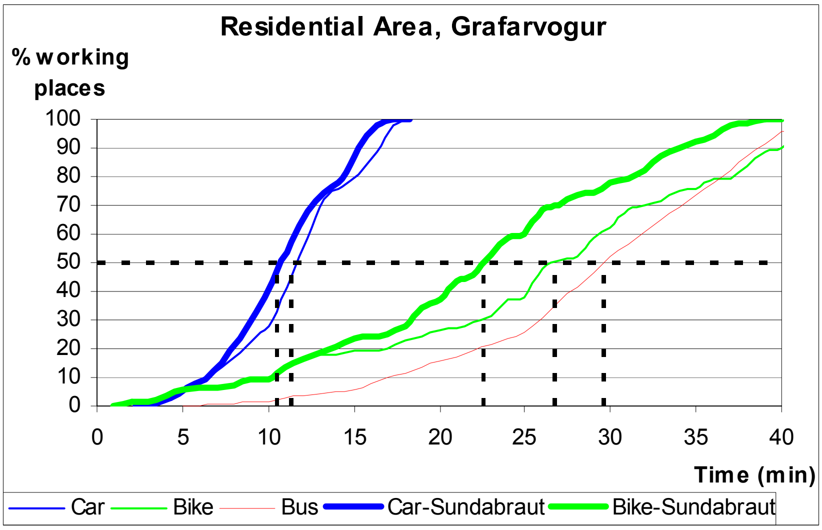
Thesis 139

Accessibility analysis for Reykjavík, Iceland



Hörður Bjarnason

2005

Lund University

Lund Institute of Technology
Department of Technology and Society
Traffic and Road

Accessibility analysis for Reykjavík, Iceland

Hörður Bjarnason

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Hörður Bjarnason

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Keywords:
Reykjavík, accessibility, network, working places, travel time, car, bus, bicycle

Abstract:
Over the last decades our global society has been highly influenced by automobility planning. Growing mobility has been seen as an indication of a well-functioning transport system and a society with increasing welfare.

It can be difficult to measure accessibility in the right way. Geographical Information Systems (GIS) provide a favorable working environment since transport data are spatial in nature. The aim of the study is to measure the accessibility between home and work and between home and the main places in Reykjavík by comparing the transport modes car, bicycle and bus in Reykjavík city, the capital of Iceland. With large number of car ownership in Reykjavík, increasing interest in cycling to work and new bus system that took place summer 2005 it is interesting to do accessibility analysis for the city.

The results show that the sea surrounding Reykjavík works as barrier for one of the major residential areas east of the city (Grafarvogur). This study also reveals that the car has great advantage comparing to bicycle and bus. Long parking time and walking time from car affects the accessibility for bicycle and bus positively, especially in the centre where the best bicycle and bus accessibility is.

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Institutionen för Teknik och samhälle
Lunds Tekniska Högskola
Trafik och väg
Box 118, 221 00 LUND, Sverige

Department of Technology and Society
Lund Institute of Technology
Traffic and Road
Box 118, SE-221 00 Lund, Sweden

Preface

In the beginning of the year 2005, my tutor Bengt Holmberg, held a lecture in one of my traffic courses about accessibility analysis for towns and cities. I thought it could be interesting to do such an analysis for the city of Reykjavík and this study is the result from that idea.

I would like to thank the personnel at the Department of Technology and Society, Lunds Institute of Technology for the last couple of years. Also I would like to thank my tutor Bengt Holmberg for being so positive when I came to him with this idea for a thesis and helping me getting started.

I would like to thank Hnit Consulting Engineers in Iceland, Reykjavík City and Strætó bs. (responsible for the public transport in Reykjavík) for all the information and data they provided me. Also thanks to Micael Runnström at GIS Centre and Hanna Larsson at Department of Technology and Society for all data help.

Last but definitely not the least I would like to thank my wife, Vala, for good advices and cozy time doing our thesis at home in the study room! And to my beautiful angels, Tómas Helgi and Ísabella Helga, I would like to say that daddy is now back…

Lund, November 2005

Hörður Bjarnason

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SUMMARY

One of the Nordic countries is Iceland, an island in the Atlantic Ocean, with around 300,000 inhabitants. The capital is Reykjavík, a young and relatively sparse city, where almost 40% of the total population in the country live.

In Reykjavík, the private car ownership is very high (615 cars per 1,000 inhabitants) and with increasing interest in cycling and a new bus system that took place in the summer of 2005, it was interesting to do accessibility analysis for the city of Reykjavík. GIS was used throughout the analysis for the car and bicycle network but for the bus network, a simpler though more effective method was used. The aim of the study is divided into two parts:

1. *To measure accessibility between home and working places*
2. *To measure accessibility between home and interesting/important places*

This was done by comparing the transport modes car, bicycle and bus in Reykjavík.

Reykjavík was divided into 53 sub-districts and 141 plan-districts in the analysis. Information about land usage, traffic and demography was extracted from different databases and connected to the sub-districts while information about the location of all the working places in Reykjavík was connected to the plan-districts.

To be able to measure accessibility in a digital environment it was necessary to do a network analysis for cars, bicycles and busses. All relevant digital material was collected and the data then managed and prepared so a network analysis could be done.

For the network analysis for cars a new speed was created to give more realistic speed distribution. When each road segment had been assigned a speed value, a time field could be created by dividing the length of each road segment with the speed. In a network analysis like this one, it was necessary to add time to each of the car trips to account for the time it takes to walk to and from the car and potential parking time. To get more realistic values for these times a small research was made where citizens in Reykjavík city where asked about these times and the result was used in the analysis.

The quality of the data is very important and after discovering defects in the bicycle net, a network was created by adding all separate bicycle paths to the car network. The arterial roads were excluded since no bicycles are allowed on that type of road and a lot of minor adjustments were done making the bicycle network more realistic. For the bicycle network, a general speed limit was set and once speeds and length of each road segment was known, a time field could be produced and the network analysis could be undertaken. 1 minute was added to each trip traveling by bicycle to indicate potential walking from home to bike and from bike to destination.

For the network analysis for bus, 92 points where scattered over Reykjavík trying to represent the city in the best possible way. After measuring the travel time to every point from city centre and two of the major residential areas (Grafarvogur and Breiðholt), an accessibility map was made for each area. For the accessibility analysis

focusing on work trips, 5 minutes were added to all working trips as a waiting time. For the accessibility analysis for the main places, 5 or 10 minutes were added to all trips depending on the bus frequency in each sub-district. The main places used in this study are: *City centre*, *The University of Iceland*, *The National University Hospital*, *Laugardalur valley* and *Kringlan Shopping Mall*.

The resulting data obtained from the three network analyses were after that used for the actual accessibility analyses. First, data for the three specific areas mentioned above was extracted and the accessibility to all the working places in Reykjavík was analyzed. Second, data for the analysis to observe the accessibility to 5 main places in Reykjavík city from 42 sub-districts was extracted and analyzed.

Three important concepts are used in results. The first one is the investigation of how long it takes to reach half of all working places, referred to as AT_{50} (Accessibility Time 50%). The second is the *travel-ratio,* or the ratio between traveling times between bike and car or bus and car. The third is the *direct-ratio,* or the ratio between the true distance and the crow's flight distance.

For the accessibility analysis regarding trips to work, the study reveals that the car has great advantage and it's only in city centre where the bicycle threatens the car. For the bus transportation, the travel-ratio is always too high as the bus often loses a lot of time on long walking and waiting times. Not surprisingly, the city centre has the highest accessibility for all three transport modes.

In general, comparing the residential areas Breiðholt and Grafarvogur, a conclusion can be made that it is possible to reach working places faster when traveling by bicycle than by bus. Also has Grafarvogur slightly better bus transportation but the bicycle net seems to be similar for both areas when looking at the travel-ratios for the AT_{50}. When looking at how many working places can be reached from the residential areas within certain time, the situation changes. Then, Breiðholt has an advantage for every transport mode reaching more working places in shorter time. This difference can partly be explained by the geographical situation of Grafarvogur.

The accessibility pattern in the city centre is different compared to the residential areas since working places can be reached faster than from the other two areas. Both bus and bicycle accessibility is acceptable for the city centre. It is though important to realize how much impact the parking and walking time from car has on the accessibility. The most obvious example is for the city centre where these times are quite long which decreases the travel-ratio values for bus and bicycle.

The main conclusion from this thesis is that the sea that surrounds Reykjavík works as a barrier for the people in Grafarvogur so they are forced to drive or cycle quite a distance to pass it. This barrier affects the accessibility to every main place in Reykjavík negatively so that the travel- and direct-ratio values get quite high for the sub-districts in Grafarvogur. A link over the sea clearly improves the situation for the inhabitants in Grafarvogur as this thesis indicates.

SAMMANFATTNING

Ett av de nordiska länderna är Ísland, en ö belägen i Atlanten, med omkring 300 000 invånare. Huvudstaden är Reykjavík, en ung och relativt glesbygd stad, där nästan 40% av landets befolkning bor.

I Reykjavík är bilinnehavet mycket högt (615 bilar per 1000 invånare) och med ett allt större intresse för cykling och ett nytt buss-system från sommar 2005, var det intressant att göra en tillgänglighetsanalys för Reykjavík. GIS användes för analysen för nätverkanalysen för bilister och cyklister men för bussresenärer, mer enklare men effektivare metod användes. Syftet med arbetet är tvådelad:

1. Mäta tillgänglighet mellan bostad och arbete
2. Mäta tillgänglighet mellan bostad och intressanta/viktiga platser

Detta gjordes genom att jämföra bil, cykel och buss i Reykjavík.

I analysen delades Reykjavík in i 53 del-områden och 141 plan-områden. Information om markanvändning, trafik och demografi har tagits ur olika databaser och kopplat till under-områden medan information om alla arbetsplatser i Reykjavík var kopplat till plan-områden.

För att mäta tillgänglighet i digital miljö är det viktigt att göra nätverksanalys för bilister, cyklister och bussresenärer. Allt relevant digital material samlades, behandlades och förbereddes för nätverksanalysen.

För nätverksanalysen för bilister, nya hastigheter behövdes användas för mer realistisk hastighet spridning. När varje vägsegment hade fått en medelhastighet, kunde ett tidsfält skapas genom att dividera längden på varje vägsegment med hastigheten. För nätverksanalysen är det viktigt att lägga till tid för varje resa som ska redovisa gångtid till och från bilen och eventuell parkeringstid. För att skapa mer realistiska värden för de tiderna gjordes en liten undersökning där invånare i Reykjavík var frågat om de tiderna och resultatet var använt i analysen.

Kvaliten av datan är mycket viktig och det fanns brister i cykelnätet. Därför skapades det digitala cykelnätverket skapades genom att lägga till alla cykelvägar till bilgatunätet. Motorvägar togs dock bort eftersom cyklister ej är tillåtna på den gatutypen och mycket av mindre justeringar var gjorda för att göra cykelnätet mer realistisk. För cykelnätet sattes en generell hastighet på hela nätet och när varje vägsegment hade fått den hastigheten, kunde ett tidsfält skapas genom att dividera längden på varje vägsegment med hastigheten. 1 minut var lagt till varje cykel resa till att redovisa eventuell gångtid från bostad till cykel och från cykel till destination.

För nätverksanalysen för bussresenärer, 92 punkter var spridit över Reykjavík i försök till att representera Reykjavík. Efter tid mätning av varje resa till varje punkt från centrum och från två av de största bostadsområdena (Grafarvogur och Breiðholt), en tillgänglighetskarta gjordes för varje område. För tillgänglighetsanalysen för resor till arbete, lades 5 minuter väntetid till varje resa. För tillgänglighetsanalysen till huvudplatserna, har 5 eller 10 minuter väntetid lagts till varje resa beroende på turtäthet i varje under-område. Huvudplatserna i analysen är: *Centrum*, *Island University*, *National Universitets Sjukhuset*, *Laugardalur dal* och *Kringlan köpcentrum*.

Datan från de tre nätverks analyserna har använts för tillgänglighetsanalysen. Först togs datan för de tre bostadsområdena och tillgänglighet till alla arbetsplatser i Reykjavík analyserades. Sen togs datan för tillgängligheten till de 5 huvudplatserna i Reykjavík från de 42 under-områderna och analyserades.

Tre viktiga mätt på tillgänglighetanalysen har använts. Det första är tiden det tar att nå hälften av alla arbetsplatser, från och med nu kallat AT_{50} (Accessibility Time 50%). Nästa kallas *restidskvot*, jämförelser av restid mellan cykel och bil eller bus och bil. Sen är det *genhetskvot*, jämförelse mellan fågelavståndet och det verkliga avståndet.

Analysen visar för tillgänglighetsanalysen för resor till arbete, att bilen har en stor fördel framför de andra och det är bara i centrum där cykeln hotar bilen. För bussen är restidskvoterna alltid för höga för att bussen ofta förlorar mycket tid på grund av långa gångtider och väntetider. Centrum har den högsta tillgängligheten för alla transportformer.

Generellt, om man jämför bostadsområdena Breiðholt och Grafarvogur, kan man säga att man kan nå arbetsplatser snabbare med cykel än buss. Grafarvogur har lite bättre busstransporter men cykelnätet ser ut att vara ganska lika för båda områdena om man tittar på restidskvoterna för AT_{50}. Om man tittar på hur många arbetsplatser man kan nå från de områdena inom en viss tid ändras situationen. Då har Breiðholt en stor fördel för varje transportform och man når fler arbetsplatser på mindre tid. Den skillnaden kan man delvis förklara med Grafarvogurs geografiska situation.

Tillgängligheten har en helt annat form för centrum för att man kan snabbare nå arbetsplatser. Både buss- och cykeltillgänglighet är godkänt för centrum. Det är viktigt att inse hur stor påverkan parkeringstid och gångtid från bil har på tillgängligheten. Det mest tydliga exemplet är för centrum där dessa tider är ganska höga och det minskar restidskvoterna för buss och cykel.

Huvud resultat är att sjön kring Reykjavík verkar som en hinder för alla invånare i Grafarvogur så att de måste köra eller cykla långa sträckor för att hinna förbi den. Hindren påverkar tillgängligheten för alla huvudplatserna i Reykjavík negativt på det sättet att restids- och genhetskvoter blir ganska höga för under-områden i Grafarvogur. En länk över sjön skulle förbättra situationen tydligt för Grafarvogur visar den här analysen.

1 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Over the last decades our global society has been highly influenced by auto mobility planning. Growing mobility has been seen as an indication of a well-functioning transport system and a society with increasing welfare.

It can be difficult to measure accessibility in the right way. Geographical Information Systems (GIS) provide a favorable working environment since transport data are spatial in nature. The aim of the study is divided into two parts:

> *To measure general accessibility between home and working places and to compare the accessibility between home and interesting/important places*

This will by done by comparing the transport modes car, bicycle and bus in Reykjavík, the capital of Iceland. The results will be maps of various types, which are easily interpreted.

Reykjavík is a very distributed city with around 114,000 inhabitants and a value of 615 cars per 1,000 inhabitants which is very high. With this large number of car ownership, increasing interest in cycling and a new bus system that took place in the summer of 2005, it is interesting to do accessibility analysis for the city of Reykjavík. GIS is used throughout the analysis for the car and bicycle network but for the bus network, a simpler though more effective method was used.

1.2 METHOD AND SETUP OF THE REPORT

The report is divided into two parts

Literature study

- General overview of Iceland's and Reykjavík's history with special emphasis on traffic and transport.
- General text about city structure, planning and accessibility analysis
- Accessibility analysis for the city of Reykjavík comparing car, bus and bicycle.

The literature study is supposed to describe the history of Reykjavík and its scenario regarding traffic and transport. Also there will be a general overview over city structure and planning and the concept accessibility will be defined.

The analysis is carried out using Geographical Information Systems (GIS) and different databases and/or researches. The analysis can be described as figure 1.1 shows:

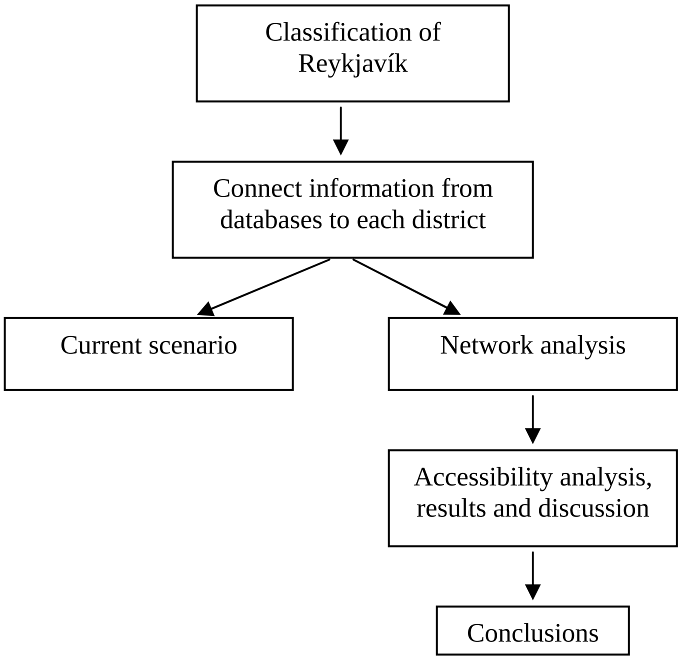

Figure 1.1 Description of the analysis

- *Classification of Reykjavík*. Chapter 4 shows Reykjavík City Master plan 2001-2024. There is also information about how the city is divided into sub-districts from 10 main districts. Furthermore, there is a map that shows how Reykjavík is divided into 141 so called plan-districts. All this is done in the GIS-program ArcView.
- *Connect information from databases to each district*. When the division was finished, information about working places could be connected to the plan-districts and information about demography, land usage and traffic could be connected to the sub-districts. This was also done in ArcView.
- *Current scenario*. Chapter 5.1 describes demography, land usage and traffic situation (car possession and flow) for every sub-district in Reykjavík. This is done by various maps in ArcView.
- *Network analysis*. To be able to measure accessibility in a digital environment it was necessary to do a network analysis for cars, bicycles and busses. After description of how all necessary data was collected (chapter 5.2) and how the data was managed and prepared (chapter 5.3) a network analysis could be done (chapter 5.4).
- *Accessibility analysis, results and discussion*. The resulting data obtained from the three network analyses mentioned above were now ready for the actual accessibility analyses. First, data for three specific areas will be extracted and analyzed for a more focused accessibility analysis (chapter 6.1). Second, data for the analysis to observe the accessibility to 5 main places in Reykjavík city from every sub-district will be extracted and analyzed (chapter 6.2). Results with potential solutions will also be discussed in chapter 6.
- *Conclusions*. Finally, conclusions from the analyses will be discussed with general thoughts about the work.

1.3 MATERIAL, LIMITATION AND QUALITY OF DATA

The focus will be on trips in Reykjavík and the boundaries of the study area are shown in figure 1.1.

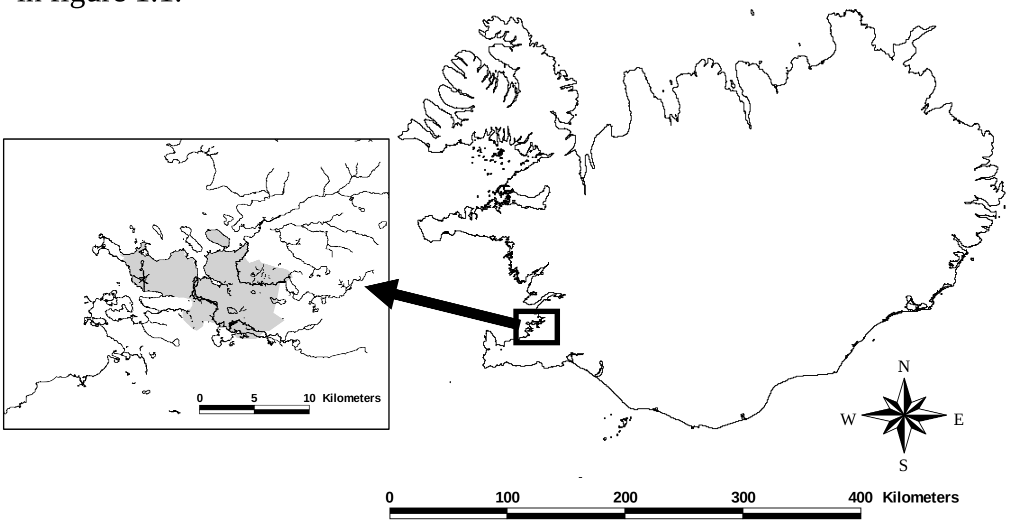

Figure 1.2 The study area Reykjavík City, marked grey, and the location in the southwest part of Iceland

Several generalizations must be taken in this study like when dealing with bicycle accessibility. The issues of biking at night, in rain, in winter time etc. will not be taken into the account. In other words, this study only assesses the actual time aspect, without individual preferences or beliefs. It is also assumed that all trips are carried out straight from home to work and other places without stopping or taking any breaks. Furthermore, great delays of any kind (like traffic jams or delays at peak hours) are not taken into account.

In this study the Reykjavík speed data for cars was extracted from the Swedish city Västerås. Both Västerås and Reykjavík have similar population and both cities have quite many traffic signals but of course there can be a difference in the actual speed patterns for the cities. To give a more realistic interpretation of the actual speed patterns it was decided that the dataset for Västerås would be the best available speed data for the Reykjavík case.

The bicycle speed was set to 16 km/h in this study. However, there is a great variability in cycling speeds and it’s normally between 10 and 20 km/h in Sweden. Because of the geographical situation in Reykjavík (lot of height differences) it could have been more convenient to use lower speed but since there was no available speed data for Reykjavík it was decided to use the average speed in Sweden.

When analyzing the accessibility for each district, one point in the middle of each area will be selected. This point represents the whole district but the situation and the travel time can of course vary in other parts of the area.

Because every sub-district had to be made in ArcView there didn’t exist any direct information about demography, land usage and traffic for these areas. The data was instead extracted from different sources and then connected to each sub-district in ArcView. This entails a small error but should not affect the outcome.

The accessibility is sometimes measured as the number of job opportunities that can be reached within a certain time period from all residential areas. For Reykjavík city there doesn’t exist any data for the job opportunities but information about every working place exist for the plan-districts and is therefore used to make the accessibility analyses. This database for the working places is not perfect. Multi-situated companies like banks are only marked as one working place situated where the head quarters are. This causes an error but it was decided to overlook it since it can be assumed (in most cases) that these companies have their operations evenly scattered over the whole city so the error gets small looking in bigger perspective.

When working with the accessibility for the working places (chapter 6.1) the time taken to reach the 141 plan-districts is measured. These plan-districts are of various sizes that brings a certain degree of lack in quality of the geographical coverage. The districts near the city centre have a finer division than the ones further away from city centre. The error is though rather small since there are not many working places situated in the edge of the city compared to the number of working places near the city centre.

2 REYKJAVÍK – HISTORICAL OVERVIEW

Iceland (see figure 2.1) is located in the North Atlantic Ocean just south of the Arctic Circle and is the world's 18th largest island[1] with a population of 299,577[2]. Iceland is located on a geological hot spot on the Mid-Atlantic Ridge. This combined location means that the island is extremely geologically active, having many volcanoes.

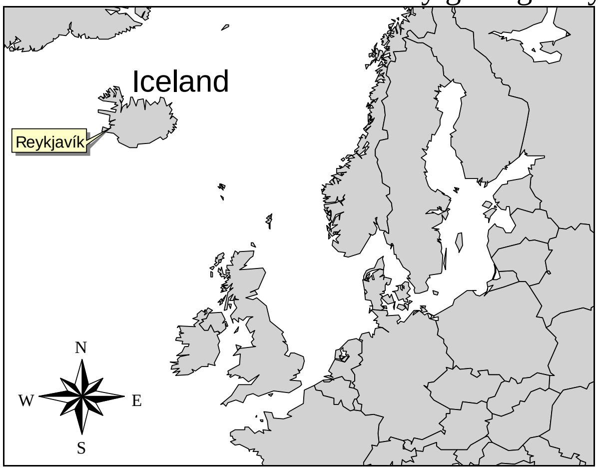

Figure 2.1 Iceland (ArcView maps)

Iceland remained one of the world's last larger islands uninhabited by humans until it was discovered and settled by Norwegian immigrants from Western Norway in the late 9th century. The families were accompanied by servants and slaves, whereof many were Celts from Scotland and Ireland (Wikipedia 2005-10-18). According to historical tradition and existing written sources, Iceland's first permanent settler was Ingólfur Arnarson, who made his home at Reykjavík around AD 870. Legend claims that the decision to settle in Reykjavík was placed in the hands of the gods when Ingólfur threw his high-seat pillars, carved in the likeness of the Norse gods, into the sea, and swore to settle where the pillars washed ashore. It is, however, more likely that the place was chosen for its natural advantages (Árbæjarsafn 2005-10-18). The place was named Reykjavík – "Smoky Bay" - after the columns of steam that rose from the hot springs in the area and made such a profound impression on the original settlers.

Iceland was fairly independent from Norway until 1262 when it became a Norwegian crown colony. From 1397 Iceland was in practice ruled by Denmark, following the Kalmar union[3]. In 1904, Iceland was granted partial autonomy, called Home Rule, and Iceland had its own minister, who was answerable to parliament, and government offices were established in Reykjavík. Then Reykjavík took over Copenhagen's historic role as a capital of Iceland and this evolution was completed when Iceland attained autonomy under the Danish crown in 1918. Foreign relations and defense remained under the authority of Denmark until the World War II military occupation of Denmark by Germany in 1940. In the spring of 1940, the British military occupied Iceland and the year 1944, the current republic was founded in the absence of Danish authority.

[1] Iceland is 103,000 km^2

[2] In december 2004

[3] The Kalmar Union was a series of personal unions (1397-1520) that united the three kingdoms of Denmark, Norway and Sweden under a single monarch.

Even though the history of settlement begins in Reykjavík, it didn't become a market town until 1786 when Denmark ended the monopoly trade in Iceland. About 39,000 inhabitants then lived in Iceland and about 800 lived in a very sparse Reykjavík (Arndals 1989). With rising population and industrialization at the beginning of the 19th century, Reykjavík Town Council could no longer shirk responsibilities. Various new projects had to be undertaken and at 1902, the first engineer in Reykjavík, Knud Zimsen, was appointed and that was the beginning of Reykjavík as a city (Valsson 1986). Sewage system was established in Reykjavík at 1902 and the office of mayor was instituted in 1908. The first major project was the provision of a water supply in 1909, a system of drains was also laid and hygiene improved dramatically. In 1910, the Reykjavík gasworks was founded which was the first power plant in Reykjavík but the town council's most ambitious project was the construction of a harbor in the years from 1913 to 1917 (Árbæjarsafn 2005-10-18).

Iceland's traditional rural society was being transformed into a modern urban-industrial society, with Reykjavík as its oversized centre. People migrated to Reykjavík, leading to population growth which lasted almost continuously throughout the 20th century (figure 2.2) (Árbæjarsafn, 2005-10-18).

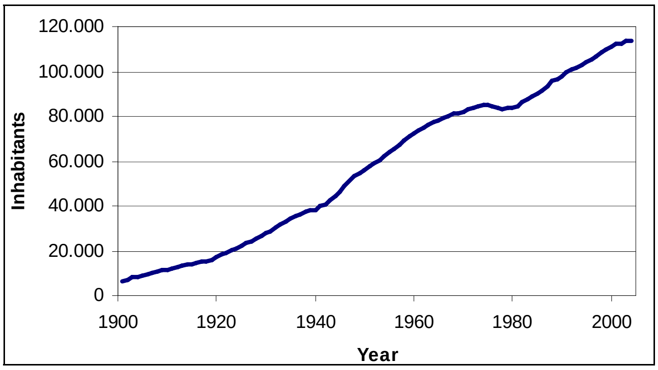

Figure 2.2 Population growth in Reykjavík 1901-2004 (Statistics Iceland 2005-06-24)

The first car came to Iceland on the 20th of June 1904, but the beginning of an increasing car import didn't start until the year 1913 when one of the world famous T-Fords, which Henry Ford managed to manufacture cheap and quick (The Antique Automobile Club of Iceland 2005-10-20). But times changed and car ownership in Iceland and Reykjavík (see figure 2.3) is now among the highest in the world[4] but Reykjavík is not severely affected by this since the city is rather spread out. Most of its urban area is in the form of low-density suburbs and houses are usually widely spaced. The outer residential neighborhoods are as well widely spaced from each other and between them run the main traffic arteries and a lot of empty spaces with little aesthetical or recreational value. The young age of the city has contributed the most to this kind of urban planning.

[4] Year 2003 where 574 passanger cars per 1,000 inhabitants in Iceland and 615 in Reykjavík

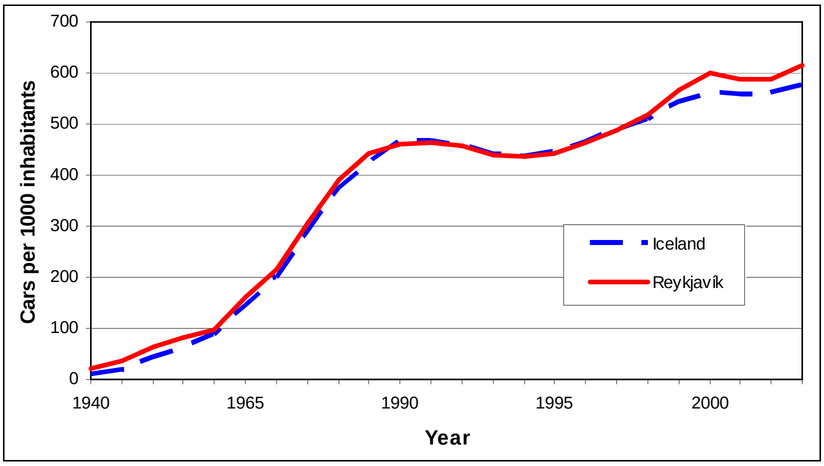

Figure 2.3 Passanger cars per 1,000 inhabitants in Iceland and Reykjavík from 1940 (Statistics Iceland 2005-06-24, The Road Traffic Directorate 2005-10-19, Sigurðsson 2005-09-30).

It is also interesting to look at the changes in the car ownership for Reykjavík and compare them to the population changes, the road system evolution and the bus passenger changes. From 1965 to 2003, the population of Reykjavík increased by 45%, the road system grew by 148% and the number of bus passenger decreased by 45%, while the number of private cars increased by 457% (see figure 2.4).

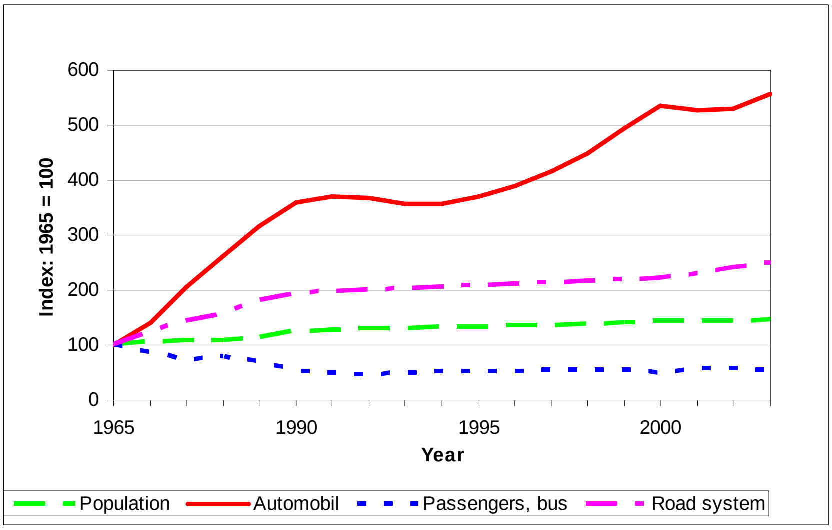

Figure 2.4 Indexes of population, automobile, bus passengers and road system in Reykjavík 1965-2003 (Statistics Iceland 2005-06-24, The Road Traffic Directorate 2005-10-19, Sigurðsson 2005-09-30).

Long time ago most of the population lived in the country site, but to day about 63% live in the Greater Reykjavík area and 39% live in Reykjavík[5]. There are six other municipalities in the Greater Reykjavík area which are shown in figure 2.5. The grey area represents the part that this study applies to.

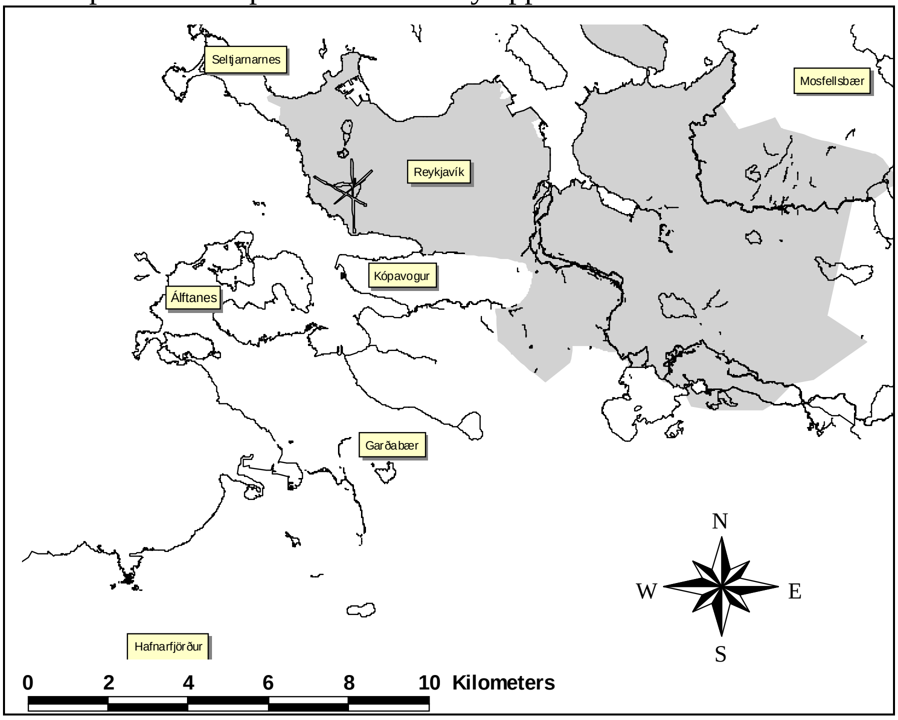

Figure 2.5 The Greater Reykjavík area. The grey area represents Reykjavík (ArcView maps).

Reykjavík is a center for the Greater Reykjavík area and in certain aspect for the whole country. In Reykjavík, most of the Government administrative activities takes place, and the University of Iceland, main hospitals and many companies that people not living in Reykjavík daily attend are located there. For this reason the traffic is more than for a normal city with slightly more than 100,000 inhabitants.

Research over trips in Reykjavík implies that most of the trips are by cars[6]. Public transportation only exists in the form of a bus system[7] and it has been more and more difficult for the bus to be competitive in the rising and always more scattering car friendly city of Reykjavík. Bicycle is almost never used as a means of transport although that the City of Reykjavík has recently made an effort of changing that. It is though important to keep in mind that the research was made during wintertime and the use of bicycle is more common during summer[8].

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[5] The population of Reykjavík in 2004 was 113,848, of Icealand 293,577 and of the Greater Reykjavík area 184,101.

[6] In February 2002 a research was made for Reykjavík City and Reykjavík public transport company (Strætó bs.). According to the research 75.3% of all trips in the Greater Reykjavík area were done with car, 19.5% by feet, 4.0% with bus and 0.3% with bicycle (Sigurðsson 2005-09-30).

[7] The Reykjavík Bus Company was founded in 1931, initially as a private company (Árbæjarsafn 2005-10-18).

[8] The relationship summer/winter in traveling by bicycle is 5/1 for the city of Stockholm (Holmberg, Hydén et al. 1996).

Looking at trips to work in the Greater Reykjavík area, 88% are by car (80% as drivers, 8% as passengers), 4% use public transport and 8% walk. The trips by bikes are classified under “other trips”[9] which only covers 0.5% of the trips to work (Sigurðsson 2005-09-30). Thus, seen from these numbers, the use of car going to work is very high while the public transport use is only 4%.

Train has never been used as a transport method in Iceland and the only train existing in Iceland was used under the construction of the harbor 1913-1917 transporting stones from stone pits to the harbor (Arnalds 1989).

The second largest airport in the country is positioned inside the city, just south of downtown (see figure 2.6). It is mainly used for domestic flights and was built there by the British occupation force during World War II on the outskirts of, then much smaller, Reykjavík. The airport has recently been renovated (from the year 2000 to 2002) in spite some controversy regarding the location of the airport since it takes up a lot of valuable space in downtown Reykjavík, and causes noise and pollution.

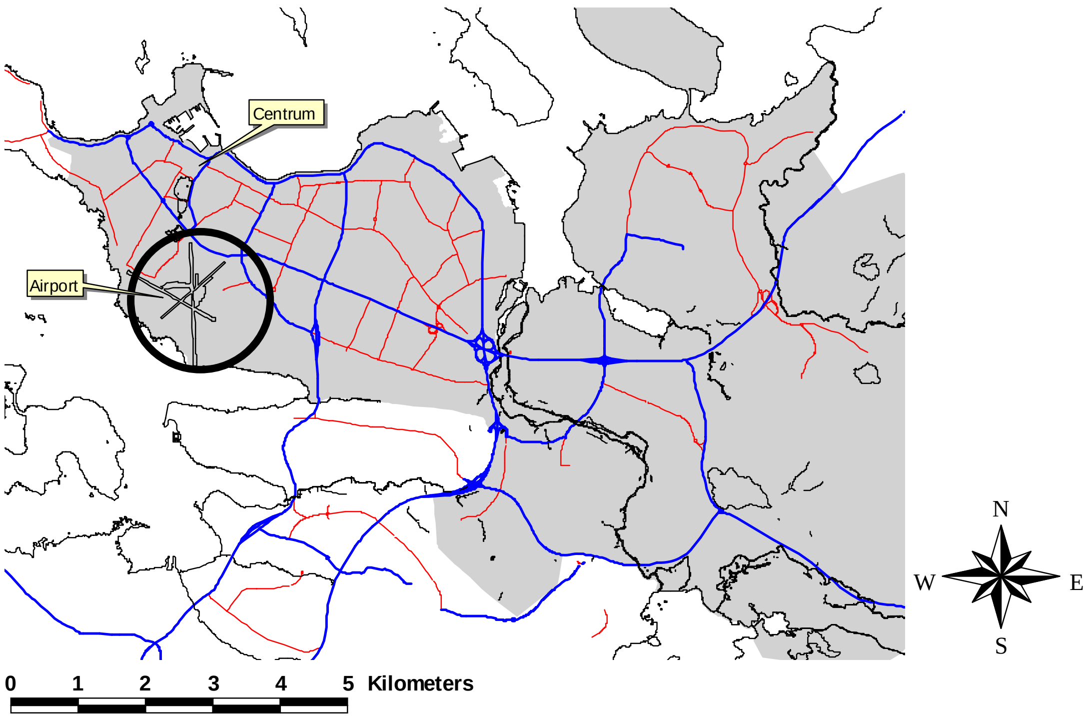


Figure 2.6 Location of the airport in Reykjavík (ArcView maps).

[9] “Other trips” are for example trips with bicycle, taxi, coach or motorcycle

3 STRUCTURE, PLANNING AND ACCESSIBILITY

Karin Book (Book, Eskilsson 2001) has summarized how the development of the society has changed the city structure in the Western World. She describes how the society has changed from concentration to scattering, from centralization to decentralization, from integration to separation and from public transport to private transport solutions.

A city structure is a central concept and can be defined as figure 3.1 indicates. The figure shows how the relation between the built environment and transport structure constitutes the city structure. Furthermore, there are some basic conditions, such as culture, age, climate and physical geographical conditions, which influence the transport structure and built environment. This analyses of the city structure is based on a book by Book and Eskilsson (2001), "Stadens struktur – varför och hur".

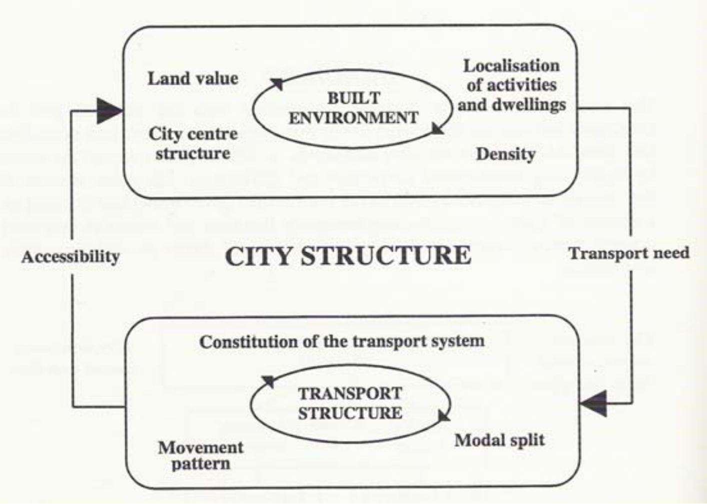


Figure 3.1 City structure (Book, Eskilsson 2001).

<u>Built environment</u> in a city is a result of the mutual interplay between *land value*, *localization of activities and dwellings*, *density* and *city centre structure:*

- *Land value* has a meaning for localization of different activities and is, among other factors, affected by accessibility and attractiveness of places.
- *Localization of activities and dwelling,* or land use, is mainly determined from the different land users' willingness of paying land rent.
- *Density* is defined as population per area but can also, for example, mean closeness of working places.
- *City centre structure* refers to the overall distribution of the city center's functions. Figure 3.2 shows different types of city centre structure (centralized, multi centered, corridor based and scattered).

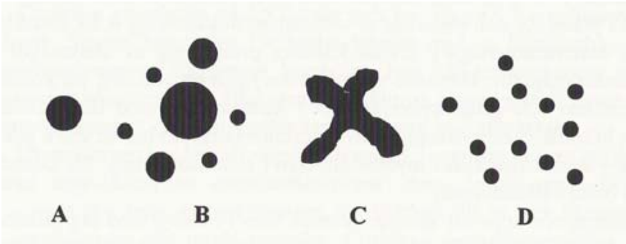


Figure 3.2 Different city centre structure: A) centralized, B) multi centered, C) corridor based and D) scattered (Book, Eskilsson, 2001).

Transport structure is based on the interplay between the *constitution of the transport system*, *modal split* and *movement pattern:*

- *Constitution of the transport system* is dependent on the physical shaping of the transport network.
- *Modal split* describes in what extension the people use different means of transport.
- *Movement pattern* is created from different choice in means of transport and the choice of service the passengers take.

The built environment and the transport structure therefore result from an interplay between many factors. The built environment influences the transport structure by generating a certain transport need and the transport structure influences the built environment by creating different accessibility to different locations (see figure 3.1). In a traditional city there is a main centre where most activities are located, creating a radially shaped transport network. In cities built on car dependence, decentralization and sprawl create dispersion of locations and movements (Book, Eskilsson 2001). This gives rise to two very important concepts in urban and traffic planning: *accessibility* and *mobility*. *Accessibility* is a lot more difficult to define and measure but is here defined as physical accessibility, which represents how easy it is to reach the city's working places, service, recreation, along with different supplies and activities from a certain origin (usually home) with different means of transportation at a certain time of day. This depends for example on travel time, travel cost, comfort, regularity and reliability (Svenska kommunförbundet 1998). Accessibility can also be described as "the individual's possibility to take advantage of resources with a fixed location in space that requires presence. It is obvious that access to resources is restricted by the possibility to overcome distance. Mobility requires resources in terms of time, money, fixed capital, environment etc." (Berglund 2001). *Mobility* is a measure of an individual's resources to move, i.e. age, sex, health, economy and access to driver license and car. Mobility is in a physical sense an index on how easily an individual can move (Hagson 2000), is easy to measure (vehicle kilometers traveled, vehicle occupancy, passenger kilometers, traffic speed or vehicle ownership) and has frequently been used as a welfare indicator.

The accessibility to a city centre is often very high which leads to high land value. Activities which take a lot of space often chose localization with lower land value, but with good accessibility. Areas with the lowest land values often involve poor accessibility (Book, Eskilsson 2001). Examining accessibility can help to determine how suitable a site is for a new business. It can also help to identify what is near an existing business to help to make other marketing decisions (ESRI 1996).

During the 20th Century, people's geographical mobility has increased explosively. As figure 3.3 shows, the mobility has increased from only a half kilometer per day and person in the beginning of the Century to about 50 km/day and person in Sweden (Holmberg, Hydén et al. 1996). This has also been the trend in other industrial countries.

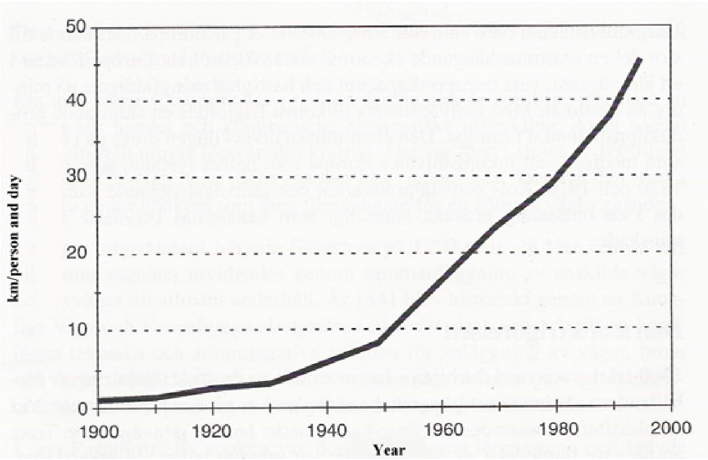


Figure 3.3 Mobility in Sweden from 1900 (Holmberg, Hydén et al. 1996).

From figure 3.4 the transition from the pre-industrial society, where distance was the major friction, to the present service society can be seen. At first, there were few unutilized areas within the urban body and population and building density were high. The home was usually also the space for recreation and work and the possibility to transport was not high. With the industrialization, rail traffic grew and the daily space expanded which enabled separation of work and residential areas. The service society today is characterized by high mobility, geographical flexibility and growing traffic. Cities have grown larger and wider and suburbs are more common (Book, Eskilsson 2001).

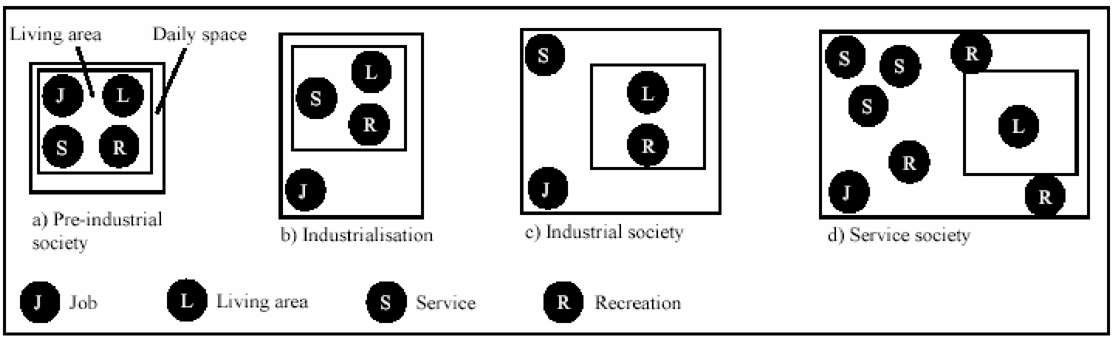


Figure 3.4 Activity location a) in the pre-industrial society, b) during the industrialism, c) in the industrial society and d) in the service society (Lyborg 2000 adapted from Wärneryd 1990). The smaller box represents the living area and the large the daily space.

The main cause for this trend is the evolution of the car. After the World War II the changes have been drastic and for the city of Reykjavík the private car ownership has increased from 36 cars per 1,000 inhabitants at year 1945 to 615 cars at year 2003. It is also interesting to look at the car's meaning in the society's evolution. The car made it possible to build more sparsely than before and its space demand has entailed more scattered settlements. With new traffic roads, transport became faster and more reliable which increased the attractiveness in the areas around these roads. More localization of activities around them increased the traffic in the area and new roads had to be built which led to new localizations and so on (Holmberg, Hydén et al. 1996). In spite of this evolution it is interesting to look at the fact that even though the car has given people new ways to travel fast and comfortable, the time used to travel has not changed. There is a rule called “Zahavis law” or “Hupkes constant” that says that a person spends an average of 70-80 minutes per day moving (or transporting), irrespective of the moving speed (Holmberg, Hydén et al. 1996). This fact partly explains why the mobility has increased so explosively. More scattered settlements and the evolution of the car has entailed that the foundation for public transport and service has decreased which has strengthened the segregation. More flexibility came with the car but nobody foresaw that it would entail more energy use, emissions, higher noise level, scattered settlements and traffic safety problems. This evolution will hopefully change in the future to strengthen the city structure.

4 CLASSIFICATION OF REYKJAVÍK

Fig 4.1 shows Reykjavík City Master plan 2001-2024. From the figure you can see that the residential areas are quite distributed over the whole city.

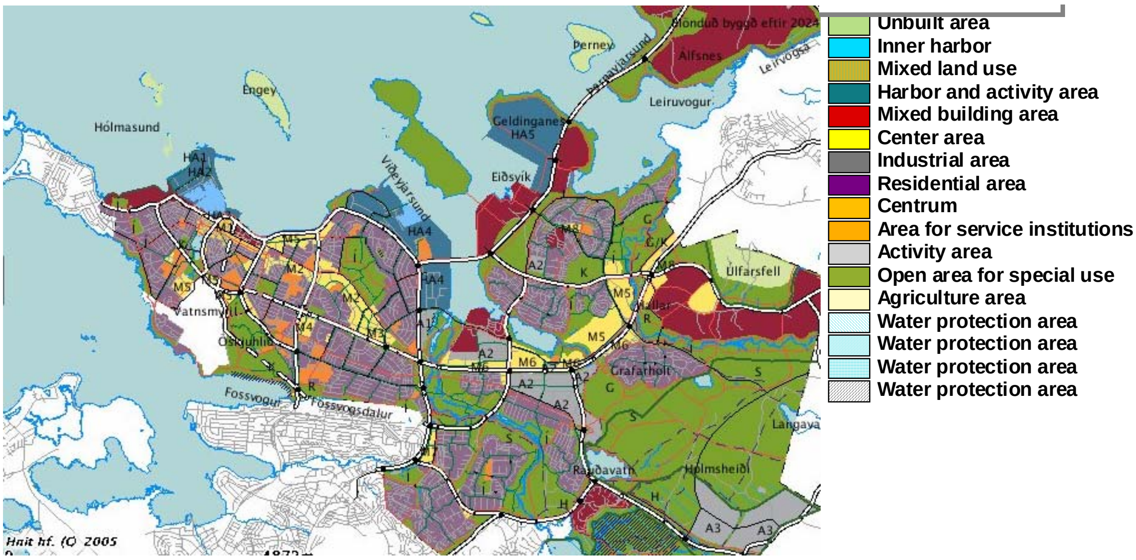


Figure 4.1 Reykjavík City Master plan 2001-2024 (Reykjavík City 2005-07-06)

Reykjavík City is divided into 10 main districts and every district is then divided into even smaller districts, here called sub-districts (see figure 4.2). In the following chapters and analysis, main focus will be on those sub-districts. Appendix I shows information for every sub-district.

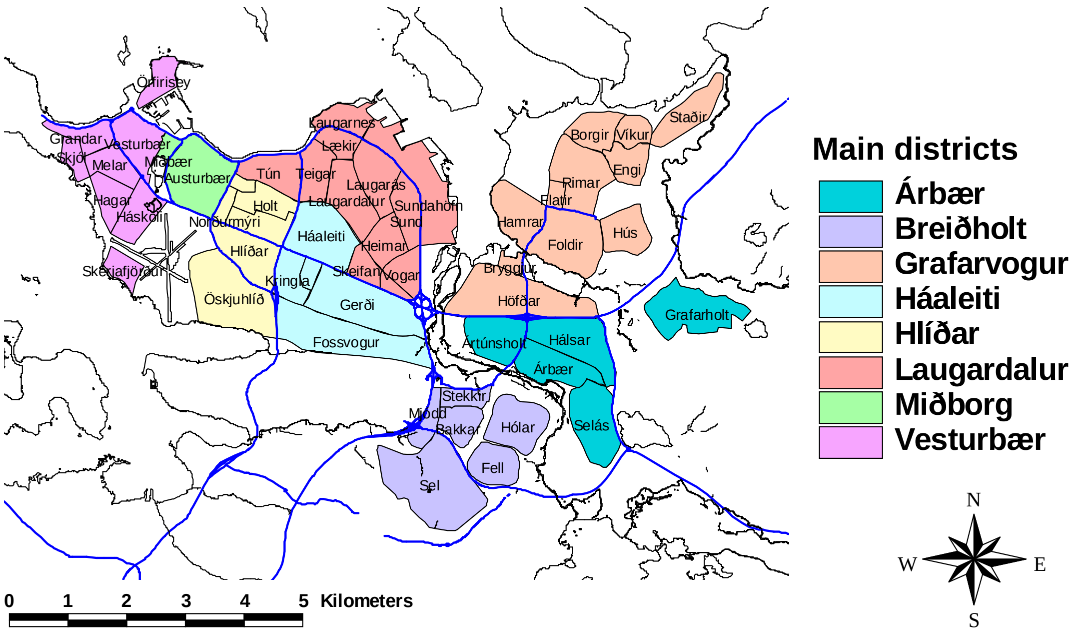


Figure 4.2 The main districts are divided into sub-districts (Reykjavík City 2005-07-06)

Reykjavík City is also divided into 142 plan districts where it is possible to find information about the working places. These plan-districts are of various sizes and the districts near the city centre have a finer division than the ones further away from city centre (see figure 4.3). No connection is between the plan- and the sub-districts.

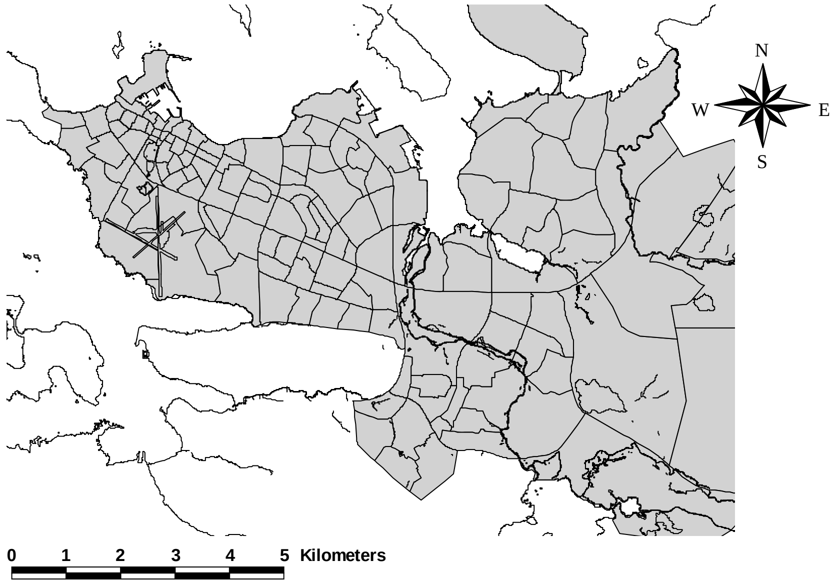


Figure 4.3 The 142 plan-districts in Reykjavík.

5 THE REYKJAVÍK CASE STUDY

An accessibility analysis can be performed in several different ways. In this case, GIS is used as the main tool to analyze and present the results from the Reykjavík case study. First the accessibility will be measured as the number of working places that can be reached within a certain time period from city centre and two residential areas, comparing car, bicycle and bus. Accessibility to five important or interesting locations from every sub-district in Reykjavík is also estimated. A digital copy of the Reykjavík road network enables realistic driving patterns and for this type of study, relevant data has to be collected and analyzed so that a network analysis can be performed. The output will mainly be shown in two different ways. First, the result is maps showing the proportion of work locations that can be reached by bus and bicycle compared to car within a time period. On the other hand the result is maps showing the time difference in traveling from all the residential areas to the five main locations chosen for the city of Reykjavík.

5.1 THE REYKJAVÍK STUDY AREA AND CURRENT SCENARIO

Reykjavík has a dispersed built structure and therefore it can be a subject of a more compact spatial planning. Most of the city's urban area is in the form of low-density suburbs and houses are usually widely spaced.

The fact that the city of Reykjavík is built dispersed is an important aspect because of the following relationship: The sparser the city is the higher facility costs and operational costs for infrastructure and public transport (Hagson 2000). Also it's important to realize the relationship that the lower population density is in an area, the longer distance the inhabitants have to travel for different service. This low service standard is partially explained by the fact that in low population density areas the customers are not many and therefore not preferable for companies to be situated there (Hagson 2000).

5.1.1 YEAR OF CONSTRUCTION

Figure 5.1 shows the average year of construction for every sub-district in Reykjavík. City centre is in the oldest part of Reykjavík. Since then, the city has grown to east as the figure shows clearly.

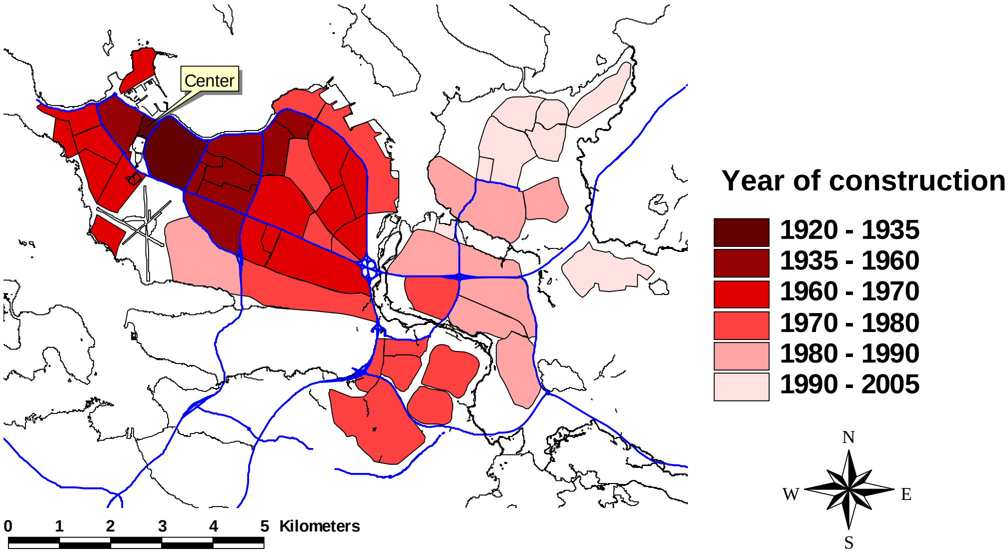


Figure 5.1 Year of construction for different sub-districts in Reykjavík (LUKR data).

5.1.2 POPULATION

The population of Reykjavík in the year 2004 was 113,848 inhabitants which is about 39% of Iceland's population and 62% of the population in the Greater Reykjavík area.

The charts in figure 5.2 show the age distribution in every district in Reykjavík. The size of the chart indicates the total population.

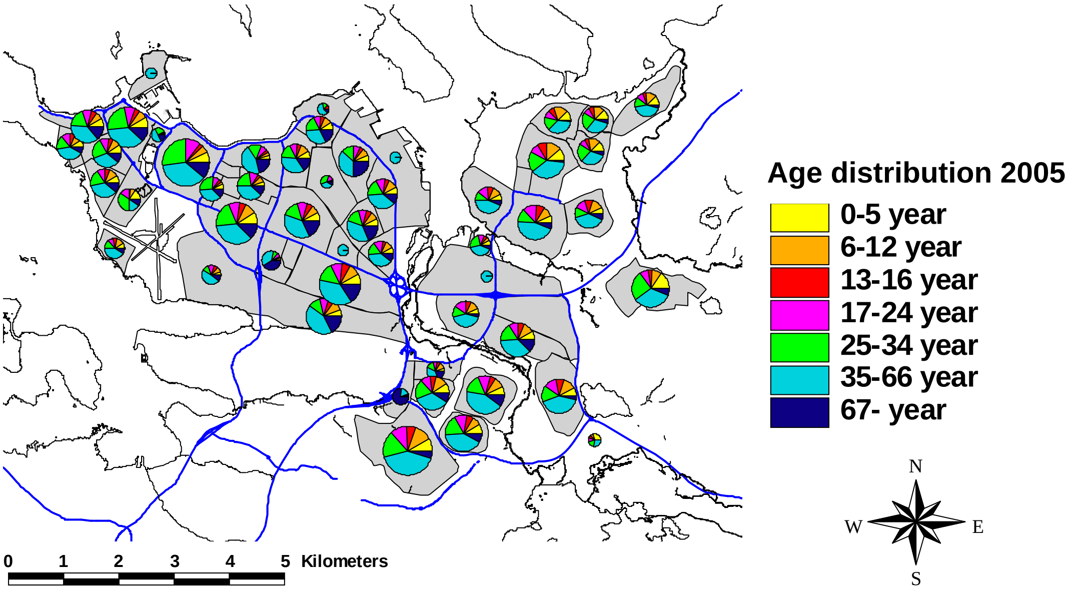


Figure 5.2 Age distribution in Reykjavík. The size of each chart indicates the total population (LUKR data).

To show the population density it is better to use total inhabitants per area like in figure 5.3. The figure shows that the densest districts are in the areas round the city centre, west of Snorrabraut. In some districts in Breiðholt (see figure 5.3) the density is also quite high. The cause of this high density is many high rise buildings in that area.

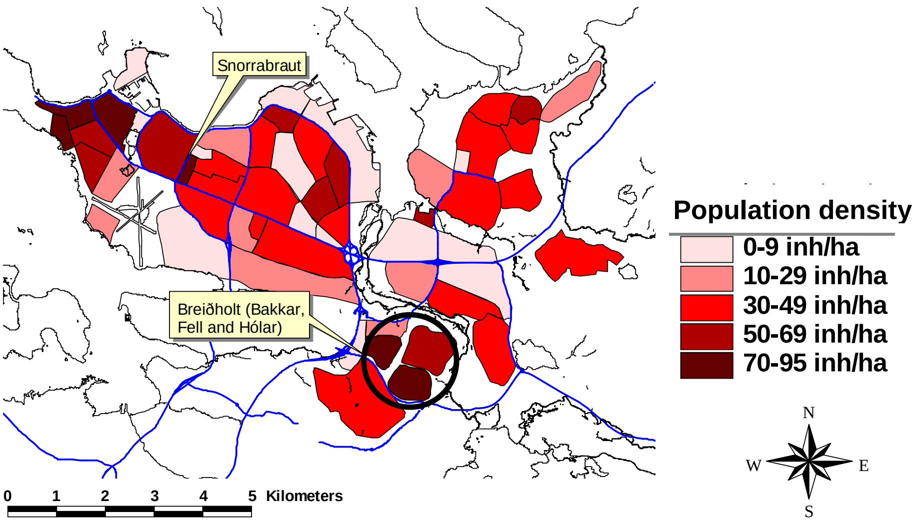


Figure 5.3 Population densities for the sub-districts in Reykjavík (LUKR data).

The population density for all the districts used in the analysis above is around 34 inhabitants/hectare[10].

[10] For the total area of Reykjavík city, the net population density year 2000 was around 27 inh/ha and gross population density around 17 inh/ha (Örn Sigurðsson 2005-10-22)

5.1.3 LAND USAGE

Land usage in Reykjavík is shown in figure 5.4. It shows how big part of the built-up area that is residential. The figure shows that the suburb areas in the north-east and south-east have the highest percentage of residential area.

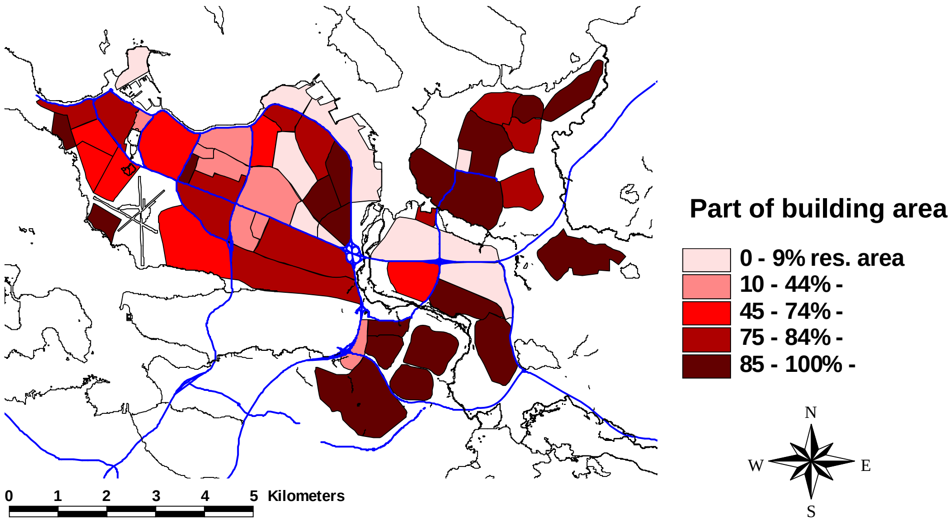


Figure 5.4 Land use in Reykjavík's sub-districts (LUKR data).

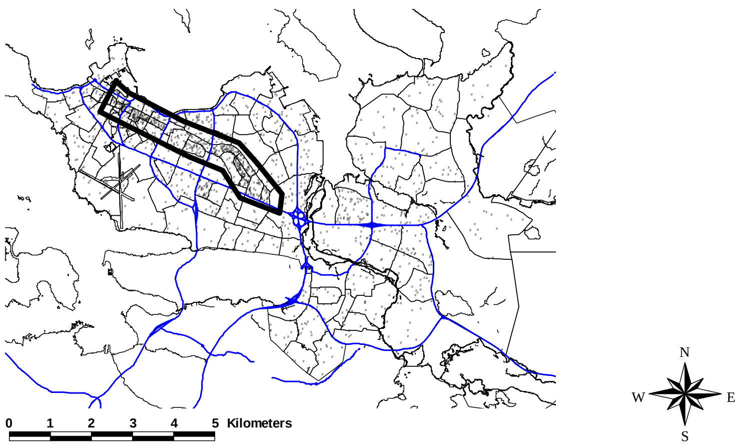


Figure 5.5 Location of working places in Reykjavík. Every dot represents 4 working places. The marked area has the densest working places (LUKR data).

In this analysis, there are about 5,900 working places located within the city border. Figure 5.5 shows the location of all the working places in Reykjavík where every dot represents 4 working places. It can be seen that most of the working places are located around the city centre and east of the city centre (see market area on figure 5.5).

5.1.4 CAR POSSESSION

Car ownership in Iceland is among the highest in the world with 615 private cars per 1,000 inhabitants at the year 2003.

Figure 5.6 shows how the car possession was divided on Reykjavík's post-codes year 2004. The lowest number of private cars per 1,000 inhabitants was in one of the oldest part in Reykjavík, west of city centre with 449 cars. The highest number was in one of the biggest residential areas in Reykjavík, Árbær, with 780 private cars per 1,000 inhabitants which is incredible high[11] (Krisinsdóttir 2005-10-24).

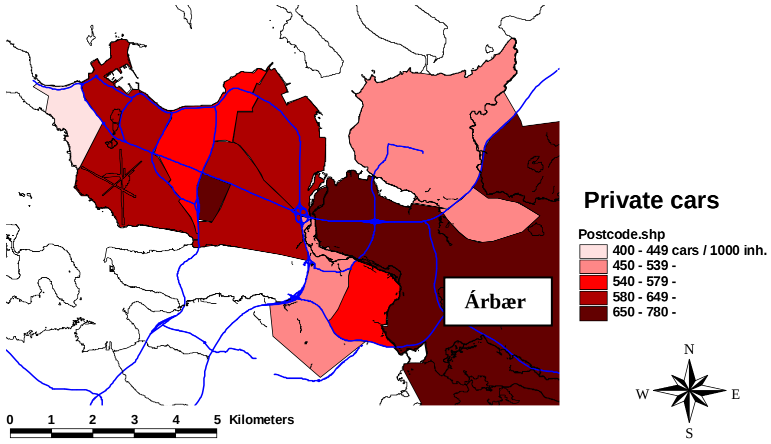


Figure 5.6 Car possessions in different postcodes of Reykjavík 2004 (Krisinsdóttir 2005-10-24).

5.1.5 TRAFFIC

Figure 5.7 shows the traffic in Reykjavík, year 1997. The highest traffic flows is along the entrances in Reykjavík and along the main streets. In the crossings where Miklabraut traffic meets the traffic from the municipalities in south, Kringlumýrarbraut and Reykjanesbraut, the ADT[12] is about 70,000 vehicles respective 100,000 vehicles.

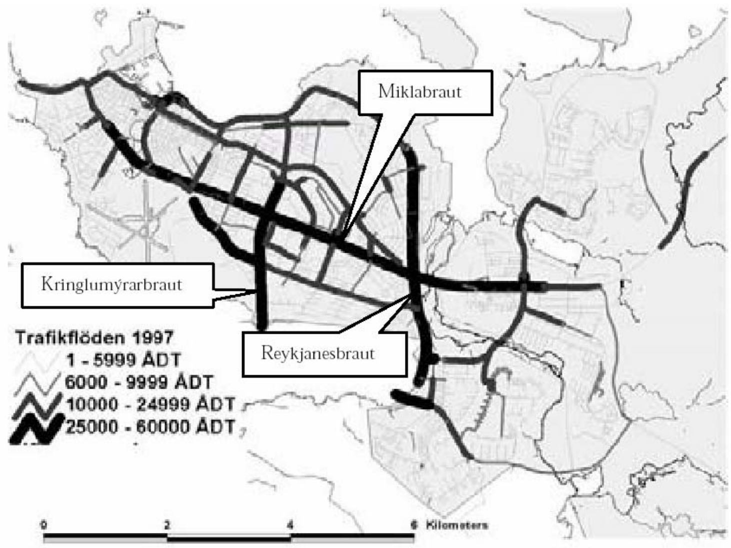


Figure 5.7 Traffic in surveyed sites in Reykjavík 1997 (Erlendsdóttir 2003).

[11] Today, many experts say that the saturation level is 800 cars per 1,000 inhabitants (Holmberg, Hydén et al. 1996).
[12] ADT is the Annual Daily Traffic.

5.2 COLLECTION OF DATA

All relevant digital material was collected, with permission from Reykjavík City, from Hnit Consulting Engineers in Reykjavík which has been consultant to the Reykjavík geographical information system project (also called LUKR) from its beginning in 1988. LUKR is a joint GIS-system of the municipal technical departments of the city of Reykjavík and the Telecommunications of Iceland, including the entire public utilities systems in Reykjavík. The system was built up to establish and run a coordinated GIS system for the entire city and is intended for the input and processing of both graphical and text based data that are related to certain areas or places[13]. The buildings and lots in LUKR are connected to corresponding records in the Building Inspector's database and the National Real Estate Registry, which has connections to the National Population Registry. Data that was connected to the digital material mentioned above was collected through the “City Web View” (“Borgarvefsjá”, http://www.borgarvefsja.is) which is a tool for the public to get maps and information out of LUKR and connected databases, see figure 5.8.

Figure 5.8 ”City Web View” www.borgarvefsja.is

The most important data collected is:

- A GIS street layer (PolyLines) of Reykjavík city with associated attributes, such as street name, type and speed limit. This street layer was also used as a bicycle layer with some modifications.
- A GIS layer of all bicycle paths within the city limits. Because of faults in this bicycle layer it was instead used as a guideline, modifying the street layer so it could be used as a bicycle layer.
- A GIS-based polygon layer of coded plan districts for the Greater Reykjavík area. The layer consists of 229 polygons but only the ones located within the city of Reykjavík were used in the analysis, or a total of 141 polygons.
- Data containing information about the total number of working places in each of the 141 districts in Reykjavík city. This data was connected to the GIS-based polygon layer of the coded plan districts described above.
- Data containing information how the city of Reykjavík is divided into sub-districts, received from the “City Web View” (http://www.borgarvefsja.is).

[13] The LUKR-system covers the Reykjavík municipality area of 270 km^2, including an urban area of 45 km^2.

- Data about the bus routes in Reykjavík city and the systems timetable, received from the public transport company in Reykjavík (Strætó bs.) through their homepage (http://www.bus.is).

Data from LUKR is stored in a coordinate system called ISN93 which is based on a Lambert Conformal Conical projection[14] (see figure 5.9).

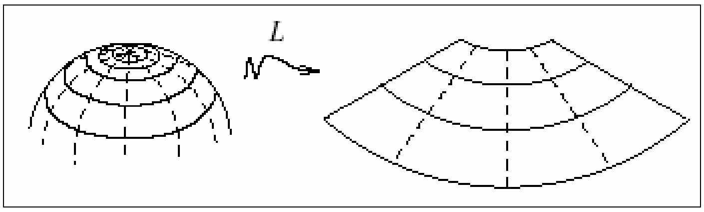


Figure 5.9 Lambert Conformal Conical projection (Bou-Rabee 2005-10-24)

5.3 DATA MANAGEMENT AND PREPARATION

The GIS material received was delivered in Shape format,[15] so the first step was to import it into the GIS software ArcView GIS 3.3 where all the analyses were performed. The quality of the data is very important and very early in the analysis, defects in the bicycle net were found. It is very crucial when working with network analysis that all intersections and roads are interconnected but for the bicycle net it was not the case. The bicycle layer did not have this topological consistency and there were a lot of dangling nodes (see figure 5.10, left).

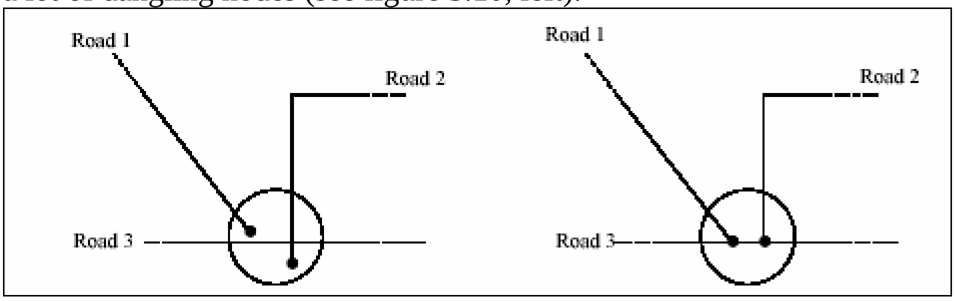


Figure 5.10 To the left the dangling nodes are shown. To the right the dangling nodes have been cleaned and there are proper intersections between the roads (Lyborg 2000).

Often it is sufficient to “clean” such layer from these nodes and create new nodes instead (figure 5.10, right) but in this case the dangling notes were found in almost every intersection and therefore quite many. Instead it was decided to make some adjustments to the car street layer and it was therefore imported in ArcMap 8.3 since that program offers a more convenient working tool dealing with such problems. After the adjustments the layer was again imported in ArcView GIS 3.3 for the bicycle network analysis. Figure 5.11 shows one example how the car layer was modified making the bicycle layer. To the left is the original car layer and to the right is the

[14] The projection is with two standard paralles of 64° 15' N and 65° 45' N and is centered at 65° N and 19° W.
[15] Shape is ArcView’s internal format for vector data. Associated to the Shape file, there is a file to handle attributes and an index file. Nearly all other GIS programs can import this format.

bicycle layer adjusted from the car layer. The big arterial roads and the roads crossing have been taken away (see grey colored roads to the left) and bicycle paths placed instead. Also, a lot of minor adjustments (like assembling car road ends with bicycle paths) were done and can be seen in the figures.

Figure 5.11 Example how the car layer was modified making the bicycle layer. To the left is the original car layer and to the right is the bicycle layer adjusted from the car layer (ArcView maps).

Bridges, under- and overpasses, one-way streets and streets closed for car traffic are other important features of the network. In the data received for the analysis no adjustments had to be done because of this.

The working place database was joined with the polygon with the coded plan districts layer to create a layer with all the business information. A layer was also produced for the real property data, so that each district polygon in Reykjavík contains information about the number of people living there.

5.4 NETWORK ANALYSIS

When measuring accessibility in a digital environment, several studies are based on the air distance multiplied with a factor as an estimate of the real distance between two places or within a certain radius (Lyborg 2000). With ArcView's software *NetWork Analyst* (ESRI 1996) a digital version of the real street network can be used to calculate the closest or the fastest route between two points. The *NetWork Analyst* also provides a tool, called *service area*, to evaluate accessibility. Service areas are built by forming a region that can cover the accessible streets from a specified point or decision. Once it's built, you can use the service area to identify how many work places are within the area. When working with a network it is necessary that all roads are linked, information about how the links are connected exist and distance information for each road segment is available. With knowledge about the length and speed of each road segment, the time it takes to travel along the road can be calculated and once this is done, the network can be analyzed. Figure 5.13 shows an example of a network.

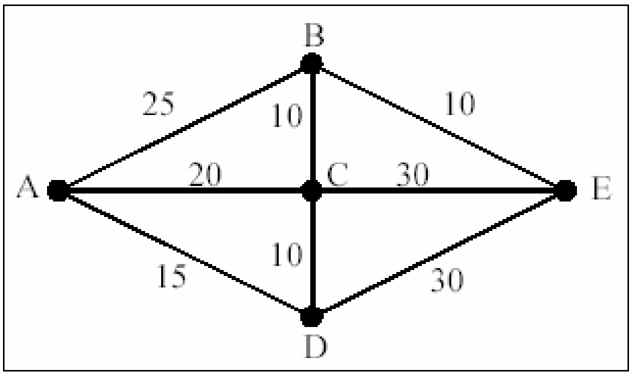


Figure 5.12 A network consisting of five nodes connected with roads. Travel time is given at each road segment. Travel time and distance are not the same in the network, since some roads have higher speed (Eklundh 1999).

Network Analyst software determines the best route by using an algorithm which finds the shortest path, developed by Edgar Dijkstra in 1959. With this algorithm it is possible to find out that the quickest route from A to E is A-B-E (see figure 5.12). Dijkstra's algorithm is the simplest path finding algorithm, even though to this day many other algorithms have been developed. Dijkstra's algorithm reduces the amount of computational time and the power needed to find the optimal path and strikes a balance by calculating a path which is close to the optimal path. The algorithm breaks the network into nodes and the paths between such nodes are represented by lines. In addition, each line has an associated cost representing the cost of each line needing to reach a node. There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order (Steward 2005-10-25).

5.4.1 NETWORK ANALYSIS FOR CARS

In the received data for the car layer, information existed about the length, the type and the speed of each road segment. The speed given in the attribute field in ArcView is the maximum speed allowed on each road segment. To give more realistic speed, another attribute field with new speed was created. These speeds were retrieved from a study undertaken in the city of Västerås in Sweden by Lic. Dr. Eva Ericsson at the Department of Technology and Society, Traffic Planning, Lund Institute of Technology. Ericsson has among other factors measured the speed from the beginning of the road to the end on different road types including intersections (Ericsson 2000).

According to Stefán Guðlaugsson (2005-07-06) at Hnit Consulting Engineers in Reykjavík there is no definite information about average speed for the streets in Reykjavík. Average speed can vary a lot and for example change from a decrease of 20-30% in peak hours to an increase of 10-20% at night and weekends. After discussing with Eva Ericsson (2005-08-25) it was decided that the dataset for Västerås would be the best available speed data to be used for the Reykjavík case since it gives a more realistic interpretation of the real traffic data over the whole day. Both Västerås and

Reykjavík have similar population[16] and both cities have quite many traffic signals, but of course there can be a difference in the actual speed patterns for the cities. Another source of error is that the streets with a speed limit of 30 km/h had few cases in Ericsson's study. They are however included in this study since they were the best available measure of the actual speed on 30 km/h roads.

The dataset for Reykjavík street network was first divided into two subgroups, street type and speed limit. After insertion of the data into the Reykjavík GIS database, 8 street types (table 5.1, number 1-8) could be distinguished out of the 21 used in the Västerås study and 11 street types had to be added (table 5.1, number 9-19).

Table 5.1 The 19 street types with average speed used in the analysis.

Number	Street type	No lanes	Speed limit (km/h)	Average speed (km/h)	Standard error (km/h)
1	Local res. str.	2	30	20,2	4,2
2	Main res. Str.	2	50	46,9	0,5
3	Main res. Str.	4	50	35,6	0,8
4	Local ind. Str.	2	50	27,1	1,2
5	Main ind. Str.	2	50	46,7	1,6
6	Main ind. Str.	4	50	43,7	1,2
7	Local CBD, str.	2	30/50	14,3	0,8
8	Main CBD, str.	2	50	26,6	1,0
9	Main ind./res. Str.	2	30	20,2	
10	Main ind./res. Str.	4	50	39,7	
11	Arterial	2/4	50	40,4	
12	Main ind./res. Str.	2/4	50	43,2	
13	Main ind. Str.	2/4	50	45,2	
14	Arterial	4	60	45,4	
15	Main ind./res. Str.	2	50	46,8	
16	Main ind. Str.	2	60	49,8	
17	Main res. Str.	2	60	49,9	
18	Arterial	2/4	70	52,9	
19	Arterial	2/4	80	69,7	

The 11 street types had to be added because of following reasons:

- Information about number of lanes was missing in the dataset for Reykjavík street network.
- Often it was difficult to separate residential and industrial areas.
- Some streets in Reykjavík have a speed limit of 60 and 80 km/h. Street types of that kind are not used in Västerås.

For these street types, Eva Ericsson (2005-08-25) suggested that an average value from the Västerås study should be used. For example for number 17 (table 5.1) where the speed limit is 60 km/h in a two lane main residential street, the average value for 50 and

[16] The population in Västerås year 1998, when the data was collected, was around 125,000 (Västerås stad 2005-10-26) and around 115,000 in Reykjavík year 2004.

70 km/h from similar street type from the Västerås study is used. Figure 5.14 maps the different street types present in Reykjavík.

This study is based on both peak hour traffic and "normal" traffic so a speed difference could be needed. However, according to Ericsson (2005-08-25) there was only a slight change in speed during peak-hours in Västerås. In a heavily trafficked city like Reykjavík this could be more interesting but for this study it was decided to ignore this. Not enough information exist for the exact places where the traffic is most at peak hour so it could be difficult to make the changes for the network analyses. One could of course change the speed of some road segments and make them very low or close to zero but as was said, that would include too much guessing and could therefore damage the analysis.

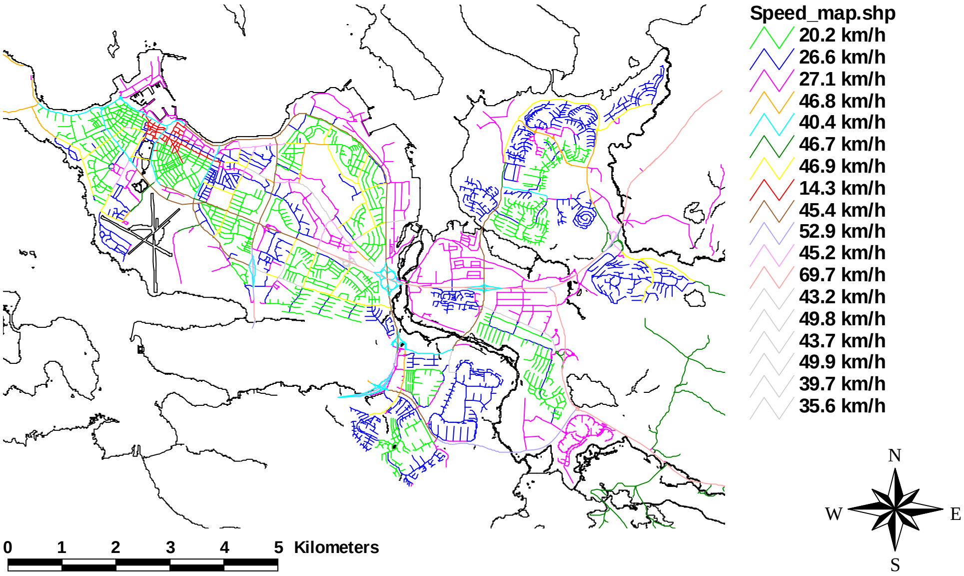


Figure 5.13 The 19 street types with assigned average speed for the Reykjavík road net.

When each road segment had been assigned a speed value, a time field could be created by dividing the length of each road segment with the speed. Thereafter all the necessary data was in place and the network analysis could be performed.

In a network analysis like this one, it is necessary to add time to each of the trips to account for the time it takes to walk to and from the car and potential parking time. To get more realistic values for these times a small research or opinion poll was made where 50 citizens in Reykjavík city where asked about these times. The results from the research can be seen in table 5.2 and in figure 5.14.

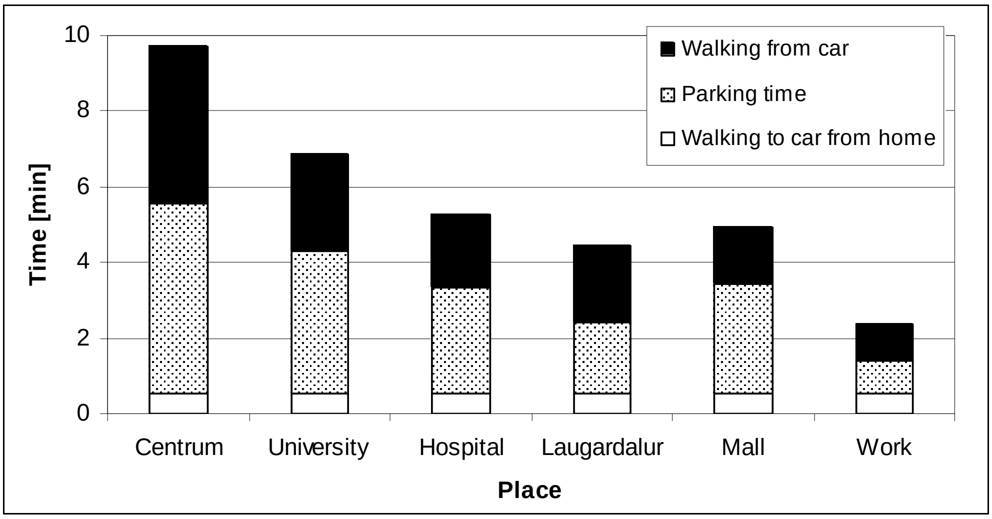


Figure 5.14 The results from the research for average time added.

Table 5.2 The results from the research for average time added

Walking to car from home (min)	0.6	0.6	0.6	0.6	0.6	0.6
	Destination					
	City centre	University	Hospital	Laugardalur	Mall	Work
Parking time (min)	5.0	3.8	2.8	1.9	2.9	0.9
Walking from car (min)	4.1	2.6	2.0	2.1	1.5	0.9
Total time added (min)	**9.7**	**6.9**	**5.3**	**4.5**	**4.9**	**2.3**

For example when analyzing trips to city centre, it is necessary to add 9.7 minutes (figure 5.14, table 5.2) to the driving time. For the working trip analysis, 2.3 minutes were added in general to each trip as table 5.2 indicates. Information about the research can be found in Appendix II.

5.4.2 NETWORK ANALYSIS FOR BICYCLES

The digital bicycles network was created by adding all separate bicycle paths to the car network, assuming that bicycles can travel along the road network. The arterial roads were excluded since no bicycles are allowed on that type of road. Also, a lot of minor adjustments (like assembling car road ends with bicycle paths) were done making the bicycle network more realistic (see figures 5.10 and 5.11 in chapter 5.3). Another feature not included in the digital layer was bike paths located on each or one side of a road, since that does not affect the network analysis.

The bicycle network analysis is very similar to the car network analysis, except for the fact that the layer was not divided into several different street types for correcting the speed. Instead, a general speed was set. Several studies have been performed regarding general bicycle speed. Bikers’ actual speed normally varies between 10 and 20 km/h with an average speed of 16 km/h (Holmberg, Hydén et al. 1996) and in this study, that speed has been used. Once speed and length of each road segment was known, a time field could be produced and the network analysis could be undertaken.

1 minute was added to each trip traveling by bicycle to indicate potential walking from home to bike and from bike to destination.

5.4.3 NETWORK ANALYSIS FOR BUSSES

Strætó bs. is the public transport company which operates city busses in Reykjavík and surrounding towns and suburbs. The busses run approximately every 20 minutes on weekdays but every 30 minutes during weekends and evenings. On the main routes, the busses run every 10 minutes during rush hour. There are 19 routes in all, 6 of them are so-called 'trunk routes' that run between the main terminal at Hlemmur and the various residential neighborhoods on the city's outskirts; these use the main traffic arteries and are thus the fastest routes available. 6 routes are general routes that also stop at Hlemmur terminal but go deeper into the different neighborhoods on slower streets. Finally, there are 7 neighborhood routes that run within or between the suburbs and don't stop in downtown Reykjavík (figure 5.15) (Strætó bs. 2005-10-29).

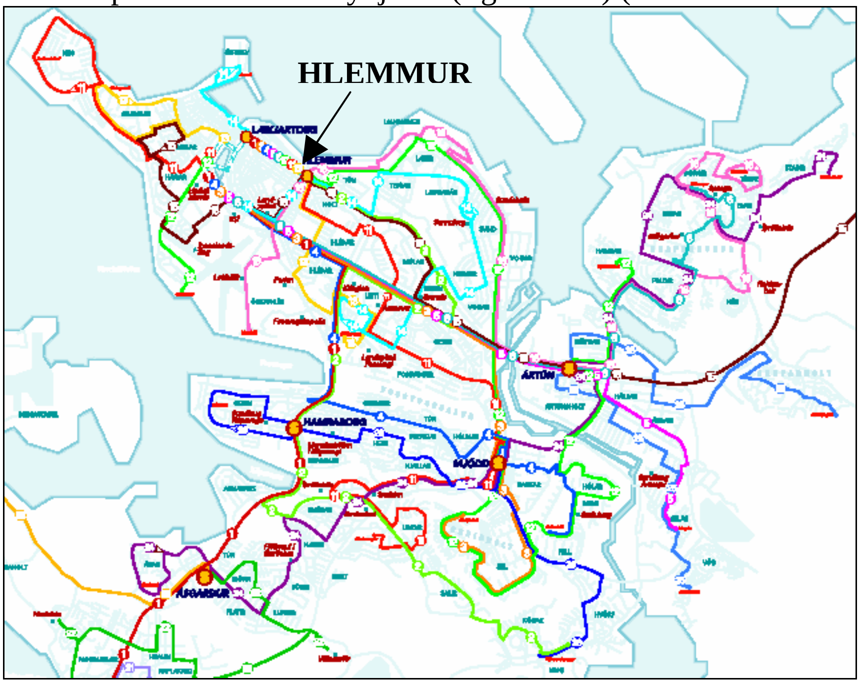


Figure 5.15 Bus routes in Reykjavík city (Strætó bs. 2005-10-29).

When creating the bus network, the first idea was to use a Swedish/German software called VIPS which is a comprehensive tool for public transport planning that enables advanced calculations of different route alternatives. But after knowing the scope of simulating the bus system in Reykjavík it was decided to try something else. Also, the bus system in Reykjavík was not considered suitable for simulating in VIPS because of the structure of it. The passenger's need of changing busses often, like for the Reykjavík system where the bus lines are divided into 'trunk routes' and general routes, is often difficult to simulate. Instead, 92 points where scattered over Reykjavík (see figure 5.16). These points are supposed to represent the city in the best possible way including all the outskirts of Reykjavík and also, quite many points were places along the main routes in Reykjavík.

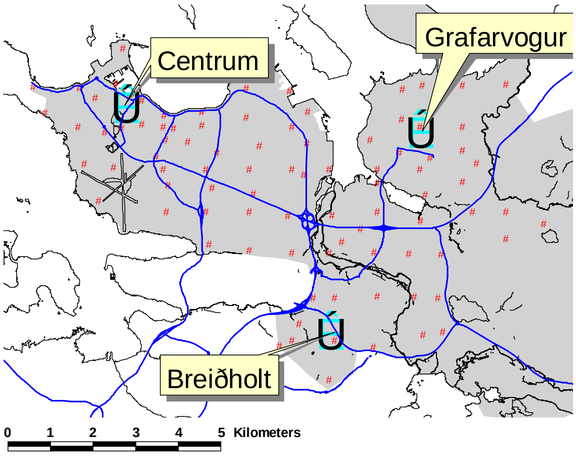


Figure 5.16 Scattering of the 92 points over Reykjavík (ArcView maps).

When analyzing the accessibility to all the working places from the three points representing city centre and two of the major residential areas (Breiðholt and Grafarvogur) the travel times from these areas to each of the 92 points are measured. The measures were collected from the bus company's homepage (Strætó bs. 2005-10-29) where it is possible to find exact times from and to any street number in Reykjavík city.[17] The data is based on the wintertime table (valid from 15th of October) and for the time period around 7.00-8.30. For some routes the frequency is 10 minutes during this time of day ('trunk routes'), while for other routes the frequency is 20 minutes (general routes). The walking distance is included in the times taken from the homepage and the walking speed is around 4 km/h. For the accessibility analysis focusing on work trips (*accessibility to working places from residential areas)*, it is assumed that people know when and from where the bus leaves. Five minutes are therefore added to all working trips as a waiting time. For the other analysis (*accessibility to 5 main places from every sub-district)* 5 or 10 minutes were added to all trips depending on the bus frequency in the sub-district.

The travel time between areas or districts are therefore based on:

- The time it takes to walk to and from the bus stops with speed around 4 km/h
- A set time for waiting for the bus in the beginning of the trip, 5 or 10 minutes
- A time waiting if a bus transfer is necessary
- The actual time spent on the bus

'Hidden waiting time' will not be included in this analyses, but that is waiting time in the beginning or the end of a trip due to that the time table doesn't for example fit working hours, visit to the cinema and so on (Holmberg, Hydén et al, 1996).

The public transport network analysis differs a bit from the car and the bike network analyses. When searching for times from the bus company's homepage, there is often more than one possibility choosing a route in order to reach a destination. In this analysis, the fastest transfer time was always chosen though there is a possibility that the passengers don't always do the same. Their decisions depend in general on many

[17] The street numbers for the 92 points, City centre and the points representing Breiðholt and Grafarvogur can been seen in Appendix III.

variables, e.g. the in-vehicle travel times, walk time, transfer time, number of transfers, the headways and the irregularity of the routes. The approach is therefore rather different from a car network, where the drivers try to find the fastest path from origin to their destination. One should be aware of this when interpreting and comparing the results of the three network analyses.

After measuring the travel time to every 92 points from city centre and the two residential areas, an accessibility map could be made (see figures 5.17-5.19). The figures show how much area of Reykjavík city it is possible to cover from city centre and the two residential areas under the time given, including waiting time.

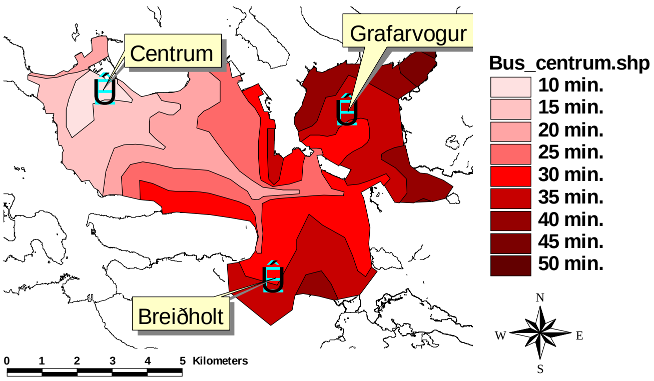


Figure 5.17 Accessibility map for bus from city centre

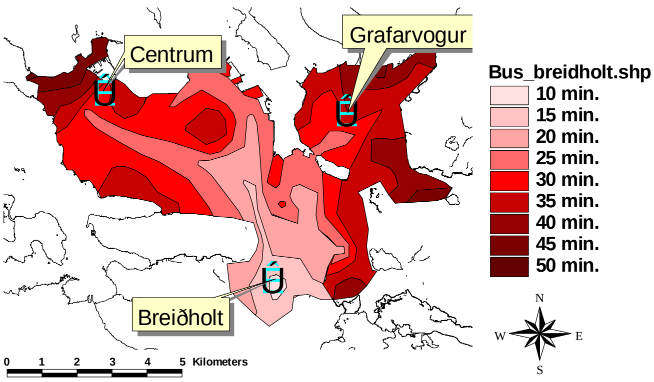


Figure 5.18 Accessibility map for bus from Breiðholt

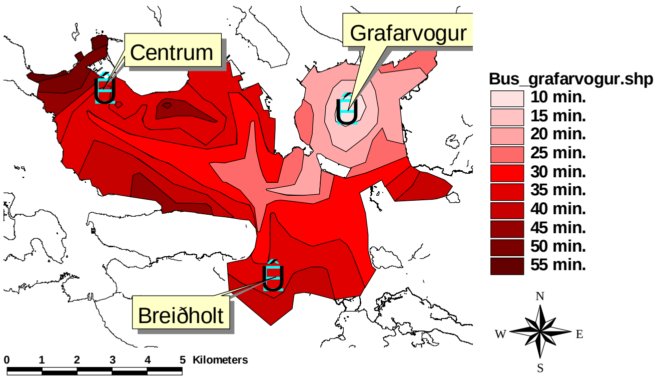


Figure 5.19 Accessibility map for bus from Grafarvogur

5.5 ACCESSIBILITY ANALYSIS

The resulting data obtained from the three network analyses were now ready for the actual accessibility analyses. When analyzing the accessibility for Reykjavík city, the analysis was divided into two parts.

In the first part, the accessibility to all the working places in Reykjavík from three specific areas in Reykjavík is analyzed. The areas were chosen to represent two major residential areas with high population density in the outskirt of Reykjavík city (Breiðholt and Grafarvogur) and the city centre. One measure used is the investigation of how long it takes to reach half of all working places, from hereon referred to as AT_{50} (Accessibility Time 50%).

The second part analyzes the accessibility to the 5 most important or interesting places in Reykjavík from 42 sub-districts in the city (see figure 5.20). There are a total of 53 sub-districts in Reykjavík but it was decided to skip the ones that have fewer than 100 inhabitants (11 sub-districts not included). These 5 main places are:

- *City centre*. Reykjavík's city centre with the old harbor, picturesque old quarters of the town with their 19th century houses, shops, museums, art galleries, cafés and restaurants.
- *The University of Iceland*. A state university, founded in 1911. Today, the University provides instruction for about 8,000 students in eleven faculties. With its 423 tenured teachers, some 1,800 non-tenured teachers, and about 280 researchers and administrators the University of Iceland is the largest single work-place in Iceland.
- *The National University Hospital*. The biggest hospital in Iceland. The hospital is located in various buildings in Reykjavík but the accessibility to the building in the sub-district Fossvogur, where the emergency room is situated, will be analyzed.
- *Laugardalur valley*. The centre for sports and recreation in Reykjavík. There is a youth hostel and campsite, the largest outdoor swimming pool in Reykjavík, Reykjavík's main sport stadium, sport hall, an indoor ice rink, a beautiful Botanical Garden and The Family Park and Zoo.
- *Kringlan Shopping Mall*. The biggest shopping mall in Reykjavík with about 170 shops, restaurants and service outlets. It is located near the geographical centre of the City of Reykjavík and adjoins the intersection of two of the main roads in the city.

Of course there are many other important or interesting places in Reykjavík and the choice of exact these 5 places is rather subjective than a fact. Different individuals have different opinion about which place is importand or not, but in this study it was decided to make the analysis with these places.

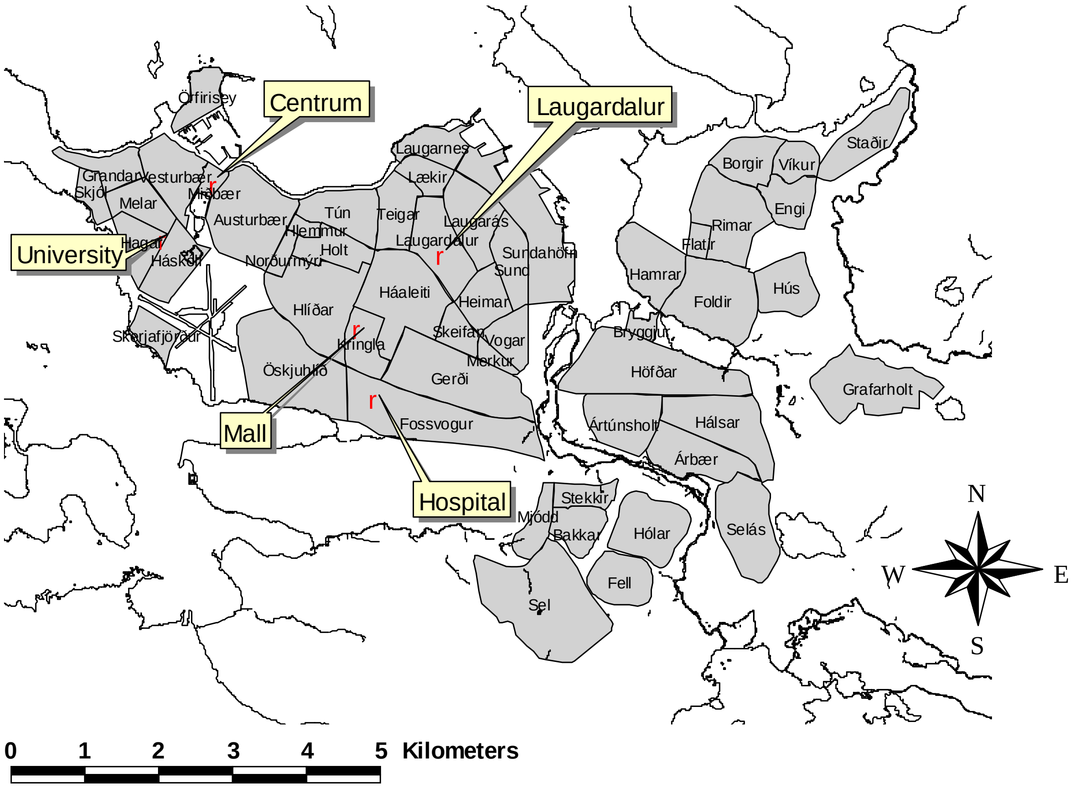


Figure 5.20 The 5 main places and the sub-districts in Reykjavík (ArcView maps).

6 RESULTS AND DISCUSSION OF THE REYKJAVÍK CASE STUDY

The results are divided into two subchapters depending on the type of accessibility measures used.

- In Chapter 6.1 the number of working places that can be reached from the residential areas are evaluated.
- In Chapter 6.2 the accessibility to 5 important or interesting places in Reykjavík city from every district in Reykjavík is evaluated.

Some statistics about the maximum length of the trips for the three transport modes are presented in Table 6.1. It is interesting to see that the car can reach any of the 141 plan-districts in less than 20 minutes, starting from the residential areas. The maximum time a bicycle trip takes is about 2.6 times as long as the car trip, while the maximum time for taking bus is about 2.8 times as long.

Table 6.1 Some statistics about the maximum length of the trips.

Trip length	Car (min)	Bicycle (min)	Bus (min)
Maximum	18	46	50

6.1 HOW MANY WORKING PLACES CAN BE REACHED FROM THE RESIDENTIAL AREAS?

In this chapter the focus is on the two residential areas (Grafarvogur and Breiðholt) and city centre and how many working places can be reached from these districts. The residential area Breiðholt has about 52 inhabitants/hectare (for the districts used in the analysis) whereas the residential area Grafarvogur has a population density about 35 inhabitants/hectare. The city centre is certainly a commercial area, but at the same time, the area around it is one of the most density areas in the city with around 72 inhabitants/hectare (for the districts used in the analysis). This is the main reason for showing the figures for city centre also.

The time of 20 minutes is used for two reasons. First, if traveling by car, the entire city is reachable in this time period from all the residential areas. Second, if using a general bike speed of 16 km/h, then 20 minutes correspond to a 5 km trip, which is quite acceptable. Research has also shown that 76% of all trips in Reykjavík are less than 5 km long[18].

Figures 6.2-6.4 illustrate bicycle and public transport accessibility from Grafarvogur, Breiðholt and city centre. Green areas show from which districts one can travel by bike in 20 minutes and red areas are districts from which one can travel by bus and bike in 20 minutes. The car can travel anywhere within the city boundaries in 20 minutes. Figure 6.5 shows the location of all the working places in Reykjavík where every dot

[18] According to the research made in February 2002 76% of all trips were less than 5 km long and 62% less than 3 km (Sigurðsson 2005-09-30).

represents 4 working places. The figure shows that most of the working places are located around city centre and east of the city centre (see marked area in figure 6.5).

Figures 6.6-6.8 illustrate the proportion of working places that can be reached at different time periods from the two residential areas and the city centre. Figures 6.9-6.11 demonstrate the relations between the three areas in terms of the trip lengths for car, bicycle and public transport, respectively.

From neither Grafarvogur nor Breiðholt (figures 6.2 and 6.3) the centrum can be reached in 20 minutes by bus or bicycle. From Grafarvogur the working places access with bus is only 15% in 20 minutes (figure 6.6). The bus accessibility for Breiðholt is rather higher or about 25% (see figure 6.7), mainly because areas where there are quite many working places can be reached (see figure 6.5).

If traveling by bicycle (figure 6.10), similar situation occurs as traveling by bus. You can reach 26% of the working places by bicycle in 20 minutes from Grafarvogur but almost half of the working places (46%) from Breiðholt. The reason is the same as for traveling by bus; traveling from Breiðholt you can reach bigger area of the big working place area east of city centre.

Comparing the accessibility by car (see figure 6.9), the difference is also quite high. In 10 minutes, 30% of the working places from Grafarvogur can be reached but 61% from Breiðholt or more than twice as much. In 15 minutes the numbers are 81% for Grafarvogur and 99% for Breiðholt. This difference can partly be explained by the geographical situation of Grafarvogur. The sea that surrounds Reykjavík works as a barrier for the people in Grafarvogur so they are forced to drive or cycle quite a distance to pass it. Also, there is only one big 'entrance' in Reykjavík from these two residential areas, through the intersection Vesturlandsvegur-Reykjanesbraut (see figure 6.1) where the AADT[19] is about 150,000 vehicles (Reykjavík City 2005-10-20) which is very high (year 2004).

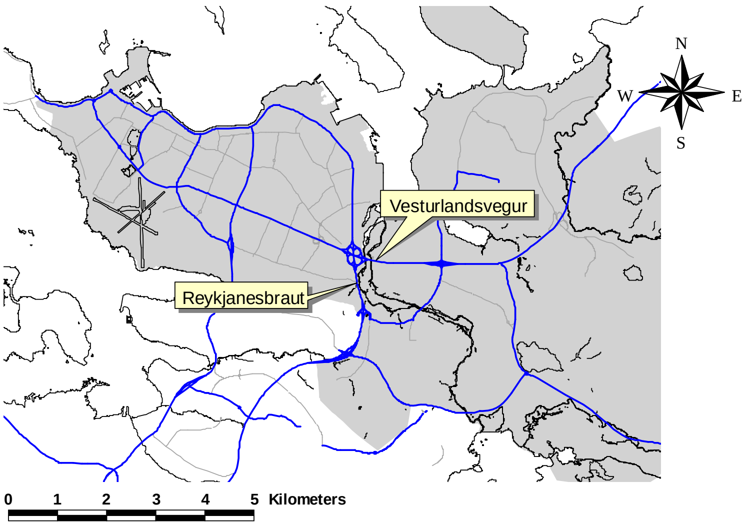


Figure 6.1 The intersection Vesturlandsvegur -Reykjanesbraut.

[19] AADT is the Average Annual Daily Traffic.

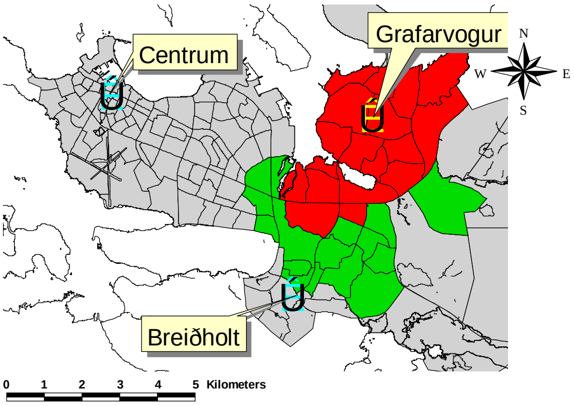


Figure 6.2 Accessibility from Grafarvogur. You can reach all green and red areas by bike and all red areas by bus in 20 minutes.

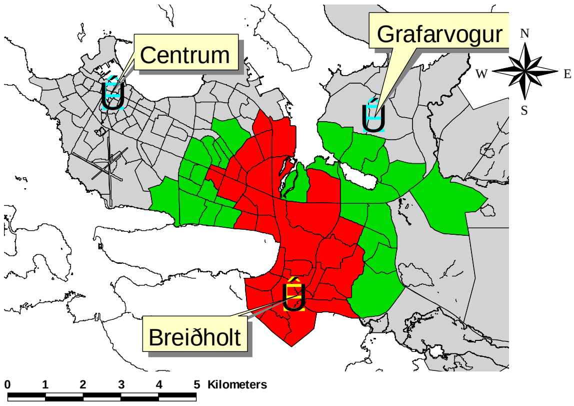


Figure 6.3 Accessibility from Breiðholt. You can reach all green and red areas by bike and all red areas by bus in 20 minutes.

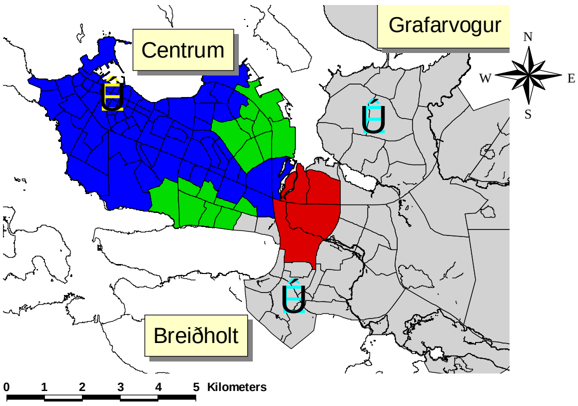


Figure 6.4 Accessibility from City centre. From City centre you can reach all blue and green areas by bike and all blue and red areas by bus in 20 minutes.

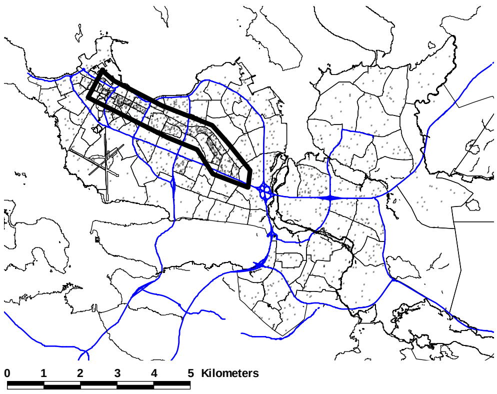


Figure 6.5 Location of all the working places in Reykjavík. Every dot represents 4 working places.

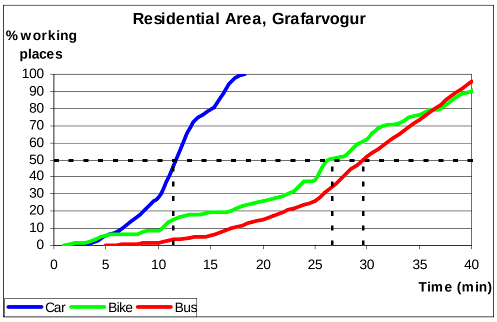


Figure 6.6 The proportion of working places that can be reached at different time periods from Grafarvogur.

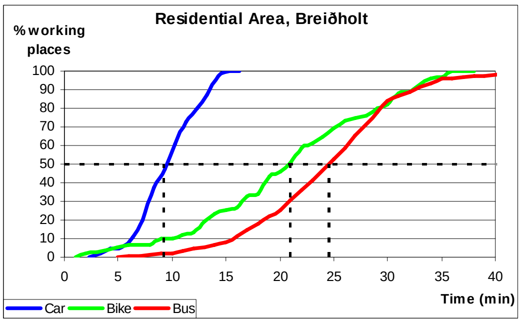


Figure 6.7 The proportion of working places that can be reached at different time periods from Breiðholt.

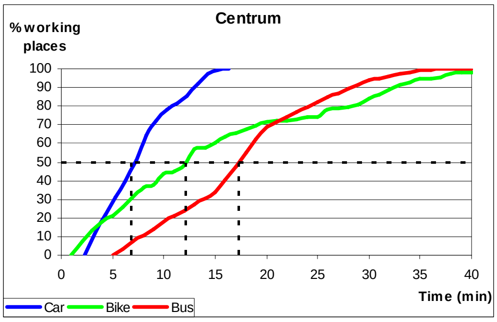


Figure 6.8 The proportion of working places that can be reached at different time periods from City centre

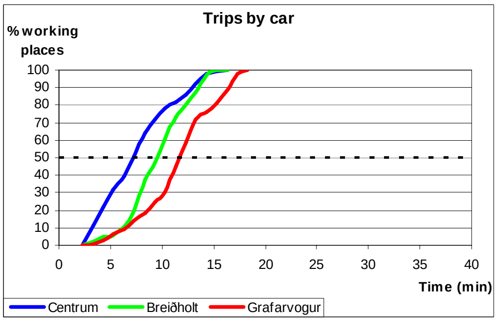


Figure 6.9 The proportion of working places that can be reached at different time periods from the two residential areas and City centre by car

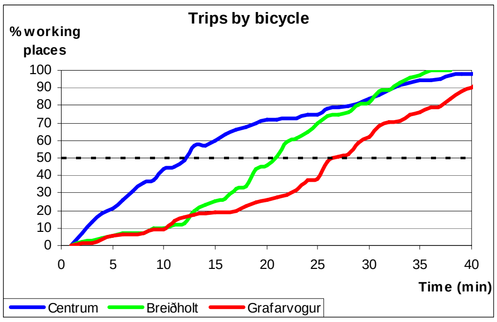


Figure 6.10 The proportion of working places that can be reached at different time periods from the two residential areas and City centre by bicycle

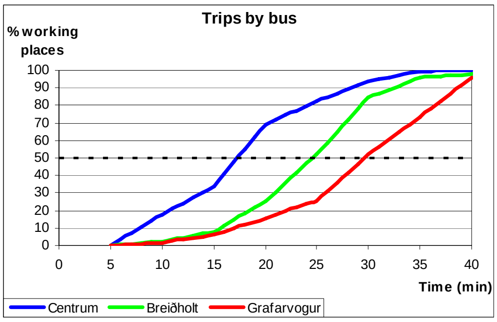


Figure 6.11 The proportion of working places that can be reached at different time periods from the two residential areas and City centre by bus

The accessibility pattern in the city centre is different compared to the residential areas (figure 6.8). First of all, working places can be reached faster than from the other two areas. Even the bus accessibility is acceptable – 69% of all working places can be accessed within 20 minutes. In 20 minutes traveling by bike, 72% of all the working places can be reached which is also quite acceptable. The 'bottleneck" in the intersection mentioned above has also obvious impact on the trips from city centre, especially by car and bicycle. From figures 6.9 and 6.10 it can be seen how the situation suddenly gets worse after traveling 10 minutes by car and 15 minutes by bicycle. The reason for this is that you are then reaching the intersection barrier and it takes quite a long time to reach the working places situated in the edge of the city in south and north.

When having all the results in mind, it is quite obvious how much advantage the car has regarding trips to work. For bicycle it is said that the travel-ratio (the ratio between traveling times) between bike and car should be around 1.5 but never 2.0 or more (it should never take more than twice as much time to bicycle than to drive a car). For bus the ratio should be around 2.0 (Trast 2004).

Table 6.2 AT_{50} – the Accessibility Time in which 50% of all working places can be reached.

District	**Car (min)**	**Bicycle (min)**	**Bus (min)**	***Bicycle/Car Travel-ratio***	***Bus/Car Travel-ratio***
Grafarvogur	11.4	26.7	29.6	*2.3*	*2.6*
Breiðholt	9.2	21.0	24.6	*2.3*	*2.7*
City centre	6.9	12.1	17.3	*1.8*	*2.5*

Table 6.2 shows the AT_{50} value for all the residential areas. From the table it is possible to see that it's only in city centre where the bicycle threatens the car with 1.8 in travel-ratio which is quite acceptable. For the bus transportation, the travel-ratio is always too high as the bus loses a lot of time on long walk times and wait times. This can be seen in figures 6.6-6.7 where the bus riders in Grafarvogur and Breiðholt do not reach any working place until around 10 minutes have passed because of walking and waiting time. Not surprisingly, the city centre has the highest accessibility for all three transport modes.

In general, comparing the residential areas Breiðholt and Grafarvogur, you can say that traveling by bicycle is faster than by bus and that Grafarvogur has slightly better bus transportation than Breiðholt while the bicycle net is similar for both areas (when looking at the AT_{50} travel-ratios).

6.2 HOW ACCESSIBLE ARE THE MAIN PLACES?

In this chapter the focus is on the accessibility to the 5 most important or interesting places in Reykjavík from 42 sub-districts in the city. In the analysis the numbers of each sub-districts will be used instead of their names (see figure 6.12 and table 6.3). Like described in chapter 5.5 the main places are:

- *City centre*. Reykjavík's city centre.
- *The University of Iceland*. A state university, the largest single work-place in Iceland.
- *The National University Hospital* The biggest hospital in Iceland.
- *Laugardalur valley*. The centre for sport and recreation in Reykjavík.
- *Kringlan Shopping Mall*. The biggest shopping mall in Reykjavík.

This analysis is devided into three chapters:

- Chapter 6.2.1 is about the accessibility by bus to the 5 places from the sub-disticts in Reykjavík. The analysis was done by checking the travel-ratio (the ratio between traveling times) between bus and car.
- Chapter 6.2.2 is about the accessibility by bicycle to the 5 places from the sub-districts in Reykjavík. The analysis was done by checking the travel-ratio (the ratio between traveling times) between bicycle and car.
- Chapter 6.2.3 is also about the accessibility by bicycle to the 5 places from the sub-districts in Reykjavík. In this case, the analyses was done by checking the direct-ratio which is the ratio between the true distance and the crow's flight distance between two places.

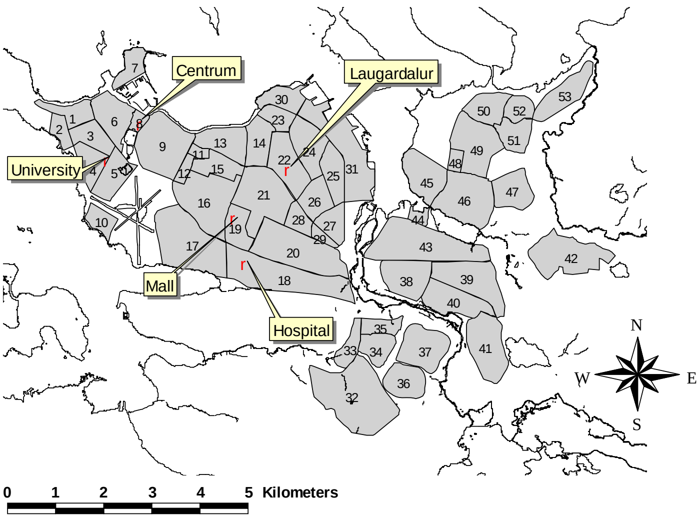


Figure 6.12 The 5 main places and the number of each sub-districts in Reykjavík.

Table 6.3 The number and name of each sub-district. Grey districts are not included in the analysis.

Nr.	Name	Nr.	Name	Nr.	Name	Nr.	Name	Nr.	Name
1	Grandar	12	Norðurmýri	23	Lækir	34	Bakkar	45	Hamrar
2	Skjól	13	Tún	24	Laugarás	35	Stekkir	46	Foldir
3	Melar	14	Teigar	25	Sund	36	Fell	47	Hús
4	Hagar	15	Holt	26	Heimar	37	Hólar	48	Flatir
5	Háskóli	16	Hlíðar	27	Vogar	38	Ártúnsholt	49	Rimar
6	Vesturbær	17	Öskjuhlíð	28	Skeifan	39	Hálsar	50	Borgir
7	Örfirisey	18	Fossvogur	29	Merkur	40	Árbær	51	Engi
8	Miðbær	19	Kringla	30	Laugarnes	41	Selás	52	Víkur
9	Austurbær	20	Gerði	31	Sundahöfn	42	Grafarholt	53	Staðir
10	Skerjafjörður	21	Háaleiti	32	Sel	43	Höfðar		
11	Hlemmur	22	Laugardalur	33	Mjódd	44	Bryggjur		

6.2.1 ACCESSIBILITY BY BUS, TRAVEL TIME

Figures 6.13-6.17 show the accessibility by bus to the 5 main places in Reykjavík from every sub-district. If the bus is supposed to be competitive to the car it is said that the travel-ratio (the ratio between traveling times) between bus and car should be around 2.0 for bus trips shorter than 5 km and below 2.0 for trips longer than 5 km (TRAST 2004). Therefore the changing from green (acceptable value) to red (unacceptable value) is set to 2.0 in the analysis and can be seen in the figures (6.13-6.17). Appendix IV shows the travel-ratio values for the sub-districts to every place for bus.

Figure 6.13 shows the accessibility to the University. The only sub-districts that fail are the one in the east edge of the city (no. 42 and 53) and the one that are close to the University (no. 1, 5, 6 and 15). For the edge districts the frequency is 20 minutes so the waiting time was set to 10 minutes and that is probably the reason. The travel-ratio for these districts is though very close to 2.0 (light red). For the districts close to the University the reason is probably that the bus system is not destined for people traveling such a short distance.

Figure 6.14 shows the accessibility to the Kringlan Mall. Many sub-districts fail but the ones that have the highest travel-ratio value are those situated north of the Mall (no. 13, 14, 21, 24 and 25). The reason for this is probably that no bus line goes direct between the Mall and those areas so you have to travel quite a distance going this short distance. For the sub-districts west of the city centre the bus frequency is only 20 minutes which is probably the reason for the bad situation in the area.

Figure 6.15 shows the accessibility to the Hospital. Even more sub-districts fail here and the reason is probably that there are not many bus lines connected to the area where the Hospital is situated. The sub-districts east of the Hospital and the districts in Breiðholt are the only ones not failing because there is a bus line that lies direct between Breiðholt and the area near the Hospital.

Figure 6.16 shows the accessibility to the Laugardalur valley. Every sub-district fail (all red) so it can be assumed that the bus conditions for the valley is unacceptable and has to be improved. One reason for this is that when taking bus to the valley, you have to walk about half a kilometer from the nearest bus station and that could affect the result. Parking time in the valley is also low, or 1.9 minutes (see table 5.2), which affects the accessibility for the bus negatively.

Figure 6.16 shows the accessibility to the city centre. Every sub-district has an acceptable value (travel-ratio under 2.0) which is very good since the city centre is often considered to be the most important place or destination for a city. The reason for this is probably the parking time (5.0 minutes) and walking time from the car (4.1 minutes) while the bus stops right in the city centre.

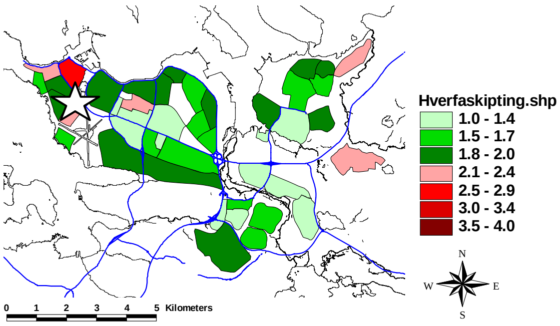


Figure 6.13 Accessibility for bus to the University from every district in Reykjavík. Bus/car travel-ratio.

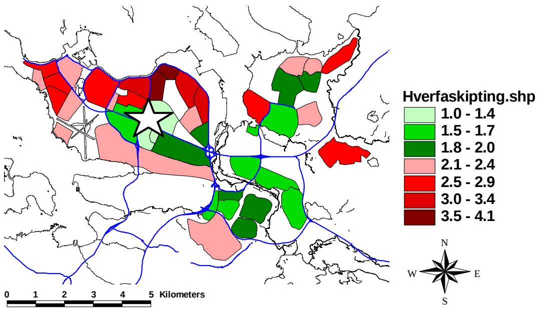


Figure 6.14 Accessibility for bus to the Kringlan Mall from every district in Reykjavík. Bus/car travel-ratio.

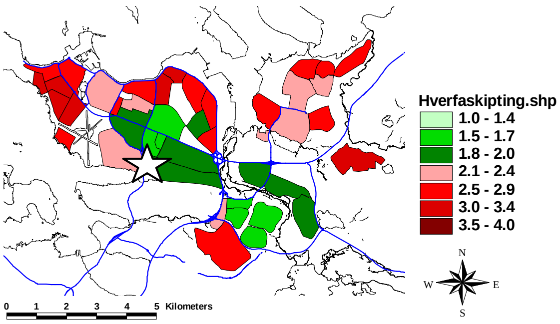


Figure 6.15 Accessibility for bus to the Hospital from every district in Reykjavík. Bus/car travel-ratio.

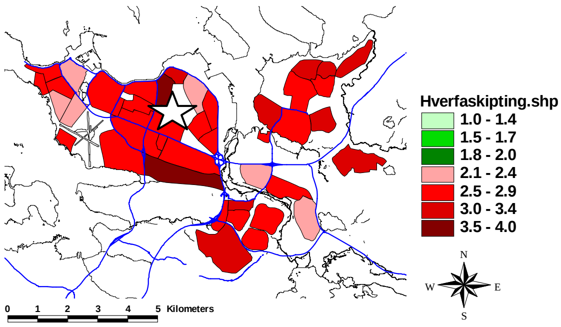


Figure 6.16 Accessibility for bus to the Laugardalur valley from every district in Reykjavík. Bus/car travel-ratio.

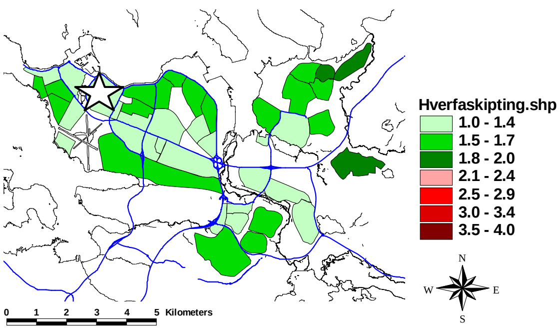


Figure 6.17 Accessibility for bus to the City centre from every district in Reykjavík. Bus/car travel-ratio.

6.2.2 ACCESSIBILITY BY BICYCLE, TRAVEL TIME

Figures 6.18-6.22 show the accessibility by bicycle to the 5 main places in Reykjavík from every sub-district. If the bike is supposed to be competitive to the car it is said that the travel-ratio (the ratio between traveling times) between bike and car should be around 1.5 but never 2.0 or more (TRAST 2004). Therefore the changing from green (acceptable value) to yellow (less acceptable value) is set to 1.5 in the analysis and the changing from yellow to red (unacceptable value) is set to 2.0 as can be seen in the figures (6.18-6.22). Appendix V shows the travel-ratio values for the sub-districts to every place for bicycle.

Figure 6.18 shows the accessibility to the University. The only sub-districts that fail are the one in the north-east and east edge of the city (no. 42, 47 and 53). These edge districts are all situated more than 5 km (which is often regarded as an acceptable bike ride) from the University so in that perspective it isn't strange that the travel-ratio is that bad. The figure also shows how the condition gets worse as the distance from the University gets longer. The sea barrier between the sub-districts in Grafarvogur and the main city area has also a clear effect here since the travel time increases a lot as one has to bicycle by it.

Figure 6.19 shows the accessibility to the Kringlan Mall. A similar situation occurs for this case as for the University. Because the Mall is situated closer to the edge sub-districts in east and north fewer districts should fail. This is not the case here because of the parking time and walking time from the car which are much lower for the Mall than for the University. That has negative effects on the accessibility for bicycle so more sub-districts fail. Because of the distance from the Mall to the sub-districts in west, some of them get a travel-ratio value just over 1.5.

Figure 6.20 shows the accessibility to the Hospital. Because of the closeness to the Kringlan Mall, a very similar situation occurs. The only difference is that the parking time and walking time from the car is lower for the Hospital than for the Mall. That is why the accessibility to the Hospital is better than to the Mall so fewer sub-districts fail.

Figure 6.21 shows the accessibility to the Laugardalur valley. The only two sub-district with unacceptable travel-ratio value (red) are in the north-east edge of the city (no. 53) and in the east edge (no. 42). The sub-districts around these two districts even get close to failing (with travel-ratio 1.8-2.0) though the distance is only about 4-5 km. But as mentioned before, the sea barrier has the effect that the travel time increases a lot as you have to cycle around it.

Figure 6.22 shows the accessibility to the city centre. No sub-districts fail because of the parking time and walking time from the car which are very high (around 9.1 minute from table 5.2). When cycling it is assumed that it can be walked from the bicycle to the heart of the city centre in 0.5 minute.

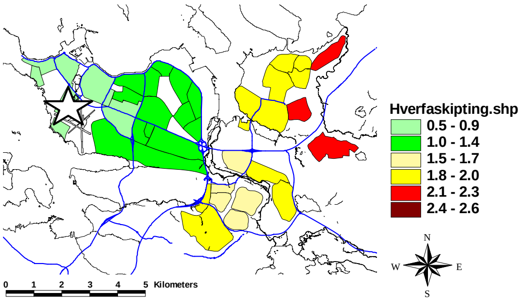


Figure 6.18 Accessibility for bicycle to the University from every district in Reykjavík. Bike/car travel-ratio.

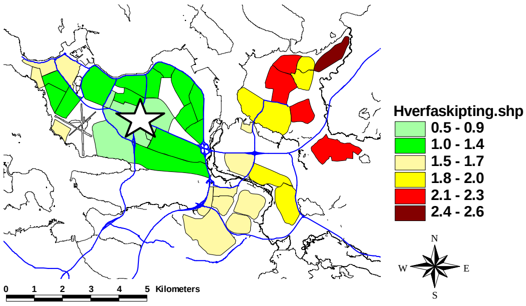


Figure 6.19 Accessibility for bicycle to the Kringlan mall from every district in Reykjavík. Bike/car travel-ratio.

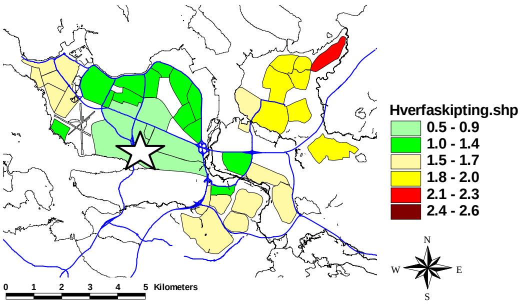


Figure 6.20 Accessibility for bicycle to the Hospital from every district in Reykjavík. Bike/car travel-ratio.

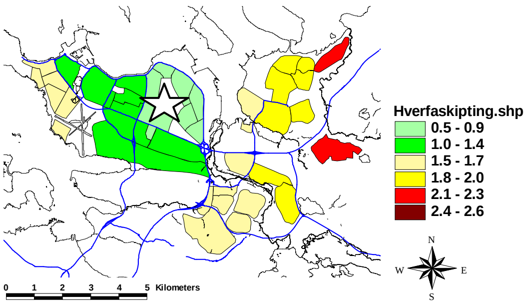


Figure 6.21 Accessibility for bicycle to the Laugardalur valley from every district in Reykjavík. Bike/car travel-ratio.

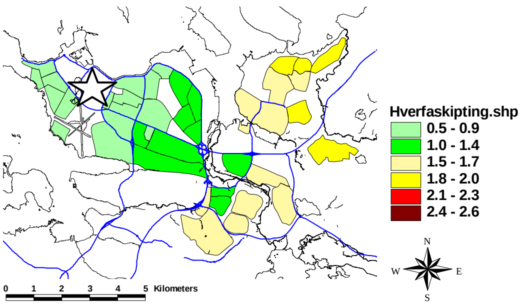


Figure 6.22 Accessibility for bicycle to the City centre from every district in Reykjavík. Bike/car travel-ratio.

6.2.3 ACCESSIBILITY BY BICYCLE, DIRECT-RATIO

Figures 6.23-6.27 show the accessibility by bicycle to the 5 main places in Reykjavík from every sub-district. The direct-ratio (the ratio between the true distance and the crow's flight distance) should be around 1.25 but never 1.50 or more (TRAST 2004). Therefore the changing from green (acceptable value) to yellow (less acceptable value) is set to 1.25 in the analysis and the changing from yellow to red (unacceptable value) is set to 1.50 as can be seen in the figures. Appendix VI shows the direct-ratio values for the sub-districts to every place for bicycle. It is also necessary to realize that the direct-ratio analysis is very affected by how long or short distances are being measured. The shorter the distance is the bigger effect a certain detour has.

Figure 6.23 shows the accessibility to the University. The sub-districts that get close of getting unacceptable are the ones in Grafarvogur. As mentioned before, the sea barrier has the effect that the travel time increases a lot as you have to cycle around it. The sub-districts that are closest to the University (no. 4, 5 and 6) also get a direct-ratio near 1.50. The reason for this is probably that often when traveling short distances you have to overcome an obstacle of some kind which can affect the direct-ratio negatively, for example a road that you have to cycle along.

Figure 6.24 shows the accessibility to the Kringlan Mall. In this case there are mainly three different reasons why there are so many sub-districts that get high direct-ratio value. For the districts located in Grafarvogur the sea barrier affects the travel time. For the districts located very close to the Mall the big routes around it affect the accessibility. You maybe need to bicycle along a road quite a while to cross it. Finally for the sub-district west of the Mall (with direct-ratio over 1.50), the airport is the main barrier which you have to cycle around.

Figure 6.25 shows the accessibility to the Hospital. Because of the closeness to the Kringlan Mall, almost the same situation occurs. The only difference is that the situation for the sub-districts in Breiðholt gets worse. That is because of the big arterial road (Reykjanesbraut) west of Breiðholt which can entail a detour.

Figure 6.26 shows the accessibility to the Laugardalur valley. This is the most obvious example of how the sea barrier between the sub-districts in Grafarvogur and the main Reykjavík area affects the accessibility for the inhabitants in Grafarvogur. For example for the district no. 45 (called Hamrar) the crow's flight distance is 2.8 km while the distance you have to bicycle is 5.9 km which gives a direct-ratio value 2.1 which is very high. For the sub-districts closest to the valley with direct-ratio values around or over 1.50, the problem is probably because of small detours that affect the direct-ratios negatively.

Figure 6.27 shows the accessibility to the city centre. Almost exact same situation occurs here as for the University because of the closeness between the two places. The only difference is that the situation for the sub-districts in Grafarvogur gets worse because that the effect from the sea barrier is clearer.

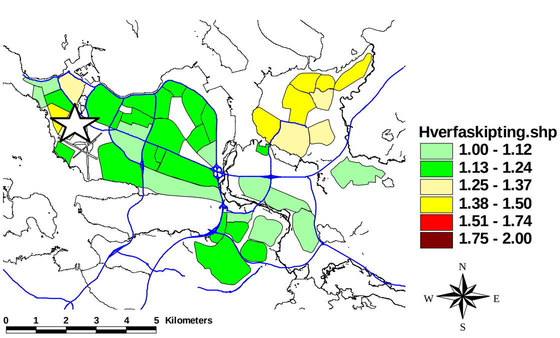


Figure 6.23 Accessibility for bicycle to the University from every district in Reykjavík. Direct-ratio.

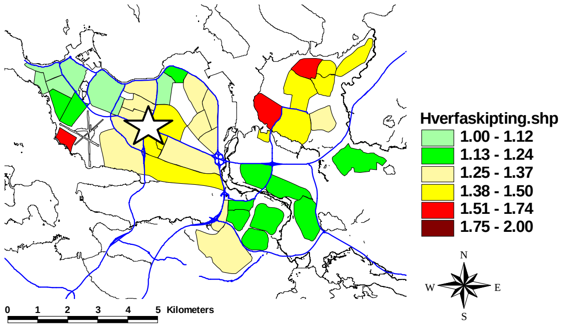


Figure 6.24 Accessibility for bicycle to the Kringlan Mall from every district in Reykjavík. Direct-ratio.

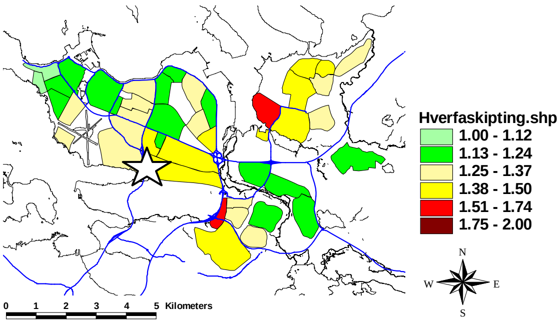


Figure 6.25 Accessibility for bicycle to the Hospital from every district in Reykjavík. Direct-ratio.

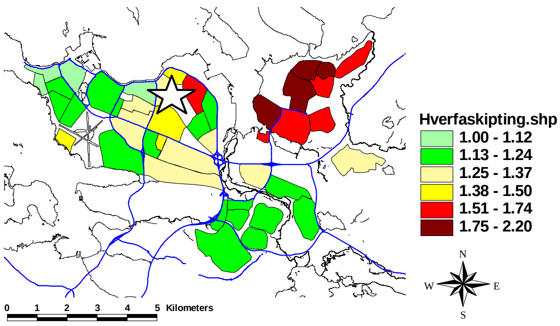


Figure 6.26 Accessibility for bicycle to the Laugardalur valley from every district in Reykjavík. Direct-ratio.

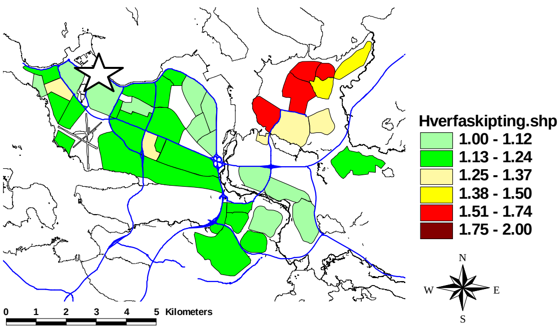


Figure 6.27 Accessibility for bicycle to the City centre from every district in Reykjavík. Direct-ratio.

6.3 POTENTIAL SOLUTIONS

It is rather obvious from the accessibility analyzes above that the situation is worst for the inhabitants in Grafarvogur, both regarding the accessibility to the working places and accessibility to the main places in Reykjavík. It is therefore interesting to observe potential solutions for the district.

Reykjavík City has in recent years been studying the possibility of a better connection between Grafarvogur and the main part of the city. The solution that now has been chosen is to build a link over the sea west of Grafarvogur. This link is not only meant to be a solution for the inhabitants in Grafarvogur but also for every citizen in Reykjavík. This link has been called Sundabraut (“Channel-Road”) and will be an important link in Reykjavík main street network according to Reykjavík City Master plan 2001-2024 (see figure 4.1) and is also an presumption for new building areas around Grafarvogur. Furthermore, Sundabraut has a great meaning for transportation outside the Reykjavík area and the settlement development on the south west corner of Iceland (Reykjavík City 2005-10-22). Three main alternatives have been chosen for Sundabraut (see figure 6.28):

- *Route I-high bridge*
- *Route I-bottom tunnel*
- *Route III-island solution*

Figure 6.28 Alternative routes for Sundabraut (adapted from Reykjavík City 2005-10-22)

In this study, *Route III-island solution* was chosen for further examination. The main reason is that the bicycle situation is better for that alternative. For *Route I-high bridge*, the walking- and bicycle connection is more difficult and a certain number of bikers will not use the bridge because of the height. For *Route I-bottom tunnel*, walking- and bicycle connection is not a reality without great additional cost and is therefore excluded (Reykjavík City 2005-10-22). Figure 6.29 shows a computer made picture of the alternative *Route III-island solution*.

Figure 6.29 *Route III-island solution* in the future (Reykjavík 2005-10-22).

Route III-island solution was therefore added to the car and bicycle network and analyzed. The car speed was set to 80 km/h (and therefore the average speed was set to 69.7 km/h as table 5.1 indicates) and the bicycle speed was set to 16 km/h as before.

__Accessibility to working places__

For the working place analysis (see chapter 6.1), following changes occurred (figure 6.30).

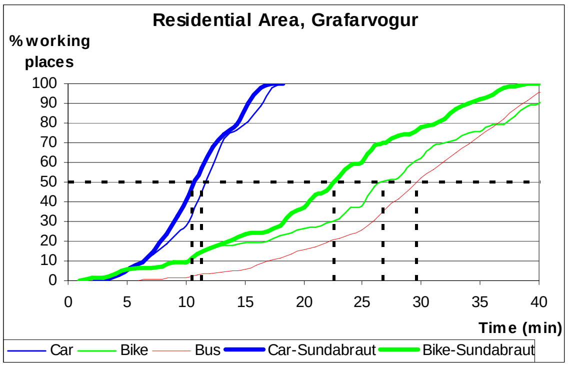


Figure 6.30 The proportion of working places that can be reached at different time periods from Grafarvogur. Changes with Sundabraut are marked bolder.

For the bicycle network the improvements are quite clear. In 20 minutes is it now possible to reach 37% of all working places instead of 26% without Sundabraut which is more than 42% increase. The AT_{50} value also gets better; it decreases from 26.7 to 22.6 minutes which is around 15% improvement.

For the car network the changes are also rather drastic. In 10 minutes it is possible to reach 44% of all working places instead of 30 % which is almost 47% increase. If traveling in 15 minutes the improvement will only be 11% (from 81% to 90%). The AT_{50} value decreases from 11.4 to 10.5 minutes or by 8% which is not very high.

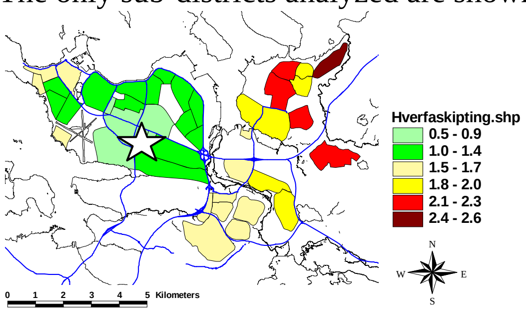
The bus network was not analyzed with Sundabraut.

<u>Accessibility to the main places</u>

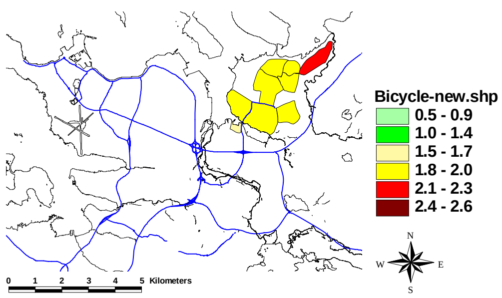
For the main places analysis (see chapter 6.2) it was decided to observe only the accessibility for bicycle to the Kringlan Mall with the bike/car travel-ratio (see figure 6.18) and to the Laugardalur valley with direct-ratio (see figure 6.26). These two were the most critical ones and were therefore chosen to see the effects from the new Sundabraut link.

<u>Accessibility for bicycle to the Kringlan Mall with the bike/car travel-ratio</u>

Only the sub-district farthest away from the Mall fails (no. 53, Staðir) but the situation for the area still gets better after Sundabraut (travel-ratio value from 2.4-2.6 to 2.1-2.2). The only sub-districts analyzed are shown on the figure to the right.



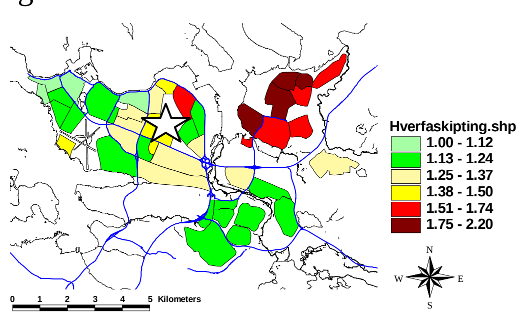
Before Sundabraut



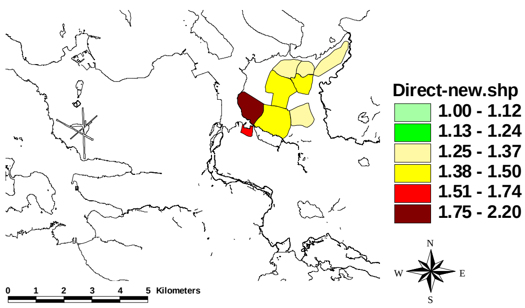
After Sundabraut

<u>Accessibility for bicycle to the Laugardalur valley with direct-ratio</u>

The situation for every sub-district gets better except for two. The one that is red with ratio 1.5.-1.74 (no. 44, Bryggjur) has the same direct-ratio as before because it is still shorter to bicycle by the sea instead of using Sundabraut. For the one that is dark red with ratio 1.75-2.20 (no. 45, Hamrar) the district fails because that the bicycle net that was constructed doesn't allow any shortcuts from the district to Sundabraut. Therefore it is necessary to cycle quite a long way just to get to Sundabraut. In reality this will probably not be the case. The only sub-districts analyzed are shown on the figure to the right.



Before Sundabraut



After Sundabraut

7 CONCLUSIONS

From *Chapter 2* it is possible to conclude that Iceland's traditional rural society has transformed into a modern urban-industrial society with people migrating to Reykjavík. Car ownership in Reykjavík is now among the highest in the world and most of the city's urban area is in the form of low-density suburbs and houses are usually widely spaced. *Chapter 2* also shows that from 1965 to 2003, the population of Reykjavík has increased by 45%, the road system grew by 148% and the number of bus passenger decreased by 45%, while the number of private cars increased by 457%. Research over trips in Reykjavík implies that most of the trips are by cars and public transportation only exists in the form of a bus system. Bicycle is almost never used as a means of transport.

Chapter 3 shows how the development of the society has changed the city structure in the Western World and describes how the society has changed from concentration to scattering, from centralization to decentralization, from integration to separation and from public transport to private transport solutions. Accessibility was defined as physical accessibility, which represents how easy it is to reach the city's working places, service, recreation, along with different supplies and activities from a certain origin with different means of transportation at a certain time of day. Mobility is a measure of an individual's resources to move, i.e. age, sex, health, economy and access to driver license and car. *Chapter 3* also reveals how the people's geographical mobility has increased explosively during the 20th Century and shows the transition from the pre-industrial society to the present service society. Cities have grown larger and wider and suburbs are more common. The main cause for this trend is the evolution of the car which made it possible to build more sparsely than before and its space demand has entailed more scattered settlements.

Chapter 5 shows that the sparser the city is the higher facility costs and operational costs for infrastructure and public transport. It also shows the relationship that the lower population density is in an area, the longer distance the inhabitants have to travel for different service.

Chapter 6 concludes that regarding trips to work, it is quite obvious how much advantage the car has as it is possible to reach every working place within the city boundaries in 20 minutes traveling by car. The AT_{50} value for bicycle is lower than for bus in all the three residential areas analyzed, which indicates that using bicycle is faster than using by bus. It's only in city centre where the bicycle threatens the car with 1.8 in travel-ratio which is quite acceptable. For the bus transportation, the travel-ratio is always too high as the bus often loses a lot of time on long walking and waiting times. Not surprisingly, the city centre has the highest accessibility for all three transport modes.

In general, comparing the residential areas Breiðholt and Grafarvogur, it is possible to say that traveling by bicycle is faster than by bus and that Grafarvogur has slightly better bus transportation than Breiðholt. The bicycle net seems to be similar for both areas when looking at the travel-ratios for AT_{50}.

When looking at how many working places can be reached from residential areas Breiðholt and Grafarvogur, the situation changes. Then, Breiðholt has an advantage for every transport mode reaching more working places in shorter time. As mentioned often in the results, can this difference partly be explained by the geographical situation of Grafarvogur. The sea that surrounds Reykjavík works as a barrier for the people in Grafarvogur so they are forced to drive or cycle quite a distance to pass it.

The accessibility pattern in the city centre is different compared to the residential areas since working places can be reached faster than from the other two areas. Even the bus accessibility is acceptable with 69% of all working places accessed within 20 minutes. In 20 minutes traveling by bike, 72% of all the working places can be reached which is also quite acceptable.

The accessibility to the University is acceptable. For the bus system the only sub-districts that had low accessibility to the University were the ones where the bus frequency was 20 minutes. For bicycle, the accessibility was good for the sub-districts situated less than 5 km away from the University (which is often regarded as an acceptable bicycle ride). When looking at the direct-ratio values the sea barrier has the effect that the travel time increases as you have to cycle around it.

For accessibility to the Kringlan Mall, the situation varied. For the bus system many sub-districts north of the Mall failed because that no bus line goes direct between the Mall and those areas. For the sub-districts west of the city centre the bus frequency is only 20 minutes which is probably the reason for the bad situation in that area. For bicycle, a similar situation occurs as for the University. But because of lower parking time and walking time from the car the bicycle situation is better for the Mall. When looking at the direct-ratio values the sea barrier affects the travel time for Grafarvogur.

For accessibility to the Hospital, the situation was very similar as for the Kringlan Mall. More sub-districts failed because that there are not many bus lines connected to the area where the Hospital is situated. The sub-districts east of the Hospital and the districts in Breiðholt are the only ones not failing because that there is a bus line that lies direct between Breiðholt and the area near the Hospital. For bicycle, a similar situation also occurs as for the Kringlan Mall but because of lower parking time and walking time from the car the situation is better for the Hospital.

The accessibility to the Laugardalur valley was not good. For the bus system, every sub-district failed so it can be assumed that the bus conditions for the valley is unacceptable and has to be improved. Low parking time and walking time from the car affects the accessibility for the bus very negatively. For the direct-ratio values for bicycle every sub-district in Grafarvogur fails. This is the most obvious example of how the sea barrier between the sub-districts in Grafarvogur and the main Reykjavík area affects the accessibility for the inhabitants in Grafarvogur.

The accessibility to the city centre was very acceptable. For the bus-system, every sub-district has an acceptable value which is very good since the city centre is often considered to be the most important place or destination for a city. The reason for this good accessibility is probably the long parking time and walking time from the car while the bus stops right in the heart of the city centre. For bicycle, no sub-district fail when looking at travel-ratio values because of the long parking time and walking time from the car. Looking at the direct-ratio values almost exact same situation occurs as for the University because of the closeness between the two places. The only difference is that the situation for the sub-districts in Grafarvogur gets worse because that the effect from the sea barrier is clearer.

It was rather obvious from the results that the situation is worst for the inhabitants in Grafarvogur, both regarding the accessibility to the working places and accessibility to the main places in Reykjavík. When adding the link over the sea west of Grafarvogur, Sundabraut, the improvements were quite clear for the car and bicycle accessibility. For the car network the increase in reaching the working places in 10 minutes was almost 47%. The AT_{50} value decreased by 8% which is not very high. For the bicycle network the increase in reaching the working places in 20 minutes was more than 42%. The AT_{50} value decreased by 15%. Accessibility for bicycle to the Kringlan Mall with the bike/car travel-ratio got much better and the accessibility for bicycle to the Laugardalur valley with direct-ratio also got better.

It was also obvious how long parking time and walking time from car affects the accessibility for bicycle and bus positively, especially in the centre where the best bicycle and bus accessibility is.

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APPENDICES

APPENDIX I: Information about the sub-districts

No.	Sub-district	Area [m^2]	Population	Density [inh/ha]	Land use [% res. area]
1	Grandar	364.953	2.995	82	81
2	Skjól	218.609	1.628	74	95
3	Melar	394.291	2.204	56	74
4	Hagar	383.171	2.077	54	69
5	Háskóli	508.795	978	19	53
6	Vesturbær	609.672	5.165	85	78
9	Austurbær	1.133.527	7.406	65	55
10	Skerjafjörður	265.341	685	26	93
12	Norðurmýri	132.229	1.234	93	88
13	Tún	582.801	1.583	27	29
14	Teigar	479.911	2.181	45	65
15	Holt	411.089	1.800	44	36
16	Hlíðar	1.179.686	5.493	47	76
17	Öskjuhlíð	1.444.008	555	4	68
18	Fossvogur	1.465.471	3.791	26	78
19	Kringla	402.701	549	14	25
20	Gerði	1.333.187	5.555	42	84
21	Háaleiti	1.132.778	3.709	33	37
23	Lækir	274.068	1.866	68	84
24	Laugarás	645.529	2.492	39	83
25	Sund	461.573	2.343	51	89
26	Heimar	433.766	2.722	63	88
27	Vogar	343.845	1.476	43	86
32	Sel	1.816.315	8.117	45	87
33	Mjódd	290.200	256	9	29
34	Bakkar	374.999	3.272	87	93
35	Stekkir	260.724	420	16	93
36	Fell	513.509	4.103	80	85
37	Hólar	748.388	4.527	60	85
38	Ártúnsholt	695.597	1.593	23	72
40	Árbær	701.584	3.366	48	86
41	Selás	889.382	3.482	39	92
42	Grafarholt	1.035.695	4.159	40	91
44	Bryggjur	116.936	698	60	84
45	Hamrar	686.949	1.648	24	88
46	Foldir	1.072.379	3.504	33	88
47	Hús	537.180	2.110	39	75
49	Rimar	916.147	3.813	42	90
50	Borgir	464.122	1.610	35	81
51	Engi	400.269	1.630	41	79
52	Víkur	280.835	1.630	58	92
53	Staðir	603.842	1.272	21	96

APPENDIX II: Results from survey

Description	
Object	Examine walking and parking times under different circumstances for inhabitants in the Greater Reykjavík Area
Time of research	September 19th to October 20th
Method	Survey with e-mail
Sample	Sample of 126 Icelanders from the Greater Reykjavík Area

Sample size and response	
Original sample	126
Living outside the Greater Reykjavík Area	15
Final sample	111
Not answering	60
Answering	51
Percentage answering	45.9%

Results

	Average	**Standard error**
How long time does it take you in average to walk from your front door at home to your car?	0.6 min	0.6 min
------------------------------------		
How long time does it take you in average looking for car park at:		
The Kringlan Shopping Mall?	2.9 min	2.1 min
The Laugardalur valley?	1.9 min	1.9 min
The National University Hospital?	2.8 min	2.9 min
The city centre?	5.0 min	3.8 min
The University of Iceland?	3.8 min	3.2 min
Your work?	0.9 min	1.7 min

How long time does it take you in average to walk from the car park to:		
The entrance to the Kringlan Shopping Mall?	1.5 min	1.1 min
The Laugardalur valley?	2.1 min	1.7 min
The entrance to the National University Hospital?	2.0 min	1.6 min
The city centre?	4.1 min	2.6 min
The entrance to the University of Iceland?	2.6 min	1.9 min
The entrance to you work?	0.9 min	1.4 min

APPENDIX III: Information for the 92 bus points

	All times in minutes	From				All times in minutes	From		
		Breiðholt	**Grafarvogur**	**Centrum**			**Breiðholt**	**Grafarvogur**	**Centrum**
no.	**To [adress]**	[Engjasel 1]	[Rósarimi 11]	[Lækjartorg]	**no.**	**To [adress]**	[Engjasel 1]	[Rósarimi 11]	[Lækjartorg]
1	Eyjarslóð 11	39	46	13	47	Guðríðarstígur 6	28	24	25
2	Öldugrandi 1	41	48	10	48	Jónsgeisli 63	34	30	33
3	Hringbraut 121	38	45	10	49	Marteinslaug 16	35	31	34
4	Ægisgarður 7	31	38	4	50	Þorláksgeisli 122	36	32	35
5	Skúlagata 4	27	33	5	51	Fossvogsblettur 1	26	36	24
6	Skúlagata 15	27	33	6	52	Grundarland 5	21	37	23
7	Borgartún 25	21	32	12	53	Traðarland 10	15	27	22
8	Héðinsgata 1	17	28	14	54	Rafstöðvarvegur 10	15	25	22
9	Korngarðar 11	21	27	17	55	Kistuhylur 4	13	22	25
10	Klettagarðar 14	24	30	18	56	Hraunbær 113	25	21	22
11	Gufunesvegur 3	27	13	34	57	Tunguháls 8	28	24	25
12	Tröllaborgir 18	33	12	30	58	Álfabakki 14	7	22	19
13	Hamravík 54	36	15	33	59	Dvergabakki 26	11	26	23
14	Bakkastaðir 5	28	14	37	60	Krummahólar 1	12	25	26
15	Barðastaðir 81	34	20	41	61	Klapparás 1	15	26	27
16	Sörlaskjól 90	33	39	8	62	Reykás 21	26	22	23
17	Neshagi 9	29	35	5	63	Tungusel 10	11	30	27
18	Sóleyjargata 1	21	27	8	64	Seljabraut 36	3	28	25
19	Barónsstígur 23	27	33	6	65	Nönnufell 1	9	34	32
20	Sóltún 2	20	40	9	66	Brekknaás 5	31	27	28
21	Sundlaugavegur 30	23	30	12	67	Þverás 39	28	24	25
22	Efstasund 2	16	23	18	68	Klyfjasel 10	8	32	29
23	Sægarðar 7	20	27	22	69	Grensás	14	20	13
24	Leiðhamrar 46	26	19	33	70	Lágmúli 8	24	30	11
25	Rósarimi 11	30	0	27	71	Kringlan	17	23	12
26	Laufengi 174	25	11	27	72	Snorrabraut 87	20	26	8
27	Þorragata 9	22	28	5	73	Hringbraut	19	25	4
28	Fluggarðar 32	24	30	9	74	Lækjartorg	23	29	0
29	Eskihlíð 12	18	24	10	75	Básbryggja 51	17	12	19
30	Bólstaðarhlíð 44	19	25	13	76	Skautahöllin	29	35	19
31	Ármúli 32	25	31	13	77	Stangarholt 11	24	35	11
32	Langholtsvegur 110	16	23	19	78	Skólavörðustígur 28	29	35	8
33	Kjalarvogur 14	19	26	26	79	Túngata 38	35	41	4
34	Dverghamrar 40	21	15	22	80	Skógarsel 12	12	27	24
35	Frostafold 38	20	8	22	81	Stuðlasel 16	14	31	28
36	Logafold 66	25	13	27	82	Ártún	13	13	15
37	Suðurhús 7	33	18	30	83	Silungakvísl 18	20	22	24
38	Keldnaholt	30	14	27	84	Viðarrimi 45	22	8	29
39	Fáfnisnes 16	24	30	7	85	Vífilsgata 8	23	29	9
40	Vesturhlið 9	27	36	20	86	Skógarhlíð 20	23	29	14
41	Neðstaleiti 24	23	29	18	87	Njörvasund 35	12	19	19
42	Breiðagerði 7	17	23	18	88	Vatnagarðar 40	13	20	18
43	Rauðagerði 25	11	17	14	89	Vesturfold 54	20	9	27
44	Malarhöfði 4	21	23	25	90	Fannafold 247	20	6	22
45	Hamarshöfði 8	17	13	19	91	Garðhús 49	31	15	28
46	Stórhöfði 45	26	22	25	92	Hlemmur	23	29	7

APPENDIX IV: Travel-ratio values, bus/car

No.	Sub-district	Street	Kringlan Mall						University						Hospital						Laugardalur Valley						Centrum					
	Bus waiting time	5 or 10 minutes	Time to car [min] 0,6 min Parking time [min] 2,9 min Time from car [min] 1,5 min **extra** **4,9** min						Time to car [min] 0,6 min Parking time [min] 3,8 min Time from car [min] 2,6 min **extra** **6,9** min						Time to car [min] 0,6 min Parking time [min] 2,8 min Time from car [min] 2,0 min **extra** **5,3** min						Time to car [min] 0,6 min Parking time [min] 1,9 min Time from car [min] 2,1 min **extra** **4,5** min						Time to car [min] 0,6 min Parking time [min] 5,0 min Time from car [min] 4,1 min **extra** **9,7** min					
			Crow's [m]	Bus [min]	Bus [+extra]	Car [min]	Car [+extra]	Ratio Bus/Car	Crow's [m]	Bus [min]	Bus [+extra]	Car [min]	Car [+extra]	Ratio Bus/Car	Crow's [m]	Bus [min]	Bus [+extra]	Car [min]	Car [+extra]	Ratio Bus/Car	Crow's [m]	Bus [min]	Bus [+extra]	Car [min]	Car [+extra]	Ratio Bus/Car	Crow's [m]	Bus [min]	Bus [+extra]	Car [min]	Car [+extra]	Ratio Bus/Car
1	Grandar	Boðagrandi 1	4122	19	29	6,8	11,7	2,5	1329	11	21	3,3	10,2	2,1	4866	25	35	7,9	13,2	2,7	4762	22	32	8,6	13,1	2,5	1553	8	18	3,3	13,0	1,4
2	Skjól	Ægisíða 129	4008	17	27	6,4	11,3	2,4	1126	7	17	3,0	9,9	1,7	4676	29	39	7,5	12,8	3,1	4807	24	34	8,9	13,4	2,5	1694	10	20	3,3	13,0	1,5
3	Melar	Grenimelur 24	3391	18	28	5,7	10,6	2,6	562	8	18	2,2	9,1	2,0	4107	26	36	6,8	12,1	3,0	4147	23	33	8,2	12,7	2,6	1064	9	19	2,5	12,2	1,6
4	Hagar	Tómasarhagi 36	3307	17	27	6,0	10,9	2,5	557	7	17	2,3	9,2	1,9	3900	27	37	7,1	12,4	3,0	4277	20	30	8,5	13,0	2,3	1517	10	20	3,3	13,0	1,5
5	Háskóli	Eggertsgata 20	2865	15	25	5,4	10,3	2,4	677	10	20	2,8	9,7	2,1	3384	25	35	6,4	11,7	3,0	3967	19	29	7,8	12,3	2,4	1638	9	19	3,6	13,3	1,4
6	Vesturbær	Túngata 31	3320	14	24	5,5	10,4	2,3	835	14	24	2,1	9,0	2,7	4120	21	31	6,6	11,9	2,6	3893	18	28	7,4	11,9	2,4	685	4	14	1,6	11,3	1,2
9	Austurbær	Skólavörðustígur 30	2190	20	25	5,0	9,9	2,5	1048	14	19	3,0	9,9	1,9	3041	21	26	6,0	11,3	2,3	2784	21	26	6,0	10,5	2,5	566	8	13	2,0	11,7	1,1
10	Skerjafjörður	Bauganes 14	2886	15	25	6,6	11,5	2,2	1330	6	16	3,4	10,3	1,6	3220	25	35	7,7	13,0	2,7	4162	28	38	9,1	13,6	2,8	2250	9	19	4,4	14,1	1,3
12	Norðurmýri	Gunnarsbraut 26	1466	11	16	2,6	7,5	2,1	1517	8	13	3,1	10,0	1,3	2314	17	27	4,2	9,5	2,8	2258	13	23	4,3	8,8	2,6	1295	8	18	3,2	12,9	1,4
13	Tún	Nóatún 4	1572	19	24	2,8	7,7	3,1	2369	13	23	4,6	11,5	2,0	2540	17	27	4,5	9,8	2,8	1511	15	20	3,1	7,6	2,6	1712	9	19	3,2	12,9	1,5
14	Teigar	Hraunteigur 5	1706	24	34	3,4	8,3	4,1	3095	16	26	6,2	13,1	2,0	2598	25	35	5,1	10,4	3,4	947	16	26	2,5	7,0	3,7	2403	12	22	4,3	14,0	1,6
15	Holt	Stangarholt 26	1200	14	19	2,3	7,2	2,6	2057	14	24	4,0	10,9	2,2	2150	12	22	3,9	9,2	2,4	1700	16	21	3,4	7,9	2,7	1635	10	20	3,8	13,5	1,5
16	Hlíðar	Mávahlíð 45	685	5	10	1,7	6,6	1,5	2199	10	15	3,9	10,8	1,4	1489	11	16	3,3	8,6	1,9	1895	17	22	4,2	8,7	2,5	2120	12	17	4,1	13,8	1,2
17	Öskjuhlíð	Víðihlíð 12	780	10	20	3,5	8,4	2,4	2903	18	23	5,5	12,4	1,9	683	9	19	3,4	8,7	2,2	2263	25	30	6,3	10,8	2,8	3032	17	27	5,9	15,6	1,7
18	Fossvogur	Helluland 9	1744	15	20	4,2	9,1	2,2	4531	22	27	7,3	14,2	1,9	995	11	16	2,8	8,1	2,0	2311	28	33	4,8	9,3	3,6	4489	24	29	7,8	17,5	1,7
19	Kringla	Miðleiti 4	483	7	7	1,9	6,8	1,0	3070	15	20	5,5	12,4	1,6	539	6	11	1,5	6,8	1,6	1892	21	26	4,9	9,4	2,8	3072	16	21	6,0	15,7	1,3
20	Gerði	Háagerði 85	1489	11	16	3,8	8,7	1,8	4364	17	22	7,3	14,2	1,6	1047	12	17	3,6	8,9	1,9	1795	18	23	4,2	8,7	2,7	4212	19	24	7,6	17,3	1,4
21	Háaleiti	Safamýri 45	525	8	8	3,1	8,0	1,0	3080	13	18	6,7	13,6	1,3	1339	9	14	3,3	8,6	1,6	987	18	23	3,9	8,4	2,8	2769	14	19	6,2	15,9	1,2
23	Lækir	Rauðalækur 33	2217	24	34	4,5	9,4	3,6	3556	18	28	7,2	14,1	2,0	3058	25	35	6,2	11,5	3,0	1100	16	26	3,2	7,7	3,4	2777	14	24	5,3	15,0	1,6
24	Laugarás	Austurbrún 21	2207	22	32	5,4	10,3	3,1	4212	16	26	8,2	15,1	1,7	2830	19	29	6,1	11,4	2,5	706	9	19	4,0	8,5	2,2	3543	14	24	6,3	16,0	1,5
25	Sund	Skipasund 58	2065	21	31	4,3	9,2	3,4	4492	20	30	7,9	14,8	2,0	2461	16	26	4,5	9,8	2,7	737	10	20	3,2	7,7	2,6	3944	18	28	6,4	16,1	1,7
26	Heimar	Goðheimar 23	1655	15	20	3,6	8,5	2,3	4332	19	24	7,2	14,1	1,7	1888	13	18	3,9	9,2	2,0	830	13	18	2,6	7,1	2,5	3913	17	22	6,9	16,6	1,3
27	Vogar	Nökkvavogur 25	1975	14	19	4,7	9,6	2,0	4781	18	23	8,2	15,1	1,5	1926	17	27	4,7	10,0	2,7	1405	16	21	4,0	8,5	2,5	4428	20	25	8,1	17,8	1,4
32	Sel	Hjallasel 15	4483	25	30	8,7	13,6	2,2	7093	29	34	12,2	19,1	1,8	3587	30	35	8,2	13,5	2,6	4929	37	42	9,3	13,8	3,1	7194	31	36	12,5	22,2	1,6
33	Mjódd	Þangbakki 10	3582	14	19	6,3	11,2	1,7	6330	18	23	9,8	16,7	1,4	2768	18	23	5,8	11,1	2,1	3878	26	31	6,8	11,3	2,8	6326	20	25	10,1	19,8	1,3
34	Bakkar	Arnarbakki 3	3975	15	20	7,4	12,3	1,6	6769	19	24	10,9	17,8	1,4	3209	14	19	5,8	11,1	1,7	4120	28	33	6,9	11,4	2,9	6721	21	26	11,2	20,9	1,2
35	Stekkir	Skriðustekkur 22	3704	17	22	6,8	11,7	1,9	6540	21	26	10,3	17,2	1,5	3002	13	18	6,3	11,6	1,6	3748	32	37	7,4	11,9	3,1	6442	23	28	10,6	20,3	1,4
36	Fell	Unufell 35	4862	23	28	9,0	13,9	2,0	7625	27	32	12,6	19,5	1,6	4063	19	24	8,6	13,9	1,7	5014	36	41	9,6	14,1	2,9	7609	29	34	12,8	22,5	1,5
37	Hólar	Suðurhólar 25	4659	21	26	8,2	13,1	2,0	7507	25	30	11,7	18,6	1,6	3972	17	22	7,7	13,0	1,7	4576	34	39	8,8	13,3	2,9	7385	27	32	12,0	21,7	1,5
38	Ártúnsholt	Bleikjukvísl 26	3743	12	17	5,6	10,5	1,6	6618	16	21	9,2	16,1	1,3	3331	17	22	5,8	11,1	2,0	3265	18	23	6,2	10,7	2,2	6324	18	23	9,4	19,1	1,2
40	Árbær	Hábær 31	4879	13	18	6,8	11,7	1,5	7760	17	22	10,3	17,2	1,3	4396	20	25	7,0	12,3	2,0	4403	25	30	7,3	11,8	2,6	7479	19	24	10,6	20,3	1,2
41	Selás	Skógarás 1	5792	16	21	8,8	13,7	1,5	8671	20	25	12,3	19,2	1,3	5197	23	28	9,0	14,3	2,0	5458	28	33	9,3	13,8	2,4	8461	22	27	12,6	22,3	1,2
42	Grafarholt	Prestastígur 1-3 1R	6837	33	43	9,7	14,6	2,9	9626	33	43	13,2	20,1	2,1	6561	35	45	9,9	15,2	3,0	5947	38	48	10,2	14,7	3,3	9163	31	41	13,5	23,2	1,8
44	Bryggjur	Naustabryggja 14	3742	16	21	7,2	12,1	1,7	6480	20	25	10,8	17,7	1,4	3636	23	28	7,5	12,8	2,2	2804	28	33	7,8	12,3	2,7	6015	22	27	11,1	20,8	1,3
45	Hamrar	Hlaðhamrar 42	3962	24	34	8,8	13,7	2,5	6528	28	38	12,3	19,2	2,0	4037	26	36	9,0	14,3	2,5	2773	36	46	9,3	13,8	3,3	5956	28	38	12,6	22,3	1,7
46	Foldir	Frostafold 25	4704	17	22	8,3	13,2	1,7	7364	21	26	11,8	18,7	1,4	4646	24	29	8,5	13,8	2,1	3622	29	34	8,8	13,3	2,6	6827	23	28	12,1	21,8	1,3
47	Hús	Hlíðarhús 3-7 3R	5704	21	31	9,1	14,0	2,2	8334	25	35	12,6	19,5	1,8	5642	28	38	9,3	14,6	2,6	4581	33	43	9,6	14,1	3,1	7763	27	37	12,9	22,6	1,6
49	Rimar	Rósarimi 11	5089	23	28	9,3	14,2	2,0	7497	27	32	12,8	19,7	1,6	5237	30	35	9,5	14,8	2,4	3771	35	40	9,9	14,4	2,8	6830	29	34	13,1	22,8	1,5
50	Borgir	Vættaborgir 9	5650	26	36	11,2	16,1	2,2	7870	30	40	14,8	21,7	1,8	5898	33	43	11,4	16,7	2,6	4240	38	48	11,8	16,3	3,0	7129	32	42	15,0	24,7	1,7
51	Engi	Reyrengi 2	5922	25	30	11,1	16,0	1,9	8332	29	34	14,6	21,5	1,6	6038	32	37	11,3	16,6	2,2	4611	37	42	11,6	16,1	2,6	7653	31	36	14,9	24,6	1,5
52	Víkur	Breiðavík 13	6211	32	37	10,7	15,6	2,4	8500	36	41	14,3	21,2	1,9	6399	37	47	10,9	16,2	2,9	4835	42	52	11,3	15,8	3,3	7772	38	43	14,5	24,2	1,8
53	Staðir	Bakkastaðir 23	7257	34	44	11,6	16,5	2,7	9500	38	48	15,1	22,0	2,2	7446	36	46	11,8	17,1	2,7	5868	46	56	12,2	16,7	3,4	8745	40	50	15,4	25,1	2,0

APPENDIX V: Travel-ratio values, bicycle/car

			Kringlan Mall						University						Hospital						Laugardalur Valley						Centrum					
	Time to bicycle [min] 0,5 min Time from bicycle [min] 0,5 min **extra 1,0** min		Time to car [min] 0,6 min Parking time [min] 2,9 min Time from car [min] 1,5 min **extra 4,9** min						Time to car [min] 0,6 min Parking time [min] 3,8 min Time from car [min] 2,6 min **extra 6,9** min						Time to car [min] 0,6 min Parking time [min] 2,8 min Time from car [min] 2,0 min **extra 5,3** min						Time to car [min] 0,6 min Parking time [min] 1,9 min Time from car [min] 2,1 min **extra 4,5** min						Time to car [min] 0,6 min Parking time [min] 5,0 min Time from car [min] 4,1 min **9,7** min					
			Crow's	**Car**		**Bicycle**		**Ratio**	**Crow's**	**Car**		**Bicycle**		**Ratio**	**Crow's**	**Car**		**Bicycle**		**Ratio**	**Crow's**	**Car**		**Bicycle**		**Ratio**	**Crow's**	**Car**		**Bicycle**		**Ratio**
No.	**Sub-district**	**Street**	[m]	[min]	[+extra]	[min]	[+extra]	Bike/Car	[m]	[min]	[+extra]	[min]	[+extra]	Bike/Car	[m]	[min]	[+extra]	[min]	[+extra]	Bike/Car	[m]	[min]	[+extra]	[min]	[+extra]	Bike/Car	[m]	[min]	[+extra]	[min]	[+extra]	Bike/Car
1	Grandar	Boðagrandi 1	4122	6,8	11,7	17	18	1,5	1329	3,3	10,2	6	7	0,6	4866	7,9	13,2	20	21	1,6	4762	8,6	13,1	20	21	1,6	1553	3,3	13,0	7	8	0,6
2	Skjól	Ægisíða 129	4008	6,4	11,3	16	17	1,5	1126	3,0	9,9	5	6	0,6	4676	7,5	12,8	19	20	1,6	4807	8,9	13,4	20	21	1,6	1694	3,3	13,0	7	8	0,6
3	Melar	Grenimelur 24	3391	5,7	10,6	14	15	1,4	562	2,2	9,1	3	4	0,4	4107	6,8	12,1	17	18	1,5	4147	8,2	12,7	18	19	1,5	1064	2,5	12,2	5	6	0,5
4	Hagar	Tómasarhagi 36	3307	6,0	10,9	15	16	1,4	557	2,3	9,2	3	4	0,4	3900	7,1	12,4	18	19	1,5	4277	8,5	13,0	19	20	1,6	1517	3,3	13,0	7	8	0,6
5	Háskóli	Reykjavíkurvegur 35	2865	5,4	10,3	13	14	1,4	677	2,8	9,7	3	4	0,5	3384	6,4	11,7	17	18	1,5	3967	7,8	12,3	18	19	1,6	1638	3,6	13,3	7	8	0,6
6	Vesturbær	Túngata 31	3320	5,5	10,4	14	15	1,4	835	2,1	9,0	4	5	0,6	4120	6,6	11,9	18	19	1,6	3893	7,4	11,9	16	17	1,4	685	1,6	11,3	3	4	0,3
9	Austurbær	Skólavörðustígur 30	2190	5,0	9,9	9	10	1,0	1048	3,0	9,9	4	5	0,6	3041	6,0	11,3	14	15	1,3	2784	6,0	10,5	12	13	1,2	566	2,0	11,7	2	3	0,3
10	Skerjafjörður	Bauganes 14	2886	6,6	11,5	17	18	1,6	1330	3,4	10,3	6	7	0,7	3220	7,7	13,0	16	17	1,3	4162	9,1	13,6	22	23	1,7	2250	4,4	14,1	10	11	0,8
12	Norðurmýri	Gunnarsbraut 26	1466	2,6	7,5	6	7	0,9	1517	3,1	10,0	7	8	0,8	2314	4,2	9,5	11	12	1,2	2258	4,3	8,8	10	11	1,3	1295	3,2	12,9	6	7	0,5
13	Tún	Nóatún 4	1572	2,8	7,7	7	8	1,1	2369	4,6	11,5	11	12	1,0	2540	4,5	9,8	12	13	1,3	1511	3,1	7,6	6	7	1,0	1712	3,2	12,9	7	8	0,7
14	Teigar	Hraunteigur 5	1706	3,4	8,3	7	8	1,0	3095	6,2	13,1	14	15	1,1	2598	5,1	10,4	11	12	1,2	947	2,5	7,0	5	6	0,8	2403	4,3	14,0	11	12	0,8
15	Holt	Stangarholt 26	1200	2,3	7,2	6	7	0,9	2057	4,0	10,9	10	11	1,0	2150	3,9	9,2	10	11	1,3	1700	3,4	7,9	8	9	1,1	1635	3,8	13,5	7	8	0,6
16	Hlíðar	Mávahlíð 45	685	1,7	6,6	3	4	0,7	2199	3,9	10,8	9	10	0,9	1489	3,3	8,6	7	8	0,9	1895	4,2	8,7	9	10	1,2	2120	4,1	13,8	9	10	0,7
17	Öskjuhlíð	Víðihlíð 12	780	3,5	8,4	4	5	0,6	2903	5,5	12,4	13	14	1,1	683	3,4	8,7	3	4	0,5	2263	6,3	10,8	11	12	1,1	3032	5,9	15,6	14	15	0,9
18	Fossvogur	Helluland 9	1744	4,2	9,1	9	10	1,1	4531	7,3	14,2	19	20	1,4	995	2,8	8,1	6	7	0,8	2311	4,8	9,3	11	12	1,3	4489	7,8	17,5	20	21	1,2
19	Kringla	Miðleiti 4	483	1,9	6,8	3	4	0,6	3070	5,5	12,4	14	15	1,2	539	1,5	6,8	3	4	0,6	1892	4,9	9,4	9	10	1,0	3072	6,0	15,7	14	15	1,0
20	Gerði	Háagerði 85	1489	3,8	8,7	7	8	1,0	4364	7,3	14,2	18	19	1,4	1047	3,6	8,9	6	7	0,7	1795	4,2	8,7	9	10	1,2	4212	7,6	17,3	19	20	1,1
21	Háaleiti	Safamýri 45	525	3,1	8,0	3	4	0,5	3080	6,7	13,6	13	14	1,0	1339	3,3	8,6	6	7	0,8	987	3,9	8,4	6	7	0,8	2769	6,2	15,9	12	13	0,8
23	Lækir	Rauðalækur 33	2217	4,5	9,4	9	10	1,1	3556	7,2	14,1	15	16	1,2	3058	6,2	11,5	14	15	1,3	1100	3,2	7,7	6	7	0,9	2777	5,3	15,0	12	13	0,9
24	Laugarás	Austurbrún 21	2207	5,4	10,3	11	12	1,2	4212	8,2	15,1	18	19	1,3	2830	6,1	11,4	13	14	1,3	706	4,0	8,5	4	5	0,6	3543	6,3	16,0	15	16	1,0
25	Sund	Skipasund 58	2065	4,3	9,2	10	11	1,2	4492	7,9	14,8	20	21	1,4	2461	4,5	9,8	11	12	1,2	737	3,2	7,7	3	4	0,6	3944	6,4	16,1	16	17	1,1
26	Heimar	Goðheimar 23	1655	3,6	8,5	8	9	1,1	4332	7,2	14,1	19	20	1,4	1888	3,9	9,2	9	10	1,1	830	2,6	7,1	4	5	0,7	3913	6,9	16,6	16	17	1,0
27	Vogar	Nökkvavogur 25	1975	4,7	9,6	9	10	1,1	4781	8,2	15,1	20	21	1,4	1926	4,7	10,0	10	11	1,1	1405	4,0	8,5	7	8	0,9	4428	8,1	17,8	18	19	1,1
32	Sel	Hjallasel 15	4483	8,7	13,6	22	23	1,7	7093	12,2	19,1	33	34	1,8	3587	8,2	13,5	20	21	1,5	4929	9,3	13,8	22	23	1,7	7194	12,5	22,2	33	34	1,5
33	Mjódd	Þangbakki 10	3582	6,3	11,2	18	19	1,7	6330	9,8	16,7	29	30	1,8	2768	5,8	11,1	16	17	1,5	3878	6,8	11,3	18	19	1,7	6326	10,1	19,8	29	30	1,5
34	Bakkar	Arnarbakki 3	3975	7,4	12,3	18	19	1,6	6769	10,9	17,8	29	30	1,7	3209	5,8	11,1	16	17	1,5	4120	6,9	11,4	18	19	1,7	6721	11,2	20,9	29	30	1,4
35	Stekkir	Skriðustekkur 22	3704	6,8	11,7	17	18	1,5	6540	10,3	17,2	27	28	1,7	3002	6,3	11,6	14	15	1,3	3748	7,4	11,9	17	18	1,5	6442	10,6	20,3	27	28	1,4
36	Fell	Unufell 35	4862	9,0	13,9	22	23	1,7	7625	12,6	19,5	33	34	1,7	4063	8,6	13,9	20	21	1,5	5014	9,6	14,1	22	23	1,7	7609	12,8	22,5	33	34	1,5
37	Hólar	Suðurhólar 25	4659	8,2	13,1	21	22	1,7	7507	11,7	18,6	31	32	1,7	3972	7,7	13,0	18	19	1,5	4576	8,8	13,3	21	22	1,6	7385	12,0	21,7	31	32	1,5
38	Ártúnsholt	Bleikjukvísl 26	3743	5,6	10,5	16	17	1,6	6618	9,2	16,1	27	28	1,7	3331	5,8	11,1	15	16	1,4	3265	6,2	10,7	15	16	1,5	6324	9,4	19,1	27	28	1,4
40	Árbær	Hábær 31	4879	6,8	11,7	21	22	1,9	7760	10,3	17,2	31	32	1,9	4396	7,0	12,3	19	20	1,7	4403	7,3	11,8	20	21	1,8	7479	10,6	20,3	31	32	1,6
41	Selás	Skógarás 1	5792	8,8	13,7	25	26	1,9	8671	12,3	19,2	35	36	1,9	5197	9,0	14,3	22	23	1,6	5458	9,3	13,8	24	25	1,8	8461	12,6	22,3	35	36	1,6
42	Grafarholt	Prestastígur 1-3 1R	6837	9,7	14,6	30	31	2,1	9626	13,2	20,1	41	42	2,1	6561	9,9	15,2	29	30	1,9	5947	10,2	14,7	29	30	2,1	9163	13,5	23,2	40	41	1,8
44	Bryggjur	Naustabryggja 14	3742	7,2	12,1	19	20	1,7	6480	10,8	17,7	30	31	1,8	3636	7,5	12,8	19	20	1,6	2804	7,8	12,3	18	19	1,5	6015	11,1	20,8	29	30	1,5
45	Hamrar	Hlaðhamrar 42	3962	8,8	13,7	24	25	1,8	6528	12,3	19,2	34	35	1,8	4037	9,0	14,3	23	24	1,7	2773	9,3	13,8	22	23	1,7	5956	12,6	22,3	34	35	1,6
46	Foldir	Frostafold 25	4704	8,3	13,2	25	26	2,0	7364	11,8	18,7	35	36	1,9	4646	8,5	13,8	24	25	1,8	3622	8,8	13,3	23	24	1,8	6827	12,1	21,8	35	36	1,6
47	Hús	Hlíðarhús 3-7 3R	5704	9,1	14,0	29	30	2,2	8334	12,6	19,5	40	41	2,1	5642	9,3	14,6	28	29	2,0	4581	9,6	14,1	28	29	2,0	7763	12,9	22,6	39	40	1,8
49	Rimar	Rósarimi 11	5089	9,3	14,2	29	30	2,1	7497	12,8	19,7	39	40	2,0	5237	9,5	14,8	28	29	2,0	3771	9,9	14,4	27	28	1,9	6830	13,1	22,8	39	40	1,7
50	Borgir	Vættaborgir 9	5650	11,2	16,1	32	33	2,1	7870	14,8	21,7	43	44	2,0	5898	11,4	16,7	32	33	2,0	4240	11,8	16,3	31	32	1,9	7129	15,0	24,7	42	43	1,8
51	Engi	Reyrengi 2	5922	11,1	16,0	32	33	2,0	8332	14,6	21,5	42	43	2,0	6038	11,3	16,6	31	32	1,9	4611	11,6	16,1	30	31	1,9	7653	14,9	24,6	42	43	1,7
52	Víkur	Breiðavík 13	6211	10,7	15,6	34	35	2,2	8500	14,3	21,2	45	46	2,2	6399	10,9	16,2	34	35	2,1	4835	11,3	15,8	32	33	2,1	7772	14,5	24,2	44	45	1,9
53	Staðir	Bakkastaðir 23	7257	11,6	16,5	39	40	2,4	9500	15,1	22,0	49	50	2,3	7446	11,8	17,1	38	39	2,3	5868	12,2	16,7	37	38	2,3	8745	15,4	25,1	49	50	2,0

APPENDIX VI: Direct-ratio values, bicycle

No.	Sub-district	Street	Kringlan Mall Crow's [m]	Kringlan Mall Real [m]	Kringlan Mall Ratio Genhet	University Crow's [m]	University Real [m]	University Ratio Genhet	Hospital Crow's [m]	Hospital Real [m]	Hospital Ratio Genhet	Laugardalur Valley Crow's [m]	Laugardalur Valley Real [m]	Laugardalur Valley Ratio Genhet	Centrum Crow's [m]	Centrum Real [m]	Centrum Ratio Genhet
1	Grandar	Boðagrandi 1	4122	4470	1,08	1329	1468	1,10	4866	5444	1,12	4762	5243	1,10	1553	1805	1,16
2	Skjól	Ægisíða 129	4008	4263	1,06	1126	1213	1,08	4676	5189	1,11	4807	5360	1,12	1694	1889	1,12
3	Melar	Grenimelur 24	3391	3638	1,07	562	678	1,21	4107	4646	1,13	4147	4809	1,16	1064	1351	1,27
4	Hagar	Tómasarhagi 36	3307	3881	1,17	557	831	1,49	3900	4807	1,23	4277	5161	1,21	1517	1843	1,21
5	Háskóli	Reykjavíkurvegur 35	2865	3544	1,24	677	914	1,35	3384	4423	1,31	3967	4906	1,24	1638	1971	1,20
6	Vesturbær	Túngata 31	3320	3732	1,12	835	1064	1,27	4120	4873	1,18	3893	4205	1,08	685	734	1,07
9	Austurbær	Skólavörðustígur 30	2190	2448	1,12	1048	1186	1,13	3041	3697	1,22	2784	3150	1,13	566	585	1,03
10	Skerjafjörður	Bauganes 14	2886	4535	1,57	1330	1619	1,22	3220	4189	1,30	4162	5897	1,42	2250	2707	1,20
12	Norðurmýri	Gunnarsbraut 26	1466	1561	1,07	1517	1845	1,22	2314	2819	1,22	2258	2726	1,21	1295	1502	1,16
13	Tún	Nóatún 4	1572	1961	1,25	2369	2873	1,21	2540	3196	1,26	1511	1661	1,10	1712	1997	1,17
14	Teigar	Hraunteigur 5	1706	1897	1,11	3095	3713	1,20	2598	2988	1,15	947	1285	1,36	2403	2836	1,18
15	Holt	Stangarholt 26	1200	1538	1,28	2057	2544	1,24	2150	2799	1,30	1700	2142	1,26	1635	1778	1,09
16	Hlíðar	Mávahlíð 45	685	906	1,32	2199	2389	1,09	1489	1895	1,27	1895	2411	1,27	2120	2452	1,16
17	Öskjuhlíð	Víðihlíð 12	780	1008	1,29	2903	3339	1,15	683	904	1,32	2263	2803	1,24	3032	3645	1,20
18	Fossvogur	Helluland 9	1744	2493	1,43	4531	5072	1,12	995	1488	1,50	2311	3046	1,32	4489	5377	1,20
19	Kringla	Miðleiti 4	483	729	1,51	3070	3805	1,24	539	804	1,49	1892	2349	1,24	3072	3862	1,26
20	Gerði	Háagerði 85	1489	1964	1,32	4364	4915	1,13	1047	1495	1,43	1795	2453	1,37	4212	4934	1,17
21	Háaleiti	Safamýri 45	525	748	1,42	3080	3469	1,13	1339	1612	1,20	987	1477	1,50	2769	3137	1,13
23	Lækir	Rauðalækur 33	2217	2508	1,13	3556	4103	1,15	3058	3602	1,18	1100	1530	1,39	2777	3227	1,16
24	Laugarás	Austurbrún 21	2207	3031	1,37	4212	4772	1,13	2830	3551	1,25	706	1182	1,67	3543	3895	1,10
25	Sund	Skipasund 58	2065	2630	1,27	4492	5230	1,16	2461	2848	1,16	737	900	1,22	3944	4371	1,11
26	Heimar	Goðheimar 23	1655	2179	1,32	4332	4985	1,15	1888	2398	1,27	830	1006	1,21	3913	4258	1,09
27	Vogar	Nökkvavogur 25	1975	2493	1,26	4781	5299	1,11	1926	2712	1,41	1405	1778	1,27	4428	4901	1,11
32	Sel	Hjallasel 15	4483	5972	1,33	7093	8729	1,23	3587	5264	1,47	4929	5955	1,21	7194	8760	1,22
33	Mjódd	Þangbakki 10	3582	4829	1,35	6330	7635	1,21	2768	4186	1,51	3878	4812	1,24	6326	7617	1,20
34	Bakkar	Arnarbakki 3	3975	4902	1,23	6769	7707	1,14	3209	4258	1,33	4120	4884	1,19	6721	7690	1,14
35	Stekkir	Skriðustekkur 22	3704	4493	1,21	6540	7299	1,12	3002	3860	1,29	3748	4476	1,19	6442	7281	1,13
36	Fell	Unufell 35	4862	5999	1,23	7625	8805	1,15	4063	5356	1,32	5014	5982	1,19	7609	8787	1,15
37	Hólar	Suðurhólar 25	4659	5515	1,18	7507	8320	1,11	3972	4882	1,23	4576	5497	1,20	7385	8303	1,12
38	Ártúnsholt	Bleikjukvísl 26	3743	4281	1,14	6618	7087	1,07	3331	3904	1,17	3265	4119	1,26	6324	7069	1,12
40	Árbær	Hábær 31	4879	5531	1,13	7760	8337	1,07	4396	5142	1,17	4403	5370	1,22	7479	8320	1,11
41	Selás	Skógarás 1	5792	6574	1,14	8671	9380	1,08	5197	5954	1,15	5458	6511	1,19	8461	9362	1,11
42	Grafarholt	Prestastígur 1-3 1R	6837	7996	1,17	9626	10802	1,12	6561	7619	1,16	5947	7834	1,32	9163	10784	1,18
44	Bryggjur	Naustabryggja 14	3742	5166	1,38	6480	7972	1,23	3636	5037	1,39	2804	4701	1,68	6015	7855	1,31
45	Hamrar	Hlaðhamrar 42	3962	6341	1,60	6528	9147	1,40	4037	6212	1,54	2773	5876	2,12	5956	9030	1,52
46	Foldir	Frostafold 25	4704	6623	1,41	7364	9428	1,28	4646	6494	1,40	3622	6157	1,70	6827	9312	1,36
47	Hús	Hlíðarhús 3-7 3R	5704	7814	1,37	8334	10619	1,27	5642	7554	1,34	4581	7348	1,60	7763	10503	1,35
49	Rimar	Rósarimi 11	5089	7627	1,50	7497	10433	1,39	5237	7498	1,43	3771	7162	1,90	6830	10316	1,51
50	Borgir	Vættaborgir 9	5650	8609	1,52	7870	11414	1,45	5898	8480	1,44	4240	8143	1,92	7129	11298	1,58
51	Engi	Reyrengi 2	5922	8420	1,42	8332	11225	1,35	6038	8291	1,37	4611	7954	1,72	7653	11109	1,45
52	Víkur	Breiðavík 13	6211	9082	1,46	8500	11888	1,40	6399	8953	1,40	4835	8617	1,78	7772	11772	1,51
53	Staðir	Bakkastaðir 23	7257	10340	1,42	9500	13146	1,38	7446	10211	1,37	5868	9875	1,68	8745	13029	1,49