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The Royal Climate Garden

A design proposal on how to adapt Kungsträdgården, Stockholm, to a warmer future climate

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Abstract

The aim of this thesis is to find strategies to mitigate the negative effects of an increased temperature and apply them in a design proposal to an urban space of social importance. The chosen site was Kungsträdgården, which is located in central Stockholm, Sweden. Climate change is a contested political debate and a global issue. The United Nation's Intergovernmental Panel on Climate Change (IPCC) has in recent years established that it is with 95% certainty human activities that is causing the change in the global climate. The impacts will affect people and ecosystems around the world and the effects will be most noticeable in cities. Cities generally experience a higher temperature than their non-urban surroundings. This phenomenon is referred to as the Urban Heat Island effect (UHI). The elements, which increase the temperature in cities, are the large amount of impervious surfaces, buildings, lack of green spaces and the large amount of traffic. In order to define mitigating strategies, literature studies to determine what elements that help decrease temperature were conducted.

The strategies to decrease temperature included vegetation such as trees and open grass, biodiversity, location of the green space and wind corridors. They also included water features such as fountains and ponds with vegetation. Vegetation at several levels are important for maximum cooling effect and to allow the cool air to spread. Along with the literature study, a site study were conducted to determine the physical features of the site today (2017). This to understand what is heating and cooling the space. Although people are major contributors to climate change, cities are spaces made by and for people. Therefore, this work does not only focus on the climate aspects of the site, but the social aspects as well. Thus, social studies were conducted to determine how the space is used. This thesis is an attempt to try out solutions for temperature decrease and to learn what is required of urban spaces in the future. Our final design is a conceptual idea of how an urban space in a city can be re-designed in order to cope with the future climate in the aspect of temperature increase. We decided to create a multifunctional space with five different parts, each with its own climate benefits based on our found climate strategies. The parts are an entrance with pond and amphitheatre, an event surface with semi-permeable ground material, a broadleaved forest, a raised boardwalk and an open grass surface and waterfront.

This thesis highlights the importance of green spaces as a way to reduce the impacts of climate change in cities. It also shows the difficulties of balancing between climate aspects and social aspects when designing an urban space. In order to adapt an urban space to climate change and an increased temperature, vegetation is vital, and the removal of impervious surfaces. We think landscape architects have a responsibility to plan for a sustainable future, and we need to be the voice for the changes that needs to be made. Hopefully before it is too late!

Sammanfattning

Bakgrund

Klimatförändringar och urbana värmeöar

Klimatförändringarna är ett hett diskuterat ämne inom världspolitiken idag. Klimatförändringarna är en konsekvens av ett ökat koldioxidutsläpp som, enligt FN:s klimatpanel, till 95% säkerhet beror på mänsklig aktivitet. Effekterna av dessa kommer att påverka människor över hela jorden och förändra eller utrota ekosystemen som vi känner dem idag. Klimatförändringarna märks tydligast i städerna eftersom de är ömtåliga system som lätt tar skada vid externa förändringar eller påfrestningar. Samtidigt är städerna en stor bidragande faktor till vårt allt varmare klimat, eftersom de är källor till stora koldioxidutsläpp.

Städer har ett generellt varmare klimat än den omkringliggande landsbygden. Detta fenomen kallas urbana värmeöar och beror på den höga andelen ogenomsläppliga ytor, byggnader, brist på grönytor och mycket trafik. Urbana värmeöar uppstår med eller utan klimatförändringarna men förstärks av dessa.

Vi ansåg att det idag finns för få stadsrum som är designade med syftet att sänka temperaturen och som är anpassade till ett framtida varmare klimat. Människor i Sverige är inte anpassade till eller vana vid höga temperaturer, vilket är en anledning till att de kommer att påverkas särskilt av en höjd temperatur.

Sverige Meterologiska & Hydrologiska Institut (SMHI) förutspår att Sverige inom 20 till 30 år kommer ha sin första dag med en temperatur över 40 ºC. Detta innebär en strålningstemperatur på över 60 ºC för solexponerade platser i Stockholm.

Kungsträdgården, Stockholm

Den här uppsatsen syftade till att omgestalta en socialt viktig plats, och valet föll på Kungsträdgården i Stockholm. Kungsträdgården är placerad i Stockholms innerstad och är ett populärt besöksmål för både turister och boende i Stockholm. Parken är placerad i Norrmalm, vilken är Stockholms mest tätbebyggda stadsdel. Detta gör att Kungsträdgården är viktig som social plats samt för Norrmalms grönstruktur.

Syfte & Frågeställning

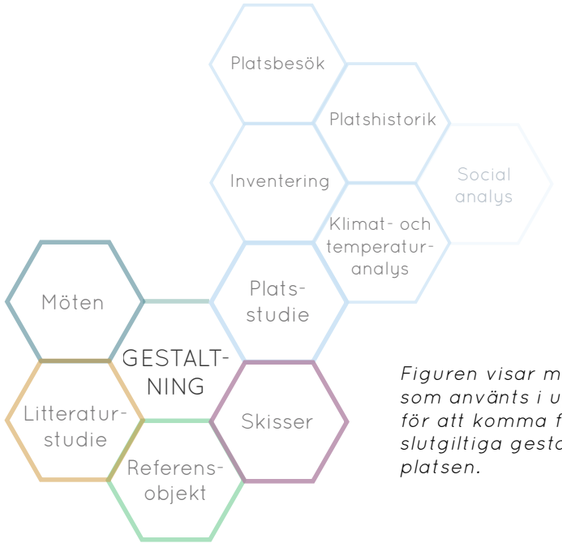
Syftet med vårt arbete var att undersöka hur ett socialt viktigt stadsrum kan anpassas till ett framtida varmare klimat. Målet med arbetet var att hitta strategier för att lindra de negativa effekterna av en höjd temperatur i en stad och hur dessa kan implementeras i ett stadsrum samtidigt som de sociala värdena bibehålls.

Frågeställningar

- Hur kan ett stadsrum gestaltas utifrån enbart ett klimatperspektiv gällande en ökad årsmedeltemperatur?
- Hur kan gestaltningen se ut om även de sociala aspekterna tas i beaktande?

Metod

För att svara på våra frågeställningar genomförde vi möten med personer inom olika expertområden, litteraturstudie, studerande av referensobjekt och eget skissande. Vi gjorde även en platsstudie som innehöll platsbesök, inventering, klimat- och temperaturanalys, platshistorik samt social analys. Då klimatet var vårt största fokus fick det större utrymme i platsstudien. För att dock kunna behålla Kungsträdgården som en social plats lades även det sociala lagret på.



Figuren visar metoderna som använts i uppsatsen för att komma fram till den slutgiltiga gestaltningen för platsen.

Process

Framtidsscenario och hållbar utveckling

För att få hjälp att definiera vad vår framtid skulle innebära och för att avgränsa vår gestaltning fastställde vi ett framtidsscenario för vår uppsats. Framtiden är svår att förutspå och därför valde vi ett scenario framtaget av FN:s klimatpanel som kallas RCP (Representative Concentration Pathways) 8,5. RCP 8,5 innebär att temperaturen i Stockholm antas öka mellan 4-6 ºC till år 2100 och scenariot är baserat på att vi människor fortsätter leva som vi gör idag.

För att kunna planera för framtiden krävs ett hållbart planerande, och hållbar utveckling är ett begrepp som innehåller många olika aspekter. För att definiera och förtydliga dessa har FN betonat sju dimensioner i alla fungerande mänskliga boplatser. Dessa dimensioner har sedan utvecklats till ett ramverk för hållbar stadsutveckling som består av sju mätbara resurser som förkortas i akronymen PEBOSCA. PEBOSCA representerar fysiska, ekonomiska, biologiska, organisatoriska, sociala, kulturella och estetiska aspekter. I vår design valde vi att fokusera på några av aspekterna för att nå längre i vår gestaltning. Vi fokuserade mest på B (biologiska aspekter) och P (fysiska aspekter), men även S (sociala aspekter).

Urban uppvärmning

Genom vår litteraturstudie definierade vi faktorer i urbana miljöer som bidrar till uppvärmning av staden. Dessa faktorer är städers höga andel hårdgjorda ytor, städers brist på grönytor, den stora mängden trafik samt byggnader.

Vegetation är nyckeln

Grönska och grön infrastuktur kan bidra till att förbättra klimatet i städer och därigenom också förbättra hälsan hos invånarna. Storleken på ett grönområde behöver inte betyda allt även om ett större område ofta är att föredra. Grönområden kyler luften både inom området men kan även sprida den kylda luften till dess bebyggda omgivning.

Klimatstrategier för kylning av stadsrum

Baserat på de faktorer och strategier som kan sänka temperaturen i urbana miljöer, formulerade vi klimatstrategier. De baserades på vår litteraturstudie och visar på hur det går att sänka temperaturen i urbana miljöer. Klimatstrategierna är generella och behandlar storleken på ett grönområde, träd, öppet gräs, biodiversitet, vindkorridorer och placering av grönytor. De innefattar även vatten, som kan ha både en temperaturökande och temperatursänkande effekt. Vatten i rörelse, som till exempel rinnande vatten eller fontäner, har en större kylande effekt än stillastående vatten. Även vatten i kombination med vegetation har en större kylande effekt.

Klimatanalys av Stockholm

Det finns idag få temperaturreglerande ekosystemtjänster i centrala Stockholm. De temperaturreglerande tjänsterna är starkt kopplade till grönområden. Centrala Stockholm är sämre på att reglera temperaturen nattetid än dagtid på grund av att Stockholm är omgivet av vatten, vilket värmer luften under natten.

Kungsträdgårdens historia

Kungsträdgården har haft många olika utseenden och användningar under årens lopp. Från kunglig kålgård på 1400-talet, till fransk barockträdgård på 1700-talet och vidare till den offentliga park den är idag. Vår design är ett bidrag till den ständigt föränderliga parken för att möta de framtida behov vi identifierade.

Inventering

Parken består av mycket hårdgjorda ytor. Trädkronor utgör den största delen av den synliga vegetationen. Parkens placering gör även att stora delar av parken är solexponerad under sommartid.

Program

För att definiera vad vi ville göra på vår plats och göra våra klimatstrategier platsspecifika formulerade vi programpunkter. De hjälpte oss förtydliga vad vi ville att vår design skulle åstadkomma på vår plats. Utifrån dessa gjorde vi en klimatdesign som helt fokuserar på klimatet och att sänka temperaturen maximalt. Vi ville dock ha med ett socialt perspektiv och formulerade därför även ett program med fokus på de sociala värdena. Programpunkterna för klimatet tillsammans med de sociala programpunkterna lade sedan grunden för vår slutgiltiga gestaltning.

Koncept och inspiration

Som koncept till vår design valde vi hexagonen som form. Den är strikt med sina hörn, samtidigt som den är organisk eftersom den återfinns på många ställen i naturen. Vi ville behålla det historiska, strikta formspråket från barockträdgården men addera organiska former. Hexagonen hjälpte till att uttrycka detta. Det är även en flexibel form som kan skapa nya former, och flexibilitet var viktigt för oss i vår design.

Referensobjekt

För att hitta inspiration till designlösningar för hur vi kunde implementera våra klimatstrategier på vår plats, studerade vi ett flertal referensobjekt. Som exempel på ett klimatanpassat stadsrum studerades även floden Cheongyecheon i Sydkorea som blivit omgjort till ett stort parkstråk.

Design

Kungliga Klimatträdgården

Grundidén till vår design var att skapa en klimatpark som samtidigt är en fungerande social plats, och att skapa en park med många lager för att kunna svara mot olika framtida behov. Trots vårt definierade framtidsscenario, är framtiden svår att förutspå. Vi ville också prova olika sätt att använda våra klimatstrategier och implementera dem i olika designsammanhang. Parken är uppdelad i fem delar med olika karaktär för att skapa flera lager och möjligheter att kunna sänka temperaturen på.

Norra entrén och dammen

Entrén till parken signalerar en grön oas. Träd ställda i ett hexagonmönster bildar en genomsläpplig portal som leder besökaren in i parken. Entréytan mynnar ut i en delvis gräsbeklädd amfiteater som omringar dammens norra del. Dammen är omgiven av vegetation och går att korsa på gångvägar som omges av fontäner. Fontänerna fyller luften med små, svalkande vattendroppar.

Eventytan

En öppen yta söder om dammen möjligör för parken att ha event och marknader. Halvgenomsläppligt markmaterial används på marken för att klara av mycket mänsklig aktivitet samtidigt som andelen hårdgjord yta minskar.

Skogen

Skogen är hjärtat i vår temperatursänkande park. Höga ädellövträd skuggar såväl skogsmarken som södra delen av eventytan. Genom skogen löper träspänger vilket gör den tillgänglig för människor.

Boardwalken

Det nyaste inslaget i parken är en upphöjd boardwalk som är placerad på enplansbyggnaderna som finns längs parkens västra sida. Den skapar en högre nivå av vegetation vilket göra att den kalla luften kan spridas längre och den är även ett intressant socialt inslag.

Waterfront och öppen gräsyta

Längst i söder finns en stor öppen gräsyta som kopplas ihop med en waterfront. På gräsytan finns små kluster av träd. Den befintliga bilvägen i öst-västlig riktining i parkens södra del görs om till shared space och blir smalare. Detta minskar barriäreffekten, andelen hårdgjort material och mängden trafik.

Tidslinje

Vår gestaltning är en stegvis förändring av den befintliga parken. Detta för att parken ska ha kvar temperatursänkande egenskaper medan de nya elementen etableras. Den befintliga gestaltningen kommer successivt att försvinna för att ge plats åt den nya.

Slutsats

För att anpassa urbana miljöer till ett framtida varmare klimat är vegetation och minimering av hårdgjorda ytor essentiellt. Grönytorna i staden är viktiga för att buffra mot klimatförändringars negativa effekter, och det är en utmaning att balansera klimataspekter och sociala aspekter i en gestaltning för ett stadsrum.

Vårt mål var att skapa ett stadsrum som kunde hjälpa till att sänka temperaturen och på samma gång behålla sin status som en viktig social plats i staden. Vår design är en av många lösningar till en temperatursänkande gestaltning av Kungsträdgården och vi hoppas att den ska kunna inspirera andra landskapsarkitekter samt lyfta fram vikten av att planera för framtiden.

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Acknowledgements & Foreword

We would like to thank our supervisor Susan Paget for many important imputs and for pushing us to go further in our work, and Emily Wade for valuable opinions and for mentioning Kungsträdgården in the very beginning. We would also like to thank our examiner Per Berg and support examiner Anna Robling.

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We hope this thesis will provide you with inspiration and knowledge about this important subject!

Introduction

This thesis is the final piece of work from our five years as landscape architect students. As this is the case, we wanted to produce a project that had a different starting point from the projects we have designed previously. The majority of design interventions throughout our education have had people as main focus. However, in this project, we wanted to change our focus and investigate what happens when the priorities in the design are switched around to climate change.

Climate change is everywhere around us, an issue that is always present and hanging over our heads. Therefore, we chose to look into climate change and, especially, one of the essential issues that climate change implies - a temperature increase.

Subsequently, in this project we looked into the effects of an increased temperature in an inner city public space in Stockholm. We looked into how different measures of design and landscape architecture can mitigate the negative effects of this process; now and in a hundred years time. In essence, this research will bring to light other services that a multi-functional public space could provide to the surrounding city, rather than just benefiting the users of the space. What services can a public space actually provide for us and the surrounding city?

It is also investigating whether an urban space that is of high social and cultural importance to a city, also can be adapted to climate change. What do we need to give up, and what can we win by doing so?

As landscape architects, we have an important role in creating future urban spaces and cities. We have a responsibility to create sustainable spaces today that can last for decades and encompass future demands and climate change. This thesis is an attempt to try out solutions for temperature decrease. Our final design is a conceptual idea of how an urban space in a city can be re-designed in order to cope with the future climate in general and increased temperature in particular.

In our opinion, there are numerous documents and research about the importance of adapting to a warmer future climate. However, when it comes to action, many public spaces are designed for commercial purposes and public use only, rather than ecological purposes. Nevertheless, climate change is happening. It is a future that is already here, and it is time that we take this threat seriously and realise that action needs to be taken - now.

Background

In this section, different aspects of climate change and its impacts on cities will be presented. We will also describe the issues with urban heat islands and an increased temperature, and also present our site.

Climate Change

Climate change remains to be an important and contested debate in world politics, and has been for several years. Debates consider, for example, whether it is real or not, the degree to which climate change can affect us at different scales, and the most effective solutions to slow down and stop this process.

The temperature on earth has always been changing, and our planet has ongoing temperature cycles (Bernes, 2016; SMHI, 2015). Throughout time, the planet has experienced periods of both warmer and colder climates than of today (Bernes, 2016; SMHI, 2015). However, at this point, we are experiencing abnormally rapid changes in our climate (WWF, 2017a).

In recent years, it has been determined by the Intergovernmental Panel on Climate Change (IPCC), which is the climate panel of the United Nations (UN), that humans are, by 95% certainty, the dominant cause of global warming since 1950 (IPCC, 2013; Bernes, 2016). One of the main causes to an increased temperature, which leads to climate change, is carbon dioxide emissions (Bernes, 2016). Carbon dioxide emissions have increased significantly throughout the world, particularly due to widespread industrialisation in the 1800's (Bernes, 2016).

Climate change will affect the average temperature and the average increase of precipitation and storms (SMHI, 2015). It will also cause extreme events of the mentioned weather phenomena, including heat waves, thunder storms and extreme rainfall (SMHI, 2015). This has many possible effects. For example, it will lead to a gradual shift in seasons, the melting of polar ices, and a rising sea water level (Bernes, 2016). As a consequense of this, it will result in higher releases of carbon dioxide and methane emissions, and a change in large-scale ocean currents (Bernes, 2016). This is affecting millions of people and ecosystems around the globe with consequences such as shrinking water supplies, decreased crop yields, increase of forest fires and seas becoming more acidic (Bernes, 2017; WWF, 2017a). Ecosystems known today will change or even be destroyed as invasive species will be out-competing non-invasive species (WWF, 2017b).

Fundamentally, it is predicted that if current levels of carbon dioxide emissions fail to decrease, the earth and its climate will become particularly hostile to humans and ecosystems that are known today, i.e. the earth's ecosystems will not recover during the age of humans (WWF, 2017a).

The Sensitive City

Cities are seen as a major contributing cause to climate change because of the large amount of carbon dioxide emissions that these urban centres emit (C40 cities, 2017; Brown & Southworth, 2008). Today, over half of the world's population live in cities (UN, 2014). With the current urbanisation and population increase, this is a number that is likely to continue to rise (UN, 2014). Consequently, as cities continue to grow, the release of emissions will continue to increase if we continue our way of living.The urbanisation also implies that the majority of people affected by climate change and its impacts, are those living in cities.

The land in the city is valuable. Due to the population increase and urbanisation there is a high demand on providing housing for people and providing other built elements, such as parking spaces. As a consequence, new developments, sometimes at the expense of green space, are being added to the cities, making them even denser (Lenzholzer, 2015).

Despite our modern building technique of today, cities are sensitive systems and are vulnerable to external changes and impacts (C40 cities, 2017; Bernes, 2016; UN Habitat, 2012). The infrastructure of cities such as transport systems, power lines, mobile networks and water pipelines are fragile and become easily damaged in extreme weather events (Bernes, 2016; C40 cities, 2017.). With a high percentage of impervious surfaces, a high density of buildings and a low percentage of green space, cities tend to cope poorly with the impacts of climate change (Lenzholzer, 2015). This is a paradox, as cities are a major contributing cause to changes it cannot handle.

Adapting to climate change has numerous benefits. For instance, it can help reduce costs for when systems break down and reduce the need of artifical cooling of buildings (Boverket, 2010). It can also improve air quality by removing pollutants such as carbon dioxide and particles, and help cities protect themselves from storms and other extreme weather events (Boverket, 2010).Adapting cities to climate change can be done in many ways. However, the way in which urban spaces are designed is of significant importance (Boverket, 2010).

The planet is heating up due to climate change.

Ongoing conclusions

- Climate change is a consequence of increased carbon dioxide emissions due to human activity.
- Climate change will affect us, and the earth, in many ways and need to be reduced in order to save the planet as we know it.
- Climate change has a greater impact in cities because they are vulnerable systems.
- Climate change affects more humans in the cities, because more people live there, and due to urbanisation the number will continue to grow .

Temperature Increase & the Urban Heat Island Effect

We identified three main aspects of climate change: an increase of temperature, increased precipitation, and increased storm events and storm intensity (Bernes, 2016). In order to address climate change in a public space, and to create a design that had specific rather than general solutions, we chose to focus on one of the aspects. Due to the lack of temperature designed urban spaces, there is a lack of measures to deal with heat waves (Boverket, 2010). Because of this, we decided to focus our work on an increased temperature to highlight the importance of this aspect of climate change. An increased temperature caused by climate change means that the annual average temperature around the globe will increase (NASA, 2014).

Increased precipitation and storm events are perhaps the most noticeable impacts of climate change, as they are more obvious in day to day life than increased temperature (Lenzholzer, 2015). The temperature is more abstract in the way that we do not instantly experience the problems it may cause, in comparison to for example rainfall where the actual excess of water is a visible problem. Throughout our education we have encountered a number of urban spaces designed to mitigate and reduce those problems, such as public places in Copenhagen, Amsterdam and Kristianstad. As a result of this, we believe that northern European cities seem to be focusing more on increased precipitation and storms rather than on the increasing temperature. This implies that there already are numerous urban spaces designed for an increased precipitation, and we thought an increase of temperature would be more interesting to look into.

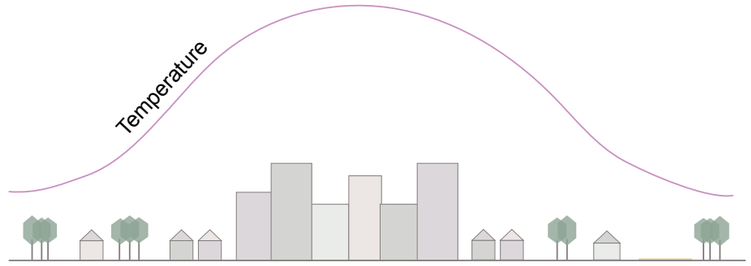
The climate in cities differ to the climate in suburbs and rural landscapes. For example, cities have an average higher temperature than the non-urban surrounding landscape (Boverket, 2010; Bernes, 2016; Lenzholzer, 2015). This phenomena is referred to as the Urban Heat Island effect (the UHI effect) and occurs with or without the presence of climate change (Lenzholzer, 2015; Boverket, 2010). However, a global temperature increase will contribute to an even more significant UHI effect (Lenzholzer, 2015; Boverket, 2010). The UHI effect occurs in cities due to high percentage of impervious surfaces, lack of green space, industries, densely built areas and the large amount of traffic in cities (Kleerekoper et al, 2012).

In cold countries such as Sweden, an increased temperature can be considered as a positive change (Bernes, 2016). However, despite becoming a more pleasant outdoor temperature, a warmer climate can have multiple negative effects for people.

Heat waves causes the most deaths of all weather phenomena (Barthel et al, 2015). During heatwaves in Europe 2003, 4400 people died, mainly elderly (Swedish Government, 2007). An increase in temperature can cause major health problems, such as cardiovascular diseases, lung diseases, kidney failure and dehydration (Bernes, 2016; Boverket, 2010). Elderly, small children and people with heart and lung diseases are high risk groups (von Sydow et al, 2016; Barthel et al, 2015). Sweden is adapted to a colder climate and this implies that severe heat waves will have negative consequences for civic functions and high risk groups (von Sydow et al, 2016).

Research also shows that aggressiveness among people increases during heat waves (MSB, 2015). Moreover, it can affect air quality, increase emissions and energy usage as people will need to cool their homes in artificial ways because their homes are not built to withstand heat (Bernes, 2016; von Sydow et al, 2016).

Swedish Meteorological and Hydrological Institute (SMHI) predicts that within 20-30 years Sweden will have the first day with a temperature above 40 ºC, which equals radiation temperature far above 60 ºC for sun exposed spots in Stockholm (Barthel et al, 2015).



The Urban Heat Island effect refers to that the air temperature is higher in the city than in the surrounding non-urban landscape, which is explained in the graph above.

"To plan for an increased temperature is essential for human health and safety, as well as for social development"

(Translated from von Sydow et al, 2016, p. 32)

Ongoing conclusions

- Cities have a general higher temperature than surrounding non-urban landscapes, referred to as the Urban Heat Island effect (the UHI effect).
- The UHI effect occurs with or without climate change, but will be more severe due to climate change.
- Sweden is not used to a warm climate, which is a reason why Swedish people will be significantly affected by an increased temperature.

Kungsträdgården, Stockholm

The aim of this thesis was to re-design an urban space with social importance. As that was the case, we looked for a site that met that criteria. Our choice fell quickly on Kungsträdgården in Stockholm. We are both familiar with the place, and there is an on-going debate of the future of the site, which has got strong opinions from the public. Both inhabitants of Stockholm and visitors, and it is not the first time Kungsträdgården is object for debates (Olsson, 2017). This indicated the importance of the space, and made Kungsträdgården topical and interesting.

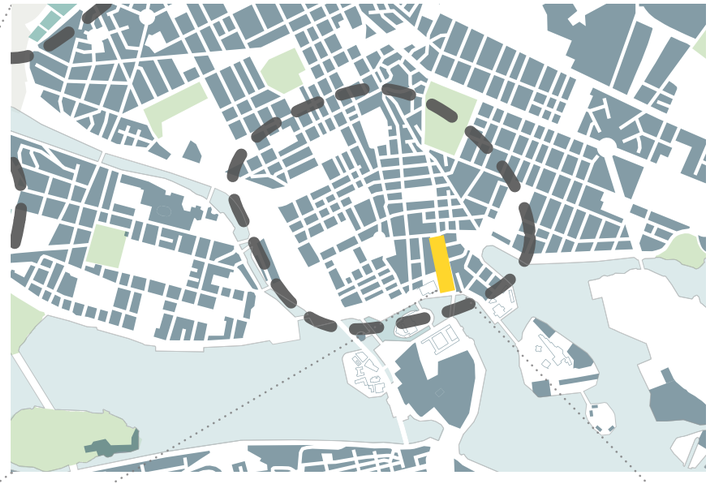
Kungsträdgården is a park in the urban district of Norrmalm in central Stockholm. Norrmalm has a population of 75,000 and is the most densely built urban district in Stockholm, with few larger green spaces (Stockholms Stad, 2007). With its central location, Kungsträdgården is one of Stockholm's most important urban spaces in which a large number of people pass through every day (Stockholms Stad, 2015a). We both have a connection to the site, as we have passed through many times, despite the fact that neither of us have lived in Stockholm city centre.

In 2015, the Stockholm City Council began the process of letting the company Apple build a flagship store in Kungsträdgården (Stockholms Stad, 2016). Apple has bought the estate in the north part of the park, adjacent to the street Hamngatan (Stockholms Stad, 2016). Today the estate is owned by T.G.I. Fridays, a restaurant and patio with outdoor seating. Apple, however, considers the existing building to be too small for their store and have therefore suggested a change in the local plan for the site to widen the space for commercial purpose. The proposal has become very controversial and has got a lot of publicity in the press. People are referring to it as the City Council is "selling out" and commercialising the most important public space in Stockholm.

Because of this procurement, the dialogue about the future of Kungsträdgården was raised. It has also started an initiative from Architects Sweden with the aim to shed light on the Apple project and encourage people to send in their own thoughts and proposals for the space.

We felt strongly against the proposed change and wanted to contribute to the debate. We wanted to create a design proposal that highlights the future of public places with the capacity to mitigate and adapt to future climate change. A future we are already facing.

Kungsträdgården is located in Stockholm, the capital of Sweden.



Stockholms Stad, 2010

Kungsträdgården, 2017. The site is indicated with yellow on the map above.

Ongoing conclusions

- Kungsträdgården is located in central Stockholm and is an important public space.
- There is an on-going debate about the future of the site, as Apple has made a proposal to build a store in the northern part of the park.
- Kungsträdgården is located in the most densely built urban district of Stockholm.

Aim & Objective

The objective of this thesis was to investigate how to adapt an urban space of social importance to a warmer future climate. It aims to find strategies to mitigate the negative effects of increased temperature in a city, and how to implement these in an urban space whilst maintaining the social aspect.

Research Questions

- How can Kungsträdgården be designed from a specific climate perspective regarding an increased annual average temperature?
- How can a park with focus on climate change be designed if social aspects also are taken into consideration?

Limitations

Future Scenario

In order to make our design more reality-based and to have guidelines for the predicted temperature increase, a time aspect was determined within the chosen climate aspect. We decided to use the future scenario referred to as RCP8.5 by IPCC (2013), which means an increase of 4-6 degrees celsius. We chose this scenario because it is based on business as usual. That means that aspects such as economic growth, urbanisation and population increase will continue to increase at the same scale as it is today.

A temperature aspect

To create a design that had specific rather than general solutions, we chose to focus on one aspect of climate change, which was an increased average annual temperature. This was due to the lack of existing temperature designed urban spaces and that we found this aspect interesting - what could it mean for a space in Sweden.

Geographical limitation

Our design is geographically limited to Kungsträdgården in Stockholm, Sweden. We have chosen to not include the buildings or road systems surrounding the site in our work.

Seasonal limitation

This work was focused on the summer season. This was due to the fact that it is the time of the year when Stockholm is experiencing the most solar radiation. It is also the time when severe heat events are most likely to happen.

Glossary

Below follows a description of how we chose to use different terms in this thesis.

Climate change: According to IPCC (2001) climate change is “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”.

Public places: An outdoor place in the city that is open and available to all citizens.

Urban spaces: Openings between buildings in a city, independently of its size.

Methodology

In order to answer our research questions, we divided our work into several steps. However, as a design process is rarely linear, the steps will overlap throughout our process and does not have a specific order. The methodology includes a literature study, meetings with experts, sketches, a study of projects around the world, and a site study, which included several steps. Finally, our work will be presented in a design intervention in which the analytical procedures and results obtained from our studies will be used.

Meetings

Throughout the working process, conversations with experts were carried out in order to get inspiration and different inputs into our work. The experts were in different and relevant fields to our work, such as sustainable urban space, the social aspects of Kungsträdgården, and sustainable planting. The meetings were semi-structured, starting with an opening question about the topic, and then letting the respondent speak freely about the subject. The meetings were between one and two hours long.

Meeting 1: Per G. Berg

Professor in landscape architecture in sustainable built environment

Date: 3 February 2017 15.00-16.00
A meeting to discuss different approaches and perspectives of adaptable urban space, climate change and what tools to use. Moreover, the PEBOSCA Framework and the different aspects of sustainable development were discussed.

Meeting 2: Jonas Olsson

Expert on Architecture Design Stockholm, and one of the people behind the project "Re-think Kungsan"

Date: 8 February 2017 14.30-16.00
A meeting about the history of Kungsträdgården and the importance of Kungsträdgården as a public space in Stockholm.

Meeting 3: Emily Wade

Landscape Architect at Landskapslaget and one of the people behind the project "Re-think Kungsan"

Date: 17 March 2017 15.00-16.30
A meeting to discuss Kungsträdgården as public space in Stockholm, both the future and the past. It was also a meeting about the importance of urban spaces and how an increased temperature affects the environment and the climate in cities. An early draft of our design was also discussed.

Meeting 4: Maria Ignatieva

Professor in Landscape Architecture and Botany

Date: 31 March 2017 10.30-11.30
A meeting to learn about different types of lawns, biodiversity in planting, and resistant permeable surfaces.

Literature Study

A literature study was conducted to get a deeper understanding of climate change and increased temperature in cities. It included research about how to decrease temperature in an urban context, the Urban Heat Island effect, and urban design strategies on how to reduce air temperature in public spaces.

Our literature study were focused on climate change and urban heating. It included the following aspects of climate change: The main impacts, what the expected effects are, how it affects cities and humans, how it is expressed in Sweden and the Stockholm area and ways to reduce the effects of it. The literature study also highlighted how physical elements regulate temperature in cities.

We read books and articles about climate change's main impacts and its effects in cities, such as 'A Warmer World' (Bernes, 2016), 'Weather in the City' (Lenzholzer, 2015), and 'How to make a city Climate-Proof' (Kleerekoper, van Escha & Salcedo, 2011). To determine a future scenario, we used 'A Warmer World', SMHI and the governmental document 'Sweden Facing Climate Change – Threats and Opportunities'. 'Weather in the City', 'How to make a city climate-proof', and 'Regulating ecosystem services' (Barthel et al, 2015) were used when defining what is regulating temperature in cities. This was later used when formulating our climate strategies.

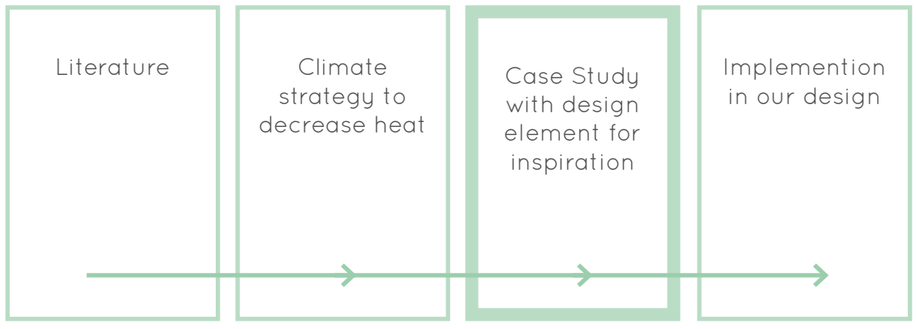
We tried to limit our search for information to material that was produced in recent years, preferably after 2010. This was in order to have as accurate information as possible, especially regarding climate change, as theories tend to change quickly.

Case Studies

A selection of international and domestic urban spaces were studied to gain a wider perspective of how to design public space, and to get inspiration in the design process.

As stated in the introduction, we found little evidence that many cities are focusing on developing urban spaces that are designed for an increased temperature. As a consequence of this, there are few case studies to look into that are relevant for our climate perspective. Instead, we chose to look for inspiration in case studies to visualise our climate strategies that we defined based on our literature study.

We only looked until we found something that we thought worked well with our design. We did not limit our search for case studies geographically or to a certain amount of case studies. When we had found a design element that could help us, we did not look further for the same sort of element in other studies.



The case studies were used to find inspiration to how to visualise our climate strategies in an urban context. The figure above shows where in our process and how the case studies where used.

Sketches

Sketches were used at different stages of the process. When starting our work, sketching was used to help determine what climate aspect to choose. Later on, it was used to get to know the place and to create a better understanding of the space's dimensions, relation between different elements (roads, paths, movement, topography), and it helped identifying problems and conflicts within the site.

When the climate aspect of an increase of temperature was chosen, we used quick sketches to develop alternative design interventions. The sketches were used as a tool to try out new design elements and find possible design solutions for the space. We worked with different pre-set themes such as music genres, colours and phrases. This was in order to get new perspectives of the site, and of the different solutions to decrease temperature with urban design. The sketches were done over a limited time period to encourage fast decisions and to keep a low-level of detail. The time spent on each theme varied from fifteen minutes to two hours. The sketches had a low level of detail to quickly find a variety of solutions to the identified problems and complicated aspects of the site.

The results obtained from the sketches were later used to determine the final layout of our design and it helped us in finding a design concept.

"Sketching enables one to understand the relation between buildings, surroundings and people, and the dimensions of a space"

(Cold, 2008, p. 32).

In order to understand and get to know the site, a variety of studies were conducted. Our site study includes site visits, a literature study about the site, and a historical background study. We also studied the site through a temperature perspective and a social perspective.

Site Visits

Throughout the work, the site was visited at various times; during morning, noon and evening, between February to April. This was carried out to determine the physical features and the social aspects of the space. In order to document the site, written notes and photographs were taken. The physical feature analysis was later used when determining the climate aspects of Kungsträdgården. Moreover, the social study was conducted during all our site visits.

Site Context

Aerial photos were studied and on-site visits were carried out to study the surrounding area, road hierarchy and important landmarks close to our space. In addition to the site visits, literature was studied as a part of our site study. In order to put Kungsträdgården into city context, the Comprehensive plan for Stockholm and the Vision for Stockholm inner city (Stockholms Stad, 2010) were studied to get a general view of the urban planning in Stockholm today and in the future. Moreover, the Stockholm Park Programme and the Park Programme for Norrmalm part 1 and 2 (Stockholms Stad, 2015a, 2015b) were used to learn about recreational spaces in the city. Lastly, “Mapping and analysis of Ecosystem services in Stockholm” (Barthel et al, 2015) were examined to understand temperature regulating services in Stockholm today.

To deepen our understanding of the different facilities in Kungsträdgården, and to understand the legally determined purposes of the land, the local plan (Stockholms Stad, 2010) for Kungsträdgården was studied. In addition to the research about the site today, historical maps and documents were studied to determine the different historical layers of Kungsträdgården and how the park has changed over time.

Physical Features

Based on our literature study regarding how to reduce temperature and the UHI effect, a study of the existing physical features in Kungsträdgården was conducted. The features were identified both at on-site studies and through maps.

Based on the literature study, the following aspects were looked into:

Ground materials

- How much is covered by impervious surfaces and where are they. Impervious surfaces includes cobblestones of different sizes, bitumen, concrete and artificial turf.
- How much is covered by permeable surfaces and where are they. Permeable surfaces are grass, flowerbeds and vegetation of any sort

Vegetation

- What kind of vegetation and where it is

House shade

- What shade the surrounding buildings give over the year

Traffic

- Road hierarchy within and around the site

Water

- What kind and where

Surrounding buildings

- Building usage

Climate Context & Temperature Analysis

A study of the local climate around and within the space was carried out based on our literature. This was in order to determine the existing space's ability to adapt to a warmer climate and mitigate the negative effects of this.

Based on the results from the physical features study and the literature study, a temperature analysis of Kungsträdgården were conducted. The analysis was used to determine which heating and cooling elements there are on the site today. The analysis were divided into day time and night time.

Social Study

So far, this work has focused on the climate change perspective and how Kungsträdgården can adapt to and mitigate the negative effects of a future warmer climate. Nevertheless, as stated in the introduction, the park is today an essential social public space for Stockholm. We wish it to remain an important and accessible place for humans. Because of this, a complementary social study were undertaken in addition to our climate study. To understand and define the social functions of Kungsträdgården, we conducted a social analysis inspired by Lynch analysis and Gehl analysis.

Lynch inspired analysis

A Lynch inspired analysis were used to understand how people use the space today. Typical aspects of enclosure, connectivity, legibility and people movement were considered. Key nodes, focal points and visual and physical barriers within and around the space were also included.

A Lynch analysis is based on people's memories, e.g. mental images, and experiences of a space, and is to be conducted through interviews with people using the space (Lynch, 1960). However, we used Lynch's concept of defining nodes, barriers, landmarks for example, but applied it ourselves on the space instead of interviewing people.

We used a Lynch-inspired analysis because this is an analysis method we used a lot during our education and are familiar with. It is a fast way of getting an understanding of a site's important features, strenghts and weaknesses. The method is also easy to modifiy to suit ones needs. This is because it contains various independent aspects and one can choose which aspects is required for individual study.

The aspects looked into were:

- Nodes - where does people meet and change direction?
- Landmarks - sites that you remember and can see clearly in the space, and walk towards.
- Visual barriers - physical elements can operate as barriers to the visual aspect of the surrounding area.
- Physical barriers - a physical barrier can be a road with heavy traffic that is hard to cross, or other elements such as water, railway, fences or plantations that decrease the accessibility to a space.
- Paths - the patterns in which the people using the space are moving.
- Districts - areas with a common character.

Gehl inspired analysis

In addition to the Lynch analysis, an analysis inspired by Jan Gehl (2010) was added to the study. This was to look into the human activities on the site and the different characters of the space in the aspect of enclosure. The analysis was conducted during the site visits. One day during the working week, one day during the weekend and one evening were studied.

The aspects looked into were:

- Human scale
- Traffic and walkability

Opportunities to:

- walk, sit, stay and stand
- see, listen and talk
- activites and play
- enjoy positive climate aspects
- positive sensory experiences, such as views, vegetation, water and materials.

Social analysis

Lastly, the two analyses were summed up and the space were divided into different sections - character areas. Each area with its own character based on the studies and analysis we conducted.

These two analysis methods were used for the social study as it is the most people friendly analysis we have encountered during our education. It does not necessarily involve interviews or public surveys but rather allows us to observe people (interaction, movement and use). It is also a way for us to get a quick understanding of how people used and moved over the space.

Ongoing conclusions for the Methodology section

- Case studies, meetings, sketching, literature study and site study were used as methods in our work.
- The site study was divided into site visits, site context, physical features, climate context & temperature analysis and a social study.
- The climate aspect is the most important and is therefore analysed in more detail.
- The social aspect is added to keep Kungsträdgården as the important public urban space it is today.

Process

"A continuous action, operation, or series of changes taking place in a definite manner".

Nationalencyklopedin, 2017.

In this section the results obtained from our research will be presented. The gathered data is the basis for our design strategies and our final design.

Future Scenario

As the objective with this thesis was to design for a warmer future climate, we needed to define what this future is. It was also needed to help us understand what an increase of temperature means and what effects it will have. We decided to set a scenario until the year of 2100 and this helped us in our design to know what future our design would be facing and by that, what measures that could be needed.

According to the IPCC (2013) future climate is difficult to predict, and so is the future human use of fossil fuels and emission of carbon dioxide. There is no certain scenario of what will happen or known ways to cope with it. However, there are scientific predictions, and in order to limit our design and to keep it reality based, we used these predictions for a future scenario.

The IPCC has determined four scenarios describing human impact on global climate by the year 2100 (Bernes, 2016). The different scenarios, known as Representative Concentration Pathways (RCP's), are based on how we will change our way of using fossil fuels and the amount of carbon dioxide emissions and other greenhouse gases that we will produce in the future (Bernes, 2016). The first scenario, RCP 2.6, describes the effects if action is taken today, resulting in decreased carbon dioxide emissions and the human impact on climate (Bernes, 2016). This scenario would keep the temperature from rising further than approximately 1- 2º C in the Stockholm region (SMHI, n.d.).

The future scenario we have chosen is the RCP 8.5, which is the fourth scenario defined by the IPCC (2013). This scenario is based on business as usual. We chose this scenario because it is based on that we will continue living as we are today, i.e. not decrease our carbon dioxide emissions. This scenario is stated by the IPCC as a worst-case scenario, as we will need to decrease our emissions to be able to save our planet and its ecosystems (SMHI, n. d.). The RCP 8.5 scenario means that there will be an average annual temperature increase of 4-6º C in the Stockholm region by the year 2100 (SMHI, n.d.). This temperature increase will however not be evenly spread out over the year, but can mean that some days or seasons will experience 11º C warmer than average and sometimes less than 4-6º C warmer.

This scenario could mean that Stockholm by 2100 has a climate similar to the climate by the latitude of central France. A climate like southern Europe might sound very pleasant, but what does 4-6 degrees warmer really mean? According to a study made by the Swedish Government (2007), 4-6º C warmer means that the number of warm days per year will increase significantly. By 2080 it will be over 40 more days over 20° C, and those days are likely to be 25º C (Swedish Government, 2007). Moreover, the winters in Sweden can get as much as 11º C warmer (Swedish Goverment, 2007). Swedish Meteorological and Hydrological Institute (SMHI) predicts that within 20-30 years Sweden will have the first day with a temperature above 40º C, which equals radiation temperature far above 60º C for sun exposed spots in Stockholm (Barthel et al, 2015).

Another manifestation of the warmer climate is the increased occurrence of tropical nights, i.e. when the temperature does not fall below 20° C (Swedish Government, 2007). An increase of temperature have significant negative health effects on humans.

An important aspect in understanding what the increase of 4-6º C means for Stockholm is solar radiation. Because of the nordic location of Stockholm, the solar radiation is different to other more southern countries. At this latitude, the sun sets at 22.00 and rises at 3.30 at solstice (21st June) (SMHI, 2017). Furthermore, because of the position of the earth at this time of year, it never gets completely dark during the night. All this makes it hard to compare with a country with warmer climate today on a more southern latitude.

The global goal on how much the annual average temperature is allowed to increase was decided at the climate conference in Paris to stop at 1,5º C, and definitely not exceed 2º C (Bernes, 2016). However, as claimed previously, if we do not change our way of living rapidly, RCP 8.5 and a 4-6º C warmer world is the future we are facing. Climate scientists have not agreed on what will happen, but they agreed on that it will have significant consequences. Climate change outcomes are complex, and can have many spin off effects.

A complication with a warmer climate is that the hardiness zone will change. A hardiness zone is a place or latitude of which a plant can live and thrive without help from humans (Svensk Trädgård, 2017). As a consequense of this, some species, such as the beech tree, might not keep up with the rapid change and therefore become extinct (WWF, 2017a). Today Stockholm is in hardiness zone 2 but with the predicted temperature increase we can assume that this will change. Additionally, a warmer climate can cause an increase of diseases and pests (WWF, 2017a). Without the cold winter we will experience that more pests such as fungus can survive and spread (WWF, 2017a). Moreover, it will most likely create chain reactions, causing effects we cannot yet predict (Bernes, 2016).

The hardiness zones of Sweden. Stockholm is located in hardiness zone 2.

"Prediction is very difficult, especially if it's about the future".

Nils Bohr

Ongoing conclusions:

- The future climate is hard to predict.
- In this work, the RCP 8.5 scenario from IPCC was used, which means 4-6º C warmer in Stockholm by 2100.
- A future warmer climate has numerous effects on both ecosystems and humans.

Sustainable Development

To address climate change and reduce negative effects of it, planning for the future is essential (Planning and Climate Change Coalition, 2012). For our site to last for decades, a sustainable approach to planning is needed.

Sustainable development became recognised as an established term at the World's first Earth Summit in Rio 1992 (Hållbarhetsforum, 2017) and can be defined in various ways. The most common definition is described in "Our common future", also known as "The Brundtland report", by the UN:s World Commission on Environment and Development (WCED) (1987) as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

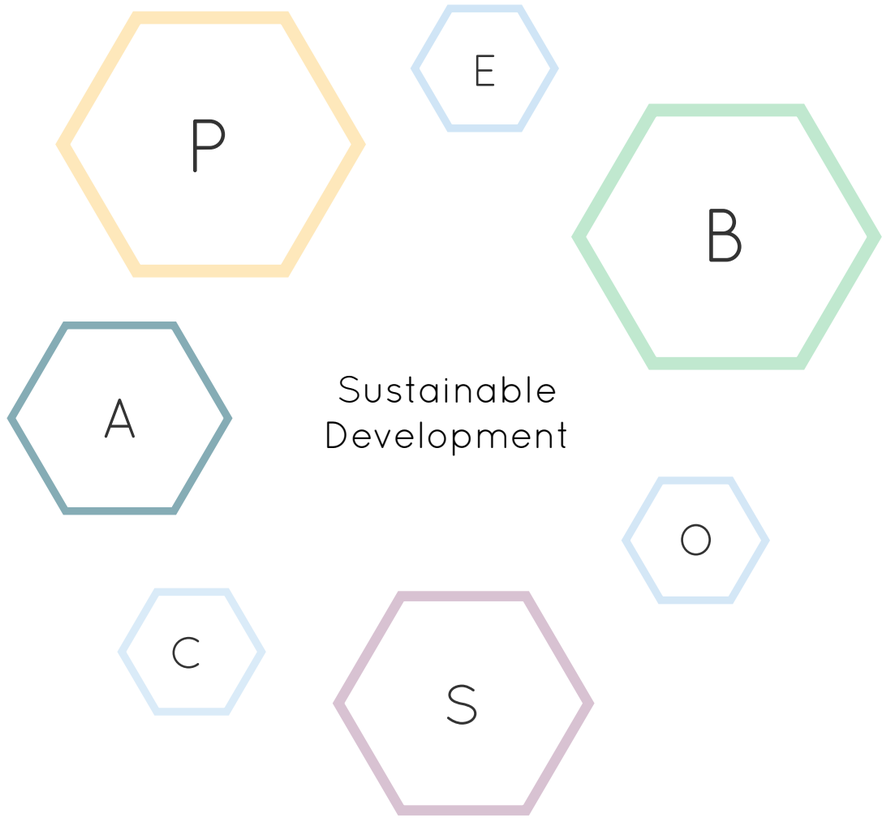
An increased awareness of the environment and the changing climate has forced planning agencies in Sweden to do significant changes in their planning policies in the latest years (Cars, n.d.). A way for cities and communities to define how to plan for future generations is through sustainable development (Stockholms Stad, 2010). Sustainable development contains a large number of aspects, and one way to define it is PEBOSCA.

PEBOSCA is a framework that was developed by the UN at their habitat conference in 1996 in order to define and specify sustainable development (Berg, 2009). It is an acronym made from the different resources and aspects of sustainable development; Physical (P), Economic (E), Biological (B), Organizational (O), Social (S), Cultural (C), and Aesthetic (A) resources (Berg, 2017).

In this thesis PEBOSCA was used as a tool before and during our design process to explain what aspects of sustainable development that is applied in our design. It was also used to show and understand that all resources in sustainable development relate to one another. This thesis was primarily focusing on the Physical and Biological resources as they related most to our chosen topic. Additionally, social resources were a part of our work as we did a design for a public space that we aimed to remain being a social environment. To limit our design and to be able to go further into our chosen subject, it was necessary to choose some aspects and not look into all of them.

According to the IPCC, Physical resources consists of water, air, energy, earth and materials (Berg, 2009). Biological resources are ecosystems and biotopes in natural and cultural shaped landscape (Berg, 2009). Social resources include communications, relations, and collaboration, health and condition in the community (Berg, 2009).

Since the resources contains several aspects that is not relevant to our thesis we limited the Physical and Social resources into relevant aspects, such as air, water and materials, communications, and health.



Above, the different aspects of PEBOSCA is displayed. The symbols' size are based on their relevance in this thesis. P - physical resources and B - biological resources have the main focus. S - social resources are our seconadary and A - aesthetic resources are minor to the other three.

Ongoing conclusions:

- When planning for the future, sustainable development is key
- Sustainable development can be defined in various ways, and one way to define it is PEBOSCA
- PEBOSCA includes Physical, Economic, Biological, Organizational, Social, Cultural and Aesthetic resources.

Adapting a City to Climate Change

There are many consequenses of climate change in cities. As cities are vulnerable to external changes, there is a demand on cities to be able to manage and mitigate the effects of a changed climate. In Multifunctional spaces (Boverket, 2010) Boverket, the National Board of Housing, Building, and Planning of Sweden, establishes that public spaces need not only to be adapted to these climate changes, but also need to help reduce the negative effects of climate change.

There are numerous ways to adapt cities to the changing climate; technical solutions, design of buildings and building layout, and by adding and restoring green infrastructure are some examples (Boverket, 2010; Lenzholzer, 2015). In order to make cities more sustainable and to mitigate the negative effects of climate change, the local green infrastructure has an essential role in decreasing temperature (von Sydow et al, 2016).

Regarding designing urban spaces with the purpose of cooling the air, there are several different aspects to take into account. From the results obtained in the literature study, we have found which elements that cool and heat the air in an urban environment. Furthermore, we have found climate strategies how to plan green spaces to maximise the cooling effect.

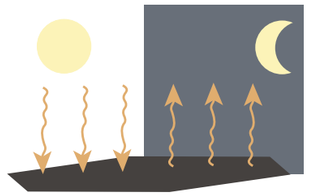
"By reducing the accumulation of heat and applying cooling techniques, citites can mitigate their UHI effect"

(Kleerekoper et al, 2012 p. 31).

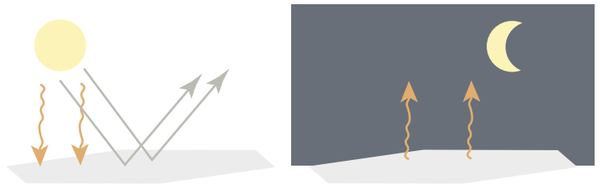
Urban Heating

Urban heating occurs for various reasons. Heat occurs mainly because of that built materials in buildings and ground surfaces accumulate heat during the day and releases heat during night time. Dark impermeable surfaces, buildings, industries and traffic are all sources of heat (Kleerekoper et al, 2012). Additionally, a lack of green spaces means that there is nothing that absorbs the heat and thereby can help cooling the air (Lenzholzer, 2015). All these aspects contribute to a higher air temperature.

Impervious surfaces



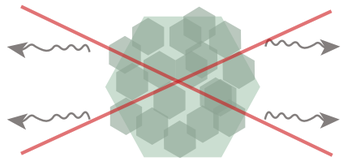
Dark, impervious surfaces store heat during the day, and release heat during night time (Lenzholzer, 2015). This is one of the major causes of the Urban Heat Island effect (Kleerekoper et al, 2012). Examples of impermeable surfaces that store heat are concrete, stone and asphalt.



Light, impervious surfaces reflect the sunlight better during the day, and therefore store less heat than dark surfaces (Kleerekoper et al, 2012). During night time however, the stored heat is released and the surface does not contribute to cooling the air (Kleerekoper et al, 2012).

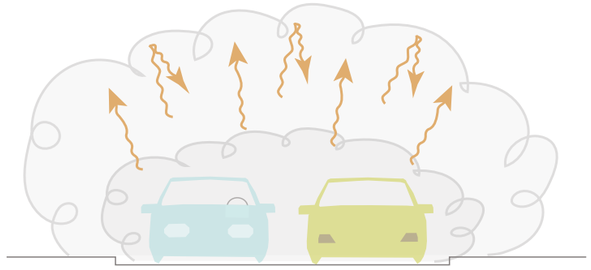
Light stone materials are better from a heat perspective as it does reflect some sunlight, however, light wooden materials are more preferable as they store least heat (Lenzholzer, 2015). Another aspect of light materials is that, as they are light, they can blind people (Lenzholzer, 2015).

Lack of green spaces



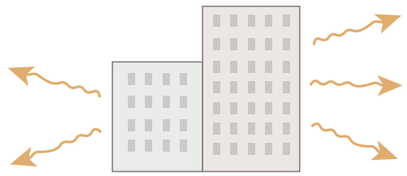
The lack of green spaces and an insignificant green infrastructure contributes to a warmer temperature in cities as nothing is shading the ground and nothing is helping to absorb the heat (Lenzholzer, 2015). An absence of green spaces also increases the night temperature as nothing is releasing cool air.

Traffic



Traffic contributes to a higher temperature in the city due to pollution (Glaeser & Kahn, 2010). The pollutants creates a lid preventing the heat from reaching the atomspehere, thus the heat stays close to the ground and continues to heat the air (Bernes, 2016). Cars are also a major contribution to carbon dioxide emissions, which is the main source of climate change (Kleerekoper et al, 2012; Bernes, 2016).

Buildings



Buildings are sources of heat (Glaeser & Kahn, 2010). Ventilation systems and heat that leaks out from buildings contributes to a warmer urban temperature (Kleerekoper et al, 2012).

The material of which buildings are built can accumulate heat during the day, which releases during the night (Kleerekoper, 2012). Roofs are exposed to sunlight during long periods as nothing shades them, and are also often made of dark materials (Kleerekoper et al, 2012). This contributes to a greater accumulation of heat and therefore a greater release of the same (Kleerekoper et al, 2012).

Short-wave radiation from the sun gets trapped between buildings and the ground surface by multiple reflection, and this also causes heat (Kleerekoper et al, 2012).

Vegetation is the Key

The opposite to built materials is nature. Although innovative solutions have been made in cities for the past hundreds of years (C40 cities, n.d.), nature has spent the past billions of years researching, adapting and developing, becoming resilient and sustainable (Biomimicry, 2017). Subsequently, by protecting and improving our green infrastructure, we can use the solutions of nature and its ecosystems to control the microclimate in cities, and reduce the effects of climate change (Keane et al, 2014).

Green infrastructure is a planned network of green areas, designed and manage to provide a wide range of ecosystem services (EU, 2016). According to the European Commission green networks can improve environmental conditions and by that also the health of the citizens (EU, 2016).

Research at the University of Manchester has estimated that a 10 percent increase of green spaces in agglomerations could decrease the temperature in our cities to up to 4º C (Boverket, 2010). Larger parks (>50 ha) often have a significant lower temperature than built areas, 1-2º C, and also have the ability to decrease the air temperature in areas 300- 400 meters away from the parks (Boverket, 2010). According to Kleerekoper (2012) the size of a green area does not necessarily have to be very large in order to have a cooling effect. A study in Tel Aviv has shown that a park of only 0.15 ha had a cooling effect of 1.5 - 3º C which was noticable from a 100 m distance (Kleerekoper et al, 2012). A park in Gothenburg of 156 ha had however, a cooling effect of up to 5,9º C, noticeable 1100 m from the green area (Kleerekoper et al, 2012)

Vegetation with dense green mass, such as shrubs and trees, is therefore important to the microclimate in the city (Boverket, 2010). Trees are particularly efficient when regulating climate as they can shade impervious surfaces, preventing them from heating up and thereby controlling the microclimate (Boverket, 2010). Deciduous trees have the advantage compared to conifers that they can regulate shade during summer, but let the sun through in winter when it is more desirable (Boverket, 2010).

Biotopes as temperature regulators

Based on Barthel et al (2015) we have listed below a classification of how biotopes regulates temperature during day time and night time in cities.

Biotope	Temperature regulating daytime
Surfaces with dense buildings and no vegetation	Little to no capacity
Open grassland and scattered buildings	Some capacity
Semi opened grassland and open water	Significant capacity
Dry and semi-damp forest	Large capacity
Broadleaved forest, forest moor and damp forest	Very large capacity

Biotope	Temperature regulating night time
Impervious surfaces, water and buildings	Little to no capacity
Open grassland	Some capacity
Semi opened grassland (with trees and bushes)	Significant capacity
Dry and semi-damp forest	Large capacity
Broadleaved forest, forest moor and damp forest	Very large capacity

Table 1

Vegetation Strategy

Instead of determining specific plant species for our design, we chose to set up a vegetation strategy for the choice of planting. We wanted to create an urban space that is not only beneficial to the microclimate in short-term, but also sustainable in our future scenario of 2100. After the meeting with Maria Ignatieva (2017), we came up with certain criterias for a vegetation strategy. The strategy includes guidelines for the choice of plants, so that the vegetation meets particular characteristics. Below follows our vegetation strategy:

- Trees should have a longer lifespan than 50 years in order to last up to year 2100 to prevent replanting
- Plants and trees should be viable in hardiness zone 1. As the hardiness zones are moving north, our vegetation needs to withstand a change to a warmer climate.
- Monocultures should be avoided, and use a diversity of species and plants in order to avoid spreading of diseases and pests among the vegetation. This includes that grass surfaces also should consists of a variety of species.
- Sterile plants and trees should be avoided as they do not contribute to biodiversity.
- Seasonal dynamic should be considered to contribute to a long season of shading.
- Native plants should be used to avoid foreign pests and invasive species to spread and to retain the native flora.

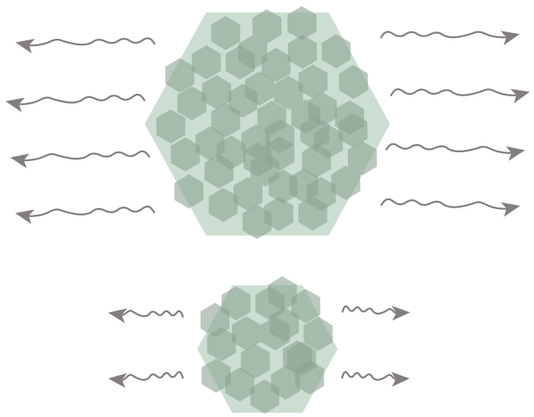
Ongoing conclusions:

- Impervious surfaces, lack of green space, buildings and traffic are all contributing to urban heating.
- Vegetation is vital to reduce the effects of climate change in urban environments
- We have defined a vegetation strategy rather than determining specific plants to our design.

Climate Strategies for Urban Cooling

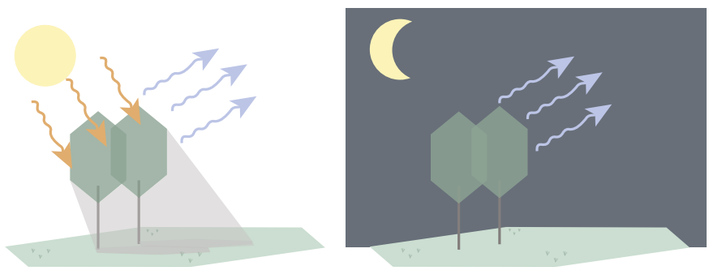
In this section, our found climate strategies to cool urban environments will be presented. The strategies are based on the findings and results obtained in our literature study. They are general, to be able to apply on any urban space.

Bigger is better



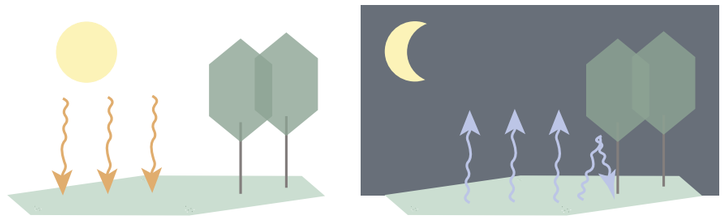
Vegetation cools the air, and the bigger the green space is, the better (Kleerekoper et al, 2012; Lenzholzer, 2015). Preferably, the green space should be seven times as wide as the closest surrounding building block (Lenzholzer, 2015).

Trees



Trees create shade during the day, which has a cooling effect on the ground below (Kleerekoper et al, 2012). They also release cooling air through evaotranspiration during day and night time (Kleerekoper et al, 2012). Trees have a large cooling effect, and it depends on the canopy shape and density (Barthel et al, 2015). Broadleaved trees have the largest cooling effect (Barthel et al, 2015).

Open grass



Open grass absorbs heat during the day and releases cool air during night (Lenzholzer, 2015). Although, where there is tree canopy, the air is not released to the same extent, which is why it is important to have open green surfaces as well as trees (Lenzholzer, 2015). Open grass surfaces are essential for the cooling at night time (Barthel et al, 2015). In a health perspective, the night is also the time when it is most important to decrease temperature.

Biodiversity

As the temperature gets higher the spreding of pests and diseases among plants will increase (Bernes, 2016). Biodiversity can help protect the plants and prevent further spreading of pests (Ignatieva, 2017) and thereby extend the lifespan of the plants. It also helps to provide a longer season of shading as different plants gets and drops their leaves at different times.

The future is uncertain, and the changing climate entails a change in our ecosystems. This means a variety in the green infrastructure is needed, to promote biodiversity. A diversity of planting is essential for a sustainable and resilient environment (Willis & Lagerblad, 2014).

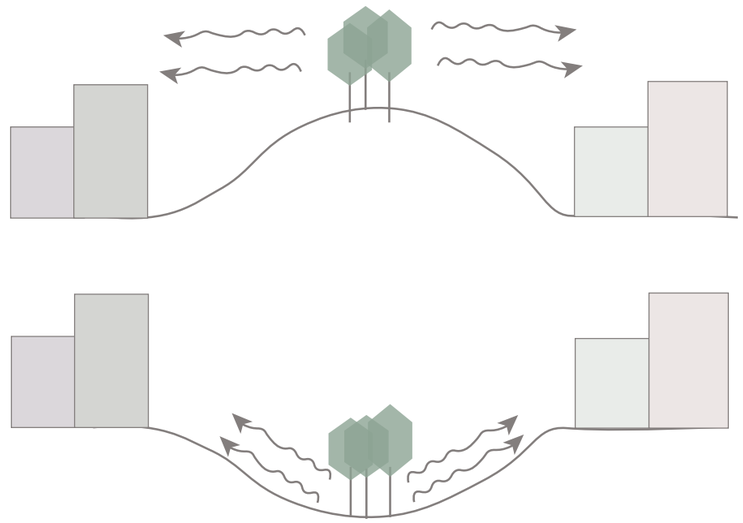
Location

Although vegetation is the best at cooling the air, the best results are obtained by knowing how and where it should be placed, as this can affect the cooling effect.

Warm air rises, whereas cool air stays close to the ground (Andersson, Mohammadi & Petersson, u.å.). In order to spread the cool air to a large area, green spaces are best placed on hills (Lenzholzer, 2015). If green spaces are placed in low points the cool air does not spread at the same extent, because the warmer air creates a lid preventing it from rising (Lenzholzer, 2015).

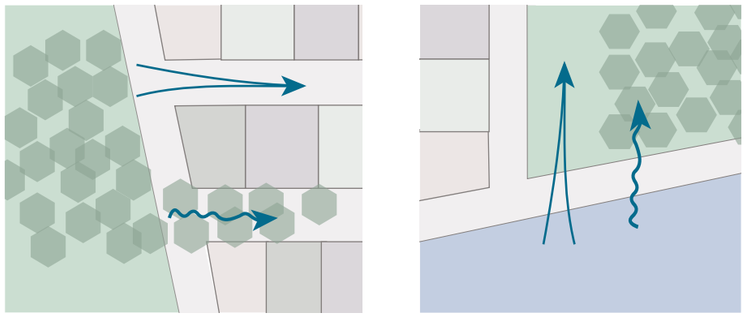
Another important aspect when creating green spaces or green infrastructure is to avoid blocking streets or water fronts as they provide an in- and outlet for the wind - so called windcorridors (Lenzholzer, 2015).

Hill vs low point



It is important how the green space is located; it is better to place green space above buildings to facilitate the cool air to spread (Lenzholzer, 2015).

Windcorridors



In addition to how green space is located, wind corridors are of significant impact for the spreading of cool air (Lenzholzer, 2015). A way of making it possible for the air to spread, is to not have trees all the way out in the more narrow, surrounding streets (Lenzholzer, 2015). If lower vegetation grows there, the wind can spread out from the green space to the streets (Lenzholzer, 2015).

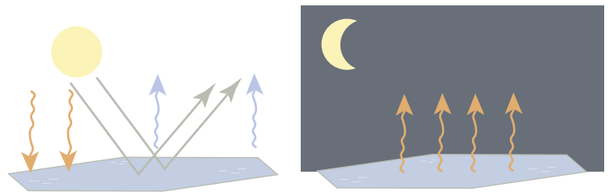
The same strategy can be used by a waterfront, so that the cooler air from the water can blow in over the space (Lenzholzer, 2015).

Water - the in-between

While green infrastructre has only positive effects for cooling and grey has only negative effects, blue infrastructure has both positive and negative effects on the temperature. Water evens the temperature, as it stores both cold and warm, depending on the air temperature. This means, in a simplified way, that if it has been a warm day, the water stores the heat and releases it during night. However, if it has been a cold day, the water gets cold and helps cool the air.

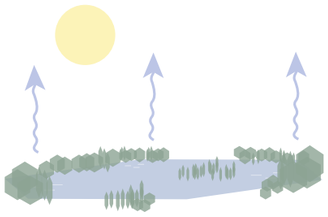
Another aspect of water as a cooling element in urban spaces, is sprinkling water. A fountain fills the air with water drops, which creates a cooler microclimate.

Water



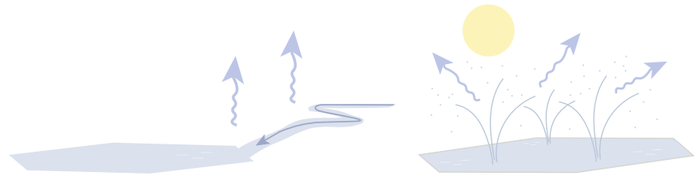
Water absorbs heat and reflects the sunlight during the day (Lenzholzer, 2015). However, during night, the water releases the heat and contribute to a warmer night temperatur (Barthel et al, 2015).

Water and vegetation



Water in combination with vegetation can help cool the air during night time (Lenzholzer, 2015).

Flowing and sprinkling water



Flowing water has a larger cooling effect than stagnant water (Kleerekoper et al, 2012). However, sprinkling, or dispersed, water from a fountain for example, has the largest cooling effect (Kleerekoper et al, 2012). The sprinkling water fills the air with small water drops, which creates a cooling of the air (Kleerekoper et al, 2012).

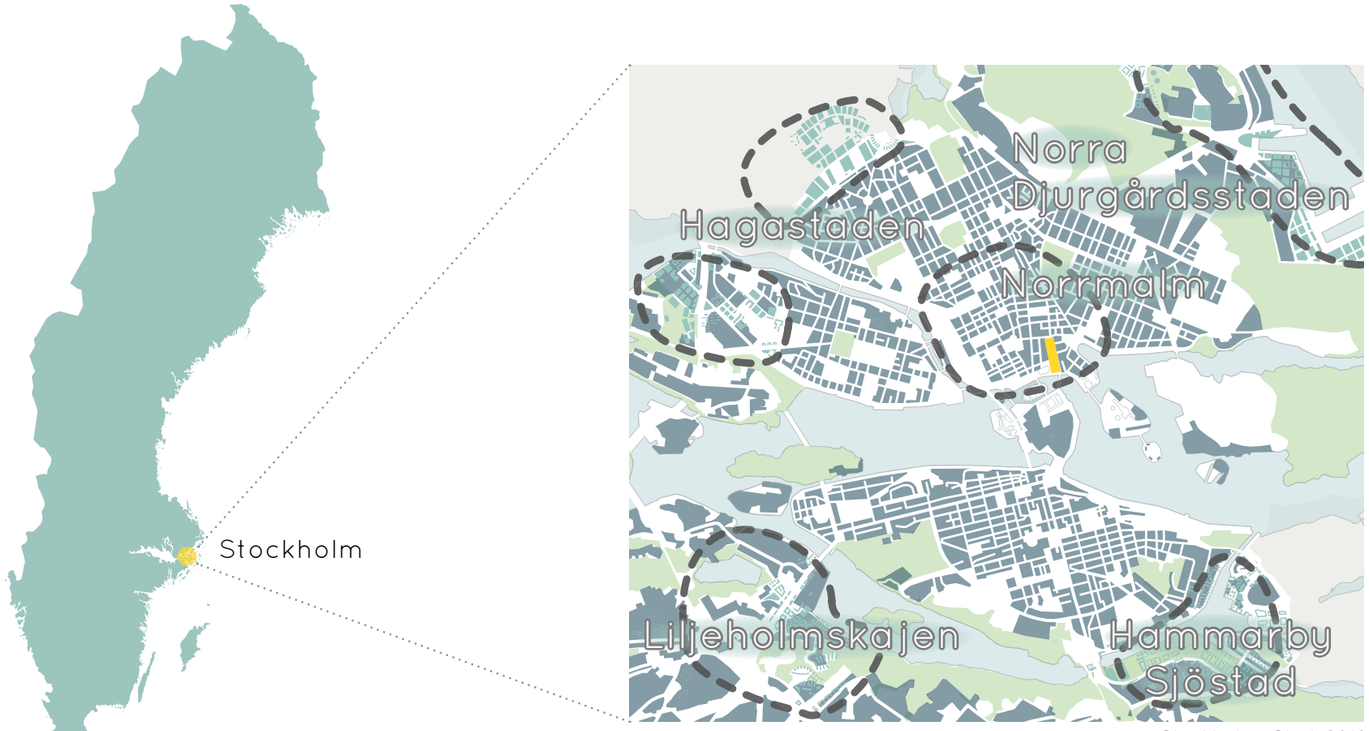
Ongoing conclusions:

- We have defined climate strategies for cooling in urban spaces. These include size of the green space, trees, open grass, biodiversity, the location of the green space and wind corridors.
- Water can operate as both a heating element and a cooling element.

Stockholm

Today, the inner city of Stockholm has a population of about 900,000 people (Stockholms Stad, 2016) and greater Stockholm a population of 2,1 million (von Sydow et al, 2011). Due to urbanisation, Stockholm is growing fast and the demand for residential buildings are increasing rapidly (Stockholms stad, 2016). To meet this demand, a circle of new residential developments are starting to form around the existing city centre (Stockholms Stad, 2014). The new ring of developed areas consists of the urban districts Hammarby Sjöstad in southeast, Liljeholmskajen in southwest, Hagastaden in northwest and Norra Djurgårdsstaden in northeast (Stockholms Stad, 2010).

Stockholm is an unique capital considering the green belts that lead into the city and has because of this a better developed green network than many other capitals (Berg, 2016). Despite this, the inner city is dominated by impervious surfaces and a high density of buildings. This makes small urban spaces even more important with regards to creating green qualities in the city and to a future climate adaptation. A space like Kungsträdgården with its central location has the potential to promote green public spaces, and health and climate benefits of green space.



Stockholms Stad, 2010

Kungsträdgården indicated with yellow. New residential developments are shown in the circular shapes.

Norrmalm is, as shown in table 2, the most densely built district in Stockholm, closely followed by Södermalm, which is located just south of Kungsträdgården (Stockholms stad, 2016). This density and lack of vegetation are the main reasons why Norrmalm has little to no temperature regulating services. Despite the density, the city council of Stockholm is planning on developing Norrmalm further and build 1000 more homes in the area (Stockholms stad, 2016).

This creates a demand to maintain existing green areas and develop them further in order for the district to be able to regulate temperature in the future.

© Lantmäteriet 2017

Kungsträdgården is indicated with yellow, dashed line. The park is located in the dense urban district Norrmalm, with few green spaces in the surroundings. Nearby are the landmarks the Royal Castle, the Parliament and the Royal Opera.

Urban Districts of Stockholm

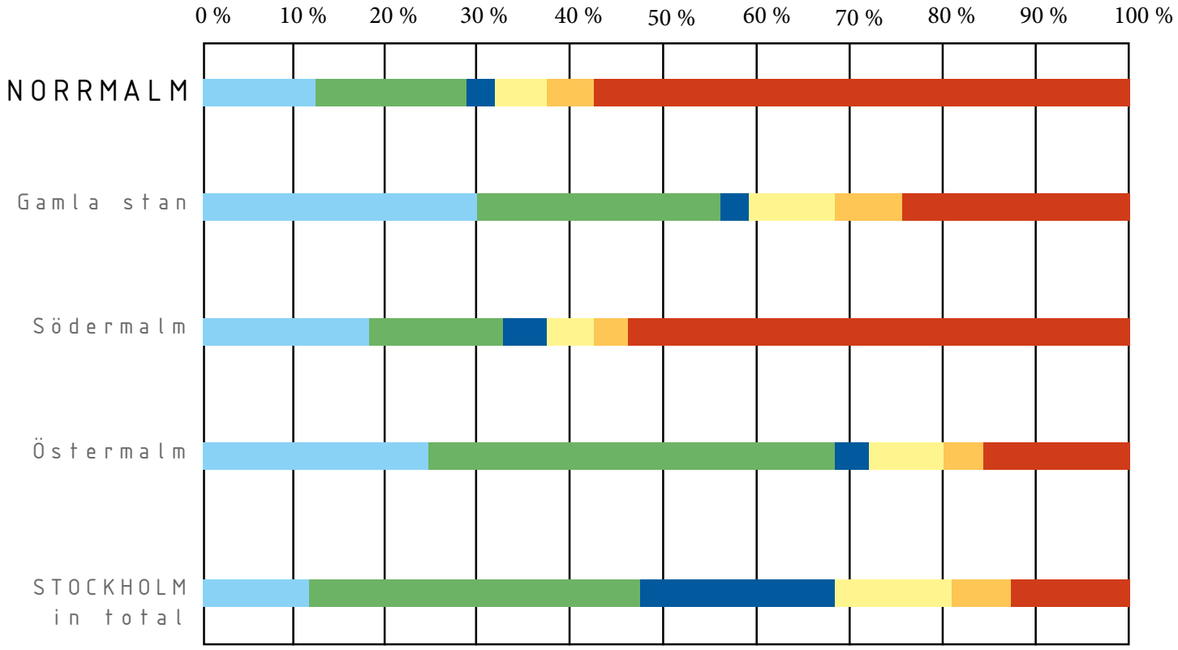
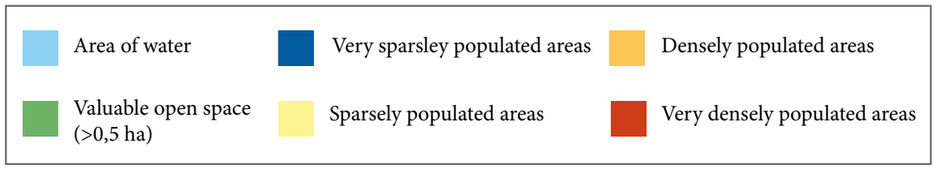


Table 2

Table content from Jonsson et al, 2007.



Ongoing conclusions

- Kungsträdgården is important to keep as a park to maintain the green spaces in inner Stockholm.
- Kungsträdgården is located in the most dense urban district in Stockholm with few green spaces.
- The site is an important and popular place in a social perspective in central Stockholm, providing a great range of events.
- The surroundings of Stockholm inner city is developing and becoming more dense.

Climate Context

Temperature Regulating Ecosystem Services in Stockholm

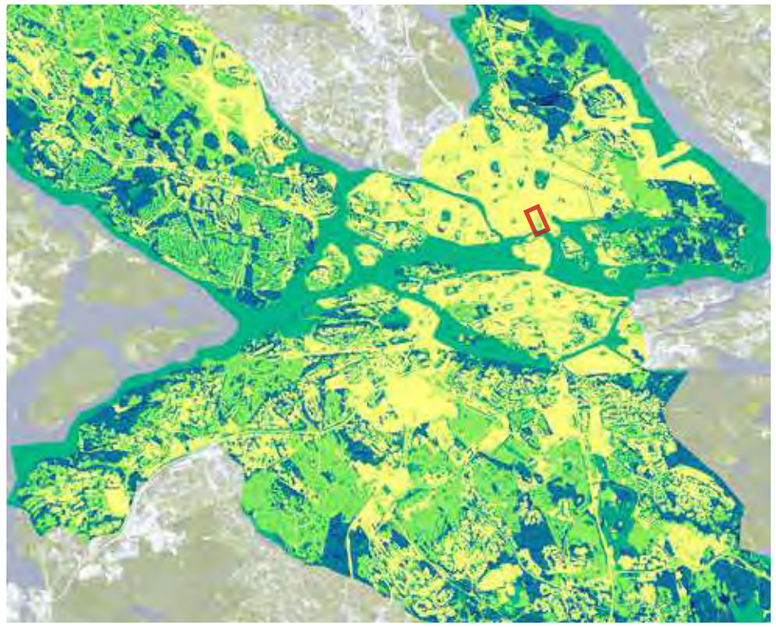
Ecosystem services are aspects of sustainable development that combines the Physical and Biological aspects. Ecosystem services can help facilitate the work towards sustainable cities, and they can also help to understand how cities can benefit from nature (Keane et al, 2014). The basic concept is that nature already has the solutions to many of those sustainability issues we are dealing with (Biomimicry, 2017).

A significant aspect of our work is the site's ability to adapt to a warmer climate and mitigate the negative effects that entails. With that in mind, we studied maps produced by the Stockholm City Council of temperature regulating ecosystem services in Stockholm to determine how Stockholm manages heat (Barthel et al, 2015). The maps are based on table 1.

The maps indicate that temperature regulating services are strongly connected to green space and tree coverage. Areas with well regulating services are located in the forested surroundings of the city. Another conclusion based on the maps are that there are few temperature regulating ecosystem services in the inner city in Stockholm, and this is to be considered as due to lack of green space. Furthermore, an important observation is that the water is decreasing temperature during day time but not during night time, as stated in the previous section explaining temperature decreasing physical elements in urban space.

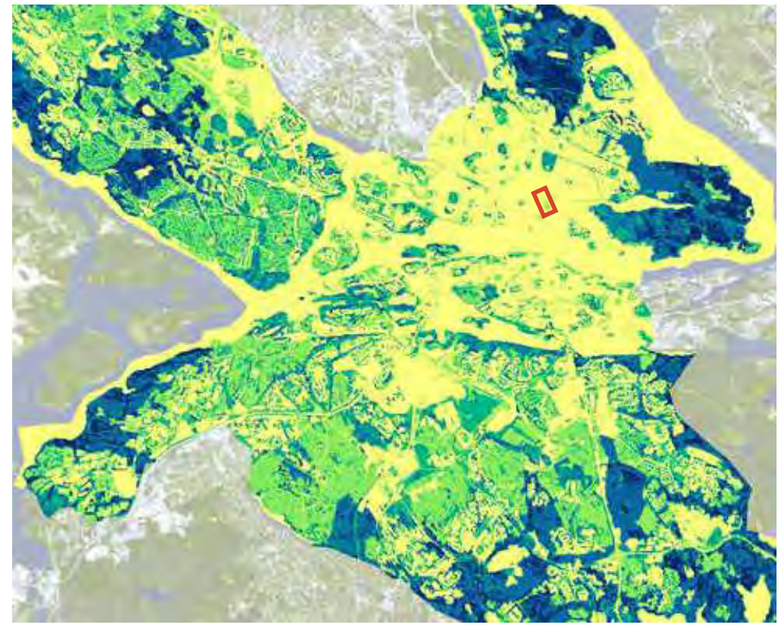
Even though Stockholm inner city regulates temperature poorly during the day, it regulates temperature even less during the night. As stated in the introduction, due to health reasons, it is more important to reduce temperature during the night than the day (Lenzholzer, 2015).

Day time



Temperature regulating ecosystem services during day time in Stockholm.

Night time



Temperature regulating ecosystem services during night time in Stockholm.

Map content from Barthel et al, 2007.

Kungsträdgården

No regulating services

Well regulating services

Ongoing conclusions:

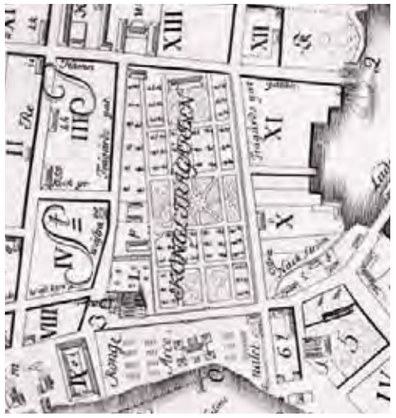
- The temperature regulating ecosystem services are few in the inner city of Stockholm, where Kungsträdgården is located.
- Stockholm is regulating temperature less during night time than day time.

Historical Context

There are several historical layers of Kungsträdgården, which helps explains the existing layout and elements of the park.

Kungsträdgården is one of Stockholm's oldest public parks (Stockholms Stad, 2015a). The site dates back to the 15th century, when it was a royal orchard (Stockholms Stad, 2015a). Since then it has had various appearences. From a royal garden exclusively for a small selected group of people during the 1700's, to an exercise ground for the miltary, to a French formal garden, and finally a contemporary public space. Its layout and function has changed due to the style and demands of the age. Different decision makers have been in charge of the use of Kungsträdgården. In the 1700's it was the royal family and in later ages, it was the politicians in power that decided the layout and purpose of the park.

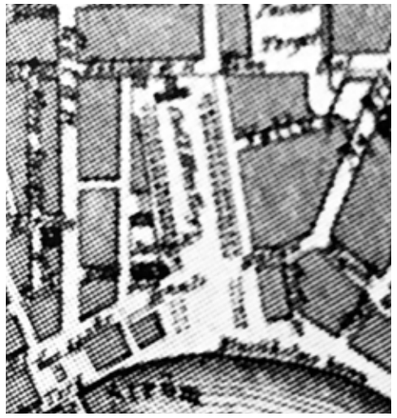
Although the appearance of Kungsträdgården has varied over the years, the boundaries limiting the park have hardly changed since the 1700's. The buildings and roads surrounding the space have been very similar throughout the years, with linden tree avenues framing the park. In the early 1700's to mid 1800's the site was somewhat smaller than today as the palace Makalös stood there (Karlsson, 2010).



Tillaeus, 1733

1733

Royal Baroque Garden with the castle Makalös to the south.



Meyer, 1843

1843

Military Exercice Ground

Brodin & Dahlman, 1870

1870

French Formal Garden - the road Arsenalsgatan cuts the park into two pieces.

Lundgren & Markman, 1883-1885

1885

French Formal Garden - Arsenalsgatan is made smaller.

Hanzon & Påhlman, 1930

1930

French Formal Garden - The Royal Opera is build in southwest.

Gram, 1969

1969

Pond and stage have been added.

Today

Kungsträdgården is used for a variety of purposes, the park operates as a lunch room and is a popular place to linger for a while (Stockholms Stad, 2015a). It also hosts different kinds of markets and events throughout the year, and is very famous for when the cherry trees blossom in April (Stockholms Stad, 2015a).

In 1953 the stage, the tea house and the restaurant adjacent to Hamngatan (today TGI Fridays) was built (Stockholms Stad, 2015a). When Stockholm was the Cultural Capital of Europe, in 1998, Kungsträdgården got its iconic Japanese cherry trees and the large pond in the northern part of the park (Stockholms Stad, 2015a). The octagonal shaped ice rink was also built at this time (Stockholms Stad, 2015a). In recent times there has also been an involuntary tree rejuvenation, as the old linden trees became diseased and had to be changed (Wade, 2017).

As stated in the introduction, Kungsträdgården has in later years been an object for strong public opinions, which proves the value the site has in Stockholm city.

Our design of Kungsträdgården is yet another proposal to the park that meets the present and future demands that we have identified.

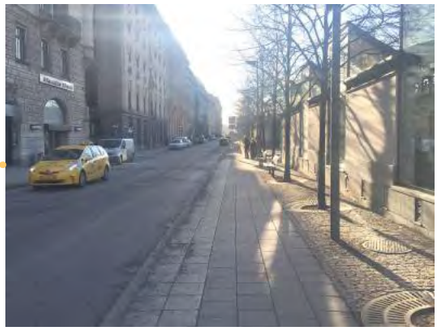
From our site visits, the following conclusions were derived regarding today's layout of Kungsträdgården.

The north part of the park consists of a restaurant with patio during the summer, cherry trees in straight lines and a pond. The pond has seatings on steps and is a popular social spot.

South of the pond, there is an artifical turf surface surrounding a statue.During winter, this surface operates as an ice rink.

An open area that can host events is located south of the artifical turf surface. This part includes a stage, which is used for a variety of purposes.

Along the north east side, there are three restaurant glass buildings that were built in recent years. During summer, there is outdoor seating in front of each one of them.



The eastern street is significantly separated from the park. The restaurant glass buildings create a sharp edge to the street, which also creates a monotone streetscape.

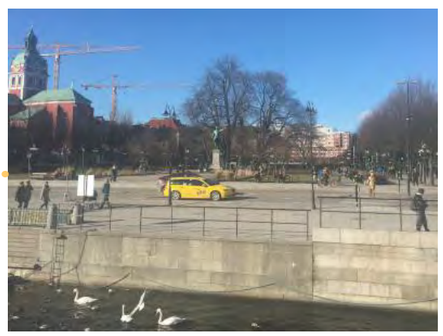
Low restaurant and cafe buildings are located along the western side of the park.

The elm trees, that were object for strong opinions during the 70’s. when they were planned to be cut down. The trees are still there today, surrounding a tea house.

Through the park, in east-west direction, there is a path for pedestrians and bicycles. The path is heavily used and an important connection between east and west.

Behind the stage, there is a fountain surrounded by gravel walkways and willow trees.

The southern part of Kungsträdgården consists of a grass area with an axis of gravel dividing the grass into sections. This is a popular social spot where people gather.



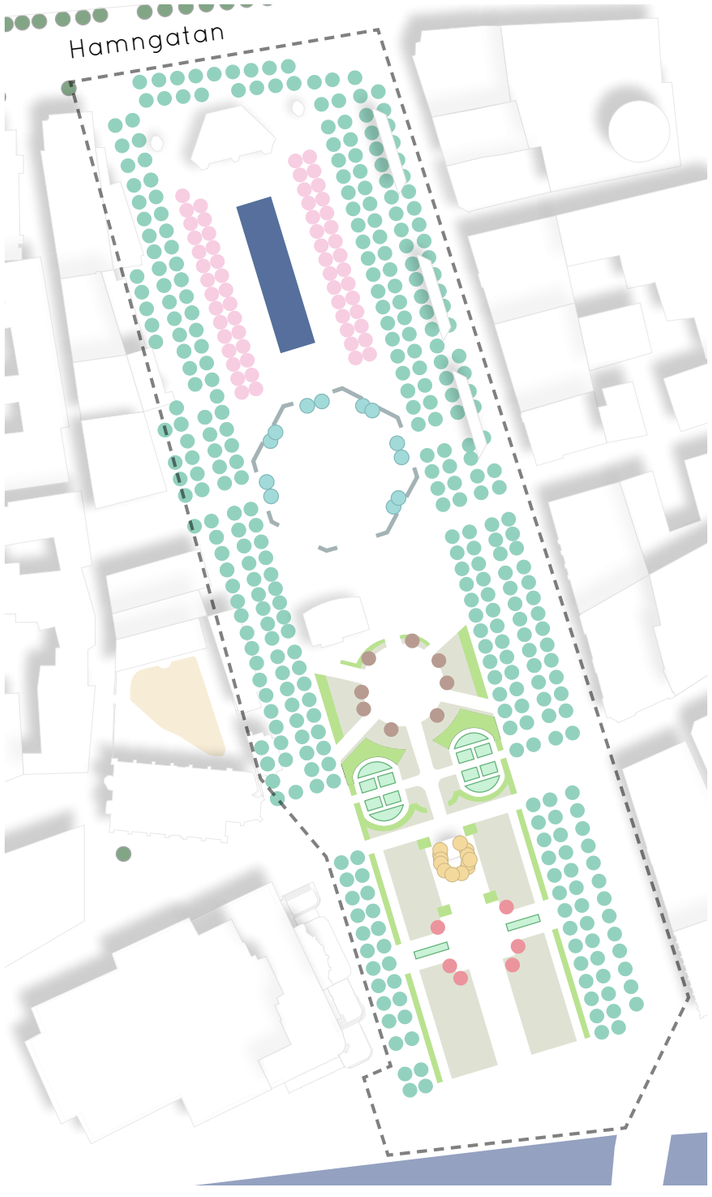
A busy road with three lanes operates as a barrier and cuts the park off from the water.

Ongoing conclusions:

- Kungsträdgården is always changing to meet the demands of the time.
- Our design is a contribution to the ever changing park to meet present and future demands we have identified.

Physical Features

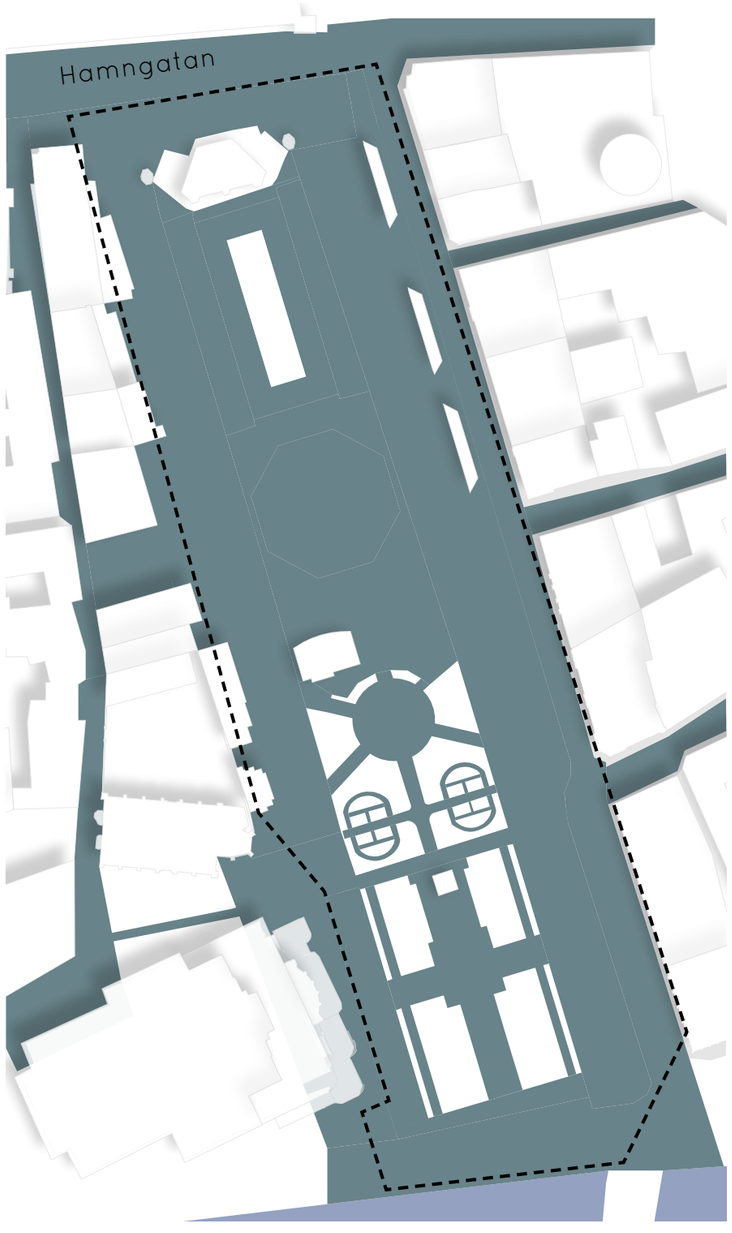
Green & Blue Infrastructure



- Linden tree
- Japanese cherry tree
- Hornbeam tree
- Hedge (coniferus)
- Willow tree
- Other grass
- Grass
- Hedges (deciduous)
- Flower bed
- Elm tree
- Hawthorn tree
- Other tree
- Open water
- Pond

The vegetation on the site today mainly consists of trees. A large part of the site, especially along the east and west side, is covered with tree canopy. The centre includes a few sections of bushes and grass surfaces can only be found in the southern part. A shallow pond is the only water feature, and is located in the northern part of the park.

Ground Materials



- Impervious surface
- Open water

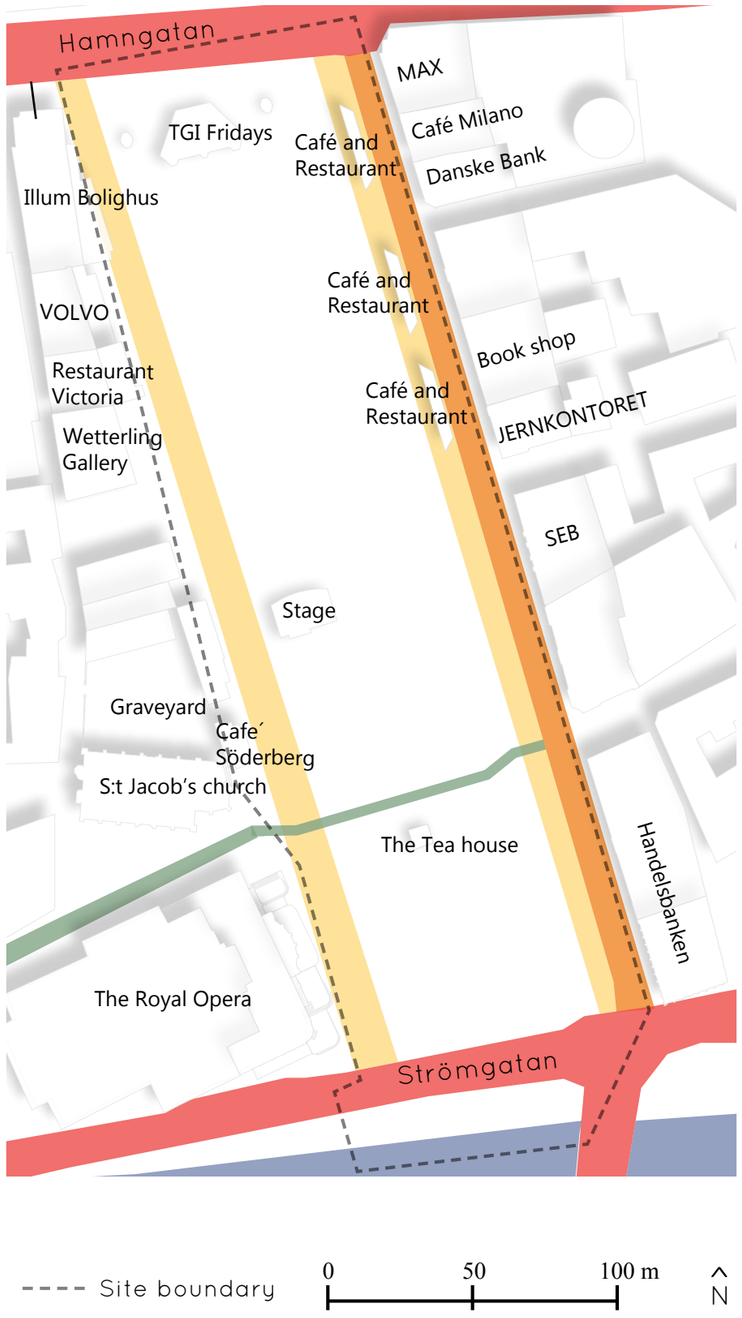
Despite the fact that a majority of the park is covered by trees, Kungsträdgården is dominated by impervious surfaces. Asphalt, slabs of concrete and gravel are the most common ground materials. Only in the southern part is the ground material permeable in the form of grass.

------ Site boundary

0 50 100 m

N

Road Hierarchy & Building Usage



North of Kungsträdgården, the street Hamngatan is located. It is a busy and important road, with cars, buses and trams, as well as pedestrians and cyclists. From here most visitors enters the park as there are a lot of shops and cafes along this road.

South of Kungsträdgården is the street Strömgatan, which is also a rather busy road with cars and tourist buses. East of the park, in north-south direction, is a smaller road with mostly cars and commuter buses. Through the park, in north to south direction on each sides, are two pedestrian paths. These paths enables express movement through the park. Additionally, there is a major pedestrian and cyclist path running across the park.

On the east hand side of Kungsträdgården most of the buildings are quite old and hosts several bank headquarters, and some restaurants and cafés on the bottom floor. On the west side there are a department store - Illum Bolighus, a car show room, some galleries and restaurants and cafés. Closer to the water on the left is the St. Jacob church and even further down is the Royal Opera.

Ongoing conclusions:

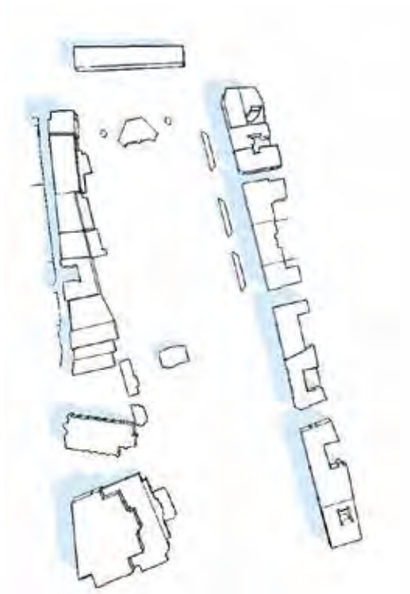
- The vegetation on the site today mainly consists of trees.
- The ground material in Kungsträdgården is dominated by impervious surfaces.
- There are busy roads with cars and public transport in the southern and northern end of the park.
- The buildings surrounding the site are mainly old buildings, with a variety of uses.

Shade Study

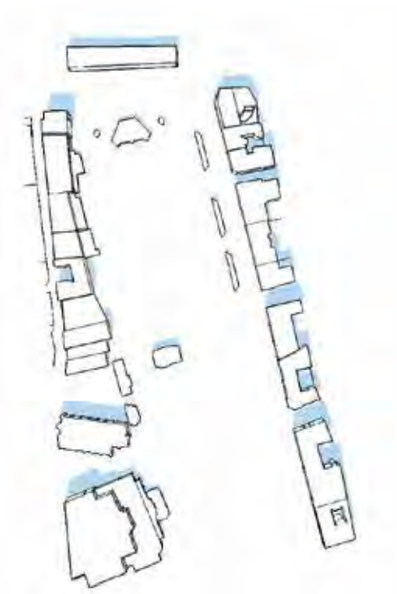
A shade study was conducted to map the shade of the space throughout the day and the year. 21st of June was picked becuase it is the date of the summer solstice, the day of the year with maximum daylight. 21st of December is the day of winter solstice, which is the day with the shortest time of daylight. The spring/autumn is picked by the date of the equinox, which is the date when day and night are exactly the same length.

Although Kungsträdgården is surrounded by buildings, it has a favourable position regarding solar radiation, allowing the sunlight to reach the park during most of the day at summer.

21st June 9.00

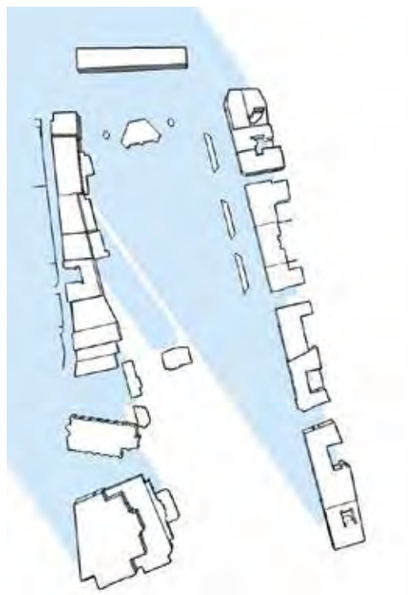


21st June 12.00



21st June 17.00

21st December 9.00



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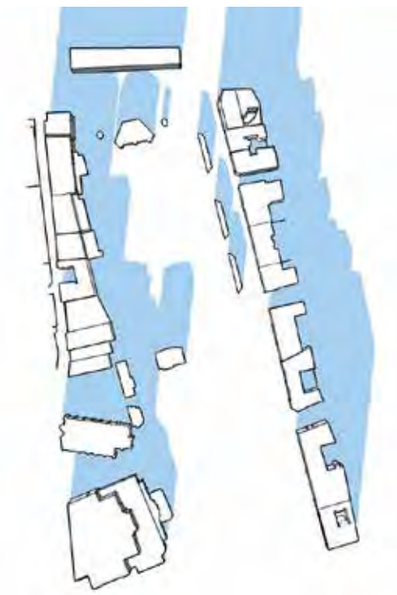


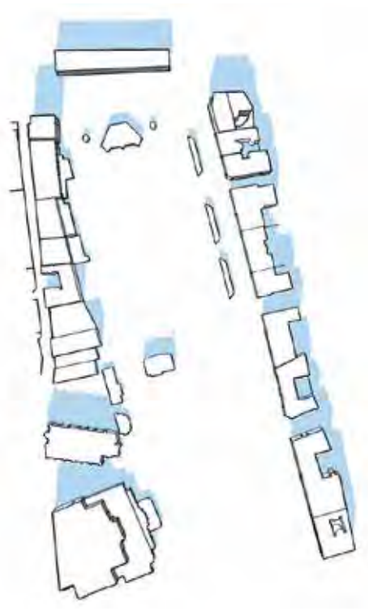
21st December 17.00

During winter the sun sits too low to reach over the roof tops, resulting in little sunlight.

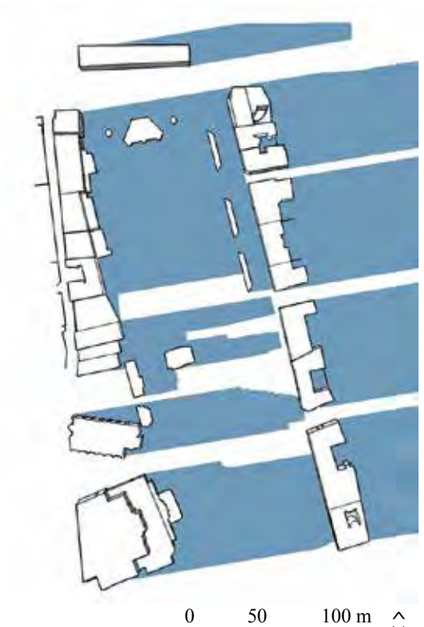
During sunny summer days the trees help shade the park. At spring time however, the sun reaches the ground level of the park since the trees not yet have leaves.

Spring/Autumn

Spring/Autumn



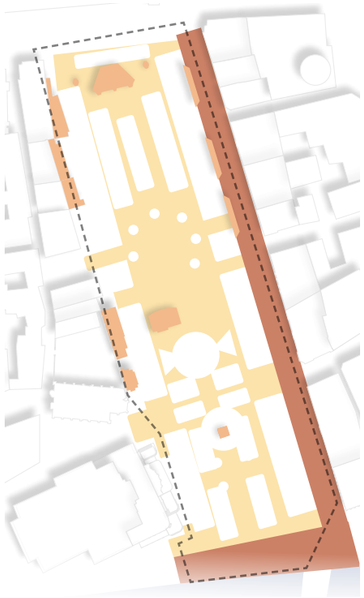
Spring/Autumn



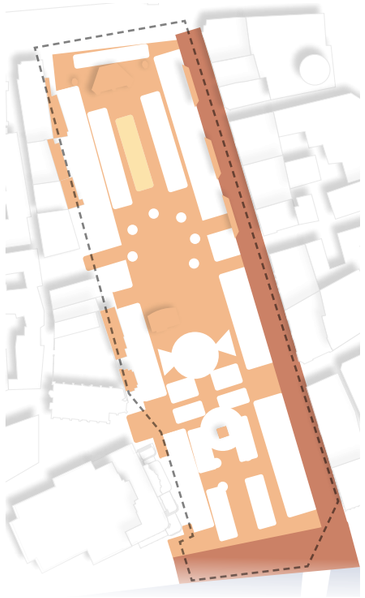
Temperature Analysis

The maps below shows the heating and cooling elements in Kungsträdgården during day time and night time. We chose to divide the elements into three gradients to make them easier to read. The maps are based on the literature study.

Heating day time



Heating night time



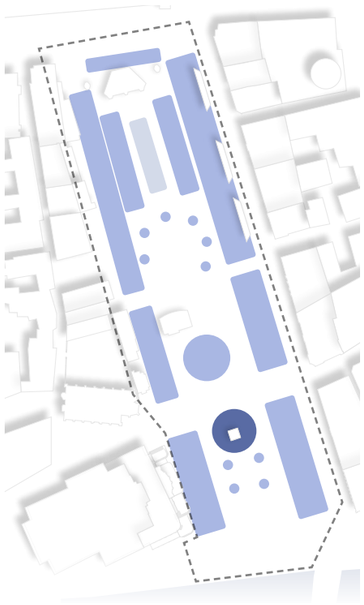
Some heating effect

Medium heating effect

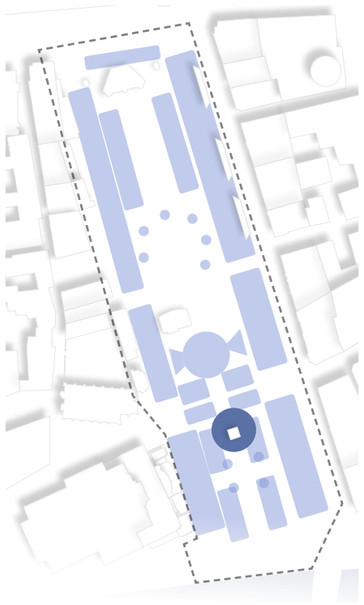
Large heating effect

The main heating effect during day time comes from the large amount of impervious surface and the roads surrounding the park. They store heat during day time and releases it during night time. The roads have a larger impact because of the traffic which causes pollutions. Buildings in the park also contributes to an increased temperature.

Cooling day time



Cooling night time



Site boundary

Some cooling effect

Medium cooling effect

Large cooling effect

The shade from the trees provides some cooling effect. However, as most of the existing trees are not broadleaved they do not cool as much during night time. The flower beds and open grass surfaces help to decrease the temperature during night time. The elms standing in the south part, provides the largest cooling effect, as they are broadleaved trees.

N 0 50 100 m

Design Strategies

To make our climate strategies, which are general and can be applied on most public spaces, more site specific, we formed design strategies for our design. These defined what we wanted to achieve with our design on our site from a climate perspective. The design strategies are based on our site study regarding climate.

General

- Create a flexible space that includes our suggested climate strategies

Vegetation

- Use a diversity of species and create a variety of canopy density
- Create multiple layers of vegetation - ground level, bush level, tree level.

Shade

- Create a variety of shade, daily and annually

Wind

- Utilise windcorridors for spreading of cool air

Materials & Physical Elements

- Minimise impervious surfaces
- Water elements should be combined with vegetation
- Enhance water features, such as fountains and sprinkling water

Traffic & Built Elements

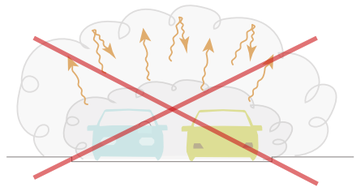
- Minimise traffic & built elements
- The built elements that are needed should be beneficial from a temperature decrease aspect

The Maximum Climate Design

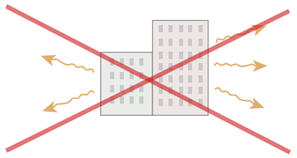
This is an example of how a layout for Kungsträdgården could look like if it was designed solely out of a climate perspective - a maximum climate design. All the warming elements that we have defined are removed from the site, and our climate strategies for temperature decrease are applied.

Climate Strategies

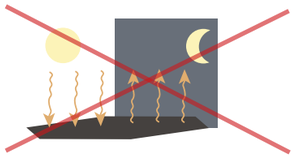
Traffic



Buildings

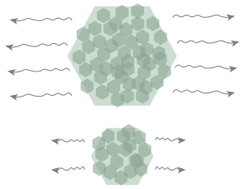


Impermeable surfaces

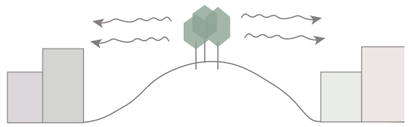


As stated in our heating section, cars, buildings and impervious surfaces are the main reasons to urban heating. Therefore, these elements are removed from the site. For the vegetation to grow and thrive to achieve maximum cooling effect, humans are excluded from the space. This is done by a fence that surrounds the whole site.

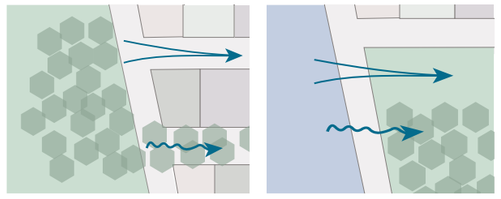
Bigger is better



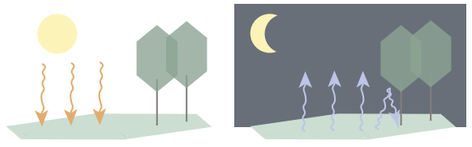
Located on a hill



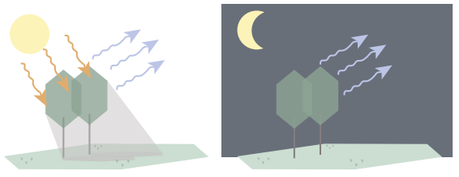
Wind corridors



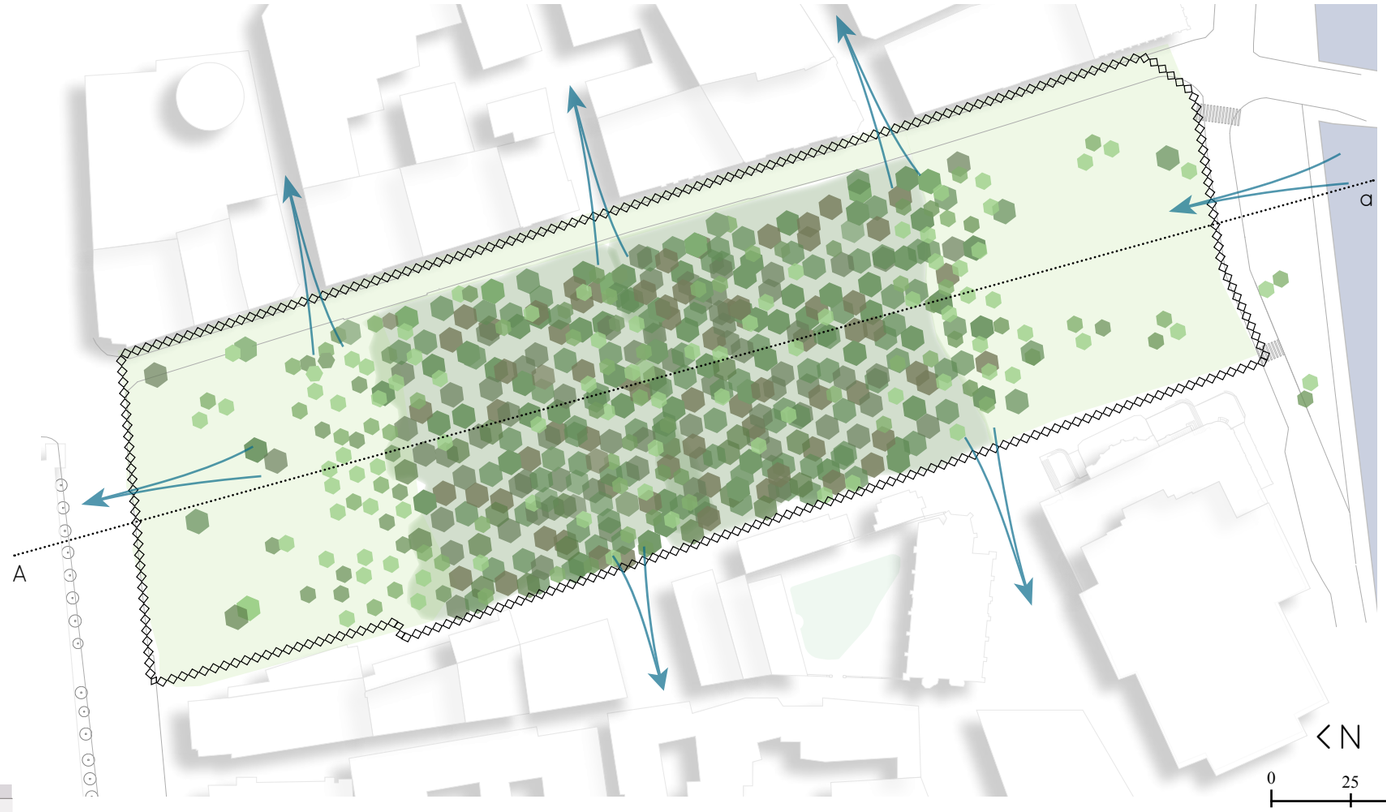
Open grass



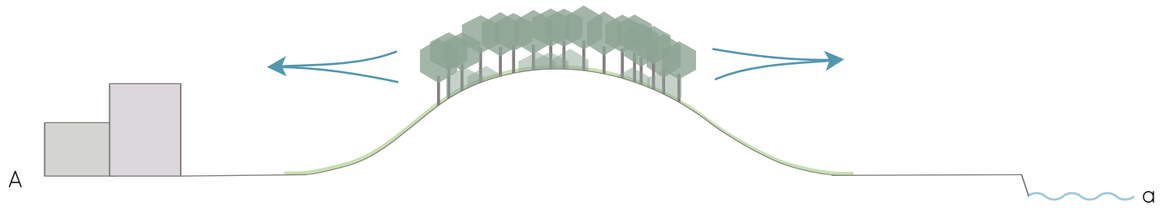
Trees



Biodiversity



The sketch shows a design for Kungsträdgården only from a climate perspective, according to our temperature decrease strategies. The arrows show the air flow.



The cross section is schematic and shows an exaggerated elevation to demonstrate the principal of vegetation that is placed higher than the surrounding buildings. The blue arrows demonstrates the cool air that spreads from the vegetation.

The bigger the green space is, the better the cooling effect is, therefore the green space is expanded maximum on the site. For the cool air to spread in an efficient way, the green space is placed on higher ground than the surrounding built area. The vegetation is low closest to the adjacent streets, so that the cool air can spread. There is also a variety of tree cover and open grass surfaces for cooling during day time and night time.

The trees are on top of the hill for the cool air to spread. Open grass surfaces are used on the slope for cooling during night time and to make it possible for wind to travel down to the streets.

The tree that are used are mainly broadleaved trees with large canopies for maximal shade and evapotranspiration. A diversity of species should be used for a resilient green space.

Social Study & Analysis

The social study of the site today is presented below. The site was divided into sections and each section was evaluated from its strengths and weaknesses out of a social perspective.

Strength
Weakness

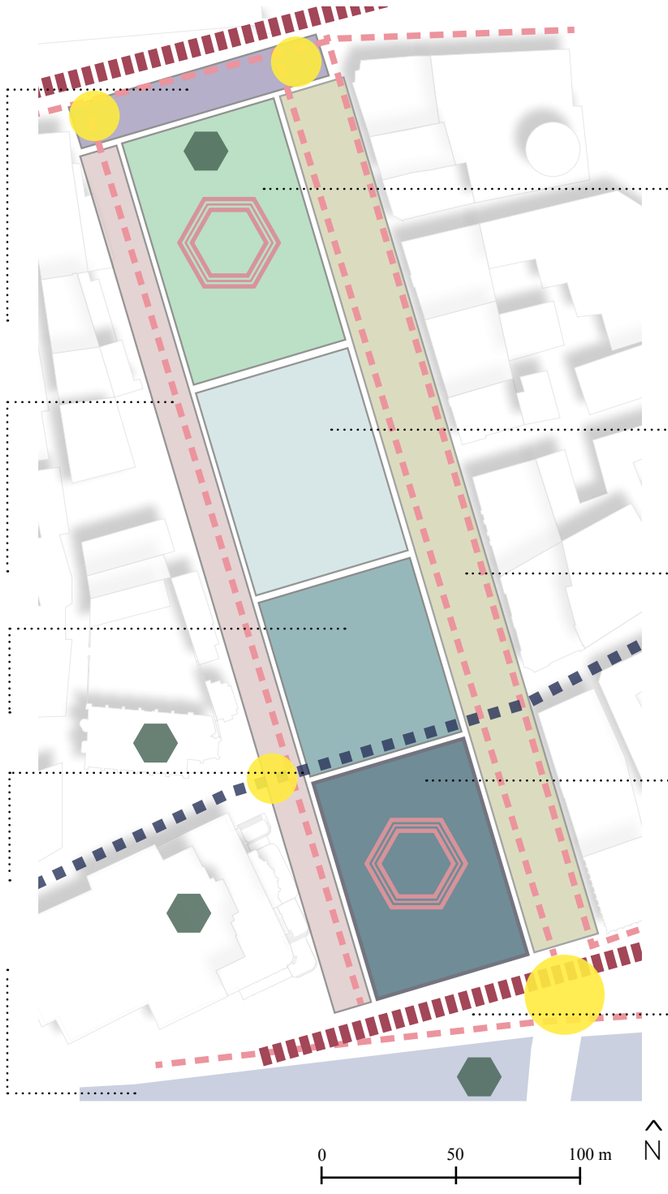
North entrance
- Lots of movement
- Important connections north
- Unclear entrance
- Low legibility
- Poor sightlines
- Noise pollution from road

West walkway & alley
- Important path
- Weak connection between park and buildings
- Trees act as visual barrier towards buildings

Statue
- Dark
- Unclear function

Bicycle track
- Important path for bicycles and pedastrians
- Barrier to walk into the park

Waterfront
- Water view
- No water connections
- Road acts as a physical and visual barrier between water and park



Human activity centra
Node
Focal point
Pedestrian movement
Important bicycle path
Road acting as a barrier

The pond & seating
- Lunch and pause space
- Staying for shorter and longer time
- Decorative trees and pond
- No function during the winter season

Event surface
- Activity
- Open character
- Lack of seating

Street
- Important path
- Weak connection between buildings and park
- Traffic acts as a physical and visual barrier

Picnic area on grass
- Open character
- Seating on benches and grass
- Lot of vegetation
- Flowers
- Activity
- Some connection to the water

South entrance
- Lots of people movement
- No defined entrance
- Trafic operates as visual and physical barrier

Design Strategies - Social

Our findings from the social study lead us to our design strategies regarding the social aspect and what we wanted to achieve with our design in this aspect.

General
- Create a coherent and flexible space that can be used by a variety of people

Enclosure
- Create spaces with different characteristics for a multifunctional park

Water
- Enhance the presence of water

Movement
- Prioritise pedestrian movement and enhance permeability

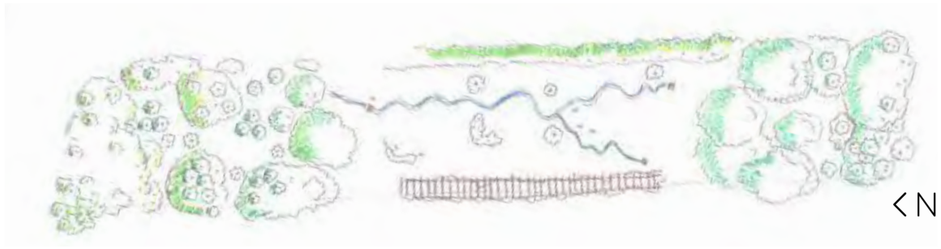
Streets
- Claim the site as a pedestrian space and park

Entrance
- Indicate a green oasis and allow easy access to the park

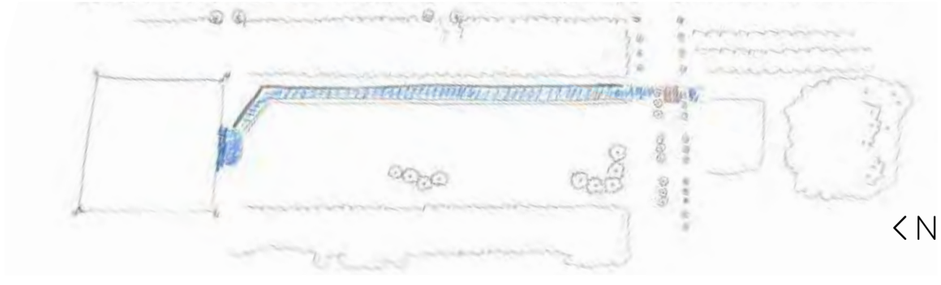
Sketches

Below, sketches that were conducted throughout the process are displayed. The sketches helped us find a design concept for our layout.

This sketch focuses on tree and leafy shade. It is divided into three rooms with different characters. To the north there is a forest with a coherent tree canopy and winding walkways. In the centre is a meadow with open grass and scattered clusters of trees. The centre part is divided from the southern part with a water feature with stepping stones. The southern part is an open grass field with smaller hills that provides a nice view over the open water.



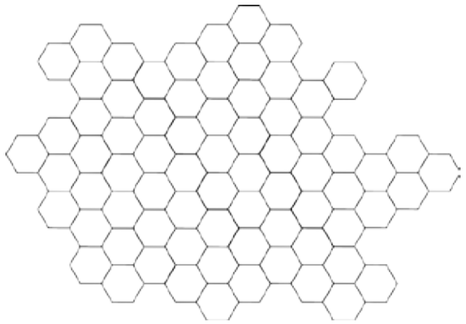
This sketch focuses on both how human can cool themselves but also what and how elements and vegetation can prevent sun radiation. The north part is a forest, inspired by North American national parks with tall trees and a high canopy. The centre is an open shrub and grass layer with a stream running through it, somewhat inspired by the Englischer Garten (English Garden) in Munich. The centre part is framed on each side of either an avenue of trees or a pergola. To the south is yet another forest that can shade the centre part.



Here, the northern part is covered by a screen or a roof that can help reflect some of the sun radiation. From the roof there is a waterfall creating a wall of water for people to walk through. Along the park there are tree avenues with a coherent canopy and in the center is a open grass surface with scattered tree and bush clusters. The water from the waterfall runs on a raised water block which is lowered the more south it gets. In the south is a minor forest.

Inspiration & Design Concept

Photo by Karunakar Rayker on Flickr Licens: CC (by 2.0)



Below is our main design concept explained and a summary of our inspiration. A design concept was used to create a coherent space, where our climate strategies and case study inspiration was implemented in our layout.

Two characters into one

Our design concept is based on the hexagon shape. Today, Kungsträdgården follows a rather strict layout based on the original baroque park, with straight axes and regular shaped parterres. We wanted to keep the strict concept as it relates to the history of the park, but we also wanted to add some organic shapes and dimensions.

Hexagons are often encountered in nature. Not only in beehives; snowflakes, the shells of turtles, pineapples and basalt columns are all composed by hexagons.

The hexagon is both a rounded, organic shape at the same time as it is strict with several corners. It is a building block that can be easily combined in different ways. It allows you to reach into every corner and build intricate and flexible patterns.

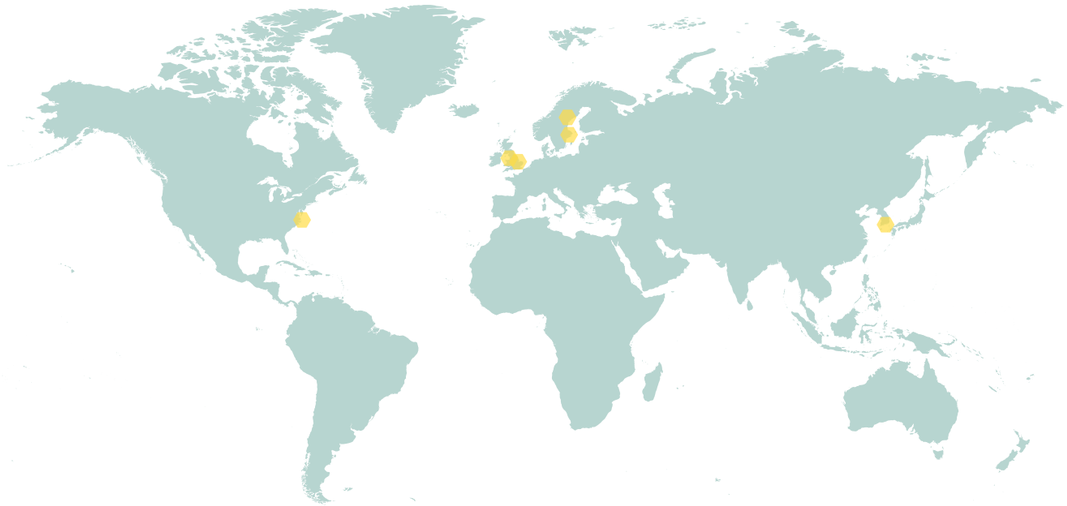
We wanted flexibility as another aspect of our design concept. A space that is flexible is more likely to respond to unknown future demands. We also wanted a space that was flexible in use that can be used in numerous ways, based on the needs of the time.

A greener place

We wanted to find inventive solutions on how to implement vegetation in an urban context, to make Kungsträdgården a greener space.

Case Studies

Case studies were used to visualise how our strategies would function in practice. As for inspiration, each case study includes at least one design element that we found useful during our design process.



The map shows the geographical spread of the case studies.

Climate Example:

Cheongyecheon river, Seoul, South Korea

This case study was picked as the only climate adapted urban space in our survey. The river was up until 2005 covered by a 16 meter wide highway, but is today transformed into a popular public park. The large scale project provides a green lung to the busy city and also helps decrease the air temperature by removing traffic and impervious surfaces, and replacing it with vegetation and water. This project shows how to succesfully change existing developments and turn it into a functional green area.

Photo by Aleksandr Zykov on Flickr Licens: CC (by-nd 2.0)

Design interventions, studied visually:

Paley Park, NYC, USA

The trees in Paley Park provide a light and semi-transparent shade thanks to its high tree canopy. The height of the trees and their thin trunks creates a good view into the space. Because of their irregular placing, the space appears to be open while also creating small rooms within the space. Moveable seating allows visitors to choose from a variety of shades.

Photo by Aleksandr Zykov on Flickr Licens: CC (by-nd 2.0)

Brindley Place, Birmingham, UK

At Brindley Place they have created walkways over a water feature with fountains that entails a sprinkling feature, which cools the air and people. The walkways are good as they allow people to get closer to the water and touch it.

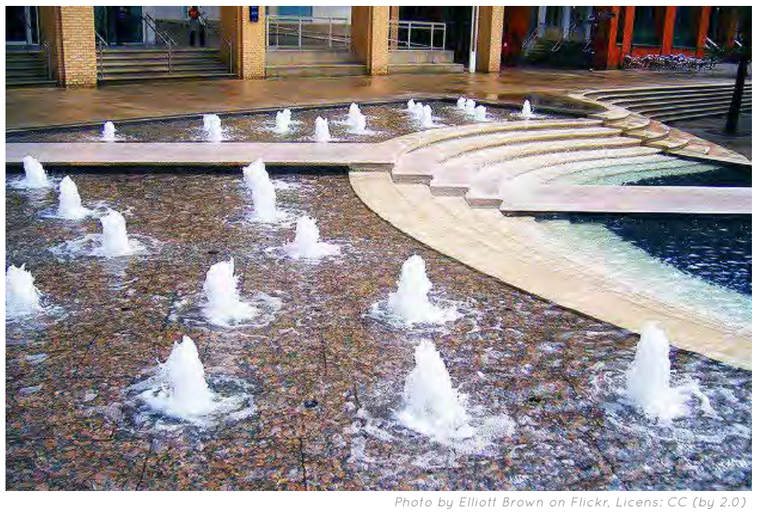


Photo by Elliott Brown on Flickr, Licens: CC (by 2.0)

High Line Park, NYC, USA

As an alternative to a hill a raised boardwalk can provide that elevated level of vegetation that is positive from a cooling perspective. The High Line Park in New York served as an inspiration to a raised walkway with a public rooftop garden. The garden is an appreciated element with native vegetation to prevent foregin pests and sickness among the plants.

The light coloured ground material prevents the boardwalk from storing all the heat and irregular placing of the flowerbeds creates small spaces along the boardwalk.

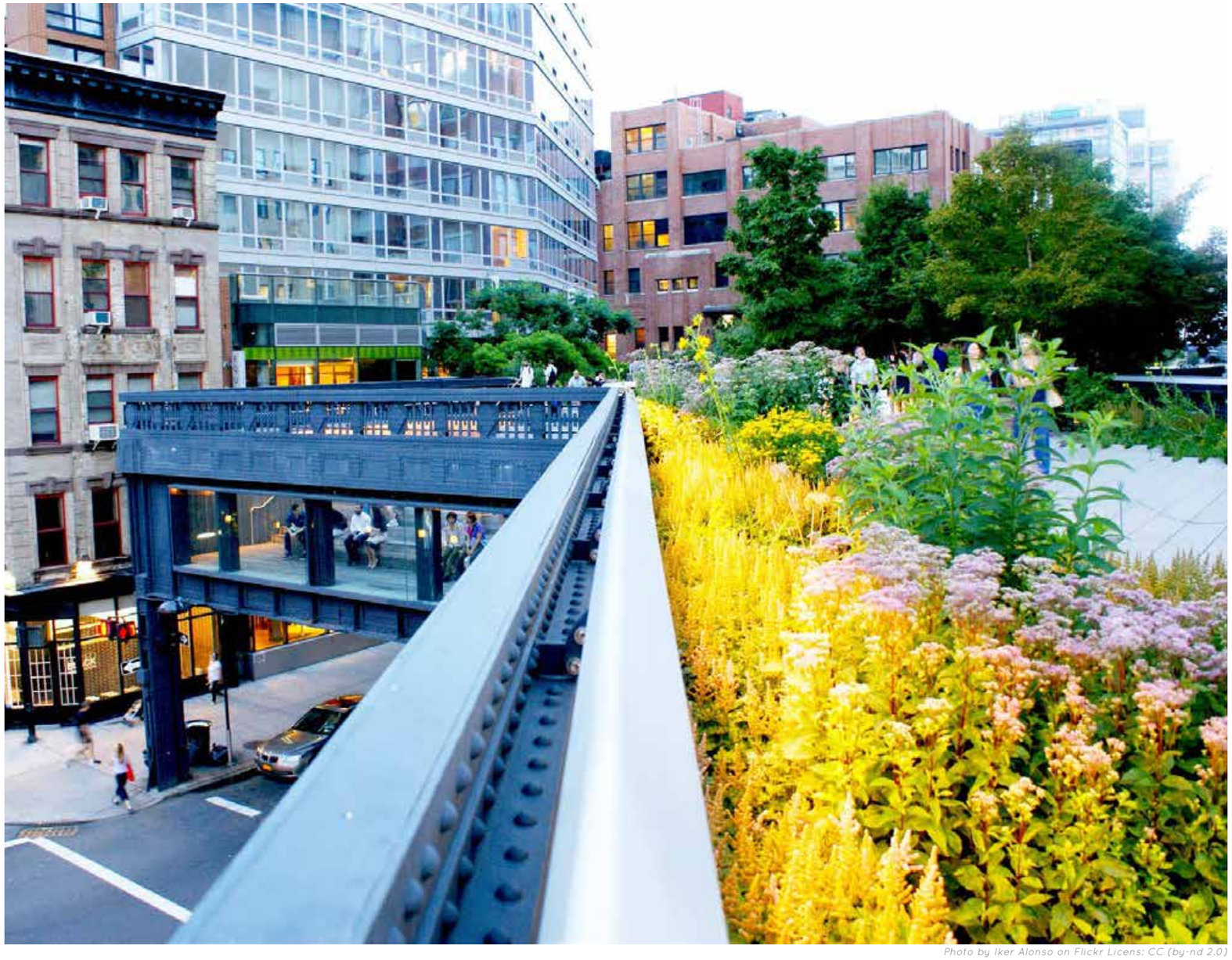


Photo by Iker Alonso on Flickr Licens: CC (by-nd 2.0)

Design interventions, visited:

Rådhusparken, Umeå, SWE

Rådhusparken has a similar location to Kungsträdgården, as it is a central park by the water. In our opinion, the park is a good example of a green space integrating the waterfront into the park. The waterfront is built in steps, and creates a public environment close to the water. Additionally, a road is succesufully integrated in the park, operating as a shared space.

Central Park, NYC, USA

Central Park proves it is possible to have a forest in the middle of a busy and dense city.

© Google maps 2017

More London, London, UK

More London is a newly designed space in central London. The space includes a high tree canopy ceiling, providing a light shade from the sun without interfering with the sightline. Additionally, water is used in interesting ways through the space; raised water blocks make it possible to touch the water, and a small canal that travels through the walkway clearly guides the pedestrian through the space.

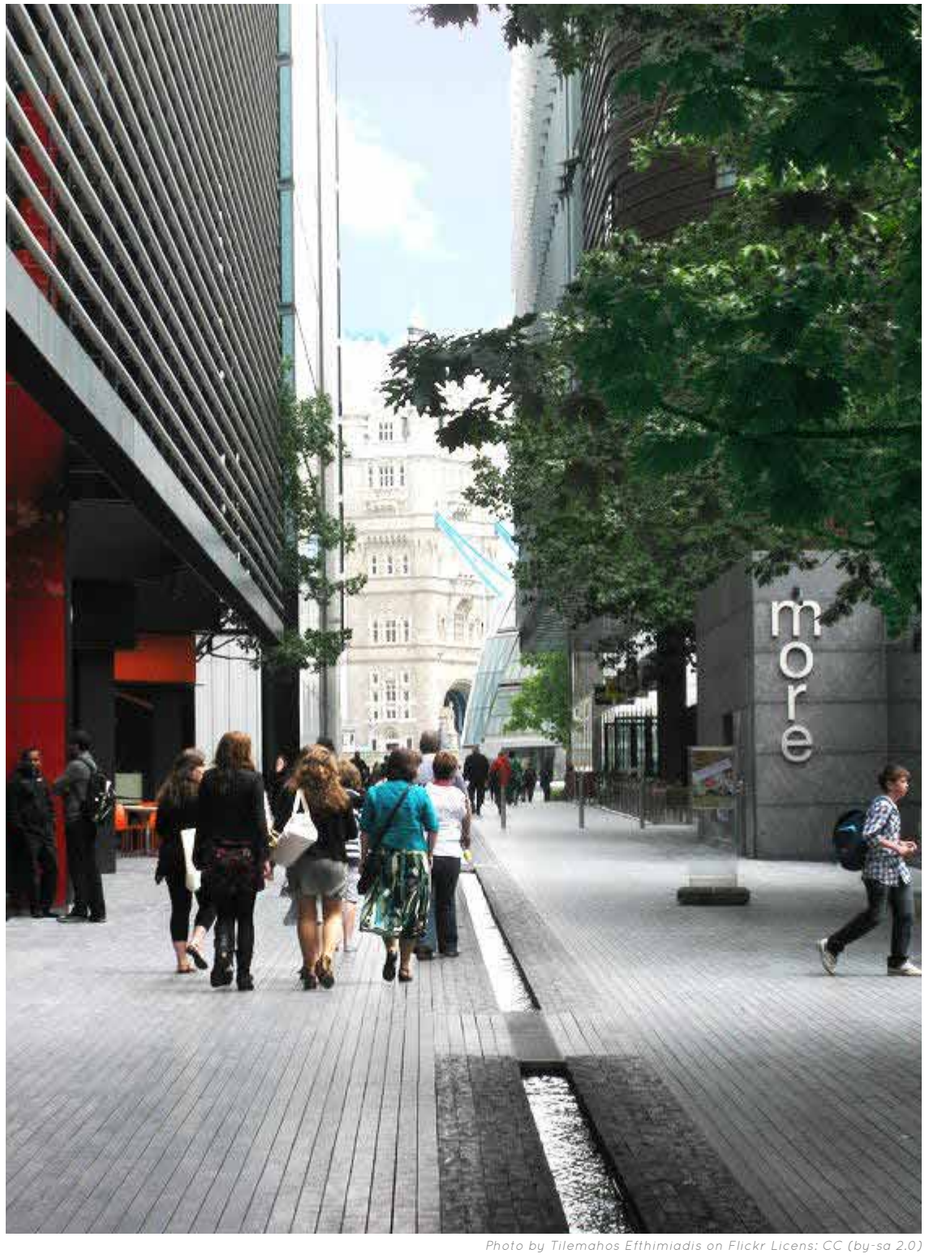


Photo by Tilemahos Efthimiadis on Flickr Licens: CC (by-sa 2.0)

Photo by Garry Knight on Flickr Licens: CC (by 2.0)

Ongoing conclusions:

- There are few urban spaces designed to decrease temperature
- The case studies were used in an inspirational purpose, to find ways to implement our climate strategies in to our site

Compromising between climate aspects and social aspects

Semi-Permeable Ground Materials

As previously stated, based on our literature study, it is clear that the most efficient ground materials to lower air temperature are grass surfaces and vegetation. However, from a social perspective grass surfaces or vegetation are not always suitable as ground materials as they are not accessible nor resistant to heavy usage. As a compromise between concrete and grass surfaces there are semi-permeable solutions. They have the accessibility and durability qualities of concrete and bitumen, and have at the same time the permeability of grass and vegetation. This makes them better from a climate perspective.

In areas of a park where large numbers of people are likely to dwell and move, semi-permeable materials can be used to allow high usage, without interfering with the purpose to cool the air.

An example of a semi-permeable ground material that combines concrete and grass.

Photo by Life fanclub on Flickr Licens: CC (by-sa2.0)

An example of a semi-permeable ground material where grass grows between concrete slabs. This allows heavy use at the same time as getting the benefits of grass.

Buildings and Green Space

According to our literature, buildings do not have temperature decreasing qualities. However, as some buildings are hard to remove on our site because of historical and cultural values, solutions to make them more climate beneficial were needed to be found. By placing vegetation on top of them, climate benefits can be achieved while keeping the building underneath.

Another positive effect that can be achieved by doing so, is that the vegetation is placed higher up. To obtain the best cooling effect from vegetation, it is most beneficial to place it on a hill. As a hill can be hard to create in a city, especially in a dense district with no undeveloped space, one way to go around it can be by creating roof top garden on top of existing buildings. Another way can be by placing a raised boardwalk garden on top of existing roofs or converting an existing train line or elevated motorway into a park.

Ongoing conclusions

- For surfaces that are heavily used, a semi-permeable ground material can be used, such as concrete with grass in the joints.
- Vegetation on top of buildings are better in a climate perspective
- An alternative to a hill can be a raised boardwalk to get a higher level of vegetation.

Design

In this section, our design will be presented, showing the different layers and climate benefits of our layout.

The Royal Climate Garden

The Royal Climate Garden is designed to decrease the air temperature in Kungsträdgården and its direct vicinity.

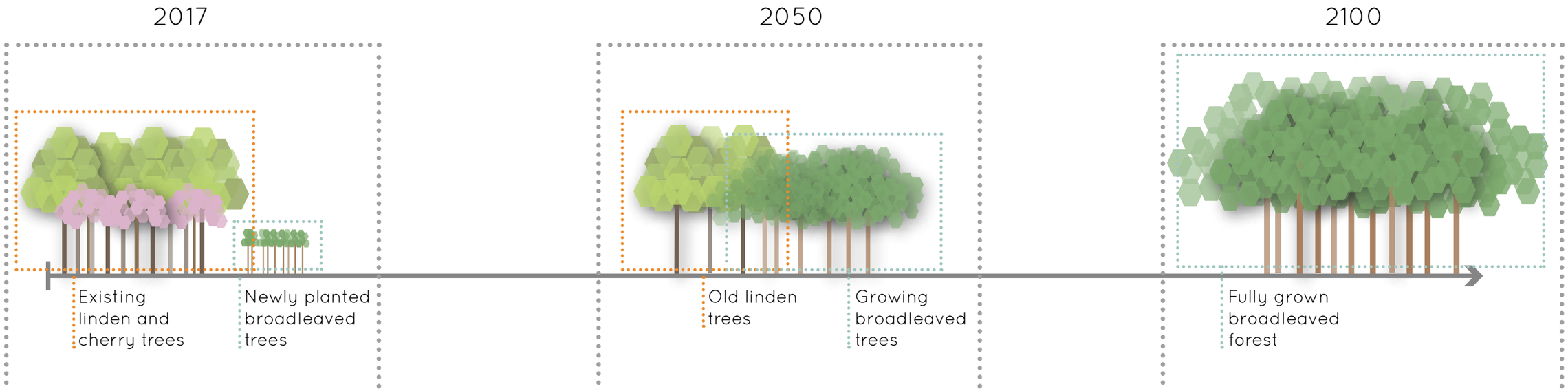
Based on our climate strategies, we wanted to create a flexible park with multiple layers of climate benefits to respond to a warmer future climate.

Placing and choice of vegetation and a climate beneficial choice of materials was essential in our layout. Through these concious decisions, a park with several characters was created where climate aspects had first priority, without compromising the social importance of the site.

The following pages will show the design and each section of the park in more detail. The illustrations are conceptual, and rather inspirational than exact images, to give an idea of what each part of the park can look like.

Timeline

The aim is that our design is a slow change of the site over time and the new layout will be implemented gradually. In this timeline, we demonstrate how the vegetation will change over time.



2017

Vegetation

The initial stage is started today, 2017. The broadleaved forest is planted first as it needs to grow large in order to fill its purpose. As the park needs some larger trees to provide shade during the growing phase of the forest the Japanese cherry trees and linden trees are kept.

The boardwalk is built to allow the vegetation planted there to adjust and grow. With the building of the boardwalk some of the linden trees to the west are removed.

The existing building in the north part is removed and replaced by a green entrance.

Traffic

To remove traffic was an important aspect for us. However, when looking more in depth how to do this, we realised how essential the east road and the south road were for the road system in Stockholm. This resulted in that we could not just remove them at once, we needed to find a strategy how to do this. The solution we found was to make the change gradually, and step by step remove the traffic from the roads.

Step one was to allow cars on the roads, but minimise their impact on the space. This was made with several strategies: Strategy one was to make the roads into shared spaces to slow down the speed in order to make the roads pedestrian friendly. Strategy two was to have another ground material on the roads in the park and allow patios and other outdoor seating adjacent to the roads to indicate that this is a park - not a road only for cars. Strategy three, the vegetation was an important aspect in indicating that this is a park. However, as the eastern road also operates as wind corridor, we could not fill it with trees. The vegetation needed to be of lower kind, but by using raised planting beds in the driveway, the cars still have to make way for the plants.

2050

Vegetation

By now the forest has gained some height, providing more shade in the park. The Japanese cherry trees have died, as their lifespan is no more than 50 years. The existing pond has been replaced with a larger pond with sprinkling water features and walkways.

Some of the linden trees have died due to age and stress caused by mistreatment during former public events (Wade, 2017).

The entrance area, the picnic area and the boardwalk are in full use, creating different rooms and layers of vegetation to the park.

Traffic

The second step in removing traffic from the park, is to only allow public transport on the roads. These will also need to go in a lower speed.

2100

Vegetation

At this time the forest is almost fully grown. The former linden trees are all gone due to age and stress. By now the park provides maximum cooling benefits.

Traffic

Our third step, is to remove all vehicles from the space. With the alternative of, depending on the demands in the future, to build a tram line on the eastern road. Our hope is that the southern road can be completely without traffic and that the park can be fully expanded all the way to the water.

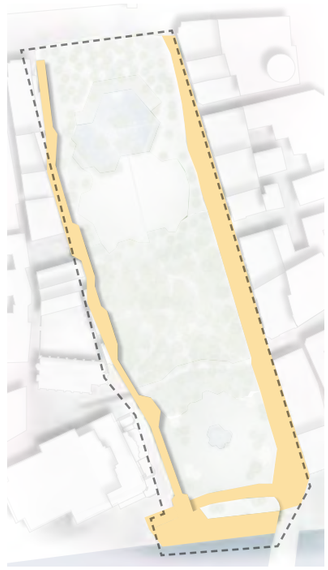
Explaination of the Design Proposal

Vegetation

- Semi-permeable surface
- Open grass
- Scattered trees
- Broadleaved forest
- Water with vegetation
- Raised vegetation

This maps illustrates our different levels and types of vegetation. In order to obtain the most cooling effect a variety of vegetation is required. We widened the park by adding more green elements and vegetation to the existing roads in the east and to the south. We replaced the previous large impervious surfaces into grass or semi-permeable surface to enhance the amount of vegetation. The boardwalk with vegetation in the west provides a raised level of greenery.

Heating day time



Heating night time

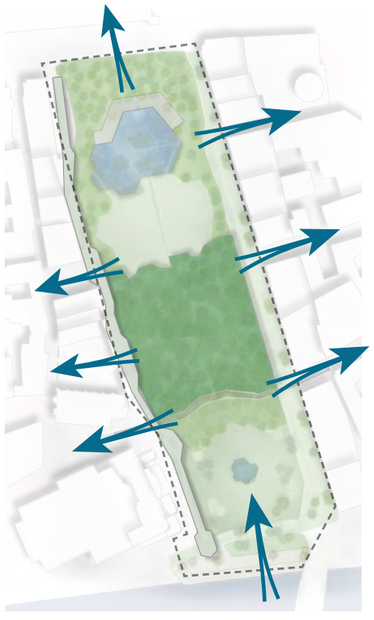
- Some heating effect
- Medium heating effect
- Large heating effect

As we tried to use as little impervious surfaces and other heating elements in our design as possible there are only a few features that contribute to an increased temperature.

The roads are made from semi-permeable materials, which leads to some heating. There will also still be some traffic adding to the heat.

The boardwalk is a built element and therefore contributes to a heating effect. The walkway on it is made of light coloured impervious material which, although reflecting some of the heat, also contributes to a heating effect.

Wind

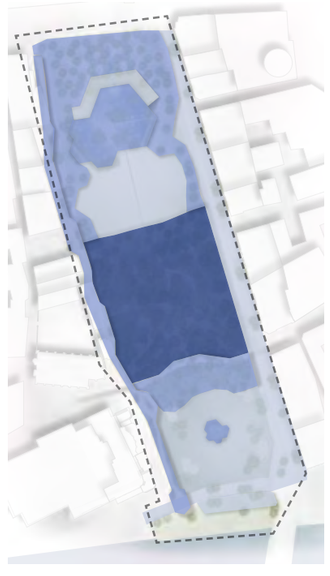


To allow the cool air to spread to the surroundings we did not place large trees adjacent to the connecting roads. The vegetation is also kept low to keep the adjacent roads open.

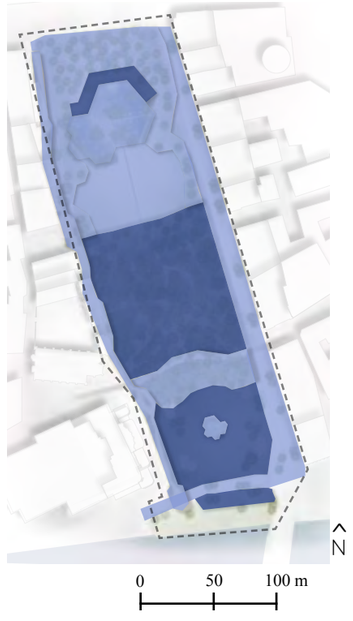
We also kept the park quite open on the east and west side to utilise the wind from the open water to help cool the air. Moreover, a wind corridor in the middle of the water front is kept open.

Compared to the 2017 layout, the wind can now travel over the site better.

Cooling day time



Cooling night time



- Some cooling effect
- Medium cooling effect
- Large cooling effect

Most of our design help to decrease the temperature in the park, both during day time and night time. The forest have the main cooling effect as it decreases the temperature both during day time and night time.

With the new layout, the cooling effect of the site is improved significantly compared to the 2017 layout. This is because of the added vegetation, and the removal of impervious surfaces. It is also due to the choice to use broadleaved trees and by adding vegetation to the water features.

North Entrance and Pond

Detail of the north entrance to the park, the raised up water block (2), amphitheatre (4) and pond (5). The small map shows the approximate position of the illustration and the A-a and B-b lines show the approximate position of the cross sections.

Cross Section A

The trees are placed to create a light canopy and smaller spaces. The placing also open up the sight lines into the garden.

Cross Section B

The large amphitheater in grass and wooden decking provides seating for visitors and also helps cool the air in the park. Water from the water block flows into the pond.

The entrance to the Royal Climate Garden is a green permeable portal from Hamngatan. The permeability makes it possible for people to enter from all directions and enables easy movement through the space. It is a multifunctional space with several climate benefits, providing cooling during both day time and night time.

North Entrance and Pond

Climate Benefits

1 The entrance consists of higher and lower vegetation. A semi-transparent tree canopy provides a light shade, creating a protection from the sun during hot days. The trees also protect the ground from heating up and storing heat. Moreover, the placing of the trees creates “holes” in the canopy so that lower vegetation can release cold air during night time. The cold air from the trees can also spread along Hamngatan, creating a better microclimate in closest surroundings.

2 The raised water helps cool the air. It can also be used to cool people as you are allowed to touch the water.

3 The existing dark, impermeable ground material is removed. However, as the surface will be heavily used, the ground material will need to be resistant towards the large number of people passing by. Therefore, a light coloured paving stone with grass allowed to grow in the joints are used. As a result, a cooling effect from the grass can be achieved.

4 Each level of the amphitheatre is covered in grass except for closest to the edge where there is a wooden seat. Grass helps cooling the temperature during nights, and wooden seating is used as it does not store heat as much as concrete, stone or asphalt.

5 The pond helps decrease the air temperature during the day and by adding vegetation to it, it can also help cool during the night. There are walkways on the water with fountains that sprinkles out water into the air. Sprinkling water decrease the air temperaure and gives a cool splash when sitting in the theatre and when walking by. As the water is flowing and runs down from the water block down to the pond, the water gets a better cooling effect than if stagnated. Additionally, the falls creates sprinkling water.

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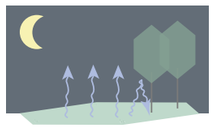

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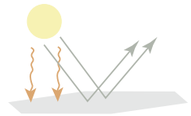

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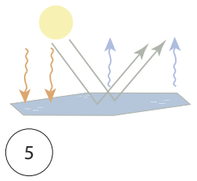

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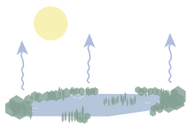

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Inspiration from the Case Studies

Paley Park, NYC, USA

Photo by Aleksandr Zykov on Flickr Licens: CC (by-nd 2.0)

Tall trees that create a semi-transparent tree canopy.

More London, London, UK

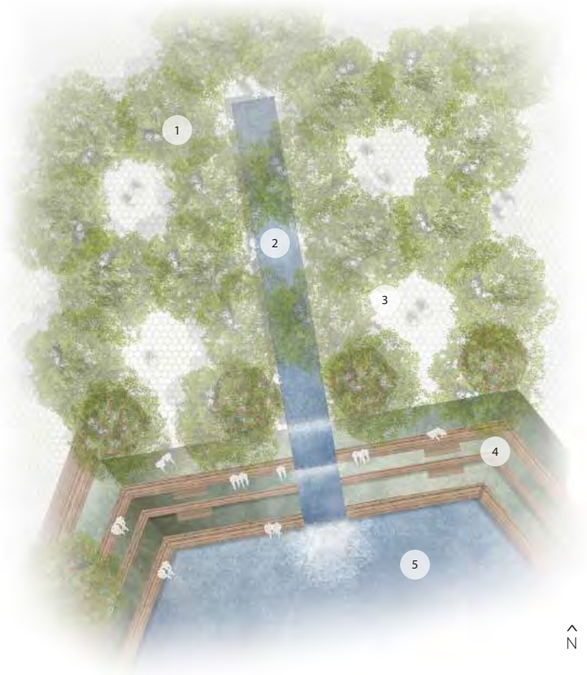
Photo by Garry Knight on Flickr Licens: CC (by 2.0)

Water block as as an interesting example of a water feature in an outdoor environment.

Brindley Place, Birmingham, UK

Photo by Elliott Brown on Flickr, Licens: CC (by 2.0)

Sprinkling water features and a walking path over a pond.



Social Aspects

The street of Hamngatan is a busy street with lots of people in movement. The entrance is designed so that you easily can enter the site from all directions, and either pass by or sit down on a movable chair under a light tree canopy.

The trees provide a visual buffer between the busy street and the park. The water feature is raised up, which makes it possible to touch the water. It also creates a low sound of running water to mitigate the sound of traffic and over hearing conversation.

An amphitheater makes it possible for many people to sit, and at the same time it is located by a water feature for the view. The falling water creates a sound for the people seated in the amphitheatre, and gives a pause from the vibrant city outside.

Event Surface

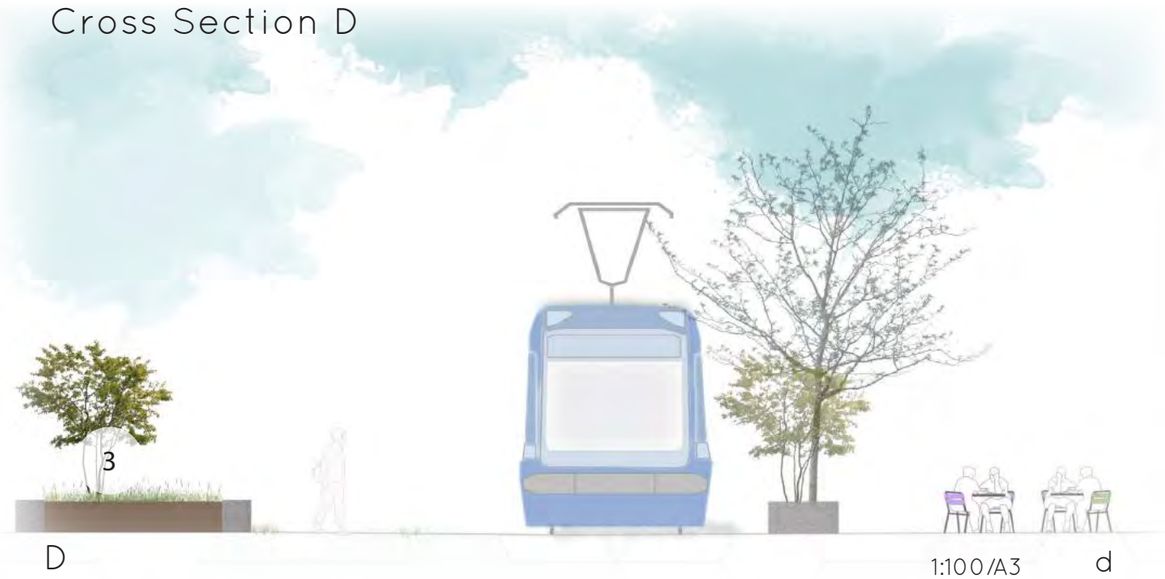
Detail of the event surface showing the open space that provides space for markets and social events. The rill crossing the space adds a water feature and extends the presence of water. The small map shows the approximate position of the illustration and the C-c and D-d lines show the approximate positions of the cross sections.

On the event surface it is possible to host markets, concerts and other types of events. The ground is designed to stand large numbers of people and activity, and therefore will be resistant to a lot of movement. To meet demands of our climate aspect, we have used semi-permeable surface as ground materials, allowing vegetation to grow in the seams. Moveable seating allows visitors to chose where they want to stay, also providing the possibility to chose shade.

Cross Section C

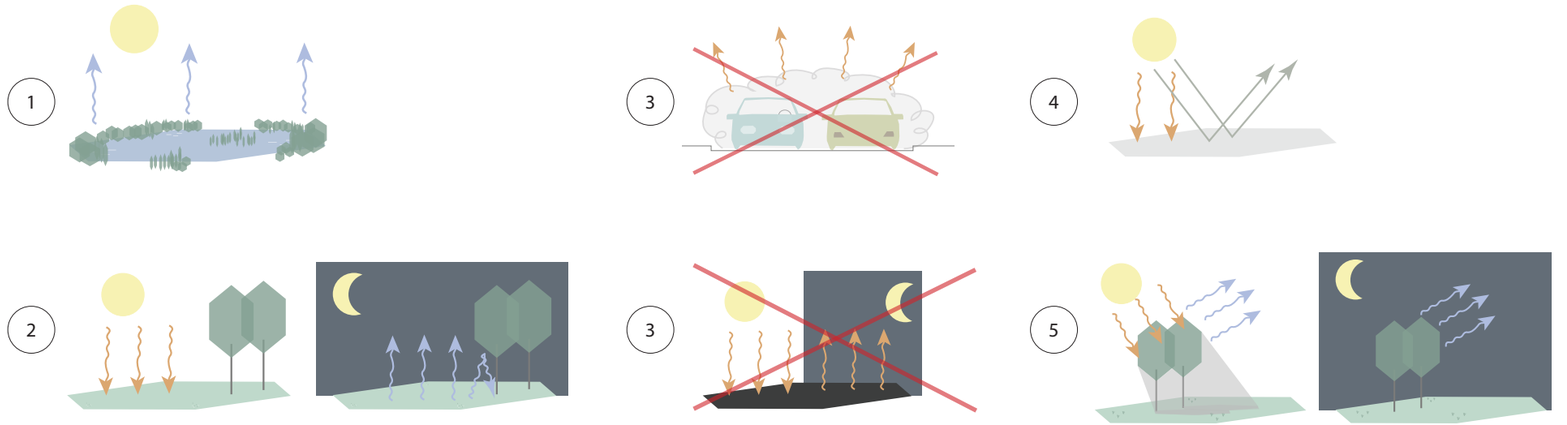
The fountains along the walkways fill the air with water drops, cooling both air and people. The vegetation in the pond helps cool the air during night time.

Cross Section D



In 2100 car traffic is replaced by trams. The shared space also includes pedestrian paths, cycle paths and outdoor patios. The former road is transformed into an extension of the park.

Event Surface



Climate Benefits

1. The vegetation together with the water in the pond provides a cooling effect.
2. The ground material on the event surface is semi-permeable which allows vegetation to grow in the joints between the stones. This help to reduce the heat during day time as vegetation absorbs the heat and also cool the air during night time.
3. The eastern road is turned into a shared space which decreases the amount of dark ground materials and also reduces traffic which both otherwise causes the temperature to increase.
4. The semi-permeable surface is made of light coloured material to reflect some of the heating sun radiation and thereby decrease the amount of heat stored in the material.
5. The scattered trees and plants in the edge of the surface provides shade, both for the ground around them but also for people.

Inspiration from the Case Studies

Paley Park, NYC, USA

Photo by eric wittman on Flickr Licens: CC (by-nd 2.0)

Moveable chairs and tables makes the event surface a flexible space, possible to use at various times, providing different options for the visitors.

Social Aspects

The space provide possiblities for the park to host larger events. It is also a place where people can gather and socilise. The moveable chairs provides different seating options in selective shade. Walkways from the event surface across the pond provides shortcuts to the amphitheater.

The Forest

Detail of the forest. The small map shows the approximate position of the illustration.

This perspective illustrates our vision of the characteristics of the forest area. The tall trees with dense canopies give shade from the heating sun and wooden walkways are used to minimise storage of heat in ground material. In the background, the historical fountain that is on the site today is visible. The fountain can be integrated in the forest and operate as a cooling element.

The broadleaved forest is the heart of our temperature decreasing climate garden. This is the main source of cool air, and the tall trees with dense canopies provide shade from the heating sun. The forest also shades the southern part of the event surface during day time, which, according to our shade study, used to be very exposed to the sun. Through evapotranspiration the trees decrease temperature during day time and night time.

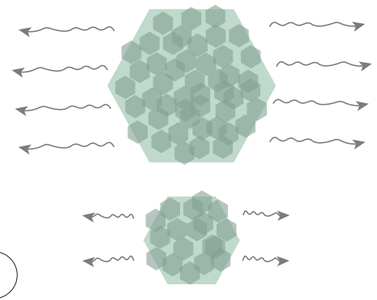
Wood is used for the walkways to minimise storage of heat in the ground material.The zigzagging walkways through the forest is a historical allusion to the former french formal garden.

The ground vegetation consists of herbs and grass and the walkways lead the way through the forest to prevent that the vegetation on the ground gets damaged by large numbers of people walking there.

Although the forest consists of mainly broadleaved trees, we wanted a diversity of species. This to provide shade during a longer period of time over the year, and also to prevent the forest from dying due to diseases.

The Forest

N



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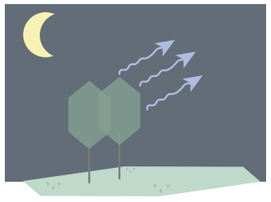

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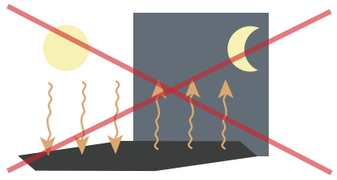

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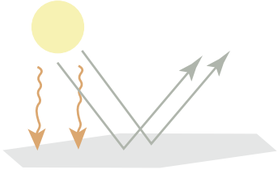

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Climate Benefits

1 A forest is better than a for example grove as the larger the area that is covered in trees, the better the cooling effect. The dense canopy shades the ground underneath. It also shades the event surface during the days. Broadleaved trees are used as they are the most beneficial in a temperature decreasing aspect.

2 The forest, though mainly consisting of broadleaved trees, has a variety of species to promote biodiversity and prevent diseases to spread. As the species are varied, they also blossom and get their leaves at different times in spring, and also looses their leaves at different times during autumn. This has the effect that shade are provided during a long period of time over the year.

3 Impervious surfaces are removed, and wooden walkways are used. Wood stores heat less than other ground materials and are therefore the chosen material. The walkways also prevent the lowest level of vegetation to become damaged by people walking there.

Inspiration from the Case Studies

Central Park, NYC, USA

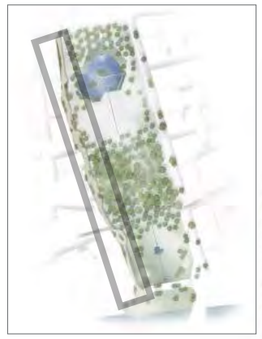
© Google maps 2017

The forest in Central Park in New York City was an inspiration how to implement a broadleaf forest into a cityscape. The case study proves that it is possible to plant a large number of trees in a dense city, although Kungsträdgården is of a smaller scale than Central Park.

Social Aspects

Wooden walkways lead the way through the forest. The trees create shade and a pause from the surrounding city. Along the walkways there are seating areas that makes it possible to stay and sit down.

It is also possible to make this into an educational path, informing about the purpose of the park, climate change and temperature decrease.



The Boardwalk

^
N 1:250/A3

Detail of the Boardwalk. The small map shows the position of the full length boardwalk whereas the illustration shows a part of the boardwalk. The E-e line shows the approximate position of the cross section.

Boardwalk Event Surface Cross Section

1:200/A3

This cross section illustrates the boardwalk along the event surface, which is not shown in the detail image to the left. The boardwalk without buildings under is a hint to the existing linden avenue. The trees adjacent to it creates a sense of walking among the tree tops. Moveable chairs and tables underneath creates a variety of seating possibilites.

Cross Section E

E e

1:200/A3

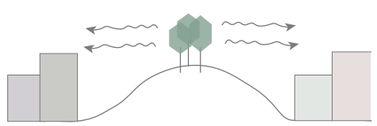
The cafe under the boardwalk has a patio by the edge of the forest.

The Boardwalk

As we wanted to maintain Kungsträdgården as a social place, we decided to keep the low cafe buildings that run along the west side. To compensate the space they claim we placed a boardwalk with a public garden on top of them.

Climate Benefits

1 The raised boardwalk with its flower beds creates a higher layer of vegetation, which enables the cooler air from the vegetation to spread in a more efficient way and reach a more widespread space.



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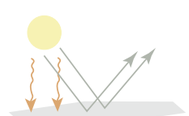
2 The light coloured ground material helps to avoid storing of the heat as it reflects some of the sun light and therefore also decreases the releasing of heat during night time.



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3 As the vegetation on the boardwalk is mainly low without trees, the ability to cool the air during night time increases.

3

4 The vegetation consists of a variety of flowers, grass and smaller bushes and trees to create a seasonal dynamic and to avoid monoculture.

4

Inspiration from the Case Studies

The Highline Park, NYC, USA

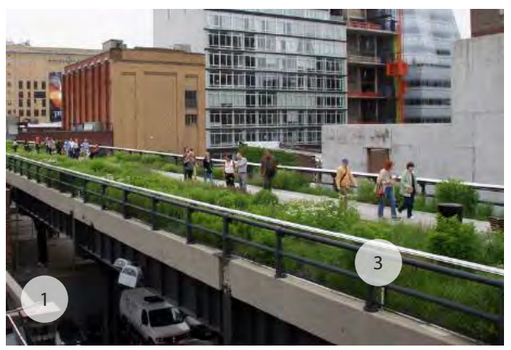


Photo by joevare on Flickr

A raised boardwalk that add an additional layer of vegetation to the park. Lower vegetation is mainly used.

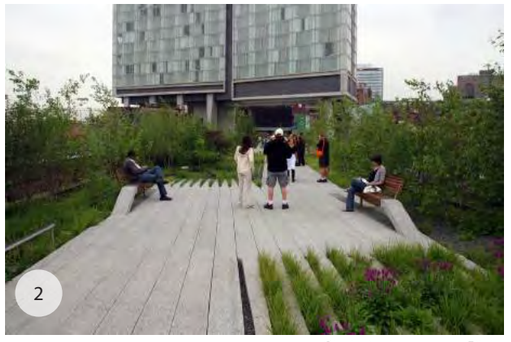


Photo by joevare on Flickr

A light coloured pavement and planting beds in the walkway prevents the ground to store heat.

Social Aspects

The boardwalk creates an extra dimension to the existing park, allowing people to get a better view of the park and Stockholm. It has several entrances, both ramps and stairs, to enable easy access and facilitate a good flow of visitors. Cafées and restaurants underneath allows people to bring their lunch or coffee up to the boardwalk.

Benches are placed along the boardwalk to provide the ability to sit, stay longer and enjoy the view and plants. Lights are placed in the handrails to create a nice light during evenings in order to make the boardwalk feel safer.

Waterfront & Open Grass

N 1:400/A3

Detail of the waterfront & open grass in the southern part of the park. The small map shows the approximate position of the illustration.

This perspective illustrates our vision of the characteristics of the grass surface.

The most efficent way to decrease temperature during night time is through open grass surfaces. We opened up for wind corridors by limiting the high vegetation. Keeping the vegetation low and open up for the wind went well with the social aspect to maintain it as a picnic area.

In order to limit the traffic and its emissions we first changed the existing road into a shared space. By 2100 the road is only a pedestrian and cycling path. Narrowing the road also reduces the amount of dark impervious surface.

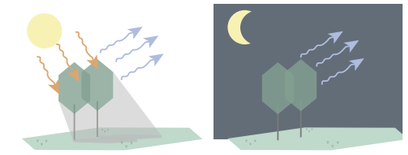
By keeping the site close to the water open, we allow the wind to blow into the park and thereby help cool the air. While keeping it open for the wind we also created a more social area which extends the park all the way to the water. The design also allows for a possible future raise of the water level.

Waterfront & Open Grass

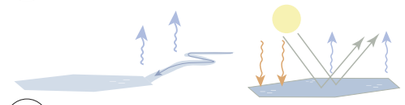
Climate Benefits

1 The open grass absorbs the heat during the day and releases cool air during night time.

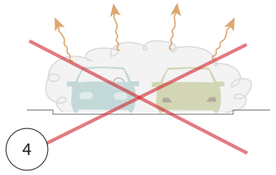
2 Scattered trees provides shade during hot days and helps cooling the air during night time.



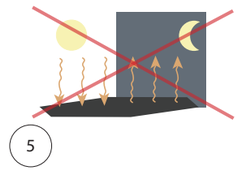
3 The small stream running down in the middle helps cool the air and people as it allows people to touch the cool water.



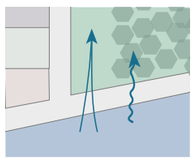
4 The shared space limits the traffic, which helps to decrease the amount of emissions and also reducing the heat.



5 As the road is narrowed, the amount of dark impervious surface is decreased thus reducing the ability to store heat.



6 Cool air from the open water can blow into the park and help cool the air. The air corridor is kept open to enable the air to reach further into the park.



7 The waterfront is given a light wooden deck that does not store heat and therefore does not release as much heat either. Some trees are placed on the deck to create shade during hot summer days.

Inspiration from the Case Studies

Rådhusparken, Umeå, SWE

A shared space is integrated in the park, behind the water block to the right in the image.

The park ends with a waterfront with seating by the water and a view of the water from the park. The waterfront is kept open, which makes it possible for wind to blow in.

Social Aspects

The open grass is, in addition to the amphitheater, the place where people will hang out the most. It will be busy with all kinds of activities from picnic to sunbathing to coffee breaks and playing. Placed on the grass are four raised wooden decks that allows seating and playing. Additional seating in terms of movable chairs and tables are also placed all over the grass. Movable seating allows people to chose where they want to sit and in what kind of shade or sun light.

Shared space helps slows down the traffic which creates a safer environment for people helping people to easier reach the waterfront from the open grass and vice versa. As the road is narrowed the previous physical barrier is reduced.

The waterfront brings a new room to the park as it allows people to get closer to the stream and enable them to use the place for longer breaks and meetings. The trees placed on the deck brings a nice shade and the raised flower beds creates seating possibilities.

Discussion

The Royal Climate Garden - the temperature decreasing park

The objective of this thesis was to investigate how to adapt an urban space of social importance to a warmer future climate. It aimed to find strategies to mitigate the negative effects of increased temperature in a city, and how to implement these in an urban space whilst maintaining the social aspect.

In order to investigate this we conducted site studies and a literature study to be able to answer our research questions:

- How can Kungsträdgården be designed from a specific climate perspective?
- How can a park with a focus on climate change be designed if social aspects also are taken into consideration?

To determine what was needed to create a design for Kungsträdgården out of a climate perspective, we defined climate strategies for cooling air in urban environments. Our climate perspective design illustrated the essential elements required in an urban space in order to decrease the air temperature in the most efficent way, according to our found climate strategies. This was the first step to our final design, which would take the social aspects into consideration while keeping the climate perspective. From our case studies we gathered inspiration to visualise our climate strategies and to implement them in a social context.

There are many ways to implement climate aspects in a social context and our design is one of them. It is a contribution to the climate debate to highlight the importance of sustainable planning and to consider the future.

A wide range of aspects

The task of a landscape architect is to be able to consider a wide range of aspects and take various angles in design projects into account. We need to be able to see a wider perspective, as our design projects often include numerous different aspects. It is difficult however to handle every aspect of a public place with the same emphasis.

This project taught us that in order to give an urban place a certain focus, other aspects need to be limited in order to make your focus stand out and be clear. Priorities always need to be made, and it is a question of what is more important than something else.

To address climate change as landscape arhictects, we discovered that many elements in the urban environment regulate temperature, and there are also different strategies to decrease temperature in cities. We also realised that, regarding a site's ability to cool the air, the site needs to be rather big to have an impact on the surroundings, but also that small spaces matter. Furthermore, it can be hard to measure the exact cooling effect a site has, both within it and on its surroundings.

While writing this thesis, it became even clearer to us that climate change is already here. No matter if we change today, right now, and become completely carbon dioxide neutral, the change in our environment and climate is a process that has already started. It is inevitable that we have a changed climate in a few years time, with effects we cannot be sure of as the future is hard to predict. We can only make qualified guesses of what will happen, based on scientific theories. It is a question of *how much*, not *if*. Now, the question is how we will cope with it, and how much we can slow down and finally stop the already advanced process.

From creating this design we learnt that it is in people's attitudes the biggest change needs to be done. The IPCC has determined that climate change is by 95% certainty due to human activity. There is also strong scientific evidence that we will struggle to adjust to the changes that this entails. This means that we, as humans, need to change our way of living, thinking and understanding.

During this work, we experienced that people had strong opinions about our design. To many, it was provocative that we removed historical elements and the historical layout of Kungsträdgården. We learned that people can be quick to judge, and have strong opinions - opinions they do not necessarily want to change. We realised how important it is to explain what you want to achieve with a design, what you are doing, and why. By doing this design we have also come to understand, even more than before, just how strongly people care about their public places and that they have a very strong connection to the outdoor environment in the city.

We have found that the cultural and historical layers of a public place gets intensified because of the site's social importance. The more socially important a public place is, i.e. the more a place is used by people, the more important the history of the place is. As Kungsträdgården is a popular and heavily visited site, a lot of people have strong connections to it. We think that this means that there are a lot of people with strong opinions about the place and its future. This is probably the main reason as to why the Apple store got so many and strong objections, and a reason to why we have met strong reactions to our design.

Another reflection is that if people are that concerned about propsed changes of a public place in order to improve the microclimate in cities, they might be equally concerned about changing their way of living. This is problematic, since in order to preserve our history or have the posibilities to re-tell our history, we need to change our ways and take action.

Also, change is a slow process and people sometimes adjust in a slow pace. But climate change is happening right now, and we are running out of time if we want to find solutions and implement them before it is to late.

The maximum climate design

After our literature study, we could compile the best physical and biological elements regarding decreasing temperature. Then, we created a design idea only based on the physical and biological aspects. This lead us to our maxmimum climate perspective design, with a hill with trees in the middle of the park. The maximum climate design were used to clarify what was needed in the park from a climate perspective. We found it necessary to establish this first, in order to create the final design where both climate and special aspects were taken into consideration.

The maximum climate design proposes that humans should be excluded from the park. As mentioned earlier, human activity such as emitting carbon dioxide, is the major cause to climate change. This implies that in order to optimise a space's ability to mitigate the effects of climate change, to let the vegetation grow without human interference, human presence should be removed from the park. Consequently, the best solution, from a solely climate perspective, was to remove people and let the vegetation do the job.

A design only from a climate perspective could be hard to execute, as it requires the current layout of Kungsträdgården to be removed all at once, in order to create the hill in the center. This implicates to that between today (2017) and approximately 50 years ahead there would not be any large trees which can help cool the air and create a better microclimate.

The climate design would have little or no significant effect on the

climate in the entire Stockholm area. The climate benefits that can be derived from our design will probably only be noticed in its direct vicinity. To achieve a regional difference to the climate it would require that all available spaces in the inner city, regardless size, had a similar design to our maximum climate design.

In addition, there is the social aspect as well. People require somewhere to escape the busy city life and with the temperature rising, somewhere to escape the increasing heat. To ban people from places where the temperature is proven lower could have severe health consequences. In order to deal with the climate issue and create sustainable solutions to it, exluding people from the city scape is thus not an optimal scenario.

The relation between maximum climate design and final design

Our choice of site contributed to the difficulties of excluding the social aspect from our design as it has an important social function in the city. We struggled with finding ways to balance the aspects climate and social, and when to prioritise one over the other. As we are landscape architect students, we are used to consider the humans using the place and the social aspects of an urban space.

Our initial thought was to create a space only beneficial in a climate aspect, as our maximum climate design suggests. However, our site is located in the very heart of the city and it did not make sense to us to create a space that was not to be used by humans. Nor was it what we wanted with our work. We wanted to try out if any public space can be designed to face future climate change, and still maintain its social purpose. All this made us include the social layer to our design as well. This did yet not solve our problem of finding a balance between the two aspects. Throughout the work, we constantly got back to asking the same questions - what is most important here and what do we want to achieve?

The social aspect of sustainable planning contains various parts, as stated within the PEBOSCA model. We therefore needed to decide what part was to be given most significance within our design. Events and larger social gatherings which require large areas and preferably impervious surfaces, was given less room than health and comfort as they could more easily be combined with our climate aspect. Our aim was to not only decrease the temperature in the city, but to create a sanctuary for people to come for shade and cooling.

Initially, we considered it necessary to separate the two aspects, to show what decisions was based on climate benefits and what was based on social aspects. However, from early on in our design process, when we were trying out different solutions, we realised just how hard it is to separate the two aspects. As a start we needed to, somewhat, establish the most important functions of each aspect and determine which we wanted use in our design. A lot of the functions, however, could be placed in both aspects. A tree's shade is beneficial from a climate aspect as it prevents the ground around it to heat up and thereby prevent the general temperature to increase. Trees also contribute to the cooling of the air during night time because of the evapotranspiration. At the same time, the shade is good from a social aspect as it provides shade for humans during hot sunny days. As the social aspect also contains health, the possibility to stay out of the sun provide health benefits as well. Consequently, the shade of a tree is positive from both aspects and this makes it hard to determine what is climate and what is social. This lead to that in the end we decided that all that was not solely social was chategorised under the climate aspect.

The Design

The fact that people have strong connections to their outdoor environment was something we knew from before, but we were still surprised about the strong opinions that our proposal arose. In our design we propose that the existing layout, meaning the historical layout, is changed. By 2100 the existing layout should be replaced by a new layout that can be of better benefit from a climate perspective. We considered that our design proposal could have been more radical. We could have developed our climate perspective design further and made our final proposal more similar to that. Despite this, we were still met by strong opinions.

Although our design proposes a complete change of the existing Kungsträdgården, the change is made gradually. This might make it easier for people to accept the change. A large amount of trees needs to be planted already today in order to be fully grown by 2100, but historical elements will remain, as well as some of the existing trees. As we believe people adjust slowly to change, our perception is that this gradual change will allow people to be more positive.

Rather than being a perfect solution to an increased temperature, we think that our final design can operate as a guideline; an indicator of what needs to be done in order to have a chance to help future generations. It also shows that the process most start already today. Even if our design is applied in a quite small park and therefore cannot decrease the temperature regionally or globally it can have an impact on people, both direct and indirectly. People located in the park's vicinity will obtain the positive benefits, socially and climatically, that the park contributes to. They can escape the heat during hot days and recover in the park. They can also take the concept of the park with them, and thus spread its character and qualities to other places, in Stockholm, Sweden and other places in the world.

Our design is based on the present and future temperature of Stockholm. Cities in countries with a larger solar radiation than Stockholm will probably get higher temperatures. This means that our design might not be directly applicable to other places. However, our climate strategies can be used as guidelines to how physical elements regulate temperature in cities. For example, that impervious surfaces need to decrease in order to handle the negative effects of climate change.
We would also like to argue that through our design, the space can be used in a multifunctional way. We have tried to make it a varied place, with a variety of climate strategies applied. Moreover, in a social aspect, creating a more flexible space than today was also a focus. For example, by adding moveable seating to the park, visitors are provided with a choice to individually determine their shade. This allows the park to be used during more hour of the day and also during more months throughout the year.

Along the process, we realised the difficulties in changing existing social structures. We also realised that it is difficult to change physical structures. For example, the roads were a challenge. The historical research showed that the roads around the space have remained almost the same throughout history, with the exception of that one road through the space had become smaller. To remove traffic was an important aspect for us.

However, when looking more in depth how to do this, we realised how essential the east road and the south road were for the road system in Stockholm. This resulted in that we could not just remove them at once, we needed to find a strategy how to do this. The solution we found was to make the change gradually, and step by step remove the traffic from the roads.

Buildings are non-beneficial in our climate aspect and we removed all built elements within the space. However, the buildings surrounding the park have remained almost unchanged throughout history. Because of this, we saw the surrounding building structure as something that was hard to change. Instead, we tried to open up the streets between the buildings for wind. By keeping lower vegetation there, the cooling could spread out from the park.

Our only larger added built element is our boardwalk, which is a garden itself. The cafes and shops underneath was kept of a historical purpose and a social purpose, and is compensated for by the public garden on top of them. The boardwalk was also interesting to add for us to try out how to compensate for built elements. By adding vegetation on top of them, the cafes on the west side could still be a part of the park.

Climate Strategies

The climate strategies were our key to understanding how we could decrease temperature in our park. It was a useful and clear way to

identify what is decreasing temperature in an urban space.

We realise that our climate strategies were a simplyfied way of describing temperature decreasing elements in an urban context and there is room for improvement and further development. However, we believe it was good to make them general to be applicable in any urban space.

The Site

Because of Kungsträdgårdens importance and central location in Stockholm, we both already had our own connection and relationship to the park. This contributed when we chose site.

As we got more acquainted with the park, its history and elements, we realised how important Kungsträdgården is and has been to the inhabitants of Stockholm and its visitors. Therefore, changes to or removing of the existing elements needed to be thought through and well argued for. This helped strengthen our motives with our design and also helped us re-
evaluate our decisions. It also made us determine what is imoprtant and what is not, which helped us limiting our design. Instead of fearing people's possible negative reactions to a new design of Kungsträdgården, we chose to use its popularity to our advantage.

We suggest that with Kungsträdgården's central location, and its large flow of visitors every day, our design would affect a large number of people and be more noticed here than perhaps anywhere else in Stockholm. The more people that passes through the park, the more people can benefit from it, the better. In this way we took advantage of people's interest in the park to maximise our purpose.

METHODOLOGY

Site Study

We decided to divide the site study into a climate study and a social study. This was because the two aspects were given different priority in our design and our main aim was to create an urban space adapted to climate change.

The social study was easier to conduct as we already had useful tools and experience from previous projects during our education. We decided to use methods that we were familiar with and that were easy to apply to our site. This was in order to not to spend too much time on the social aspects.

The climate study was more challenging as we found it hard to find a good method regarding how to determine the climate aspects of a public place, especially when focusing on temperature. Aspects such as wind, shade and vegetation was easier to determine. However, we wanted a more detailed study to learn what other aspects that contribute to an increased temperature and also what elements that help cooling the air. Because of this, we decided to base our site study on our literature and focus on the heating and cooling elements in the city. That way we could determine what elements within Kungsträdgården that have heating and cooling effects today.

Our way of studying the climate might leave some aspects out as it is quite general, only managing individual elements not specifying quantity nor type. Since our climate study also mainly focused on the summer months, this might also get results that is not completely reliable, seen over a year. Summers in Sweden are the periods with most solar radiation and the highest temperature and people from Sweden are not accustomed to heat. Because of this, we thought it is during this period that increased temperature will cause the most stress to vegetation, people and buildings.

In our site study, we decided to consider all ground materials that is not grass or vegetation as impervious and to not make a difference of different types of impervious surfaces and their level of permeability. During our education however, we have learned that gravel has some permeable properties depending on the fractions of the gravel, its composition, and level of density. This might have affected our temperature analysis somewhat, and could imply that Kungsträdgården is cooler than our climate study shows. Yet, our literature only distinguished between dark and light material and between impervious and permeable surfaces, which is why we decided on doing likewise. Without any scientific relation between gravel and bitumen's capacity to increase temperature it was hard for us to make assumptions on each material.

Furthermore, the literature does neither present a specific list of species that are better to decrease the temperature than other. It merely points out the positive benefits of broadleaved trees and grass surfaces. As a result of this we decided to not make a list of the specific plants we wanted in our design as we felt that it would suffice to explain the character of the plants and the different rooms in our design.

Literature Study

To find solutions and to be able to answer our research questions we had to get more knowledge about climate change and its aspects, climate change in cities and future prospects. However, as much as there is written about climate change, we found it sometimes difficult to decide what was relevant literature to us. As our site is located in Sweden, which is a part of the world where temperature increase is not a priority in public spaces, we struggled to find comparable studies that we could apply to our space. This resulted in a mix of different literature that we based our work on. However, we tried to use numerous sources and we believe we found a good variety of Swedish and international research. As climate change is a global concern, there was a large variety of international scientific research to be found. This was an advantage, to widen our scientific base. Nevertheless, for our work, research made from Sweden was of significant important too, which is why we tried to find a variety of sources.

There are many articles and research about the urban heat island effect. However, less so with actual real examples, and these were often in southern countries or mega cities, which was more difficult to apply to our site. Likewise, Swedish City Council documents spoke about climate change in the aspect of temperature increase, and the importance of sustainable development. However, we did not manage to find actual hands-on examples on how to do it.

Case Study

The case studies were very helpful in our design process. It was inspirational and allowed us to create a mix of ideas with our own ideas. As the places are spread around the world we were not able to visit all the places. Consequently, we can not know if the elements we only studied visually will achieve the desired effect. The sites visited were easier to implement in the right way, as we were there and could percieve them. This is harder to do from a photo. However, we found it succesful to use the visually studied case studies for inspiration.

As stated in our work, we found few case studies specifically designed for temperature decrease. Therefore we studied single elements, to visualise our climate strategies into a design context.

We thought the sites we had visited were not enough, which is why we continued our research and studied case studies visually as well. As we did not look further once we found something we found useful, this probably affected the outcome of our case study. In retrospect, we think that we could have widened our search to a more global perspective, looking for inspiration in countries such as Australia or in the Middle east. Nevertheless, we found it successful to first define our climate strategies and then visualise them and implement them with inspiration from case studies. That way, we could identify exactly what we wanted our design elements to achieve in a climate aspect.

Meetings

The meetings helped us in our initial stage. Therefore, they were more inspirational than for a scientific and research purpose. The meetings

rather helped us find a way to look at our project and how we could develop our ideas and move on with our climate aspect. It was also very helpful to understand what Kungsträdgården is, what it means today and what it has been over the years.

The future and sustainable development

We mentioned in the introduction how hard it is to determine the actual outcome of climate change, and therefore to know what it is that needs to be done to decrease the effects of it. Consequently, it was hard to find concrete solutions, answers and prospects to work towards. We used the pre-established future scenarios formulated by the IPCC. This was to work towards a scientifically approved and based assumption rather than guessing and imagining a future outcome ourselves.

The solutions we found can be difficult to implement in an urban context as they often require large areas, which can be hard to find in densely built cities. This meant that we had to modify large scale solutions and apply them in a dense city context.

Since the future is hard to predict, it is also possible to plan for a future that never comes. It is hard to decide what actions to take and how far into the future one should plan. Today, the future is an increased average temperature and precipitation, but tomorrow might have another future scenario. Thus, urban spaces needs to be multifunctional to better adapt to different effects of climate change and different future scenarios. Our design, with several areas, each with its individual character and function, is one way to meet different needs and outcomes.

What we also realised is that it is hard to design regarding only one climate aspect. The three main impacts of climate change (increased temperature, increased precipitation and storm events) often relate to each other and so do the solutions to decrease the effects of them. For example, our two ponds in the Royal Climate Garden are low points where water can be stored during heavy rainfalls. The increased amount of vegetation is also benefitial in increased rainfalls and storm events. The vegetation absorbs water and the permeable ground allows water to infiltrate. The trees also provides shelter from rains and wind, and it prevents wind turbulence.

The PEBOSCA model indicates that everything is connected. Initially we tried to mainly focus on Physical and Biological resources, and Social as our secondary focus. However, as we also realised in the begining, all resources are relying on each other and it is hard to exclude some. Nevertherless, it did help us to limit our work and go further into our subject. Even though we primarly focused on three of the resources, we gained benefits in other fields.

The balance and relationship between the resources are complex. We realised in our work that it is difficult to do everything, and think of every aspect, but it is just as difficult to exclude aspects.

Conclusion

As difficult as it was to balance the two aspects of climate and social, it made our work more interesting. Design is complex and it was never to be an easy process. In our opinion, our design is a good example of a balance and a collaboration between the two.

There is an ongoing conflict in cities today. Urbanisation and growing population creates a demand for housing, which results in new, fast developments. At the same time, the climate is changing, and cities are experiencing heat waves, flooding and storms, which only get worse in high density areas. Decisions need to be taken of what is most important and new development needs to be multifunctional to meet both the social and climate demands. We hope that the future design of Kungsträdgården and other public spaces will be designed not only from a social perspective but to have other benefits as well. We think it is possible, as we tried to prove in this work.

We think landscape architects have a responsibility to plan for a sustainable future, and we need to be a voice for changes that need to be made. Hopefully before it is too late!

Future research questions

How can the climate strategies be further developed and used on other urban spaces?

How can the importance of green space in cities be more emphasized as a solution to the negative impacts of climate change?

How can people be more enganged in climate change, and the importance of changing our way of living and thinking?

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Meetings

Berg, P. G. February 3rd, 2017. Professor in landscape architecture in sustainable built environment.

Ignatieva, M. March 31st, 2017. Professor in landscape architecture and botany.

Olsson, J. February 8th, 2017. Expert at Architecture Design, Stockholm.

Wade, E. March 17th, 2017. Landscape architect.