A GIS Approach for Improving Transportation and Mobility in Iqaluit, Nunavut Territory

by

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B.A., University of British Columbia, 2003

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Supervisory Committee

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Abstract

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Planning for transportation within northern Canadian communities presents unique challenges, but new research tools offer opportunities for testing potentially innovative solutions that might help improve mobility within these communities. In particular, problem solving has been enriched in recent years by using the spatial modeling methods offered by Geographical Information Systems (GIS). This thesis first reviews various GIS methods before applying one method – the 'Route Utility Theory' –to a newly-developed set of metrics for determining the cost of alternate modes of intra-community transportation. This set of metrics is applied to a data set that represents the trips or journeys made by non-car users in Iqaluit, the capital city of Nunavut Territory. GIS data on roads, walking trails, land contours, and public and residential neighbourhoods are analyzed. The results facilitate comparisons between road options and trail options for improving the movement of people within Iqaluit. Five bus routes were then custom designed and compared using the study's metrics. The study found that increasing bus and trail options within Iqaluit would provide more efficient options for non-car users. It is argued that the study's metrics can be adapted for application in other northern communities, and possibly in other isolated and rural communities in different world situations.

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All photos taken by Robert Copithorne.

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Chapter 1

INTRODUCTION

Iqaluit's Planning Background

Remote communities around the world have unique requirements for urban and regional planning. Canada's northern communities are indeed remote, with relatively small populations. The population of Canada's Nunavut territory is reported as less than 32,000.[1] Communities in the Yukon, Northwest Territories and Nunavut are not only geographically distant from Canada's large urban centres, but are physically remote from each other (Figure 1.1). Each community is its own isolated world, often with no external highway network or seabound freight service, only communication by air. Developing a fully fledged community level planning office is not possible in many remote communities, due to staffing and budgetary issues. As a result, community planning ventures take place on federal, territorial and municipal levels, with Indian and Northern Affairs Canada and the Government of Nunavut having a strong presence in regional planning. One goal of all three levels of planning is to facilitate easy and efficient movement of people within and between the communities, within the limits of the physical environment. In communities large enough to support a municipal planning department, community level planning plays a crucial part in the running of individual communities, as separate entities from the territory as a whole. Iqaluit[2], Nunavut's capital and largest community, supports a planning department. The City of Iqaluit's urban planning measures have been extensive and innovative, while subject to budgetary and logistical constraints. As a community large enough (6,000 to 7, 000 people) to require and implement systematic planning measures, Iqaluit is an ideal research site for Northern planning initiatives and studies. This study will integrate northern studies with the fields of transportation planning and Geographical Information Systems (GIS), with Iqaluit serving as the study locale.

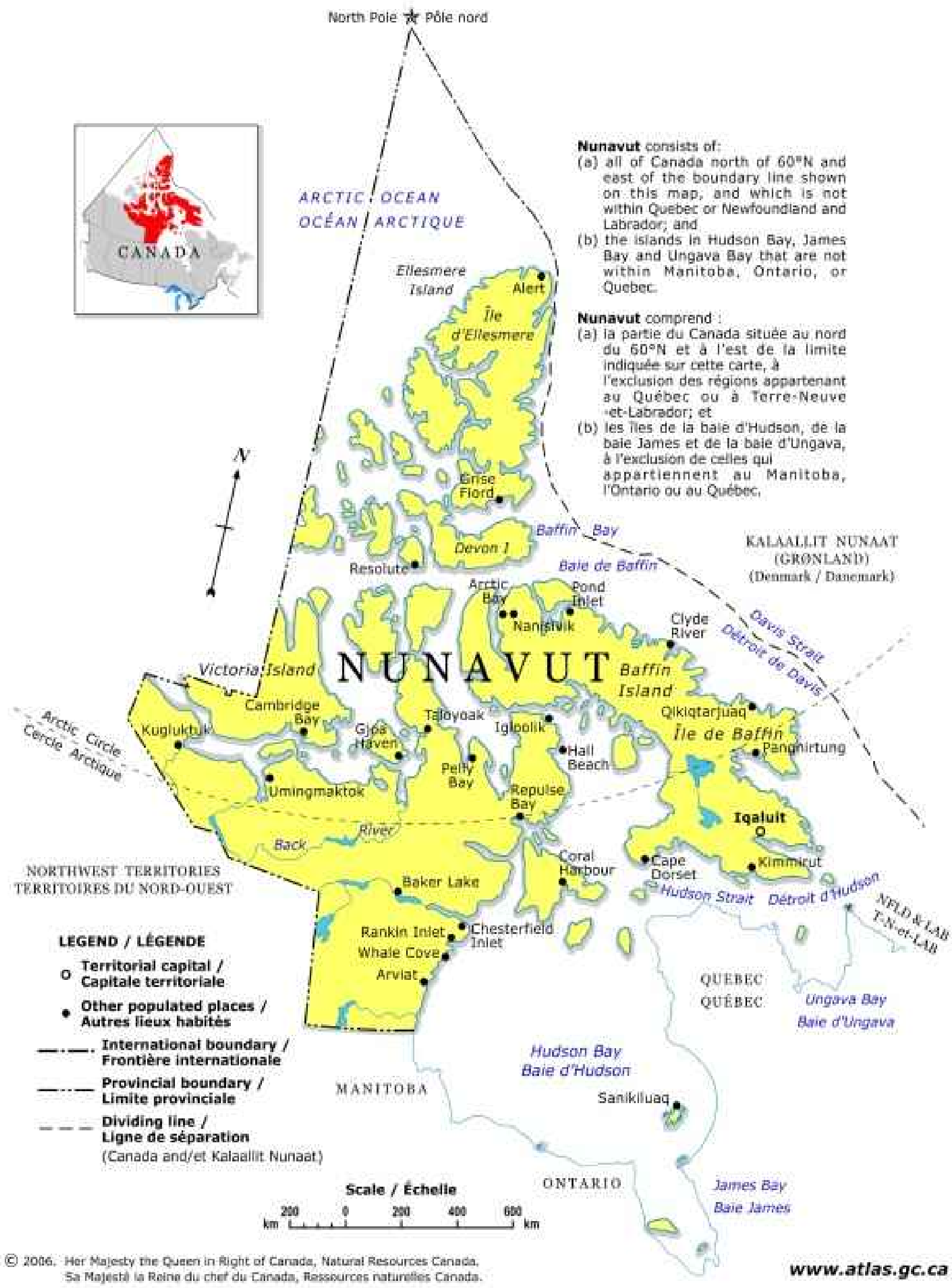


Figure 1.1 Map of Nunavut Territory, showing location of Iqaluit.

In this introductory section, some of the geographical and urban landscape features of Iqaluit are introduced. As well, background about the planning environment of the City of Iqaluit will be discussed[3] to give the reader a sense of the environment that will be the focus of the study[4], to bear in mind while reading the literature review section. The introduction is not a comprehensive overview of the study area. A more detailed description of specific places in Iqaluit, as elements of the study, can be found in the data section that follows the literature review.[5]

Iqaluit is located in the southern region of Baffin Island, the largest and furthest east island in Canada's Arctic (Figure 1.1). Positioned on Koojesse Inlet, at the western end of Baffin Island's Frobisher Bay, Iqaluit's locale bears the brunt of ocean winds and winds from overland to the north. This fact is unavoidable to a foot traveler in the city. For a pedestrian or driver, the physical environment, with its rough topography and striking landforms, takes on larger significance than might be the case in southern or flat environments. Iqaluit is a small city, but it is not spatially compact. Neighbourhoods are arrayed on ridges to the north and east of the town centre, and the centre of town itself is dominated by both hill features and the presence of the ever changing ocean at its southern edge. (Figure 1.4).

Figure 1.2 Sign featuring Inuktitut syllabics.

Figure 1.3 Iqaluit welcome sign. English, French, Inuktitut written in syllabics, and Inuktitut written in English script.

Figure 1.4. Iqaluit viewed from the sea ice on Koojesse Inlet, looking north into the town.

The Iqaluit airport was the first feature to be developed, in the 1940s, as part of an American military base, and the town site was chosen because of its proximity to this ideal airstrip area. Inuit people did not traditionally live in the precise modern location of Iqaluit, but lived seasonally in the relatively protected area that is now the suburb of Apex[6]. The Distant Early Warning Line or DEW line, a system of radar stations, was built during the cold war, and Iqaluit became a base of operations for construction, with an increase in both Inuit and non-Inuit populations. Due to this early influx of settlers, Iqaluit has a mixed population of Inuit people that includes Inuit from different communities throughout the Arctic.[7] "Iqaluit" replaced "Frobisher Bay" as the official name of the community in 1987. In 1999, the territory of Nunavut was created, with Iqaluit as its capital. Iqaluit gained official city status in 2001.[8] It is a centre for federal, territorial and regional level government, with branches of Parks Canada and Indian and Northern Affairs Canada (INAC). It houses the Government of Nunavut's Legislature Building. The Inuit land claims organization, Inuit Heritage Trust Incorporated, and other non-governmental organizations are based in Iqaluit. The population was estimated in 2006 at 6,184 and is anticipated to be 10, 000 by the year 2022 (SLB *et al.*, 2004). The population of Iqaluit is approximately 60% Inuit and 40% non-Inuit.

Figure 1.5 Left: Historic Hudson's Bay Company buildings in Apex. Right: Historic boat at Iqaluit's boatyard.

Figure 1.6 Government of Canada building.

The current planning initiatives in Iqaluit aim to enhance coherence and accessibility in the urban landscape, as well as the environmental sustainability of the city. Land suitable for building is scarce, so there is great impetus to densify the city core and make better use of currently available land. *The Core Area and Capital District Redevelopment Plan*[9] (hereafter COCRDP) (FoTenn *et al.*, 2004) outlines detailed plans for improving housing and transportation in the central region of Iqaluit. It also establishes context for my study. The central region is considered to be the area in the environs of the Ring Road, including the low lying areas in the Southeastern part of town that follow a grid road structure and allow for high density use. This area is a mixture of residential, commercial and governmental uses and is the oldest area of Iqaluit. At the heart of the COCDRP are measures to create attractive and usable public spaces, and measures to restrict vehicle use of public spaces while increasing pedestrian accessibility and encoding a set of courtesy rules for snow machine drivers[10]. It is reported in the COCDRP that the 2001 census found 51% of commuters used a car or truck, while 34% walked and 14% used a taxi, snowmobile or ATV[11] (FoTenn *et al.*, 8). The separation of cars and pedestrians has been more problematic in Iqaluit than in most cities, as unbuilt areas have been, in the past, largely indistinguishable from roads. Drivers of cars are accustomed to parking in any area they can access, and the resulting climate poses safety risks for pedestrians. The COCDRP attempts to remedy this by creating barriers between designated car and pedestrian areas (FoTenn *et al.*, 87-98).

Figure 1.7 Wooden barriers between vehicle, snow machine and pedestrian areas.

As of my visit to Iqaluit in 2008, when I did field work for this thesis, a series of posts along the lower side of the city's central Ring Road separates the walking path alongside the road from the road itself (Figure 1.7). The walking path along the lower half of the Ring Road is wide and often has a large number of pedestrian travelers making use of it. However, two areas along this trail, located in front of the major shopping amenities, Arctic Ventures and North Mart[12], still experience a rather chaotic mingling of pedestrians and vehicles. At Arctic Ventures, cars park nose-forward in a row in front of the store, with pedestrians filtering through in unused spots and at the backs and fronts of the row of vehicles. As of 2008, vehicles also parked in the blank area across the road from Arctic Ventures, which is not zoned for parking but has no other current use. In front of North Mart, there is store parking, with pedestrians filtering through the parked and parking vehicles from the road to the store.[13] While Iqaluit's subdivisions fan outwards from the Core Area in a low density pattern, the Core Area and its roadways and pathways experience congestion and crowding. The public spaces in place at the time of my 2008 field work created areas that were not accessible to vehicles because they were being blocked by rock features and decorative rock sculptures. These public spaces include Iqaluit Square and Nunavut Square, designed to commemorate Iqaluit and Nunavut Territory respectively (FoTenn *et al.*, 100). Medium density housing projects were, in 2008, in the process of being built to replace low density housing in the central area of Iqaluit.

Figure 1.8 Wooden barriers on the Ring Road to define vehicle and pedestrian space.

Figure 1.9 Stone sculptures decorate and define space in downtown Iqaluit. They also provide symbols of Inuit culture and community in the urban environment.

The COCDRP also supports the creation and maintenance of several trail amenities, designed to improve the pedestrian realm. These trails were in evidence in 2008, and provided an attractive character for much of Iqaluit. Parking has also been formalized in accordance with the COCDRP. In 2008, cars appeared to park mainly in designated areas. The redevelopment plan is largely concerned with defining the space in the central region of Iqaluit, by designating pedestrian, snowmobile and car areas. As

Iqaluit develops from a small northern outpost to a major government and cultural centre for the eastern Arctic, the land use patterns must change to reflect the population pressures and vehicle pressures. Legally and illegally-placed sea containers, shacks and building additions are evaluated on a case by case basis by the City of Iqaluit staff, in an attempt to create the best possible use of urban space (Figure 1.10). There is a trend toward intensifying city space, and to increasing the efficiency and safety of the urban transportation network. Major road paving was being undertaken in 2008, to improve the air quality by dampening dust from gravel roads and to improve the definition of road space.[14]


Figure 1.10 Examples of Land-use in Iqaluit. Left: Community Greenhouse. Right: Beach shacks.

A feasibility study for the Plateau Subdivision, the *Sustainable Arctic Subdivision Feasibility Study*[15], was prepared in 2004 (SLB *et al.*, 2004). According to the Feasibility Study, Iqaluit's rapid population growth, of 24% between 1996 and 2001, has created great stresses on housing and other amenities. The Feasibility Study reports that over 50% of Iqaluit's Inuit population was living in overcrowded housing at the time of the study. The Feasibility Study cites Iqaluit's 2002 general plan, which called for 1700 additional units of housing to be created in Iqaluit by 2022, to meet the pressure of the growing population (SLB *et al.*, 1). The Plateau Subdivision, as planned by the Feasibility Study, is designed to be a model sustainable subdivision for northern cities. The measures for sustainability include walking and snowmobile trails, as well as energy efficiency standards for houses such as passive solar design, insulated windows and water conserving devices. The sustainability recommendations also cite allowances for medium density housing and for clustered single family dwellings, which facilitate simpler utility servicing (SLB *et al.*, 25). As Iqaluit's newest subdivision, the Plateau can be seen as a model for the future development of residential areas in the city. The Feasibility Study points to changing land use patterns in Iqaluit, which focus on environmentally friendly building, cohesive neighbourhood planning, and allowances for walking and transit accessibility.

Figure 1.11 Example of houses with passive solar design. Large windows face to the south, and south-facing rooms have high ceilings. North faces have small windows and lower ceilings. The development pictured here is in Lower Iqaluit.

The research in this study is in keeping with the goals of the COCDRP and the Feasibility Study. It supports the use of land by non-car travelers, and attempts to articulate the accessibility of the urban environment using quantitative methods. Like the studies already mentioned, this thesis will be concerned with efficiency and coherence of the urban environment. It will provide a further case study for the development of transportation in an urban environment by attempting to estimate factors in the efficiency and coherence of the existing urban environment and of a set of proposed additions to the environment. The study aims to be relevant to future planning initiatives in Iqaluit, by articulating aspects of the physical environment in great detail and attempting to draw out best practices concerning the physical environment. The goals of this study will be set out in greater depth following the literature review, which sets up the research background of the study.

The target audience for this report is decision makers at all levels of government, from municipal to territorial and federal. While municipal personnel are responsible for the implementation of planning initiatives in Iqaluit, financial and other support for transit reform may be required from outside of the community. Northern cities have high budgetary needs, so it is in the best interests of federal decision makers to facilitate efficient northern cities. If bus and trail amenities in the North are improved, costs for shipping fuel and vehicles to northern Canada could be decreased. Specifics of the financial requirements from various transit modes in the north are outside of the realm of this study, however, efficient and functional northern communities could lower costs to the rest of Canada and improve life throughout the nation. At the territorial level, improvements to the capital, Iqaluit, offer a guideline for improving the other communities in Nunavut. Planning in the Government of Nunavut takes place at a regional level, with planning staff frequently travelling around the territory, and implementing ideas successful in one community in other communities where appropriate and feasible. Indian and Northern Affairs Canada also has a strong presence in Iqaluit, and would be an ideal audience for this report, as the creation of strong northern communities, with greater equality and independence, is part of their mandate.

The study will provide further backing for the City of Iqaluit in any attempts to improve the transit and trail environment in Iqaluit. With its strong focus on fostering equality between the various neighbourhoods and groups in Iqaluit, the study will serve as an additional source of information regarding community development. Though the study has a strong technical component, the focus on improving the lives on non-drivers makes the study a pro-community study. In Iqaluit, there is noticable inequality in terms of car use, with most pedestrians being Inuit people. A plan that enhances the ability of people who do not own cars could offer a chance to foster more equity in the community.

The subjective nature of the decisions that I made, in terms of choosing physical elements in the Iqaluit landscape to shape the GIS study, is based partly on my personal experience of walking in Iqaluit. This first-hand experience enhances my ability to make decisions regarding the available GIS data. That being said, I've attempted to be transparent throughout the study as to the subjective nature of many of the decisions. My work term at the City of Iqaluit, performing tasks to assist the planning department, gave me a sense of the goals of the local planning staff in terms of community development, and the improvement of life for those living in the community. The decisions that I made in the development of the study were made by me individually, while bearing in mind what I had observed while working in the City of Iqaluit.

It should be noted that Iqaluit is not completely without public transit. School buses operate and serve the local elementary, middle and secondary schools. For this reason, and for the schools' proximity to other destination points that were chosen, no schools have been chosen as focal points in the study.

The choice of Quantum GIS, a freeware GIS software application, reflects my support of open software initiatives, in their pursuit of an accessible technical realm, regardless of users' economic status. While proprietary software such as ESRI's ArcGIS system offer the advantage of ready-made applications for a variety of study types, freeware GIS software offers the opportunity to share ideas with an international community, and to produce GIS solutions at a very low cost.

Chapter One notes

1 http://en.wikipedia.org/wiki/Nunavut
2 Note on pronunciation: Iqaluit is pronounced like 'Ee-Ha-luit', with a sound that is between a 'k' and an 'h'. There is no 'u' following the 'q' in Iqaluit, as it is not the 'q' sound used in English.
3 A detailed history of Iqaluit is available on Wikipedia at "http://en.wikipedia.org/wiki/Iqaluit,_Nunavut".

4 Unless used in the context of describing another study in the literature review, the term 'the study' or 'the project' refers to the study that is the subject of this research project.
5 The unorthodox structuring of the study area information is to give the reader enough information to begin formulating an image of Iqaluit, without introducing terms and concepts that are best presented in the literature review section. Once the reader is familiar with the background literature, the landscape of Iqaluit is returned to in much greater detail as an area of geographical study.
6 Local information, unsubstantiated.
7 While working in Iqaluit, people often spoke of their migration experiences. One woman who had moved to Iqaluit from elsewhere in Nunavut earlier in her life said that it had been interesting to watch the changes in the community over the decades.
8 Historical information is taken from the wikipedia entry 'Iqaluit, Nunavut'.
9 The 'Core Area and Capital District Redevelopment Plan' will be referred to as the 'COCDRP' through the next section.
10 Snow machines are commonly referred to as snowmobiles or ski-doos.
11 All-terrain vehicle. A four wheeled vehicle with a single passenger seat and thick tires that can travel though snow and mud and over rocky terrain.
12 These two stores are described in greater detail in the Study Area section.
13 Personal Observation, 2008.
14 Observation based on personal experience at the City of Iqaluit.
15 Referred to as the 'Feasibility Study' throughout the text.

Chapter 2

REVIEW OF LITERATURE

Geography has been enriched in recent years by the use of Geographical Information Systems, or GIS. Transportation geography, which is concerned with the movement of people across an environment, has been enriched by GIS-based methods of spatial analysis. Both quantitative and qualitative studies can be undertaken using GIS methods. Some of these methods described in this review have direct connections to spatial science methods, while others are based more on conventional statistics or in transportation engineering and systems studies. GIS borders on many other disciplines, as does geography itself, and in drawing from many fields, uncovers spatial patterns and processes in the real world. As a foundation for this study, a review is made of some transportation geography studies that are based on GIS. Of these spatial methods, an adapted version of the 'Random Utility Theory' (Bovy and Stern, 1990) will be applied to the idea of spatial travel cost factors, and will serve as the basis of the main study. While the subject of the Iqaluit study is not based directly on transport users' choices, it will make use of the random utility concept as a means of estimating possible travel cost factors.

Studies of transportation dynamics using spatial analysis methods have been based on guiding principles such as the reduction of trip times, the optimization of the transport network, and the improvement of measuring capabilities for travel cost. In developing multiple and subtle forms of measurement, modern spatial analysis of transportation has moved away from mechanistic views of a transport network toward a more realistic interaction between the individual trip and the overall network. While in a very large congested traffic network, problems of traffic flow volume and capacity must necessarily be considered, there must also be a value placed on the improvement of the journey for individuals within the network, and of the need to make options that are desirable to users. With the great versatility of modern spatial analysis tools, a balanced view of transportation concerns has become more feasible.

However, the basic problem remains the same: “How best to organize the routing systems by which people move about their environment?” But the focus can vary greatly in the ways that available data can be interpreted. This review will not be an exhaustive summary of spatial methods being applied to transportation, but will highlight some innovative methods that are being developed to understand and enhance the geography of transportation and transportation cost. The methods applied to the study at hand are much simpler than many of the spatial science methods being developed, but a discussion of these methods serves as a context for the methods that have been chosen for the Iqaluit network case.

The methods used by transportation researchers can be divided into two broad categories: Those that operate at the level of the transport network itself and consider individuals moving around the network as variable elements of the network; and those that take the individual traveler or household as the basic unit and develop network concepts based on these users. Both the network level studies and individual-based studies seek to optimize travel. They do so by determining the factors that should be of highest priority in decision making processes about the travel network. Put in terms of the GIS representations of networks as vectors and rasters, the network level studies tend to focus on the path vectors connecting all points on the network, or on the network as a raster grid based on proximity to routes. The household or individual based studies place focus on the origin point in the network, building neighbourhood structures around these points, either as vector polygons or raster value grids emanating from the points.

In presenting a multi-faceted collection of background reading, the aim here has been to convey the variety of angles, methods and techniques available for observing the problem of transportation networks and cost minimization. Threads from these studies will be used in the Iqaluit research, in an attempt to provide an enriched view of the existing and potential transportation network of the area. The next sections will describe in depth the methods used in the study, and the physical environment of Iqaluit as it appears to a traveler. The application of GIS methods to this northern community should take into account factors that are quite different from those in many of the available studies. Few environments on earth are like Canada's eastern arctic, and as a closed system with no roads in or out, Iqaluit stands as a unique and quickly developing area of research potential.

The goal of this study is to develop a technical framework for evaluating costs in the transit and walking use environment of Iqaluit. Specific objectives are fourfold. 1) To develop software plugins that enable analysis of the existing data for specific measurements. These plugins provide a technical framework that can be carried over into other research on northern communities and community transportation. 2) To develop metrics that enable the data created by the plugins to be distilled into cost attribute estimates. The metrics, in addition to the plugins, or separately from the plugins, could be adapted to further research in any of the areas of northern community planning and transportation planning. The metrics are based on physical attributes of the landscape, and so are particularly geared towards remote rural environments, where the natural landscape exerts a strong influence over transportation issues. 3) To develop a formula for estimating travel cost that integrates the metrics created in the second objective. This formula will add to the currently existing formulas for estimating transportation costs, and will, in conjunction with the metrics and plugins or separately, present another option for future research into transportation planning. 4) To evaluate the results created by the cost estimation formula, as well as by their constituent metrics independently. Evaluating the walking and transportation options in the study in terms of the the formula will provide conclusions as to the potential gains for transit users and walkers in Iqaluit with each transit and trail option. This will potentially provide guidance for further transportation planning initiatives in Iqaluit.

At the most theoretical level, a transportation geography problem can be seen as a set of conflicting and interacting priorities, the optimal satisfaction of which is the goal of an efficient transportation system. Surapati Pramanik and Tapan Kumar Roy (2008) outline a method for using fuzzy parameters and goal-oriented programming to attain the most satisfactory solution to a transportation systems problem. Greatly simplified, the method tests values of transportation cost matrices as 'fuzzy sets' and chooses the set of parameters that satisfies the goals of the problem. Based on theories that can be applied to many different problem solving contexts, the goal-oriented programming method can be adapted to cases where the reduction of travel cost is a major priority. Choosing one parameter as the top priority parameter and ordering others in multiple ways around this parameter, a group of solutions can be made that satisfies the main priority and to a varying extent, the secondary priorities that are being valued. The values of secondary parameters can change within the interval contained by their fuzzy set, so the non-concrete element of travel cost parameters can be taken into account. The concept of fuzzy parameters, as Pramanik and Roy demonstrate, can be applied to real world decision making scenarios at the transportation network level.

Another method that functions at the entire network level was developed by Darren Scott, David Novak, Lisa Aultman-Hall and Feng Guo (2006) and is termed the 'Network Robustness Index' or 'NRI' . They approach the problem of highways and the need for adequate road links between all urban areas on a network. In conventional studies, volume and capacity have been the defining factors in deciding which highway links require upgrading and maintenance. The authors propose a new method, based on determining which links contribute most to network robustness, reliability and flexibility. These are links which increase the ability of the network to withstand disruption, such as natural disasters and traffic accidents. The related concept of 'most vital links' refers to those which cause the greatest increase in travel costs when they are disrupted. The network's points are connected by a variety of routes, so if there is a disruption in one of the most vital links, alternative routes can suffice with a minimized increase in travel cost (Scott *et al.*, 3). Thus, a network with greater connectivity between points will have a greater NRI.

At the transportation systems level and at the individual level it is relevant to take into account the geographical features present that influence use of the network. This distinction is what separates geographical studies of transportation from traditional systems approaches. Drawing meaning from the spatial context using geographical information systems creates detailed and relevant data about transportation networks. For example, Antonio Páez (2006) examined San Fransisco's BART system of urban rail transit and adapted a statistical method called a probit model for determining if proximity to BART stations has a correlation with land use changes. In the probit type model, referred to as a 'Geographically Weighted Regression Model' or GWR, surfaces are created that show the spatial distribution of variables over a local area, by using a distanced based function to determine the probable variance of the variables. In the probit model, the probability surface of a given variable that represents an outcome is seen in relation to one spatial point, with a distance decay function determining the variance of the probabilities spanning outward from this point. The possibility of land use change may be more probable in locations closer to the focal point, which may be a transportation hub. For the next focal point, the parameters will be based on each estimation point's distance from that focal point, so the formulas for each focal point will be tailored to that local scenario, rather than determined by a global 'stationary' variance structure.[1] This approach contrasts with spatial logit models, which produce a global set of coefficients for the area as a whole, based on a constant value of the variance of parameters, that does not decay over distance. Patterns that are drawn out by the locally-determined probit model may be less visible in logit model results. Páez's adaptation allows for a more nuanced exploration of the the interrelation of transportation and land use variables with spatial factors.[2]

A study of transportation systems and geographical space that relates directly to travel cost estimations by Ahmed and Miller (2007) focuses on time-space transformations. Using the Salt Lake City metropolitan area as an example, the author examine changes in the fabric of the area's travel time landscape through use of the technique of 'multi-dimensional scaling' (MDS), thus creating representations of geographical space that are both time and space dependent. These techniques model travel times as a form of spatial surface, for example a warped grid, where travel times between locations determine their position on the spatial grid.[3] By comparing the changes in these surfaces over time, Ahmed and Miller present a way to envision the temporal-spatial patterns that shape transportation networks.

Another study that integrates the idea of travel time as a cost factor was done by Julii Brainard, Andrew Lovett and Ian Bateman (1997). The study focuses on isochrones and recreational travel to Lynford Stag, a park in the United Kingdom. 'Isochrones' are surfaces based on the lengths of travel time that separate physical locations. The researchers demonstrate, by comparison to real data, that their method of predicting guest arrivals at the park is a fairly accurate method. They propose multiple forms of the method, with varying resolutions of the map grid, inclusion of different statistical variables, and use of different numbers of time range bands. They believe it is essential to compare multiple forms to enhance accuracy to real conditions. Their goal is to create indices of 'recreational potential' for woodland areas, and thus aid in the valuation of natural resources through their connection to a transportation system.

Canadian researchers Brimberg, Walker and Love (2007) present a method for estimating travel distances on a road network by finding the inherent directional bias in the road network. They use a 'weighted norm' that reflects directional bias in order to create more accurate estimates of travel distance between points. By taking into account this geographical information, a more realistic surface of travel costs can be created. The researchers illustrate that even in road networks where the directional bias is not obvious, such as in European cities, the sets of estimates of travel cost based on each angle of orientation from 0 to 90 degrees can be evaluated for goodness of fit. The set that is closest to correct is based on the angle that best fits with the directional pattern of the road network. In this case, spatial methods that take into account the geography of the network have an improved capability to estimate transportation costs.

O'Kelly and Niedzielski (2008) propose methods of improving the transportation network by bringing in the experience of the individual in the travel network, and by setting a reduction of required travel 'effort' within the network as a desirable goal. The spatial methods used allow for these reductions without assuming perfectibility in the network. This takes into account the fact that a system with humans who are located in geographical and social space will not reconfigure itself towards perfect use of the network. O'Kelly and Niedzielski focus on creating an improved situation that is still probable given the human dimensions of the network. They employ, among other variables, the concept of 'entropy', which means the level of chaotic or random behavior in the network. Systems that employ either the longest or shortest trip patterns possible have low values of entropy, and a system that is somewhere between the most and least efficient case has the highest value of entropy. O'Kelly and Niedzielski apply their model to American cities at the whole city level. They determine how much of a change in entropy (how much effort, in other words) will be required to create a three percent reduction in trip lengths. They propose implementing their model at a local level as well, with a further inclusion of social and spatial features.

As a counterpoint to these mainly network based methods for integrating GIS methods with transportation cost research, some examples of studies based at the level of the individual travel route or household are described below. The Iqaluit study is based on a large set of individual routes, to be analysed at both the individual and system wide comparison level.

Builiung and Kanaroglou (2006) list numerous studies that focus on the household sphere of activity. They further develop the idea of a household's activity location network by tabulating data from the state of Oregon, using an object-relational database, and by making use of object oriented analysis techniques to find meaningful patterns in the data. Object oriented approaches make use of interacting data 'objects' which can be categorized and explored. Viewing the daily space-time paths of the members of a household as a 'bundle', the activity space that the household occupies in its surrounding area can be isolated from the large amount of data in the object relational database. Activity spaces of varying households can then be compared for the purposes of transportation, social and economic planning for the community and the region.

Transportation hubs, as well as households, can be seen as a basic node for the development of travel cost schemes. Upchurch and his colleagues (2004) propose the creation of polygons around light rail stations - as 'service areas' - using the linked on-off network (LOON) algorithm. The service area concept is similar to the concept of activity spheres surrounding a household. However, in the case of the activity sphere, actual paths are used to estimate the sphere, while with service areas, spatial costs inherent to the physical surroundings of the stations are used to estimate probable path origin boundaries around the stations. The LOON algorithm is based on the additional travel costs from off the rail network and from on the rail network for every cell surrounding the stations. Cells that are below a given cost threshold are considered to be within the service area of the station. GIS methods such as the LOON algorithm illustrate the spatial elements of travel cost.

De Palma and Rochat (2000) explore the use of transportation networks by individuals and focus on the question of mode choice. They develop a large set of variables, primarily socioeconomic and travel habit related. They use a nested logit model to evaluate the relative utility of each mode for users, and in this way determine an individual's likelihood of choosing to drive a car or to use public transit. Users in the study rated their own mode choice's perceived benefits, and these were included in the logit model as utility factors of each mode. The decision to own one car or more was also determined by the nested logit model. Spatial characteristics such as travel time and distance were important factors in the route choice, as were factors such as comfort and accessibility. Car ownership decisions were also linked to socioeconomic factors. Unlike many other models described here, the logit model does not rely on a spatial view of the costs, routes or other factors explored. It is based more on conventional statistical methods than on geographical information systems.

An element of the physical environment that bears relevance to the Iqaluit situation is that of weather, particularly cold temperature and snow. Datla and Sharma (2008) have studied the impact of snow and cold on traffic volumes in southern Alberta. They propose a model for predicting the effects of weather on traffic volume that uses expected traffic flow volumes and incorporates variables to represent snow and cold temperatures. From their available sample, they find that on commuter roads, conditions of ice and snow create a decrease of between 6 and 15 percent in traffic volume. On recreational roads, the decrease is from 18 to 60 percent. They also found that traffic volume decreases more with progressively cold temperatures. Weekend, discretionary trips decreased the most. Traffic volume reductions in response to snow are from 7 to 17 percent for a snowfall of 10cm and up to 51 percent during a snow storm with 30cm of snow. Datla and Sharma's work demonstrates that weather effects can have a severe impact on traffic volumes.

Combining the ideas of trip reduction found in O'Kelly's and Niedzielski's work with the idea of the household sphere explored by Builiung and Kanaroglou is the focus of Daniel Rodríguez's (2004) study of bank tellers and excess commuting in Bogota, Columbia. Many of the tellers were found to work at a branch that was not the closest to their homes, even though jobs were largely interchangeable. In the traditional literature, this is considered 'excess commuting'. In fact, up to 48 percent of total commuting distance for the bank tellers was 'excess'. In this study, the voluntary and involuntary aspects of excess commuting were taken into account, and it was found that 68.2 percent of excess commuting was involuntary, due to choices beyond the control of the commuter. Rodríguez questions the validity of the excess commuting approach to transportation, as do Builiung and Kanaroglou. It is clear from these studies that the individual social context and the spatial characteristics of the transportation environment can be significant factors in the cost structure of transportation networks.

Piet Bovy and Eliahu Stern, the co-authors of *Route Choice: Wayfinding in Transport Network* (1990), a central text in the literature of transportation cost analysis, take into account the individual paths and the users of the transportation system. The authors point out the great difficulty in creating a valid structure for determining the cost factors that influence users choices. They provide a general set of categories of route cost factors, with four major groups affecting route choice. The first group comprises those related to the traveler, such as age, income and household structure. The next group considered are those related to the route itself, such as traffic, width and type of road, and angularity and slope of the road. The third group relates to the trip at hand, such as purpose, time budget, and number of travelers. The final group involves factors of circumstance, such as weather, time of day, and delays (Bovy and Stern, 68). Bovy and Stern refer to a study by Stern and Leiser (1989) that considered different trip lengths. Stern and Leiser found that travel distance and travel time were the most important variables, but that in medium length trips, the number of turns on the route was also a very significant factor. Bovy and Stern(80) refer to several other studies that have found either angularity or number of turns to be a significant factor. Angularity refers to the geometric properties of the route, whether the route is a straight line or contains many curves. As well, Bovy and Stern refer to studies that found road slope to be of significance in route choice. Similarly, Zibuschka's (1981) study of truck drivers in Austria found that road slope was of significance. On regional roads, road slope was the fifth highest rank cost factor, after travel time, route length, road width and route angularity (Bovy and Stern, 1990, 81). It is possible that slope concerns are under-represented in the literature about route costs, as many studies are conducted on areas of mainly flat roads. Based on this Austrian study, it is reasonable to assume that in road networks where slope is a factor, it is also a very important factor in trip cost valuation. While 'slope' is slightly different than the concept of 'elevation change', both refer to the difficulty added to a journey by the addition of hill features. Slope refers to the angle of the elevation change that a vehicle or person must travel on, while elevation change refers to the overall upwards and downward travel required of the user on a route.

Bovy and Stern adapt 'random utility theory' to the subject of transportation route costs and choices. The basic form of random utility theory is such that the total cost of an option is the sum of the values of the attributes that comprise an option. For example, route length, travel time, road straightness and road type could be the determining cost factors for a given road route. For a pedestrian route, these factors could be route distance, uphill walking requirement, and the number of roads that must be crossed. Random utility theory includes the concept of an unobservable random component that contributes to costs, and thus to choices (Bovy and Stern, 180). Bovy and Stern also apply random utility theory to route choice situations, where there are a number of options available to system users. They develop a variety of types of 'route choice utility models', such as a simple model that finds the minimum shortest path for each origin and destination pair. They also develop two models: a logit model and a probit model. The logit model estimates a parameter value for each factor included in the cost model, but does not take into account the overlap between routes that are being compared (189-194). The probit model takes into account overlap between available path choices and allows for variance in the random utility or error term (194-200). Bovy and Stern used simulation techniques to determine that the error term used in the probit model varies in very close correlation with travel time. The probit model works best with only three or fewer alternatives to choose from, due to the expense in calculating the overlapping and non-overlapping proportions of the path costs. These models strive to predict the proportion of travelers that will use one route over another. Bovy and Stern (199) point out the fact that route alternatives existing in a network reduce the perceived cost of making the trip from an origin point to a destination.

G. F. Newell 's *Traffic Flow on Transportation Networks* (1980) is a comprehensive text on transportation engineering. It contains detailed methods for calculating costs and traffic flows across transportation networks. Of use to the Iqaluit study is Newell's discussion of shortest path algorithms. These bear relevance to the software plugins created for use in the Iqaluit study. Newell points out the technical difficulties in implementing such algorithms, and the need for intuitive methods that approximate real world situations more accurately. Much has changed in the technological capabilities of computers since 1980, and GIS software has lent much benefit to these issues. Similiarly, Vukan Vuchic's comprehensive textbook on transportation systems, *Urban Transit* (2007), focuses extensively on modes, system capacities, and transit vehicles and facilities. Vuchic's text provides a wealth of technical information, particularly specifications needed for planning advanced transit systems. The Iqaluit study does not extend into the specific systems planning detail catalogued by Vuchic, but relies on "*Urban Transit*" as a reference book for the entire field of transportation, citing examples from multiple systems.

In another text, *Decision and Forecasting Models with Transport Applications* (1990), Alan Jessop provides in-depth statistical frameworks for transportation systems decisions. This text offers a formalistic background for decision making processes, drawing from many different transport-related examples. Jessop develops the concept of utility theory and its relevance to transport system decisions. From a given set of options, the option with the largest expected utility, based on a utility model, is the one that is chosen by the decision making entity. Incidentally, Bovy and Stern (1990) use utility theory to determine the probable decision making process of the traveler in a network, and therefore to guide policy decisions.

Jessop provides examples of the transportation researcher as decision maker. Both forms of utility theory attempt to optimize systems, whether for a large number of users or for another group with a vested interest in the transportation system. Jessop points out the usefulness of log and curvilinear functions to model the probability of arriving at conclusions that are likely in real world applications. Log functions can be used to show that the effect of a given factor has a maximum threshold over which added levels will make less of a difference to the decision, or will have no continued effect. These are often more realistic than linear representations of the interaction of cost factors. Jessop provides methods for finding the best fit curve to represent a correlation between two factors. He does so by plotting known measurements on a graph and building a function based on the known points. A balance must be made between relying on formalistic methods for decision making, and taking into account qualitative factors that do not easily conform to a mathematical function.

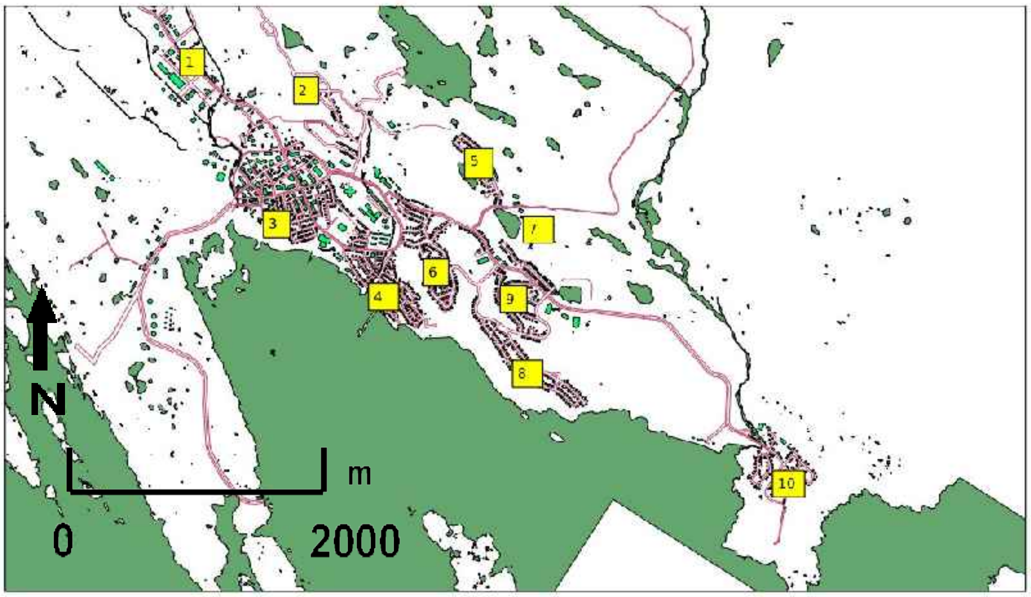
Chapter Two notes

1 A long definition of logit and probit models is beyond this review, but the two types of model represent different ways of looking at data. A probit model allows for the variance of an estimated variable's probability to vary in relation to a geographic factor such as distance. 'Non-Stationarity' is a concept to explain the change of parameters across geographic space, or the 'heteroscedasticity' of the variables. Stationarity, by contrast, assumes a stable relationship among variables regardless of spatial location.
2 Paez outlines a method for determining the coefficients for each location, using matrix algebra, as developed by McMillen, 1992.
3 A warped grid is a map representation where distances between points of interest are shown as lines, whose lengths represent the travel time between the locations.

Chapter 3

DATA

Study Area



1) Industrial	4) Lower Iqaluit	7) Lake Subdivision	10) Apex
2) Plateau Subdivision	5) Road To Nowhere	8) Tundra Valley	
3) Lower Base	6) Happy Valley	9) Tundra Ridge	

Figure 3.1 General Study Area map showing Iqaluit's neighbourhoods.

Origin and Destination Points as Spatial Structure Concepts

The spatial structure of the study rests on the idea of 'origin points' as residential places that users will journey from in their everyday lives, and 'destination points' are places that users will gravitate towards in their daily lives. The concepts follow the literature that focuses on origin and destination points, such as Brainard's (1997) isochrone study, Builiung and Kanaroglou's (2006) research on household activity spheres, and Daniel Rodriguez's (2004) study on excess commuting between places of residence and employment. As well, the Iqaluit study bears resemblance to O'Kelly and Niedzielski's (2008) work on 'effort' in the transportation system, which has the concept of origins and destinations built-in implicitly. O'Kelly and Niedzielski strive to determine how to arrive at higher levels of system efficiency, given the placement of residences and places of employment at given points in the transportation network. They estimate how many of the origin and destination points would have to change in order to optimize the system by a given amount.

The concept of destination points is used in the following section as a focal point for describing the public and commercial areas of Iqaluit, as well as the road network that provides access to Iqaluit's commercial and governmental service amenities. Following the discussion of Iqaluit's public places, the concept of the origin point is used as a focal point for describing the residential neighbourhoods of Iqaluit and their access roads. The road network itself is seen as subsidiary to the neighbourhoods, so roads are described as access points to various neighbourhoods.

In later sections of this study, the concepts of origin and destination become subsumed to a degree under the 'paths' that are created between each origin and destination pair. A 'path' is simply a measurable journey from an origin point to a destination point within a given transportation network. It is important to note that while paths are composed of road and trail segments, the origin and destination points are integral elements of the paths, and are focal points that give the transportation network its meaning.[1] For this reason, the transportation network is not given a separate section in the study area description, but is allied to the descriptions of individual neighbourhoods and amenities.[2]

Destination Points and Public Places

The destination points used in the study were chosen on the basis of service types. Grocery amenities, hospital and clinic facilities, the main office and hotel tower block of the city, and the city's newer Arena were chosen. Figure 3.2 shows the locations of the destination points chosen, along with the locations of some other important public places in Iqaluit. Figure 3.3 shows the approximate elevations above sea level of a variety of areas in Iqaluit.

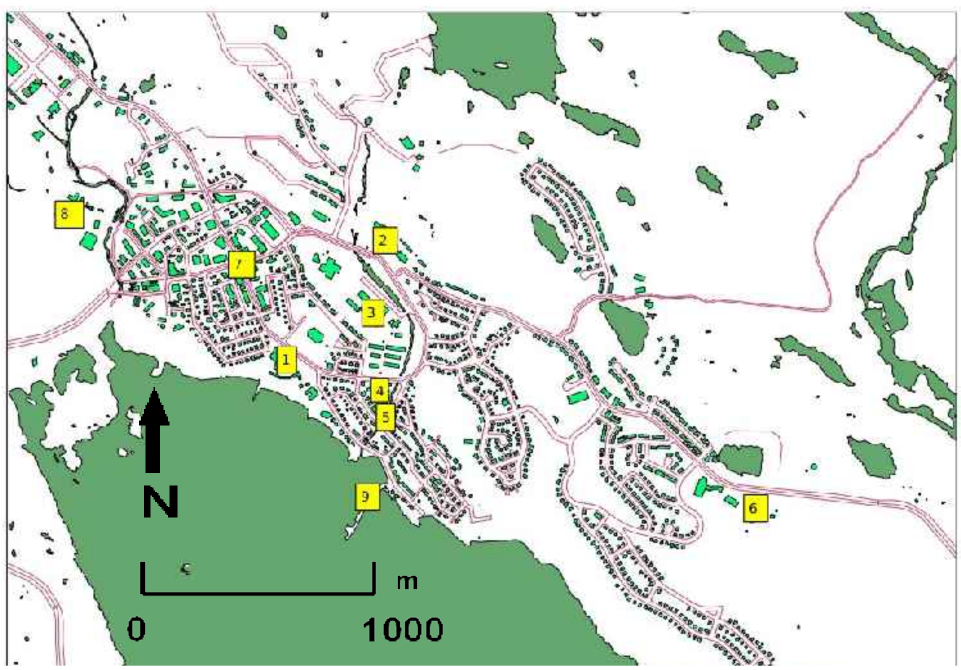


Figure 3.2 Iqaluit Destination Points: 1) NorthMart 2) Hospital Complex 3) Frobisher Complex 4) Arctic Ventures 5) Clinic 6) AWG Arena
Other Landmarks in Iqaluit: 7) Four Corners 8) Airport 9) Wharf.

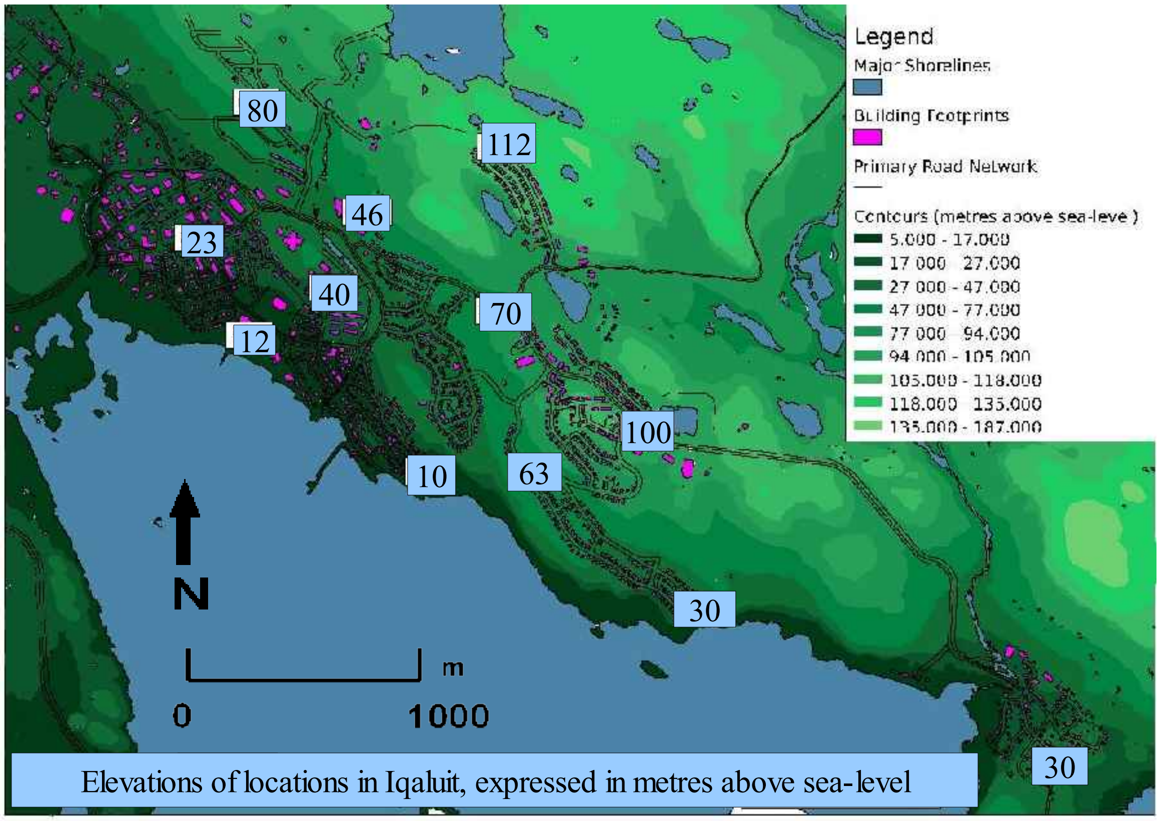


Figure 3.3 Graphic representation of elevations in Iqaluit, expressed in metres above sea-level.

The hospital complex in Iqaluit is a long building with a new and old wing accessed by different entrances. The hospital complex sits at the top of the Ring Road that forms the centre of Iqaluit's road network. Paths from either side of town leading to the hospital assume that reaching the closest entrance is adequate. The new entrance to the hospital is situated above a 'fortress-like' wall, separating it from the Ring Road. A substantial elevation gain is required in journeying up from the ring road to the New Hospital entrance. There is a winding, steeply sloped driveway, and a steep staircase cuts into the concrete wall beside the driveway (Figures 3.4, 3.5).

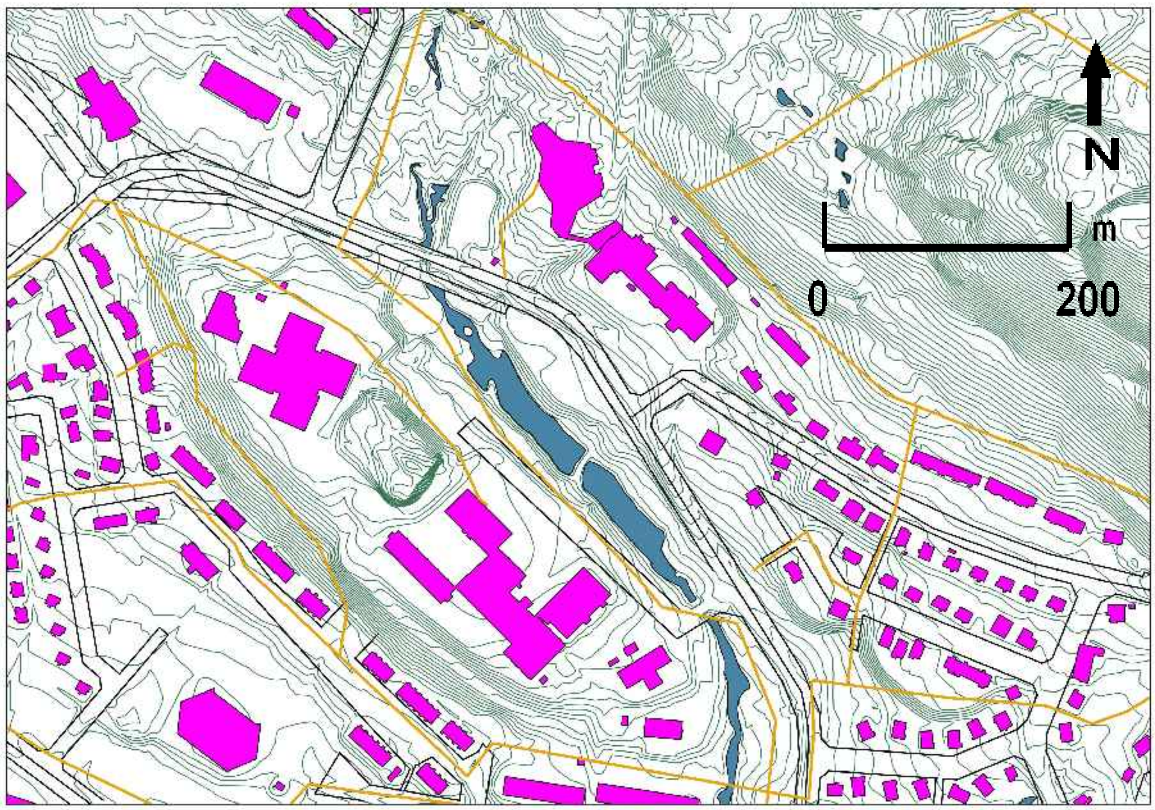


Figure 3.4 Hospital Complex and Frobisher Complex, showing roads in black, elevation contours in green and buildings in light purple. 1) New Hospital. 2) Old Hospital. 3) Frobisher Complex. 4) Inuksuk High School. 5) Nakasuk Elementary School. 6) Arctic College. 7) Ring Road. 8) Apex Road. Orange lines represent walking trails.

Figure 3.5 New building of Qikiqtani General Hospital, viewed from the Ring Road.

Across the Ring Road from the hospital, situated on another fortress-like hill, is the Astro Hill complex, which I will refer to as “The Frobisher Complex” or “the complex” since it is the location of the Frobisher Inn (Figures 3.6, 3.7, 3.8). Besides the multi-storey tower of the Inn, the complex includes an office tower for the Government of Nunavut, and an apartment tower that houses Government of Nunavut employees. The complex also includes two restaurants, a small movie theatre, a convenience store, a cafe, a video store, a sports wear shop, a drug store and an indoor swimming pool. All are accessible from a single entrance on the north side of the building, between two wings of the Frobisher Inn. The CBC North building is also located next to the complex, along the entrance road that approaches from the Ring Road. The entire complex is accessed by a bridge, as there is a riparian or watercourse area of lower elevation separating the Ring Road from the hill that the complex sits on (Figure 3.8). The riparian area has a causeway over it that is listed as a snowmobile trail on the GIS system, and can be used by pedestrians in winter. However, it is not a dedicated pedestrian trail, and lacks signage to indicate whether the causeway is passable. The complex can be accessed by a foot trail from the west, as the city's secondary school is located on the western side of the hill, and there is a foot path from the western side of the Ring Road up to the high school and along to the Frobisher Inn Complex. On the south edge of the Frobisher Complex, there are only service entrances, and there is a steep drop-off to the roads below, with no safe walking paths, unless one walks further west, where paths lead down from behind the secondary school to the roads below. The northern half of the Ring Road runs between the hospital and the Frobisher Complex, and each building is located at a higher elevation to the road, with the additional low-lying area between the Ring Road and the Frobisher Complex. The overall effect is to spatially separate two of the town's major sets of amenities by steep, impassable terrain and empty space (Figure 3.8). The unique, rocky landscape of Iqaluit makes building difficult, and the city is, to a greater extent than most, built around the physical landscape.

Figure 3.6 The Frobisher Inn Complex on Astro Hill. Viewed from the southeast, in Lower Iqaluit.

Figure 3.7 Frobisher Complex viewed from the Ring Road. In the foreground is an 'all terrain vehicle' or ATV, with a snow machine or snowmobile.

Figure 3.8 Hospital Complex (left) Ring Road (centre) and Frobisher Complex (right). The large gap between the Frobisher Complex and the Ring Road is a low elevation riparian area sometimes containing water. In the foreground are the housing units above Arctic College, and the walking trails from the Plateau Subdivision down to the town centre. The far background is Happy Valley, and Tundra Valley, with the hills that divide the neighbourhoods. In the walls in front of the hospital cut-outs for stairs can be seen.

Similar to the use of the two hospital entrances, the city's two major grocery purveyors, Arctic Ventures and NorthMart, are used as destinations for paths coming from either side of town (Figure 3.9). Both grocery stores sit at the bottom of the Ring Road, with NorthMart located to the west, near town centre, and Arctic Ventures located to the east and closer to most of the residential neighbourhoods. Distance to the nearest of either Arctic Ventures or NorthMart is considered as the distance to the nearest food amenity from each origin point. NorthMart, a branch of the Hudson's Bay Northern Stores, is the largest grocery store in Iqaluit, with a large selection of foods and deli items, plus household items, a pharmacy and clothing section. It is open only until 7pm, so becomes very crowded from 5-7pm on weekdays. It is a one-storey building that sprawls in either direction and has a very small parking area in front. The Inuit Elders' home and Iqaluit Square lie to the east, and the main row of businesses in Iqaluit is to the west. These businesses include a bank, dentist, office supply store, gift shop, and the Post Office (Figure 3.10, 3.12, 3.17). At the west end of this row of businesses is 'Four Corners', or the 'major' intersection of Iqaluit. Federal, Territorial and City offices, plus other office buildings and another large hotel, fill in this central area of Iqaluit (Figure 3.16). Arctic Ventures is a smaller grocery store, located in a two-storey building that also includes an electronics outlet and a video store (Figure 3.9). It also sells clothes, books on the North and northern gifts. It is open until 10pm, so experiences a more spaced out flow of customers than NorthMart. Not all necessities can be found at Arctic Ventures, but most grocery shopping can be done there. Other businesses and the medical clinic are located in the same street block as Arctic Ventures, but on the roads closer to the waterfront than Arctic Ventures[3]. These include a convenience and fast food store, a poutine restaurant, an outdoor survival store and the local newspaper. The medical clinic is a small building located at the opposite end of this block to Arctic Ventures. A network of footpaths links these buildings through the open centre of the block, but the eastern edge of the path is seasonal, due to a small creek. It is crossable on a board-like bridge in the summer,[4] but not during the spring thaw season. A further block below Arctic Ventures is the waterfront, where the city's small museum and library are located.

Figure 3.9 Arctic Ventures and surrounding area, viewed from Astro Hill. In the foreground is the housing area below the Frobisher Complex.

Figure 3.10 Buildings in downtown Iqaluit.

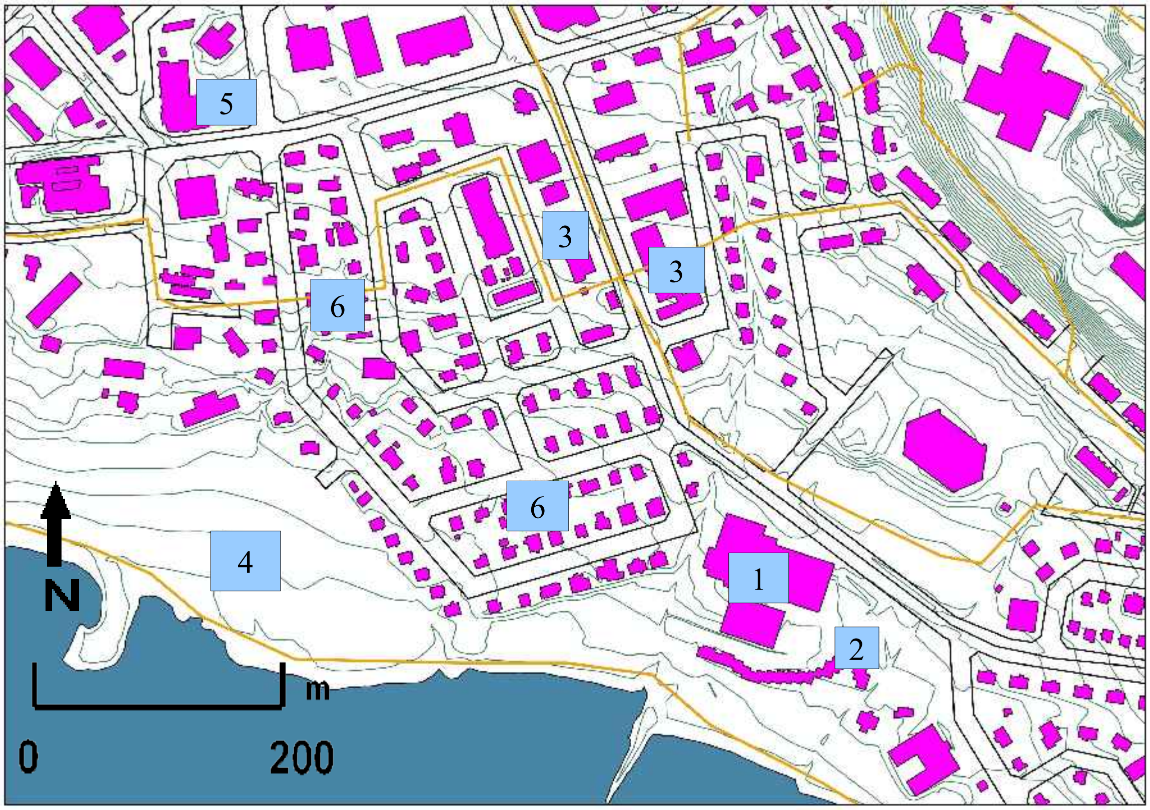


Figure 3.11 NorthMart and surrounding area. 1) NorthMart. 2) Elders' Home and Iqaluit Square. 3) Shops, bank and Post Office. 4) Boat Yard and Beach. 5) Area of restaurants and hotels. 6) Lower Base Neighbourhood. Orange lines represent walking trails.

Figure 3.12 Iqaluit's Main street viewed from Astro Hill. NorthMart is not shown but is to the left of the area shown. Downtown Iqaluit is to the right of the area shown. The Lower Base neighbourhood is in the background.

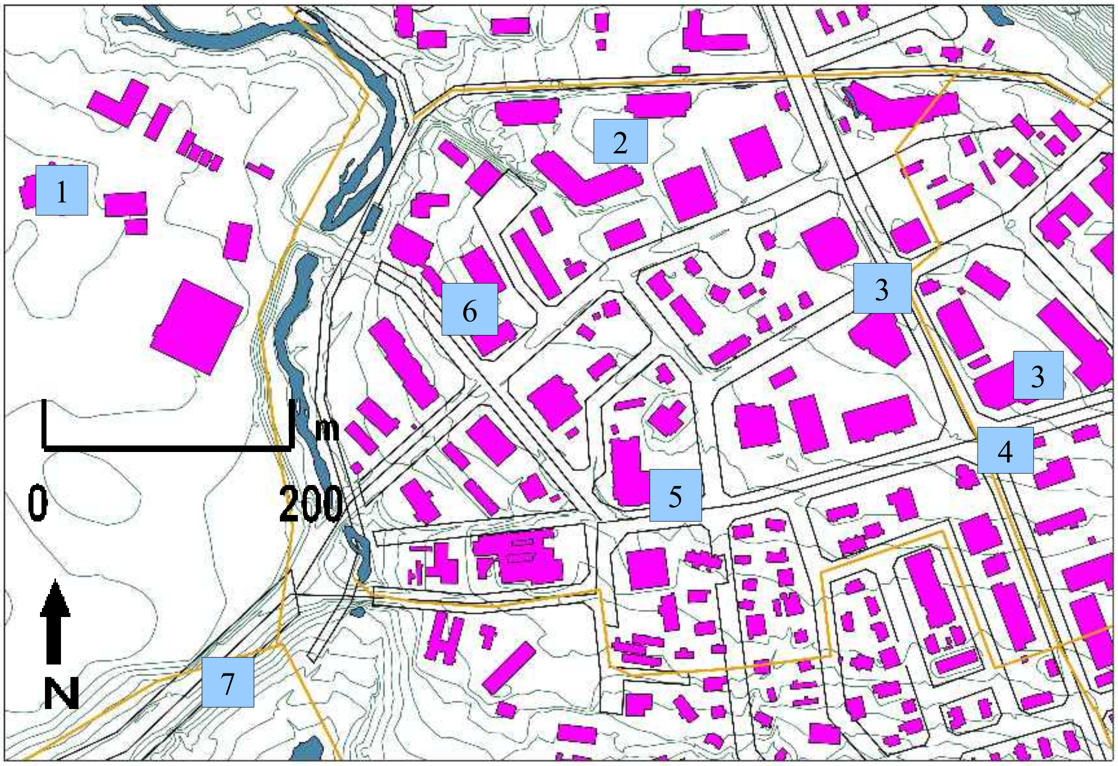


Figure 3.13 Town Centre and surrounding area. 1) Airport. 2) Inuksugait Plaza offices and apartment buildings. 3) Offices and government buildings. 4) 'Four Corners', main intersection. 5) Area of restaurants and hotels. 6) Shops. 7) Road to Sylvia Grinnell Park. Orange lines represent walking trails.

Figure 3.14 Iqaluit Airport Terminal.

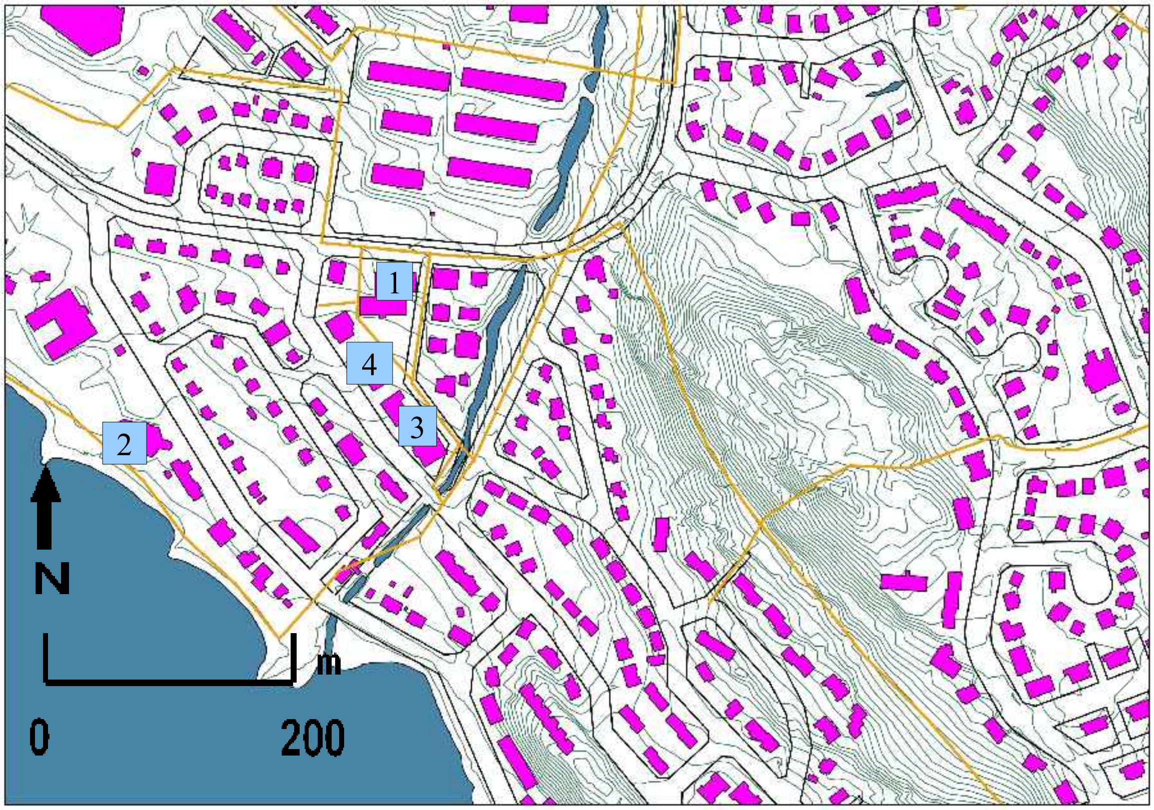


Figure 3.15 Arctic Ventures and surrounding area. 1) Arctic Ventures. 2) Museum and library 3) Clinic. 4) Shops and food outlets. Orange lines represent walking trails.

Figure 3.16 Legislature Building of the Government of Nunavut.

Figure 3.17 Looking east on Iqaluit's main street, with the sculpture garden covered in snow in the foreground and the Post Office behind it. Wooden posts are present to form pedestrian walkways.

The other destination point used, the Arctic Winter Games Arena (AWG Arena)[5], is located away from the centre of town, along the road that branches off from the Ring Road east of the Old Hospital (Figure 3.1). This road is known commonly as 'Apex Road' because it leads to Iqaluit's only spatially separate suburb, Apex, which is 2 km east of the rest of the town. Apex Road climbs steadily from the Ring Road, with houses on either side. Entrances to the Road to Nowhere Subdivision and the Lake Subdivision branch off on the northern, high elevation side. Roads that lead down to Happy Valley, Tundra Valley, and Tundra Ridge neighbourhoods branch off from the southern, lower elevation side. All of these lower suburbs have alternate entrances, but the Lake Subdivision and the Road to Nowhere Subdivision are only accessible via Apex Road. The AWG Arena is located east of the entrance roads to all the adjoining suburbs, at the crest of a hill, before Apex Road continues east and loses elevation as it approaches Apex. The city's junior secondary school is also located at the top of the hill. The elevation at the Arena is close to 100m above sea level, at about the same elevation as much of the tundra that surrounds the town.[6]

Origin Points and Residential Areas in Iqaluit

Origin points were chosen to represent each residential neighbourhood in the city, and were set out in approximate distance bands from the central region of Iqaluit. Figure 3.1 shows the locations of Iqaluit's neighbourhoods.[7] To the west of town and on a high ridge is the Plateau Subdivision,[8] Iqaluit's newest suburb (Figures 3.18 and 3.19). The entry road is steep, branching up from the ring road to the west of the New Hospital, next to Arctic College (Figure 3.20). Housing is located at elevations of up to 100m above sea level and many have views over the Bay and the airport. The subdivision was designed with sustainable planning principles in mind, and houses on the Plateau must make use of passive solar design.

Figure 3.18 Power Station, on the ridge behind the Hospital and adjacent to the Plateau.

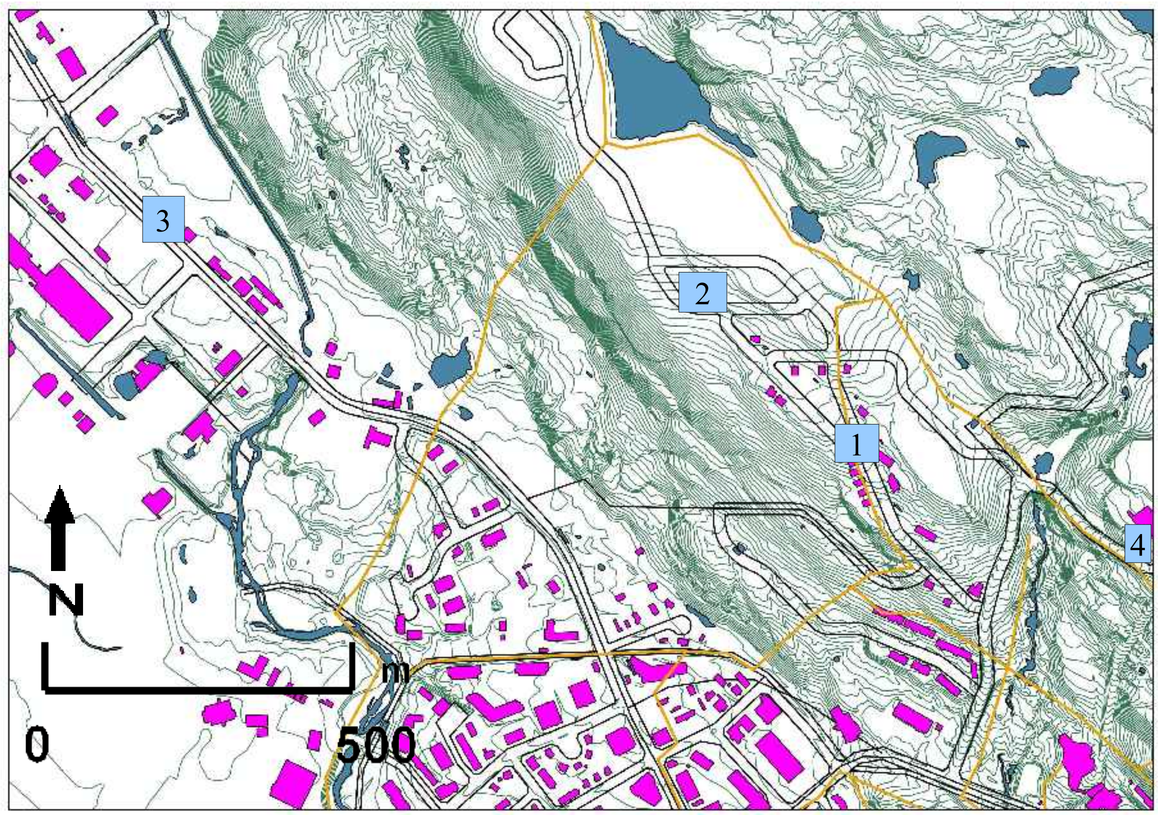


Figure 3.19 Plateau Subdivision and Industrial Area. 1) Plateau Subdivision Phase 1. 2) Plateau Subdivision Phase 2. 3) Industrial area. 4) Power Station.

Figure 3.20 Plateau Subdivision, viewed from west of town centre, towards the Industrial Area.

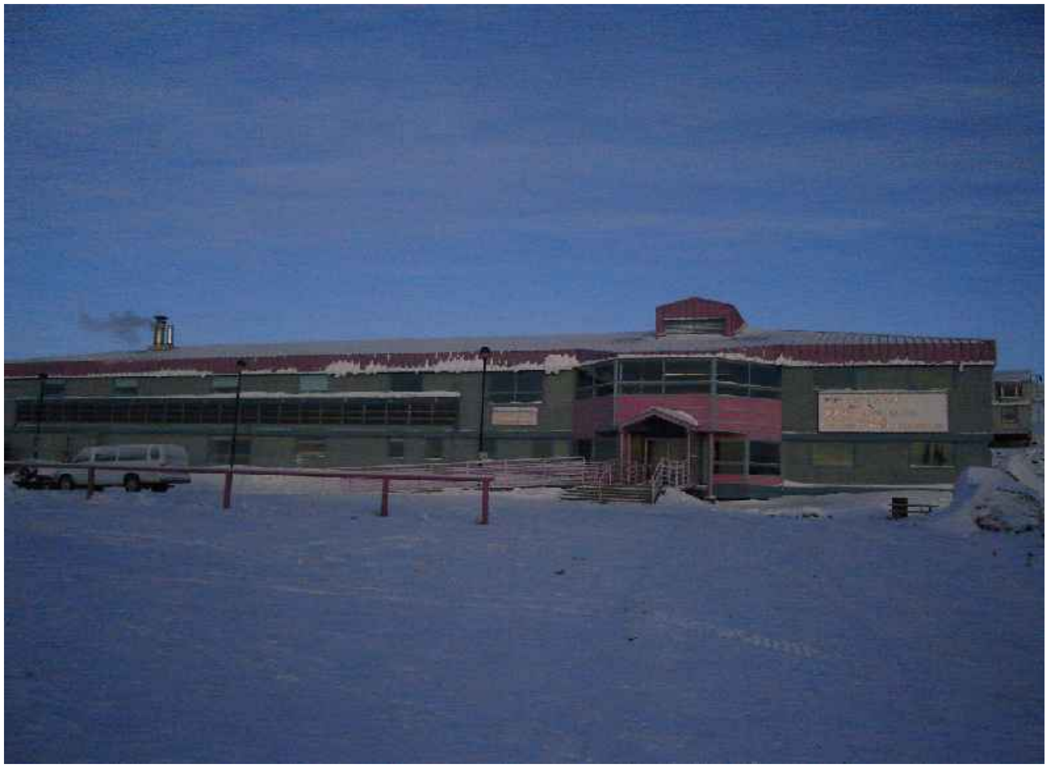


Figure 3.21 Arctic College.

Below the ridge of the Plateau, at elevations of 20-30m above sea level, is the city's industrial area (Figure 3.18), bordered on its far western edge by another rocky ridge. Roads from this end of town lead up to the location of the original military watchtowers that were built in the area, before the town was established. These roads do not lead to any other municipality, but continue east until they meet roads that run out from the northeastern suburbs.

Close in to town, the neighbourhoods of Lower Base and Lower Iqaluit flank the main shopping areas of the town. Lower Base lies to the south and west of the town's centre, and extends to the waterfront, where it adjoins shipyards (Figure 3.11 and 3.12). It is named for being the original area that the army base was near, and the first building site of the town. Shops and apartment buildings extend from Lower Base to the southeast edge of town, where a bridge leads to the small airport (Figure 3.13 and 3.14) and other industrial amenities, as well as to Sylvia Grinnell Park, one of the area's recreational destinations.

Lower Iqaluit extends east of town centre and is located below a hill slope that separates it from other suburbs such as Happy Valley and Tundra Valley (Figure 3.21, 3.22). At the waterfront edge of Lower Iqaluit is the wharf which projects outward into either ocean, ice, snow or tidal flat, depending on weather and tidal conditions. At the eastern edge of Lower Iqaluit is the City's cemetery, and a small beach that is accessible in summer.

Figure 3.22 Lower Iqaluit viewed from the wharf. Behind Lower Iqaluit is the hill separating Lower Iqaluit from Happy Valley. In the far background is the hill separating Apex Road from the Road To Nowhere Subdivision.

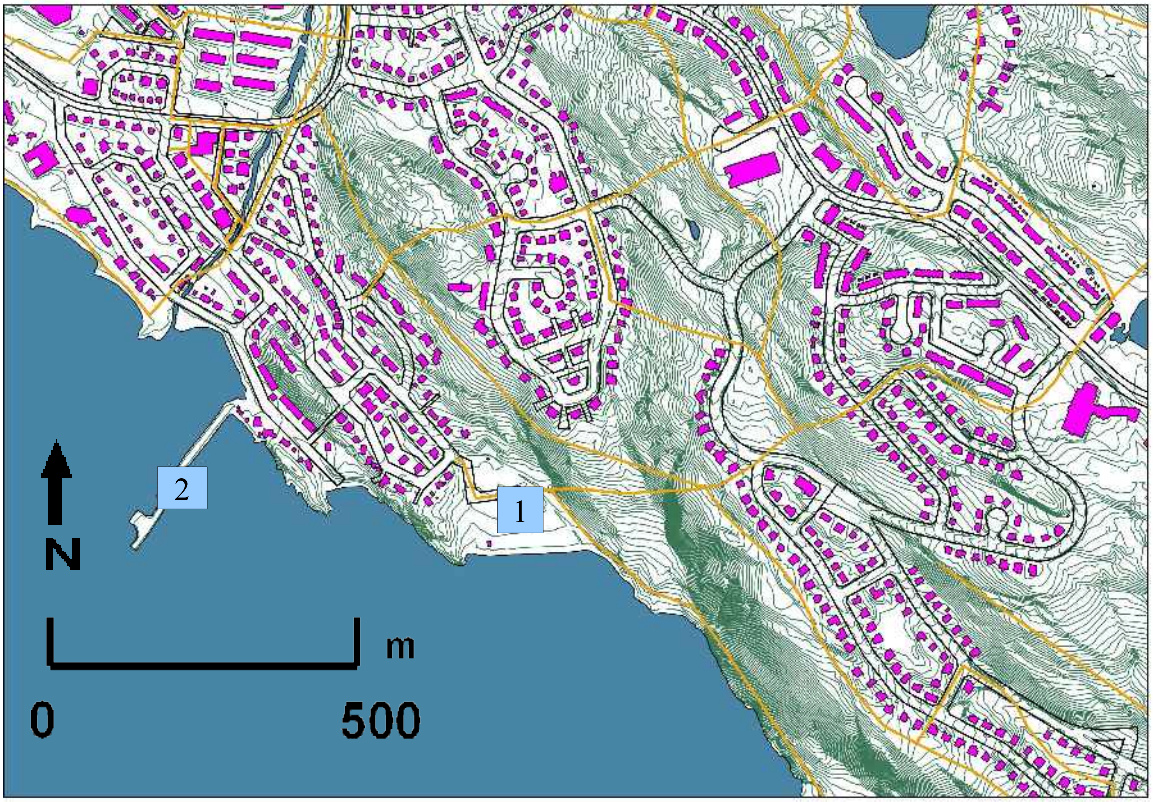


Figure 3.23 Lower Iqaluit and other neighourhoods. 1) Beach and Cemetery. 2) Wharf.

Figure 3.24 Housing in Lower Iqaluit, designed to follow the contours of the land.

Weather dependent trails lead upwards from Lower Iqaluit to Happy Valley, which is accessible by road at the eastern edge of the Ring Road. It is a loop-shaped neighbourhood that matches the contours of the land, sitting on a ridge above Lower Iqaluit and below another steep slope that leads up to Tundra Ridge. Elevation in Happy Valley is approximately 40m above sea level. There is also a trail from Happy Valley to the western entrance of Tundra Valley. Frobisher Bay can be viewed from many locations in Happy Valley. The road leading up from Happy Valley is too steep to build upon, so there is an empty area between Happy Valley and the two neighbourhoods of Tundra Valley and Tundra Ridge.

Figure 3.25 A house in Happy Valley.

Tundra Valley rests in a contour of the land above the Bay, and is a very elongated-shaped neighbourhood consisting of one road loop (Figure 3.26). Though its entrance road is higher than Happy Valley, and a steep hill must be climbed in order to reach

Tundra Valley, its furthest eastern edge is only 30m above sea level. It is below another hill that separates it from Tundra Ridge. There is a road up from the entrance of Tundra Valley to Tundra Ridge. The road from Happy Valley also accesses the western edge of Tundra Ridge. The ridge is at higher altitudes of 80-100m above sea level, with a series of short roads creating a cluster style neighbourhood on the ridge top, including some medium density housing. Further out on the ridge is another road with fewer houses and expansive views of Frobisher Bay.

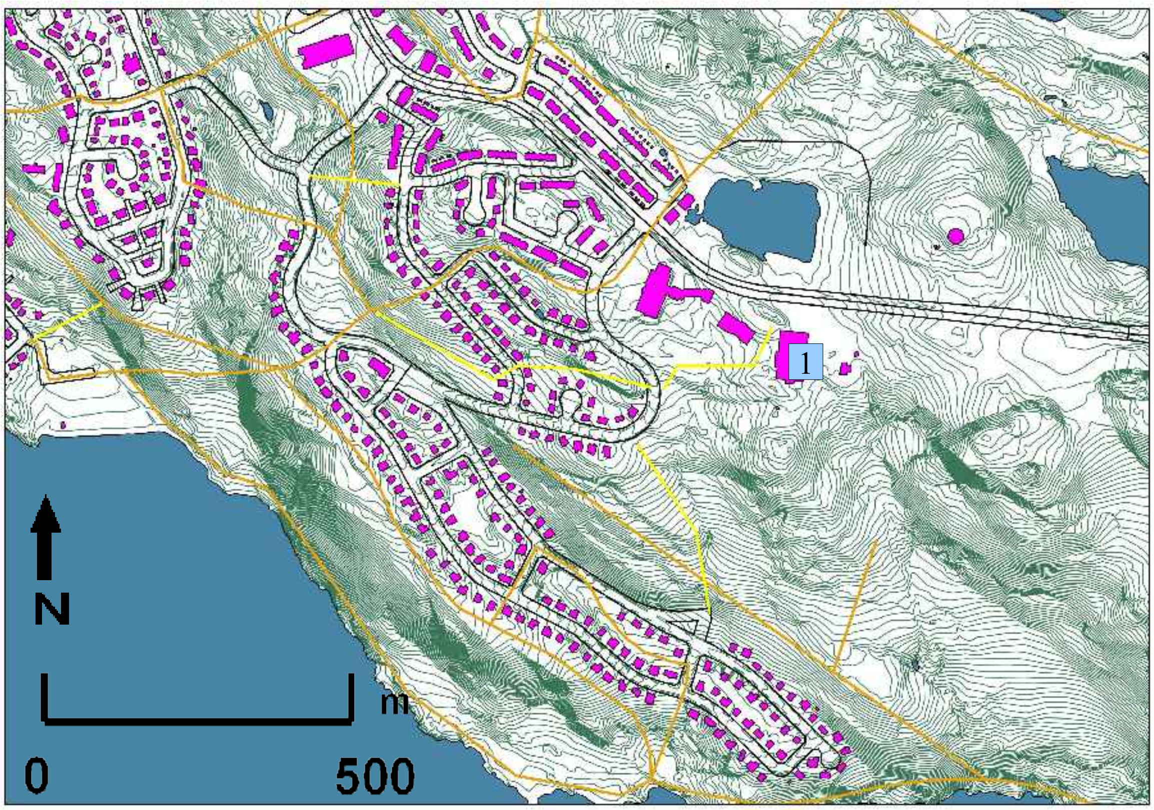


Figure 3.26 Eastern Neighbourhoods. 1) AWG Arena. Orange trails are currently listed on Iqaluit's GIS. Yellow trails are not currently existing but may be potential trail sites.

Figure 3.27 Tundra Valley in the foreground and Tundra Ridge in the background.

On the other side of Apex Road from Tundra Ridge, and at a road level altitude of 80-90m, is more medium density housing. North of this in a curve is the Lake Subdivision, which is on the north west corner of a small lake in the tundra, and backs onto the tundra. The Road to Nowhere Subdivision[9] is to the west of the Lake Subdivision and is a loop of road located at a very high altitude, (to 112m) backing onto the tundra and insulated from the ocean side by a ridge of rock.

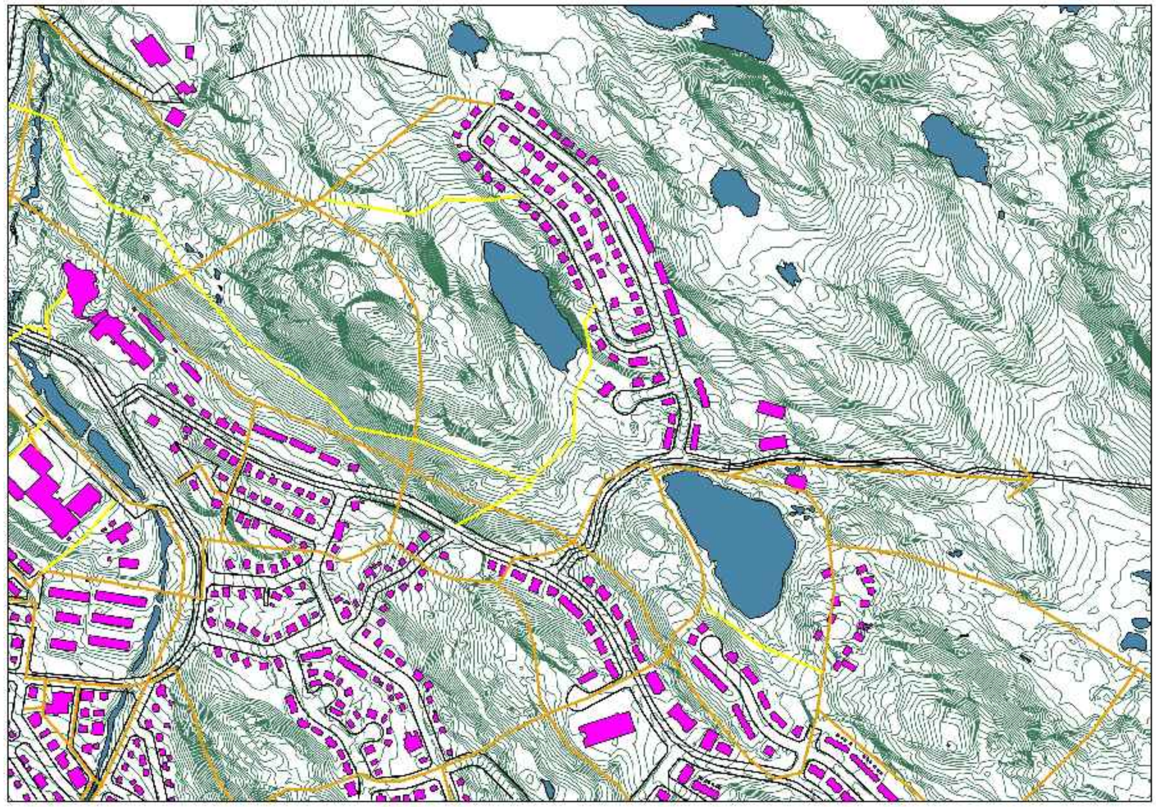


Figure 3.28 Northeastern Neighbourhoods. Orange trails are currently listed on Iqaluit's GIS. Yellow trails are not currently existing but may be potential trail sites.

Figure 3.29 The Road To Nowhere Subdivision.

Continuing east from the Arena, Apex Road passes through unoccupied tundra and then downhill and past the Apex river, to the suburb of Apex. Apex was the original location of the Inuit summer fishing ground that existed before any European settlement. Apex is hemmed in by the ocean on its south side and by rock ridges on the north and east. The original Hudson's Bay building is still intact on the shore of Frobisher Bay, next to Apex. There is currently no grocery store in Apex and no public building other than the community centre. Residents must drive or otherwise journey the 2kms to the nearest convenience store, on the Apex Road. Building in Apex is not permitted, as there is no land that is suitable for further development.

Figure 3.30 Historic Hudson's Bay Company buildings in Apex.

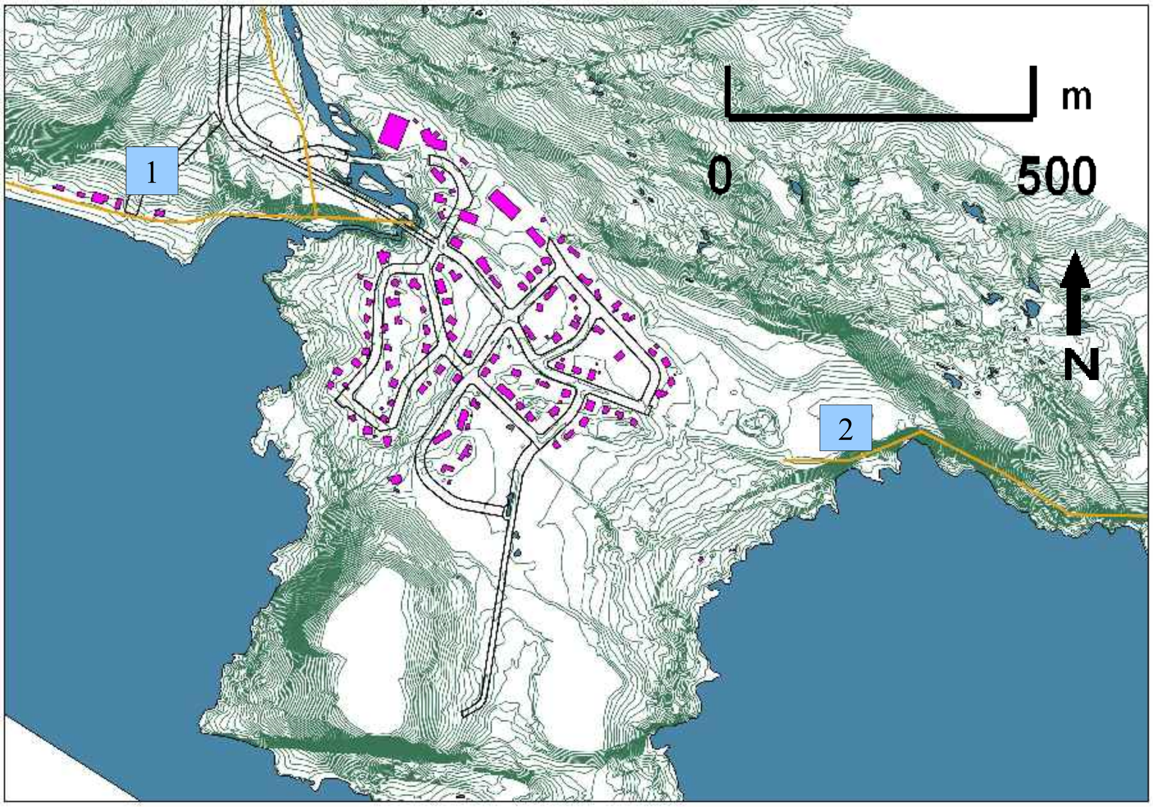


Figure 3.31 Apex. 1) Original Site of Hudson's Bay Buildings, still in existence., as well as the trail head for the Apex Trail. 2) Tarr Inlet Recreational Trail.

Figure 3.32 The Apex Trail, looking west towards Happy Valley and Lower Iqaluit.

Bus Routes

Currently in Iqaluit there is no municipal bus service. Residents rely on automobiles, taxis, snow machines and walking. A bus service was operational in Iqaluit from 2003 to 2004, but ceased to function due to financial issues (*Nunatsiaq News*, 2001, 2003, 2004). A single bus ran from Apex and circled the Ring Road during peak hours on week days. Riderships peaked at 416 passengers a week during a trial period, but dropped to 200 passengers a week, or 28 riders a day, when the service was in place. The articles do not investigate why ridership dropped, but do state that the service as it was implemented was not financially viable at that time. The failure of the 2003-2004 bus trial in Iqaluit should not be seen as a reason to abandon further research into transportation options in Iqaluit. *The Sustainable Arctic Subdivision Feasibility Study* (SLB *et al.*, 2004) cites that at the time, an extension of the city's existing bus loop was recommended, which would extend into the Plateau Subdivision, with multiple stops. As the bus service for the city was discontinued soon after the report was prepared, no bus loop into the Plateau Subdivision was ever put in place. The presence of a proposed bus loop in the plan set out by the feasibility study underscores the idea that public transit is a component of sustainable neighbourhood design.

This study looks at the transportation issue from another perspective - that of the gains to users made possible by transit options.[10] Five bus routes were custom designed for this GIS study. The bus routes were spatially located to each present a different potential for cost savings in the local transportation network. Each route has a different sequence of included and excluded regions of the town. Additionally, each represents a different trade-off between offering cost savings to multiple neighbourhoods, and creating such a long bus journey that the cost savings are minimal to the user. All bus routes start in Apex and travel along Apex Road until the Eastern edge of Iqaluit is reached.

Bus Route 1 (Figure 3.33) continues along Apex Road until it reaches the Ring Road. The route then travels around the Ring Road from Apex Road junction to Four Corners, and then back east along the Ring Road until turning south onto the road located just before Arctic Ventures. It then follows a short loop through Lower Iqaluit, before rejoining the ring road above Arctic Ventures. It continues up the eastern side of the Ring Road until it reaches the access road to the Frobisher Complex. Bus Route 1 was designed to offer the best cost savings to the very far out subdivision of Apex, while benefiting the subdivisions along Apex Road as well.

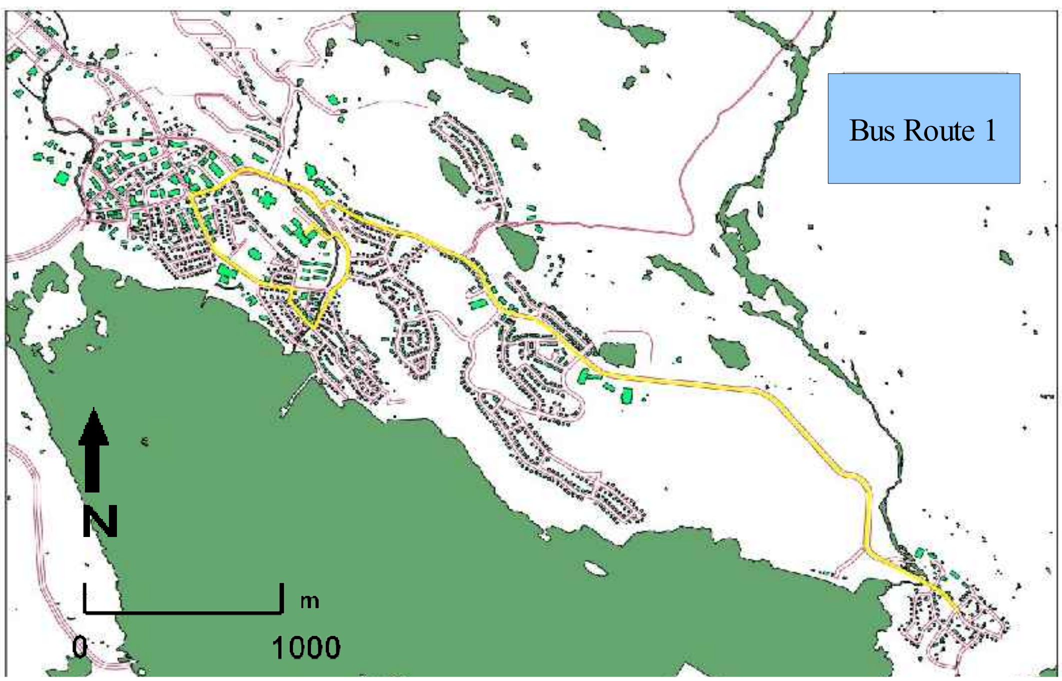


Figure 3.33 Bus Route 1.

Bus Route 2 (Figure 3.34) turns south at the first junction of Apex Road at the eastern edge of Iqaluit. It travels south and downwards in elevation through Tundra Ridge, and along the Western Edge of Tundra Valley. The route skirts the northwestern edge of Happy Valley and passes Flower Valley on its western edge before meeting the Apex Road again. From this point onwards it is a duplicate of Bus Route 1, ending at the Frobisher Complex. Bus Route 2 offers some benefit to all neighbourhoods, but some walking time will still be required for travelers from most residential origin points.

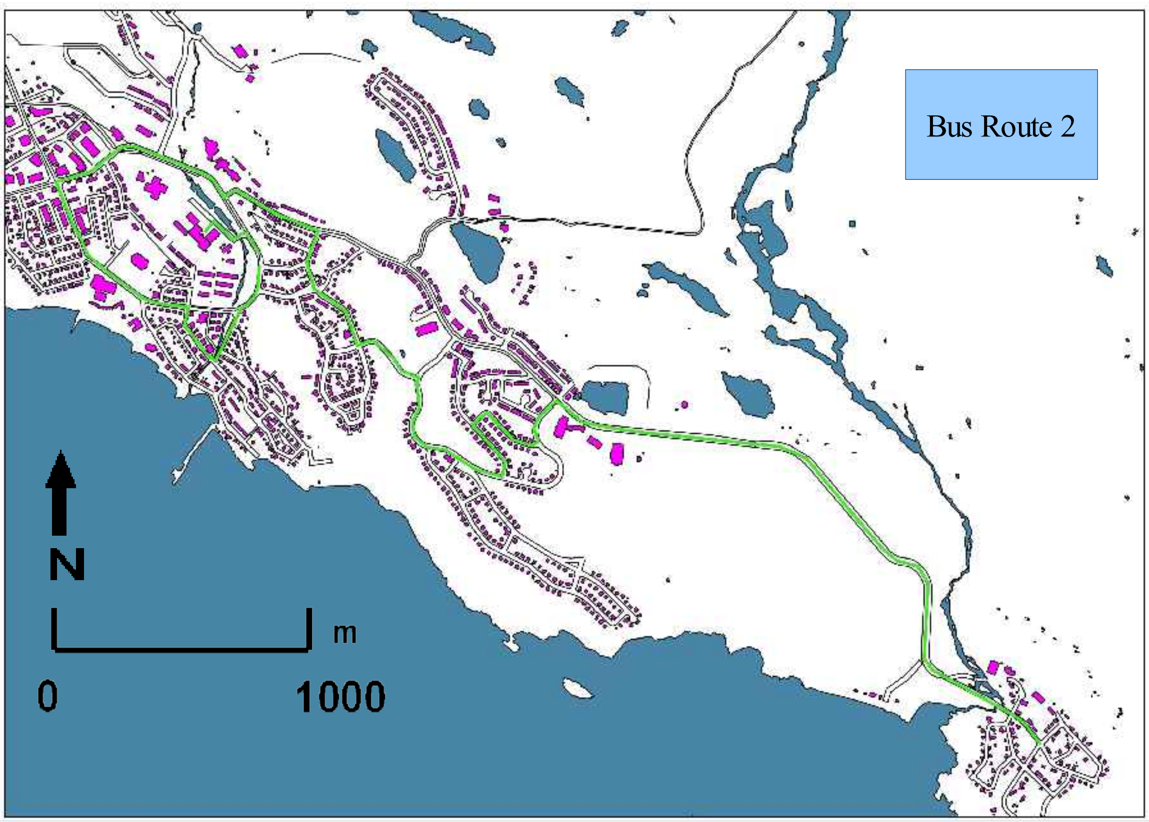


Figure 3.34 Bus Route 2.

Bus Route 3 (Figure 3.35) follows a similar course to Bus Route 2, with the exception that it makes detours to the southeastern edges of both Tundra Valley and Happy Valley, and then returns to the Apex Road via the eastern edge road of Flower Valley. It offers greater savings to those living further out on the subdivision roads, while accumulating a greater time cost for all travelers.

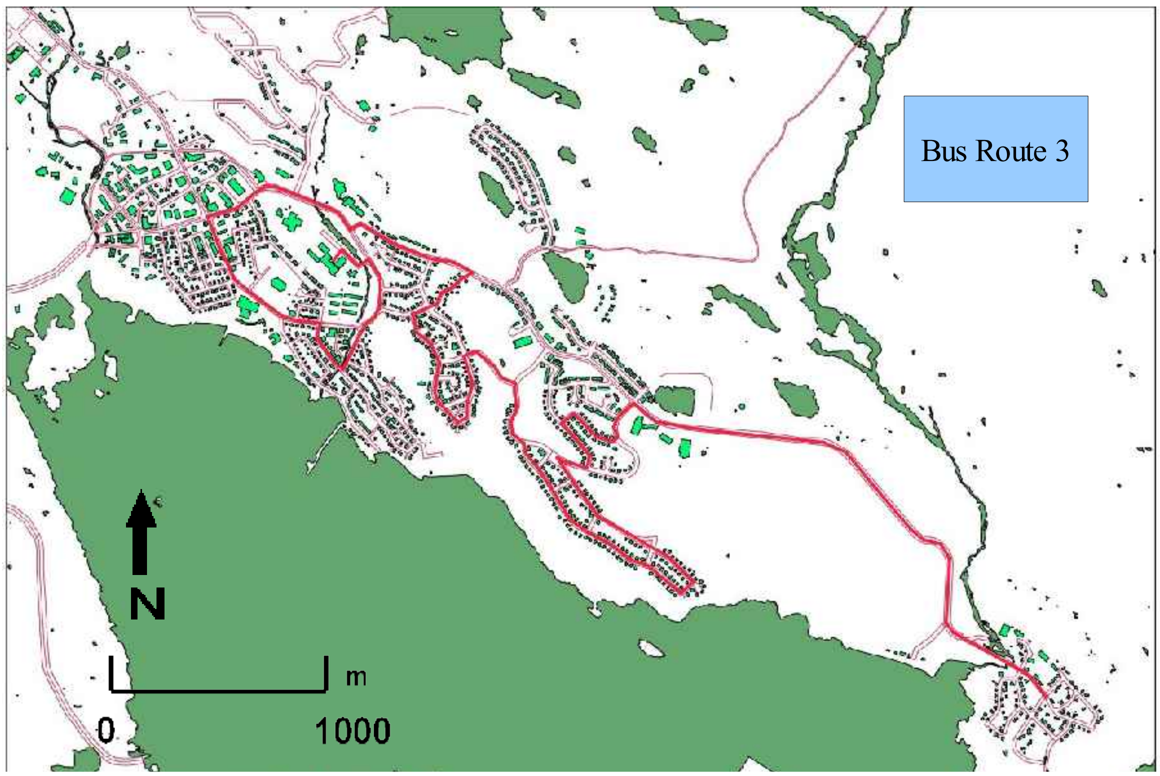


Figure 3.35 Bus Route 3.

Bus Route 4 (Figure 3.36) is the most highly detoured of the routes, and was designed to allow for maximum savings in uphill and downhill walking distance from the residential subdivisions. It follows the same course through Tundra Ridge as Bus Routes 2 and 3, then makes a detour through the western half of Tundra Valley. The route then returns to the Apex Road via the steep road at the western edge of Tundra Ridge. It continues along Apex Road until the turn-off for the Road to Nowhere, then travels up the RTN and makes a detour to the northwestern edge of the RTN loop, returning on the second road of the loop and back down the RTN to Apex Road. The maximum elevation at the end of the RTN loop is 112m above sea level. The route follows the Apex Road until it meets the Ring Road, then travels along the northern edge of the Ring Road to the access road for the Plateau Subdivision. The route travels up to the second phase of the Plateau Subdivision, at approximately 90m above sea level. From this high elevation point, Bus Route 4 returns down to the Ring Road, and follows it on the same course as the bus route already described. When it exits the Ring Road, it makes a longer detour into the Lower Iqaluit neighbourhood than the previous routes, then rejoins the Ring Road and reaches the Frobisher Complex via the same roads as the previous routes.

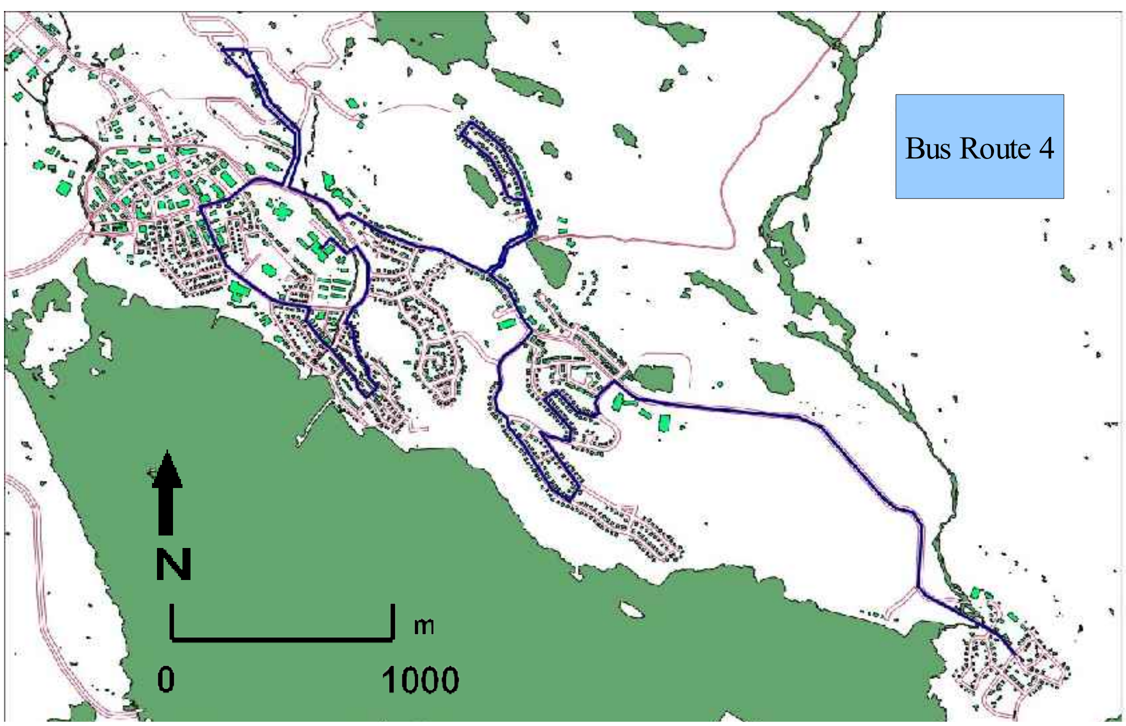


Figure 3.36 Bus Route 4.

Bus Route 5 (Figure 3.37) travels through Tundra Ridge, then makes a partial loop through Tundra Valley. It returns to Apex Road via the road to the west of Tundra Ridge, then makes a detour onto the RTN but turns around at the southeastern edge of the RTN loop, which is at 87m above sea level, without detouring into the subdivision. Continuing along Apex Road, it makes a detour down the eastern edge road of Flower Valley, to the edge of Happy Valley, then back up the western edge of Flower Valley to Apex Road. From there is follows the same course around the Ring Road as routes 1 to 3, but makes the same longer detour into Lower Iqaluit as Bus Route 4. Bus Route 5 was designed to offer some compromise to all neighbourhoods, without favouring any particular one with a full detour. Lower Iqaluit gains a longer detour in this case as journeys upslope to the hospital and Frobisher Complex are costly in terms of elevation for this neighbourhood, while passengers from further out subdivisions with destinations other than the Frobisher Complex will have mainly left the bus by this point in its course.

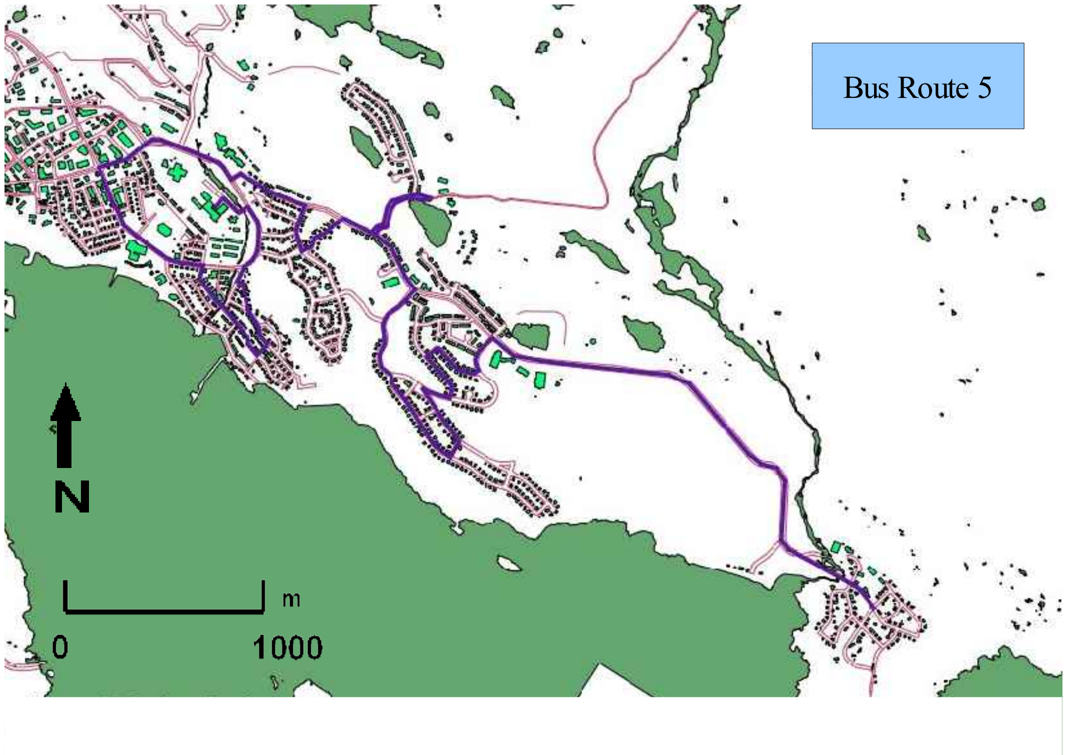


Figure 3.37 Bus Route 5.

Methods

Overview of Data and Process

The data used in this study is from the GIS database of the City of Iqaluit, obtained during a four-month work term in 2008. The GIS database includes the spatial structure of the road and trail network, building footprints and major shorelines that comprise the city[11]. The database also includes elevation data, as a contour line layer with elevation values represented. Knowledge gained about Iqaluit's walking and driving environment during my stay is beneficial for understanding the GIS database.

The data analysis methods used in this study are based on 'route choice utility theory' and employ geographical information methods in developing the data parameters for the study. All work was done in the Quantum GIS software interface. Shortest paths and travel path costs between the origins and destinations are the focus of the study. Several steps were used in preparing and analyzing the data (Figure 3.1). The following section details these steps, and Figure 3.1 is a flow chart illustrating the process and the data involved.

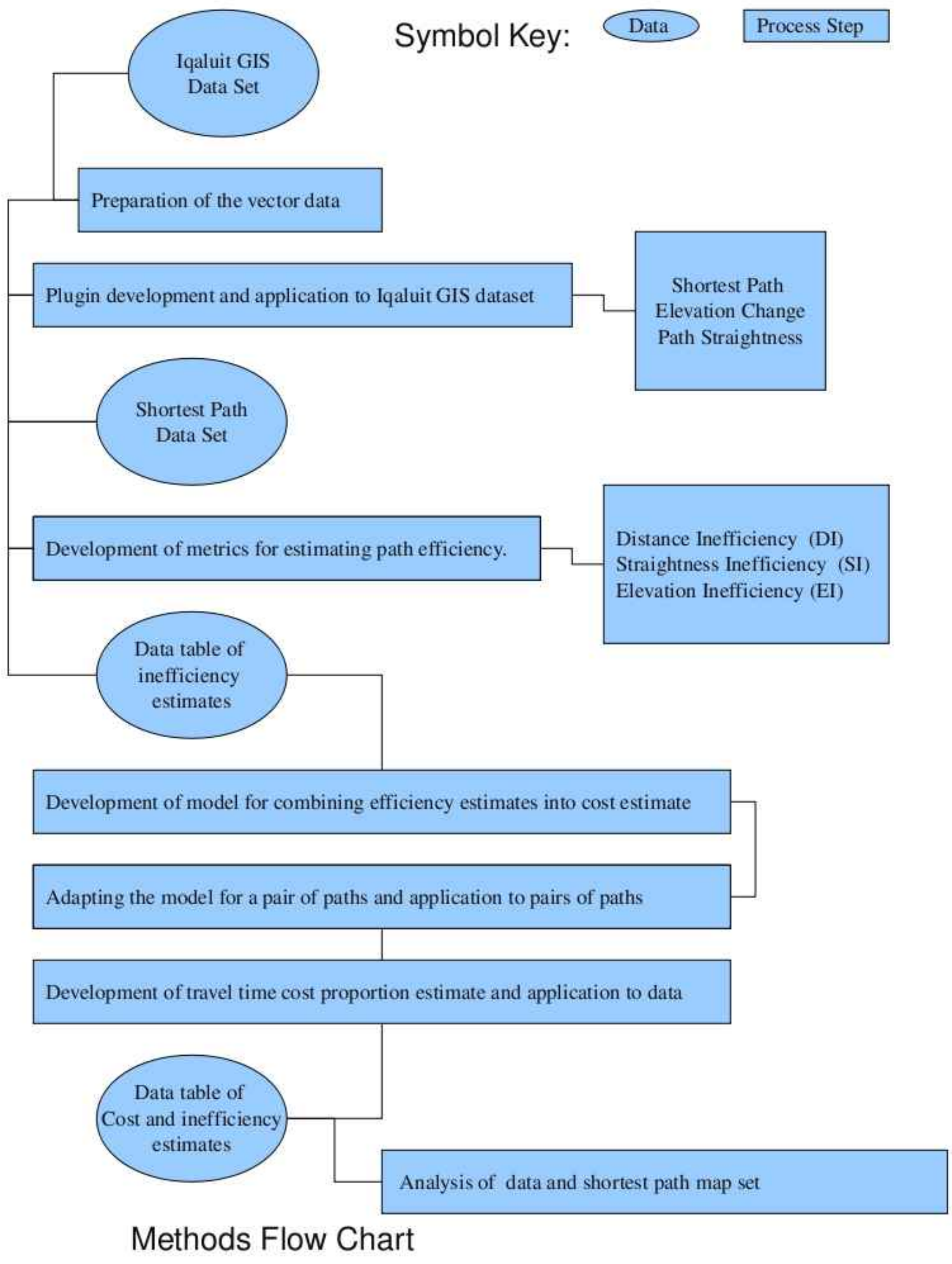


Figure 3.38 Flow Chart of Methods Processes.

Steps in the Process

1) Preparing the Vector Data

Origin and destination points were chosen in the city of Iqaluit that represent, respectively, important civic places and residential areas. Origin and destination locations were entered as vector point data. Road and trail layers, based on the layers present in the Iqaluit GIS database, were redrawn to suit the vector-based nature of the analysis. Roads and trails that were not considered relevant to the connection of chosen origin and destination points were not redrawn in the vector layers. In some cases, additional vector lines were added to the polyline structure to facilitate the creation of paths with the plugins. Bus route layers were also created as vector line layers.

2) Shortest Path Plugin Development and Application to Data

A series of software plugins was written to work with the GIS data. The aim was to develop a group of shortest paths between a group of destination points in the city and a set of origin points, and to determine the elevation data and path straightness data of each path. The plugins were developed in the Python programming language, using the PyQt framework and the PyQGIS modules of the Quantum GIS open source software. Creating plugins allows for greater customization of the data environment than simply using ready made modules.

The shortest path plugin works on an adaptation of Djkstra's shortest path algorithm (Newell, 48-55). Segments are added to the path on the basis of choosing the segment that is the shortest distance from the destination point, until the destination point is reached. There are problems with this approach, as the distance measure to the destination point was determined by physical distance, rather than by a measure of possible network-based distance. Still, the approach used works in many cases, and in cases where finding one shortest path was not possible, due to the network geometry, the two shortest paths from the origin point to a mid-point and from the mid-point to the destination point were made and combined.

The plugin allows for customization of the data set, and for the integration of the bus route layers. When a bus route layer is reached on the path being created, two actions are possible. If the distance to the destination point is above a certain threshold, the plugin assumes that the user boards the bus. If the distance to the destination point is not above the threshold, the plugin assumes that it is not worth the user's time to board the bus. If the first course of action is chosen, segments in the bus layer, which are ordered in a one way pattern from the assumed beginning to end of the route, are then added automatically until the segment that is closet to the destination point is found. The path then continues adding segments on the road layer until the destination point is reached. The plugin creates, as output, layers depicting paths from origin to destination points, with a measurement of the length of each segment on the path as a column in the layer, and an estimate of travel time as another column in the layer. The bus travel time estimate is based on approximate bus travel speeds given in the literature. Average bus travel speed is about 20km/h according to Vuchic (192). Walking speed estimate is based on my own informal measurement of my walking times in Iqaluit, and is 4-5 km/hr. So the travel time factor for the path segments is set at 5 times the segment length if the segment is a walking segment, and the segment length itself when the segment is a bus segment.

A set of paths was made to show shortest paths in the case of a road only network, and in the case of a road and trail network, based on the trail network that existed in the GIS database. An adequate level of path maintenance is assumed in the trail paths, though in reality, some of the trails may not be well maintained or available in different weather conditions. Paths in general are more passable in the summer, when they are visible and not covered by snow. Further, shortest paths were also created based on the availability of each of the five bus routes described in the study area section.

3) Elevation Change Plugin Development and Application to Data

The elevation plugin takes, as input, a path layer created by the shortest path plugin, and finds the elevation contour value closest to the start and end points on each path segment. A column is added to the segment's feature listing in the data table that shows the elevation change along that segment. The plugin was designed to determine the direction of the path, and so determine if the elevation change is positive or negative. However, the plugin failed in a very small but significant fraction of cases, creating incorrect totals for the origin to destination elevation change of the path. These were measured by hand on the map and corrected when necessary. Absolute values of the total elevation change along the path were correct in the cases tested.

4) Path Straightness Plugin Development and Application to Data

The path straightness plugin also takes as its input a path created by the shortest path plugin and determines for each segment along the path how much north-south and east-west travel is required. Number of turns and angularity are terms used by Bovy and Stern (81-109). Path straightness, the term I use for the overall level of non-geometrically direct travel in my study, is a related concept. The number of turns focuses on the actual instances of turning in the route, while angularity refers to the angle of such turns. Path straightness, as used in this study, refers to a measurement of the distances that a user is carried away from a straight line path and back during their journey. This information, plus the north-south and east-west differences between the end points on the paths, is given as output. Readings were good within a broad estimate, but were not completely accurate in many cases. When not accurate due to complexities in the algorithm, the path straightness measures were corrected by hand measurement on the map interface. The values for path length, elevation and straightness were added to a data table in Open Office's spreadsheet program.

5) Development of Metrics for Estimating Path Efficiency

The next stage in the data preparation process was to analyze the statistics created with the software and to create usable, comparable measurement statistics of the spatial attributes of the paths created. In combination with the spatial representations of the paths on the map canvas, the measurements create a detailed image of the walking and potential transit environment of Iqaluit. The term 'inefficiencies' is used to mean the estimates of inefficiency that were created by use of the metrics and formula structures described below. Inefficiency is normally used as a singular term to refer to overall discrepancy from an efficient state within a network. In this case, a plural form is used in cases where an attempt is made to articulate the constituent factors contributing to overall inefficiency.

5.1) *Distance Inefficiency Metric.* The differences between the point to point distance for each origin destination pair and the path length distance is compared as a ratio and as a difference, to gain a measure that could be referred to as 'distance inefficiency' (DI). The ratio is scaled down by dividing it by ten, thus accounting for the fact that it is a likely contributor to cost, but that it is secondary to the actual length of the path as a cost factor. The ratio measurement on its own may be misleading, as it will be proportionately larger on paths with a small overall distance. To know that a path is five times the length of the distance from its start point to its end point is useful, but has different implications for travel cost if the point to point distances being compared are different. A 500m path that joins two points only 100m apart in distance will have the same ratio as a 2,500m path that joins two points 500m apart. There is a potential problem of obscuring the real patterns in the data, particularly when more than one origin-destination point pair is being compared. This ratio should only be used in comparing two paths within an origin-destination pair's path set.

A function that looks at the difference between the point to point distance and the path length, rather than a ratio of the two, helps to get around this problem. The difference between the path length and the point to point distance gives a sense of the actual amount of extra travel that is required. However, the overall scale of the path still needs to be taken into account when points that are of varying distances apart are compared. For example, a detour of 500m probably creates a greater proportion of inefficiency on a short journey than on a longer one. To mitigate this, the difference is divided by the total path length, giving a measurement that has the benefit of taking path length into account, while still being based on the actual amount of extra travel distance required. This can be used to compare within origin destination pairs or between different pairs.

5.2) *Straightness Inefficiency Metric*. Similarly, with path straightness, latitudinal and longitudinal differences between the end points of the path and the total changes accumulated along the segments of the path can be compared as either a difference function or a ratio. In attempts to express the comparison as a ratio, the scale effects of small paths resulted in unrealistically high numbers in cases with a very small latitudinal or longitudinal change between points. In such cases, even a small amount of 'zigzagging' on the path created a large ratio of overall change to accumulated change along the path. For example, if the destination point is only 10m north of the origin point, but the total accumulated north-south travel on the path is 500m, the ratio is 100, which is far too high to be realistic, or to be incorporated into a cost formula. Thus, the function that has been chosen to compare the two measurements is a difference function. The east to west or north to south difference between the origin point and the destination point is subtracted from the total accumulated east to west or north to south travel on the path, and this difference is divided by the total path length. Two values are created, a north to south difference and an east to west difference. These are then added together and divided by two, giving the average 'straightness inefficiency' (SI) for the path.

5.3) *Elevation Inefficiency Metric.* In finding a way to express the relative cost efficiency or inefficiency of a path in terms of elevation change, the sum of elevation differences along the path is contrasted with the change in elevation between the beginning point and the end point on the path. A difference function similar to that used for distance inefficiency and straightness inefficiency was created for elevation inefficiency (EI) as well. As with other measurements, the difference function is divided by a scaling factor based on distance. However, the magnitude of the numbers being contrasted in the case of elevation is in general ten times or more smaller than the numbers in the straightness function and many times smaller than the path distance measures. To mitigate this, another scaling factor of ten was added to the denominator of the difference function, meaning that the difference between the two elevation factors was divided by only a tenth of the overall path length, rather than the total path length. This creates numbers (0 to 3.72) that are in closer range with the variance of those created for distance and straightness inefficiency values (0.0 to.88).[12] A problem with dividing by the path length, as is done in estimating DI, is that within an origin destination pair's path set, paths with a shorter distance span now have higher scores of elevation cost inefficiency. Instead, the difference function for EI values was divided by the point to point distance, so that paths within origin-destination pair sets are scaled by the same factor.[13]

Sorting the data table into groups by each origin point and by network case or bus route allows for different types of comparison. In small groups of the paths created for each origin and destination point pair, paths can be compared using a model that correlates the lengths of the paths.

Individual variations in the path geometry are also observable in these small origin point groupings, and comparisons of individual path statistics can be made. The physical landscape of the study area is made visible in the map interface of the GIS allowing for a visual understanding of the network. In addition to the data tables, figures illustrating the path set of each origin-destination pair are included in the results, to provide images of the paths on the landscape.

6) Development of Model for Combining Efficiency Estimations into Cost Estimate

In creating the sort of models described in Bovy and Stern (1990), cost parameter estimates are usually created for each factor in the utility function. These are difficult to estimate, and aim to quantify the relative effects of different cost factors. In the absence of quantified attribute parameters, the form for the travel cost on a route remains in terms of the variables used, rather than reduced to a single number. This form, for the variables explored in the Iqaluit study, could be written as:

$$Cost\,of\;\;Path\;A = aPLP + aEI + aSI + aDI + aUF$$

Figure 3.39 Formula for estimating path cost.

The terms aEI, aSI, aDI are the inefficiency metrics for Path A, aUF represents the unknown factors in Path A's cost and aPLP represents Path A's length, in the form of a proportion that is scaled to fit the equation.[14] This seems to be a realistic form for estimating the cost measurement to be left in, as it assumes that there is room for other, non-included factors to contribute to the travel cost, and for the essentially unquantifiable nature of the cost of travel.

If an attempt were to be made to estimate cost beyond the form shown above, several versions of a formula for doing so can be proposed. If pairs of two paths are being compared, a formula adapted from the random utility model described by Bovy and Stern can be used to determine a potential measure of relative cost between the two paths. This has been done for many pairs of individual paths that share an origin and destination. In the case of comparing two or more paths, making a model that includes cost estimates can illuminate the approximate potential difference between the paths, without the major obscuring effect that would occur over a larger group. Cost estimates obtained in this manner must be seen as abstract measures, and the process for attaining the estimates must be transparent.

To compare large numbers of paths and gain potential cost estimates for each network case, such as a case with a given bus route, the cost factors may be kept in the form of a vector of cost attributes; and networks can be evaluated in terms of how they fare in the individual cost attribute categories. This avoids the potential danger of simplifying the concept of cost too much across a network. It also avoids obtaining statistics that obscure the patterns in the network by not taking into account unknown factors or unknown relations between factors. For the network level comparisons, only those trail or bus route paths that offer a cost change are included in an estimate table. This gives an idea of the added benefit of each route in the attribute categories.

7) Adapting the Formula for a Pair of Paths

A variety of potential formulas for calculating cost is proposed when comparing two paths in an origin destination point pair. Path length, in order to be put into a format that fits with the formula, is expressed as a proportion. That is, one path is set as having a length of '1' and the other path's length is expressed as 1 +/- the proportion of cost difference, by dividing one measure by the other. So, for two paths, one of length 1350m and the other of length 1800m, the path lengths become 1.0 and 1.339 respectively, or .747 and 1.0 respectively. This works providing that paths are being compared to one path as the basis of comparison. It does not work in cases where multiple paths are tabulated as having a certain cost without any correlation between the costs. Scaling the cost of a large set of paths to fit into an equation is a different matter, requiring either the estimate of a scaling parameter or the establishment of a set point and the setting of lengths as proportions according to the set point. The proportion method described will only be used in the model to compare sets of paths within an origin and destination point pair's set.

Path straightness inefficiency is included in the formula as shown in Section 6, that is, as a difference function. A version of the formula tested includes the elevation change efficiency and distance efficiency as the ratio functions shown above, while another version was created that shows the difference function for each of these two cost efficiency measurements. Overall, the formula including differences function is preferred, since higher values become scaled in relation to path length. The cost of additional inefficiency of the path in terms of elevation or straightness is likely to have a decreasing additional effect on cost, rather than a continuing linear increase. If a linear increase were the case, cost estimates on longer paths would be several times greater than those for shorter paths, rather than only proportionally greater. Since distance and length are already taken into account in the path distance comparison and distance efficiency comparison, it should be factored out in the other functions, to avoid accounting for it multiple times.

The formula chosen to compare two paths becomes:

$$Cost\,of\ \ Path\ A = 1 + aEI + aSI + aDI + aUF$$

$$Cost\,of\ \ Path\ B = bPL/aPL + bEI + bSI + bDI + bUF$$

Figure 3.40 Formula for estimating path cost for a pair of paths.

The terms aEI, aSI, aDI and bEI, bSI, bDI are the inefficiency metrics for Paths A and B respectively, aUF and bUF are the unknown factors of each path, and aPL and bPL are the path lengths of Paths A and B respectively.[15]

When the formula is written this way, the variance ranges for the values included in the equations determine the 'weight' of each factor. For the path length proportions, values are mostly between .5 and 2.0, giving this factor a relatively high weight compared to others. Variances for the path straightness efficiency statistic are between 0 and .59, meaning that a path has to be very inefficient in terms of excess angular travel for the importance of this to weigh as much as a given path distance. Likewise, values for the elevation difference and path distance inefficiency figures have variances between 0 and 1 in most cases, and are less than .5 in a majority of these cases.[16]

According to the tables listed in Bovy and Stern (1990), travel distance is a highly weighted factor, with slope, path angularity and other factors exerting a lesser force that varies by the study area and by other factors known and unknown. To weight the factors as relatively large or relatively small in importance is the most that can be done with the data in its current form. By scaling the parameters to have relative weights, the step of creating artificial weights for the factors is skipped. However, it is important to realize that the relative weighting of these measurements is subjective, and creates an estimate of cost that is merely a guideline for how paths are likely to compare to each other.

8) Development of Travel Time Cost Proportion Estimates

In the case of comparing paths with a bus route component, an additional factor of travel time cost can be evaluated in relation to the difference in mode. Variables to be considered separately and as co-factors in travel time cost are: (1) the travel time cost estimate made by the plugin using the 5 times speed assumption, which will be a number between one and five times greater than the path length[17], and (2) the proportion of the travel time cost estimate to the path length. This proportion is by default '5' in the cases with no bus segments, as the walking speed is assumed to be five times that of bus speed. In paths with a bus component, the travel time cost becomes smaller, to a possible minimum of '1' for a path that is covered completely by a bus route[18]. Given the recent work on isochrones by Brainard et al.. (1997) and commute times vs. distances by O'Kelly and Niedzielski's (2008) and Rodriguez (2004), time cost estimates are significant in comparing transport modes. It must also be considered, though, that a bus route that takes longer to reach an eventual destination than a much more direct walking route, may not be worth the effort to use transit.[19]

9) Analysis of Data and Shortest Path Map Set

A problem arises when comparing walking and bus paths for determining the relative cost of elevation change and path straightness for a walker and a transit user. For a bus to go out of its way or to make turns is less of an added effort for a person on a bus than it is for a person walking. One possible way of accounting for this in the model is to add the travel time factor into the equation as a highly weighted factor. To this end, paths with no bus component have 5 added to them, while paths with a bus component have their travel time cost proportion estimate added. This method rests heavily on the correctness of the time estimates given for buses and for average walking speeds.[20]

Alternatively, the travel time cost proportion and the cost inefficiency estimate could be kept separate and viewed as two pieces of the cost potential. This would preserve the geographic information estimated by the paths, as well as giving an estimate of the travel time, a factor important enough that it should perhaps be kept on its own for consideration. In the results section that follows, both separate travel time cost estimates and total cost estimates are used, in illustrating the differences between the path options. Data tables include the inefficiency estimates, path travel time cost estimates and the travel time proportion estimates, rather than the combined cost estimates, as this makes transparent the components of the combined travel cost estimate. The combined estimate is obtained by adding together the inefficiency estimate and the travel time cost proportion estimate, and has not been included in the data tables. It is mentioned throughout the results section as a supplement to the inefficiency and travel time cost proportion estimates.

Chapter Three notes

1 The precise location of origin points can vary slightly in the path formulations, as individual neighbourhoods can be represented by one house or by another. In general, areas referred to as a destination point are within 50m of one another, and the variation occurs to facilitate the path creation process, which is discussed in detail later in the methods section.
2 While major roads are included in the descriptions of the commercial and residential areas of Iqaluit, minor roads and trails are not generally mentioned in the study area section. Trails and minor roads are described in the results section, at times when they become part of the paths that are being described.
3 A note on road names in Iqaluit: The official names for roads are in Inuktitut, but non-Inuktitut speakers that I spoke with tended to name roads based on their locations, or on English names. Long-term residents and Inuktitut speakers use the official names, but in my experience the English names were mainly used in English conversation. It is for ease of writing and reading that I use the English names here, with the understanding that the Inuktitut names are the official names for Iqaluit's roads.
4 The board-bridge was present in the summer of 2008.
5 Referred to as the “Arena” through this report.
6 The area around the AWG Arena can be seen in the following section, on the maps of the eastern suburbs. The AWG Arena is marked on the general map of Destination Points (Figure 3.1) .
7 Individual origin points within the neighbourhoods are depicted in the maps in the results section, with the shortest paths.
8 Referred to variously as the 'Plateau Subdivision', the 'Plateau', and 'PS'.
9 The area including the subdivision and its access road is referred to variously as the 'Road to Nowhere', or 'RTN'. The subdivision of is also referred to as the 'RTN loop' or the 'RTN Subdivision', while the section of the RTN that serves as access road to both the RTN loop and the Lake Subdivision is referred to as the 'Road to Nowhere' or the 'RTN'.
10 Discussions of the financial cost of transit systems are beyond the scope of this study. Financial considerations are critical at the implementation level of transportation planning, while the study here aims to provide background to the planning process by attempting to map the potential costs of transit and walking travel.
11 The trails included in the trail layer are those on the city's GIS database. Not all trails listed on the database are in good repair or accessible at all times of the year. Estimates that include trails provide for the potential for trails to be in usable condition, and can be seen as supporting the case for maintaining trails around Iqaluit.
12 The range of variance for the elevation inefficiency metric shows extreme values where point to point distance is short and the excessive elevation travel is great. 3.82 is an extreme outlier for elevation inefficiency, with most values for EI being between .01 and 1.66.
13 Point to point distance was chosen as the scaling factor in the case of EI, while path length was used in calculating DI and SI. It was decided that for EI the range of numbers in the numerator(1 to 250) make the differences between the path lengths(often in the hundreds) account for too much difference in the EI estimate. In the case of SI and DI, because of the magnitude of the numbers in the numerator (100-3300), the effects of the differences between the path lengths do not overshadow the other factors in the estimate. As the use of path length mitigates the creation of extreme values in the inefficiency estimated, path length was preferred to using the point to point distance. Aside from the difference in number magnitudes, the use of the point to point distance rather than path length in the EI measurements accounts for the more extreme values for this metric.
14 The scaling of the path length to fit equations will be discussed in Section 7. Unless otherwise stated, the PLP of the path is 1.
15 bPL/aPL is the path length proportion used for Path B. It could also be written as bPLP.
16 Elevation Inefficiencies in some cases have values as high as 3.72 for paths that include a bus component, but most values are less than 1.
17 The measure of cost is taken from the first point of the first segment to the last point of the last segment on the path, so is not truly a 'point to point' measure of path length.
18 The 1 left in the bus segment paths can be seen as a small 'wait time' penalty, for the assumed time a traveler must spend waiting for a bus, if a bus system is running on time. (Obviously, in reality this wait

time could represent a much larger cost. A study that looks at actual bus wait times in existing transit networks would be required to determine this.

19 Creating accurate measures to compare the relative costs of bus vs. walking travel is beyond the scope of the project. The study attempts to provide possible ways of measuring travel cost, but acknowledges that the estimates and comparisons made are only best estimates given the metrics being explored.

20 An alternative would be to scale the factors that contribute to the model in the bus route paths by a given factor. A justification for a scaling factor would need to be thought out that bears relation to real patterns, and the proportions of paths that are bus or walking travel would have to be considered as well.

Chapter 4

RESULTS

Findings for Individual Paths

This section will review the GIS results for paths created for origin point sets, based in the neighbourhood regions of Iqaluit. Groups of paths will be viewed in terms of their map geometry, comparative cost attributes and best fit network options. Where more than one path between an origin and destination pair is available, the paths have been compared using an adaptation of the random utility model, as described in the methods section. Paths that do not have a directly comparable alternative for their origin destination pair are reviewed individually and as part of their origin point group. The results are organized by geographical neighbourhoods within Iqaluit.

Northwestern Region

The group of origin points on the hill to the northwest of the centre of town are some of the less accessible points in Iqaluit (Figure 4.1). There is only one road leading to the Plateau Subdivision, though there are multiple roads on the ridge. This creates a 'pinch point' for travel, where all travelers from this area must be funneled down one steep road. The furthest out point chosen for the study, 'Plateau Subdivision 2'(PS2), is located in the second phase of the subdivision, which was in the development permit phase during 2008. 'Plateau Subdivision 1' (PS1) is in the first phase of the development, which is already completed and is at a lower elevation than the second phase (Figure 4.1). As shown in Tables 4.1a and 4.2a, this area is characterized by low levels of elevation inefficiency (EI) on most paths (<.25 for difference value). It is strictly downhill to most destinations in town, but the elevation change itself is great, due to topography. Elevation changes in the paths created are from -37 to -89 meters, with the only destination point higher than the Plateau points being in the northeast section of town. For the journey to the Arena, from PS2 and PS1 respectively, there are +1m and +16m elevation gains. EIs are .30 to .41, which are medium values, while the accumulated elevation changes are 90 to 123, making for EI ratios that are 5.63 to 6.88 in the case of PS1, and very high, 103-123 in the case of PS2 (Table 4.1-2a).[1]

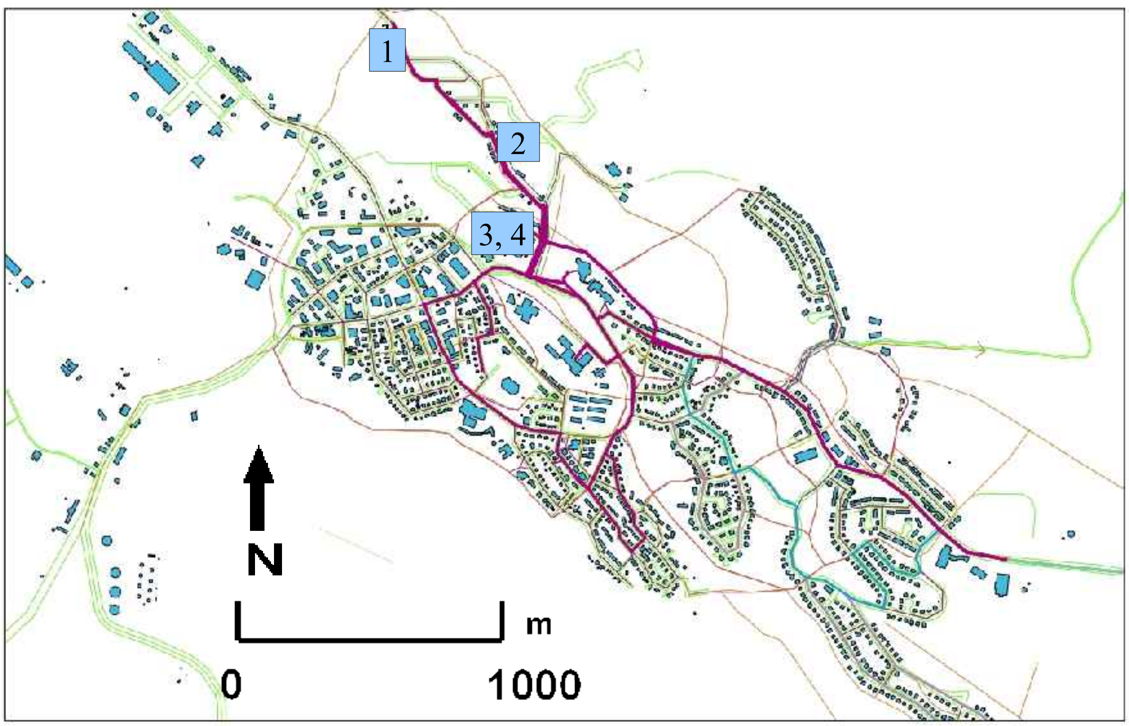


Figure 4.1 Path Set for Origin Points in the Northwestern Region. Purple lines indicate paths. 1) PS2. 2) PS1. 3) Housing Above Arctic College. 4) Arctic College.

Table 4.1a Results for GIS Analysis of Paths Originating at Plateau Subdivision 1

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-89	74	.19	.01	.13
New Hospital	Trails	-52	85	0	.13	.1
NorthMart	Trails	-87	82	.32	.11	.23
NorthMart	Roads	-87	71	.28	0	.17
Arena	Roads	1	110	.03	.38	.12
Arena	Trails	1	108	0	.30	.08
Frobisher	Roads	-58	64	.27	.25	.33
Frobisher	Bus Route 2	-57	120	.47	.87	.68
Frobisher	Bus Route 4	-47	112	.47	.78	.74

Table 4.1b Results for GIS Analysis of Paths Originating at Plateau Subdivision 1

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1325	1518	7619		5
New Hospital	Trails	595	660	3300		5
NorthMart	Trails	990	1290	6785	1.66	5
NorthMart	Roads	990	1195	5975	1.37	5
Arena	Roads	2460	2780	13900	1.53	5
Arena	Trails	2460	2660	13300	1.41	5
Frobisher	Roads	870	1290	6450	1.85	5
Frobisher	Bus Route 2	870	2680	4840	4.1	1.81
Frobisher	Bus Route 4	870	3366	3925	4.61	1.17

Table 4.2a Results for GIS Analysis of Paths Originating at Plateau Subdivision 2

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-89	97	.13	.04	.05
New Hospital	Trails	-52	54	.06	.02	.19
New Hospital	Roads	-52	69	.26	.16	.24
NorthMart	Trails	-87	87	.26	0	.28
NorthMart	Roads	-87	87	.18	0	.28
Arena	Roads	1	123	.03	.41	.11
Arena	Trails	1	121	0	.34	.08
Frobisher	Roads	-57	77	.18	.14	.26
Frobisher	Bus Route 2	-57	127	.4	.5	.55
Frobisher	Bus Route 4	-57	127	.45	.5	.64

Table 4.2b Results for GIS Analysis of Paths Originating at Plateau Subdivision 2

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1800	1891	9483		5
New Hospital	Trails	1090	1345	6725	1.21	5
New Hospital	Roads	1090	1425	7125	1.52	5
NorthMart	Trails	1380	1910	9550	1.54	5
NorthMart	Roads	1380	1910	9550	1.46	5
Arena	Roads	3000	3373	16879	1.54	5
Arena	Trails	3000	3266	16352	1.45	5
Frobisher	Roads	1400	1890	9480	1.21	5
Frobisher	Bus Route 2	1400	3128	8290	3.11	2.65
Frobisher	Bus Route 4	1400	3858	5008	3.62	1.3

From Tables 4.1 and 4.2 it can be seen that each measurement presents a slightly different angle on the question of elevation and its place in the formulation of travel cost. The elevation difference shows the actual elevation change between the start and end points, while the sum of elevation differences quantifies exactly how much vertical travel is needed. The difference function attempts to put this in the context of potential overall cost by dividing the amount of excess vertical travel required by the path length. It could be said that the difference function underestimates the EI in the case of the path from PS2 to the Arena by the road network (Table 4.2a). The vertical travel required (123m) is much larger than the overall elevation change (1m), while the EI measured by the difference function (.41) is in the lower measures of variance for that measurement (.01-3.82). However, the distance function does scale the measurement to the point to point distance, and so isolates the EI, or unnecessary vertical travel, as a separate factor to the path length. This mitigates the problem of redundant inclusion of path length.[2]

Tables 4.1 and 4.2a also show that path straightness inefficiency (SI) values are also relatively low (<.32). The neighbourhood's access road is on a diagonal angle that leads straight into town, and not much turning is needed to access destinations. Distance efficiency (DI) difference measurements range from .1 to .33, which is in the lower half of variance for this measurement. Exceptions for elevation, distance and straightness inefficiency are the paths with bus route segments, as is to be expected. SIs for the bus route paths for the Plateau origin points are .4 to .47, EIs are .5 to .87, and DIs are .55 to .74.[3]

Comparing point pairs with identical origins and destinations in Table 4.2b, the paths from PS2 to the New Hospital show differences between the network that includes trails and the network that relies only on roads. As shown in Figure 4.1b, the path along the road requires walking down to the top of the Ring Road and then walking back up the steep driveway or the staircase outside the hospital to get to the entrance (Figures 3.5, 3.8). A trail that leads off from the Plateau access road, along the ridge to the back of the hospital saves the traveler in terms of elevation, distance and path straightness (Figure 4.1). Use of this path assumes that there is a way to get into an entrance from the back of the hospital, and that the path is accessible given weather conditions and trail maintenance. The savings in elevation inefficiency on the trail enabled path is 15m of elevation change, or an EI decrease from .16 to .02, which is a very low EI difference measure (Table 4.2a). DI decreases from .24 to .19, and actual travel distance decreases from 1425m to 1345m. SI improves from .06 to nearly 0, as the path is almost directly straight to the hospital building. As can be seen in Table 4.2b, the overall 'inefficiency' (as based on the formula described in the methods section), decreases from 1.52 to 1.21 when a trail from the Plateau to the hospital along the ridge is used.

By contrast, existing trail options between the Plateau origin points and NorthMart offer little improvement over the road network (Tables 4.2a and 4.2b). Straightness and distance measurements are the same or slightly less optimal with the trail route. The existing trail options allow for a minor cost saving between the Plateau and the AWG Arena, of about 100m in distance, bringing DI down from .12 to .08. The trail to the Arena is the same trail that leads east from the Plateau access road and behind the hospital, followed further east until it meets with Apex Road (Figure 4.1). SI is near zero with the trail option, meaning there is little need to zig-zag, while it is only .03 on the road only option, meaning the change is not very great.

Comparing the bus route options with the road options gives an idea in this case of how the various bus routes proposed might fare. Time cost estimates for the paths leading from the Plateau are lower for those paths that incorporate a bus route (Tables 4.1b and

4.2b). Time costs for PS1 to the Frobisher Complex are 4840 and 3925, respectively, for all of Bus Routes (1, 2, and 3) and for Bus Route 4. The same path with no bus option has a time cost estimate of 6450.[4] The cost to distance ratio decreases from 5 in the base case to 1.81 in the case of Bus Routes (1, 2, 3, and 5) and to 1.17 in the case of Bus Route 4.

If the formula that includes straightness and other efficiency measures is combined with the time cost ratio, the values for the bus route paths are lower than for the base case path (Table 4.1b). PS1 is given as an example, but the value pattern is similar for PS2. For the base case, this is 5 + 1.85 (6.85), while for Bus Route 4 it is 4.61 +1.17 (5.77), and for the other bus routes it is 4.1 + 1.81 (5.9). Bus Route 4 creates an overall travel cost estimate of 4.92, which is lower than the others. Bus Route 4 travels up to the Plateau, making it the best travel cost saving option for the Plateau (Figure 4.1a or b). The trade-off is its negative addition to the travel costs of other paths that make an unnecessary journey up to the Plateau before reaching their destinations. As well, all of the bus routes decrease required uphill walking from 11m to 0.

The origin points of Arctic College and the medium density housing development above it have similar figures to the Plateau Subdivision, but with smaller cost saving benefits (Tables 4.3a-b and 4.4a-b) and (Figure 4.2).

Table 4.3a Results for GIS Analysis of Paths Originating at Arctic College

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-27	59	.2	.38	.28
New Hospital	Trails	11	11	.07	.07	.08
NorthMart	Roads	-23	23	.26	.26	.32
Arena	Roads	62	65	.01	.01	.05
Frobisher	Roads	5	18	.3	.3	.44
Frobisher	Bus Route 1	5	69	.51	1.49	.8
Frobisher	Bus Route 2	5	73	.52	1.6	.81

Table 4.3b Results for GIS Analysis of Paths Originating at Arctic College

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	835	1157	5818		5
New Hospital	Trails	280	305	1065		5
NorthMart	Roads	500	734	3999		5
Arena	Roads	2140	2251	11263		5
Frobisher	Roads	430	770	3850	2.05	5
Frobisher	Bus Route 1	430	2203	2203	5.66	1
Frobisher	Bus Route 2	430	2215	2215	5.81	1

Table 4.4a Results for GIS Analysis of Paths Originating at Housing Above Arctic College

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-42	74	.19	.34	.25
New Hospital	Trails	-5	15	0	.5	.22
New Hospital	Roads	-5	23	.29	.9	.51
NorthMart	Roads	-38	38	.24	0	.33
Arena	Roads	57	76	.03	.09	.07
Arena	Trails	57	78	.01	.1	.1
Frobisher	Roads	-10	30	.35	.41	.46
Frobisher	Bus Route 1	-9	83	.47	1.51	.79
Frobisher	Bus Route 2	-10	86	.47	1.55	.79
Frobisher	Bus Route 4	-11	79	.5	1.39	.83

Table 4.4b Results for GIS Analysis of Paths Originating at Housing Above Arctic College

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	950	1266	6363		5
New Hospital	Trails	200	256	1668	1.72	5
New Hospital	Roads	200	412	2069	3.31	5
NorthMart	Roads	640	955	5462		5
Arena	Roads	2150	2302	11545	1.19	5
Arena	Trails	2150	2395	11992	1.23	5
Frobisher	Roads	490	900	4412	2.21	5
Frobisher	Bus Route 1	490	2365	2915	5.4	1.23
Frobisher	Bus Route 2	490	2365	2915	5.44	1.23
Frobisher	Bus Route 4	490	2912	2912	5.96	1

Southwestern Region

To the south of the Plateau and at the west end of town are another set of points that can be interpreted as a group. There are four points in this group: a point to represent the industrial area of town, a point to represent Inuksugait Plaza (Figure 4.2.),[5] a point to represent the block of apartments on the road leading to the airport,[6] and a point to represent the Lower Base neighbourhood (Figures 3.11, 3.12) . As shown in Table 4.5a-b, the paths from the industrial point tend to have very low scores for straightness, distance and elevation inefficiency. Most values are below .2. The only exception is the road network path to the Frobisher Complex, which requires travel to the east on the Ring Road and then back west on the Frobisher Complex access road. The trail option for this path is the trail that cuts across the top of the ridge, from the west end of the Ring Road, past the high school and to the Frobisher Complex (Figure 4.2). This path is useful for all of the points in this set, and indeed the entire west side of town, in gaining access to the Frobisher Complex. Travel cost using the random utility type formula decreases from 1.47 in the base case to 1.02 with the use of the trail along the ridge. Path SI measures decrease from .13 in the base case to near zero in the trail option case. The bus routes all have similar effects on the points in this group, since all the routes designed for this GIS analysis are nearly identical after the point of the Plateau access road. For the industrial point, travel cost estimates that sum the formula with the travel time estimate give a value of 4.81 with bus routes, 6.02 for the trail option, and 6.81 for the road only option (Table 4.5b).

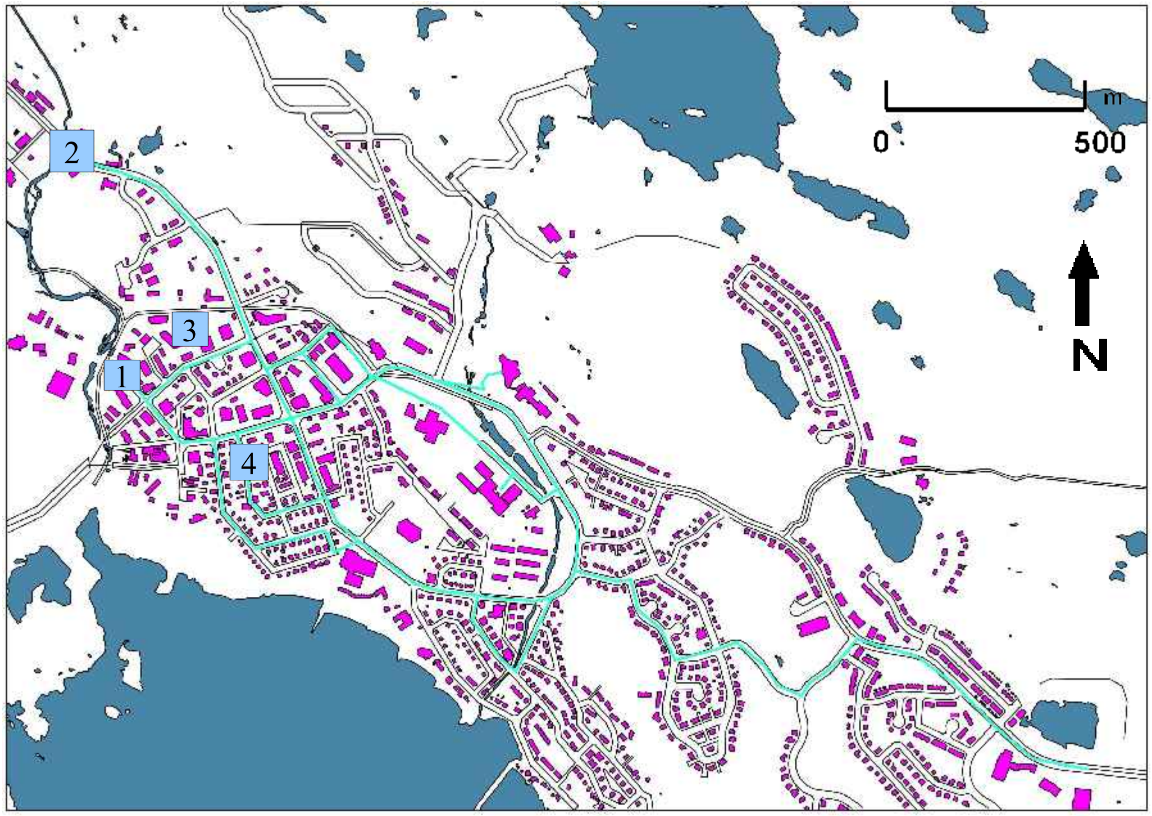


Figure 4.2 Path Set for Origin Points in the Southwestern Region. Light blue lines indicate paths. 1) Airport Apartments. 2) Industrial Area. 3) Inuksugait Plaza. 4) Lower Base.

Figure 4.3 One of the three apartment/office buildings in Inuksugait Plaza.

Table 4.5a Results for GIS Analysis of Paths Originating at Industrial Area

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-15	25	0	.05	.06
New Hospital	Trails	21	25	.05	.03	.18
NorthMart	Trails	-13	13	0	0	.02
NorthMart	Roads	-13	13	0	0	.02
Arena	Roads	74	33	.01	.2	.06
Frobisher	Roads	16	29	.13	.08	.24
Frobisher	Trails	16	140	0	.11	.1
Frobisher	Bus Route 2	16	55	.31	.25	.46

Table 4.5b Results for GIS Analysis of Paths Originating at Industrial Area

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1900	2026	10130		5
New Hospital	Trails	1410	1717	8613		5
NorthMart	Trails	1425	1450	7250	1.02	5
NorthMart	Roads	1425	1450	7250	1.02	5
Arena	Roads	3315	3540	17700		5
Frobisher	Roads	1565	2050	10940	1.47	5
Frobisher	Trails	1565	1730	8650	1.02	5
Frobisher	Bus Route 2	1565	2873	7195	2.3	2.5

For the Inuksugait Plaza point, inefficiency scores are very low for paths to NorthMart, the clinic and the Arena, due to the mainly straight line paths along the lower half of the Ring Road, and Apex Road in the case of the Arena (Table 4.6a-b). Paths to the hospital and the Frobisher Complex have higher inefficiency scores, as a walker must zig zag through side streets that are at an angle and counter to the direction of travel. As with the industrial point, the trail along the ridge to the Frobisher Complex gives a great cost saving, and the bus route option gives a saving in overall travel time cost from 1.86 to 1.64, and for DI, from 1.67 to 1.3. The bus routes give a travel cost efficiency estimate of 1.79, as opposed to the assumed 5 for the base case.

Table 4.6a Results for GIS Analysis of Paths Originating at Inuksugait Plaza

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-11	27	.08	.13	.07
New Hospital	Trails	19	27	.22	.09	.21
NorthMart	Roads	-10	14	0	.06	0
Arena	Roads	78	105	.08	.1	.16
Frobisher	Roads	20	31	.34	.12	.4
Frobisher	Trails	20	31	.16	.12	.23
Frobisher	Bus Route 1	20	62	.35	.48	.58

Table 4.6b Results for GIS Analysis of Paths Originating at Inuksugait Plaza

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1200	1290	6450		5
New Hospital	Trails	855	1080	5400		5
NorthMart	Roads	720	720	3150		5
Arena	Roads	2700	3214	16100		5
Frobisher	Roads	920	1535	7712	1.86	5
Frobisher	Trails	920	1200	6000	1.64	5
Frobisher	Bus Route 1	920	2204	3943	2.85	1.79

For the Airport Apartments and their surrounding area, inefficiency scores are low (<.22) for those paths that run with the grain of the road network, using the Ring Road and Apex Road, such as the path to the Arena and NorthMart (Tables 4.7a-b). Scores are also relatively low for accessing the Frobisher Complex by trail and only slightly higher for the path to the New Hospital entrance. Accessing the Frobisher Complex by road requires going out of one's way on either the higher or lower side of the Ring Road. Bus Route 1 gives the best saving over the base case with a travel time cost estimate of 1.94 and a total cost estimate of 4.9, which is relatively low. The point chosen in the Lower Base neighbourhood has similar results to the airport apartment block, with Bus Route 1 giving even more improvement down to 1.3 for travel time cost, and overall travel cost estimate 3.99 (Tables 4.8a-b). The Lower Base point is very close to the route and walking travel is reduced. EI and DI scores, however, are fairly high (.55 and .65) for the Lower Base bus route path.

Table 4.7a Results for GIS Analysis of Paths Originating at Airport Apartments

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
New Hospital	Trails	25	31	.25	.06	.22
NorthMart	Roads	-7	22	.05	.18	.21
Arena	Roads	80	107	.12	.1	.2
Frobisher	Trails	22	34	.15	.11	.21
Frobisher	Roads	22	38	.29	.15	.36
Frobisher	Bus Route 1	21	61	.38	.37	.53
Frobisher	Bus Route 2	22	68	.3	.43	.63

Table 4.7b Results for GIS Analysis of Paths Originating at Airport Apartments

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
New Hospital	Trails	1050	1351	6784		5
NorthMart	Roads	820	1040	5236		5
Arena	Roads	2830	3557	17873		5
Frobisher	Trails	1080	1375	6900	1.47	5
Frobisher	Roads	1080	1700	8500	2.04	5
Frobisher	Bus Route 1	1080	2310	4470	2.96	1.94
Frobisher	Bus Route 2	1080	2912	5958	3.47	2.05

Table 4.8a Results for GIS Analysis of Paths Originating at Lower Base

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-6	32	.06	0.27	.19
New Hospital	Roads	25	31	.09	.08	.07
NorthMart	Trails	-7	18	.1	.22	.27
NorthMart	Roads	-7	17	.07	.2	.26
Frobisher	Trails	26	30	.2	.05	.21
Frobisher	Bus Route 2	19	59	.39	.55	.65

Table 4.8b Results for GIS Analysis of Paths Originating at Lower Base

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	960	1190	5950		5
New Hospital	Roads	750	810	4050		5
NorthMart	Trails	490	670	3250	1.6	5
NorthMart	Roads	490	670	3300	1.52	5
Frobisher	Trails	730	929	4663	1.02	5
Frobisher	Bus Route 2	730	2065	2686	2.69	1.3

Central Region

One origin point, that chosen to represent the block of housing below the Frobisher Complex, is in the centre of the area enclosed by the Ring Road, and does not fit easily into any group of other origin points. Its path set has odd inefficiency measurements, due to its being very geographically close to the main areas of town but not close to the road network (Table 4.9a-b) (Figure 4.4). Paths to the Frobisher Complex and Old Hospital entrance have DI scores of .52 to .86, which are high for paths that do not include bus travel. There is a boardwalk trail from the road below the Frobisher Complex to the east edge of the Ring Road (Figure 4.5), that makes the trail options more efficient than the road only path options, improving DI scores from .63 to .52 and from .86 to .82. Bearing in mind that figures at the high end of the variance for this measure tend to be compressed, the differences gained by the trail option are quite high in actual distance, decreasing the path lengths by 200-230m.[7] By contrast, paths to the Arena and to the clinic from the road below the Frobisher Complex are quite efficient. Proposed bus routes do not improve overall travel costs greatly for this point for most measures made, though uphill walking can be greatly decreased, and travel time costs can be reduced from 5 to 1.69. The overall travel cost estimate is close to 6, which is somewhat lower than the 7.34 estimate for travel cost for the trail option to the Frobisher Complex, but is not as low as the scores attained by the bus route options for many other points.

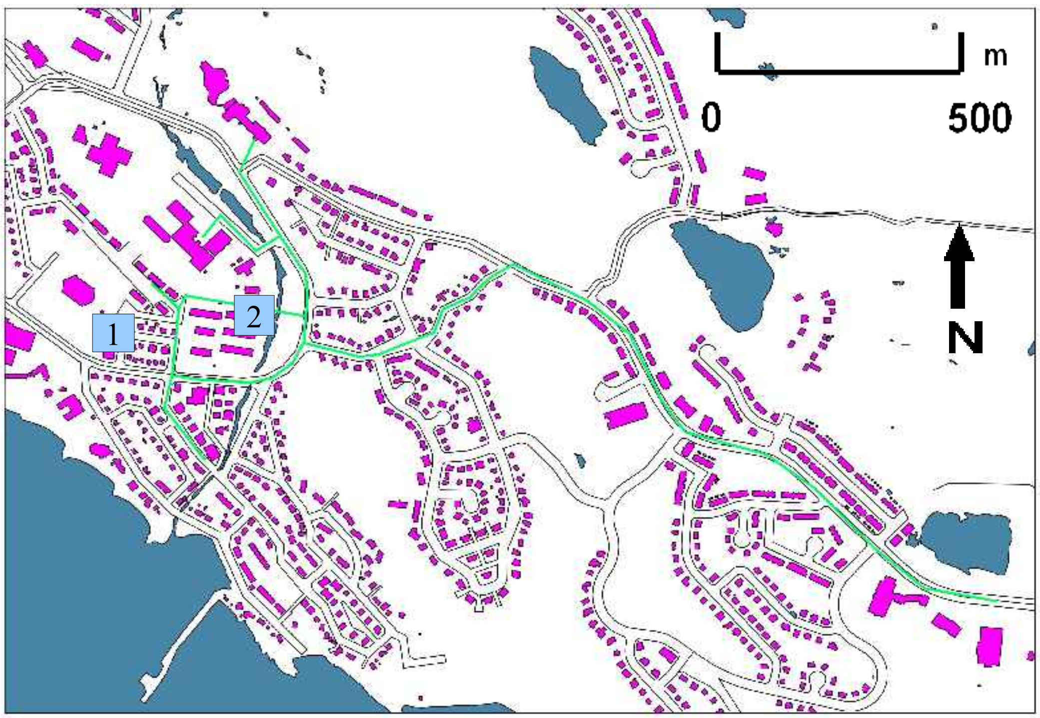


Figure 4.4 Path Set for Origin Points in the Central Region. Green Lines indicate paths. 1) Housing Below Frobisher Complex. 2) Walkway in Figure 4.5.

Figure 4.5 Board walkway from Nakasuk Elementary School and the Area below the Frobisher Complex, to the Eastern edge of the Ring Road.

Table 4.9a Results for GIS Analysis of Paths Originating at Housing Below Frobisher Complex

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-11	13	.08	.05	.1
Old Hospital	Roads	28	40	.36	.33	.63
Old Hospital	Trails	28	28	.3	0	.52
Arena	Roads	78	86	.11	.04	.19
Arena	Trails	78	91	.09	.07	.16
Frobisher	Roads	20	35	.49	1.03	.86
Frobisher	Trails	20	23	.51	.21	.82
Frobisher	Bus Route 1	21	45	.56	1.66	.88
Frobisher	Bus Route 2	21	45	.56	1.66	.88

Table 4.9b Results for GIS Analysis of Paths Originating at Housing Below Frobisher Complex

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	415	460	2300		5
Old Hospital	Roads	365	985	4880	2.31	5
Old Hospital	Trails	365	753	3765	2.08	5
Arena	Roads	1850	2290	11450	1.35	5
Arena	Trails	1850	2190	10950	1.27	5
Frobisher	Roads	145	1030	5150	3.38	5
Frobisher	Trails	145	820	4100	2.34	5
Frobisher	Bus Route 1	145	1234	2080	4.3	1.69
Frobisher	Bus Route 2	145	1234	2080	4.3	1.69

Central-Eastern Region

The next group to be reviewed is the set of points above the Ring Road on its east side, below Apex Road. A point above the Ring Road, in the middle of the long first block of Apex Road, was chosen to illustrate some of the paths in that area, while a point further up Apex Road, at its first junction away from the Ring Road, was chosen to show other trails and road options (Figure 4.6). At the second junction of Apex Road is another point, called 'Flower Valley' (FV),[8] which has its starting point in some cases at the Apex Road junction and in other cases at the junction of the road and trail down the hill from Apex Road. The neighbourhood of Happy Valley is also included in this set, as it is very geographically close by and on a similar plane of elevation. The variations in this set of origin points reflect the tightly knit nature of the roads and trails in this area. Multiple origin points were needed to create paths that made use of each trail. The cut through trail from Apex Road to the Ring Road makes for an almost completely straight path from Apex Road to the clinic, with very low inefficiency scores for all measurements (Table 4.10a). The path to Arctic Ventures has scores almost as low, with only a vertical straightness inefficiency of .19. The path to the Arena, directly along Apex Road, also requires almost no extra distance, off course travel, or excess elevation change.

For the point slightly further along Apex Road, at the first junction where a connecting road branches south, the inefficiency scores for paths to the Frobisher Complex are in the medium range (.28 -.48). Scores stay low for the clinic, hospital and the Arena, which still have fairly efficient paths, even with just the road network available for travel. Without the connecting trails, there is no efficient way to get from Apex Road point to the Ring Road without adding north-south travel on the connecting road, or east-west travel on Apex Road. The cut through paths that lead from Apex Road to the Ring Road make the Frobisher Complex more accessible than roads alone, since the road that leads most closely to the Frobisher Complex access road is a cul-de-sac and does not connect with the Ring Road. For this origin point, no paths were created with duplicate destination points, so path inefficiency estimates were calculated using "1" as the proportion of measurement for the path length. The EI, DI and SI were simply added onto "1" to gain an inefficiency estimate (Table 4.10b).

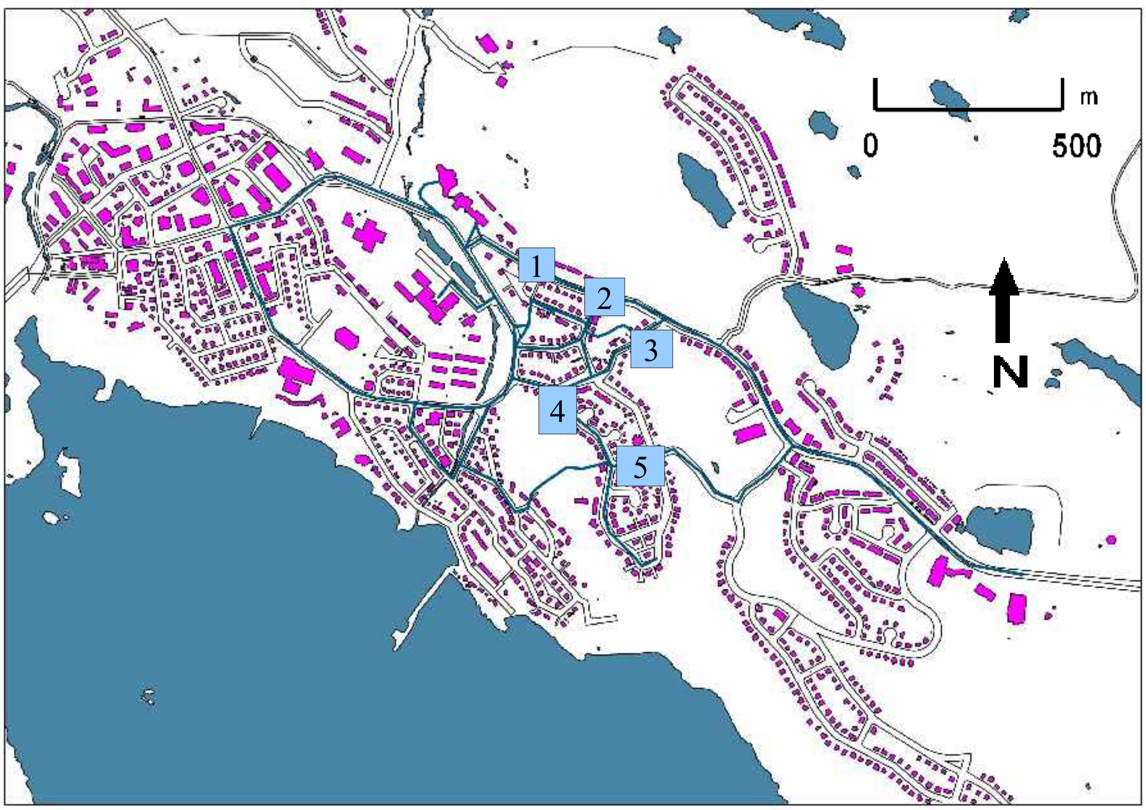


Figure 4.6 Path Set for Origin Points in the Central-Eastern Region. Blue lines indicate paths. 1) Point Above Ring Road. 2) Apex Road 1. 3) Flower Valley. 4) HV1. 5) HV2.

Table 4.10a Results for GIS Analysis of Paths Originating at Point Above Ring Road

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-39	39	0	0	.09
Arena	Roads	45	47	0	.01	.05
Ventures[9]	Trails	-34	34	.09	0	.27

Table 4.10b Results for GIS Analysis of Paths Originating at Point Above Ring Road

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	600	660	3320	1.09	5
Arena	Roads	1540	1621	8101	1.06	5
Ventures	Trails	470	640	3297	1.27	5

Table 4.11a Results for GIS Analysis of Paths Originating at Apex Road 1

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Roads	-44	44	.05	0	.06
New Hospital	Roads	-7	26	.12	.35	.19
Frobisher	Roads	-10	31	.28	.48	.37
Frobisher	Bus Route 1	-10	86	.62	1.73	.85
Frobisher	Bus Route 4	-13	181	.54	3.82	.91

Table 4.11b Results for GIS Analysis of Paths Originating at Apex Road 1

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Roads	630	670	3350		5
New Hospital	Roads	540	670	3350		5
Frobisher	Roads	440	700	3500	2.13	5
Frobisher	Bus Route 1	440	2916	2916	7.36	1
Frobisher	Bus Route 4	440	4953	4953	12.34	1

To illustrate the use of these trails, the next origin point in the set can be observed. The point called 'Flower Valley' (FV) has been named for the area of lichen and arctic flowers enclosed by the first two roads that branch south and downhill from Apex Road (Figure 4.6). Trails run through this area, between the houses, and connect to the trail that leads to the Ring Road. Inefficiency scores are very low for most of the paths that connect this point to destinations, indicating that this part of the network is quite efficient for walking, if the trails are available (Table 4.12a). The close knit network of roads in the area make it fairly easily traversed even without trails, but the trails provide additional travel options and 'short cuts' to individual destinations. The exceptions to this are the paths leading to the Frobisher Complex, which still require some out of the way distance travel (SI scores of .19 and .26 for trail and road options, respectively) and some elevation loss and regain, due to the topography of the area.

Bus route paths to the Frobisher Complex from FV have high inefficiencies, and high overall costs, but bus travel from this area to the west side of the Ring Road, such as the area around NorthMart and the government offices and shops in the centre of town, is worthwhile, particularly in bad weather. Travel to this area from the city centre by bus is also a likelihood, given its high elevation above the main area of town. Though it is not far out in distance, this neighbourhood could still benefit from transit options.

The neighbourhood of Happy Valley (HV) is located directly to the south of the FV origin point area. HV has relatively good access to the main areas of town, with low straightness inefficiency scores on most paths (Table 4.13a-b and 4.14a-b). Access to lower Iqaluit is less efficient from HV if trails are not available. The trail along the hilltop south of HV provides another option for accessing Lower Iqalulit and the waterfront area near the clinic (hill-top visible in Figure 3.22). This trail requires an additional elevation cost however, since the ridge is at a higher elevation than HV. There are benefits from all the bus routes, in a pattern that is similar to the Flower Valley area.

Table 4.12a Results for GIS Analysis of Paths Originating at Flower Valley

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-48	48	.07	0	.22
Old Hospital	Trails	-15	25	.17	.19	.2
Ventures	Trails	-43	43	0	0	.1
Ventures	Roads	-43	49	0	.1	.1
Arena	Roads	41	42	.04	.01	.08
Frobisher	Roads	-17	40	.26	.41	.34
Frobisher	Trails	-17	34	.19	.3	.17
Frobisher	Bus Route 3	-17	95	.54	1.39	.83
Frobisher	Bus Route 4	-23	191	.57	3	.9

Table 4.12b Results for GIS Analysis of Paths Originating at Flower Valley

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	660	850	4250		5
Old Hospital	Trails	540	672	3369		5
Ventures	Trails	590	655	3275	1.1	5
Ventures	Roads	590	655	3275	1.2	5
Arena	Roads	1225	1329	6639		5
Frobisher	Roads	560	845	4225	2.01	5
Frobisher	Trails	560	675	3375	1.46	5
Frobisher	Bus Route 1	560	3220	3620	6.57	1.12
Frobisher	Bus Route 2	560	5335	5335	10.77	1

Table 4.13a Results for GIS Analysis of Paths Originating at Happy Valley 1

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Old Hospital	Trails	6	34	.08	.27	.15
Old Hospital	Roads	6	30	.08	.23	.15
Ventures	Trails	-24	55	.09	.42	.22
Ventures	Roads	-24	29	.1	.07	.24
Frobisher	Roads	-1	25	.11	.26	.19
Frobisher	Bus Route 2	-1	26	.01	.27	.27
Frobisher	Bus Route 3	-1	123	.51	1.31	.77

Table 4.13b Results for GIS Analysis of Paths Originating at Happy Valley 1

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficienc y Estimate	Travel Time Proportion Estimate
Old Hospital	Trails	1045	1230	6180	1.5	5
Old Hospital	Roads	1045	120	6174	1.46	5
Ventures	Trails	740	950	4750	1.68	5
Ventures	Roads	740	970	4850	1.37	5
Frobisher	Roads	930	1150	5750	1.56	5
Frobisher	Bus Route 2	930	1268	4653	1.65	3.67
Frobisher	Bus Route 3	930	4025	4025	6.07	1

Table 4.14a Results for GIS Analysis of Paths Originating at Happy Valley 2

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Trails	-33	55	.2	.37	.22
Old Hospital	Trails	1	37	.12	.46	.2
NorthMart	Trails	-34	63	.09	.29	.15
Ventures	Roads	-30	30	.14	0	.21
Arena	Roads	56	56	.15	0	.16
Frobisher	Roads	-4	19	.13	.21	.26
Frobisher	Bus Route 2	-4	92	.47	1.22	.8
Frobisher	Bus Route 3	-4	99	.49	1.32	.82

Table 4.14b Results for GIS Analysis of Paths Originating at Happy Valley 2

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	590	760	3800		5
Old Hospital	Trails	780	975	1950		5
NorthMart	Trails	995	1165	5825		5
Ventures	Roads	605	768	3850		5
Arena	Roads	1055	1249	6245		5
Frobisher	Roads	720	975	4875	1.64	5
Frobisher	Bus Route 2	720	3560	4315	6.15	1.21
Frobisher	Bus Route 3	720	4045	6674	6.8	1.65

Southeastern Region

Lower Iqaluit is also fairly well connected with the central part of Iqaluit, and most destinations are reached fairly efficiently by roads and trails. Cost equation results are less than .2 for most paths (Tables 4.15a-b, 4.16a-b and 4.17a-b). However, access between Lower Iqaluit and the other residential areas in town is only by way of the Ring Road or seasonal trails (Figure 3.23) . The numbers for the journeys to the Arena from Lower Iqaluit reflect this, with vertical straightness inefficiencies of .44 and .52.[10] The trails that run from near Arctic Ventures to the area next to the Frobisher Complex allow for a way to walk off the Ring Road and through a more scenic area, though the elevation and straightness savings are small and did not warrant creation of a separate path on the data table. In a journey to the Old Hospital from Lower Iqaluit, this option saves about 15m of east to west travel inefficiency, or a decrease from .12 to .11 SI.

A small amount of saving from the further out areas of Lower Iqaluit to destinations in the centre of town is achieved by walking through the empty area in the middle of the block between the clinic and Arctic Ventures (Figure 4.7). Without access to this area, in-town journeys become less efficient, as some 'out of the way' travel to either the Ring Road or to the road below the street block is required. Traveling from a far out point in Lower Iqaluit (LI3) to the clinic, there is a SI estimate decrease from .11 to .6. The trip to NorthMart from LI3 has a straightness inefficiency of just .02 with this centre of block area in use. A secondary path through the same block running from north to south allows for more efficient travel to Arctic Ventures from the point referred to in the table as 'Lower Iqaluit 2' (LI2). This path still has a high SI score, .32, due to the odd road network in Lower Iqaluit, but the overall distance is short, at less than 500m.

The addition of bus routes enables easy travel uphill to the Frobisher Complex, with required uphill walking travel decreasing from 30-32m to nearly no uphill walking. Bus route travel time cost ratios for this neighbourhood are estimated at 2.27 to 2.91, with total travel cost estimates at 3.66 to 4.69. If one wanted to go to the Old Hospital from Lower Iqaluit, availability of a bus option on current routes could save 25 meters of uphill walking, with a further 10 meters uphill walking still required. Due to the unique and high cost nature of travel around the Ring Road and its destinations in central Iqaluit, an additional bus route could be proposed that just circles the Ring Road continually with the steep eastern slope being the uphill path of the bus.

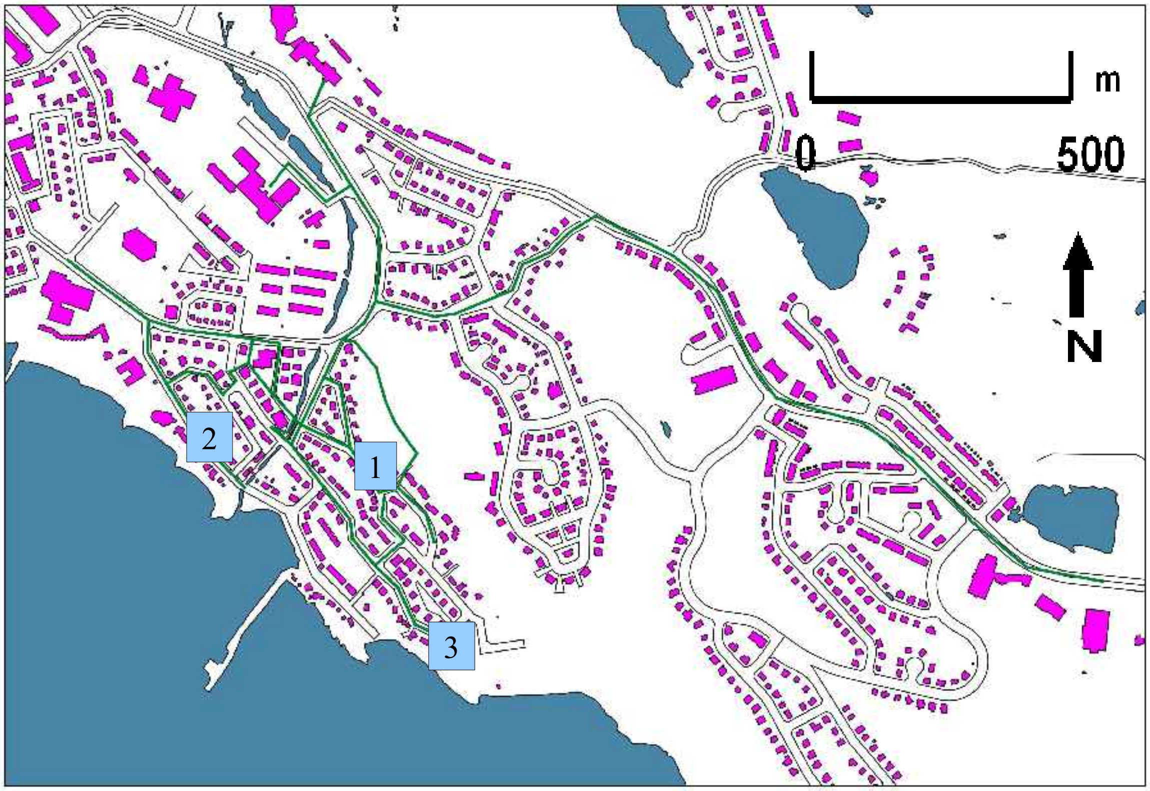


Figure 4.7 Path Set for Origin Points in the Southeastern Region. Green lines indicate paths. 1) LI1. 2) LI2. 3) LI.

Table 4.15a Results for GIS Analysis of Paths Originating at Lower Iqaluit 1

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Roads	-9	9	.12	0	.23
New Hospital	Roads	27	43	.16	.17	.15
North Mart	Trails	-6	20	0	.19	.11
Arena	Roads	66	86	.25	.14	.3
Frobisher	Roads	25	33	.22	.13	.3
Frobisher	Bus Route 2	25	33	.22	.13	.3

Table 4.15b Results for GIS Analysis of Paths Originating at Lower Iqaluit 1

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Roads	235	305	1525		5
New Hospital	Roads	920	1085	5447		5
North Mart	Trails	735	830	4150		5
Arena	Roads	1455	2065	10339		5
Frobisher	Roads	620	886	4452	1.65	5
Frobisher	Bus Route 2	620	886	1682	1.65	2.27

Table 4.16a Lower Results for GIS Analysis of Paths Originating at Lower Iqaluit 2

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
North Mart	Roads	3	7	0	.1	.1
Ventures	Trails	11	15	.32	.17	.49

Table 4.16b Results for GIS Analysis of Paths Originating at Lower Iqaluit 2

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
North Mart	Roads	420	465	2325		5
Ventures	Trails	235	460	2300		5

Table 4.17a Results for GIS Analysis of Paths Originating at Lower Iqaluit 3

Destination	Route Type	Elevation Difference	Elevation Sum of Differences	SI	EI	DI
Clinic	Roads	-14	21	.11	.2	.18
Clinic	Trails	-14	21	.06	.2	.1
Old Hospital	Roads	28	50	.12	.24	.16
Old Hospital	Trails	30	60	.11	.33	.16
NorthMart	Trails	-12	32	.02	.23	.13
Arena	Roads	75	101	.36	.2	.45
Frobisher	Roads	19	41	.2	.29	.3
Frobisher	Bus Route 2	19	41	.2	.29	.3
Frobisher	Bus Route 3	19	41	.2	.29	.29
Frobisher	Bus Route 5	19	41	.19	.29	.33

Table 4.17b Results for GIS Analysis of Paths Originating at Lower Iqaluit 3

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Roads	345	420	2100	1.49	5
Clinic	Trails	345	385	1925	1.29	5
Old Hospital	Roads	900	1070	5350	1.52	5
Old Hospital	Trails	900	1070	5350	1.61	5
NorthMart	Trails	875	1000	5000		5
Arena	Roads	1287	2332	11660		5
Frobisher	Roads	750	1064	5320	1.79	5
Frobisher	Bus Route 2	750	1064	3077	1.79	2.89
Frobisher	Bus Route 3	750	1053	3065	1.78	2.91
Frobisher	Bus Route 5	750	1120	1520	1.77	1.36

Northeastern Region

Another group of points includes the central section of Apex Road, and the subdivisions to the north of this section. The Road to Nowhere (RTN), the Lake Subdivision, and the point designated in Tables 4.18a-b as 'Apex Road 2' make up this group (Figure 3.28). The RTN loop, which branches off from the Road to Nowhere itself, is a very high elevation suburb that is relatively inaccessible from other parts of town (Figure 3.29). From a point at the end of the Road to Nowhere loop, the journey into town becomes inefficient if there are no accessible trails or bus routes. A traveler must travel east and south to the access road, and then, for most destinations in town, go west again and continue to descend. The elevation at the top of the subdivision is 112m above sea-level (Table 4.18a). Straightness inefficiency scores are fairly high in the roads only paths for this point. Elevation inefficiencies are fairly low, except for the path to the Arena, which requires an elevation drop of 25m, then a gain of 13m; and the path to the Frobisher Complex, which requires descent to the Ring Road and then ascent on the access road.

With the availability of a path that descends the ridge from the end of the RTN loop, joining the trail that runs behind the hospital, more efficient paths can be made (Ridge shown in background of Figure 3.22). SI for the path to the hospital decreases from .36 to .04. DI decreases from .58 to .26, and actual path length decreases from 1685m to 945m, approximately. For the journey to NorthMart, path length decreases from 2280m to 1995m, and the DI estimate drops from .43 to .35, and for the Frobisher Complex, a saving of more than 500m is possible. This trail, in conjunction with the trail behind the hospital, allows for greater connectivity among the northern subdivisions in town and the central destinations (Figure 4.8).

Bus Route 4 offers the best travel time cost saving for the RTN subdivision, with a travel cost ratio of 1.1 (Table 4.18b). Bus Routes 1 and 5 also bring the travel time cost ratio for the RTN below 2.0, which is a good improvement over the baseline ratio of 5.0 for walking cases. While SI scores are high for the bus route paths from RTN, the travel time cost estimate could be seen to override the straightness concern in the case of a transit vehicle. Bus Route 4's path also has high inefficiency scores, such as .54 for straightness, 1.85 for elevation, and .86 for distance. Bus Route 1 has the lowest overall travel cost estimate of 6.91, which takes into account the inefficiency scores and the travel time cost measure. Bus Routes 2 and 5 offer 7.43 and 7.67, while Bus Route 4's estimate is 8.92, despite the low travel time cost estimate. Decisions as to which route is the optimum choice would need to take into account similar trade-offs for the other neighbourhoods in the city and compare them at a network level, as will be analyzed and discussed in the section following the review of individual points.

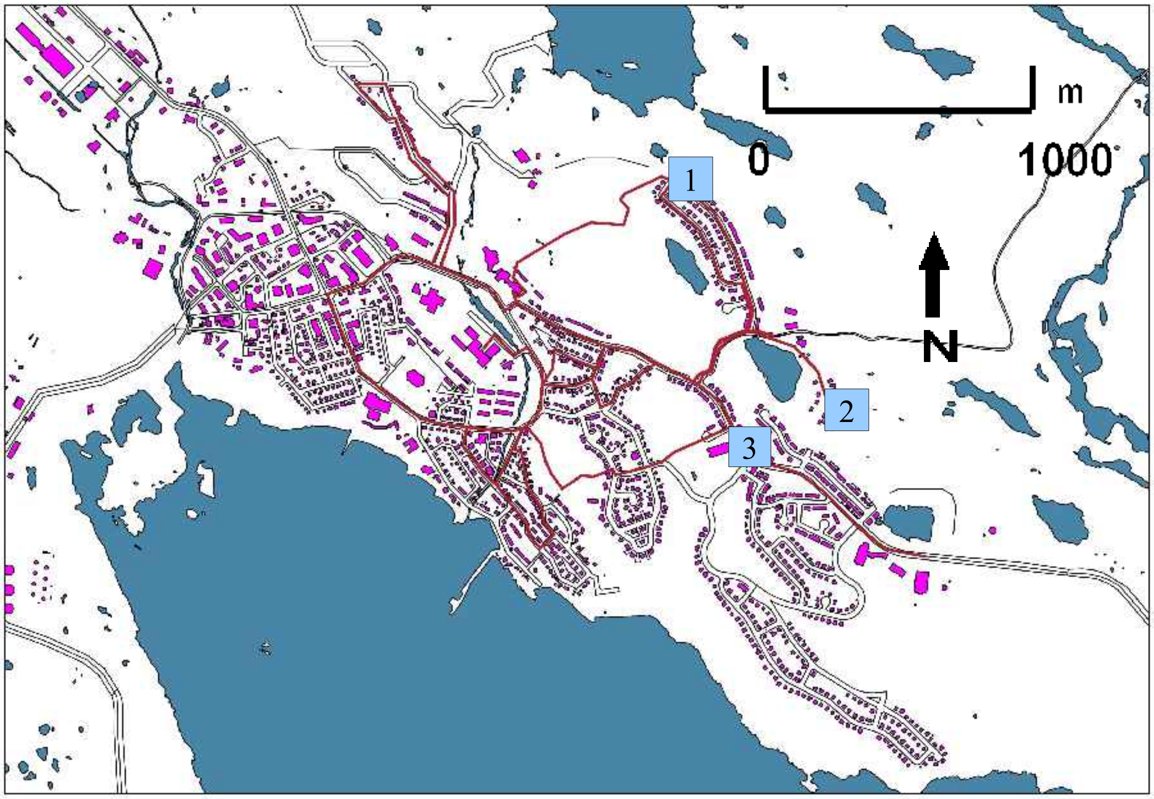


Figure 4.8 Path Set for Origin Points in the Northeastern Region. Red lines indicate paths. 1) RTN. 2) LS. 3) Apex Road 2.

Table 4.18a Results for GIS Analysis of Paths Originating at Road To Nowhere Loop

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	-102	103	.19	.01	.34
Old Hospital	Roads	-63	71	.04	.11	.26
Old Hospital	Trails	-65	69	.36	.06	.58
NorthMart	Trails	-100	130	.13	.23	.35
NorthMart	Roads	-99	105	.19	.05	.43
Arena	Roads	-71	38	.07	.16	.13
Frobisher	Trails	-71	97	.24	.29	.38
Frobisher	Roads	-12	97	.32	.29	.55
Frobisher	Bus Route 1	-71	152	.51	.89	.78
Frobisher	Bus Route 2	-71	144	.48	.8	.79
Frobisher	Bus Route 4	-71	239	.54	1.85	.86
Frobisher	Bus Route 5	-74	166	.47	1.01	.84

Table 4.18b Results for GIS Analysis of Paths Originating at Road To Nowhere Loop

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1300	1955	9775		5
Old Hospital	Roads	700	943	4724	1.41	5
Old Hospital	Trails	700	1684	8448	2.79	5
NorthMart	Trails	1300	1996	10328	1.71	5
NorthMart	Roads	1300	2280	11400	1.81	5
Arena	Roads	1645	1892	9489		5
Frobisher	Trails	910	1460	7300	1.9	5
Frobisher	Roads	910	2000	10370	2.52	5
Frobisher	Bus Route 1	910	4132	7841	5.01	1.9
Frobisher	Bus Route 2	910	4394	10282	5.09	2.34
Frobisher	Bus Route 4	910	6665	7349	7.82	1.1
Frobisher	Bus Route 5	910	5609	8479	6.16	1.51

Table 4.19a Results for GIS Analysis of Paths Originating at Lake Subdivision

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	-81	81	.13	0	.1
Old Hospital	Roads	-47	49	.14	.02	.17
Old Hospital	Trails	-47	49	.14	.02	.17
Ventures	Roads	-74	76	.16	.02	.2
Arena	Roads	8	21	.08	.19	.38
Frobisher	Roads	-50	70	.19	.16	.28
Frobisher	Bus Route 1	-50	133	.48	.67	.69
Frobisher	Bus Route 2	-50	120	.45	.56	.71
Frobisher	Bus route 3	-50	130	.48	.65	.69
Frobisher	Bus Route 4	-50	222	.56	1.39	.84
Frobisher	Bus Route 5	-50	139	.47	.72	.76

Table 4.19b Results for GIS Analysis of Paths Originating at Lake Subdivision

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1270	1414	7095		5
Old Hospital	Roads	1180	1430	7174	1.33	5
Old Hospital	Trails	1180	1430	7174	1.33	5
Ventures	Roads	1250	1560	7800		5
Arena	Roads	695	1122	5591		5
Frobisher	Roads	1240	1720	8612	1.64	5
Frobisher	Bus Route 1	1240	3953	6642	4.13	1.68
Frobisher	Bus Route 2	1240	4253	8717	4.19	2.05
Frobisher	Bus route 3	1240	3957	7315	4.11	1.85
Frobisher	Bus Route 4	1240	7518	8959	7.15	1.19
Frobisher	Bus Route 5	1240	5126	6130	4.93	1.2

The Lake Subdivision is an arc-shaped road with relatively few houses that span the area between the RTN and a point further along Apex Road (Figure 4.8). Inefficiency scores for points in this path set for walking paths are quite low, and current trail options do not create any greatly more efficient alternatives (Table 4.19a). Elevation and straightness efficiency scores are below .2 and DI scores are below .2 for all destinations except the Arena and the Frobisher Complex. All bus routes except Bus Route 2 offer travel time cost ratios below 2.0, with Bus Routes 1 and 3 offering the best combined travel time cost and efficiency estimates, at 5.81 and 5.96, respectively (Table 4.19b).

The point on Apex Road, 'Apex Road 2', also has low inefficiency scores and is quite well connected by the road network(Table 4.20a-b). Scores are mostly below .2. Bus Routes 2 and 3 offer the best improvement over the road network, with Bus Route 3 providing an overall cost estimate of 6.34. This is broken into a 1.47 travel time cost ratio component and a 4.87 cost efficiency formula estimate. Bus Routes 4 and 5 offer travel time cost ratios of 1, which means that the entire journey can be made by bus; however, their cost inefficiency scores are relatively high at 9.82 and 6.19.

Table 4.20a Results for GIS Analysis of Paths Originating at Apex Road 2

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	94	94	.17	.21	.18
Old Hospital	Trails	37	37	0	.04	.07
Old Hospital	Roads	37	37	0	.04	.07
Ventures	Trails	-64	64	.18	0	.17
Ventures	Roads	-67	67	.19	0	.16
Arena	Roads	15	15	0	0	0
Frobisher	Roads	-44	61	.2	.17	.26
Frobisher	Bus Route 2	-44	125	.48	.83	.74
Frobisher	Bus route 3	-44	139	.47	.97	.73
Frobisher	Bus Route 4	-44	293	.59	2.55	.87.
Frobisher	Bus Route 5	-44	132	.53	.9	81

Table 4.20b Results for GIS Analysis of Paths Originating at Apex Road 2

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	935	1140	5700		5
Old Hospital	Trails	970	1040	5200	1.11	5
Old Hospital	Roads	970	1040	5200	1.11	5
Ventures	Trails	905	1095	5505	1.36	5
Ventures	Roads	905	1080	7683	1.33	5
Arena	Roads	820	820	4100		5
Frobisher	Roads	975	1320	6600	1.63	5
Frobisher	Bus Route 2	975	3784	6591	4.92	1.74
Frobisher	Bus route 3	975	3560	5250	4.87	1.47
Frobisher	Bus Route 4	975	7668	7668	9.82	1
Frobisher	Bus Route 5	975	5207	5207	6.19	1

Eastern Region

On the south side of Apex Road, parallel to the Lake Subdivision, is Tundra Ridge (TR), a neighbourhood of steep hills and curving roads (Figure 3.27). Path sets with origin points TR 2 and 3 tend to have relatively high DI scores, from .17 to .53, due to the circular nature of the roads in the area which conform to the hills of the ridge (Table 4.21a and 4.22a). TR2, which sits at the height of the hill in an area of medium density housing, is the exception, with a DI score of .09 to the nearby Arena. EI scores are also higher than in some areas, at .25 to .62, with only the path from TR3 to the Arena having a lower value of .19. Path SI scores are not very high using the estimation method chosen, as the effects of the curving road structure are diffused over fairly lengthy journey paths. Significant trails in this area are ones that lead from Tundra Ridge to the entrance to Tundra Valley, and those that lead along the ridge west, parallel to and below Apex Road

(Figure 4.9).

The journey from the far east end of the ridge at TR3 to the clinic by trails is quite efficient at (.19) DI and (.16) SI (Table 4.22a). The path follows a trail from the entrance to Tundra Valley, down to Happy Valley, then another trail from Happy Valley over the next ridge to Lower Iqaluit. The extra travel distance required over the point to point distance is only 320m, which is quite low for paths from the edge of Tundra Ridge. The current trail options leading to the Frobisher Complex offer no savings over the road network, only an alternative path.

From TR2 to Arctic Ventures, trail options allow for 450m of savings over road only options, a travel cost inefficiency estimate reduction from 2.45 to 1.78 (Table 4.21a). Trail options leading to the Old Hospital offer a lower inefficiency saving, from 1.85 to 1.59, and a distance reduction of 100m, indicating that the path along the ridge parallel to Apex Road offers a small amount of savings, mostly in terms of EI, which drops as an estimate from .4 to .25. All of the bus routes proposed offer a good travel time cost benefit to this point on the ridge, with travel time ratios from 1-1.58 (Table 4.21b). Bus Routes 1 and 2 give paths that produce lower travel time cost estimates, despite requiring some walking. Bus Route 3 requires no walking, yet has higher inefficiencies and slightly higher overall costs.

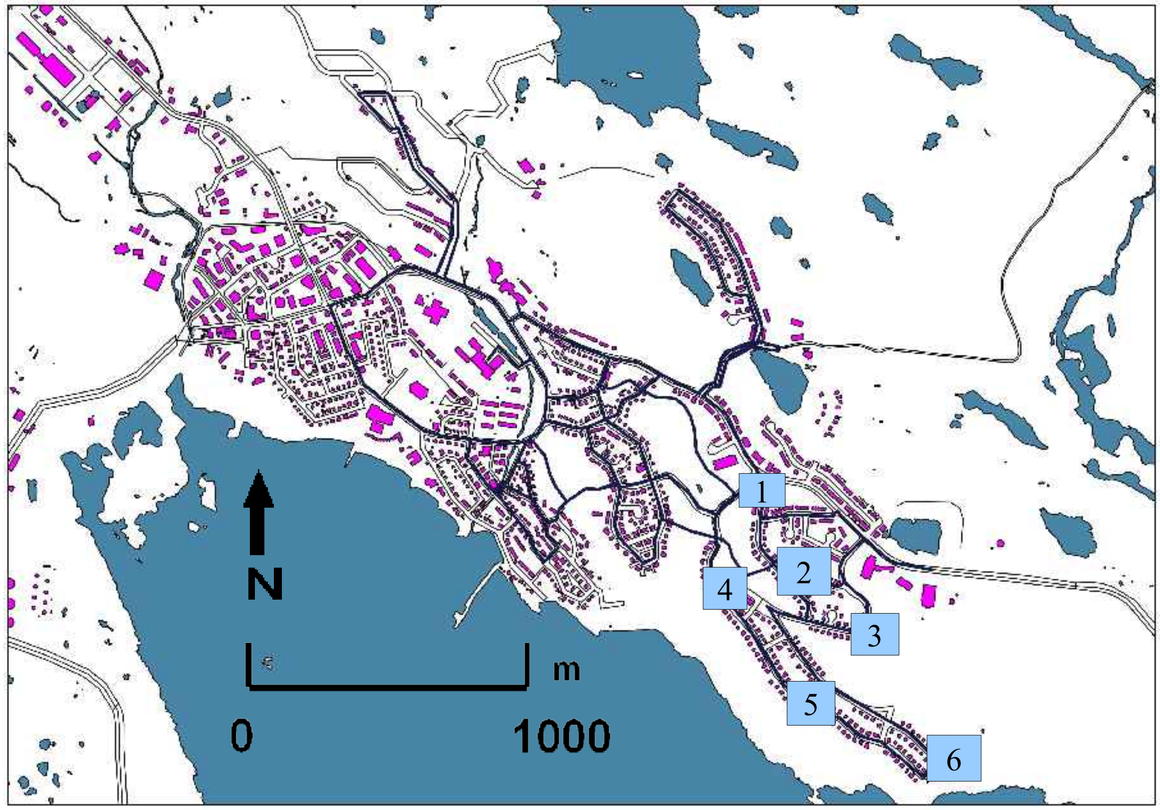


Figure 4.9 Path Set for Origin Points in the Eastern Region. Blue lines indicate paths. 1) TR1. 2) TR2. 3) TR3. 4) TV1. 5) TV2. 6) TV3.

Table 4.21a Results for GIS Analysis of Paths Originating at Tundra Ridge 2

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Old Hospital	Trails	-44	77	.15	.25	.19
Old Hospital	Roads	-44	97	.13	.4	.24
Ventures	Trails	-73	128	.12	.49	.17
Ventures	Roads	-73	128	.24	.49	.38
Arena	Roads	9	9	.25	0	.09
Frobisher	Roads	-57	98	0.1	0.27	0.23
Frobisher	Bus Route 1	-57	143	.42	.57	.67
Frobisher	Bus Route 2	-57	174	.37	.78	.72
Frobisher	Bus Route 3	-52	246	.54	1.29	.79
Frobisher	Bus Route 4	-57	382	.49	2.17	.85
Frobisher	Bus Route 5	-57	258	.47	1.34	.8

Table 4.21b Results for GIS Analysis of Paths Originating at Tundra Ridge 2

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Old Hospital	Trails	1320	1626	8165	1.59	5
Old Hospital	Roads	1320	1746	8779	1.85	5
Ventures	Trails	1120	1350	6750	1.78	5
Ventures	Roads	1120	1807	9072	2.45	5
Arena	Roads	590	647	3216		5
Frobisher	Roads	1500	1950	9750	1.6	5
Frobisher	Bus Route 1	1500	4577	7220	4.01	1.58
Frobisher	Bus Route 2	1500	5295	6881	4.58	1.3
Frobisher	Bus Route 3	1500	7288	7288	6.37	1
Frobisher	Bus Route 4	1500	9895	9895	8.58	1
Frobisher	Bus Route 5	1500	7438	7436	6.42	1

Table 4.22a Results for GIS Analysis of Paths Originating at Tundra Ridge 3

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	-77	143	.16	.47	.19
Old Hospital	Roads	15	111	.04	.62	.41
Arena	Roads	12	19	.19	.19	.53
Frobisher	Roads	-49	123	.08	.58	.38
Frobisher	Trails	-49	123	.08	.58	.38

Table 4.22b Results for GIS Analysis of Paths Originating at Tundra Ridge 3

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1400	1720	8600		5
Old Hospital	Roads	1560	2630	13195		5
Arena	Roads	370	788	3919		5
Frobisher	Roads	1275	2050	10250	2.04	5
Frobisher	Trails	1275	2050	10250	2.04	5

TR1, a point close to Apex Road, but higher up on the ridge, has path patterns similar to TR2. Trail options offer distance savings of 100-150m (Table 4.23a-b). Inefficiency scores are low, except in travel to the Arena, which requires some excess elevation loss and gain. There is a dental clinic in the area of TR1, making it a potential daytime destination point for a small number of people. As well, there is a convenience store parallel to TR on Apex Road, the only store easily accessible from the highly elevated eastern subdivisions, and the closest retail and food amenity available to Apex. Bus Route 2 offers the lowest calculated travel cost, at 5.89, while Bus Routes 3 and 5 offer estimates of 6.47 and 6.72 respectively.

Table 4.23a Results for GIS Analysis of Paths Originating at Tundra Ridge 1

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Old Hospital	Trails	-48	64	.09	.14	.16
Old Hospital	Roads	-48	48	.05	0	.07
Ventures	Trails	-78	78	.17	0	.2
Ventures	Roads	-78	78	.17	0	.21
Arena	Roads	4	32	.28	.42	.23
Frobisher	Roads	-55	79	.15	.22	.27
Frobisher	Trails	-55	79	.12	.22	.19
Frobisher	Bus Route 2	-55	150	.46	.85	.72
Frobisher	Bus Route 3	-55	145	.48	.81	.77
Frobisher	Bus Route 4	-55	304	.6	2.23	.86
Frobisher	Bus Route 5	-55	143	.5	.79	.79

Table 4.23b Results for GIS Analysis of Paths Originating at Tundra Ridge 1

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Old Hospital	Trails	1150	1367	6861	1.39	5
Old Hospital	Roads	1150	1240	6200	1.03	5
Ventures	Trails	1030	1283	6446	1.36	5
Ventures	Roads	1030	1310	6550	1.4	5
Arena	Roads	660	858	4307		5
Frobisher	Roads	1115	1525	7625	1.63	5
Frobisher	Trails	1115	1375	6875	1.43	5
Frobisher	Bus Route 2	1115	3982	4951	4.65	1.24
Frobisher	Bus Route 3	1115	4896	5864	5.27	1.2
Frobisher	Bus Route 4	1115	7886	8210	8.86	1.04
Frobisher	Bus Route 5	1115	5425	5836	5.64	1.08

Tundra Valley (TV), below Tundra Ridge, is the second furthest east-reaching of Iqaluit's subdivisions. It is composed of two long roads with mostly single-family, low-density housing. The far end of the valley is significantly lower in elevation than the end closest to town, so EI estimates are high for paths from the end of TV (TV3), with most values above .3 (Table 4.24a). Available trails shorten the journeys by less than 100m in most cases, and do not offer great elevation savings. Straightness and distance inefficiency scores are quite low for this path set, with most values below .2, except for the Arena path case. Bus Routes 2 and 3 offer good travel cost estimates, at 5.1 and 5.44, with Bus Route 3 offering the lowest travel travel time cost estimate, at 5965 and Bus Route 2 offering 7696 as an estimate (Table 4.24b).

Table 4.24a Results for GIS Analysis of Paths Originating at Tundra Valley 3

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	-22	128	.07	.56	.18
Old Hospital	Roads	15	111	.02	.43	.15
Old Hospital	Trails	15	102	.02	.39	.13
Ventures	Trails	-15	126	.03	.56	.18
Ventures	Roads	-15	104	.04	.45	.19
Arena	Roads	66	74	.46	.12	.64
Frobisher	Trails	10	102	.06	.43	.19
Frobisher	Bus Route 2	10	166	.35	.75	.57
Frobisher	Bus Route 3	10	260	.41	1.15	.64
Frobisher	Bus Route 4	10	352	.49	1.59	.78
Frobisher	Bus Route 5	10	230	.41	1.03	.68

Table 4.24b Results for GIS Analysis of Paths Originating at Tundra Valley 3

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	1880	2300	11500		5
Old Hospital	Roads	2230	2630	13195	1.6	5
Old Hospital	Trails	2230	2573	12895	1.52	5
Ventures	Trails	1975	2400	12000	1.77	5
Ventures	Roads	1975	2444	12250	1.7	5
Arena	Roads	680	1872	9360		5
Frobisher	Trails	2159	2660	13300	1.67	5
Frobisher	Bus Route 2	2159	5050	7695	3.57	1.52
Frobisher	Bus Route 3	2159	5965	5965	4.44	1
Frobisher	Bus Route 4	2159	9610	10052	6.47	1.05
Frobisher	Bus Route 5	2159	6830	8289	4.69	1.08

With TV1 and TV2 as well, Bus Route 3 offers the lowest travel time cost estimates, at 4991 and and 5397 respectively. Bus Route 2 is a close second for TV1, with a travel time estimate of 5278, and route 5 is a second in the case of TV2, with an estimate of 6306 (Tables 4.25b and 4.26b). Existing paths between the subdivisions offer only small cost efficiency benefits, with most paths having straightness inefficiency scores of .11 or less, and distance inefficiency scores of .26 or less (Tables 4.25a and 4.26a). As with TV 3, from TV1, the path to the Arena is very inefficient in terms of distance and straightness. A large amount of excess elevation gain and loss is required for most journeys, due to the hilly nature of the eastern half of town. EI scores are from .19 to .46, while actual elevation changes are from 21m to 55m and accumulated elevation travel is up to 97m.

Table 4.25a Results for GIS Analysis of Paths Originating at Tundra Valley 1

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	-55	73	0.13	.19	0.26
Old Hospital	Trails	-18	68	.03	.39	.21
Old Hospital	Roads	-18	77	.05	.46	.21
Ventures	Trails	-47	97	.07	.5	.24
Ventures	Roads	-47	65	.11	.18	.26
Arena	Roads	36	46	.34	.13	.45
Frobisher	Roads	-21	67	.1	.39	.26
Frobisher	Trails	-21	63	.1	.36	.25
Frobisher	Bus Route 2	-21	138	.37	1	.74
Frobisher	Bus Route 3	-21	147	.47	1.03	.77
Frobisher	Bus Route 4	-21	314	.59	2.45	.85
Frobisher	Bus Route 5	-21	191	.53	1.4	.79

Table 4.25b Results for GIS Analysis of Paths Originating at Tundra Valley 1

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	925	1250	6250		5
Old Hospital	Trails	1270	1600	8000	1.63	5
Old Hospital	Roads	1270	1600	8000	1.72	5
Ventures	Trails	1000	1317	6607	1.81	5
Ventures	Roads	1000	1350	6750	1.57	5
Arena	Roads	750	1373	7330		5
Frobisher	Roads	1170	1575	7875	1.75	5
Frobisher	Trails	1170	1550	7750	1.75	5
Frobisher	Bus Route 2	1170	4418	5278	4.92	1.19
Frobisher	Bus Route 3	1170	4991	4991	5.43	1
Frobisher	Bus Route 4	1170	8049	8049	9.01	1
Frobisher	Bus Route 5	1170	5588	5588	6.27	1

Table 4.26a Results for GIS Analysis of Paths Originating at Tundra Valley 2

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Frobisher	Roads	-7	85	.08	.47	.2
Frobisher	Trails	-7	81	.08	.45	.19
Frobisher	Bus Route 2	-7	151	.34	.87	.65
Frobisher	Bus Route 3	-7	160	.42	.92	.69
Frobisher	Bus Route 4	-7	337	.49	1.99	.83
Frobisher	Bus Route 5	-7	215	.45	1.25	.74

Table 4.26b Results for GIS Analysis of Paths Originating at Tundra Valley 2

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Frobisher	Roads	1660	2075	10375	.1.75	5
Frobisher	Trails	1660	2060	10300	1.71	5
Frobisher	Bus Route 2	1660	4706	7136	4.13	1.52
Frobisher	Bus Route 3	1660	5397	5397	4.64	1
Frobisher	Bus Route 4	1660	9575	10297	7.92	1.08
Frobisher	Bus Route 5	1660	6306	6306	5.48	1

Far Eastern Region

Of any neighbourhood in Iqaluit, Apex subdivision is perhaps the most in need of transit amenities. There are no grocery stores or other retail amenities, and the walk into town from Apex is prohibitively long for most purposes. In winter weather the walk is particularly strenuous, and only the most avid walker would choose to walk to Iqaluit from Apex, given other options. Paths that link Apex to the town's amenities range in length from 2,535m to the Arena, to 5,037m to NorthMart (Table 4.27b). Elevation gain from Apex to the Arena is 70m, and total accumulated elevation travel to NorthMart is 175m (Table 4.27a). Straightness and distance inefficiency scores are relatively low, since they are estimated in terms of the overall high journey lengths. All of the bus routes proposed have a high level of benefit for Apex, since it is considered to be a high need area. Bus Routes 1 and 2 offer the best overall scores, as their inefficiency equations estimate 2.7 and 3.14 respectively, while their travel time cost ratios are 1.16-7. Bus Route 1 offers a travel time cost estimate of 8,019, while Bus Route 2 offers 9,166 and the base case is estimated at 23,286 (Table 4.27b). A walking trail is in the process of being improved along the water-front from Apex to Lower Iqaluit, but this is most likely to be used as a recreational trail rather than a commuter path, since the weather and shoreline conditions vary throughout the year, and the distance would still be quite great. It is clear that Apex would benefit from bus service (Figures 3.31, 3.32, 4.11, 4.12, 4.13).

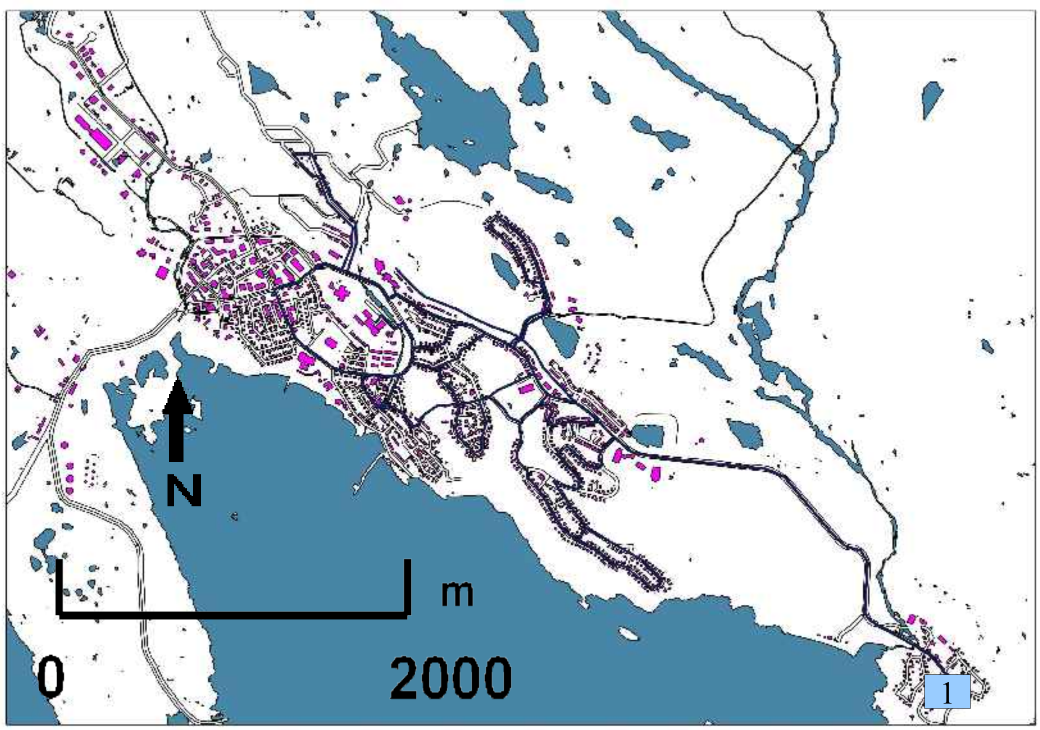


Figure 4.10 Path Set for Origin Points in the Far Eastern Region. Dark blue lines indicate paths. 1) Apex.

Figure 4.11 Apex Trail in winter.

Figure 4.12 Left: Steps on the Apex Trail. Right: Section of the Apex Trail.

Table 4.27a Results for GIS Analysis of Paths Originating at Apex

Destination	Route Type	Elevations Difference	Elevations Sum of Differences	SI	EI	DI
Clinic	Trails	-19	195	.06	.48	.2
Old Hospital	Roads	18	136	.01	.3	.1
Old Hospital	Trails	18	132	.01	.29	.1
NorthMart	Roads	-17	175	.06	.38	.18
Arena	Roads	70	82	.03	.06	.14
Frobisher	Roads	11	157	.05	.38	.17
Frobisher	Bus Route 1	11	221	.25	.54	.43
Frobisher	Bus Route 2	11	257	.31	.63	.51
Frobisher	Bus Route 3	11	341	.39	.85	.63
Frobisher	Bus Route 4	11	477	.43	1.2	.7
Frobisher	Bus Route 5	11	354	.37	.88	.63

Table 4.27b Results for GIS Analysis of Paths Originating at Apex

Destination	Route Type	Point to Point Distance	Path Length	Path Time Cost Estimate	Efficiency Estimate	Travel Time Proportion Estimate
Clinic	Trails	3660	4558	22839		5
Old Hospital	Roads	3925	4363	21852	1.41	5
Old Hospital	Trails	3925	4384	21973	1.41	5
NorthMart	Roads	4125	5037	25238	1.38	5
Arena	Roads	2175	2535	12687		5
Frobisher	Roads	3890	4670	23286	1.6	5
Frobisher	Bus Route 1	3890	6880	8019	2.7	1.17
Frobisher	Bus Route 2	3890	7914	9166	3.14	1.16
Frobisher	Bus Route 3	3890	10601	11693	4.14	1.1
Frobisher	Bus Route 4	3890	12887	13998	5.09	1.09
Frobisher	Bus Route 5	3890	10429	11233	4.11	1.08

Chapter Four notes

1 Elevation ratio is included in this case to show the extreme values created, in relation to the Elevation Inefficiency (EI) calculated by a difference function, as set out in the methods section.
2 Repeat of note from methods section: The range of variance for the elevation inefficiency metric shows extreme values where point to point distance is short and the excessive elevation travel is great. 3.82 is an extreme outlier for elevation inefficiency, with most values for EI being between .01 and 1.66.
3 The bus route paths are considered in more detail in relation to paths with identical origin and destination points in the paragraphs below.
4 There are no units of measurement for this estimate.
5 Inuksugait plaza is a group of three large multi-storey buildings, which are a mixture of high density housing and government offices.
6 This block of apartments will be referred to as the "Airport Apartments". It is understood to include as an origin point area both the apartments and the block of shops across the road from the apartments. (Figure 4.2a or b)
7 The values for DI are scaled in relation to path length. Increasingly larger values have proportionately smaller effect at the high end of the value range, since the longer path length that is also associated with the larger values scales down the effect. Plotted in relation to actual excessive distance travel, the DI values follow a curve that is steeper at its low end and becomes less steep in the larger value area. A small difference in the upper half of the range of DI values indicates a much larger change in actual distance. The DI is proportional to the path length, so that inefficiencies on longer journeys are not given extreme values, and inefficiency estimates stay within a range that more realistically affects the maximum possible effect distance inefficiency might have. Reasoning for this is based on Jessop's discussion of utility functions, which can be used to model situations where a factor will not likely continue to have higher importance in a linear way at higher values. (Jessop, 110-111) To make it clear how the DI is estimated, the actual paths lengths and point to point distances are given in the table as well.
8 This is simply the name I have chosen for the area, given the flowers that were visible there during summer. It is not an official title.
9 "Ventures"in all tables refers to Arctic Ventures, which is described in the study area section of the paper. The name is shortened to fit easily into the table format.
10 This is only the north to south component of the SI. Combining with the East to West component and then dividing by 2 gives the total SI estimate.

Chapter 5

DISCUSSION AND CONCLUSIONS

The methods chapter provides a technical framework for evaluating transit and walking costs in Iqaluit using GIS methods. The results chapter illustrates the estimates that can be made using this technical framework, for evaluating the transportation environment. The results section breaks down patterns into individual path metrics, and gives a detailed image of potential costs for walking and bus use in Iqaluit. This discussion and conclusions section will attempt to synthesize the findings set out in the results section, in terms of overall trends for areas and path sets in Iqaluit. It is broken into three sections: (1) discussion of the path inefficiency metrics in terms of overall neighbourhood trends in Iqaluit, with an attempt to identify ares of high and low walking transportation inefficiency in Iqaluit; (2) discussion of bus route cost estimates, in an attempt to compare the proposed bus transit routes to each other; and (3) conclusions from the discussion sections in relation to future transportation planning in Iqaluit. The two discussion sections will each look at a set of paths, the walking paths and bus paths respectively, to bring out trends in the Iqaluit environment. The first discussion section is organized by neighbourhood area, as in the results section. The second is structured around the individual bus routes, with a comparative focus on how each route helps individual neighbourhoods in Iqaluit. To bring emphasis back to the planning context of Iqaluit, a final section will discuss possible implications for future planning in Iqaluit, both in the pedestrian realm and in potential transit schemes.

Efficiency Metrics Discussion

The findings presented in the results section give an image of how individual paths can be viewed in terms of their inefficiency estimates and cost estimates. Individual neighbourhoods have unique patterns of path inefficiencies and cost estimates. An attempt is made to pin-point neighbourhoods in Iqaluit that are faring poorly for individual inefficiency estimates, and neighbourhoods that are faring relatively well. Neighbourhoods are rated subjectively as low, medium, or high inefficiency for different metrics, where the results are relevant. The rating is determined by the approximate location of a neighbourhood path set's inefficiency metrics, within the variance range for the metrics. If the inefficiency metrics are primarily low with their variance range, the rating is given as low. If the inefficiency metrics are highly mixed or mainly towards the middle of each metric's variance range, the rating is given as medium, low to medium or high to medium. If the inefficiency metrics are primarily high with their variance range, the rating is given as high. This rating system is qualitative and deliberately non-precise, as the goal of the study is to draw out potential generalized patterns and not to exaggerate or over-define patterns that have inherently unknown factors. For example, for all three metrics, values below .2 are considered 'low'. Values above .6 are considered 'high'. The values for EI have a greater variance than the values for SI and DI, in the path cases that include bus segments. All extremely high values of EI (higher than 1.00) can be seen to represent a 'high' level of elevation inefficiency. As shown in Tables 4.1-4.27a, some neighbourhoods, such as Lower Base, have relatively low inefficiency scores (below.3 in most cases), while other neighbourhoods, such as Tundra Ridge 2, have a mixture of inefficiency scores that are primarily medium (.2 to .6) and high (.6 to 2.17).

Where it is possible and relevant, an attempt is made to identify areas that potentially can be improved by planning measures.

Northwestern Region

The area including the Plateau Subdivision (PS or 'Plateau') and the housing development above Arctic College has relatively low inefficiency scores, considering that the distances on paths to destinations are often very long. NorthMart, Arctic Ventures and the Frobisher Complex are all well connected to the Plateau by roads and trails, though the distances and the hills involved make foot travel prohibitively difficult in many cases. Maintaining the existing trails cutting down from the Plateau could decrease inefficiencies to even smaller levels, and would increase the efficiencies of journeys to areas not included in the study as destinations, such as the industrial area and the governmental area to the west of the Ring Road (Figure 5.1).

The trail from the Plateau access road along the ridge to the back of the hospital offers a great savings in EI, DI and SI for destinations in the hospital complex, Apex Road, and to the north of Apex Road. In a planning context, developing and maintaining this trail would improve accessibility between the Plateau and hospital significantly, as well as offer greater accessibility between northern areas of town[1]. It is interesting to note that EI is only improved by a small amount, from .38 to .30 in the case of a journey from the origin point PS1 to the AWG Arena. Even with this trail, it is necessary to travel down from the Plateau and then back up to the AWG Arena. In order to allow for a much greater EI saving from the Plateau to the AWG Arena, as well as other destinations like the RTN and the Lake Subdivision, a trail would have to branch off from the Plateau access road before its junction with the access road, and follow the ridge behind the hospital at a higher elevation of approximately 67m, before rejoining the existing trail at a point further along Apex Road (Figure 5.1). Such a trail would likely necessitate higher traffic volumes between the northern suburbs of town in order to be worth the cost of winter maintenance, but could become worthwhile as the population of Iqaluit increases. The Northwestern Region is an area of relatively low to medium inefficiency, in comparison to other neighbourhoods in Iqaluit.

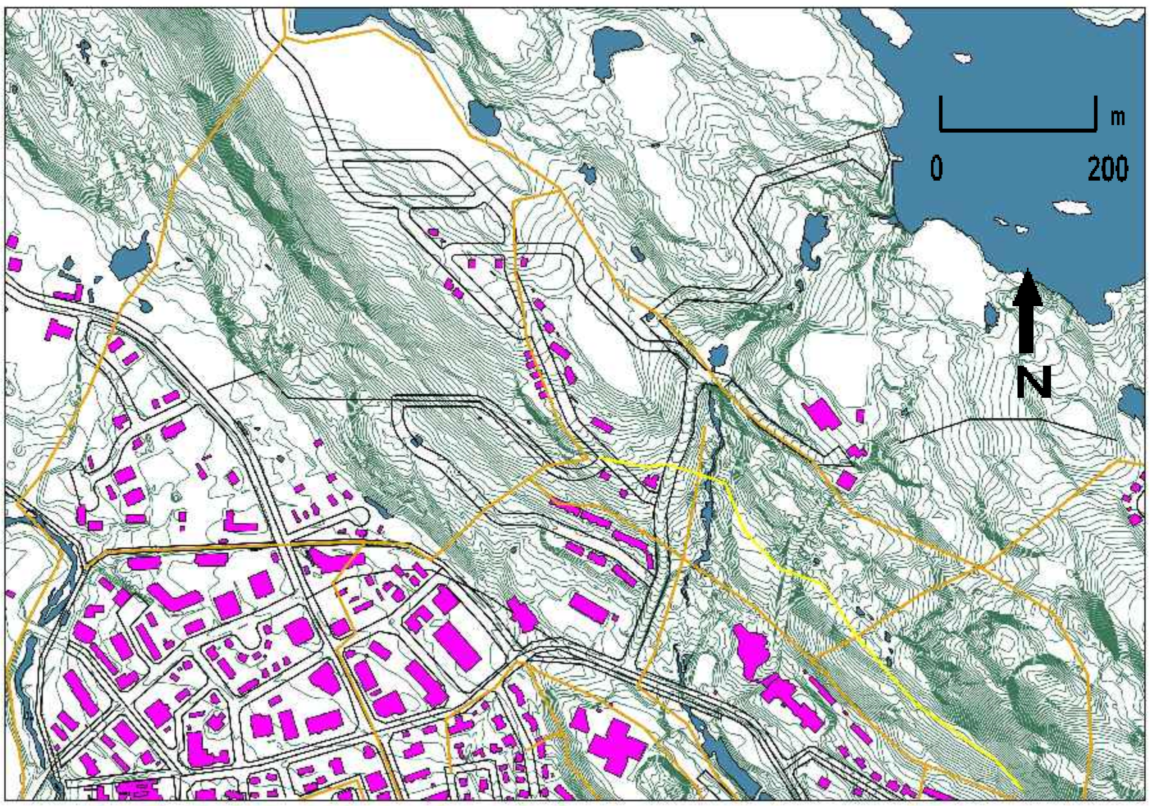


Figure 5.1 Walking trails in the Northwestern Region. Orange trails are listed on the Iqaluit GIS, or are currently in existence, but may need maintaining. Yellow trails are possibilities for new trails that are proposed in the text. The yellow trail follows an elevation of approximately 67m along the ridge behind the Hospital Complex. Green lines are 1m elevation contours.

Southwestern Region

Located close to most major amenities and in the grid-oriented, flat part of the Core Area, the Southwestern Region is very well connected to destination points in Iqaluit. Roads are adequate for trips to the hospital, NorthMart and Arctic Ventures, though the physical placement of the hospital on a high hill makes it less accessible. A key trail for the points in this area is the trail along the hilltop in the middle of town from the western edge of the Ring Road, past Inuksuk High School and along the top of the hill to the Frobisher Complex (Figure 5.2). This trail could be considered one of the most important in town for linking the isolated amenities on the ridge to the centre of town. A small cut-through trail from the southeast edge of Lower Base to the road directly beside NorthMart could offer a small DI and SI benefit, but only to a limited group of people. An issue that contributes to inefficiencies in this area is the directional bias of the road grid, which is often counter to the direction of travel towards destinations. To mitigate this, the city could consider cut-through trails in city blocks, where property lines and land uses permit.[2] In comparison to other neighbourhoods, the Southwestern Region of Iqaluit is an area of low inefficiency for foot travel.

Central Region

The area encompassing the housing developments directly below the Frobisher Complex, though located in the centre of Iqaluit, is a medium to high inefficiency area. Paths to the Frobisher Complex and the Hospital, even with existing trails, require much out of the way travel. It is is impossible to mitigate high EI scores, given the high elevation locations of the Frobisher Complex and the Hospital, but a dedicated walking path connecting a straight line from the hospital entrances to the Frobisher Complex would allow lower inefficiencies for the area below the Frobisher Complex, and for journeys between the Hospital and the Complex (Figure 5.2). Currently, there is a snowmobile path across the riparian area listed on the GIS that may be used by pedestrians, but there is no dedicated walking path across the riparian area and no signage to indicate trails. Further, a stairwell or other path directly up the steep ridge below the Frobisher would allow for more efficient travel between the Frobisher Complex and the areas located below it (Figure 5.2). Paths from the area below the Frobisher Complex to the other southern areas of town are already quite efficient, and the boardwalk trail from the road below the Frobisher Complex to the Ring Road allows for efficient walking to Happy Valley and other neighbourhoods (Figure 5.3).

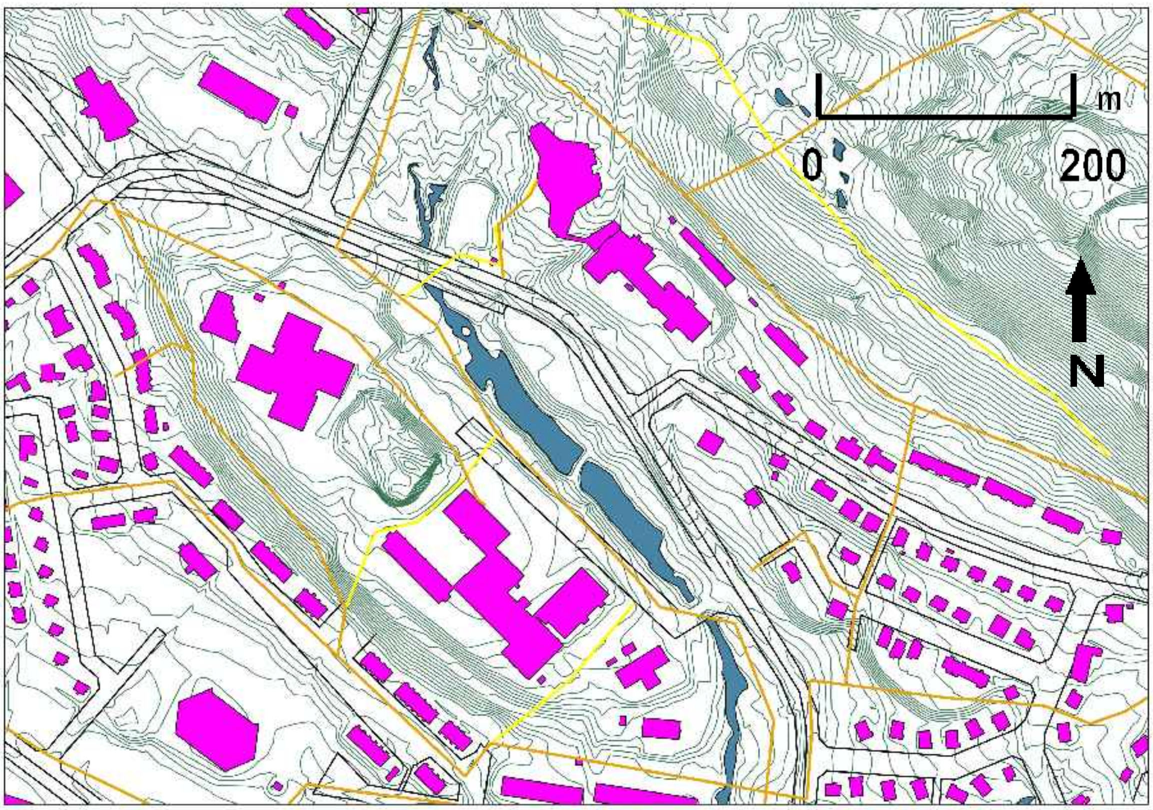


Figure 5.2 Walking trails in the Central Region. Orange trails are listed on the Iqaluit GIS, or are currently in existence, but may need maintaining. Yellow trails are possibilities for new trails that are proposed in the text. Green lines are 1m elevation contours.

Figure 5.3 Board walkway from Nakasuk school and the area below the Frobisher Complex, to the eastern edge of the Ring Road.

Central-Eastern Region

The Central-Eastern region of Iqaluit has low inefficiency scores. Trails connect most destinations efficiently, where road access is not optimal. Even though it is to the east of the Core Area of Iqaluit, it is at the town's geographical epicentre. Inefficiencies are due to the elevation patterns of the land more than to gaps in the pedestrian scheme. Maintenance of current trail amenities is likely the best way to preserve the pedestrian realm of this area. Maintenance or improvement of the trail between Lower Iqaluit and Happy Valley could increase the inter-accessibility of these two residential areas.

Southeastern Region

Lower Iqaluit, or the Southeastern Region, is in a unique position, being well connected to the central part of Iqaluit but somewhat inaccessible to other residential areas, due to topography. Efficient access to the centre of town is somewhat dependent on a cut-through trail in the block behind Arctic Ventures. This trail is accessible in winter, due to the freezing of the small creek at the east end of the block, but becomes unreliable in spring and summer (Figure 5.4). Constructing a permanent bridge over the small creek at the east end of this block would allow for more reliably efficient access to Arctic Ventures and to other amenities found on the lower half of the Ring Road. Paths to the AWG Arena, and to all the northeastern areas of town, are of medium to high inefficiency for Lower Iqaluit. Maintenance of a path from the east end of Lower Iqaluit to the east end of Happy Valley and to the west end of Tundra Valley would increase access between neighbourhoods. A currently existing trail between Lower Iqaluit and Happy Valley improves SI and DI, but requires climbing over a hill with a high elevation (55m), greatly increasing the EI of paths.

Figure 5.4 Walking trails in the Southeastern Region. Orange trails are listed on the Iqaluit GIS, or are currently in existence, but may need maintaining. Yellow trails are possibilities for new trails that are proposed in the text. Green lines are 1m elevation contours. In the upper left corner next to the Clinic, there is a trail crossing over the small creek, that is passable in winter. There was a board-bridge present in summer 2008.

Northeastern Region

This region, which includes the Road to Nowhere Subdivision (RTN), the Lake Subdivision (LS), and middle section of Apex Road, is of medium or mixed inefficiency, as the RTN has some high inefficiencies, but the other points are well connected into the network. The RTN has an odd topography, as it winds upwards through a niche in the hills above the town. Without trail access, a traveler must go far out of the way to get to most destinations. With the addition of a trail from the end of the RTN to the back of the hospital, there is some improvement, but maintaining this remote and steep trail down the hillside during cold weather may be unrealistic. The steep hill between the RTN loop and Apex Road, which has elevations of over 100m for much of its area, makes this subdivision difficult to connect to the central areas of town. As well, the currently existing trail listed in the GIS database takes off from the far end of the RTN loop, which is at an elevation of 112m, meaning that it is only likely to be an attractive option for those who live close to the far west end of the RTN loop. An alternative trail or trails could branch off from the lower half of the RTN loop, and skirt around either side of the hill at elevations of less than 100m (Figure 5.5). Being more closely positioned with a large number of houses, these trails could potentially see higher use and be more easily maintained than the trail from the far end of the RTN loop. From points within the RTN loop, distance savings of 150-300m could be possible with the addition of alternative trails.

In contrast, the Lake Subdivision (LS, or 'Lake'), which has relatively fewer housing units than the RTN, has low inefficiency scores, due to the orientation of its main road. While the lake itself acts as an obstacle, most destinations in Iqaluit lie at angles to the Lake Subdivision that do not make the journey around the lake much of a distance increase. Traveling from a mid-point along the Lake's row of houses, skirting the north side of the lake to reach a point on the RTN access road, requires only 100m of travel greater than a straight line 'crow's flight' across the lake would require. For the eastern half of the Lake Subdivision loop, trips to destinations west and south are somewhat less efficient. In theory, paths that adjoin from the Lake Road to the road leading up from Tundra Valley and to the trail over the ridge beside Apex Road 2 could allow more direct travel (Figure 5.5). It is unclear, however, whether such trails would be viable or worthwhile given the land use and terrain in the area, as such paths would only create a potential savings of approximately 100m. Apex Road 2, which is on Apex Road directly facing the Lake Subdivision, has a similar pattern of connectivity, with even more efficient road and trail accessibility.

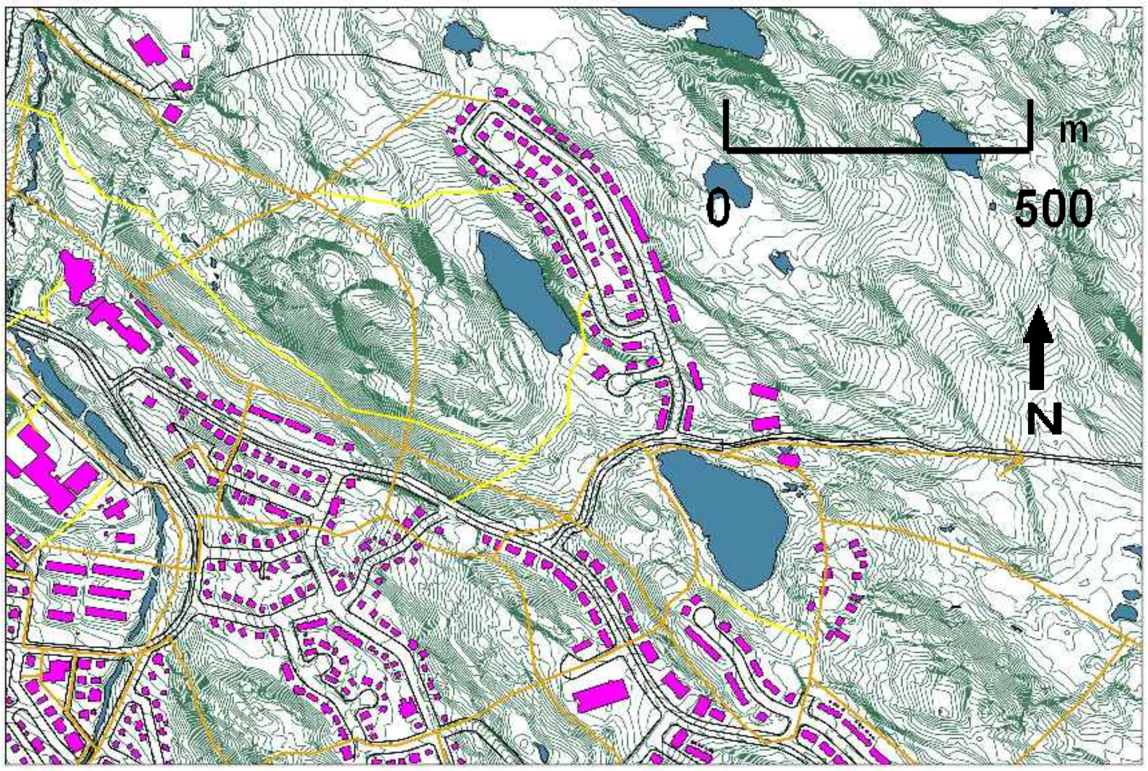


Figure 5.5 Walking trails in the Northeastern Region. Orange trails are listed on the Iqaluit GIS, or are currently in existence, but may need maintaining. Yellow trails are possibilities for new trails that are proposed in the text. Green lines are 1m elevation contours.

Eastern Region

The Eastern Region presents some of the most complex patterns of journey inefficiency in Iqaluit, particularly in the area of Tundra Ridge. The neighourhood of TR is basically circular, with 4 exit points, three of which are connected to its eastern half. The western area of TR, though it is closer to the Core Area of Iqaluit, has only one exit point, just below the Apex Road on the road leading up from Tundra Valley. Given the road structure of the TR area, trails become quite important. As shown in the results section, many paths with origins at TR2 and TR3 benefit from trail options. An additional trail could potentially cut across from the western edge of TR to meet with the T junction of roads between Tundra Valley, Tundra Ridge and Happy Valley (Figure 5.6). From TR 3, out-of-the-way travel is required to destinations in the north half of town, as one must either travel down to the entrance to Tundra Valley, up onto Tundra Ridge and then back down at the western edge, or up to Apex Road at the northeastern edge of TR. A trail from the far south east end of Tundra Ridge that connects with the existing trails across the ridge could help the small number of people who live in the eastern TR3 area. A trail from the eastern edge of TR to the AWG Arena would increase access to recreational amenities. TR is an area of medium to high inefficiency.

Tundra Valley has a much more regular road structure than Tundra Ridge, being one loop of road, connected to the rest of town at its western end only. A trail from the eastern edge of Tundra Ridge to the northern road of Tundra Valley could benefit the interconnectivity of both neighbourhoods (Figure 5.6). With currently listed trails and roads, travel west from Tundra Ridge and then travel east is required to access TV2 and TV3 areas, and to access the eastern areas of Apex Road, the Lake Subdivision and the RTN from Tundra Valley. Given its distance from the Core Area, TV is fairly efficiently connected to the Core Area, but is not so efficiently connected to many other suburbs. Trails to Happy Valley and Lower Iqaluit are listed in the GIS database, and maintenance of these trails year round would add to the cohesiveness of Iqaluit's suburban network. In light of these details, TV is rated as having low to medium inefficiency.

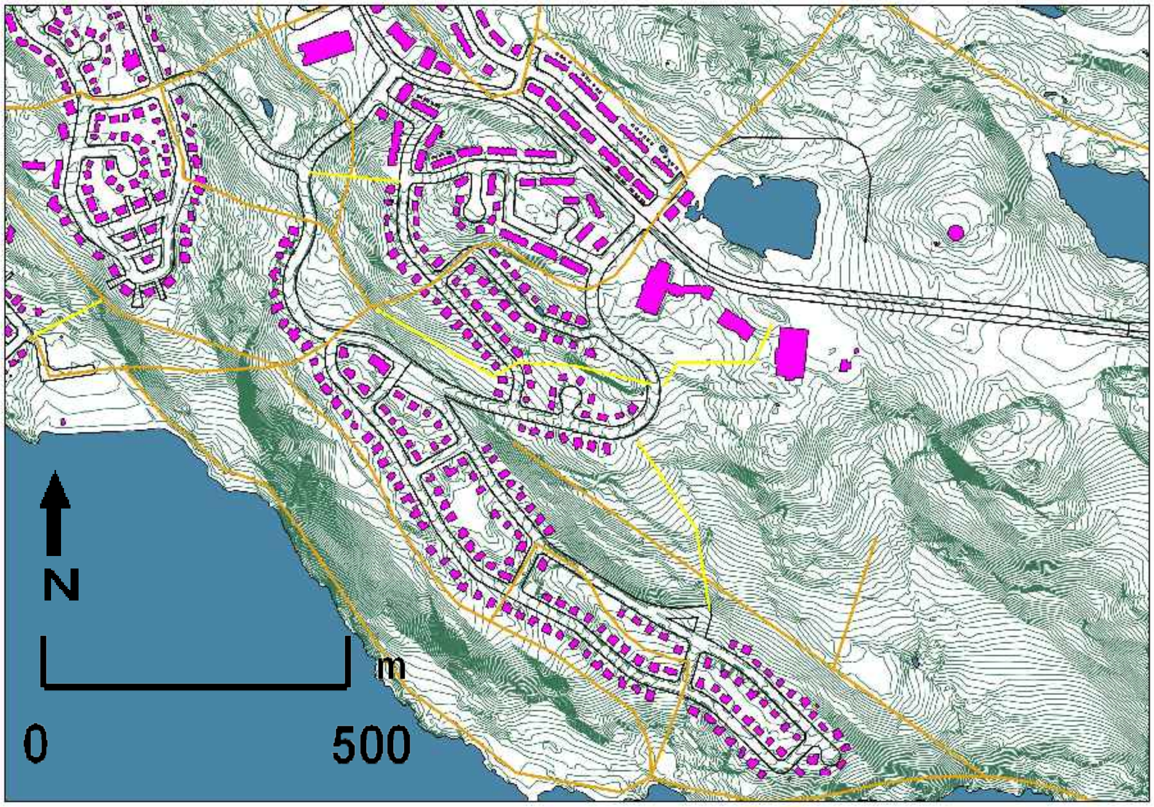


Figure 5.6 Walking trails in the Eastern Region. Orange trails are listed on the Iqaluit GIS, or are currently in existence, but may need maintaining. Yellow trails are possibilities for new trails that are proposed in the text. Green lines are 1m elevation contours.

Far Eastern Region

Apex is unique among Iqaluit's subdivisions because it is separated from the Core Area by an undeveloped stretch of road. Apex sits at relatively low elevations of approximately 30m above sea level, while its only entrance point to Iqaluit requires travel to 100m above sea level. A recreational trail being improved that spans from Apex to Lower Iqaluit along the waterfront, which could provide seasonal access to Apex and good recreational value. Of possible benefit would be a connecting trail between the western edge of Apex and the eastern edge of Tundra Valley (Figure 5.7). This would be a

1km stretch of trail. It would require ascension to only 30m above sea-level while on the trail, and would maintain an approximate elevation of 30km above sea-level. Such a trail would offer a relatively improved SI and DI for trips from Apex as well, and if maintained safely, could increase Apex's accessibility. It may be that such a trail for regular non-recreational use is unrealistic, given the current land use patterns of Iqaluit. The slope between Tundra Valley and Apex is steep and would be a difficult location to build permanent, weather-safe amenities. Journeys from Apex currently have high EI scores, and though the SI and DI scores are relatively low, the elevation change requirement place Apex in the medium to high inefficiency category.

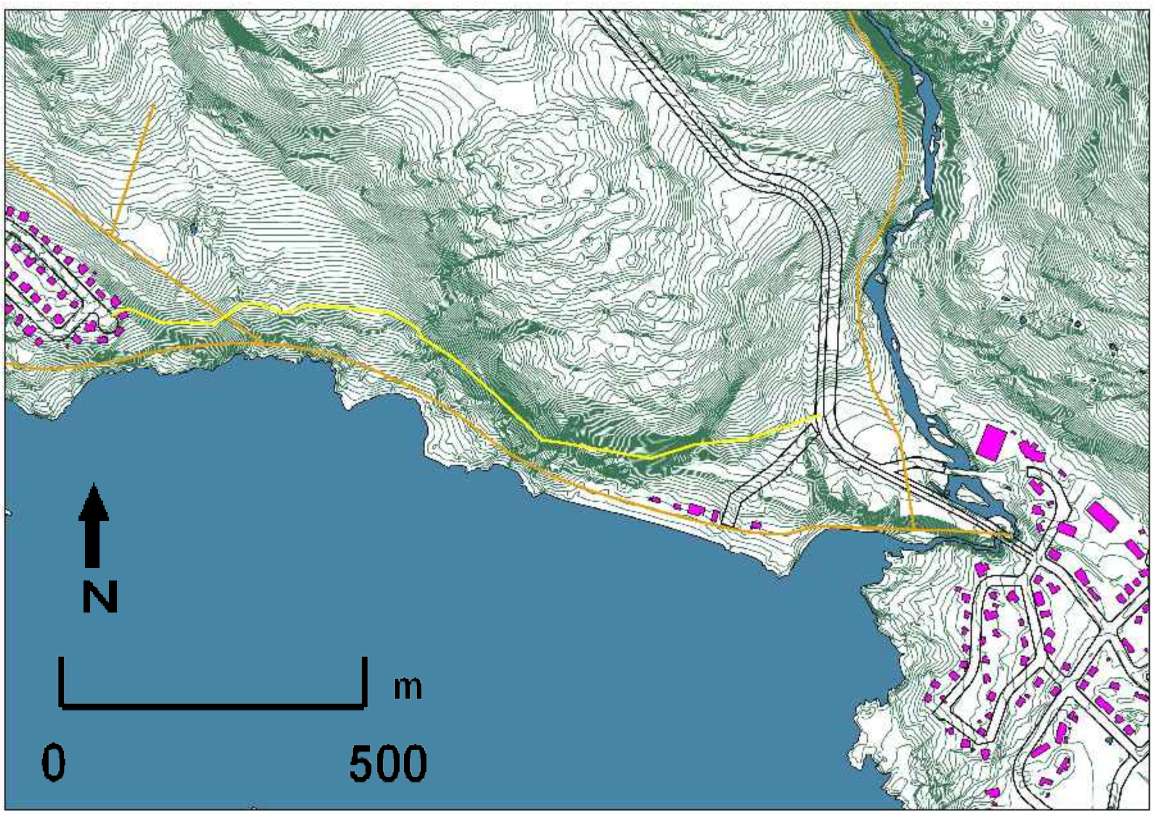


Figure 5.7 Walking Trails in the Far Eastern Region. Orange trails are listed on the Iqaluit GIS, or are currently in existence, but may need maintaining. Yellow trails are possibilities for new trails that are proposed in the text. The yellow trail follows a 30m elevation contour from Apex to Tundra Valley. Green lines are 1m elevation contours.

Figure 5.8 Sunset from the Apex Trail.

Bus Route Comparison and Discussion

Each of the five bus routes developed offer a different set of advantages and disadvantages. Bus Routes 1 and 2 are designed to provide a great deal of benefit to select neighbourhoods, while Bus Routes 3, 4 and 5 are designed to offer a more even level of benefit to multiple neighbourhoods, at the expense of benefit to further out neighbourhoods. All paths that compare bus routes have the Frobisher Complex as their destination point, as this is the final stop for all routes, and gives the best indication of the full potential of a route.

Bus Route 1 provides a benefit only to those neighbourhoods along or above Apex Road, Such as the Road to Nowhere, the Lake Subdivision and Apex. Subdivisions around the Ring Road, such as Flower Valley and Lower Base, also benefit greatly. For these origin point areas, travel time cost proportion estimates[3] are below 2.0, out of a possible scale from 1.0 to 5.0.[4] It could be argued that the outlying suburbs are in greatest need of bus amenities, and that the great savings offered to the distant subdivisions by Bus Route 1 provide a benefit to 'high need users'. As well, Lower Iqaluit and the Plateau Subdivision points have ratios of 1.8 to 3.0 for Bus Routes 1, 2 and 3, making Bus Route 1 a competitive option for Lower Iqaluit and a less competitive option for the Plateau.

Bus Route 2 provides a lower level of cost savings for the Road to Nowhere and Lake Subdivisions, with ratios of 2.05 to 2.35. There is an increased benefit to the Tundra Valley points however, with ratios of 1.19 to 1.52, which is a large saving over the relative unlikelihood that a traveler from Tundra Valley will venture up to Apex Road on foot to catch Bus Route 1. As the decrease in savings to the RTN and Lake subdivisions are quite small, the greater savings to TV points suggest that Bus Route 2 is a better overall option for the eastern subdivisions of Iqaluit. There is little disadvantage to travelers from Apex in using Bus Route 2 over Bus Route 1, as both route options offer ratios of lower than 1.2 to an Apex traveler. In terms of absolute distance, use of Route 2 adds 1km of travel onto an Apex traveler's trip length, but at an assumed average bus speed of 20km/h, an extra kilometer accounts for only an estimated 3 minutes of additional travel time. Given these advantages of Bus Route 2, and that benefits to Lower Iqaluit and to the Plateau Subdivision are identical to those offered by Bus Route 1, Bus Route 2 offers a better option than Route 1 as a transit route for the City of Iqaluit.

Bus Route 3 is similar to Bus Route 2, except for the longer detours into Tundra Valley and Happy Valley, and the re-joining of Apex Road such as the block further east, above Flower Valley. Bus Route 3 adds an additional 2.7kms of travel distance, or about 8 minutes of travel time onto a journey from Apex, as compared to the use of Bus Route 2. This increases approximate journey times from Apex to the Frobisher from about 24 minutes to about 32 minutes. It is important to bear in mind that the 8 minute increase also applies to travelers from Tundra Ridge and the east end of Apex Road. Tundra Valley and Happy Valley benefit most from Bus Route 3, with ratios decreasing from 1.2-1.50 to 1.0 in most cases. Travelers from the northeastern region, including the Lake Subdivision and Apex Road 2 benefit somewhat in comparison to Bus Route 2, with ratio decreasing from 2.05-1.74 to 1.85 to 1.47[5] and distance decreases of 2-300m. Paths starting from Tundra Valley have distance increases of 500 to 900m in changing transit options from Bus Route 2 to Bus Route 3, but this extra distance is covered by bus instead of by walking, so does not add significantly to travel cost. The extra distance represents only 2-3 minutes of additional bus time, while walking distances of 100-800m (2-12 minutes[6]) are shortened or not required. Given that the two routes offer benefits to different neighbourhoods, an assessment of whether Bus Route 2 or 3 offers benefit to the greatest population base could take into account current and projected population data for each neighbourhood, and car ownership patterns for each neighbourhood. Both Bus Route 2 and Bus Route 3 offer an improvement for most suburban neighbourhoods in Iqaluit.

Bus Route 4 requires approximately an additional 7 minutes (2.3 km) of bus travel over Bus Route 3 for users starting in Apex, Tundra Ridge or the east end of Apex Road, making the total journey time to the Frobisher Complex an estimated 39 minutes.[7] From origin points in TV, Bus Route 4 requires an additional 3 to 3.5km or 9-11 minutes of bus travel. In the case of the RTN and Lake Subdivision, ratios decrease from 1.85-2.34 to 1.1-1.2. However, actual travel distances increase by 2.2 to 3.5 km for the RTN and LS respectively, in choosing Bus Route 4 over Bus Route 2 or Bus Route 3, respectively. The LS has a higher travel time cost estimate for Bus Route 4 (8,959) than for Bus Route 3 (7,315) and RTN has a higher travel time cost estimate for Bus Route 2 (10,282) than for Bus Route 4 (7,349)[8]. Travel time cost estimate incorporates walking and bus components of a path, to give an overall idea of how much 'effort' is needed to make the journey. In other words, the LS, Bus Route 3 gives a lower and therefore better effort score than Bus Route 4, while for RTN, Bus Route 4 gives a lower and better effort score than Bus Route 2. Bus Route 4 benefits the RTN Subdivision in terms of its ratio and in terms of travel time cost, decreasing the possible journey time to about 70% (7,349/10, 282 = .715) of that required with Bus Route 2. While the benefit to the LS is smaller, the ratios(1.1-1.2) shows that nearly all of the journey from the LS to the Frobisher Complex can be made by bus with the option of Bus Route 4, with an approximately 400m or 5 minute walk along the Lake Road. The Plateau Subdivision benefits greatly from Bus Route 4, with ratio decreases from 1.81-2.65 to 1.17-1.3, with travel time cost estimates decreasing by 1000-3000. Points along Apex Road as well as Flower Valley experience a trade-off, with low ratios still possible with Bus Route 4, but with increased overall bus travel time. For Happy Valley residents, it is unlikely that the cost of walking uphill to Apex Road would be worth the overall savings in walking distance, especially given that most walks to the Core Area are mainly downhill, or have only a small uphill component. Lower Iqaluit points that are further out from the Core Area benefit from Bus Route 4 over any of the earlier routes, as the detour into Lower Iqaluit is much longer. For the point in Lower Iqaluit on the slight rise below Happy Valley (Lower Iqaluit 3), the ratio decreases from 2.9 for Bus Routes 2 and 3 to 1.36 for Bus Routes 4 and 5. To summarize, it is clear that Bus Route 4 benefits the PS, RTN, LS, and Lower Iqaluit subdivisions at the expense of the TV, TR, HV and Apex Subdivisions. As TV, TR and Apex are a considerable population base and are far from the Core Area, a bus route that leaves these neighbourhoods without transit amenities is not the best option for a single bus route in Iqaluit. Bus Route 4 could offer considerable benefit in a multi route system, where Apex and the subdivisions below Apex Road have access to another route.

Bus Route 5 shares some of the attributes of Bus Route 4, but does not make such extensive detours into PS or RTN neighbourhoods. Travel distances from Apex, TV and TR are cut by 2.5km, or 10-12 minutes of travel time, as compared to the paths created with Bus Route 4. The shorter loop into the RTN has no negative effect on the LS, but does increase the ratio for the RTN from 1.1 to 1.5. Still, the walking that is required from the RTN to the nearest bus stop is downhill, and the cost savings to all outer suburbs for not traveling up the RTN loop could make the route much more inviting to TV, TR and Apex residents than Bus Route 4. Bus Route 5 also includes a small loop into Happy Valley that adds 200m onto the route as compared to remaining on the Apex Road, improving access for those in this inner subdivision, without creating much disadvantage for outer neighbourhoods. Lower Iqaluit benefits from Bus Route 5, as it does from Bus Route 4. The only neighbourhood that suffers from Bus Route 5 in comparison to Bus Route 4 is the Plateau Subdivision. A downhill walk of 250-800m is required from the Plateau Subdivision for all route options other than Bus Route 4. The bulk of housing in the PS is centred in the area on top of the Plateau, which is 600m from the access point on the Ring Road. In order to usefully serve the Plateau's population, a bus route detour would need to extend at least 600m from the Ring Road. To incorporate a total of 1200m in detour would add at least 4 minutes onto the trip time for all subdivisions[9]. In contrast, Bus Route 5's detour into the RTN area requires only a 350m detour to provide some level of service to the LS and the eastern areas of the RTN loop. Incorporating the physically remote PS into a transit routing scheme that doesn't disadvantage the other neighbouroods of Iqaluit could be one of the city's major transit routing problems in future transit planning initiatives. If populations increase in the PS, it may be worthwhile to consider a separate transit loop for the PS that doesn't effect transit service to other neighbourhoods. With the exception of the issues relating to the PS, Bus Route 5 would seem to offer a very good transit option for most neighbourhoods, in comparison to the other routes proposed.

Of the bus routes proposed, Bus Route 5 offers the best overall benefit to Iqaluit's various neighbourhoods, with Routes 2 and 3 also offering some level of benefit. Routes 1 and 4 offer a high level of benefit to some neighbourhoods while leaving others without transit amenities, and so would only be viable routing options in multi route systems. In Iqaluit's current situation, which has no transit routes, Bus Route 5 would be the route option recommended for a potential first route in a city transit scheme.

Planning Implications for Iqaluit

The City of Iqaluit, with its isolated location, small population base, and unusual landscape considerations, presents a unique challenge in transportation planning. This study has focused on charting the pedestrian realm in the city's residential subdivisions, particularly potential patterns of mobility within and between residential districts. Existing trails serve to link neighbourhoods, but the trail network could be extended to allow for better connections from some neighbourhoods to the central core of Iqaluit. Trails must make intuitive use of the topography of the physical landscape, avoiding steep slopes in favour of flat ridges or terraces. As land use patterns in Iqaluit change and potentially densify, pedestrian trails could become of greater importance to people walking between different areas of the community.

Providing trail options gives users the opportunity to decide for themselves which is the most enjoyable or practical route between locations and this ability to choose adds to the quality of life for residents. In terms of movement by bus, of the various routes designed and investigated for this study, Bus Route 5 has been chosen as possessing the most potential for Iqaluit. The city has had bus service in the past, which have been discontinued for various reasons. A resident interviewed by the Nunatsiaq News in 2003 reported using the bus daily with her son to journey from Apex to the downtown core (Nunatsiaq News, 2003). The article also reported that Iqaluit was one of the smallest communities in Canada to offer bus service. However, Iqaluit is different from most small towns in Canada, in that it is a regional and territorial government centre. Despite its small population of some 8,000 people, it is also the largest community in Nunavut Territory. Because of this unique status, Iqaluit can be viewed more as a ‘miniature city’ than as a small town. The ambitious plans of the COCDRP, the Feasibility Study, and other planning documents prepared for the City of Iqaluit point to its special character as a ‘demonstration’ city for encouraging public transit. The addition of a transit service would do much to improve Iqaluit’s potential as a sustainable northern city.

The research design for this study was strengthened by my experience of living and walking in Iqaluit for four months during the summer of 2008. I walked through most residential neighbourhoods in Iqaluit, gaining a sense of the needs of pedestrians. In more specific analytical terms, several different metrics of transportation cost were developed for testing; and each presents a different element of potential transportation costs faced by walkers and bus users. These metrics or estimates can be viewed separately or in combination with each other. This allows for either a more complete or fragmented view of cost. The results highlight differences between the costs of various paths. The number of paths that were created contributes positively to the research design. Over 200 possible paths within the urban transportation network were tested. The research design can be adapted to other northern communities and to other rural communities where landscape, elevation and unusual road and trail networks are factors affecting mobility patterns and transportation networks.

The research design has recognizable weaknesses, but these could be strengthened by further research. One apparent weakness is the inadequate consideration of weather concerns in determining the cost of transportation in Iqaluit. A further study could model wind speeds, snow depths, and winter temperatures to estimate their effects on transportation costs. In this study, weather is modeled in the sense that some trails included in the trail network are passable only in summer weather, or only with adequate winter maintenance. The cost of winter trail maintenance is another factor that falls into the category of 'unknown' factors.[10] Thus, the comparison of paths in the study assumes a comparison given static weather conditions. The assumption is that Iqaluit's hostile weather makes all distances, slopes, and non-linear travel to be higher in cost than those of southern cities. Even though distances in Iqaluit are relatively short, travel costs are higher per distance unit, because of weather conditions. Weather factors also include mud (which makes for slower travel on road-sides) and dust (which, combined with wind, creates the need for eye and head protection) (Figure 5.9). Another potential weakness of the study is its incomplete definition of 'cost.' As used here, it does not include financial costs, socioeconomic costs, environmental costs, or cultural differences due to perception of cost. Future research should consider investigating how these costs influence planning for Iqaluit’s transportation needs.

Figure 5.9 Road and trail conditions. Left: melting snow and mud. Right: Snowy roads and footpaths.

Another possible area for improvement in the study is that of overlap or redundancy between the metrics DI and SI, especially in terms of measuring excess travel, although both were designed to examine the question of additional travel from a different perspective. DI is calculated in terms of overall path length, and gives a measure of how much of the length is 'excess' in comparison to a perfect diagonal point to point journey. SI, in contrast, works from the individual segment, aggregating how much of the additional travel in each segment is due to excess longitudinal travel, and how much is due to excess latitudinal travel. The SI measures excess travel by separating the north-to-south component from the east-to-west component, and then compares the aggregated latitudinal and longitudinal travel to the straight line latitudinal and longitudinal distance between the start point and end point of the path.[11] Though not done in this study, the two components of SI, the latitudinal and the longitudinal, could be used to determine where the inefficiency lies in the network, in terms of direction. The SI metric could be modified so that journey inefficiency is calculated by comparing the aggregated vertical and horizontal components of the path to the generalized curve of a path, rather than to a straight horizontal and vertical line from start point to end point. In modifying the SI to do this, it would become more distinct from the DI metric. Functionally, DI and SI are similar, but in working from the level of the segment to the entire path, the SI is a more adaptable tool in terms of how it could be modified to suit different research scenarios.

The use of GIS methods for transportation planning has both strengths and weaknesses, and this can be discussed in terms of qualitative and other quantitative methods. GIS produces visual results that are easily displayed on a map surface or a data table. GIS also gives an accurate reflection of the physical landscape, insofar as it is displayed in the GIS database. GIS methods are easily adapted between cases, meaning that results can be compared across locations, but only if GIS database resources are comparable. Of course, GIS methods represent only part of the group of methods that must be used in creating an accurate image of an urban or rural environment. Social, economic, and environmental factors or concerns can be mapped using GIS methods, but in order to gain a complete picture of any of these elements, GIS methods ideally should be combined with other methods. Interviewing local people, observing traffic patterns, and monitoring environmental factors serve to ensure that accurate social, environmental, and economic data are considered in doing research and making policy decisions. Any data can be entered into a GIS system, but the data collection methods and the currency of the data are of critical importance. GIS methods complement traditional quantitative studies as well, by producing easily visualized map surfaces of the data being analyzed. Overall, GIS methods have much to offer the fields of geography, urban planning and transportation engineering. Ensuring that GIS methods are used in a responsible way that serves to clarify, rather than obscure important issues facing a community, is the duty of the GIS researcher. The tools developed for this study add to the available group of GIS methods for northern and rural communities. Future researchers could add to the data pool that is available for northern research, or alternatively to the set of tools that is available for northern research.

The findings in this study relate to current transport policies, in their attempt to define and improve the urban environment. Similar to the barriers, trails and sculptures recommended in response to the COCDRP, the conclusions of this study also aim to provide an ehanced walking environment in Iqaluit. Further elements that could link the transit study to the policy goals of Iqaluit could include a system of bus shelters, or else a ride-share or car co-operative feasibility study. With its focus on offering options that make the best chance for bus and trail equality between the neighbourhoods in Iqaluit, the study is in support of Iqaluit's policies for improving the coherence of the urban environment. The trail and bus options presented here not only offer improved access between residential areas and core amenities, but between residential neighourhoods themselves.

The conclusions of this study could be presented to the target audience of decision makers and policy analyists at all governement levels via a few methods. A shorter paper that details the highlights of the study could be created and sent to relevant government agencies. As well, a presentation could be distilled from the study's content to be presented at governmental or academic conferences. In settings where a very small window is available for promoting the work, a series of posters, largely focused on the maps presented in the conclusion of this study, could be produced and displayed.

The technical framework created in this study could be adapted by another researcher, working in another community context, provided they had access to GIS-based data about their community, particularly existing road and trail networks, as well as elevation contour data. In addition, some refinements to the plugins created must be made, in order to make them easily usable to others. With the Quantum GIS system and user community, plugins can be made readily available to other researchers. The GIS software itself is user-friendly, easy to install, and takes up little computer storage space. As well, the international community of users and developers offers a great opportunity for researchers to share their technical work with others, regardless of physical location. A written guide in the form of a text file distributed with the plugins would aid other researchers in adapting the applications to their own work, and trouble-shooting when errors occur.

The goal of this study has been to present comparisons and options for future transportation planning in Iqaluit. The study has demonstrated that the existing trail network in Iqaluit enriches the urban environment by providing more efficient routes and greater choice to foot travelers in Iqaluit. By recognizing this situation, it is hoped that the case for maintenance of current trails and the creation of strategic new trails will be strengthened. As well, it has demonstrated that a variety of bus routes would offer benefit to non-car travelers in Iqaluit, and that some bus routing schemes would provide greater benefits than others. As a remote, northern community that acts as a regional centre for the territory of Nunavut, Iqaluit is deserving of future research attention in the fields of urban planning, transportation engineering, and community studies.

Figure 5.10 Way-marking sign in Iqaluit.

Chapter Five notes

1 Other measures by the City Planning Department to improve walking in Iqaluit have been implemented. For example, small wooden pillars have been placed at the edges of many busy roads, to prevent vehicles from hitting pedestrians. Stone edges have been added to some trails to give them further definition and resilience to weather. (COCDRP, throughout)

2 Placement of such trails would be a matter of much debate among city residents and property owners, and it is beyond the reach of this study to suggest locations for trails of this type through developed city property. The author appreciates the complexity of this issue and realizes it may be impossible given the nature of the city's land use regulations.

3 For brevity, travel time cost proportion estimate will be referred to in this section as the 'ratio'.

4 Recalling the formula proposed in the methods section, paths that are composed completely of walking segments have a travel time cost proportion estimate of 5.0, while paths that are composed completely of bus segments have a travel time cost proportion estimate of 1.0. This rests on estimates of average walking speeds being 4-5 km/h and average bus speeds being 20km/h. The travel time cost ratio is found by dividing the travel time estimate by the path length.

5 The RTN also benefits from Bus Route 3 over Bus Route 2, but a ratio figure was not obtained for this path set.

6 Based on an assumption of walking speed being 4-5 km/h, a possible range of required walking distances in TV is estimated as being 1-12 minutes.

7 Actual journey times become more approximate as they are longer. In addition, turning time for buses on side roads could add to the total travel time. 39-40 minutes is likely a conservative estimate.

8 Note that the travel time cost estimate is a measure with no unit, that aggregates bus segment lengths as is with pedestrian segmented lengths multiplied by five. It is a measurement to represent time estimates in a comparable form without assigning concrete time estimates. Estimates are expressed as times in some examples, where the time increase is solely bus or walking and therefore easier to gauge. In cases where the time increases and decreases are a mix of walking and bus times, the unitless travel time cost estimate allows for easier comparison.

9 A conservative estimate, based on the assumed average bus speed of 20km/h. In reality, bus turning times and slowing of speed on uphill and downhill slopes could make the detour longer.

10 Maintenance of trails could include clearing them after snow falls in winter, creating small bridges in the thaw season over running water, or clearing away of accumulated debris that may block trails. Signage guiding users to trails could also be an element of trail maintenance.

11Both SI and DI use path length as a scaling factor. This is not to be confused with the way that each is calculated before being scaled, which makes use of two different methods of distance comparison, as detailed in the text.

Appendix 1 – Table of Terms Used in Methods Section (in Approximate order presented in Text)

Term	Definition
Path	A vector polyline object that represents a journey on the map interface. Paths are composed of segments preexisting in the road, trail and bus layers. In this study, paths are walking and bus journeys between locations in Iqaluit.
Road	In this study, 'road' refers to a vehicle access route that is present on the Iqaluit GIS database and can be used by automobiles and all terrain vehicles.
Trail	In this study, 'trail' refers to a pedestrian access route that is present on the Iqaluit GIS database. Snowmobile trails are a separate issue and are not addressed in this study.
Path Length	The measurement, in metres, of a path object.
Origin Point	The vector point on the map interface that represents the starting point of a path. In this study, they are usually residential areas.
Destination Point	The vector point on the map interface that represents the end point of a path. In this study, they are usually public destinations.
Point to Point Distance	The measurement, in metres, of the distance between a given origin point and a given destination point.
Plugin	A small software application written to perform a computational task. Plugins used in this study were written in the Python programming language and use the PyQT modules to integrate with the Quantum GIS Freeware GIS software package.
Road Layer	A vector polyline layer that represents the road network in Iqaluit. Polyline objects within the layer represent individual road segments in the network.

Term	Definition
Road and Trail Layer	A vector polyline layer that represents the road network in Iqaluit as well as the existing trail network. Polyline objects within the layer represent individual road and trail segments in the network.
Bus Route	A vector polyline layer that represents a potential transit route for Iqaluit. The feature objects in the layer are ordered so that travel along the route take place in a predetermined direction and sequence.
Distance Inefficiency(DI)	A metric that that estimates the 'distance inefficiency' or extra distance travel on a path between two points, by finding the difference between the path length and the point to point distance and then dividing the result by the path length as a scaling factor.
Elevation Difference	The difference in elevation measures between the origin and destination point on a path.
Sum of Elevation Differences	The accumulated elevation change along a path, measured within each segment of the path and aggregated as absolute values.
Elevation Inefficiency(EI)	A metric that estimates the 'elevation inefficiency' or extra uphill and downhill travel on a path between two points, by finding the difference between the sum of elevation differences and the elevation difference and then dividing the result ten and by the point to point distance as scaling factors.
Straightness Inefficiency(SI)	A metric that estimates the 'straightness inefficiency' or extra non-linear travel on a path between two points. SI is estimated by first finding the north-south and east-west differences between the origin and destination points. Then, the total east-west and north-south travel accumulated along the path is calculated. The point to point difference is subtracted from the accumulated difference for both the north-south and east-west cases, and in each case the difference is divided by the path length as a scaling factor. Finally, the two values are averaged together to find a total path straightness estimate (SI).

Term	Definition
Cost Inefficiency Estimate	A subjective estimate of the total 'inefficiency' of a path, determined by adding together DI, SI, EI and a variable to represent relative path length. The path length variable is entered as '1' in cases where a path's efficiency is being measured in isolation, as the path length in itself is not a contributor to the path's inefficiency. Path length included as a proportion between two paths with identical origin and destination points, with the shorter path's length entered as '1' and the longer path's length entered as a number greater than 1.
Travel Time Cost Estimate	The travel time cost estimate made by the plugin using the 5 times speed assumption, which will be a number between one and five times greater than the path length
Travel Time Cost Proportion Estimate	The proportion of the travel time cost estimate to the path length. This proportion is by default '5' in the cases with no bus segments, as the walking speed is assumed to be five times that of bus speed. In paths with a bus component, the travel time cost becomes smaller, to a possible minimum value of '1' in cases where bus travel is possible for the entire journey.

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