DEVELOPING BROMMA AIRPORT

GE 7015 Environmental Management in planning, 15 credits
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i Foreword

This report is the result of the project part of the master’s course *Environmental Management in Planning*. The course is a mandatory part of the Master programme *Environmental Management and Physical Planning* at the Dept. of Physical Geography, Stockholm University. The programme is multidisciplinary with Swedish as well as international students and is open for students from natural as well as social sciences. The Environmental Management in Planning course comprises 15 HEC, i.e. ten weeks of study. The project part covers five weeks with the aim to give the students an opportunity to analyse an actual planning issue from a systems perspective as well as using their knowledge about urban and community planning.

This spring, 2015, the project has focused on the future development of the Bromma airfield area in Stockholm. Bromma is currently Stockholm’s city airport and claimed to be the fastest communication alternative to and from the Swedish capital for travel within Sweden. At the same time 35 000 persons per year are moving into Stockholm, while the amount of housing only increases with 7000 – 10 000 units per year. Many employers are not able to recruit staff owing to the difficulties of finding affordable housing. Consequently, there is an ongoing political discussion to shut down the Bromma airport by 2018 and turn the airfield into a housing area with less expensive apartments, and a sustainability branding.

This report aims to give a systems view of the environmental effects and the sustainability of different future scenarios for the use of the Bromma airport area. Owing to the short time span of the project work, it is not possible to fully cover all aspects in the analysis but the report gives a good overview of the sustainability of alternative future developments of the Bromma area.

The students are alone responsible for the results and conclusions given in the report. It is not the position of Stockholm University, nor can it be used as such. The project work supervisors have been Bo Eknert, Peter Schlyter and Ingrid Stjernquist.

We want to acknowledge the help all the individuals who have been generous with their time and kindly have provided the students with information, assistance, and materials as well as have been positive to give interviews and discussions. Without your help the project could not be realised.

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iii Summary

For several years the destiny of Bromma airport has caused conflicts among politicians and stakeholders. Replacing Bromma airport with apartments would help relieve the housing shortage in Stockholm but risk making Stockholm less accessible.

Bromma airport is situated close to the centre of Stockholm and 90% of the flights at Bromma airport are domestic. However, its close proximity to the centre comes with a price. Noise and air pollution affect the local environment but more importantly, it occupies attractive land for housing development.

In light of the ongoing debate about Bromma airport the purpose of this report is to examine a variety of options on how the airport area could be used, including both housing development and a scenario for business as usual (BAU), in which the airport remains. A total of five scenarios are presented.

One (BAU) scenario was created with focus on transport and housing. For transportation no differences from the current state will occur. For housing, it was concluded that 150 000 apartments can be developed without including development in the Bromma airport area. The option of developing the area around the airport more than the Ulvsunda development which is already planned for, was found to be impossible due to noise regulations.

When looking into the *Skavsta scenario*, the current amount of flights in Bromma airport are redirected to Skavsta airport. This was not an issue as it was found that Skavsta airport has ample capacity to receive all flights. The total travel time will be a bit longer compared to flying to Bromma airport, since Skavsta airport is situated further away from the City of Stockholm.

In *the High Speed Rail (HSR)-scenario* the flights are replaced by high speed rail. Two of the top ten Bromma airport-destinations; Sundsvall and Gothenburg, will have shorter travel time in this scenario compared to flying to and from Bromma airport. Some of the destinations will have a marginal amount of extra travel time. However, this scenario leads to considerably longer travel time for half of the top ten Bromma-airport destinations.

For developing the Bromma airport-area two scenarios have been suggested. *The dense scenario*, called Brommastan, offers 16 700 apartments, 9 000 working places and will have 33 400 inhabitants when finished. There will be more rental apartments than co-operatively owned apartments to increase the social sustainability in the area. Brommastan will be a green city with a lot of green areas, meeting places, low CO_2e emission and waste consumption.

The sparse scenario, called Bromma Grönstad, offers 6 720 apartments, 500 row-houses, 7 200 working places and will have 15 440 inhabitants when finished. Bromma Grönstad will be a green city with larger areas for bigger parks and meeting places, low CO_2e emissions and waste consumption. Compared to Brommastan, this area have more space available for bigger parks but not as much services and public spaces.

The scenarios were compared based on ten sustainability indicators chosen to balance social, economic and environmental factors. Once the indicators were decided, each of the five combined scenarios were assessed for each indicator independently, within a comparative matrix. One value rose was then created for each of the five scenarios to give a visual interpretation of the results.

The results show that if Bromma airport is to be closed it will be difficult to avoid an increase in travel time to and from Stockholm. Still, if national environmental factors, especially national CO_2e emissions, are to be improved it will be beneficial to completely move the traffic to rail. Regarding the building scenarios, Bromma has to be developed in order to improve green areas, add more housing and improve local transport in the area. For all aspects except green spaces a densely built housing area would be preferable.

iv Sammanfattning

Bromma flygplats öde har sedan länge skapat debatt mellan politiker och intresseorganisationer. Att ersätta Bromma flygplats med bostäder skulle bidra till att reducera bostadsbristen i Stockholm, samtidigt som man riskerar att göra Stockholm mindre tillgängligt.

Bromma flygplats är belägen nära Stockholms innerstad och 90 % av alla flyg är inrikesflyg. Närheten till staden har dock ett pris. Buller och luftföroreningar ger påverkan på de omkringliggande områdena, flygplatsen tar dessutom upp ett stort område som är attraktivt för bostadsbygge.

Syftet med den här rapporten är att undersöka olika alternativ över hur Bromma flygplats kan användas i framtiden, vilket inkluderar både utvecklingscenarion och ett business as usual (BAU)-scenario där flygplatsen är kvar. Totalt presenteras fem scenarion.

Ett BAU-scenario skapades med fokus på både transport och byggnader. Gällande transporter kommer scenariot inte innebära någon skillnad från nuläget. Gällande byggnader visades att 150 000 lägenheter kan byggas utan att flygplats-området utvecklas. Möjligheterna att bebygga områdena runt Bromma flygplats upptäcktes vara begränsade, förutom industriområdet Ulvsunda som redan är planerat för utveckling.

Skavstascenariot innebär att all flygtrafik omdirigeras från Bromma flygplats till Skavsta flygplats. Skavsta flygplats visade sig ha kapacitet att ta emot all Brommas flygtrafik. Den totala restiden kommer dock att bli något längre i jämförelse då Skavsta flygplats ligger längre ifrån Stockholms innerstad.

I *Höghastighetståg (HSR)-scenariot* ersätts all flygtrafik med höghastighetståg. Två av de tio toppdestinationerna från Bromma flygplats; Sundsvall och Göteborg, kommer att få kortare restid i detta scenario. Vissa av Brommas andra toppdestinationer kommer få en marginell ökning i restid. Över hälften av Brommas toppdestinationer kommer dock att få markant ökad restid.

Två byggscenarion presenteras för att visa hur området kan utvecklas om flygplatsen läggs ner. Scenariot *Den täta stadsdelen-Brommastan*, leder till 16 700 lägenheter och 9 000 arbetsplatser och ca 34 000 invånare kommer att flytta in. Det kommer att vara fler hyresrätter än bostadsrätter i området för att stärka den sociala hållbarheten. Brommastan kommer att utvecklas till en grön stadsdel med många men mindre grönområden, mötesplatser och låga koldioxidutsläpp samt god avfallshantering.

I scenariot *Den glesa staden - Bromma Grönstad*, kommer 6 720 lägenheter, 500 radhus och 7 200 arbetsplatser att erbjudas och den kommer att bestå av ca 15 400 invånare. I Bromma Grönstad kommer fördelningen mellan hyresrätter och bostadsrätter vara lika. Bromma Grönstad kommer också att utvecklas till en grön stadsdel men kommer få en mer utbredd grönstruktur än i Brommastan. Här kommer mötesplatser, låga koldioxidutsläpp och god avfallshantering att erbjudas, men antalet verksamheter och de offentliga platserna kommer vara färre än i Brommastan.

De olika scenariona jämfördes sedan baserat på tio utvalda indikatorer med tyngd på hållbarhet för att jämföra sociala, ekonomiska och ekologiska faktorer. Var och en av scenariona utvärderades sedan separat för varje indikator och jämförelserna presenteras i en matris. En värderos har skapats för varje scenario för att ge en visuell uppfattning av resultatet.

Resultatet visar att det blir svårt att lägga ner Bromma flygplats utan att restiden till och från Stockholm ökar. Det är dock viktigt att förflytta resandet till tåg för att förbättra vissa nationella miljöfaktorer, speciellt de nationella koldioxidutsläppen. För att underlätta bostadskrisen, förbättra det lokala transportsystemet och förbättra grönområdena bör Bromma flygplats ge plats för bebyggelse. För alla aspekter förutom för grönområden är en tät bebyggd stadsdel att föredra.

vi Definitions

Biofuel – Fuels produced by different types of organisms. Can be in different forms; solid, floating and gas.

Carbon Dioxide Equivalent – A method for standardising all greenhouse gas emissions. By converting those to the equivalent amount of Carbon dioxide needed to create the same amount of global warming. E.g. methane has a global warming potential 25 times higher than CO_2 therefor 1 tonne of methane would be equal to 25tonnes CO_2e.

Comprehensive plan – A plan made by the municipalities to state how the municipality will create a sustainable development regarding building, water- and land use. Because of the municipal planning monopoly, the municipalities have exclusive rights to develop the municipal area.

Cultural values – Historical and aesthetical value that is of importance for the public. Can be both buildings and landscapes.

Decibel - Unit of sound production level (Logarithmic scale).

A-weighted decibel - When regulating noise, guidelines and restrictions are often set and measured in A-weighted sound levels. A-weighting corresponds to the response of human ear at low sound levels.

District heating – The heat is produced in central works and are delivered to the consumers via a pipe system.

District cooling – The same system as in District heating but used for cooling instead.

Ecological light pollution – Ecological light pollution has been defined as ''artificial light that alters natural patterns of light and dark in ecosystems''.

Eutrophication – The process by which a fresh water body is enriched with nutrients like phosphates and nitrates which promotes excessive plant growth. The death and decomposition of these plants leads to high levels of organic matter and decomposing organisms (bacteria), which deplete the water body of available oxygen and thus causing the death of aquatic organisms.

Fossil fuels – Fuels formed by organic hydrocarbon compounds. These are primarily coal, oil or natural gas.

Green roofs – Roofs covered with vegetation. Can also include a drainage system and a root barrier.

Green wedges – A regional green structure near an urban area which is closely integrated with the built environment. The green wedges are important for recreation, biodiversity and cultural values.

Local – Used for referring to a scale level concerning a town, neighbourhood or district and not for larger areas. In this report local is used for referring to this general definition, but also when referring to the municipality of Stockholm or even the planning area. Thus context defines it´s meaning.

Day-evening-night equivalent level - measures a mean continuous exposure to noise levels. It weighs daytime, evening and night time noise differently, with night time noise as most significant and daytime noise least. In Sweden the designation FBN (Flygbullernivå, Eng. Air traffic noise level) is often used, but according to the Swedish transport agency (2011) these designations are interchangeable, and so in this report FBN has been substituted.

A-weighted equivalent sound pressure level A-weighted measure of a mean continuous level of noise, without taking evenings and nights into account.

National – Used for referring to a scale level concerning the nation as a whole. In this report it will mostly be used describing events within the boundaries of Sweden.

Noise - Is defined as sound pressure level.

Storm water – Water that originates from rain water, melted snow or advance ground water

PM 10 – Airborne particles smaller than ten micrometres.

Pocket parks – A smaller park created for both the public and the wildlife. Could also be called mini-park.

Real income - The income of an individual or group after taking into consideration the effects of inflation on purchasing power.

Regional – Used for referring to a scale level concerning a larger geographical region. In this report it will mostly be used describing events within the Stockholm region.

Urban gardening – Small scale agriculture in our around an urban area. In Western communities, urban gardening also is a form of social movement for creating sustainable cities.

Urban heat island effect – When human activities in an urban area makes the area warmer than its surroundings.

Waste management – management of waste from households and industries, in this report focus lies on waste from the households. The municipalities are responsible for waste management.

iv List of Abbreviations

CLD – Causal Loop Diagram

CO – Carbon monoxide

CO_2e – Carbon dioxide equivalent

dB – Decibel

dB(A) – A-weighted decibel

DEFRA – Department for Food, Environment and Rural affairs (UK gov.)

EIA – Environmental Impact Assessment

GDP – Gross Domestic Product

GHG – Greenhouse gas

GI – Green infrastructure

GRP – Gross Regional Product

ICAO – International Civil Aviation Organisation

IPCC – International Panel on Climate Change

L_{den} – Day-evening-night equivalent level

L_{Amax} – A-weighted maximum, single event sound pressure level (noise)

L_{Aeq} – A-weighted equivalent sound pressure level (noise)

LTO – Landings and take-offs

NEG – New Economic Geography

NO_x – Nitrogen oxides (includes nitrogen oxide and nitrogen dioxide).

PAH – Polyaromatic hydrocarbons

PFOS – Perflourooctane sulfonate

pH – Potential of hydrogen ions

PM – Particulate matter

SL – Storstockholms Lokaltrafik

SO_x – Sulphur oxides (includes sulphur oxide and sulphur dioxide)

v Agency name Translations

Chamber of Commerce in Stockholm – Stockholms Handelskammare

Swedish Environmental Protection Agency – Naturvårdsverket

Swedish transport administration – Trafikverket

Swedish transport Agency – Transportstyrelsen

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1 Introduction

1.1 Problem

The Stockholm region is the fastest expanding region in Sweden and currently 25% of the Swedish population live there, however the region accounts for 30% of the gross domestic product (GDP), which shows the high productivity that comes from being an economic hub. As the main economic centre of Sweden it attracts migrants from all over the country. The rapid population growth has created a high housing demand and combined with a slow building rate, new residents have a hard time finding a place to live. Hence the need to build more apartments is pressing.

Sweden is a long and narrow country with a small population desity. This leads to great travel distances and a high demand on well-functioning infrastructure. Air travel has made it possible to quickly travel long distances which has improved the national connectivity and facilitated economic development. Most of the domestic air travel goes through Stockholm and the region has three main airports Skavsta-, Arlanda- and Bromma airports. Bromma airport is situated close to the centre of Stockholm. 90% of the flights at Bromma airport are domestic and its close proximity to the city and fast check-in/out times makes it popular for business trips. But, its close proximity to the centre comes with a price. Noise and air pollution affect the local environment but more importantly, it occupies attractive land for housing development. This has for a long time caused conflict among politicians on how to best utilise the land. Replacing Bromma airport with apartments would help relieve the housing shortage but risk making Stockholm less accessible, which could have a negative impact on economic development, through a reduction of national connectivity. In the debate both Skavsta- and Arlanda airport have been suggested to receive the traffic from Bromma airport.

1.2 Aim

In the light of the ongoing debate about Bromma airport the purpose of this report is to examine a variety of options on how the airport area could be used, including both housing development and a “business as usual” scenario in which the airport remains. A total of five scenarios are presented that are designed to move Stockholm toward a higher level of urban sustainability. The scenarios are then compared based on ten sustainability indicators chosen to balance social, economic and environmental factors. This aims to show the trade-offs between the scenarios and thereby provide a better understanding of the complexities of the issue.

2 Background

2.1 Sustainable development

There are several definitions of sustainable development, but they are all based on the assumption that the natural resources of our planet are limited. The most commonly used definition is from the Brundtland report in 1987, which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Natural resources are degraded and destroyed through urbanisation and the growing ecological footprint of cities, thus the ability of meeting the future generation´s needs is compromised (Benton-Short & Rennie-Short 2008).

Another definition of sustainability is “living within the carrying capacity of supporting ecosystems”. The carrying capacity has reached its limits and since resource flows in cities are linear; consuming resources and producing waste - cities are not considered sustainable (Benton-Short & Rennie-Short 2008).

To have a decent living standard today without compromising the need of future generations, social, economic and environmental aspects must be considered. This is commonly called the three aspects of sustainability (Figure 1).

2.1.1 Economic Sustainability

In order to plan for an economically sustainable city, local authorities have to face the challenge of creating a creative and multi-functional environment where new business ideas can flourish in order to promote economic growth. Infrastructure is therefore an important component to attract new businesses (Sveriges Kommuner och Landsting 2010).

According to Reference Framework for Sustainable Cities (RFSC 2012), economic sustainability can be achieved through local knowledge and skill provisions but also by making opportunities for businesses and non-profit purposes and by maintaining good relations between different stakeholders, businesses and non-profit sectors. Another way to achieve economical sustainability is by promoting, developing and supporting sustainable local production and consumption of services and goods, but also by developing or maintaining a diversified local economy over all (RFSC 2012). It is also important to meet the needs for access to jobs and employment and to find a balance between costs and the quality of public services (RFSC 2012).

Figure 1. The three aspects of sustainable development (www.business.mmu.ac.uk/).

2.1.2 Social Sustainability

To achieve social sustainability in regard to physical planning several variables must be included, such as the need to create a society where people with different abilities and needs have equal opportunities and good living standards (See indicators 6 and 8, chapter 3.6 *Indicator Method*). This can be achieved through a well-planned and integrated urban structure (Sveriges Kommuner och Landsting 2010; RFSC 2012).

According to Boverket (2010b), making public spaces is an important part of planning for a socially sustainable city. The public spaces should include everyone, thus it is important that everyone feels safe in the area. How the open spaces are designed can affect the social life of certain groups in the society since for example elderly, women and immigrants generally feel more unsafe in public places than others. By creating spaces that offer a large visual horizon and attract a lot of movement, the area can be perceived a safer area (Sondén & Olsson n.d.; RFSC 2012).

Children are easily forgotten in planning, however, it is important to include them in the planning process as a way to implement the UN Children´s convention from 1989. To do this, the municipalities should actively invite children to take part in planning since it's mainly aimed at adults. Moreover, they should have an actual influence and not only be invited for reasons such as public relations. By having a children´s perspective much is gained in the planning process, since adults do not know everything about children's movement patterns and what is perceived as a safe environment by children (Länsstyrelsen Västra Götaland 2009).

Another important part of creating a sustainable city is to ensure housing for everyone (See indicator 8, chapter 3.6 *Indicator Method*). This means that accessibility and affordability of good housing should be planned for. This helps ensure socially mixed communities in order to avoid segregation (RFSC 2012).

Segregation in Stockholm has increased since 1995, mostly due to economic segregation where less fortunate households are getting isolated from the rest of society. Only high income households are more isolated and meetings between these groups are close to non-existing. Thus, economic factors are most important when it comes to segregation, but there is also a strong correlation between ethnicity and economic alienation (TMR 2014).

New development areas tend to have high housing costs, especially when they focus on environmental issues. To incorporate new design and technology costs a lot, which eventually is paid for by the inhabitants of the area. To create a social mix in new areas it can be beneficial to plan for both rental and co-operatively owned apartments. However, even the rental apartments tend to be expensive. In the Royal Seaport, a development area situated in the harbour of Stockholm, a three room apartment has a rent of 14,500 kronor. The rents here are the highest compared to the rest of Sweden, with the highest rents reaching over 20,000 kronor (SVT 2013).

In Gothenburg a new approach to newly developed areas has emerged, where the politicians have decided on a maximum rent per square meters and year for some of the apartments built, to lower the rents in some buildings. This fixed rent is due for 15 years and can't be changed until then. By setting these demands before the building process starts, the building companies can adapt their methods to save money in all of the building processes. According to the City of Gothenburg, they have received a lot of interest from building companies that wants to be a part of this process (Göteborg Stad 2014).

2.1.2.1 *Social infrastructure*

To plan for a comprehensive social infrastructure that meets everyone's needs is an important part of creating a socially sustainable city. Social infrastructure usually includes assets to social services. The services included can promote health, housing, education, transport, cultural and religious facilities, open spaces, recreational areas, libraries etc. (See indicators 4, 6, 7, and 8, chapter 3.6 *Indicator Method*) (NZSIF 2009; RTPI 2015). It is important that this kind of services are considered at an early stage in the planning process (Future Communities 2009).

Social infrastructure can also include less visible services such as: values, norms and trust within the community (Future Communities 2009; TREASURY 2013). These services are needed to prevent long-term problems for the economic and social well-being among citizens. In newly built areas, it usually takes time to create local identity and networks (Future Communities 2009).

High levels of social infrastructure will contribute in making the citizens healthier, happier and facilitate them in finding jobs. This leads to positive spill over for society, with welfare and lower health expenditures. An increased social cohesion in the area will strengthen the economy, because the possibilities of social disorder are less likely. This will reduce the burden on the government because social cohesion and norms will influence individual decision-making (TREASURY 2013).

A well working social infrastructure will also allow the society to function better, making the business and social transactions more efficient and attract immigration, trade and business to the area. Low levels of social infrastructure can marginalise some groups and cause the market less efficient, which would limit economic and social opportunities (TREASURY 2013).

2.1.3 Environmental Sustainability

To achieve an ecologically sustainable city, the negative impacts on the nature and climate must be reduced, both locally and globally. The reference framework for European Sustainable Cities promotes several objectives that define a sustainable city. These objectives promote to mitigate the effects and adapt to the consequences of climate change, protect and promote biodiversity, reduce pollution, preserve the quality and the availability of natural resources, preserve and promote the high functionality and quality of the built environment, public spaces and urban landscape (See indicators 1, 2 3 and 4, chapter 3.6 *Indicator Method*) (RFSC 2012).

To build a more dense and compact city is one way to reduce climate impact, due to shared spaces, improved energy efficiency and reduced transport needs. The compactness also facilitates public transportation and walkable cities (See indicator 7, chapter 3.6 *Indicator Method*) (Sveriges Kommuner och Landsting 2010; RFSC 2012). Accessibility to well-planned cycling and walking grids is a prerequisite to be able to get around easily and safely, and for people to choose public transportation instead of cars it has to be easy and attractive to walk or cycle (Fojab 2014). The use of bikes can also help to create a vibrant and attractive city, due to fewer cars and parking lots (Faskunger 2008). So practically, proximity and integration between functions in everyday life is important in order to create an ecologically sustainable city (Sveriges Kommuner och Landsting 2010).

Neuman (2005) proposes that sustainability is not related to form as much as it is to process; that how we live our lives, what choices we make and what our consumption patterns look like have far greater impact on sustainability than the density of a city. For example it is not conclusive if higher densities lead to a decrease in car travels, there might be less short local trips but leisure travel is not dependent of urban form. Travel behaviour in general has a stronger connection to fuel prices and income. (Neuman 2005) The same goes for health, some scientists mean that emotional stress and other negative psychological conditions is caused by high densities and can be alleviated with access to green spaces but others mean these correlations are not statistically established (Emmelin 2015-03-06).

With that said one can still find some pros and cons with the different city forms in general that have influence on sustainability. A dense city has better prerequisites for public transport, cycling and walking (Jabareen 2006) and provides more access to social services (Aquino & Gainza 2014). A sparse city has a higher perceived welfare (Neuman 2005) a possibility to grow more food locally and better possibilities for high biodiversity and ecosystem services. On the other hand it is found to have higher PM 10 concentrations and higher levels of tropospheric ozone than a dense city. The amount of people affected by high emissions is however greater in a dense area (Martins 2012).

When a new area is planned a risk analysis including the effects of climate change on the area is recommended. This would include estimating the future amount of rainfall and temperature as well as the area's ability to respond to the change, in order to adapt the area in the best possible way (RFSC 2012).

2.1.3.1 *Building Program and Green Space Factor*

To accomplish a high degree of sustainability in the building process, all building companies that want a permit to build in the area must agree to an environmental and social building program and present a plan on how the demands will be realised. If an architecture competition is carried out the most sustainable idea will win, as interpreted by judges. This enables sustainable thinking in the beginning of the building process, which is important in order to apply a systems perspective. The program regulates energy efficiency in buildings, indoor air quality, green spaces, biodiversity, climate adaptation, open spaces, consultations with future residents, comercial space, noise, moisture etc. It also regulates that the construction phase highly consider environmental impacts. The program have higher ambitions than current Swedish legislation and regulations.

The green and blue spaces on and around the buildings can be regulated with a tool called the Green Space Factor (GSF). It strives for a rich biodiversity including several ecosystem services and to create attractive places for people to enjoy. The GSF is calculated as an average value of the entire plot and from this there is a quota that must be reached. Different values are given to different parts of the plot depending on the type of green or blue space implemented and the ecosystem services they provide.

2.1.3.2 *Green infrastructure*

Green infrastructure is defined as an interconnected network of multifunctional natural areas and other open spaces that conserve the natural values and functions within, around and between urban landscapes, at all spatial scales (Benedict & McMahon 2006; Tzoulas et al. 2007). The concept of green infrastructure emphasise the importance of the quality and the quantity of urban and peri-urban green spaces (Tzoulas et al. 2007), the importance of interconnections and the multifunctional role of green urban areas. By integrating green infrastructure in a planning context, it provides a framework for both economic and ecological enhancement, offering possibilities to combine urban development with nature conservation and health promotion (Tzoulas et al. 2007).

The green structure in the planning area and its surroundings consists mainly of various forested areas and open grass fields (Kempe & Stolpe 1999). In the surroundings, the housing areas are relatively green, with green open spaces and gardens in between and around the built environment. In addition, there are smaller lakes, wetlands and watercourses in the nearby landscape (Figure 2).

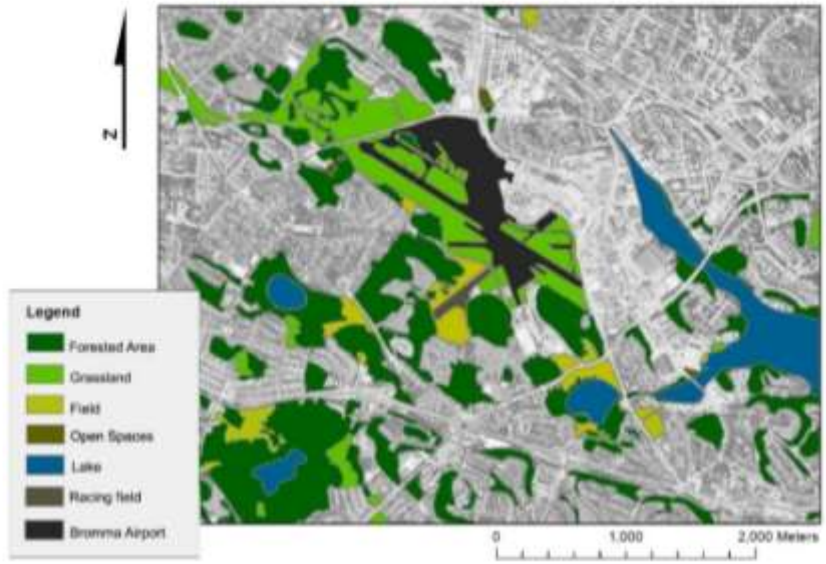

Figure 2. Green spaces in the proximity of Bromma airport.

Even though the vegetation in the planning area could be considered of minor interest for nature conservation, the value of the relatively undeveloped green structures lies in the landscape's ecological context. Core areas with greater ecological values are interconnected by the green spaces in between, serving as 'green corridors' and as such offering opportunities for species to disperse to viable habitats (Rudd et al. 2002; Tzoulas et al. 2007). The importance of the green structures in the planning area lies mainly in forming part of the innermost structure of the Görvälnkilen, one of the ten 'green wedges' in the Stockholm (Figure 3). The green wedges are formed by large, more or less connected green areas, consisting of both forested areas and open fields. These extend from the surrounding rural landscape toward the city of Stockholm, forming green wedges in between the more developed areas.

The Regional Development Plan (RUFS 2010) states that the green structures in the region have both economic, environmental and social benefits as well as aesthetic values. The challenges in managing the green structures in a planning context are therefore both to protect values of the green landscape and promoting the potential of the multifunctional role of green infrastructure in the landscape (RUFS 2010). The functioning of diverse green structures as well as the green wedges of the Stockholm region are beneficial in several aspects: providing ecosystem services and mitigating the urban heat island effect (Shashua-Bar & Hoffman 2000; Susca et al. 2011), and further offering silent and easily accessible green areas.

2.2 Ecosystem Services

Ecosystem services are the benefits people obtain from ecosystems. They can be divided into four different categories (TEEB 2015):

- *Provisioning* services include food, fresh water and other raw materials or energy resources produced within ecosystems.
- *Regulating* services are ecosystem services acting as regulators of the (local) environment, for example trees function as regulators of local air quality by removing pollutants and providing shade, whereby the urban heat island effect is dampened. Regulating services may also include carbon sequestration and storage, moderation of extreme events such as floods and landslides, waste-water treatment and pollination etc.
- *Supporting* ecosystem services include services that maintain habitat and genetic diversity, thereby supporting biological diversity.
- *Cultural* services include recreation and health, tourism, aesthetic values and spiritual experiences.

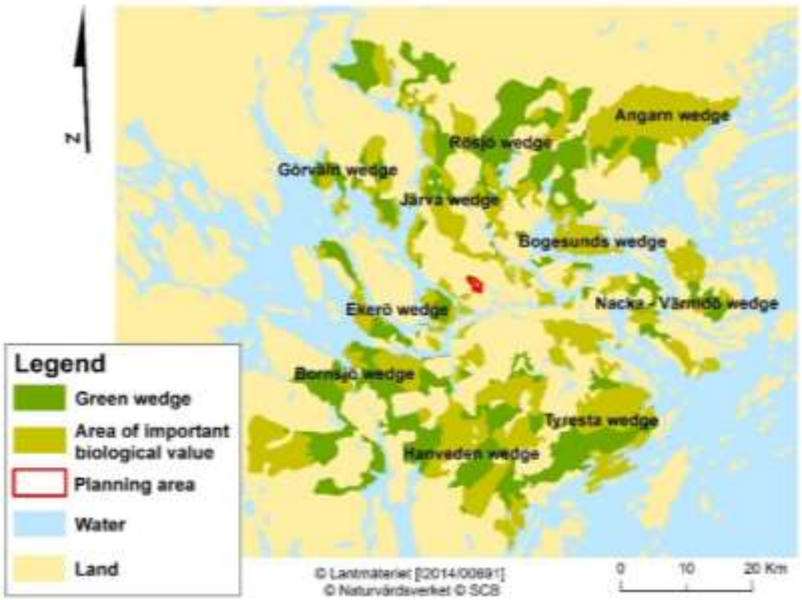

Figure 3.Green wedges and areas of biological value in the Stockholm region.

2.3 Political visions

2.3.1 Environmental Objectives

2.3.1.1 *National scale*

The Swedish Environmental Objectives System consists of one generation goal, 16 Environmental Quality Objectives (EOs) and 24 milestone targets (Naturvårdsverket 2015a). Defining the overall direction of environmental efforts, the Generation Goal indicates what sort of changes that needs to occur in all levels of society within one generation, in order to bring about a clean and healthy environment. To further progress towards achieving the generation goal, the EOs concerning different aspects of environmental issues are set within a time frame. For each of the EOs there are associated specifications describing and clarifying what the state of the environment should be in 2020. There are also a number of milestone targets, adopted by the Swedish Government in what are considered ’priority areas’ (Naturvårdsverket 2015b). Here a desired social change as well as steps ’along the way’ are identified, in order to enhance progress towards the generation goal and the Environmental Objectives. At the moment there are five milestone targets: the objective of Reduced Climate Impact, and environmental issues concerning air pollution, dangerous substances, waste and biodiversity (Nilsson et al. 2013; Naturvårdsverket 2015b).

The relevance of the different Environmental Quality Objectives to the discussion of keeping Bromma airport or not, differ according to geographical scale and point of perspective. There is some overlap regarding the relevance of the EOs to the issues transport, housing and development, as well as green infrastructure or ecosystem services. While some EOs are concerned with a specific scale, others are overlapping and include two or more geographical scales. The scenarios discussed in the context of this report concerns nine of the 16 national environmental objectives (Appendix 2).

All of the 16 Swedish Environmental Quality Objectives serve as overarching environmental objectives for the County of Stockholm. In relation to the Regional Environmental Objectives Dialogue, six of the 16 EOs have been chosen as areas of specific priority within the county (Länsstyrelsen i Stockholms län 2015a; Länsstyrelsen i Stockholms län 2015b). In relation to environmental issues of transport, housing and green infrastructure or ecosystem services, the most concerned Environmental Quality Objectives (national or regional) in the context of this report are:

- Reduced Climate Impact (National/Regional)
- Clean air (National/Regional)
- Natural Acidification Only
- A Non-Toxic Environment (National/Regional)
- A Protective Ozone Layer
- Flourishing Lakes and Streams
- Good Quality Groundwater
- A Good Built Environment (National/Regional)
- A Rich Diversity of Plant and Animal Life (National/Regional)
- Local scale – the Municipality of Stockholm

In the current environmental program of the city of Stockholm (2012-2015) there are six overarching local ’directional goals’, coordinated with the national EOs. These directional goals are further specified in local ’milestone targets’, describing the responsibilities of each of the different municipal boards in relation to the directional goals (Länsstyrelsen i Stockholms län 2015b). The environmental program of the city of Stockholm largely focus on sustainable development in relation to sustainable city development, as such, the directional goals for sustainable city planning are:

- An Effective and Environmental Transport
- Non-Toxic Goods and Buildings
- Sustainable Use of Energy
- Sustainable Use of Land and Water
- An Effective and Environmental Waste Treatment
- A Healthy Indoor Environment

2.3.2 RUFS Regional plan

RUFS 2010 (Stockholms Läns Landsting 2010) brings up the possibilities for strategical planning and future development in the Stockholm region and is an arena for sustainable development. Comprehensive view and long-sightedness are important in order to secure a sustainable development. Different actors have the opportunity to develop common visions and shared views and functional relationships rather than administrative boundaries should be the starting point for planning. RUFS is using three different time perspectives; long, middle or short perspective of development (Stockholms Läns Landsting 2010).

2.3.3 Comprehensive plan

The comprehensive plan for Stockholm municipality describes a range of general interests, and must be in accordance to the Planning and Building Act. There are a number of aspects in the comprehensive plan account for, from basic to central challenges in urban development as well as the city's long-term vision. Most of the planning specialisations that are found under different focus areas have general characteristics and can't be applied into a specific area. (Stadsbyggnadskontoret 2010)

The City of Stockholm has exclusive rights to develop and adopt zoning within the boundaries of the municipality of Stockholm because of the municipal planning monopoly. However, the Government together with the County Administrative board has mandate to stop plans that threatens the National interests or the Environmental Quality Norms. The municipalities must meet the National interests in their planning, because the interests have national significance for conservation and utilisation according to the Environmental Act (Stadsbyggnadskontoret 2010).

2.4 Planning area

The planning area of approximately 200 ha, is located in Bromma, in the north-western part of the municipality of Stockholm. Bromma airport was opened in 1936 (Luftfartsverket 2002). Despite the fact that the area is mostly utilised by the airport and its related activities, the landscape is composed of relatively large green areas. To the north-northwest and to the south of the airport, open grass fields and forested lower hills dominate. The northern grass fields are used as snow deposits during the winter season (Stockholms stad 2012). The vegetation of the forested hills is somewhat diverse, mostly consisting of deciduous forest or pine forest in fairly small, homogenous areas (Kempe & Stolpe 1999). To the west and north of the green areas are housing developments and southwest of the airport's runways there is a golf course and some allotment gardens. Along the eastern edge of the airport there is both a smaller housing area as well as various industries, commerce and

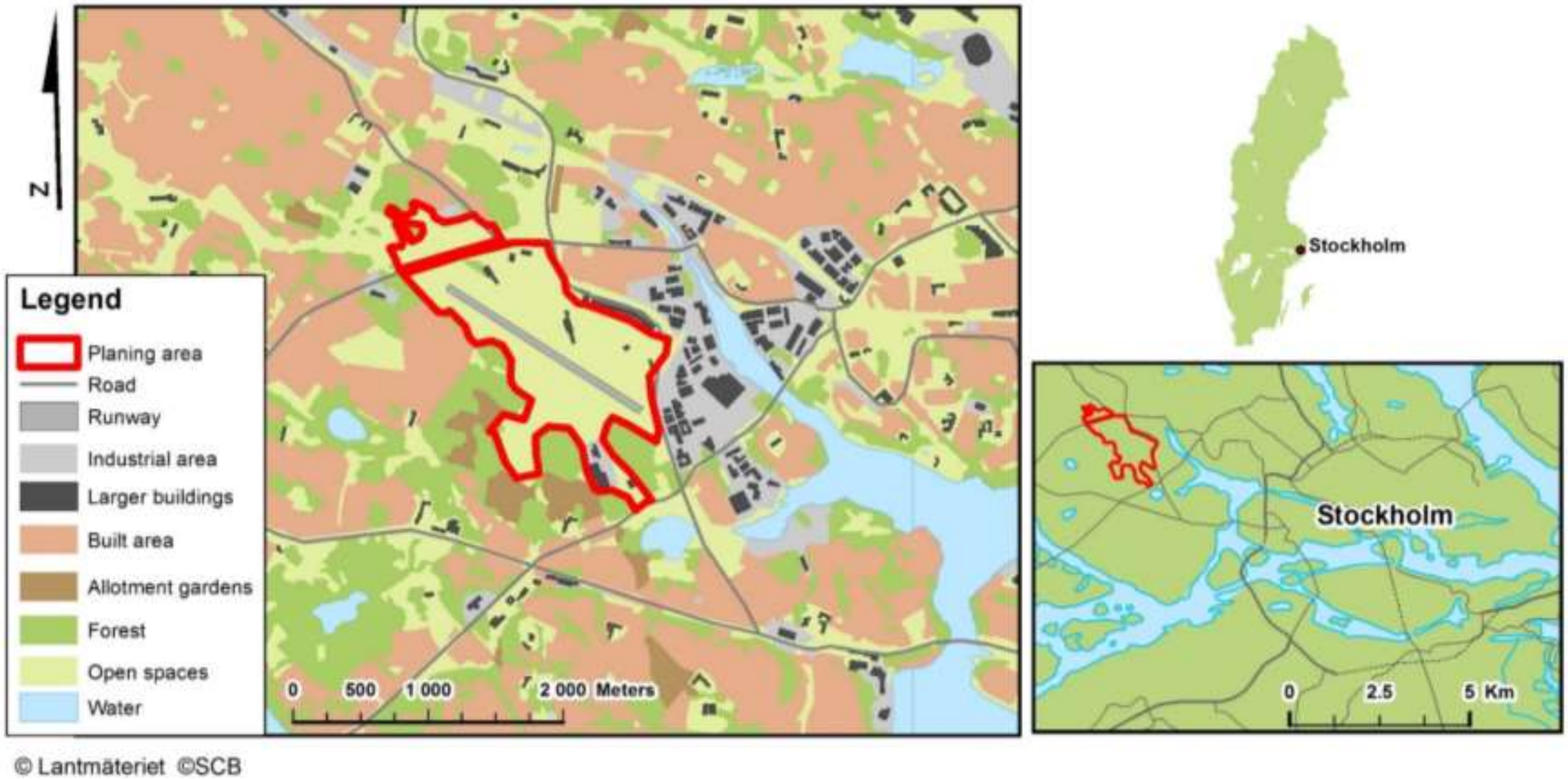

Figure 4. Overview of the study area in Bromma and its location in Sweden.

other work places. The main roads in close proximity to the area are Ulvsundavägen in the east, Bällstavägen in the north, Norrbyvägen in the south and further south is Drottningholmsvägen (Figure 5).

Bromma airport was built in a flat landscape, previously a seabed, mainly consisting of clay (Eriksson 2010). The terminal buildings are located directly on the bedrock or on moderately deep soil, but most of the airfield has an underlying soil depth of five to fifteen meters and is currently paved because of the airport activities (SGU 2015). The airport is located in a catchment basin that primarily runs to the bay

Figure 5. Ortophoto of the planning area (marked in red). Including surrounding waters and roads.

Bällstaviken and further down to Lake Ulvsundasjön in the northeast, which is connected to the east of Lake Mälaren and the water protection area. Neither of the lakes Kyrksjön or Judarsjön are in the same catchment basin as the airport, and will therefore not be affected by waterborne pollutants (Stockholm vatten 2000).

2.5 Areas of national interest

Bromma airport is itself classified as an area of national interest according to the Environmental Act, and is considered an important complement to Arlanda airport (Stadsbyggnadskontoret 2010). All Swedavia owned airports in Sweden are of national interest for communication and should be protected from actions that may hamper the utilisation of the airports (Swedavia 2015a).

Additionally, within the planning area in Bromma airport there are systems of de Geer ridges that are of national interest for conservation because of their considerable importance for the science of physical geography (Naturvårdsverket 2015a). The nearby Kyrksjön and Judarskogen nature reserve are both a part of Natura 2000 (Figure 5 & 6) (Länsstyrelsen i Stockholms län 2007a; Länsstyrelsen i Stockholms län 2007b), a network of areas within the EU preserved with the purpose of protecting a rich biodiversity and aimed at assuring the long-term survival of threatened or valuable species and habitats (European commission 2015). All Natura 2000 regions in Sweden are of national interest according to the Environmental code, chapter 4 (1998:80).

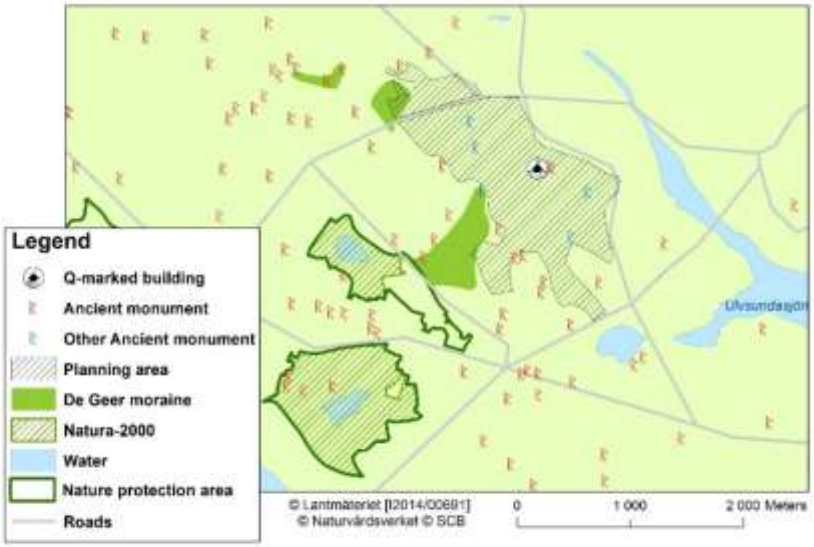

Figure 6. Protected areas close to the planning area in Bromma. Other ancient monuments are sourced from Riksantikvarieämbetet (2015).

2.6 Protected areas

2.6.1 Cultural values

Within the Bromma airfield are six ancient monuments, including burial grounds, stone engravings and gathered relics (Figure 6) (Riksantikvarieämbetet 2015). In the planning area and the surrounding region there are numerous ancient monuments that are protected according to the Cultural Act chapter 2. Special consideration is to be taken when intruding on these protected areas and a permit is needed for damaging ancient monuments (Cultural Act 2:6).

In the year 2000, two buildings within the airport were declared National monuments by the government (Luftfartsverket 2002). The previous terminal and Hangar A (today the present terminal) are preserved because of their historical importance for communication and their architecture which is typical for early modernist airports. Not only are the monuments not to be demolished or damaged, they must be actively maintained and preserved (Luftfartsverket 2002).

2.6.2 Natural values

As previously mentioned, Kyrksjön and Judarskogen are both protected nature reserves and part of Natura 2000. The lakes and surrounding deciduous forests include habitats that are valuable for amphibians and especially the EU (habitat directive) protected crested newt thrive in these reserves. Kyrksjön is also host to a diverse bird fauna and both of the areas are protected for recreational activities (Naturvårdsverket 2015a). The eastern part of Lake Mälaren is a water protection area (See Appendix 6), which borders the airfield in the north (Naturvårds-verket 2015a).

2.7 Environmental impacts of aircraft operations

According to the Environmental code, airports with runways longer than 1200 meters must always be considered to have significant environmental impacts (Naturvårdsverket 2008). Bromma airport was the first in Europe to have paved runways and has a runway of 1668 meters (Swedavia 2015b). Therefore the activities of aviation in Bromma airport are deemed to cause significant environmental impacts in Bromma and surrounding areas.

2.7.1 Fossil fuels

The combustion of kerosene by aircrafts and the ground operation vehicles burning petrol and diesel produce a substantial amount of nitrogen oxides (NO_x), carbon oxides (CO_x), sulphur oxides (SO_x), particulate matter (PM) and toxins such as benzene and formaldehyde. NO_x and CO_x are greenhouse gases (GHGs), which are the cause of global climate change and, if emissions are not dramatically reduced within the next few years, will lead to “severe, pervasive and in some cases irreversible detrimental impacts” to humans and the environment (IPCC 2014). In Sweden domestic flights accounted for just under 1% of CO_2 equivalent (CO_2e) emissions in 2013 or 0.53 million tons of CO_2e out of a total of 55.77 million tonnes (Naturvårdsverket 2015b).

The main source of an airports emissions are actually released during landing and take-off (LTO) and those released below 900 meters are generally locally dispersed by wind movement. However, from a national perspective, the emissions released during the flight is more important (Ahlberg 2014). Other than contributing to global climate change they can also be inhaled causing diseases like cancer, asthma, lungs and heart diseases (Whitelegg & Cambridge 2004). Nitrogen oxides and sulphur oxides have the ability to react with other substances in the air becoming the main source of acid rain which can damage ecosystems, buildings and monuments etc. due to its low pH. The deposition of nitrogen oxide can also result in eutrophication of water bodies at a regional level (Naturvårdsverket 2008; Whitelegg & Cambridge 2004). Chemical or photochemical reactions of carbon oxides, nitrogen oxides and volatile organic compounds (VOC) in the troposphere produces ground-level ozone (O_3), which is harmful to plants and animals (ICAO 2013; Whitelegg & Cambridge 2004). Due to the above, air pollutants will be considered both as Transport pollutants (on both the regional and national scale) and, where relevant, as CO_2e for the purposes of this report. However, while the CO_2e emissions are quantified, the local pollutants are considered purely on an estimated qualitative basis, and therefore double counting should not be an issue.

2.7.2 De-icing and anti-icing

Whenever there is any presence of ice, salt formiat is used for de-icing the runways (Swedavia 2015c) and the aircrafts are treated with de-icing and anti-icing agents before take-off. The agents contain substantial amounts of monopropylene and diethylene glycol, which in high concentrations can be poisonous to organisms (Marklund 2004). According to Swedish Environmental Protection Agency (2008) 10% of these pollutants are washed away with surface runoff to contaminate the nearby water bodies. Both glycol and formiat consume large amounts of oxygen, depleting it for aquatic life and potentially causing eutrophication of water bodies (Lokrantz 2005).

2.7.3 Fire drill sites

It is common that airports have fire drill sites where emergency workers train to extinguish fires. Discarded jet fuel is used to set fire to airplanes or car wrecks which are then extinguished using water or foam extinguisher consisting of different chemicals. Depending on the agents used in the extinguishing it can have severe environmental impacts (Lokrantz 2005).

2.7.4 Noise

Noise pollution is currently the second biggest environmental problem affecting health after air pollution (WHO 2011). In addition to that, the ICAO (2013) states that aircraft noise is the major cause of adverse community reactions in relation to operations and expansion of airports.

Noise pollution causes a reduction in cognitive ability in school-age children through affecting how they think and understand, reason, memorise and recall information (Eriksson et al. 2013). It causes disrupted sleep, stress, depression and tinnitus. Furthermore, there is increasingly strong support for a link between noise exposure and risk of cardiovascular diseases and high blood pressure (WHO 2011; Nilsson et al. 2013; 2002/49/EC).

Due to the above mentioned impacts, the Stockholm model for detailed development plans and traffic noise regulates how much noise is acceptable in residential areas. In every apartment, at least half of the rooms must be located on the silent side of the building, this side is defined as having a maximum noise level of 55 dB(A). The regulation also address the outdoor environment. Everyone should have access to a quiet outdoor space, which is defined as 55 dB(A) equivalent and 70 dB(A) maximum level. During night hours the indoor noise level cannot exceed 30 dB(A) equivalent and 45 dB(A) maximum level (Stadsbyggnadskontoret 2010).

Noise pollution is also an environmental problem affecting natural processes and biodiversity (Bradbury & Vehrencamp 2011). Kaseloo and Tyson (2004) state that animals rely heavily on sounds for various forms of communication, such as bonding with mates, defending territories from rivals, maintaining contact with social groups, etc. Different species are sensitive to different noise levels. Birds have a sensitivity to noise at 0 - 10 dB(A) while amphibians have a sensitivity from 10 - 60 dB(A). However, studies show that certain bird species have adapted themselves to daytime noise by amplifying their singing and calls or by becoming nocturnal (Helldin, 2013).

Sudden and frequent noise and vibrations disrupt the behaviour of organisms and thus lead to a loss of species diversity, increased mortality rates and increased emigration to other quieter ecosystems. Studies also show that bees fall unconscious in the presence of noise and vibrations, making them liable to being eaten by other predators in the ecosystems, hence affecting future ecosystem services. Earth worms, fundamental organisms in soil formation, are also affected as they move deeper into the earth at high frequent noise (Kaseloo & Tyson 2004).

2.8 Economic impact

2.8.1 Transportation infrastructure

In general good infrastructure decreases transportation and travel costs and therefore the cost of production for transport-dependent companies. It decreases commuter time and expands the labour market, making it easier to hire specialised labour. In some industries production per unit gets cheaper the bigger the total production is. So when improved infrastructure expands the consumer market, the industry can produce more units to satisfy the increased demand, effectively resulting in the product getting cheaper with improved productivity. At a local scale good connections can also attract companies (Klaesson & Mellander 2012). The theory regarding infrastructure is applicable to air traffic as well. Empirical literature is emerging and so far shows a strong connection between air travel and economic development. ACI (2004) has divided the regional economic effects of an airport into four categories.

- *Direct:* employment and income directly connected to the airport activity.
- *Indirect:* employment and income from the service supporting the airport.

- *Induced:* employment and income generated by the consumption of people working at the airport or the supporting services.
- *Catalytic:* employment and income created by the airport through its effect on productivity, tourism and how attractive a region is for firms and residents.

Among these the catalytic effects have by far the greatest impacts in the long term. It is important to keep in mind that there is a big risk of reversed causality when looking at correlation between airport activity and economic development. Does the airport lead to economic development or does the airport become busier in more economically developed cities? The answer is most likely both, and most studies try to control for this dual effect.

The main body of studies is from the United States including Brueckner (2003) who finds that frequency of flights and number of destinations has a positive impact on the establishment of service-related industries in the surrounding metro area. He stresses the importance of the catalytic effects when an airport increases productivity as it facilitates face-to-face interaction and attracts new businesses. This greater effect on service-related businesses is also found by Florida et al. (2014) with results indicating that moving people compared to goods generates twice the economic output. Green (2007) gets complementary results with a positive correlation between airport activity and regional employment growth and Bloningen (2012) finds significant results on its effect on regional economic growth and population growth rate. Another American study looks at the effects of local airports on remote communities. Their findings show that communities that lost their local airport experienced 20% lower growth in income over a 20 year period (Özcan 2014).

Redondi et al. (2013) has found that Sweden would, relative to other European countries, experience a big decrease in airport accessibility if small airports (<2 million annual passengers) were closed down. This is an effect of the great distances in Sweden. Still, the study shows that only 7.6% and 4.3% of the population would suffer a 10% and 20% increased travel time respectively on its average connectivity to any other destination in Europe.

2.8.2 Lack of housing

Trends of increased economic activity in growing urban regions can be observed internationally as well as nationally. The economic growth as measured in total expenditures on wages has developed very differently in low and high population regions (VGR 2005). Regions with more than half a million inhabitants grew by 52% in 1987-2001 whereas regions with less than 10 000 inhabitants only grew by 4%. The same discrepancy exist for the level of employment where for the small regions it fell and for the big regions it was kept constant (VGR 2005).

However, the growing population must be housed. A lack of housing leads to higher housing prices, causing the level of household debt to rise which could lead to a financial downturn if the high prices were suddenly to fall, as in the case of the 2008 housing bubble (Gjerstad & Smith 2009).

When labourers cannot find a place to live this will inhibit a smooth hiring of labour. Additionally, the knowledge of a housing crisis may stop job seekers from even considering that area as an option. Both these effects will make good match-making difficult (Englén & Wigren 2013).

A third perspective from which to analyse the effects of the housing crisis is a prominent theory concerning the appearance of strong regional economies, the new economic geography (NEG). The NEG state that highly populated regions have a number of benefits that improve its economic performance. The reason for this is twofold, lower transport costs and economics of scale (Englund et al. 2008). Economics of scale means that the more units a company produces the lower the average cost per unit will be. Such companies will want to establish themselves close to a big market where demand is big and where it can use its advantage. Also, by being located close to many customers transport costs are kept at a minimum. In these two ways productivity is kept high and price levels low. A high concentration of people also allows for a more diversified supply of goods and services. The low prices and diverse markets in turn attract people to move to the region. This closes a reinforcing loop with more people moving in making it more attractive for firms to establish themselves which in turn attract even more people to move in. The result is a more productive economy with more innovations, more specialisation and a higher diversity of goods and services (VGR 2005).

2.9 Current state

2.9.1 Environmental state

In Bällstaviken bay there are currently high amounts of phosphorus and bacteria and occasionally low oxygen levels at the bottom. The groundwater contains high levels of heavy metals, bacteria, petroleum, hydrocarbons and polyaromatic hydrocarbons (PAH) (Lücke 2009). Furthermore there are high amounts of Polychlorinated biphenyls (PCBs) in the sediments. The greater part of the pollutants derive from the environmentally hazardous activities in the catchment basin, which includes the airport but also the industrial areas. However, Bällstaviken has the largest catchment basin in the region, which makes it difficult to estimate the individual impact of the airport activities on its environmental state (Stockholm vatten 2000).

In the fire drill site within the airport, the toxic polyflourooctane sulfonate (PFOS) has been detected (Eriksson 2010). Therefore Swedavia have collected soil samples in order to identify the polluted area. It is likely that the PFOS derives from the previously used foam extinguishers. In year 2008, PFOS was banned in the EU (Bengtsson 2012), but it is still detected in the soils because of its chemical stability and resulting resistance to biodegradation (Carpenter 2013). The inventory also indicates elevated levels of heavy metals and PAH in the soil. Because of the occurrence of PFOS, the airport has been given the risk category 3 – moderate risk (Eriksson 2010). Excluding PFOS, the airport’s risk of impacts on soils and waters are only categorised as small (Eriksson 2010).

The conditions for building in the area are not ideal according to a report in 1996 (Eriksson 2010), but neither it is unusual in the Stockholm area. The report further claims that no remarkable amounts of pollutants are found in the ground, even though it has hosted aviation activities for 60 years (Eriksson 2010). The flight traffic has increased in Bromma airport since the 90's, but there have also been limitations in the usage of environmentally hazardous pollutants, more energy and fuel efficient aircrafts and stricter regulations for mitigating processes (Eriksson 2010). It is therefore unclear to what extent the area is currently affected by local pollutants. Prior to a change in land use a thorough inventory of the soils and waters should be conducted (Eriksson 2010).

2.9.2 Housing

Stockholm is one of the fastest growing cities in Europe (Stockholms stad 2014a), and the shortage of housing is severe; currently 121 975 extra apartments are needed. The reason for this is a fast growing population, a tightly regulated housing market and neglected housing construction. (Stockholms Handelskammare 2014b)

The shortage of housing is not expected to decrease over time, by year 2030 a need for 400 000 new apartments is estimated (Stockholms Handelskammare 2014b), but the municipality of Stockholm have only planned for 150 000 apartments for 2030 (Stockholms stad 2014a). In order to deal with the population growth, 24 000 apartments have to be built each year (Stockholms Handelskammare 2014b).

If a shortage of housing inhibits the growth of the Stockholm region the positive economic effects of increased agglomeration will not occur and match-making difficulties on the labour market will persist. WSP (2013) has attempted to estimate these losses in terms of the number of labourers in the Stockholm region. By comparing two scenarios, one with a constant building rate and one where it's twice as high, they find the size of the working force to be between 86 000 and 140 000 day-time labourers smaller in 2030 if building rates are kept at today's level. Inferred from these results the Gross regional product will (GRP) be 3.6-7.2% lower.

2.9.3 Transport patterns

In 2014 approximately 2.4 million passengers travelled through Bromma airport, almost 90 % of the traffic was domestic and 70% was business related (Swedavia 2014). The ten most common destinations were in order: Malmö, Gothenburg, Umeå, Visby and Ängelholm, Halmstad, Östersund, Ronneby, Kalmar and Sundsvall (Figure 7) (Swedavia 2014), with travel times shown in Figure 8. Comparing total traffic distribution among destination cities from Bromma it can be seen that 80% of the total air traffic goes to or from the top five destinations, and the two most popular destinations together stand for over 50% of the traffic. While Arlanda airport handles approximately 70% of the domestic air traffic within the Stockholm region, leaving the remaining 30% to Bromma airport (Transportstyrelsen 2015), it has been argued that Bromma airport plays an important role in connecting the north of Sweden to Stockholm (Länsstyrelsen Jämtlands län 2014). However, according to Swedavia's data (2015d) only 18% of the total domestic traffic from Bromma airport goes to Norrland. In 2014, sixteen different cities in the north of Sweden were connected by air to Stockholm, with Arlanda airport connecting to all of them whereas Bromma airport only had traffic to nine of these. Of the 400 000 norrlandic passengers traveling to or from Bromma airport that year, 99% travelled through the airports of Umeå, Sundsvall or Östersund. Over the same time frame, Arlanda airport handled approximately three million norrlandic travellers and had in total substantially more passengers traveling to or from all of the sixteen cities. 12% of Stockholm regional traffic to Norrland is handled by

Bromma airport and the remaining 88% goes through Arlanda airport (Swedavia 2015d).

There are cities to which Bromma airport handles the majority of air traffic to and from Stockholm. These are: Trollhättan, Visby, Växjö, Ängelholm and Halmstad. Bromma airport also administers a significant proportion of the passengers from Malmö and Gothenburg.

However, all of the above mentioned cities are situated south of Stockholm; one might conclude that Bromma airport has a greater role in connecting Stockholm to these cities and to the south of Sweden rather than the north. For each of the top ten Bromma airport-destinations, flying is the most time efficient transport alternative today. Bromma airport offers good time slots to domestic flights, which some argue is an important factor to connect and create a friendly business climate in rural regions (Waldfogel 2014)

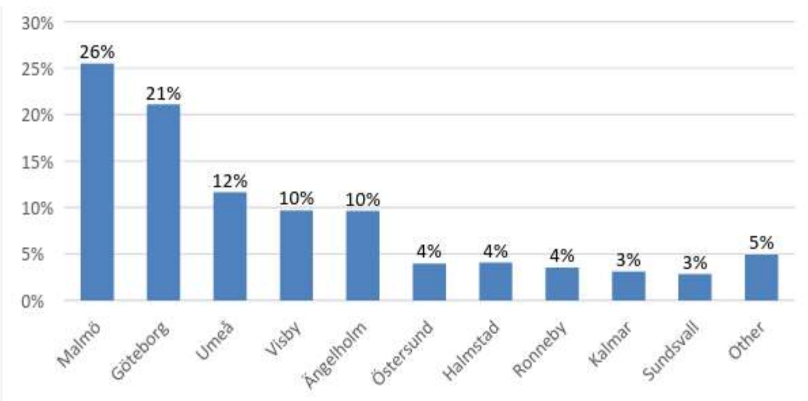

Figure 7. The distribution of Bromma's domestic passengers between destinations (Data source: Swedavia 2015d).

Figure 8. Total amount of Bromma airport passengers from 2014, divided by destination with estimated travel times (Data source: Swedavia 2015d).

2.9.4 Noise

Noise pollution in Bromma airport and surrounding areas is from both aviation noise such as aircraft LTOs, and ground noise such as taxiing towards and away from the runway, starting aircraft engines, and noise from service vehicles within the airport. Noise generated from the aircrafts is usually from LTOs, depending on the types of aircraft, and the airport's ground operations (Nilsson 2015). Swedavia (2014) explicitly states that Bromma residents live in close proximity to the airport, and as close as 180 meters from the airport runway, thus exposing the residents to ground vibrations and noise.

In 2004 people living close to Bromma airport and Arlanda airport represented 94% of the national number of people exposed to noise equal to 55 dB(A) L_{den} or more. Out of those ca. 7 500 people, 4 888 lived around Bromma airport (Boverket 2009). In 2012 this number increased to 12 500 out of a national total of 15 100 (Ahlberg 2014). Also in 2004, out of 180 000 people exposed to the maximum level of 70 dB(A), 137 500 were situated in the vicinity of Bromma airport (Figure 9)(Boverket 2009).

These figures do not include those commuting to work and go to school in the area, who are also affected. According to the local network *Barnen* and *Brommaflyget* there are currently 8 000 children studying in the area, with schools housing a further 3 000 pupils already planned (Ahlberk et al. 2014). Also, a study on inconvenient experiences related to noise showed that residents close to Bromma airport tended to spend less time outside than residents close to other airports, and that the proportion of people who feel negatively towards the adjacent airport are significantly higher in Bromma compared to other airports (Nilsson et al. 2013). There are few studies that show the impacts of noise pollution on ecosystem life in Sweden (Nilsson 2015; Helldin 2013), and none that document its effect specifically in Bromma.

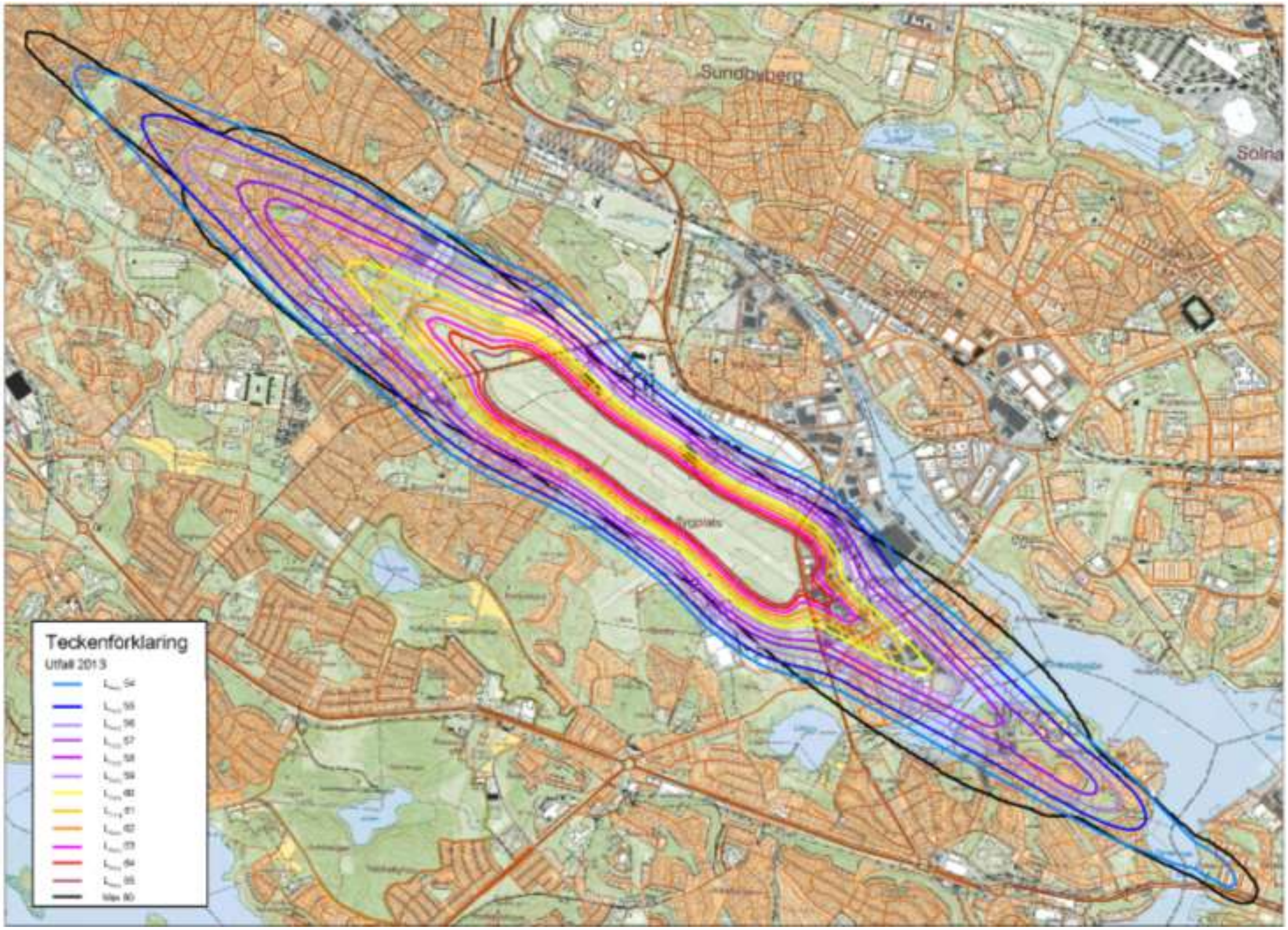

Figure 8. Noise levels in dB(A) at Bromma airport in LAeq, i.e. not weighted for evenings and nights. Note that the black curve representing maximum level 80 dB(A) means that 70 dB(A) should affect an even larger area (Swedavia 2015e).

2.9.5 Economic Impact

A few Swedish studies on the economic impacts of closing an airport have been conducted by the environmental consultancy WSP (WSP, 2011; WSP 2010) and one study from Jönköping University (Klaesson & Mellander 2012). The reports from WSP all use the same economic model (RUT-3). The model uses data between 1980 and 2000 from all 289 municipalities, and then estimates the effect of "accessibility" on long term (25-60 years) regional economic development (WSP 2010; WSP 2011). It has so far been applied to Växjö, Kalmar, Sundsvall-Gävle and Västerås. The results can be seen in (Table 1) and represent the effect on the entire surrounding region.

Klaesson & Mellander (2012) use a simpler model, but get results in the same range where closing down Jönköping airport would result in 3200 and 650 lost jobs and firms respectively. These cities only have access to one airport and extrapolating the results on Bromma airport is difficult as other flight options exist, such as Arlanda airport and Skavsta airport. Still, an airport evidently has a big impact on the regional economy

2.9.6 Prognosis of domestic air-traffic

The domestic air travel in Sweden reached a peak of 9 million travellers in 1990 and has since been at a fairly stable level between 6 and 7.5 million. Since then increases in air travel taxes, the Gulf war, 9/11 and the recession have affected the number of travellers but no long term trend can be observed. It has been suggested that the lack of a long term trend in domestic air travel could be an indicator of the domestic market being saturated, and based on this assumption, prognosis' for the industry have been mostly negative (Rogestam 2007).

Multiple tools have been used to make a prognosis on domestic air travel. The Swedish transport administration (Sw: Trafikverket) (Trafikverket 2012) state that computer models have performed poorly and have been of no use so far. According to them simpler models are used by The Swedish transport agency (Transport-styrelsen), who (2014) released a prognosis on air travel until 2020, in which they note that the number of annual passengers lies between 6 and 7 million over 2004-2013 (Figure 10) and conclude that there is no reason to assume that this will change in the coming years. Contradictory to this they use the same time series data to estimate a trend, reaching the conclusion that the number of domestic passengers will increase by 0.9% annually, totalling 7.6 million in 2020. The Swedish Transport Administration (2012) made a prognosis to 2050 and their analysis finds no reason for the domestic air travel to increase except possibly that excesses on airline protection will be removed. However potential future environmental legislation and continued urbanisation is suggested to reduce air travel.

Table 1. Effects of closing airports in respective region (Data source: WSP 2010; WSP 2011; Waldfogel 2014).

	Västerås	**Kalmar**	**Sundsvall-Gävle**	**Växjö**
Jobs Lost	970	5420	910	6890
Firms Lost	290	1890	2300	3120

Additionally they note that no correlation exists between real income and domestic travel. But, in their highest likely prognosis they assume that increasing real income will have an effect on the passenger kilometres which will increase by 1% each year until 2050. In their lowest prognosis they assume no growth in passenger kilometres.

It must be pointed out that the prognosis results presented do not include number of flights, instead they concern number of passengers and passenger kilometres. Historically the planes are carrying an increasing number of passengers and the trips are getting longer (Trafikverket 2012; Transportstyrelsen 2014). The Swedish Transport Agency expect the trend for passengers per plane to continue at least until 2020 which means the number of flights will not increase at the same speed as number of passengers. Whether or not the average length of the trips continues to increase is uncertain.

Specifically at Bromma airport The Swedish Transport Administration (Karyd 2013) made the prognosis that the number of travellers would reach 2.4 million in 2050, this emphasizes the inadequacy of the prognosis, as this number of travellers was reached in 2014 (Swedavia 2014).

As a whole no good arguments can be found for a future increase in total domestic air travel. Rather the opposite is true with potential environmental legislation limiting air travel. Therefore, the low prognosis from The Swedish Transport Administration (2012) with a zero growth in air travel will be used in this report.

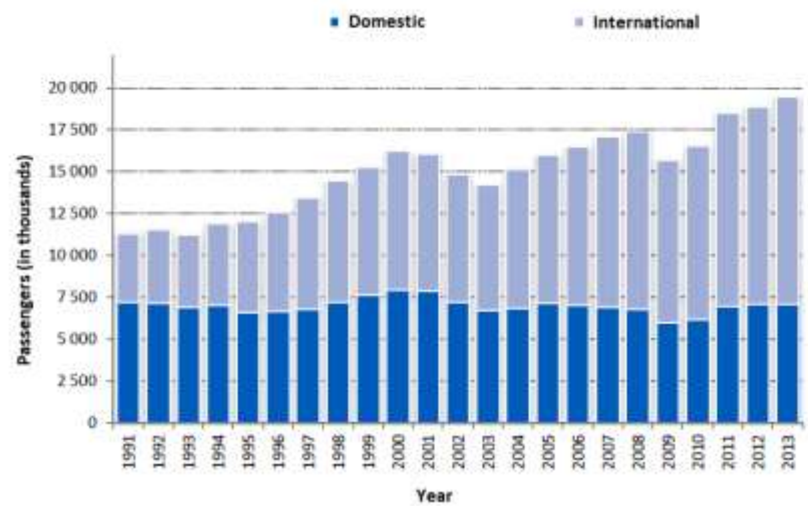

Figure 9. Number of departing passengers at Swedish airports, 1991-2013 (Data source: Transportstyrelsen, 2014).

3 Methods

3.1 System Perspective

In this report what is called a system perspective has been used. A system can exist at any scale and is defined by the interconnection and interdependency of its variables and factors. Systems analysis is about gaining a holistic understanding of these connections and relationships and discovering insights into their organisation. It is about helping to understand components and feedback relationships. Systems thinking is mental modelling and is used to define a problem and its symptoms, as well as communicating system understanding (Haraldsson, 2005). The main method used for this is the Causal Loop Diagram (CLD), which will be discussed in section (3.5 *CLD*)

3.2 Boundaries

3.2.1 Time

The time horizon has been set to 2050. The agreement with Swedavia has a three year period of notice (Stockholms Handelskammare 2014a). In the calculations on developing the area a time period of 30 years has been used. To be able to finish the project on time, the agreement must thus be cancelled by the year 2017 so that construction can start in 2020. The political majority in Stockholm are aiming at cancelling the agreement by 2019 (SVD 2014), so this scenario is two years ahead of those plans. However, the year 2050 is often used when creating future scenarios or making prognosis for reports or assessments. Thus it will be easier to put this report in a wider context. Therefore, the starting date had to be pushed forward which is considered reasonable. Within this period it was assumed that the majority of the development suggestions made i.e. housing development and fast rail development can be realised. Future developments after 2050 are therefore not considered in this report.

3.2.2 Scale delineation

The discussion concerning Bromma airport inherently contains different scales, both in time and space. This multifacetedness is what makes the Bromma discussion both complex and complicated.

To address the ongoing debate, different aspects must therefore be considered at their respective geographical scales in order to get a wider understanding of the discussion as a whole. Regarding the spatial scale, both the local and the national scale concerns the discussion of Bromma airport. The local level concerns the airport area itself and possible development options. The national scale relates to national connectivity in different transportation options.

Opportunities in alleviating the housing crises is often contrasted with the loss of favorable domestic transport in the discussion regarding Bromma airport. However, comparing such different issues as transport and housing is challenging as they act on different geographical scales or several geographical scales simultaneously. These conditions have had some implications in choosing relevant indicators.

In this report the local and national scale are considered but are to a large extent handled separately. The local scale is examined in two “building scenarios” and the national scale in two “transportation scenarios”. As a consequence, the sustainability indicators used have been separated into two groups: those that have local and regional influences and impacts, and those that affect the nation as a whole. What could be described as a zero-alternative, where Bromma airport continues its operation, is also included.

When investigating the development of buildings only the impacts on a local scale in the nearby area was considered. A brief summary of other developments in the Stockholm region will be made, although no further analysis will be made of these areas. When assessing the development of transport and infrastructure it has been done mainly from a national perspective, for example changes in travel to and from Stockholm.

Regarding the time scale, no from well to tank (fuel) or cradle to grave analysis was done during this report. Furthermore any construction effects/impacts have not been considered due to a lack of data and time.

3.2.3 Political

The issues concerning and deriving from private/public ownership and/or running of transport and developments will not be investigated in this report, and neither will the consequences of contract abandonment (i.e. Swedavia contract).

3.2.4 Alternative fuels sources

All modes of transport will be discussed according to the current fuel type used. The pros and cons of nuclear, biofuel or any other energy or fuel source for transport is beyond the bounds of this report.

3.2.5 Governance issues

The indicators used have specifically excluded anything related to sustainable governance, this is because the report is specifically concentrated on development of the area and alternative, not anything after development is completed.

3.2.6 Movement of goods

When assessing the impacts of the national transport options only passenger km were assessed, no transportation of goods was considered, although these would impact many variables, such as Business attractiveness and emissions.

3.3 Primary and secondary data

This report is based on both primary and secondary data. Secondary data used were collected in the form of literature studies such as books, articles, reports or electronic sources. To get information about different visions of the future residential construction in the city of Stockholm, information from the comprehensive plan, the Stockholm Chamber of Commerce (Sw: Stockholms Handelskammare) and City of Stockholm are mainly used.

The majority of primary data has been collected through interviews including visits, phone communications and communications by e-mail. There has also been data collected by analyses and calculations which are presented more in detail below.

3.3.1 Calculations for time proximity and National connectivity

To estimate the effective time that it takes to fly from Bromma airport, Arlanda airport and Skavsta airport to each of the top ten Bromma airport-destinations data in a report by the Swedish Chamber of Commerce was used (Waldfogel 2014). The travel time from the centre of Stockholm to the respective airport was also added and how long before departure you have to be at the airport i.e. the sum of check-in and security time and how long before departure the gate closes. Then it was calculated and included what time it takes to travel from each of the top-ten airports to the closest city, using google maps travel description. This is an optimistic time assumption since some time consuming activities are left out, such as time added for baggage claim and transfer time from airport to other transportation mean. How long time before departure you have to be at Arlanda airport or Bromma airport is a recommendation from Swedavia. This number came from simply calling the customer service.

Due to similar airport size, it was assumed that Skavsta airport can offer the same check in and security time as Bromma airport for domestic flights.

To estimate the effective travel time by fast train connecting Gothenburg and Malmö to Stockholm the estimated travel time from two different reports was used (Region Skåne 2012; Banverket 2008). To calculate the effective travel time from Stockholm to Umeå and Sundsvall to Umeå the distance was multiplied by the standard speed for fast rail, 250 km/h, assuming that the train stops at four other stations before reaching Umeå every stop adding 5 minutes. The method was tested to assess the effective travel time to Gothenburg and Malmö by fast rail. The result differed +/- 5 minutes from the travel time estimated in the above-mentioned reports.

To estimate the travel time to the remaining destinations potential extra transfer time to other trains was excluded. Then, different internet travel planners were used to calculate the fastest route by train from the closest station, connected to the future fast rail, to the destinations in question. This is also an optimistic time assumption since no train transfers are this effective. On the other hand you have to take into consideration that an average speed of 250 km/h for fast rail is a low value and thus a time pessimistic assumption (Network rail 2009).

3.3.2 CO_2e calculations

The total Bromma airport passenger numbers per destination were obtained from Swedavia (2015d). These passengers include both departing and arriving passengers, meaning that comparing this to other domestic flight calculations may be impossible as some of these passengers may be considered as “belonging” to other airports. However, for the task at hand this approach seemed the best, as all of these passengers do use Bromma airport, and would therefore have to change their transportation methods if Bromma were closed. These passenger numbers were multiplied by their respective distances travelled and summed to get the total passenger km, which was then multiplied by the 320g estimated CO_2e emissions per passenger per km traveled (DEFRA 2013). The choice of using 320g CO_2e emissions deserves further explanations. Depending on sources CO_2e emissions per passenger km for air travel are between 86-660g, (EEA 2011, DEFRA 2013). The reasons for these differences in estimates are to a small extent dependant on which class you fly in (i.e. space you occupy) and the distance travelled. The largest difference in estimates comes from the inclusion of the IPCC (1999) recommended multiplier which accounts for the uncertain effects of releasing greenhouse gases (GHG) at high altitudes (Sausen et al. 2005). DEFRA (2013) calculates domestic flights for the average passenger resulting in 170 or 320g/passenger km, depending on the inclusion of said factor. Hence this report used the IPCC (1999) guidlined figure of 320g.

For Scenario 3 the same number of passengers was multiplied by the longer distances associated with over-land travel, and then multiplied by the smaller 25g CO_2e emissions per passenger km (DEFRA 2013). HSR CO2e emissions are internationally between 12g per passenger per km for 74% nuclear powered Eurostar electric rail (DEFRA 2013, EDF 2013) and 50g per passenger/km for diesel rail (EEA 2011, DEFRA 2013). These numbers mostly depend on fuel type, but to a smaller degree on distances between stops, occupancy rates and operational characteristics (Wee et al. 2003). Therefore, even though Swedish electricity is close to 70% non-fossil fuel based (IEA 2013), 25g/passenger.km CO_2e emissions will be used, to take into account the relatively short distances between stops on the southern routes, and the possibility of low occupancy rates in the North due to low population density (it is still likely to be a gross overestimation). It must be noted that no life cycle CO_2e estimates were made for fuel types.

In scenario 1 and 2 CO_2e are only estimated for the flight, not getting to or from airports. This underestimate of emissions was thought to be balanced by the fact that in scenario 3 all modes of transport from relevant city centre to central station Stockholm are calculated as train CO_2e even though they may be bus/car etc. This is done for all except the Visby trip, which is divided into ship (according to DEFRA 2013, 19.2g CO_2e per passenger/km) and train.

Distances were estimated as straight lines between airports for scenarios 1 and 2 (which may be a slight underestimate). For scenario 3 distances were estimated following the projected route of the High Speed Rail (HSR) and adding in existing public transport routes where needed.

3.3.3 Calculating number of apartments, row houses and number of inhabitants

In order to estimate how many apartments that can be built in the scenarios, different densities were estimated. In the dense scenario, Brommastan, the density is approximately 100 apartments per hectare, and in the sparse scenario, Bromma Grönstad, the density is approximately 70 apartments per hectare. These levels of density was chosen after comparing to other places in Stockholm; Östermalm and Hammarby Sjöstad (Table 3). These areas have a city like structure which was aimed for in Brommastan.

Therefore, a density level that corresponds to Östermalm and Hammarby Sjöstad were chosen for Brommastan. Although, the density level will be a bit higher in Brommastan since the buildings are planned to be higher than in Östermalm and in Hammarby Sjöstad. For Bromma Grönstad, a less dense structure than Brommastan was chosen.

The areas reserved for apartments in both scenarios were calculated in GIS. Then the number of apartments per hectare (density level) was multiplied with the area.

In Brommastan, the density is approximately 100 apartment/ha in order to represent a dense area. The average square meter per each apartment and communal area is 100 m2. The area reserved for 3-5 floor buildings is 80 hectares, which will result in 8000 apartments (100 x 80). The area reserved for 5-9 floor buildings is 87 hectares and will result in 8 700 apartments (100 x 87). Altogether, the total area reserved for buildings will result in 16 700 apartments (Figure 19). In Bromma Grönstad, the area reserved for high rise buildings of maximum five floors is 96 hectares which will result in 6 720 apartments (98 x 70) (Figure 29).

To calculate the number of row houses in Bromma Grönstad, one row house was calculated to have a total area of 100m2. The area reserved for row houses were 62 hectare, therefore 620 row houses can fit in the area. Although, some space have to exist between the houses, so the number was rounded off to having 500 row houses in the area.

To calculate the number of working places, the areas reserved for these were measured in GIS and then multiplied with different density levels; in Brommastan 100 apartments per hectare and in Bromma Grönstad 80 apartments per hectare. The result was then multiplied with ten, since it was assumed that each “apartment” include ten working places.

The area reserved for working places in Brommastan is nine hectare and will consist of 9000 working places approximately. The area reserved for working places in Bromma Grönstad is also nine hectare. In this area a density of 80 apartments per hectare is calculated on, leading to 7200 working places.

To calculate how many inhabitants the areas will consist of, the apartments in Brommastan are assumed to have three persons in average living in them, and the apartments in Bromma Grönstad are assumed to have two persons and in the row houses four people in average are assumed to be living in them.

The assumed number of inhabitants in each apartment and row house are then multiplied with the number of apartments and row houses. In Brommastan, the dense scenario, 33 400 inhabitants are assumed to move in and in Bromma Grönstad, the sparse scenario, 15 440 inhabitants are assumed to move in.

During the construction time of 30 years (year 2020-2050), 856 apartments and working places per year will be built in Brommastan (25 700/30=856) and 481 apartments, row houses and working places will be built per year in Bromma Grönstad (14 420/30=481).

Above calculations are just estimates and no exact numbers. The scenarios are more or less on a visionary level and thus no detail plan. The aim was to have some reference on how many apartments and row houses that is realistic to fit in the areas, the real number might be both higher and lower, but considering the time limit and the scope of this project these estimates are considered to be enough.

3.4 Maps and visualisation

Geographic Information System (GIS) was used to visualise the demarcation area, as well as give an overview of how the various scenarios would look like in reality. GIS have also been used to visualise how different factors in the different scenarios affect their environment spatially. The software used are *ArcCatalogue* and *ArcMap*, of ArcGIS, and all input data used in ArcGIS is taken from the National Land Survey (Lantmäteriet), the Swedish Geotechnical Institute (SGI) and the Swedish Environmental Protection Agency (Naturvårdsverket).

For visualisation of the different building scenarios, the design program *Sketch-up* has also been used.

The noise pollution data was analysed with a population map from Statistics Sweden (© SCB [I2014/00691]), noise pollution maps for Skavsta airport was acquired from WSP Akustik (2006) and rectified in a geographical information system. Shape files from the noise pollution in Bromma airport was acquired from the Swedish Natural Protection Agency (Naturvårdsverket 2011). The affected population was selected and the total amount of people affected by the noise was calculated for both Skavsta airport and Bromma airport.

All the maps of the local boundary area are in scale 1:15 000. That makes it easier for the reader to orient themselves if all maps that shows the same area are uniform. For the same reason, all the maps has a similar layout. Maps showing the infrastructure at regional or national level, however, are adapted to the scale that is most optimal for their purpose.

3.4.1 SketchUp

The visualisations of the building scenarios were created through *SketchUp*. *SketchUp* is a 3D modelling software allowing visualisation of physical structures.

3.5 CLD

A causal loop diagram (CLD) is a modelling tool used in systems dynamics to illustrate the causes and effects of a problem and how variables influence each other within the system structure. In systems perspectives, a CLD is used as a method to analyse behaviour of systems and bring understanding to the complexities and dynamic interactions between variables (Kirkwood 1998)

3.5.1 Guidelines on reading a Causal Loop Diagram

3.5.1.1 *Plus (+) signs and a Minus (-) signs*

A Plus sign (+) signifies that a change in the variable occurs in the same direction as the change in the prior variable, that is to say that one variable adds to another (Haraldsson 2004). For example, *increase* in burning of fossil fuels will lead to *increase* in Emissions. In the same way a *decrease* in burning of fossil fuels will lead to a *decrease* in Emissions.

A Minus sign (-) signifies that a change in the variable occurs in the opposite direction to the prior variables change, that is to say, that the variable subtracts from another variable (Haraldsson 2004). For example, an *increase* in disturbed ecological functions will lead to a *decrease* in biodiversity. In the same way a *decrease* in disturbed ecological function will lead to an *increase* in biodiversity.

3.5.1.2 *Positive (R) and Negative (B) feedback loops*

A positive feedback loop (R) is when a loop is reinforcing. This is symbolised by the letter R with an accompanying loop arrow showing the direction of reinforcing behaviour (Haraldsson 2004).

A negative feedback loop (B) is when a loop is balancing. This is symbolised by the letter B with an accompanying loop arrow showing the direction of the balancing behaviour (Haraldsson 2004). For example (Figure 11) B1 is balancing loop 1, whereby more people moving in to town will lead to less available jobs, which in turn will decrease the amount of people wanting to move, thus balancing the flow.

3.5.1.3 *Delay mark (lag)*

A delay mark is a link or an arrow showing the interconnection that occurs before the actual state is perceived. Links with delays have an arrow with a strike-through line (Haraldsson, 2004). For example, in Figure 11, loop B3, the building of houses will, after a certain amount of time (a delay) lead to a decrease in the Stockholm housing deficit.

3.5.2 Bromma CLD

The CLD (Figure 11) shows the authors' conceptual understanding of the Bromma airport system in a simplified representation of the problems related to the scenarios (see chapter 4, Scenarios) either keeping or closing down Bromma airport. Clearly some important variables of the system have been excluded within the presented overview; either due to the decided boundaries or because they are discussed in the scenarios individually (more in depth area specific CLDs are present in the Appendix 1). The CLD can be used as a tool to understand how the different scenarios (marked in red) will generally affect the regional development in Stockholm. The CLD can also be used to show how the indicators (see section 3.6) are interconnected with other variables which are important for achieving a sustainable society on both the national and local scale and thus use it to motivate the choice of indicators for the analysis. The indicators used to assess sustainability are marked in pink.

The scenario is the main input to the system and is connected to three variables, the air infrastructure, the improved train infrastructure and available land. The different scenarios will affect those variables differently. Keeping Bromma airport means more air infrastructure, which leads to more national connectivity, a prerequisite for more traveling and thus more regional economic activity and growth. On the other hand keeping Bromma airport will mean less available land, and less possible construction of housing. The lack of housing is an existing problem in Stockholm and also a limitation for more economic activity. This is the core of the problem, how should the area now occupied by Bromma airport be utilised in the future?

In this CLD scenario 1- "Business as usual" is shown. The input-scenario decides the polarity of the arrows. Scenario 2 (Dense-Skavsta) and 3 (Sparse-Skavsta) will, in contrast to scenario 1, lead to more available land but less air infrastructure. This is also the case for scenario 4 (Dense- fast rail) & 5 (Sprawl – fast rail) but with an additional arrow leading to more train infrastructure.

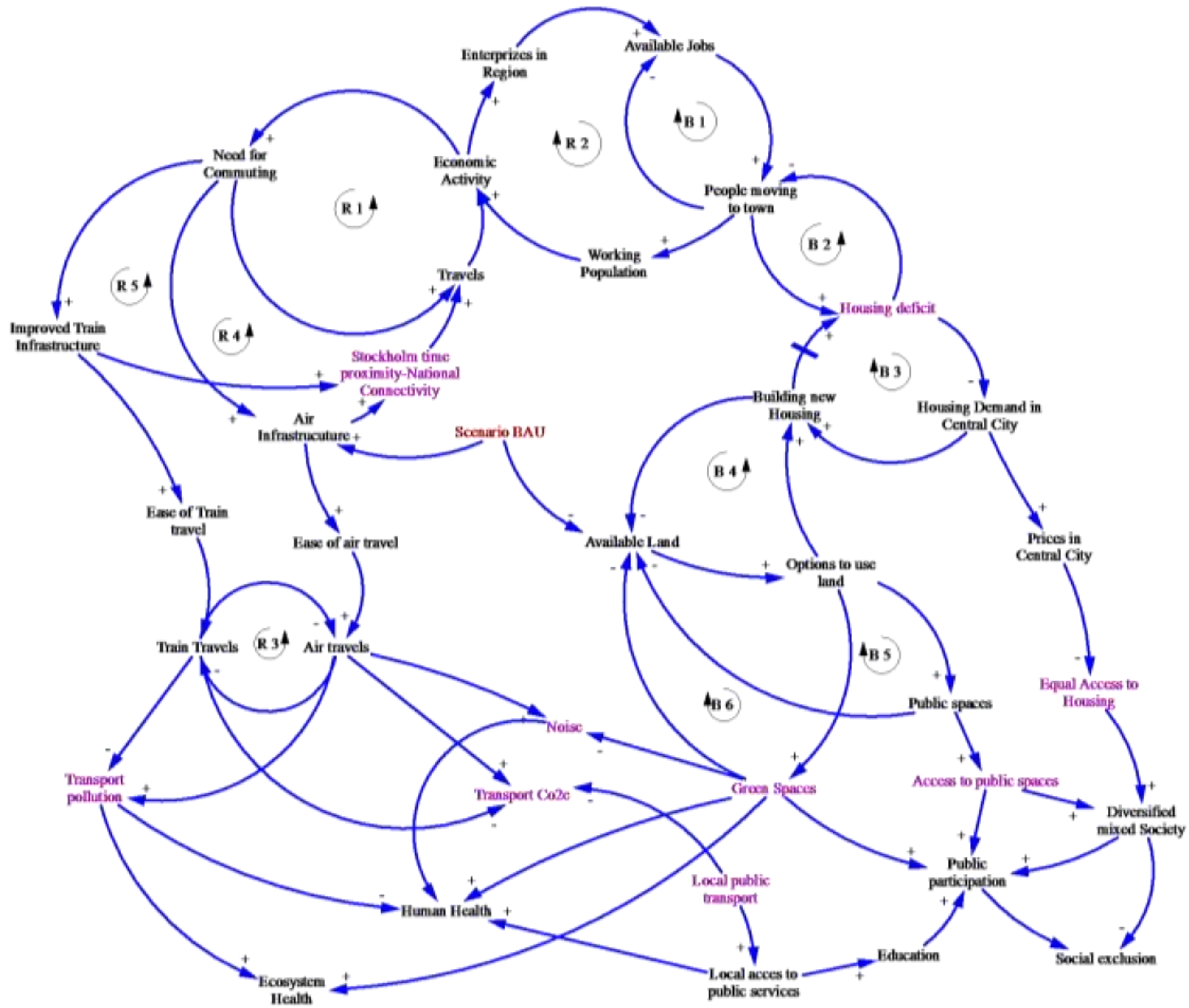

Figure 10. Simplified, over-arching CLD of Bromma airport project. The CLD shows the simplified interactions within the Bromma airport systemised by the authors to conceptualise the impact of the different scenarios considered and the key elements used as indicators for sustainable development.

3.5.2.1 *Impacts on infrastructure and transport*

Economic activity is one of the factors that have often been discussed in relation to Bromma airport. The important question is if Bromma airport is a prerequisite for maintaining and developing the regional level of economic activity.

The economic activity affects how much need for commuting there is, and the travel supply, i.e. train infrastructure and air infrastructure. This is where Bromma airport comes into the picture. More infrastructures leads to more national connectivity. More national connectivity in turns leads to a larger potential work force Figure 10 from travels which increases regional business (Figure 11) leading in turn to an increase in economic activity. Thus infrastructure is important for the regional economy, since it affect the national connectivity and decides how many people can travel at once and to what destinations.

The total number of travels consists of either train or air travels. If there are more air travels the share of train travels will decrease and vice versa. The proportional use of each transport means depends on its ease of access and travel time which in turn contribute to the total comfort of travel (Figure 10) which is ultimately dependent on the amount of infrastructure. A higher proportion of train travels will have benefits such as less CO_2e emissions and less pollution in general, which will have positive effects on human health and ecosystem health.

3.5.2.2 *Social and housing impacts*

On the right hand side of the CLD social sustainability is investigated starting with connecting the scenario to the variable available land. If there is more available land this could be used to either build housing and to create green areas or public spaces, or for other purposes outside of the boundaries of this project.

How to use the land is a policy decision, more green areas might have benefits for human and ecosystem health, as well as increasing public participation. More public space would also positively affect public participation, which in turn leads to less social exclusion. More housing would mean that more people could live in Stockholm, which would create a larger working population and therefore lead to more economic activity. If instead there is a lack of apartments, the housing demand will be higher, which will lead to higher prices in the central city and less equal access to housing. Equal access to housing is important to create a diversified, mixed and integrated society, which also will lead to less social exclusion.

3.6 Indicator methods

Ten indicators were chosen in order to compare the five proposed scenarios. This was done with guidance from the reference framework for EU sustainable cities (RFSC 2012, See Appendix 3) and the European foundations “Urban sustainability indicators” (Mega and Pedersen 1998). The indicators were chosen according to one main factor; relevance to the project at hand. For example the support of local food production was not included in this project as it was considered more of a governance issue which is not within the stated boundaries of this report. Other important indicators which were not included are public awareness of environmental and resource issues and waste production. The prior was deemed difficult to assess on a development level, while the second risked becoming an indicator for displaced effects, as humans will create waste and pollution wherever they live. However, due to the high importance of both of these variables, those influencers that could be defined (such as water meters, recycling methods, sewage treatment etc.) will be equally present in all development scenario.

Due to the breadth of this report, the local, regional and national effects must be assessed between scenarios so each indicator has an assigned scale in brackets, resulting in four national, two regional and five local indicators (confusingly, Transport pollution is measured on two scales) (Table 2). Another important point is that the indicators with a red background are negative indicators, so their values were inverted in the matrix.

Once the indicators were decided, each of the five combined scenarios was assessed for each indicator independently, within a comparative matrix, using the above defined variables (for a more in depth methodology for indicator valuation and significance see Appendix 4). The reason for the comparative approach, rather than an absolute "threshold" approach is a lack of time and data.

The scenarios were each given an ordinal number value from one to five. The scenario with the best results (or least affected in the inverted indicators) was always given a five, but the other scenarios could be assigned any value, i.e. not all numbers in the scale must be used. The fact that not all indicators will have all values is likely to skew the significance across indicators, but in this way the significance of differences between scenarios within each indicator can be presented. It was decided that any influences arising from the construction methods/work would not be assessed within the indicators. This is a major drawback to the report, but time constraints are unforgiving.

One value rose was then created for each of the five scenarios to give a more visual interpretation of the results. The different colours each denote an aspect of sustainability represented within the indicator. The numbers in the matrix were changed to colours, ranging from dark (five) to light (one) in order to avoid confusion as to the actual unit value of the indicator ratings, and to avoid the "adding up" of different indicators.

It must be emphasised that the indicators have not been given an absolute significance or value, and different individuals assessed and assigned significance to each indicator value, so the indicators cannot be compared in any absolute way. This leads to each reader/stakeholder being able to decide which indicators are most important to them, and draw their own conclusions. Furthermore, the scenarios are assessed relative to each other, therefore their indicator values cannot be compared to any alternative not mentioned in the report.

In the BAU scenario for the buildings three of the indicators were not relevant for use and therefore excluded from both the indicator table and value rose. The indicators Equal access to housing, Access to public space and Building CO_2e are all only applicable in comparing the Sparse and Dense building scenarios with each other, because they just do not apply to an airport for example, to put the airport in a context of the share of rental and cooperatively owned apartments is of little use. So even though these indicators work on a local scale they are only relevant in comparing building scenarios to each other, and not to airport activities. This is of course a weakness in our method of comparing the aggregated BAU to the four other scenario combinations. However it would be misleading to keep these indicators when comparing them with the other scenarios.

To the greatest extent, quantitative data is the foundation on which to evaluate the indicators, as these are easier to measure/grasp. But whether or not these quantitative data are relevant for their respective indicator is still uncertain. For example, the number of additional apartments in the dense and sparse scenarios is used as a basis for the "equal access to housing"-indicator. As this indicator is clearly affected by other factors as well, the evaluation will not reflect the whole complexity of the issue but rather specific implications. Another problem is that for several of the indicators, the basis for evaluation is how the scenarios are expected to be realised. It cannot with certainty be known that the physical structures created in the dense and sparse scenarios will in actuality generate access to public spaces, social services and certain travel patterns.

Table 2. Indicators used to compare scenarios, with scale of effect and sustainability aspect for each indicator. RFSC numbers refer to specific objectives within the reference framework for EU sustainable cities which are thought to be by each indicators (see appendix for full list of objectives). Red backgrounds indicate a negative indicator (inverted value.

	Indicator name and brief explanation	**Sustainability Aspect**	**RFSC reference (Appendix 3**	**Scale of influence**
1	Transport pollution Run off from transport modes as well as air pollutants that are not GHGs.	Environmental	14, 15	Regional/ National
2	Transport CO_2e Total CO_2e emissions from domestic travellers currently transiting Bromma airport.	Environmental	13	National
3	Building CO_2e Local transport and domestic energy usage.	Environmental	13	Local
4	Green Spaces Total area of green spaces, included in this are for example, parks and outdoor leisure areas,	Environmental	12, 13, 14, 17, 25	Local
5	Noise Amount of people affected by noise disturbances above current guidelines.	Environmental / Social	14, 15	National
6	Access to public spaces Amount of public squares, meeting places and purely pedestrian streets. Concentrates on the	Social	11, 12, 17, 25	Local
7	Local public transport Accessibility and variety of public transport options	Social	3, 5, 7, 8, 9, 11	Local
8	Equal access to housing in Bromma Range of prices for rental and mortgage housing in the area	Social/ Economic	10, 11, 25	Local
9	Stockholm time proximity Average length of commuter travel time from Bromma airports top 10 destinations to	Social/ Economic	1, 3, 25	National
10	Relieve housing deficit Amount of housing developed in relation to the Stockholm housing deficit and the housing	Economic	1, 6, 10, 11	Regional

4 Scenarios

4.1 Scenario Descriptions

Due to the different scales which need to be addressed when discussing Bromma airport the structure of the scenarios created needs a special explanation. The importance of Bromma airport as a domestic airport means that national interests must be assessed, while the development of the area into housing within the Stockholm region calls for a more local approach. For this reason, apart from the "business as usual" scenario, two transport (national) alternatives and two separate building (local) alternatives were created. Due to this different focus it was decided best not to fix one local alternative to a specific national alternative, but to try all different combinations, resulting in four new scenarios and one business as usual, with the name of the scenario e.g. Sparse - Fast rail as a guide to which combination is being used**.**

4.1.1 Transport Scenarios – Skavsta and High Speed Rail (HSR)

The other four scenarios involve closing Bromma airport. Two different transport scenarios were created; one where all flight traffic is displaced to Skavsta airport and one where domestic traffic is replaced by High Speed Rail (HSR), while international traffic goes to Skavsta airport.

4.1.2 Building Scenarios- Dense and Sparse

There are two building alternatives; one dense and one sparse In the dense-scenario, called Brommastan, the housing density will be higher and more public local transport will be available, while the sparse scenario, called Bromma Grönstad, involves less housing density but more green spaces.

Thus, in total five different scenarios were assessed.

4.2 Scenario – Business as usual

4.2.1 Business as Usual

Business as Usual (BAU), in which Bromma airport is kept and operating as it is in current state. The infrastructure stays the same but some housing development will occur in areas close to the airport.

4.2.2 Transport

In the scenario of keeping Bromma airport, no change will be made from the transport perspective, due to the prognosis of no growth in the domestic flight sector. Bromma airport will continue to cater to predominantly domestic flights with relatively small planes.

4.2.2.1 *Capacity*

If the prognosis for a steady state is followed (see Current state), no changes are needed, however it seems that Swedavia is expecting growth, which may lead to some problems considering that the maximum capacity of Bromma airport during rush hours has already been reached (Littorin 2012), and that land is lacking in the area to build another runway. Bromma airport will have to increase their number of larger aircraft (while still meeting the stringent maximum values they are allowed) to meet any future growth in traffic. In this way it will be possible to increase the amount of passengers without having to increase the amount of operations (Nilsson and Wallin, pers.com. 2015-02-25). However, considering that the demand in domestic flights is strongly bound with the peak hours (Nilsson, pers.com. 2015-02-25) and the regions of flight departure are too small to meet the need for bigger aircrafts, other alternatives must be considered.

4.2.2.2 *Fossil Fuels*

In order to understand future alternatives it is first important to know the amount of current emissions of CO_2e resulting from Bromma airport. Here the IPCC (1999) and DEFRA (2013) guidelined figure of 320g CO_2e emissions per passenger km will be used along with Swedavia´s passenger numbers. The result is that in 2014 Brommas domestic passenger flights alone accounted for 0.5% of Sweden's total 2013 CO_2e emissions, or 0.27 million tons of CO_2e (Swedavia 2015d). More recent total national statistics are as yet unattainable, however the trend has been that of a steady decrease since 2007, whilst domestic flight emissions increased between 2012 and 2013 (Naturvårdsverket 2015c). This figure would likely be higher if domestic goods transportation were taken into account.

4.2.3 Buildings

In the scenario of keeping Bromma airport, the severe shortage of housing in Stockholm will still exist. Thereby, other areas in the city will have to be developed to create the housing that is needed. Since no political decision has been made yet regarding Bromma airport, there are other plans for development that do not include the possibility to develop the Bromma airport-area. These plans will briefly be presented below. After that the possibilities of building around the existing airport are presented.

4.2.3.1 *Plans for other development*

__The comprehensive plan__

The Stockholm comprehensive plan presents four strategies to strengthen sustainable development. These four strategies are; continue to strengthen the inner parts of the Stockholm area; focus on attractive focal points; connect the city districts and provide a vibrant urban development. These strategies are connected to specific, central areas which are; Odenplan, Slussen, Norra Djurgårdsstaden/The Royal Seaport, Norra station, Albano, Alvik, Västra Kungsholmen, Fridhemsplan, Liljeholmen, Telefonplan, Årstafältet, Hammarby Sjöstad, Gullmarsplan and Ulvsunda. (Stadsbyggnadskontoret 2010)

Other strategic areas for development in the suburbs of Stockholm are Kista, Vällingby, Spånga, Skärholmen, Farsta, Fruängen, Älvsjö, Högdalen and Brommaplan, but the comprehensive plan does not mention any future plans for the Bromma airport area. (Stadsbygg-nadskontoret 2010)

The area of Ulvsunda, which is close to Bromma airport, is a strategic area, which will be developed into a new housing area. The Administrative County Board believes that the area needs more attention and should be supplemented with more guidelines in the comprehensive plan, due to possible hazards from the airport. (Stadsbyggnadskontoret 2010)

City of Stockholm

Stockholm has a good potential both for growing and becoming denser (Figure 12). At the same time laws and rules such as demand for accessibility create a more extensive planning process and higher costs. Protection of cultural and natural values and the technical ability to build on certain places are other restrictions. One might say that there are both restrictions and driving factors, such as the lack of housing, when it comes to planning for exploitation and development. (Stockholms stad 2014a) The City of Stockholm have created three development scenarios:

- *Low*: few driving forces and many restrictions leading to little development, just a few spots where little densification occurs. This scenario leads to 73 000 new apartments.
- *High*: a lot of driving forces and few restrictions, leading to a lot of development in many places.
- *Comprehensive plan*: the scenario of *high* occurs within areas pointed out by the comprehensive plan and the scenario of *low* within other areas. This scenario leads to 150 000 new apartments. (Stockholms stad 2014a)

These 150 000 new apartments could be divided into 39 000 apartments within the areas pointed out by the comprehensive plan, 49 000 within the growing parts of the city (near the subway) and 62 000 apartments in other places like Royal Seaport and Hagastaden. (Stockholms stad 2014a)

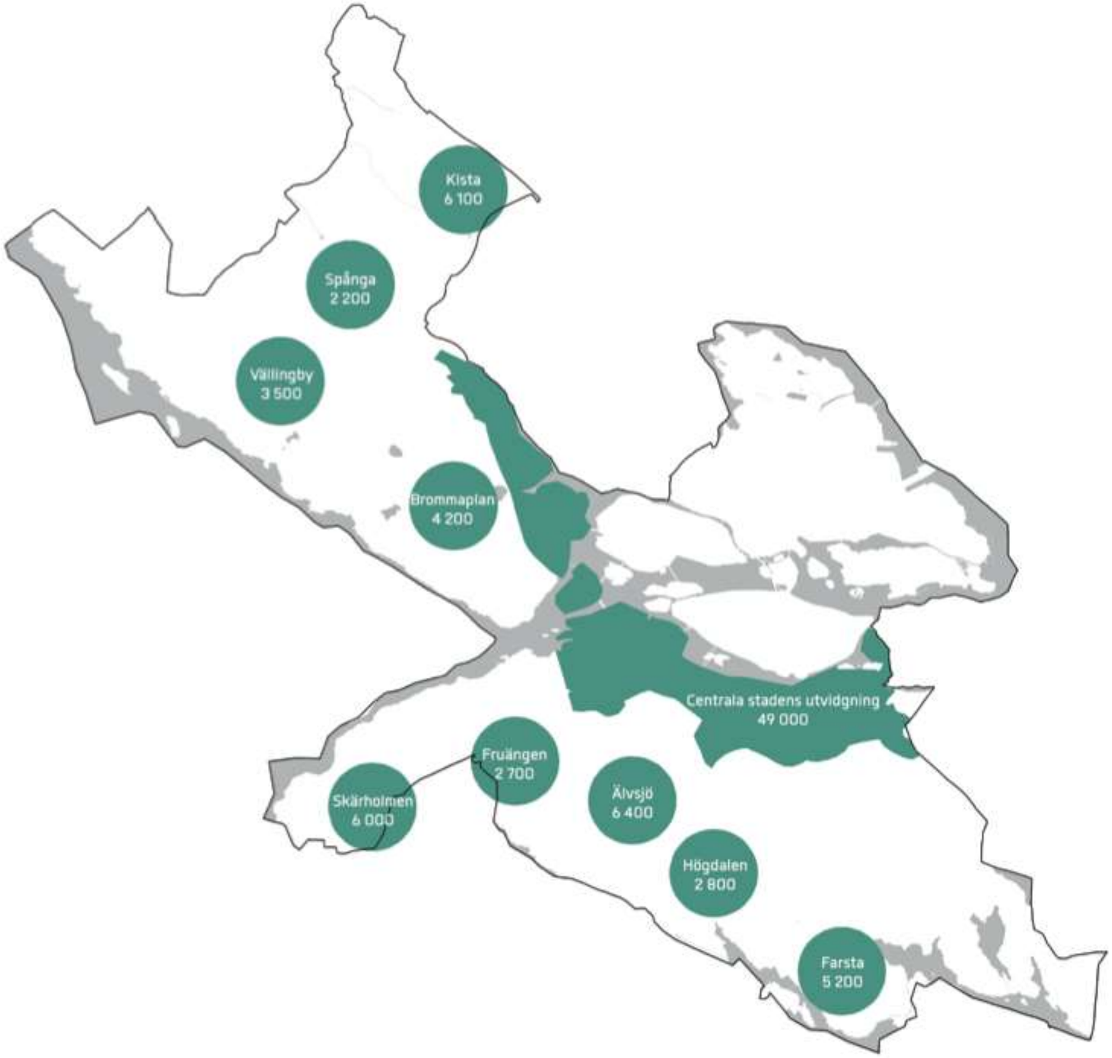

Figure 11. The amount of housing that can be built in different parts of Stockholm, excluding the Royal Seaport and Hagastaden (Stockholms stad 2014a).

Stockholm Chamber of Commerce

Even though the Stockholm Chamber of Commerce (sw: Stockholms Handelskammare) claims that there is a lack of apartments in the Stockholm region, they are critical of removing Bromma airport and using the area for housing. They approve of the city of Stockholm´s report in which 150 000 apartments can be created without removing the airport. Furthermore, focusing on the region as a whole they suggest that 350 000 apartments can be developed. According to them, over 70% of the land in the region is under developed (Stockholms Handelskammare 2014a).

They also want to focus on development close to the city and more specifically on development along the existing metro lines. According to them the possible development sites are; Täby, Arninge, Danderydsberg, Akalla, Barkarbystaden, Kymlinge, Hagastaden, Tekniska Högskolan, Östermalmstorg, Marieberg, Skärholmen, Masmo, Farsta and Skarpnäck. Also, they have pointed out areas that could be densified; Lidingö, Nacka, Söderort, Norsborg, Brommaplan to Hässelby Strand and the areas around Hjulsta, Akalla and Kista. However, they do not specify the amount of apartments in these areas, but overall this should lead to 350 000 new apartments. (Stockholms Handelskammare 2014a)

4.2.3.2 *Can the areas around the airport be developed?*

One way to both keep the airport and develop more housing in the Bromma airport-area is to develop the surrounding areas of the airport. But in order to develop these areas the noise levels have to be investigated as they are probably the biggest problem when looking into development in the surrounding areas. Even though the airport is located within an urban environment, the extension of the agreement for the airport was possible due to the unique condition whereby the airport is closed at night.

According to *The Stockholm model for detailed development plans and traffic noise*, new buildings have to be constructed in a way that indoor noise level during the night hours do not exceed 30 dB(A) equivalent and 45 dB(A) maximum level. (Stadsbyggnadskontoret 2010) More information about noise levels, check chapter 2.7.4 *Noise*.

Ulvsunda is an industrial area, between Bromma airport and Bällstaviken. This area is, as mentioned above, pointed out by the comprehensive plan of Stockholm as a strategic area. It is part of a major regeneration area surrounding Bällstaviken in Stockholm and the adjacent municipalities of Solna and Sundbyberg. In the Ulvsunda area 3500 new homes, more parks and attractive public spaces are planned.

The new rental agreement for Bromma airport gives opportunities to build new housing within the Ulvsunda area where the noise levels today are below 55 dB(A) L_{den} and 80 dB(A) maximum level and there are some other areas that also have the same noise levels. If a new housing area are built in the Ulvsunda area, the government will ensure that national interests will be taken into account (Stadsbyggnadskontoret 2010).

The western parts have a problem with noise pollution, which means that housing is not possible there and the area should be reserved for commercial use.

Except for the plans for development mentioned in the comprehensive plan the possibilities for further development in the surrounding area are limited. The potential areas to develop are scattered with no big continuous areas of land. These are mainly green areas that are of importance to biodiversity and recreation. Noise pollution from the airport has large impacts on the surrounding area, especially in the northern and southern parts of the runway (Swedavia 2015e). This limits the possibilities of building.

According to The Swedish National Heritage Board (Riksantikvarie-ämbetet 2015) there are several ancient remnants in these areas which are of cultural value. Also a water catchment reserve is located west of the planning area that may affect the possibilities of development (Naturvårdsverket 2015c).

4.3 Scenarios – Closing Bromma airport

In the event of closing Bromma airport two different transport scenarios are presented below describing different ways of redirecting the traffic elsewhere. In the first scenario all Bromma air-traffic will be displaced to Skavsta airport and in the second scenario all flights will be replaced by High Speed Rail (HSR).

Furthermore, once the area is made available for development it could be used to mitigate the shortage of available housing in Stockholm if added to the existing plans for the Stockholm region that is mentioned above.

To visualise how the area can be planned, two building scenarios have been developed using two different approaches to sustainable city building; the dense city, *Brommastan*, and the sparse city, *Bromma Grönstad*. Some argue that by building a dense city everything will be closer and thereby less transport and energy is needed. However, the dense structure compromises on the availability for green spaces and public areas leading to a decline in health etc. (Benton-Short & Short 2008).

In both scenarios a building programme will be established (see 0 Building program and Green space factor) to make sure that the building companies follow the goals set for both environmental and social sustainability. However, due to the limited time frame of this report no further details of the programme´s content was made.

Current services that are within the area today are for example a golf course and a golf range, a retrieval plant, and a plant store. None of these, but some of the ancient remnants mentioned above, are taken into account in these scenarios. All of the current services can be moved into other surrounding areas, like Bromma Blocks, the surrounding industrial area Ulvsunda and Täby Golf Course.

4.3.1 Redirecting flights to Skavsta Airport

Travel patterns and Stockholm time proximity.

In a report from the Stockholm Chamber of Commerce (2012) it is assumed that neither Skavsta airport nor Arlanda airport have extra
4.3.1.1 capacity to receive Bromma air-traffic. While this may be true to some extent for Arlanda airport, for Skavsta airport it is far from accurate (Friberg, pers.com. 2015-03-02). Based on updated capacity information, this scenario will involve all airline capacity moving to Skavsta airport, hence it is assumed that the airports and cities connected to Bromma airport will not be affected as the same travel 4.3.1.3
patterns will be maintained. Still, the level of service may be reduced in the area of increased travel time for some destinations and for some transferal options.

This scenario also incorporates present plans for a fast rail to Skavsta airport, reducing travel time from Stockholm to Skavsta airport to 40 minutes (Nissen 2007). Since Skavsta airport is also a small airport, it has been assumed that no extra check–in or security time will be needed compared to Bromma airport. This results in an extra 20 minutes effective travel time compared to Bromma airport. If all Bromma airport flights are moved to Skavsta airport, it should not be an issue with transfers between domestic flights, although there may be some insignificant increases in travel time for those who would otherwise have been transferring between Bromma airport and
4.3.1.2 Arlanda airport.

Economic impacts

The existing literature indicates that the increase in travel time might lead to reduced growth in employment, GRP and business attractiveness in the Stockholm region (WSP 2010; WSP 2011). Knowledge based industries and services are more dependent on good accessibility, making Stockholm susceptible to this decrease in travel service (Stockholm Business Region 2012). But no studies have looked explicitly on only increased travel times and it is therefore problematic to infer the magnitude of their effect on economic development. However, seeing as the additional effective travel time is so small it is assumed to be marginal and is therefore not expected to have any major disadvantages for long term social or economic sustainability in Stockholm or other parts of Sweden.

Time slots/capacity

Based on a schedule of an example week running through the busiest season, the summer season (Figure 13), the traffic in Skavsta airport is not as dense as in Bromma or Arlanda airport, and the largest number of flights are observed on Thursdays and Saturdays. The maximum number of flights does not exceed fourteen per hour and, as of yet, Skavsta airport has no stated hourly maximum capacity due to the fact that they have never been close to encountering any capacity issues or limitations. Bromma has a maximum capacity of 19 flights per hour which they reach during peak hours, mornings and evenings. Taking into account that currently the main purpose of Skavsta airport is to host low-cost leisure flights and the fact that their maximum peak occurs on Saturday and Thursday at lunchtimes, there is a high possibility to expand the airport's traffic to meet the need of redirecting peak time commuter flights from Bromma airport (Friberg, pers.com. 2015-03-03).

The only current capacity limitations for Skavsta come from the ascribed environmental standards of 75,000 flights/year (Friberg, pers.com. 2015-03-03). But, currently they are not using even half of this possible number of flights (Friberg, pers.com. 2015-03-03).

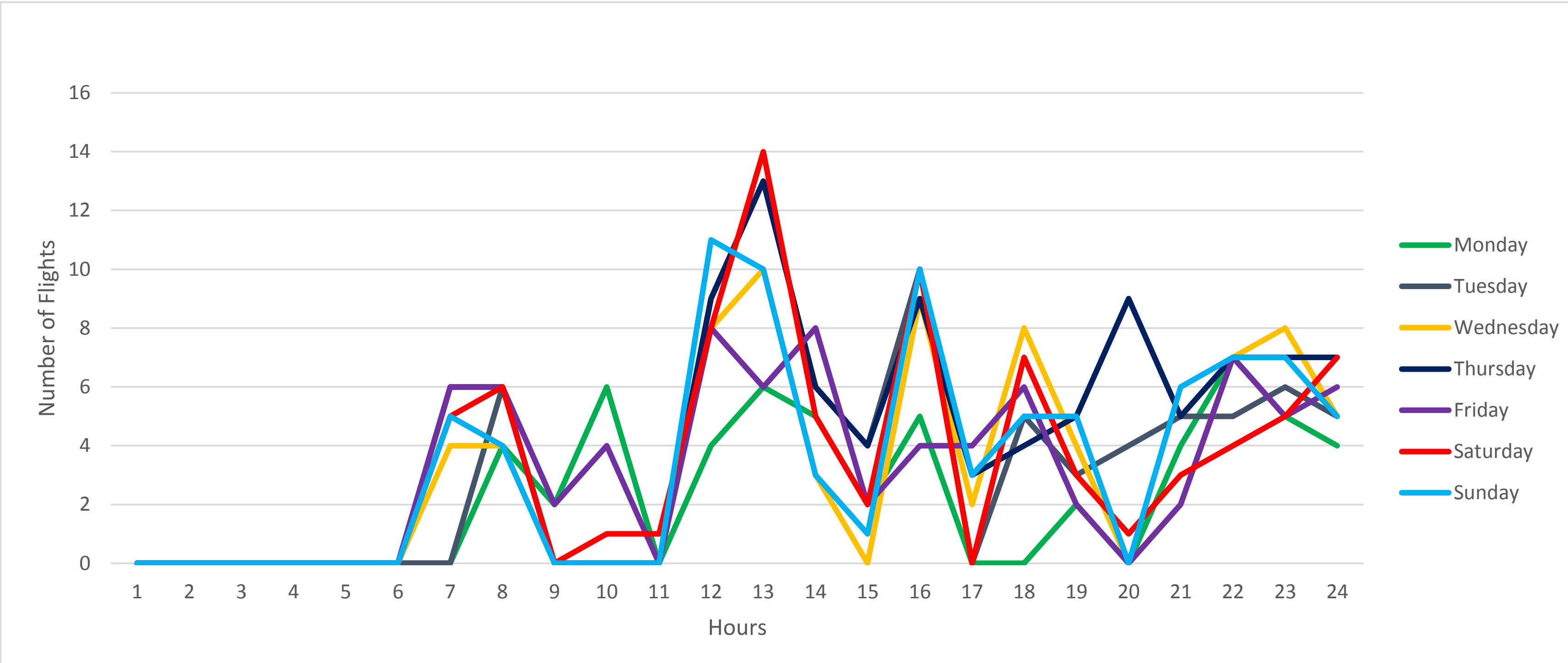

Figure 12. Total (maximum) number of flights during the summer season (29.03-24.10) in Skavsta. Number of flights can vary throughout the season (Data source: Friberg, Stockholm Skavsta airport, pers.com. 2015-03-02).

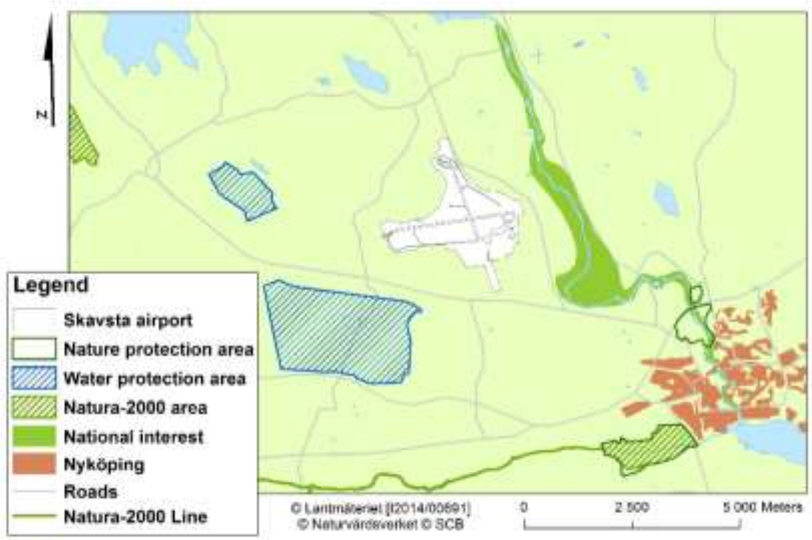

Figure 13. Protected areas in close proximity to Skavsta airport.

4.3.1.4 Environmental impact

The river Nyköpingsån and its surroundings east of Skavsta airport is of national interest for recreation and nature conservation (Figure 14), because of its good water quality, rich biodiversity and agricultural landscape and further down the river in Nyköping is a nature preserve (Naturvårdsverket 2015a). The river contains a great amount of fish species and the red listed thick shelled river mussel, *Unio crassus* (Naturvårdsverket 2015a). In the southwest are two protected water sources and along river Kilaån-Vretaån in the south is a nature preserve which is also a part of the network Natura 2000 (Figure 14). Skavsta airport is placed within the water catchment basin of Nyköpingsån, and might therefor affect the protected areas (Naturvårdsverket 2015a). An increase in air traffic at Skavsta airport would implicate further risks of damaging the valuable waters but with good mitigation major impact on the surrounding environment could be prevented. It is unclear to what extent the airport activities would affect its surroundings and therefor an EIA needs to be conducted. On a national scale, the benefits from closing Bromma airport could make up for the local negative effects in Skavsta, where the environment is already affected by air traffic.

CO_2e emissions would remain the same, as the number of flights would not vary, and the slight increase in transport km from the airports to the city is deemed insignificant.

Closing Bromma airport will evidently mean an end to noise from activities related to the airport, which will instead affect the airports where the activity is moved. Since this scenario aims to move all of this traffic to Skavsta airport, the effects on these will be reviewed below. Due to the location of Skavsta airport it avoids affecting as many people as Arlanda airport or Bromma airport. No major areas are affected by noise above 55 dB(A) L_{den} or 70 dB L_{Amax}, and would not be affected if Skavsta utilised the full capacity of 75 000 operations (Figure 15 & 16). Since no data is available on how many residents are affected by noise from Skavsta airport, new calculations were made using noise maps of the affected areas if the current permit's full capacity were reached and population GIS-data from Statistics Sweden. Maps of 55 dB(A) L_{den} and 70 dB L_{Amax} were used. The L_{Amax} value was calculated from noise generated from the loudest of the current airplanes trafficking the airport, the Boeing 737 - 800. The results showed that, as long as no significantly louder airplane is utilised, residents affected by 55 dB(A) L_{den} at full capacity would be ca 300 (Appendix 5. Figure 1). The number affected by 70 dB L_{Amax} would be ca 580. Skavsta airport is also looking into changing the approach of the airplanes to possibly reduce impact further (Friberg pers. comm. 2015-03-02).

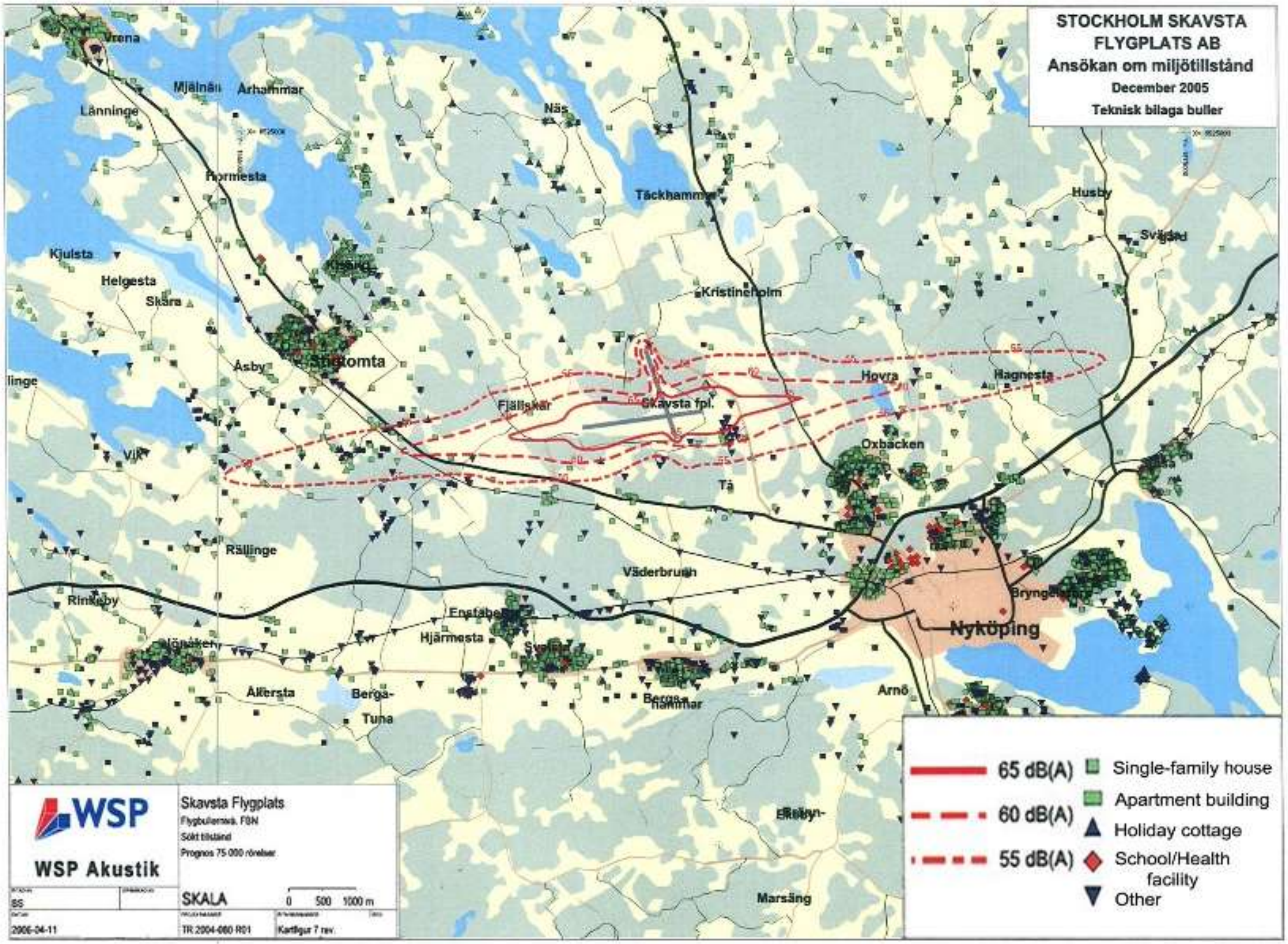

Figure 14. Calculated 55 dB(A) L_{den} (outmost line) generated at full capacity according to permit (WSP Akustik 2006).

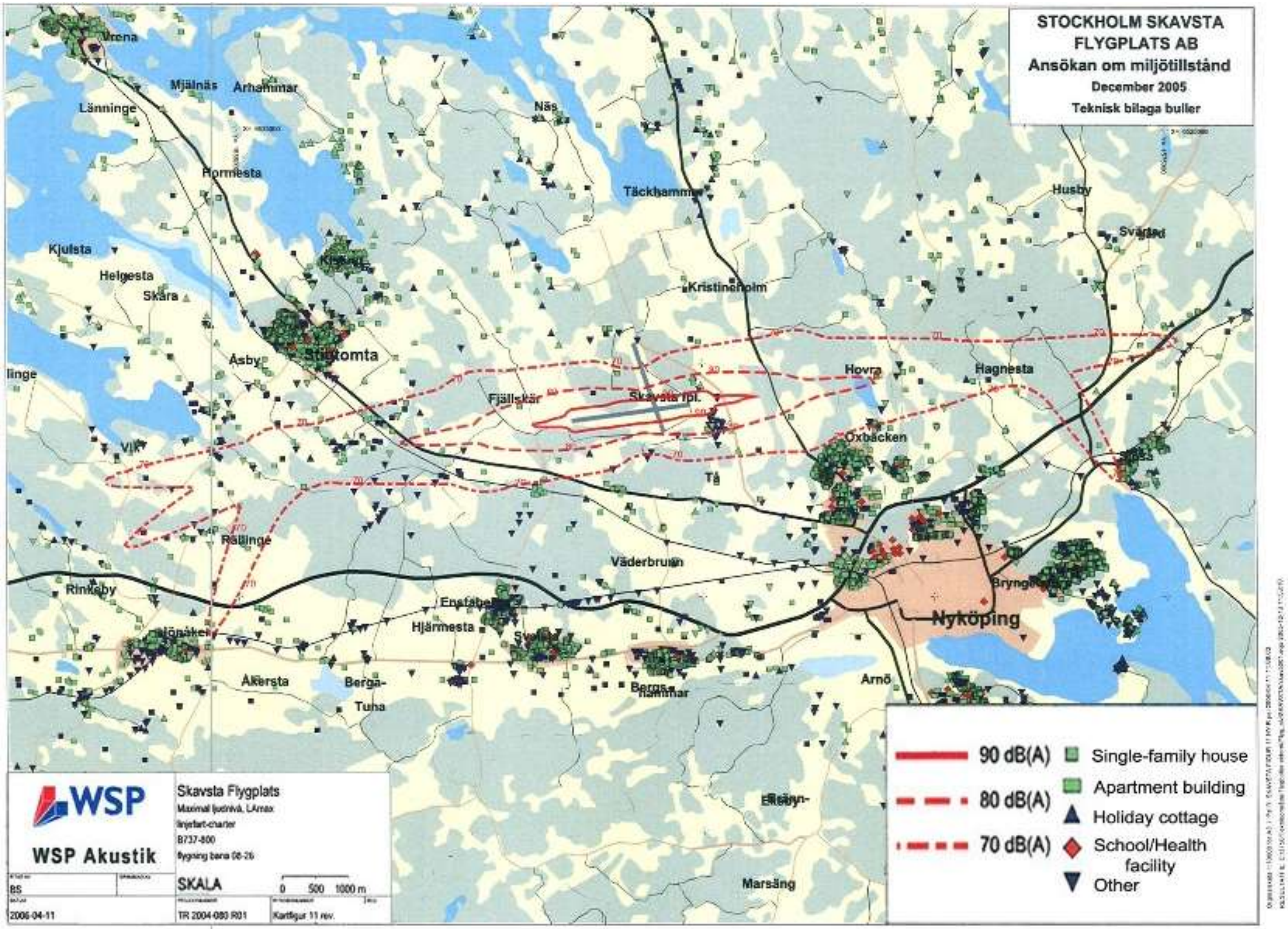

Figure 15. 70 dB(A) L_{Amax} (outmost line) as generated by Boeing 737-800 at full capacity according to permit (WSP Akustik 2006).

Arlanda alternative

Travel time

Moving the domestic traffic from Bromma to Arlanda will most likely increase the effective travel time to domestic destinations. Bromma is a smaller airport and can offer faster security and check-in times compared to Arlanda (Waldfogel 2014). Swedavia customs practices mean that one would need to be at Arlanda roughly 15 minutes earlier than at Bromma when flying domestically, however this change is considered marginal and insignificant.

Capacity

Due to Arlanda and Bromma having overlapping rush hours, moving the air-traffic over would lead to some conflict in schedules. While data suggests (Brobeck pers. Comm. 2015) that rush hour operations are still well below the 90 operations per hour maximum capacity of Arlanda (Antagandehandling 2006), approaching that theoretical maximum would likely reduce Arlanda's ability to adapt to extreme circumstances, e.g. emergency landings, knock on delays etc., and is not desirable. Commuters will therefore have to travel outside the rush-hour traffic, later in the day, making daily commuting less attractive. Since these time slots are most important for people traveling in business, this option will have some negative impact on regional business friendliness in Stockholm or other parts of Sweden (Svenska handels kammaren 2014). Another possibility could be that the airport reduce the amount of non-business operations over rush hours (Wallin, pers.com. 2015-02-25). But the effect of this reduced level of travel options cannot be properly assessed here and will have to be studied further. The lack of rush hour capacity is considered a large negative factor, and the main reason for excluding Arlanda as a separate scenario.

Noise

Residents affected by noise levels above 55 dB(A) L_{den} from Arlanda Airport were ca 2 200 in 2004, and the number affected by maximum level 70 dB(A) were 11 400 (Boverket 2009). Arlanda airport already affects the second largest number of people in Sweden, after Bromma.

4.3.2 Redirecting flights to High Speed Rail (HSR)

In this scenario all domestic Bromma flights will be replaced by three HSR lines, two running to the south to Malmö and Gothenburg and one to the north to Umeå (Figure 17). The international flights will be moved to Skavsta airport, but will not be discussed here as Skavsta airport capacity has already been addressed and is not a constraint.

4.3.2.1 *Travel patterns and Stockholm time proximity*

With increasing complaints of bad service unless expressly paid for and thoughts on "standing room only" flights (Tuttle 2012), rail travel has an increasing possibility to compete with short to medium distance flights. Rail offers increased personal space and comfort and more flexible options for time usage, for example by having specifically designated carriages for dining or silence (Lane 2012), while the difference in GHG emissions which is over an order of magnitude smaller for electric rail (DEFRA 2013). The only barriers to rail overtaking air travel that can reasonably be mentioned are cost and speed, the difference of these factors between transport modes can however be expected to shrink. Fröidh (2008) suggests that with the adoption of yield management, rail networks could already compete with air travel in the area of ticket pricing. Add this to the expected rise in fossil fuel prices from decreasing supply (Hirsch et al. 2005) and the advantage may yet be reversed. Similarly, technological advances leading to the HSR, including Magnetic levitation (Maglev) trains, combined with ever more congested and time consuming airport stays make for comparable city-to-city travel times between rail and air (Nelldal 1998; Engström et al. 1997; Fröidh 2008).

For these reasons, discussions and investigations into building fast rail connecting Stockholm to southern and western parts of Sweden have been ongoing for the last two decades (Region Skåne et al 2012). The most discussed alternative is building new fast rail going from Stockholm to Gothenburg and Malmö via Jönköping, making Jönköping a new rail junction (Figure 18) (Banverket 2008). Other stops will most likely include at least Norrköping, Linköping and Borås on the Gothenburg line with the addition of Hässleholm on the Malmö line, resulting in all but two uninterrupted stretches being less than 100 km long. The average speed of these discussed lines would be around 250 km/h (Banverket 2008; Region Skåne et al 2012), this speed would likely be increased if the distance between stops were increased.

Scenario 3 will propose the use of the above mentioned HSRs in the south, combined with a hypothetical HSR going north, stopping at Gävle, Hudiksvall, Sundsvall, Örnsjöldsvik and Umeå, resulting in stops around 80 – 170km apart.

However, can Stockholm be connected to other parts of Sweden by HSR and be a realistic replacement for domestic flights from Bromma airport? Research suggests that for domestic business travellers the price of travel in the south of Sweden is already higher for air than for rail (Carlsson 1999). For air passengers meanwhile, improvements to environmental impacts resulting from their mode of transport is worth paying extra for and travel time is highly valued at 150 SEK/hr (Carlsson 1999). This means that the most important impacts to assess for the competitiveness of this scenario are time for and of travel and environmental gains.

When comparing effective travel time between the current situation and that proposed in Scenario 3, it has been found that two of the top ten Bromma-destinations; Sundsvall and Gothenburg will have shorter travel time in scenario 3, and thus would benefit from this scenario

Three of the cities; Malmö, Ängelholm and Umeå, will experience a marginal amount of extra travel time, where less than 35 minutes will be added in scenario 3. For the remaining five destinations; Halmstad, Kalmar, Ronneby, Visby and Östersund, the extra travel time will be considerably higher, between 70 min and 225 minutes.

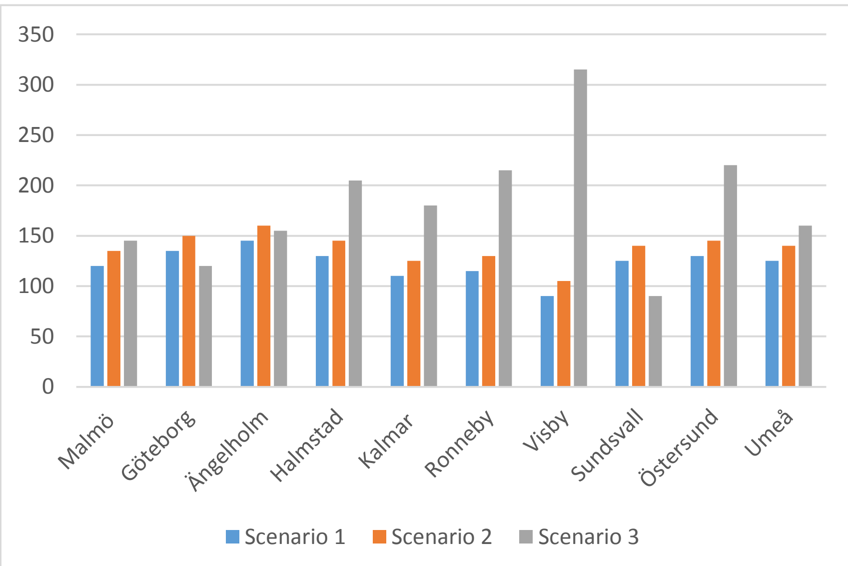

Figure 16 Comparison of travel times to Bromma's top 10 destinations between all transport scenarios (Data source: Waldfogel 2014).

*Figure **17**. What the HSR and rail infrastructure will look like in scenario 3. It also shows the time proximity from Stockholm to Bromma's top ten destinations will be around 250 km/h (Data source: Banverket 2008; Region Skåne et al 2012).*

However, these airports together handle 25 % of today's Bromma airport traffic. This means that 24% of travellers would experience a decrease in travel time, 51% a marginal increase and 25% a large increase in travel time in scenario 3 when substituting air traffic from Bromma airport with fast rail and rail.

4.3.2.2 *Economic impacts*

Just like in the Skavsta scenario increased travel times will likely decrease growth in employment, GRP and business attractiveness in Stockholm and connected regions (WSP 2010; WSP 2011). As also stated previously, no studies have looked explicitly on only increased travel times and it is therefore problematic to infer the exact magnitude of their effect on economic development.

Regions experiencing better travel times will likely see better opportunities for economic development and those parts experiencing travel time increases up to 35min will likely experience only marginal disadvantages. The remaining regions with larger increases in travel time will experience greater negative economic impacts.

However, the economic consequences for these most affected regions are coupled with even greater uncertainty. The reason being that it is impossible to predict the effect on destination airports. Practically all air traffic goes through Stockholm and the smaller regional airports already run with financial deficits which are covered by their respective municipality. There is therefore a chance that some of these airport will be forced to close down operations when deficits increase, but the chances of this are not assessed. For example, in the case of Kalmar 5000 jobs would be lost if the airport was to close down (WSP 2011), although this study does not account for better travel times by train. At the very least we know that traffic will be reduced in these areas and only their Arlanda flights will remain. These effects will clearly be smaller than if the airport were to be shut down altogether.

4.3.2.3 *Time slots/Capacity*

As has now been established, the restricting capacity is the per hour capacity, rather than daily or annual, therefore this is the capacity which will be assessed here. Considering that the capacity of Bromma airport is currently 19 flights per hour (Brobeck, pers.comm. 2015), and the maximum capacity of airplanes travelling through the airport is 112 people (Malmö aviation 2015), it can be estimated that maximum hourly traffic through Bromma airport is approximately 2128 people. However, according to 20% of those would be going north and 80% south. As train size has not yet been defined (Region Skåne et al 2012), it is assumed that they will be similar in capacity to Eurostar who can accommodate 766 passengers per train (Rail Europe 2007). This would mean that the northern route would need only 1 train over rush hour (possibly reducing the number of carriages to increase efficiency) and the southern route would need only 2.5 trains per hour. This is however nowhere near maximum capacity as 12 trains per hour is considered a good HSR line capacity in Europe (Connor 2011).

However, this is a very rough estimation and other factors, such as current train movement times and frequency, as well as more precise destination preference need to be taken into account. The factor that is potentially the most constraining in this scenario is Stockholm railway station available capacity, for which no data could be found, but research would need to be done. A possible solution to lack of capacity could be to create a new "terminal" and separating northern destinations from the southern ones.

4.3.2.4 *Environmental impacts*

The resulting calculation shows emissions of 0.02million tons CO_2e, resulting in savings of up to 0.25million tons CO_2e, or over 0.45% of total Swedish CO_2e in 2013 compared to the current situation.

In comparisons made by Naturvårdsverket (2002) it is clear that train has significantly less impact then airplane when travelling. In examples between Stockholm – Gothenburg and Umeå – Stockholm, train consistently performed better in categories Climate, Acidification and Ozone damage. On a scale where 0 is the best result and 1 the worst, train was at or close to 0 and airplane at or close to 1. However, train have higher effects in regards to land use, and slightly more people affected by noise. Also, construction impacts are not considered.

4.3.2.5 *Noise*

Making train travel a viable option through infrastructure investments would further reduce the number of people affected by air traffic related noise. In this scenario Skavsta airport will only receive the 9700 international flights of the total 47 300 from the 2013 figures (Swedavia 2015b). In 2006 there were 225 000 people affected by 55 dB L_{Aeq} related to rail traffic noise in Sweden (Eriksson et al. 2013). Using the current infrastructure for trains would not increase this number, however new tracks will need to be built in some areas, thus influencing new areas, but depending on the type of train used there might be a reduction of noise levels.

Noise from commuter and inter-city trains is both easier to reduce by walls and windows, and easier to mitigate then road traffic noise. This is due to train traffic noise having less energy in the low-frequency part of the spectrum (Eriksson et al. 2013). It is unclear whether train noise has the same advantage over air traffic. On the other hand, the problem with air traffic is that people don't have access to a quiet side of the building as they can have with train and road traffic. Having access to a quiet side is shown to have some positive effect on how people experience the noise (Eriksson et al. 2013).

MagLev

Magnetic Levitation trains are an option within the HSR scenario, however the lack of consistent data in the literature, and the short term experiences garnered so far have prevented the authors from using it as the main scenario. The Maglev functions by using magnetism to keep the carriages from ever touching the rails whilst in transit, reducing friction to almost zero. In theory this should lead to reduced noise and vibration, reduced maintenance costs, higher theoretical speeds, lower energy usage and lower construction costs (e.g. Kidd 2008; Chopade and Sharma 2013; Wee et al. 2003). However, critics state the opposite to be true, often also citing the irrefutable disadvantage of incompatibility with existing rails (Lee et al. 2013, Vuchic and Casello 2002). What cannot be denied is that Maglevs are able to navigate tighter corners and increased gradients at higher speeds (Chopade and Sharma 2013) which along with the fact that tracks are raised reduces the need to mould the environment around the tracks, especially in mountainous terrains. The raised tracks also dilute the barrier effect often prevalent in HSR (Campos and De rus 2009, Lane 2012).

It might also be worth considering that new technologies can help attract foreign researchers and investors, so the fact that the technology is still underdeveloped and researched may indeed be counted as a pro, rather than a negative uncertainty (OECD, 2004).

4.3.3 Dense city – “Brommastan”

Introduction

In the scenario of the dense city, Brommastan, focus will be placed on creating a dense area with many different functions. The area will be 4.3.3.1 a mix of high rise buildings, commerce, services and meeting places (Figure 19 & 20). The need for transportation will be low and focus is on prioritising bicycling and walking ahead of car use. This will be an area for people who want to live in a city like-area; families, single-households, students and elderly. Green spaces will be available, although in a smaller format like pocket parks.

Figure 18. New housing structure in Brommastan, SketchUp model.

Brommastan should be a place where everyone can and wants to live through all stages of life. Therefore, Brommastan should have both rental apartments and cooperatively owned apartments, the proportions being 70% rental apartments and 30% cooperatively owned. Increasing the share of rental apartments in Stockholm as a whole is an important part of resolving the segregation problem. However, as mentioned earlier most newly developed rental apartments are expensive. Maybe after the success of Gothenburg’s rent controlled apartments (see Social Sustainability), the politicians of Stockholm will follow. Brommastan would be a good place to try this out.

Buildings

The political majorities’ main argument for closing Bromma airport is to use it for a housing development and thereby solve a part of the lack of housing in Stockholm. The green party have their vision of building 50 000 apartments and create 30 000 jobs in less than 15 years. However, this vision was strongly argued against by the Stockholm Chamber of Commerce in Stockholm. According to them, it is only possible to build circa 600 apartments per year, which makes building 50 000 apartments within 15 years unrealistic (Stockholms Handels-kammare 2014a).

Another argument by the Stockholm Chamber of Commerce was that building 50 000 apartments makes the area too dense. The area of Brommastan is around 200 hectare which would give a density of 250 apartments/hectare in the Green Party vision. In Hammarby Sjöstad only 11 500 apartments are planned to be built in an area of 160 hectare, giving a density of 72 apartments per hectare. This gives an example of how dense it would be in the Green Party´s vision if 50

000 apartments were to be developed. (See Table 3 for an illustration of density levels).

According to the calculations in Method (3.3.3). Brommastan will consist of 8000 apartments in 3-5 floor buildings, 8700 apartments in 5-9 floor buildings and 9000 workplaces (Table 3, Figure 21). In total there will be 25 700 apartments and working places in 2050, which means that 856 apartments will be built each year.

The area will consists of approximately 33 400 inhabitants.

4.3.3.3

Table 3. An illustration of the density level and number of apartments in Brommastan compared to other dense areas in Stockholm (Stockholms Handelskammare 2014a, Stockholms stad 2015).

	Hammarby sjöstad	Östermalm	Brommastan
Planned area [Ha]	160	250	200
Apartments	11 500	20 000	16 700
Inhabitants	28 000	40 000	33 400
Working alaces	5000	40 000	9000
Density [Apartments/Ha]	72	80	100

Figure 20. Visualisation of Brommastan, SketchUp model.

Energy use in Multifamily Buildings

The energy use in multifamily buildings, like in the high rise buildings planned in Brommastan, needs to be as low as possible. In 2006, the average energy use for domestic hot water and space heating in multifamily houses using district heating was 153 kWh/m^2 a number that decreased to 148 kWh/m^2 in 2008 (Swedish Energy Agency 2009). Today, the national requirements for new properties are 110 kWh/m^2, a number the planned buildings in Brommastan are to follow or lie below.

To accomplish this, the buildings need to be designed to be as energy efficient as possible. There are several ways that this can be done; triple-paned windows, the best available insulation, ventilation with heat-recovery or radiated heating and cooling in the buildings as well as natural shading for cooling. The design of the buildings will be decided upon by the construction companies following the building programme.

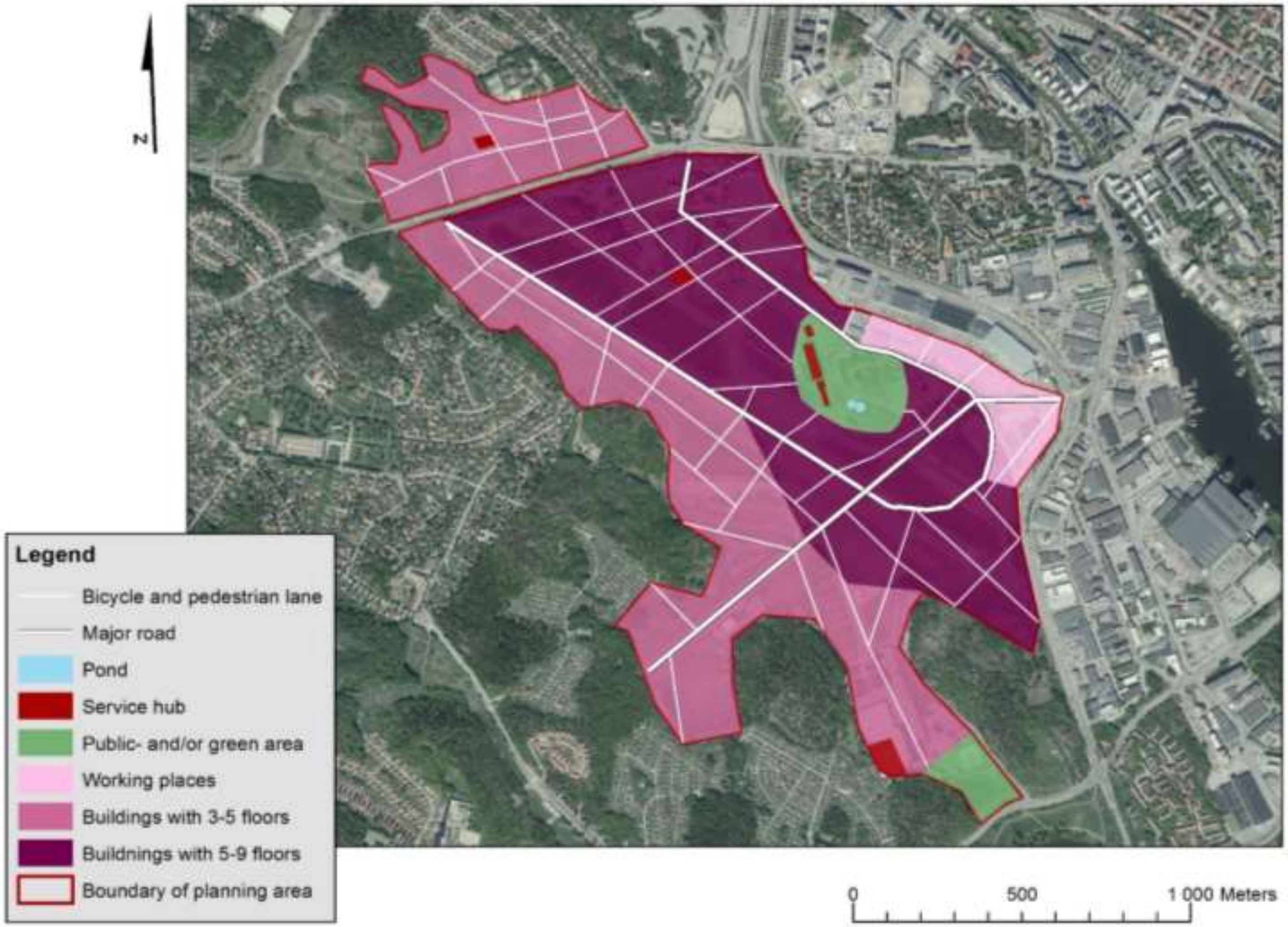

Figure 19. An overview of the planning area in Brommastan.

Some roofs will have solar panels installed to make them energetically self-sufficient and others will have green roofs with a living surface of plants growing in a soil layer on top of the roof. The advantages of this kind of roofs are numerous: green roofs save energy through good insulation, they protect the roof membrane and retain and filter rainwater (Greenroofs 2015). It is also possible to combine green roofs with solar panels. Many Swedish companies already propose this kind of product (Veg Tech 2015). In Brommastan, roofs will be used as is suitable in each instance, but residential, commercial and service buildings roofs will all be utilised in some way.

However, technical solutions are worth nothing without making the people living in the buildings more aware of their energy consumption. Therefore, smart meters in each household will be installed to measure energy and water consumption. This will help residents to decrease their energy and water consumption by being aware of how much they consume.

4.3.3.4 *Water management in the buildings*

Today 200 litres of water are used per person per day in Stockholm (Hultman, 2009). In Hammarby Sjöstad, a newly developed area in Stockholm, the city of Stockholm aimed at reducing the water consumption by 50%. Today the level is at 150 litres of water per person per day (Stockholms stad 2007), achieved by installing washing machines and dishwashers with energy class A, low flush toilets and air mixer taps. By having the same installations in Brommastan, the goal is to reduce water consumption to 100 litres per person per day.

Waste, water and sewage

When planning for solutions regarding energy, waste, water and sewage in Brommastan, the same kind of model will be used as in Hammarby Sjöstad; the Hammarby Eco-Cycle Model (Figure 22). Food waste will be used to produce biogas that fuels vehicles, whilst the mulch becomes nutrient-rich fertilizers that can be used in agriculture. Combustible waste is converted into district heating and electricity. The system is built to produce energy locally; organic waste will be separated and used in biogas production while other solid waste will be incinerated in Högdalen’s combined heat and power plant (Stockholms stad 2007).

In Hammarby Sjöstad waste water goes to Henriksdal waste water treatment plant where it is treated and then used in production of district heating and cooling. In this plant biogas is extracted from the sewage plant (Stockholms stad 2007). In Brommastan a similar solution will take place when a suitable waste water treatment plant is found. The Bromma sewage treatment plant will be shut down in 2018 and plans for building a tunnel from Bromma to Sickla (near Hammarby Sjöstad) exists. Henriksdal will then be expanded and renovated to be able to take care of the expanded waste input.

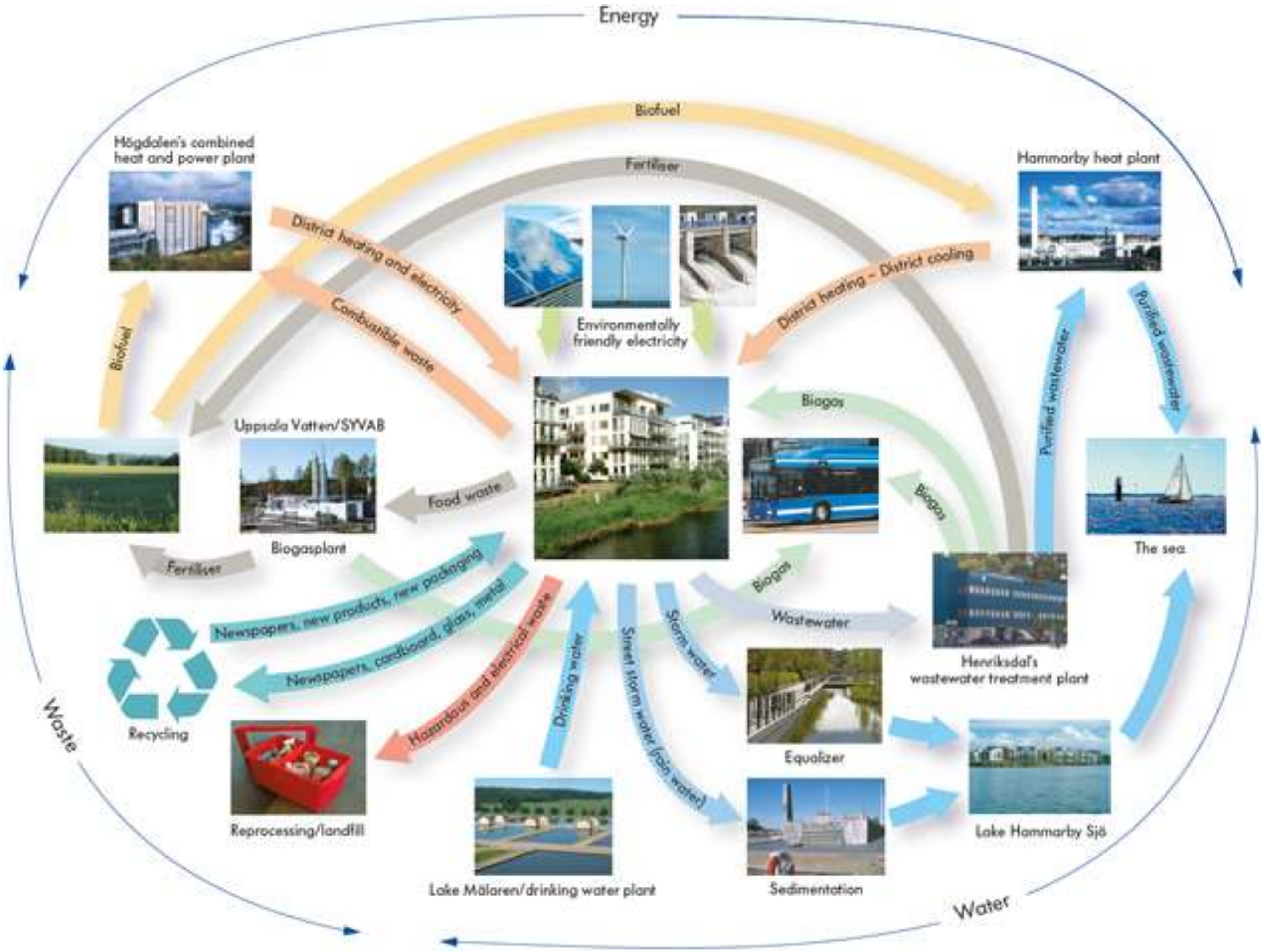

Figure 20.Hammarby Eco-Cycle Model, Stockholms stad, 2014b. Environment. GlashusEtt- environmental information centre.

The rainwater from the streets will be treated locally in Brommastan using the green and blue structures and hence does not burden the wastewater treatment plant in Henriksdal. Rainwater from courtyards and roofs, which is not absorbed by the green structures, is planned to be led off into Bällstaviken.

4.3.3.5

Värtaverket provides the Bromma area with heat and electricity. It uses coal (55%) and biofuel (45%) to produce electricity and heat. Fuel and ash are handled in a closed system in order to minimize dust, odours and noise. Värtaverket consists of a heat and power plant (KVV6) which provides 50% of the local heat demand. KVV6 also has flue gas condensation to recover heat energy from combustion in the power plant. Flue gases contain water vapour and by cooling them, hot condensate is released and used for district heating in Bromma. Electricity and heat are also produced in the second heat and power plant (KVV1). In this plant liquid fuels such as bio-oil are used (Fortum, 2014).

Coal is a fossil fuel and is used in Värtaverket to produce both electricity and heat, it can however be replaced by 100% bio fuel or by combustible waste such as food waste (Figure 22). Mälarenergi (2012) have this technology available and consider 75 % of waste to be a renewable energy fuel, in for example Västerås they already use food waste for heat production. This could be applied in Värtaverket but it would need to be upgraded since food waste requires special furnaces. In this way the waste is returned to the community as a resource instead of ending up in landfills.

With today's waste combustion technology, toxic and hazardous organic substances are combusted. Pollutants that are not combusted such as heavy metals are separated in several purification steps. (Fortum, 2014) Another benefit with using waste as an energy source is that waste is resorted and recycled again before entering the furnace.

Waste Management

A vacuum system for municipal waste transportation is planned for Brommastan. The system is based on an underground pipe system and a terminal building located outside the area (Figure 23). Each type of waste has its own chute i.e. plastics, metals, combustible waste etc. All chutes are connected to a system of pipes that are connected to a central collection station with a waste container for each waste type. The chutes are emptied one at a time by an automatic computer controlled system whenever they approach capacity. It takes approximately 30 seconds to empty each chute. When emptying the waste, it is sucked through the pipe system with a speed of approximately 70 km/ hour with the use of a large fan system. The air flow is then purified through a filter before being released into the surrounding air.

Figure 21. Illustration of the Envac underground waste system (Envac 2015).

The large waste containers are then transported by container vehicles (Hämtaavfall.nu, 2010) with combustible waste transported to a biogas plant to produce biogas (on which the container trucks run) or to a heat and power plant to produce heat and electricity.

By having the terminal outside of the area fewer large vehicles need to transit the area liberating the space for other uses.

All the mentioned system solutions require time and financial investments. But these investments are put in long term solutions that will serve Brommastan by providing the area with environmental benefits in the form of reducing CO_2e emissions, reducing consumption and making the area more available and attractive for the residents.

In order to implement the ideas behind Bromma eco-cycle model, more research is necessary. Different stakeholders such as municipality officials, companies and politicians should cooperate to implement this model in its earliest stages. Experience from the Hammarby model can be useful in the planning process for Brommastan since a similar closed cycle model will be developed.

It's also important that different companies are involved in the planning process in order to consider different aspects in the model. The municipality should involve waste recycling companies, Fortum and Stockholm Vatten, in the planning process to find the best available environmental solutions in relation to energy, waste, water and sewage. Hammarby experiences have shown that there are different ideas of how the model should be built and connected to the existing system. The future systems should go hand in hand with the pre-existing systems in the area.

Behavioral aspects

As mentioned earlier, one of the main aspects in successfully implementing models like the Hammarby Eco-Cycle Model is to increase residential awareness about their behaviour towards energy, waste and water management. Combining direct and indirect feedback from energy suppliers has big potentials for changing consumer's behaviour and achieving energy savings. Direct feedback includes information provided directly to the consumer through computers, smart phones and meters combined with in-home displays. Indirect feedback could be bills containing historical and comparative information on energy consumption.

Community based initiatives can also lead to long term behavioural changes as they result in new social norms. These initiatives can for example be information sharing, like Allmännyttans energy saving campaign (2012) based on providing simple and practical tips on how to reduce consumption on their website (Allmännyttans energispar-kampanj 2012), or friendly competitions between neighbours in the community to reduce consumption and waste production. The municipality and its residents should work together to promote similar initiatives.

4.3.3.6 *Social infrastructure*

Stockholm is a city for everyone, regardless to gender, social status, age or origin. In order to create such a vibrant and accepting city, good physical planning is needed. According to Stadsbyggnadskontoret (2010) Stockholm is going to be the most accessible capital with streets, parks and squares and the design of buildings helping to enhance children's needs of safe and inspiring environments.

Having adequate public services within a short distance of citizens is very important for long term urban development (Stadsbyggnadskontoret 2010), both for reductions in transportation needs and for accessibility for those less mobile. Recently there has been a strong critique towards the trend that the public services, such as schools and day-care services, are concentrated in larger but fewer units and that these services are not expanded as fast as they should be. Indeed, Stockholm now wants to promote local centres instead of the post-war service structures that were developed in the external suburbs (Stadsbyggnadskontoretarchello 2010).

A safe urban development is important in urban planning. Women, elderly and young people often feel unsafe in neighbourhoods after dark, and this concern impacts everyday life. Integration efforts are also one way to make people get to know each other, which can result in people feeling safer in new areas. People with similar backgrounds and interests often tend to live near each other, and even though mobility increases, people seldom visit areas where people with different background live. Therefore, it is important to increase public areas like streets, squares and parks so they can work as a platform where people with different kinds of backgrounds can meet in a natural and relaxed way (Stadsbyggnadskontoret 2010).

Mobility is an important feature inside the area as well as outside. The main issues concerning mobility are often poorly cross-connected public transportation, road barriers and insecure areas. Cars are often prioritised in planning, which make it more difficult for the mobility of elderly and children. In order to improve the connections and communications for everyone, pedestrians, cyclists and public transportation should be given good conditions throughout the area as well as outside of it (Stadsbyggnadskontoret 2010).

Brommastan will be one of the areas in Stockholm that contributes to these aspects, helping it to transform into a vibrant and safe city with services close to the citizens.

The new settlement will include mixed functions in order to suit different life stages and styles. The historical buildings in the area will be preserved and used for cultural activities such as a concert hall together with other usages that are available for people both inside and outside of the Brommastan area.

In order to build a new dense area with as much functionality as possible, the structure of the neighbourhood will be as efficient as possible with a tight grid which prioritises pedestrians and cyclists but with efficient public transportation.

In this dense city design, people have the possibility to both work and live. The area will consist in restaurants, gym, grocery stores, banks, schools and preschools. The area will be a lively area throughout the day, a place where you can have a coffee break in the middle of the day as well as visit a good restaurant in the evening. A place where it is easy to live and deal with everyday chores.

4.3.3.7 *Public spaces*

In Brommastan, the main street makes it possible to combine the dense structure with public areas. By having the main street in a u-shape it will be easy to access for all inhabitants. Along this street a small town-feeling will be created by having shops and markets along the street with plants on the sides. Having a lot of movement in the area gives it a safe feeling. Along the other streets the bottom floors in some buildings will be set aside for smaller commerce and laundry rooms. Having people doing laundry on the street level creates a constant presence in the streets. Of course, all the public areas will be adapted for the disabled and the elderly.

The area around the buildings marked as cultural heritage will function as a meeting place as well. Here, cultural events, restaurants, libraries and other services will gather making this a place for both the inhabitants but also for people from other parts of the city.

In a dense city the streets are narrower and perhaps darker due to blockage of the sun, thus it is important to plan for good lighting. To achieve a more efficient land-use, the area around the street lights could be used for an outdoor gym as seen on the picture below Figure 22(Figure 24), or for a bench, litter box etc. An innovative design of the lights will also give the area a sense of modernity.

Figure 22. An example on how to use the area around the street lights (LED Lighting Blog 2013).

In a dense city the open spaces will have to be limited as mentioned above. Thus it is even more important to make the available open places as good for children as possible. In Brommastan, playgrounds will be located close to apartments and a large central playground will be placed in the middle of the u-shaped main street. Exactly how these are designed should not be decided only by the planners but together with children. By for example having them draw the playground of their dreams the children will be included in the planning process. Apart from playgrounds, all outdoor environments will be friendly for children. Since there will be few cars driving around in the area, the streets will be available for biking, playing and meeting other children.

Another way to create meeting places is through urban gardening. Urban gardening is not a new concept, during the Second World War people were farming in the cities to increase the food supply and allotments have been used for many years. However, urban gardening is more connected to a social movement and to creating meeting places than actual food supply, even though growing your own vegetables is of course an important part of the concept. Moreover, it focuses on pedagogical and recreational values. It is a good way for both being able to do gardening in a dense place and for integrating different people with different ages and background with each other (Nilsson 2013).

A positive aspect of urban gardening is that it does not need that much space. It can be done on arable land and in pallet rims, on roof tops, along walls (vertical gardening) and other forgotten spaces in the city (Nilsson 2013).

4.3.5.8 *Green infrastructure*

Even in the dense city, or maybe even more so in the dense city, it is important to make room for the green infrastructure so that the benefits from its different values can be of use. Not least the values of providing better human health and mitigating the consequences of climate change are essential in the dense city with its pollution levels, stressful living conditions and impermeable, heat absorbing surfaces.

Although bigger green areas lower city temperatures more than smaller areas (Dimoudi & Nikolopoulou, 2003) and can also absorb more storm water runoff (Boverket 2010). It is important to remember that it is not just the quantity of green space but also the quality of it that decides the amount of values that can be brought from it. In this sense an urban garden might contribute more to biodiversity than a formal park, or a thick green roof contributes more to a reduction in storm water runoff than a thin green roof does. To include water surfaces in the city helps to reduce the urban heat island effect. Larger surfaces generally have a bigger effect but running water and especially fountains are also quite efficient (Kleerekoper *et al.* 2012) while simultaneously serving as an aesthetic and calming element in the city design. Water surfaces can also be designed to absorb storm water runoff, for example in the form of canals or wetlands.

Ways of integrating green infrastructure in a dense city are many. By using the buildings and open spaces in the area a lot of green spaces can be created. In Brommastan the roofs and walls of the buildings will be used to integrate more vegetation into the city, and this will also be a place for possible urban gardening. The environmental and social building program and the green space factor will make sure that the construction companies include green and blue spaces on and around their buildings. In the area a central park with a pond will work as the major green area. Furthermore, smaller pocket parks and other

Figure 23. An example on how vertical gardening and pocket parks can look and be used (Future Green Studio 2014).

green spaces will be created between the buildings, these will also be places for urban gardening (Figure 25).

To make the streets greener, trees will be planted along their sides, these will be of various species to strengthen resilience against diseases and pests. The trees along with smaller plantations along the sides will absorb the rain water run-off from the streets as well as improving biodiversity and being of aesthetical use. To include more water elements some fountains will be located in the area.

Although the area itself will contain only smaller green areas, there are forest areas surrounding Brommastan which are easily accessible for the inhabitants.

4.3.3 *Transportation within the area*

When aiming for a sustainable city, the use of cars should be kept to a minimum due to their high CO_2e emissions, noise pollution and the high costs associated with building and maintaining roads (Selman 2000). Transportation stands for about half of the county's CO_2e emissions (Stadsbyggnadskontoret 2010), therefore walking, cycling and public transportation will be the main focus of getting around in the area.

In the area a main boulevard will be made from a U shaped extension of the existing landing strip. This will function as an important element of transportation and commerce for the area.

A well-developed cycling and walking grid will characterise the area while cars essentially just occupy the boulevard and a few main roads, along with trams and buses. The cycling and walking grids will consist of wide, and well connected lanes that focus on creating a safe environment for both pedestrians and bicycles, making it accessible for all, even children. One way of increasing the safety is to highlight the bike-lines with colour-markings or vegetation. By having a lot of crossings and well lit walkways it is also safe for the pedestrians. By making the cycling grid well integrated and easy to navigate, it will provide a good alternative to driving a car. There will be many well located parking spaces for bicycles in the area, which will be easy to find and well connected to other means of transport and important locations.

To travel to and from the area, several bus-routes with frequent departures and a tram will be centrally located. The stops will be located around the hot-spots of the area but will also be easy to reach for all people living there. By making specific bus-lanes a timely and frequent bus-route is ensured.

A tram-system will also be constructed with several stations in the area. This could be a part of the Tvärbana Norr, kistagrenen project with planned start of construction in 2016 (Figure 26). The tram will start from the station Norra Ulvsunda and continue in to the Brommastan area.

There are problems associated with constructing a new subway due to the building costs and the long distance to connect to existing subway lines as well as the fact that a new line would only benefit the residents of Bromma (Stockholms Handelskammare 2014a)**.** Even though building a subway is a big and expensive project, it is a sustainable mode of transport for the future and therefor planned within this scenario. There will be an extension of the green line from Brommaplan station in the south, through the area with several stations (Figure 27) with possibilities to change to the tram-line, and then extend north to Spånga where it connects to the commuter train. This could promote further use of public transport and maybe relieve surrounding roads from heavier car traffic.

Even though the use of cars should be limited, travels by car will occur in the area. However, the aim is to have little traffic in the area with low speed limits and many speed bumps so that a safe environment is enabled for pedestrians, cyclists and children. In the centre, a car free area will be created where people can enjoy moving around without having to negotiate with cars. This area is inspired by the Stellwerk 60 block in Köln, Germany with carts and carriages on loan free of charge. The concept has been very successful and popular. (Fojab 2014)

To decrease incentives to have a car, the number of parking spaces will be limited to 0, 5 per household, of which a large percentage will be available in underground garages. Furthermore, due to the efficiency of economic instruments such as pricing on parking in affecting the choice of transport and energy use for transportation (Fojab 2014), parking in the area will be expensive and separated from housing costs to make the cost visible.

To lower the need for cars, the inhabitants in Brommastan will have easy access to carpools and electric cars. Charging stations for electrical cars will be available in the area. Goods deliveries will be made in underground garages, and, as afore mentioned, waste collection will occur outside of the main area thanks to the vaccum system.

The existing roads around the area do of course concern Brommastan. Therefore, Ulvsundavägen that runs through the western part of the area will be buried underground to remove a barrier and create a natural transition to Ulvsunda. This will also reduce noise pollution.

Figure 24. The planned extension of the tram line (Stockholms Läns Landsting 2015).

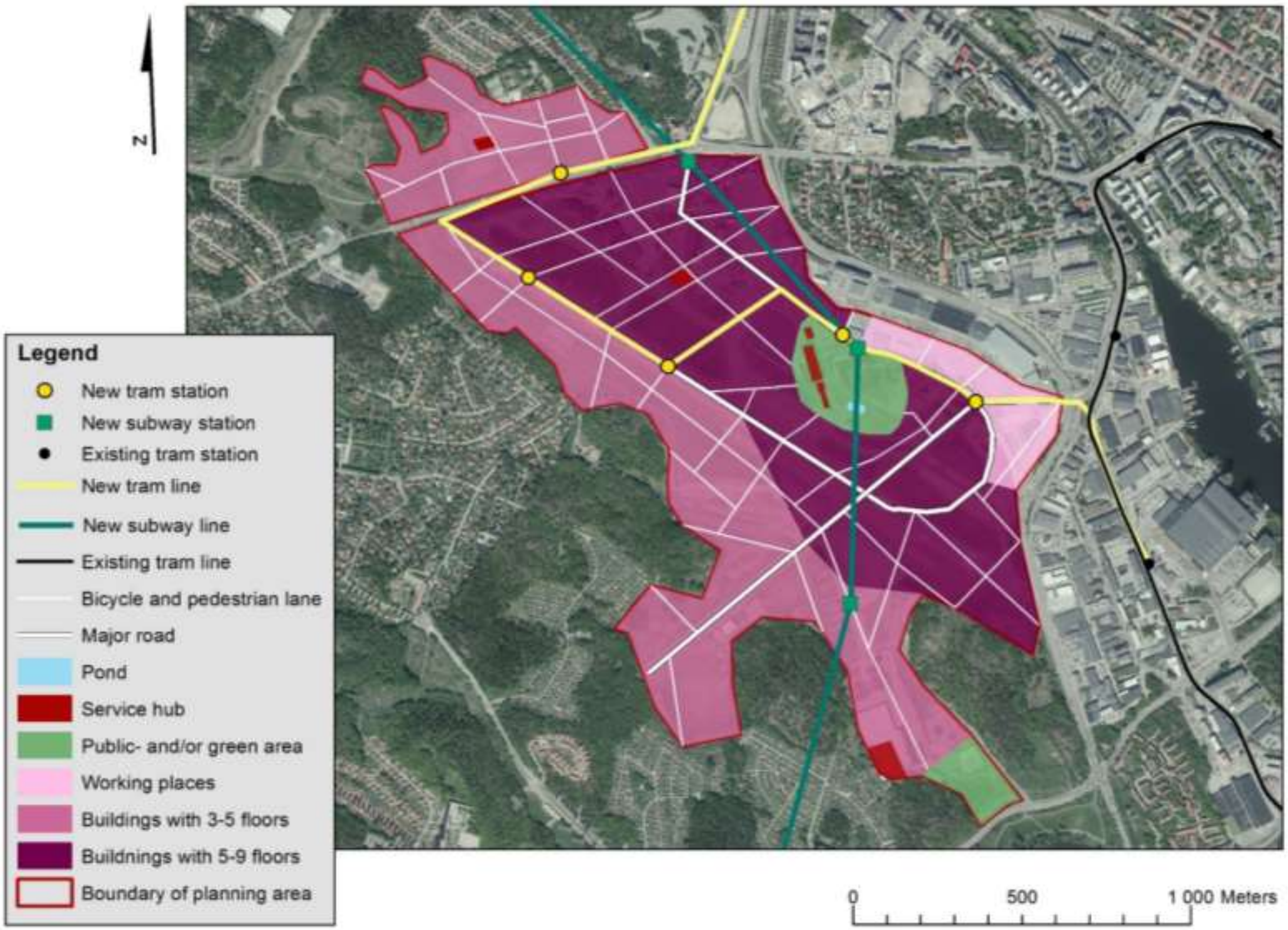

Figure 25. An overview of the public transportation in Brommastan.

4.3.4 Sparse city – “Bromma Grönstad”

4.3.4.1 *Introduction*

In the scenario of the sparse city, Bromma Grönstad, focus will be on creating a green area for good health, recreation and a high quality of life. The area will be a mix of apartments in high rise buildings of maximum five floors and row houses (Figure 28). This mix will cater for families, single-households, students and elderly. By planning for row-houses less apartments can be built for solving the shortage of housing. However, it will enable families to live more centrally and not have to move outside of the city and commute. In this way another need is covered.

In the area, the green spaces will be many and easy to access for all, and can be used for recreational purposes as well as for farming and pedagogical purposes.

To create a sparser city like Bromma Grönstad less apartments can be built and therefore the housing costs will increase. Like in Brommastan, the share between rental apartments and cooperatively owned will be 70% rentals and 30% cooperatively owned and some of the apartments should be built to enable lower rent. Regarding the row-houses, the share between rentals and owned housing will be 50-50.

Thus, this scenario might lead to some segregation within the area, with people living separately in the row-houses and the high rises. To try and tackle this problem many meeting places will be created, such as urban farming land, squares and parks.

Figure 26. New housing structure in Bromma Grönstad, SketchUp model.

Buildings

In this scenario two different types of buildings are planned for: multifamily and row-houses (Figure 29, Figure 30).

4.3.4.2

Considering previous experiences of building in Hammarby Sjöstad and the Royal Sea Port, 5 floors are planned to be built in each building, where ground floor is planned as a shopping area including supermarkets, shops, and cafes, this will lead to less travel inside the city for shopping. An underground floor is considered for laundry rooms (washing machine and dryer).

According to the calculations in Method (3.3.3) Bromma Grönstad will consists of 6 720 apartments in 3-5 floor buildings, 500 row houses and 7 200 workplaces (Table 4, Figure 31) In total there will be 14 420 apartments, row houses and working places in 2050, which means that 481 apartments will be built each year.

The area will consist of 15 440 inhabitants approximately.

4.3.4.3

Energy and water use

The new buildings in Bromma Grönstad will have the same demands on energy efficiency as the buildings in Brommastan (See 4.3.3.4, 0), therefore the energy use cannot exceed the national requirements for new buildings; 110 kWh/m^2.

In Bromma Grönstad, the same suggestions for energy efficiency solutions are made as in Brommastan; green roofs, triple-paned windows and the best available insulation are technical solutions, while a focus will also be on trying to change people´s behaviour towards more environmentally friendly. The consumption goal for water is a 100 litres of water per person per day as in the Brommastan scenario (For more information see 4.3.3.5.1 Behavioural aspects).

Table 4. The differences in density and number of apartments in scenario Brommastan and scenario Bromma Grönstad.

	Brommastan	**Bromma Grönstad**
Planning area [Ha]	200	200
Apartments	16 700	6 720
Row Houses	0	500
Inhabitants	33 400	15 440
Working Places	9 000	7 200
Density [Apartments/Ha]	100	70

Figure 27. Visualisation of Bromma Grönstad, SketchUp model.

4.3.4.4 *Waste Management (See 4.3.3.5 Waste Management)*

4.3.4.5 *Social infrastructure*

The social infrastructure in the Bromma Grönstad will not be as dense as in the scenario of Brommastan because of fewer inhabitants, but the aims of the social infrastructure will be similar (see 4.3.3.6 Social infrastructure). However there will still be a lot of new housing so the area will consist of everyday services, like supermarkets, schools, cafés, sports activities etc., but some of the services will be shared with the surrounding areas, e.g. Brommaplan, Bromma City and Bromma Blocks.

The area will consist of row houses and high rise buildings with a maximum of 5 floors. The area will consists of different kind of housing and designs and will therefore attract different kinds of people with different lifestyles, which will also promote integration. Much of the housing will be a continuation of the already existing residential areas in the Bromma surroundings, with the same type of housing. This gives possibilities for families that want green areas and private yards, but do not want to move to municipalities further from the city centre. This is also a question about gender perspective, where women usually have a longer commuting times due to urban sprawl and generally take greater responsibility for children (Kummel 2006). By providing the opportunity of different types of housing and lifestyles, many families can stay in the area for a long time.

The area will be planned to be safe throughout the whole day, the different structures of the residential areas will be well connected, with no dark and unsafe areas.

Figure 28. An example of row houses in an urban environment (Utopia 2015).

4.3.4.6 *Public spaces*

In a sparse city, more room can be made for the citizens and for facilitating meetings between them. In Bromma Grönstad areas of agriculture/agroforestry/urban gardening will be planned for in the outskirts of the area to make it more self-sufficient. To grow more of the food locally reduces the need for importing food and thus reduces the ecological footprint of the city (Limén 2011). As large a part of the green infrastructure as possible should be eatable and thus serving multiple purposes. For example, there will be a lot of fruit trees and berry bushes in the area.

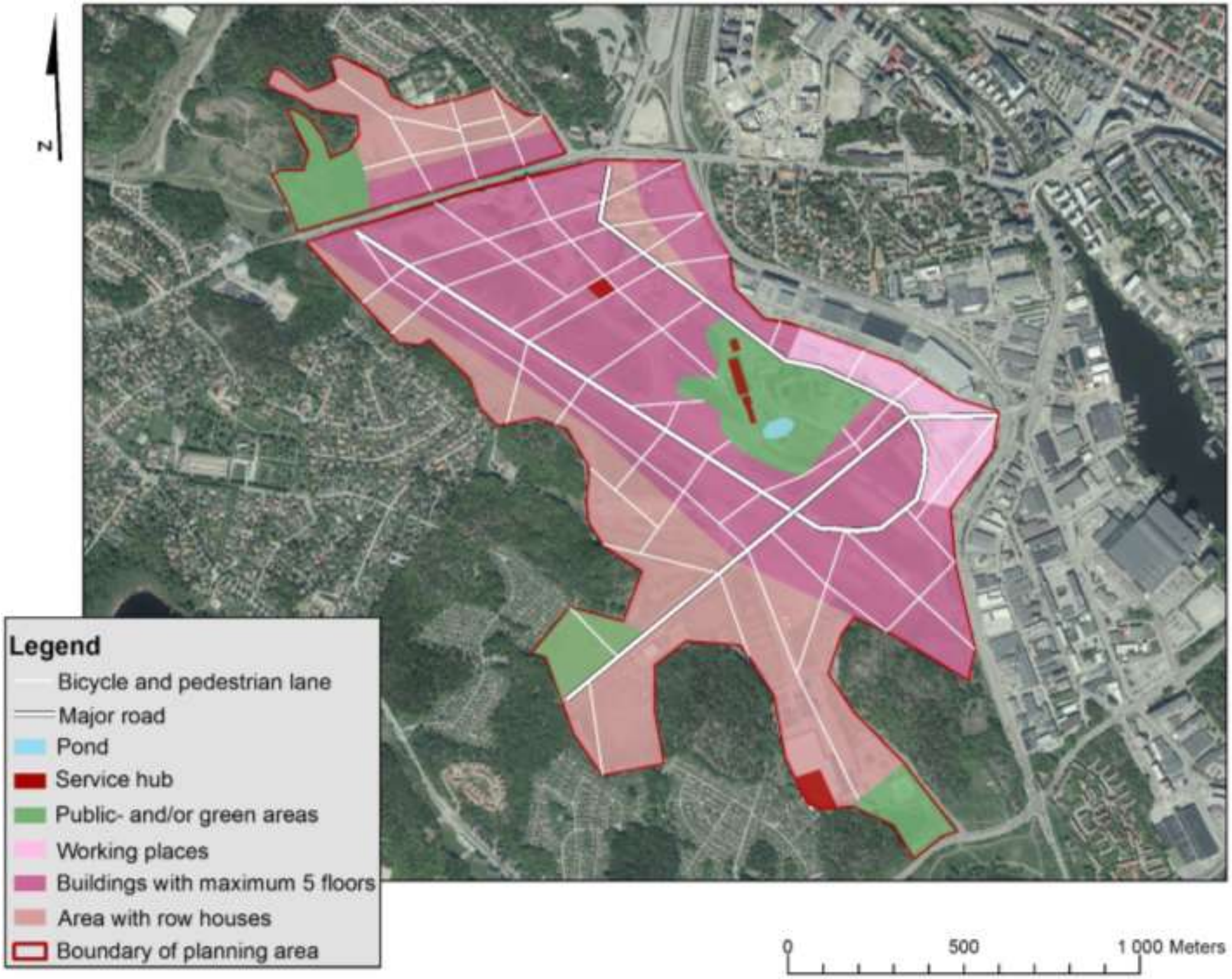

Figure 29. An overview of the planning area in Bromma Grönstad.

Around the row-houses in the north (Figure 31) larger areas will be set aside for small scale farming and permaculture. This does not mean that the social part of urban gardening will get lost, instead even more people will be able to gather around the farming duties. Here, room will also be made for smaller animals like hens and perhaps even pigs.

Larger green areas will be created in this scenario. Besides good impacts on ecosystem services these areas can also have a pedagogical use for the inhabitants living in the area, especially for the children. To create a good learning environment, diversity in both biological values and structure is important. In Bromma Grönstad, the forests around the area connecting into the housing area are good places for green learning environments. These areas are part of the green wedges, which have high nature values and thus are protected. Since they are so close to Bromma Grönstad, the accessibility for both children and others is high.

As in the dense area, playgrounds will be created for the children and by the children. In this scenario, certain activity areas will be created. These should be blank until the children in the area have started to move in which enables them to be a part of planning them. Including them in the planning process ensures that these activity areas are planned for both boys and girls, and thus an area for all children will be created instead of just the traditional ball-court.

Since Bromma Grönstad will have less people moving in, less services will be available along the main street. The area around the buildings marked as cultural heritage will function as a meeting place with restaurants, shops, a library and other public services. This area will be larger than in Brommastan, and consist of more green space, making it both possible to meet people but also find a quiet spot for just reading a book (Figure 32).

Figure 30. An example on how to create a green meeting place in an urban environment (Archello 2015)

4.3.4.7 *Green infrastructure*

In a less dense city or suburban area there are more possibilities for the green infrastructure than in a denser area. Here it is possible to create bigger coherent areas or parks and more easily design them to obtain as many of the ecosystems services that the green infrastructure can provide as possible, to create well adapted multifunctional areas and well connected wedges. Here there are also bigger possibilities to create open water surfaces that can be used to clean stormwater, serve as water reservoirs during heavy rainfall, decrease temperatures, increase biodiversity and for visual beauty (Boverket 2010; Kleerekoper *et al*. 2012).

Nevertheless the green roofs and walls discussed in the section of green infrastructure in a dense city should not be forgotten here. Even if they are not essential for the uptake of storm water, they can still serve as isolation for the buildings reducing their need for energy for heating or cooling and also increase the lifespan of the roofing membrane as well as increasing the albedo of the buildings (Getter & Rowe, 2006). The buildings in Bromma Grönstad will have green roofs and/or walls to a large extent and between the buildings there will be many green areas. In this way a green environment is created for both those living in the row houses and in the high rises. The detailed design of the green infrastructure within the yards and on the buildings will be up to the building companies to decide. The environmental and social building program and the green space factor will make sure that the companies include green and blue spaces on and around their buildings.

It is important that the green infrastructure is planned together with the rest of the infrastructure in a systems perspective to see how and where they are best used (Boverket 2010). The green infrastructure should also be as diverse as possible so that most people will be able to find a place that suits them. Well planned green infrastructure lessens the need for people to seek places for recreation outside of the city thus lowering the amount of travel and the greenhouse gas emissions (Boverket 2010). In Bromma Grönstad, trees will be planted along the sides of the streets along with other vegetation and there will be a city park with a pond in the centre. The forests surrounding the area will be easily accessible for the inhabitants.

A small stream with some ponds surrounded with slightly inclined green slopes and running down to a wetland area is to be constructed (Figure 33). This blue structure will help to store and clean some of the grey water from the area and the green slopes will serve as flood control at times with heavy rainfall. The ponds and wetland will have suitable vegetation for reducing nutrients and hindering pollution from accessing the groundwater. If a stream is to be made in a flat terrain some modelling of the ground may be needed (Malmö Stad, 2008).

Figure 31. An example of how ponds and water can be integrated in an urban environment (Earthwork Studios)

4.3.4.8 *Transportation within the area*

Bromma Grönstad will be planned much less densely in comparison to the scenario of Brommastan. Due to longer distances between services and housing, cars and bicycles are going to be the main means of transport within the area. This requires special measures in planning to make sure the city will still be environmentally friendly. Bromma Grönstad will have the same U-shaped boulevard as the scenario of Brommastan and pedestrians and bicycles will still be prioritised in this area.

Promoting cycling as a way of transport in the city is of great importance, especially in a sparse city, since there is a high risk of traffic congestion. The cycle and walking grids will consist of wide lanes that are connected to important locations and major roads. Focus is on creating a safe environment for pedestrians and cyclists, making it accessible for all, even the children. One way of increasing the safety is to highlight the bike-lines with colour-markings or vegetation and by having a well-developed lighting system (Figure 34). By having a lot of crossings and well lit walkways it is also safe for the pedestrians.

By making the cycling grid well integrated and easy to navigate it will make a good option for not driving a car. There will be many and well located parking spaces for bicycles in the area, which are easy to find and connected to other means of transport and important locations. There will also be rent-a-bike stations, where you can rent a bike for just riding to and from your house to the bus-stop for example.

Figure 32. An example of glow in the dark bike-lines (Smart Highway 2015).

The public transport will be the same in Bromma Grönstad as in the Brommastan scenario, with busses, a tram line with several stations in the area as well as a metro extension of the green line (Figure 36) with possibilities to change to the tram-line, and then extend north to Spånga where it connects to the commuter train. This could promote further use of public transport and maybe relieve surrounding roads from heavier car traffic. The stops will be located near the hot-spots of the area, for example the square. The routes will be rapid and frequent.

The car infrastructure will be more developed and the city will not be as “walkable” as in Brommastan. There will be more car parks and garages. However, focus is still on creating a safe environment for cyclists and pedestrians with speed bumps although the speed limits will be higher in this scenario.

Carpools will be promoted in Bromma Grönstad, and also charging stations for electrical cars (Figure 35).

Parking in the area will, as in the scenario of Brommastan, be expensive and separated from housing costs to make the cost visible. The amount of parking places will be 0.8, which is a little higher than in Brommastan. This is because it was planned for a more car friendly structure in this scenario, with row-houses for example. Some parking places will be connected to the residence buildings but mostly through underground garages.

The existing roads around the area is of course concerning Bromma Grönstad. Therefore, like in the Brommastan scenario, Ulvsunda-vägen that runs through the western part of the area will be buried underground to remove a barrier and create a natural transition to Ulvsunda. This will also reduce sound pollution.

Figure 33. An example of how a charging station for electrical cars might look (Wikimedia 2014).

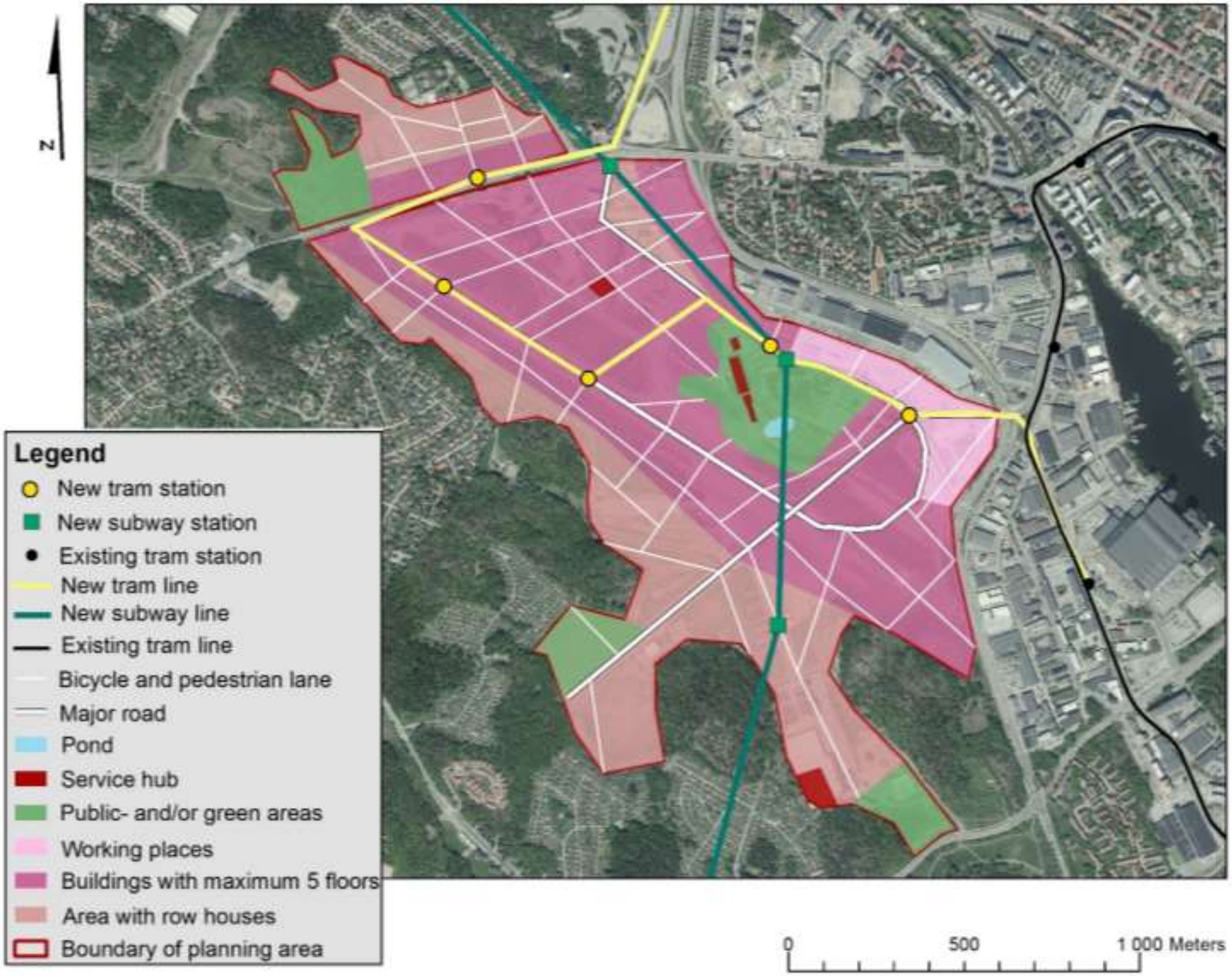

Figure 34. An overview of the public transportation in Bromma Grönstad.

5 Results

5.1 Indicators and criteria

Colour scale indicates performance of each indicator in a sustainability perspective (Table 5). Darker hues indicate better performance while lighter hues indicate worse performance. Grey represents an unranked scenario. Indicators Noise, Transport pollution, Building CO_2e and Transport CO_2e are inverted values, which means that a higher score represents a lower presence of the indicated substance.

Table 5. Comparison between the five scenarios based on the 10 sustainability indicators. Darker colours indicate a better performance. Grey is unranked.

Indicator	BAU	Dense/ Skavsta	Sparse/ Skavsta	Dense/ HSR	Sparse/ HSR
Equal access to housing					
Access to public Spaces					
Local public transport					
Noise					
Transport pollution					
Building CO_2e					
Green spaces					
Transport CO_2e					
Relieve housing deficit					
Stockholm time proximity					

5.2 Value roses

Each value rose shows one scenario and how well it performs from a sustainability perspective. The value roses consist of 10 different pie pieces, each representing one indicator and each pie piece is further divided into five parts representing a five-degree scale from 1- 5 where five, is the best relative value. The further away from the centre of the value rose, the better the performance.

The different colours indicate which sustainability aspect is assessed by the indicator. Red means social sustainability, green means environmental (often referred to as "ecological" by Swedes) and blue means economic sustainability.

5.2.1 Business as usual:

- Bad compared to other scenarios. Performs worst in the environmental and social sustainability aspects.
- This scenario performed best regarding Stockholm time proximity.
- Performs worst of all scenarios on all indicators except "Stockholm Time Proximity".

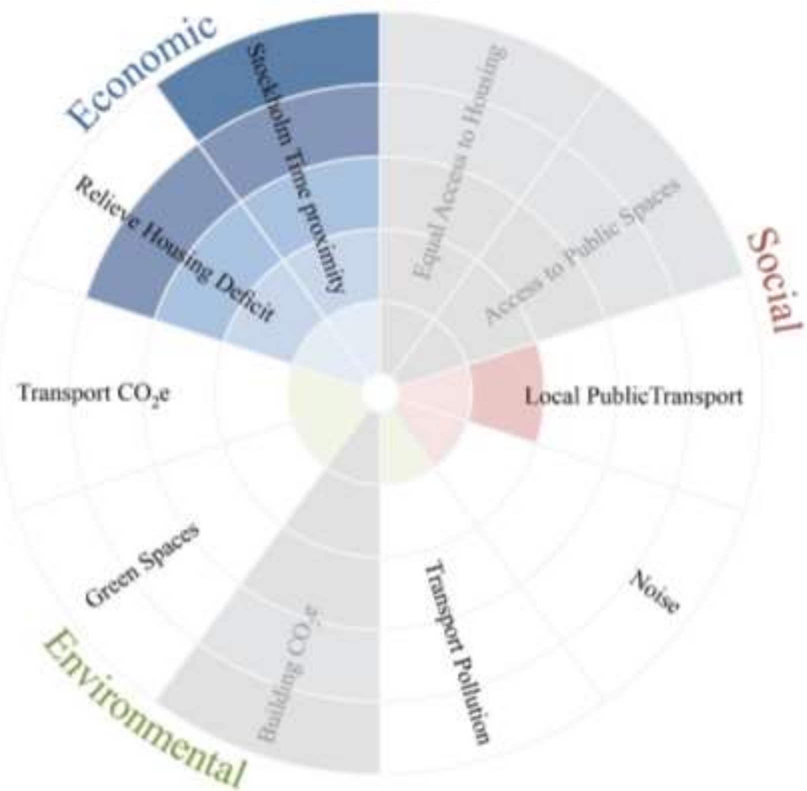

Figure 35. Sustainable performance for scenario 1 – Business as usual.

5.2.2 Scenario 2 – Dense/Skavsta:

- Performs rather well both economically and socially, helps relieve housing shortage and has continued national connectivity.
- Major drawbacks of this scenario are mostly ecological.

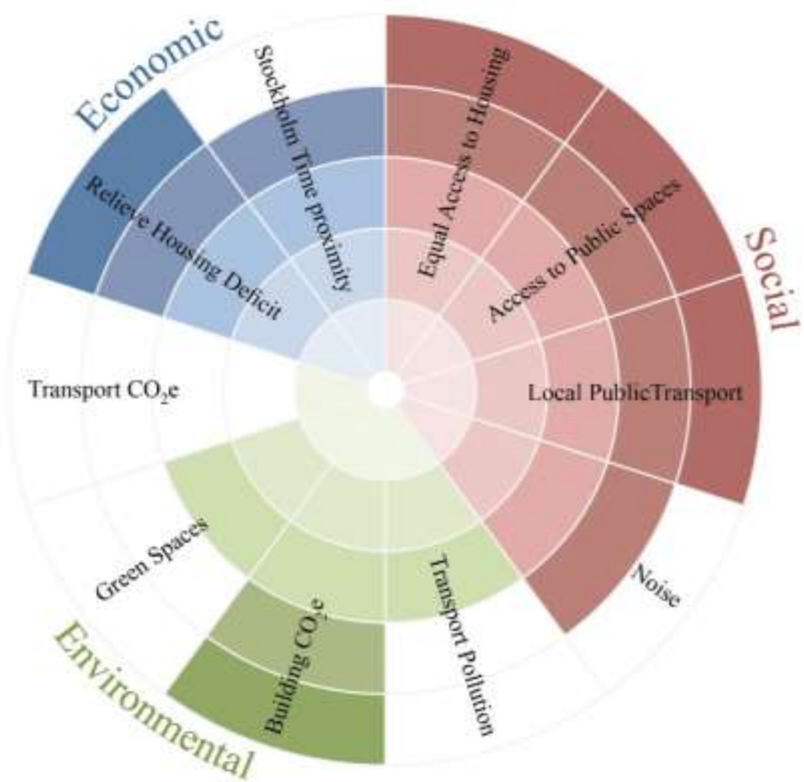

Figure 36. Sustainable performance for scenario 2 – Dense/Skavsta.

5.2.3 Scenario 3 – Sparse/Skavsta:

- Performs rather well economically, helps relieve housing shortage and has continued national connectivity - same as Dense/Skavsta economically. In relation to other scenarios the social performance is weak.
- Uneven performance environmentally, with a lot of green spaces but high CO_2e emissions.

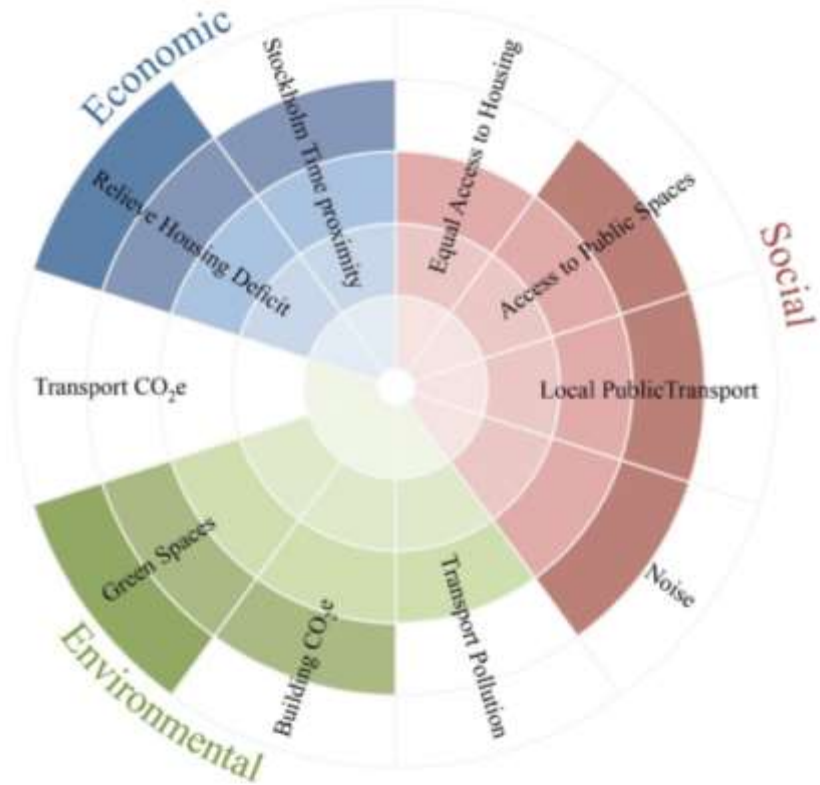

Figure 37. Sustainable performance for scenario 3 – Sparse/Skavsta.

5.2.4 Scenario 4 – Dense/HSR:

- Relatively weak performance economically.
- Performs best socially and well environmentally relative the other scenarios.
- Performs best of all scenarios in all indicators except "Stockholm Time Proximity" and "Green Spaces".

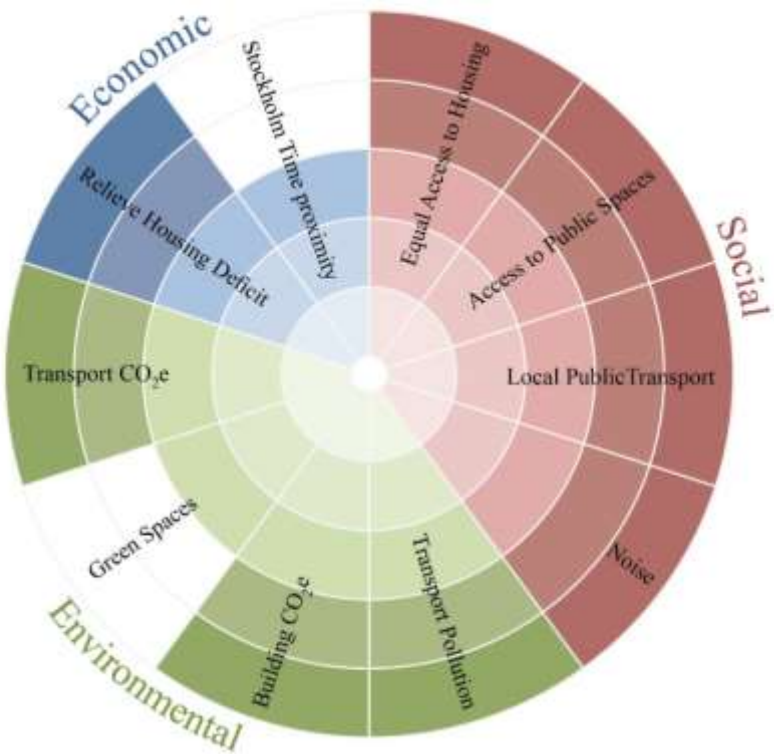

Figure 38. Sustainable performance for scenario 4 – Dense/HSR.

5.2.5 Scenario 5 – Sparse/HSR:

- Relatively weak performance economically.
- Performs best environmentally.
- The second worst performing scenario in social performance.

Figure 39. Sustainable performance for scenario 5 – Sparse/HSR.

6 Discussion

As the Bromma airport is situated close to the center of Stockholm, it is an important infrastructural hub for air travel, most of it is business related. But, the proximity of the Bromma airport to the city center also means that people living close to the airport are affected by noise and air pollution. Furthermore, the land is attractive for other purposes such as housing, and the possibility to build apartments in this area could help alleviate the housing crises in Stockholm. In relation to the debate of alleviating the housing shortage versus the need for efficient transport, the use of scenarios has been a way of highlighting trade-offs.

This report has dealt with two separate development paths, how to handle the need for national transportation and how the airport area could be developed. For a greater understanding of the pros and cons of the different alternatives, the building- and transportation scenarios are initially separated when assessing the different performances within the sustainability indicators. Then the building and transport scenarios are again combined and compared, before comparing these four combined scenarios to the BAU. Lastly, a methodological analysis will conclude the discussion.

Table 6. Comparison between the three transport scenarios based on the relevant sustainability indicators. Darker colours indicate a better performance.

Indicator	BAU	Skavsta	HSR
Noise			
Transport pollution			
Transport CO_2e			
Stockholm time proximity			

6.1 Comparison of the scale separate scenarios

In the report three transportation scenarios and two building scenarios have been developed. As the building and transportation alternatives are relevant for different indicators, evaluation of these respective development paths will be done separately.

6.1.1 Comparison of the transport scenarios

For the three transportation scenarios Business as usual (BAU), Skavsta and HSR, a clear trend can be observed: the higher the national connectivity the lower the environmental performance (Table 6). The HSR scenario performs very well on the three environmental indicators: noise, pollution and CO_2e emissions. Although the HSR will cause more noise than regular trains this is assumed to be outweighed by the reduction in noise at all destination airports connected to Bromma airport. But, improved environmental performance comes at the price of reduced national connectivity. The average travel time will be longer in the HSR scenario, although the effects are unevenly distributed: while most regions get minor increases in travel times, there are some destinations that will see a shortening of travel times. Most severely affected will be the east coast and the northern inland destinations with travel times so long that day trips will be very unattractive and thus could have a negative impact on their regional business climate and economic development. As opposed mostly to the HSR scenario, the BAU scenario performs poorly on environmental factors but is the best scenario for national connectivity.

The Skavsta scenario can be seen as a compromise between economic and environmental values. Travel times are within reasonable levels to allow day trips and retain the business attractiveness of Stockholm and its connected destinations. Furthermore, noise and pollution are displaced to a location where less people will be affected. But, the Skavsta scenario performs poorly for the CO_2e indicator as air traffic is kept at current levels. The reduction of CO_2e emissions and pollution when moving travel to train is significant and is estimated to reduce total Swedish emissions by 0.5% assuming fossil-free electricity is powering the fast trains.

A minor issue regarding the three transport scenarios is that calculated travel times only consider travel from the airport to the centre of Stockholm. This a simplification of actual travel patterns as many travelers are going to destinations closer to Bromma such as Kista, Sollentuna and Solna. Hence it is likely that changes in travel times will be slightly larger than what is captured by these scenarios.

6.1.2 Comparison of the building scenarios

For the two building scenarios, a clear trend is less discernable. The dense scenario scores higher than the sparse one from a social sustainability perspective and is slightly better in comparison to the sparse one when it comes to public spaces (Table 7). In the Business as usual (BAU) scenario there are no public spaces at all, which is why it scores the lowest relative the other scenariosAlthough there will larger public spaces in the sparse scenario, the accessibility in the dense scenario is much better due to a higher number of residents living in close proximity to them. This, together with a better developed public transportation system, optimizes the accessibility of the public spaces in the dense scenario.

Table 7. Comparison between the three building scenarios based on the relevant sustainability indicators. Darker colours indicate a better performance. Grey is unranked.

Indicator	BAU	Dense	Sparse
Equal access to housing			
Access to public Spaces			
Local public transport			
Building CO_2e			
Green spaces			
Relieve housing deficit			

The Building CO_2e incorporates public transportation emissions as well as CO_2e emissions released from the everyday running of the developed area (apartment/workplace energy usage etc.) The number of motorized trips will probably be higher in the sparse scenario than in the dense scenario, resulting in higher CO_2e emissions, while electricity usage should be similar. Therefore, the sparse scenario performs less well in this context, compared to the dense scenario. To be noted, the main issues in evaluating this indicator are mainly due to spatial boundary issues of the local CO_2e emission.

The sparse scenario has more green spaces than the dense scenario, thereby there is more opportunities for variability in the sparse scenario, making this scenario more environmentally sustainable than the other scenarios. Furthermore, the more green spaces, the better the climate change adaptation possibilities for example due to a greater water retention capacity and increased opportunity to promote biodiversity. The BAU scenario has a few large green spaces, the size of these areas are beneficial but since they are of limited variation, this scenario is less beneficial for biodiversity.Therefore the sparse scenario gets the highest value from an environmental point of view.

Due to the focus of the sparse scenario on including more green spaces in between buildings, the resulting fewer numbers of apartments planned in the sparse scenario contributes less to alleviating the housing shortage in Stockholm. When assessing the indicator of relieving the housing deficit the regional scale of the issue is considered. This means taking into account the report from the city of Stockholm, when comparing the above presented scenarios. This means that the existing development plans proposing the building of 150 000 new apartments in Stockholm area until the year of 2030, will stand as our business as usual scenario, while the remaining scenarios will only add to this initial figure, hence the insignificance given to the difference in housing numbers between dense and sparse. Still, it must be kept in mind that the difference of 6000 apartments is a considerable amount on a more local scale and will provide housing for many people. It is slightly problematic that this vision extends to the year 2050 while the report from the city of Stockholm only extends to 2030. Furthermore, it is likely that the city will have built additional housing by then, but as there are no way of knowing, this could not be considered in the indicator.

There is of course a possibility that the proposed Bromma apartments will actually be replacing some other Stockholm city development plans, but currently there is no way of knowing. However, even if that were the case it is reasonable to believe that Bromma would be a good development site because of the relatively low biodiversity and already impermeable surfaces. Other development areas might have higher values and thus can be saved.

6.2 Comparison of the combined scenarios

In the four combined scenarios the traffic at Bromma airport is moved and the area is developed. Firstly, the four combined scenarios (Table 8) are compared as a whole in relation to each other, with regard to sustainability. Thereafter, these four combined scenarios are compared as a whole with regard to the business as usual scenario.

6.2.1 Trade-offs between the four combined scenarios

The four combined scenarios consist of combinations of the two building and transport scenarios where the scenarios are valued as a whole (Table 5).

All four scenarios perform very similarly, with only minor differences between them. Bromma airport is moved in all four cases and therefore local environmental performance is improved, as well as both travel times and the number of houses in Stockholm increasing.

Economically the scenarios are almost identical, with just the increased travel times when moving traffic to rail causing some difference. From a social perspective all scenarios receive a relatively high ranking as well. The Dense + HSR scenario performs the best as noise is minimized and its high population density allows for higher social values on the local scale. For the environmental indicators Dense + HSR and Sparse + HSR get the highest rankings but with the trade-off of green spaces versus local carbon dioxide emissions. The same trade-off exist for Dense + Skavsta and Sparse + Skavsta but with air traffic remaining high their carbon dioxide equivalent emissions remain high.

6.2.2 Trade-offs between the combined scenarios and the Business as usual scenario

Only in the BAU scenario is the Bromma airport kept. The Business as usual scenario will here be discussed in comparison to the other four scenarios. Since these four scenarios, discussed above, are relatively similar to each other, the BAU will be compared to them as a whole instead of separately.

Reading table 6, the BAU scenario only performs better on two indicators compared to the combined four, local CO_2e and national connectivity. But, as the local CO_2e emission are a faulty indicator for the BAU due to spatial boundary issues, the only remaining benefit of the BAU is therefore national connectivity. Basically, for all social and environmental values examined closing Bromma is the preferable

Table 8. Matrix showing how the two transport scenarios and the two building scenarios have been combined.

Scenario	Dense	Sparse
Skavsta	x	x
HSR	x	x

option. The situation is therefore one with a trade-off between national connectivity and all other factors.

Beside noise, pollution and national CO_2e, all indicators were BAU performs poorly have a regional or local focus. The benefits of moving the air traffic from Bromma airport are thus unevenly distributed over Sweden with Stockholm City receiving all the gains. In contrast, the negative economic effects are shared nationally. The conflict of alleviating housing shortage versus travel opportunities is thus in part a conflict between regional and national interests.

Although the BAU scenario performs better only in one variable in comparison to the four combined scenarios, one must not jump to the conclusion that the BAU scenario is the worst outcome altogether. The analysis does not allow any such conclusion as no objective comparison between indicators can be made. Whether or not the economic performance outweighs the other factors remains open to question.

The decreased connectivity, and related decrease in economic development, following a close-down of Bromma airport is one of the most commonly used arguments in the debate. For some regions, it can have negative consequences, especially when replacing the flights with HSR. For example, in the HSR scenario the east coast and northern inland will become more isolated. In contrast, this report shows that for other regions, travelling by HSR will actually be a faster alternative than going by plane. It can be argued then that a better connectivity will further economic development in these regions. But, as this report lacks a thorough analysis of the economic impacts, a good economic comparison is not possible, neither when traffic moves to Skavsta airport nor when it moves to HSR. What may be concluded though, is that if connectivity is greatly reduced at the destination airports this will likely have a greater impact on national economic development than not building an additional 16 700 apartments in Stockholm.

However, the development of additional housing in Stockholm will allow the city to grow further and facilitate economic development regionally. Therefore two ways to facilitate economic growth are in conflict. It must be noted though that the economic benefits of building apartments will only occur if these are additional. This means that if the housing planned in the building scenarios will replace other housing developments in Stockholm, economic performance will not improve.

Furthermore, in the scenario comparison there appears to be clear local social benefits of building housing in the Bromma airport area. But what has been excluded are the effects on social sustainability of a change in economic growth following different travel times. In general, a lower economic performance will have negative social impacts, and higher economic growth a positive social impact. These social consequences are excluded in the indicator ranking but are no less present although very difficult to quantify and coupled with much uncertainty.

6.3 Problems with working towards the scenarios

As the scenarios are meant to illustrate alternative futures and used primary for comparisons, it is important to realise that implementing them is coupled with difficulties. As in the case of transport patterns, other factors such as personal preferences, costs and habits affect the choice of transport besides how the built environment is planned. Aspects such as equal access to housing and accessibility to public spaces and services has similar difficulties for evaluation. Therefore, one must be aware of these difficulties if aiming for these scenarios.

The scenarios chosen in this report allow for little flexibility within themselves, thus it is important to point out that a combination of scenarios is also possible. A positive suggestion could be a modification of the HSR scenario in which severely affected areas of the east coast and northern inland could keep air travel service at current levels. This could for example be achieved by moving this air traffic to either Arlanda or Skavsta. This would accomplish a reduction in air travel whilst actually reducing mean travel times

7 Conclusion

The ongoing debate about whether or not to close down Bromma airport mainly focuses on a discussion of transport versus housing on a general level. For example, the debate concerns housing as such but not how the effects of different housing alternatives would be. Similarly, options to transport and close-to-city center flights that have been discussed has largely focused on how to move flight traffic and in that case only to Arlanda airport. By trying to give a more holistic understanding of the issues at hand, the purpose of this report has been to evaluate several solutions for *both* the transport and the housing issues and from a sustainability point of view. Moreover, in having different scenarios, trade-offs between them can be visualised, furthering the general understanding of the issues concerned.

Thus, our results show that if Bromma airport is to be closed, it will be difficult to avoid an increase in travel times to and from Stockholm. Still, if national environmental factors, especially national carbon dioxide emissions, are to be improved it will be beneficial to completely move the traffic to rail. Regarding the building scenarios, Bromma has to be developed in order to improve green areas, add more housing and improve local transport in the area. But, concerning additional housing, this could still be achieved if other areas are constructed to compensate. For all aspects except green spaces, a densely built housing area would be preferable.

Futhermore, our results show that most benefits of developing a new housing district befalls Stockholm. In contrast, national environmental benefits and negative economic impacts are shared among all connected regions. The conflict of alleviating housing shortage versus travel opportunities is thus in part a conflict between regional and national interests.

As the scenario method enables a holistic overview of trade-offs it can be concluded that when two development paths (air travel and housing) conflict on multiple scales it is good to still do a more detailed assessment of both. For example, by creating two building scenarios a clearer depiction of costs and benefits of constructing Bromma airport can be made.

For this to be valuable indicators with a well-defined purpose must be chosen. But working with the report has shown the difficulties in choosing indicators able to in a balanced way represent sustainability aspects in multiple geographical scales.

Although not shown in the scenarios, the analyses indicate a possible solution where good transportation does not stand in direct conflict with developing housing in the Bromma airport area. If high speed rail were to be complemented with continued air service to the east coast and northen inland, a compromise could be reached with both a new sustainable district and a continued good national connectivity.

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Appendix 1 CLD

1.1 CLD explaining the building system in Bromma area

The CLD (Figure 1) shows a few problems that Stockholm is currently facing:

- Lack of available land for new construction projects
- Lack of apartments
- Environmental problem due to intensive economic development

Stockholm is one of the fastest growing cities in Europe (Stockholm city plan 2010), however more available land is needed to be find in order to build more apartments. Both buildings on brown sites and building on green land can be considered for on-going development projects in Stockholm.

Considering these issues the research question for this CLD is**:**

- ***How to develop Bromma area considering social, economic and environmental issues.***

The CLD contains two loops, one is balancing and another reinforcing. Both are related to the problems with building new infrastructure and land availability. The first balancing loop shows the causality between housing built and land that is available for building. The more houses are constructed the less land remains available, and less land available leads to less houses being built. The second loop describes the reinforcing behavior of two variables: building on green land and building on a brown site. The brown sites that are developed, the less is going to be built on green land, and less building on green sites will lead to even more building on brown sites.

The CLD also touches environmental issues. There is an eco-cycle model where energy consumption and waste production are minimized, and resource saving and recycling are simultaneously maximized. Regarding energy use, two factors are taken into account: 1. how new technologies could assist to make buildings more energy efficient and 2. How environmental awareness could lead to people being more aware of energy and water consumption. The CLD shows that making districts more sustainable with more green areas, sustainable transportation, and promoting the city as being more walkable will eventually lead to an improved standard of living and human health, therefore these factors have been prioritized in the following scenarios.

The CLD represents a model of the district where car free areas, bicycles and public transportation are promoted leading to less CO_2 emissions due to a decreasing number of cars and increasing number of biofuel buses.

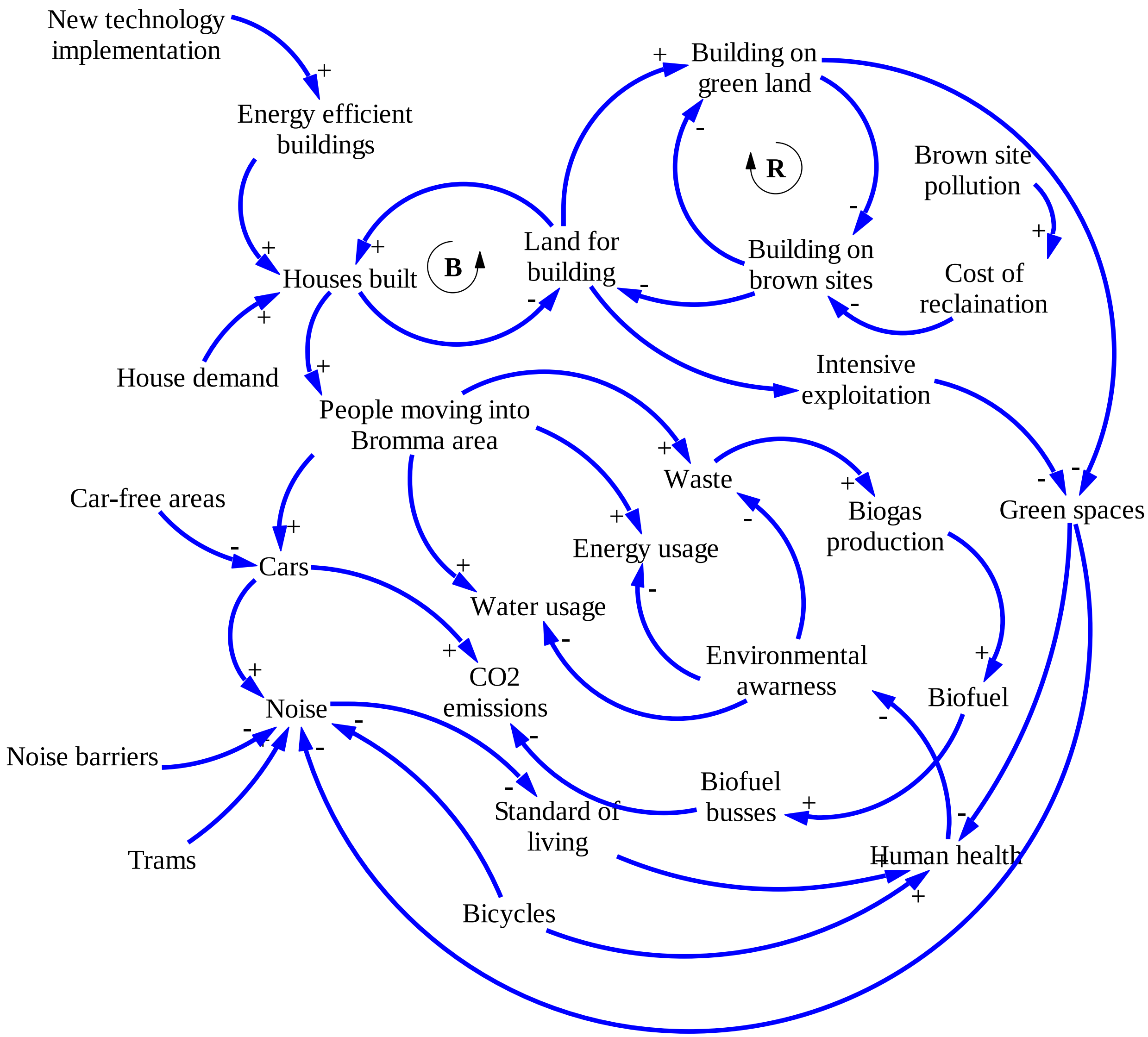

Figure 1. In-depth CLD of Building system in Bromma area.

1.2 CLD explaining the impacts of aircraft operation on the environment

Environmental problems are complex and multi-dimensional in nature meaning that the cause of a problem might be difficult to identify. The purpose of using the CLD in this part of the Bromma airport project is to analyse how aviation is impacting the environment. The question posed was:

- ***What are the impacts of aircraft operations on the environment?***

Variables were identified to show the causes and effects of the problem and how these variables are interrelated and connected in the system structure. The CLD (Figure 2) shows key variables that are influencing the situation, and these key influencing variables are; travel demands, flights, government subsidies, earnings and government awareness.

The systems behaviour is reflected in a way that number of flights will always increase as long as there is travel demand. This will lead to an increased amount of earnings in the aviation company. Government subsidies given to the aviation company - Swedavia as a reward for striving to reduce the amount of emissions, also boosts the total earnings which is then re-invested into the aircraft operation business. Re-investment of the earnings signifies airport expansion and an increase in the number of flights to different destinations. Therefore as long as there are flights, there shall always be environmental impacts from aircraft operations if environmentally sustainable methods and principles are not incorporated and practiced in the aircraft operations.

Nevertheless as flight operations continuously impact on the environment, environmental problems increase leading to government awareness. Government awareness through delay in consultation and decision making influences the decrease in flights and airport expansion.

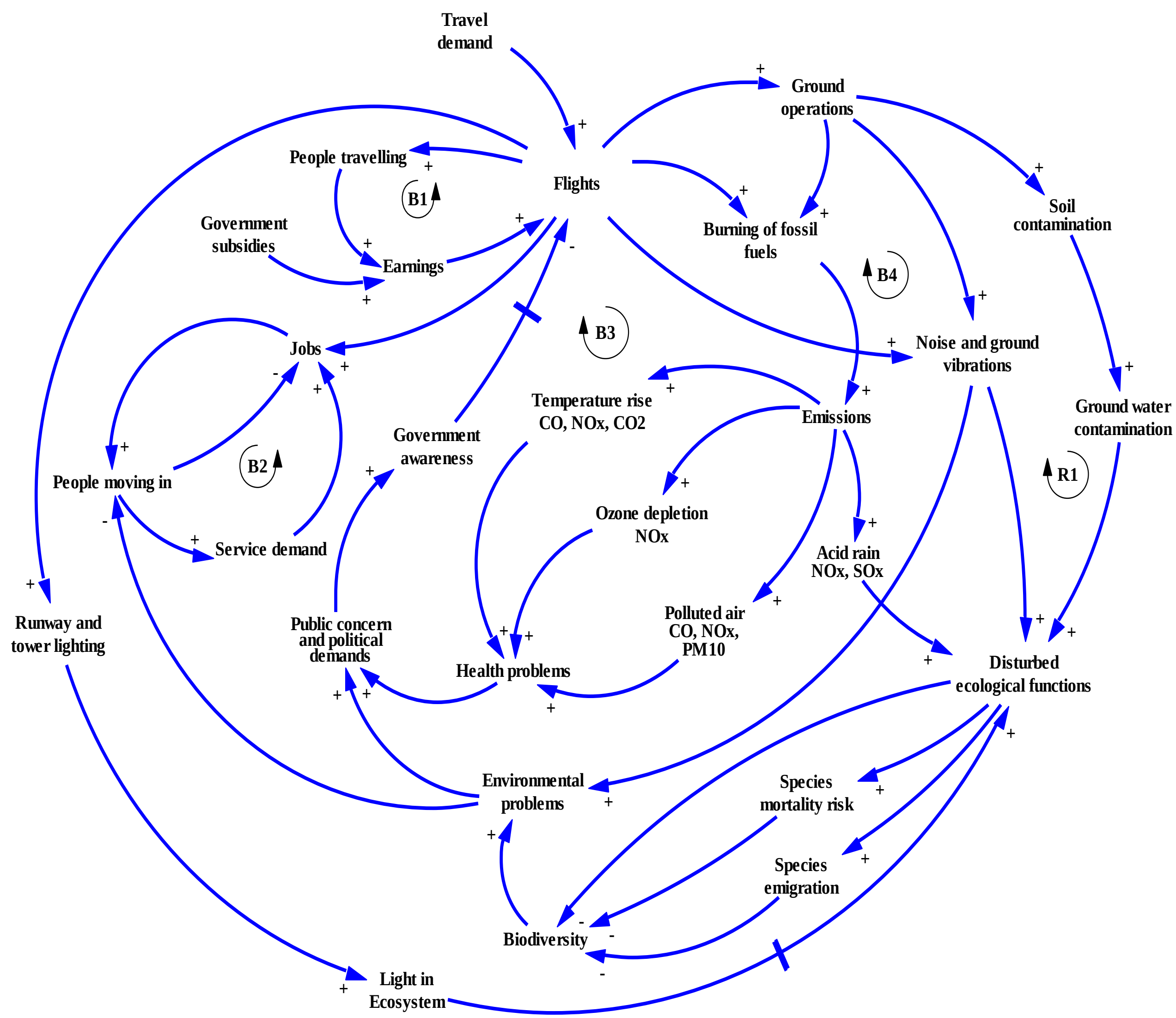

Figure 2. In-depth CLD of airport operations and impacts on the environment.

1.3 CLD explaining the transport system connected to Bromma airport

The question used when creating this CLD (Figure 3) was:

- ***What will the impacts on domestic travelling and infrastructure be?***
- ***How does the dynamics work considering train- and air traffic?***

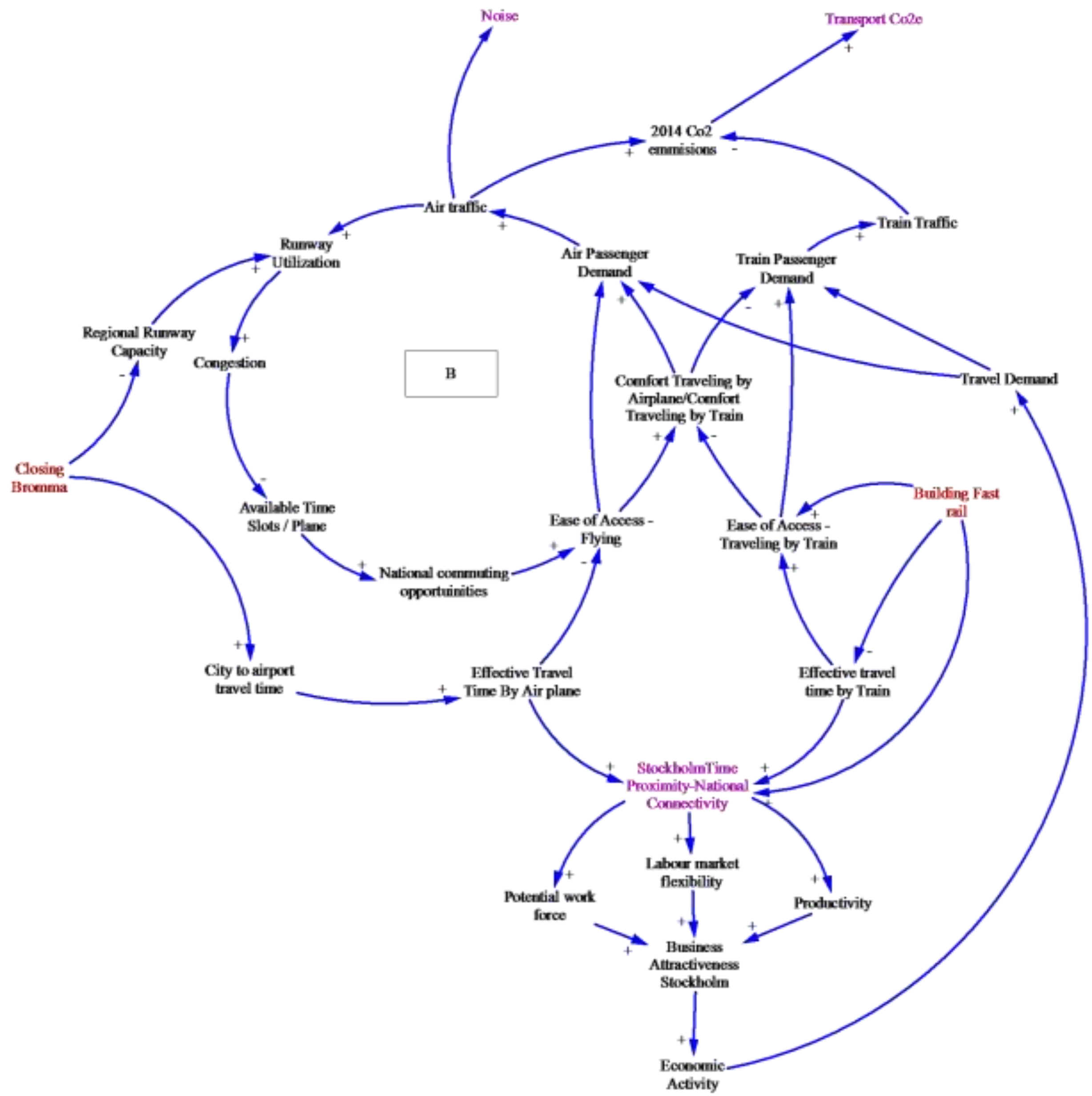

Figure 3. CLD of transport system connected to Bromma airport

Appendix 2 Environmental Objectives

Table 1. Description of the National Environmental Objectives concerned by issues of transport, housing and development, and green infrastructure or ecosystem services in the context of this report (Naturvårdsverket 2012).

Environmental Quality Objective	**Description**
Reduced Climate Impact	The concentration of greenhouse gases in the atmosphere must be stabilised at a level preventing dangerous anthropogenic interference with the climate system.
Clean Air	The air must be clean enough so that neither human health, animals, plants nor cultural assets are damaged.
Natural Acidification Only	The acidifying effects of deposition and land use must not exceed the limits of what can be tolerated by soil and water.
A Non-Toxic Environment	The occurrence of extracted or man-made substances in the environment must be in such concentrations as to not represent a threat to human health or biological diversity.
(A Protective Ozone Layer)	The ozone layer must be replenished so as to provide long-term protection against harmful UV radiation.
Flourishing Lakes and Streams	Ecological sustainability of lakes and watercourses and variability of habitats must be preserved. Furthermore, natural productive capacity, biological diversity and cultural heritage assets must be conserved as well as recreational assets must be safeguarded.
Good Quality Groundwater	The groundwater must provide a safe and sustainable drinking water supply, as well as contributing to viable habitats for flora and fauna in lakes and watercourses.
A Good Built Environment	The built environment must provide healthy living environments as well as contributing to a good regional and global environment. Physical planning must be in accordance with sound environmental principles, so as to promote sustainable management of land, water and other resources.
A Rich Diversity of Plant and Animal Life	Biological diversity must be preserved and used sustainably, and species habitats and ecosystem functioning must be safeguarded for the benefit of present and future generations. Furthermore, a good natural and cultural environment must be accessible in order to promote human health, quality of life and well-being.

Appendix 3 Reference framework for European sustainable cities

1 - Reinforce the economic attractiveness of the city/region/territory

2 - Develop the local economy through knowledge and skills provision

3 - Ensure city connectivity and the provision of efficient infrastructures

4 - Develop/promote/support appropriate sustainable local production and consumption of goods and services

5 - Meet the needs of the population in terms of employment types and access and jobs

6 - Maintain or develop a more diversified local economy

7 - Improve the quality and accessibility of public services for everyone

8 - Ensure that everyone can benefit from a good level of education and training

9 - Promote good public health for everyone

10 - Ensure high-quality housing and neighbourhoods for everyone

11- Promote social inclusion and access to opportunities for everyone

12 - Promote cultural and leisure opportunities and ensure access for everyone

13 - Mitigate, and adapt to, the effects of climate change

14 - Protect and promote biodiversity

15 - Reduce pollution

16 - Preserve the quality and availability of natural resources

17 - Preserve and promote the high quality and functionality of the built environment, public spaces and urban landscape

18 - Develop an integrated vision for the sustainable development of your city

19 - Pay special attention to deprived neighbourhood areas

20 - Organise the management structures of your city to achieve sustainable urban development

21 - Take steps to ensure the financing of the integrated sustainable development of your city

22 - Monitor and evaluate progress

23 - Cooperate with other authorities from different levels

24 - Promote active stakeholder and citizen participation

25 - Promote networking and exchange of knowledge

(RFSC, 2012).

Appendix 4 Methodology for indicator valuation

Relieve housing deficit

In the report it is assumed that the housing at Bromma is additional to the 150 000 apartments planned in the Stockholm comprehensive plan until 2030. We chose this prognosis as no alternative exist, although it is problematic that our scenarios run until 2050. The indicator is based on how much the housing shortage will be alleviated by the construction of new housing on Bromma airport. Meeting housing demand will facilitate the economic growth of the Stockholm region (for more info see background).

Scenario Sparse & Scenario Dense – 5p

The more housing is constructed the better. It is unlikely that 168 000 apartments will meet demand so the risk of causing over production is highly unlikely. As 6000 apartments is not a significant amount when building over one hundred thousand apartments scenario Sparse also receives a 5.

Scenario BAU – 4p

150000 additional apartments in Stockholm will, relative to the above scenarios, alleviate the housing crisis well. It is judged to be only marginally worse than the best case scenarios.

Time Proximity to Stockholm

Time proximity and travel time affect both social activities, recreation and the possibility of visiting acquaintances, economic values such as labour market size, worker productivity and business attractiveness. This is valuated on a national scale. For this indicator economic factors are given the larger weight. To assess the changes of time proximity to Stockholm in the different scenarios, Bromma's top 10 destinations have been used.

Scenario BAU – 5p

This scenario means keeping Bromma and has the best overall travel time and national connectedness to Stockholm and Bromma's top ten destinations.

Scenario moving traffic to Skavsta – 4p

Compared to business as usual this scenario increases travel times by 20 minutes for all destinations. This will not decrease the opportunity for daily commuting and hence we deem business travel to be minimally affected. Daily commuters will get 40 minutes longer travel time both ways which will decrease labor market size, but considering the low number of people commuting by air the effects are still seen as marginal and is given a 4.

Scenario moving traffic to trains – 3p

The average trip will be 35 minutes longer compared to scenario BAU and 15 minutes longer than the Skavsta scenario. Unlike the scenario where traffic is moved to Skavsta the effect is unequally distributed among the destinations. This scenario has the worst effect for the south-east coast regions with traveling times so long that day trips are unattractive. Visby, Österstund, Halmstad, Ronneby and Kalmar get increased traveling times between 1h10min and 3h45min. These cities together stand for 28 % of the traffic at Bromma. Göteborg and Sundsvall, constituting 24% of total traffic, will see better travelling times. Malmö, Ängelholm, Umeå get a small increase in travel time with a maximum of 35 min, which represent 48% of total travelers. Because this scenario has an on average longer travel time than Skavsta and that some regions are particularly affected it is given a 3.

Local public transport

This indicator deals with transport on a local level and access to public services like schools and hospitals. Access to public services is dependent on the ways of transportation.
There are no specific public services planned in either scenario because it's not possible within this timeframe. So an assumption is made that all kinds of services are represented in each scenario with the same rules, e.g. 1 school for every 3000 inhabitants. Therefore transport is the decisive factor for accessibility to public services.

Scenario Dense – 5p this scenario has high focus on public transportation, cycling and walking which is very positive for transportation for different kinds of people. People with no access to a car, children and elderly people have very good possibilities for getting around. A densely built area creates shorter distances to services. Therefore it's the best scenario.

Scenario Sparse – 4p is in several aspects very alike the dense scenario but has less public transportation and more car use. Good but not as good as the dense scenario, therefore this scenario is valued at a level 4.

Scenario BAU – 2p

In this scenario the focus is in transportation in the adjacent area outside of the airport, because the airport itself doesn't have transportation (when leaving air traffic out).
Public transportation is working but not so well. People use cars more than in the other two scenarios (Dense and Sparse) which is a way of transport but not all people have access to cars. The airport can in this case be seen as an obstacles since people would need to travel around instead of through the airport. Transportation in this scenario works but not very well in comparison to the other two scenarios that is why it is valued at a level2.

Building CO_2e

In this scenario the CO_2e emissions from the airplanes is not accounted for, just for the CO_2e emissions from the airport itself. That means cars in the area and energy use and so on. This could maybe be problematic to leave CO_2e from the planes out, but it's difficult to make difference between local and national emissions. It was decided that emissions from airplanes will be dealt with on a national scale in another indicator. The indicator least transport CO_2e deals with CO_2e on a national scale.

This scenario deals with the energy use of the different house types, but not the construction process for building the area. The evaluation is based on a general understanding of emissions from different house types and a comparison between the different scenarios ways of transportation. The major source of emissions is in transportation.

BAU scenario - 5p emits the least amount of CO_2e because the planes is left out and the airport don't use much energy by itself, especially when comparing to the other scenarios.

Dense scenario - 5p Have a large focus on public transportation, cycling and walking which emits little CO_2e. Will have some cars and use energy from the houses which emits CO_2e. Compared this built up scenario with several thousand households to an airport, this scenario is a much bigger source of CO_2e emissions. That is why it's not that good as BAU.

Sparse scenario - 4p Very alike the dense scenario but have more cars. But use less energy per households because of different house types that emits less CO_2e. That is why it gets a value of 3.

Green Spaces

In relation to this indicator we have taken into account the area of green spaces and the variety of these green spaces. Furthermore the evaluation is based on how the green areas promote opportunities to cultural and leisure activities as well as accessibility. Also the indicator includes how much the green spaces and structures mitigate and adapt the urban area to the effects of climate change in relation to the role of ecosystems. The area and the variability of the green spaces are also of importance when it comes to promote and protect biodiversity and has thus been evaluated accordingly.

Sparse scenario - 5p

In this scenario the planning area is more sparsely built. More space for green areas is thus available making it possible to create both more green spaces and a greater variety of the green spaces. Due to this potential for variability everyone can find something that suits their needs in relation to recreation and other kinds of leisure activities. From a climate change perspective this scenario is the most beneficial since the green spaces will be larger and more diverse. This facilitates mitigation and adaptation to the effects of climate change. In this scenario it is also easier to connect the green spaces within the planning area with the ones in the surrounding landscape, which is beneficial for biodiversity.

Dense scenario - 3p

Since the structure of the planning area in this scenario is denser, the green spaces will be smaller leading to less room for variation. The green spaces will therefore be more homogenous with more urban parks rather than a variety of green spaces. Due to less potential for variability as well as the green spaces being smaller, this scenario offers fewer options in relation to recreation and leisure activities. In spite of the density of this scenario, the area is planned to include as much green structures as possible and to some extent this will replace the green areas that are diminished. Therefore from a climate change perspective this scenario is still rather good. Since the priority of this scenario is having as much apartments as possible, it will be more difficult to link the green spaces in the area to the ones in the surrounding landscape. Thereby this scenario will be less beneficial for biodiversity.

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Business as usual scenario (BAU) - 2p

By keeping the airport as it is no new green structures will be created. The variety of the green spaces in the area is somewhat limited. Some of the green spaces that exist in the planning area are unavailable due to airport activities restricting entrance. From a recreation point of view this scenario is therefore the least beneficial. In relation to climate change there are less potential for using green structures for mitigating and adapting to the effects of climate change. Due to there being somewhat large green spaces in the area, the potential for enhancing connectivity exists although the area as a whole is also affected by pollution and disturbances from the airport activities, thereby with potential impact on biodiversity.

CO_2e Transport

The CO_2e emissions from transport are measured on a national scale. This indicator takes into account only the emissions from Bromma flights and their alternative transportation options within the scenarios. When considering scenarios 1 and 2 (Bromma and Skavsta) emissions from local transportation modes to and from the airport were not considered, equally in scenario 3 (HSR) local transport to and from the relevant city centers were discarded.

Scenario HSR – 5p

The HSR scenario gets the highest value in this indicator due to the extremely low emissions resulting from a mostly fossil-free electric rail system. The final calculated emissions for all 2014 Bromma trips, if moved to HSR result in 0.02million tons CO_2e.

BAU and Skavsta scenarios – 1p

Scenarios 1 and 2 were given the same value as they propose the same amount of domestic flights. The reason for the large difference between these and the HSR scenario is that the emissions from flights compared to HSR over the same distance, with the same amount of passengers is over an order of magnitude higher. The resulting emissions for all 2014 Bromma flights was 0.27million tons of CO_2e

Transport pollution

This indicator is the only one that is evaluated on both a regional and national scale. Most of the literature and the ecological footprint calculations state that the significant impacts occur at landing at take-offs (LTO). In contrast, research suggests that a significant amount of the harmful emissions are released during cruising (Yim et al 2015), thus impacting all areas underneath. However, as this research is quite recent in the evaluation of transport pollution in this report, the regional scale is considered the more important. This is so, mainly due to the fact that included in the evaluation of the effect on the regional scale is also the number of people in close proximity to the airport area.

Scenario HSR – 5p

In this scenario, air traffic will be replaced with HSR. The pollution related to the flights at Bromma airport will no longer occur. Therefore, this scenario has the least negative impacts on the environment from a pollution perspective.

Scenario Skavsta – 3p

In this scenario, the effects of pollution on the regional environment are moved from Bromma airport to Skavsta airport. However, the number of people affected in the Skavsta surrounding is much less than the number of residents near Bromma airport, hence the significant difference between this scenario and that of Bromma. Furthermore, an increase in flights might not have a major impact on the local environment. Thereby the Skavsta scenario gets a medium value.

Scenario BAU – 1p

In the BAU scenario, it is assumed that the number of flights will be approximately the same as in the current state. Thereby, the level of local pollution remains the same. Furthermore, in this scenario the greatest number of people will be affected. Thereby, this scenario is considered the least preferable.

Noise

Given the effects on human health noise pollution is proved to have and the increasing support for other effects, it should be of importance to minimise the exposure. This indicator aims to quantify the number of people affected by noise levels above current guidelines for airport related noise nationally. The evaluation of the scenarios is then based on how they perform in minimising the number of people affected, demonstrating the most favourable option.

Scenario HSR – 5p
By closing down Bromma airport the amount of people affected by airport noise over current guidlines will be dramatically reduced, both by eliminating the air traffic noise disturbance at Bromma and reducing it at other airports around Sweden. However, people affected by rail traffic noise will probably increase with regards to building new tracks. This is however easier to mitigate than is air traffic noise. Therefore the alternative redirecting flights to High Speed Rail will be given a 5.

Scenario moving traffic to Skavsta – 4p
Closing Bromma and shifting the air traffic to Skavsta still includes the benefits of noise no longer affecting the large number of residents close to Bromma. Although our calculations for residents around Skavsta Airport are somewhat rough, they are significantly lower than the amount of people living around Bromma airport. Skavsta will also be closer to full capacity resulting in a higher noise pollution effect and there will be no positive effects at other airports. Therefore, moving all air traffic to Skavsta will get a 4.

Scenario BAU – 1p
Considering the very high number (in itself and relatively in Sweden) of people affected by airport related noise close to Bromma Airport, the scenario of keeping the airport will be given a 1.

Public spaces

Scenario BAU – 1p

If the airport remains, there will be no public spaces available in the area. An airport is a closed area where you need permits of some kind to access the area. The only areas available are the parking lots and the terminals, therefore this scenario gets value one.

Dense scenario - 5p
In this scenario many public spaces will be created and be easy accessed for the inhabitants and others. The public spaces consists of a square and along the boulevard, although the other streets will also function as meeting places since the car traffic will be minimized in the area. With many, smaller public places scattered out in the area the accessibility is high for all. This will lead to many meetings between the inhabitants, even though you own your apartment or rent it, the public spaces will be a place where everyone are welcome.

Sparse scenario – 4p

In this scenario fewer, but bigger public spaces will be created. Larger areas are of course positive but since the public spaces will be more concentrated to one, bigger area, it will be harder to access for the people living in the outskirts. Although, with people having to gather around the same public space meetings between people from the different areas within the area meet which is very positive in this kind of sparse area. However, since the accessibility is not as high in this scenario it can only get a value of 4.

Equal access to housing

Scenario BAU – 1p
There is a severe shortage of housing in Stockholm, and by keeping the airport less apartments can be built or putting more development pressure on other areas in the city. Other areas have a limit though, thus by keeping the airport it will be harder to solve the housing problem. On a more local level, the area will remain homogenous in regarding both housing structure and socio-economic aspects.

Dense scenario - 5p
To take advantage of such big area many buildings will be developed. This leads to a more efficient land-use and in the end lower housing costs. In this scenario over half of the apartments will be rentals, and some apartments will have a limit for rental levels. In this way, everyone can afford living in the area, leading to a better social mix both within the area and with the surroundings. By building as many apartments as possible the housing shortage will decrease.

Sparse scenario - 3p
By developing a less dense structure, less housing can be built. In this scenario apartments will be mixed with row-houses. By developing less housing the development costs will increase leading to higher housing costs. Over half of the apartments will be rentals and half of the row-houses as well to still try to include as many as possible. Although, not everyone will afford to live in the row-house area since these will be more expensive and not included in the rental level-principle described above. This might lead to segregation within the area, with richer people living in the row-houses areas and poorer in the apartments. However, this scenario prevents urban sprawl to some extent by developing row-houses on such central location. This scenario will not decrease the shortage of housing as much, though.

Appendix 5. Area affected by 55 dB(A) L_{den} in Skavsta airport vicinity

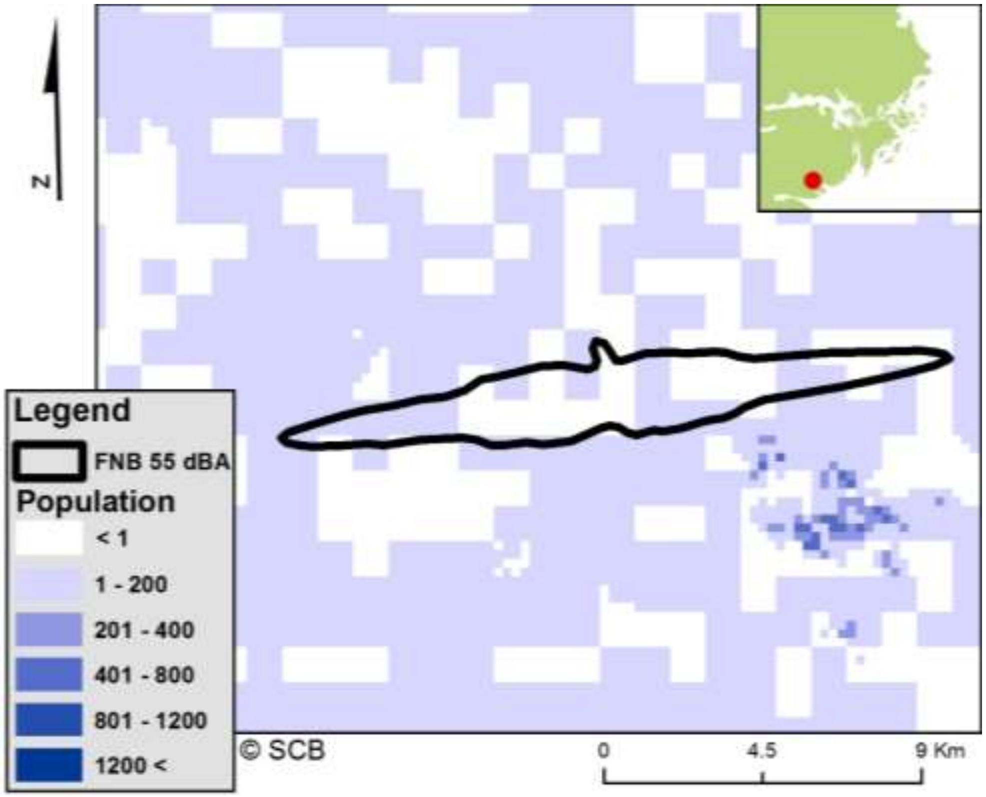

Figure 1. Area affected by 55 dB(A) L_{den} with data layer showing population located around Skavsta airport.

Appendix 6 The ground water protection in Stockholm

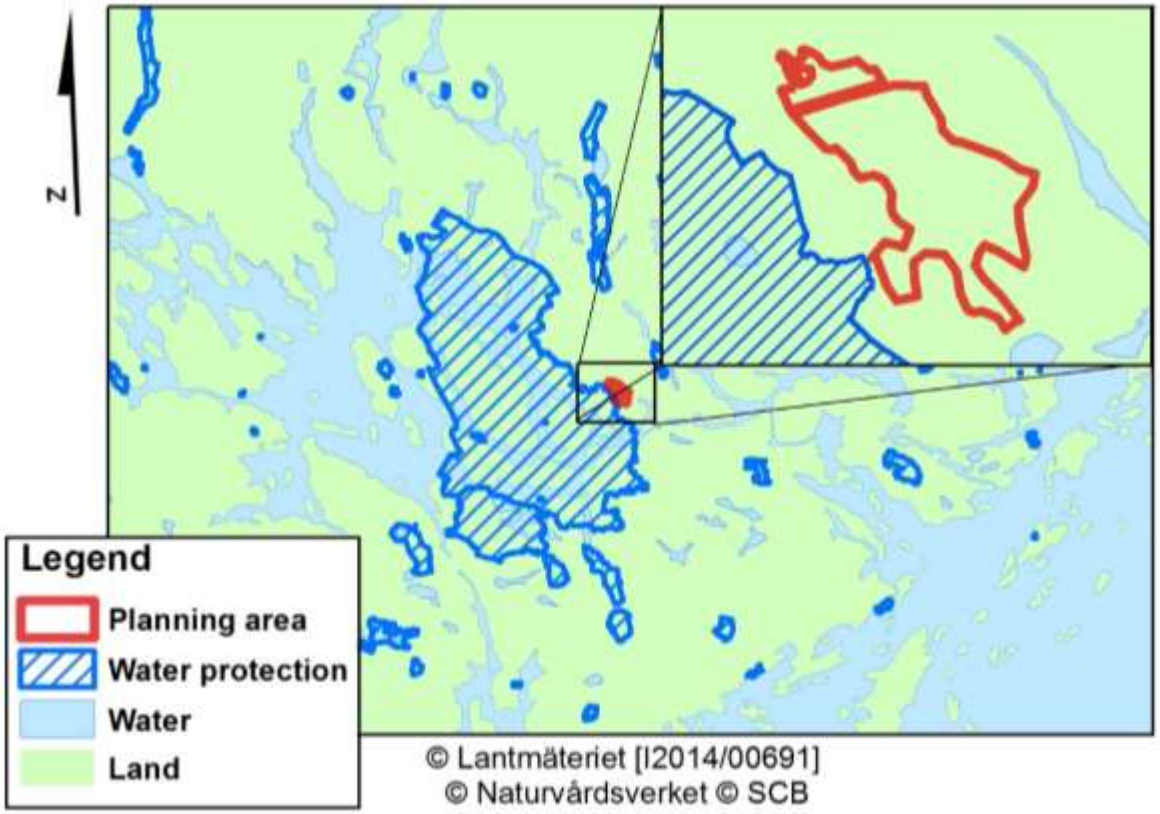

Figure 1. The ground water protection in Stockholm.