Measuring and Analyzing Accessibility to Green-Blue Areas and Public Transportation

A study of Stockholm’s progress in achieving the United Nations Agenda 2030’s SDG 11

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Abstract

The rapid urbanization of populations from rural areas to cities calls for more sustainable focused urban planning to combat the negative effects of urban sprawl. The United Nations’ Agenda 2030 includes the 17 Sustainable Development Goals (SDGs) and 169 targets that aim to unite both developed and developing countries in transforming humanity and the planet for a more sustainable future. One of these goals is SDG 11, making cities and human settlements inclusive, safe, resilient and sustainable. A large part in achieving the targets of SDG 11 is measuring the current access urban residents have to things such as public green-blue spaces as well as public transportation. This thesis will aim to study Stockholm’s achievement of SDG 11 sub-targets 11.2 and 11.7 of Agenda 2030. In order to meet this aim, the following objectives will be pursued. The first objective is to study the degree to which Stockholm County currently has universal access to green-blue areas and public transportation by conducting a GIS-based analysis. The second objective is to improve our understanding of the socio-economic status of residents who have and do not have accessibility to green-blue areas and public transportation by statistically analyzing correlations between environmental and socio-economic indicators. The methodology included qualitative methodologies such as a literature review, interviews and collaborative focus group meetings with Södertörnsanalysen as well as quantitative methodologies such as spatial analysis and statistical analysis. The results show that while Stockholm has impressively high accessibility for its residents, it has yet to meet Agenda 2030 SDG 11 targets 11.2 and 11.7 because the accessibility was not universal. The results also found that people with lower income, people who own their flats/homes and people with children have higher accessibility to green areas. It was also shown that people with higher income, people who rent their flats/homes and have no children have higher access to public transportation. This result can be expected as the bulk of people with higher incomes are living in the inner city where they have high access to urban services and rail stops, but not necessarily green areas. It is important to state that at 300 m from residencies, both access to green areas and access to public transportation is almost 100%. At 500 m from residencies, access to blue areas is close to 35 %, which is not almost complete, but still a high percentage since access to blue areas is a bit of a luxury. This thesis ultimately demonstrates the importance of understanding environmental and socio-economic indicators in urban planning especially if the goals of Agenda 2030 are to be met. This thesis also took steps towards building a methodology for quantifying accessibility and it is recognized that further studies can be conducted to further contribute to sustainable urban planning and development.

Key Words: urbanization, compact cities, Agenda 2030, Sustainable Development Goals (SDGs), accessibility, GIS, spatial analysis, statistical analysis, green-blue areas, public transportation, Södertörnsanalysen, Södertörnsmodellen
Sammanfattning


Nyckelord: urbanisering, kompakt städer, Agenda 2030, Sustainable Development Goals (SDGs), hållbarhetsmål, tillgänglighet, GIS, rumslig analys, statistisk analys, grönblå områden, kollektivtrafik, Södertörnsanalysen, Södertörnsmodellen
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List of Abbreviations

CORINE: Coordination of Information on the Environment
CLC: CORINE Land Cover
EU: European Union
GIS: Geographic Information System
HLPF: High-Level Political Forum
SCB: Statistics Sweden
SDGs: Sustainable Development Goals
UN: United Nations
1 Introduction

1.1 Context

In 2008, the urban population outnumbered the rural population and it is expected that two-thirds of the earth’s population will be living in an urban environment by 2050 (UN SDG Knowledge Platform, 2015). A common pattern of urbanization, referred to as urban sprawl, is when the physical extents of a city expands faster than the urban populations (Angel et al., 2011; Seto et al., 2013; Hennig et al., 2015; UN, 2015). Urban sprawl often is characterized by incremental development with little public planning, more dependence on private transportation as well as less functional open space (Ewing, 2008; Botequilhs-Laitão, 2012). This leads to urban areas being more vulnerable to things like climate change, high traffic congestion and less connectivity to the environment.

Given these challenges that reduce humans’ overall quality of life, the compact city approach combats urban sprawl by promoting compact, high density development that require minimum transport while still valuing open spaces and accessibility to ecosystem services (Mörtberg et al., 2017). However, the high-density development often comes conjointly with lower proportions of green areas and poorly connected public transportation networks without sustainably focused urban planning.

During the United Nations Sustainable Development Summit in September 2015, the 2030 Agenda for Sustainable Development was enacted. This agenda includes the 17 Sustainable Development Goals (SDGs) which are an urgent call for action by both developed and developing countries. In short these goals, “recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests (UN SDG Goals Knowledge Platform, 2015)”. The SDGs have the potential to promote integration, coordination and coherence across the planning cycle (UNDP, 2016). The integrated nature of the SDGs and their framework encourages cross sectoral planning and better implementation because more stakeholders will invest their resources into the same goals and have better, cohesive planning together (UNDP, 2016).

Focusing in on SDG 11, Sustainable Cities and Communities, the goal is to make cities a safer, healthier and more sustainable place so residents can live a healthier and happier life. (UN, 2016).” It was recognized for the first time that sustainable development could not be achieved without first transforming the approach of how cities design, build and manage their urban spaces (Al-Zu’bi and Radovic, 2019). In order to achieve SDG 11 of Agenda 2030, cities across Europe are called to develop a vision of what their cities can be and what it will take to achieve this vision.

A large part in achieving the targets of SDG 11 is considering the current access urban residents have to things such as public green-blue spaces as well as public transportation. Public green-blue spaces can be defined as areas in an urban ecosystem that provide ecosystem services to its residents. Green areas are defined more specifically for this thesis as parks, gardens, urban forests, nature reserves, corridors along waterways, vegetated playgrounds, open fields, wetland as well as other miscellaneous recreational open spaces (Dai, 2011; La Rosa, 2013). Blue areas are defined as oceans, lakes, rivers or any other open body of water. For this thesis, public transportation can be defined as all metro, train, tram and bus stops in the Greater Stockholm Area.
1.2 Scope

This thesis will aim to study Stockholm’s achievement of SDG 11 sub-targets 11.2 and 11.7 of Agenda 2030. In order to meet this aim, the following objectives will be pursued:

1. Study the degree to which Stockholm County currently has universal access to green-blue areas and public transportation by conducting a GIS-based analysis.
2. Improve our understanding of the socio-economic status of residents who have and do not have accessibility to green-blue areas and public transportation by statistically analyzing correlations between environmental and socio-economic indicators.

This thesis was conducted using both qualitative and quantitative methodology. An analysis of Stockholm County residents’ accessibility to green-blue areas and public transportation addressed a gap in research in the local urban planning sector. This thesis exemplifies how geographical and demographical data processed and analyzed together can be used to begin quantifying social indicators such as accessibility. This will better meet the need for more informed urban planning in Stockholm and could be applied in other European countries.

This thesis also provides calculated and prepared data regarding accessibility to green area, blue area and public transportation to be incorporated into Södertörnsanalysen, a part of the project Södertörnsmodellen. As well, the usability of socio-economic indicators for a statistical analysis will be shown from Södertörnsanalysen. More information about Södertörnsmodellen can be found in chapter 3.2.
2 Theoretical Background

2.1 Compact Cities: Combating Urban Sprawl

In Europe, the concept of a compact city was devised in order to regulate and contain urban sprawl (Chhetri et al., 2013). It can simply be defined as “a spatial form which is characterized by its physical compactness, high-density development and well-equipped public transport (OECD, 2012; Artmann et al., 2019)”. A compact city has many advantages in addition to containing urban sprawl; better access to amenities, reduced dependency on cars, and more frequent use of public transportation (Chhetri et al., 2013). But, high density populations in the form of a compact city does not automatically guarantee these benefits, rather, they are dependent on the state of a city’s infrastructure, employment, access to services and access to amenities (Chhetri et al., 2013). Counter arguments against compact cities include depletion of open spaces, overcrowding, pollution to air and water as well as inflated housing markets (Chhetri et al., 2013). Compact cities also do not completely mitigate the dependence on private transportation since private mobility is a luxury among other economic and social reasons (Bertaud et al., 2004).

However, even with the challenges presented of compact cities, it is still widely accepted by policy and science that compact cities are a viable option to combatting urban sprawl (Artmann, 2019). The main aspect for a compact city to be sustainable is to have accessibility to public transportation and green and blue areas (Mörtberg et al., 2017). A main constraint to accessibility of green areas is the low proportion of urban green spaces in a compact cities (Haaland and van den Bosch, 2015; Neuman, 2005; Artmann, 2019). Urban planners and researchers need to consider this challenge as they embark on creating more sustainable, accessible cities (Artmann, 2019).

2.2 The UN’s Agenda 2030 and the Global Sustainable Development Goals (SDGs)

The term sustainable development simply means “development that satisfies the needs of today’s society without compromising the opportunities of future generations to come” (European Commission, 2015). The United Nations recognized the need for a more ambitious, thorough agenda that would involve all countries in the world working towards the same goal of sustainable development. In 2015, The United Nations’ general assembly created a global agenda for sustainable development titled Agenda 2030. It consists of 17 global sustainable development goals (SDGs) that span over many societal challenges with an aim of creating an inclusive, sustainable, peaceful and fair society for all (UNDP, 2015). The 17 SDGs have in total 169 sub-targets with 230 indicators (UN General Assembly, 2015). The global agreement was that over the next 15 years, all participating countries of the United Nations would be committed to changes that would ultimately lead to the achievement of all 17 SDGs and 169 sub-targets and thus resulting in a more sustainable future. Agenda 2030 will guide decisions and requires commitment from all levels (global, national, regional and local) of government.

The UN also made sure to commit to engaging in systematic follow-up and to review the implementation of Agenda 2030 at a national level, but using global indicators (UN, 2015). This is important because it recognizes the difference between the different nations and that changes will look different country to country. This also means it is the responsibility of each nation to respond to this global agenda and implement changes that are needed to reach all 17 of the SDGs and 169 sub-targets.
One important aspect of sustainable development is making sustainable cities and communities. This is exactly the premise of Agenda 2030’s SDG number 11. The goal is to make cities inclusive, safe, resilient and sustainable (UN General Assembly, 2015). This goal is important because since 2008, the urban population has outnumbered the rural population and it is expected that two-thirds of the earth’s population will be living in an urban environment by 2050 (UN SDG Knowledge Platform, 2015). Rapid urbanization puts pressure on valuable resources as well as the living environment (UN General Assembly, 2015). Even the compact city approach needs sustainable planning to insure high density development doesn’t lead to other environmental setbacks such as high pollution, congestion or lack of accessibility to ecosystem services.

For SDG 11, 10 global sub-targets and 15 global indicators have been identified. Each sub-target needs to be complemented by measurable indicators in each country at the regional and national level that is relevant to each country’s priorities (Al-Zu’Bi and Radovic, 2019). Indicators are essential in assessing if sub-targets have been achieved. It is stated by the United Nations Statistical Division, “The global indicator framework was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and agreed to as a practical starting point at the 47th session of the UN Statistical Commission held in March 2016” (UN Statistics Division, 2019).

Specifically, sub-targets 11.2 and 11.7 are within the scope of this thesis. Sub-target 11.2 reads “By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons” (UN SDG Knowledge Platform, 2015). It is suggested by the UN that this sub-target’s indicator is “to measure the proportion of population that has convenient access to public transport, by sex, age and persons with disabilities” (UN SDG Knowledge Platform, 2015).

Sub-target 11.7 reads “By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities” (UN SDG Knowledge Platform, 2015). It is suggested by the UN that this sub-targets indicators are to measure “the average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities and to measure the proportion of persons victim of physical or sexual harassment, by sex, age, disability status and place of occurrence, in the previous 12 months” (UN SDG Knowledge Platform, 2015).

The UN created a central platform to follow-up and review Agenda 2030 and its 17 SDGs (UN, 2015). This platform is known as the High-Level Political Forum (HLPF). In 2018, the HLPF’s theme was ‘Transformation towards sustainable and resilient societies’ (UN SDG Knowledge Platform, 2019). During the 2018 forum, the progress of SDG 11 was discussed and the future methodology of monitoring was enacted. A core monitoring recommendation that was concluded was the following:

“Goal 11 monitoring and reporting presents significant and unique challenges. National Statistical Offices need to coordinate with local authorities in the data collection process, including the integration of spatial information. Strengthening national and local capacities is therefore paramount for collecting, analyzing and disseminating data and information including different forms of disaggregation, accompanied by spatial analysis, and the necessary mechanisms to aggregate urban data at the national level. This requires
partnerships, institutional coordination, adequate systems and monitoring and reporting frameworks” (UN’s HLPF Review of SDGs implementation: SDG 11 – Make cities and human settlements inclusive, safe, resilient and sustainable, 2018).

2.3 Agenda 2030 in Sweden

In response to the UN’s SDG initiatives, the Swedish government has the ambition to be leading in the work towards accomplishing the goals of Agenda 2030 (Länsstyrelsen, 2019). In 2017, the Swedish government decided on six focus areas that need to be prioritized in Sweden (Länsstyrelsen, 2019). These areas are:

- An equal society
- Sustainable communities
- A socially useful, circular and bio-based economy
- A strong industry with sustainable businesses
- Sustainable and healthy food chain
- Strong knowledge and innovation

All branches of the government are responsible for the implementation of Agenda 2030 in Sweden and a special temporary authority, The Agenda 2030 delegation, was created to support and ensure work was being carried out to achieve the goals of Agenda 2030 (Länsstyrelsen, 2019). The Swedish government also recognized that in order for Sweden to achieve the goals of Agenda 2030, the Stockholm region needs to lead the country’s efforts. This is simply because one-fifth of Sweden’s population lives in the Stockholm region and one-third of Sweden’s economy is centralized in Stockholm (Länsstyrelsen, 2019).

Sweden has experienced a large increase in population from 7.5 million in 1960 to 10.2 million in 2018 (SCB, 2018). Sweden’s capital city Stockholm specifically had a 1.6% increase in population from 2015 to 2016 (SCB, 2018). Increasing populations leads to a need for more development as the city adapts to a larger population. Stockholm has the opportunity, as it faces the challenges that come with increasing populations, to come up with smart solutions that will overall have a small ecological footprint but still provide a high quality life to its residents.

2.4 SDG Interactions

The UN Secretary-General has referred to Agenda 2030 as an “indivisible whole”. There are many sides to why this was stated. The first side is, while most of the 17 SDGs have a clear starting and ending point in one of the three pillars of sustainability, they end up crossing into the other pillars at some point in their targets (OECD, 2015; Nilsson et al., 2016).

The second side to this statement is Agenda 2030 SDGs have significant interactions amongst each other, both positive and negative (Nilsson et al., 2016). It is important to understand how the Sustainable Development Goals relate to one another so that policymakers, urban planners and other strategists can make coherent policies and better understand what groups can work together to deliver all 169 targets in Agenda 2030 for Sustainable Development (Nilsson et al., 2016; Maes et al., 2019).

Figure 1 illustrates the results of one important study conducted by Pradhan et al., (2017), who recognized these interactions between the different SDGs and found ways to quantify the interactions, both their synergies and their trade-offs. Their methodology assessed monotonic relationships between all possible combinations of the unique indicator data pairs for each
country by calculating the Spearman rho ($\rho$) value. They found that the positive correlations, or synergies, were often the result of SDGs having the same indicators (Pradhan et al., 2017). For example, the authors stated that “number of deaths, missing persons, and persons affected by disaster” and “number of countries with national and local disaster risk reduction strategies” are among the indicators for SDGs 1 (No poverty), SDG 11 (Sustainable cities and communities), and SDG 13 (Climate action).

For the scope of this thesis, it is important to understand how SDGs interact with other SDGs. It can be seen in Figure 1 that SDG 11 has extremely high synergy with SDG 13. In fact, SDG 11 and SDG 13 are the highest ranking synergy pair (Pradhan et al., 2017). This is important to understand because if policymakers and toolmakers better understand the synergies and tradeoffs of SDGs, then they can better accomplish synergetic SDGs as well as find ways to minimize trade-offs.

![Figure 1. Observed synergies and trade-offs between the SDGs as well as the ranked top 10 synergy pairs and top 10 trade-off pairs (Pradhan et al., 2017).](image)

### 2.5 Accessibility to Green-Blue Areas

Accessibility itself is a broad term that needs to be defined for this study. In social sciences and urban planning, accessibility simply means the ability to approach something (El-Geneidy and Levinson, 2006). Access to green-blue areas specifically is a topic of interest in creating sustainable cities and communities. The term green-blue areas can be defined as open land with natural or semi-natural vegetation or water-covered areas that provide environmental benefits and nature-based solutions to at least some urban problems (Goldenberg et al., 2018; Bolund & Hunhammar, 1999; Gómez-Baggethun et al., 2013; Keesstra et al., 2018; Thorslund et al., 2017).
In the urban context, green areas can be parks, gardens, urban forests, nature reserves, corridors along waterways, playgrounds and other informal green areas (Dai, 2011; La Rosa, 2013). These areas provide very valuable ecosystem services including but not limited to air and water purification, wind and noise filtering, preserving biodiversity and micro-climate stabilization (Unal et al., 2016; La Rosa, 2014; Mougia Kou and Photis, 2017; Yao et al., 2014). In addition, parks and recreational green areas in particular allow people to enjoy leisure activities thus building health and emotional stability and overall improves quality of life (Unal et al., 2016; Lee and Hong, 2013). Specifically, studies have shown that an increase in urban green spaces is related to an increase in physical activity (Richardson et al., 2013) and a decrease in people’s overall stress levels (Roe et al., 2013; Thompson et al., 2012). Specifically, access to green areas can be very beneficial for more vulnerable population groups such as women, children, disabled or elderly people. Studies have linked accessibility to green areas to helping these vulnerable groups cope with conditions such as anxiety or depression (Higgs, 2012; Maas et al., 2009; MacKerron and Mourato, 2013).

Accessibility to green space has become a topic of high debate especially in the realm of environmental justice. It has become evident that lower socio-economic groups often have less or no access to green-blue areas (Goldenberg et al., 2018). However, what qualifies as accessibility to green space is a large obstacle in the scope of this thesis because its definition can vary greatly depending on each individual’s needs and desires. For instance, the elderly population or mother with small children may consider accessibility to be accessing a local park within a 5-minute walk whereas people aged 25 and under could consider accessibility to be a 15-minute walk.

2.6 Accessibility to Public Transportation

Providing access to public transportation is also a topic of interest in building sustainable cities and communities. The use of properly planned public transportation reduces greenhouse gas emissions, leads to more social integration and encourages more homogeneity in a diverse city (Kraft, 2016; UN SDG Knowledge Platform 2016). Another social benefit is that public transportation is often the only available mode of transportation for many more vulnerable groups of people, including the elderly, handicapped, impoverished, and immigrant populations (Kraft, 2016). To meet Agenda 2030, public transportation systems also need to be affordable so they can meet the needs of all vulnerable groups including low-income residents (UN SDG Knowledge Platform, 2016). Areas of communities that are rural or lay far away from the center of cities should also be considered as new public transportation infrastructure is built (UN SDG knowledge Platform, 2016). These areas have a risk of being disconnected with the rest of the city and could lead to residents missing social and economic opportunities that cities can provide (UN SDG Knowledge Platform, 2016).

It is also important to acknowledge that for public transportation networks to be sustainable, there must be a balance between supply of new stations and demand by residents. It is at the same time crucial not to have an abundance of public transportation because roads and railway lines can cause ecological barriers, barriers for walking and biking, noise, etc., as well as decreased land value (Kraft, 2016).

2.7 Methodologies for Calculating Accessibility

There are different methods for quantifying accessibility. Two different methods include the Euclidean distance method and the Network Analysis method shown in Figure 2 (LaRosa,
2013). The Euclidean distance method is based on the Cartesian coordinate system (Cubukcu and Hatcha, 2016) and simply calculates the shortest line of path between two points with coordinates \((x_1, x_2)\) and \((x_2, y_2)\):

\[
ED = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}
\]

The Network Analysis method uses a system of interconnected elements, such as lines and connecting junctions that represent possible routes from one point to another point/polygon (ArcGIS Resource Center, 2012). It has been assumed that following a network to get from one place to another is a better approximation to the real world because it accounts for barriers and more closely mimics real life travel pathways (Levinson and El-Geneidy, 2009; Cubukcu and Hatcha, 2012). Euclidean distances can be simply calculated with different tools available in GIS systems such as ArcMap that can calculate the shortest distance path between two points. However, a network distance usually requires additional geographical data often including road networks, railway networks and the like. These kind of network datasets often requires more time and effort to create.

Figure 2 also illustrates there can be different types of end points (using accessibility to green areas as an example): polygon centroid, nearest boundary point and nearest access point (Higgs, 2012). In the context of measuring accessibility to green areas from points of residencies, all three end points can be a possible target. The polygon centroid, or in this case the green area centroid, can be represented by the main destination point in a park (Boone et al., 2009; Higgs, 2012). Perhaps it is the main playground of the park or the most popular area in the park. The centroid is often difficult to define, as it can be subjective towards whoever is setting its location. The nearest boundary point is simply the point along the green area polygon boundary that is nearest to the starting point; in this case, the point of residency (Higgs, 2012). The nearest access points can be considered as the point at which the official entrance to the green area is (Higgs, 2012). For instance, this could be a park entrance or the entrance gate to a football field.

![Figure 2. Approaches to measuring distances from one point to another point/polygon (Adopted from Higgs, 2012).](image-url)
3 Methodology

A combination of qualitative and quantitative methodologies were performed in this thesis. The methodologies included a literature review, conducting informal interviews, collaborating with professionals in the field of urban planning, data collection, data preparation/processing, performing a GIS-based spatial analysis to measure accessibility as well as a statistical analysis. This chapter will explain each methodology in full.

3.1 Literature Review

One methodology that was used was literature review. This methodology was essential in understanding the topics that would enhance the motivation for the thesis. These topics included:

- Understanding Agenda 2030 and the SDGs globally as well as in Stockholm,
- Understanding the definition of accessibility and specifically different existing methods of measuring it,
- Understand why it is important in sustainable development to have accessibility to green-blue areas and public transportation,
- Identifying and reviewing current accessibility analyses that have been conducted and explore what GIS-based approaches could be used in this thesis,
- Review statistical analysis methods to select one method that would be appropriate in accomplishing the aim and objectives of this thesis.

3.2 Interviews and Collaborations: Södertörnsmodellen

The second methodology used in this thesis was interviews and collaborations with members of the research and development project Södertörnsmodellen. Södertörnsmodellen is a collaboration between municipalities, academia, consultancies and corporations that aims to implement a new way of planning and thinking to help create a good living environment and meet Agenda 2030’s SDGs. The collaboration’s focus is mainly on the eight municipalities of Södertörn, and the analyses is extended to all municipalities within the County of Stockholm, but the hope is the practices learned can be applied to all of Sweden in the future.

The collaboration is between the Södertörn municipalities Botkyrka, Haninge, Huddinge, Nykvarn, Nynäshamn, Salem, Södertälje, and Tyresö as well as with Stockholm Region, KTH Royal Institute of Technology, Södertörn University, Nordregio, Göteborgsregionens Kommunalförbund, Skanska Sverige, Wallenstam, White Arkitekter, SKL International, 2050 Consulting and Ecoloop (Södertörnsmodellen 2018).

One part of Södertörnsmodellen is Södertörnsanalysen. This smaller group focused on the knowledge driven aspect of urban development (Södertörnsmodellen, 2018). One of their main goals was to create an open tool called Södertörnsanalysen that helps its users to visualize statistics and to better connect statistics to geographic areas (Södertörnsmodellen, 2018). The purpose is to give planners, decision-makers, consultants, researchers, residents and other actors an overview of the development in each of the 1269 base areas (city districts) of the 26 municipalities in Stockholm.

This research group’s work was vital because without their cooperation, many of this thesis’s concepts would not have been formulated. The discussions held at Södertörnsmodellen’s conferences shaped the direction and content of this thesis. As well, the data collected from
Södertörnsanalysen was essential in conducting the statistical analysis to meet objective 2 of this thesis.

### 3.3 GIS-based analysis

#### 3.3.1 Study Area

The study area of this thesis was the County of Stockholm, the capital city of Sweden. This area covers approximately 6,500 km² of land surface and 8.3% of that area is protected nature (Stockholms läns landsting, 2018). Around 630 km² is lakes and waterbodies including the largest water body, Lake Mälaren (Stockholms läns landsting, 2018). Stockholm is unique in that it is an urban, compact city while still having ample green and blue areas (Fuller and Gaston, 2009). This is because the region is composed of numerous islands in Stockholm city and is a boreo-nemoral biome (Elmhagen et al., 2015). This region includes 26 municipalities (Figure 2) with a population of 2.3 million people (Stockholms läns landsting, 2018). Each municipality is comprised of smaller base areas. In this thesis, each of the 1269 base area boundaries given by Stockholm Statistics were examined (Appendix B). No buffer outside of this area was considered primarily due to data size restrictions; though it is acknowledged that edge effect will occur close to base area boundary lines that are on the outermost boundary of the study area.

#### 3.3.2 Data Collection

To execute the spatial analysis and assess accessibility to green-blue areas and public transportation, spatial data was needed. The data used in this study is summarized in Table 1. All data was projected into Sweref99TM, the Swedish reference system and all data was taken from the year 2015. Also, all data was presented as the original dataset or was converted to a 10 m raster resolution to ensure consistency and to reduce errors. All dataset layers are shown in Appendix A.

The municipality boundaries, base area boundaries, and FastPak points were given by Statistics Sweden (SCB). The base area and municipality boundaries were needed in setting and visualizing study area boundaries. The FastPak points were essential because they provided the location of each property in the County of Stockholm. Each FastPak point also contains metadata on population size of each property. One FastPak point can represent many households or apartments that are clustered together or it can represent a single family home, depending on the property.
The public transportation stops were provided by the Stockholm Region. The blue areas were taken from a terrain map (Lantmäteriet 2018). The green areas were taken from the Coordination of Information on the Environment (CORINE) Land Cover (CLC) dataset. The CLC was one project in CORINE that was initiated by the EU with the aim of aiding the planning and implementation of EU environmental policies (EEA, 2015; Lantmäteriet 2018).

Table 1. Data sets used in the accessibility analyses

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<td>Public Transportation Stops</td>
<td>P_T_stops</td>
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<td>Blue Areas from Terrain Map</td>
<td>Blue_T</td>
<td>Lantmäteriet, 2015</td>
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<tr>
<td>Green Areas from CORINE Dataset</td>
<td>Green_C</td>
<td>EEA, 2015</td>
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</tbody>
</table>

A selection of socio-economic factors were chosen to be analyzed for this thesis, from Södertörnsanalysen. It was important to select socio-economic indicators that would add to the understanding of the demographics of the people who have access to green-blue areas and public transportation in Stockholm. All data was taken from the year 2015. The chosen variables are summarized in Table 2 below.

Table 2. Socio-economic variables (Södertörnsanalysen, 2018)

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>% Households with children</td>
</tr>
<tr>
<td></td>
<td>% Households Single without children</td>
</tr>
<tr>
<td></td>
<td>Mean Income</td>
</tr>
<tr>
<td>Income</td>
<td>Mean Income Male</td>
</tr>
<tr>
<td></td>
<td>Mean Income Female</td>
</tr>
<tr>
<td>Housing</td>
<td>% Ownership Houses/Flats</td>
</tr>
<tr>
<td></td>
<td>% Rented Houses/Flats</td>
</tr>
</tbody>
</table>

3.3.3 Data Preparation

Geographical Information Systems (GIS) is a powerful tool which is used to analyze spatial data. The ArcGIS software ArcMap version 10.4.1 was used to process data sets and perform the spatial analyses (Esri, 2011). The datasets (Appendix B) were opened in ArcGIS and the study area was constructed by adding all data layer sets from Table 1. When preparing data layers of green areas, blue areas, and public transportation, the following guidelines were followed in this thesis:
1. The area is considered a green area if it is a green urban area, sport and leisure facility, fruit trees and berry plantation, pasture, land principally occupied by agriculture with significant areas of natural vegetation, broad-leaved forest, coniferous forest, mixed forest, transitional woodland-shrub, bare rock, inland marsh, peat bog, or salt marsh.

2. The area is considered a blue area if it is an ocean, lake, river, or any open body of water.

3. The area is considered a public transportation stop if it is a bus stop, metro train station, commuter train station or tram train station.

The reclassification tool in ArcMap was used to only include these attributes in each layer. It is important to note that when deciding what area was considered a green area, areas that do not have vegetation were not included. While areas without vegetation could be used for recreation, it does not provide the same benefits that green areas do as far as socio-environmental health impact is concerned. For this reason, it was decided to leave any area without vegetation out of the scope of this thesis. It is also important to note that public transportation networks were not used. This is because residents will not be accessing public transportation at any point in the network. Rather, they will only have accessibility from designated bus stops and train/tram stations.

3.3.4 Euclidean Distance Calculations

In this thesis, a nearest boundary point approach was used to calculate the nearest Euclidean Distance between the origin point and the destination point (Figure 1). The Euclidean distance between the point of origin and destination point was calculated using the “Near” function in ArcMap. The Near function of ArcMap calculates the distance between the input features and the closest feature to another layer or feature class. A simplified illustration of this tool is shown in Figure 4.

![Illustration of Euclidean distance approaches of the near function tool in ArcMap (adapted from ArcGIS Toolbox)](image)

When measuring the accessibility to green-blue areas, a point to polygon approach was used. The distance between the starting point and polygon is a straight line without considering any barriers. This distance is always calculated to the boundary of a polygon feature, not to the center of the polygon. It is also important to recognize that if a point lies within the polygon than the distance value is zero. When measuring accessibility to public transportation stops, a point to point approach was used. The distance between the two points is a straight line connecting the points and it is calculated by finding the shortest distance between the two points without barriers.
The dataset which included each property, its respective population size and the calculated distances to green area, blue area and public transportation, as well as what base area it belonged to, was exported to Excel. Then, the data was analyzed to see what percentage of Stockholm’s base areas had access to green-blue areas and public transportation under different distance barriers. The distances ranged from under 50 m to under 500 m and a summary of each variable that was calculated can be seen in Table 3. These variables can now be referred to as the accessibility variables.

<table>
<thead>
<tr>
<th>%accessgreenC_under50</th>
<th>%accessblueT_under50</th>
<th>%accessPT_under50</th>
</tr>
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<tbody>
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<tr>
<td>%accessgreenC_under500</td>
<td>%accessblueT_under500</td>
<td>%accessPT_under500</td>
</tr>
</tbody>
</table>

### 3.4 Statistical Analysis

A simple statistical analysis was conducted to better understand the correlations between different accessibility and socio-economic indicators. The correlations between the indicators help to better understand the current state of accessibility in the Stockholm Region. Many of the input variables were found not to be normally distributed and therefore a non-parametric test, the Spearman rank-order correlation coefficient, was measured.

The Spearman rank-order correlation coefficient, or Spearman’s rho (ρ), is a non-parametric measure of the strength and the direction of association that exists between two variables measured on at least an ordinal scale (AERD Statistics, 2018). The test is ideal for ordinal variables or continuous data that has not met the requirements and assumptions necessary to conduct a Pearson’s product-moment correlation (AERD Statistics, 2018). Spearman’s rho (ρ) values span from -1 to 1 each extreme representing perfect positive or negative correlation.

Two assumptions were made in order to conduct the Spearman rank order correlation coefficients. The first was that the variables were measured on an ordinal, interval or ratio scale. In the case of this thesis they were measured on an interval scale. The second assumption is that it is idea for there to be a monotonic relationship between the two variables. A monotonic relationship (Figure 5) exists when either the variables increase in value together, or as one value increase the other decreases (AERD Statistics, 2018).

![Monotonic vs non-monotonic relationships](AERD Statistics, 2018)
In this thesis, a series of Spearman’s rhos (ρ) were calculated using Statistica. The correlations between the accessibility variables (access to green areas, blue areas and public transportation) and the socio-economic indicators chosen from Södertörnsanalysen were then analyzed to begin understand the socio-economic status of those who have accessibility to different urban services.
4 Results and Discussion

In this section, the results of the spatial analysis and the statistical analysis are presented and discussed. A general discussion as well as the limitations and uncertainties are also presented.

4.1 Accessibility to Green-Blue Areas and Public Transportation

4.1.1 Accessibility to Green-Blue Areas

The results of the spatial analysis are shown in Figure 6, Figure 7, and Figure 10. These histograms illustrate how many base areas (x-axis) have accessibility to green areas, blue areas and public transportation stops at different distance buffers. The y-axis of each histogram is the percent of the population of each base area that has access to green areas, blue areas and public transportation stops. The lower and upper quartile as well as median are also illustrated to the right of each histogram. The trend line is also shown in red. Detailed statistics for each histogram can be found in Appendix B. The x-axis represents number of base areas while the y-axis represents percent of the population in each base area with access to green areas, blue areas or public transport stops.

Figure 6. A graphical summary of each base area’s percent accessibility to green areas at varying distances.

Figure 7. A graphical summary of each base area’s percent accessibility to blue areas at varying distances.
Figure 6 presents a graphical summary of the percentage of residents in each base area who have access to green areas given different distance buffers. This histogram specifically illustrates that many base areas do not have any access to green areas under 50 m, however, there are 51 base areas that already have 100 % accessibility for all under 50 m from their residencies.

It is shown that under a short distance, accessibility to green areas increases quickly. In fact, the average accessibility to green areas of each base area goes from 22 % of base areas with access under 50 m to 61 % of base areas with access under 300 m. There are many reasons for this average increase in accessibility, some can be seen graphically. Between 100 m and 200 m, the amount of base areas with 100 % access to green areas increases from 107 to 267 base areas. This is a large increase that brings up the total average. In addition, between 50 m and 500 m, the amount of base areas with 0 % access to green areas decreases from 423 to 135 base areas. This large decrease in 0 values also contributes to the large increase in average. The average percent access to green areas under 500 m was found to be 77 %. This average appears far from 100 %, however the median percentage value was found to be 99.86 %. This low average is simply because of the large amount of base areas that still have 0 % access to green areas under 500 m from their residencies.

Figure 7 presents a graphical summary of the percentage of residents in each base area who have access to blue areas given different distance buffers. Though accessibility to blue areas is not specifically mentioned in sub-goal 11.7, blue areas can still add to ecosystem services as a public open space for recreation. Living close to water can also be seen as a luxury and can increase social interaction as well as increase residents’ overall quality of life.

It is also shown in Figure 7 that under a 500 m buffer, the average accessibility to blue areas in each base area is 44 % and the median is 38 %. It can be seen that this average value is primarily due to 389 base areas that have 0 % access and the 301 base areas that have 100 % access to blue areas. This high amount of base areas with 100 % access to blue areas under 500 m is greatly due to the base areas that lie in the islands of the archipelago.

Overall, it can be concluded that accessibility to green areas in Stockholm is high. However, there are still 135 base areas that have 0 % access to green areas. It raises the question why in some base areas do 100 % its residents have access to green area while some base areas still have no access to green area under a 500 m buffer.
After understanding that many base areas in Stockholm do not have access to green areas under 500 m from their residences, a visualization tool was needed to understand patterns in the location of the base areas with low accessibility. Södertörnsanalysen was used and Figure 8 visually illustrates the population of each base area’s accessibility to green space under 300 m. The access to green areas is shown by the color of each circle. The red circles are the base areas with the highest access to green areas while the purple circles are the base areas with the least access to green areas. It can also be seen that some areas that have 0% access can range from 200 people all the way up to 7,280 people (Figure 8b). Södermalm specifically has very high populations and all of them have very low to no access to green areas including Sofia Kyrka which has 7,280 people residents with 0% access to green area (Figure 8c). These results also show the importance of preserving green areas in newly developing urban areas. It is ideal to avoid removing green areas and this is best accomplished in the planning phase.

Further assessing the visualized data, other conclusions can be made. Figure 9 illustrates that there are base areas where large populations have little to no accessibility to green areas while other base areas adjacent have very high accessibility to green areas. This is the case in many areas, for example Norsborg shown in figure 9a. Figure 9b illustrates there are many cases when base areas that have 0% access to green areas are clustered together. Upon further inspection, areas such as Solna, Sollentuna and Taby are all areas that are being rapidly developed in Stockholm. It can be very beneficial to urban planners and policy makers to understand these patterns before carrying out further development.
4.1.2 Accessibility to Public Transportation Results

Figure 10 presents a graphical summary of the percentage of residents in each base area who has accessibility to public transportation given different distance buffers. This histogram specifically illustrates that many base areas have 0 % to 40 % access to public transportation under 100 m, and that accessibility continues to grow. With a buffer of 500 m, 967 base areas have access to public transportation in Stockholm with an average value of 89 % and a median value of 100 %. The main reason for the average not reaching 100 % are the 29 base areas that still have 0-10 % access. In addition, within a 200 m buffer, 309 base areas already have 100 % access to public transportation and continues to grow to 967 base areas having 100 % access within 500 m of their residencies.

![Graphical Summary (access public transport stops)](image)

*Figure 10. A graphical summary of each base area’s percent accessibility to public transportation at varying distances.*

However, visualizing the data using Södertörnsanalysen helps to understand the data further (Figure 11). Overall, accessibility to public transportation is high especially in central Stockholm (Figure 11a). There are still 4 base areas that have 0 % accessibility and with a buffer of 300 m (Figure 11b), but their populations are small ranging from 302 to 907 people in each base area. This gives motivation to planners and policymakers to find solutions for these lower populated base areas that will likely take less resources than larger populated base areas.

It is also interesting to see that accessibility to green areas is not very correlated to accessibility to public transportation. Generally, the inner-most city has the lowest accessibility to green areas while having the highest accessibility to public transportation.
Whereas the areas that are far from the center of the city have the highest accessibility to green areas and the lowest accessibility to public transportation.

Further assessing the visualized data, other conclusions can be made. Figure 12 illustrates that base areas that are situated at farther distance from the city center, specifically those areas close to the coastline or in the archipelago are base areas with low accessibility to public transportation. It could be beneficial for base areas such as Väto, Rådmansölandet, Frötuna Öglesbygd, Länna fastland, Riala församling to have better connectivity to one another as well as to larger more urbanized areas. In this example, better connection with Norrtälje could be a planning strategy to consider.

There are still 4 base areas that have 0% access to public transportation and 29 base areas that have only 10% access to public transportation. It raises the question how can Stockholm further increase its connectivity and how can areas that are spread out geographically be better connected to the central city. It also raises a social question of if residents living in these base areas value being removed from large city lifestyles. A better understanding of resident’s needs could help further in planning for future public transportation networks.
4.2 Statistical Analysis Results

The correlation between the accessibility variables (access to green areas, blue areas and public transportation) and the socio-economic indicators chosen from Södertörnsanalysen was analyzed by calculating the Spearman rho value for each relation. A value of -1 or 1 means the two variables have a perfect correlation. The results can be found in Table 4. The graphical results of each Spearman rho calculation can be found in Appendix C. To better visualize the results, the negative relationships are highlighted with grey while the positive relationships are kept un-highlighted.

Table 4. The calculated Spearman rho values ($\rho$) between each socio-economic variable and accessibility variable. The bolded values are statistically significant values.

<table>
<thead>
<tr>
<th>Accessibility variables</th>
<th>Socio-economic variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean income</td>
</tr>
<tr>
<td>% accessgreenC_under50</td>
<td>-0.11</td>
</tr>
<tr>
<td>% accessgreenC_under100</td>
<td>-0.14</td>
</tr>
<tr>
<td>% accessgreenC_under200</td>
<td>-0.21</td>
</tr>
<tr>
<td>% accessgreenC_under300</td>
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</tr>
<tr>
<td>% accessgreenC_under400</td>
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<td>% accessgreenC_under500</td>
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<tr>
<td>% accessblueT_under50</td>
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<td>% accessblueT_under100</td>
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</tr>
<tr>
<td>% accessblueT_under200</td>
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</tr>
<tr>
<td>% accessblueT_under300</td>
<td>0.17</td>
</tr>
<tr>
<td>% accessblueT_under400</td>
<td>0.17</td>
</tr>
<tr>
<td>% accessblueT_under500</td>
<td>0.18</td>
</tr>
<tr>
<td>% accessPT_under50</td>
<td>0.19</td>
</tr>
<tr>
<td>% accessPT_under100</td>
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</tr>
<tr>
<td>% accessPT_under200</td>
<td>-0.07</td>
</tr>
<tr>
<td>% accessPT_under300</td>
<td>-0.11</td>
</tr>
<tr>
<td>% accessPT_under400</td>
<td>-0.12</td>
</tr>
<tr>
<td>% accessPT_under500</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

After calculating all the spearman’s rho values in Table 4, they can be analyzed to better understand the demographics of the people who have accessibility in Stockholm. Looking at the first three columns of Table 4 that have to do with income, there are no correlations strong enough to make any certain conclusions. However, it is interesting to note that percent access to blue area under all distance buffers had a positive correlation. This inverts that the higher income a person has, the more accessible blue areas are. This supports the ideology that blue areas are associated with higher earning income base areas. It is also interesting to note that higher income does not mean more access to green areas for all distance buffers. The last thing to note with regard to income is there is not a significant difference in the correlation...
between accessibility to green-blue areas or public transportation and mean income of males and mean income of females.

The fourth and fifth column in Table 4 present two different types of family statuses: households with children and households with people who have no children and are not married. The results show that the base areas with higher percentage of households with children also have higher accessibility to green areas while base areas with a higher percentage of households with single people have lower accessibility to green areas for all distance buffers. It is also shown that the base areas with higher percentage of households with children also have lower accessibility to public transportation while areas with a higher percentage of households with single people have higher accessibility to public transportation. However, the Spearman rho values are not large enough to be completely certain in these findings. These results present an interesting conclusion that single people seem to have more accessibility to public transportation while having less accessibility to green areas compared to families with children.

The sixth and seventh column in Table 4 present two different types of housing: single home/flat ownership and rented single homes/flats. The results show that base areas with a higher percentage of single home/flat ownership have higher accessibility to green areas for all distance buffers while base areas with higher percentage of rented single homes/flats have less accessibility to green areas. In addition, the base areas with a higher percentage of single home/flat ownership have lower accessibility to public transportation for all distance buffers while base areas with higher percentage of rented single homes/flats have higher accessibility to public transportation. These results show that people who own homes also have higher accessibility to green areas compared to those who rent.

4.3 General Discussion

These results give a better understanding of residents’ accessibility to green-blue areas and public transportation in Stockholm. It can be acknowledged that Stockholm overall is a city that is very green and has high accessibility to both green and blue areas. As well, it can be acknowledged that Stockholm has a great connectivity and its public transportation network is far ahead of many other cities worldwide. However, accessibility can still be improved and the results of this thesis can help to localize what base areas specifically can improve their accessibility to green-blue areas and public transportation.

Overall, it can be concluded that accessibility to public transportation in Stockholm is very high. However, SDG 11, specifically sub-targets 11.2 and 11.7, can be seen not to be met because there is not universal accessibility to green areas and public transportation in Stockholm. However, it should be recognized that the term ‘universal’ used to describe sub-targets 11.2 and 11.7 was not made clear by the UN because they did not set a quantifiable target of accessibility. It can also be recognized that having perfect 100 % accessibility may not be realistic. It was though concluded that the sub-targets could be seen as not being met because there are still 135 base areas with 0 % accessibility to green areas and 29 base areas with under 10 % accessibility to public transportation.

The results of this thesis also reveals that socio-economic status of people affects their accessibility to both green-blue areas as well as public transportation. Differing income levels, home ownership status, as well as family composition all had effects on accessibility to green areas and public transportation in Stockholm. However, gender did not seem to affect accessibility to green areas and public transportation in relation to income levels.
4.4 Limitations and Uncertainties

There are limitations and uncertainties of the study that should be recognized. A GIS-based spatial analysis that included calculating Euclidean distances from points of residencies to green areas, blue areas and public transportation was conducted in this thesis. However, a network analysis would have given more realistic results. This is because network analyses take into account any physical barriers such as bodies of water, roads or the like. Thus, additional data such as road and railroad network information would have been needed to execute a network analysis. Another limitation to conducting a network analysis is getting accurate data regarding walking paths in Stockholm. Current walking path data has not been fully developed enough to the level which it would be required to conduct this analysis within the thesis.

This thesis was limited by the amount of time allotted under the scope of study. There is much potential for this thesis to be continued into future works. This thesis focused only on the year 2015 due to a lack of data for other years. However, as the CORINE and public transportation data was made available for more recent years (2016-2018) a time series data set could be used for a more in depth analysis of accessibility. Also, there are many more indicators available in Södertörnsanalysen that could be used other than the seven that were selected in this study. It is also possible for Södertörnsanalysen to be expanded adding even more indicators to be studied in the future.

There is also potential to expand this thesis and take into consideration that not all green area is valued the same. It can also be examined further is some green areas are being used by too many people or is unable to provide the same ecosystem services to all simply because it services too many people.

There are always uncertainties in conducting a GIS analysis. It is uncertain if the best raster pixel size was chosen for this thesis. It is also recognized that there is some bias in this thesis. For instance, when creating the green area map given the CORINE dataset, choices were made in what was considered a green space and what was not, and smaller green areas would not be included. It was decided to not include any man-made grey areas. However, in Stockholm, these areas could also serve the same purpose as green areas in providing recreation space. Thus, some areas, especially in Stockholm municipality, appear to have 0 % accessibility to any green space when they do have access to small parks or urban grey parks that still have recreational value.

There were also uncertainties in the conducted statistical analysis. The resulting Spearman rho values of the statistical analysis did not reach -0.50 or 0.50 when ideal values would be closer to -1 or 1. Thus, it is difficult to say the results presented are undoubtedly accurate since statistical data can have uncertainties, even if they were statistically significant.
5 Conclusion

This thesis determined that residents of Stockholm County have impressively high access to green-blue areas and public transportation. However, Stockholm has not achieved 100 % accessibility to green-blue areas and public transportation for all residents so it could be seen as not having achieved SDG 11, specifically targets 11.2 and 11.7. Stockholm still has 10 years to improve accessibility and better meet sub-targets 11.2 and 11.7.

It was shown that people with lower income, people who own their flats/homes and people with children have higher accessibility to green areas. It was also shown that people with higher income, people who rent their flats/homes and have no children have higher access to public transportation. These results can be expected as many people with higher incomes are living in the inner city where they have high access to urban services and rail stops, but not necessarily green areas. It is important to state that at 300 m from residencies, both access to green areas and access to public transportation is almost 100 %. At 500 m from residencies, access to blue area is close to 35% which is not the larger part of the population, but still a high percentage since access to blue areas is a bit of a luxury.

This thesis illustrated the impressive usability of Södertörnsanalysen. This tool has the capacity to help users understand how social, environmental and economic indicators effect one another, which is very valuable when it comes to achieving the SDGs that are interlinked to one another. This tool can help better understand SDG interactions as well as give Stockholm urban planners a better sense of what SDGs have synergies and which SDGs have tradeoffs. It is important to further support multidisciplinary, long-term knowledge collaborations that can come up with monitoring plans to keep the tool updated as time passes as well as improve the tool from its current state.

Södertörnsanalysen also showcases the importance of visualizing statistics so that it can become more understandable to planners, policymakers and members of the community. The results of future studies can contribute to the expansion of existing tools such as Södertörnsanalysen or other future tools. This thesis provides a step towards a methodology for calculating distance values from the points of residencies to the points of interest. These distance values can be seen as residents’ accessibility to green areas, blue areas and public transportation. This methodology can be repeated to assess residents’ accessibility to other ecosystem and urban services. This thesis overall supports the importance of utilizing quantitative analyses for urban planning.
6 Appendices

6.1 Appendix A.

Appendix A provides illustration of each Data Set layer used in the spatial analysis. All spatial data used was from © Lantmäteriet. The spatial analysis was conducted using ArcMap version 10 (Esri, 2011).

Figure 13. The study area is shown with the municipality boundaries (purple) and the base area boundaries (red). The outermost purple municipality boundaries represent the study area boundaries.
Figure 14. The study area with the location of each FastPak point (red points) is shown as well as the base area boundaries (black line).
Figure 15. The study area with all green areas from the CORNIE dataset (green polygons) and the base area boundaries (black lines).
Figure 16. The study area with all blue areas (blue polygons) and the base area boundaries (black lines).
Figure 17. The study area with all public transportation stops (yellow points) and base area boundaries (black lines). The public transportation data was obtained from SL.
6.2 Appendix B.

Appendix B shows more in depth statistics of histograms showing percentage accessibility of each base area for each distance buffer (Statistica 2019).

<table>
<thead>
<tr>
<th>Distance Buffer</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>L-Qrt</th>
<th>U-Qrt</th>
<th>Variance</th>
<th>SD</th>
<th>Std.Err</th>
<th>Skw</th>
<th>Kurt</th>
<th>95% Conf SD</th>
<th>95% Conf Mean</th>
<th>Lower</th>
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</thead>
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<tr>
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<td>1269</td>
<td>21,48</td>
<td>8,963</td>
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<td>100</td>
<td>0</td>
<td>31,73</td>
<td>810</td>
<td>28,46</td>
<td>0,998</td>
<td>-0,804</td>
<td>1,006</td>
<td>95% Conf SD</td>
<td>95% Conf Mean</td>
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<td>23,05</td>
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<tr>
<td>100 m</td>
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<td>22,41</td>
<td>0</td>
<td>100</td>
<td>0</td>
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<td>0,700</td>
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<td>95% Conf SD</td>
<td>95% Conf Mean</td>
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<td>51,00</td>
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<td>1547</td>
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<td>95% Conf Mean</td>
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<td>100</td>
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<td>-1,368</td>
<td>-0,297</td>
<td>95% Conf SD</td>
<td>95% Conf Mean</td>
<td>79,37</td>
<td>75,51</td>
</tr>
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</table>

Figure 18. The graphical summary of percent access to green areas of each base area for each distance buffer.
Figure 19. The graphical summary of percent access to blue areas of each base area for each distance buffer.
Figure 20. The graphical summary of percent access to public transportation of each base area for each distance buffer.
### Appendix C.

Appendix C shows the graphical results of the spearman rho calculations between different indicators.

<table>
<thead>
<tr>
<th>Access GreenC 50 m</th>
<th>Access GreenC 100 m</th>
<th>Access GreenC 200 m</th>
<th>Access GreenC 300 m</th>
<th>Access GreenC 400 m</th>
<th>Access GreenC 500 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean income</td>
<td>Mean income male</td>
<td>Mean income female</td>
<td></td>
<td></td>
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</tbody>
</table>

**Figure 21.** The graphical statistical results of mean income, mean income males, and mean income females compared to access to green areas under 50m, 100m, 200m, 300m, 400m, and 500m.
### Spearman rank order correlations - mean income and Blue T

<table>
<thead>
<tr>
<th></th>
<th>Mean income</th>
<th>Mean income male</th>
<th>Mean income female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access BlueT 50 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access BlueT 100 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access BlueT 200 m</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Access BlueT 300 m</td>
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<td></td>
<td></td>
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<tr>
<td>Access BlueT 400 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access BlueT 500 m</td>
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<td></td>
</tr>
</tbody>
</table>

Figure 22. The graphical statistical results of mean income, mean income males, and mean income females compared to access to blue areas under 50m, 100m, 200m, 300m, 400m, and 500m.
Spearman rank order correlations - mean income and public transport stops

<table>
<thead>
<tr>
<th>Access public transport stops 50 m</th>
<th>Mean income</th>
<th>Mean income male</th>
<th>Mean income female</th>
</tr>
</thead>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Access public transport stops 100 m</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Access public transport stops 200 m</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Access public transport stops 300 m</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access public transport stops 400 m</td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Access public transport stops 500 m</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Figure 23. The graphical statistical results of mean income, mean income males, and mean income females compared to access to public transportation stops under 50m, 100m, 200m, 300m, 400m, and 500m.
Spearman rank order correlations - households and GreenC

Figure 24. The graphical statistical results of households 2 adults and children, households single, single house ownership and rented flats compared to access to green areas under 50m, 100m, 200m, 300m, 400m, and 500m.
### Spearman rank order correlations - households and Blue-T

<table>
<thead>
<tr>
<th></th>
<th>Households 2 adults and children (%)</th>
<th>Households single (%)</th>
<th>Single houses ownership (%)</th>
<th>Rented flats (%)</th>
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</thead>
<tbody>
<tr>
<td>Access BlueT 50 m</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
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<tr>
<td>Access BlueT 100 m</td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
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<tr>
<td>Access BlueT 200 m</td>
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<td><img src="image10" alt="Graph" /></td>
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<tr>
<td>Access BlueT 300 m</td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
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<tr>
<td>Access BlueT 400 m</td>
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<td><img src="image18" alt="Graph" /></td>
<td><img src="image19" alt="Graph" /></td>
<td><img src="image20" alt="Graph" /></td>
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<tr>
<td>Access BlueT 500 m</td>
<td><img src="image21" alt="Graph" /></td>
<td><img src="image22" alt="Graph" /></td>
<td><img src="image23" alt="Graph" /></td>
<td><img src="image24" alt="Graph" /></td>
</tr>
</tbody>
</table>

Figure 25. The graphical statistical results of households 2 adults and children, households single, single house ownership and rented flats compared to access to blue areas under 50m, 100m, 200m, 300m, 400m, and 500m.
Figure 26. The graphical statistical results of households 2 adults and children, households single, single house ownership and rented flats compared to access to public transportation under 50m, 100m, 200m, 300m, 400m, and 500m.
7 References


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