities in physician density between geographies. Kernel density estimation is different from other methods used to estimate supply and demand in that the size of the supply (e.g., number of doctors at a clinic) is used in conjunction with a grid overlay for the entire area under study and its population. Each supply point is given a decay radius as are the population points (i.e., demand decreases with distance). The supply surface is overlaid on the demand surface to measure the demand:supply ratio. This ratio can then be overlaid on the census geography to compute mean values for a given census geography. The strength of this methodology is that both demand and supply can be represented as continuous surfaces across census geographies. Unfortunately, the methodology requires a lot of expertise to choose the appropriate grid sizes and the appropriate band width size (smoothing)³⁷.

Guagliardo et al. (2004)³⁸ used kernel density estimation to examine the spatial patterns of pediatric primary care physicians in Washington, DC. Their analysis showed that despite the city having an overabundance of physicians, there were strong racial and SES disparities in the distribution of physicians.

Kernel density estimation was used to explore physician and nursing resources in Nicaragua³⁹. The results were counter-intuitive in that the rural areas had better supply of physicians and nurses per population than urban areas. The low density of physicians in the rural areas was outweighed by the high density of people in urban areas. The authors also point out that kernel density estimation requires a lot of guess work to pick the correct grids size and band width.

Access to prenatal care was studied using kernel density by McLafferty and Grady (2004)⁴⁰ in Brooklyn, NY, using census data, birth data, socio-economic data and location of prenatal clinics. For the overall population, need (based on income and insurance status) was well matched to the location of the clinics. The authors did find pockets of high need areas that could be better served by being closer to services.

A few papers compare the benefits and disadvantages of kernel density, gravity and floating point catchment methodologies^{28,41,42}. Kernel density was found to be the least accurate of the methods due to problems with artificial boundaries created by political boundaries. Modified gravity and floating point catchments were more realistic as they allowed demand to stretch across census boundaries.

The research reviewed above reveals two synergistic trends that are providing epidemiologists (and others) with tools to better understand access. The first trend is that methodologies to measure access accurately are growing rapidly. Coupled, or perhaps spurred by the growth in methodologies and computation power, are rich geographically linked data sets of socioeconomic factors, health measures and outcomes.

GIS Applications in Regionalization of Health Services

In this section I am going to review the application of GIS to regionalization of health services. Regionalization for a health service is said to occur when services are stopped at many locations in a region, in favor of opening a single (or a few) larger centers that specialize in the service. There are two main reasons for regionalization of many services such as cancer care, heart care, or surgery. The first reason is based on the observation that patients experience better outcomes at high volume clinics (reviewed by Halm et al. 2002⁴³). (The relationship (or lack of relationship) between health outcomes and volume is in itself as thesis topic). The second reason for regionalization is that it is less expensive to maintain fewer sites for complex care than many. This review will focus mostly on regionalization of time sensitive (emergency) services as trauma and myocardial infarctions and related conditions. For the other time insensitive conditions (i.e., do not need immediate treatment, such as cancer surgery, cancer care, palliative care) the literature is not nearly as well developed.

If a scalpel is a surgeon's first tool for surgery, then GIS is the first tool for planning of regional emergency medical services (EMS). GIS is able to answer critical questions of: what percent of the population is within 1 hour of the service, or where to locate a new EMS to cover the greatest percent of the population, and to identify populations that are at high risk for EMS. GIS can be used in this context to implement the maximum coverage problem⁴⁴, whereby the location of a emergency room is chosen to maximize the number of citizens within one hour of the facility. An interesting implementation of the maximum coverage model was done by Messina et al. (2006)⁴⁵.

They showed the percentage of citizens within 16 and 32 km radii of all Michigan hospitals with emergency rooms and how these percentages would change if emergency departments were added to certain hospitals. The results of the study were used to make policy recommendations on appropriate driving radii to emergency room facilities. The GIS model was also able to determine the optimum location to add new emergency facilities to maximize access for all residents in the state.

The importance of timely access to EMS was elucidated by Trunkey (1983)⁴⁶. He found a trimodal distribution of deaths after trauma when plotted against time. The first mode is death occurring at the trauma site. The second mode occurs one to two hours after the trauma. The third mode occurs days or weeks after the initial trauma. It is in the second mode where quick intervention can prevent deaths. Not only is time to hospital important for patient outcomes, it also allows ambulances quicker turn around times and hence more time in service.

The gravity model is also applicable to understanding patterns in emergency room use. Henneman et al. 2010⁴⁷ modeled patient flow between emergency departments of different hospitals along the Massachusetts and Connecticut border. They found that distance was an important factor to travel time, but so were time of day (people travelled further during day light hours), bridge crossings, state border and severity of the injury. The authors seem to have missed the point that time of day, bridge crossings are just different factors affecting perceived distance. That is, the same trip distance seems to take longer at night due to lower visibility. The bridges mentioned were under construction during the study, leading to traffic delays, which is equivalent to a longer route, due to the time taken to cross the bridges.

Emergency Services: Routing and Location of Ambulances

Poor placement of ambulances makes for longer response times and is a poor use of resources. GIS was used in a retrospective study of Erie County, NY emergency visits to determine the zones where ground or helicopter transport should be used to transport patients⁴⁸. The results were not intuitive. Some areas in close proximity to the hospital had better response times by helicopter than ground ambulance. Road type and the location of the helipad interacted to determine which zones were better served by air or ground transport. Peleg and Pliskin (2009)⁴⁹ used GIS to model the best location for ambulance response times in Israel. Prior to GIS modeling, mean response times were 12.3 and 9.2 minutes for a rural zone and an urban zone respectively. GIS was used to create a set of polygons (ambulance territories) that would have at least 95% of the population experience an eight minute response times. The calculations also took into account road speeds during congested periods as well as weekly patterns of emergency calls. The simulation also showed that fewer ambulances would be needed than were currently being used.

In a series of papers, Schuurman et al.^{50,51} used GIS to model access to trauma centres in British Columbia. The first paper⁵⁰ defines “rational” catchment areas for using drive time analysis to deal with British Columbia’s mountainous geography. This analysis was the portion of the population within one hour of different levels of emergency care. The second paper⁵¹ added socioeconomic attributes of a location that are associated with risk of injury (e.g., household composition, labor force and educational characteristics). By combining drive times with socioeconomic they were able to determine percentages of the population not adequately served by trauma centers and

which communities were in greatest need of EMS. The interesting result of the study was that communities that were least isolated from trauma centres were also those at the lowest risk of injury.

Percutaneous coronary intervention (angioplasty) is another health service that is extremely time sensitive. The current standard for time to intervention is 90 minutes⁵². With this standard in mind, researchers have used GIS to examine the proportion of residents within 90 minute drive time polygons (isocrones) to angioplasty service. For example, Patel et al.(2007)⁵³ used GIS to create 90 minute isocrones around Alberta's two angioplasty facilities. The results showed that 70% of the adult population was within the 90 minute isocrones. Kansagra et al. (2004)⁵⁴ showed that the regionalization of angioplasty would actually decrease travel time for a small number of patients in three US states (New York, New Jersey and Florida). They were also able to show a slight decrease in relative risk of mortality after switching to a regional model. Birkmeyer et al. (2003)⁵⁵, simulated the effects of having all US Medicare recipients travel to medium or high volume hospitals for pancreatic or esophageal surgery. For travel to the medium volume hospitals, 76% of patients would have to travel an additional 30 minutes for surgery. To travel to high volume centers, about 80% of patients would have to travel an additional hour. These additional times were not viewed as excessive for complicated surgeries. For patients in rural areas, travel times would increase to greater than 2 hours for 80% of the population to reach a high volume hospital.

In a multi-country study (Canada and the USA), Grumbach et al. (1995)⁵⁶ found that closing low volume coronary artery bypass surgery centers in favour of larger centers

would result in an average increase in drive distance for only 5% of current patients
(most of these in rural areas).

Chapter 3

GIS Methodology

In Chapter 3 I will describe in detail the methodologies developed and used to meet the goals and objectives laid out in Chapter 1 of the thesis. The first part of the Chapter will deal with the collection of general surgery data, and how the postal code data was used to ultimately measure drive time accessibility for the different Communities of Care within the Champlain LHIN. The next sections deal with the details of how the “best” site to add surgeries to was developed and then modeling of a scenario. The second part of Chapter 3, will describe the methods used to collect transit times for the city of Ottawa’s 92 neighbourhoods and how these data can be matched with socioeconomic data to measure inequities in access to a single hospital within Ottawa.

Drive time methodology

The work flow of the GIS drive time methodology is outlined in Figure 2.

Step 1: Data Collection

For this thesis, data on patients was acquired from Ontario’s Provincial Health Planning Data Base. The Provincial Health Planning Data Base contains the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) for inpatient services. The Provincial Health Planning Database was queried to extract all inpatient general surgeries for Champlain LHIN residents in fiscal year 2006/07. Attributes collected for this query included hospital of surgery, patient postal code, patient municipality and county.

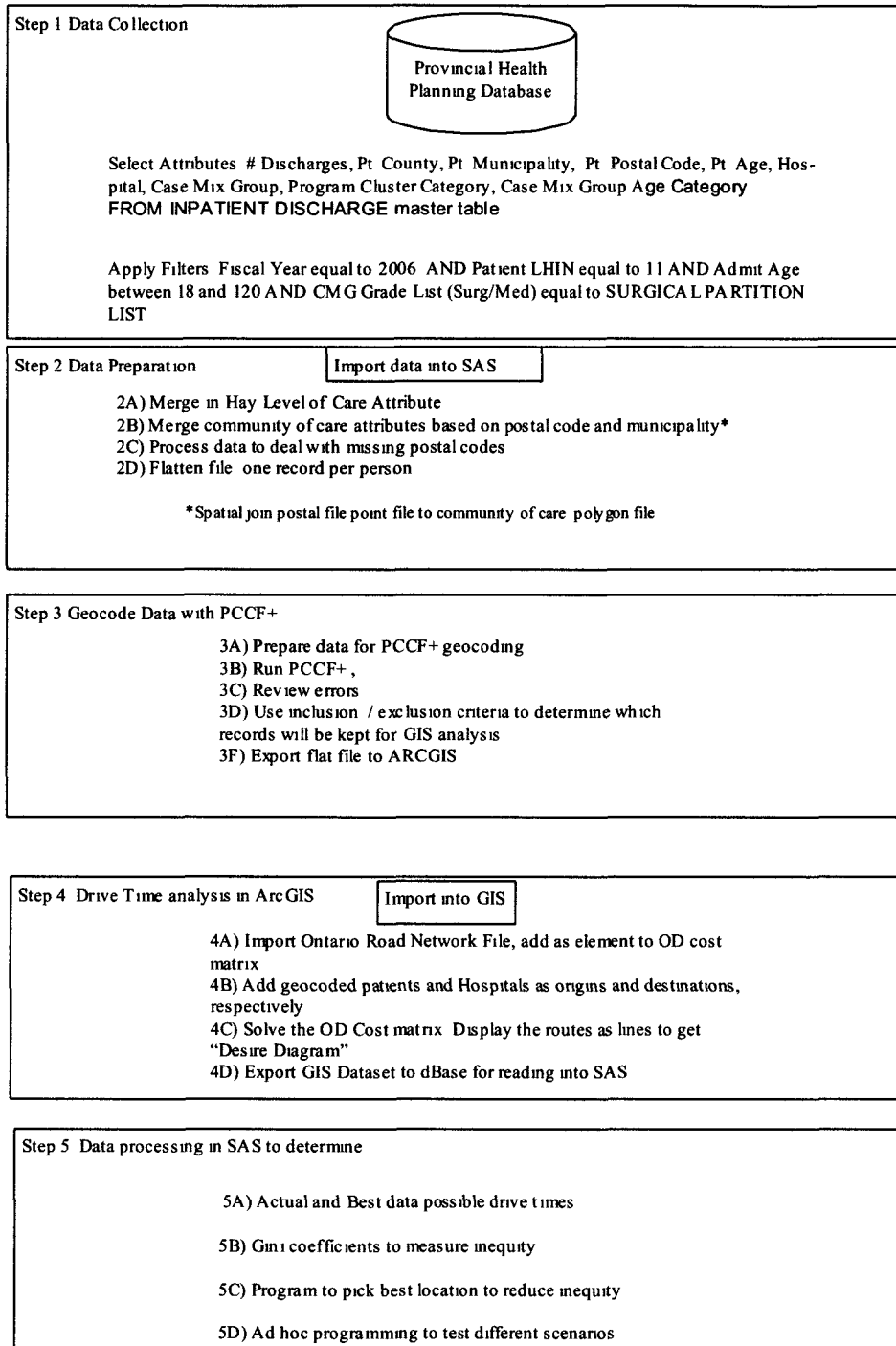


Figure 2. Model of the GIS surgical services drive time methodology

The general surgery data were tabulated by hospital to determine the volumes at each hospital in a given year (data not shown). Hospitals with less than 10 general surgeries per year (Glengarry Memorial Hospital, Kemptville and District Hospital, Deep River and District Hospital, St. Francis Memorial Hospital (Barry's Bay)) were excluded from the study because they are located in remote parts of the Champlain LHIN and it is highly unlikely that they would be able to take on more surgeries in terms of space or surgeons.

Specialty hospitals within the LHIN (Children's Hospital of Eastern Ontario, University of Ottawa Health Institute, Bruyere Continuing Care, and the Royal Ottawa Mental Health Centre) were also excluded from the analysis as they currently do not perform general surgery.

Step 2: Data Preparation

The SAS code used to manipulate raw Provincial Health Planning Database data into a form that can be used by the GIS software is found in Appendices A and B. All SAS keywords are in capital letters and the font is 10 point Courier New. File and variable names are in small letters. All comments are between /* */ symbols with Verdana 12 point font. The code could be written more efficiently in many cases, but was kept simple to make reading the code easy. Note that all file names assume the work directory in SAS. Attribute names were chosen to be simple and meaningful. The code can be copied directly into SAS and run, provided that the formats found in Appendix A are run first.

Step 3: Geocoding with PCCF

There are many commercial geocoding programs available, but the Postal Code Conversion File (PCCF+ ⁵⁷) from Statistics Canada was chosen for three reasons. First, PCCF+ provides highly accurate geocoding to census tracts or dissemination areas, where they exist. When postal codes are larger than a single dissemination area, PCCF+ is able to probabilistically assign a location based on population densities of the dissemination areas under consideration. Second, PCCF+ clearly distinguishes between residential postal codes and commercial postal codes, which other programs do not. Third, PCCF+ is free of charge for student use and is the standard geocoding tool used in Canadian healthcare research.

About 5% of the data the within Health Planning Database have either missing or clearly incorrect postal codes. A health record is assigned to a Local Health Integration Network by using the municipality attribute of the record and not the postal code attribute. Therefore a record can be assigned to Ottawa, for example, even if the postal code is missing. With this in mind, all missing or wrong postal codes were reassigned as follows: all named municipalities except for Ottawa, were geocoded to the population center of the municipality. For the municipality of Ottawa, patients will be randomly assigned to one of three points located in the population center of Ottawa West, Ottawa Centre or Ottawa East (Figure 1). The assignment was based on population weights from the 2006 Canadian Census: i.e., Ottawa West, Ottawa Centre and Ottawa East will have 44%, 27% and 21% of population respectively (Figure 1). The population center of a given area is easily calculated by most geographic information systems provided there is

a finer level of geographic detail (in this case census tract data) on which to base the calculations.

Step 4: Drive Time analysis in ArcGIS

Drives times were calculated using ArcGIS Network Analyst extension. The geocoded patients were mapped onto a base layer of the Champlain LHIN (Figure 3). All data points that were acceptably close to the border of the Champlain LHIN (within 5 km) were included in the analysis. Once the patients were added to the map, the Ontario road network file was added⁵⁸. These data were then used by the Network Analyst extension of ArcGIS to “solve” the network. An origin-destination analysis was to “drive” each patient (origin) to every hospital (destination) that was included in this analysis. Table 3 illustrates what the matrix would look like for four different patients going to three different hospitals. This data can be used to test different scenarios without having to rerun the analysis. Solving the 2,769 patient origins to 13 hospital destination takes a 2.3 Gigahertz Dual Core Xenon Processor (5140) with 3 Gigabytes of RAM about 45 minutes to solve.

Table 3. Sample Origin-Destination Matrix for General Surgery Patients in the Champlain LHIN.

Patient ID (origin)	Hospital (destination)	Total Minutes traveled
Patient 1	Ottawa Hospital Civic Site	139
Patient 1	Almonte General Hospital	127
Patient 1	Winchester Memorial Hospital	182
Patient 2	Ottawa Hospital Civic Site	148
Patient 2	Almonte General Hospital	136
Patient 2	Winchester Memorial Hospital	191
Patient 3	Ottawa Hospital Civic Site	4
Patient 3	Almonte General Hospital	39
Patient 3	Winchester Memorial Hospital	47
Patient 4	Ottawa Hospital Civic Site	4
Patient 4	Almonte General Hospital	39
Patient 4	Winchester Memorial Hospital	47

Two key issues data issues need to be resolved to make Network Analyst give timely and correct results. First and foremost, all the origins and destinations must share the same projection and coordinate system. While ArcGIS can display features on a map with different projection systems by doing the projection conversion “on-the-fly”, these additional calculations cause the Network Analyst extension to “hang” or crash. The second data issue was with how the road network file was coded. In the version of the road network file currently being used, the OC Transpo Transitway roads, that are for supposedly for public transport buses only, were useable as routes for patients to reach hospitals. Transitway road segments were coded with a “time-to-pass” of 999 minutes, but the distance was correctly measured in meters. This coding made for strange results, in that some drives were taking days to complete but had short distances. This problem was overcome by not allowing any routes to use roads that had 999 minutes as their “time-to-pass”.

One of the most powerful features of ArcGIS is its geoprocessing capabilities. Geoprocessing works like a macro language in that it is suitable for repetitive or well defined tasks. Further, little or no coding is required to use the feature. To this end, I made the geoprocessing model seen in Figure 4 to complete the steps required to the analysis. The model stores all of the settings that are used to solve the origin-destination analysis as a single tool on the menu bar. All parameter values and model settings can be found in Appendix E. After developing the model, the analysis simply requires clicking the tool and all the results are exported to SAS for further analysis and summarization. The tool could also be configured to directly import the data from SAS. Using the model saves about five minutes of clicking through the menus, and it is not prone to the possibility of human errors in selecting important options.

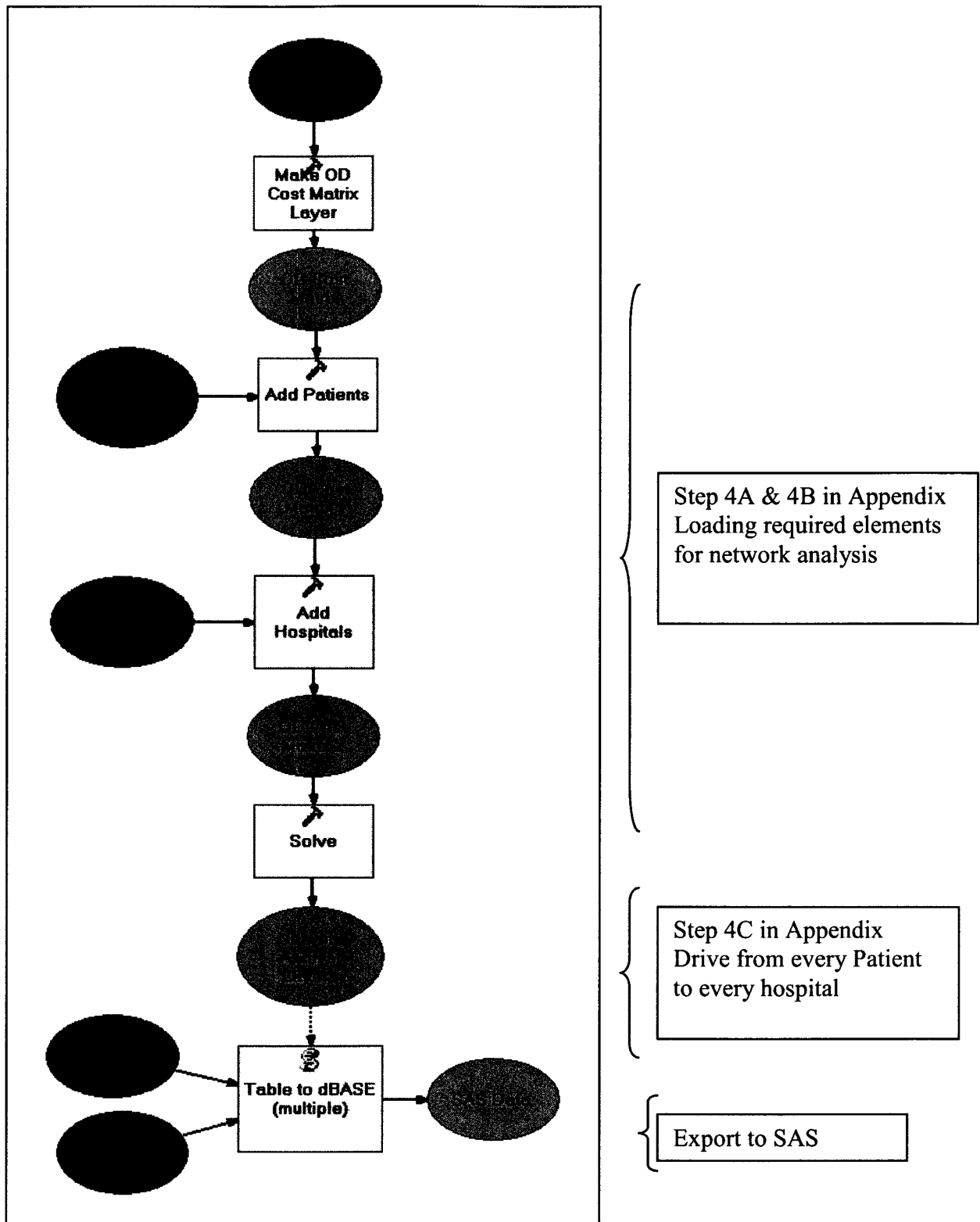


Figure 3. Geoprocessing model used to solve the origin-destination network analysis

Part 2: Transit Times by Public Transportation:

Public transportation still plays a significant role in transporting people in urban areas. The city of Ottawa estimates that 15%⁵⁹ of all trips during the work day are done using public transportation. Low-income people and the student population make up a significant portion of the demographic that uses public transportation.

Total transit time travelling by public transportation includes time spent on the bus and time spent walking from a person's origin to the bus stop and then walking to the final destination. To encourage increased public transportation ridership transit systems throughout the world have invested heavily in route planning software to make trip planning easier for their customers. This software allows customers to enter their home address, their destination and desired time of travel to a public facing web site which will then reply with detailed travel information such as how far it is to walk to the closest bus stop, which bus to take and if any transfers are required.

The only transit system in the Champlain LHIN with route planning software that interfaces with the public is OC Transpo, managed by the city of Ottawa. As such, I restricted the analysis to patients from the city of Ottawa and only travelled to the four hospitals within city limits (Queensway Carleton Hospital, The Ottawa Hospital (General and Civic campuses) and the Montfort Hospital). I further reduced the data set by only considering travel from the mostly densely populated dissemination area from each of Ottawa's 92 populated neighbourhoods.

Part 3: Methods

The process used to go from dissemination area centroids to public transportation travel times is listed in Figure 4. Route planning software requires street addresses (or intersections) as origins and destinations. However, the surgical data only comes in postal codes. To overcome this mismatch, the postal code data was converted to latitude and longitude using PCCF+. To convert from latitude and longitude to street address requires a process called reverse geocoding. In reverse geocoding incident data are mapped to the closest street and address number. I used the batch reverse geocoder in ArcGIS⁶⁰. These street addresses were then used in a SAS macro program (Appendix E) to query the OC Transpo travel planner. The returned results were parsed within the SAS macro and the data further compiled in SAS.

The SAS macro program has a few nuances that are worth mentioning if one wants to recreate the data sets. Transit times are all sensitive to the time of day and the weekday that the trips are planned due to time dependent bus service levels. All the trips were planned so as to arrive at the four hospitals as close to 4 pm on a Thursday. This time was chosen as the patient checking into the hospital in the evening before the surgery the next day. In addition the specific time, the website is specific to the date, that is, if the URL (see Appendix E) is pasted into a browser today, the travel planner will return an error stating the trip occurs in the past. In working on this code, it was easier to manually get a new URL by entering the origin and destination each day and modifying it for macro use. This method also takes care of any problems that the sessionid tag might cause. All of the hospitals destinations were identified in the OC Transpo travel planner

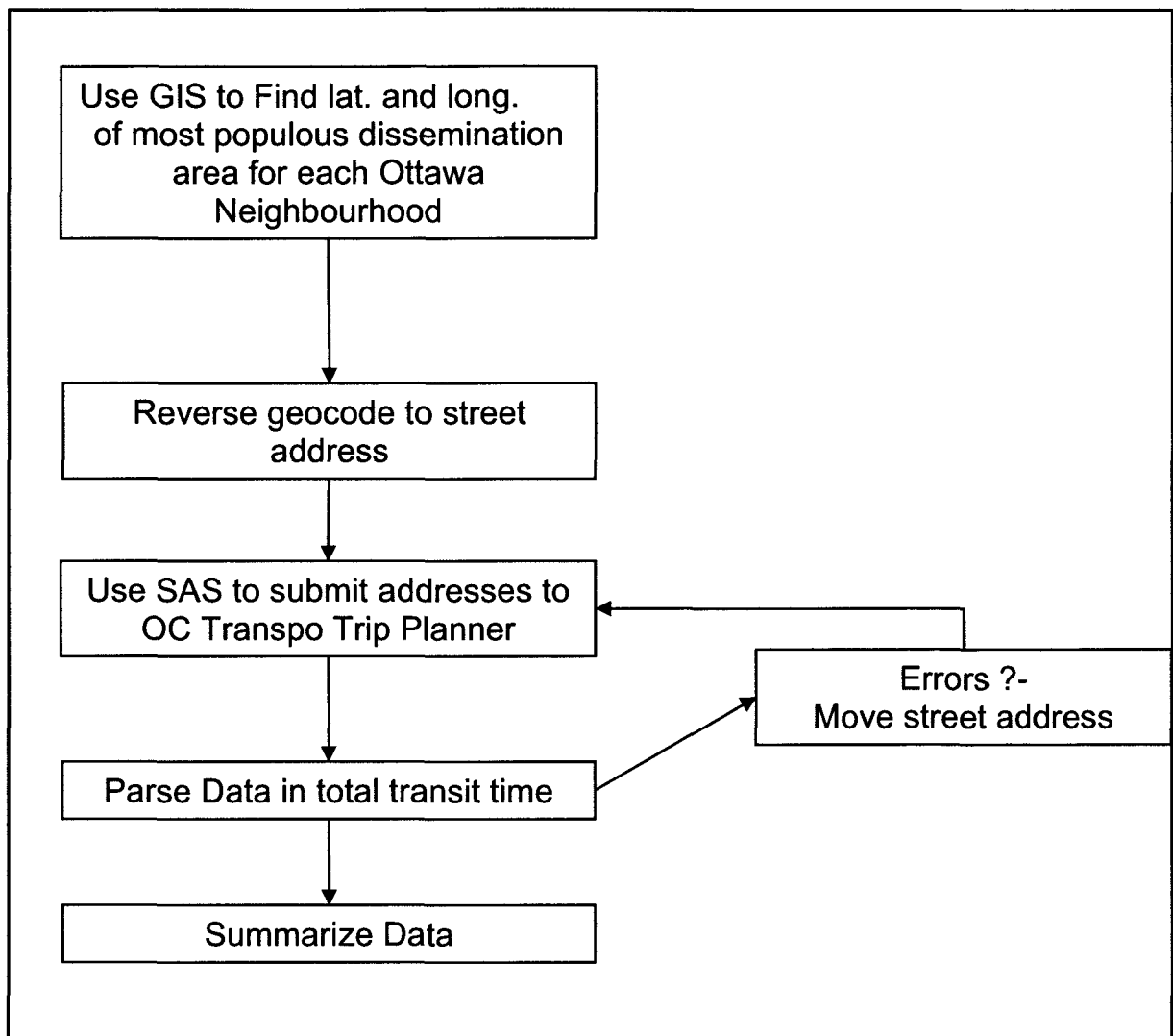


Figure 4. Overview of process used to create transit time data set for 92 neighbourhoods in Ottawa to the Ottawa Hospital General Site

as landmark type = “Hospital”. A final note is that the street addresses, even though in no way connected to patients that had surgery are not listed in this work for privacy reasons.

Three types of errors occurred with the interaction of the reverse geocoding results and the OC Transpo travel planner. The first error was when OC Transpo did not recognize the origin address because the street number was invalid. These errors were easy to fix as the travel planner returned an error stating the correct block of addresses to use. The second type of error occurred when the travel planner did not recognize the origin. After verifying that the origin did exist by using a different road database (Google Maps), there error could be fixed by choosing another street within the dissemination area. The third type of error was the same as the second, but I could not fix the error and remain with in the original dissemination area. These neighbourhoods (Munster Hamlet – Richmond, Navan – Vars, Greely, Cumberland, Kars – Osgoode, Metcalfe, Manotick - North Gower, Fitzroy Harbour - West Carleton, Carp - Hardwood Plains) were all located in the furthest reaches of the city.

Socioeconomic inequities between neighbourhoods with respect to drive time and transit time to the Ottawa Hospital General Campus were estimated by examining neighbourhood income and the percent of recent immigrants (immigrants who came to Canada between 2000 and 2004). The income variable used was the percent of the population below the low income cut-off (LICO). LICO values “represent levels of income where people spend disproportionate amounts of money for food, shelter, and clothing. LICOs are based on family and community size; cut offs are updated to account for changes in the consumer price index.”⁶¹. These values were extracted from the

PCCF+ files. Data on the percent of recent immigrants (arrived between 2001 and 2006) were extracted from the Ottawa Neighbourhood Study⁶² and then grouped in quintiles of: 0% - 5% (N=7), 5% - 10% (N=22); 10%-15% (N= 27); 15%-20% (N=20); .20%- Max (N=16). The highest % of recent immigrants was 39%. The data were analysed using SAS⁶³ general linear model procedure. The model was run with and without neighbourhood size (total population) as a covariate.

Chapter 4

Illustration of GIS Methodology Utility

Geographic distribution of general surgeries in Champlain LHIN

The data extracted from the Provincial Health Planning Database found 3,124 general surgeries for Champlain LHIN residents age 18 and older in fiscal year 2006/2007 (Table 4). A large proportion (11%) of general surgeries were performed outside the Champlain LHIN compared to the average of 2% when looking at all inpatient surgeries. The reason for the large amount of inter-LHIN general surgeries was due to over half of these occurring at the Shouldice Hospital, which is a hernia speciality hospital for the Province of Ontario. When the hernia surgeries are removed from the data, the amount of inter-LHIN surgery is 3.5%, much closer to the Champlain LHIN's overall average.

PCCF+ was able to locate every postal code in the dataset. Several non-residential postal codes were found in the data. All nursing home addresses were considered valid and kept for the study, whereas the other commercial addresses such as post office boxes or business addresses were omitted. There were 19 records with missing postal codes and

Table 4. Results of PCCF+ geocoding Champlain LHIN's General Surgeries (age 18+, 2006/07 fiscal year).

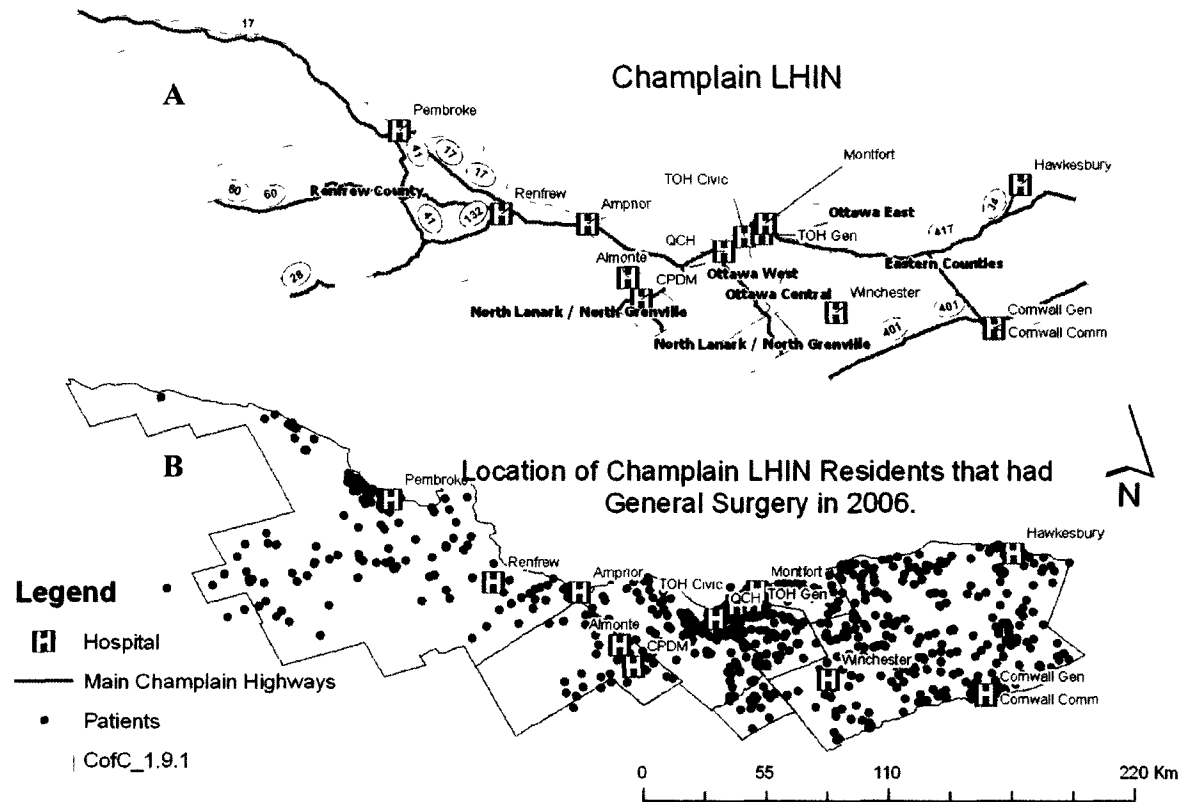
Criteria	Count
Total General Surgeries by Champlain LHIN residents in 2006/07	3,124
Surgeries outside of the LHIN	-335*
Surgeries at small hospitals with in LHIN (and speciality hospitals)	-11
PCCF+ commercial addresses	-9
PCCF+ Nursing homes	27 -- not deleted
PCCF+ unknown	19 -- All missing values; not deleted, assigned by municipality
Number of tertiary and quaternary level of care surgeries (considered non-moveable)	- 369
Final Total	2,400

* 266 occurred at Shouldice Hospital. The remaining were quaternary or tertiary surgeries or occurred at facilities that had less than 10 visits from Champlain LHIN residents.

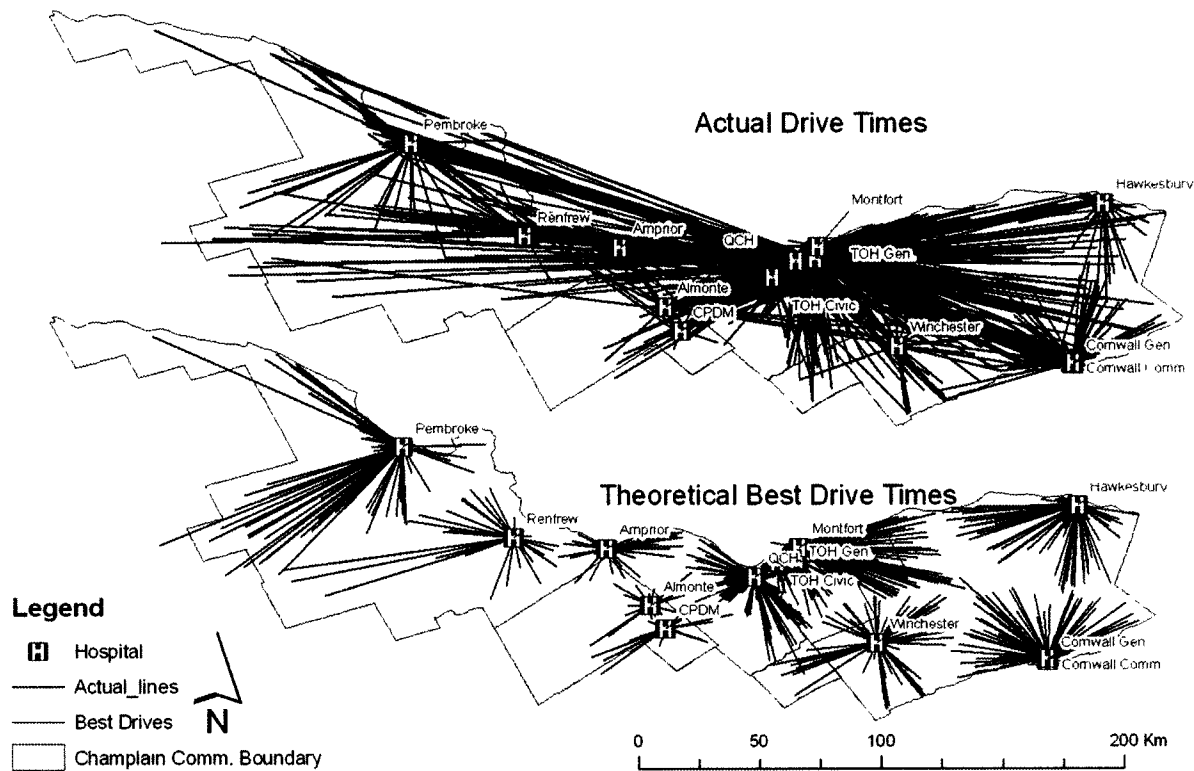
these were assigned to the municipality name given in the record as described above.

Three hundred and sixty-nine records were also removed from the analysis as these were at the tertiary or quaternary level of care, yielding 2,400 records (Table 4). Tertiary and quaternary level of care cases were removed from the analysis because it is unlikely that many of these surgeries could be moved to smaller hospitals due to staffing and equipment limitations.

The actual drives that were completed by Champlain LHIN residents for general surgeries are shown in Figure 6. Figure 6 is known as a “desire diagram” or “star chart” and is used to simplify the presentation of the all the drives from each origin to each destination as straight lines instead of showing all the turns and twists that actually occur along the road network. All the drive time figures in this thesis use desire diagrams, but all the calculations of drive times are based on the underlying road network distances. Figure 6 shows that there is a great deal of travel from the rural areas (Eastern Counties and Renfrew County) to the urban areas of Ottawa. Urban residents (Ottawa West, Centre and East) drove between 9 and 11 minutes on average to surgeries compared to rural residents (Eastern Counties and Renfrew County) driving on average 43 and 60 minutes respectively (Figure 7).



**Figure 5 A. Map of Champlain LHIN and Location of Hospitals
B. Location of Patients that had General surgery in 2006/07**



**Figure 6 A. Desire diagram of patient drives to the actual hospital where surgery occurred
 B . Same as A, but patients drive to closest hospital, “theoretical best”.**

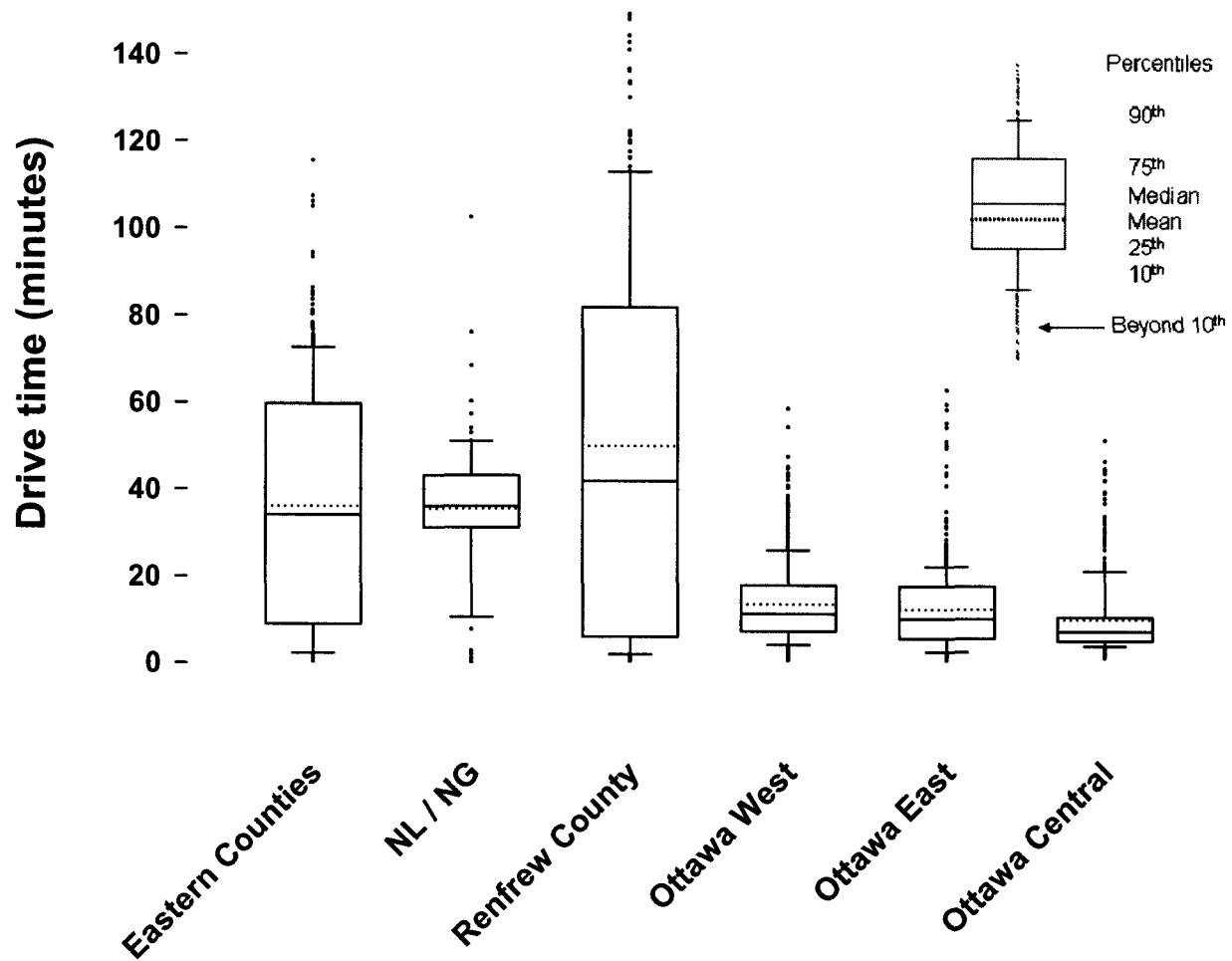


Figure 7. Distribution of actual drive times by Community of Care for Champlain residents aged 18 and older receiving general surgery in 2007/08.

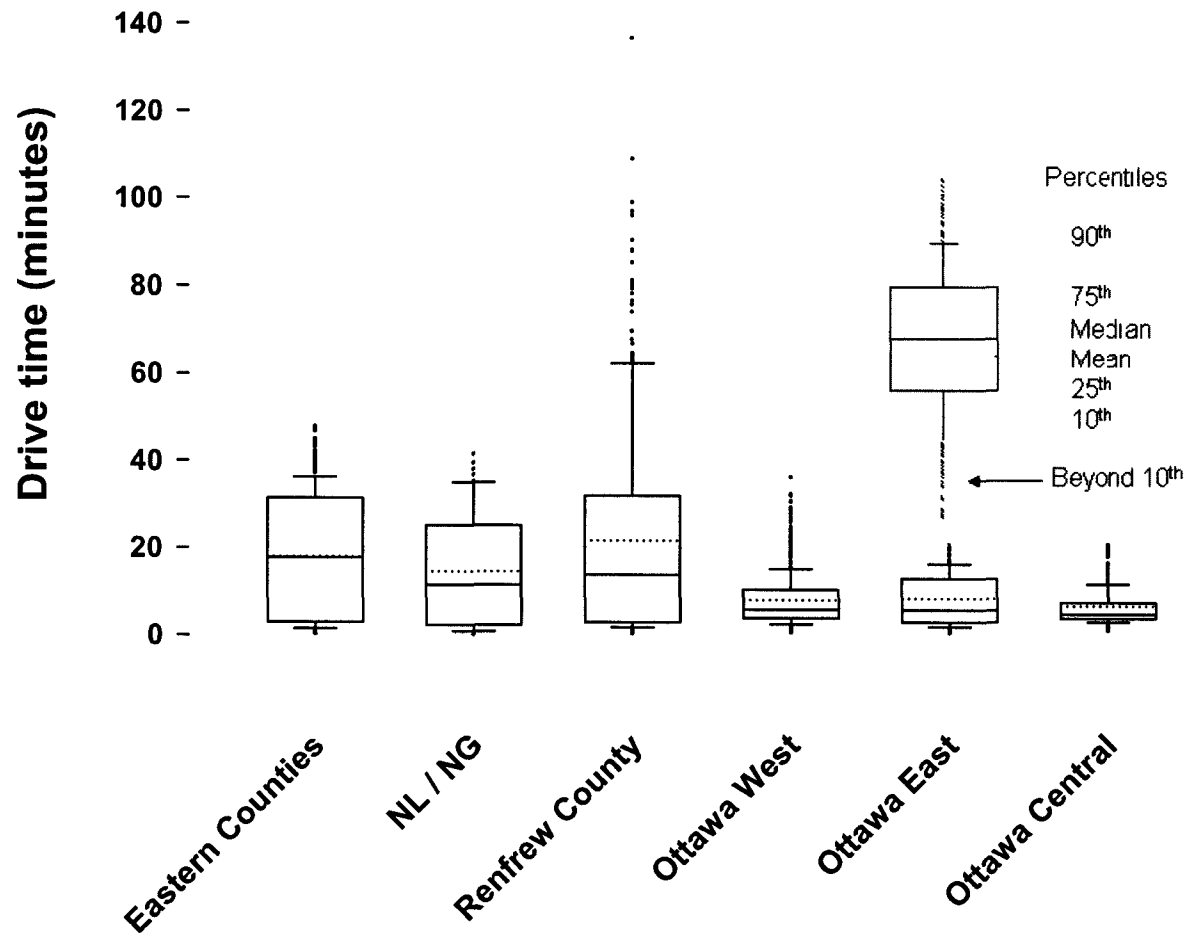


Figure 8. Distribution of theoretical best drive time if every Champlain resident was able to have surgery at the closest hospital to their homes.

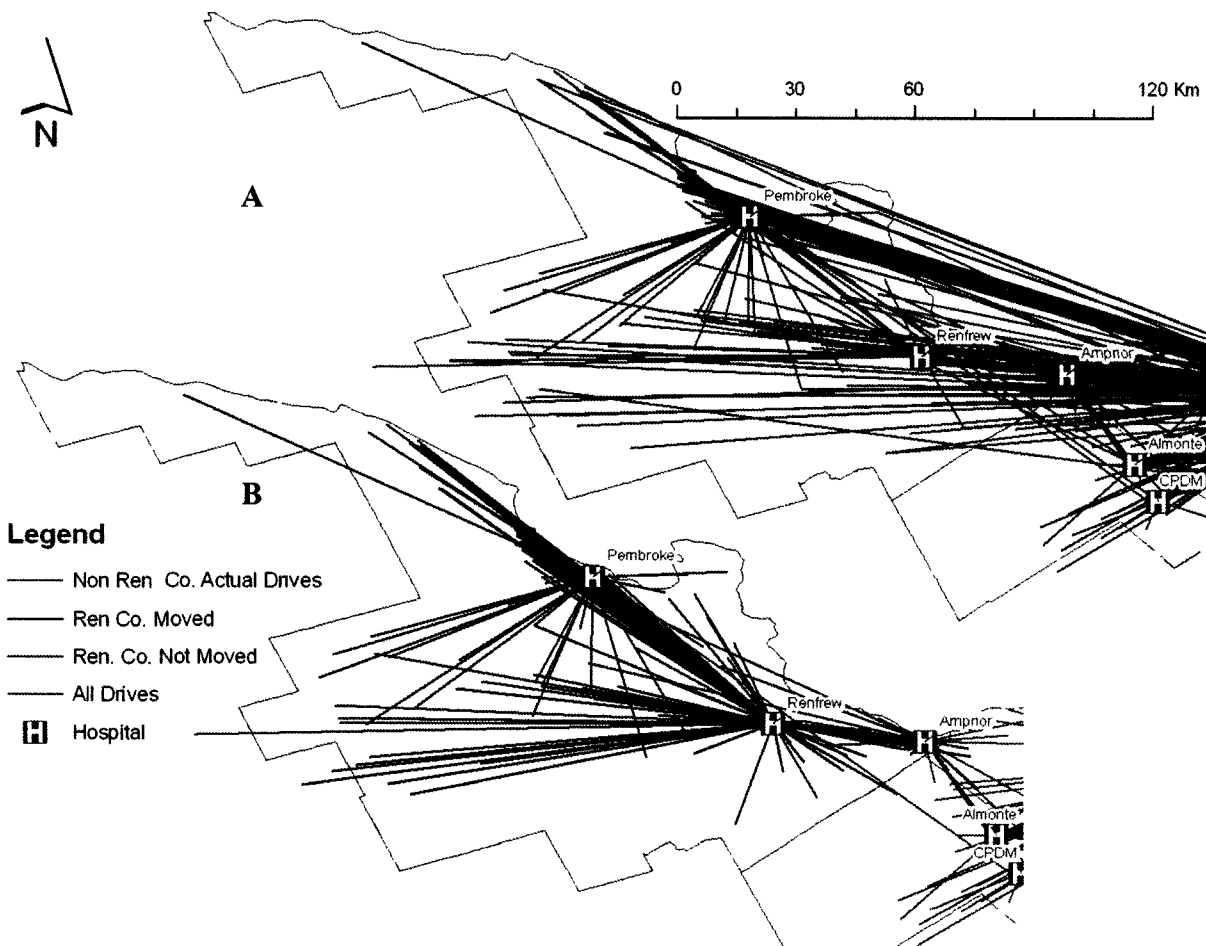
By solving the drive time problem using an origin–destination approach, one can compute a theoretical best drive time by allowing every patient to go to their closest hospital. The results of such a scenario are shown in Figure 8. While such a scenario is not feasible due the Queen’s Way Carleton Hospital and the Montfort Hospital not having the capacity to deal with the extra volume it would create at these sites, it does provide a benchmark for comparison of other scenarios. Instead of allowing every patient to go their closest hospital, a more realistic scenario was developed in which only one hospital in Renfrew County would be allowed to increase surgical volumes to accommodate all of the surgeries that Renfrew County residents had outside of Renfrew County (218 cases). Further realism was added to the scenario by not changing the actual hospital of a Renfrew County resident that had surgery within Renfrew County, even if it was closer to the “new” site with the added volumes. The results of the analysis are visualized in Figure 9, and numerically summarized in Figure 10. The scenario requires that all Renfrew County hospitals be tested to determine which would be the “best” location to add the extra volumes. The results for each hospital are listed in Table 3.

Table 5. Drive Times as a Result of Repatriating 218 General Surgery Cases to Renfrew County Hospitals.

Hospital	Total Time Driven (Minutes)
Arnprior and District Hospital	8,646
Pembroke and District Hospital	7,609
Renfrew Victoria Hospital	7,538

Under these conditions, Renfrew Victoria Hospital would be the “best” place to add volume to equalize inequity in driving times and distances. Note there is not much practical difference between the Pembroke and District Hospital and the Renfrew Victoria Hospital. This outcome can be seen as an opportunity in that the modelling presented here doesn’t distinguish which hospital is currently better suited to take on the additional volume, be it due to staffing, space or other limitations, but rather only represents which is best for improving geographic accessibility.

The second scenario investigated in this thesis was what would happen if all primary and secondary level of care cases were moved out of the Ottawa Hospital (both acute care campuses, the Civic and the General). This scenario is of great interest to health system planners of the Champlain LHIN, because the Ottawa Hospital is doing too many primary and secondary level surgeries compared to its teaching hospital peers in the Province (86% vs. 75%, based on number of cases and case weights, unpublished data). Moving these cases could potentially alleviate the alternative level of care problems also experienced at these hospitals. The results of this analysis are visualized in Figure 10 and numerically summarized in Figure 11. A little more than half (1,333) of the general surgeries performed in the Champlain LHIN every year would be eligible to be moved from the Ottawa Hospital (Table 4). The effect of implementing this scenario is to reduce the overall drive time for patients because Ottawa West is the most populous Community of Care in the Champlain LHIN (29% of the total) and these patients are now “able” to go to the closer Queensway Carleton Hospital. The effects moving all the primary and secondary level of care surgeries out of Ottawa Centre is minimal: an



**Figure 9.A. Current drives for Renfrew County residents.
 B. Repatriated surgeries (black) and unchanged drives (red)
 if Renfrew Victoria Hospital is selected for increased surgical volume**

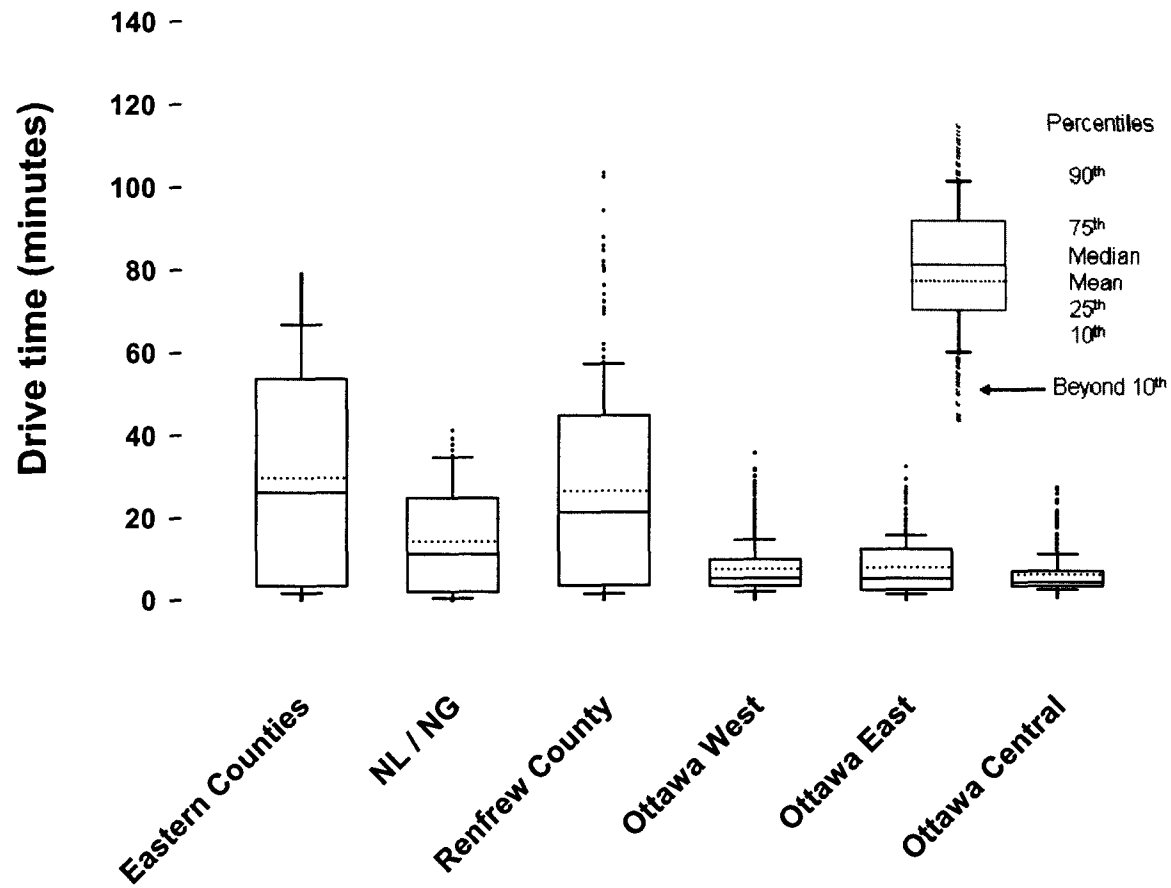
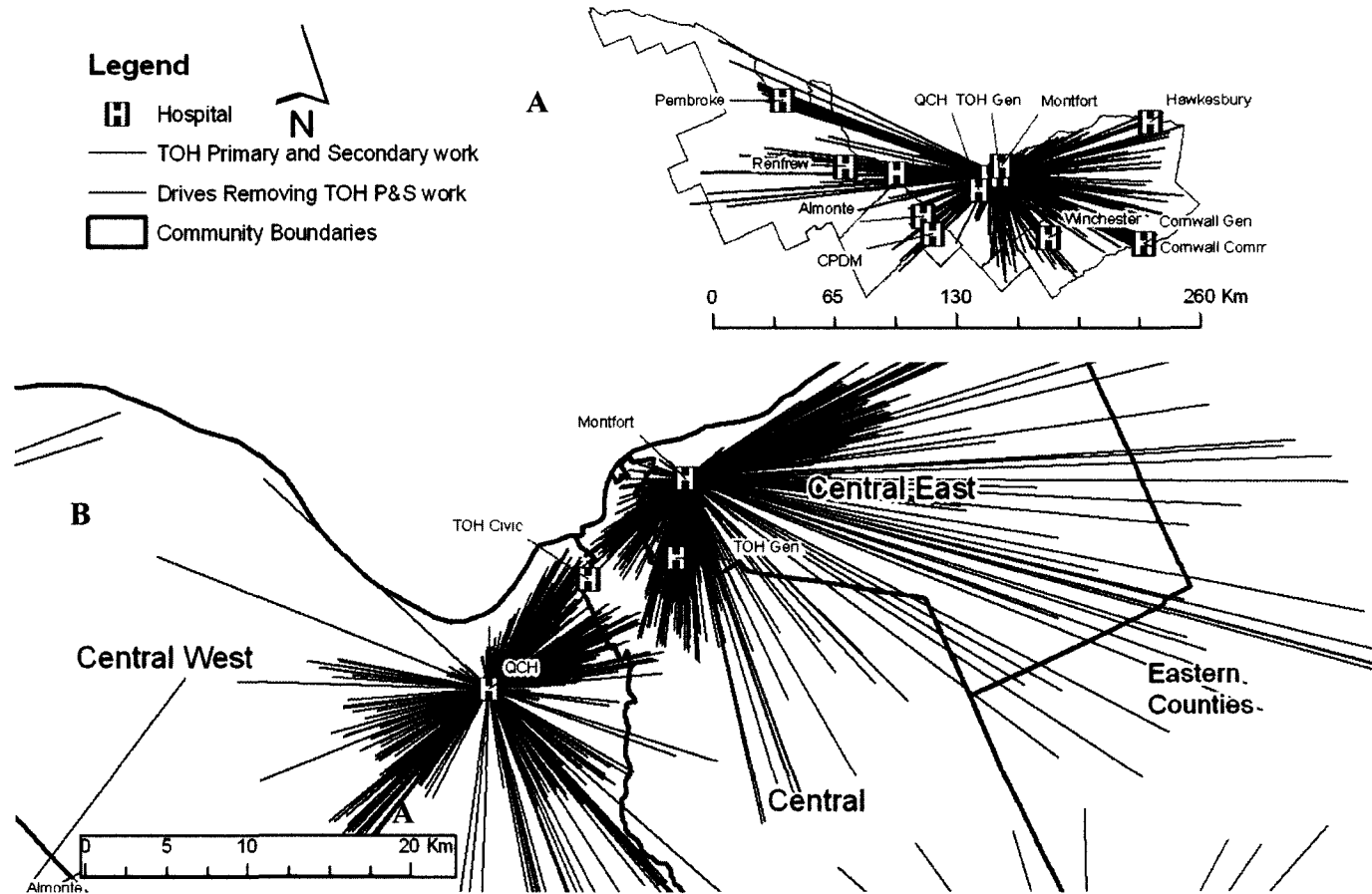


Figure 10. Distribution of drives when volume is allowed to increase at the Renfrew Victoria Hospital for Renfrew County and at Cornwall Community Hospital in Eastern Counties.



**Figure 11 A. Current drives of primary and secondary level of care surgery at the Ottawa Hospital (General and Civic Campus).
 B. Large scale view of how the drives would look if all Ottawa Hospital general surgery was moved to other hospitals in Champlain**

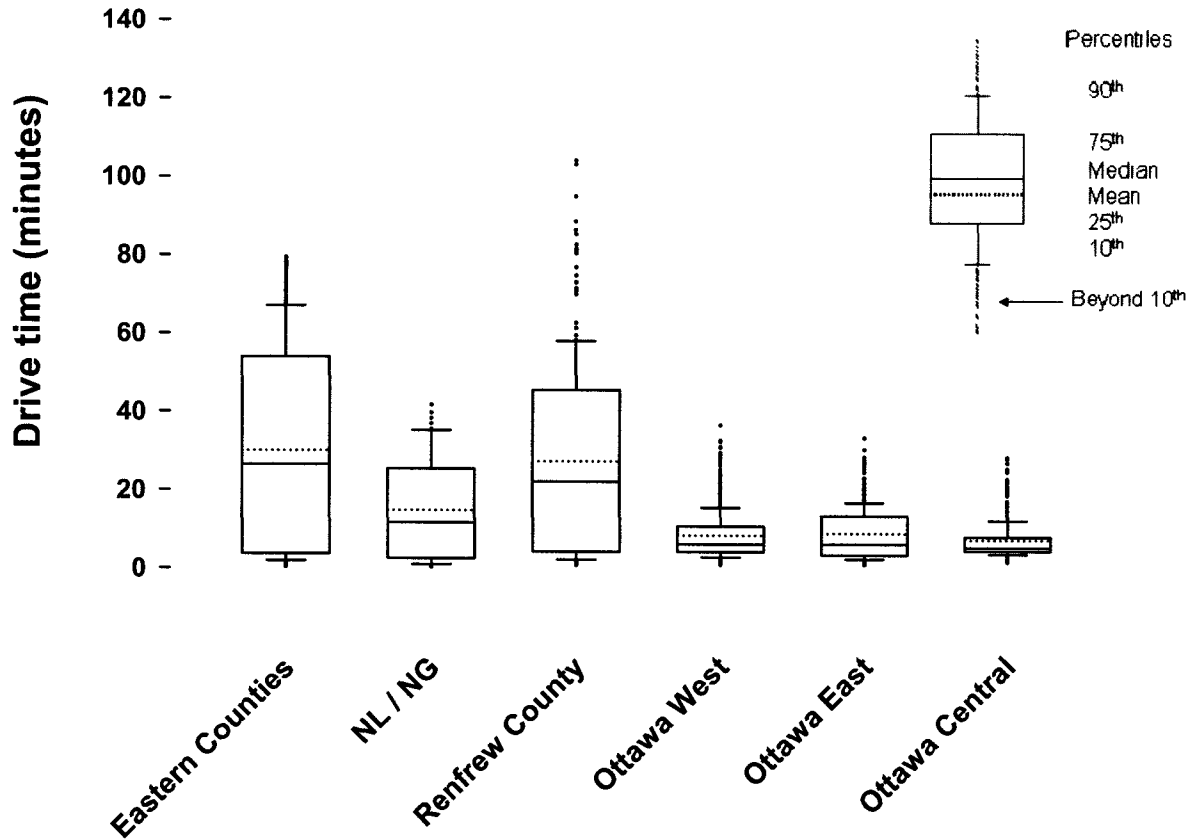


Figure 12. Results of moving the primary and secondary work from the The Ottawa Hospital. The scenario reallocates all Ottawa Centre people to either Hopital Montfort in the East or the Queensway Carleton Hospital in the West. Renfrew County residents are relocated to Renfrew Victoria Hospital, Eastern County Residents are reallocated to the Cornwall Community Hospital General Site and North Lanark / North Grenville residents are reallocated to the Carleton Place and District Memorial hospital. The destination of these reallocations were determined as described above.

average drive time increase of 2 minutes (cf. Table 7 with Figure 12). The practical problem of implementing this scenario is whether or not the Queensway Carleton Hospital and the Montfort Hospital can accommodate the additional volumes.

Illustrations of inequities in access to the Ottawa Hospital

The results of the transit and drive time analysis by neighbourhood with respect to income and recent immigration status is presented in Figures 12 through 15. There were no differences detected between neighbourhoods based on immigration status with respect to access to the Ottawa Hospital General Campus based on drive time, but there was a difference between the neighbourhoods with the highest percent of recent immigrants relative to the neighbourhoods with 5% to 10% recent immigrants (Figs. 13 & 14). The trend is that neighbourhoods with a high percentage of new immigrants have shorter drive and transit times compared neighbourhoods with fewer recent immigrants.

There was a significant difference in drive and transit times with respect to neighbourhood income (Figs. 12 & 13). Interestingly, the result shows that the highest income neighbourhoods experience the longer drive and transit times to the General Campus than lower income neighbourhoods. This result arises because the General Campus is located within the city core and many of the wealthier neighbourhoods being located on the periphery of the city (Figure 15).

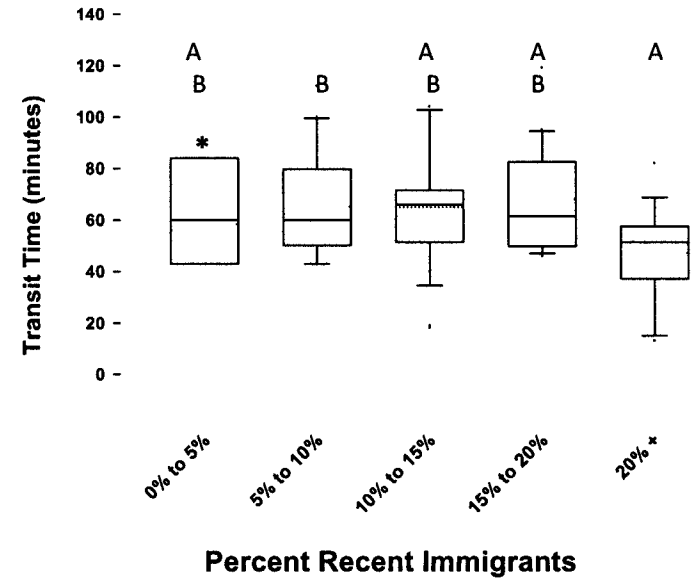
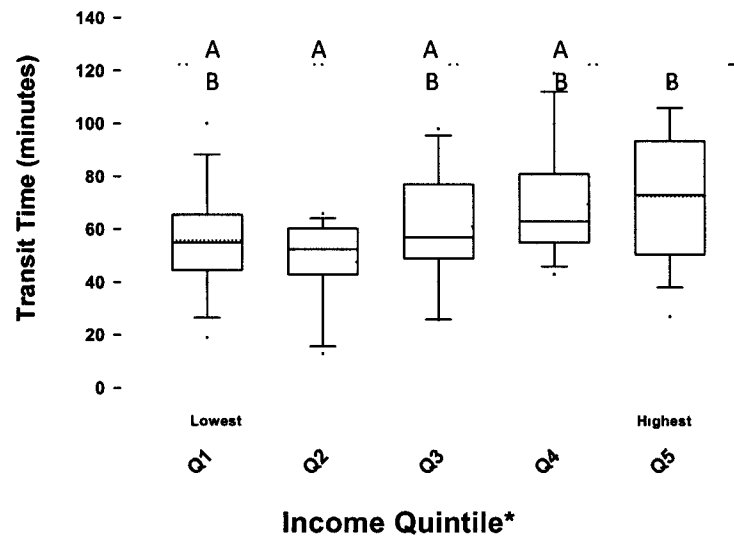


Figure 13 . Examination of inequity between neighbourhoods by income quintiles and percent recent immigrants for transit time to the Ottawa General Hospital. Groups that share the same letter are not significantly different from each other. * Not enough values to calculate 25th and 75th quartiles. Box plot symbology as in Figure 12.

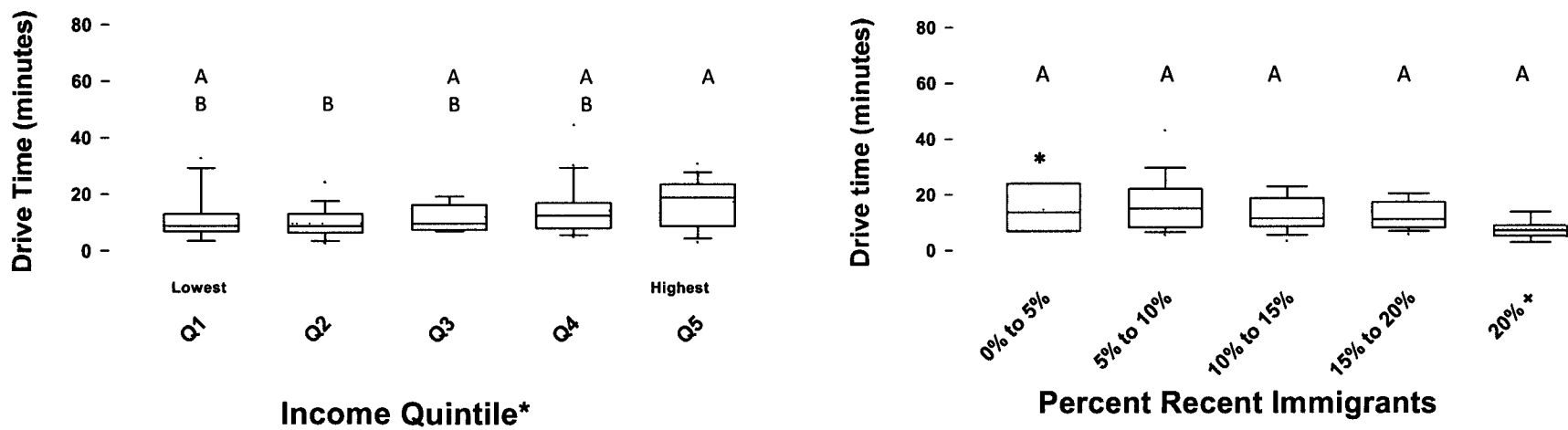


Figure 14 Examination of inequity between neighbourhoods by income quintiles and percent recent immigrants for driving time to the Ottawa General Hospital. Groups that share the same letter are not significantly different from each other. * Not enough values to calculate 25th and 75th quartiles. Box plot symbology as in Figure 12.

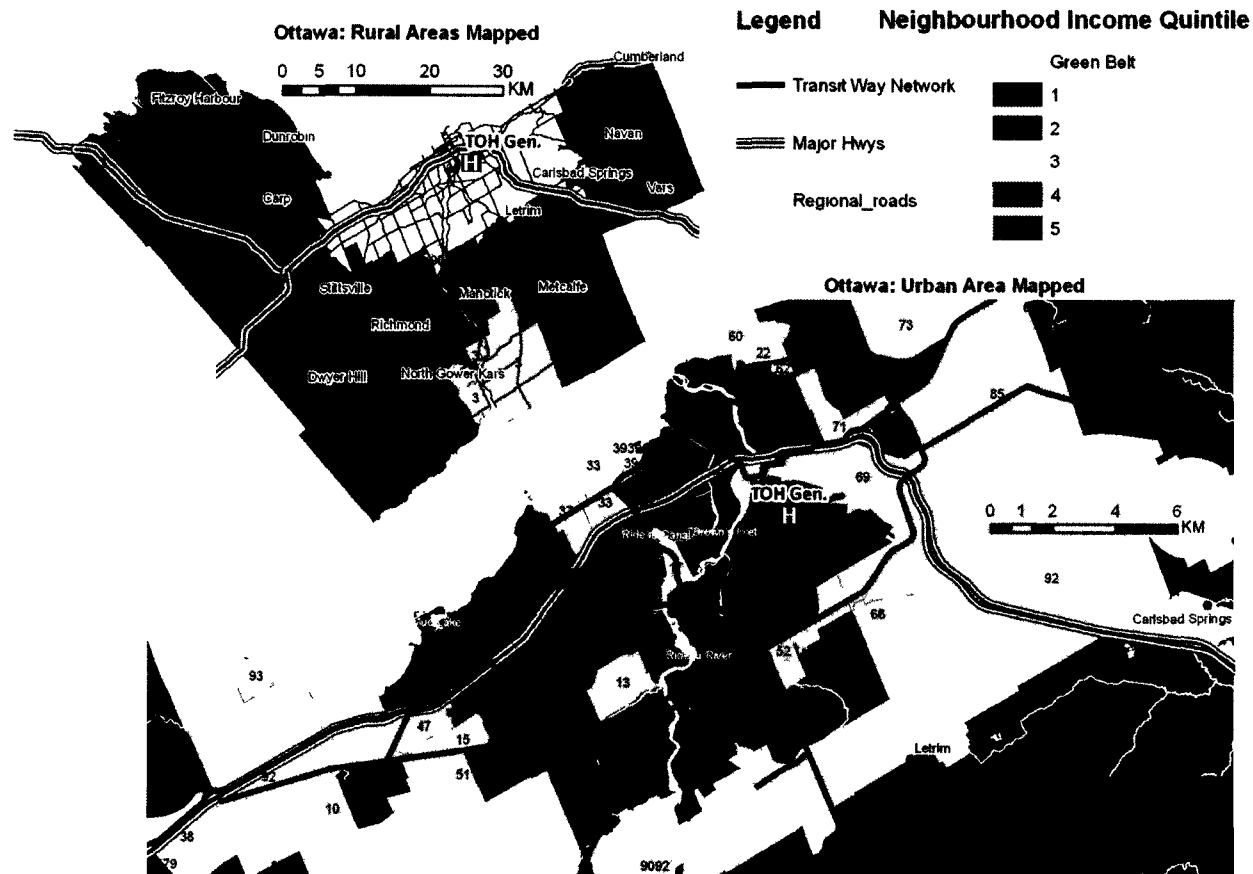


Figure 15. Distribution of income quintiles in Ottawa neighbourhoods. Numbers indicate neighbourhood names found in Table 6.

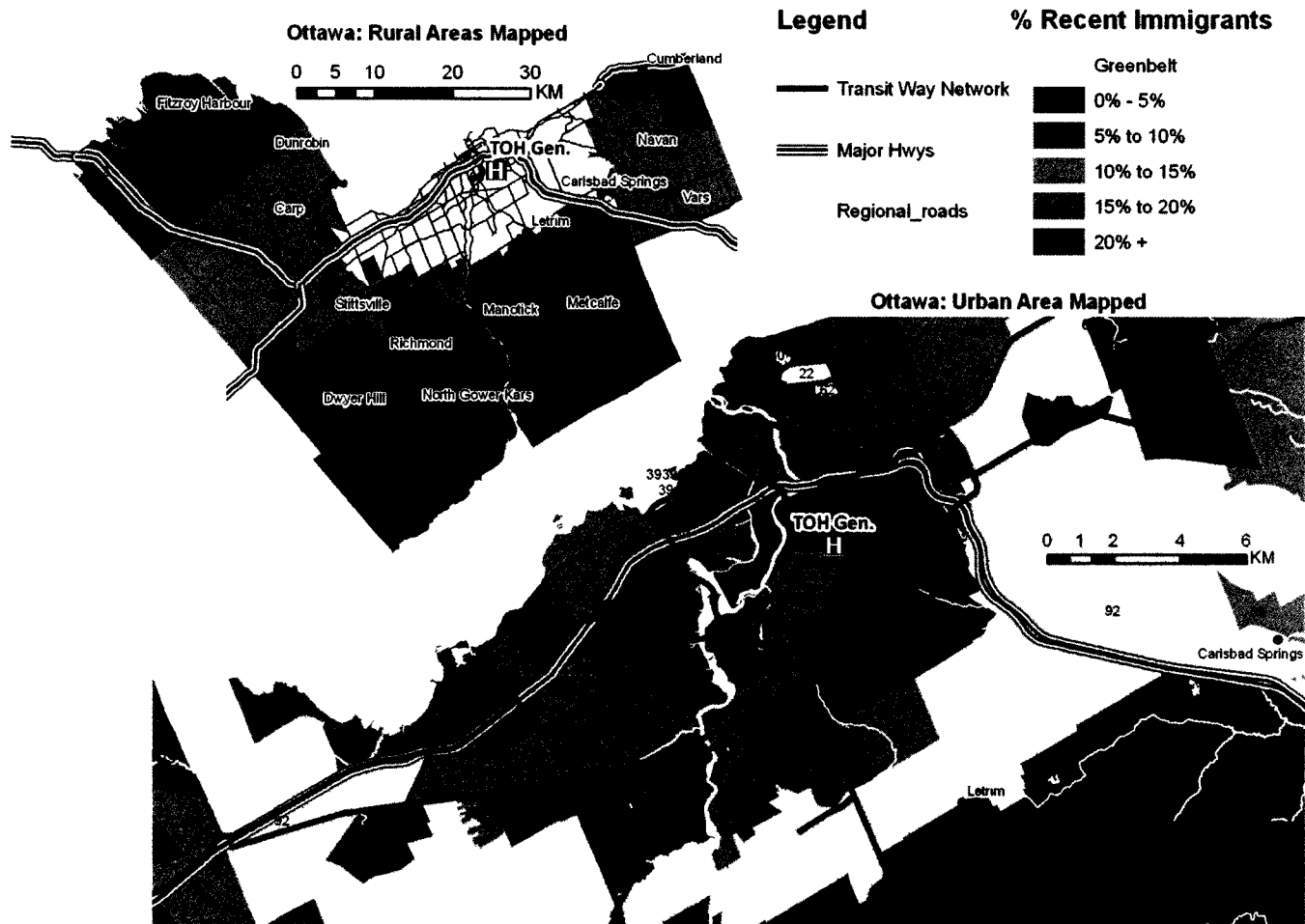


Figure 16. Distribution of % recent immigrant quintiles in Ottawa neighbourhoods. Numbers indicate neighbourhood names found in Table 6.

Table 6. Legend for Figures 15 and 16.

Neighbourhood Name	Map ID Number	Neighbourhood Name	Map ID Number
Cumberland	1	Island Park	37
Fitzroy Harbour - West Carleton	2	Katimavik - Hazeldean	38
Kars - Osgoode	3	Ledbury - Heron Gate -	
Metcalfe	4	Ridgemont - Elmwood	40
Barrhaven	5	Lindenlea - New Edinburgh	41
Bayshore	6	Lowertown	42
Beacon Hill South - Cardinal Heights	7	Orleans Village - Chateaufeuf	43
Beaverbrook	8	Overbrook - McArthur	44
Bells Corners East	9	Pineview	45
Bells Corners West	10	Playfair Park - Lynda Park -	
Billings Bridge - Alta Vista	11	Guildwood Estates	46
Hunt Club Upper - Blossom Park -		Qualicum - Redwood Park	47
Timbermill	12	Orleans Queenswood Heights	48
Borden Farm - Stewart Farm -		Riverside Park	49
Parkwood Hills - Fisher Glen	13	Sandy Hill - Ottawa East	50
Braemar Park - Bel Air Heights -		Trend-Arlington	51
Copeland Park	14	South Keys - Heron Gate -	
Briar Green - Leslie Park	15	Greenboro West	52
Carleton Heights - Rideauview	16	Tanglewood	53
Carlington	18	Vanier South	54
Laurentian	19	West Centertown	55
Carlingwood West - Glabar Park -		Westboro	56
McKellar Heights	20	Whitehaven - Queensway	
Carson Grove - Carson Meadows	21	Terrace North	57
Centrepoinde	23	Woodvale - Craig Henry -	
Centretown	24	Manordale - Estates of	
Orleans Chapel Hill	25	Arlington Woods	58
Cityview - Skyline - Fisher Heights	26	Woodroffe - Lincoln Heights	59
Civic Hospital-Central Park	27	Rockcliffe - Manor Park	60
Crestview - Meadowlands	28	CFB Rockcliffe-NRC	61
Emerald Woods - Sawmill Creek	29	Vanier North	63
Glebe - Dows Lake	30	Orleans North West	64
Greenboro East	31	Hunt Club South Industrial	66
Hawthorne Meadows - Sheffield		Orleans Central	67
Glen	32	Hunt Club Park	68
Hintonburg - Mechanicsville	33	East Industrial	69
Hunt Club - Ottawa Airport	34	Elmvale - Eastway - Riverview	
Hunt Club East - Western		- Riverview Park West	70
Community	35	Cummings	71
Iris	36	Merivale Gardens - Grenfell	
		Glen - Pineglen - Country	
		Place	72
		Rothwell Heights - Beacon Hill	
		North	73

Table 6 continued

Neighbourhood Name	Map Id Number
Orleans Chatelaine Village	74
Carp - Hardwood Plains	75
Stittsville	76
Glen Cairn - Kanata South Business Park	77
New Barrhaven - Stonebridge	78
Kanata Lakes - Marchwood Lakeside - Morgan's Grant - Kanata North Business Park	79
Hunt Club Woods - Quintarra - Revelstoke	80
Stittsville - Basswood	81
Bridlewood - Emerald Meadows	82
Orleans Avalon - Notting Gate - Fallingbrook - Gardenway South	83
Orleans Chapel Hill South	84
Blackburn Hamlet	85
Manotick - North Gower	86
Munster Hamlet - Richmond	87
Greely	88
Navan - Vars	89
Chapman Mills - Rideau Crest - Davidson Heights	90
Riverside South - Leitrim	91
Greenbelt	92
Crystal Bay û Lakeview Park	93
Britannia Village	94
Byward Market	95
Ottawa South	96
Ottawa East	97

Chapter 5

Discussion of Results and Methodology

Discussion of results

Origin Destination Matrix

The results of the drive time analyses done with the GIS methodology might seem trivial in that anyone can look at a map and know that people in rural areas need to drive further than those in urban areas to receive service. However, without the GIS methodology there is no way to actually quantify this knowledge. Further, because health services have traditionally been planned by meeting benchmark rates in a region, for example, beds per 1000 population, it is entirely possible that a rural region appears to have the same access to service as a densely populated urban area. The origin-destination drive approach avoids the benchmark problem by using specific patient locations rather than an aggregated approach. These results are extremely valuable to healthcare planners because they quantify the differences in access in easy to understand numbers (minutes travelled).

The results of the drive time methodology were as expected: rural areas experienced further drive times to surgical services compared the Communities of Care within the city of Ottawa (Figure 7). The value of the methodology was its ability to choose the best location to add surgical services. The methodology chose Renfrew Victoria Hospital (with the Hawkesbury General Hospital being a close second) as the site that would reduce travel times the most for Champlain LHIN residents. This result

can then be matched to other data such the number of surgeons or operating rooms available (Table 1). The information listed in Table 1 suggests that the Renfrew Victoria Hospital would not be an easy choice to add surgeries as there is only one general surgeon present, no additional operating rooms available and a full occupancy rate. It would be easier to add surgeries to the Hawkesbury General Hospital under these considerations given that there is already an under utilized operating room.

It is also important to recognize that the results presented here also represent a best case scenario in that the methods assume that all general surgeons can perform all general surgery procedures. There may be important heterogeneity in procedures that is missed in the case mix groups presented in Table 2. A better understanding of this heterogeneity could be had by examining the Canadian Ambulatory Case Classification System, which codes for the exact procedure used. Further, expert input from surgeons to better understand the surgical data and what it means in practical terms to surgeons performing the work.

The magnitude of the differences in drive times between rural and urban areas requires some comments. A one minute difference to a ten minute drive will hardly be noticed in an urban area even though it is a ten percent increase in time. For the typical rural resident a one minute savings would also not be noticed, and this difference is much smaller in percentage terms (say 2% on a 50 minute drive). However a ten percent time savings drive time for a rural resident is more likely to be noticed for a rural resident (five minutes for the above example). The reverse is also true: a ten minute increase to 15 minute drive is a huge difference for an urban resident, whereas it is not as big a

difference to a two hour drive for a rural resident. For this reason, differences in drive time should be considered separately for different geographic settings.

Effects of moving Primary and Secondary Care in Ottawa

The results from testing the scenario in which all the primary and secondary level of care surgeries were removed from the Ottawa Hospital was also interesting because unlike the obvious differences between rural and urban travel times, the results of this analyses are not easily predictable, yet alone quantifiable. The results of this analysis were unpredictable in that closing two facilities to general surgery for urban and rural residents reduces the total drive time for all Champlain LHIN residents (Figure 12). This result occurs because the urban core of Ottawa Centre does not have as high a demand for general surgeries as the more suburban Ottawa West and Ottawa East.

While this scenario is not likely to occur all at once, or ever, it is important to know that moving services between hospitals within the city of Ottawa is not going to have large effect on geographic access for patients. It is also interesting to note that this scenario could also be used to test changes in geographical access when an entire facility is closed.

Drive Time and Transit Time Inequities

Inequity in access between neighbourhoods was detected with respect to income and immigration for drive times and transit time, but it was not in the direction expected. The general expectation was that poorer neighbourhoods and those with a greater number of recent immigrants would experience less access to health care, along the lines of Hart's (1971)⁶⁴ inverse care law, which states that health care services are distributed

inversely to need. The contrary results found here may be due to several factors. First, as Hart points out, the “law” becomes harder to discern as market forces diminish. There is no known competition between hospitals for more affluent patients in the Champlain LHIN. Second, the differences in access measured are statistically significant, but would hardly be reason to change policies to correct the problem (10 minutes drive time and 23 minutes transit between the highest and lowest groups). Third, the problem is not really addressed by this analysis. I used a single health care provider for a single type of surgery and only two measures of social inequity.

Nevertheless, the results found here are not unique. Adams and White (2005)⁶⁵ showed that electoral wards in North Eastern England with lower income, employment and education had better access to general practices (using straight line distances) than more affluent wards. Likewise, Jordan et al. (2004)⁶⁶ could not show a correlation between access to doctors and morbidity nor to an index of social depravity in a mix of rural and urban UK counties. In the USA, Mansfield et al. (1999)⁶⁷ could not demonstrate a link between access to health care and morbidity; however, socioeconomic status and race explained 55% of the variation in premature mortality.

No relationship was found between immigration status and access to the General Campus with respect to transit time. This result might be explained by the missing data for transit times in the outlying areas of the city (Table 7). Seven of nine of these neighbourhoods are in the lowest two quintiles of recent immigrants. Further investigation of these rural neighbourhoods revealed that some (Navan, Manotick, Munster Hamlet - Richmond and Carp- Hardwood Plains) do have bus service, but it only runs towards the city during the morning rush hour. Therefore, under the constraints

I gave the travel planner, these neighbourhoods are effectively not served. Rerunning the analysis, giving missing neighbourhoods their morning transit times, did not change the results.

Table 7. Distribution of income and immigrant status by neighbourhood.

Neighbourhood*	Income Quintile	% recent immigrant group
Munster Hamlet - Richmond	4	5% to 10%
Navan - Vars	5	10% to 15%
Greely	2	5% to 10%
Cumberland	5	5% to 10%
Kars - Osgoode	3	0% to 5%
Metcalfe	1	0% to 5%
Manotick - North Gower	1	0% to 5%
Fitzroy Harbour - West Carleton	4	5% to 10%
Carp - Hardwood Plains	5	10% to 15%

*Neighbourhoods listed from closest to furthest from the Ottawa Hospital General Campus

Discussion of the Methodology

Refinements to the existing model

Certain assumptions used in the methodology could be tested and then improved upon. One of the largest assumptions used in this methodology was to treat missing postal code data as the geographic center of the municipality attribute of the record (except for Ottawa, where the center of Ottawa West, Central and East were used weighted by population). This assumption was chosen because it is fairly simple to do and requires no additional data. A more accurate treatment of this data would have been to move the postal code to the population weighted centroid of the municipality using dissemination area data. For example, Apparicio et al. (2008)⁶⁸ demonstrated that

aggregation errors caused by using census tracts instead of census blocks could lead to errors in access estimation of up to 30% for five to 10 percent of census tracts studied in urban Montreal.

Another way to deal with missing postal code data would be to choose a random location in the named municipality. This option would be easy to implement, but impossible for others to replicate because of the random selection of the census subdivision centroid.

A third possibility to deal with missing postal codes would be to place these records at the center of the largest town (population centre) or randomly within a defined part of the largest population center. This method would be somewhat painstaking, but manageable as there are only 25 census divisions in the Champlain LHIN.

A final way to deal with the missing postal codes would be to omit them from the analysis. In this analysis only 19 of 3,124 records or 0.6% of the data had missing postal codes. Deleting them or geocoding them using any of the described methods is unlikely to bias the results.

The methodology could also use a set of formalized rules to deal with missing or nonsense results. For example, rules should be made for dealing with patients that get geocoded to Quebec or for unusually long drive times. For instance, there was one drive time that was 82 km longer than any other drive time in the data set. This patient was the only patient who had surgery at the hospital furthest from their home. As cases like this may be explained by a desire to be near family after surgery care or other factors, it was decided to keep all of these data points in the analysis. However, simple cut-off rules could be applied to deal with such points.

Additions to the Methodology

The research presented thus far has dealt with the distribution and redistribution of health service with the only outcome measure of interest being time spent travelling. While time spent travelling to and from health services is known to be important in patient choice and outcomes (see Chapter 2) other factors could be considered by patients in choosing a health provider. Cost is generally not considered as a factor in determining patient choice for procedures such as surgery because it is rarely an out-of-pocket expense. Little is known about patient's personal choice of a specific surgeon; however, one could assume that the results are similar to those discussed below with respect to patient's perception of quality. Quality, although being the most studied factor in patient choice, is a difficult concept to quantify, and health services researchers have used both procedure level and hospital level measures to estimate quality. In recent years, regulatory agencies (such as the Veteran Association and Medicare and several US states, UK and Canadian Health authorities) have been publishing quality indicators with respect to certain procedures such as angioplasties, acute myocardial infarction and cancer surgeries. The outcomes of interest are rates of: in-hospital mortality, 30 day post discharge death and 30 day readmission rates. Thirty day readmission is thought to reflect the quality of the original procedure and patient education in caring for themselves post hospitalization. All these measures are corrected for patient age, sex, pre-existing comorbidities and socioeconomic status. Independent organisations such as the Leap Frog Group⁶⁹ publish rates for hospital, procedure and physician level quality indicators on their web site. Noticeably, very few hospitals submit their data to independent organisations.

The UK developed a hospital standard mortality rate in 2000, which has since been adopted by several jurisdictions including Canada^{70,71}. Rather than a procedure by procedure death rate, the HSMR is the ratio of observed deaths to expected deaths over a larger region. The HSMR is also corrected for comorbidities, admission type (emergency vs. elective), transfer type (if applicable), age and sex and is only evaluated on the top 65 case types.

So do these publically published quality indicators matter to patients in choosing hospitals? Luft et al. (1990)⁷² suggested that quality matters to patients and provided evidence to suggest that patients selected hospitals based on quality even before the public publication of quality reports. However, the conclusions did not match the data presented. Only five of seven surgical and two of five medical procedures show the expected relationship between outcome and volume (after correcting for case mix, age and comorbidities). No account was taken for length of stay which could also explain the relationships.

Romano and Zhou (2004)⁷³ examined admission rates to California and New York hospitals before and after publication of hospital quality indicators. Only in New York was there evidence of changes in admissions rates. Hospitals with low complication rates for CABG experienced higher admission rates within a month of publication of the results whereas hospitals with high complication rates experienced lower admissions rates two months post publication. Changes in rates were transient with admission rates returning to pre-publication rates after three months. There were some differences between groups of users. Whites and HMO insured patients changed their patterns of use in California, while Medicare patients in New York changed theirs. The

authors suggest that the reasons for the lack of action amongst the population to the quality studies was that the information was not widely enough disseminated, patients may have preferred their doctor's advice over the report, or that the patients did not think the report applied to them. The lack of a correlation between hospital mortality rates and patient behaviour has been documented in several other studies⁷⁴⁻⁷⁶.

Despite the lack of evidence that report cards matter to the public, the report cards do have predictive value. Jha and Epstein (2006)⁷⁷ showed that choosing a top ranked physician or hospital would result in having half the chance of dying compared to lower ranking hospitals. Data also showed that low ranked surgeons were more likely to leave their practices after the publication of report cards. As in other studies, better performance did affect hospital market share. The value using surgical mortality rates was questioned by Dimick et al. (2004)⁷⁸. Using the national surgical database they showed that hospitals do not perform enough procedures (of a given kind) to be able to detect changes in mortality rates below 50%.

Patient choice can be added to the origin destination model as a "friction coefficient" to travel. Once patient preferences are determined for each destination (by survey data, or HSMR), a friction coefficient can be estimated, and then applied as penalty to each destination.

Limitations of GIS models

There are several factors that can reduce the validity of the GIS models of spatial access to health services. These factors were aggregated by Guagliardo⁷⁹ into the following groups: data accuracy, geographic scale, temporal scale, improper attribution of cause based on ecological relationships, transportation modality and activity space. In

the next few paragraphs I will discuss how this thesis (or the literature) has dealt with each of these problems.

Data Accuracy

The input for GIS models used in this research were: inpatient location, location of hospital, postal code conversion file, road network, and census data. Poor accuracy of any of these data sources brings all the results into question. Fortunately, I am able to make some statements as to the validity of the data. Inpatient data were obtained from the Canadian Institute for Health information which recently undertook a three year study to review the accuracy of their database by randomly re-abstracting health records for the province of Ontario (CIHI 2004⁸⁰). Non-medical data elements such as data of birth, location and gender had extremely low coding error rates. Only date of discharge disposition did not match the new abstraction 100% of the time for the three years of study and its match rate was 96%. Original and re-abstracted medical data matched 91% of the time for primary diagnosis. These coding errors led to 10.6% of the case mix groupings (a collection of diagnosis codes and other factors) being changed, but only affected 4% of the main clinical category (based on case mix groups. As this study used case mix groups as the primary clinical categories, I would expect a similar error rate of 4% in this thesis. A general finding of the CIHI study was that procedure driven or intervention driven conditions were better coded than diagnosis driven conditions.

Other administrative healthcare studies found good agreement between the DAD and their gold-standards. Austin et al. (2002)⁸¹ found the specificity, sensitivity, and positive predictive value of the most responsible diagnosis for AMI were 93%, 89% and 88% respectively. For other cardiac related diagnoses the specificity was at least 94%.

The results were consistent with Cox et al. (1997)⁸² and Levy et al. (1999)⁸³ who found specificities and positive predictive values of at least 89%.

Moving to the geocoding process, the results of PCCF+ need to be checked very carefully. Errors are found from time to time and the weight file is generated from census postal codes, which are “only minimally checked for logical consistency” (R. Wilkins, pers. comm.).

There is almost no information on the validity of the Ontario Road Network file, except that it is accurate to 10 meters⁵⁸. I did find problems with miscoding of the OC Transpo Transitway in Ottawa. Private cars were able to enter the Transitway, which they are not supposed to do. The road file is constantly being refined with new road and directional information. It is possible that newer versions could yield slightly different results.

There is no information available on the accuracy of the OC Transpo trip planner web site.

Geographical Scale

As reviewed in Chapter 2, one must use the proper level of spatial aggregation to get the proper answer. The first part the thesis used drive times and disaggregated surgical data to measure spatial access, thereby avoiding many of the pitfalls of areal measurements of access. In the second part of the thesis, individual transit times were used along with dissemination area LICO scores and neighbourhood level immigration statistics. The neighbourhood level aggregation could be criticized for missing spatial patterns that might occur within neighbourhoods. The neighbourhoods used in this thesis were chosen because they match a current system in use, namely that of the Ottawa

Neighbourhood Study. The data from this study could be added to the Ottawa Neighbourhood Study which provides even more demographic and neighbourhood characteristics such as recreational opportunities, food stores and sense of belonging which are can be related to population health.

Alternatively, instead of using predefined neighbourhoods, one could use GIS to find “hot spots” of low income or high percent of recent immigrants using spatial statistics such as Getis-Ord or Moran’s I. These spatial groups could then be analyzed for differences in travel and transit times to surgical services. As with all studies, the level of spatial granularity should be chosen *a priori*, with the intent to answer the question being asked and with knowledge of the data available.

Transportation modality

The first part of the thesis used the personal vehicle as the modality of transportation. For the rural regions of the Champlain LHIN, this modality is justifiable. Even within the city of Ottawa, only 15% of trips occur by public transportation⁵⁹.

The second part of the thesis examining equity used both personal transportation and public transportation as modalities. Transportation by foot was not included as it seems likely that people who require surgery will not likely be walking to the Ottawa Hospital. However, for other health services, walking is a possible modality, especially in less developed countries or more densely populated neighbourhoods. It should be noted that walking time data is gradually becoming available on web sites such as Google Maps, which is currently available as a beta release.

Activity space

Activity space refers to the fact that people do not spend all their time at home and therefore, residential address may not be a suitable proxy for location^{84,85}. Many health services are accessed from the place of work or during shopping and therefore the spatial accessibility should be measured from those locations. For this thesis, not recognising activity space is probably not important to the results, as surgeries are infrequent events for most people and it takes at least a day for an inpatient procedure. Further, for the purposes of planning using thousands of demand points, determining the exact location of patients before they access services is simply not possible.

This thesis looks at how geographical information systems can be used to minimize drive times for patients to a specific service at predefined locations under different constraints. The broader question of how to optimize health service delivery for Champlain LHIN residents in general would require a broader understanding of demographics, current and future incident rates of all illness and current location of all services. Demographics are extremely important to health services because it lets one know the current and likely future needs of the population. The Champlain LHINs rapidly aging population will present challenges to health system planners to move from an acute care based system to a more chronic disease management system. Further, understanding where older populations are tending to move as they age (or not) will be important in knowing where to provide these services.

Summary and Conclusions

The work in this thesis and the literature reviewed showed that GIS can be a very useful tool for understanding geographic access to services and finding inequitable access

to services. The origin-destination methodology used in this thesis will allow health system planners to leverage their administrative data by using it in a geographic information system to find the location that minimizes overall drive times for patients. The methodology also allows testing of “what if” scenarios. For example, how would geographical access to long term care beds change if new beds were only added in facilities with less than 30 beds? Or, which neighbourhood’s experience the greatest inequity in access to substance abuse treatment clinics?

What should not be lost is that GIS is only a single tool of many that is required as part of the decision making process of where to locate services. I recommend that GIS be formally incorporated into decision making process for health care planning. To aid the planning process, Figure 17 demonstrates which access issues and areas that GIS could best serve. Planning of emergency services is the area GIS can best inform the decision making process. The number of people within one hour the emergency department and routing of ambulances are problems well suited for GIS to answer and have direct effects on health outcomes. In contrast, GIS does not offer as much to the planning of inpatient services at a single hospital. GIS could provide per capita rates of disease, treatments, market share but does not provide much else, unless planning on where to locate a new hospital. In health clinics, where the penetration of interventions, such as vaccination or disease screening, are important to public and population health, GIS is a critical planning tool as was seen in the mammography screening section of Chapter 2. GIS is also very important to the planning of system wide health services. Matching population health characteristics to services over large areas is next to impossible without full

knowledge of spatial coverage of services. GIS may be a less important tool to the decision making process in dealing with issues of inequitable access to health services due to socio-economic factors. GIS can find and describe the problem, but political and social factors will offer solutions through policy. Likewise GIS can find and quantify inequitable distribution of family doctors, but policies such as incentivizing physicians to work in rural or remote areas will offer the solution to the problem.

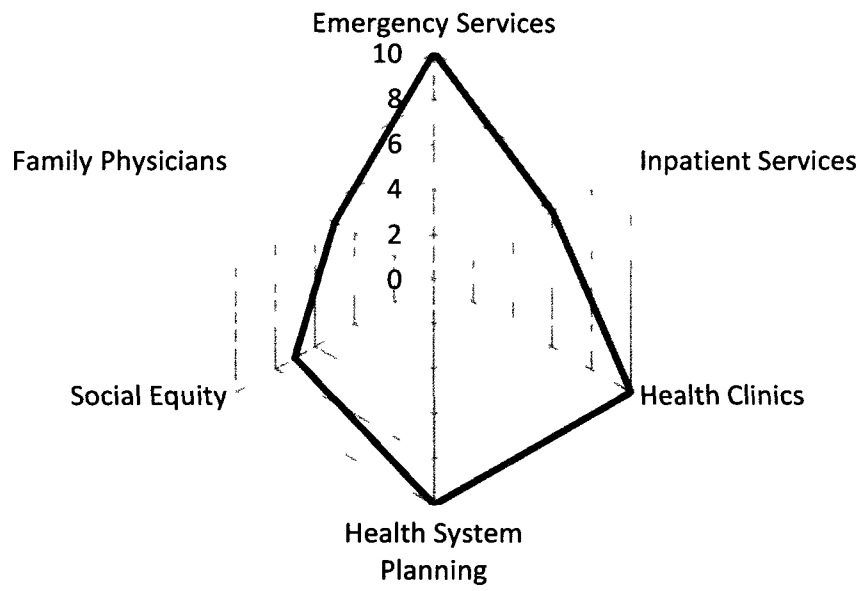


Figure 17. Representation of the importance of GIS in the decision making process to different areas of health services planning.

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Appendices

Appendix A . The five most frequent surgical case mix groups in fiscal year 2007/08.

Renfrew Victoria Hospital

Case Mix Group	Total
Major Intestinal and Rectal Procedures	15
Non-Extensive Unrelated O.R. Procedures	3
Less Extensive Esophageal, Stomach and Duodenum Procedures	2
Other Admissions with Surgery	2
Bilateral Hernia Procedures	1
<i>Top 5 Subtotal</i>	<i>23</i>
<i>(% of Total)</i>	<i>(79%)</i>
<i>Remaining Case Mix Groups</i>	<i>6</i>
<i>Grand Total</i>	<i>29</i>

Pembroke Regional Hospital

Case Mix Group	Total
Major Intestinal and Rectal Procedures	34
Total Mastectomy for Breast Malignancy	18
Subtotal Mastectomy and Other Breast Procedures for Malignancy	10
Bilateral Hernia Procedures	7
Less Extensive Esophageal, Stomach and Duodenum Procedures	7
<i>Top 5 Subtotal</i>	<i>76</i>
<i>(% of Total)</i>	<i>(68%)</i>
<i>Remaining Case Mix Groups</i>	<i>35</i>
<i>Grand Total</i>	<i>111</i>

Queensway-Carleton

Case Mix Group	Total
Major Intestinal and Rectal Procedures	66
Subtotal Mastectomy and Other Breast Procedures for Malignancy	32
Bilateral Hernia Procedures	31
Total Mastectomy for Breast Malignancy	30
Laparoscopic Cholecystectomy	16
<i>Top 5 Subtotal</i>	<i>175</i>
<i>(% of Total)</i>	<i>(73%)</i>
<i>Remaining Case Mix Groups</i>	<i>66</i>
<i>Grand Total</i>	<i>241</i>

Arnprior & District Memorial

Case Mix Group	Total
Bilateral Hernia Procedures	13
Major Intestinal and Rectal Procedures	11
Subtotal Mastectomy and Other Breast Procedures for Malignancy	10
Thyroid Procedures	4
Abdominal Laparoscopy	2
<i>Top 5 Subtotal</i>	<i>40</i>
<i>(% of Total)</i>	<i>(74%)</i>
<i>Remaining Case Mix Groups</i>	<i>14</i>
<i>Grand Total</i>	<i>54</i>

Almonte General Hospital

Case Mix Group	Total
Bilateral Hernia Procedures	4
Breast Procedures Except Biopsy and Local Excision without Malignancy	4
Plastic Surgery	4
Cholecystectomy	2
MNRH Procedures for Injury or Complication of Treatment	2
Top 5 Subtotal <i>(% of Total)</i>	16 <i>(94%)</i>
Remaining Case Mix Groups	1
Grand Total	17

Carleton Place Hospital

Case Mix Group	Total
Plastic Surgery	7
Total Mastectomy for Breast Malignancy	7
Non-Extensive Unrelated O.R. Procedures	4
Breast Procedures Except Biopsy and Local Excision without Malignancy	3
Other Dermatological Procedures for Malignancy or Skin Ulcer or Cellulitis	3
Top 5 Subtotal <i>(% of Total)</i>	24 <i>(96%)</i>
Remaining Case Mix Groups	1
Grand Total	25

Hopital Montfort

Case Mix Group	Total
Major Intestinal and Rectal Procedures	89
Bilateral Hernia Procedures	37
Unilateral Hernia Procedures (MNRH)	26
Total Mastectomy for Breast Malignancy	25
Laparoscopic Cholecystectomy	24
Top 5 Subtotal <i>(% of Total)</i>	201 <i>(63%)</i>
Remaining Case Mix Groups	120
Grand Total	321

Hawkesbury Hospital

Case Mix Group	Total
Major Intestinal and Rectal Procedures	17
Laparoscopic Cholecystectomy	7
Bilateral Hernia Procedures	5
Total Mastectomy for Breast Malignancy	5
Subtotal Mastectomy and Other Breast Procedures for Malignancy	4
Top 5 Subtotal <i>(% of Total)</i>	38 <i>(65%)</i>
Remaining Case Mix Groups	14
Grand Total	52

Ottawa Hospital General Site

Case Mix Group	Total
Major Intestinal and Rectal Procedures	189
Thyroid Procedures	73
Less Extensive Esophageal, Stomach and Duodenum Procedures	66
Bilateral Hernia Procedures	43
Subtotal Mastectomy and Other Breast Procedures for Malignancy	41
<i>Top 5 Subtotal</i> <i>(% of Total)</i>	<i>412</i> <i>(56%)</i>
<i>Remaining Case Mix Groups</i>	<i>332</i>
<i>Grand Total</i>	<i>744</i>

Ottawa Hospital Civic Site

Case Mix Group	Total
Major Intestinal and Rectal Procedures	143
Bilateral Hernia Procedures	86
Less Extensive Esophageal, Stomach and Duodenum Procedures	56
Thyroid Procedures	47
Total Mastectomy for Breast Malignancy	46
<i>Top 5 Subtotal</i> <i>(% of Total)</i>	<i>378</i> <i>(64%)</i>
<i>Remaining Case Mix Groups</i>	<i>211</i>
<i>Grand Total</i>	<i>589</i>

Winchester Hospital

Case Mix Group	Total
Major Intestinal and Rectal Procedures	13
Total Mastectomy for Breast Malignancy	5
Thyroid Procedures	4
Subtotal Mastectomy and Other Breast Procedures for Malignancy	3
Less Extensive Esophageal, Stomach and Duodenum Procedures	2
<i>Top 5 Subtotal</i> <i>(% of Total)</i>	<i>27</i> <i>(90%)</i>
<i>Remaining Case Mix Groups</i>	<i>3</i>
<i>Grand Total</i>	<i>30</i>

Cornwall Community

Case Mix Group	Total
Major Intestinal and Rectal Procedures	61
Unilateral Hernia Procedures (MNRH)	17
Total Mastectomy for Breast Malignancy	16
Bilateral Hernia Procedures	15
Subtotal Mastectomy and Other Breast Procedures for Malignancy	13
<i>Top 5 Subtotal</i> <i>(% of Total)</i>	<i>122</i> <i>(66%)</i>
<i>Remaining Case Mix Groups</i>	<i>63</i>
<i>Grand Total</i>	<i>185</i>

Appendix B. Formats used in SAS

```
PROC FORMAT;
```

```
VALUE NOSMALLVALUES 1,2,3,4,5 = '- '
;
```

```
picture pctfmt low-high='009 %';
```

```
value $HSPTL_ORDER (NOTSORTED)
```

```
'PEMBROKE REGIONAL HOSPITAL INC.'='Ren. Co.'
'RENFREW VICTORIA HOSPITAL'='Ren. Co.'
'ST FRANCIS MEMORIAL HOSPITAL'='Ren. Co.'
'DEEP RIVER & DISTRICT HOSPITAL HOSPITAL'='Ren. Co.'
'ARNPRIOR & DISTRICT MEMORIAL HOSP. (THE)'='Ren. Co.'

'QUEENSWAY-CARLETON HOSPITAL'='Ottawa West'

'KEMPTVILLE DISTRICT HOSPITAL'='NL / NG'
'ALMONTE GENERAL HOSPITAL'='NL / NG'
'CARLETON PLACE AND DISTRICT MEM HOSPITAL'='NL / NG'

'ROYAL OTTAWA HLTH CARE GRP-BROCKVILLE MH'='Ottawa West'
'ROYAL OTTAWA HLTH CARE GROUP-PSYCH SITE'='Ottawa West'

'OTTAWA HOSPITAL ( THE )-CIVIC SITE'='Ottawa Center'
'OTTAWA HOSPITAL ( THE )-GENERAL SITE'='Ottawa Center'
'CHILDREN'S HOSPITAL OF EASTERN ONTARIO'='Ottawa Center'
'UNIVERSITY OF OTTAWA HEART INSTITUTE'='Ottawa Center'
'OTTAWA HOSPITAL ( THE )-RIVERSIDE SITE'='Ottawa Center'
'SISTERS OF CHARITY HOSPITAL OTTAWA'='Ottawa Center'

'HOPITAL MONTFORT'='Ottawa East'

'WINCHESTER DISTRICT MEMORIAL HOSPITAL'='East. Co.'
'HAWKESBURY AND DISTRICT GENERAL HOSPITAL'='East. Co.'
'CORNWALL COMMUNITY HOSP-GENERAL SITE'='East. Co.'
'CORNWALL COMMUNITY HOSPITAL'='East. Co.'
'GLENGARRY MEMORIAL HOSPITAL'='East. Co.'
OTHER='Other';
```

```
VALUE $h_name (notsorted)
```

```
'HOPITAL MONTFORT'='Hopital Montfort'

'SISTERS OF CHARITY OF OTTAWA HOSPITAL'='SOC'
'ROYAL OTTAWA HLTH CARE GRP-BROCKVILLE MH'='Royal Ott. MH'
```

'ROYAL OTTAWA HLTH CARE GROUP-PSYCH SITE'='Royal Ott.
Psyc'
'OTTAWA HOSPITAL (THE)-GENERAL SITE'='TOH-General'
'OTTAWA HOSPITAL (THE)-CIVIC SITE'='TOH-Civic'
'OTTAWA HOSPITAL (THE)-RIVERSIDE
SITE'= 'TOH-Riverside'
"CHILDREN'S HOSPITAL OF EASTERN ONTARIO"='CHEO'
'UNIVERSITY OF OTTAWA HEART INSTITUTE'='UOHI'

'WINCHESTER DISTRICT MEMORIAL HOSPITAL'='Winchester
Hosp.'
'HAWKESBURY AND DISTRICT GENERAL
HOSPITAL'='Hawkesbury Hosp.'
'CORNWALL COMMUNITY HOSPITAL'='Cornwall Comm Hosp.'

'CORNWALL COMMUNITY HOSP-GENERAL SITE'='Cornwall
Comm. Hosp. Gen.'
'GLENGARRY MEMORIAL HOSPITAL'='Glengarry Mem Hosp.'

'QUEENSWAY-CARLETON HOSPITAL'='QCH'
'KEMPTVILLE DISTRICT HOSPITAL'='Kemptville Hosp.'
'ALMONTE GENERAL HOSPITAL'='Almonte General'
'CARLETON PLACE AND DISTRICT MEM HOSPITAL'='CPDMH'

'PEMBROKE REGIONAL HOSPITAL INC.'='Pembroke Hosp.'
'RENFREW VICTORIA HOSPITAL'='Renfrew Hosp.'
'ST FRANCIS MEMORIAL HOSPITAL'='Barrys Bay Hosp.'
'DEEP RIVER & DISTRICT HOSPITAL HOSPITAL'='Deep River
Hosp.'
'ARNPRIOR & DISTRICT MEMORIAL HOSP.(THE)'='Arnprior
Hosp.'
OTHER= 'Other'

;
RUN;

Appendix C. Data preparation for PCCF+ and ArcView

Step 2A --Join Data to Hay Group Level of Care The starting data set imported from PHPDB is called `inpatient_surgery` **

```
PROC SQL;
CREATE TABLE new AS
  SELECT A.*, B.*
  FROM inpatient_surgery AS A
  LEFT JOIN new AS B
  ON A.cmg_code = B.cmg_code AND a.cmg_age = b.cmg_age;
```

/*Step 2B Join Patient Postal Codes to Community of Cares*/

```
PROC SQL;
CREATE TABLE PC1 AS
  SELECT A.*, B.*
  FROM WORK.NEW AS A
  LEFT JOIN coc_postal_codes AS B
  ON A.PCODE= B.POSTAL_CODE ;
  /*coc_postal_codes was created by doing a spatial join in ARCGIS
  between the community of care polygons and the master list of 23,000
  postal codes in the Champlain LHIN **/
```

/ Step 2C Process data to deal with missing postal codes** If the community of care is missing due to a non matching postal codes, the community of care is assigned by municipality. Fix the non matches by municipality, Then fix the community of cares that are missing due to missing postal codes. The second step will assign a COC if the postal code is missing. ****/**

```
DATA pc2; SET pc1;
R=RANUNI(345345398)*100;
IF coc='' and municipality in
  ('ADMASTON/BROMLEY', 'ARNPRIOR', 'BONNECHERE VALLEY',
  'BRUDENELL,LYNDOCH ETC', 'DEEP RIVER', 'GREATER MADAWASKA',
  'HEAD,CLARA & MARIA', 'HORTON', 'KILLALOE,HAGARTY&RICH',
  'LAURENTIAN HILLS', 'LAURENTIAN VALLEY','MADAWASKA VALLEY',
  'MCNAB/BRAESIDE',
  'NORTH ALGONA WILBER.', 'PEMBROKE', 'PETAWAWA',
  'PIKWAKANAGAN', 'RENFREW', 'WHITEWATER REGION')
THEN coc='Renfrew County';
  ELSE IF coc='' and municipality in
  ('AKWESASNE 59', 'ALFRED & PLANTAGENET','EAST HAWKESBURY',
  'RUSSELL', 'SOUTH DUNDAS','SOUTH GLENGARRY','SOUTH STORMONT',
  'CASSELMAN', 'CORNWALL','CLARENCE-ROCKLAND', 'HAWKESBURY',
  'NATION','NORTH DUNDAS','NORTH GLENGARRY', 'NORTH STORMONT',
  'CHAMPLAIN') THEN coc = 'Eastern Counties';
  ELSE IF coc ='' and municipality IN ('BECKWITH','CARLETON
  PLACE','MISSISSIPPI MILLS','NORTH GRENVILLE', 'LANARK
  HIGHLANDS') THEN coc= 'NL / NG';
```

```

ELSE IF coc='' and municipality ='OTTAWA'
THEN DO;
/* Assign to Ottawa Community of care based on population density */
IF ( 0=< r <= 41 ) THEN coc ='Central West';
ELSE IF ( 41 < r <= 70 ) THEN COC='Centre';
ELSE coc='Central East';
END;
RUN;

/* Step 2C part 2 --FIX MISSING POSTAL CODES by MUNICIPALITY */
DATA pc3; SET pc2;
R=RANUNI(115398)*100;
IF postal_code='' AND municipality IN ('ADMASTON/BROMLEY', 'ARNPRIOR',
'BONNECHERE VALLEY', 'BRUDENELL,LYNDOCH ETC',
'DEEP RIVER', 'GREATER MADAWASKA',
'HEAD,CLARA & MARIA', 'HORTON', 'KILLALOE,HAGARTY&RICH',
'LAURENTIAN HILLS', 'LAURENTIAN VALLEY',
'MADAWASKA VALLEY', 'MCNAB/BRAESIDE',
'NORTH ALGONA WILBER.', 'PEMBROKE', 'PETAWAWA',
'PIKWAKANAGAN', 'RENFREW', 'WHITEWATER REGION')
THEN coc='Renfrew County';
ELSE IF postal_code='' AND municipality IN
('AKWESASNE 59','ALFRED & PLANTAGENET','EAST HAWKESBURY',
'RUSSELL', 'SOUTH DUNDAS', 'SOUTH GLENGARRY','SOUTH
STORMONT', 'CASSELMAN', 'CORNWALL', 'CLARENCE-ROCKLAND',
'HAWKESBURY', 'NATION', 'NORTH DUNDAS', 'NORTH GLENGARRY',
'NORTH STORMONT', 'CHAMPLAIN')
THEN coc = 'EasternCounties';
ELSE IF postal_code ='' AND municipality IN
('BECKWITH', 'CARLETON PLACE', 'MISSISSIPPI
MILLS', 'NORTH GRENVILLE', 'LANARK HIGHLANDS')
THEN coc= 'NL / NG';
ELSE IF postal_code='' AND municipality='OTTAWA'
THEN DO;
IF ( 0=< r <= 41 )
THEN coc ='Central West';
ELSE IF ( 41 < r <= 70 )
THEN COC='Centre';
ELSE coc='Central East';
END;
RUN;

/* Create New & New1 datasets. They are the same, except New is
passed to PCCF+ with only the necessary variables. All the extra
attributes slow down the processing significantly. Later will remerge
the PCCF results with New1 */
DATA new;
SET PC3;
WHERE pcc_description="General Surgery";
/* CHANGE VARIABLE NAMES TO WHAT PCCF+ IS EXPECTING AND
CREATE THE ID */

```

```

        rename postal_code = pcode;
        id=PUT(_n_,$12.); /*CREATE THE RECORD NUMBER!!!*/
        fsa=substr(postal_code,1,3);
        ldu=substr(postal_code,4,3);
        KEEP id fsa ldu postal_code;RUN ;
    DATA new1;SET PC3;WHERE pcc_description="General Surgery";
        RENAME postal_code = pcode;id=PUT(_n_,$12.);
        fsa=substr(postal_code,1,3);ldu=substr(postal_code,4,3);*keep id
        fsa ldu postal_code; /* want all the variables for back merging */
    RUN;

```

/* CALL THE PCCF MASTER FILE IT NEEDS THE WORK FILE "NEW" AS THE INPUT (CREATED ABOVE)*/

```

%INCLUDE
"C:\PATH TO CONTROL FILE\*.SAS";

```

/* MERGE BACK ALL THE DATA TO HEALTHOUT FILE*/

```

PROC SQL;
CREATE TABLE HEALTH_OUT1
AS SELECT a.* , b.* FROM hlthout AS a
    /*hlthout is the file produced BY PCCF+ with the geolocated postal
        codes */
LEFT JOIN new1 AS b
ON a.id = b.id;

```

/* Based on results of PCCF+, delete "bad" records*/

```

DATA Healthout2; SET healthout1;
    IF postal_code IN(/*"bad" postal codes go here */)*/
        THEN DELETE;
    RUN;

```

/*disaggregate the data file – PHPDB aggregates the data, so that one postal code may have multiple separations. Here I make all discharges equal to one BY replicating each row BY the number of discharges.

Note that ARCGIS can handle the data in aggregated form. However it easier to do the calculations on the disaggregated data.*/

```

DATA healthout3; SET healthout2;
    Discharge =1; /* make a new variable from summing discharges */
    DO I = 1 TO count;
    OUTPUT;
    END;
    RUN;

```

Appendix D. Geographic centers of each municipality

```
/* FINAL STEP: Assign
latitude and longitude to
records with missing postal
codes based on municipality
attribute. Within the Ottawa
Municipality, the latitude
and longitude were derived
using ArcGIS from the
population weighted center of
each community of care (from
census tract data). For all
the other municipalities, the
geographical centre was used
for the latitude and
longitude. */
```

```
DATA HEALTH_OUT_FINAL; SET
HEALTH_OUT2;
IF municipality ="LAURENTIAN HILLS"
THEN DO;
Long = -77.51300403360; lat
=45.98792207950; END;
else if municipality ="HEAD, CLARA
AND MARIA" THEN DO;
Long = -78.06161896490; lat
=46.17515442330; END;
ELSE IF municipality ="MADAWASKA
VALLEY" THEN DO;
Long = -77.68850776070; lat
=45.50858012590; END;
ELSE IF municipality ="KILLALOE,
HAGARTY AND RICHARDS" THEN DO;
Long = -77.51672745000; lat
=45.61475918740; END;
ELSE IF municipality ="SOUTH
STORMONT" THEN DO;
Long = -74.93880455770; lat
=45.07420948150; END;
ELSE IF municipality ="CORNWALL" THEN
DO;
Long = -74.74302621950; lat
=45.04020976610; END;
ELSE IF municipality ="SOUTH DUNDAS"
THEN DO;
Long = -75.26962303880; lat
=44.94932467070; END;
ELSE IF municipality ="NORTH DUNDAS"
THEN DO;
Long = -75.37449258660; lat
=45.08681780210; END;
ELSE IF municipality ="GREATER
MADAWASKA" THEN DO;
Long = -76.90564008130; lat
=45.27290600250; END;
ELSE IF municipality ="BRUDENELL,
LYNDOCH AND RAGLAN" THEN DO;
Long = -77.42251131390; lat
=45.31261039980; END;
ELSE IF municipality ="BONNECHERE
VALLEY" THEN DO;
Long = -77.15675193240; lat
=45.45528770080; END;
```

```
ELSE IF municipality ="PIKWAKANAGAN (GOLDEN
LAKE 39)" THEN DO;
Long = -77.24556950470; lat =45.56555026440;
END;
ELSE IF municipality ="ADMASTON/BROMLEY"
THEN DO;
Long = -76.86867600340; lat =45.49549698980;
END;
ELSE IF municipality ="WHITEWATER REGION"
THEN DO;
Long = -76.84003682700; lat =45.71446297960;
END;
ELSE IF municipality ="PEMBROKE" THEN DO;
Long = -77.11554023190; lat =45.82194207140;
END;
ELSE IF municipality ="NORTH ALGONA
WILBERFORCE" THEN DO;
Long = -77.19073052570; lat =45.61502122350;
END;
ELSE IF municipality ="LAURENTIAN VALLEY"
THEN DO;
Long = -77.24233828170; lat =45.74589229570;
END;
ELSE IF municipality ="MISSISSIPPI MILLS"
THEN DO;
Long = -76.28995691720; lat =45.25084965580;
END;
ELSE IF municipality ="ARNPRIOR" THEN DO;
Long = -76.35596349600; lat =45.42570760390;
END;
ELSE IF municipality ="MCNAB/BRAESIDE" THEN
DO;
Long = -76.49001719460; lat =45.41895815410;
END;
ELSE IF municipality ="HORTON" THEN DO;
Long = -76.64903069560; lat =45.50619920950;
END;
ELSE IF municipality ="RENFREW" THEN DO;
Long = -76.67972451290; lat =45.47412554670;
END;
ELSE IF municipality ="CARLETON PLACE" THEN
DO;
Long = -76.13827724640; lat =45.13788323460;
END;
ELSE IF municipality ="LANARK HIGHLANDS"
THEN DO;
Long = -76.52112120230; lat =45.09382413270;
END;
ELSE IF municipality ="PETAWAWA" THEN DO;
Long = -77.30976127710; lat =45.89445924490;
END;
ELSE IF municipality ="DEEP RIVER" THEN DO;
Long = -77.43171787660; lat =46.06561309770;
END;
ELSE IF municipality ="BECKWITH" THEN DO;
Long = -76.08230192130; lat =45.08600753290;
END;
ELSE IF municipality ="NORTH GRENVILLE" THEN
DO;
Long = -75.65072095210; lat =44.97009752910;
END;
ELSE IF municipality ="OTTAWA" THEN DO;
Long = -75.77621260250; lat =45.29364229170;
END;
ELSE IF municipality ="ALFRED AND
PLANTAGENET" THEN DO;
Long = -74.96547993030; lat =45.54726936050;
END;
ELSE IF municipality ="CLARENCE-ROCKLAND"
THEN DO;
```

```

Long = -75.21041408760; lat
=45.47969299910; END;
ELSE IF municipality ="RUSSELL" THEN
DO;
Long = -75.31373134780; lat
=45.27190551550; END;
ELSE IF municipality ="NORTH
STORMONT" THEN DO;
Long = -75.01408263930; lat
=45.20501762210; END;
ELSE IF municipality ="THE NATION
MUNICIPALITY" THEN DO;
Long = -74.98754815720; lat
=45.38702778270; END;
ELSE IF municipality ="CASSELMAN"
THEN DO;
Long = -75.09081873740; lat
=45.31339950780; END;
ELSE IF municipality ="AKWESASNE
(PART) 59" THEN DO;
Long = -74.55176635860; lat
=45.06670191560; END;
ELSE IF municipality ="SOUTH
GLENGARRY" THEN DO;
Long = -74.56340639910; lat
=45.18227138460; END;
ELSE IF municipality ="NORTH GLENGARRY" THEN
DO;
Long = -74.68265284590; lat =45.35013514740;
END;
ELSE IF municipality ="EAST HAWKESBURY" THEN
DO;
Long = -74.48782496660; lat =45.51023185840;
END;
ELSE IF municipality ="CHAMPLAIN" THEN DO;
Long = -74.68829363810; lat =45.56115824780;
END;
ELSE IF municipality ="HAWKESBURY" THEN DO;
Long = -74.61124863860; lat =45.60852219130;
END;
ELSE IF municipality ="OTTAWA WEST" THEN DO;
Long = -75.81232365300; lat =45.32241252660;
END;
ELSE IF municipality ="OTTAWA CENTRAL" THEN
DO;
Long = -75.56103587350; lat =45.44754746770;
END;
ELSE IF municipality ="OTTAWA EAST" THEN DO;
Long = -75.65622000940; lat =45.36995286520;
END;
RUN;

```

Appendix E. How to Query the OC Transpo Travel Planner

```

/*****
SAS macro to query OC Transpo Travel Planner Web Site.
Macro Loops through all street addresses stored in dataset new.
Addresses have the format Number+StreetName+StreetType.
For each webpage returned, a series of Perl regular expression is
used to parse the walking time and the bus time. Bus times over an
hour required a different regular expression. It seems that the
travel planner will not allow any walks over 30 minutes to the
closest bus stop.
*****/

/*the filename was too long, so it was broken up into two parts
part b is constant so it can be represented by a macro constant */

%let b=OTTA&destination=THE+OTTAWA+HOSPITAL+-
+CIVIC+CAMPUS&landmarksDestinationState=2&timeType=4&hour=10&minute=00&
pm=True&day=20100304&submitBtn=Plan+my+route!&sess=DD007B4BD29A8388E7A3
5A6249F5E4F7;

options symbolgen mprint mlogic;

/*Create the Macro variable containing
all the addresses */
%macro adds;
proc sql;
select address into:address separated by '-'
from new;
quit;

/*Loop through all the Addresses */
%do i = 1 %to &sqllobs;

/*create a variable filename containing the
URL of interest */
filename foo url
"http://www.octranspo1.com/travelplanner/travelplanner?origin=%Qscan(&a
dress.,&i,'-*)&originRegion=&b"
lrecl=5000;

/* SAS will try to resolve each '&' in the b macro variable as a macro
variable,
notes will be written to the log that these macro variables are
undefined. */

/*Read the URL into a SAS data set
Data set name is unique to the address*/
data CIVIC._%sysfunc(translate(%Qscan(&address.,&i,'-'),"_","+"));
/* use the translate function to get rid of the plus because they are
illegal for use in sas dataset names*/
infile foo length=len;
input record $varying5000. len;
run;

```

```

/*Parse the Data set for values of interest using Perl regular
expersions*/
data a &i;
set CIVIC._%sysfunc(translate(%Qscan(&address.,&i,'-'),"_"+""));
informat durationr 6.0;
format durationr 6.0;
informat walk 6.0;
format walk 6.0;
;
if _N_ = 1 then
do;
retain ExpressionIDr;
retain ExpressionIDHour;
retain ExpressionIDwalk;

/*When total duration is less than one hour*/
patternr = '/Duration:\s\d\d?\s\minutes/';
ExpressionIDr = prxparse(patternr);

/* when duration is greater than one hour */
patternhour = "/Duration: 1 hour,\s\d\d?\s\minute\D?/";
ExpressionIDhour = prxparse(patternhour);

/* All walks were less than one hour */
patternwalk = '/Walking:\s\d\d?\s\minutes/';
ExpressionIDwalk = prxparse(patternwalk);

end;
call prxsubstr(ExpressionIDr, record, positionr, lengthr);
if positionr ^= 0 then
do;
matchr = substr(record, positionr, lengthr);
durationr =(substrn( record, (positionr + 10), ((lengthr -10 - 8)
))) *1; * length - start -(length of Minutes);
end;

call prxsubstr(ExpressionIDhour, record, positionh, lengthh);
if positionh ^= 0 then
do;
matchhour = substr(record, positionh, lengthh);
durationhour =(substrn( record, (positionh + 18), ((lengthh -(18)
- 7) ))) *1 +60; * length - start -(length of Minutes);
end;

call prxsubstr(ExpressionIDwalk, record, positionw, lengthw);
if positionw ^= 0 then
do;
matchwalk = substr(record, positionw, lengthw);
walk =(substrn( record, (positionw + 9), ((lengthw -9 - 8) ))) *1
; * length - start -(length of Minutes);
end;

run;

/* Collapse Data set onto one row that contains the duration(s) and the
walking time*/

```

```

PROC SQL;
create table _%sysfunc(translate(%Qscan(&address.,&i,'-'),"_","+"))_4
/*_4 just to make a new identifyer on these data sets */
as SELECT
sum(durationr) as total_less_than_hour,
SUM(DURATIONhour) AS TOTAL_TRAVEL,
SUM(WALK) AS TOTAL_WALK
FROM a_&i;
quit;

/* Append all the data sets together. The number of rows should
be equal the number of addresses in the macro variable */
/* NB: DELETE THE DATA SET ALL_COMBINED AFTER RUNNING THE MACRO,
OTHERWISE THE NEXT RUN WILL CONTAIN ALL THE RECORDS FROM THE PREVIOUS
RUN!!*/
proc append base=all_combined
data=%sysfunc(translate(%Qscan(&address.,&i,'-'),"_","+"))_4
force;
run;

%end; /* stop this iteration of the loop, restart or not based on value
of &i*/

%mend ; /*end macro */

%adds; /*run the macro */

```

Appendix F. Data processing in SAS to determine outcomes

```
/* IMPORT data from ARCGIS */
PROC IMPORT OUT= WORK.new1
DATAFILE= "C:\path\filename.csv"
          DBMS=csv REPLACE;GUESSINGROWS=32000;
          GETNAMES=YES;
          DATAROW=2;

RUN;
/* Join this data to health_out which has the "actual hospitals" and
other health information stored with it.*/

PROC SQL;
CREATE TABLE one AS SELECT
a.*, b.* , (total_meters /1000) AS total_km
FROM NEW1 AS a
LEFT JOIN
od AS b
ON a.id = b.originid
;

DATA two;
  SET one;
  h_name=put(hospital,$H_name.);
  h_coc=put(hospital,$Hsptl_order.);
  /*NEED TO PARSE THE HOSPITAL NAMES FIELD AND NEED TO KNOW THE
ACTUAL HOSPITAL THE PATIENT WENT TO */

          start=PRXMATCH("/-/",name);
          c2=SUBSTRN(name,start+2);
          IF c2=hospital THEN actual = 1;
          DROP start;

RUN;

/* dataset two is a master file
   Make it a permanent dataset*/

DATA drives.analysis_dataset;
SET two; RUN;

/*keep the records of interest- the actual distance and the minimum
(closest or best) distance. Make three datasets to work with 1) the
actual route, 2) the best route and 3) both data sets combined with a
location indicator variable */

PROC SORT DATA=two; BY originid; RUN;

DATA actual best both ;SET two;
BY originid;
  IF actual=1 THEN DO;
    location = "Actual";
    OUTPUT actual both;
  END;
```

```

                IF destinationrank=1 THEN DO;
                    location= "Best";
                    OUTPUT best both;
                END;
RUN;

/*****
                Actual and Best Drive Times
*****/
/* Actual Drive time */

ODS HTML STYLE=MINIMAL;
TITLE "Total Drive Time Actual";

PROC MEANS DATA= actual SUM NOPRINT;
    VAR TOTAL_MINUTES TOTAL_km;
    OUTPUT OUT=M_ACTUAL SUM=TOTAL_TIME TOTAL_DISTANCE;
    FORMAT TOTAL_time COMMA12.0 TOTAL_km COMMA12.0;
RUN;
PROC PRINT DATA=m_actual Canda noobs;
    VAR total_time total_distance;
RUN;
ODS HTML CLOSE;

/* Best Drive Time */

ODS HTML STYLE=MINIMAL;
TITLE "Total Drive Time Best";
PROC MEANS DATA=best SUM NOPRINT;
    VAR TOTAL_MINUTES TOTAL_km;
    OUTPUT OUT=M_BEST SUM=TOTAL_TIME TOTAL_DISTANCE;
    FORMAT TOTAL_time COMMA12.0 TOTAL_km COMMA12.0;
RUN;

PROC PRINT DATA=m_best noobs;
    VAR total_time total_distance;
    RUN;
ODS HTML CLOSE;

/*****Calculate total drive time*****/

PROC SORT DATA = actual; BY coc;RUN;

TITLE "Total Drive Time -- Actual";

PROC MEANS DATA=actual SUM N NOPRINT;
    BY coc;
    VAR TOTAL_MINUTES TOTAL_km;
    OUTPUT OUT=M_ACTUAL SUM=TOTAL_TIME TOTAL_DISTANCE ;
    FORMAT TOTAL_minutes COMMA12.0 TOTAL_km COMMA12.0;
RUN;

```

/* Create a few variables of interest for printing */

```
DATA m_actual; SET m_actual;
  avg_drive_time = total_time / _freq_;
  avg_drive_distance = total_distance / _freq_;
  LABEL avg_drive_distance="Avg. Driving Distance (km)";
  LABEL avg_drive_time="Avg. Driving Time (min.)";
RUN;
ODS HTML STYLE=MINIMAL;

PROC PRINT DATA=m_actual NOOBS LABEL;
  VAR coc _freq_ total_time avg_drive_time total_distance
  avg_drive_distance;
  FORMAT avg_drive_distance comma12.0 avg_drive_time comma12.0;
  LABEL _freq_ = "Separations";
  LABEL coc= "Comm. of Care";
RUN;
ODS HTML CLOSE;
/*****
Best drive times --- everyone to closest hospital
sort of a gold standard
*****/

PROC SORT DATA = best; BY coc; RUN;
ODS HTML STYLE=MINIMAL;
TITLE "Total Drive Time Best";
PROC MEANS DATA=best N SUM NOPRINT;
  BY coc;
  VAR TOTAL_MINUTES TOTAL_km;
  OUTPUT OUT=M_BEST n =separations SUM=TOTAL_TIME TOTAL_DISTANCE;
  FORMAT TOTAL_time COMMA12.0 TOTAL_km COMMA12.0;
RUN;

DATA m_best; SET m_best;
  avg_drive_time = total_time / _freq_;
  avg_drive_distance = total_distance / _freq_;
  LABEL avg_drive_distance="Avg. Driving Distance (km)";
  LABEL avg_drive_time="Avg. Driving Time (min.)";
RUN;

ODS HTML STYLE=MINIMAL;
PROC PRINT DATA = m_best NOOBS LABEL;
  VAR coc _freq_ total_time avg_drive_time total_distance
  avg_drive_distance;
  FORMAT avg_drive_distance comma12.0 avg_drive_time comma12.0;
  LABEL _freq_ = "Separations";
  LABEL coc = "Comm. of Care";
RUN;
ODS HTML CLOSE;
/*****
```

**How to pick a single best hospital for each community of care
- Note this is fairly conservative in that it allows for everyone in
Renfrew (or other Community of Care) to keep going to P&S surgery
as long as it is in Renfrew Co.**

Two data sets are needed:

-the first dataset rc_move identifies the visits that should be moved because the surgeries occurred outside of Renfrew County.

-- must look at each hospital individually for the new totals (doing the means if all moved will give different results because the stay" data can be very different"

The second data set are the people who had p&s surgery in Renfrew County, these patients do not have to move

Next the data are joined and summarized

The objectids are output for ArcView to be used as selection criteria,
*****/

```
PROC SQL;
    CREATE TABLE RC_MOVE AS
        SELECT * FROM TWO
            WHERE C2="RENFREW VICTORIA HOSPITAL" AND
                ORIGINID IN
                    /*SUB QUERRY TO PULL CORRECT ROWS*/
                    SELECT ORIGINID FROM TWO
                        WHERE coc='Renfrew County'
                            AND hospital NOT IN (
                                "ARNPRIOR & DISTRICT
                                MEMORIAL HOSP.(THE)",
                                "PEMBROKE REGIONAL HOSPITAL
                                INC."
                                "RENFREW VICTORIA HOSPITAL")
                            AND loc IN ('P', 'S' ) and
                                ACTUAL=1
;

CREATE TABLE RC_STAY AS SELECT * FROM TWO
WHERE coc= "Renfrew County" and hospital
    IN (
        "ARNPRIOR & DISTRICT MEMORIAL HOSP.(THE)",
        "PEMBROKE REGIONAL HOSPITAL INC."
        "RENFREW VICTORIA HOSPITAL") and loc in ('P', 'S')
and actual =1;

PROC SQL;
CREATE TABLE BOTH AS
    SELECT *
    FROM RC_STAY
    OUTER UNION CORR /* A SIMPLE "SET" IN A DATA STEP*/
    SELECT *
    FROM RC_MOVE;
```

```
/* What is the new total drives and distances for RC with just  
changing to Renfrew Victoria Hospital*/
```

```
ODS HTML STYLE=SEASIDE;  
Title "Renfrew County Fixed for Repatriating General Surgery";  
Title2 "to Renfrew Victoria Hospital";  
SELECT  
    COUNT(*) AS CASES,  
    SUM(TOTAL_MINUTES) AS T_MIN FORMAT COMMA12.0,  
    SUM(TOTAL_METERS) / 1000 AS T_DISTANCE FORMAT COMMA12.0  
FROM both  
;  
ODS HTML CLOSE;
```

```
/** pick out the object ids for plotting */
```

```
DATA _NULL_ ;  
    SET RC_MOVE;  
    PUT OBJECTID ', ' ;  
RUN;
```

```
DATA _NULL_ ;  
    SET STAY  
    PUT objectid', ' ;  
RUN;
```

```
DATA _NULL_ ;  
    SET TWO;  
    WHERE coc NE 'Renfrew County'  
    AND actual = 1;  
    PUT objectid', ' ;  
RUN;
```

```
/******SCENARIO TESTING *****/
```

What would happen if TOH's primary and secondary case load were moved to the next closest facility?

Need two data sets. First data set finds all the surgeries for Ottawa Centre community of care that occur within the Community of Care. These are then reranked and selected based on the closest facility outside of Ottawa Center.

The second data set finds all the Ottawa Centre community patients that went to a hospital outside of Ottawa Centre. These people are not moved

```
*****/
```

```
DATA OC_MOVE;  
    SET two;  
    IF hospital IN ('OTTAWA HOSPITAL ( THE )-CIVIC SITE',  
                   'OTTAWA HOSPITAL ( THE )-GENERAL SITE') AND  
    loc NOT IN ('T', 'Q') and coc='Ottawa Centre';  
RUN;
```

```

DATA OC_MOVE2; SET OC_MOVE;
    IF c2 IN ('OTTAWA HOSPITAL ( THE )-CIVIC SITE',
             'OTTAWA HOSPITAL ( THE )-GENERAL SITE') THEN DELETE;
RUN;

PROC SORT DATA=OC_MOVE2;
    BY originid total_minutes; RUN;

DATA OC_MOVE3;
    SET OC_MOVE2;
    BY originid total_minutes;
RETAIN NEW_RANK;
    IF FIRST.originid THEN DO;
        new_rank = 0;
    END;
new_rank= new_rank + 1;
    IF new_rank= 1 THEN OUTPUT;
RUN;

/* For the Ottawa centre CoC surgeries that go to a hospital outside of
Ottawa Centre.*/

DATA OC_ELSEWHERE;
SET two;
IF hospital not IN ('OTTAWA HOSPITAL ( THE )-CIVIC SITE',
                   'OTTAWA HOSPITAL ( THE )-GENERAL SITE') AND loc NOT IN ('T', 'Q')
   and coc='Ottawa Centre' and actual = 1;
RUN;

/*JOIN THE THREE TABLES TOGETHER */
PROC SQL;
    CREATE TABLE OC_ALL AS
    SELECT *
        FROM OC_MOVE3
        OUTER UNION CORR
            select *
                FROM OC_ELSEWHERE
;

ODS HTML STYLE=SEASIDE;
Title "Ottawa Centre moving all Primary and Secondary Surgery";
Title2 "to closest hospital outside Ottawa Centre";
SELECT
    COUNT(*) AS CASES,
    SUM(TOTAL_MINUTES) AS T_MIN FORMAT COMMA12.0,
    SUM(TOTAL_METERS) / 1000 AS T_DISTANCE FORMAT COMMA12.0
    FROM oc_ALL
;
ODS HTML CLOSE;

/*****
The create table RC_move is the same logic as used for picking the
"best" site, but the conditional where statements have been removed

```

because they no longer apply, i.e., there are no "actual" drives in this data set and the Primary and Secondary case type has already been accounted for in the data x and data y data steps.

```
*****/
DATA x;
  SET two;
  IF hospital IN ('OTTAWA HOSPITAL ( THE )-CIVIC SITE',
    'OTTAWA HOSPITAL ( THE )-GENERAL SITE') AND LOC NOT IN ('T',
                                                                'Q');
RUN;
```

```
DATA y; SET x;
  IF c2 IN ('OTTAWA HOSPITAL ( THE )-CIVIC SITE',
    'OTTAWA HOSPITAL ( THE )-GENERAL SITE') THEN DELETE;
RUN;
```

```
ODS HTML STYLE=SEASIDE;
PROC SQL;
  CREATE TABLE RC_MOVE AS
    SELECT * FROM y
      WHERE C2="RENFREW VICTORIA HOSPITAL" AND
        ORIGINID IN
/*SUB QUERRY TO PULL CORRECT ROWS*/
    SELECT ORIGINID FROM y
      where coc='Renfrew County'
        AND hospital NOT IN (
          "ARNPRIOR & DISTRICT MEMORIAL
HOSP.(THE)",
          "PEMBROKE REGIONAL HOSPITAL INC."
          "RENFREW VICTORIA HOSPITAL")
;

```

```
CREATE TABLE RC_STAY AS SELECT * FROM y
  WHERE coc= "Renfrew County" and hospital
  IN (
    "ARNPRIOR & DISTRICT MEMORIAL HOSP.(THE)",
    "PEMBROKE REGIONAL HOSPITAL INC."
    "RENFREW VICTORIA HOSPITAL") ;
```

```
PROC SQL;
  CREATE TABLE both AS
  SELECT *
    FROM RC_STAY
    OUTER UNION CORR
      select *
        from RC_MOVE
;

```

```
/* Finally, what is the new total drives and distances for RC with
just changing to
  Renfrew hospital*/
```

```
ODS HTML STYLE=SEASIDE;
Title "Renfrew County Fixed for Repatriating General Surgery";
Title2 "to Renfrew Victoria Hospital";
```

```
SELECT
    COUNT(*) AS CASES,
    SUM(TOTAL_MINUTES) AS T_MIN FORMAT COMMA12.0,
    SUM(TOTAL_METERS) / 1000 AS T_DISTANCE FORMAT COMMA12.0
FROM both
;
```

```
ODS HTML CLOSE;
```

/*Repeat for Eastern Counties etc. */

Appendix G. Geoprocessing Model Details (parameter values)

Variables

GIS Dataset

Data Type:Table View

Value:OD Cost matrix\Lines

New Folder

Data Type:Folder

Value:C:\YOUR_PATH\YOUR_FILES\New Folder

Ont. Road Network

Data Type:Network Dataset Layer

Value:ON_ORNStreets_ND

OD Cost Matrix

Data Type:Network Analyst Layer

Value:OD Cost matrix

Geocoded Patients

Data Type:Table View

Value:C:\YOUR_PATH\YOUR_FILES\Bruce file geodatabase.gdb\gen_surg_geocoded

OD Cost Matrix 1

Data Type:Network Analyst Layer

Value:OD Cost matrix

Valid Champlain Hospitals

Data Type:Table View

Value:C:\YOUR_PATH\YOUR_FILES\Bruce file geodatabase.gdb\ch_hospitals

OD Cost Matrix 2

Data Type:Network Analyst Layer

Value:OD Cost matrix

Network Analyst Layers

Data Type:Network Analyst Layer

Value:OD Cost matrix

SAS Data

Data Type:Folder

Value:C:\YOUR_PATH\YOUR_FILES\New Folder

Processes

Tool Name:Make OD Cost Matrix Layer

Tool Source:C:\Program Files\ArcGIS\ArcToolbox\Toolboxes\Network Analyst Tools.tbx\Analysis\MakeODCostMatrixLayer

Parameters:

Name	Direction	Type	Data Type	Value
Input analysis network	Input	Required	Network Dataset Layer	ON_ORNStreets_ND
Output layer name	Input	Required	String	OD Cost matrix
Impedance attribute	Input	Required	String	Minutes
Default cutoff	Input	Optional	Double	
Default number of destinations to find	Input	Optional	Long Multiple Value	
Accumulators	Input	Optional	String	Minutes;Meters
U-turn policy	Input	Optional	String	ALLOW_UTURNS
Restrictions	Input	Optional	Multiple Value	
Use hierarchy in analysis	Input	Optional	Boolean	FALSE
Hierarchy rank settings	Input	Optional	Network Analyst Hierarchy Settings	
Output path shape	Input	Optional	String	STRAIGHT_LINES
Network Analyst Layer	Output	Derived	Network Analyst Layer	OD Cost matrix

Tool Name:Add Locations

Tool Source:C:\Program Files\ArcGIS\ArcToolbox\Toolboxes\Network Analyst Tools.tbx\Analysis\AddLocations

Parameters:

Name	Direction	Type	Data Type	Value
Input network analysis layer	Input	Required	Network Analyst Layer	OD Cost matrix
Sub layer	Input	Required	String	Origins

Input locations	Input	Required	Table View Network Analyst Class	C:\YOUR_PATH\YOUR_FI LES\ Bruce file geodatabase.gdb\ gen_surg_geocoded
Field mappings	Input	Required	FieldMap	CurbApproach # 0
Search tolerance	Input	Required	Linear unit	5000 Meters
Sort field	Input	Optional	Field	
Search criteria	Input	Optional	Value Table	Ont_roads SHAPE; ON_ORNStreets _ND_Junctions NONE
Find closest among all classes	Input	Optional	Boolean	TRUE
Append to existing locations	Input	Optional	Boolean	TRUE
Snap to Network	Input	Optional	Boolean	FALSE
Snap Offset	Input	Optional	Linear unit Network Analyst Layer	5 Meters
Network Analyst Layer	Output	Derived	Layer	OD Cost matrix

Messages:

Tool Name:Add
Locations

Tool Source:C:\Program Files\ArcGIS\ArcToolbox\Toolboxes\Network Analyst
Tools.tbx\Analysis\AddLocations

Parameters:

Name	Direction	Type	Data Type	Value
Input network analysis layer	Input	Required	Network Analyst Layer	OD Cost matrix
Sub layer	Input	Required	String	Destinations C:\YOUR_PATH\YOUR_FI LES \Bruce file geodatabase.gdb \ch_hospitals
Input locations	Input	Required	Table View Network Analyst Class	Name Name #;CurbApproach # 0

FieldMap

Search tolerance	Input	Required	Linear unit	5000 Meters
Sort field	Input	Optional	Field	Ont_roads SHAPE;ON_ORNStreets_ ND
Search criteria	Input	Optional	Value Table	_Junctions NONE
Find closest among all classes	Input	Optional	Boolean	TRUE
Append to existing locations	Input	Optional	Boolean	TRUE
Snap to Network	Input	Optional	Boolean	FALSE
Snap Offset	Input	Optional	Linear unit	5 Meters
Network Analyst Layer	Output	Derived	Network Analyst Layer	OD Cost matrix

Messages:

Tool Name:Solve

Tool Source:C:\Program Files\ArcGIS\...Network Analyst Tools.tbx\Analysis\Solve

Parameters:

Name	Direction	Type	Data Type	Value
Input network analysis layer	Input	Required	Network Analyst Layer	OD Cost matrix
Ignore invalid locations	Input	Optional	Boolean	TRUE
Network Analyst Layer	Output	Derived	Network Analyst Layer	OD Cost matrix

Messages:

Tool Name:Table to dBASE
(multiple)

Tool Source:C:\Program Files\...\To dBASE\TableToDBASE