CHALMERS

Development of an accessible and flexible planter module for shared greenhouses

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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ELINA LINDQVIST

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenborg, Sweden 2014

Department of Product- and Production Development
Division of Design & Human Factors

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ABSTRACT

This master thesis describes the process and outcome of a product development project that concerns a growing container for cultivation in community-shared greenhouses. The project was carried out at Chalmers University of Technology by Elina Lindqvist and Anna Lindahl, master students at the programme Industrial Design Engineering.

Growing vegetables in cities is a global trend, and shared greenhouses are increasingly common in urban areas. The purpose of shared greenhouses is both to facilitate cultivation, and to serve as social meeting places that create a feeling of community and identity among neighbours. Research shows that there are many positive effects from the existence of strong local communities; it reduces crime, increases the feeling of safety, builds a sense of belonging and identity, and a strong support network can actually improve people's health.Moreover, with a basis in an unsustainable global food situation and system, with increasing demands for food production and at least 75 % of our food's biodiversity being lost due to industrialised agriculture, the visionary aim of the development of the product was to encourage and contribute to environmental sustainability by facilitating and encouraging urban farming and promote raised awareness and sustainable attitudes towards food.

The goal was therefore to develop a product that facilitates and encourages the activity of growing vegetables in a shared greenhouse, intended for housing associations in the city. Characteristics of the intended user group and use context were investigated through a variety of data collection methods, including interviews, observations and questionnaires. The collected information was organised and analysed, and subsequently translated into requirements and guidelines for concept development.

The end result was a flexible and accessible planter module that fits into the greenhouse environment and enables everyone to take part in the activity of cultivation. The planter module allows the user to work in an ergonomic height, is soil efficient and easy to empty. It provides seating possibilities to encourage socialising in the greenhouse, and is movable to suit different needs and greenhouse layouts.

Key words: Cultivation, Greenhouse, Product development, Growing vegetables, Sustainability

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Elina Lindqvist and Anna Lindahl

CONTENTS

Figure 1. Plant from SLU Alnarp's greenhouse.

1 INTRODUCTION

The following chapter describes the project brief and framework, other involved actors, intended user group and environment, aim and goal, delimitations, and a process overview.

1.1 Aim and goal

The aim of the project was to develop a product which enables, facilitates and encourages cultivation of vegetables in community-shared greenhouses in urban environments in Sweden. Additionally, the product should facilitate social interaction in the greenhouse. On a meta level, the visionary objective was that the product, by facilitating and encouraging the activity of growing vegetables in the greenhouse, should contribute to social and environmental sustainability. The goal was to develop a product concept and an academic report that describes the project process and outcome.

1.2 Project framework

The predetermined conditions for the development of the product were the following:

- The product should be designed for greenhouses shared by apartment residents in urban areas
- The product is primarily intended to be purchased by housing associations
- The product will be either collectively owned and shared by the residents
- The product is intended for hobby/household cultivation
- The product should be accessible to different people in the community
- The product should be designed primarily for the Swedish market

1.3 Involved actors

The project was initiated together with Sara Renström, a PhD student within Design for Sustainable Behaviour at the Division of Design and Human Factors.

The idea of a community-shared greenhouse was a concept created during her research project (together with Göteborg Energi) on how product or service design can promote sustainable usage of energy. The project team has consisted of two students, Elina Lindqvist and Anna Lindahl, at the master programme Industrial Design Engineering, Chalmers University of Technology.

Parallel to this thesis project, another thesis concerning the design of the greenhouse has been conducted by two students, Charlotte Farrouch and Lisa Kihlström, from the architecture department. Their project focused on how to create a community-shared greenhouse that is sustainable and energy efficient and a meeting place for the residents in the housing community and parts of the research were done collaboratively

1.4 Intended user group

The product will be used and shared by different people in the community. This means that the user group includes people of different ages, genders and backgrounds living in the housing area, having different physical and cognitive capabilities as well as varying experience of growing vegetables. However, younger children under the age of 15 are assumed to use the product together with an adult. The critical users can be defined as older adults and people with disabilities, who have reduced physical and cognitive abilities.

1.5 Intended use environment

The intended use environment is a shared greenhouse in urban areas. In order to provide an example of how the use environment may look, as well as for measurement estimations, a shared greenhouse designed by two architecture students at the master programme Design for Sustainable Development at Chalmers University of Technology has been used as a reference. Their concept is modular, and thus adaptable in size, but an example was made where 10 households share a greenhouse of 54 square meters (Farrouch and Kihlström, 2014). Thus, the shared greenhouse will be relatively large.

1.6 Scope and delimitations

In order to adjust the scope according to the given time frame of 20 weeks, a number of delimitations were made. It was therefore decided that the following aspects would not be covered:

- Detailed construction material
- Exact cost calculations for production

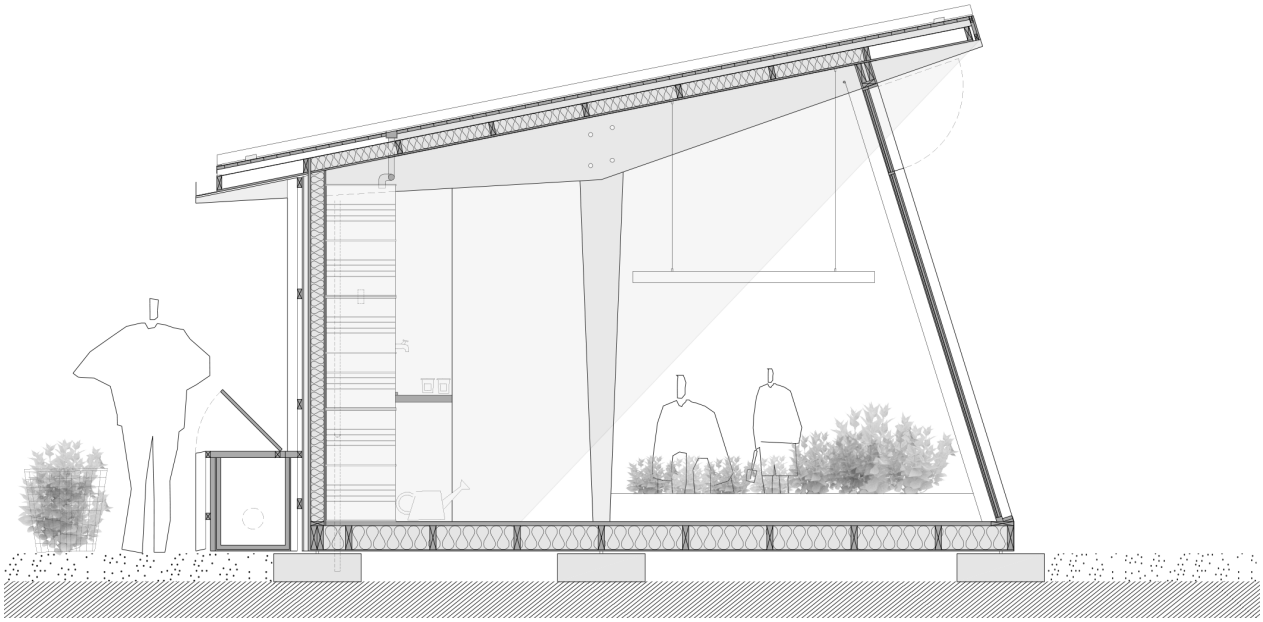


Figure 2. Greenhouse concept created by the parallel thesis group (Farrouch and Kihlström, 2014).

1.7 Process overview

The project process and its different phases are illustrated in fig. 3. Although it is presented as a linear sequence, the process has to a great extent been iterative and non-linear, and many phases have been overlapping or performed parallel to each other.

1.8 Report disposition

The thesis generally follows the project process as described in section 1.7. Each chapter begins with a brief introduction to the phase that it concerns. Moreover, each chapter is structured by process and results. The theory and methods used during the project process have been described in a separate chapter.

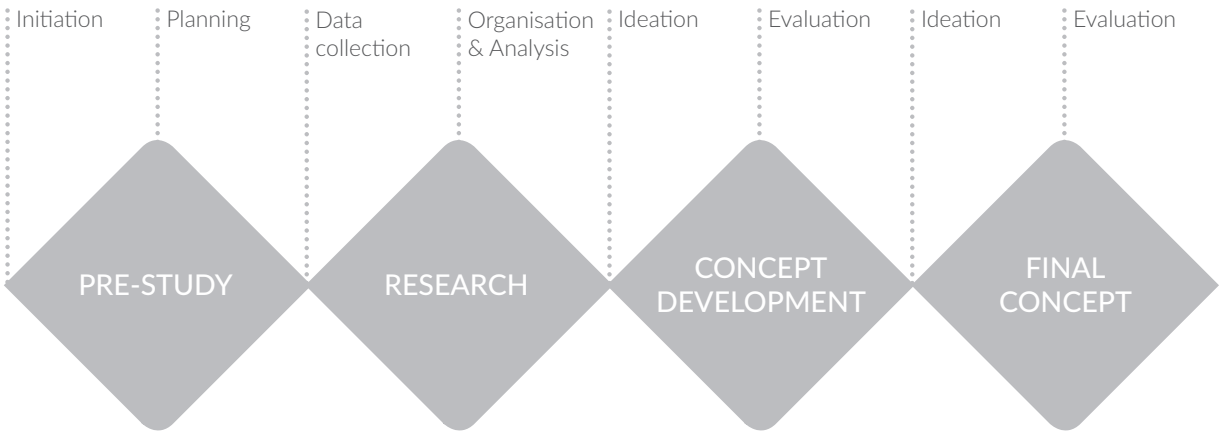


Figure 3. Process overview.

Figure 4. Urban farming, Gothenburg.

2 BACKGROUND

This section provides a description of the underlying topics and issues that are relevant to the initiation of the project. The intention is to give an understanding of the benefits and consequences of growing vegetables in a shared greenhouse in a broader context.

2.1 The global food situation

Food is a basic human right and something we all need in order to survive. However, providing the world's population with food is an ongoing challenge, which is predicted to get even more difficult in the near future.

2.1.1 Challenges of food security

Food security refers to the availability, access and utilisation of food, as well as its stability over time. According to the Food and Agriculture Organisation of the United Nations (FAO), food security "exists when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2014).

Regarding food accessibility, the world is currently producing more than enough for everyone. The problem is, however, that the food is unevenly distributed among the world's population, and does not reach the world's poor people to the necessary extent (Naturskyddsföreningen, 2011). According to the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), around one billion people suffer from hunger and chronic malnutrition while at the same time a large part of the human population suffer from obesity and chronic diseases caused by obsessive intake of calories.

Moreover, the accessibility of food is expected to decrease as the demand for food is going to increase heavily in the future. The world population is predicted to grow by 2-3 billion before 2050, requiring a 60 % rise in food production (FAO, 2012). Trends also point towards an increased per capita income in the developing countries along with continued urbanisation and raised living standards, resulting in increased consumption. Consequently, market food demand will most likely continue to grow (FAO, 2009).

Urbanisation is another aspect that poses a threat to food security in terms of accessibility. Around 70 % of the world's population is predicted to live in cities by 2050 (FAO, 2013), and their access to food will be dependent on food import to the cities. Additionally, the impact of climate change is expected to magnify the problem of food availability, access, utilisation and stability (FAO, 2011).

2.1.2 The unsustainable food system

The issue of food safety is integrally related to our food system (Hueston and McLeod, 2012). The term food system refers to the production, processing, transportation, consumption and disposal of food. Food systems developed at the beginning of civilisation, as agriculture and permanent settlements came about. Since then, they have been constantly evolving, as science and technology successively have introduced new ways of

producing, processing, storing and transporting food (Hueston and McLeod, 2012).

The current food system is global and complex, which is clearly illustrated by the fact that a classic cheeseburger includes "more than 50 ingredients sourced from countries in every continent of the world except the Arctic" (Hueston and McLeod, 2012). This makes the system vulnerable, since a big, complex system allows for more things to go wrong and more people are potentially affected on a larger scale (Hueston and McLeod, 2012). Moreover, it has also become more and more evident that the current food system is unsustainable, causing great damage to the environment and, in effect, to humans.

Over the past hundred years, food production has moved from the hands of small-scale farmers to big, commercial companies, and the way food is produced has changed radically with the development of new technologies, fertilisers and pesticides (Swedish Society for Nature Conservation, 2013). This development has enabled multinational companies to maximise production in response to the increasing consumption (Tansey and Worsley, 2014). From a short-term, economic viewpoint, this approach has proven successful, but there has been little consideration of how this intensification of production through artificial means affects the biological systems.

However, there has been a growing concern about the ecosystems' vulnerability and productive capacity in the long term (IAASTD, 2009) as the devastating effects of conventional agriculture have become evident. The Millennium Ecosystem Assessment concluded that the global availability of natural resources is shrinking, and over the past 50 years the ecosystems have changed more rapidly than in any comparable period of time in human history (IAASTD, 2009). As a result, there has been a substantial and largely irreversible loss in the diversity of life on earth over the last century. FAO estimates that 75 percent of our food's biodiversity has been lost due to industrialised agriculture. For fruit and vegetables, the unimaginable 97 percent has been lost, and the genetic diversity of the world's crops continues to decrease by two percent every year. Not more than 150 species are cultivated large-scale, commercially, and out of the thousands of species that have been domesticated, merely three percent can be found in the industrial food chain. In other words, just a few generations back, there were actually more food choices than today and the assortment of the supermarket is, to some extent, an illusion of choice (Cockrall-King, 2012).

Transportation is another issue of the current food system. Every day, the food takes a crucial journey to arrive at our plates, a journey that is unsustainable, costly and damaging to the environment (Orru et al., 2011). As the world's cities are increasing in numbers and size, food transportation is a major challenge. FAO (2011) argues that the food system has not been paid enough attention in city planning and that there is ignorance towards food security in the cities. With today's system, the supply of food in urban households would only last for three to four days among younger people (Lindgren and Fischer, 2011).

The problems regarding food consumption and utilisation lie at the sharp end of the food system, with the consumers. In the developed countries, high living standards and abundance of food has led to increased consumption, especially of meat which has increased by over 50 % the last 20 years (Swedish Society for Nature Conservation, 2009) and today, about four earths would be needed to sustain the world on a US diet (Steel, 2009). As the developing parts of the world are catching up with increased living standards, a similar development can be seen regarding consumption. For example, Chinese meat consumption stood at 2 kg per person per year in I960 while today it is at 60 kg and rising fast (Steel, 2009).

Furthermore, food loss and food waste is a huge issue, and it is estimated that approximately one third (1.3 billion tonnes) of all food that is produced for human consumption, globally, is lost. The loss of food occurs in several steps of the supply chain, and can be identified all the way from agricultural production, handling and storage as well as distribution down to consumption on a household level. At the final consumption stage, food loss is generally described as food waste, which concerns consumers' behaviours and attitudes towards food.

FAO (2011) identifies expiration of "best-before-dates" and a careless attitude from high-income consumers as primary reasons for the high amount of food waste. The careless attitude is argued to be a result of people's loss of connection to, and awareness of, the production of food. Having cheap and conveniently available food in the supermarkets, many people do not reflect on the efforts and resources that were necessary to bring it there. Also, being able to get access to most types of fruit and vegetables all year around is taken for granted, which causes the risk of people loosing the sense of seasonal food (Cockrall-King, 2012).

Changing the current food system into one that is more sustainable, while at the same time solving the issue of food security, is one of the major challenges of our time. According to IAASTD, new ways of thinking regarding food production are necessary in order to move towards more sustainable methods. FAO (2011) promotes a more localised food system in connection with national as well as international food systems, and a raised awareness of food among consumers to reduce food waste.

2.1.3 Agriculture and the Swedish food situation

In Sweden, a reaction towards the current global food situation and its negative environmental impact can be seen by a continuing growth in the market for organic food, which showed an increase of 13 percent during 2013 compared to previous year. There is also a clear trend towards conscious eating and an awareness of food content and additives, as well as production and origin of crops (Ecoweb, 2014). According to Lantbrukarnas Riksförbund (LRF, 2014), the demand for locally produced food has never been greater. However, the organic production of food does not increase at the same rate, and approximately 50 percent is imported. Fruit and vegetables is the category of organic food that is most imported to Sweden.

Concerning conventionally grown food, Sweden imports about twice as much as is exported, primarily from other EU countries and Norway (Jordbruksverket, 2014). Sweden is self-sufficient in e.g. butter and cereals whereas some are limited by natural geographic and climate conditions. Further, some food is supplemented by import during off-season (Livsmedelsverket, 2011).

Aside from being dependant on import, our food system in general is complex and multifaceted. A supply chain of several steps and actors in combination with a number of technical systems implies weak points that could easily be disrupted in case of a crisis (Livsmedelsverket, 2011). Historically, people have always been able to handle and store agricultural products to be self-sufficient throughout the year, but with industrialisation, most knowledge is lost on a household level.

2.2 Urban farming

Urban farming, or urban agriculture, is one of the solutions to the current food issue and a phenomenon that is spreading like wildfire around the world. Even though the idea is not new, it has taken a new spin on food provision in the cities. Vegetables as well as some farm animals are growing and thriving in the middle of urban areas, along with people's interest to be a part of it. In Sweden, urban farming is often thought of as merely production of vegetables, but the broader term of urban agriculture can include forestry, aquaculture, livestock breeding and horticulture. The concept can apply to anything from private balconies to commercial activities in the city (Naturskyddsföreningen, 2012).

Urban farming is a contributing solution to the problem of food availability in the world since it utilises unused space in the cities, such as rooftops, for production of food. Moreover, urban and peri-urban agriculture is of increasing importance, as it contributes to reliable food supply for people in the cities and provides employment for a large number of urban poor, especially women (IAASTD, 2009). It also shortens the distance from production to consumption and reduces the dependency on the global transportation system, giving people access to food that has a lower environmental impact and is more fresh and seasonal. Even though rural farming will probably remain the most important source of food for the urban

population, there is a great capacity in the cities for some extent of self-reliance. In Hanoi, Vietnam, the urban and peri-urban agriculture supplies the city with about one half of the food demand (IAASTD, 2009).

In Sweden, Andersson et al. (2008) at Sveriges Lantbruksuniversitet, identifies a potential in private/hobby farming for food production. Available area for such farming is estimated to 300 000 hectares, which theoretically could produce 10 million tonnes of vegetables and feed approximately 4 million people.

Growing vegetables adjacent to the home has always been of great importance for food sustenance. Even though it is less crucial in today's society, its popularity is growing for other reasons, and is rated the second most appreciated outdoor activity after walking (Björkman, 2001).

History has shown that during wartime (when there are generally more complicated conditions for import and logistics), the amount of allotments increased in Sweden and even parks were utilised as cropland. For a long time, Sweden had a crisis plan for how to be self-sufficient in food and was prepared to manage isolation for up to three years. However, by the end of the 20th century (along with joining the European Union), the high level of preparedness was discontinued when it was considered of less importance (Andersson et al., 2008).

Naturskyddsföreningen (2012) argues for benefits of urban farming such as social networks and inclusion, increased sense of responsibility and reduced vulnerability in the cities, but also the actual outcome – fresh vegetables with shorter transport distances. Further, Naturskyddsföreningen (2012) claims that urban farming can generate knowledge of environmental issues and the importance of biodiversity.

2.3 Social sustainability in urban communities

A community is a group of people who know and identify themselves with one another because they have something in common, such as values, cultural assumptions, interests, goals or backgrounds (Community Tool Box, 2013). Historically, the sense of community has been a natural effect of the fact that people were born and lived their lives in the same place with people they had always known. However, in today's globalised society, people are less bound and prone to live their entire lives in the same city, or country, than they were only a few generations ago. Furthermore, the increasing urbanisation means that the cities become bigger, more diverse and multicultural. Thus, many people find themselves living in new, unfamiliar places and neighbourhoods where they might not know any neighbours at all, and the community is defined by geography and economics rather than by shared customs, culture and knowledge. Also, studies in Sweden has shown that people in modern communities are less dependent on collaborating with each other and therefore have less contact, compared to communities in the 1930s when certain tasks such as washing and chopping firewood were done collectively and brought people closer together (Olsson, 2012). One of the big challenges of today's urban societies is therefore to create a sense of community among people from diverse backgrounds, ethnicity and culture (Community Tool Box, 2013).

One might ask why is it important to create local communities, since the Internet has enabled people to connect with others sharing similar values and interests and thus to be part of communities regardless of geographical location. Although this is true, and positive in the sense that it removes the physical constraints to community and increases connectedness globally, the importance of local community should not be underestimated. Research shows that there are many positive effects from the existence of strong local communities; it reduces crime, increases the feeling of safety, builds a sense of belonging and identity among the people in the community, and a strong support network can actually improve people's health and prolong their lives. On the opposite, it has been seen that when places lack community and social networks, it can affect the social and economic wellbeing negatively. Moreover, creating strong communities is simply a question of increasing the social connectedness, i.e. the actions, feelings and interactions that tie people

together. Research has shown that this is a crucial factor for people's health, an important aspect of society and also a way to increase economic development (Community Tool Box, 2013).

To create a sense of community, it is necessary to bring people together so that they can get to know each other and learn about one another's culture, backgrounds and develop common goals or interests. Especially new residents need local social networks and shared community experiences to build a sense of belonging and identity in new places. This can be done by providing spaces where all members in the community can meet naturally and interact. However, although much is known about the environmental challenges and how to increase the environmental sustainability when it comes to building new communities, there is less knowledge on how to plan, design and develop socially sustainable neighbourhoods that enable and encourage residents to meet (The Young Foundation, 2009). Thus, one of the challenges of creating socially sustainable communities is to incorporate natural gathering places and good places for interaction into the design of cities and residential areas.

2.4 Community-shared greenhouses

Community-shared greenhouses is an emerging trend that is connected both to the ecological and social sustainability issues.

In Sweden, it is getting increasingly common for the municipal housing companies to build shared greenhouses in connection to apartment blocks in urban areas, either as free standing structures or in connection to the house, on rooftops or adjacent to the building. The greenhouses are built both in response to the growing interest in gardening and vegetable cultivation, as well as the overall trend of environmentally and socially sustainable housing.

Incorporating plants and greenery in built environments is a global trend, since it has been shown that it has multiple benefits, for example by improving air quality, decreasing noise, making spaces more attractive and increasing people's health. In addition, the greenhouses can also serve a purpose in a building's infrastructure, for example by cleaning wastewater, utilise waste heat and serve as insulation and thereby save energy (Andersson, 2013).

The shared greenhouses also have a purpose of being a place for social interaction among the residents. It has been shown that shared spaces, such as greenhouses, can increase the social sustainability by encouraging social interaction among neighbours, as well as increase the awareness about ecological sustainability (Örneblad, 1997). The purpose of shared greenhouses is thus both to enable cultivation, and to serve as a social meeting place that creates a feeling of community and identity among the residents (Andersson, 2013).

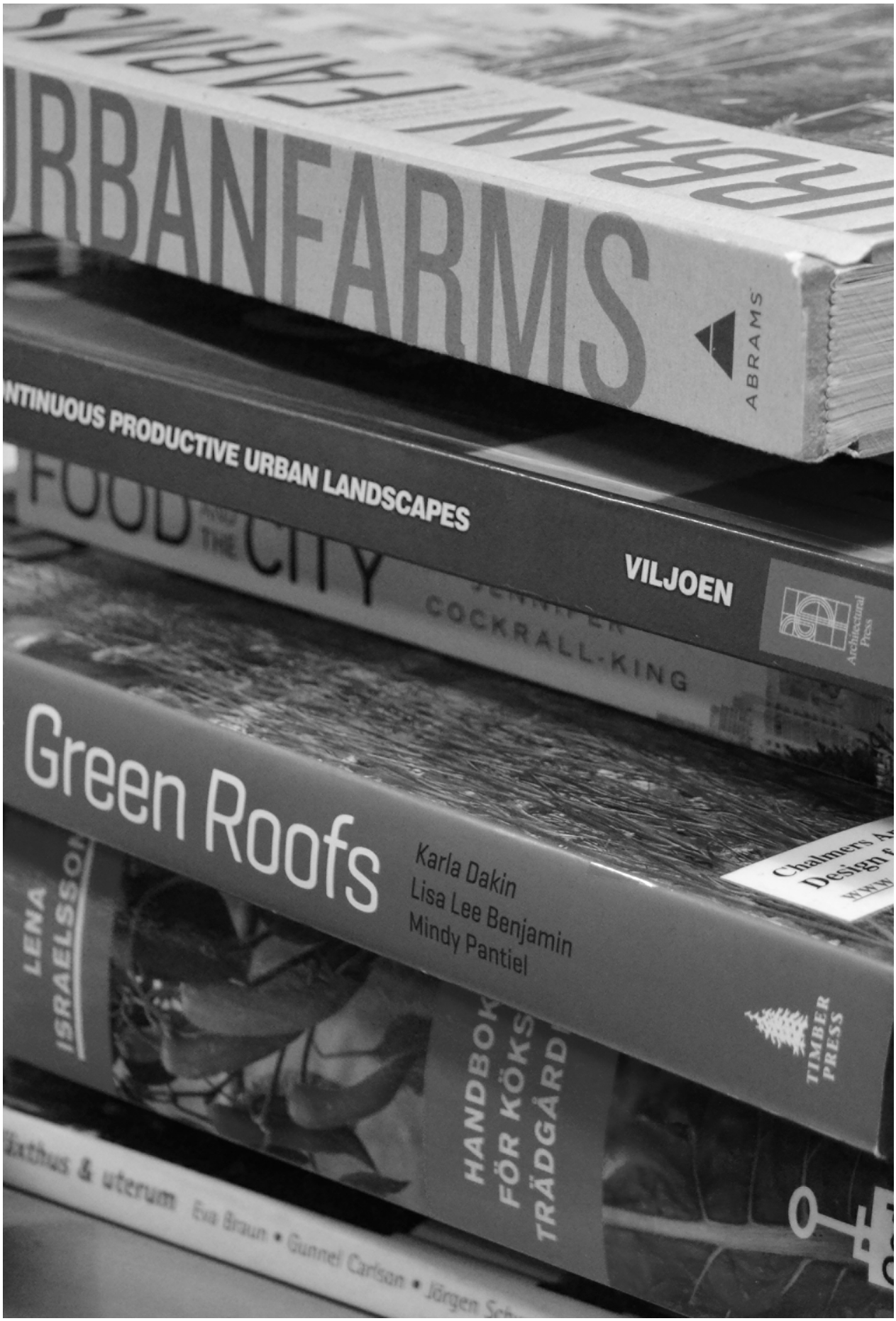


Figure 5. Books from literature study.

3 THEORY

The following chapter describes technical theory about greenhouses, cultivation and social spaces, as well as selected design theories that were used during the development of the product.

3.1 Technical Theory

The technical theory was gathered through field visits and interviews with a postgraduate specialised in greenhouse cultivation at the University of Agricultural Sciences in Alnarp, members of the association Odla i Stan in Malmö and an organic farmer outside of Gothenburg (see Appendix IV for complete list of questions), as well as through literature studies.

3.1.2 Greenhouses

3.1.2.1 Sizes and Shapes

As seen both during visits to various greenhouses and in studied literature, greenhouses can have various shapes and sizes (often rectangular), from merely a few square meters to very large. Door sizes generally vary with size of the greenhouse. Retailer Willab Garden (2014) has a compact model with a door size of 600 mm, otherwise the doors are often at least 700 mm.

3.1.2.2 Flooring and Wall Materials

Both during visits, literature studies and studies of available greenhouses on the market, it was found that the flooring most commonly is made of concrete or stone tiles. The greenhouse structure can be made of metal (steel or aluminium) or wood, and have different shapes. The glazing can be made either of glass, or of polymer materials such as polycarbonate or acrylic.

3.1.2.3 Light, Temperature and Humidity Levels

The greenhouse climate involves the parameters light, temperature and humidity. The values of the parameters can vary quite a lot during a day, as well as over the season. The relative humidity in greenhouses is around 70%-85% (compared to 60% in normal indoor climates). When humid air comes into contact with surfaces of a lower temperature than the air, condensation will occur at the surface. This often happens during night and early in the mornings, when the greenhouse and the plants are cooler than the air, thus causing the water steam to condensate.

Regarding the temperature, 30 degrees Celsius is the maximum temperature that many plants can stand without taking harm. However, during very warm and sunny days, it is possible that the temperature might go slightly higher for a short period of time. In winter time (in the extreme case of a northern Swedish climate and in a non-heated greenhouse) the temperature in the greenhouse might fall below zero.

A greenhouse is designed to take in as much daylight as possible. In order to optimise the production of vegetables in northern countries such as Sweden, it is necessary to have additional, artificial lighting in the greenhouse during spring and fall.

In order to adjust light, temperature and humidity, many greenhouses have ventilation shutters (usually at the ridge) and screens along the windows, which are opened or closed. They can be manually or automatically controlled. (Jordbruksverket, 2008)

3.1.2.4 Pest Control and Hygiene

It is important to keep the windows clean from dirt and algae during the growing season, so that they let in as much light as possible. Furthermore, the greenhouse should be cleaned regularly, normally before and after the growing season (in the spring and fall) in order to avoid pests and fungi (Willab Garden, 2014).

3.1.3 Vegetable Cultivation

In order to cultivate vegetables, the basic requirements and aspects that affect the plants' life and development, i.e. the conditions for photosynthesis to take place, must be considered. These basic aspects include access to sunlight, water, nourishment and carbon dioxide (air). The plant also needs certain temperatures to develop and grow.

3.1.3.1 Plants and their needs

Water and light

Water is essential for the plant, e.g. for taking up and transporting nutrients and regulate temperature. The amount of water a plant needs varies depending on the culture and the surrounding climate. As an example, on a warm summer day a cultivation of cucumbers may need up to 5 litres per day. In general, a plant needs 16 hours of light per day (Bergstrand, 2014).

Nutrients and PH values

The plant is provided with nutrients through the soil. The nutrients, which are bound in the soil, are dissolved by the water, after which the plant's roots can absorb it. In order to ease the plant's uptake of nutrients from the soil, the roots need to be well developed. Thus, drainage is important because the roots uptake is hindered when the soil is too moist. Another important aspect for root development is good soil structure, which can be improved by adding organic material and by cultivating in raised beds. Today, new technologies enable cultivation without soil, such as hydroponics, where the plants are grown in a growing medium such as mineral wool and are provided with nourishment through water.

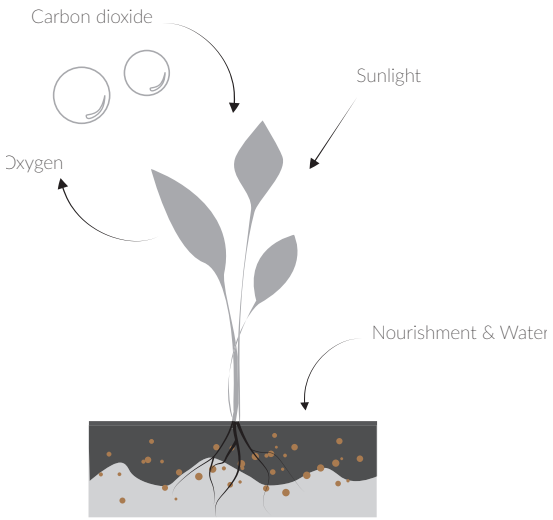


Figure 6. The basic needs of a plant. The photosynthesis is the process by which plants, with the help of the green chlorophyll, use sunlight to transform carbon dioxide and water into oxygen, starch and water.

Root depth, plant height and spacing

Different plants have different root depths and heights, which can vary greatly depending on what type of vegetable and species it is. The illustration below shows an example of the root depth and plant height of some of the most common vegetables grown in Sweden.

3.1.3.2 The process of growing vegetables

Growing vegetables is an activity that includes a number of steps and tasks. The process differs slightly depending on what type of plant that is grown and if the vegetables are grown outdoors or in a greenhouse. For example, in a greenhouse, there is less need to protect the plants from animals, whereas the closed greenhouse system means that water, soil, light and temperature have to be kept under closer control.

The process of growing vegetables in a greenhouse consists of the following main steps:

- Planning
- Precultivation and repotting
- Preparation of greenhouse and growing container
- Mounting and organisation of cultivation containers
- Adding soil and nourishment
- Planting and sowing
- Planting of precultivated plants or sowing of seeds, labelling plants
- Caring and tending
- Watering, binding tall and twining plants, pollinating, picking weeds, checking for pests
- Harvesting
- Emptying and cleaning
- Documentation

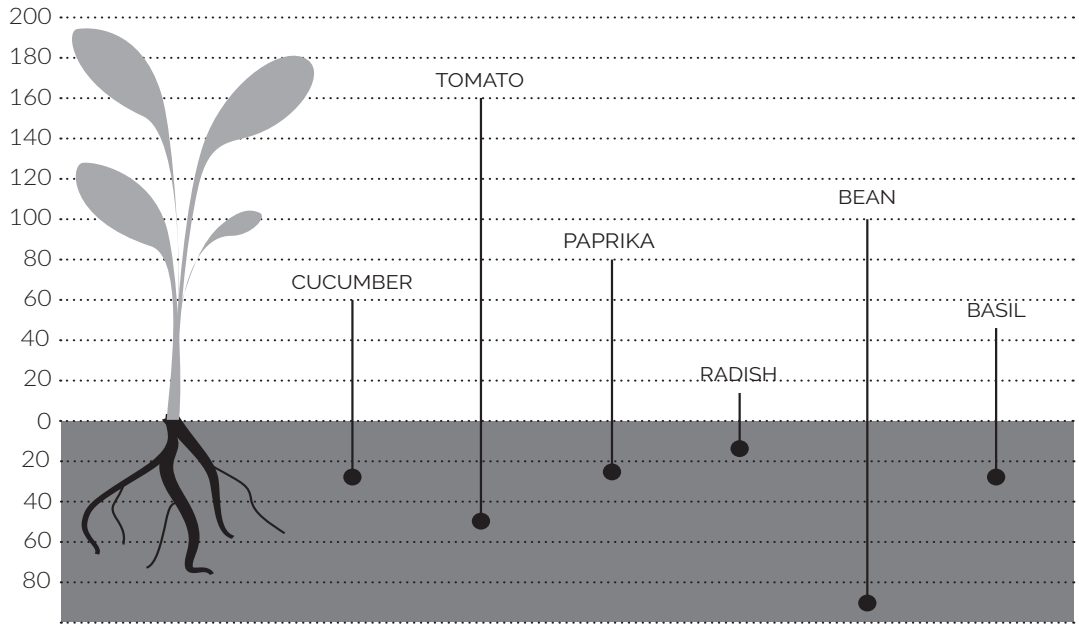


Figure 7. Root depths and plant heights of common vegetables.

3.1.4 Designing social and interactive spaces for communities

According to The Community Tool Box, a service of the Work Group for Community Health and Development at the University of Kansas, good places for interaction are places where people from different parts of the community and with diverse backgrounds meet naturally and interact comfortably and pleasurably because of the nature of the space and/or the activities associated with it (Community Tool Box, 2014).

When designing a place for interaction among members of a community, it is ideal if the users themselves can affect the design of the space. Participating in the development and creation of a space makes people feel more engaged and thus more prone to maintain and care about the space. It is also a way to get people in the community to work together towards a common goal and purpose.

The following guidelines are set up by the Community Tool Box, for creating good places for interaction:

The space should encourage people to visit

Making people want to visit a space means that one has to provide an activity that attracts them. It could be by enabling activities such as sitting in the sun, cooking, eating, or watching/participating in events.

The space should encourage people to stay

An effective way to make people stay is to offer comfortable places to sit. Movable chairs and tables are preferable, since it gives people the chance to sit where they like, and to sit either in groups or alone. Providing both intimate and large spaces makes it possible for people to be alone, have private conversations or gather in larger groups. However, the more people can face each other, the more likely is it that they will interact and engage in conversation. Apart from seating there are other ways to facilitate the use of a space. Making the space interesting and pleasant to walk around in, will also engage people to stay. Providing food and drinks, or facilitating consumption of food and drinks that they have brought themselves, is another way to inducing people to stay. Furthermore, an aesthetically pleasant space, especially one with greenery, makes people more inclined to stay. If the space is outdoors, providing a space that has a mix of sun and shade can also be a way to make people stay longer. It is preferable if the space offers a variety of things to do and watch, in order to cater different people's preferences.

The space should make people feel safe and comfortable

A space that is clean from litter and dirt and has good lighting, especially natural light, makes people feel more comfortable. Also, a calm and quiet environment is often experienced as comfortable. The presence of other people in a space will also increase the feeling of safety. Having windows that enable people to see in and out of the space is therefore important, both because it invites people to enter the space and because it increases the feeling of safety when people in the space can see if other people are nearby. Making the place safe also means that the space itself and the objects in the space, for example furniture, should be safe and comfortable to use.

The space should be welcoming and accessible to all

An important factor is that everyone in the community should be able to use the space and the products inside it, i.e. it should be accessible for elderly, children, people in wheelchairs or other disabilities and people of different sizes and heights.

3.2 Design Theory

3.2.1 Inclusive Design

Within the concept of inclusive design, a central factor is to expand the target group so that it includes as many as possible, while not sacrificing either customer satisfaction or profit (Clarkson et al., 2003). It can be argued that a disability is not bound to an individual, but is rather caused by a poorly designed product, service or environment. Clarkson et al. (2003) state, "If people can be disabled and excluded by design, they can also be

enabled and included by thoughtful, user-aware design".

The user pyramid is a model initially used by ErgonomiDesigngruppen (Bengtzon, 1993,1994). The pyramid is a representation of all potential users, who have different abilities and conditions that affect their daily lives. The base of the pyramid symbolises people with no or small limiting disabilities. The middle section represents people that have disabilities that imply a need for assistance or technical aids, and the upper part consists of users that have significant disabilities and thus need advanced technical aids. Well-designed products will place more people in the lower sections of the pyramid, and a design focus on the pyramid's top may result in solutions that suit and enable all users (Paulsson, 2006).

3.2.2 Physical Ergonomics and Anthropometry

For kitchen counter design (which is used as a reference), it is recommended to keep the workspace for hands at elbow height or slightly below. Arbetsmiljöverket (2011) describes a well-designed workspace as a place where it is possible to work in an upright position with lowered shoulders and the upper arms close to the body. Suitable heights for a small woman are 80-110 (average of 95) cm and for a large man 100-140 (average of 120) cm, but Swedish women are often taller than these measurements whereas Swedish men are often shorter. For wheelchair users, the workspace can be placed even lower (Kroemer, 2006).

Human beings are intended to be walking and standing. When the back is in its natural posture, i.e. when all vertebrae and lamellas are naturally positioned, loads are most evenly distributed. Back problems are among the most frequently recurring health issues, and usually increase with age (Kroemer, 2006). The best way to work around an injury is to avoid strainful body exertions, which includes working in stooping as well as twisted or asymmetric positions (Bohgard et al., 2010). For older adults in particular, working heights that do not imply bending are preferable (Kroemer, 2006).

Reaching distance measurements differ between men and women. For zones of convenient reach, recommended measurements are 60 cm for an average woman and 66.5 cm for an average man (Pheasant, 1996). These measurements are estimated when standing/sitting directly in front of the surface and will thus be shorter for a wheelchair user if it is not possible to fit the wheelchair underneath the plant container.

3.2.3 Usability

Usability refers to the quality of the interaction between a product, a user and a task. In simple words, it can be thought of as how easy a product is to use, its "user-friendliness". According to the International Standards Organisation (ISO) usability can be defined more specifically as "the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments" (Jordan, 1998).

Effectiveness refers to the extent to which a goal can be achieved, efficiency refers to the amount of effort required to achieve a goal and satisfaction refers to the level of comfort a user feel when using a product and how acceptable the product is to the users.

Moreover, usability can be divided into five components;

- **Guessability** - first time use of a product for a particular task
- **Learnability** - the number of task repetitions required to learn a particular task
- **Experienced User Performance** - the level of performance an experienced user can achieve
- **System Potential** - the theoretical optimal performance obtainable with a product for particular tasks
- **Re-usability** - the level of performance achieved when a user returns to a task with a product after an extended period of non-use

The design characteristics associated with usability can be summarised in Jordan's ten design principles.

- **Consistency** - Designing a product so that similar tasks are performed in similar ways
- **Compatability** - Designing a product so that its method of operation is compatible with users' expectations based on their knowledge of other types of products and the "outside world"
- **Consideration of user resources** - Designing a product so that its method of operation takes into account the demands place on the users' resources during operation.
- **Feedback** - Designing a product so that actions taken by the user are acknowledged and a meaningful indication is given about the results of the actions.
- **Error prevention and recovery** - Designing a product so that the likelyhood of user error is minimised and so that if errors do occur the can be recovered from quickly and easily
- **User Control** - Designing a product so that the extent to which the user has control over the actions taken by the product and the state that the product is in is maximised
- **Visual Clarity** - Designing a product so that information displayed can be read quickly and easily without causing confusion
- **Prioritisation of functionality and information** - Designing a product so that the most important functionality and information is easily accessible to the user.
- **Appropriate transfer of technology** - Making appropriate use of technology developed in other contexts to enhance the usability of a product.
- **Explicitness** - Designing a product so that cues are given to its functionality and method of operation.

(Jordan, 1988)

3.2.4 Design for sustainable behaviour

The term "sustainable behaviour" refers to using a product or service in a way that has less negative impact on the environment than conventional ways of using similar products or services.

A product's use phase is often the part of its life cycle that has the most negative environmental impact, which partly is due to the user's behaviour. Design for sustainable behaviour aims at reducing the negative environmental impact during the use phase by addressing the users' behaviour, through the use of different design strategies.

The model for for sustainable behaviour includes the five strategy categories called Enlighten, Spur, Steer, Force and Match. The first four categories involves changing the user's behaviour, whereas the fifth strategy category involves adapting the product to the user's existing behaviour. Further, the different categories relate to different levels of user control versus designer control.

Match - The product or service is adapted to the user's current behaviour. Both the user and the designer are in control, since the user decides his or her behaviour but the designer can control the outcome of the behaviour.

Enlighten - The product or service is designed to motivate the user into having a sustainable behaviour, by influencing their knowledge, values or attitudes. This can e.g. be done by providing information, feedback or encourage reflection. This category involves the highest level of user control.

Spur - The product or service is designed to encourage and tempt the user to perform the desired behaviour, by focusing on creating positive consequences of the desired behaviour or making the behaviour itself a positive experience. This can be done by e.g. incentives or competition.

Steer - The product or service is designed to guide the user by making sustainable behaviours the evident choice. The user can be guided either physically or cognitively, through e.g. constraints or affordances.

Force - The product or service is designed to compel the user into a sustainable behaviour, by restraining the unwanted behaviour through limited functionality. In this category involves the highest level of designer control.

(Lidman & Renström, 2011)

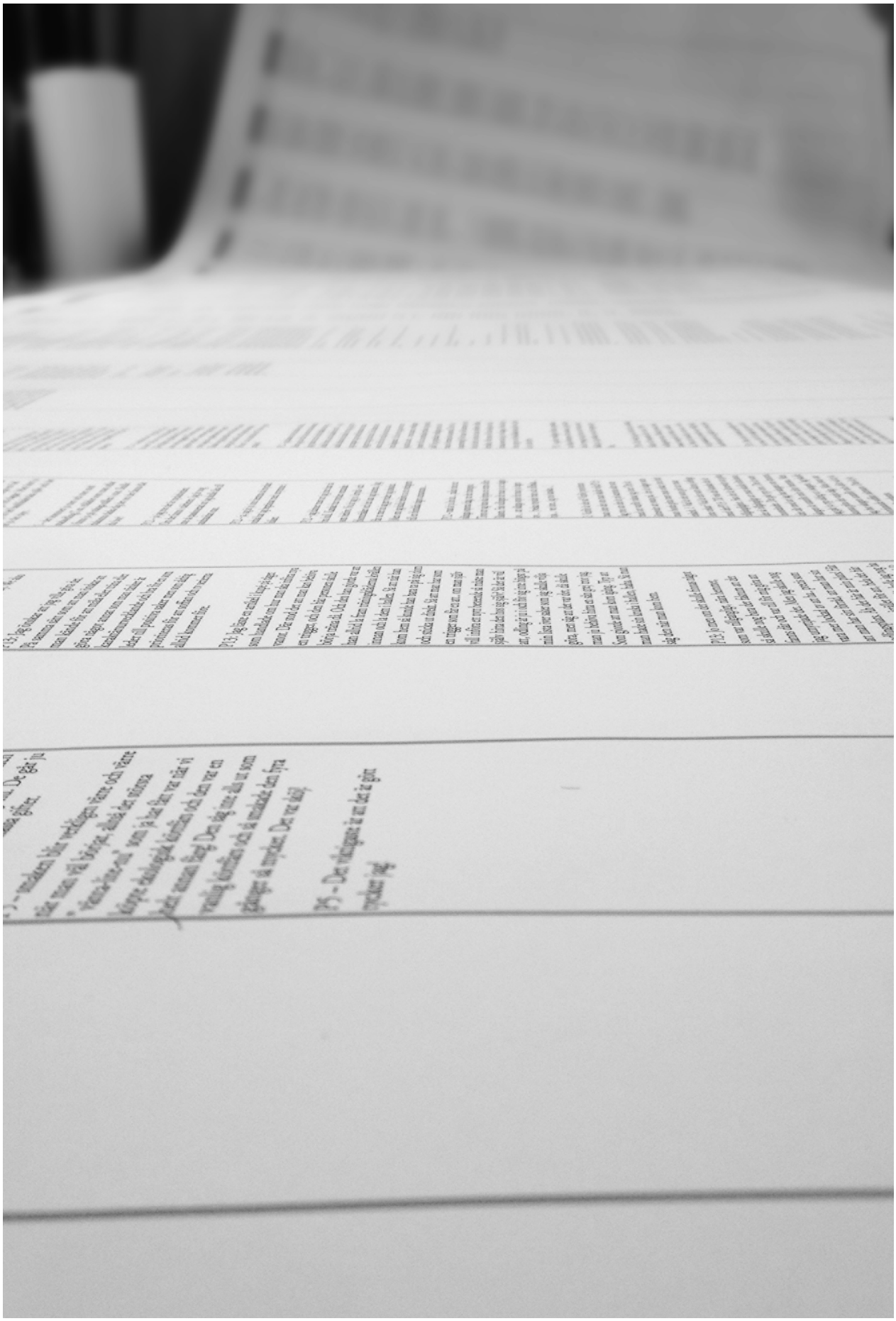


Figure 8. KJ Analysis.

4 METHODOLOGY

This chapter gives a brief description of the various methods that have been utilised during the process. The methods are placed into sections according to their purpose, which are data collection, analytical, creative, evaluative and communicative methods.

4.1 Data collection methods

4.1.1 Interviews & observations

Interviews and observations are primarily used for collecting qualitative data, such as opinions and information from users, experts or different stakeholders. They are versatile methods that can be used throughout the design process.

There are several types of interviews, e.g. personal, group or phone interviews. Additionally, an interview can in general be characterised as structured, semi-structured or unstructured. An unstructured interview consists of open-ended questions, which makes it possible for the respondent to steer the discussion towards topics that she/he finds important. A semi-structured interview implies that the interviewer has prepared topics but is otherwise of open character. Structured interviews are based on a pre-defined set of questions and the acquired data can be analysed according to strict guidelines. A semi-structured or unstructured interview is better suited for obtaining personal opinions and emotional responses regarding a product (Jordan, 1998).

Observational studies can be performed separately or in combination with an interview. A person is observed in her/his natural environment, or the environment where a product is normally used. The user is often requested to follow her/his regular agenda while the researcher is observing, but the researcher can also ask additional questions about hypothetical scenarios. Through observations, it is possible to identify certain behaviours that the user is either unaware of, or does not mention in an interview (Jordan, 1998).

4.1.2 Object-based techniques

Unlike most other data collection methods, which are based on eliciting needs by talking and listening, object-based techniques help the users express themselves through objects. The technique helps participants to express feelings, thoughts and tacit knowledge that they cannot describe in words. The method is a good complement to other data collection methods, especially during the early, divergent stage of a project when the goal is to widen the scope and do explorative research.

Object-based techniques can be dialogic, generative or associative. The dialogic techniques stimulate discussion by showing the participants things such as images, objects or performances. Showing concrete things rather than just letting the participants imagine them is more effective in triggering responses. The generative techniques let participants express knowledge, thoughts and feelings by creating objects. The objects are created either by using a tool kit of basic elements provided by the researcher, which subsequently limits the freedom of the participant to some extent, or by an open ended process. Generative techniques are

helpful when wanting to understand the participants' mental models of a product, process or service. Lastly, the associative techniques involve letting participants organise information, for example by sorting and grouping cards with photos or words, according to how they relate, prioritise or categorise concepts. This technique is most useful at a later stage in the process when the scope is narrowed down, since one must know what information that needs to be organised (Goodman et al., 2012).

4.1.3 Focus groups

Focus groups are structured and moderated group discussions, aimed at identifying a target group's conscious thoughts, feelings, motivations and values about a topic. It is one of the oldest and most widely used techniques for researching the user experience (Goodman et al., 2012). A moderator frames and steers the discussion by asking questions and using probing, i.e. asking follow-up questions.

4.1.4 Questionnaires

A questionnaire-based survey is a quantitative or qualitative, structured method that is based on either fixed or open-ended questions. Questionnaires are less flexible than personal interviews but can be used to collect data from a large number of respondents or from respondents that are difficult to reach for an interview (Karlsson, 2010).

4.2 Analytical Methods

4.2.1 The Jiro Kawakita (KJ) Analysis

The KJ Analysis, or affinity diagram, is a method for organising and structuring qualitative data. Its purpose is to compile an overview of the data and to provide an efficient way of communicating the results. The data, which can be in the form of quotations or written notes, is organised by grouping them into categories according to how they relate to each other (Karlsson, 2010).

4.3 Creative Methods

4.3.1 Brainstorming and negative brainstorming

Brainstorming is an ideation method with the purpose of generating many ideas through free association, where the group members are prepared and familiar with the topic. For successful brainstorming, the participants should go beyond their usual thinking and combine different ideas into new ones. The ideas should not be criticised or evaluated during the process. Negative brainstorming is based on the same principles as regular brainstorming but is supposed to stimulate criticism of an idea or a solution (Johannesson et al., 2004).

4.3.2 Morphology chart

A morphology chart is a method used to ensure that no ideas are overlooked in the concept development. The method is commonly based on a function analysis and is often applied in the early stages of idea generation (TU Delft OpenCourseWare, 2014). All ideas are categorised and combined into different overall solutions (Johannesson et al., 2004).

4.3.3 Idea shifting

In the idea shifting method, the participants create ideas and solutions one by one and document them by sketches and descriptions. After a certain time (e.g. a few minutes), the papers rotate around the table so that each participant can proceed and elaborate on the previous person's ideas. Each idea circulates one lap and can thus reach all participants and pass through several approaches. This is a democratic method since all ideas receive equal attention (Johannesson et al., 2004).

4.4 Evaluative Methods

4.4.1 Pugh's matrix

Pugh's method is based on a decision matrix used for rating and ranking sub-functions of a concept.

It is used to compare different solutions and eliminate the less good options, and it is also possible for new solutions to appear from combinations of previous ideas. A relative decision matrix compares technical solutions in a list of selected criteria, to a chosen reference solution. The reference is given a value of 0 in all categories and the remaining are rated + (better than the reference), - (worse than the reference) or 0 (equal to the reference). Subsequently, the assessments are summarised to a net value. It is often preferable to determine which criteria that have the greatest impact on the overall evaluation (Johannesson et al., 2004).

4.5 Communicative Methods

4.5.1 Personas

A persona is a fictive user, that represents and communicates who the real users encountered during research are. It is created to make it easier to understand and relate to the user in terms of e.g. her/his life situation, attitude or goals, and is put together to a representative story (Jordan, 2000).

4.5.2 Requirement Specification

In a requirement specification, all criteria that the product should fulfil is documented and structured according to specific areas. The criteria are based on the information collected during the research phase and literature study. Further, they are divided into categories of functional or limiting, and are classified as either a requirement or a wish. The specification is used throughout the process, as a support to ideation as well as construction. The document is revised and expanded during the project, as more detailed concepts and design solutions emerge (Johannesson et al., 2004).

4.5.3 Mock-ups

A mock-up is a simple prototype, or physical model, that in a fast and cheap way can be used to evaluate a concept three-dimensionally (Österlin, 2010). It can also be a basis for determining surface characteristics and colour (Johannesson et al., 2004).

4.5.4 Computer Aided Design

Computer Aided Design (CAD) tools can be used to make a geometry model for visualisation and for viewing a design solution from different angles before a physical prototype is made. It is also often used to study the processes in moving mechanical systems, through animation (Johannesson et al., 2004).

Figure 9. Visiting Långströmsparken, Göteborg.

5 RESEARCH

The aim of the research phase was to obtain an understanding of the users and their needs, the use environment, the activity of growing vegetables and existing cultivation-related products, and to define the requirement they impose on the product.

5.1 Benchmarking

A study of products and equipment used for cultivation outdoors, on balconies and in greenhouses was conducted throughout the research phase. The benchmarking was limited to products that use soil as a cultivation medium, which thus excludes cultivation techniques such as hydroponics and aquaponics. The benchmarking was intended for inspiration, to explore different product solutions in use and on the market, and to identify potential gaps and competition.

5.1.1 Data Collection

During all study visits to greenhouses and to city farming spaces, the growing containers (such as planter boxes, pots etc.) were examined and documented by photos. There was also a section in the interview guide covering the users' opinions on their chosen material and solutions. Additionally, the growing solutions at greenhouses of larger scale were examined at the Gothenburg Botanical garden.

For the Swedish range of cultivation products, the project team visited different gardening product retailers, such as Hornbach, to learn more about everything from automatic irrigation systems to balcony planter boxes. Moreover, the Swedish fair "Nordiska trädgårdar"/"Nordic gardens" was visited. The 2014 theme was "Urban bloom" and the purpose was to get inspired by the latest gardening and cultivation products, as well as attending open talks and seminars on urban farming.

Lastly, the Internet was used to search for products within all above mentioned categories. The combined results are documented in section 5.1.2 as a list of the most common solutions for growing vegetables in Sweden and a few reference products that can be seen as competitors.

5.1.2 Findings

The findings showed that there are no current growing containers specifically designed or marketed for greenhouse environments, and especially not for shared greenhouses.

Only considering the basic needs a plant has in order to grow, it is certainly possible to use merely a water resistant container of any kind. However, seeing to the whole activity of growing in a shared greenhouse there are aspects that the current product range does not satisfy, mainly regarding accessibility and flexibility aspects.

For private use, there are some specially designed products on the market, however, most of them having a limited set of features. While there are many clever or nice-looking solutions for small-scale growing, not all would classify as accessible for everyone, nor are they completely suitable for a

shared greenhouse.

In general, the urban farmers are often inventive and create custom made solutions that fit their specific needs, such as constructions for irrigation or twining plants, and custom-making individual products out of cheap or re-used material seems to be a common mentality. However, seeing as the intended product would be purchased by a housing association that requires a flexible and accessible solution, it can be argued that there is a market need for an a growing container specifically designed according to the requirements posed by a shared greenhouse environment.

Figure 10. Pallet collars.

Pallet collars/homemade wooden boxes

- Surface area: 0.96 square meters
- The most common solution
- Can be adapted both shape-wise and height-wise
- Older pallet collars can be pressure-treated and thus contain unhealthy chemicals
- Possible to reach a better working height when stacking several collars (á 20 cm)

Figure 11. Odlarbänken (Löfstedt, 2014).

Odlarbänken

- Surface area: 0.6 square meters (small version) or 1 square meter (large version)
- Elevated Swedish planter container
- Is promoted as an accessible growing bench that facilitates the growing process, especially for people with limited mobility
- For private balcony use
- Has a tilted bottom plate for drainage

Figure 12. Ggrowing beds from Solhusen.

Fixed wooden or brick growing beds

- Surface area: varying (often large)
- Common in greenhouses
- Adapted for each greenhouse and custom-made rather than a product that is produced and sold
- Can be elevated or on the ground

Figure 13. Hasselforsbänken (Hasselfors Garden, 2014)

Hasselforsbänken

- Surface area: 0.94 square meters
- Wooden box that can be stacked and adjusted height-wise
- Garden product of the year in Sweden 2010 Similar to pallet collars

Figure 15. Hasselfors plant bench (Hasselfors Garden, 2014)

Plant bench on legs - Hasselfors

- Surface area: 0.4 square meters
- Elevated wooden box
- Comes with a trellis
- Has a shelf underneath
- For balcony use

Figure 16. Pots in Solhusen.

Pots

- Surface area: available in several sizes, relatively small compared to other solutions
- Common in greenhouses and for small-scale growing
- Clay or plastic
- Can be moved around easily
- Can have self-irrigation features

Figure 14. Plants in pipes and plastic bags, Berlin.

Re-use of other products

- Surface area: varying
- Common in urban farms and among people that grow vegetables for ideological/environmental reasons
- Can be anything that can contain soil - milk cartons, PET bottles, soil bags etc.

5.2 User study

The user study had a holistic approach and investigated the whole activity of growing vegetables rather than the use of a specific product. It proved difficult to get in contact with enough people growing vegetables in shared greenhouses, and hence, it was decided to include various types of growers in the study; people growing vegetables individually as well as collectively and in different contexts, who together could represent the target user group. The aim was also to cover both experienced and inexperienced users.

5.2.1 Data collection

The data was collected using various methods such as interviews, observations and focus groups at various locations. The data collection is described more in detail in the subsequent section.

5.2.1.1 Focus group

A focus group was carried out in order to gather qualitative data about people's attitudes, thoughts and feelings on the activity of growing vegetables as well as sharing the plot and/or greenhouse space together with neighbours. The group consisted of five participants of ages 24-33 years old, one moderator and one observant. The participants had varying degrees of experience in cultivation. See list of questions in Appendix II. Information was documented through voice recordings and written notes.

5.2.1.2 Collage workshop

A collage workshop was carried out with two participants, 27 and 29 years old, who grow vegetables at an allotment with a group of friends. The data was collected by using an object-based, generative technique where the participants were asked to describe and map down the process of growing vegetables at their shared plot into a collage. They were provided with an empty sheet of paper, pens and a variety of printed images. While creating the collage, they were also asked to speak aloud to describe their thoughts and feelings concerning the different parts of the process. The workshop was done in order to identify implicit needs, and it had an exploratory purpose rather than to find answers to specific questions. It provided an understanding of the participants' attitudes and knowledge about cultivation.

5.2.1.3 Interviews & observations

In order to cover a variety of potential users and identify their individual needs and wishes, a number of different people with various degrees of experience in growing vegetables were interviewed at various occasions.

A visit was done at a community-shared greenhouse in Gårdsten, north of Gothenburg. The area has two shared greenhouses that were built as a part of a project called Solhusen, where the entire neighbourhood (including 10 houses and

Figure 17. Visiting Solhusen, Göteborg.

255 apartments over three blocks) was transformed into a sustainable housing area. One of the greenhouses was visited, and data was collected through a semi-structured interview with the caretaker and through observations, documented by photos and written notes. See Appendix IV for complete list of questions.

Two separate, semi-structured interviews were held with people without any experience of growing vegetables. The participants were 25 and 27 years old, both living in the city and leading busy lives. The aim was to investigate their mental models of cultivation, their personal barriers to growing vegetables and their attitudes and thoughts on a hypothetical scenario of growing vegetables in a greenhouse shared with their neighbours. The interviews were recorded and subsequently transcribed. See Appendix III for list of questions.

A third, semi-structured interview was carried out with two members of an urban community growing association in Malmö that initiates urban farming around the city as a means to promote ecological and social sustainability. Both interviewees had experience of growing vegetables at shared outdoor plots as well as in a shared greenhouse. The interview focused on needs related to growing vegetables collaboratively. See Appendix IV for complete list of questions.

Furthermore, a semi-structured interview was conducted with a member of an urban farming association at their allotment in a suburb of Gothenburg. The allotment is situated in a park nearby a residential area and has 20-25 members of different ages. Each member has a separate plot where they grow vegetables and the allotment also includes a shared shed for equipment, compost and watering facilities. The aim was to identify needs related to the practical aspects of growing vegetables and the social and organisational aspects of sharing the allotment. The interview and observations were documented through voice recordings, written notes and photos. See Appendix V for list of questions.

For further knowledge about the needs and issues related to growing vegetables collaboratively, two members from a community growing association were interviewed. The association, Tillsammansodlingen, has about 40 members, and about one hectare of land where they grow vegetables together. The group members share everything, the land, the work and the crops. The interview focused on the issues related to the collaboration between the members and the organisation of the group work. See Appendix IV for list of questions.

5.2.1.4 Online questionnaire

To reach out to a wider group of users, an online questionnaire was created and distributed in various Internet forums and social media group sites. The questionnaire included both multiple choice questions and open-ended questions to generate both quantitative and qualitative data. See detailed questionnaire in Appendix VI.

5.2.1.5 Tillsammansodlingen's questionnaire

As an addition to the online questionnaire, Tillsammansodlingen provided the results from a yearly questionnaire carried out within their growing cooperative. The survey covered attitudes towards membership, workload, social community, knowledge, etc.

Figure 19. Growing beds from Solhusen, Göteborg.

5.2.2 Findings

The collected raw data (in the form of written text, photos and transcripts of audio recordings) was organised and analysed using the KJ method, in which the data was grouped and categorised according to their character and subsequently interpreted. The insights that were gained from the analysis of the data are presented in the sections below.

5.2.2.1 Description of User Group and Personas

As mentioned in the introduction, the targeted user group consists of the residents in the community, thus, a variety of people of different ages and backgrounds. The user study confirmed this pre-consumption of the intended user group, as it was seen during the study that the activity of growing vegetables is carried out by people of all ages. Regarding the user group, it was also found that people have varying aims and motives for growing vegetables (described more in section 5.2.2.2 on insights and identified needs).

Furthermore, apart from their differences in physical abilities (see section 3.2.2 on physical ergonomics and anthropometry) it was noted that the users have varying degrees of knowledge about vegetable cultivation. Their attitude towards knowledge was, however, also very different. One reason seemed to be that their mental models of the cultivation process differ significantly. Some imagine that merely soil, water and a seed is needed for growing vegetables, whereas some seemed to view the process as more complicated than it actually is. While some people saw the lack of knowledge as an obstacle for starting to grow vegetables, others had a more relaxed attitude.

Personas

Three different user types are depicted through personas in the section below.

Malin, 24 and Johanna, 25

Malin is a student and lives by herself in the city. She likes eating healthy and organic food, so she decided to use her plot in the greenhouse. However, she does not spend much time at home and tries to manage cleaning and cooking between long hours at school and meeting friends. Although she would like to put more time into the plot there always seems to be other things at the top of her priority list.

When a friend of hers, Johanna, moved to the same housing community a while ago, they decided to grow together and combine their plots in the greenhouse so that they can share the work. They find that being able to meet in the greenhouse for a cup of coffee now and then, and follow the process of their plants is a great way to socialise. During the season they take a lot of photos of the plants which they send to each other or proudly post on Instagram. They both have little experience with growing vegetables but usually they will have at least something to harvest at the end of the season.

Johan, 36, Maja, 5, & Emil, 1

Having learned about cultivation since childhood, Johan is a dedicated grower and an active member in the greenhouse. He enjoys the process of caring for his plants as well as the outcome: getting to cook his own vegetables. For Johan, planning and dreaming of the upcoming season is a big part of the joy in growing. He enjoys searching for rare species that cannot be found in the stores, and orders seeds online from foreign websites. Johan and his children often spend time together in the greenhouse, where he lets his oldest daughter grow a small part of the plot herself and teaches her about how to grow vegetables.

He has gotten to know some of the others and likes to switch a cucumber for a carrot from time to time, but would not be interested in growing together. He is the kind of person that prefers to be in control of his own work and has a negative attitude towards sharing responsibility with someone else – they can never be trusted to do their part, not to mention sharing the vegetables! There would always be someone taking all of the tomatoes without doing the work.

Saida, 73

Saida has lived in the housing community for over 30 years. She enjoys spending time in the greenhouse where she can meet with the neighbours and have a chat, and having a reason to leave the apartment and do something else. She often brings a snack and sits by the plot while clearing out some weeds and saying hi to the neighbours.

Since she lives by herself, Saida's main incentive for being in the greenhouse is the social aspect- even though it is nice to get some fresh herbs, she could just as well go to the supermarket. She used to have a plot outdoors, but bending and kneeling has become too hard for her.

5.2.2.2 Insights and identified needs

The following section presents the insights about the users' attitudes, emotions and practical issues, concerning vegetable cultivation in a shared greenhouse. The section also presents needs related to growing vegetables collaboratively, i.e. as a group activity. The needs are also presented in a list in Appendix XX.

Emotions & attitudes

The study showed that the users have quite different objectives and reasons for growing vegetables. Of course, the vegetables are an incentive for everyone, however it was also shown that **the process** of growing is as much of an incentive as the end result. To many, growing vegetables is simply a hobby that they enjoy. The practical and physical work is a contrast to their everyday jobs in the city and a way to **relax and put the stress aside**. For others, it is the ideology of having a **sustainable lifestyle**, access to organic vegetables and **control over the food** that they eat that is important. Moreover, some have a genuine interest in plants and cultivation and like to grow unusual vegetables or species that cannot be found in Swedish supermarkets. Economics is not mentioned as a reason for growing. Some growers at an urban farm allotment state that the plot cost them more money than they gained, while in Solhusen some are virtually self sufficient in vegetables during the summer and fall.

> HALF OF THE REASON IS THAT IT IS COZY AND RELAXING

> ALL STRESS RUNS OFF WHEN YOU COME HERE

The **rewarding feeling** and the **emotional bond** that arises when having grown something from a seed, is also mentioned. Many users enjoy following the process (e.g. photographing), both for their own sake and for sharing the experience with friends.

> WHEN YOU INVITE SOMEONE FOR DINNER AND CAN SAY THAT I HAVE GROWN THIS MYSELF, THAT'S COOL.

There is also a current trend in growing your own vegetables, and a positive image related to being the kind of person that grows their own vegetables, as well as a feeling of **satisfaction and pride** in being able to cook self-grown vegetables for your friends. Another aspect that seems important to many users, who are people living in the city, is the feeling of getting closer and more **connected to nature**. The natural, slow and predictable process of following a plant from seed to harvest is something people find pleasing, as a contrast to an otherwise stressful lifestyle.

> EVEN IF YOU BUY THE WORLD'S BEST PRODUCT, THAT REWARDING FEELING IS NOT THERE. THE THINGS THAT I HAVE MADE MYSELF, I FEEL MUCH STRONGER FOR, AFTER HOURS OF WORK.

> YOU GET CLOSER TO NATURE.

In general, one can say that most of the users are positive towards growing vegetables together with friends or people they knew well, and in which case the **social aspect** is the driving factor rather than the cultivation of vegetables. However, when it comes to growing together with people they do not know, such as neighbours or community organisations, the users have varying opinions on whether they prefer to **grow vegetables together with others or by themselves**. Some users prefer to have their own plot, because they want solitude and **peace and quiet** when they tend to their plot. Moreover, they do not want to grow with others because they **fear getting into arguments and disputes** about tasks and schedules or about what vegetables to sow and how

> BUT IF YOU'RE SHARING PLANTS, THE PEOPLE THAT COME FIRST WILL PICK THE NICEST TOMATOES...

> PEOPLE ARE SHARING ANYWAY IN THE SENSE THAT THEY HELP EACH OTHER. I GET SOME CABBAGE FROM HER AND SHE GETS SOME TOMATOES FROM ME... AND YOU SHARE YOUR SEEDS, BUT YOU STILL HAVE SOMETHING THAT IS YOUR OWN THAT YOU CAN CONTOL. YOU DON'T HAVE TO SHARE THE PLOT.

to share the harvest. They want to have **control** and make their own decisions **without being dependent on others**. Instead, they mention that there are **other ways of sharing** and achieving the feeling of community, and find that being able to ask for advice or exchanging seeds or vegetables with your plot neighbour would generate the same social benefits as sharing all the work.

> DURING THE GROWING SEASON YOU CAN GO DOWN TO THE GREENHOUSE EVEN THOUGH THE PLANTS DON'T NEED ANYTHING. YOU CAN SIT THERE AND HAVE A COFFEE AND YOU ALWAYS MEET SOMEONE.

At Solhusen, each household grow their own crops on their assigned plot. They have chosen not to share their plots or grow crops collaboratively, since they prefer to be independent. However, everyone shares the greenhouse space and the equipment, and the growers think that merely sharing the space has increased the social sustainability in the area.

> YOU TALK WHILE YOU'RE WORKING AND GET TO KNOW EACH OTHER, IT'S AN IMPORTANT SOCIAL APSECT.

On the other hand, the interviewees that grow vegetables collectively (meaning that they share the plot and the work) are mostly positive and experience that the benefits exceed the problems. Their motive behind growing together with others varies. For many, ideological motives (environmental or social) play a big role. It might also be that they want to grow vegetables but prefer to be part of a group so that **the practical work becomes less demanding** when it is spread out to several people. Above all, the **social aspect is mentioned as the most important**. It is a way to get to know new people, share knowledge and take part in common activities. Several of the respondents mention staying at the plot when the work is finished, just to **sit down and talk to people.** It is clear that many interviewees value opportunities to socialise, to **get something more from the activity other than the actual task**.

> IT'S NICE TO HAVE COMPANY, IT STRENGTHENS BONDS OF FRIENDSHIP.

The interviewees' attitude towards automation and technological aids that facilitate the growing process or improve the results varies slightly. It was also found that the activity of growing vegetables is more or less controlled and/or automated depending on the user's reason for cultivating vegetables. If the aim of the growing is to produce the maximum amount of vegetables, a more controlled and automated process is important. If the user see it as a leisurely activity for relaxing and enjoying practical work, other aspects such as the experience of actually performing all the tasks by oneself and learning and experiencing the process, is more important than to get optimal results. It can be noted that many who grow in the city appreciate the low technology aspects and are quite negative towards bringing too much technology into cultivation in general. However, some users mention a system that tells them when to water, such as an app, or even an automatic watering system.

Several participants in the study mention that they have had problems with people **stealing vegetables,** which is something that they worry about. This is mostly mentioned by growers at city farms located in public areas, although it is also an issue in the shared greenhouse at Solhusen, where the growers have put up big signs warning people from taking crops from other people's plots.

Figure 20. Greenhouse at Hållbar Hälsa, Svenshögen.

Practical Issues

Some users mention the **handling of soil** as a demanding and tiring aspect. In a greenhouse environment it is necessary to change the soil more often and in raised beds this becomes an even more demanding task. At Solhusen, the households' growing areas are connected and thus, they **need to be filled with soil regardless of whether they are used or not**. Having connected growing beds it was also difficult to **distinguish where one plot ends and another one begins**. The **amount of users in the greenhouse varies from season to season**, as residents move in or out of the community. This meant that many plots are **unclaimed and unused,** resulting in large parts of the growing beds being superfluous and only taking up floor space. The structure of the growing areas is very **inflexible** and consequently, those that have their plot closest to the glazed greenhouse walls/ceiling are **never allowed to have plants that grow tall,** as can be read in the list of common rules posted in the greenhouse. According to the janitor, they would not redo the layout of the growing beds since it would be too complicated to move and rebuild them.

Many users mention **watering as the main practical issue**, both in the sense that it can be a demanding and time-consuming task during warm summer days, but also that it is difficult to know when and how much one needs to water the plants. Different plants require different amounts of water. Both over and under watering are common mistakes among inexperienced growers.

> TECHNICALLY, IT IS WATERING THAT I FIND THE MOST DIFFICULT

> TO GET IT RIGHT, WITH THE SPACING BETWEEN ALL THE DIFFERENT SEEDS. YOU THINK "THIS LITTLE SEED AND THAT LITTLE SEED WITH A 30 CM DISTANCE, THAT CAN'T WORK..." AND THEN YOU PUT ANOTHER FIVE IN BETWEEN. USUALLY IT DOESN'T TURN OUT TOO GOOD.

For best results, different species need different **spacing between the seeds**. Some of the users mention that they find it difficult to know the appropriate distance between the seeds when sowing. This information can often be found on the seed package, but nevertheless, it is a common mistake to place the seeds too closely.

It was observed that many of the growers at the urban farming plots have trellises, to **bind and support tall and twining plants.** The trellises are constructed out of various kinds of materials, from readily bought ones to self-made creations of wood or old bicycle wheels, and they seem to have an additional purpose of **decoration and identification**. It was also noticed that plants such as tomatoes and peas, which grow tall and need to be tied up, were common crops. One participant mentions that they have had problems binding the plants, which had consequently damaged them.

> BINDING OUR PLANTS, THAT IS ONE AREA WHERE WE FAILED.

Pests are a difficult issue that can affect plants both when growing in the open and in greenhouses. Some species particularly like the greenhouse climate and can be difficult to get rid of. Many users mention problems with snails, or bigger animals such as rabbits. However, in a greenhouse context this would not be an issue, but rather smaller bugs and fungi.

Cleaning the greenhouse is done every season, and then it needs to be emptied. Also, and all the growing beds are emptied from plants. This can be more or less difficult depending on the users' types of planter boxes or the layout of the greenhouse, and is often considered one of the least fun parts of cultivation. The ambition level and enthusiasm is said to be highest at the beginning of the season, why **closing up can be boring and demanding.**

Regardless of whether the interviewees grow together or by themselves, a topic that is widely elaborated on is eating and drinking. Merely bringing a coffee thermos can make the experience of looking after your plot into something else and all of the collective growers mention **food and drinks as an essential part of the growing activity**. At

> YOU HAVE SOME MORNING COFFEE AND CHECK ON THE PLANTS.

the shared greenhouse at Solhusen, the residents sometimes visit the greenhouse only to have coffee with the neighbours.

Physical obstacles, such as kneeling in the garden plot, make growing **inaccessible for many elderly and other people with limited mobility**. At one of the urban allotments, the members had taken the initiative to design a raised growing bed that was more accessible for **people in wheelchairs.**

Storage is mentioned as a problem for some of the users. They find it difficult to take care of all the produce, since most of them live in apartments in the city. They have also had problems with everything ripening at the same time, and need to freeze or **store the parts of the produce**. This is, however, mentioned by people growing outdoors who have bigger plots than those growing in the shared greenhouse at Solhusen.

> STORAGE IS ONE OF THE BIGGEST PROBLEMS.

Since the greenhouse at Solhusen was visited before the growing season had started, there were no plants/vegetables growing in the greenhouse. However, it was observed that some of the plots are used for **storage of potted plants** during the winter. The pots are placed directly on the soil in the growing beds. Additional storage in the form of a table, a few shelves and hooks are used to store pots and equipment.

At almost every greenhouse and urban growing plots that were visited, there were benches or chairs that have been brought to the location, indicating the users' **wish to have places to sit.** At Solhusen, the space has a table and four chairs where the residents socialise and have coffee. At Tillsammansodlingen, some growers also mention that they find the seating possibilities at the plot insufficient.

> I WOULD LIKE NICER PLACES TO SIT.

Group organisational issues

The following areas can be more or less problematic depending on the group's size and goals, and if they grow collaboratively (share the plots) or merely share the greenhouse space.

The study showed that growing vegetables collectively involves **organisational issues**, both on a group level and on a practical level for the allotment. With a larger group, such as Tillsammansodlingen, there are greater needs for organisation, compared to a smaller group of friends. Since Tillsammansodlingen also has a much bigger allotment, about one hectare, there are also greater demands on production and consequently more tasks to be planned, carried out and documented.

> IT'S A PROBLEM WE HAVE. HOW DO YOU KEEP TRACK OF EVERYTHING?

The collaborate growers expressed needs concerning **planning and documentation** of the allotment and the tasks, of what, when and how things have been done and by whom. Especially when running a crop rotation, documentation is important to know from year to year for good results.

> IT'S BEEN A PROBLEM KNOWING WHEN THINGS SHOULD BE DONE.

In Solhusen, where the users grow vegetables independently, the organisational needs primarily concern sharing and maintaining the greenhouse space. They also have a group that is responsible for **organising the growers** at the start of each season and **organising the greenhouse space**. Apart from handling the distribution of plots, they also furnish the greenhouse and arrange common meetings and cleaning days.

For collective growers, the **distribution of responsibility** can be an issue, especially when the group has many members. In some groups the members are assigned responsibility areas, e.g. planning or storage area, but **managing routine tasks**, such as watering, is more difficult. Opinions on the structure vary between interviewees, some wish for more regulations and some feel strongly for a system of free responsibilities. For the smaller groups

of collective growers, **responsibility is shared among everyone**, and each member take as much responsibility as he or she can and want to. In order for this to work, they state that everyone must have the right attitude and accept the differences in ambition. However, for the larger group of collective growers at Tillsammansodlingen, sharing the responsibility between everyone has not worked out. Since this requires meetings and involvement from the members, it assumes that some are willing to accept the commitment. Seeing as many members have some kind of responsibility position in their professional lives, and merely consider growing a relaxing hobby, not everyone is interested in taking responsibility. They are hesitant towards the matter, since **regulations and musts diminish the joy of growing.**

> I WOULD LIKE TO COME AND WORK WITHOUT HAVING TO TAKE ANY RESPONSIBILITY.

> WE HAVE THE PROBLEM THAT ONLY A FEW ENGAGED PEOPLE ARE DRIVING THE GROUP FORWARD.

Those growing collectively mention that there is a **difference in ambition and involvement** among the members. Especially in the big group at Tillsammansodlingen, the project is **dependent on a few enthusiasts** pulling the heavy load. A lot of passive members make it difficult to estimate the workload for the season and how to distribute the harvest. Despite their ideological starting point with working towards social sustainability and a system where everyone can contribute and be involved according to their own ambition, they have been forced to set a lowest participation level to even it out. However, interviewees in smaller groups argue that varying ambition and involvement levels are less of a problem since they know each other, and are aware of each other's attitudes and accept them. In all groups, the ambitions and involvement is strong at the beginning of the season, but decrease as the season went on. Thus, there is a problem to **keep up the ambition and involvement levels over the season**.

The feeling of having **influence and control** over the plot and **ability to affect the group agenda** is identified as an important factor when growing together. Some interviewees discuss that motivation and the emotional bond to the plant is lost if you cannot influence the result, or if someone else is doing all the work for you. It would not feel any different from buying just any locally produced vegetable.

A **difference in knowledge/experience level** among the members of a group does not necessarily have to be a problem. However, in combination with insufficient planning and documentation, some of the more experienced members spend a lot of time instructing and teaching, and thus end up in a responsibility position that they are not comfortable with. On the other hand, having skilled group members is a valuable asset for the less experienced, and asking for advice about the plants is a good way to start a conversation and getting to know each other.

> THE LEVEL OF KNOWLEDGE WITHIN THE GROUP DIFFERS.

For the collective growers at Tillsammansodlingen, the **communication and reaching out to all members** is a problem. They wish for a better communication tool that they can use for all kinds of information regarding events, tasks and guidelines for the group. The current communication is done through several different channels, both digital and analogue, and many find the tools **difficult to use and understand**. Furthermore, someone needs to update the information of what should be done, what has been done and when. They also express a wish for being able to know when members intend to go there to work. For users that grow individually and merely share the greenhouse space, there are fewer things that need to be communicated. In Solhusen, much information is shared on notes and boards in the greenhouse, as well as mouth-to-mouth, which is an efficient way in a smaller and more confined space such as the greenhouse, and since it is situated in connection to their homes, everyone will automatically see the information. The growers also specifically mention that they want more of an overview of the plot - what is planted where.

Sharing the harvest is something one could expect to be a reason for conflicts, and so it has on a few

occasions according to an interviewee, but is not considered a big issue. At Tillsammansodlingen, the system works in a way where members are allowed to harvest enough for one week of household use when they are there to work. Consequently, those who are there more often can take more vegetables and the distribution will thus be just. Since it often evens out in relation to each member's amount of work put into the plot, the problem can rather be that some vegetables (such as lettuce leaves) need to be picked more often so that new ones can grow. Nor has it been a problem that people would come more often during harvest season.

> I CAN PICK TWO LITRES OF BERRIES - I DON'T NEED MORE THAN THAT. IT IS GREAT THAT SOMEONE ELSE CAN TAKE CARE OF THE REST!

For the collective growers in particular, but also for the individual growers sharing an allotment or greenhouse, it seems important to the growers to **get to know each other** and be a coherent group. At Tillsammansodlingen, they mention that it is important to get to know **new members** and make them feel welcome.

> I'VE GOTTEN SO MUCH MORE CONTACT WITH MY NEIGHBOURS.

5.2.2.3 Selected focus areas

The user study revealed a multitude of various needs, and addressing all of them would be too comprehensive for a single product, and not possible considering the limited time frame of the project. Therefore, it was necessary to select a focus area for the concept development.

One of the main decisions to be made was if the development of the product should focus on people growing individually or collaboratively (sharing the plots or not) since this would affect what type of needs that were relevant.

It was noted that the practical issues (both regarding the vegetable cultivation in general and as well as regarding the shared greenhouse space) existed regardless if the growers had shared or individual plots. On the other hand, the organisational issues mainly concerned the people growing collaboratively, i.e. sharing plots, since a group activity naturally involves more aspects of organisation and communication. Thus, in order to limit the scope, a reasonable solution would be to exclude the organisational issues for collaborative growers. Moreover, many of these issues would apply to any group activity and are thus not specific for the activity of growing vegetables. Another argument for not designing a product specifically for collective growing was that many people in the study had expressed a negative attitude towards growing with neighbours and instead preferred to grow individually.

Furthermore, solving the needs regarding communication and organisation would also most likely mean moving towards a digital product solution, whereas the practical issues would move the project towards the development of a physical product. Since digital solutions for organisation and communication within groups are quite abundant, and since the result of the benchmarking study (section 5.1.2) indicated a market potential in developing a flexible and accessible plant container, the arguments for a physical product were stronger.

Therefore, it was decided to disregard organisational and communicational aspects and focus on the practical needs regarding cultivation and sharing the greenhouse space (but not the plots). Hence, a scenario was presumed where people will have individual plots, but having the possibility to form groups and grow collaboratively by combining individual plots.

Additionally, it was decided to proceed with low technology, non-automated product solutions. The main aspect that influenced this decision was that ecological sustainability was stated in the framework of the project. Since electronical components increase the complexity of parts and materials, can have a short life cycle, are energy consuming and imply harmful materials, implementing technology would make the product less sustainable. Secondly, the user study indicated a hesitation towards technological aids among people growing vegetables

on a hobby/leisurely level. Moreover, there are plenty of product solutions available on the market that facilitate growing, both for hobby and for large-scale cultivation, including everything from irrigation systems to phone application-connected sensors that the users may add if they wish to.

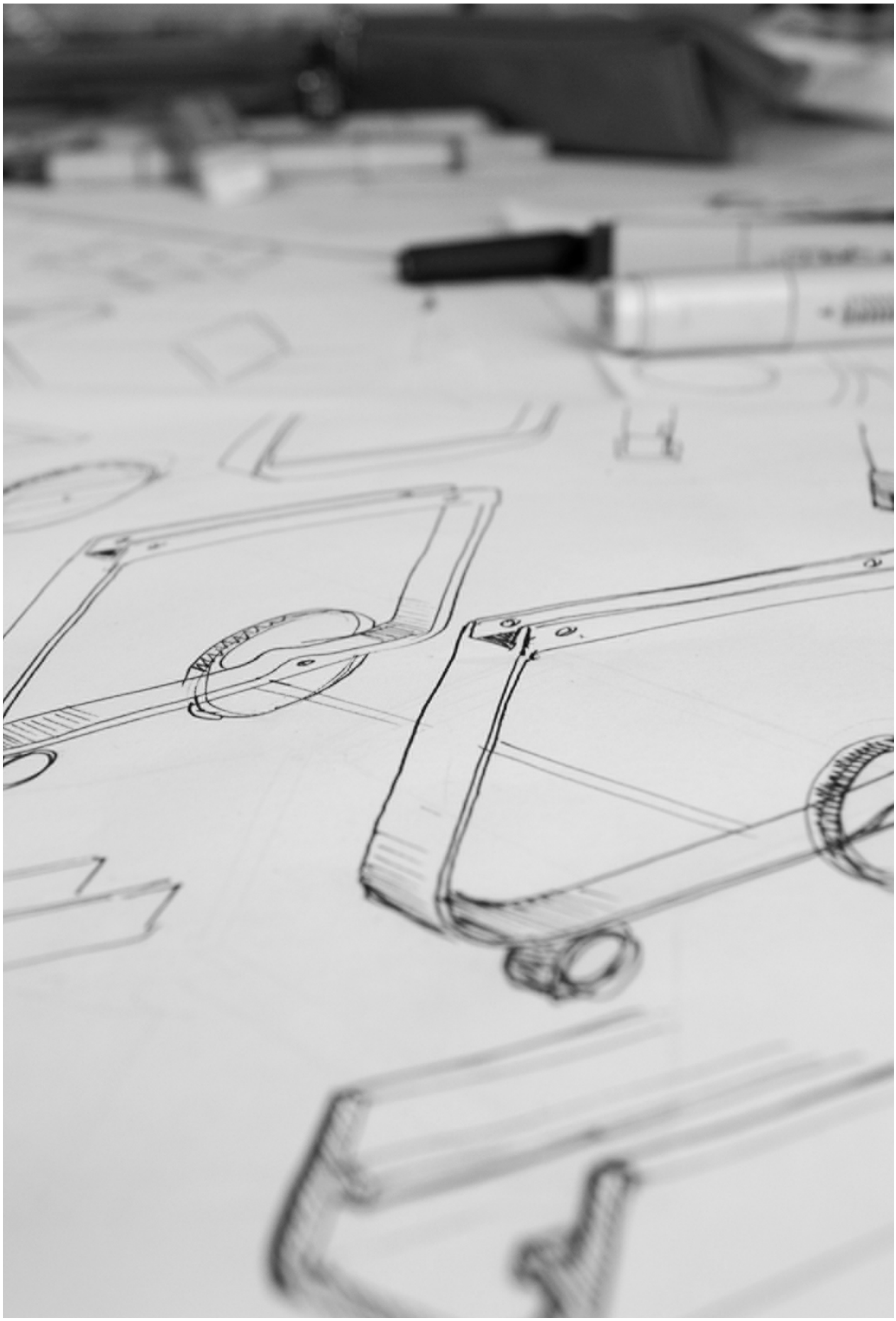


Figure 21. Sketches from concept development.

6 CONCEPT DEVELOPMENT & EVALUATION

The process of concept development involved several steps such as ideation, combination of solutions into concepts, and evaluation and verification of technical solutions. The process can be described as iterative and non-linear, where the various steps were repeated until a satisfactory solution had been reached.

6.1 Geometric shape and dimensions

As an initial step in the concept development phase, the product's geometry and shape were defined. Different primary shapes were explored by sketching different versions in Adobe Illustrator and with a paper models. The greenhouse space (created by the parallel thesis team) was sketched in miniature scale, whereupon small pieces of paper were moved around to create different grouping/placement combinations.

The shapes were then evaluated according to a number of different aspects. Firstly, an important aspect was which shape that would generate the largest growing surface based on the maximum width of 65 cm, a measurement based on anthropometric data for reaching distances and information about doorframe sizes (which had been previously specified in the product specification, Appendix VII). Secondly, the shapes were evaluated according to how space efficient the product would be when grouping several products into different combinations. A "worst case" placement scenario, where the containers would have to be placed as tightly as possible and the user only has access to one side or section, was considered. Another aspect was how the placement and grouping of the various shapes would affect the accessibility in terms of creating aisles and pathways. Since the greenhouse should be as accessible as possible, also for people in wheelchairs, straight aisles were preferable. Thirdly, finding a reasonable balance between maximising the growing area and facilitate movability (i.e. not being too heavy) was also taken into consideration. As for depth, the aim was to accommodate as many plants' needs as possible while not making the product too heavy, or exceed the maximum height of 60 cm specified in order to enable accessibility for people in wheelchairs.

The area calculations showed that the square and the rectangle allow for the largest growing area compared to the circle and the hexagon. Regarding placements, the quadrangular shapes do not generate any unusable space, as opposed to the circular. Since the container needs to be placed between other products, the square is superior to the rectangle (as it should have the longer side along the wall, which makes parallel parking difficult). For the same reason, the square is more adaptable to different greenhouse measurements and was thus selected as a primary shape.

The depth of the container was decided to 45 cm at its maximum depth, as this would facilitate most plants' root needs while at the same time have a weight that would be reasonable to move and a height that enable access by people in wheelchairs (and leaving a margin for wheels or other functionality that might require space). According to a test of different brands of soil bags (of 50 litres, which is a common size), their weight vary between 12.5 kg and 22.5 kg, depending on moist proportions and composition. This equals 0.25-0.44 kg/l. However, the weight of soil is highly affected by how much water it contains, why its weight is difficult to estimate exactly when watered frequently. The volume of a 65 cm * 65 cm * 45 cm container

equals 190 litres (0,19 square meters) which would weigh 47.5-83.6 kg un-watered. With moist soil, and full grown plants and vegetables, an estimated maximum weight would be 200 kg. This weight is considered possible to move, however, it rules out lifting as a means for moving the container.

6.2 Ideation

After defining the dimensions and geometry, an iterative ideation phase began. Initially, ideas and solutions were created for each of the functional requirements specified in Appendix VIII. The ideation was done in a systematic manner, addressing each of the functional requirements in a structured the process.

Several brainstorming sessions were held, both within the project team and on two occasions as a workshop together with other design students. At the brainstorming sessions with design students, the environment and scenario were described and a list of the functional requirements were presented. A timer was set to three minutes per requirement, during which the participants created solutions one by one, and visualised them with a pen and a paper. Subsequently, each person presented their ideas and thereafter the participants switched papers and developed each other's ideas further or created new ones.

The ideations resulted in a broad spectrum of more or less realistic ideas. The sketches and written ideas were organised into categories in order to create an overview, and redundant or less realistic ideas were sorted out.

Figure 22. Concept development.

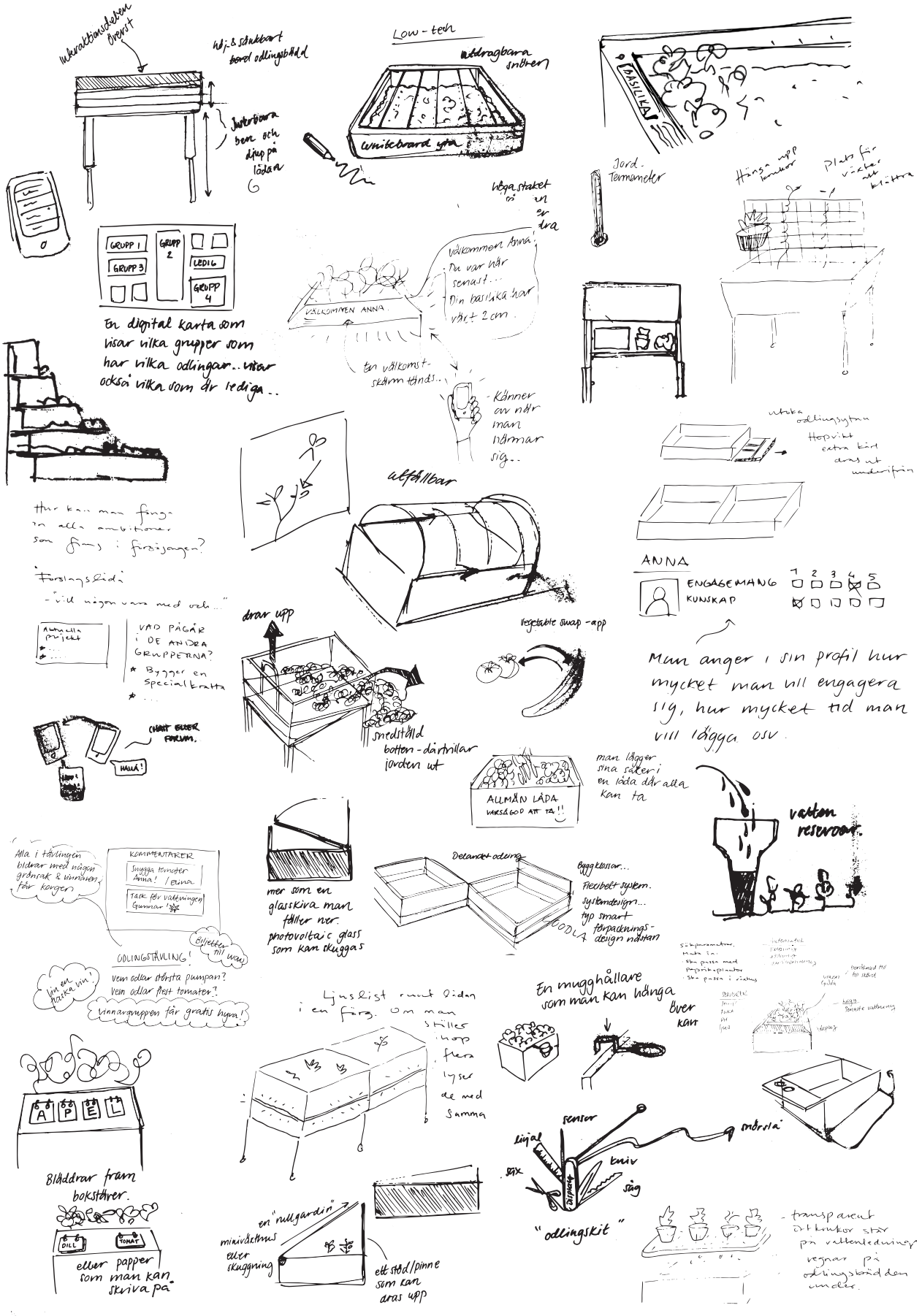


Figure 23. Concept development.

6.3 Concept creation

Some of the features demanded more complex technical solutions and were structurally dependent on one another and therefore had to be verified and developed in combination. The other features, that were less interdependent, were developed in parallel, but separately. The requirements with interdependent design solutions were:

- Enabling two height levels of the growing area
- Enabling different soil depths
- Facilitate emptying and filling of soil
- Providing seating possibilities
- Enabling movability

The solutions for movability are affected by the solution for enabling different height levels of the growing area, since the product should be able to move both in its low and high position. The solution for enabling different soil depths is also strongly connected to the solution for enabling height levels, since these parameters jointly make up the total height. Lastly, the solutions for providing seating area are dependent on the solutions for different heights, since the seating solution needs to work both in the high and low position. Moreover, in to save space, the solution for enabling seating should be integratable in the product and therefore it is connected to the adjustment of soil depth as well.

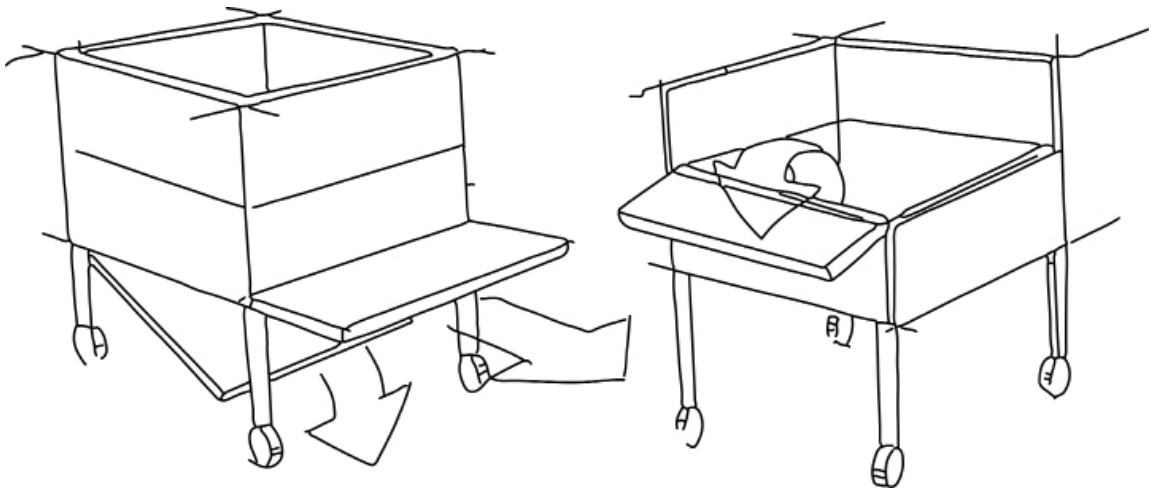
The various solutions to each of these requirements were combined into basic and conceptual concepts, in order to be able to evaluate and verify whether their technical solutions worked together or not.

The solutions were put into a morphology chart (See appendix IV) and combined into three concepts.

6.3.1 Basic concepts

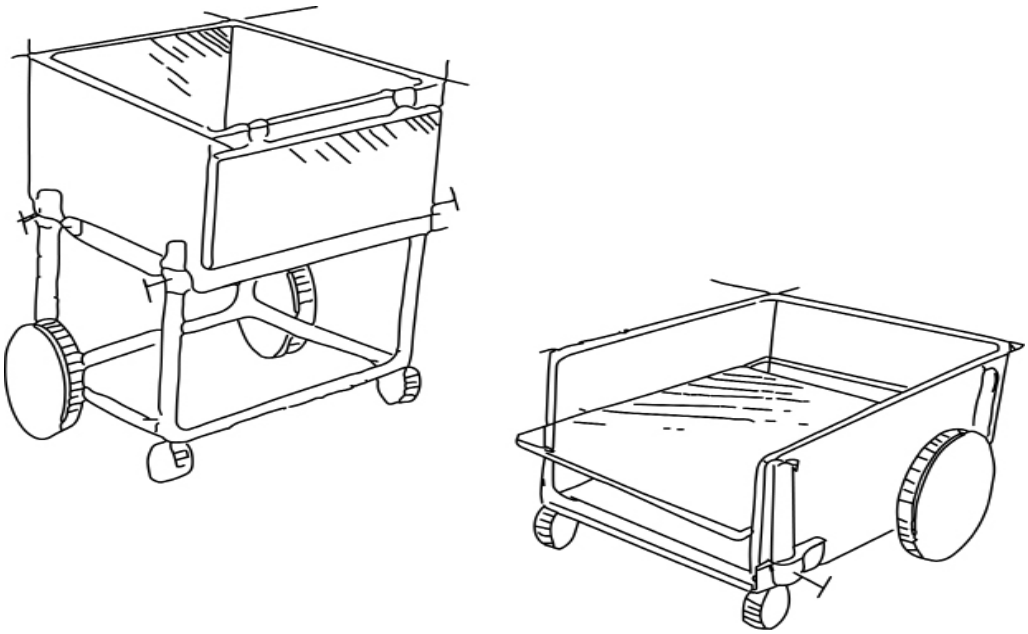
Concept 1 - Double version

This concept is based on providing a product line two product versions of the same square-shaped container, one higher and one lower, to get solution that is mechanically as simple as possible. A bench comes with the higher version and is pulled out from underneath. The container has an opening bottom plate for emptying and foldable edges to adjust soil depth. Both the higher and the lower have four swivel caster wheels.



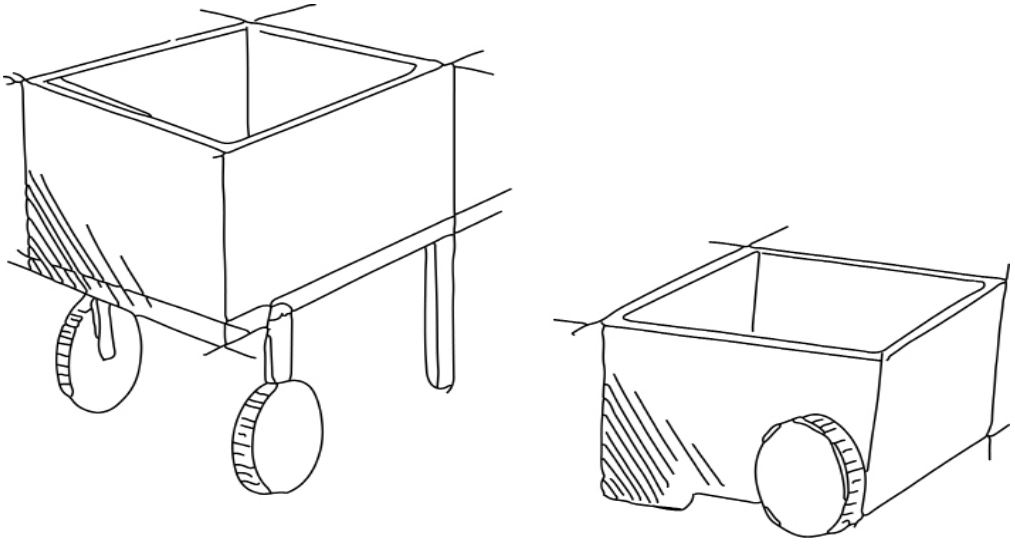
Concept 2 - Flexible

This concept is flexible and adjustable in both depth and height, to accommodate all users and plants. The container can be moved up and down along a fixed construction with a pin solution, and can thus be placed on several height levels. It has four wheels for transportation; two regular and two swivel casters. To adjust soil depth, it has a movable bottom plate similar to a bookcase, which works well with the opening side that also facilitates emptying. A bench hangs on the side of the container and can be attached at both the top and the bottom.



Concept 3 - Foldable

This concept is based on a wheelbarrow principle and has folding legs with two wheels that work in both high and low position. With a fixed medium depth, most plants' needs are met and it is possible to fill up with hydrograins in the bottom. One side opens for emptying, and the container can also be tilted due to its wheelbarrow function. A bench is hidden underneath.



6.4 Evaluation

The combined concepts, as well as the various solutions and ideas for the requirements that were independent, were evaluated in a number of ways. The evaluation process was iterative, especially regarding the technical solutions that were evaluated and readjusted repeatedly until all possible solutions had been considered and a satisfactory combination has been achieved.

6.4.1 Mock-ups and discussion with experts

The complexity and feasibility of the technical solutions required for the different features were tested with mock-ups and sketches, and thereafter evaluated and discussed together with various experts within manufacturing and solid mechanics.

6.4.2 Concept evaluation with Pugh's chart

The three concepts were evaluated using a Pugh's chart that can be seen in appendix X. The ratings were based on several parameters, such as mechanical complexity, estimations of how easy they would be to manage for the user and how well the features worked in combination with each other.

Enabling height levels
Regarding the solutions for enabling two height levels, concept 1 was rated the lowest since it was decided that the product should, in itself, be

Figure 24. Mock ups.

adaptable in height rather than providing a product line with two different height versions. This was considered to be more in line with the inclusive design principles. Since it is not the users who will be making the decision about whether to purchase the low, the high or both versions, there is a risk that the consumers (i.e. housing associations) would look to the price rather than considering accessibility for all the people in the community. Thus, a problem might arise where only the low version of the growing container would be purchased (it would be cheaper than the high container since it does not include as many components and lack the bench feature). Therefore, the decision was made to steer the consumers into being socially sustainable through design, by only providing a single product that is adjustable and accommodates everyone, and thereby eliminates the possibility for the consumers to, actively or accidentally, exclude some of the residents from participating in the growing activity.

For the remaining two concepts, 2 and 3, the mechanical simplicity of the height adjustment solution where the container slides along the leg frame and is fastened with pins was valued higher than the solution with folding legs. The mechanism for folding the legs while at the same time enabling the wheels to function in both positions, proved to be too complicated. Even though the container needs to be lifted in order to raise it to the higher level, this is assumed to be that height adjustment is done with an empty container and maximum once per season or when switching owners.

Enabling movability
As for movability, concept 2 has four wheels, of which two are swivel casters in order to allow for easy rotation of the product. While the solution with two wheels might look simpler and gives the product a wheelbarrow shape (a well known archetypal shape associated with gardening and cultivation), four wheels are more stable and makes the product easier to move considering its weight.

Enabling different soil depths
The solution with a medium soil depth was considered to be the most simple, whereas on the other hand, the solution with foldable sides was considered too complex, and not very easy and efficient to use. The solution with a movable bottom plate was seen as almost as simple to construct and use as the medium depth. Moreover, it is more beneficial for the user in the sense that it makes it possible to reduce the amount of soil that is necessary to fill up the container (for example when growing herbs or other shallow rooted plants) and thereby save money, time and effort. Moreover, the movable plate could be integrated with a drainage solution, which in any case would be needed at the bottom of the container.

Facilitate emptying and filling of soil
Opening one of the sides of the container to facilitate filling and emptying of soil was assessed to be superior to the solution where the bottom was opened. In order to open the bottom of the container it would have to be in the high position (since it is not possible to access the bottom in the low position), and it would be too heavy and complicated to raise the container from low to high position when it contains soil. Furthermore, it would only facilitate emptying and not filling of soil, and in addition it requires a wheelbarrow to fit underneath to collect the soil as it is emptied. Opening the side of the container was consider to be a much simpler solution, and it also works well in combination with the movable bottom plate for enabling different soil depths.

Providing seating possibilities
The bench solutions were judged to be equivalent in complexity and usability. The benefits of the hanging bench, however, are that it works better in both heights and that it does not interfere with the leg/height construction.

As a total result of the Pugh evaluation, the concept scoring the highest was number 2.

6.4.3 Evaluation with users

In addition to the Pugh matrix, evaluations were conducted with potential users, in the form of discussions with a group of people that have experience in growing plants and vegetables as well as a background in industrial design engineering. The aim was to get their input on the pros and cons of the different solutions and features as well as their usability.

The solution with foldable legs with wheels that work in both heights was considered interesting but the general opinion was that the simplest solutions possible were best suited for a cultivation product. Even though concept 1 is technically the simplest solution, it was considered less context appropriate, as the product will switch "owners" regularly. In general, concept 2 was rated highest, given the shared since it is flexible but at the same time simple to use and understand.

Regarding movability, some doubted that the four swivel casters of concept 1 would be easy enough to manoeuvre and crossing thresholds. Moreover, although the wheelbarrow concept gave strong associations to cultivation and gardening, a few participants were worried that the container would be too heavy for some users.

Being able to adjust the soil depth was an appreciated feature, especially when solved as easily as in concept 2. The folding sides were considered a little more complicated than the movable plate, since they require several hinges and locking mechanisms, and would also interfere with height.

The idea of including a trellis feature was well received, especially since many plants in a greenhouse grow tall. However, it was discussed whether it would shadow other containers if it was too high.

Concerning grouping/connecting the containers, several ideas were given positive feedback, but that it should not hinder movability, and hence be easily separable (if something that physically locks the containers together).

The requirement of facilitating the user in planting and seeding was discussed based on sketches of some different tools. Mostly, the solutions were considered fun, but not necessary. A ruler on the edge of the container was the most appreciated idea, since that would not require any extra mechanism (compared to e.g. the extensible measuring tape) and was seen as decorative as well as functional.

6.5 Selected features

Based on the evaluations, concept 2 was selected. Additionally, a number of extra features were added.

Trellis, connecting the containers and preparation area/shelf

It was decided to proceed with a trellis solution that is detachable and can be placed anywhere in the soil. Also, it can be put over the edges of two neighbouring containers and thus create a shared shelf for pots. The intention was that neighbours in the greenhouse would have a small joint space while not having to go as far as to grow everything collectively. Further, the side edges of the container are slightly wider to provide the possibility to place smaller things there.

Aid for sowing and planting

As a graphical pattern and a tool for placing the seeds according to the instructions on the package, a ruler was included inside of the container's upper edge.

Labelling of container

The possibility tag the container with each person's name was included, to facilitate identification (as they can be moved around) and to make it more personal than e.g. an apartment number.

Figure 25. Final concept in high and low position.

7 FINAL CONCEPT

This chapter describes the concept refinement, which includes detailed design solutions, form and expression, materials and visualisation. Thereafter, the final result and outcome of the project is presented.

7.1 Further Development

7.1.1 Detailed design and technical solutions

The concept was developed further by making detailed design solutions for the various features, and making the product and its parts into a unified whole. This was done by making sketches, mock-ups and digital models to test and verify the technical solutions.

7.1.2 Form and expression

The product should be **friendly** in the sense that it is accessible and welcoming to everyone in the community. Also, it should be experienced as a helpful growing companion. Thus, one could say that friendly, in this case, means that it should feel accessible and flexible.

The product should be perceived as **simple** to use. By making the product seem simple, the aim is to make people think of the growing activity as simple as well, which might encourage more people to participate in the greenhouse and grow vegetables. Furthermore, a simple and somewhat unpretentious aesthetic expression was desired, both since this was considered to be in line with the down-to-earth growing activity, as well as in order to enhance the expression of sustainability, described in the following section.

Contributing to sustainability and ecological awareness is one of the overall objectives of the development of the product and its use. Also, making the product itself sustainable has been an important aspect throughout the process of design and construction. Thus, **eco-friendliness** is important to convey through the aesthetic expression. Additionally, since the product will be used for growing vegetables, it is important that it is perceived as ecological/sustainable and thereby free of harmful materials and chemicals.

The product is highly functional and utilitarian, since it aims to be an aid or tool that meets many practical needs in a shared greenhouse, in an analogue and low-tech manner. In this case, **functionality** also means robustness, since this is important in order for it to be suitable for the activity of growing vegetables. Therefore, its functional nature should be shown through its aesthetic expression.

In order to achieve the desired expression, a multitude of sketches as well as a variety of computer models were created. Also, an inspiration board containing various form elements and products that matched the desired expression was used as inspiration and guidance. The inspiration board contained various products, such as garden furniture, folding tables and a variety of carts.

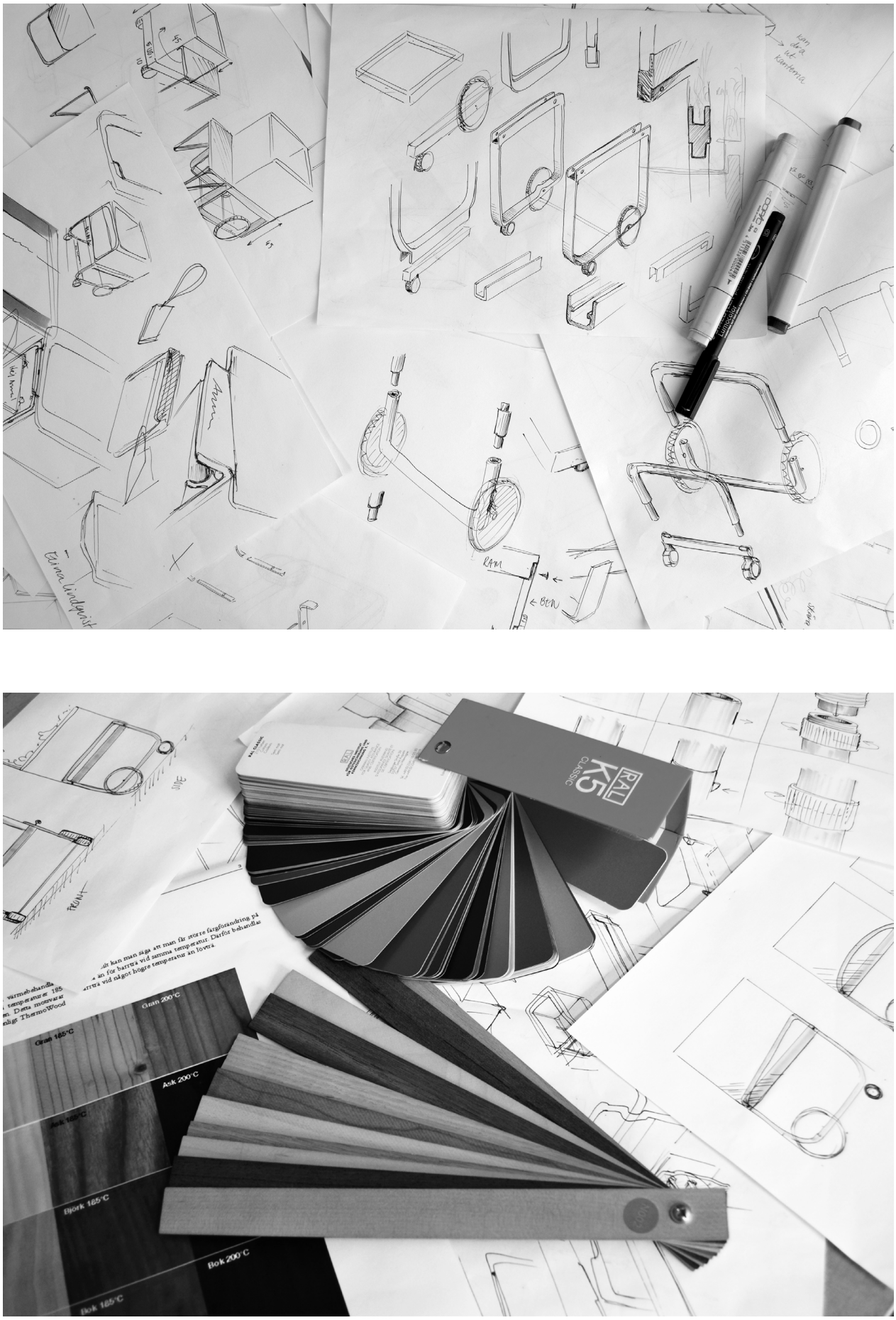


Figure 26. Sketchning, colour and material suggestions.

The expression was evaluated with help from professional product designers on several occasions, both with respect to shape and colour. The product's colour scheme was determined by investigating the natural hue of different materials and by using a NCS index.

7.1.3 Material selection

For the product to be as environmentally sustainable as possible, it should preferably include a minimum of different materials (that should also allow for easy disassembly). Other criteria that were considered included:

- Resistance - the material should withstand temperature changes, humid air, soil and water contact and use wear
- Strength and solidity - the container should hold the weight of soil and water, and the bench should allow for one person (or two smaller) to sit on it
- Expression - the material should correspond with the desired look and feel, stated in Appendix VII.
- Sustainability - for environmental reasons and since it is intended for vegetables, the materials should be sustainable and not be treated with any harmful chemical preservatives
- Manufacturing techniques - cost and environmental impact should be minimised

Material selection was based on studies of websites, literature and discussions with two material experts. Moreover, material was studied in combination with calculations of applied mechanics, where an associate professor at Chalmers University of Technology was consulted regarding construction and safety concerning solidity and overbalancing.

7.1.4 Digital construction and visualisation

The product concept was constructed and visualised digitally, using computer modelling, with the CAD softwares Alias Automotive and CATIA. The models were visualised with renderings produced in Keyshot and Adobe Photoshop.

7.2 Final result

The final concept is a flexible and accessible planter module that allows for everyone to participate in the activity of growing their own vegetables, which encourages a more environmentally sustainable approach to the food system, and enables social networking among neighbours.

7.2.2 Parts and assembly

The product consists of a wooden container that is attached to a metal construction, which in turn is made up by three separate parts, an upper frame to which the wooden container is attached, a leg construction and lastly a bottom frame on wheels. The different parts rests on one another and are locked with four pins. Additionally, the product has a number of detachable parts, a metal grid forming an inner bottom plate for the container, an inner plastic container, two detachable metal trellises resting in the bottom frame, a detachable bench resting in mountings under the container and a name sign hanging over one of the edges of the wooden container. The different parts are shown in the picture below.

The wooden container has four independent and separable sides panels, which are held together by metal mountings in the corners. Each side panel is constructed by ten transverse boards, each 50 mm high. On two of its sides, the container's edges are extended 50 mm to form wider edges/shelves at the top. The outer measurements of the wooden container are 700 x 700 mm (with the extended edges at the top) and the inner measurements are

Figure 27. Final concept

700 x 600 mm. It has a depth of 500 mm (out of which 450 mm is available soil depth and 50 mm is used for water drainage and to attach it to the upper metal frame). The inner plastic container is 660 mm x 560 mm x 400 mm. One of its sides can be opened and closed with buttons.

The upper metal frame has brackets in which the wood container is placed, and has a closed bottom in order to collect drainage water. The bottom of the frame also has a drainage hole and a plug for letting the water out. The bottom is slightly tilted inwards to collect the water at the outlet. The metal frame has hooks along two of its sides, which enables it to be placed/hanged onto the leg construction. Furthermore, two rails are situated under the frame, holding the bench.

The leg construction consists of a single metal profile, with a rectangular shape. It has a quadratic cross section with a width of 20 mm.

The bottom frame consists of a U-profile, in which the leg construction is placed. The frame has four wheels attached to it. The two front wheels are swivel casters, with a diameter of 80 mm and width of 50 mm, to ease steering. Their dimensions are estimated based on similar wheels that can withstand a payload of 100 kg each (Tellus, 2014). The back wheels are larger, with a diameter of 250 mm and width of 300 mm, to manage obstacles.
bild

The different parts are stacked on one another and four pins lock the container, the upper frame, the leg construction and the bottom frame together so that it is possible to slightly lift the whole module e.g. when running over a threshold.

The product can easily be assembled and disassembled without using any tools. When disassembled, the parts can be stored space efficiently, making it easy to adjust the number of modules according to the number of growers.

Figure 28. Separated parts

7.2.3 Use and handling

7.2.3.1 Adjustable height

The planter module can be used in two different height levels, which makes it more accessible to everyone in the user group. In the high position, the growing area is at 95 cm, which is within the limits for an ergonomic working height for adults. Working in a standing position is preferable from an ergonomic viewpoint, especially for people who have problems kneeling or bending. In the lower position, at 60 cm, the module is better suited for children or wheelchair users.

The possibility to have the module at a high or low level is also beneficial in the sense that it accommodates different plant heights. When growing small plants, such as herbs, the user has better access in the high position. However, if the user grow tall plants, such as tomatoes or cucumbers, the module can instead be mounted into the low position and thereby providing more room for the plant to grow vertically, reducing the risk of shadowing other modules, and making it easier for the user to access the plant and the crops.

The planter module is designed to be easily mounted into either the low or the high position. When changing position, the user simply pulls out the pins that lock the container, the leg construction and the wheel frame together. Thereafter the user lifts off the container, turns the leg frame upside down (i.e. rotates it 180 degrees), places the container back in position and locks it by putting back the pins. This procedure can be done without having to use tools or add any extra components.

It is preferable to change the height when the container is empty, such as at the beginning of the season, since it can weigh 150-200 kg when filled with moist soil and plants. It is, however, possible to change the height while having soil and plants in it, by being two or more people lifting off and on the container.

Figure 29. Two height levels.

Figure 30. Height adjustment, child using the product.

7.2.3.2 Flexible bench

Apart from enabling and facilitating cultivation of vegetables, the planter module also aims to encourage and facilitate social interaction among the users in the greenhouse. Therefore, the planter module has a bench, which enables the users to sit down and relax in the greenhouse, or have a coffee while talking to the other growers. It can also be an aid for older adults that might need to sit down and rest.

In order to save space, and provide flexibility, the bench is retractable and rests in rails underneath the container. When wanting to use the bench, the user pulls it out from underneath the container, folds out the legs, and hangs it onto the leg construction with a hook.

The bench can be used when the module is in its low and high position, and the procedure is the same in both cases. The seating area is placed at 450 mm above ground in both positions.

Several containers can be placed together to form bench constellations that accommodate a group of people. It is also possible to create a small room within the greenhouse, for the users that wish for solitude and come to the greenhouse to relax and unwind. Elderly or weaker users can fold out their own or the neighbour's bench to sit down, and children that do not reach the higher container can climb up and kneel on it. If the greenhouse is spacious enough, it is possible to keep the bench folded out during winter season to hold pots.

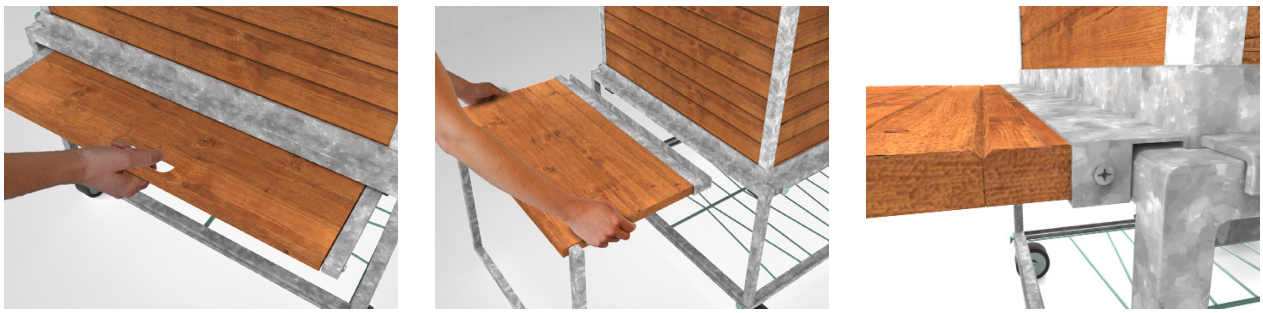


Figure 31. The bench in both height positions- how to pull out the bench.

Figure 32. Man using the bench.

Figure 33. Coffee in the greenhouse

7.2.3.3 Movability

Since the shared greenhouse is a dynamic and changing environment, the planter module has wheels so that it can be moved around and placed in different layouts. This allows the users to organise and arrange the greenhouse space according to how many growers there are, and how they prefer the space to be like. The modules can be grouped in various formations if neighbours decide to get together and share their plots or be placed according to different plant heights so that they do not shadow each other. Moreover, the planter modules can be moved aside or brought outdoors when cleaning the greenhouse, or merely to work outdoors on sunny days. It has two large, fixed wheels that can manage thresholds and obstacles, and two smaller swivel casters to facilitate steering.

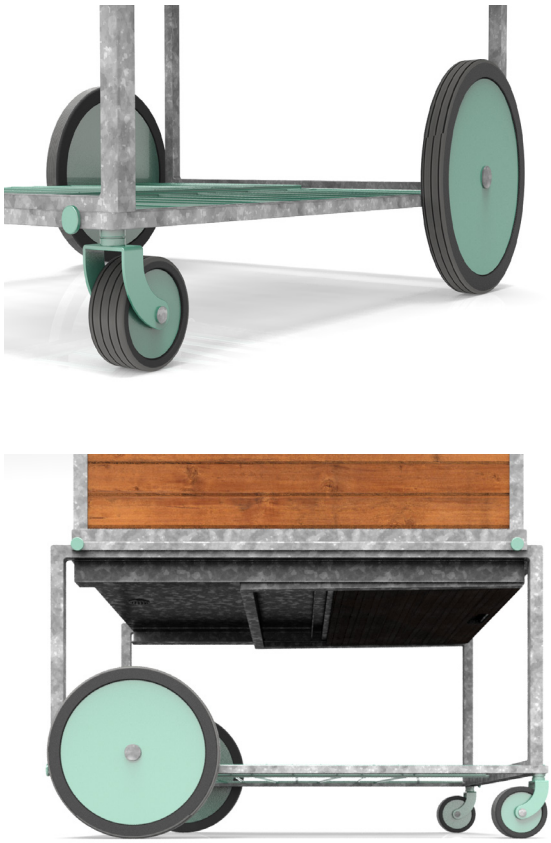


Figure 35. Wheels.

Figure 34. Moving the planter module.

7.2.3.4 Opening side

The planter module facilitates the task of handling soil by enabling the user to open one of the container's sides, making it easier to fill and empty the soil. The user simply removes the panel on the container's rear end by lifting it upwards, using the carved handle.

7.2.3.5 Protective inner container

The planter module has an inner container, which protects the wood from getting into direct contact with the moist soil. One of the sides of the inner container can be opened and closed, using snap buttons, when filling or emptying soil. The container's bottom is made in a loosely woven net structure to enable drainage of water.

The user places the inner container on the grid inside the wood container and fills it up with soil. The container is made of a waterproof and durable material (see more section 7.2.4 on materials), which can be washed and reused.

7.2.3.6 Adjustable soil depth

Since different plants have different root depths, the bottom grid can be placed at two different heights inside the container, in order to make the container deeper or shallower. This allows the user to adapt the depth to specific plants and choose whether to fill the whole container with soil or not, which saves both energy, money and material. The grid works similar to a closet shelf and is supported by the container's metal mountings in the corners. The grid structure enables drainage of excess water, which is collected in the metal frame holding the container.

Figure 36. Open side with grid and inner container.

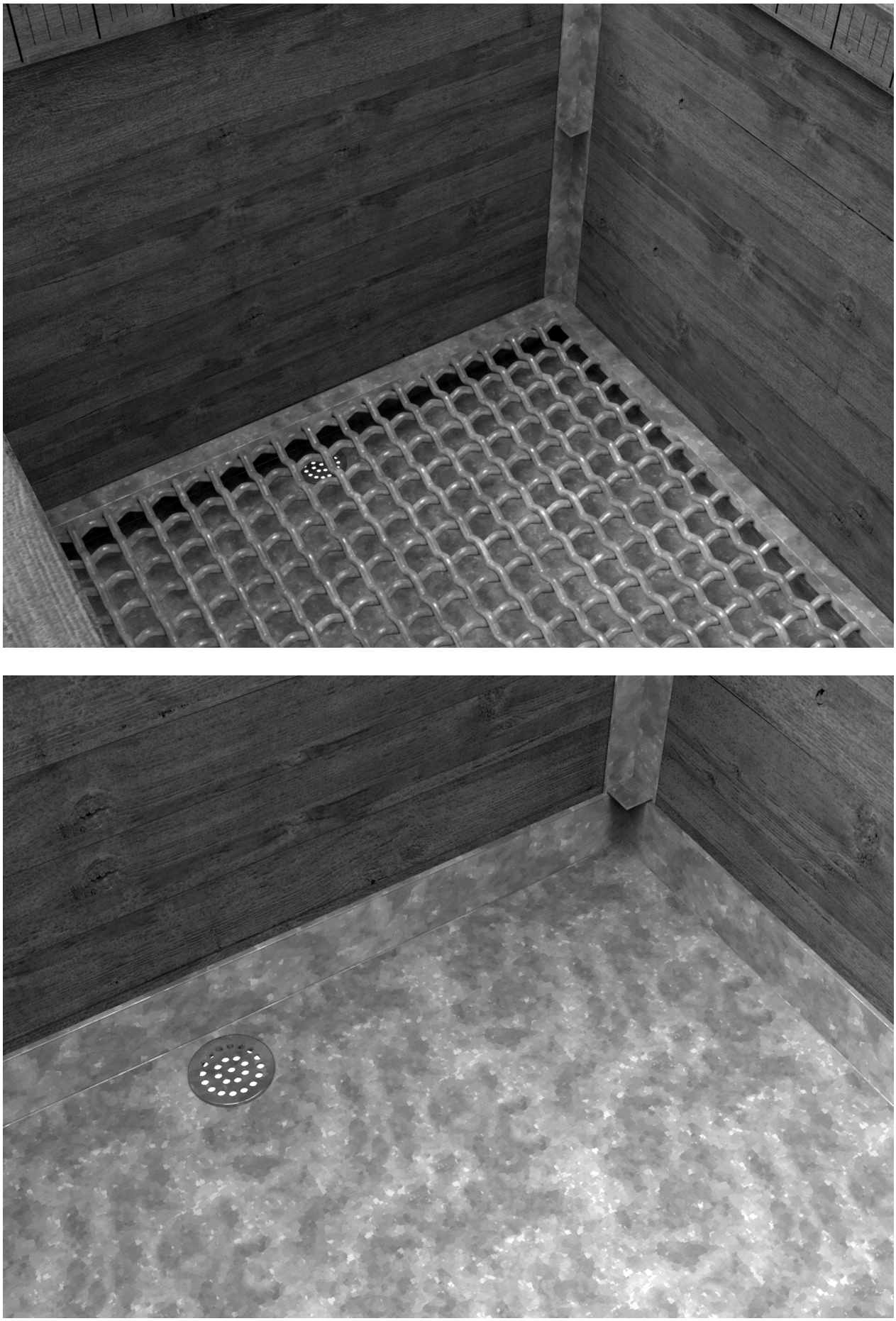


Figure 37. Grid and bottom plate with drainage hole.

7.2.3.7 Ruler pattern

In order to assist the users when sowing and planting, the planter module has a ruler pattern on the inside of the container's edge. The ruler pattern consists of small carvings in the wood (which are laser cut and thereby given a darker colour) and can help the user to create correct spacing in between seeds or create straight lines. It is as a decorative as well as functional feature.

7.2.3.8 Flexible name sign

In order to be able to identify the planter modules (since there might be up to 30-40 modules together depending on the size of the greenhouse and the housing community) there is a detachable and movable chalkboard name sign where the users can write their names. The name sign is simply hung over the edge of the container, enabling the user to place it on the side that is most visible depending on the current placement of the module, or hang several signs onto one container if it is shared by a group of people. The chalkboard also enables a more personal atmosphere is the greenhouse, since people are encouraged to identify their modules with hand-written names (or any kind of drawings and text) rather than by anonymous apartment numbers. The chalkboards can also be used for writing down other information, such as what kind of plants that is grown in the container. It could also be imagined that people growing in groups can write notes or messages to each other on the chalkboard.

Figure 38. Ruler and name sign.

7.2.3.9 Trellis

Each container comes with two metal trellises of size 350 * 700 mm, that can be used in three different ways. When placed at the bottom, in the wheel frame, they form a storage area for e.g. soil bags or tools. They can also be put directly into the soil so that the plants can climb and twine around them. Lastly, they can be placed between two neighbouring containers, onto the containers' edges, and create a shared shelf for potted plants or to place tools while working. Thus, the neighbours that use the greenhouse are not forced to share containers and the growing area, but are still enabled and encouraged to have a small, shared area in between their containers.

Figure 39. Trellises.

7.2.4 Material

The container's sides consist of panels of thermowood; heat-treated pinewood. Heat-treatment is an environmentally friendly method that increases the biological resistance of the wood, without any chemical preservatives. The wood obtains properties similar to tropical wood and is thus suited for the humid climate in the greenhouse. The method consists of drying and heat-treatment in over-heated steam at one atm, drying at a temperature above 100 degrees Celsius, heat treatment at 185-212 degrees Celsius and lastly cooling and hydration to a moisture level of 4-6 degrees Celsius. Another benefit is that the reduced moisture uptake from the air, and consequently reduced expansion and contraction, makes the material more dimensionally stable. Moreover, ongoing research indicates that heat-treated wood is less likely to mould (LTU Skellefteå, 2012).

The sides of the inner container are made of material Xx, a waterproof but yet sustainable material that is free from harmful substances. The bottom of the container is made in a net structure in the same material, which allows water to drain through the container down into the metal frame underneath.

All other parts of the product are made of galvanised steel. When galvanising steel, the metal is dipped in molten zinc that alloys to its surface, which increases the life of the material by 40-100 years. Compared to untreated metal that easily corrodes, galvanised metal is protected from the elements why its structural integrity is maintained. The method is relatively cheap and sustainable in the sense of increased life span, that the unused zinc is collected and reused, and that zinc in general can be recycled over and over without losing its chemical or physical properties (Thompson, 2007).

Additionally, the wheels, trellises and pins are powder coated to create colouring.

7.2.5 Form & expression

The planter module has been designed to have a simple, functional and eco-friendly expression (see section 7.1.2 for more information on why this expression was desired). This has been achieved in different ways, both through form and colouring as well as through the design solutions.

The product is designed to be low-tech and so that its functionality and construction is visible, making it possible to see what parts it consists of and how the different parts are attached to each other. This was done in order to provide a high level of explicitness and visual clarity to the user, which enhances its usability. It also makes the product express simplicity and honesty, which also is connected to the feeling of eco-friendliness. The low-tech design is also in accordance with the natural and simple activity of growing vegetables. The fact that it is low-tech and simple also makes it more accessible and attractive to elderly, who might be discouraged from using the product if it was too complicated and high-tech. The simple and functional design also gives it a high level of compatibility, i.e. it corresponds to other existing gardening products and outdoor furniture.

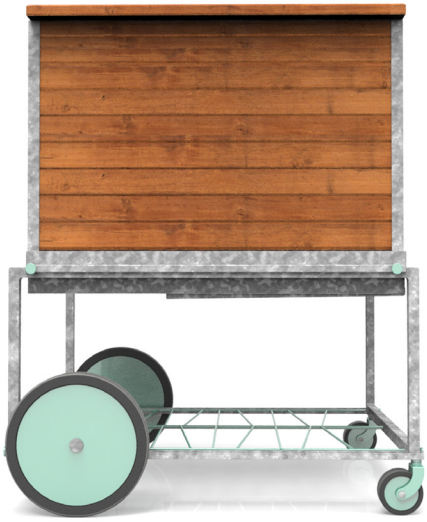
The product is also constructed to provide a high level of user control, for example deciding if and when to have the product in a high or low position, when to use the bench and when and how to use the trellises. This enhances its expression of flexibility and accessibility.

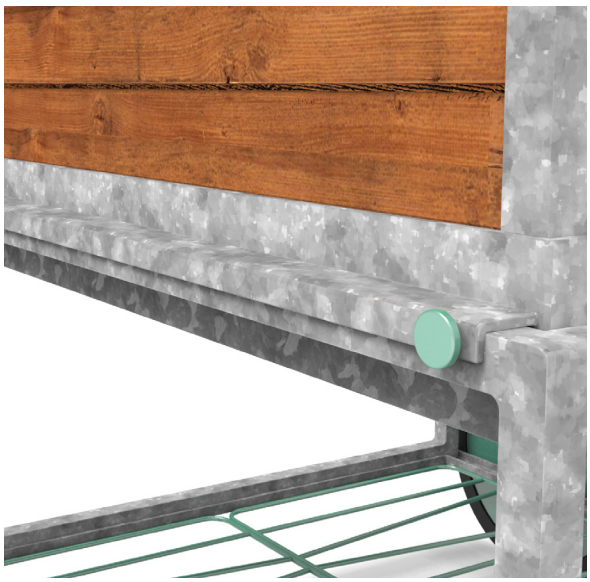
The product has two big wheels in order to give clear cues to its movability, and enhance the feeling of movability. The two large wheels also give the product a hint of playfulness, giving it a more friendly expression.

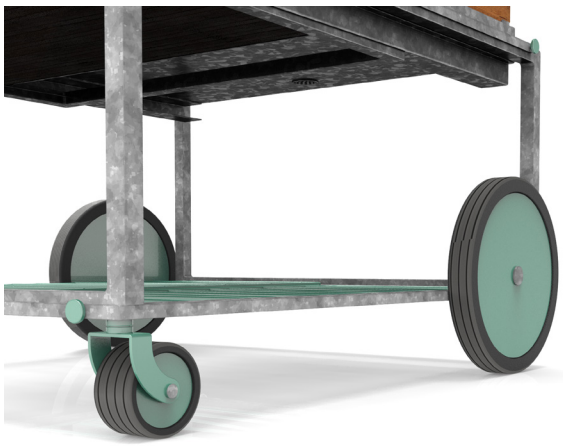
The planter module has an airy and open leg construction, which makes the product feel less heavy and stationary, and thereby more movable and flexible. It also helps create a more airy and light space in the greenhouse. The simple shape and design of the leg construction also enhances its expression of simplicity, both in how it is used and how it looks.

The product consists of two main materials, wood and metal, which are two robust and resistant materials that makes the product feel reliable and resistant to soil and water. By letting the product's materials have their natural colours, the simple, eco friendly expression is also enhanced. The choice of materials is both in line with similar, existing outdoor products as well as the nature of the growing activity.

The product's otherwise natural materials are complemented by an accent colour on the wheels, trellises and pins, in order to create a contrast and make the product expression more interesting. Moreover, it strengthens the feeling of playfulness and friendliness, as well as increases the explicitness by highlighting some of the parts that represent important functionality. The trellises' asymmetrical pattern of diagonal lines also acts as a contrast to the otherwise straight and symmetrical shapes.







8 DISCUSSION

The following chapter elaborates on the master's thesis as a whole; the process, the product, lessons learned and hypothetical recommendations for further improvements.

8.1 Project process

8.1.1 Starting point

The project had a relatively open starting point, aiming to create a product that would enable, facilitate and encourage cultivation in a shared greenhouse. Merely defining what this task actually implies and what type of product that would be best suited as a solution resulted in a wide and comprehensive research phase. Further, since there was no partnering company involved, decision-making was a challenge throughout the process. While it is a fun experience being able to develop a product without constraints or limitations, there was sometimes a lack of realistic framework. Consequently, the scope was kept too wide throughout the majority of the project, which made it difficult to match the high ambitions for the project within the time frame.

With that being said, the overall project process was successful and the chosen methods generated valuable information. It was particularly interesting to include an object-based technique, which was the method that was most new to the project team. Creating a collage together gave great insight into the users' emotional experience.

8.1.2 Research

As mentioned previously, the research scope was very wide and covered different types of users as well as the whole experience of growing vegetables and growing together. This was both due to the fact that the problem was not defined on a detailed level, and thus required as wide scope, and also because it was not possible to gain access to people representing the exact target group. In retrospect, after having chosen a concept track, a narrower scope for the research would have been useful in order to get more specific and deeper information about the task-related problems that are associated with greenhouse cultivation and the current growing containers.

Moreover, since the research aimed to investigate both individual and collective vegetable cultivation, the study actually included two distinct user groups. When interviewing users growing vegetables in groups, the issues primarily concerned group organisation and communication rather than the actual vegetable cultivation. This meant that, after choosing to focus on one of the user groups, (the individual growers), half of the collected data was no longer useful. Had more time been available for the project, it would have been preferable to conduct an iterative study after choosing the target user group, in order to gather more specific data.

Moreover, a major difficulty in the research phase depended upon the season. Since the data collection primarily was conducted in February and

March, it was not possible to study the users while performing the growing activity or study the current products in use.

One might also consider the validity of the results from the study, since many of the interviews were conducted with users that were not fully representative for the targeted user group, in the sense that they were growing vegetables outdoors rather than in greenhouses. Although it would have been desirable to include more people growing vegetables in greenhouses, this does, however, not necessarily imply that the obtained information is inaccurate (since the growing activity still is similar) but rather that some greenhouse-specific issues could have been missed out on. Additionally, there could have been a wider and more even distribution of age groups in the study, in order to increase the validity of the results.

Regarding the reliability of the results from the study, one could argue that when performing individual interviews with users, there will always be a variation in the responses, especially when collecting qualitative data about soft values such as emotions and attitudes. Nevertheless, it was concluded that people have different attitudes and motives for growing vegetables, and this would most likely be proved if conducting the study again. Also, many of the participants expressed similar problems, indicating that the results can be considered to be reliable. The observations made in the shared greenhouse might also vary depending on what greenhouse one visits, however, the conclusions drawn, e.g. regarding flexibility and accessibility, are likely to be valid for all shared greenhouse environments.

8.1.3 Concept development

Concerning the product development phase of the project, it was conducted such that a distinct product track was determined whereupon basic concepts, that all fulfilled some specific requirements, were created. An alternative approach could have been to maintain a broader perspective and evaluate concepts that differed more in character, which may have generated another outcome and user response.

Again, a lack of limitations and definitions resulted in a very wide scope also for the concept development, thus requiring much iteration and being time consuming.

Another major challenge during the project was the interdependency of the technical design solutions for some of the features. Since the construction of the design solutions had to be compatible and verified in combination with each other, and changes in one design solution impacted the others as well, the detailed design and construction of the product proved extremely difficult and complex. Consequently, many of the solutions were chosen based on compatibility and combination possibilities. This means that some solutions may have been better stand-alone, but were not compatible in combination with the other solutions.

Since each concept had to be taken to a detailed level in order to verify that the various solutions were compatible, and all aspects has to be considered simultaneously, the iterations were very time consuming. The process was further complicated by the high demands regarding usability, accessibility, flexibility, and space efficiency imposed on the technical design solutions.

All of the specified requirements for the product were not quantified and it is consequently difficult to determine whether the final concepts fulfils them completely. For exact measurements of dimensions, tests and expert evaluations would be needed.

8.2 Final concept

8.2.1 Fulfilment of aim and goal

The aim of the project was to enable, facilitate and encourage cultivation of vegetables, as well as social interaction, in shared greenhouses used by residents in a housing community. This aim includes a number of different aspects, which can be interpreted and achieved in different ways.

Regarding the aspect of enabling cultivation, the

product is able to contain soil and withstand water, which are two basic necessities for enabling plants to grow. There are, of course, other aspects that are needed for cultivation, for example providing light and appropriate temperatures, but these were considered to lie beyond the product boundaries since they are fulfilled by the greenhouse environment.

The product also enables cultivation from the users' point of view, by being accessible to as many as possible within the target user group and thereby including as many as possible in the growing activity. Since accessibility in this case mainly concerns how the product caters different physical abilities among the users, the product has features such as being adjustable in two height levels, having an opening side for emptying soil and a bench. This makes the product and the activity of growing vegetables more accessible to users with reduced physical abilities.

When it comes to facilitating the activity of growing vegetables in a shared greenhouse, the product fulfills the aim in a number of different ways, both in regard to the vegetable cultivation as well as in regard to the shared greenhouse space. Firstly, the product has features which make it easier for different plants to grow and thrive, e.g. enabling drainage of water, providing different soil depths and making it possible to move the module between sunlit and shadowed areas in the greenhouse. Additionally, the product has a number of features that are aimed at facilitating the growing activity in general, or, making it easier for the users to perform certain tasks that were considered more demanding. For example, the planter module makes the entire growing activity easier by enabling the user to work in an ergonomic position, whereas features such as the opening side, ruler pattern and trellises facilitate specific tasks such as handling of soil, sowing and supporting plants.

One might argue that the product could facilitate the vegetable cultivation to a higher extent by providing more features or a higher level of automation. However, it was considered that providing more features would make the product too complex, both to construct and to use, and thereby would counteract its purpose of facilitating the activity. The extent to which the actual vegetable cultivation could be facilitated also had to be balanced with the aim to facilitate the use of the shared greenhouse space, which imposed limitations on size and complexity. Furthermore, it was decided to exclude automated features, for e.g. watering, and instead make a low-tech product. There are several arguments for this decision, which can be found in section 5.2.2.3. It is arguable that the decision to make a low technology product excluded many ideas and technical solutions that could have generated a higher innovation level or that could have constituted a selling point. However, based on the research findings, it was decided that an analogous product would be the right way to go.

Furthermore, in this case, facilitating the activity of growing vegetables also meant to facilitate the sharing of a greenhouse space. Thus, the product is adapted to shared greenhouses in the sense that it is flexible, both by being movable and adjustable in height, but also through its symmetrical shape which allows for easier placement and grouping. This means that people can grow plants of different heights, form group and grow vegetables collaboratively, change the layout according to the number of users and to simply make the space more attractive and dynamic. Moreover, the product is easy to assemble and disassemble and is designed to be as space efficient as possible.

The product encourages urban residents to grow vegetables as an indirect effect of making it possible and easier to carry out the activity. It lowers the threshold for people who are currently not growing vegetables to try it out, and includes people that otherwise would not have been able to participate, such as elderly or people in wheelchairs, by being more accessible. The product also encourages people to grow vegetables in the sense that it contributes to making the greenhouse space more attractive and easy to use, and thereby making it more likely that people want to spend time there.

As for the aim of enabling, facilitating and encouraging social interaction in the greenhouse, the product again has an indirect effect by making more people interested to visit and spend time in the greenhouse, and thereby making it more likely that the residents will interact with each other.

However, the product also contributes to social interaction in a more direct way, by providing a bench that enables people to sit down and spend time in the greenhouse, not necessarily to cultivate vegetables but also to relax, have a coffee and meet with friends and neighbours.

The product does not force people to collaborate, but provides the possibility for the growers to interact and collaborate to a higher extent if they want to, by enabling the users to group the modules if forming groups, or creating a shared shelf area by placing the trellis in between their modules.

Interaction can also be encouraged by the fact that the product is movable and adjustable in height, since this gives the user freedom to arrange the greenhouse space as they prefer, which most likely will involve some kind of collaboration and discussion. The users might also be encouraged to collaborate if a module with soil in it will have to be adjusted in height, which encourages cooperation between neighbours.

8.2.2 Ergonomics and accessibility

Ergonomics and accessibility was a key aspect during the product development. The planter module is available in heights up to 95 cm, which means that very tall persons will not be able to stand and work in an optimal way. However, when forced to prioritise, it was decided that short persons' ability to reach was a more important factor than a comfortable elbow height position.

Raising or lowering the container is intended to be done when the product is empty, and since the weight of the empty wood container is relatively low, the action will require little physical effort by the user and can be done by a single, healthy person. For people with limited physical abilities, the action will require two persons. The sequence of changing the height has also been considered, so as to consist of as few steps as possible and without the need for tools or extra parts. Changing the height does, however, require some effort both physically and time wise, but since it is presumably done maximum once per season, it was decided that some level of effort from the user would be acceptable.

For wheelchair users, a more beneficial shape would allow for placing the chair and legs underneath the container. Product dimensions that would have met those requirements were given a lower priority since they do not combine well with other features such as container depth and bench solution. The product's side length is adapted to a maximum reaching distance when sitting sideways along the container.

Further, compromises had to be made concerning reaching distances and growing area (in combination with door size restrictions etc.). In general, the smaller the product's growing area is, the more difficult is it to motivate extra features, extra material used and consequently a higher price. However, the quadratic shape has steering advantages over the rectangle, which settled the decision.

A four-wheel solution was chosen since the construction and watered soil will be relatively heavy, but nevertheless, it may be difficult to move around for weak or elderly users. However, it was assessed that a smaller product would not be an alternative due to the combination of features that meet other requirements.

8.2.4 Sustainability

The product can be considered environmentally sustainable in the sense that it has few materials that are easily separable. Moreover, the wood has not been chemically treated. When seen as a part of a system, collaborative use and ownership is more sustainable than individual purchases.

The issue of food waste and unsustainable attitudes towards food among high-income, urban people was discussed in section 2.1.2. While the product does not in itself promote an alternative attitude, the intention was to create a product that facilitates and encourages an activity that contributes to higher awareness.

As for social sustainability, the product is made to be accessible for as many as possible, which is a prerequisite. Hopefully, the product and the greenhouse together will make people want to spend

time and interact with each other.

8.2.5 User response and market potential

Since the current range of functional and accessible planter containers is limited, there are merely a few to evaluate against. Comparing the product to other commonly recurring solutions, such as pallets, would not serve any purpose, as they have different purposes and target groups. The product will inevitably cost more due to its many features. However, the type of shared/public space that it is primarily intended for sets demands on flexibility and accessibility that cannot be met with the cheaper solutions. Further, it is assumed that there also will be a market possibility for private use, such as on balconies. In a context of design furniture, there is a market for all price ranges.

Considering the relevance of the product, it seems plausible that a product of this character would be purchased for shared greenhouses. Urban agriculture is increasingly common and there is an apparent lack of flexible and accessible growing furniture. Assuming a scenario where a housing association purchases and builds a large (and assumably rather expensive) greenhouse, it can be argued that there also would be a budget for interior furniture. Thus, another valid question concerns whether it is likely for a housing association to build greenhouses in the first place. However, this was given as a prerequisite in the project and will not be elaborated upon.

A crucial factor that will differentiate the users' attitude towards the product is probably its size. An area of 0.42 square meters will be too small for a dedicated user that aims to grow for household sufficiency. However, it was judged that the chosen size is reasonable for a shared greenhouse space (and, secondly, for a balcony). Seeing as lack of knowledge and confidence was identified as an obstacle for some to start growing vegetables, the absence of automated "support-systems" may disappoint a few of the inexperienced users whereas some will appreciate the sustainability aspect of not including electrical components.

8.3 Recommendations

- Build a functioning prototype
- Make further evaluations of physical handling, weight, stability and strength needed
- Make further evaluations of users' understanding of the different features
- Explore manufacturing possibilities

9 CONCLUSION

The aim of the project was to develop a product that enables, facilitates and encourages cultivation of vegetables in community-shared, urban greenhouses. The planter module enables cultivation, since it in the simplest sense contains soil and allows for a plant to grow. It facilitates cultivation in terms of accessibility and flexibility in the greenhouse and it makes some of the demanding tasks easier for most users in the target group. Consequently, this answers to parts of the aspects that encouraging cultivation would imply. Further, as it is more than merely a container, it can encourage people to spend time in the greenhouse and thus also cultivation.

The project's visionary aim was that the product should contribute to social and environmental sustainability. The product is, in itself, environmentally sustainable to a large extent, since materials and manufacturing methods were chosen to a high degree based on this prerequisite. Moreover, its purpose is to facilitate an activity that in turn leads to a more sustainable approach to food. Concerning social sustainability, the product along with the greenhouse space provides an opportunity for a stronger community within the neighbourhood. The planter module is designed to minimise obstacles and allow for as many as possible to take part in the activity. It does not force people to grow collaboratively, but gives the opportunity for people to organise, rearrange and be involved in the greenhouse. The bench and the fact that it is movable makes it possible to adapt the layout according to different people and groups' wishes. Residents that do not grow themselves may also use the space as a picnic place so that the greenhouse prolongs the season for the shared yard.

The product is realisable in terms of materials and manufacturing techniques, and fits the greenhouse environment. It can also be applied to other use situations, and a secondary market potential can be found in e.g. private balconies. Since no functioning prototype has been built, additional evaluations are needed to optimise functionality, material dimensions and usability before commercialisation of the planter module.

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APPENDICES

I. Interview guide - Experts within cultivation

II. Focus group guide

III. Interview guide - People who do not grow

IV. Interview guide - Solhusen, Tillsammansodlingen and Odla i Stan

V. Interview guide - Urban farmers

VI. Questionnaire

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IX. Morphology chart

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XI. Shape and dimensions table

I. Interview guide – Experts within cultivation

What types of growing containers do you prefer?

How do you use the space most efficiently?

What are the major differences between growing on open land and in a greenhouse?

What aspects do you need to consider?

How do you determine if the growing conditions are good?

How do you change soil?

How often?

What types of containers are better/worse when changing soil?

Is it better to grow plants of different species separately or in the same container?

How do you fertilise the plants?

How do you water the plants?

What do you appreciate most about cultivation?

Which aspects are the least fun/most demanding? Why?

What takes most time?

How do you organize the cultivation and work?

What do you think about hydroponic farming?

What are your thoughts about heated greenhouses?

II. Focus group guide

[Introduction]

What role does food play in your everyday life? How would it be if you had more time/money/etc.?

What do you consider important about the food that you eat? [origin, ingredients, price, etc.]

How do you feel about the activity of growing vegetables? What feels easy/difficult?

What are your thoughts about growing your own food?

What would you like to do yourselves and what would you like to share with someone else?

Would you prefer to grow in a greenhouse or outdoors?

Would you prefer to grow alone or with others?

What would you like/dislike about growing with with your neighbours?

What would you like/dislike about growing with your best friends?

Do you have any previous experience of sharing a space or a product? How did it work? Why?

What would make you happy to see when you came to the greenhouse?

What would make you angry?

Imagine that you share the greenhouse with your best friends, describe how it would be when you spent time in the greenhouse and grew together?

Future scenario

Imagine that you find yourself 50 years from now. You live in a future sustainable city, in a residential area where there is a common greenhouse where you can grow together.

If you would describe your future dream greenhouse, what would look like and what would be there? [Make sketches]

Can you describe the atmosphere and the feeling you want to get when you come into the greenhouse?

If you would make growing as pleasant as possible (in the future) what would it imply for you?

If there was a super nice future product…

III. Interview guide – People who do not grow

Do you have any previous experience in farming?

What do you picture when I say "grow vegetables"?

How do you feel about that?

Would you consider growing your own food?

What is you primary reason for not wanting to grow?

If you had [e.g. unlimited time] would you have wanted to grow food, or is there something else that would stop you?

What do you feel is the most difficult part?

Can you think of something that would have been fun?

If you did not have to be solely responsible for the cultivation but that you were a group, would it feel any different?

If you had to be part of a growing group, which aspect would you have wanted to be responsible for? Why?

If there had been a greenhouse/community area, where you could also grow, in connection to your apartment building, can you think of something would make you want to be there?

IV. Interview guide - Solhusen, Tillsammansodlingen and Odla i Stan

How is the age distribution in the greenhouse?

How big is the interest for the greenhouse among the residents?

How much experience do people have?

What are the pros and cons of sharing a greenhouse?

Why do you grow vegetables? [relaxation/socialising/food production/etc.]

How does your growing containers work?

Are there any problems?

How do you water the plants?

How do you change soil in the growing beds?

How many of you share a plot?

What types of plants do you have?

(If growing collaboratively) how do you agree on what types of plants to grow?

How do you share responsibilities in the greenhouse?

How do you organise the work? [meetings/platform/etc.]

How do you share the harvest?

How to know when something has been done?

Do you need to know who did what?

How often do you come here?

Is there anything that you particularly like about the greenhouse?

Is there anything that you miss, that would have been nice or helpful?

V. Interview guide – Urban farmers

For how long have you been growing here?

How come you started to grow vegetables?

Why do you grow? What motivates you to grow? [food/socialise/etc.]

What is your goal?

What previous experience do you have?

How many are you in this area?

What types of people grow here?

Did you know any of the others before?

How much time do you spend at the plot?

What aspect takes the most time?

Would you like to spend more or less time and work at the plot?

Could you describe the process of work at the plot?

What tools do you use?

What would you mostly like to see someone else responsible for? Why?

Which crops do you prefer to grow?

How do you think the plot could be improved?

What is the most enjoyable aspect of growing? Why?

What makes you happiest?

What is the most boring aspect of growing? Why?

What can make you angry/annoyed?

What are you most satisfied with?

If you could wish for anything that you wanted for the plot, what would it be?

How would your dream plot be like?

VI. Questionnaire

Age?

How much experience do you have of growing? [1-5]

Have you been part of a growing group before

What is your experience of growing collaboratively? [1-5]

What is positive/negative about being part of a group?

How many members are there in your group/association?

What are the members' ages?

Did the members know each other before? [none/some/all/other]

How do you perceive the team spirit within the group? [1-5]

How well is the distribution of work and responsibilities working? [1-5]

How do you grow? [outdoors/greenhouse]

What types of growing containers do you use? [ground level beds/raised beds/pots/bags/other]

What aspects of cultivation do you perceive as difficult/demanding?

How is the growing area divided? [shared and individual areas/shared/individual]

What is your attitude towards technological aids and automation in connection to cultivation? [1-5]

How do you communicate within the group? [meetings/text messages/phone/platform/chat group/other]

How well does the communication work? [1-5]

Do you have any additional comments, thoughts or ideas about urban farming and group farming?

VII. List of user needs

USER GROUP
It should be possible to work in an ergonomic position
It should be possible to grow plants with different root depths
It should be possible to grow both tall and short plants
It should be possible to grow different amounts of crops
It should be possible for the user to follow the plant's process
It should be possible to prevent vandalisation and theft
It should be possible to perform different tasks in a time efficient way
It should be easy and efficient to water the plants
It should be easy and efficient to harvest
It should be possible to perform tasks in time
It should be possible to create the correct spacing inbetween seeds
It should be possible to identify the plants
It should be easy and efficient to compost
It should be possible for to bind/support plants
It should be possible to store potted plants
It should be easy and efficient to add/ remove soil
It should be possible to prevent pests
It should be possible for the user to store all the harvest
It should be possible to organise and find tools
It should be possible to clean the space and product
It should be possible to have an emotional bond to the plants
It should be possible to relax and unwind
It should be possible to feel closer/ more connected to nature
It should be possible to eat and drink during the growing activity
It should be easy to avoid conflicts with neighbours
It should be possible to share and cooperate in different ways and to varying degrees
It should be possible to stay motivated and interested in the plants

It should be possible to have varying degrees of knowledge and experience
USERS DOING COLLABORATIVE CULTIVATION OF VEGETABLES
It should be possible to organise the group and the growing activity
It should be possible to plan the different tasks (what, when, how and by whom)
It should be possible to document the tasks (what, when, how and by whom)
It should be possible to share and distribute responsibility
It should be possible to be involved and engaged to varying degrees
It should be possible to feel spontaneous and free of demands and pressure
It should be possible to have individual influance in the group
It should be easy to communicate within the group
It should be possible to have access to sufficient information
It should be easy and efficient to access the information
It should be possible to have a coherent and united group
It should be possible to get to know new group members
It should be easy to make decisions within the group
It should be possible to share knowledge within the group
It should be possible to conduct other group activities in connection to the growing activity
PLANTS & ACTIVITY OF GROWING VEGETABLES
It should be possible to provide the plant with soil
It should be possible to let the plant have access to sunlight
It should be possible to provide water to the plants
It shoud be possible to drain water
It should be possible to provide different soil depths according to root depths
It should be possible to provide different amounts of space vertically according to plant hight
It should be possible to remove plants
It should be possible to clean the container
It should be possible for as many as possible to carry out the growing activity
THE SHARED GREENHOUSE ENVIRONMENT

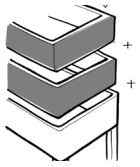
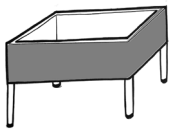
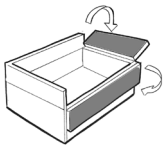
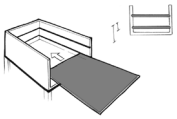
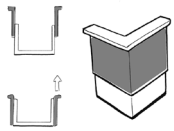
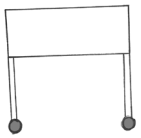
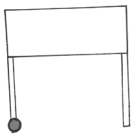
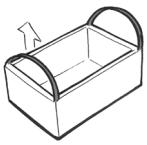
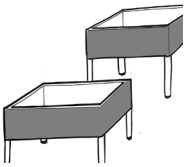
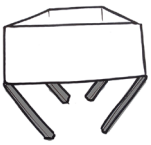
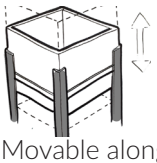
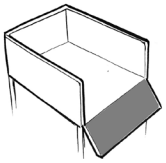
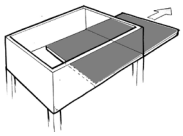
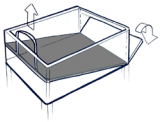
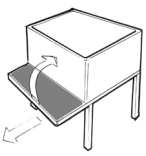
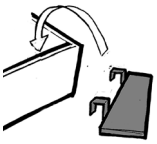
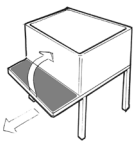
It should be possible to use the product in up to 85% air humidity
It should be possible to use the product in contact with water
It should be possible to use the product in very bright light
It should be possible to use the product in up to 35 degrees celcius
It should be possible to use the product on concrete, cobble stone or stone tiled flooring
It should be possible to use the product outside for shorter periods of time
It should be possible to adjust to different amounts of growers
It should be possible to socialise and interact with other growers
It should be possible to have solitude and quiet
It should be possible to use the greenhouse space efficiently
It should be possible to rearrange the greenhouse space
It should be possible for the user to distinguish and identify the different plots
It should be possible to group the plots
It should be possible to clean the greenhosue with water
It should be possible to meet others and socialize
It should be possible to sit down to socialise or rest
It should be possible for everyone to use and access the greenhouse space

VIII. Requirements Specification

REQUIREMENTS SPECIFICATION					
Chalmers University of Technology					
Master Thesis Project					
Last modified: 2014-06-24					
Ref. no	**Requirements**	**D/G**	**F/L**	**Reference/Metric**	**Validation**
1. GEOMETRY & DIMENSIONS					
All parts					
1.1	Contain as few parts as possible	Guideline	L	Y/N	Calculate
1.2	Fit through a doorway	Demand	L	Y/N	Calculate/test
1.3	Be space efficient	Guideline	L	Y/N	Calculate
Container					
1.4	Facilitate grouping and various placements of several units	Guideline	L	Y/N	Test/calculate
1.5	Contain soil	Demand	L	Y/N	Test/calculate
1.6	Accomodate roots (min. 25 cm)	Guideline	L	Y/N	Test/calculate
1.7	Provide enough growing area for one household (0.4 m2)	Guideline	L	Y/N	Test/calculate
1.8	Allow sunlight access	Demand	L	Y/N	Test/calculate
1.9	Facilitate cleaning	Guideline	F	Y/N	Test
1.10	Protect roots from direct sunlight	Demand	L	Y/N	Test/calculate
Wheels					
1.11	Manage thresholds	Demand	L	Y/N	Test/calculate
1.12	Facilitate turning	Demand	L	Y/N	Test/calculate
Legs					
1.13	Withstand weight of container, soil and plants (200 kg)	Demand	L	Y/N	Calculate
Bench					
1.14	Withstand weight of two users (200 kg)	Demand	L	Y/N	Calculate
2. FUNCTIONALITY					
2.2	Hold soil	Demand	F	Y/N	Test/calculate
2.3	Accomodate different root depths	Guideline	F	Y/N	Test/calculate
2.4	Accomodate different plant highs	Guideline	F	Y/N	Test/calculate
2.5	Accomodate different amounts of crops	Guideline	F	Y/N	Test/calculate
2.6	Facilitate cleaning of the product	Guideline	L	Y/N	User test
2.7	Facilitate emptying/filling of soil	Guideline	F	Y/N	User test
2.8	Enable drainage of excess water	Demand	F	Y/N	Test
2.9	Facilitate assembly and disassembly	Guideline	F	Y/N	User test
2.10	Facilitate sowing and planting	Guideline	F	Y/N	User test
2.11	Enable identification of container	Guideline	F	Y/N	User test
2.12	Enable identification of plants	Guideline	F	Y/N	User test
2.13	Be movable	Guideline	F	Y/N	User test
2.14	Facilitate placing and grouping of containers	Guideline	F	Y/N	Test/calculate
2.15	Facilitate watering of the plants	Guideline	F	Y/N	User test
2.16	Facilitate binding/supporting of plants	Guideline	F	Y/N	User test
2.17	Prevent pests	Guideline	F	Y/N	Test/calculate

2.18	Facilitate placement of potted plants	Guideline	F	Y/N	User test
2.19	Facilitate storage	Guideline	F	Y/N	User test
2.20	Facilitate following of the plant and the growing process	Guideline	F	Y/N	User test
2.21	Facilitate eating and drinking during/after the growing activity	Guideline	F	Y/N	User test
2.22	Facilitate organisation of the greenhouse space	Guideline	F	Y/N	User test
2.23	Facilitate cleaning of the greenhouse	Guideline	F	Y/N	User test
2.24	Facilitate outdoor usage (for short periods of time)	Guideline	F	Y/N	User test
2.25	Be adaptable to different amounts of gardens in the greenhouse	Guideline	F	Y/N	User test
2.26	Facilitate socialising and interaction between the users	Guideline	F	Y/N	User test
2.27	Facilitate sharing and cooperation between users	Guideline	F	Y/N	User test
2.28	Enable solitude and quiet	Guideline	F	Y/N	User test
2.29	Accommodate varying degrees of knowledge and experience	Guideline	F	Y/N	User test
2.30	Utilise the greenhouse space efficiently	Guideline	F	Y/N	Test/calculate
2.31	Enable management of the greenhouse space	Guideline	F	Y/N	Test/calculate
2.32	Enable identification of the plots	Guideline	F	Y/N	User test
2.33	Enable grouping of the plots	Guideline	F	Y/N	Test/calculate
3. ERGONOMICS					
3.1	Enable an ergonomic standing working position for adults	Demand	L	Anthropometric data	Test
3.2	Enable an ergonomic working position for people in wheelchairs	Guideline	L	Anthropometric data	User test
3.3	Enable access for wheelchair users	Demand	L	Anthropometric data	User test
3.4	Enable reaching across growing area	Demand	L	Anthropometric data	User test
4. USABILITY					
4.1	Be easy and efficient to use	Guideline	L	Time/errors	Usability Test
4.2	Have high guessability	Guideline	L	Time/errors	Usability Test
4.3	Have high learnability	Guideline	L	Time/errors	Usability Test
5. AESTHETICS & EXPRESSION					
5.1	Be aesthetically pleasing in combination with several containers	Guideline	F	Subjective	User Test
5.2	Make the user feel relaxed and invited	Guideline	F	Subjective	User Test
5.3	Make the user feel closer/ more connected to nature	Guideline	F	Subjective	User Test
6. DURABILITY & RESISTANCE					
6.1	Withstand humid air (65 %)	Demand	L	Time	Test
6.2	Withstand water and moist soil	Demand	L	Time	Test
6.3	Withstand heavy loads (max. 200 kg)	Demand	L	Y/N	Calculate
6.4	Withstand temperature changes (-5 till +35)	Demand	L	Y/N	Test
6.5	Enable material expansion	Guideline	L	Y/N	Test
6.6	Withstand sunlight exposure	Demand	L	Time	Test
6.7	Manage different flooring (stone tiles, cobble stones, concrete)	Demand	L	Y/N	Test
7. SUSTAINABILITY					
7.1	Contain as few materials as possible	Guideline	L	Y/N	Calculate
7.2	Enable separation of materials	Demand	L	Y/N	Test
7.3	Enable reuse/recycling	Demand	L	Y/N	Calculate
7.4	Imply environmentally friendly manufacturing techniques	Guideline	L	Y/N	Calculate
7.5	Contain no chemical preservatives	Demand	L	Y/N	Test

IX. Morphology Chart

FUNCTIONS	SOLUTIONS				
ADJUSTABLE IN DEPTH	 Stackable sides	 Fixed medium depth	 Foldable sides	 Movable bottom plate	 Elevating sides
MOVABLE	 Four wheels	 Two wheels	 Carrying with handles		
ADJUSTABLE IN HEIGHT	 Two versions	 Foldable legs	 Telescoping legs	 Movable along a side construction	
EASE HANDLING OF SOIL	 Opening side	 Opening bottom plate	 Opening side w. tilting plate	 Opening side w. tilting container	
PROVIDE BENCH	 Foldable bench	 Removable bench	 Pull out bench		

X. Pugh's Chart

CONCEPT / CRITERION	1	2	3
Mechanical complexity	0	0	-
Loose components	0	+	+
Movability	0	0	0
Easy depth adjustment	0	+	+
Soil efficiency	0	+	-
Accessibility	0	0	0
Easy emptying	0	+	+
Stability	0	+	-
Easy height adjustment	0	-	-
Bench functionality	0	+	0

XI. Shape and dimensions table

Shape				
Dimensions	A side length of 65 cm lets it fit through a standard door easily, while it is still possible to reach across the diagonal (92 cm). These measurements generate a growing area of 0.42 square meters.	Side lengths of x*2x are preferable due to combination possibilities. Most flexible in terms of maximum size and can provide a larger growing area than the others while remaining reachable across the short edge.	A diameter of 65 cm gives a growing area of 0.33 square meters, which is less space efficient.	For a width of 65 cm, the growing area will be 0.27 square meters, which is the least space efficient.
Comments	Good combination possibilities. Can (theoretically) be placed in all four directions. Easiest of all shapes to move around with a wheel solution. Automatically smaller than the rectangle due to size restrictions for reaching and fitting through a door.	Narrow paths in the greenhouse and probable parallel parking in between other containers restricts side length. Easy to reach across, from the long side. Fits better in narrow spaces. Easier to reach when placed in a corner, compared to the square. Less flexible in terms of combinations	Easy to reach all parts due to possible implementation of rotation function. Difficult to combine with leg structure as well as bench and storage surfaces. Not space efficient when placed in a group of other circles.	Space efficient and allows for many different types of combinations (although it might be best to keep passageways straight for accessibility reasons). Easy to reach all parts due to possible implementation of rotation function. Difficult to combine with other functions.

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