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Urban trees are thriving

An explanation of the innovation of the Stockholm soil system

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Preface

This Master's thesis is the final part of my education in landscape architecture. I want to thank my supervisor Sofia Eskilsdotter for guidance and inspiration along the way. I want to thank Héléne Littke, Sara Linderoth, Joseph Greaves, Love Edenborg, Timmy Fredriksson and Ulla Myhr for comments. Lars Hylander, Joakim Hermansson, Elisabeth Nyman and Björn Westin for discussions. Anna Pettersson Skog and Irina Persson at Sweco Environment for information and for providing me with a place to work. I want to thank Therese Selén for all the support throughout this intense period of time. And finally I want to give a special thanks to all of the respondents who participated in the interview study and for sharing their knowledge with me. This study was made possible thanks to all of you.

Sammanfattning

Introduktion

Växter bidrar med många fördelar i städer. De används både för rumsskapande och för ekosystemtjänster. Men urbana miljöer utgör tuffa växtplatser. Träd och andra växter placeras ofta i ytor som används för många andra ändamål, så som transport, lek, motion, rekreation, boende och service. Många ytor i städer är därför hårdgjorda för att tåla hårt slitage och för växternas rötter innebär detta begränsningar i möjligheten att få det syre och det vatten som de behöver för att etableras och att vara livskraftiga. En lösning på dessa problem är att plantera träd i så kallad skelettjord, ett system där stenkross i en grov fraktion används för att bära vikten från den hårdgjorda ytan, kombinerat med växtjord eller luft mellan stenarna där växternas rötter får de förhållanden som de behöver.

En variant av ett sådant skelettjordssystem har utvecklats av Stockholms stad och har där använts för att rädda ett par tusen träd från tidigare dåliga förhållanden. I Stockholm har de noterat att träd som växer i dessa jordar har en tillväxttakt som motsvarar den de skulle ha haft om de vore planterade i parkmark.

Tjänstemän på Stockholms stad har också experimenterat med olika substrat, det vill säga det material som växterna planteras i. Bland annat har pimpsten och biokol testats, och används nu för att förbättra den vatten- och näringshållande förmågan i många av stadens växtjordar. Denna utveckling har varit framstående och inte minst arbetet med biokol har fått stor internationell uppmärksamhet. Stockholms stad har börjat använda trädgårdsavfall för att skapa egen biokol. Med användningen av biokol har tillväxttakten hos de träd som planterats i sådana jordar varit mycket hög.

En annan viktig anledning till att stärka arbetet med skelettjordar och alternativa substrat är klimatförändringar. Dessa ställer ytterligare krav på stadens grönytor som i framtiden behöver hantera större mängder dagvatten än tidigare. Detta har ytterligare påskyndat utvecklingen av hur urbana jordar kan användas för att tillgodose både växternas behov och kravet på dagvattenhantering. Till exempel i Norra Djurgårdsstaden, ett stort stadsutvecklingsprojekt, har Stockholms stad utvecklat nedsänkta växtbäddar för att kunna temporärt magasinera dagvatten.

De tekniska fördelarna med att utveckla nya sätt att arbeta med urbana växtbäddar, set system av jord och växt som får växten att trivas i hårdgjord miljö, är därmed flera. Och Stockholms stad har lyckas ta fram innovativa lösningar på de utmaningar som finns. Det finns därmed ett värde i att undersöka vilka faktorer som möjliggjort denna innovation. Detta är i stort sett odokumenterat idag och därmed finns en forskningslucka.

Syftet är därför att identifiera och förklara de viktigaste faktorerna för innovationen av Stockholms stads växtbäddar och att främja förståelsen för hur dessa börjat användas av Stockholms stad Den forskningsfråga som ställs är: Vilken är den mest framträdande faktorn för innovationen av Stockholms marksystem?

En förståelse för detta kan bidra med att landskapsarkitekter bättre förstår vad det innebär att arbeta med växtbäddar för växtgestaltning i hårdgjorda uterum i Stockholm. Detta är också relevant för andra platser där liknande system kan tänkas användas eller för andra aktörer som också vill arbeta med utveckling av växtbäddssystem.

Uppsatsen inkluderar de standardiserade sätt som används av Stockholms stad i deras växtbäddar och inkluderar även de växtbäddar som används i det stora stadsutvecklingsområdet Norra Djurgårdsstaden. Lösningar som endast används i speciella fall inte inkluderade. Uppsatsen hanterar inte några tekniska detaljer hos systemen i annat syfte än att förklara hur de fungerar som en del i bakgrundskapitlet.

Metod

Uppsatsen är en fallstudie av Stockholms stads framtagande av växtbäddar för hårdgjord miljö. Den är baserad på en hermeneutisk, abduktiv och explorativ ansats. Studien grundades på en empirisk undersökning, och använde teori för att bättre tolka och förstå empirin. Något teoretiskt ramverk användes därför inte före det att datainsamlingen var gjord eftersom valet av teori utgick från data. Detta gjordes för att undvika att påföra några abstrakta teoretiska ramar på insamlingen. Anledningen till att detta arbetssätt valdes var att fallstudier till sin natur är unika händelser och att kunskapen om det specifika därför är mer relevant än vad generella teoretiska lagar är.

De datainsamlingsmetoder som användes var semi-strukturerade intervjuer med sex experter som valdes specifikt för deras sakkunskaper, samt en litteraturstudie. En semi-strukturerad intervju utgår från ett antal öppna frågor, men anpassas efter respondent och situation. Detta bidrar till att intervjuerna blir målinriktade på den information som eftersöks men samtidigt finns en stor möjlighet för ny information att träda fram. Som stöd i formuleringen av intervjufrågor användes litteratur inriktad på växtgestaltning och val av växter i urban miljö.

Litteraturstudien var en genomgång av journalistiska artiklar från dagstidningar och magasin. En tolkande analys utfördes sedan med syfte att identifiera centrala faktorer för innovationen. Vidare analyserades resultatet genom en kategorisering enligt Innovation Adoption Theory, en teori som beskriver vilka kriterier som är viktiga för att en innovation blir använd. Slutligen påfördes ytterligare ett steg i analysen genom att ett komplexitetsteoretiskt perspektiv för att ytterligare analysera resultatet.

Teori

Innovation Adoption Theory användes i analysens andra steg. Enligt denna är innovationsadoption beroende på fem olika kategorier av faktorer. Dessa är Individuella/personal, Innovationen, organisationen, Externa/Sociopolitiska och Klient/Användare-faktorer.

Komplexitetsteori används för att vidare analysera resultatet. Centrala begrepp så som självorganisering, feedback-loopar, initiala skeden och timing beskriver hur organisationer fungerar. I grunden säger komplexitetsteorin att organisationer är komplexa och svåra att överblicka men att det finns vissa mekanismer som alltid går att hitta.

Resultat och analys

I resultat- och analyskapitlet redovisas de faktorer som identifierats i datainsamlingen och analysen. De fem kategorierna från Innovation Adoption Theory används som rubriker under vilka de olika faktorerna förklaras. Faktorerna presenteras som en kombination av intervjucitat från datainsamlingen och forskarens tolkning av dessa, vilket förklarar varför just dessa delar ur data är viktiga för att besvara forskningsfrågan.

Under kategorin Individuella/personal finns ett flertal faktorer. Dessa inbegriper bland annat en experimentell arbetsmetod och ett personligt engagemang.

Under kategorin Innovationen visas att den tekniska lösningen i sig självt har vissa fördelar som gör den anpassad till dagens situation. Under organisationen syns olika teman som verkar vara prioriterade inom organisationen och som har påverkan på innovationen. Liknande faktorer finns under rubriken Externa/Sociopolitiska, där olika trender och händelser i omvärlden finns med. Och slutligen finns ett par faktorer listade under Klient/Användare-faktorer, vilket främst berör på vilket sätt människor använder den urbana grönskan.

Slutligen presenteras en analys utifrån ett komplexitetsteoretiskt perspektiv för att vidare analysera resultatet. Här framgår att positiva Feedback-loopar sannolikt är en del i hur utvecklingen fortskrider, att vissa händelser kan ha varit viktiga till en början, och att

organisationen idag har organiserat sig på ett sådant sätt att detta växtbäddssystem nu är en integrerad del av dess arbete.

Diskussion

För att svara på syftet och forskningsfrågan användes intervjuer och en litteraturstudie för datainsamling. I resultatet presenterades de faktorer som identifierats. En förväntad del av resultatet var att faktorer som är viktiga vid arbete med växter i städer är härdighet och tålighet för ståndorten. Det är faktorer som tas upp i den litteratur som använts som stöd för att formulera intervjufrågorna. Oväntade resultat var dock att många faktorer var relaterade till organisatoriska egenskaper. Och den främsta upptäckt som studien gjort är kopplade till detta. Sannolikt är det inte den exakta konfigureringen av systemet i sig som gjort att denna innovation skett i Stockholm. Utan snarare den arbetsmetod som legat till grund för att utveckla systemen. Först och främst visar studien hur innovationsprocessen bakom växtbäddar i Stockholm varit dynamisk och ickelinjär och väldigt beroende av personligt intresse och en experimentell arbetsmetod. En annan viktig upptäckt är vikten av att organisationen är öppen för förändring och att våga testa nya tekniker och metoder i sina verkliga utemiljöer. Detta visas genom intervjurespondenternas svar och tolkningen av dem i resultat och analyskapitlet. Det framgår till exempel i resultatet att verkliga stadsmiljöer kan vara svåra att emulera i experiment och tester tar ofta många år och en framgångsfaktor i Stockholm är ett stort antal försök i verkliga situationer. Slutsatsen som presenteras är därför att den verkliga framgången bakom Stockholms växtbäddar är en arbetsmetod och en organisation som är anpassad till den arbetsmetoden.

Studien bidrar härigenom med en förklaring av innovationen bakom Stockholms växtbäddar har sett ut. Detta kan bidra med en förståelse hos landskapsarkitekter och andra yrkesverksamma, för de organisatoriska och sociala egenskaper som kan ha en roll att spela för innovation kopplad till nya sätt att anlägga träd och andra växter i urban miljö. Denna förståelse kan användas av andra aktörer som vill arbeta med innovation inom sin egen organisation. Studien ger också en inblick i betydelsen av en praktikanknuten forskning då den belyser betydelsen av praktiken i detta fall och dess vikt för hur Stockholms växtbäddar har utvecklats.

Abstract

The situation for urban trees is often highly problematical. Due to the high proximity between different functions in cities, space is often quite limited which makes it hard for plants to establish and grow. To overcome these challenges, the City of Stockholm's tree officers have been developing ways to make plants thrive even in hardscape environments with only small volumes of space available below as well as over-ground. To a larger extent, this is done by using structural soils. These are soils that combine a load-bearing structure of some kind that are able to sustain the hard surfaces often used in cities, with a more porous soil or volume of air. In the porous part, roots are able to grow and receive the water, air and nutrients that they need to survive. The City of Stockholm have been developing their own kind of structural soils, and also experiment with different substrates as alternatives to more traditional soils. In particular, the use of biochar has been very successful and gained the city an international reputation.

The technical function and construction of this system are documented in several journalistic magazines, books and in a technical manual provided by the City of Stockholm. Literature explaining the process of how the organisation adopted this innovation is limited, though, and this study therefore aims to identify and explain the key factors for the innovation of the Stockholm soil system and to facilitate an understanding for how it has been adopted by the City of Stockholm. The research question is: Which is the most distinguishing factor for the innovation of the Stockholm soil system? It can be valuable for landscape architects and city officials with a responsibility for street trees in other cities to understand how a new system for planting and establishing trees in Stockholm has been created and implemented. Transferable similarities from the experiences in Stockholm may act as an aid in how such a process can be managed elsewhere too.

The scientific approach in this study was hermeneutic, abductive and explorative. The data gathering was performed as an interview study with experts selected for their particular insight and knowledge of the subject. This was combined with a review of journalistic articles. The data was then analysed using a content analysis, structured according to Innovation Adoption Theory and finally analysed by Complexity Theory. On one hand, this shows that factors related to individual/staff characteristics have been an important part in the innovation of the Stockholm Soil system. On the other hand, it also shows that there are factors related to the Innovation, the Organisation, External/Socio-political- and Client-factors that are important as well.

The main findings and conclusion to this study is that the most important factor for the success of the Stockholm soil system is a working method of constant experimentation and evaluation, and that the organisation has self-organised itself to incorporate this approach.

The main contribution that the study makes is that it shows how a multitude of different factors have been important to the development of the Stockholm soil system. The main part of this is that the organisation seems to accept changes to the soil system as a key ingredient of constant innovation. It also shows that innovation in how urban trees are established might be most successful when it is closely related to practice, as urban environments are hard to emulate in other research situations. For landscape architects, this is valuable as it shows how having an innovative approach to their field can help to improve on current conditions and working methods.

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1 Introduction

Plants are important elements of urban public space. They hold significant value for people by providing a variety of cultural and natural eco-system-services (Hitchmough and Dunnett 2005, p. 2; Deak Sjöman, Sjöman and Johansson 2015, pp. 214, 234, 235; Gunnarsson 2015, p. 21). Compared to most design elements and structures in cities, plants need to be used in a rather special way due to the fact that they are alive (Robertsson 1991, p. 68; Robinson 2011, pp. 10-1; Clouston 1990, pp. 8, 26). To make them thrive in urban situations, there are several issues that need to be handled (Sjöman and Slagstedt 2015, pp. 332-334). One of the main difficulties being that tree roots often lack the space that they require (Clouston 1990, pp. 8, 26; Deak Sjöman, Sjöman and Johansson 2015, pp. 310-314; Andersson and Stål 2015, p. 11; Sanders and Grabosky 2013, p. 203). The reason for this is that proximity between people and functions is one of the main benefits of cities. Such elements as stores, workplaces, homes and public areas need to be spatially distributed in a way that makes them sufficiently (Gehl 2010, pp. 19, 65) accessible, and this may put constraints on available space. In addition, urban soils are often too shallow, which may lead to soils becoming saturated by water and receiving a lack of oxygen for tree roots arise (Slagstedt, Gustafsson and Stål 2015, p. 560; Grip and Rodhe 2009, pp. 24-27). Lack of water is also a common issue since most urban streetscapes have hard surfaces that prevent water from infiltrating the soil (Goodwin 2017, p. 91). Such problems cannot be solved by simply providing a greater volume of soil with a permeable surface, since there are many other factors that also affect urban soils and make it more difficult for plants to thrive. One of the most problematic issues is compaction. It is caused by pressure on soils from human activity and results in the available porosity in soil becoming reduced. Moreover, the gas exchange between the air above ground and the soil decreases (Yang and Zhang 2015, pp. 31-33; Slagstedt, Gustafsson and Stål 2015, pp. 562-570; Ericsson et al 2011, p. 185). The effect of this is that plants cannot establish and grow in a healthy way, and, therefore, do not provide their full potential of values. For example, this can be seen in the way in which trees do not become as large as they would have given better conditions. It can also be seen in that they are more prone to sickness, dropping their leaves earlier in autumn and having a slow growth rate (Andersson and Stål 2015, p. 1; Goodwin 2017, p. 91).

1.1.1 Solving the issues by using structural soil

A solution that is used to provide the trees with everything they need, even when they are surrounded by hard surfaces, is structural soils. These soils are systems that combine a sturdy structure that is able to carry the load of traffic on the hard surface combined with a growing medium, often a planting-soil, for plant roots (Sjöman & Slagstedt 2015, p. 601).

Different types of structural soils are used in different places, and the two most common solutions for structural soils are *suspended pavement* and *skeletal soils*.

Skeletal soil is composed of crushed stone that is compacted to carry the loads of the pavement. In the volumes between the stone materials a *planting soil* is commonly used to provide a living space for plant roots (Bartens, Wiseman and

Smiley 2010, p. 333; Page, Winston and Hunt 2015, p. 41; Stockholms stad, 38). Suspended pavement systems, also known as structural support systems, instead use a type of plastic structure to bare the load of the pavement (Goodwin 2017, p. 160; Page, Winston and Hunt 2015, p. 41).

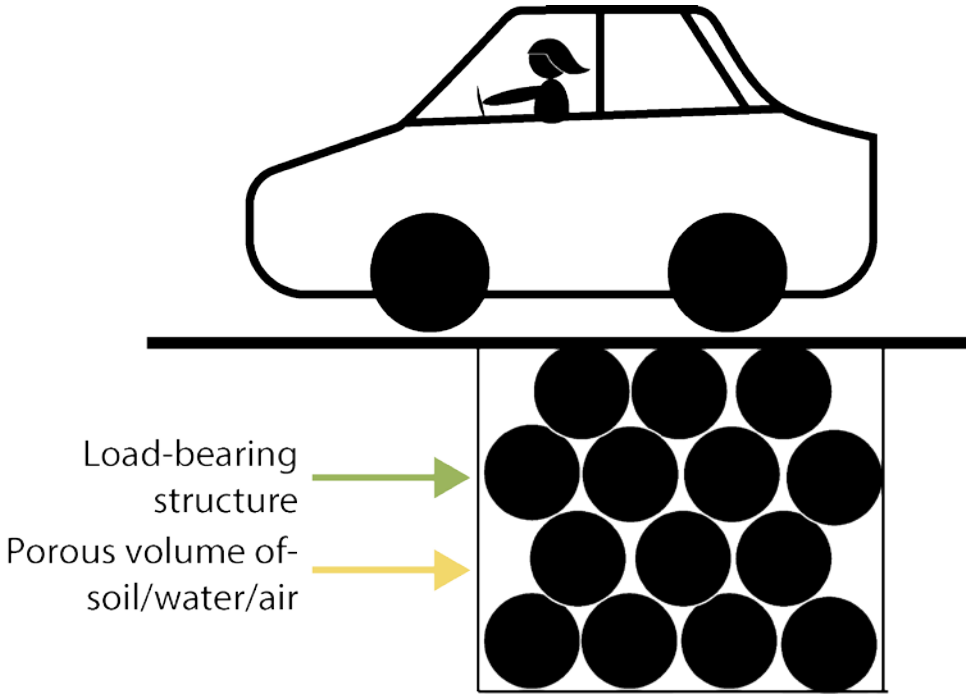


Figure 1 - Schematic illustration of a structural soil. Illustration: Jonathan Nyman

1.2 The situation for urban trees in Stockholm

It has been found that trees planted in the 19th and early 20th century do not show the above mentioned symptoms to the same degree as trees that were planted in the second half of the 20th century. The reason being that trees planted earlier were surrounded by permeable surfaces and likely had more available soil to grow in. Though the problems seen in trees planted during the second half of the 20th century may also be due to a decline in competence among maintenance personnel, which in turn may be an effect of a higher degree of regulation compared to before. Another factor may be that communication between different actors within the green sector is lacking (Andersson and Stål 2015, pp.1-2).

The civil and architectural engineering and construction industry in Sweden together own a company known as Svensk Byggtjänst. The aim of the company is to create common standards of procedure for construction and use of materials (Svensk Byggtjänst 2017). *AMA-Anläggning* is one of the publications that they produce and one of the subjects that it covers is directions as for how to construct urban plantings (Svensk Byggtjänst 2014, pp. 217, 333). It is a regulation that seems to be highly used and trusted today (Andersson and Stål 2015, p.2).

AMA includes a concept known as *växtbädd* in Swedish (Stockholms stad, 2009. pp. 1-10; Svensk Byggtjänst 2014, pp. 217, 333). It literally means *planting-bed* and refers to the system constructed to support plants. It includes specifications for soils as well as the design of the system. For instance, the layering of soil and side-support construction. For the rest of this thesis, the term *planting-bed* is used with this meaning.

1.2.1 The Stockholm soil system

The structural soil solution that has gained most popularity in Sweden is the skeletal soil type (referred to as structural soil for the rest of this thesis). Quite little is known today regarding the long-term effects of structural soils (Sjöman and Slagstedt 2015, pp. 332-334; Slagstedt, Gustafsson and Stål 2015, pp. 601-604; Goodwin 2017, p. 152).

The City of Stockholm have been developing new ways to improve the conditions for urban trees since 2001, which includes a skeletal structural soil (Stockholm's stad 2009, p. 2; Philip 2017). The system is based on a structural soil of crushed stones 100-150 mm in size. When the system is installed, the structural soil is compacted and then flushed with water mixed with planting-soil. The structural soil is then topped by a 200 mm deep *aerated bearing layer,* constituted of crushed stone in the size 32-63 mm. This layer is also compacted but not filled with any soil. Inlets that allow both water and air to pass between the soil and the air above are then installed before the pavement is applied on top. The hard surfaces are designed with slopes so that storm water is directed to the soil through the inlets (Goodwin 2017, pp. 157-158; Stockholm's stad 2009, p. 38). This system is hereafter referred to as the *Stockholm Soil System* for the purposes of this thesis. The system is presented in *The Stockholm Technical Handbook* from 2009, together with other methods for planting and establishing trees, such as in new and existing parks (Stockholm stad 2009). The system has been used with great effect and a couple of thousand existing street trees that used to be in poor condition have been restored by using it (Sjöström, 2016).

1.3 Innovation of the Stockholm soil system

The initiative of first developing the Stockholm soil system and to experiment with biochar comes from the tree officer Björn Embrén (Stockholms stad 2009, p. 2; Philips, 2017). The Traffic Office has two tree officers that together are responsible for the City's 40,000 street trees. Ground vegetation and other greenery (such as parks) are managed by the City's different districts (Stockholm 2017a).

Embrén has also been the project leader of the Stockholm Technical Handbook. It is a brochure produced by the Traffic Office at the City of Stockholm to communicate their preferred methods for how trees are to be planted. It is mainly aimed at contractors performing such work and is based on a combination of scientific studies and the practical experience of the authors (Stockholm stad, 2009. pp. 1, 5). In a newspaper article, Embrén explains that the condition of Stockholm's street trees has been really poor and that this had led to the development of the Stockholm soil system (Gyllenberg 2009).

In Stockholm, they have also experimented with other materials such as using crushed concrete instead of crushed stone for the skeletal part of the soil (Goodwin 2017, p. 158). Different mixes of planting-soil have been tested as well (e.g.

Stockholm stad 2009, p, 15). This testing of different methods and materials has also been done by others in cooperation with the tree officers.

Figure 2- Stockholm Structural soil. This image shows a picture with the 100-150 mm skeletal soil on the bottom of a planting-bed. It has been topped by the 32-63 mm aerated bearing layer and the storm water inlets have been installed. Photo: Björn Embrén. Permission to publish has been granted by Björn Embrén.

Figure 3- The Stockholm soil system. The image shows the structural soil at the bottom, topped with an aerated bearing layer and inlets that allow storm water and air to pass through the soil. The large storm water inlets and the aerated bearing layer are the features that makes this system different to other structural soil systems. This is an advance copy from the 2017 Technical handbook. Published by permission from the City of Stockholm.

1.3.1 Example project 1: Kungsbroplan

Figure 4 – Photo: Kungsbroplan in 2002 with the two Tilias in the middle. Photo: Örjan Stål. Permission to publish granted by Örjan Stål.

A project of relatively high importance in the innovation of the Stockholm soil system was a renovation of two Tilias at a square named Kungsbroplan. Even though the two Tilias were at least a hundred years old, they were in a bad condition and had been planned to be removed. An investigation took place to see what may have caused their bad condition, and it was found that a deep layer of compacted gravel was choking the root system. A restoration of the trees was tested in 2002. 100-150mm crushed stone was added in a 60cm deep layer and planting soil added. The effect was obvious already after one year. Later on, after ten years, it was evaluated that the trees had continued to grow to the same extent as trees standing in a park would have done (Andersson and Stål 2015, pp. 38-19).

Figure 5 – Kungsbroplan in 2012. The Tilias growth rate was increased and they now contribute with healthy green canopies to the place. Photo by Örjan Stål. Permission to publish granted by Örjan Stål.

1.3.2 Example project 2: Full-scale trial in Norra Djurgårdsstaden

Figure 6- One of the trial plantings in Norra Djurgårdsstaden. A tarpaulin was used to guide storm water to the planting-bed. Two of the four trees and some of the perennials from the second round are seen. Photo: Anna Pettersson Skog. Permission to publish granted by Anna Pettersson Skog.

One project where a new type of planting-soil was tested was initiated by the City Development Office (*Exploateringskontoret*). It is part of a large scale development project in Stockholm known as Norra Djurgårdsstaden. The district has been appointed as an environmental profile area to serve as a good example of sustainable City development. It has won international awards such as the C40 Cities as a sustainable City district (Stockholm's stad 2017b).

The environmental profile of the project has also played a part in work with urban greenery and a Green Area Factor for the public, as well as private development is being used (Stockholm's stad 2014, p. 5). The work also includes the management of storm water in combination with the green elements of the area (Sweco 2011, p. 5).

The idea with the planting-beds was to make them lower than street-level so that they would be able to store storm-water on top. This could be regarded as bio-filters.

Bio-filters are regarded as a special type of planting bed, and they are systems made to handle water with the help of vegetation (Blecken 2016, p. 50). Other names used for this type of system include rain gardens, bio-retention basins and flow-through planters (WSUD 2006, p. 2). Fundamentally, these are planting beds with high infiltration capacity. Although definitions vary in most literature, 'bio-filter' seems to be used as an overall concept for different variations of planting beds with high infiltration capacity (Lindfors, Bodin-Sköld, Larm 2012, p. 4). Infiltration refers to the process of water passing through soil by filling its pores, mainly downwards due to gravitational forces (Kirkham 2014, p. 201).

Whereas the aim of using bio-filters is to mimic nature's way of dealing with pollutants, the main focus is on pollution removal (Blecken 2016, P. 51).

Vegetation is an essential part of these systems, mainly by providing an op-opportunity for bio-film to be created. It also helps with oxygen transport in the soil which increases biological activities that transform pollutants (WSUD 2006 c. 5 p. 2).

The planting beds in the trial in Norra Djurgårdsstaden also used a new variation of substrate based on a mixture of construction spoil and pumice. Pumice is a porous stone created in volcano eruptions. Its porosity makes it able to bind water at a tension that makes it available to plant roots (Bara mineraler, 2017).

The essential point of the trial was to evaluate root growth in this particular setup. The proportions of how to mix pumice and construction spoil had already been made in advance (Pettersson Skog and Banach, 2012, p. 3; Pettersson Skog 2011, p3). Two trial beds were constructed in 2011 and four trees were planted along with 24 perennials (Pettersson Skog and Banach, 2012, pp. 1-4).

Two planters were constructed: one with two oaks and one with two willows. The reason for planting two of each species was that there were a couple of years available to evaluate the outcome of newly planted trees while in its application one tree should be able to survive for at least 50 years.

Due to a winter storm, the two oaks fell during the first winter. Subsequently, new oaks were planted in the following summer. Perennials were tested throughout two winters. The first season, 22 plants of Geranium (doftnäva) were planted and had a survival rate of 50%. The winter was harsh with a lot of snow and, towards the final weeks of winter, an ice-pan was formed on top of the soil. A second round of perennials were tested between July 2013 and July 2014 using eight species of 6-11 of each. The survival rate of these were then evaluated by Sweco (*The results are unpublished but permission to use have been granted and is shown below in figure 7)*. The second winter was mild and the cause of death for plants was a drought during the summer. It was concluded that drought-tolerant plants were preferred (Personal communication, Anna Pettersson Skog 2017-07-08).

Species	2013	2014
Homerocallis citrina	10	9
Onoclea sensibilis	6	0
Lythrium salicarlia	11	9
Carex paniculata	9	1
Geranium sanguineum	13	12
Knautia makedonia	7	7
Nepeta fassenii	5	5
Sesleria nitida	6	6

Figure 7 - Table showing the survival rate of perennials in the full-scale trial in Norra Djurgårdsstaden. Information provided by Anna Pettersson Skog, Sweco.

1.3.3 The biochar project

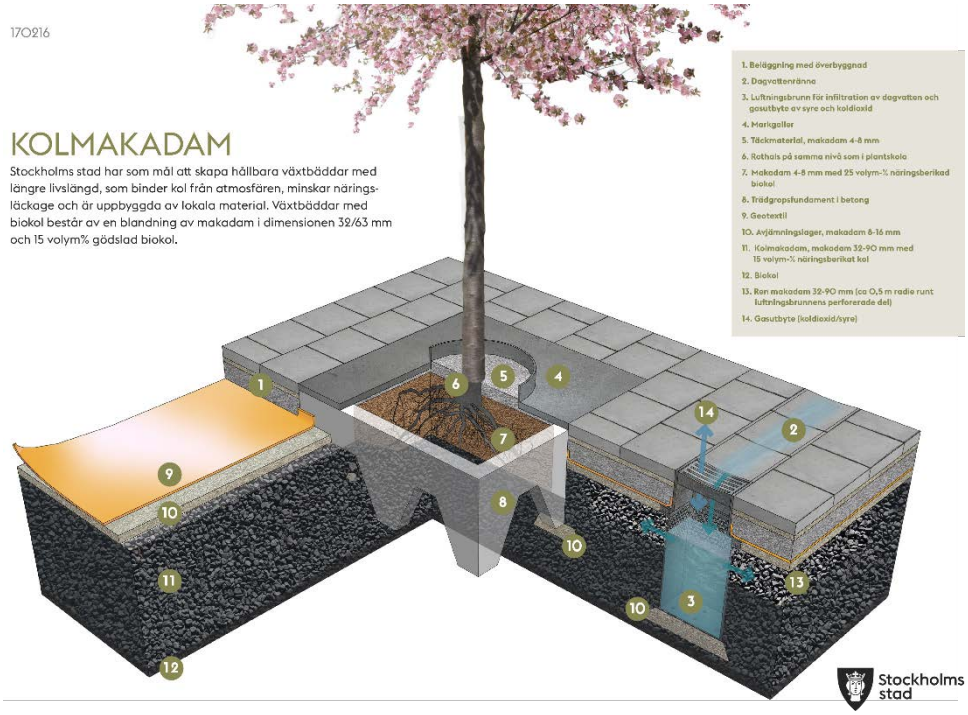


Figure 8- Skeletal soil with biochar. In this version of the soil system, the whole profile is a mixture of 32-63 mm crushed stone and biochar soil. This is an advance copy from the 2017 Stockholm Technical handbook. Changes in the final version may appear. Permission to publish has been granted by the City of Stockholm.

A substrate that has been tried in Stockholm with promising results is biochar. The initiative to experiment with biochar comes from the tree officer Björn Embrén (Bloomberg 2017).

Mixing biochar into the planting-soil has greatly improved the growth rate for plants in Stockholm's urban environment (Bloomberg 2017).

Biochar is a product that comes from heating biomass in a container that has a low oxygen level. This is a result of a process called pyrolysis. It has the potential to bind nutrients and thereby contribute with such to plants roots. This is also useful for the pollution-removal of storm water (Stormtac 2017, pp. 1-6). Notwithstanding that, the final product differs depending on the source material and pyrolysis process (Lehmann and Joseph, 2009, p. 1).

Biochar has been used in 1,000 tree plantings in Stockholm (Abrahamsson, 2015).

Biochar has also been tested in the sunken planting beds of Norra Djurgårdsstaden (Stockholm 2016) and has replaced the use of pumice (Personal communication, Gösta Olsson 2017-03-02).

1.3.4 Example project 3: Herrhagsvägen

In one trial, Prunus avium was planted in three different soils, consisting of one soil based on the prescription in AMA, one soil mixed with biochar and one consisting of rock only. It was found that the growth rate after 4-5 years was 35% greater in the one with biochar, with shoots growing longer as well (Fransson et al. 2014, pp. 8-13). Furthermore, biochar is now used in a combination with structural soil (Personal communication, Britt-Marie Alvem 2017-03-10).

1.4 Research problem

The Stockholm structural soil system has been used to a large extent and with great success (Sjöström 2016; e.g. Fransson et al. 2014). Particularly, with the inclusion of biochar, it has received an international reputation (e.g. Bloomberg 2017). There is, however, no literature that fully covers how this innovation has been adopted by the City of Stockholm. In essence, to understand which factors that has made this adoption of this innovation possible and successful is the primary focus of this thesis.

As the innovation of planting-beds is aimed at improving the living conditions for urban trees, this study is thematically focused on the use of plants and planting-beds in the streets of Stockholm. It focuses mainly on the work conducted by the Traffic Office.

It can be assumed that the Stockholm soil system has implications for how landscape architects can design with plants in Stockholm's urban hardscape environments, and that an understanding of the system may be helpful in doing so. Furthermore, this study may highlight obstacles and solutions in trying to implement new technologies in the landscape department of a municipality. This study may also contribute with a historical value in documenting aspects of the innovation process of the Stockholm soil system.

The reason to perform such a study within the field of landscape architecture is based on my experiences from studying the subject at a Swedish university. During my studies, I have come into contact with the Stockholm soil system in several situations and understood that it is rather unique. But the reasons for why it has been developed by officials working at a municipality and how the process behind that development has evolved is something that has been hard to understand. As landscape architecture is a practically inclined profession, the foundation for this study enquires into the work of practitioners involved in this innovation, to try to understand how it has been performed.

The study has been conducted within the scientific field of landscape architecture, as it requires a certain level of expertise to be able to interview experts and understand their answers. It can be argued that it also is beneficial not to be an expert oneself so that basic (but potentially important) questions aren't missed (Kvale, 2015) which may make it suitable to perform this study at a master thesis level.

1.4.1 Research Aim

The aim is to identify and explain the key factors for the innovation of the Stockholm soil system and to facilitate an understanding for how it has been adopted by the City of Stockholm.

1.4.2 Research question

Which is the most distinguishing factor for the innovation of the Stockholm soil system?

1.4.3 Delimitations

The Stockholm technical handbook includes methods for planting trees in parks, but such methods are not included in this study as it only focuses on urban hardscape environments. In this thesis, the term *Stockholm Soil System* is thereby referring to soil systems used in hardscape environments; although in other

circumstances it could be used to describe other methods for tree planting in Stockholm as well. In spite of the fact that other situations are mentioned in the results, they do serve a purpose of explanation in showing the importance of the structural soil systems.

The study is delimited to the City of Stockholm in Sweden. Specifically the Traffic Office and the City Development Office.

It does not go into detail with regard to any technical functions of the soils or systems, as that has been documented in various other instances.

It does not elaborate on the consideration of choosing specific species of plants, but only on which type of plants that are used. Thus, plants are discussed in terms of trees, shrubs and perennials. How plants are used in parks, at squares and other green elements of the City will not be part of the main research question, but will still be considered as part of the empirical data. Relations to overall green networks, agricultural land, wetlands or forestry are not included in the study.

This study does not consider site-specific influence on plants, such as street proportions, building height or microclimate for any particular case. It only considers effects on plants and planting-beds in general terms, based on the climate of Stockholm.

It does not consider ownership of land and the impacts of private green space.

Neither are the networks between different actors and people involved in the development of the soil system and their internal relations included.

1.4.4 Central concepts

In this study, *innovation* is understood as the creation and implementation of something new. It can be separated from creativity, which is associated with creation but not with implementation. It can also be separated from entrepreneurism, which in public organisations can be seen as being closer related to the use and spreading of a certain way of doing something (Forslund 2013, p. 370; Tidd and Bessant 2009, p. 16).

Factors, as used in the research aim and question, are understood as meaning any ongoing processes that influence the way that the Stockholm soil system has been created or is being implemented.

An *organisation* is often understood as a whole private company or public institution. No clear definition exists and all organisations may be completely different to one another. However, three common denominators for all organisations are that they are formalised groups that abide by a set of rules, that they are complex, and that they strive to reach certain goals (Bakka 2006, pp. 11-16). They are constituted by active processes of change (Bakka 2006, p. 234). When the word ‘organisation’ is used in this thesis, it mainly refers to the City of Stockholm, but this study primarily focuses on a small part of that organisation - the part that is concerned with working with urban trees in different ways. In light of this, the above description may still be regarded as an organisation independently.

Planting-bed refers to a system of soil and other construction elements that combined are used to support plants (Stockholms stad, 2009. pp. 1-10; Svensk Byggtjänst 2014, pp. 217, 333).

Structural soils are systems that combine a sturdy structure that is able to carry the load of traffic on the hard surface combined with a growing medium for plant roots (Sjöman & Slagstedt 2015, p. 601).

2 Method

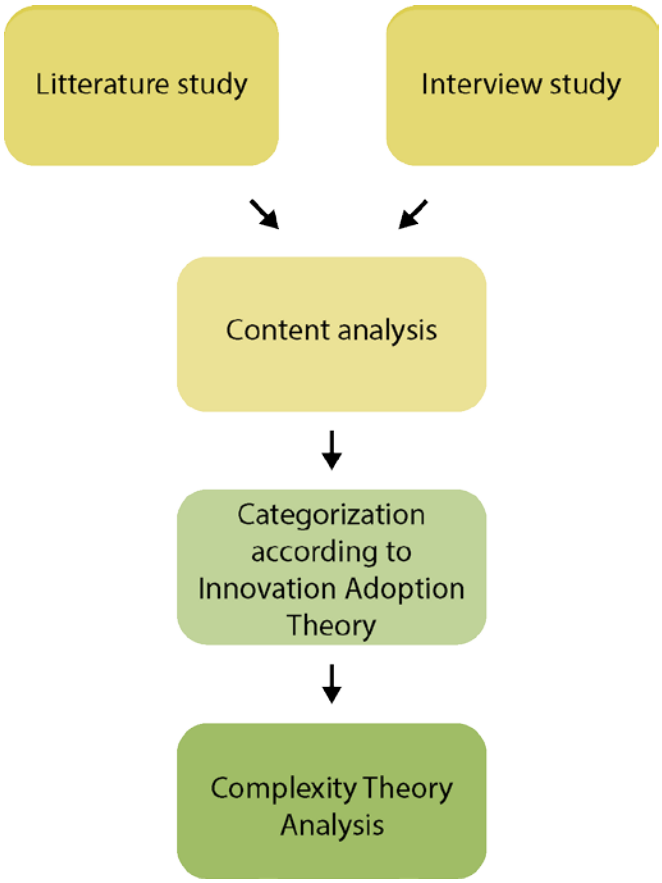
Landscape architecture has a disciplinary relationship to the natural sciences, the social sciences as well as the arts and humanities. It is therefore important to explain what scientific traditions this study has derived its language from (Thompson 2017, pp. 40, 41, 49). The study was conducted in a social scientific tradition, as it was a qualitative case study.

Bent Flyvbjerg describes case studies in the following manner:

> "Context-dependent knowledge and experience are at the very heart of expert activity. Such knowledge and expertise also lie at the centre of the case study as a research and teaching method or to put it more generally still, as a method of learning" *(Flyvbjerg 2006, p. 222).*

Case studies are essentially aimed at understanding of a particular project (Francis, 2001, p.16) and a qualitative methodology was therefore the most appropriate for this study. Some scientists even argue that case studies and qualitative research are the same thing (Bryman 1997, p.106).

The following figure shows the basic outline of how the methods correlate to the other parts of the thesis.



2.1 Scientific approach

A hermeneutic approach was used in this thesis. The essence of hermeneutics is to gain understanding through the act of interpretation (Føllesdal 2001, pp. 133-136). Central to hermeneutics is the hermeneutic circle. It illustrates that the whole and its parts are interconnected and cannot be understood without one another. It can also be used to describe that achieving understanding is dependent on the pre-understanding of the interpreter. When new understanding is gained through interpretation, pre-understanding is expanded which enables further interpretation and so on (Alvesson and Sköldberg 2008, pp. 193-211).

In addition to the hermeneutic approach, an abductive approach was used. Alvesson and Skjöldberg describes abduction as a philosophical way of reasoning based on empirical data. Though it often uses theory to better understand and interpret the data, and vice versa. According to them, abduction is the way of reasoning that is most likely to be used in case studies (Alvesson and Sköldberg 2008, pp. 55-56).

In addition, this study had an exploratory approach aimed at widening the existing understanding of the case by studying it from a new angle.

2.2 Interview study

The primary data of this study was gathered through interviews. They were semi-structured and had a low degree of standardisation (Trost 2010, pp. 32,132).

2.2.1 Population

Björn Embrén was interviewed in 2017-02-13. He works at the City of Stockholm Traffic Office as tree officer which he has been doing for the last 16 years. He has a background as park-worker and foreman and started his professional career in 1980. He initiated the work with the Stockholm soil system.

Örjan Stål was interviewed in 2017-02-20. He is a specialist consultant in urban soil and trees. He has a University Degree in Landscape Management and started his professional career in 1991. He has also been involved in the creation of the Stockholm Technical Handbook.

Patrick Bellan was interviewed in 2017-02-22. He works as a plant advisor and has a background as landscape engineer and he started his professional career in 2008. He has also got working experience from plant nurseries.

Britt-Marie Alvem was interviewed 2017-03-10. She has been working for the City of Stockholm since 1997, when she started her professional career as a landscape architect. She has been working as a tree officer for the City of Stockholm's Traffic administration since 2007. Alvem and Embrén are together responsible for approximately 40 000 street trees in Stockholm.

Gösta Olsson was interviewed in 2017-03-22. Since 2001 he works at the City of Stockholm Development Office as a project manager. He has a background as gardener and consulting landscape architect and started his professional career in 1987, after also having worked as an intern park-worker. He is responsible for all procurement of landscape architecture services in Norra Djurgårdsstaden.

Britt Berntsson was interviewed in 2017-03-29. She works at the City of Stockholm Development Office with public space planning. She has a background as consulting landscape architect and started her professional career in

1985. She has also worked as the editor of the part of AMA dealing with greenery and planting-beds for the versions that were released in 2010 and 2013. A work that was conducted during 2009-2013.

The choice of respondents was goal-oriented. When doing time-consuming interviews, Jan Trost proposes a small group of respondents that are familiar with the subject but that also contains some heterogeneity within the group (Trost 2010, p 137).

Respondents from the City of Stockholm were deemed as essential and especially The tree officers at the Traffic Office were more or less fundamental to the study, as they were assumed to have a unique understanding of the Stockholm soil system. And as Norra Djurgårdsstaden was included as well, Gösta Olsson was selected. Britt Berntsson was added because of her knowledge of AMA. Two consultants were also added, as they work in a larger geographic context and may contribute with other perspectives. One of them is Örjan Stål, who also has insight into the Stockholm soil system, having worked with them in a lot of projects. Patrick Bellan was selected because of his work with plants and plant nurseries. Plants generally come from plant nurseries and someone with such a background seemed to be able to add an extra dimension to the study, and add to the heterogeneity within the group of respondents.

Only respondents with a high degree of understanding of urban plants as well as urban soil were included as that was required to be able to provide reliable answers to the interview questions.

2.2.2 Execution

All respondents were first contacted through telephone. If they were not possible to reach through phone call, the first contact was instead established through text message or e-mail. The interviews with City officials took place at their offices. The interview with Örjan Stål took place at SLU, Uppsala and the interview with Patrick Bellan was done through a phone call due to the geographical distance. Specific dates and places were decided together with the respondents who were given opportunity to take initiative to suggest a place, which they all did.

Following Trost, interview questions were asked depending on the person being interviewed and his or her particular field of knowledge (Trost 2010, pp. 19-23). The respondents were allowed to speak freely and ask counter-questions and the order of the questions was flexible. If the respondent happened to come into another of the interview questions the order of the questions was changed.

Based on the fact that urban soil is used to support urban plants, the interview questions were aimed to identify what factors that are the most important to consider when working with urban plants.

The landscape designer Nick Robinson's theory of planting design and the researchers Henrik Sjöman and Johan Slagstedt's method of choosing plants served as an aid in formulating the questions (Robinson 2011, p. 3). According to Nick Robinson, the values that are attained through planting design are aesthetic, ecological and functional values (Robinson 2011, p. 3). When choosing plants for urban environments, Henrik Sjöman and Johan Slagstedt propose a method for plant selection to find plants that are well adapted to their particular contexts. It contains the seven steps: *hardiness*, *succession*, *tolerance to the place of growth*, *function/historic values*, *maintenance*, *type of growth* and *aesthetic and social qualities (authors' translation)* (Sjöman and Slagstedt 2015, pp. 332-334).

Sjöman and Slagstedt emphasize that hardiness not only concerns soil factors but all factors of the environment (Sjöman and Slagstedt 2015, pp. 332-334).

After all of the interviews had been conducted, a few follow up questions were asked to some of the respondents. These were made by phone calls and e-mail.

The questions that were asked are presented in Appendix A. The respondents were also asked if they wanted to contribute their name to the study and that they had the right to be anonymous.

Notes were the primary way of documentation and was followed by transcription as soon as possible. Sound recording was used as a backup method for the interviews when transcription wasn't possible to perform during the same or the following day (Trost 2010, pp. 9, 74).

2.3 Literature review

As initial searches were made in the scientific databases Scopus, Web of Science and Swepub, no relevant articles were found that had dealt with this research issue. The secondary data comes from a few Swedish newspapers as well as a number of different magazines.

The secondary data was found through searches in the search-engine Google. And the terms that were used were "Stockholm structural soil" and "Stockholm soil". This resulted in approximately 700 hits. Out of these, eight were relevant in answering the research question. This was based on reading their titles and the short-description visible in the search engine.

2.4 Data analysis

Before analysis, the interviews were transcribed. That was done in a linguistic manner with emphasis on readability and meaning rather than the linguistics of the interview (Kvale 2015, pp. 206, 213). Elements such as pauses, intonation or counter questions were not included.

The transcriptions were then condensed and translated to English, as all of them were conducted in Swedish. This demanded an extensive amount of rephrasing to match the dissimilarities in the way language is written in Swedish compared to English. Repetitions and unclear wordings were also removed. This resulted in transcriptions that were somewhat linguistically different to the way that the respondents expressed themselves. The respondents were then asked to read the parts of the transcriptions that ended up in the results section of this thesis. This was done to make sure that they felt comfortable with the way that they had expressed themselves after the translation of the texts. All quotes in this thesis have thereby been approved by the respective respondent.

2.4.1 Step 1: Qualitative content-analysis

A qualitative content-analysis focusing on meaning interpretation was used to answer the research question. Factors were identified through interpretation of the data. The results from this does not only include the basic reading of the data but also how it relates to its context (Boréus and Bergström 2005, pp. 44-45; Kvale 2015, pp. 235, 236).

All the transcriptions were divided into quotes which then were color-coded based on words from the text. This resulted in five different piles that were related to *social/human, water, plants, soil,* and *other* elements. The quotes in each pile were then compared to each other and combined to create the basic *factors* aimed at answering the research question.

2.4.2 Step 2: Categorization according to Innovation Adoption Theory

After the content-analysis, all identified factors were categorized by using categories from Innovation Adoption Theory presented in a paper by Wisdom et al (2014). This was done without following any strict criteria for inclusion and the meaning of each category were therefore interpreted by the author.

2.4.3 Step 3: Complexity Theory analysis

When having achieved the categorization in step 2, a complexity theory perspective was added to further analyse if the different factors could be considered as key to the innovation.

2.5 Ethical considerations

There are many ethical considerations to transcription. The first one is that oral language will look incoherent when written (Kvale 2015, p. 206-209). As the main focus of the interviews conducted were on the meanings being expressed rather than the linguistics themselves, the transcriptions were made into a more readable story (Trost 2010, pp. 127, 134). The respondents were therefore offered to read the quotes that were to end up in the final version, so that they would feel comfortable with what that had been said.

Trost discusses the aspect of respondents reading the transcriptions and the interpretations as being problematic (Trost 2010, p. 112). While this is a matter of taste according to him, I have chosen to let all respondents read the transcriptions. This is partly due to the factor that information may be lost during these stages, especially translation, and that the approval of the respondent after this stage adds credibility to the study.

Another consideration relates to anonymity. In this thesis the interview persons were especially selected based on their knowledge of the research topic. This study would have been difficult to conduct without some of the respondents. And due to the specific nature of the subject, they would also be more or less identifiable due to their special knowledge and insight into these matters. Though regardless of this, all respondents were informed that they had the right to be anonymous but they all agreed on having their names published. This was also an important reason for the decision to ask all of the respondents to read their quotes.

2.6 Reliability and validity

As the respondents have all agreed on having their names published, this should strengthen the reliability of the primary data material.

Trost argues that providing the interview questions enhances the trustworthiness as the study can be examined (Trost 2010, pp. 19-23), which has been done in appendix A. The reliability has also been somewhat strengthened through the combined use of the interview study and literature review.

All interview respondents were chosen on the basis that they would contribute with valid answers due to their professional background and expertise. They were thereby also considered as Truth-Sayers as the main source criticism took place in the actual selection of respondents by trying to find respondents with expertise in the subject being studied.

During the analysis, a decision of how to regard reliability had to be made. Two ideas were balanced. It could either be interpreted that the answers of the tree officers were more reliable than all others due to their proximity to the research subject. On the other hand, other respondents seemed to add context by elaborating on the issues from another point of view. It was therefore concluded that the answers from the tree officers may be regarded as the most reliable though all answers could be seen as being valid. This meant that the answers of the tree officers are were the first choice to show in the results chapter when several respondents had provided similar answers.

2.7 Critique of the methodology

A critique that could be raised towards this method is whether its interpretive nature can contribute any scientific values. With regards to the interpretations, it isn't possible to gather single pieces of data, such as quotes, and argue that they hold as absolutely true (Bryman 1997, p. 95). By transferring the data into the horizon of understanding of the author, there will undoubtedly be an influence of certain assumptions and values that the author holds which will have affected the way that interpretations were done. This study could thereby have a weakness in that the interpretations are wrong. Although cases are interpretable only when looked upon with one´s own understanding (Thomas 2010, p. 578). So this also means that the results in this study will be interpreted again when read. In an interpretive study, the relevance of findings in its context will therefore be more important to judge rather than its generalizable value (Ponelis 2015, p. 545)

With the transfer of data from a source to the author, and then to the readers of this text, using source criticism can be a way to filter the data (Alvesson and Sköldberg 2008, p. 220). Although this study made the basic assumption that the respondents were Truth-Sayers, which may be a weakness of its validity.

According to Yin (2009), the main difficulty with case study research is that the complexity of real life needs to be handled. To overcome this a mixture of methods is generally used (Yin 2009, p. 3). This thesis uses the combination of interviews, literature review and theory to better understand the subject being studied. A weakness that became apparent in this triangulation was the lack of written documentation describing the research subject. Many papers, documents and articles that were found relate to the technical achievements of the City of Stockholm, but very few described the story behind the innovation. They were in part also authored by some of the respondents, which made the addition of the extra sources less meaningful. It is therefore mainly reliant on the interview study.

Another way to deal with the problematic nature of interpretation, is by using respondent-validation of the results. Bryman discussed this as being problematic, as the interpretations in essence aren't the same thing as the views of the respondents and that may therefore serve as a limit to interpretation (Bryman 1997, p. 96). It is also important to note that since particular cases are interpretable only

when transferred into one's own horizon of understanding (Thomas 2010, p. 578) and the researcher as well as the context always has an influence on the result, other interpretations than the ones made by the author may be possible as well (Alvesson and Sköldberg 2008, pp.15, 211, 212).

Simon Swaffield describes that an important feature of case studies is to provide new insights that might be useful for projects beyond the case being researched. And that the way the case study is set up often is dependent on each specific study and its focus (Swaffield 2017, pp. 106). Swaffield goes on to say that the possibility to compare, and thereby create generalizable knowledge is limited when choosing cases on an opportunistic basis (Swaffield 2017, pp. 107). But instead of being seen as opportunistic, the choosing of this case could also be regarded as the study of a paradigm or an extreme case.

Critique towards the lack of generalizability in case study research can also be questioned. For example, Mats Alvesson and Kaj Skjöldberg describe ideographic research, as this study is, as not striving to acquire generalizable data to be formulated into laws (Alvesson and Skjöldberg 2008, p. 130). And according to Bent Flyvbjerg the case being studied and how it is selected is defining for the ability to generalize. And when understanding of a particular phenomenon is wanted it may be more appropriate to choose an exact case rather than to use random sampling (Flyvbjerg 2006, pp. 225-227). Gary Thomas delves deeply into the aim of case studies. He argues that it is induction rather than generalizability that isn't possible in case studies, as in the way it is in natural sciences and any critique to the lack of generalizability of case studies has failed to perceive this. "It fails, in other words, to recognize the offer that can be made in local circumstances by particular kinds of looser generalization, whatever one calls these". (Thomas 2010, p. 576-577). This kind of generalization is therefore possible for this study as the results may be transferable to other similar situations.

3 Theory

This chapter presents the theoretical framework. The chapter should serve to illustrate the main ideas from Innovation Adoption Theory and Complexity Theory related to the study of Innovation within organisations.

3.1 Innovation adoption theory

Innovation is linked to *innovation adoption*. In an overview of 20 studies on innovation adoption, Wisdom et al (2014) shows that there are a large number of mechanisms that decide whether an innovation will be adopted by an organisation or not. They identified that the mechanisms are related to quite different aspects of the process. They can be either “Socio-political and external influence”, or more internal such as “Organisation Characteristics”, Innovation Characteristics” and “Staff/individual characteristics”. They can also be related to “Client characteristics”. They also identified that adoption of an innovation is preceded by a state of pre-adoption when the staff of an organisation somehow come into contact with innovation and have to make the decision if they should implement it or not (Wisdom et al 2014, pp. 6, 14, 15, 26).

3.2 Complexity theory

This section describes the main concept from complexity theory applied on organisations.

3.2.1 Complexity

The word *complexity* may need some further explanation for how it is used in this thesis.

As social science studies reality and historical events, a central part is the study of so called complex systems. Complex systems are unpredictable, non-linear and change along the cause of time (Byrne 1998, pp. 14-17). These aspects also apply to organisations, which make them difficult to overview (Forslund 2013, p. 393; Andersson 1999, p. 217). To map a complex system in order to gain understanding of the world so that we can shape it in accordance with our goals is thereby a task that may prove to be difficult (Byrne 1998, p. 19).

3.2.2 Complexity theory concepts

Complexity theory sprung out of the natural sciences but has been applied in a variety of other fields including social sciences (Teisman et al 2009, pp. 3-7; Byrne 1998, p. 17; Forslund 2013, p. 393).

Magnus Forslund has used complexity theory to describe characteristics that may make an organisation oriented towards renewal (Forslund 2013, p. 393).

The first idea that Forslund presents is that organisations are complex systems and that *feedback-loops* are an essential part in this (Forslund 2013, p. 394). These are inherent to all organisations and are used to describe how a certain event decides what the next event becomes based on feedback. If an event is met with positive feedback it may accelerate action on a path that differs from the initial state which over time may create a series of events following one another.

Negative feedback on the other hand tends to be a force that strives to maintain stability within a certain frame (Forslund 2013, pp. 394-400).

Also *initial states* are important as they are highly determinant for future effects. The most famous example of this is the butterfly effect that is used to describe how a small event may trigger much larger ones (Forslund 2013, p. 395; Byrne 1998, p. 17).

Forslund also points out that *shifts between chaos and stability* always exist within organisations based on the different feedback loops. In a situation with a high degree of positive feedback the organisation will move towards chaos while a lot of negative feedback may make the organisation more resistant to change (Forslund 2013, p. 396). Complexity theory emphasises that chaos never prevails, as there often exists an inherent inclination towards *self-organisation* (Forslund 2013, p. 397). This happens because the agents in a system are striving to reach their goals even when conditions change. Self-organisation cannot be replaced by control of an organisation (Andersson 1999, p. 223; Teisman et al 2009, pp. 9-11). Self-organisation is dependent on certain limits in each particular case. Changes are for example limited by physical, jurisdictional, human and other factors (Forslund 2013, pp. 396-398).

Another point that Forslund makes is that *organisations aren't always open to change* to the same degree at all times. A state of instability or an inclination towards a more chaotic state often makes an organisation more open to change. Also *timing* is highly important and that there needs to be enough forces endorsing the change to allow it to be implemented (Forslund 2013, pp. 398-399).

To be aware that self-organisation always exists in organisations is therefore important to understand for managers, as it in essence cannot be avoided (Forslund 2013, p. 400).

4 Results and analysis

In this chapter, the data and analysis is presented. The data has been structured into *categories* and *factors* during the analysis. All *categories* come from innovation adoption theory (Wisdom et al 2014). They contain sets of *factors* that have been interpreted as having more resemblance to one another than to the other factors. Although, this is not a solid differentiation in reality. The *factors* are any factors found during the content-analysis. Where the aim is to explain the context of innovation, factors may relate to the creation and/or implementation of the Stockholm soil system.

Each factor is presented in a *setup-quote-comment* structure. The *setup* describes the interview question that was asked or what subject that was being discussed during one or more of the conducted interviews. This is then followed by one or several *quotes* from the interview transcriptions, sometimes with brief comments by the author in between them. Finally, a *comment* is given that explains why the particular quote(s) are shown and why they are important. Secondary data is presented in some instances to support the chosen quote(s). The comment is entirely made up of the author's interpretation of the text and other readings may therefore be possible. Reflection on the authors pre-understanding and use of research questions is also embedded in some of the comments.

The last section of this chapter is a concluding analysis where the third step of analysis, the complexity theory perspective, is presented.

4.1 Category 1: Individual/staff characteristics

This category covers all factors that were closely linked to the individuals working with soil innovation in the City of Stockholm. These are to a large extent related to the creation of the system but a clear distinction between creation and implementation may not exist in all instances since they are both part of innovation.

4.1.1 Interest and commitment

A common denominator for all of the respondents is that they showed a lot of interest in the subject during the interviews. One example of this comes from the interview with the tree officer Björn Embrén. He was asked how they work with plants and the following is an excerpt from his answer:

> "I sometimes keep an eye on a particular tree for years. In that way I'll notice all changes to its growth rate. And if something happens I will try to figure out what it is so that I can learn from it" (Embrén).

This quote shows an interest in trees as a source of learning and in other words, to gain knowledge. Embrén explains in the magazine *Tidningen Utemiljö* that experimentation with biochar has been taking place since 2009-2010 in Stockholm. A further notable point was that the two major advantages were that it spurs tree growth and purifies storm water (Fredriksson, 2015). In 2017, the magazine *Ny teknik* interviewed the project leaders of the Stockholm biochar project. In the FAQ of the article, Embrén is attributed with being the one who generated the idea for the project (Nohrstedt, 2017).

The connection between work and personal interest is also seen in an article from the newspaper *Dagens Nyheter* in 2016, where Embrén is interviewed and says that his interest in biochar started when he experimented with substrate for some of his orchids at home. He tried the biochar in a few projects and saw amazing results on plant growth (Ritzén, 2016).

Such an interest was also evident in the interview with Alvem when discussing the full-scale trial in Norra Djurgårdsstaden:

> "I remember that it was a harsh winter since I noticed it at home as well. My garden is always my reference project and if something doesn't make it there it probably won't do it in other places either. I and Björn (Embrén) often compare plants in our gardens since they are in different climates" (Alvem).

This quote also shows how work and leisure may be somewhat the same for these respondents. In a larger context, this may be a trait of people who have become experts of their fields. In this case, being an expert is a criteria of the population chosen for this study. Therefore, the chosen population may be constituted of highly committed people which makes this result less surprising. It can still be an essential factor which becomes clearer in combination with the factor that now follows.

4.1.2 Experimental approach

A certain way of improving on current conditions through experimentation is mentioned by both of the tree officers. This is shown when Embrén was asked how they work with selecting new plant material:

> "We experiment wildly. And when we find plants that meet our criteria it is important to list them and use as a standard assortment" (Embrén).

This quote shows that an experimental approach to plant material is used. A similar notion is shown in their work with soil:

> "We have worked for many years with both pumice and biochar by mixing it into the soil. I first started out by experimenting in my own garden to find mixtures that gave a good infiltration capacity" (Embrén).

This is important as it highlights that experimentation with soil as well as plants has probably played a large part in coming up with different ways to improve the conditions for urban plants.

When Embrén was interview by the *Swedish Radio* in 2015, he explained that they try various ways of using soil in their plantings and in 2015 they had planted more than a thousand trees using biochar (Abrahamsson, 2015).

Embrén himself writes in *The Biochar Journal*, a magazine focused on finding innovative uses for biochar. He briefly explains the systems used in Stockholm and the use of biochar in particular, describing that he first tried biochar when looking for a substrate that would work for some of his orchids (Embrén, 2016).

Another example from this interview study was when Embrén answers the question of how they use biochar:

> "Everything seems to grow extraordinarily well in the biochar soils. For perennials, we use a mix of 25 percent biochar and for trees and shrubs we use 15 percent. This is mixed with crushed rock in the size 4-8 mm. At about 25 percent biochar, the infiltration is really fast while there is still enough water for the plants. The infiltration capacity helps keeping the soils dry during winter time which is positive. Both pumice and biochar enable the growth of a healthy biofilm and biochar is

> most effective for this as well. Mycorrhiza loves biochar and grows a whole lot in these soils, and helps feeding the plants. One uncertainty with biochar though, is its shifting pH, which needs to be controlled in each particular case" (Embrén).

This quote is important as it can be interpreted to hold a bit of surprise at the good results which may indicate that the method of achieving the mixture was experimental.

Embrén was also asked about the difference between choosing plants today compared to 20-30 years ago and one aspect that he mentioned was the following:

> "The biggest problem today is that plants will grow too big. Species that were commonly used before will grow too large for the often narrow streetscapes. A good thing is that more species with beautiful blossom have become useable as street trees. For example, we can now use Magnolia kobus as a street tree as it will reach 15 meters in height" (Embrén).

It should be clarified that the effect Embrén mentions is thanks to the use of biochar.

This is interesting in relation to the previous quote. To summarise, while the previous one could be interpreted to say that the best mixture has been found and that experimentation will now end, the last quote shows that the effects of a certain way of doing things are hard to foresee and that experimentation in itself may lead to a need for more experimentation. In this case, the experimentation with biochar has led to new possibilities for urban tree selection, i.e. experimentation.

4.1.3 Experience

Experience is closely related to the two previous factors, commitment and experimentation. The connection to experimentation is shown through a quote also by Berntsson:

> "When it comes to civil engineering there is a lot of knowledge. Roads can be built in a swamp if necessary. But when it comes to creating biologically sound soils there is almost no competence. The knowledge of how to build planting-beds is rare. It basically falls on us in the landscape profession, and we aren't particularly good at it either if I'm to be honest" (Berntsson).

This argument indicates that very few, if any, individuals possess such knowledge relevant to improve the conditions for urban plants. One testimony to the tree officers having relevant experience was interpreted from an answer given by Alvem when answering the question about the use of pumice versus biochar and if they have tried biochar in any gravel walking path:

> "We use pumice for walking surfaces. Using biochar in such a surface has never crossed my mind. I believe that it would become a dirty surface if you used biochar, whilst the pumice is 'clean' in a way. With biochar, the surface would become black, which might work in a planting but not in a surface for walking where people can get dirty" (Alvem).

It seems that it was more or less unconsciously obvious to Alvem that the biochar would be inappropriate to use for walking surfaces. One's own lack of knowledge as researcher helped me to realise that the mentioned "wild experimentation" is not reckless, but strategic and based on experience. This was something that I did not foresee due to my theoretical and in this sense, limited

relationship to biochar. In short, this leads to the next factor - that working with the problems at a practical level may be an important driver for innovation.

4.1.4 Practice-based

The fact that the Stockholm soil system has been developed by the City of Stockholm, which is a municipality, seems to be related to the fact that it is a practice-based organisation. To actually have a city to experiment with has been crucial. This is shown in a part from Alvem's answer to the question of the conclusions from the trial in Norra Djurgårdsstaden:

> "I and Björn (Embrén) always work that way. Each planting we make is a trial for the next one, which we then try to evaluate. But maybe not documented as thoroughly as the trial in Norra Djurgårdsstaden. It's more like him and I say three words to each other and then we know what to do differently the next time. And I think that it is nice to see that they used this kind of thinking for the trial in Norra Djurgårdsstaden as well. Though it's hard to build test environments I think. That's what's good about us doing this in a real city because such aspects are hard to emulate" (Alvem).

Each trial is, in a way, based on former experience and new experience is constantly gained.

It seems reasonable to argue that to be able to understand urban soil and plant issues fully, witnessing the problems and opportunities in reality is useful. This might explain why the Stockholm soil solution has been developed by the municipality, as they have the long-term responsibility for urban plants. However, only a few people within the organisation have this responsibility, and for these individuals to get new ideas accepted within the organisation has likely been key for any change to happen at all. When talking about the usefulness of their system, Embrén said the following:

> "Below ground, we have found solutions to the lack of space by using structural soil. We also put piping as far away from the plants growth substrate as possible, with large piping in the middle of the roadways and smaller piping as close to the buildings facades as possible" (Embrén).

But this is dependent on another aspect that Embrén mentions when he explains that a period of reorganisation was an important part in the process behind the Stockholm soil system:

> "The work with structural soils has taken many years. At first it was hard to get through with the idea of using porous soils under the streets. The first relief I had with this was when the city accepted the construction and it became a little easier to introduce new ways of working. It is now our standard working method for street trees" (Embrén).

To get the idea through with the organisation seems to have been important. Notably, the Stockholm structural soil seems to be a product derived from facing resistance when first trying to implement the use of structural soils. During a follow-up phone call, Embrén was asked to clarify the unique features of the Stockholm structural soil system:

> "The unique feature of our system is the use of a pure layer of stone on top of the skeletal soil that acts as a ventilation and infiltration layer. And to this we have added proper storm water inlets. I heard the mentioning of some kind of use of piping for ventilation in structural soils in Germany. But I think that those were only five centimeters in diameter and were not possible to rinse. And I've seen none of it for real. How are they to be maintained? Proper inlets are possible to

> rinse. Developing this system was pushed forward based on the way that streets were constructed" (Embrén).

This shows that the struggle itself has played a role in the way that the system is designed, which may indicate that working in practice may mean that the system is immediately met with the constraints of reality, and has to be adjusted according to those. In juxtaposition, another source seems to indicate that resistance isn't required for an innovation to be successful. After having won the Mayor´s challenge, Embrén was interviewed by the organisation *Bloomberg*, and explained that initiating the biochar project was easy due to his former successful projects (Bloomberg 2017). Thus, without any organisational resistance, the addition of biochar to Stockholm's planting-beds still became successful. Essentially, the final interpretation of this is that the actual knowledge gained by being based in practice is in itself an important factor for the innovation adoption.

4.1.5 Dealing with ambiguity

Related to the previous factor, dealing with ambiguity seems to be a major part of practice, which may force innovation in a direction that it would not take if only being based on theoretical assumptions. In the interview with Örjan Stål he explains some of these matters:

> "Many believe that concrete is harmful to plants because of its high pH, or that road salt will kill the plants. But if the plants needs are met, they can handle such stresses without problem. But if plants are weak, it may be harmful to them. With high infiltration capacity, road salt isn't a problem. And look at all VA-piping with root intrusion. It's made out of concrete. For example a high pH may be the tipping point for a tree in bad condition but it's not the fundamental cause for its bad growth rate, as long as all of its basic needs are met" (Stål).

This quote shows a couple of concerns related to planting-beds. Within the following quote, Stål elaborates on the kind of porous structural soil used in Norra Djurgårdsstaden:

> "An artificial groundwater surface is needed to create the moist gradient in the whole planting. The bottom needs to be relatively impermeable to bring up condensation that favours root growth. Small roots will eventually die and create their own humus. This adds to the water holding capacity and the nutrition levels in the long run. It will also be positive for creating biofilm. But in this system with a water surface at the bottom of the planting-bed, there needs to be an overflow discharge close to the inlet in the case of extreme runoff events. If rain from events such as 5-years events occur, it won't be so harmful, though. But would the planting be completely filled during extreme event such as a 40-year rain, there is a risk that the whole pore volume will be filled and that trees are harmed. But the time that water stays in the planting-bed is likely to be limited thanks to the high porosity in such a facility" (Stål).

These are highly technical considerations, but they have been included to show how multi-faceted the issues in using planting-beds can be. What Stål said was compared to AMA, which has basic descriptions for all planting-beds that states that planting-beds should be designed so that they are drained and no water stays at the bottom. Berntsson was then asked about the difference between these two objectives:

> "That description in AMA is basically aimed at avoiding the creation of a 'bathtub' in the planting-bed. That would drown the trees. And there are many examples of that happening. But in a situation where the trees might get too little water, you have to consider the context that they are in and how much condensation that

actually will be created. In some cases water may be coming from below while in others storm water runoff is the only source of irrigation" (Berntsson).

The fact that there are many interrelated issues when dealing with planting-beds is surely a source that drives new innovation. To deal with this ambiguity means that all issues may not be resolved at once, and a constant prioritisation between objectives may have to be made. It might also be the case that the system is refined over time to solve more of the potential issues. Nonetheless, this means that there may always exist a need for new solutions due to different demands. This is likely to drive innovation and spur experimentation.

4.1.6 Seeking knowledge and inspiration

Besides experimentation, another source of knowledge is to learn from others. Alvem mentions that the tree officer who worked before her and Embrén taught her a lot. When Alvem was asked about the differences of designing with plants today compared to 20-30 years ago she mentioned something related to this factor:

"I think that trends affect how the number of plants that are used in landscape design differs. I also think that we use larger tree-sizes now compared to before. But that is not a difference in Stockholm, I think. We have done so for a long time. I want to accredit PerOla Fritzon, the former tree officer, for being the one who started to purchase large tree sizes and for teaching me how to choose plants. But with the planting-beds, the trees have also gotten an opportunity to flourish and thrive" (Alvem).

This quote shows that some of the knowledge of the tree officers probably has been passed down from others, and it seems as if the improvement on how trees are planted has been going on for a long time in Stockholm. None of the respondents mention that a boss or any other authority as being the initiator of trying new ideas. Inspiration has been sought elsewhere as well. In a newspaper article, Embrén explains that he contacted a professor in environmental analysis to gain more knowledge on the functions of biochar. He has since learnt that the biochar also has the potential to bind pollutants which help with the cleaning of storm water (Ritzén 2016). Embrén and Alvem have also authored an article of their own in *AXE, the quarterly journal of the municipal tree officers association*, explaining the Stockholm system (Embrén and Alvem 2015). They describe their inspirations as coming from various sources, for example from other projects in the Netherlands and Germany but also magazines and books.

4.1.7 Quantity matters

As seen in the practice-based factor, experimentation is conducted through many different projects.

The trial in Norra Djurgårdsstaden was discussed during all of the interviews. The respondents were asked if it was possible to draw any conclusions based on the results from the perennial trial:

"There are eight types of perennials. I don't think you can draw any conclusions from that. It is too small of a number and the time-frame is too short. Chance might have been too big. The plants might have been faulty or anything else may have affected the results. Some of the ones that prefer wet environments have died. Can you draw any conclusions from that? I don't think so" (Berntsson).

"Overall, it is the plants that require a moist environment that have died out. These are the Carex and the Onoclea. The reason for this is that they come later in the

> ecological succession and are found in nature growing in the protection of other plants. The plants that have fared the best come from open and sunny environments. In habitat terms we find Hemerocallis and Lythrum somewhere in the middle of the plants that have been used. Hemerocallis is a robust plant but the results do not say anything about its status. Lythrum has a broad spectrum and seems to have fared well even though it's a plant found mainly in moist environments" (Bellan).
>
> "It is a small trial and we have seen better results in the other planting-beds" (Embrén).

The main point of showing these quotes is that it may be hard to draw conclusions from a single trial. While Bellan explains the results and that they correspond to the conclusion made by Sweco (see page 12), Embrén and Berntsson point out that this is one trial limited in size. This implies that quantity of trials may be positive. Quantity is therefore something that the city of Stockholm has got a lot of when it comes to planting trees.

4.1.8 Communication

While learning from others is effective, teaching is also a factor that seems to be part of the implementation of the Stockholm soil system. One great means of communication is probably the Technical Handbook. There are, however, other ways as well. Olsson explains that Embrén sometimes offers lectures:

> "Embrén held a lecture yesterday. You should have been there. He has them once in a while to explain the soil systems they use and to talk about any new ideas that they might have" (Olsson).

This shows that the tree officers recognise that there is a need to teach the knowledge of their system to the business as a whole. In addition, the fact that the respondents are participating in this study, and that they have authored articles (as seen in the previous factor) also shows an interest in communicating the system.

4.1.9 Supervision and control

One aspect related to communication is control, which seems to be important due to problems expressed by Alvem. A part of the answer to what the differences are when working with plants today compared to 20-30 years ago:

> "But then there are of course risks with the fast pace that things are being built at today, for example carelessness during the construction or trying to save money from using other materials will be harmful in the long run" (Alvem).

Following this, a solution is also mentioned by Embrén:

> "We control the whole chain from investment budgets to maintenance and that is a very positive aspect" (Embrén).

This is important as it plays an essential role to the implementation.

In the article from *AXE, Embrén and Alvem* state that supervision of any implementation of the system is highly important to success. They supervise the design and construction of the projects and also adapt to each site's context. Local materials, ground water level and renewability issues are considered. They also describe that they have witnessed a few problems that are common during implementation, such as how the air inlets are placed or that the wrong soil is used (Embrén and Alvem 2015).

4.2 Category 2: Innovation characteristics

These are aspects related to the innovation itself, that is, the soil system. While such aspects can be considered as purely technical, there are also aspects regarding the system that are based on certain ways of reasoning.

4.2.1 Keeping it local

Having a system adopted to a particular geographic region seems like a successful aspect of the Stockholm soil system.

Berntsson, who has been the editor of the chapter concerning soil and planting-beds in AMA, describes AMA as being inspired by the City of Stockholm's work. Stockholm were already using soil-fraction curves when they were introduced in AMA, according to Berntsson. I asked if this meant that Stockholm was leading in this type of urban soil innovation:

> "In some ways. But you can't say that it's like that for all parts. Because the Stockholm soils are made for their particular context. In the work with AMA, we were first inspired by Stockholm, and because of that that we were criticized by other parts of the country for being too focused on Stockholm. For example, in the southern part of the country there are lots of naturally created soils that they can use in urban plantings. And those didn't quite fit into our proposed soil fraction curves. While in Stockholm, we basically always use made soils. So Anna-Pettersson Skog who worked with this (Consultant from Sweco, authors note), took this seriously and tried to incorporate this. I remember that we heard from somewhere in the north that their silty soils didn't fit into the curves either. And in Gothenburg they had their own curve since a long time back" (Berntsson).

> "The aim of AMA is that it should be a well-tested method that works in the whole country at a decent price. It should be a little Average-Joe. When it came to structural soils there was something of a schism in academia regarding how these should be constructed. Two methods existed. The Stockholm method that first fills the planting with crushed stone and then flushes soil down through the pores. And the Gothenburg method, that premixes them and then puts them into the plantings. The Gothenburg method was criticized for being less stable and prone to subsidence of the streets. But in Gothenburg, they have clayey soils that are sensitive to the flushing of water and therefore the Stockholm method would risk that the terrace is eroded. Both systems were included in AMA as both of them were in use" (Berntsson).

This is an important quote and it is of pertinent relevance to understand the background of AMA if one is to understand the Stockholm Technical Handbook. The Stockholm Technical Handbook is related to AMA; a general described procedure as to how to do things. In short, it bares a similar resemblance to Stockholm as to what AMA is to Sweden. It is likely to be well adapted to Stockholm as a whole. Adding to this, another interpretation is having a system developed for your particular context is arguably more effective than working with a general system, if it fits poorly into a certain context. The use of the Stockholm Technical Handbook is likely to be an aid in this, as having a system for a particular context is probably a factor in succeeding with implementation, as is shown by the difficulties that Berntsson described in the work with AMA.

4.2.2 In line with today's construction business

One factor of the successful innovation of the Stockholm soil system also seems to be that it fits well into today's construction industry. An issue raised by Embrén when discussing the pros of the system:

”The pros with the structural soils are many. Not only technical ones. During many years there has been a decline in knowledge of gardening among maintenance personnel. As well as an increase in using external personnell for such services. And structural soils are much easier to manage compared to traditional soils due to their technical nature” (Embrén).

This is meaningful as it highlights that the innovation fits in with current practises. Regardless of the technical aspects of the innovation, a solution that cannot be applied would likely not be implemented.

4.3 Category 3: Organisational characteristics

These are a set of factors that are related to the overall work of the City of Stockholm, and how that affects their urban plants.

4.3.1 Maintenance budgets

One of the most frequently mentioned topics during the interviews was management of public green space. Embrén was asked about the most important factors when selecting plants:

“They need to be robust” (Embrén).

And when asked to elaborate, he said:

“That they have some kind of quality to them, such as staying green for a large part of the season, self-proliferate in a good manner or bloom for a long period of time” (Embrén).

This may indicate that the plants need to be easily managed. Berntsson was asked the same question and gave the following answer:

“Of course the character is important. But I have come to believe that management is very important. Because I think that the plants should look good after five to ten years as well. But it still doesn’t have to be completely mainstream” (Berntsson).

It can therefore be seen that Berntsson also puts emphasis on management.

The interpretation made here is that management has a defining importance in the long run, but the underlying reason for this seems to be related to financial matters.

When asking Olsson, at the City Development Office if he wanted to add something to our interview, he augmented the notion of the use of perennials and other plants in the urban environment:

“I think that we will move more towards using low shrubs. If we use perennials, we will choose ones that are robust and good and not so many special ones. Something ground covering and then the trees. And maybe use perennials in certain places and choose them carefully. Probably to reduce management costs. As for trees I believe it is possible to try more new things as it is likely that they will live longer” (Olsson).

Olsson argues that management costs are an important factor, and that perennials are the hardest and costliest to manage. To extend on this interpretation, it has to be put into a context of municipal finances and how different aspects are prioritised in the municipality as a whole. The impression given by the interviews is that the organisation’s maintenance budgets are a limiting financial factor. Innovation in systems that are easily managed are therefore likely to be successful.

4.3.2 Technically advanced city development

Another factor related to how Stockholm works is how they work with the development of new housing areas.

Berntsson has been involved in a project aimed at producing a manual for green roofs. It was a collaboration between public and private actors. The reason for collaborating was, according to her, to establish a common understanding for how green roofs can be constructed under Swedish weather conditions to avoid leakages. One of the reasons that the city was involved was due to the many large-scale development projects in which greenery is being placed on top of other constructions. Hagastaden in Stockholm as well as the Tensta project are two examples of extreme situations for greenery, Berntsson says. They are both built on top of concrete caps, which stretch over highways, and are designed with large parks placed on top. Berntsson explains this:

> "This could be one reason that drives innovation, because it's a new type of situation to solve. In the 60-ies a lot of squares were constructed on top of decks of joists, with stores under, but not much greenery was placed in such situations. In general the City hasn't put greenery on top of anything else before. Though a lot of developers have done so with green roofs. But for the City, that is now starting to change. In Hagastaden, we will build a large park on top of a bridge deck aimed at creating new land above a large road. And another example is in Tensta where the same kind of project will be done. And such development is probably getting more common everywhere. But how do you construct the soils for these situations? How do you provide enough water for the plants and make it stay in the soil for long enough? " (Berntsson).

This quote shows that designing systems to solve the current issues might not be sufficient since urban planning and new development projects constantly put new demands on the functions of urban plants and soil. Plants are desired in increasingly difficult situations and that is a driver for innovation. Albeit, it is probably a risk as well.

Bellan was asked about what the most important factors when selecting plants are. A part of his answer included the following:

> "Plants need to be selected on the basis that they are long-term sustainable in the environments that they are used. The green construction elements need to have the same dignity as other construction elements and come early into the planning process" (Bellan).

This was a rather general statement, but an important one nonetheless. It seems to indicate that urban greenery isn't that prioritized in today's urban planning. Bellan continues with an example:

> "But one should keep in mind that if calculating leaf-area-index, a large oak for example, could be worth just as much as ten small cherry trees" (Bellan).

In this study, it can't be evaluated if this quote is correct in terms of numbers, but it still proves an important point in the planning of green space. Urban plants do provide lots of benefits, but they will not be able to do so if they are not nurtured to grow and flourish. These are considerations of preservation, development and planning. The relevance of showing this is that planning affects urban plants to a large extent. Berntsson continues when discussing the deck developments:

> "We have to solve these situations. Regardless of whether we do so or not, they are getting built" (Berntsson).

Urban planning and development are therefore all-encompassing factors that affect innovation.

4.3.3 Renewability of materials

Renewability is something that seems to be an important part for the City of Stockholm. Alvem approached the subject of renewability when we discuss the use of biochar and pumice,

> "A huge part of this work is concerned with renewability. Soil is a finite resource that should be used mainly for arable land. In Stockholm, we import indescribable amounts of soil each year while at the same time carrying away lots of other, maybe usable materials" (Alvem).

Concomitantly, Embrén emphasises that the city of Stockholm will be producing most of the biochar themselves. In the magazine *Ny teknik*, where the project leaders for the biochar project who work at the municipal water company Stockholm Vatten, explains that they have acquired a facility for pyrolysis that will make it possible to reuse garden waste by turning it into biochar (Nohrstedt, 2017).

4.3.4 Climate adaptation

Sustainability is also related to a changing climate and it is also correlated to other municipal organisations and the Stockholm soil system has an active role in this. One objective of developing new types of planting-beds is to help with pollution-removal of storm water. Olsson was asked about this work in Norra Djurgårdsstaden:

> "Climate adaptation had not been on the agenda earlier. For example not in Hammarby Sjöstad *(An earlier large scale development in Stockholm, authors comment)*. The reasons for working with climate adaptation is to manage storm water and achieve a healthy vegetation. So we decided early on to regard storm water as an asset for the plants rather than a problem. We sort of turned it around and said - we want this many trees. How much water do we need? How wide do the planting-beds need to be?' The dimensions of the plantings in Norra Djurgårdsstaden have therefore been made to accommodate large runoff events as well as to provide enough water for the vegetation" (Olsson).

This seems to imply that the aim of climate adaption comes from the organisation and isn't unique to the development in Norra Djurgårdsstaden. Linked to this, a quote by Alvem shows that this is being experimented with outside of Norra Djurgårdsstaden as well:

> "At Swedenborgsgatan *(a street in Stockholm, authors comment)* we have tried two different types of using layers of biochar in the planting-beds. We first tried a layer of biochar beneath the aerated bearing layer, as all water enters there and we assumed that it would flush through the biochar, like a filter. But then we tried to place a layer of biochar at the bottom of the planting-bed instead, as water gathers there and pollutants can accumulate over time" (Alvem).

This is important because it shows that climate-adaptation, at least when considering storm water management, is an important consideration that seems to be high on the agenda in the organisation. However, the adaptation is of course needed because of the external influence of a changing climate. This is somewhat an external factor, it has a connection to the following category.

4.4 Category 4: Socio-political and external characteristics

This category covers the factors that are external to the organisations work with planting-beds. It includes factors related to climate and the environment as well as socio-political and planning related factors.

4.4.1 Water-scarcity and irrigation practises

Drought and water scarcity seem to be the main problems facing urban plants. When asking about their work with plants, one thing that Embrén emphasised was the following:

> "We have a constant lack of water and to make use of all available storm water is a must. Even when doing so it is hard to meet the plants need for water and we are constantly chasing after more" (Embrén).

With regard to this, there may be situations where irrigation systems are useful. It was Berntsson who mentioned that when asked about plant use in public space:

> "The norm in municipal practice is that you never use irrigation systems for plantings. Which differs from cemeteries for example. Except from in Enköping. Stefan Mattson *(former master gardener in the Swedish city Enköping, authors note)* said that irrigation systems were a prerequisite for their plantings. The environmental aspect of using irrigation-systems may need to be considers as well" (Berntsson).

With water scarcity and a municipal norm, interpreted as being a norm in the whole of Sweden, that irrigation systems aren't used, this is an external factor with high relevance for what type of soil systems that are needed. This should be a factor that drives innovation that utilises other sources of water, such as the utilisation of storm-water in the Stockholm soil system.

4.4.2 Ideals of what a city should look like and the use of street trees

All respondents seem clear on the idea that vegetation is an important and basic ingredient of the urban structure and that trees are the main green elements to work with. When discussing the planning of green areas in Norra Djurgårdsstaden, Olsson emphasises that:

> "We have aimed for a broad range of plants since we don't know how the climate will change. We have focused on trees since they are the elements that we know will stay for a long time" (Olsson).

This shows that trees are prioritised and that the choosing of trees is affected by climate considerations and the importance of trees is obviously central to the use of the Stockholm soil system. Embrén was asked if there was any particular factor that had been important in developing the soil system:

> "That lots of trees in urban environments are in poor condition" (Embrén).

This also becomes evident when considering the title that Embrén and Alvem have, namely tree officers. In a newspaper article from 2009, Embrén explained that the situation for Stockholm's street trees was highly negative (Gyllenberg 2009).
In another article, he explains that about a third of the inner city trees in Stockholm were dying in 2002. Structural soil has been used to change that and at least 2000 trees have recovered (Sjöström, 2016).

An increased use of street trees seems to be a current trend. This was seen when Alvem elaborated on her answer to the question of the conclusions from the trial in Norra Djurgårdsstaden:

> "One trend that I have spotted is that all of the streets have trees. In earlier development projects only the main streets had trees. Maybe it has to do with difficulties to find space for parks today" (Alvem).

Alvem was also asked about what typologies they use for street greenery and mentioned another trend of street-scape design:

> "In the inner city, pavement is the standard and in the outer city grass-strips are the most common. But we are seeing that pavement is getting increasingly common in the outer city as well. Very seldom do we have plantings below the trees. And I believe it's because of management costs and lack of space. We have a few streets with low shrubs beneath the trees but very rarely perennials" (Alvem).

The interpretation of this is that more trees in hard surfaces make for more opportunities to experiment, construct and try new planting-beds. A planning trend that probably has a part in driving innovation.

It could also be interpreted that perennials are an up-and-coming trend as they are so extensively used in Norra Djurgårdsstaden, but based on what Olsson and Alvem says, shrubs seem to be the main option in use, if any other greenery is used in addition to the trees at all.

4.4.3 Market availability

All respondents point at the fact that there is a greater range of plants available on the market today compared to 20-30 years ago. When Olsson was asked what the most important factors of choosing plants are, he said:

> "That they are robust and that they are available on the market" (Olsson).

The quote is representative of ideas expressed by several respondents. Alvem also mentions this:

> "We started using pumice some years before we introduced the biochar. Pumice is available on the market and is after all imported from the reasonably nearby country Iceland. It is a renewable material as it is formed during volcano eruptions" (Alvem).

To be able to access the materials needed is an obvious but important factor for the possibility to innovate by experimentation. It is also possible that new materials and plants may come into the market that change the way things are done. Bellan was asked about important factors to consider in plant-selection and in particular plant-selection for biofilters:

> "I get so many questions about plant selection for rain-beds today. We do have the technological knowledge of how to calculate water flow, pollution-removal, percolation and such technical matters, but when it comes to plants we are still at square one. There are a lot of educated guesses on which plants that are best suited to these environments, but no scientific evidence. I do know, however, that some research in this area is about to start. But it will take years before we have any results from that" (Bellan).

This quote shows that also in terms of plants, availability on the market may provide new ways of doing things. In general, this factor is an important external influence to the possibility to innovate. It may, however, also be true that innovation spurs market availability of new products as new demand is created.

4.4.4 The ecological trend

One external factor is mentioned in Berntsson's answer to what the difference is in designing with plants today compared to 20-30 years ago:

> "One difference today is also the ecological trend that has been going on for a while. It also applies to plants. But people think about it a bit differently. On the one hand we have those who claim that native vegetation must be the best to use since it's likely to be the most resistant to problems that might occur in our climate conditions. And on the other side we have those aiming at having as high a diversity as possible" (Berntsson).

And seen in Alvem's answer to the same question:

> "But we are more ecologically aware these days and don't design the horrible monocultures that were very common in Sweden some decades ago" (Alvem).

Based on these answers it can be interpreted that this is something outside the organisation that still has a big impact on the way that they work. Although, it can't be evaluated to what extent monocultures are avoided today. It is positive, nonetheless, that Norra Djurgårdsstaden, Stockholm seems to strive for high art diversity, which is evident when Olsson answers a question regarding plant diversity:

> "We mix a whole lot and have very long lists of species that we use. We also take trees from a variety of climate zones" (Olsson).

Ecological matters are thus seemingly important and on a practical level the respondents mostly relate these to matters of biological diversity.

4.5 Category 5: Client characteristics

Clients are here understood as all users of public space and the following factors are mainly related to the kind of effects that they may have for the innovation of soil systems.

4.5.1 Wear of public space and artificial materials

Urban public spaces are subject to wear, which increases the more they are used. Berntsson mentioned this when talking about the reason for testing new types of planting-beds:

> "We are to use surfaces to the maximum and therefore they should be multifunctional. This means more people per square meter and a higher wear. And the wear is driving us to try new planting beds" (Berntsson).

An example of the effects of this is also given:

> "During the last ten years, I have witnessed how even existing kindergartens and pre-schools are changing their turfs to artificial alternatives. And in many of the newly built neighbourhoods, a lot of young people move in who might be starting families which means that there are a lot of children. And the pre-schools get small surfaces, so they use public parks to a much higher extent than has been common before. So the question is what should parks look like? In the part of the city where I work we are therefore trying new soils in parks as well. We are testing a pumice-mixed soil in a park to get the air that the roots need. I don't know if it's any good yet but we are testing it. And in another park we are using biochar-based structural soil with the help of Björn Embrén. We use it for turfs, shrubs and all other vegetation. Compaction may become too intense for other soils to work.

> But not all of my colleagues think so. But that´s probably because I work in Liljeholmen, where the central city is expanding at a fast pace and the parks are quite small. But I think that eventually these issues will arise further out in the city as well" (Berntsson).

This is an example that reaches beyond urban hardscapes, and bares relevance as it is interpreted as a driving factor as the Stockholm soil system now is central to all urban plants; not just street trees.

It is obvious that the way spaces are used has a defining impact on the possibility for urban plants to establish and live. As seen in the quote above, new types of substrate may help to deal with this issue.

4.5.2 Acceptance of planting design aesthetics

Design ideas and water availability might sometimes be hard to combine. This is seen in the interview transcription when Olsson describes the use of irrigation in one planting-bed in Norra Djurgårdsstaden:

> "There is a large planting that actually isn't a storm water planting-bed in the way that we have worked in all other cases. Even though it may look like one. It actually has an irrigation-system. And that may have had an effect on the good growth that we've seen. But I don't think so because it was added rather late in the season. (*Suggesting that the use of biochar and pumice is the main reason for the good results, authors note*)" (Olsson).

The interpretation of this quote is that a certain visual character was intended and to make sure that it was achieved, irrigation was added. An alternative might have been used for more drought-tolerant species, but if that would have resulted in an undesirable expression it wasn't a valid option.

Ideas of design seems to be constantly changing, and Olsson elaborates on this when answering the question of what is different in designing with plants compared to 20-30 years ago:

> "In the way that I was schooled it was unthinkable to use alleys with different distances between the trees or to use different species in the same avenue. But today it's almost the complete opposite that holds true. Some plant compositions are almost chaotic. Even in the street-scape. It differs a lot compared to before and a lot of flowering species are being used. Plants are really used for design today and a garden-character is achieved in another way than before. It used to be predominantly monocultures. I think that all of this reflects that knowledge of plants is higher in the profession today" (Olsson).

Based on this, it might be reasonable to say that ideas of design and how plants should be placed in the hardscapes of cities is part of driving the way in which innovation is done. The trends in planting aesthetics are likely to differ over time. One interpretation could be that the ideas of planting aesthetics today puts a limit on experimentation with plants. If drought tolerant species would have been aesthetically preferred, water scarcity wouldn't be as prominent of a problem as it seems to be.

4.6 Complexity theory perspective

This is the final section of the results and analysis chapter and it presents the last part of analysis. Complexity theory is used to further understanding of the results. The main terms from the theory chapter have been used as headlines.

4.6.1 Initial states and feedback-loops

The importance of an initial state can be seen in the sense that Embrén talks about first having tried biochar when working with his orchids at home, as seen under *Communication and inspiration*. An event that in the end led to the biochar project.

As part of the working method, described under the factor *Experimental approach*, the tree officers seem to constantly evaluate and learn from creating new planting-beds. This evaluation is a feedback loop that is achieved through the possibility to experiment, as seen under the factor *Practice-based*. In essence, while experimentation is an important factor, the main part of this is the possibility to continue the experimentation so that they get feedback and develop their knowledge.

The initial resistance that faced the use of structural soil in Stockholm, also seen under the factor *Practice-based*, could be interpreted as a negative feedback-loop. This is where innovation lead to the creation of the Stockholm soil system. Although, Bloomberg (2017), it was easy to initiate the biochar project thanks to former achievements. A positive feedback-loop can therefore be noticed, as an acceleration on a path that constantly deviates from the initial state appears to exist. In this situation, the initial state could be interpreted as being the point in time when the use of structural soil was met with resistance within the organisation.

4.6.2 Self-organisation

Complexity theory includes the concept self-organisation as a means for an organisation to reach its goals. One clear goal by using the Stockholm soil system is to achieve healthy and thriving urban trees. And as seen in the results, this is an approach that gradually has been incorporated in the city's work with street trees, and self-organisation in accordance to this working method is therefore likely to have taken place, as no indications of a political decision to initiate this working method seems to have been given.

The organisation has likely organised itself according to this during a relatively long period of time, which now makes the use of the urban soil system an integrated part for how innovation moves forward.

4.6.3 Timing

In this context, the factors presented under the category *Planning and Architecture* are relevant to mention.

The way that Forslund (2013) presents *timing* as being an important part of doing new things in an organisation seems to apply for another external influence as well, namely climate factors. As Olsson says, climate adaption is now a prioritised matter when working with plantings in Norra Djurgårdsstaden. Alvem describes that renewability is an important part of their experimentation with new substrates. Clearly, the win in the Mayors challenge supports this claim. Thus, the implementation of the biochar is likely to have been well-timed.

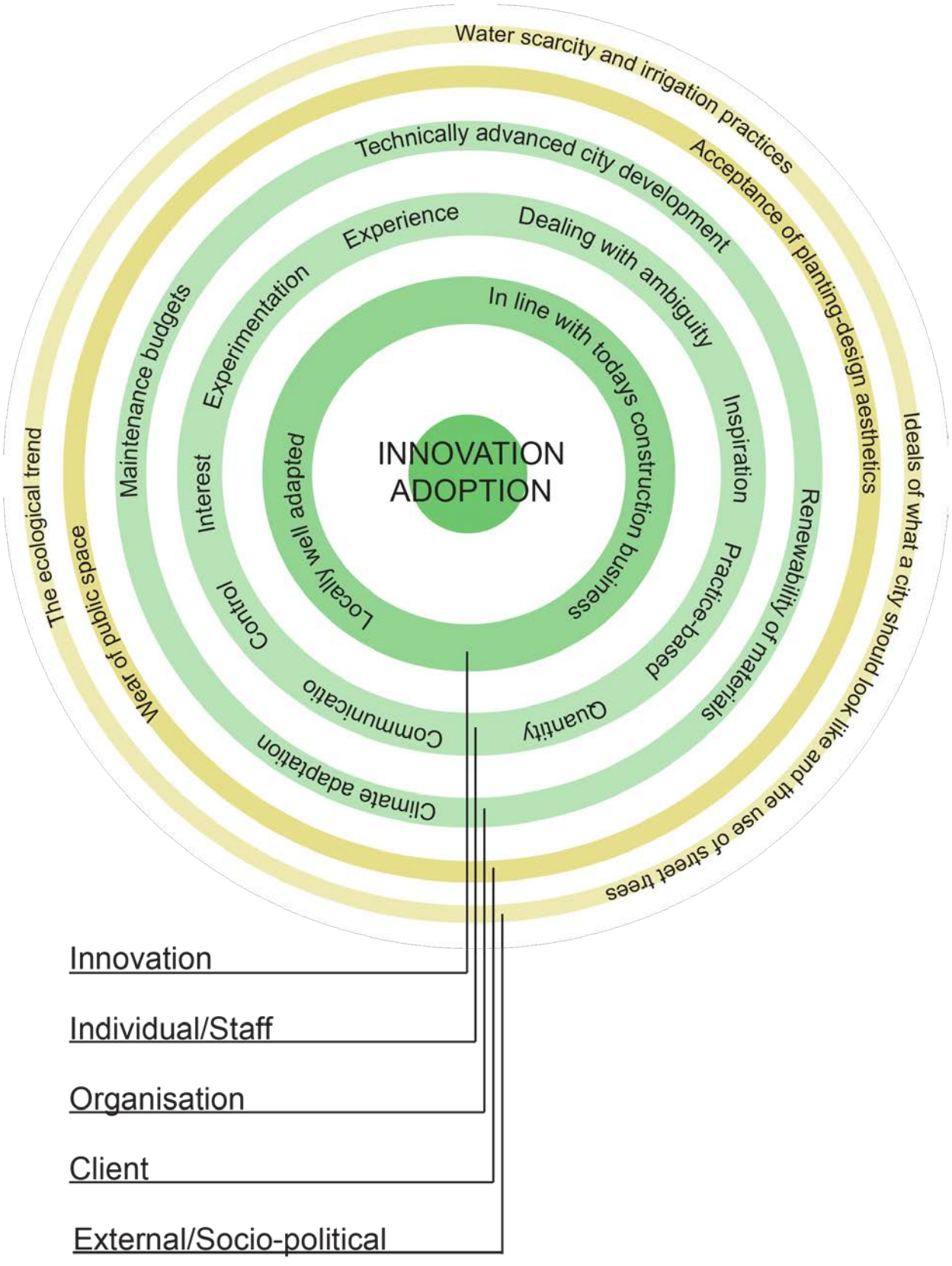


Figure 9 - Conceptual illustration of the factors and their interrelations. The illustration shows the innovation characteristics at the centre, which is affected by the individual factors which in turn are affected by the organisation, the users of urban space and then the external factors which have an effect on all other factors. The aim of this illustration is not to say that the innovation characteristics are the most important but rather to show that all of these factors are important to the innovation adoption but work at different scales. Illustration: Jonathan Nyman

5 Discussion

The aim of this study was to identify and explain the key factors for the innovation of the Stockholm soil system. Additionally, the aim was to identify and explain the key factors for the innovation of the Stockholm soil system and to facilitate an understanding for how it has been adopted by the City of Stockholm. The research question posed was as follows: Which is the most distinguishing factor for the innovation of the Stockholm soil system?

The introduction shows a number of examples of this innovation. Though these do not provide information on the adoption within the organisation of these innovations. The essence of this thesis is therefore to understand what factors that has made this adoption possible and successful.

By interviewing experts with deep insight into relevant issues, several factors associated with this innovation were identified. A literature review was also conducted that found journalistic articles relevant in answering the research question.

The discussions chapter clarifies what the main findings are, what the value of these may be, shows potential weaknesses of the study and compiles a number of ideas for further research.

5.1 Summary of findings

This section shows the main findings and final conclusion of the study. Further explanations of the results will then be given in the later sections.

5.1.1 Many different factors interrelate

There are several factors that are important to the creation and implementation of the Stockholm soil system. This is illustrated in the figure at page 37.

In the analysis, it was identified that several of these factors are related to *Individual and staff characteristics,* and the amount of such factors may indicate that these seem to lie at the heart of the innovation. Together with the factors categorised as *Innovation characteristics*, these make up a set of factors that seem to promote innovation. They are factors related to taking action and initiative, utilising initial stages and generating feedback loops, as seen under *Complexity theory perspective* in the analysis.

It can also be seen in the results and analysis chapter that the factors listed under *Organisational characteristics, Socio-political and external characteristics* have a tendency to put limits or constraints on technical solutions. Therefore, these could be considered as the most influential in the way in which they set the scene for how innovation can be conducted at all. For example, the introduction of biochar might have been more difficult if not being timed with the current urge to improve on climate adaptation practices, as seen under *Complexity theory perspective* in the analysis.

It is therefore a basic finding that both factors that promote the innovation as well as constraining factors have played essential parts in how the Stockholm soil system has been developed.

5.1.2 An openness to change

In the analysis it can be seen that feedback-loops are an important part of this work in two different ways. First, it is the possibility to constantly get feedback, which is accelerated by a multitude of possibilities to experiment with new methods. Secondly, it is the increased support for the work that is done, as seen under *the complexity theory perspective.* This is related to the effects of change. As complexity theory states: organisations change unpredictably during the course of time. For examples sake, suppose that, at a current state in time, managers decide that the Stockholm soil system has reached an optimum phase of development and is the best potential system it can become, then negative-feedback loops are likely to have started. That is the will to stay at a certain stage of equilibrium. Although, the results in this study show that the main reason for the success of the Stockholm soil system has been an openness to the changing nature of innovation and to constantly evaluate and evolve. One example of this openness has been the switch from using pumice to using biochar in the planting-beds in Norra Djurgårdsstaden (See page 11). But the most important example is likely to be the ongoing experimentation performed by the tree officers. To try something new and to possibly fail, evaluate and then to try something different is likely to be key in the innovation process.

The implications of doing something in a certain way are hard to foresee and as an organisation it is important to have an openness towards this. This finding is in line with Forslund's description of complexity theory, which states that the best way to deal with change for managers is to be aware of self-organisation, as it always exists in organisations (Forslund 2013, p. 400).

5.1.3 The experimental approach

In the example with Kungsbroplan, it is described how a certain fraction of crushed stone was used to great effect. Similarly, technical configurations of planting-beds have led to successful plant growth in the cases of Norra Djurgårdsstaden (see page 11) and Herrhagsvägen (See page 13). A common feature of all these cases is that something new is tested, which also seems to be true for the general working method of experimentation described by the tree officers. The experimental approach is therefore likely to be a key part in the innovation of the Stockholm soil system.

5.1.4 Conclusion

Although many factors interrelate, the ones that are the seemingly most active ingredients in the innovation of the Stockholm soil system are the ones related to *Staff/individual characteristics.* The main ingredients in this seem to be a certain approach to improving on current conditions through an openness towards change. Thus, it is not a certain technical configuration of a soil system, or the finding of a best practice that is the key factors for the innovation, but rather a type of working method that includes constant trial and evaluation. Adding to this, the fact that this working method seems to be an integrated part of how the organisation creates and implements, that is innovates, in new soil systems. What this study shows is therefore that experimentation, and evaluation is done at several occasions and is constantly going on. The amount of feedback is therefore very high compared to single trials.

A thought-experiment best depicts this importance. If considered for example, that the Stockholm soil system would be used by another actor or municipality. It

would then be likely to function as long as the local context was similar to that of Stockholm. But what if it didn't work? How would problems be solved? The main findings of this study suggest that they may not be solved if that organisation does not have the same staff and organisational resources to evaluate and experiment on further solutions as they currently do in the City of Stockholm. So the development of a working method, that has received resources and acceptance within the organisation, is likely more important than the actual soil system in itself.

Ultimately, the conclusion is that it is the working method that is the most important key factor to the innovation of the Stockholm soil system. This includes adopting the risks of trial and error and having an openness to change, so that innovation doesn't cease.

5.2 Explanation of the results

The results of this thesis includes both expected and unexpected factors. This chapter of the discussion will explain what the expected findings were and in what way the findings differs from these.

5.2.1 Expected results

The questions that were asked to the respondents were formulated based on the knowledge of the author at that specific time. The questions were also based on Nick Robinsson´s theory of planting design and Henrik Sjöman and Johan Slagstedt's (2015) ideas of plant selection. Respectively, factors related to those theories were expected to emerge in the data. The basic expectations of the author were that this study in large would be related to technological achievements and working methods (to a large extent the results were). For example, some factors were mentioned by several of the respondents and to a much higher degree than other factors. Out of these, the robustness of plants and management were the most frequently mentioned. This is in line with Sjöman and Slagstedt's theory as basic criteria to consider when choosing plants (Sjöman and Slagstedt 2015). They also allude to the fact that the suitability of place for growth is important, which can be seen under the factor *keeping it local* in the Results and Analysis chapter. In this case, one of the respondents explains the evolvement of AMA. Ecological factors were also mentioned to a high degree in the results which was expected based on the formulation of the interview questions. Ecological factors are mentioned by Robinsson as well as Sjöman and Slagstedt (Robinsson 2001; Sjöman and Slagstedt 2015).

Nonetheless, many factors didn't seem to be first and foremost technical when interpreted in the hermeneutic tradition. This was due to the fact that, behind all of the technical, aesthetical and ecological considerations, there seemed to be other factors with a part to play.

5.2.2 Unexpected results

During the analysis, a considerable amount of factors emerged that didn't exist in the literature that was used to formulate the interview questions. It was to be expected that factors would revolve strictly around factors mentioned in literature used to formulate the questions, such as technical, ecological and aesthetical considerations. Factors that might be seen as fundamental parts of all considerations in landscape architecture. When factors related to the organisation and individual

characteristics started to emerge, the study changed character in a way that was unexpected. An example of this is the way that the creation the Stockholm soil system seemed to be more dependent on personal curiosity, as seen under the factor *Interest and commitment,* rather than deciding exactly how a procedure of working with plants and soil should be performed. The main findings of this study were therefore - to a higher degree - related to social factors than what had been expected at first. Henceforth, while having assumed that all factors would relate mainly to technical factors, some new considerations became important to make. At this point, it was also evident that the empirical data needed to be related to a theoretical framework to be further analysed; and thus the two sets of theory were introduced. However, having performed the second step of analysis, the categorisation according to Innovation Adoption Theory, some deliberations were required. The primary issue was to define what *key* factors really means. On the one hand it could be interpreted that the factors most closely related to the work of the tree officers should be deemed as key, as they are working with the innovation hands-on. On the other hand, external factors such as climate change might be seen as key as they are affecting all things in the physical world. An example could be the wish to have urban plants in a city is fundamental to innovation in urban soil. It can also be suggested that factors related to soil and plants are more or less the same everywhere, at least under the same climatic conditions, while the factors behind the Stockholm soil system are likely to be unique to this particular case. Simultaneously, hermeneutics emphasises that both the whole and its parts are needed for it to be understood (Alvesson and Sköldberg 2008, pp. 193-211), so it seemed limiting to the study to reduce any of the factors based on their character. This links to the Innovation Adoption Theory (Wisdom et al 2014) that includes innovation characteristics in a broad sense and does not reduce it to any single type of characteristic. So in accordance with abductive reasoning (Thomas 2001, p. 576) and complexity theory (Forslund 2013) it would be very difficult to provide an exact description of social reality. Even whilst including all factors, there are likely to be some that are missing in this study. One such factor might be how financial factors relate to the possibility to experiment, and is likely a factor that have changed slowly together with the incorporation of experimentation as a standard working method with urban planting-beds.

A question of prioritisation between the different categories also existed. Could it be purported that the external factors are more important than the individual characteristics? Or vice versa? The findings may not have a completely unequivocal answer to this, but to extend on the findings, a short deliberation on the question can be made. If it is to be assumed that one of the categories was not real and ever-changing, but rather completely static, would this result in a lack of innovation? The most obvious is that even if all other categories were static, the individual/staff category would likely mean that innovation would have happened anyway. As the interview data shows, trees were already in a bad condition and somebody who witnessed this and wanted to change it was needed. Although, as that would be a theoretical situation, in real-life, all of the factors shown in the results are likely to play a part in the innovation.

5.3 Limits to the value of these findings

Some aspects that may put a limit to the usability of the findings in this study are presented below. They may serve as guidance to further related research.

5.3.1 Considerations on Innovation Adoption Theory

The main decision during analysis was to not include the differentiation of pre-adoption and adoption presented by Wisdom et al (2014). The reason for this was that the basic understanding of the word 'Innovation' in this study both included creation as well as implementation, and that these terms seemed more or less the same as pre-adoption and adoption respectively. In addition, the passing of time is constant and the Stockholm soil system seems to be under constant development. It would have needed a definition of a certain point in time that was defined as adoption and that everything before that point would have been pre-adoption.

Another consideration was regarding the category *Clients* that Wisdom et al (2014) use. The term was used in this thesis and interpreted as meaning the users of urban space. Though the users of urban space aren't mentioned to any great extent, it is of course the people who experience urban space. As seen in the introductory chapter, people also cause the issues that urban plants face. So while they are a sort of end-users of urban greenery, they are also the cause for many of the issues that urban plants face to begin with. This is, however, a generalisation, and the article by Wisdom et al also states that more research is needed in this area (Wisdom et al 2014, p. 491). It might mean that the conclusion of this thesis is somewhat biased towards other categories, whilst failing to value the importance of client factors.

5.3.2 A delimitation of reality

In identifying *Socio-political* aspects, it can be interpreted that an elaboration on such factors could continue indefinitely. It is, in a sense, an enlarging of the context. Factors such as *Ideals of what a city should look like* can supposedly be assumed to be effects of economic growth and related to densification which in turn is dependent on availability of humans and so on. The thesis was fundamentally explorative, but still had to put a limit on how far the context could be expanded. It will therefore surely be a falsification of reality.

5.3.3 Theoretical perspective and analysis

In general, problems tend to arise when analysing *Organisation Characteristics.* According to complexity theory, all organisations are self-organising. Although, due to the limited amount of data sources, the whole organisation of the City of Stockholm is not included in this study. The study only includes a minor part of the work conducted by the Traffic office and City Development Office, which in turn are small parts of the whole City of Stockholm. It is an apparent weakness in that it uses organisation theory to analyse something that is just a fraction of an organisation. Alternatively, the definition of what an organisation is cannot be clearly defined and it could be interpreted as if the tree officers make up an informal organisation of their own. For example, they have a set of complex rules and strive to reach certain goals (Bakka 2006, pp. 11-16).

5.3.4 The use of these results

Due to the limited number of respondents, this study can't claim to have provided a holistic description of the factors behind the innovation of the Stockholm soil

system. But given that most of the respondents were particularly knowledgeable of the system, *many* of the important factors are likely to have been identified. As a product of this, the study might serve as a first step in trying to document a phenomenon that in many ways may deserve more attention from researchers due to the great impact that the Stockholm soil system has had on the conditions for urban plants.

5.3.5 Presentation of the results

In showing the results both linguistically and visually, it has made a simplification of reality that is likely to be a more or less false model. Since this study recognises that the world is complex and changing, the full range of factors that influence innovation is unlikely to be covered in such an un-real and static format.

5.4 Summary

This thesis provides an understanding of the Stockholm soil system from an innovation adoption and complexity theory point of view. It is a system that is used in the Swedish capital Stockholm and has also been mentioned in literature coming from other countries (e.g. Goodwin 2017) and to understand where such a system is coming from may be helpful in many ways. It might be used to compare other ways of innovation of urban soil systems, and to analyse why they may differ. More importantly, it has found that individual and organisational factors are highly important for the innovation that has taken place. The findings are also important as they show that innovation in landscape architecture and related fields is possible when it is based on practice. Moreover, in some ways it may even be advantageous to have such research based on practical situations. As landscape architecture is a field that works with physical space, Flyvbjergs definition of what a case study is will be repeated:

> "Context-dependent knowledge and experience are at the very heart of expert activity. Such knowledge and expertise also lie at the centre of the case study as a research and teaching method or to put it more generally still, as a method of learning" *(Flyvbjerg 2006, p. 222).*

Public urban space is, as seen in the results, a type of environment that is difficult to emulate and to test new solutions, trials can be done in real settings. The implications of this is that managers may have to be accepting of the quite long and extensive process of evaluating a new system for how urban soil and plants are constructed. These systems require long periods of time to be evaluated, not least considering that plants are living material (Clouston 1990, pp. 8, 26). This is for example seen in the case on Kungsbroplan in the background chapter (See page 11) with useful evaluation being possible still, ten years after construction. With this in mind, it may somehow sum up the importance of continued evaluation, as ten years still as a short period of time in this context.

Very little is known about the general long-term effects of structural soils (Sjöman and Slagstedt 2015, pp. 332-334; Slagstedt, Gustafsson and Stål 2015, pp. 601-604; Goodwin 2017, p. 152) and further evaluation as well as research is valuable to perform from several different standpoints. It is also the case that innovation as a process seems to take place quickly in Stockholm, which may make it difficult to fully evaluate a system before it is reconfigured again.

One must also consider the fact that many cities already have large thriving trees that can be hundreds of years old. As can be seen in Andersson and Stål (2015), these are likely to have been planted before most surfaces in cities were paved. Such changes to ground covers in urban areas may happen again in unexpected ways, with further unforeseen effects on the lives of urban plants.

It is anticipated that this thesis will provide an understanding for students in landscape architecture of how Stockholm have achieved the many thriving urban trees that they now have. Being an exploratory study, it attempts to focus on the subject from a new angle. Extended research in this topic, or similar research on other topics, are therefore possible continuations of this study.

The usefulness of this study for landscape architects who work as practitioners can be that it serves as an example for how a certain attitude to innovation may lead to successful results. All organisations may be able to benefit from the type of method that is exemplifies by the way that the Stockholm soil system has been developed.

5.5 Further research

While conducting the study, some ideas for further research have aroused which will be presented in this last section of the thesis.

5.5.1 Research on this topic

This study provides a solid basis from which the primary topic can be researched further in the future. Whilst further research could be conducted to attempt to identify more factors that are relevant for the adoption of the Stockholm soil system, the main idea for research that came during the study was to analyse what might happen in the future. As today's innovation seems to revolve around a low number on individuals, it may be beneficial to see what future scenarios this personal dependence may lead to. The main area of further research is probably how the findings of this study may be applied. How it is possible to, not just develop a new soil and plant system, but rather to develop an organisation that supports creation and implementation of new methods. An organisation that actively tries new ideas of how to use plants in urban situations in a strategical and sustainable manner. There is likely to be an endless amount of factors related to such an endeavour, as all organisations are complex.

A mapping of all the systems used in Stockholm today may also be a valuable resource to create. This would ensure that plenty of background information exists which, in turn, can be further evaluated for many years to come so that the long-term effects of these systems are better understood.

5.5.2 Research on urban soil systems

This study delimited all other types of urban soil systems and the same kind of research may be conducted for suspended pavement systems or other versions of skeletal soil systems, which would enable a comparison to this study's findings. That could be the beginning of a broader understanding for what makes a system for urban soil successfully developed. Though as all geographical and jurisdictional contexts may differ, it may be so that the most rewarding research lies in identifying the differences in the context itself. Are there for example market forces or organisational factors that differ in other places compared to the City of

Stockholm? And how does that affect innovation adoption or systems such as structural soils or green roofs etcetera?

Another aspect that can be researched a lot more is how attitudes towards trees and other plants affect the implementation of these systems. Are there for example cities where issues such as compaction aren't at all problematic due to public behaviour? And also, will structural soil systems themselves have an effect on shaping the public's attitude towards vegetated areas and surfaces? Will people who use lawns planted on biochar soil come to believe that all lawns function in that way and can handle the same type of use?

5.5.3 Research on innovation in landscape practices

There may be other innovations or working methods that can be studied in the same way as this thesis studies the Stockholm soil system. Some cases in Sweden may be the creation of the E-planta system or the famous use of perennials in public plantations in the city of Enköping.

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Appendix A

The questions asked during the interview study are presented here. All questions were asked in Swedish and has then been translated into English along with the results.

6.1.1 Questions posed to all respondents

- Can you shortly describe your background?
- What are the most important factors to consider when choosing plants for urban environments, focusing on street-scape environments?
- How is the possibility to design with plants in urban environments different today is compared to 20-30 years ago?

These questions were used to see if recent innovations may have changed the way that urban plants and soils are worked with. They were designed to be open and not to impose any pre-conceived ideas on the respondents.
The timeframe in the second question was chosen on the basis that I wanted the respondents to reflect back to a period when the use of structural soils definitely wasn't in use. At the same time, I couldn't pick a time too far back as judging by age they would have had harder to relate to this period. The main reason for this plant is to see in the mentioning of new urban soils were part this, and how their answers would relate to theory.

-What is your insight into the trial in Norra Djurgårdsstaden?

- Is it possible to draw any conclusions based on the results from the trial plantings in Norra Djurgårdsstaden and the survival rate of perennials there? (The results from Sweco's investigation was shown to the respondent).

I asked all of the respondents about the full-scale trial in Norra Djurgårdsstaden. The reason for this was that initially the trials in Norra Djurgårdsstaden seemed interesting as they may or may not provide an understanding for how development of new soil systems were done in Stockholm. So by comparing to that case a way leading into the subject seemed to be possible.

In addition to these questions, specific question was asked to each respondent based on their particular background. These are presented below.

6.1.2 Additional questions posed to Björn Embrén

- What factors have the greatest effect on plants ability to survive in urban environments?
    - Are these different for trees, shrubs and perennials?
- What type of plants (meaning trees, shrubs and perennials etc.) are used in the street-scape?
- What is the role of art diversity in urban plant use?
- What is your experience of biochar?
    - Will biochar or pumice, be the most common substrate in urban plating-beds?

Question by phone call (2017-05-02)

- Would you like to explain the Stockholm structural soil system and how it came to be?
- **Question by e-mail (2017-06-07)**
- Are there any important factors in the innovation you have performed that you would like to emphasize?

6.1.3 Additional questions posed to Örjan Stål

- What are your experiences of biochar?
- Are there any alternatives?

6.1.4 Additional questions posed to Patrick Bellan

- Do you have any experience of biofilters?
    - Is the way that plants are chosen for such facilities different compared to other urban plantings?

6.1.5 Additional questions posed to Gösta Olsson

- On what basis have plants been chosen in Norra Djurgårdsstaden?
    - Has art diversity played any part in this?
    - Have the plants been included in the pollution-removal idea?
- What type of substrates are you using?
    - What is your experience of biochar?
- How is maintenance organized?
- What is the most important factors if you would redo a similar trial as the one in Norra Djurgårdsstaden again?

6.1.6 Additional questions posed to Britt-Marie Alvem

- Does the biochar have a fraction?
- How does biochar compare to pumice?
    - Have you tried biochar in walking surfaces as well?
- How do you choose trees in Stockholm?
    - Has that been based on aesthetics as well as on ecology?
    - How was tree selection done in Norra Djurgårdsstaden?
- What types of typologies, or sets of plants, do you normally use in urban streetscape environments?

6.1.7 Additional questions posed to Britt Berntsson

- Would you like to describe the work of the City Development Office?
- Can you describe how your work with AMA has been?
- In the DCL-code in AMA there is a passage that reads: “It must be ensured that water does not remain standing on the terrace *(author’s translation from Swedish*)”. How would you say that relates to porous structural soils where the aim might be to detain storm water for the production of condensation?
- What is your view on the use of pumice, biochar and other alternative substrates?
    - Do you think that this trend is to continue?