CHALMERS

Sorting out waste

The development of a recycling station for public indoor environments in Gothenburg

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

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2013

Department of Product- and Production Development
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ABSTRACT

This Master Thesis was executed at the department of Product and Production Development at Chalmers University of Technology by Anna Johansson and Agnes Lindahl. The project was conducted at the request of the municipality of Gothenburg and the organization for collaboration "Trygg, vacker stad" ("Safe, beautiful city").

There is at present a political wish to increase the sorting of waste in the public areas of Gothenburg, and this project is part of achieving that goal. The aim of this project is to develop a recycling station for public indoor environments, such as stadiums, theatres, museums, public baths, schools, exhibitions halls, libraries, etc. The recycling station should be inviting and should simplify and encourage the sorting of waste. It should also be sufficiently large, visible, and easy to use, and the design should impede vandalism. The recycling station should be designed to meet the ergonomic needs of different types of users, for example people throwing waste, emptying, installing, repairing or cleaning the station.

The final result is a modular and flexible recycling station called IDA (Identify, Detect, Assort). The design strikes a balance between discretion and attention-seeking. It blends into most public indoor environments but is sufficiently noticeable when needed. The dimensions of the recycling station are adapted to fit the user group, which includes children above the age of seven and adult citizens of Gothenburg, as well as people with different types of physical or cognitive needs.

The modular system allows for a high level of adaptation. The lids that distinguish the waste fractions are exchangeable, which also prolongs the lifespan of the recycling station. Other important features are the separate collection of deposit cans, the detachable inner floor (which allows for easy cleaning), and the tactile letters (which make the recycling station accessible to users with visual impairment). The inner container is designed so as to make the emptying process ergonomically advantageous. It also has a built in floor to support the bag and prevent leakage. The inner container is detachable in its entirety. This is to simplify cleaning and allow for easy access.

An initial theoretical study was carried out so as to provide guidelines and information regarding physical ergonomics, anthropometry, and cognition. A description of the waste management system in Gothenburg in relation to public indoor environments was developed, and a benchmarking study was carried out, which provided a picture of what the system looks like and what solutions exist today. The public indoor environments were divided into four different categories depending on their characteristics: sport facilities, cultural facilities, event facilities, and schools.

An extensive user study was performed which included both sorters and collectors. The study was conducted by the means of interviews, observations, and surveys. The different types of public indoor environments were visited and four concepts were developed on the basis of the findings. The concepts were presented and discussed with various interested parties and facility managers at the municipality. As a result the functionality and main features of the final concept could be ascertained.

The development of the final concept was an iterative process, which was carried out through further studies and consultations with experts in various fields such as materials, colours, manufacturing, accessibility, and expression. The validation confirmed that the recycling station fulfilled the demands. To further evaluate the product it is appropriate to make a prototype that could be tested in a public indoor environment.

THANK YOU.

This Master Thesis project involved many people and collaborative actors that were very helpful. It was inspiring to see the engagement of these people. They helped making the project important, both as part of our education and as a result, contributing to the city. The result fulfils a social function, addresses environmental issues, labour matters, and encourage the involvement of Gothenburg residents.

We, the project group, would like to thank the people who made this project possible and those who will keep it alive after we have let it go. Thank you to all the participants in the user study: the collectors, the sorters, and others of Valhalla public bath and sport center, Björlanda sport center, Liseberg amusement park and arena, and Scandinavium, Härlanda library and Hovås high school. Also, participants who have been answering our different surveys on Chalmers recycling station, on waste recycling in general and on geometrical shapes of slots. Thank you to the collectors at Renova, who guided us through a morning of waste collecting. Without your help and time the project would not have been possible.

We would also like to thank the administration of Traffic and public transportation (Trafikkontoret) in Gothenburg municipality, who initiated this project, the administration of Circulation and water (Förvaltningen Kretslopp och vatten) for inspiring us, and all important actors with knowledge of accessibility, of administrating the facilities, and of technical expertise.

The support we had from Chalmers was very helpful, thank you to all our supervisors: Antal Boldizar for the material choice, Märit Lagheim for colour and form, Håkan Almius for CAD, and a special thank you to our supervisor Isabel Ordonez Pizarro and our examiner Ralf Rosenberg.

Thank you to all our friends and families that have been very, very supportive during this project.

Anna Johansson & Agnes Lindahl

CONTENTS

11. REFERENCES

1. INTRODUCTION

In this chapter, the background of the project is described and important actors connected to the project are presented. The introduction is the first presentation of what the project involves and describes the project's aim, goal, research questions, and delimitations.

1.1. BACKGROUND

1.1.1. Safe, beautiful city

During the last couple of years, the city of Gothenburg has worked with an organization for collaboration called "Trygg, vacker stad" – "Safe, beautiful city". Administrations, the municipality, NGOs, and companies are working together to increase the beauty and the sense of security in Gothenburg. The vision of the organization reads: "Gothenburg is a beautiful, open, safe city that makes us proud and where the urban environment contributes to meetings between people" (Göteborg stad, 2012a [our translation]).

"Safe, beautiful city" organizes a number of different collaborative projects regarding, for example, urban lighting, handling of graffiti, plants and flowers in the city. The initiatives stretch from creating and strengthening spaces where people can meet, to working towards a cleaner urban environment.

In a motion from Gothenburg City Council the suggestion was made that a recycling station for the separation of outdoor waste should be implemented. The administration of Traffic and Public Transportation (Trafikkontoret) was, in 2013, commissioned to review the current management of waste in the city, suggest improvements, and provide a more uniform expression for recycling stations in Gothenburg. In 2013, a project was carried out and completed in which recycling stations for outdoor usage were developed, and the result is currently being evaluated.

Political actors are at present expressing the desire that a recycling station for indoor usage in public places should be developed, and that is the basis for this project.

1.1.2. Actors

The initiatives taken by the organization "Safe, beautiful city" are being processed in project groups. In each project group, relevant actors (administrations, organizations, and companies) are cooperating. These actors are financed by the public sector, although many projects are carried out together in private - public partnerships (Göteborg stad, 2012a).

Some of the relevant actors in this project are listed with a brief description in the following section.

The administration of Traffic and public transportation (Trafikkontoret)

The municipal administration of Traffic and public transportation manages the municipal road and rail construction and maintenance. The administration is led by a committee, which decides upon tasks and activities (Göteborg – Trafikkontoret, 2012). The administration of Traffic and transportation is the main client and partner for this project.

The administration of Circulation and water (Förvaltningen Kretslopp och vatten)

The municipal administration Circulation and water manages sewage, water supply, and household waste from the population and private actors in the city. The authority is led by a committee that takes Swedish environmental laws and regulations into account in its work (Göteborgs stad, 2013).

Packaging and newspaper collection service (Förpacknings- och Tidningsinsamlingen AB, FTI)

The Packaging and newspaper collection service is a company whose main task is to collect and recycle packaging and newspapers in Sweden. The company is responsible for recycling stations that are available for the population around the country. The owners of FTI AB are different material companies responsible for plastic, metal, paperboard, newspapers, and glass. The material companies are in turn owned by other material companies, but also by packaging manufacturers, fillers, importers, distributors and traders, and other membership organizations (FTI, 2013).

FTI AB's packaging services are partly financed by its owners, who are subject to a governmental regulation demanding weight based packaging fees from the packaging producers. These producers are the companies that import goods and package and sell a product. The newspaper waste is, however, financed by its own material company (FTI, 2013).

Other actors

Besides the actors administering the projects, other stakeholders, consultants, and entrepreneurs represent an asset for detailed expertise. In this project – the development of a recycling station for indoor usage – these are, for instance, the producer and manufacturer of the product. In addition, other municipal administrations also participate as project actors, such as the administration of Sport and club activities (Idrott- och föreningsförvaltningen) and the Culture department (Kulturförvaltningen). The activities of these administrators influence the user and may result in demands on the product. They are also responsible for the facilities and the contexts in which the product will be placed, which means different demands on the aesthetic design as well.

1.1.3. Previous projects

There are mainly two previous projects that are of significance for this study, and these are presented below. The studies performed during these projects are considered to be important reference material.

Design of an inviting litter bin with the purpose of reducing littering in Gothenburg

This project was carried out in 2009 at the department of Products and product development, at Chalmers University of Technology. In this project a litter bin was developed with the aim of encouraging people to dispose of their waste in a more responsible way (Bjursten and Mårtensson, 2009). This litter bin is currently being used by the city of Gothenburg and is an important part of the urban landscape.

Recycling bins for the urban environment of Gothenburg

The second project was carried out during the spring of 2013 at the department of Products and product development, Chalmers University of Technology. The purpose was to develop a collection unit for recycling material that could be used during various events (Nikell and Sundberg, 2013). This collection unit is currently being evaluated.

1.2. AIM AND GOAL

The aim of this project is to develop a recycling station for the collection of recyclable waste. The recycling station should be designed for indoor usage, and no resources should be used to adapt the recycling station for outdoor conditions. The recycling station should be developed for public environments, such as stadiums, theatres, museums, public baths, schools, exhibitions halls, libraries, etc. In addition, the recycling station should be designed to meet different demands (functional as well as aesthetic), according to the context and environment in which it will be placed.

The recycling station should be inviting and should simplify and encourage the sorting of waste. It is also important that the recycling station should be sufficiently large, visible, and easy to use, and that the design should impede vandalism.

The recycling station should be designed to meet the ergonomic needs of different types of users, for example people throwing waste, emptying, installing, repairing or cleaning the station.

1.2.1. Research questions

This section lists some of the research questions that were used as a means for guiding and focusing the study.

- How do you motivate people to sort their waste?
    - What is the need for sorting waste in public indoor areas?
- Are there common denominators between the different environments?
- Do the demands differ in some significant way between the different environments?
- Who are the people sorting their waste?
- Does somebody throw her or his waste on the floor? Who? Why?
- What attributes characterize a recycling station?
- What are the ergonomic demands that need to be fulfilled?
    - For those who throw the waste?
    - For those who empty the recycling station?
    - For those who repair/install it?
- How could you prevent vandalism?
- How could you make the recycling station in itself more environmentally friendly?

1.3. DELIMITATIONS

There were two delimitations in this project:

The recycling station was designed for indoor usage. Adaptation for outdoor conditions was not considered in this project.

The recycling station was adapted for the city of Gothenburg in terms of design and target groups; other locations were therefore not considered.

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1.4. PROJECT AND REPORT STRUCTURE

This project was carried out as a Master of Science Thesis in the Master's Degree Program of Industrial Design Engineering between September and January 2013-2014.

To provide structure, the project was divided into five different phases illustrated in *Figure 1* below. The phases are presented in succession, although they were carried out in an iterative manner.

These phases have been distributed over a timeframe of 20 weeks or 30 university credits. A presentation for the municipality before Gothenburg City was planned after the completion of the concept development, when about half of the project time had passed. The final presentation was held at two occasions: the first was held in the final week of the project before the municipality of Gothenburg City and other concerned actors. The second was held two weeks later at Chalmers University of Technology before the examinator, the supervisor, and two opponents.

The results of each phase are described in the corresponding chapter of this report. Each chapter contains a description, the methods and processes, and the results of the phase activities. In addition to these chapters, the report contains theory and validation supporting the study.

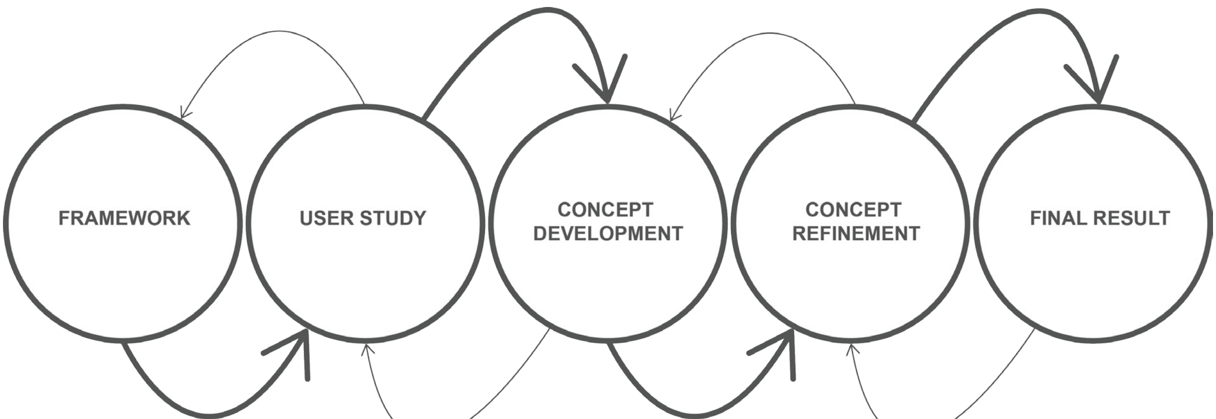


Figure 1. The project was divided into five different phases which were carried out iteratively

2. THEORY

This chapter describes the theoretical information connected to the project studies and design result, compiled into several fields within ergonomics, usability and accessibility. The theory supports the findings and the results of the studies made.

2.1. PHYSICAL ERGONOMICS

The definition of physical ergonomics is basically the human interaction with the environment in mechanical terms. It includes the mechanical work, forces, and torque, but also the work environment. This is why physical ergonomics cannot exclude psychological aspects when one examines human injuries and pain (Bohgard, 2008).

The following section describes ways to prevent illness and accidents, as well as biomechanics. Furthermore, the section describes Swedish labour regulations that affect the people who will handle the product, and adds an anthropometric description, based on the whole product user group, which will be the dimensional basis for the development of the product.

2.1.1. Prevention of illness and accidents

There are physical design approaches that will meet the needs of persons in a work environment, such as those handling the recycling station for public indoor use. The work is assumed to be performed in standing postures.

The muscle force required for the work depends more on body postures than on individual capacity. However, there are recommended general postures:

- Vary the working postures as much as possible
- Avoid postures that means leaning forward
- The upper arms should be close to the body; no or few lifts above the head
- Avoid twisted and asymmetric postures
- Avoid postures that will strain the joints in their extreme positions for extended periods of time
- When there are high muscle forces the muscle should be in its most powerful position

(Bohgard, 2008)

The individual postures are mainly affected by the height of the work performed and by the floor. Too high a working height results in an elevated positioning of the arms, which puts static strain on the shoulders. Too low a working height results in increased muscle strain on the back and the neck due to the forward leaning position. Lifts should be performed with knees bent, in a forward body position, without body rotation or back bending. The following are recommended working heights for performing standing work:

- Delicate precision work: 50-100 mm above elbow height
- Precision work involving force: 50-100 mm below elbow height
- Light manual work: 50-100 mm below elbow height
- Heavy manual work: 100-250 mm below elbow height
- For lifting and handling work: between mid-thigh and mid-chest level – close to waist level

(Pheasant, 2006)

- Every type of standing work should provide stable feet position

(Bohgard, 2008)

2.1.2. Biomechanics

Biomechanics is a discipline that applies methods and principles from mechanical physics to biological materials. This field of study can be used in several disciplines including product development and physical ergonomics if, for instance, one is studying how forces from manual work affects different tissues, skeletal or muscular structures of the human body (Bohgard, 2008).

Biomechanical calculations could be used if different work scenarios are examined: when showing possible improvements or when identifying critical elements of work (Bohgard, 2008). In the product development it is possible to compare the results to reference values, limits or recommended levels, such as labour law regulations.

When performing biomechanical calculations it is important to make an approximate model of the reality as to avoid performing complex mathematics. The approximations are:

- The human body segments are seen as rigid – there is no deformation that will change the force distribution
- The joints have no friction
- The human body segment's mass, the centre of mass, and lengths of torques are retrieved from statistical tables of anthropometric measurements
- The external torque is absorbed by a muscle or muscle group, and this muscle group exercises force in only one direction
- There is no counteractive muscle force
- Support forces are simplified

In biomechanical calculations, static equilibrium is assumed, which means there are no acceleration forces and all forces are in balance with each other. The torque is calculated as the product of the force and the perpendicular distance between the rotation centre and the force. As the distance between the rotation centre increases, the more difficult the load becomes to lift (Bohgard, 2008).

Biomechanical calculations can provide the product development with convincing results; due to the approximations, however, they have some limitations. The data used in the calculations is based on population data and not individual data; hence the calculated forces on the human body become approximate. Further, the assumption of static equilibrium is a simplification of forces since a real work situation has many complex dynamical elements, for instance, slow or snatch movements. In addition the biomechanical calculation only gives snapshots of work situations and does not describe how exhausting the work could be perceived (Bohgard, 2008).

2.1.3. Labour law

The Swedish labour law (Arbetsmiljölagen) consists of rules and regulations for preventing illness and accidents in work environments, regarding both physical and psychological aspects. The law must be followed by both the employers and by others responsible for environmental protection (Arbetsmiljöverket, 2013a). In the product development of a recycling station for public indoor areas, it is important to recognize these rules and regulations in order to meet the needs of the people handling the product every day.

The regulations from the labour law concerning physical ergonomics that were important to acknowledge when developing a recycling station are listed as models below (Arbetsmiljöverket, 2013b). Further measurements that are important to acknowledge for the handling of the product are part of the results from the anthropometrical study (see section below).

Black=Not suitable

Grey=Needs closer evaluation

White=Acceptable

Horizontal distance from lumbar to the load´s centre of mass	In forearm distance, ~30 cm	In three quarter arm distance, ~45 cm

Table 1. Model to estimate risk of lifting work

The model for estimating the risks of lifting work (see *Table 1)* takes into account the weight of the load and the distance between the body and the load's centre of mass, and serves to clarify good ergonomic conditions such as symmetric two hand grip in standing postures. The model is valid for both men and women.

The model for estimation of lifting work shows that all loads above 25 kg are not suitable to carry.

Force (N)	Black	Grey	White
Starting	>300	300–150	<150
Continuous	>200	200–100	<100

Table 2. Model for estimating risks of work that contains push and pull movement.

The model for estimating risks of work that contains push and pull movements (see *Table 2*) illustrates the need for symmetric two hand grip, well-designed handles in suitable height, and good environmental conditions.

None of the models take into account work related factors that could impair the conditions, such as time, heights, grips, and repetition that has to be accounted for when estimating risks.

2.1.4. Anthropometric measurements

Anthropometry deals with body measurements, such as size, shape, strength, mobility, and working capacity (Pheasant and Haselgrave, 2006).

There are very different users of a product such as the recycling station. It will be used by sorters who of different age, nationality, gender, and educational background. In addition to the sorters, there are the collectors, cleaners, and repairers who will be handling the product on an everyday basis. It is important to design the product to meet all user needs, which is why anthropometric measurements will satisfy the 5th to the 95th percentile population.

Furthermore the recycling station needs to be accessible to people in wheelchair as well as to children above the age of seven.

Things that should be reachable from a wheelchair should be placed at a height between 80-100 cm (Handisam, 2012).

Table 3 lists anthropometric measurements that are of interest when designing the recycling station. *Figure 2* shows the measurements. All the numbers are from Pheasant and Haselgrave (2006). The men and

	[mm]	Men		Women		Children, age 7	
		5th	95th	5th	95th	5th	95th
1	Eye height	1520	1740	1435	1635	995	1215
2	Shoulder height	1345	1545	1255	1455	870	1050
3	Elbow height	1020	1180	905	1145	665	805
4	Knuckle height	720	800	675	795	460	585
5	Shoulder-grip length	615	715	555	635	380	505
6	Elbow-fingertip length	440	510	405	475	290	355

Table 3. Anthropometric measurements for men, women, and children age 7.

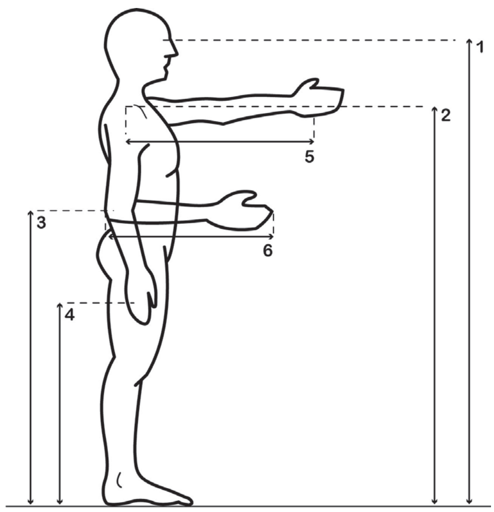


Figure 2. Chart of anthropometric measurements

women are Swedish adults, and child measurements are from British children, who are considered to be comparable to Swedish children of the same age.

Visibility

Information or other things that should be visible and accessible are dependent on a correlating bond between angle and height. If the information is angled upwards, the critical users are 5th percentile seven year olds. This information needs to be placed below 100 cm. If the information is placed on a side facing the user, the critical group is 95th percentile men. This information would however be easier to access for everyone, since the critical user in this case could compensate by stepping away from the recycling station.

Reach

If the slots are placed within reach of wheelchair-bound people (between 80-100 cm) it will also be within reach of children. Between these levels the slots are also placed above the fingertip height for 95th percentile men and below the 5th percentile shoulder height for children, age seven, which means that all these groups should be able to reach it without bending or stretching.

The user should not have to stretch the arm further than 38 cm, since this is the shoulder-grip length for the 5th percentile of children.

Lifting and emptying

Humans are strongest in the zone between elbow height and fingertip height for standing postures. If the recycling station is emptied from a height between 72-90 cm, it will be higher than the knuckle height for 95th percentile men and lower than the elbow height of 5th percentile women; hence it will be within the strength zone for 90% of the population.

A lift is also made easier if it is made closer to the body. Therefore, it is important that the collectors can come so close to the recycling station so that they do not need to stretch their arms when lifting. The critical length is set by the elbow-fingertip length for 5th percentile women at 40 cm.

2.2. COGNITIVE ERGONOMICS

Since an important goal for this project is to design a product that is accessible and easy to use and understand, theory about cognition and decsion making was considered relevant.

2.2.1. The senses

The senses can interact or counteract with each other when perceiving information. If the senses are counteracting each other the result might be that one sense dominates the other, or it might result in a sort of balance (Robinson-Riegler, 2008).

Multimodality is the phenomenon that several senses are involved in transmitting information from the environment at the same time. Every sense has its strengths and weaknesses, but to activate different senses at the same time might compensate for some types of problems.

It might be beneficial to explore wether multimodality can be used in some way or another to better communicate the purpose of the product and how to use it correctly. Multimodality was therefore considered during the concept development.

However, the different senses have different drawbacks with regard to the particular product that is developed in this project. Auditory information calls for attention (Bohgard, 2008), and since there is no occasion in the use situation where the user needs to take immediate action, adding auditory information could lead to increased stress where there is no need for it. If auditory information are to be used it should support the visual information, without unnecessary additions to the sensory load. Another aspect is that the recycling station is often placed in an environment where many people are moving about at the same time, doing unrelated things. Adding auditory information could have a negative impact on this environment as a whole.

Haptic information has the drawback that people do not like to touch waste bins in general (Bjursten and Mårtensson, 2009).

2.2.2. Decision making

According to Bohgard et al. (2008) there are three typical levels of performance, namely skill-, rule-, and knowledge-based performance. Skill-based behaviour represents sensory-motor based performance that takes place without conscious control. In rule-based behaviour the operator follows a sequence of subroutines in a familiar work situation, controlled by a stored rule. The rule might have been acquired on previous occasions or communicated from other persons' instructions. Knowledge-based behaviour occurs in unfamiliar situations in which no know-how or rules for control are available.

Skill-based behaviour requires knowledge that is fortified to such a degree that performing a task is like 'riding a bike'. Many of the users will handle the recycling station only at rare occasions, when they visit the public areas where it is placed. There will also always be many users (tourists and visitors) who are new to the recycling station. Most of the users are, however, used to recycling as a concept. They do it at home and at work. Therefore, the decision-making that occurs when sorting waste (what to put where etc.) is most likely rule-based.

2.3. USABILITY

The International Standards Organization defines usability as '… the effectiveness, efficiency and satisfaction with which a specified user can achieve specified goals in particular environments' (ISO DIS 9241-11).

Effectiveness means, according to Jordan (1998), the extent to which a goal or task is achieved. Efficiency measures the amount of effort required to accomplish the goal. Satisfaction refers to the level of comfort the user feels when handling the product and how acceptable the product is to the user as a means of achieving their goals.

Some important terms that are used in the field of usability are guessability and learnability. Guessability describes the level of effectiveness, efficiency, and satisfaction a first time user can achieve when handling the product. Learnability describes how learnable the product is by measuring the effectiveness, efficiency, and satisfaction when a user performs a task on a product after previous use (Jordan, 1998).

2.4. ACCESSIBILITY

The county of Västra Götaland has developed support material to be used as guidelines for designing signs in public areas (Göteborgs Stad, 2011). The municipality of Gothenburg uses these guidelines to address the issue of accessibility in public areas. The whole population is taken into account, including people with different types of special needs: perceptive, cognitive, physical. The goal of these guidelines is to develop, by means of colours, symbols, notations and names, consistent signs that make it easier for the visitors to orientate themselves.

The information should be placed so that persons in wheelchairs could read it. The information sign's lower edge should be placed at a maximum of 0,8 meter above ground and should have an angle of 45 degrees from the wall.

The sign should have the right amount of lighting that comes from above and does not dazzle the user.

The information should be consistent and easy to understand. Symbols should be added, if possible. When choosing symbols, the Swedish standard (SIS) should be used primarily and established pictograms secondarily. In addition, the information should have tactile letters and braille properties.

Signs with different components should be arranged in the following order, left to right: arrow, symbol, text, and colour. It might be more difficult to perceive colours when suffering from reduced sight; the colours should therefore be seen only as complements.

2.5. INTERFACES

Important aspects that support communication between the user and the interface are formation, colour, direction, and symbols.

Formation can be explained through the gestalt laws. These describe how different visual patterns are perceived. The four most commonly used of the gestalt laws describe similarity, proximity, continuity, and closure (Bohgard et al., 2008).

Similarity means that objects of the same colour, form or size are perceived collectively (see *Figure 3*).

The *proximity* law implies that objects close to each other are perceived as groups (see *Figure 4*).

The law about *continuity* states that visual, auditory, and kinetic patterns are expected to continue in the same direction rather than taking a new direction (see *Figure 6*).

Closure explains how images that are not entirely complete are often perceived as complete. We read things into pictures and complete them in our minds, turning them into something we recognize (see *Figure 5*).

Colours are tricky to use, since they have different meanings in different cultures and are subject to personal taste. To avoid problems with colour blindness, red and green should not be used in combination. There are several types of catalogue systems for colours. Two of the most commonly used are NCS and RAL.

Cultural norms could also be applied when it comes to directionality. People normally interpret upward, right, and clockwise as an increasing value, while downward, left, and counter-clockwise represent a decreasing value.

Symbols must be unambiguous. Symbols can be used at different levels of abstraction. They can represent reality graphically, or be more abstract by representing a concept. Letters and digits are also a type of symbol. Compared to text, symbols have the advantage that they can be read at a further distance, the information will be discovered faster, and they are language independent (Bohgard et al. 2008). Symbols are of help to people with cognitive difficulties and people who speak other languages. Information on signs should therefore include both text and symbols. When the symbol is the main source of information, the text should be centred under the symbol (Göteborgs stad, 2011).

Colours, contrast, and gloss

Symbols and pictograms should always be negative (white on a dark background) with a contrast relation of brightness between text/symbol/pictogram and background of minimum 0,4 according to NSC (Natural Colour System). The text colour on signs with a dark background colour should have a broken white colour to prevent it from ”glowing”. The colour combinations red/green, orange/brown, and blue/green should not be used as they have an insufficient contrast relation with each other.

To prevent reflections that could cause disturbance for the user, the surface of the sign should be matte.

Text

The typeface should be Arial and the letters should not be stretched out. This would make it difficult to interpret the word.

If the text is presented on dark background (negative text), the letters may have to be fattened. Otherwise the text could be harder to read than the text in positive signs.

Words that are written on non-tactile signs should start with a capital letter and be followed by lower case letters. Single words that are written on signs that could be read up-close should be written in capital tactile letters and with a minimum text size of 15 mm and a maximum size of 40 mm. This makes it possible to feel the tactile words, which should have a minimum of 1 mm relief and braille. Having tactile letters makes it possible to understand the signs without knowing how to read braille. The tactile words answer to the needs of, for example, older people with reduced eyesight that have not been able to learn braille.

The braille should be printed on the same sign close to the other text (Göteborgs stad, 2011).

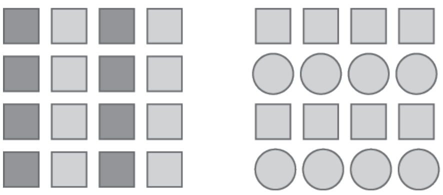


Figure 3. Gestalt law - Similarity

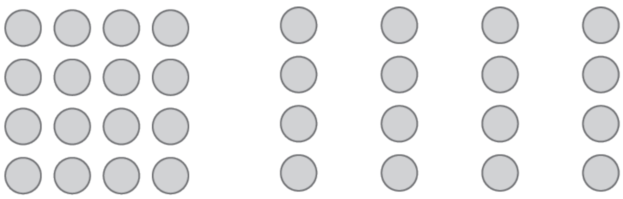


Figure 4. Gestalt law - Proximity

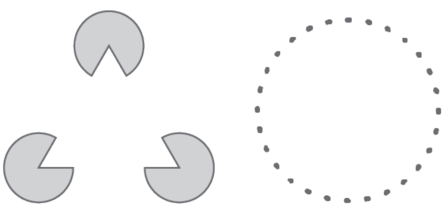


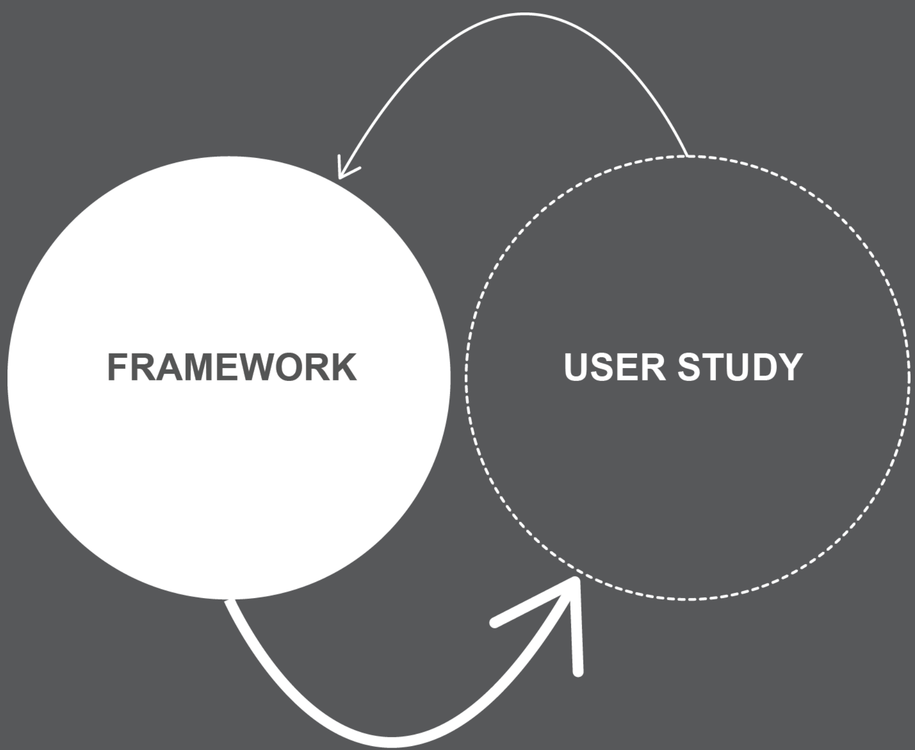
Figure 5. Gestalt law - Closure

Figure 6. Gestalt law - Continuity

3. FRAMEWORK

The framework provides the basis for the project study and includes a description of waste and the waste management system for public indoor areas in Gothenburg. The description summarizes important elements of understanding the problem area, and also includes a field study at the waste management company Renova.

The chapter also presents the users and the facilities where the final product will be placed. The project framework is concluded by a benchmarking study, which lays the foundation for the studies to be presented in the next chapter.



3.1. THE WASTE MANAGEMENT SYSTEM

The following sections describe the environment and the infrastructure that the product will be part of.

3.1.1. Definition of terms

There are terms and conditions which are important to explain in order to understand the waste management system in Gothenburg City.

The administration of Circulation and water (Kretslopp och vatten förvaltningen) is, on behalf of the municipality of Gothenburg, responsible for the management of waste that is not included in the producers' responsibility. This includes organic and combustible waste. Waste collection inside or adjacent to the buildings where the waste is produced is called curbside collection (Fastighetsnära Insamling – FNI) (Avfall Sverige, 2013). This includes both private and public facilities. The waste company that manages the curbside collection of the combustible and organic waste in Gothenburg City is Renova (Renova, 2013a). Their commission is financed by the property owners (Göteborgs Stad, 2013a). They are also responsible for public recycling centres (Återvinnings-central – ÅVC) where all waste fractions can be disposed (Renova, 2013b), including waste from public outdoor areas. These public outdoor areas are, for example, streets, parks, recreation areas etc. The recycling centres and the waste collection from the public outdoor areas are financed by taxes.

The waste that is included in the producers' responsibility is managed by the Packaging and newspaper collection organization (Förpacknings- och tidningsinsamlingen – FTI AB) which is financed by the packaging producers. The company is responsible for the curbside collection of packaging and newspaper, and for the recycling stations (Återvinningsstationer – ÅVS) that are available to the population around Gothenburg City (FTI AB, 2013).

3.1.2. What is waste?

Waste, or garbage, is something discarded that is no longer useful or wanted. This section describes the hierarchy of waste and the different types of waste that are of interest in this project.

Most of the waste that occurs in a society can be categorized as domestic waste. According to the Swedish Environmental Code (SFS:1998:808, 15 kap, §2) domestic waste means waste originating from households and accordingly also comparable waste originating from other activities.

In 2012 about 460 kg of domestic waste, per person was treated in Sweden. According to Sveriges avfallsportal (2012a) this waste can be divided into methods of treatment as follows:

- 15 percent biological treatment
- 32 percent recycling
- 51 percent incineration with energy recovery
- 0.7 percent deposition

Hierarchy of waste

Almost all the waste that we produce comes from some type of consumption. When an item has served its purpose, and is considered 'consumed', it is garbage. This can, however, occur in different stages of an item's lifecycle and some items can have many lives.

In June of 2011 the City Council of Gothenburg approved a new regional waste plan. One of the goals expressed in the waste plan was that the volumes of waste should not increase and that the resources in the waste should be utilized as much as possible. This goal is based on the hierarchy of waste (see *Figure 7*). The priority of the waste hierarchy is approved by EU and can be seen in the picture below (Göteborgs stad, Kretslopp, 2012).

The municipality of Gothenburg is working to move all waste management higher up the hierarchy. The aim is to move all waste to as high a level as possible and to improve the quality within each step. The purpose of this project is to move waste from landfill and energy recovery to material recycling.

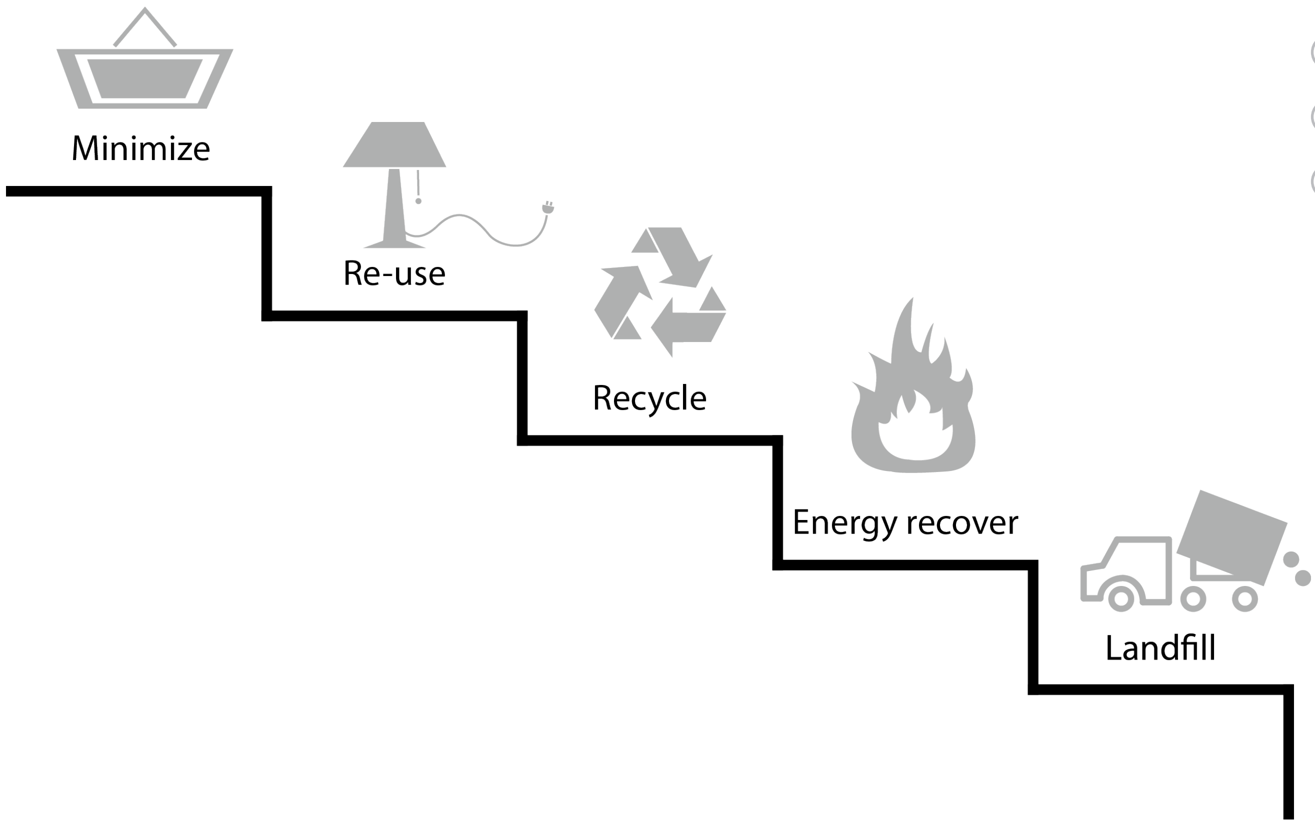


Figure 7. The waste hierarchy where the goal is to minimize waste

The different fractions of waste and how they are recycled

At the site sopor.nu (Sveriges avfallsportal, 2013) the waste is categorised into three different types, namely packaging and newspaper, dangerous waste, and other waste. Below follows a short description of what characterizes the types of waste and what differs between them.

Packaging and newspapers

In Sweden, companies that produce or import packaging material are required by law to take responsibility for that material. The total recovery (recycling and energy recovery) was for all packaging, in 2011, 81 percent (Naturvårdverket, 2013).

Packaging material is common in public indoor areas and will therefore be considered when developing the recycling station for this environment.

Plastic packaging

Plastic packaging includes, for example, bottles and cans of plastic, lids, caps, plastic wrap, Styrofoam, and straws (Sveriges avfallsportal, 2012b).

Since 2008, it has been possible to leave both hard and soft plastic for recycling. Hard and soft plastic packaging are divided in an automated sorting facility by using air. The soft plastic is blown or sucked away.

The plastic is then sorted according to its chemical composition, and sometimes by even colour. The material is then sold to companies that manufacture plastic products.

In 2011, 28 percent of plastic packaging was recycled; hence the national goal of 30 percent recycling was not reached. In the same year, PET-bottles were recycled to the degree of 84 percent, the goal being 90 (Naturvårdverket, 2013). The reason PET-bottles are recycled to such high extent is that there is a pawn system in place to encourage the collecting of these.

Paper packaging

Pasta boxes, milk cartons, flour bags, paper bags, toilet rolls, wrapping paper, and corrugated cardboard are examples of paper packaging (Sveriges avfallsportal, 2012b).

The national goal is that 60 percent of paper packaging material should be collected. The producers have achieved this goal. In 2011, 76 percent of the material within the group was utilized (Naturvårdverket, 2013).

Packaging material of paper is delivered to a sorting facility where foreign material is filtered out. The material is then pressed into bales and transported to the papermill.

The quality of the material is controlled by drilling samples from randomly selected bales. The contractor who sells the material is paid depending on how good the quality turns out to be, i.e. how well sorted and homogenous the material is.

The paper is then mixed with water, in a rotating barrel, until it has dissolved into fibres. At this stage, the fibres are separated from fibres that are too worn and other materials, such as the plastic layer on the inside of milk cartons. The material that have been filtered out is incinerated. The remaining pulp is turned into new cardboard that is sold to various companies and used for new packaging material (Sveriges avfallsportal, 2012b).

Metal packaging

Cans, tealight holders, caviar tubes, and aluminium foil are examples of metal packaging. But even lids and caps of metal are classified as packaging that can be sorted and recycled.

Material that does not belong is sorted out by hand at a sorting facility. Steel and aluminium are then separated by means of a powerful magnet. The two materials are compressed into bales and transported to a melting plant (Sveriges avfallsportal, 2012b).

In 2011, metal packaging was recycled to a degree of 69 percent, so that the national goal of 70 percent was not reached. The rate was lower compared to the previous year (Naturvårdverket, 2013).

Glass packaging

Bottles and jars constitute glass packaging. Coloured and clear glass should be sorted separately.

A truck that is divided into two compartments and can carry coloured and clear glass at the same time, usually retrieves the glass. The first sorting is done by hand in order to sort out bigger pieces of material (rocks, metal, plastics) that do not belong. Smaller pieces are sorted out automatically using magnets, metal detectors, and vacuum suction. The coloured glass is divided into green and brown by means of photoelectric technology. Finally the glass is crushed in order to be used as raw material in new products (Sveriges avfallsportal, 2012b).

Glass packaging is the type of packaging material that is recycled to the highest degree. In 2011, 92 percent was recycled (Naturvårdverket, 2013).

Newspapers and printed material

Newspapers, magazines, office paper, flyers, brochures, catalogues, books, and other printed materials belong in this category. The material is brought to a sorting facility where contaminators are removed, both by machine and by hand.

The paper is transported to one of the seven mills that receive recycled paper in Sweden. There the ink is removed and the paper is dissolved and turned into pulp. The water is then removed and the old fibres are mixed with virgin fibres and pressed into new paper. Nearly half of the raw material used in new paper may consist of recycled fibres and the rest of the virgin fibre. The fibres are placed on a wire – a fabric with small holes – where the water runs off, and then go into the paper machine where they are pressed into new paper (Sveriges avfallsportal, 2012b).

Dangerous waste

Dangerous waste means waste that cannot be safely incinerated together with other waste and that can harm the environment if left in the wrong place. It is true for all types of waste that it is beneficial to separate different materials and to recycle if possible, but with dangerous waste it might be directly harmful if it is mixed with domestic waste and incinerated, or flushed down the drain. It can be left at the municipality's recycling central, at some recycling stations, and in some places at certain stores and gas stations (Sveriges avfallsportal, 2012b).

Dangerous waste includes for example chemicals, pharmaceuticals, and electronics. The need to dispose of these types of waste does not commonly arise in public indoor areas. For this reason dangerous waste will not be described to any further extent in this report, nor will it be considered when designing the recycling station.

Other waste

Other waste includes everything that is not packaging material or dangerous waste. This includes for example bulky refuse, garden waste, food waste, and combustible waste (Sveriges avfallsportal, 2013). Food waste and combustible waste commonly occur in indoor areas and are described below. They are both handled by the municipality and paid for by taxes and fees.

Combustible waste

The waste that is put in the garbage bag should be the waste that does not fit into any other category. This could for example include diapers, envelopes, plaster, and various other things.

This waste is incinerated, and the energy is partly recovered and used for heating and electricity (Sveriges avfallsportal, 2012).

Food waste

In Gothenburg it is also possible to separate the organic material from the combustible waste. The organic waste is then used for bio-gas. Organic waste includes all kinds of food leftovers, paper tissues, flowers, and pot plants (Göteborgs stad, miljö, 2013).

3.1.3. System overview

The system of waste recycling in public indoor areas is closely connected to the waste management system in Gothenburg as a whole. The product design is therefore closely affected by this system. For this reason an overview of the waste management system in Gothenburg has been sketched. The result is described in a comprehensive analysis map as seen in *Figure 8*. The product's connection to the environment and infrastructure is thereby visualized and valuable information that can be drawn from this is taken into account in the concept development phase of this project.

The waste management system for public indoor areas in Gothenburg

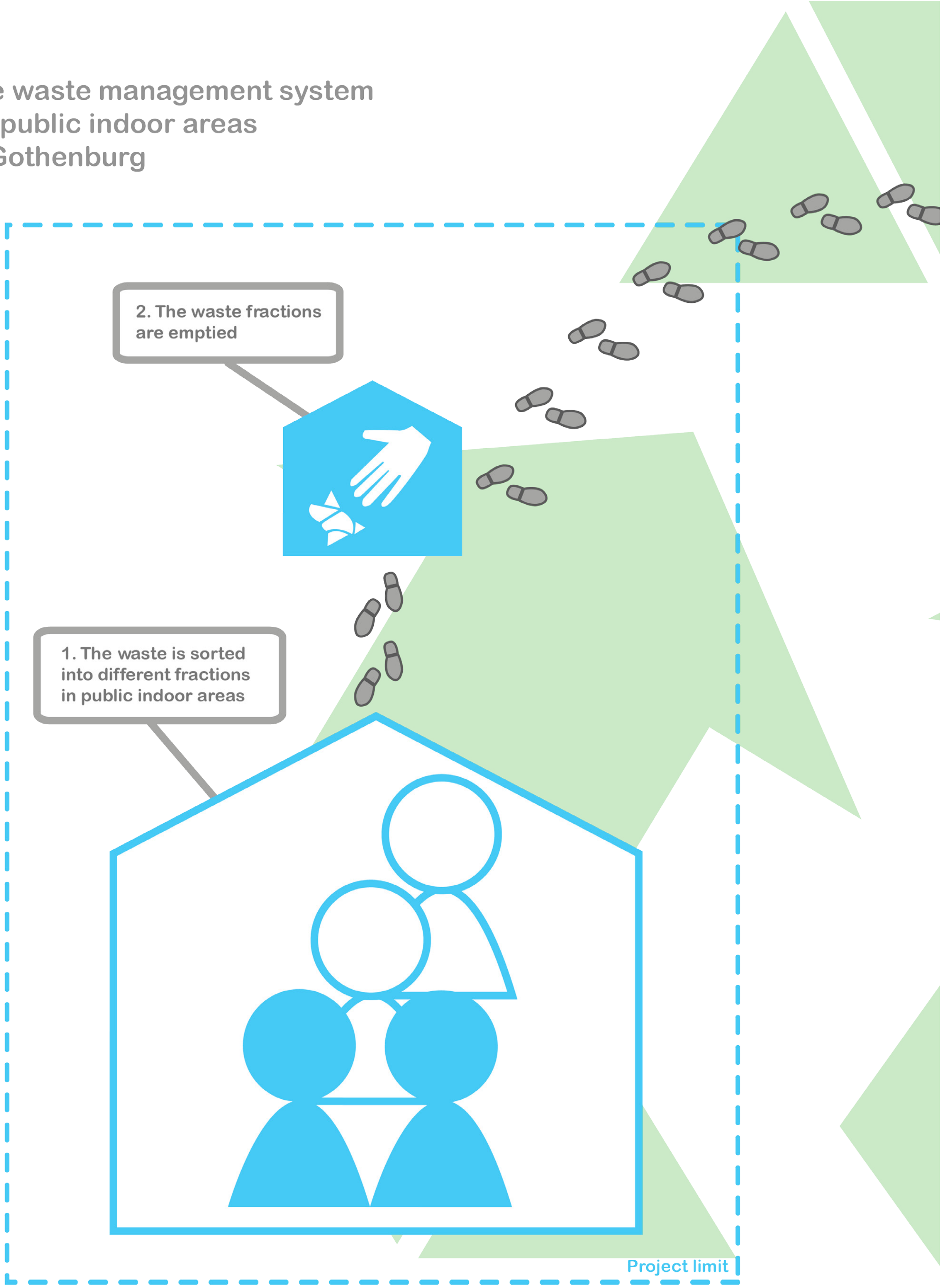
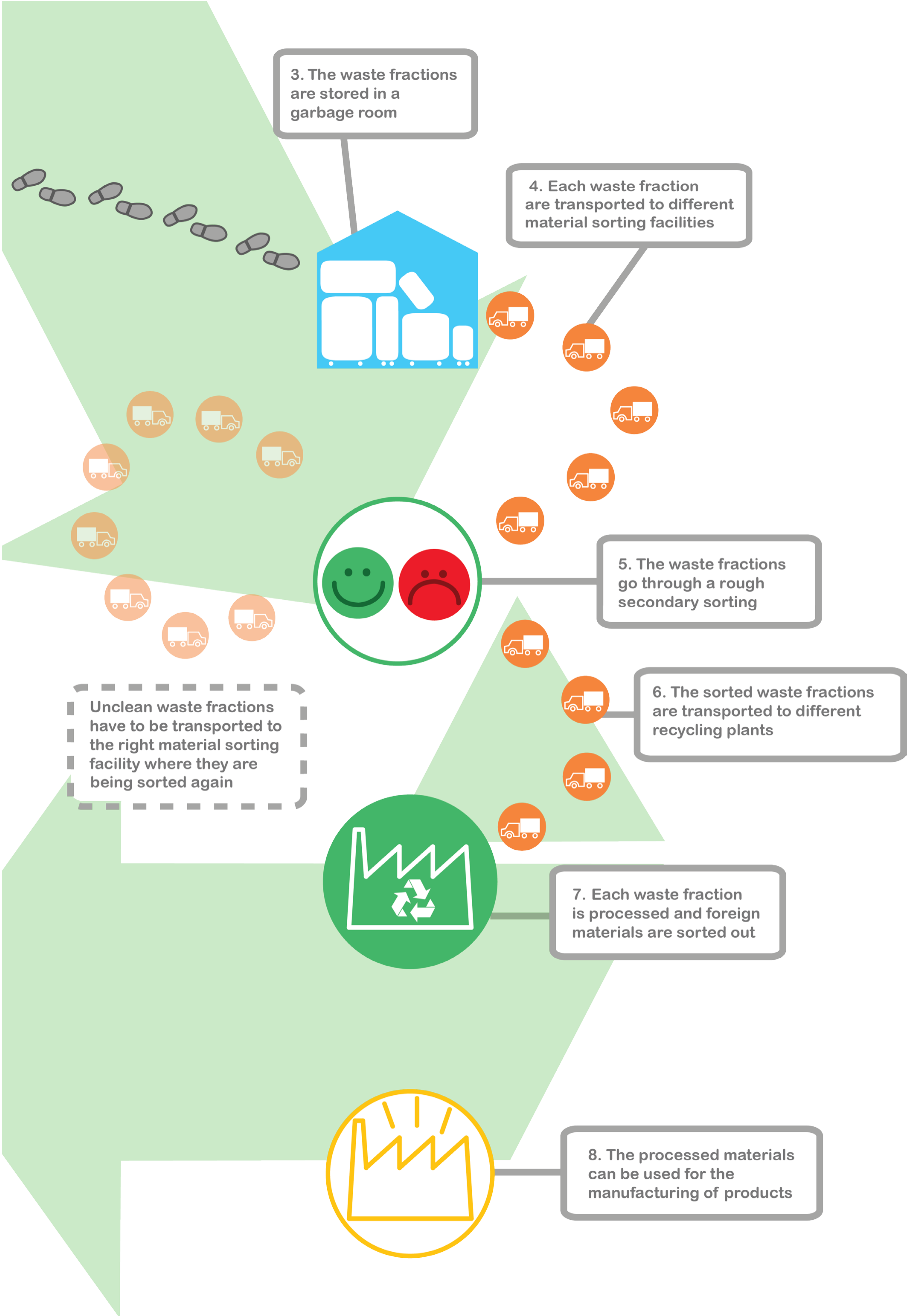


Figure 8. Description of the waste management system for public indoor areas in Gothenburg


3. The waste fractions are stored in a garbage room
4. Each waste fraction are transported to different material sorting facilities
5. The waste fractions go through a rough secondary sorting
Unclean waste fractions have to be transported to the right material sorting facility where they are being sorted again
6. The sorted waste fractions are transported to different recycling plants
7. Each waste fraction is processed and foreign materials are sorted out
8. The processed materials can be used for the manufacturing of products

Field study at Renova

A complementary study of the waste management system in Gothenburg was performed at Renova. Renova is a company that offers waste management including waste collection and transportation in the Gothenburg city region. It is also the company that the municipality of Gothenburg city hires for the collection and transportation of domestic waste.

To be able to procure as extensive information as possible about the waste management system and secondary user groups, a half-day field study of the collection and transportation of waste was performed. The study made it possible to identify user requirements from groups that do not directly appear related to the product but are affected it. Even though the waste collectors at Renova have no direct contact with the product since they collect the waste from garbage rooms, they could be affected indirectly by work environmental issues and routines.

The study was performed during four hours of a shift where the investigators followed two waste collectors in Gothenburg city centre. The investigators were able to perform many of the workers' tasks, such as rolling out containers from garbage rooms, locking the containers to the garbage truck and manoeuvring the lift and compressor of the garbage truck (see *Figure 9*)

The locations included restaurants, offices, private apartments, and Valhalla public bath (which was also one of the public locations that were included in the user study).

During the study, questions of work environmental issues and routines such as stress, working shifts, weather, load, etc. were explored. In addition, personal attitudes and opinions on waste recycling were investigated.

The result indicated problems related to the garbage room and its locations, such as high thresholds, but also to the streets that are built with cobblestone. Problems with waste containers that had small wheels and that were consequently difficult to manoeuvre on uneven ground were also mentioned.

Moreover, all waste that had not been sorted properly went to the combustible waste. This was due to work environmental issues such as heavy lifts, risks of getting cutting wounds, and time limitation.

The waste collectors were positive towards the suggestion that waste bags should change from black to transparent which would enable them to see what kind of waste the bag contained. This would help them to predict risks of getting cutting wounds from glass and other sharp objects. In addition, the glass made loud noises when the waste containers were emptied and compressed in the garbage truck. The noise was also something the waste collectors could be warned of and protected from if the waste bags had been transparent.

The waste collectors' personal attitudes and opinions towards waste recycling were often connected to the work related issues discussed above.

Result from the study which related to the recycling station for indoor usage mainly concerned ways to achieve unmixed fractions, which would improve the waste collectors' work environment.

Figure 9. The investigators could perform many of the collector´s tasks, including locking the containers to the garbage truck, maneuver the lift and compressor of the truck and roll in and out the containers from the garbage room

3.2. THE FACILITIES

In the framework, four different types of facilities were identified as the most likely surroundings for the product. These were cultural facilities, sport facilities, event facilities, and schools. The reason for dividing the facilities into different groups was to identify potential differences and similarities. To get a feel for the environment of public indoor areas, an image board is presented for each type of facility.

3.2.1. Cultural facilities

Cultural facilities refer, for example to libraries, museums, and cultural centres. In general the environment in these facilities is calm. They receive a stream of visitors when open (see *Figure 10*).

3.2.2. Sport facilities

Sport facilities include sport centres and public baths. They are similar to cultural facilities in the sense that people are coming and going during the day (see *Figure 11*).

3.2.3. Event facilities

Event facilities include, for example, concert halls and arenas for sport events. They differ from the previous facilities by the way people move about there. Event facilities receive a lot of people at the same time. The atmosphere varies a lot depending on the event (see *Figure 12*).

3.2.4. Schools

Schools are a special kind of environment since they are the 'place of work' for the students. Preschools were not included in the study, and the product will not be adapted to children under the age of seven. It is, however, a requirement that children above the age of seven should be able to use the product without assistant from an adult (see *Figure 13*).

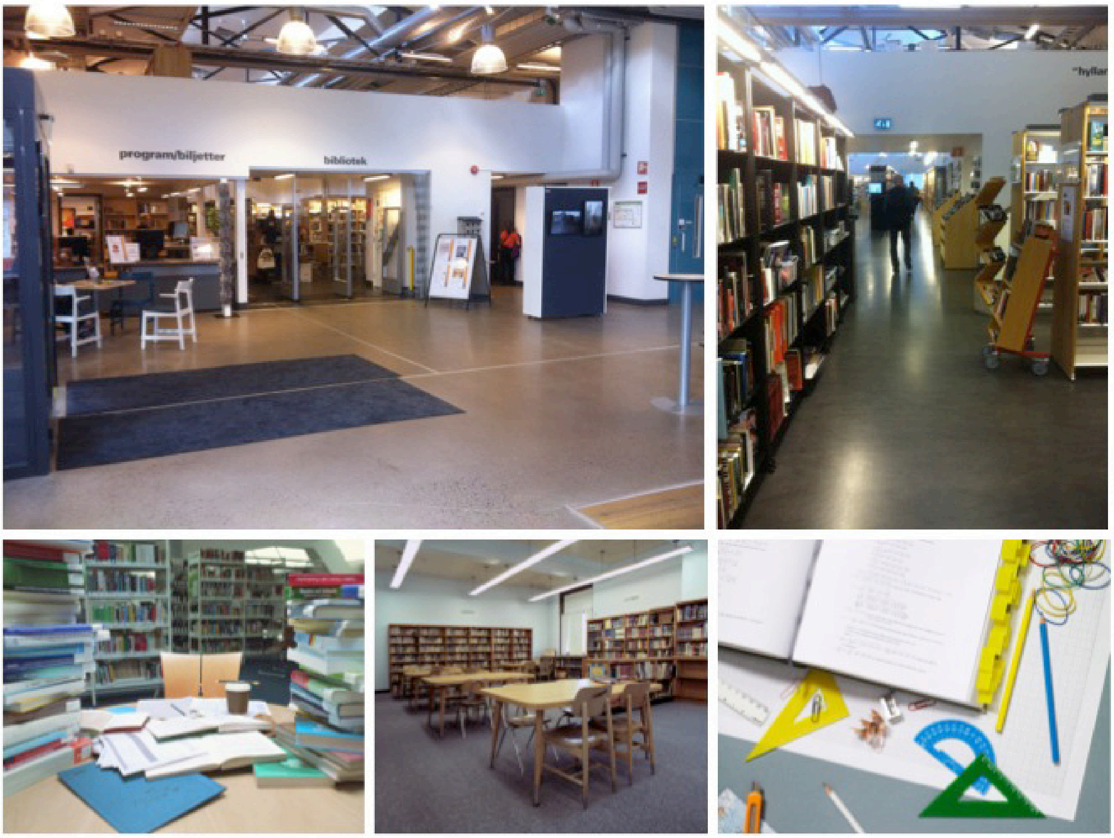


Figure 10. Image board of cultural facilities

Figure 11. Image board of sport facilities

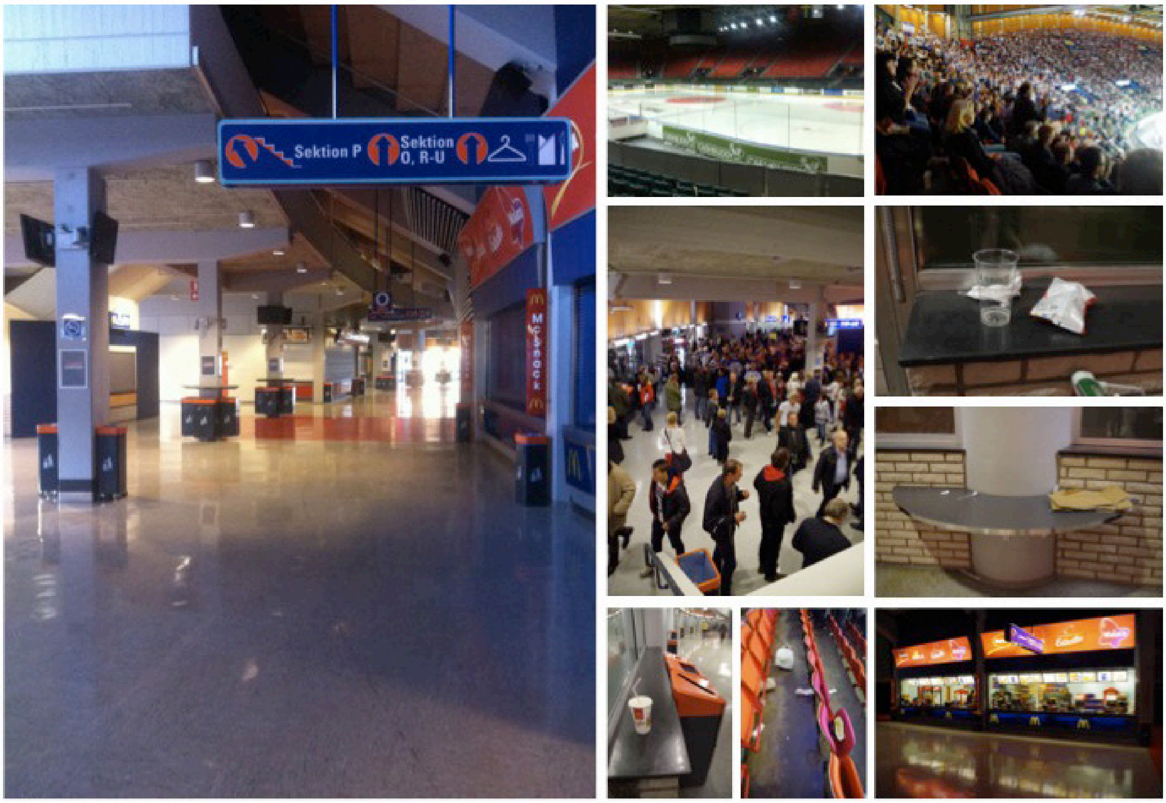


Figure 12. *Image board of event facilities*

Figure 13. *Image board of schools*

3.3. THE USERS

The users were divided into two main groups, namely sorters and collectors. There were other groups as well that were taken into consideration when designing the recycling station, such as maintainers and manufacturers. The focus of the user study lies however on the first of these two, because they use the recycling station more frequently.

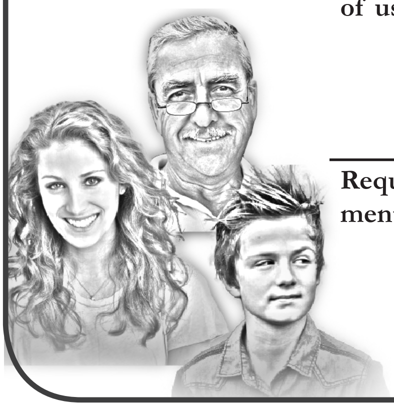
The maintainers clean and repair the sorting station. They are often the same people as the collectors. Sometimes it might be that there are cleaners who empty the recycling station, while a janitor, for example removes graffiti and repairs damages. On average it is estimated that the maintainers handle the recycling station a few times a year. The maintainers are professional users with demands regarding mainly access and cleaning possibilities.

The manufacturers handle the product in the beginning and sometimes also the end of the lifecycle and they have needs regarding accessibility when constructing the recycling station.

Below follows a summary of the two main user groups.

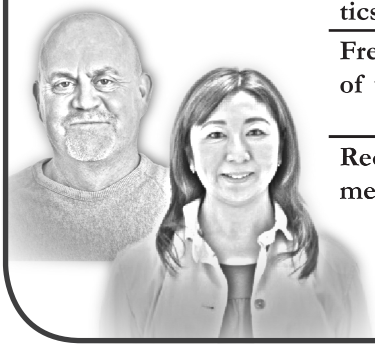
3.3.1. Sorters

Personal characteristics	The sorters are the ones throwing the waste in the recycling station. Children under the age of 7 were not taken into consideration, but apart from that this group includes virtually everyone. The majority of this user group speaks Swedish and lives in Gothenburg, but there are also tourists. This user group also includes people with special needs. These are, for example, visually impaired or blind people. It could also mean people with physical impairments, such as wheelchair-bound people, or people with cognitive difficulties.
Frequency of use	The sorters use the sorting station with different frequency. In some cases, for example in schools, it might be that the sorter uses the station every day, but this is rarely the case. The sorter might be a tourist visiting an event who will only use the sorting station once. The product should therefore be developed with this in mind.
Requirements	The sorter only ever sees the outside of the product. Their task is to interpret the waste station and to throw their waste in the right fraction. Therefore the sorting station needs to be intuitive and easy to understand.



3.3.2. Collectors and maintainers

Personal characteristics	The collectors are those who empty the sorting station. They are usually cleaners or janitors at the facility. They are adults, that is, between 20-65 years old.
Frequency of use	They handle the sorting station every day while working. This means that the collectors have the opportunity to learn and accomplish even more complicated tasks.
Requirements	Since the collector uses the sorting station so frequently, it does not need to be intuitive from their point of view (they will learn how to handle it), but the physical requirements are are high since work related injuries need to be prevented.



3.4. BENCHMARKING

In the beginning of a product development process it could be beneficial for the investigators to examine existing products in order to form a point of reference when evaluating the new product. The examination of existing products could for include, for instance, technical solutions and/or usability properties, and the result could be used for setting minimum requirements for the new product (Jordan, 1998).

Existing solutions within the product group were used as reference points in the concept development phase.

The data from the benchmarking was gathered by investigating "recycling solutions" in general as well as existing products used in the Swedish municipal public areas at the time of this study. The purpose of this approach was to create a comprehensive overview of existing solutions with a focus on the municipal public areas, since Gothenburg has similar prerequisites as other municipalities. Since there are not that many indoor-recycling solutions, outdoor solutions were also included in the study. Consequently, additional assumptions of conditions for indoor usage must be added in the analysis.

The result of the benchmarking is presented in the sections below. The focus lies on different properties that could be distinguished by studying pictures of the recycling solutions.

3.4.1. Recycling solutions in the municipalities of Sweden

The following sections summarize information about recycling design solutions that have been collected from other municipalities in Sweden.

Helsingborg

The Urban Planning Department (Stadsbyggnadskontoret) at Helsingborg municipality has placed nine recycling containers around the city's public outdoor areas. In addition, they deploy ten more containers at events. The containers are of a standard model from the manufacturer Sortify and holds up to four different waste fractions (see *Figure 14*).

The municipality's idea was that Sortify's different waste fractions should be easily accessible; hence it is possible to reach the slots from different directions (Lindkvist, 2013). In addition, the container is easy to empty and sufficiently stable to fulfil the outdoor environmental requirements.

The different waste fractions are: paper, glass, plastic, and residual waste. The glass fraction collects both coloured and clear glass which are transported to the colour glass material recycling facility. The waste in the paper and plastic fractions are often too contaminated and/or too mixed to recycle and are therefore being recycled to a very small extent.

Ten of the recycling stations have an QR-code connecting to a song that is related to the specific city location, which is intended to encourage sorting.

Figure 14. The recycling container Sortify is used in Helsingborg's public outdoor areas where the differences in content are being communicated to the user by text (Helsingborgs Kommun, 2013)

Hässleholm

The Urban Planning Department (Stadsbyggnadskontoret) and the Environment Department (Miljökontoret) at Hässleholm municipality have started a project, KOM till Hässleholm, whose goal is to improve the recycling in the municipality (Hässleholm, 2013). One of the results of the project has been the development of recycling stations for public areas in the municipality.

The fractions of the recycling stations seen in *Figure 15* and *Figure 16* have been developed based on an analysis of the waste commonly to be found in public outdoor areas. The analyses resulted in three main waste fractions which were most common: paper, plastic, and combustible waste. In addition, the containers that were set up were, complemented by containers for deposit cans which were mounted on lampposts (Krantz, 2013).

The containers are of a standard model from the manufacturer Citycan, and the signs can be customized. The signs describing each fraction were developed in collaboration between the project "KOM till Hässleholm" and Citycan and were mounted on the lids. The recycling containers were set up close to each other, and the separate containers for combustible waste indicated how long it would take to get to a recycling station (see *Figure 16*).

Figure 15. The recycling stations in Hässleholm's public outdoor areas are set up close to each other and has three different fractions – plastic, paper, and combustible waste (Photo: Kranz, 2013)

Figure 16. The regular combustible waste containers in Hässleholm's public outdoor areas have information on how long it takes to get to a recycling station (Photo: Kranz, 2013)

Figure 17. The recycling containers are used in Malmö public outdoor areas where the differences in content are communicated to the user by means of colour, slot shapes, and graphics (Photo: Mattsson, 2013)

Malmö

The Streets and Parks Department (Gatukontoret) in Malmö City is cooperating with other municipalities in the Skåne region, the waste manager VA SYD, and the organisation "Håll Sverige rent" to introduce recycling in public areas. Together with PWS AB (a company providing products for waste management and recycling) they have developed a recycling station consisting of modules, for public outdoor areas (see *Figure 17*).

The recycling containers have different colours and slots so that the user can easily distinguish the contents. In addition, the users can recognise the colours of the containers because these are the same ones used by that the Packaging and newspaper organization (FTI AB) for their graphics. Further, the modules have the dimensions 3000x1300x600 mm and are intended to hold a 120-litre roller container (Mattsson, 2013).

The development of the station is based on an analysis of the waste from different public areas and the type of waste that was most frequently thrown there. The result showed no significant differences in the composition of the waste between different public areas. The waste fractions of the recycling station are: coloured glass, clear glass, plastic packaging, paper packaging, combustible waste, and deposit cans.

As a result of this initiative more of the waste is being recycled instead of incinerated. The vision of the city of Malmö is to further develop the concept by labelling the packaging material and the containers in the same way, so that the users will recycle correctly (Mattsson, 2013).

Stockholm

The administration of Traffic and Public Transportation (Trafikkontoret) in Stockholm do not manage recycling stations for public areas in the city, either for outdoor or indoor use. However, at local grocery stores, the administration is responsible for containers available to the residents that want to dispose of dangerous waste (Söderqvist, 2013).

3.4.2. Recycling solutions with communicating properties

In the following section, different properties that were discovered in the benchmarking study are described.

Content

By communicating the product's content, the usability increases since the user will better understand the purpose of the product, i.e. to sort waste, and act accordingly. However, the user must often have basic knowledge of waste recycling for the communication to succeed. The content can be communicated by different design elements, which are presented below.

Colour

By applying different colours to the different fractions, it will be easier for the user to distinguish the containers from one another. He or she will understand that the waste has to be separated and will try to find more information on where to put it. The colour differences of the containers are therefore not sufficient and need to be complemented by additional information.

An example of the communication of different content using colour is shown on the recycling station used in Malmö (see *Figure 17*).

Different slots

The different content could also be distinguished by using different shapes of the slots, which can be seen in *Figure 17*. In some cases the shape of the slot correlate with the shape of the waste intended for the container. If the shapes of the slots differentiate only in relation to each other, the user needs more information on how to sort the waste.

Graphics

Another way to distinguish between different types of waste is by adding graphical information that visualize the different waste fractions (see example in *Figure 15* and *Figure 17*). The graphics do not need additional text if the user understands the meaning of the illustrations, by which they could bridge language barriers. However, graphics could be wrongly interpreted, and that is why they often have complementary text for clarification.

Shape

The content could be communicated through different shape of the containers. An example of this can be seen in the recycling station "Go Eco" by Goodss Passion (2013). Communication by means of shapes crosses language barriers but is limited and may need complementary information.

Text

By adding text that explains the content of the container, the fractions are further distinguished from one an other. The text message requires, however, that the user understand the language.

One example of using text to communicate the content is shown in *Figure 15*. The recycling container is used in the public outdoor areas of Helsingborg.

Transparency

The content of the container could be communicated to the user by using transparent material. The user will understand that the content of the containers are not the same and that the waste needs to be sorted, and will try to find the right container for the waste. However, if the container is empty or the user has the wrong kind of waste, or if waste in the container is incorrectly sorted, the user will need complementary information. Transparency literally shows what is inside the bag and this might also serve an educative purpose.

One example of the use of transparency as a method of differentiating between waste fractions and as a means of calling attention to waste issues, was at the Olympic games in London, 2012 (Marlow, 2012).

Figure 18. The recycling container by Rolighetsteorin makes recycling of glass more fun – an initiative from Volkswagen on changing people's behaviour (Rolighetsteorin, 2013)

Encourage sorting

Design elements that encourage the user to take pro-environmental actions could increase the recycling of waste.

Constraints

There are user constraints that encourage the user to sort waste. One way is to make the container for combustible waste smaller and lower in order to encourage the user to use the more accessible recycling containers. This was done at the Olympic games in London 2012 (Marlow, 2012).

Gamification

By encouraging the user to sort waste through gamification, the game thinking and competitive nature of the user is being stimulated. This could mean, for instance, design elements that allude to sports or video games, or that the user is performing tasks through a competitive approach, or that the users get rewarded if the task is performed correctly. One example is the Bottle Bank Arcade (Tomglasspelet, *Figure 18*) from Rolighetsteorin, which have lights above the slots to indicates where to put the glass and also a system to count how much glass the user throws.

Inform about the purpose of recycling

If the user were to be informed about the purpose of recycling, he or she would know why the waste has to be sorted and act accordingly. The purpose of recycling could be communicated by means of pictures that have visual environmental elements such as organic shapes, colours, and graphics, or it could be explained through text.

Playfulness

Design elements that establishes a playful relationship to the user could be used to encourage him or her to act pro-environmentally. This would give the user a happy user experience which may enhance the waste recycling actions. The recycling container in *Figure 18* is an example of the gamification attribute as well as of playfulness. In addition, playful design elements could be expressed through attributes – form, colours, and expressions – which are associated with children and children's play.

Practical solutions

The following practical solutions from the benchmarking study are examples on how to use and empty the containers.

Sorting

The sorters perform only one task with the containers and that is to sort waste. The part of the container that the user will interact with is the slots. The slots can either be open so that the user can put the waste in the container without touching it, or there can be lids which the user has to open to be able to put the sorted waste in the container. Lids have the advantage of containing bad smell as well as preventing waste from being scattered by wind or animals.

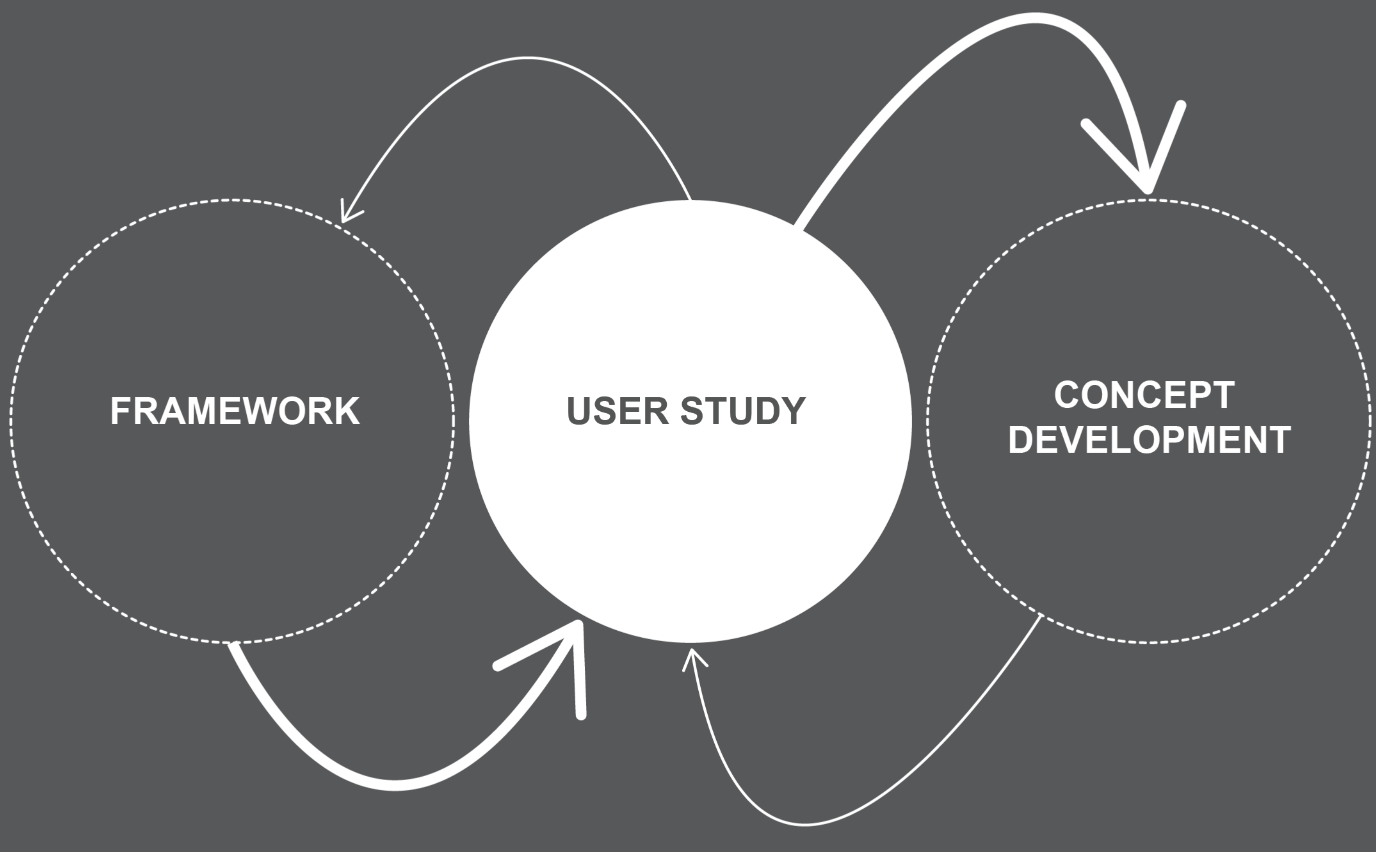
Emptying

The next practical solution concern the task of emptying the containers. There are many ways to do this: from above, from the side or from an angle. The unit could have reusable containers, or they could have disposable plastic bags.

4. USER STUDY

The user study consists of two parts: the study of the sorters and the study of the collectors. The two parts, which were conducted in parallel, formed the basis for determining the different user demands that the product would have to meet.

The user study is based on the findings made in the framework and the result is compiled in the specification of requirements. This specification was then used to audit the result during the concept development and the concept refinement.



4.1. METHODS AND PROCESS

In this section the methods used during the user study are described along with the process. Two different types of users – sorters and collectors – were studied in this phase of the project, and the methods used during the field study are described below.

4.1.1. Methods used during the field study

Information on the sorters were gathered through observational studies and surveys. The result was used to decide upon necessary functions of the product and to compile requirements to fulfil the needs of the sorters.

The user studies of the collectors were conducted by means of observations and interviews. These methods were used at the same occasion, at different types of public indoor areas where the product might be implemented. The result showed differences and similarities between the sites and was used as a basis for requirements to meet the collectors' needs. This was then used as a basis for the concept development.

Observational studies

Unlike interviews and surveys, in which language plays a predominant role, observational studies operate by sensory impressions and can often yield unexpected insights. This has many advantages, and can result in unexpected insights. It is possible to study unconscious behaviour and things that people routinely do that are often hard to put into words (Krippendorff, 2006).

Pilhammar Andersson (1996) presents a list of information that should be included in field notes from observations:

- Where the observation took place
- When the observation took place
- Which activity that took place
- What was said
- What was done
- Atmosphere, rhythm, and tempo

This list was taken into account when developing the observational protocols. The observational protocol for the sorters and the collectors can be seen in *Appendix I* and *Appendix II*, respectively.

The reason for performing an observational study of the sorters was to investigate possible unconscious behaviour, and to see if the qualitative data, gathered in the interviews and surveys, could be supported.

The purpose of the observational study of the collectors was to gather information on differences and similarities between the facilities. This was conducted by gathering data on waste, work routines, and work environments. The study included observations on the collection of waste, how it was performed, and what the waste contained. The study further registered the social environment, the atmosphere, and the work tempo of the waste collectors.

The studies of the sorters and of the collectors were for the most part conducted at the same time. Consequently, many of the facilities that were included in the study were the same for the sorters and the collectors. These facilities were:

Culture: Härlanda library

Sport: Björlanda sport center; Valhalla public bath

Event: Liseberg amusement park and arena; Scandinavium

Schools: Hovås high school

In addition to these, observational studies of the collectors were also conducted at Valhalla sport centre, Ullevi arena, and Chalmers University of Technology. At these facilities there were no visitors/students present at the time of the study, and hence only the collectors were included.

Surveys

To gather information on the personal views and preferences of the sorters, surveys were used.

Surveys are often distributed to a large number of potential respondents. The questions need to be standardized and the information you can get is limited, because the questions always reify the researchers' concepts (Krippendorff, 2006). Nevertheless, surveys are a good way to collect certain types of data and are often less time consuming to analyse than qualitative data.

In this study, the majority of the surveys were distributed via Internet to different age groups. The questions were adapted to the specifics of the different facilities, meaning there were four different surveys for culture, sport, event, and schools respectively. Since the questionnaires were very similar, apart from the term used of the facility type, only one (for sport facilities) is included in this report (see *Appendix III*).

The questions targeted people's personal views on waste recycling and investigated their recycling habits both in private and in public areas. The questions also treated the waste situation at the different facilities.

The data from the surveys were analysed through a combination of KJ-analysis and quantitative analysis depending on the nature of the information.

Interviews

Interviews are a well-known method to collect data from users and other interested parties. An interview can be based on open questions or be strictly controlled by structured questions. An unstructured, deep interview is a qualitative method, hence it is especially useful when researching 'soft' values and opinions (Johannesson, Persson, and Pettersson, 2004). Structured interviews, where the questions are prepared beforehand and a rigid structure is followed, result in more quantitative data that can be turned into statistics.

The collectors were interviewed in order to gather qualitative data about their opinions, work situation, and behaviour. The result from these interviews contain rich and informative data that could not have been collected by any other means. The collectors could, with their own words, narrate the user scenario as perceived.

The interviews in the study were semi-structured and supported by an interview guide, which allowed for the possibility of probing the interviewees through the session to gather additional information. The interview guide contained demographic questions of age and gender and had three main sections: attitudes, work routines, and work environment (see *Appendix IV*). The purpose of these sections was to gather data that could affect the usage of the product.

The interviews were mostly held while the collectors were working or, on some occasions, in lunchrooms or while they were guiding through the facilities.

The data from the observational studies and the interviews was summarized in a KJ-analysis, where the data was grouped in appropriate categories. From the KJ-analysis, a series of user demands could be deduced and added to the specification of requirements.

4.1.2. Analysis

Different methods were used when analysing the gathered data from the main study. The section below describes KJ-analysis, quantitative evaluation, function analysis, and specification of requirements.

KJ-Analysis

KJ-analysis is a way to structure small and disparate pieces of information. The information is collected and written down on, say, a number of post-its. The post-its are then arranged into different categories. The categories are in turn connected, and the result is a tree where the initially unstructured data has been arranged (Straker, 1995).

The data from the main study contained many qualitative responses that were perceived as unstructured information, difficult to survey. Therefore, a KJ-analysis was performed in order to structure and analyze the data. Through the structured categories in a KJ-analysis, the unstructured data becomes accessible and easier to apply as user demands in the specification of requirements.

Quantitative evaluation

In addition to the qualitative data, there were also quantitative data in the user study. This data was almost exclusively collected through the surveys directed towards the sorters. Because of the nature and amount of the data, it was analysed by the means of diagrams, where trends and relationships could be deduced.

The answers from the surveys were evaluated either depending on the age of the sorter or on the facility that he/she had been visiting. Attitudes and habits were evaluated depending on age. These age groups were 15-19, 20-39, 40-59, and 60+. The reason for having a much narrower age span for teenagers was because it was assumed that this group differs somewhat in terms of habits and opinions, and it was considered interesting to see to what extent. No children were included in the study. The reason for this was that the user group does not include children below the age of seven; hence this group was not investigated (see *Chapter 3.3*). Children between the ages of seven and fifteen were included in the observational study, but due to limited time and lack of appropriate communication channels, they could not be reached for the survey.

Questions that were specific to the respective facility (such as the type of waste the sorters dispose of and whether they see the need for sorting waste at this specific facility) were evaluated accordingly.

Function analysis

By performing a function analysis, basic requirements of the human-machine system are described and divided into a detailed specification of part-systems and functions. The purpose of dividing the demands into functions is to make it easier to divide the problem into accessible parts. Each function can then be analysed in detail (Bohgard et al, 2008).

When performing a function analysis the main function, sub-functions, and possible support functions are identified. The function analysis leads to the separation of features and provides a comprehensive view of the system with the possibility of freely analysing each part (Bohgard et al, 2008).

The function analysis in the study was made with the purpose to support the idea generation during concept development. Each function could be deduced and its purpose would then be easier to understand. In addition, the division facilitated creative thinking during idea generation.

Specification of requirements

In the specification of requirements, demands of functionality and performance are defined. These demands are used to support the product design and construction. The specification is created after the analysis of the result from the data collection. It contains defined demands of what the system (product) should perform – not, however, of the manner of its performance. It could be, for example, demands on ergonomics, economy, functionality, aesthetics, and manufacturing (Bohgard et al, 2008).

The specification was based on the project description complemented by various needs and demands through the whole study. The requirements were formulated in a way that prevented them from being restrictive during concept development and concept refinement. The formulations could therefore provide as much room as possible for innovative solutions. In addition, the requirements were formulated in such a way that they, as much as possible, could be measurable. The requirements were categorised as requests or demands and graded from 1-5, where 5 stands for the highest priority. The difference between requests and demands is that demands need to be fulfilled by the product, while the requests are product features that would add value, but that are not essential to the functionality of the product.

The specification of requirements was updated throughout the project as new needs and demands on the system were identified.

4.2. RESULTS

The result from the user study formed a basis for the specification of requirements and allowed the project group to form a more general picture of the waste management in public indoor environments. The result included both quantitative information, such as the amount or type of waste, and qualitative information, such as the general ambiance or aesthetic expression of different public indoor environments.

4.2.1. The waste situation at the different facilities

Below follows a description of the waste situation at the different facilities. This information is the result from the observational studies performed at the facilities. There were a lot of differences between the facilities, especially with regard to the volume and type of waste. But one thing that all the facilities had in common was that they all had some amount of food waste.

Cultural facilities

In general the study shows that there is very little waste in these types of facilities. It is not permitted to bring any food or the like into museums; hence there is not a lot of waste generated. At libraries and cultural centres there is more waste. People come to libraries to study and bring fruit and snacks. Compared to some of the other facilities, however, the quantities are very small.

Sports facilities

At sports facilities there were food waste in the form of apple-cores, banana peels, and the like. There were also candy wrappers, soda cans, and plastic bottles. In the changing rooms there were containers for sanitary articles such as shampoo and body lotion. This was especially common at the public bath. At the public bath the staff mentioned that it also occurred that the visitors brought wine and left the bottles in the waste bins.

In general the sports facilities have fairly small quantities of waste each day. However, they sometimes host events then the quantities may be higher.

Event facilities

Event facilities have a lot of waste compared to the cultural and sports facilities. At cultural facilities or sport facilities, the waste is generated at a continuous rate as the visitors come and go. At event facilities there is a lot of waste at the same time. The waste is concentrated around a few particular types. There is very little metal or glass, since items made of these materials are not allowed in the arenas. Instead there is a lot of plastic and paper, since drinks that are purchased at the events comes in cups made of those materials.

Schools

From what the project group gathered, the waste that is generated outside the classrooms mostly consists of candy wrappers, soda cans, and plastic bottles. There is also some food waste. Inside the classrooms there are some paper (this is especially true for computer rooms with printers). There was also some particular waste, for example, from woodworking or art class.

4.2.2. KJ-Analysis

The information from the KJ-analysis was mainly gathered from the study of the collectors. The reason for this was that the collectors were interviewed, whereas the sorters answered a survey. Consequently the answers from the collectors were more extensive and qualitative in nature. Only some of the answers from the sorters were qualitative and analysed by KJ-analysis. *Figure 19* shows the process of performing the KJ-analysis.

The information from the analysis resulted in additional product requirements. Examples of requirements that were derived from the KJ-analysis were: 3.2 Prevent theft; 3.2 Allow variation of placement; 3.3 Allow movability; 4.12 Facilitate transportation of waste; and 9.2 Allow access for maintenance (see *Table 4*).

4.2.3. Quantitative evaluation

The result of the quantitative evaluation is shown in *Appendix V*, in the form of diagrams, but will be summarized and interpreted in this section.

There were a total of 84 participants that took the survey. Of these, a considerable majority (42 participants) belonged in the age group of 15-19. As a result, these answers are more representative. There were fewest respondents in the age group of 20-39 (11 answers). The reason for this was the manner of distributing the survey. Through connections at the municipality two high schools were contacted, which generated a large number of responses, but there were no similar opportunities for reaching the other age groups, and these surveys were therefore distributed through personal connections.

The first question was how important the respondent considers sorting waste to be, grading it from 1 (not important at all) to 5 (very important). The result shows that the age group of 15-19 considers it to be of less importance than the older respondents. However, most of the respondents considered it very important.

When asked whether the respondents usually sorted the waste at home, the answers correlated quite well with the answers to the previous question. The choice was a scale from 1 (never) to 5 (always) and about 79 percent of the respondents ranked it as 4 or 5. The distribution was similar to the previous question where the youngest age group was the most critical one, sorting to a lower degree.

In question number three the respondents were asked what type of waste they sort at home. Packaging material seems to be recycled to a very high degree. The categories that people do not sort are bulky refuse, chemicals, and food waste. In the first two cases it might be that people do not have the need for sorting this type of waste very often. The situation with food waste might be partly due to the different living situations, and to the possibility of sorting food waste not being accessible to everybody. It could also be

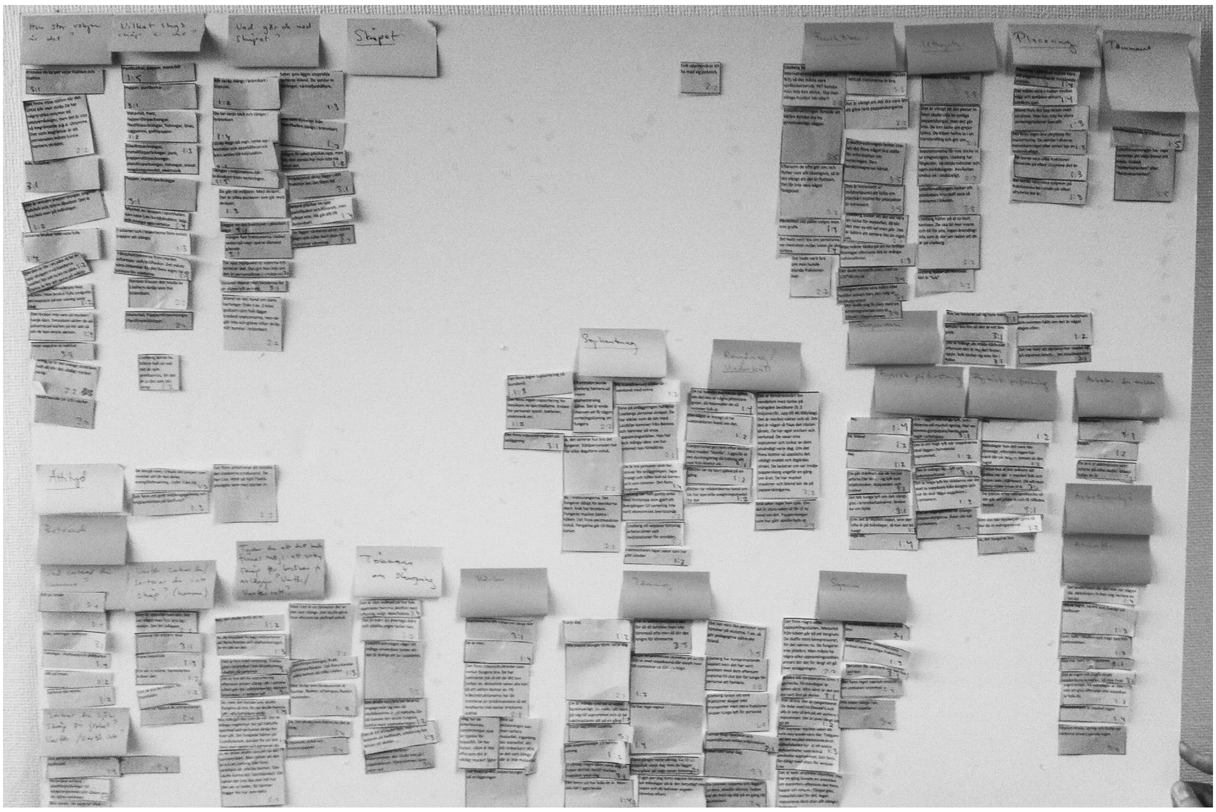


Figure 19. The KJ-analysis was performed with citations, observational notes, and post-its

a question of habits, and separating food waste and combustible waste might still new to many.

The participants were then asked why they sort waste at home, with the possibility of choosing more than one option. The great majority answered that they sort waste because it is better for the environment. A few people in each age group also answered that they do so because it makes the work easier for the people handling the waste. Fewer still answered that they sort waste to save money. Another option was that they sort waste because somebody had told them to. This answer was most common in the age group of 60+.

When asked how important they considered sorting food waste to be – graded from 1 (not important at all) to 5 (very important) – the answers ranked a little lower than the ones in the second question about the importance of sorting waste in general. However, sorting food waste is still considered to be important or very important to most people.

As a way of evaluating the participants' awareness and knowledge, they were asked if they knew what happens to the food waste in the municipality. They were presented with the options that (1) it is used for producing bio-gas; (2) it is composted; (3) it is incinerated; and (4) they do not know. The correct answer is that it is used for producing bio-gas, though the residual material is composted and used as fertilizer. The answers were distributed almost fifty-fifty between (1) bio-gas and (2) composted, with a just a few more choosing the biogas option, especially in the age group of 60+. This age group also seems to be the most knowledgeable, where none of the participants chose the "do not know"-option.

The next question was: What they do you do with the trash if they do not find a waste bin? This question was asked in order to investigate people's behaviour patterns. A great majority of the respondents answered that they bring the trash with them. However, in the age group of 15-19, 19 percent answered that they put the trash somewhere or throw it on the ground.

There were also some questions about the facility to which the respondent was connected. Since the majority of the participants were young people attending school, the answers in this category are the most reliable. In the case of event facilities, the answers were too few to provide any valuable data, and the project group will hence rely on the result of the observational study of event facilities. The result shows that schools and cultural facilities have more mixed waste. Paper is very common, especially in schools. The result from the survey shows that there are very little glass and metal at the facilities, which is consistent with the observational study.

In general people are very familiar with the concept of sorting waste, which further emphasizes that there is a need for the possibility of recycling in public spaces. People seem to be motivated mostly by their concern for the environment, which is something that can be used for the expression of the product and for the related information.

The most critical age group is 15-19, and extra effort will therefore be put into reaching this group.

4.2.4. Function analysis

The function analysis is illustrated in *Figure 20*. The main function "Enable sorting waste in public indoor areas" was assessed to have four central part systems, each with its own functions and support functions. The part systems were: "Encourage recycling", "Enable separation of waste", "Support environmental adaptation", and "Support maintenance", each with own demands on the system.

It turned out that the support functions sometimes demanded properties from both the product and its surroundings. For example, it will be difficult to encourage recycling through education or engagement if the surrounding environment does not support it or if contextual activities are not added. The surrounding environments are in this case the facilities where the product will be placed and contextual activities means additional efforts not located on the product or in the facilities, for instance, campaigns in the facilities or the city, education in schools etc. That is why the support functions "About product" and "Near Product" had to be included in the analysis.

The product is meant to encourage a new behaviour by making people recycle waste in public areas, a task that a product itself may have difficulty to achieve. This makes the support from its surroundings an important part. The product surroundings, in this case, are both the static inventories at the facilities and the administrative organisation held by its staff.

The function analysis structured the product's different parts and their relations and was mainly used in the idea generation during concept development.

Figure 20. The function analysis with the main function, part functions, and support functions

4.2.5. Specification of requirements

The specification of requirements had a central role in the project, as it contained a list of demands and requests that were essential in order to make the product system work successfully. The specification acted as a means of auditing the result during the concept development and the concept refinement. It was also a means by which the product could be evaluated (see *"8.2. Fulfilment of requirements"*). The specification of requirements was updated throughout the project as additional demands and requests were identified.

A simplified version of the specification of requirements follows below. It was divided into categories so as to provide structure and clearness. The requirements were marked as either demands or requests, where demands must be met, whereas requests are not necessary for the product to succeed. These are marked in the specification as D (Demands) and R (Requests). The requirement was graded from 1 (not important) to 5 (very important).

A more detailed version in Swedish (with target values and verification methods) can be seen in *Appendix VI*.

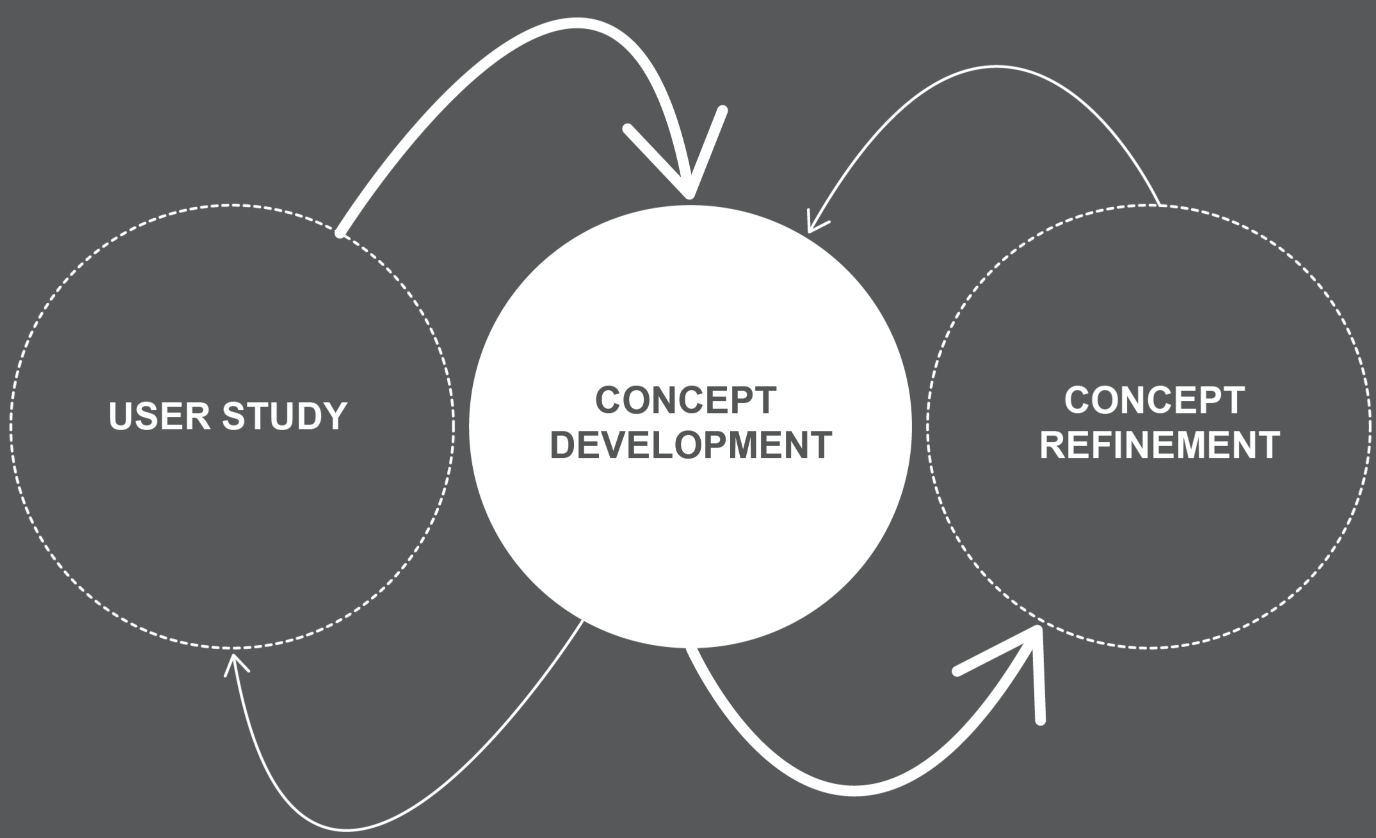
	Criteria			D/R	Grade
			Allow sorting of waste in public indoor environments	D	5
1	Performance				
		1.1	Maximize lifespan	R	4
		1.2	Volume of the inner container	D	4
		1.3	Dimensions of the outer container	D	4
		1.4	Carrying capacity of construction	D	5
		1.5	Dimension for circumference of standard sized bags	R	5
2	Manufacturing				
		2.1	Minimize manufacturing cost	D	3
3	Placement				
		3.1	Prevent theft	D	2
		3.2	Allow for variation of placement	D	3
		3.3	Allow for movability	R	4
		3.4	Allow for variation of fractions	D	2
		3.5	Allow for variation of volume	D	2
		3.6	Allow for changeability of fractions	R	5
4	Usage				
			Sorters		
		4.1	Allow for sorting of packaging material	D	5
		4.2	Allow for sorting of food waste	D	5
		4.3	Allow for sorting of combustible waste	D	5
		4.4	Communicate difference between fractions	D	5
		4.5	Acquire language independence	D	3
		4.6	Prevent sorting errors	D	2
		4.7	Prepare the user for acting	R	5
		4.8	Allow access of slots	D	5
			Collectors		
		4.9	Allow for lifting within the length of the forearm	D	5
		4.10	Limit work involving pushing and pulling	D	5
		4.11	Facilitate emptying	D	5
		4.12	Facilitate the transport of waste at the facilities	D	4

5 System requirements				
	5.1	Maximize the purity of the waste fractions	D	5
	5.2	Minimize the contamination of food waste	D	5
	5.3	Maximize the degree of sorting within each fraction	D	5
	5.4	Increase the proportion of packaging material in relation to other material	R	5
6 Other features				
	6.1	Allow for separate collection of deposit cans	D	2
	6.2	Prevent odours	R	5
	6.3	Prevent leakage	D	5
	6.4	Prevent placing of items on product	D	3
	6.5	Off-load the bag when emptying	D	4
	6.6	Enable locking	D	5
	6.7	Provide sealing possibility	R	3
	6.8	Minimize flying glass shards	R	3
	6.9	Allow storage of plastic bags	R	3
7 Information				
	7.1	Utilize the gestalt laws	D	5
	7.2	Communicate purpose	D	5
	7.3	Clarify information	D	5
	7.4	Make the information accessible	D	5
8 Expression				
	8.1	Express simplicity and discretion	R	5
	8.2	Conform to the identity of Gothenburg	R	5
	8.3	Express recycling	R	5
	8.4	Strengthen identifiability	R	5
	8.5	Encourage use	R	5
	8.6	Express “welcoming” & “friendly”	R	5
	8.7	Express stability & durability	R	5
9 Maintenance				
	9.1	Facilitate cleaning	D	5
	9.2	Allow access for maintenance	D	5
	9.3	Minimize graffiti/posters on product	D	3
	9.4	Minimize chemical maintenance	D	4
	9.5	Prevent contamination	D	3
10 Environment				
	10.1	Allow separation of product materials	D	4
	10.2	Allow replacement of worn components	D	4
	10.3	Use environmentally friendly materials	D	4
	10.4	Minimize the amount of material used	D	4

Table 4. Specification of requirements

5. CONCEPT DEVELOPMENT

In the concept development chapter, a number of different concepts are presented that were developed based on findings from the previous studies. The purpose was to develop concepts that met the specified requirements but were different from each other, so that pros and cons could be weighed. From this evaluation, one concept was chosen which was then refined during the concept refinement.



5.1. METHODS AND PROCESS

During the concept development, ideas were generated both spontaneously and methodically, and evaluated through the specification of requirement. The methods and tools that were used are described in the sections below.

5.1.1. Idea generation

Two different methods were used during the idea generation to get a wide diversity of ideas and a higher level of innovation. The methods were brainstorming and the "Design with intent"-toolkit which are described in the sections below. The idea generation during concept development was based on user needs and concerns, for example technical solutions and usability.

The results from the idea generation were sketches that synthesized the functions of the system. At this stage, the sketches represented ideas of functions but not of the expressions. Form, aesthetics, and visual expression were addressed during the concept refinement phase.

Brainstorming

Brainstorming is a very well known method for generating ideas. During a brainstorm session it is important that the atmosphere is relaxed. No criticism (or self-criticism) should be allowed while brainstorming. The aim is to maintain a great number of ideas, and during the session there is no time for filtering. The number of ideas can also be increased by combining and complementing already expressed ideas. Afterwards the material is gathered, evaluated and might be processed further (Österlin, 2003).

The function analysis had a central role in the idea generation as it supported the brainstorming method. Each of the function analyses were given a timed brainstorming session. The purpose of using the function analysis was to produce a variety of ideas while taking into account the whole system. The purpose of the time limit was to create a positive stress effect so that the idea generation would not stagnate.

The "Design with intent"-toolkit

Design with intent refers to "design that is intended to influence or result in certain user behaviour" (Lockton, 2013). The intentions create opportunities for designers to consciously address social or environmental behaviour issues through design.

The "Design with intent"-toolkit has been developed through this approach and address the design for behavioural change. There are 101 cards in the toolkit that target eight different field of research or interest areas such as "Architectural", "Error proofing", and "Interaction". The toolkit can be used in the idea generation as inspiration for ideas by asking questions and giving real examples. They can be applied to different solutions such as products, services, interfaces, and environments (Lockton, 2013).

The "Design with intent"-toolkit was used as a supplement to the function analysis by a similar procedure – each card of the toolkit had a timed brainstorming session. The purpose of the toolkit was to stimulate the idea generation and design with the intent to change user behaviour towards more sustainable actions.

Visualizations

During the idea generation, it is often necessary to use different types of visualization methods to be able to understand the feasibility of the solutions and to evaluate them as thoroughly as possible. The different methods of visualization are described in the sections below.

Sketching

A visual image is a powerful tool for expressing, developing, and communicating ideas. While sketching, ideas are forced to take on a more concrete form, and it is easier to see if something is not correct or does not work. Ideas that would demand an extensive explanation in words can often be easily described and communicated with an image. Sketches are therefore a very useful communication tool, both within the project group and in relation to other interested parties (Österlin, 2006).

In the project, simpler sketches were produced as a basis for discussion. The discussions resulted in even more sketches and in further development of the concepts.

Physical models

Sketch models, or mock-ups, are simple models used to get a feel for the physical form, dimensions, size, and features of the products. The three-dimensional model is even more descriptive than the two-dimensional sketch, especially if it is in full scale (Österlin, 2003). Different models have different purposes. While a mock up model is used to understand the product's shape and real size during the design process, a prototype is a functional model of the actual product, and there is a wide range of variations between the two.

In the project the physical models were used as verifications of size in relation to form.

CAD

CAD (Computer Aided Design) is used for "virtual prototyping", i.e. modelling and simulation using a computer. The purpose is to study a geometrical model from different angles before a physical model has been built (Johannesson, Persson, and Pettersson, 2004). There is a lot of different software for CAD. In this project Alias Automotive (for surface modelling) and CATIA (for solid body modelling) were used both to validate shapes and positions and to include the product in the actual environments.

5.1.2. Morphological chart

A morphological chart is used to combine different solutions to the part functions of a system. The chart is built upon the function analysis's part and support functions where several solutions have been developed within each function. The part and support functions are placed in the chart's left column and the solutions are listed to the right. Through the morphological chart the solutions of the different functions can be combined into overall solutions (Johannesson, Persson, and Pettersson, 2004).

The morphological chart served two purposes in the concept development phase. It made it possible to structure the ideas into a schematic summary and to develop or reject ideas by evaluating them through the specification of requirement.

The sketched ideas were depicted on a chart with part and support functions on the left and the ideas on the right (see *Appendix VIII*). Thereafter, the different solutions to the functions were combined into concepts. The combined concepts were sketched as combinations of the function solutions and of each other resulting in a wide variety of concepts (see *Figure 21*).

Some of the concepts were evaluated through physical models, and the final concepts were developed into the first presentational material with simpler CAD models and renderings.

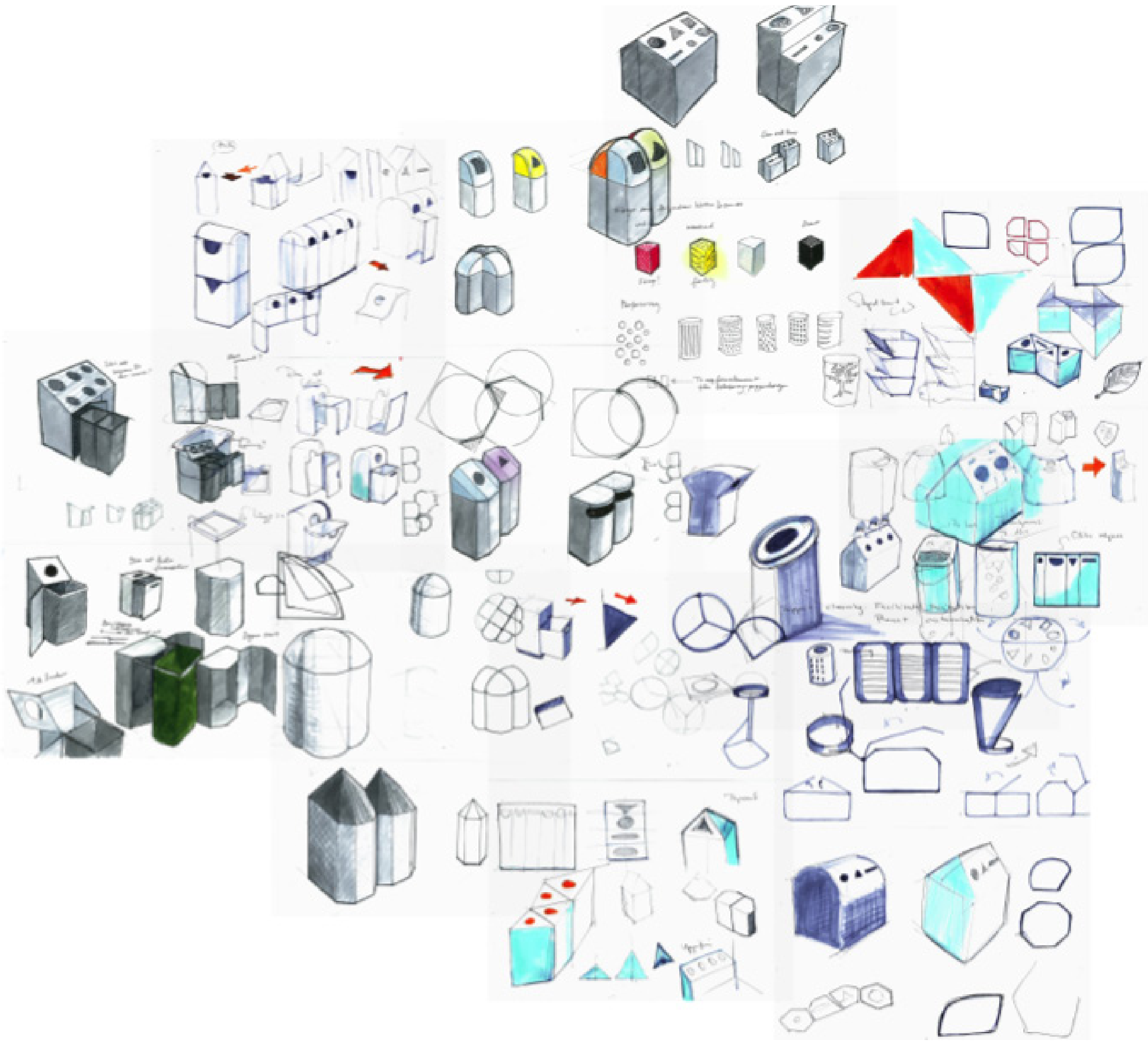


Figure 21. Sketches from the idea generation

5

5.2. RESULTS

The concept development resulted in four concepts, representing different features with emphasis on functionality. These concepts were used as a basis for discussion when meeting with actors from the municipality. In the concepts, four different ways of showing the difference between fractions and three different ways to empty the waste station are presented. The four ways of differentiating the fractions are: by different lids, different shapes of the slots, different sizes, and different shapes of the container. The ways to empty the container are: by a ring rotating on a hinge, by a frame on wheels, and or by sliding the bag out on rails. The concepts also represent different possibilities of adaptation. Concept three and four are highly adaptable, since they have different shapes and sizes, while concept two is less adaptable since the modules are built by pieces including at least three fractions.

All concepts contain bags that are exchanged when the recycling station is emptied, since solid containers were ruled out during the user study and concept development phase.

The height of the concepts were at this stage set to 110 cm, and the slots were placed at between 80-100 cm above the floor, which is the required height for the whole user group to be able to reach (see *"2.1.4. Anthropometric measurements"*). To get a sense of the proportions, *Figure 22* depicts three of the concepts together with three representatives of the user group: an adult male, a person in a wheelchair, and a child about 7 years old.

Figure 22. Three representatives of the user group with three of the concepts

5.1.3. Concept 1

The top surface of the first concept is sloping, to prevent the users from putting waste or other items on top of the recycling station. It has different lids, which can be exchanged so that the same container can be used for different fractions. This would be an especially useful feature for facilities hosting events, since the waste often varies between these events. It would then be possible to store lids representing a variety of fractions and to have a fewer number of stationary containers.

This concept is emptied by rotating a metal ring on a hinge. This is how the waste bin Robin is emptied (Bjursten and Mårtensson, 2009), and it is a common way to empty waste bins outdoors. One advantage that Robin has in this case is that since each waste bin is placed by itself, it is possible to open wide, using double doors. This is not possible when designing a recycling station, because the containers are placed directly next to each other.

Concept 1 is illustrated in *Figure 23*.

5.1.4. Concept 2

The second concept also has a sloping top surface, to prevent users from putting things there.

This concept consists of two larger pieces that can be placed in front of each other. The user study showed that the amount of waste varied a lot between the different fractions, and this construction results in three smaller and three larger volumes. To work with this type of construction would mean that there is less possibility to adapt the recycling station for the specific needs at each facility. It does however emphasize the purpose of the product – that waste should be separated into different fractions – and it removes the possibility of using the separate units as waste bins.

In this concept the different fractions are distinguished by the different shapes of the slots. The specific shapes are just examples at this stage. The bags are attached to a frame and the concept is emptied by sliding out the frame on wheels. This is not a common way to collect the waste, and the solution is relatively specific to this concept.

One might place the concept in the middle of the room so as to enable the users to sort from two sides.

Concept 2 is illustrated in *Figure 24*.

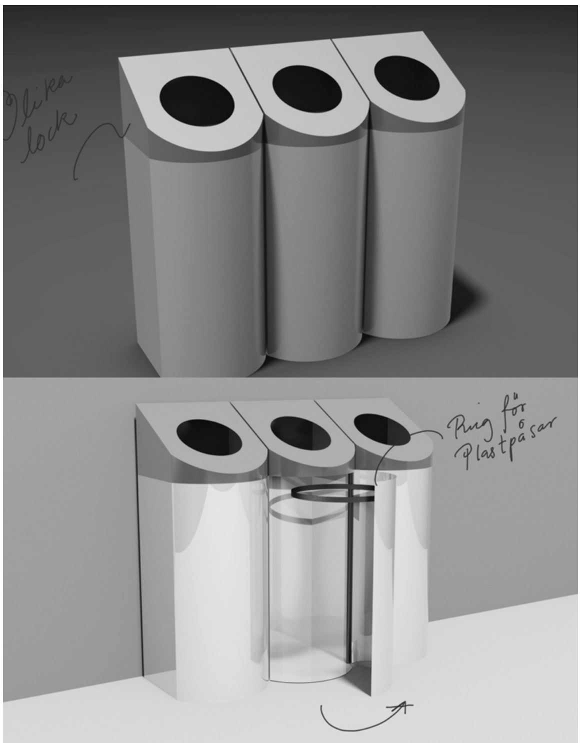


Figure 23. Concept 1

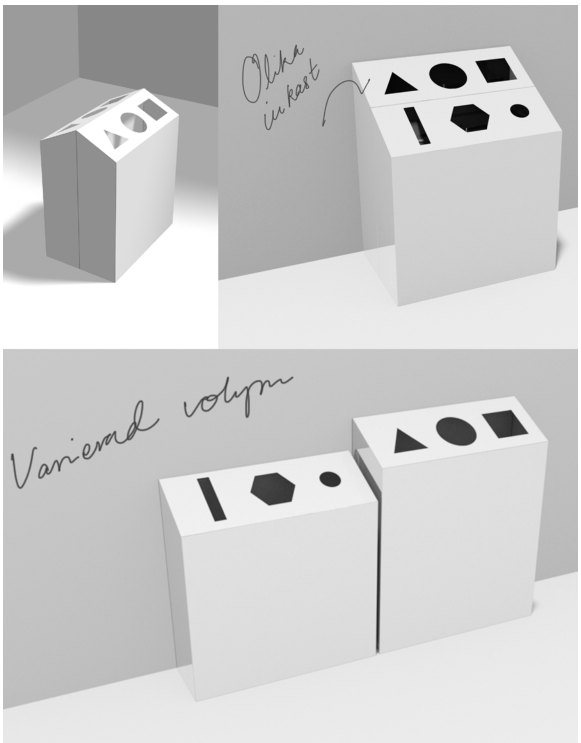


Figure 24. Concept 2

5.1.5. Concept 3

The third concept consists of modules in two different sizes. This means that the recycling station as a whole can be built in a variety of sizes. It is possible to use smaller modules for fractions with a lesser amount waste or for fractions that you want to empty more frequently. If the space is limited it is also possible to use only smaller modules, to make the total size as small as possible. The opposite would also be possible, of course, i.e. if there is a lot of waste and enough space (which is often the case at events) one could opt to use only the larger modules.

This concept is emptied by sliding the frame out on rails, like a drawer. This is a common solution for waste bins indoors.

Concept 3 is illustrated in *Figure 25*.

5.1.6. Concept 4

Concept four is made up of modules in two different shapes. This concept shows how the flexibility can be taken even further and that the modules can be used as building blocks, creating tailored solutions for each facility.

Concept 4 is illustrated in *Figure 26*.

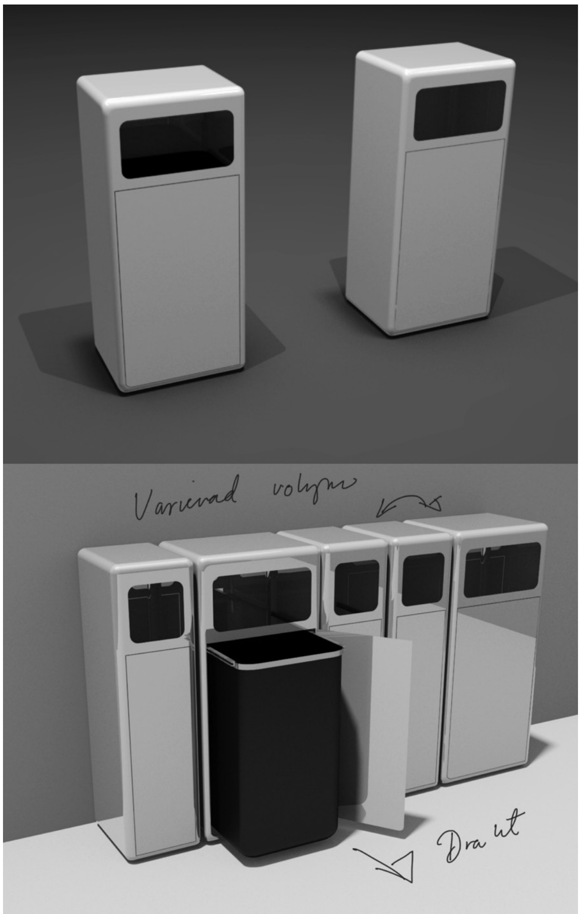


Figure 25. Concept 3

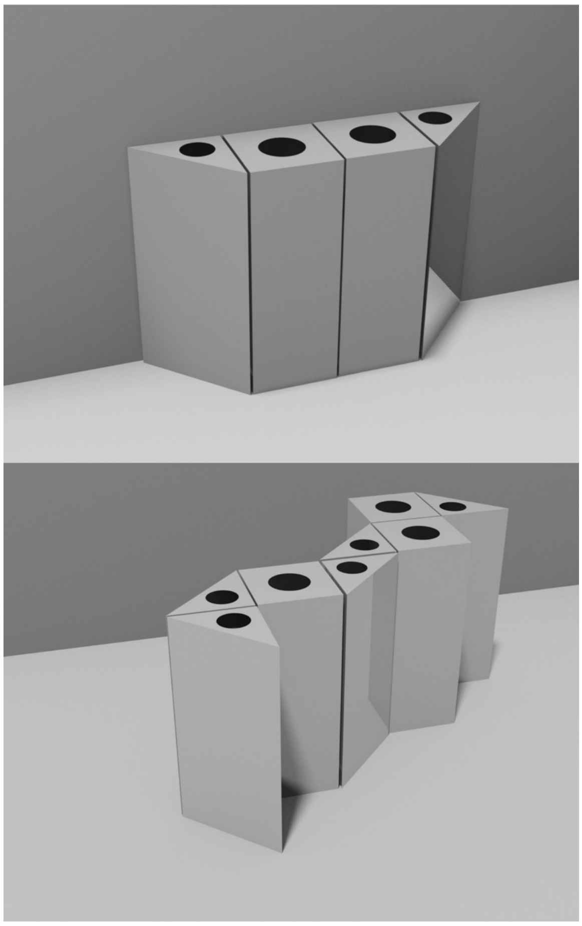


Figure 26. Concept 4

5.1.7. Other features

Other features that were discussed at the meetings with the actors were transparency, a tilted bottom surface, elevation from the floor, and different bags for different fractions (see *Figure 27* and *Figure 28*).

Transparency could be used to visualize what the fraction contains and to further emphasize the difference between the containers.

A tilted floor could make the job of cleaning the inside of the container easier. The question was also raised whether it would be preferable to place the sorting station directly on the floor or to keep it elevated. If it were to stand on legs, it would be possible to clean underneath, but if it were to stand directly on the floor there would hopefully be no need to do so.

To avoid the situation where the collectors have to empty the bags in the garbage room, one suggestion was to have different bags for different fractions. Plastic would be put into a plastic bag, food waste into a bag made of paper or organic plastic, paper into a paper bag, etc. The bag could then be recycled together with the waste, avoiding one of the operations in the process of collecting the waste.

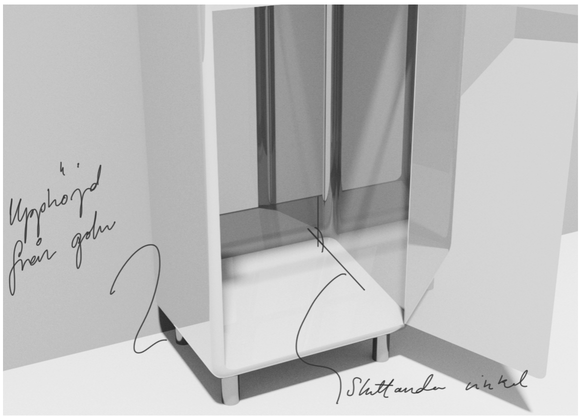


Figure 27. Elevated from the floor with tilted bottom

Figure 28. Transparency

5.3. EVALUATION AND FURTHER DEVELOPMENT

The discussions at the meetings with the municipality resulted in the decisions presented below.

• In general, the representatives from the different administrations prefer the concepts with more flexibility, which leads to the conclusion that the recycling station should be constructed as separate modules. They also like that there are different sizes of the containers.

• When the recycling station is emptied the bag should not be hanging freely, since it is a common problem that the bag tears from something sharp so that the waste would be spilled onto the floor. It would therefore be good to have a floor supporting the bag when the recycling station is being emptied.

• The recycling station should be adapted to standard sizes of bags. It is of less importance if the fastening should be smaller than the bag, as long as it is easy to attach the bag and that the fastening is not too large so that the bag stretches.

• There will be different lids that can be exchanged if needed. The representatives liked this idea, and it further strengthens the adaptability of the product.

• The recycling station should be standing directly on the floor. This is very common with furnishing in public indoor areas, because most of the cleaning is done by machine. To leave a space underneath would only result in extra work for the cleaning personnel.

• The recycling station should collect fluid. Especially food waste contains a lot of fluid, and in case the bag would tear or leak the fluid should be contained. This also rules out a tilted floor, since that would mean that the fluid could leak out, and it is not considered to be sufficiently beneficial for the cleaners.

• The recycling station should have a tilted top surface. This would mean enhanced visibility for a large part of the user group. It also makes it difficult to put waste, or other items, on top of the recycling station where it would create a messy and unattractive expression. The representatives from the administration of sport and club activities (Idrotts- och föreningsförvaltningen), also pointed out that there are a lot of young people visiting their facilities and that they sometimes climb or sit on furnishing that is not designed for this purpose, and a sloping top surface would also help in remedying this behaviour.

• There should be a rubber cover for the glass slot to reduce the speed when the glass is put through and to avoid flying shards.

• The recycling station should not only be adapted for visually impaired users, but also to blind people.

.

Other requests that emerged from the discussions at the meetings are presented below. These requests will also be considered in the further development of the product.

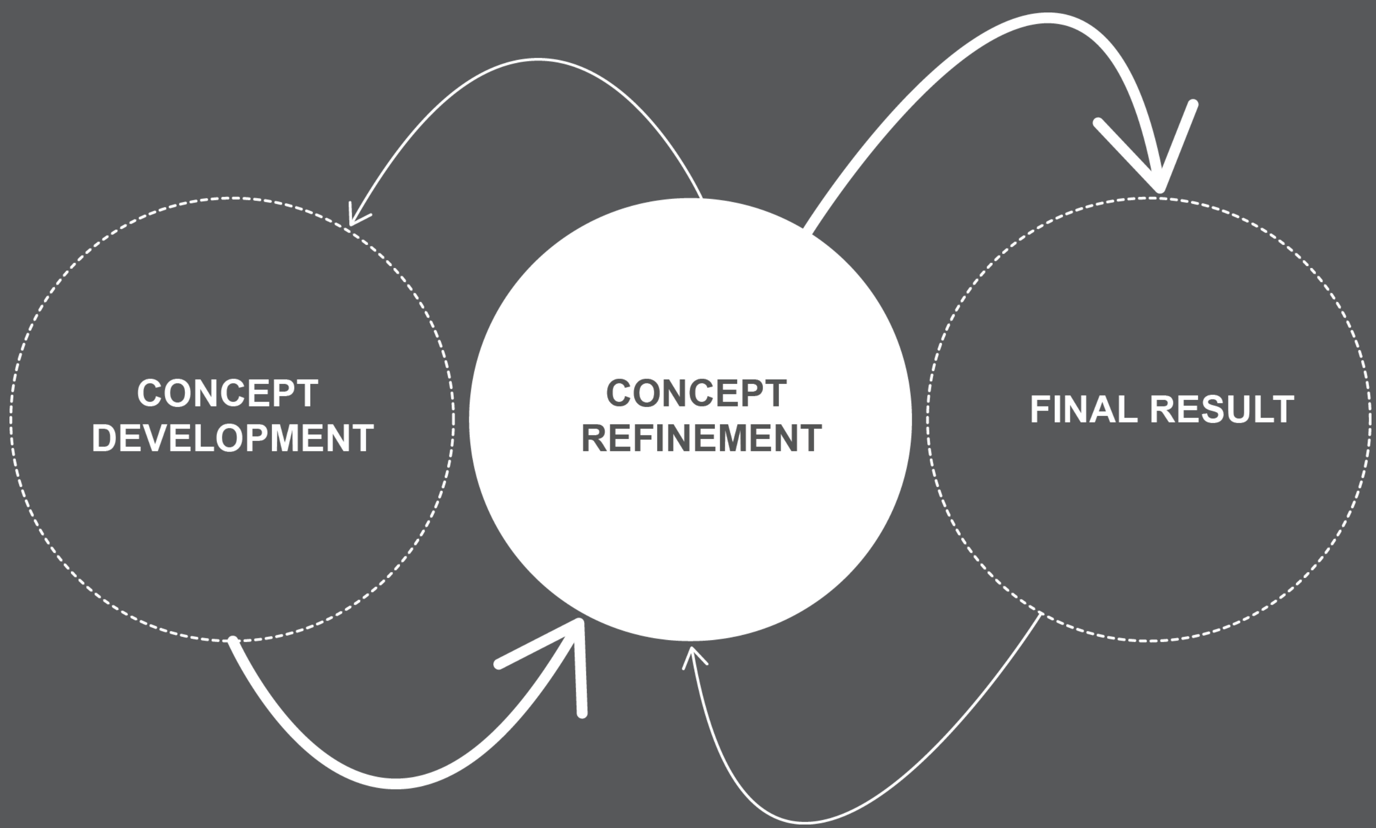
• There could be a special container for collecting fluids. The representatives from Liseberg AB noted that they sell a lot of sodas and that people often do not finish them. To have a lot of soda with the waste is problematic, because it is very heavy and contains mostly water, which means that it is more expensive and less energy efficient to handle. It would therefore be beneficial if there were a way to collect the soda, so that it could be disposed of separately.

• There should be an option of attaching a hatch to be able to lock the recycling station.

• There should be a compartment for storing bags inside the recycling station. This is especially relevant if different kinds of bags are used, so that the collectors do not have to carry all these bags with them when they collect the waste.

6. CONCEPT REFINEMENT

The purpose of the concept refinement phase was to thoroughly work with demands of a chosen concept in order to refine it towards the desired design. This chapter presents the choices made in the concept development, refined into the final result. It presents the process of determining the material, form, aesthetics, and semantic meaning.



6.1. FROM CONCEPT DEVELOPMENT TO CONCEPT REFINEMENT

In the previous phase (concept development) the concepts were developed based on functionality. The solutions to different functions were therefore what was brought forward from the concept development phase to the concept refinement phase. These solutions were:

- To support flexibility and adaptability, the recycling station should be constructed as modules.
- The modules should be offered in different sizes to accommodate the different needs of the facilities.
- Pulling the bag straightforward, out of the container, solves the emptying.
- An inner structure with a floor should support the bag when the recycling station is emptied, since this would prevent leakage and tearing of the bags.
- The top surface should be tilted to prevent people from putting things there.
- The sides of the recycling station should be straight to allow for more flexibility in placement.
- The information should be presented on exchangeable lids to maximise the flexibility of the recycling station and make it possible to adapt to the needs of different facilities.
- The information should be accessible to blind and visually impaired people.
- It should be possible to fasten the recycling station to a wall or floor.
- The waste fractions should be differentiated by text, colour, graphics, and different shapes of the slots.
- There should be some space provided for storing bags.

The concept refinement phase focused on form, material, and construction, none of which had been dealt with previously. These areas were mostly treated as separate subjects but the studies were carried out simultaneously, contributing to bringing the refinement phase forward. An example of this process with regard to form can be seen in *Figure 29*.

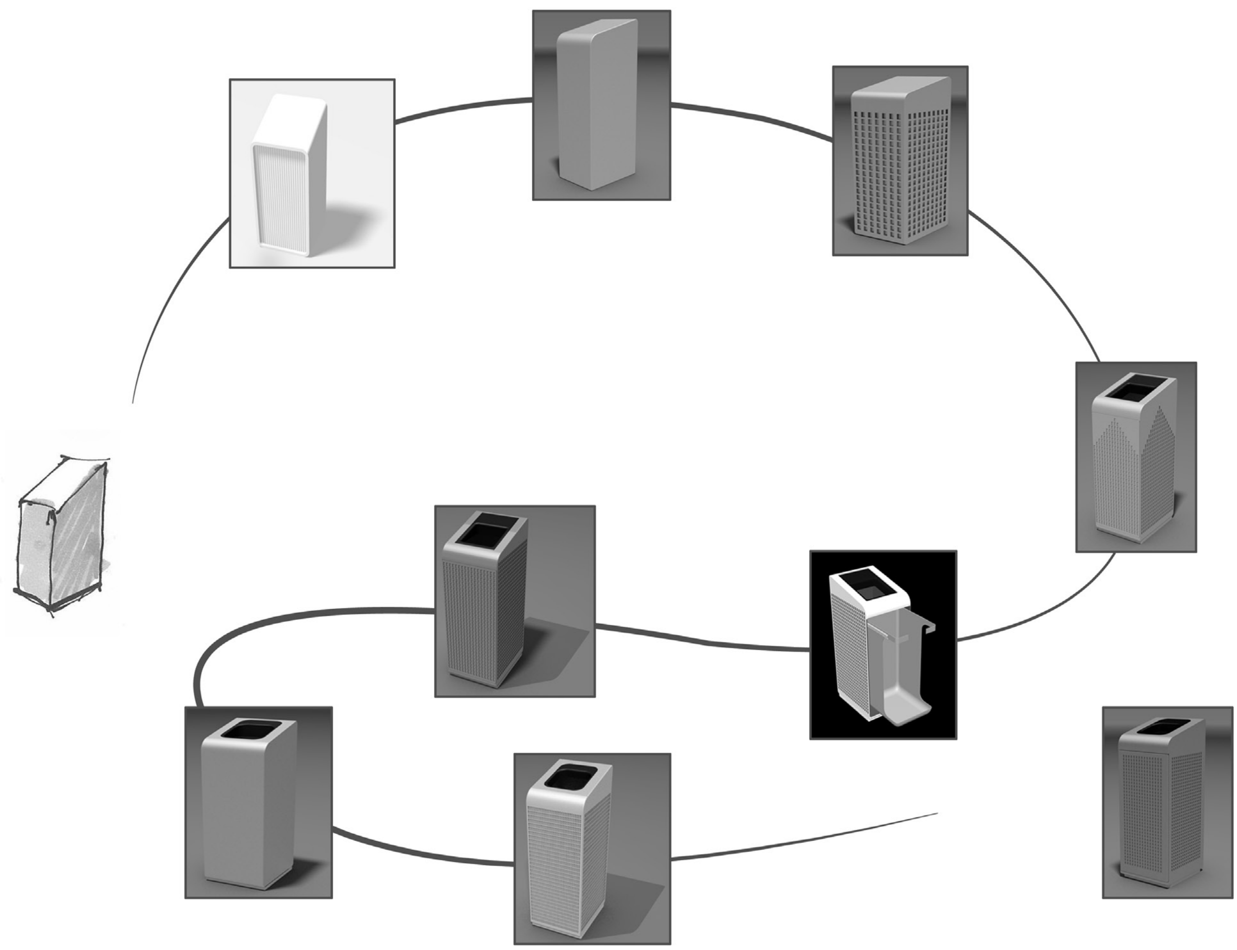


Figure 29. The figure shows the process of applying the generated forms to the functional surfaces

6.2. METHODS AND PROCESS

The following section describes the process and the methods used to acquire the desired concept design.

6.2.1. Material selection

Since there was no predefined material selection made for the product, a quite extensive study was performed to decide upon a suitable material. As a basis for this study the material properties and level of performance were listed (see section below). The software CES was used to compare the materials to each other with regard to some of the properties. Experts and manufacturers were then consulted, and three potential materials were decided upon. After further comparisons between these three materials, discussions about manufacturing possibilities, and evaluation against the material properties, different materials were selected for the different parts.

Material properties

The material selection was made on the basis of certain requirements. The material requirements are listed below:

- Water resistant
  - The product should withstand corrosive environments such as public baths.
  - The product should be resilient with regard to water and cleaning detergents. The product should not be negatively affected by repeated contact with water, from rinsing and cleaning.
  - The material should not be negatively affected when in contact with waste containing liquid.
- Acceptable with regard to fire safety
  - Materials with naturally good fire resistance, such as solid wood, metals, wool, glass, etc., should if possible be used. This will reduce the amount of flammable materials in indoor environments (Räddningsverket, 2013).
- Price
  - The cost with regard to the material itself and the possible manufacturing methods should be kept low. An acceptable cost per unit will be derived from discussion between the project group, manufacturers, and the mandator (the traffic and public transportation office).
- Tough
  - The material should be able to withstand rough physical treatment, both from impacts and from chemical detergents.
- Aesthetic expression
  - Fit for indoor environment.
  - Show affinity with the products from the two earlier projects (see *"1.1.3. Previous projects"*).
- Environmental considerations
  - Parts made by different materials should be possible to disassemble.
  - The lifespan of the product should be at least 10 years. Parts with a shorter estimated lifespan should be exchangeable.
  - The material should be recyclable, so that the impact at the end of life of the product is minimized.

CES

The software CES was used as a tool for making a first culling of the materials. CES is a PC application that enables product development teams to find, explore, and apply materials property data (Granta, 2013).

The software was used to compare the prize, amount that is recycled today and eco-indicator 99 for various materials. Eco-indicator 99 is a commonly used impact assessment methods in LCA, which allows the environmental load of a product to be expressed in a single score (Bauman, and Tillman, 2004). The diagrams can be seen in *Appendix VII*.

Unfortunately, using CES did not result in a narrow enough list, since the software does not consider manufacturing possibilities, cost of tools, etc. However, the diagrams in *Appendix VII* could be used as a basis for discussion.

Expert consultation and discussion with manufacturers

The project group met with Antal Boldizar, professor at the institution of materials and manufacturing technology at Chalmers University of Technology and expert of polymeric materials and composites. He planted the idea of investigating the possibility of using laminate, since this is a material with interesting properties. Apart from this, the advantages and disadvantages of the polymers PBT (Polybutylene terephthalate), PP (Polypropen), and PE (Polyethylene) were discussed.

Amongst the metals, powder coated sheet steel was considered especially interesting, since this material was used in the previous projects by Bjursten and Mårtensson (2009) and Nikell and Sundberg (2013). This means that, in addition to having desirable material properties, it would support recognition and kinship between the products.

Three types of materials were then investigated further:

- Sheet steel, zink treated and powder coated
    - **Advantages:** Highly recyclable, resembles the previous products.
    - **Disadvantages:** Excessively robust for indoor environment, limited with regard to shaping possibilities.
- Laminate and melamine formaldehyde
    - **Advantages:** Large graphical freedom (allows for the possibility of making patterns and printing text), fit for indoor environments.
    - **Disadvantages:** The material is not recyclable and it has very limited shaping possibilities.
- The polymers PBT (Polybutylene terephthalate), PP (Polypropen), and PE (Polyethylene)
    - **Advantages:** Allows for colouring and is highly shapeable.
    - **Disadvantages:** The tools for manufacturing are very expensive.

The evaluation of these materials was mainly conducted by the questioning of manufacturers. The result is presented in *"6.3.1. Material selection"*. The manufacturers that were consulted are listed below.

- Interwood, Jörgen Plymouth
    - Interwood deals with a variety of wood materials, including laminate. The properties, cost, and manufacturing possibilities of this material were discussed with them.
- Riboverken, Peter Olesen
    - Riboverken has been involved in the manufacturing of the waste bin and recycling station from the previous projects Hence they has expertise when it comes to the difficulties of producing these products, which are both made of sheet metal which is a material commonly handled by Riboverken.
- Andrén Plast, Håkan Jarestad
    - Andrén plast is a company that manufactures products using vacuum moulding. They were consulted when injection moulding was deemed too expensive.

6.2.2. Construction

The construction of the recycling station was developed through an iterative process that was initiated by the form generation and continued in parallel with the material selection to become continuously more detailed. Expert consultation was provided by teachers at Chalmers and by construction designers at ÅF technology.

Some main principles were kept in mind when constructing the recycling station:

- The design should be conducive to disassembly.
- Parts that are made of different materials should be detachable to enable disassembly and for reasons of functionality.
- The construction should allow for easy access when the recycling station is assembled.
- The construction should allow for easy access during cleaning and maintenance.

The following were the methods primary used for the construction:

Physical models

Physical models were important tools to get a feeling for the actual size and shape of the product.

CAD

Using CAD-models allowed for a better understanding of how the parts would fit together.

Sketching

Sketching is a quick way to visualise ideas and an important tool when discussing and comparing different options.

6.2.3. Design Format Analysis

A Design Format Analysis (DFA) was performed on the waste bins from the two previous projects. The purpose of this was to explore which features are the most characteristic, so that the recycling station might be made recognizable and communicate that it belongs in the city of Gothenburg.

DFA is a method to explore the occurrence of selected design features among a variety of products. The method is useful for analysing the explicit cues that construct visual recognition. Various features such as shapes, materials, and colours can be analysed through the DFA method (Karjalainen, 2007). The selection of the features can be based on a number of criteria. In this project the selection was based on which features were deemed most visually prominent through a subjective analysis by the project group.

The occurrence of a feature is graded, so that a strong occurrence equals two points, while a weak occurrence equals one point (see *Figure 33*). By summing up the occurrences, design features and products can be ranked in terms of their importance for the visual recognition of the brand (Karjalainen, 2007).

6.2.4. Communicating features

Communicating the purpose of the product to the user through different design features will support the usage and decrease the possibility of user error. The following sections describe the communicating features of texts, graphics, and slots, all of which are used in the product.

Text and graphics

By communicating the differences of content between the containers through information in the form of text and graphics on the recycling station, the sorters will better understand the purpose of the product – to sort waste. Information on the recycling station will therefore increase the guessability of the product and the user will better understand the product.

Another user group is the collectors who need support when emptying the containers. The collectors often empty the containers every day, and that is why there is no product demand stating that they need to know how to do it the first time. However, it is important to strive for high learnability in the product to increase the effectiveness, efficiency, and satisfaction in the usage. That is why the emptying should require low cognitive and physical effort.

Information about the content of the containers will support the collectors' perception of what kind of waste is put where, which will enable them to collect more efficiently, effectively, and satisfyingly by relieving the cognitive burden. In addition, a construction that supports a comfortable usage would relieve the physical burden.

In order to increase the guessability and learnability of the product, the information has been worked out with regard to perception, decision making, and interface design.

The recycling station will be placed in public areas in the municipality of Gothenburg. The information will therefore reach sorters with different prerequisites and needs around Gothenburg City. It is important to achieve consistency in order to make the product recognizable and accessible. To achieve this, the guidelines on accessibility used in Gothenburg City has been applied to the product.

Slots

By using different slots to communicate the different contents of the containers, the sorters will better understand the purpose of the product – to sort waste. This would enhance the guessability of the product and the usage would increase.

Using different geometrical shapes for the slots is one way of differentiating them. This called for a study of suitable shapes.

The study contained a survey that was developed with the purpose of finding out if there were any relations between different geometries and specific waste fractions. Eight waste fractions were presented together with FTIAB's graphics and colours as well as nine different geometrical shapes. The graphics and colours were selected by their consistency with existing recycling stations for domestic waste, and the geometrical shapes were selected by their typicality. The respondents of the survey were asked to connect the waste fractions to a matching geometry (see *Appendix IX*).

6.2.5. Form generation

Form generation means generating ideas of form applied to the chosen functional concept. The purpose of the form generation was to explore the form of the chosen concept in order to achieve a final form that conveys function as well as aesthetic expression.

The form was explored as widely as possible in order to refine it towards the desired expression matching the specified requirements. Since the concept was based on technical and user requirements from the previous phase, the form could be based on functional as well as aesthetic demands.

The forms were generated both spontaneously and methodically. The methods provided a structured form synthesis – i.e. sequenced, ordered forms – that resulted in a basis of information. This structured way of working enhanced the probability that the form was explored as widely and deeply as possible. Therefore, the basis of information supports the decisions during the form evaluation. The methods can also help in overcoming inner inhibitions and conventional thinking, and consequently the solutions will be guided towards a higher level of innovation.

The sections below describe some of the methods used during the form generation. Sketches, physical models, and simple CAD models were the main visualization tools.

Form benchmarking

The form generation started with a form benchmarking that served to find form attributes that could be applied to the chosen concept from the previous phase. By finding the similarities in the product group a base of existing and typical forms was provided. This was important since the recycling station would need a strong identity that could easily be recognised by the user.

Expression association web

Desired expressions from the project description as well as results from the user study, formed the basis of an expression association web in the form of a of word cloud (see *Figure 30*).The word cloud held the desired semantic meaning that would engage the users and guide them towards correct usage.

An expression association web has a communicative and inspiring purpose similar to that of the expression board. However, the expression association web uses adjectives rather than images (Wikström, 2010).

The expression association web resulted in four form drivers that worked as tools supporting the form generation. By using form drivers in the earliest stage of form generation, the chosen expression could be widely explored. Form drivers work as stimulating tools to achieve the desired expression during the form generation. The form drivers that were used were: simple, contrast, curious, and attract (in Swedish: enkel, kontrast, nyfiken och locka). See *Figure 31* for examples from the form generating process.

Figure 30. The expression associating web forms a word cloud that communicates the expression (in Swedish)

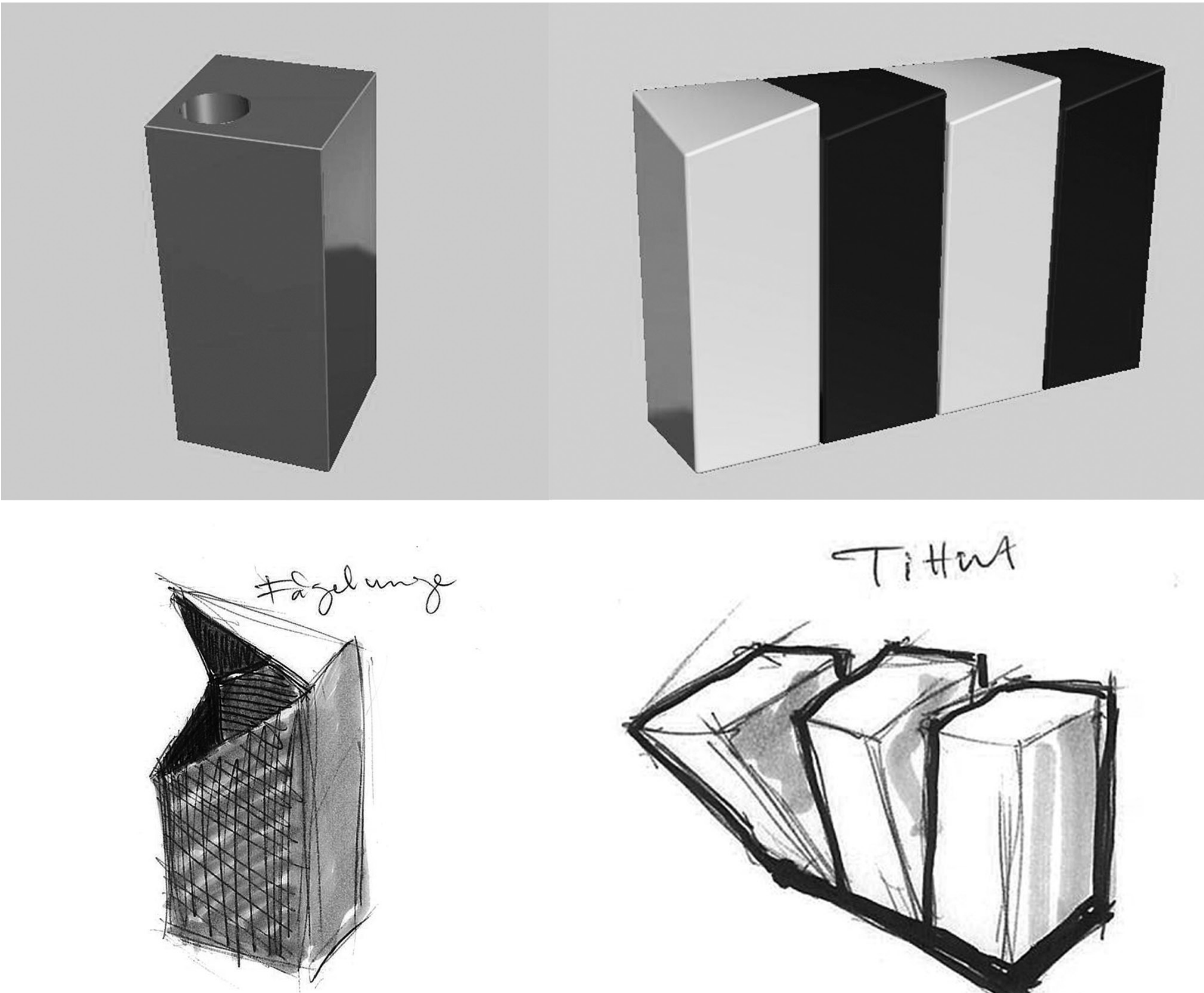


Figure 31. Examples of the form drivers contrast (upper right), simple (upper left), curious (lower right), and attract (lower left) in CAD-models and pen sketches

6.2.6. Colours

The colours on the recycling station had many physical, technical, and semantic demands deriving from the specification of requirement and the expression association web.

The physical demands were related to the interiors of the facilities: how well the colour would blend in and at the same time attract attention. The technical demands were related to how well the colour would last and not look soiled. The semantic demands relates to how well the colour communicates meaning and achieves the desired expression.

The choice of colours for the outer container was therefore of great importance since the fulfilment of the product demands were closely related to this. The colour of the inner container, however, was not as important because it does not have to meet any of these demands. The demands on the inner container were instead related to the construction.

The colours are in turn strongly related to the material, since the perception of the colours depends on how the material is perceived. The material was therefore decided upon before the colours.

The components that are visible to the sorters are: the outer container, the perforation, and the lids. Colour choices would therefore have to take these three into consideration.

The colour choices were based on the specified demands and the evaluation was made by means of a focus group and through consultations with industrial designer Märit Lagheim (Lagheim, 2013-2014).

6.2.7. Form evaluation

The form was, like the colours, evaluated through a focus group and also through consultation with industrial designer Märit Lagheim (Lagheim, 2013-2014).

Focus group

Focus groups generate qualitative input from the users and involve one or more representative user groups of about five to fifteen people per group. It is motivating to gathering people who are comfortable in each other's company, since this could result in rich discussions and creativity around the chosen topic (Johannesson, Persson, & Pettersson, 2004).

The discussions are led by a moderator who will make sure to involve all participants and lead the discussion towards the topic at hand. Focus groups are used with exploratory purposes where unexpected results and ideas can emerge from the associations with the other participants (Johannesson, Persson, & Pettersson, 2004).

Two focus groups were conducted at Chalmers University of technology and involved two and three of the master students respectively from the program Industrial design engineering. The participants had experience in product development and could easily understand the problem. The focus could therefore be on the form expression rather then the functions which had already been evaluated in the concept development phase.

Four chosen form concepts had been developed based on results from the form and colour generation to convey the desired expression. How well the this was achieved by the each concept was evaluated in the in the focus group.

Mediating visualizations of these concepts had been modelled in CAD (see *Figure 32*).

The chosen concepts were distinguished from each other by different perforations, lids, and colours. The concepts were presented at different distances and in different constellations: as single items, together, and in a representative environment. The concepts were, by means of these visualizations, presented in a way that made them comparable, and easy to discuss.

The groups were asked to talk freely about their associations. They were also asked to answer a questionnaire where adjectives from the expression association web was used. The questionnaire contained explanations of the adjectives to leave as little room for misinterpretations as possible. Each adjective was provided with an opposite word, and the participant was asked to place the concept at an appropriate point between them. (See the survey in *Appendix X*).

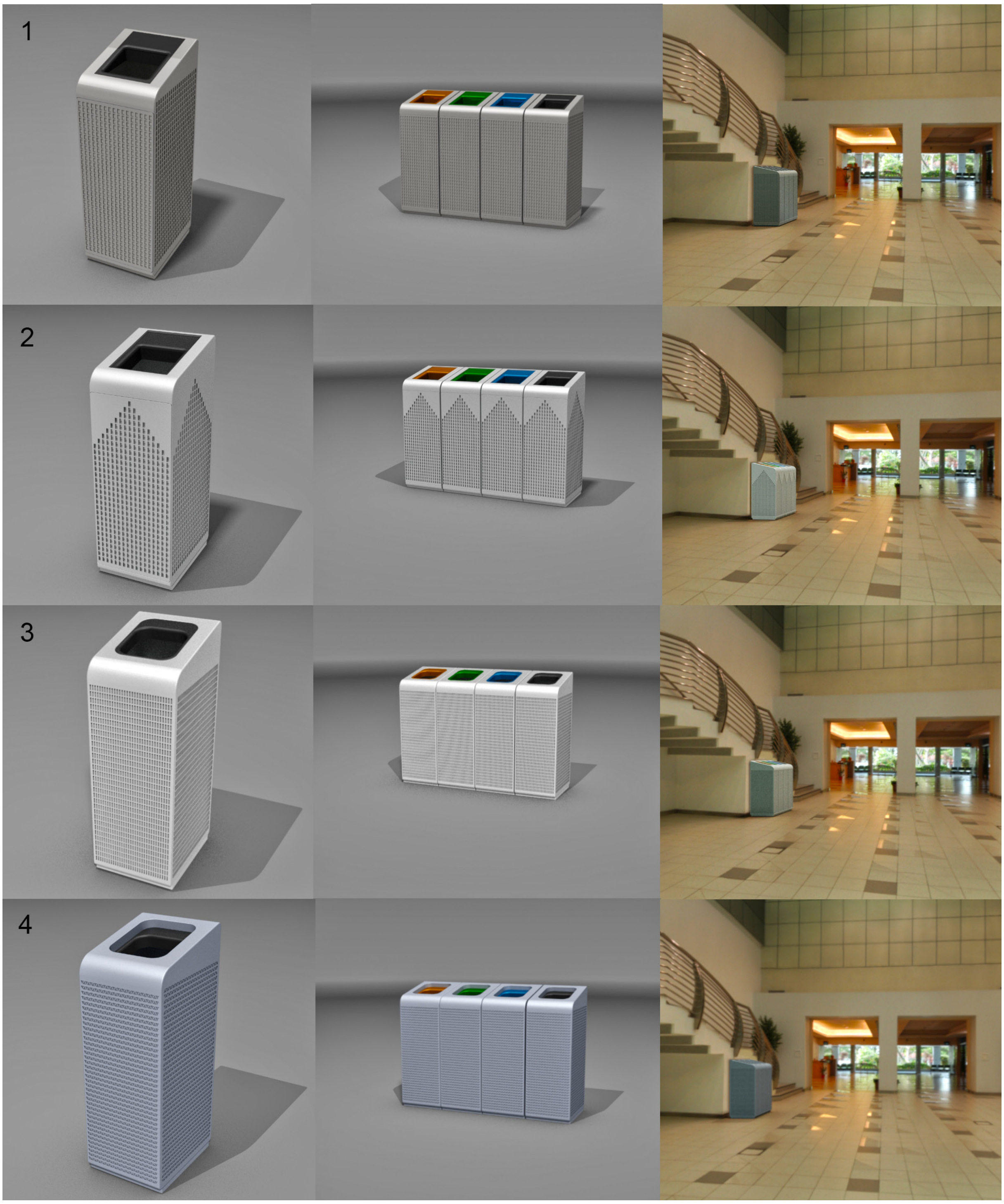


Figure 32. Mediating visualizations of the four form concepts that were used in the focus groups to evaluate the expression

6.3. RESULTS

The following section describes the result from the concept refinement phase. The design attributes of the final concept will be presented in more detail in the next chapter (*"7. Final Result"*).

6.3.1. Material selection

Of the three materials that were investigated further, two were chosen for the products. The outer container should be made of sheet steel, and the inner container and lid should be made of a polymer. In the sections below follows a description of these materials.

Powder coated sheet steel with zink alloy

Steel has the excellent property that it can be recycled an infinite number of times without having to compromise on quality. When the galvanized steel is recycled and the steel re-melted, the zinc coating ends up as dust in the smoke and can in turn be collected for recycling (Jernkontoret, 2014).

Both the waste bin from the project by Bjursten and Mårtensson (2009) and the recycling station by Nikell and Sundberg (2013) are made of 4 mm thick sheet metal with a zinc coating that makes for a 10 year-warranty against perforation by rust (RZ Group, 2014). The thicker the zinc coating, the more durable the product, which in turn leads to a more sustainable product, since the maintenance and replacement of the product requires natural resources (Nordic Galvanizers, 2013).

However, since the recycling station developed in this project is designed for indoor usage only, it will not be necessary to use the same thickness. Indoor environments are less corrosive, and to use a thinner material would convey a lighter expression that would be more fitting in these surroundings. It was concluded that a material thickness of 2 mm would suffice.

Polymers – PBT, PP, or PE

Polymeric materials were selected for the inner container and the lids to fulfil technical demands and to achieve the desired form and expression. Which specific type of polymer that should be used is left to be decided by the manufacturer. It should be noted, however, that there are high demands on surface quality (especially for the lid) and that the material should be resilient to physical damage. Since it is not necessary to adapt the product for outdoor usage it is not required for the material to withstand temperatures below zero.

One of the things that affected the material selection for the lid was the round, inviting curvature of the edges of the slots. This is impossible to keep if using laminate, since this material can only be manufactured as flat boards. The lids could be manufactured using sheet metal, but the tools would be quite expensive, costing about 30 000 sek a piece, which would mean a total of 210 000 for all seven slots (Olesen, 2013). As a result a polymer was deemed to have the most desirable properties.

To colour the material would be very expensive for small quantities. It would therefore be better to make the lids of a polymer using the same colour and have them powder coated afterwards. It would then be possible to make the lids in any preferable colour and it would not spoil the possibility of recycling (Jarestad, 2013). For the inner container the colour of the plastic will be good enough and no additional colouring is needed.

6.3.2. Construction

The construction will be described in detail in the next chapter (*"7. Final Result"*) but some of the main points are presented below.

- The final concept is made up of modules
- It is suggested that two sizes (one standard size, one slimmer model) should be offered. The slimmer model could be used by facilities that do not have as much space, or waste.
- Three sizes are suggested for the inner container: two sizes for the standard sized container and one for the slimmer version. To use a smaller size for the fractions with less quantities of waste means that space is left inside the recycling station which can be used, for example, to store plastic bags.
- A total of seven different fractions are suggested for the recycling station: plastic, metal, glass, paper, printed material, food waste, and combustible waste.
- The different fractions are only distinguished by the lids, which are detachable.
- The printed information (graphics and text) is placed on a sign, which is manufactured separately. This makes it possible to use tactile letters.

6.3.3. Design format analysis

The result of the DFA can be seen below in *Figure 33*. The result shows that four features were deemed most prominent, since they had a strong occurrence in both analysed products. These four features were the square perforation, the matt surface, the different colour in the perforation, and the tilted top surface. It was decided that two of these features should be used, in order to emphasize the relationship between the products. These were the square perforation and the tilted top surface.

6.3.4. Communicating features

The users' behaviour will be rule-based, since most users are familiar with recycling from home. (See *"2.2.2. Decision making"* for more information on rule-based behaviour.) It is important to create consistency in the communicating features so that the users may easily understand. This could be achieved by using existing text, graphics, and colours on the product.

The result of the studies of communicating features such as text, graphics, and slots is presented below.

Text and graphics

Using text to describe the content of the containers will explain the differences between them and support the usage of the product. However, information in text relies on language skills that are not common to the different users. The Swedish language (which is the mother tongue of the majority of the sorters) should therefore be supported by the more internationally accepted English language.

Graphical information supports the text information and communicates in a universal language that can be understood by a wide range of people. This is important since the recycling station will be used by people with different kinds of cognitive difficulties. Graphical information can communicate the differences of content by itself and is visible at a further distance. It could, however, also be wrongly interpreted without complementary text.

To make the text and graphical information accessible to users who are visually impaired, they should be set in high contrast compared to the background. In addition to this, there should be braille, and the ordinary text should be tactile to aid those who do not know braille.

Both the visual and haptic information have the merit of increasing the multimodality in relation to the product. Tactile letters and braille have, however, the disadvantage of making the users touch the product, something that is not appreciated according to Bjursten and Mårtensson (2009). But the accessibility is of a higher priority since the product should be available to all residents of Gothenburg.

Text and graphics should be presented in the same colour and close to each other to convey affinity. Furthermore, they should follow conventional directionality of upward, right and clockwise to support the interpretation. For more detailed information, see *"2.5. Interfaces"*.

The information could be negatively affected if it were to be presented with the wrong placement, lighting, colours, or finish. That is why height, light, and background should be acknowledged in the final result. For more detailed information, see *"2.4. Accessibility"*.

Slots

The result of the survey showed that many respondents had the same associations with regards to some geometrical shapes in relation to a specific type of waste (see *Appendix X* for the whole result). These were the hexagon for metal, the rectangle for paper, the circle for glass, and the thin rectangle for printed material. The result for glass, paper, and printed material, showed similarities to geometrical shapes already used for these fractions. The hexagon used for the metal waste had an interesting similarity to a metal nut, which might be what the respondents thought of when choosing this shape.

The other shapes and waste fractions were more difficult to connect because the results were more diverse. The half-circle was similar to a smiling mouth which gave associations to food waste. The ellipse was different from the other shapes which was a reason to use it for the last type of waste, plastic.

The square was the largest shape which was a reason for using it for combustible waste. This had to do with the waste management system and with the ambition to keep the waste fractions as clean as possible. If the user does not know where to put the waste it would be better to throw it in the combustible waste fraction than to throw it in the wrong fraction.

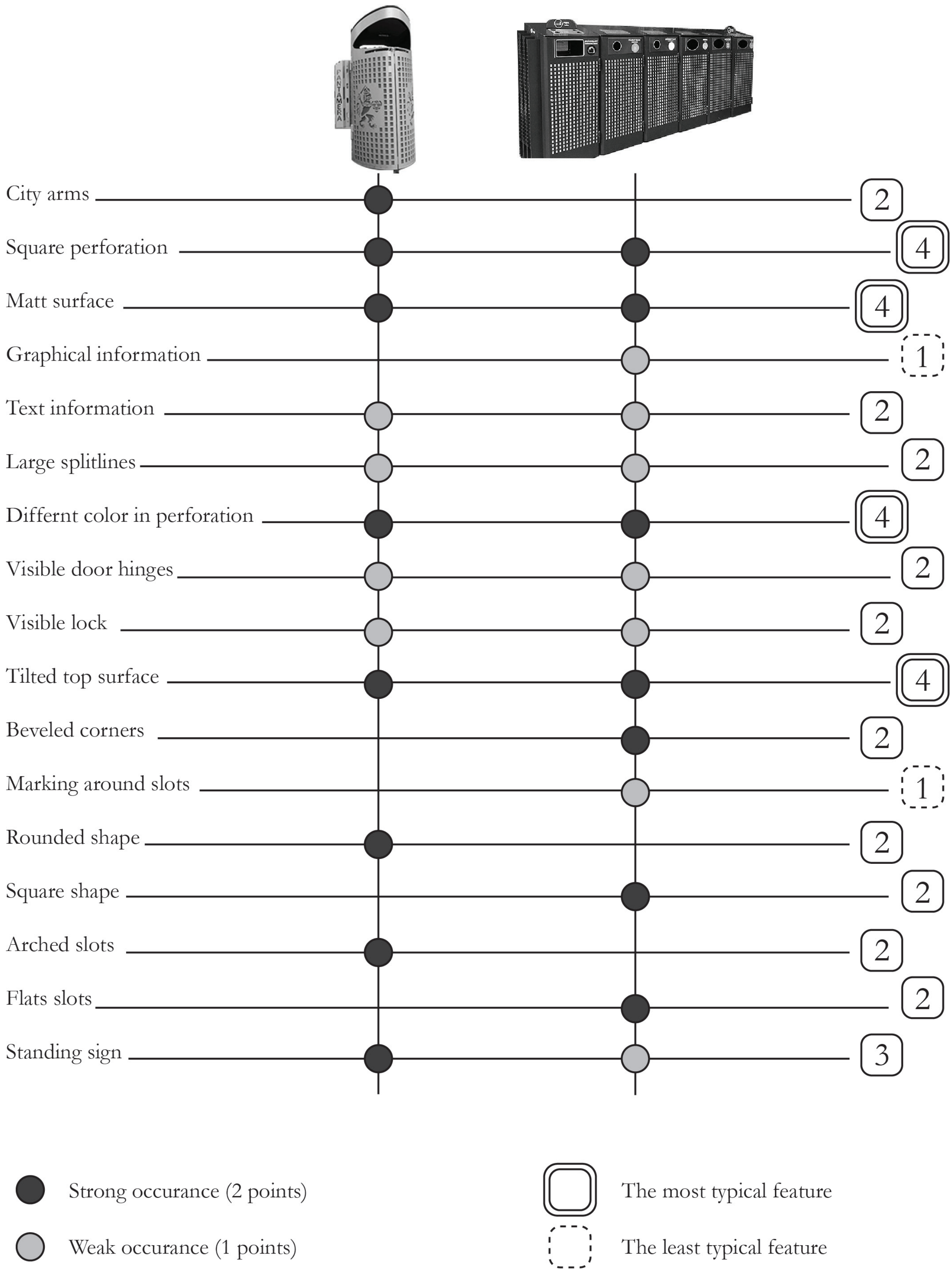


Figure 33. Result of Design Format Analysis

6.3.5. Form generation

One of the main results from the form generation was the decision of functional surfaces that the chosen concept should be composed of. The generated form could thereafter be applied to the functional surfaces.

The functional surfaces derived from the technical and user requirements shown in the concept development phase, such as the modular system and the tilted top surface. In addition, the typical characteristics of the product group shown in the DFA and form benchmarking, also formed a basis for the decision. The functional surfaces therefore fulfil the requirements and also provide a strong product identification. *Figure 34* shows the functional surfaces that were decided upon.

Figure 29 shows the process of applying form to the functional surfaces, although it is important to note that the figure is very simplified representation, since the process was iterated several times.

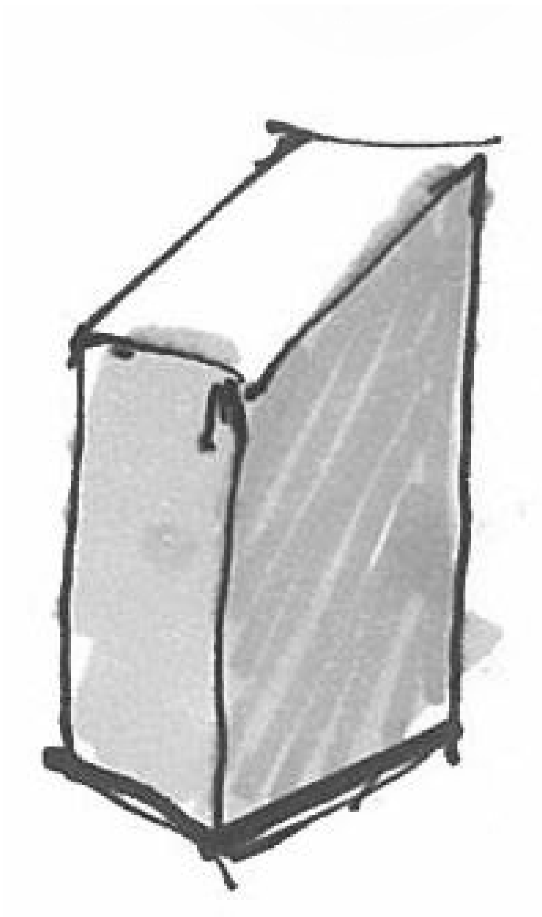


Figure 34. The functional surfaces on which the form was applied were based on technical and user requirements

6.3.6. Colours

The colour decision concerned three elements: the outer container, the perforation, and the lids.

The outer container and the perforation

The material selected for this part was a sheet steel with a zinc alloy, which made it possible to choose colours from the RAL system. It was possible to choose NCS as well, but this would be very expensive since large quantities would then have to be bought. Compared to the NCS system, the RAL system is less extensive with fewer hues and nuances, which limited the choice somewhat.

The colour covers the majority of the product, and the choice was made with respect to the specified requirements. These requirements were, for example that the recycling station should blend into the environment where it is placed (requirement *8.5 Express simplicity and discretion*), but at the same time be sufficiently noticeable when needed (requirement *4.7 Prepare for acting* and *8.4 Strengthen identifiability*; see chapter *"4.2.5. Specification of requirements"*). Colours that were faithful to the properties of the chosen material were preferred.

The lids

The material chosen for the lids was painted plastic, which made it possible to choose colours from the NCS system.

It was decided that the colour choices (together with the text, graphics, and the shapes of the slots) should explain the differences between the waste fractions. Enhancing the difference between the waste fractions would increase the possibility of correct usage.

It was therefore decided that the colours should be the same as the ones used by FTIAB for paper, printed material, metal, glass, and plastic. These are colours that are already nationally established; hence they fit the mental models of the users. The colours used for the food waste and combustible waste are developed by the administration of Circulation and water (förvaltningen Kretslopp och vatten) and are used in the municipality of Gothenburg.

6.3.7. Form evaluation

The concepts that were evaluated by the focus group can be seen in *Figure 31* and an overview is presented in *Figure 35* below. The result of the focus groups showed that concept 2 and 4 had the most motivating expression, concept 3 the friendliest and simplest expression, concept 2 the strongest identification, and concept 1 had the most stable expression.

Below follows some of the comments from the focus group:

Concept 1: The concept was said to be the most typical one, boring and insignificant. When the lids are on the same level as the outer container, they are more visual and give a more motivated expression.

Concept 2: The concept was said to give the most strongly identified expression because of the arrow pattern of the perforation, which gives it an aggressive but at the same time playful expression that attracts attention. The perforation is more visible when forming a pattern. The bright colour was perceived as the most appealing one.

Concept 3: The concept was said to give a friendly expression with the round corners of the lids. Round corners were said to be more aesthetically appealing than sharp ones. When the lids are on the same level as the outer container, they are more visible, which gives a more motivating expression. The thin perforation is hard to look at and gives a feeling of "a bit too much". The bright colour was perceived as the most appealing one.

Concept 4: The sunken lid made the colours more discreet even though the sharp edges around the hole gave a hard expression. To have a sunken lid might also be more motivating for the user.

Concept 2 and 3 achieved the most desired expression and colour. The rounded corners of the lids in concept 3 were perceived as the most aesthetically appealing. The thin perforation did not give a desired expression.

Figure 35. Overview of the concepts from the focus group

7. FINAL RESULT

The final result is based on all design features and expression choices made in the concept refinement phase. The chapter describes the result thoroughly and concisely and contains the product's construction, communicating features, and aesthetic expression, as well as the user's perspective and the product's environmental placement. It ends with a section on recommendations and further development.

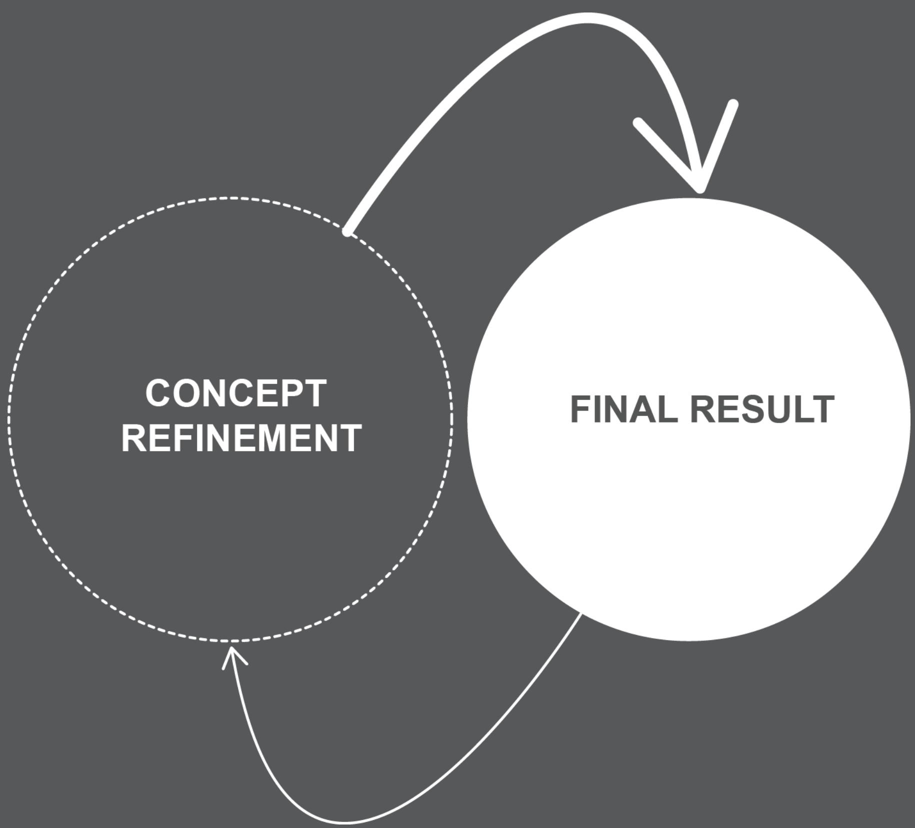
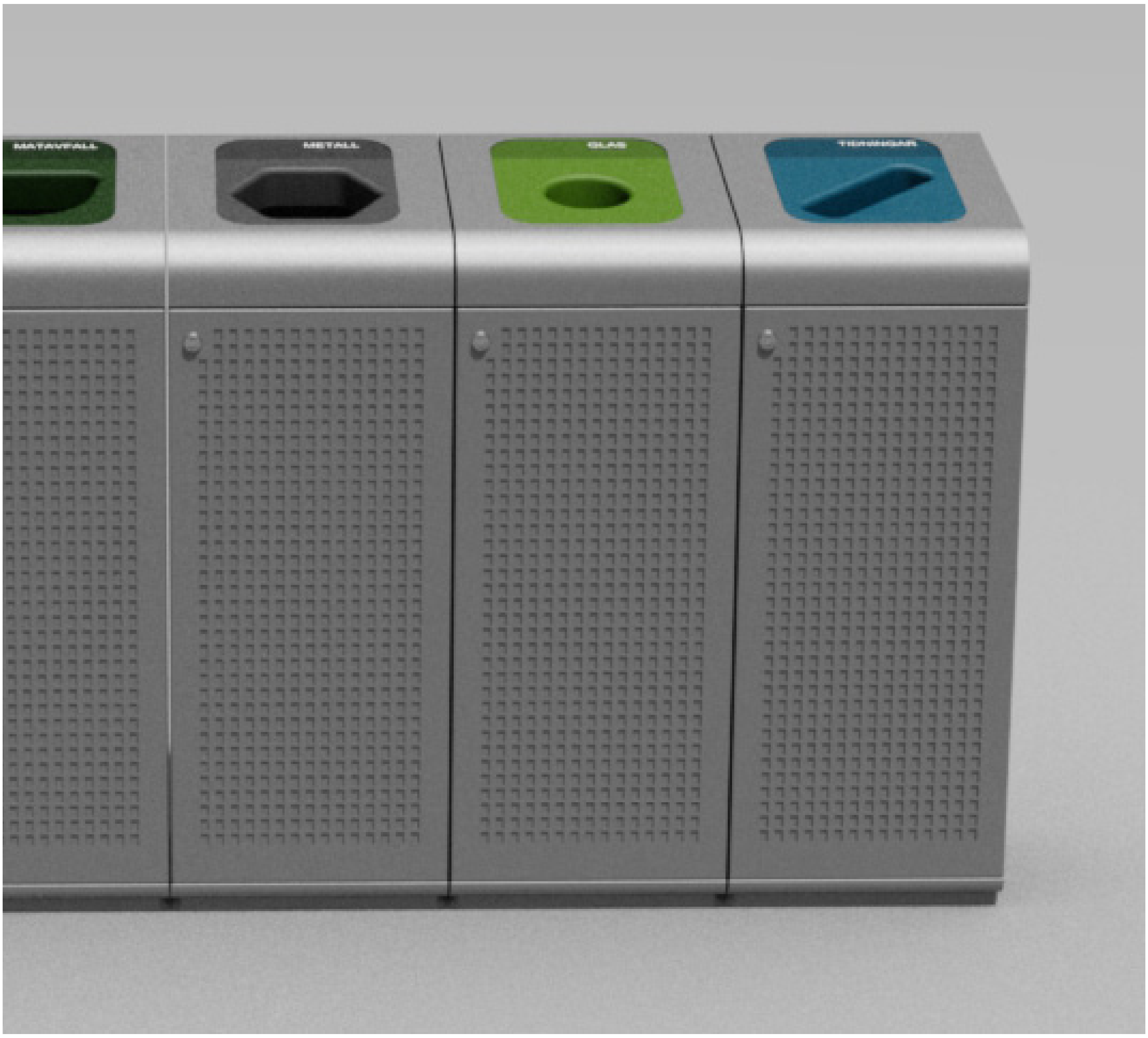


Figure 36. *IDA: Identify, Detect, Assort*


MATAVFALL
METALL
GLAS

7.1. ABOUT IDA

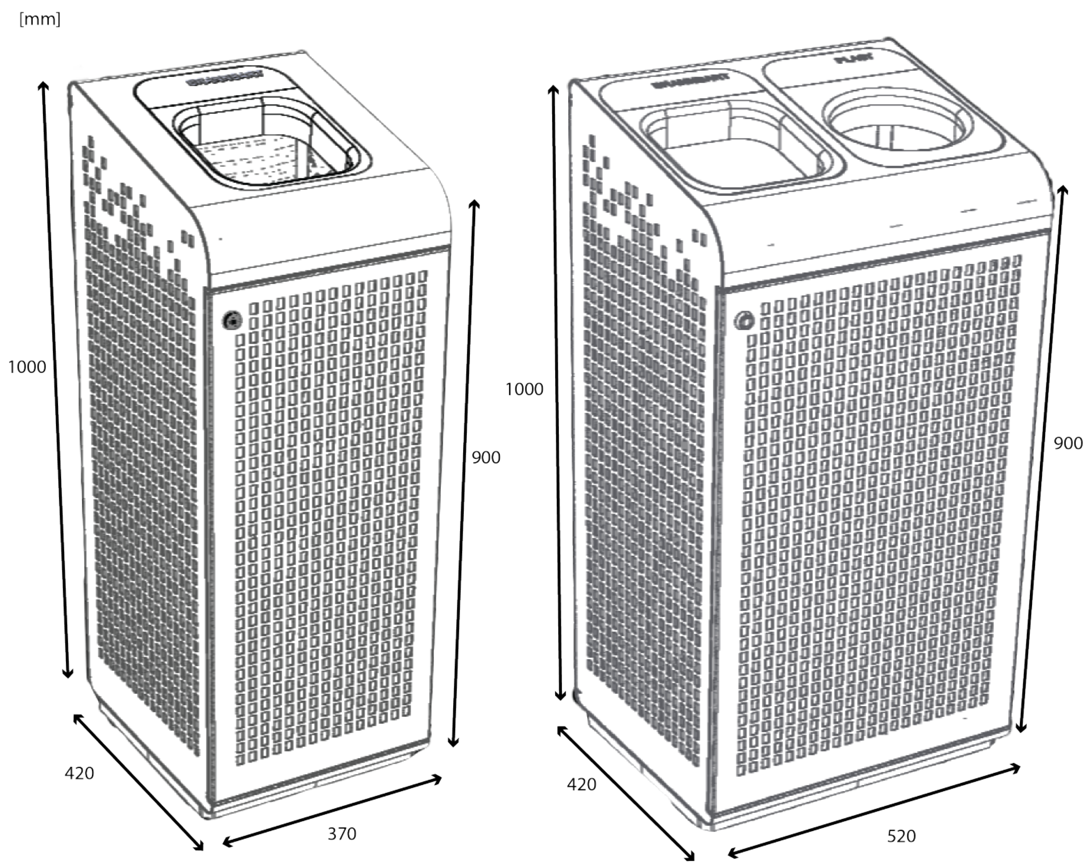
The final result is a flexible recycling station called IDA, which stands for Identify-Detect-Assort. These three steps summarize the product experience from the sorters' perspective. IDA is a flexible and durable recycling station. It can be adapted to a multitude of situations and accommodate many different types of needs. The design strikes a balance between discreet and attention-seeking.

The use of a total of seven different fractions is suggested for the final concept. These are plastic, metal, glass, paper, printed material, food waste, and combustible waste. The choice of fractions is based on the result from the observational studies (when the quantities and type of waste at the different facilities where registered) and on the fractions used by FTI (Förpacknings- och Tidningsinsamlingen). The choice was made not to include dangerous waste (such as batteries, electronics, or chemicals) because the quantities that occur in public indoor environments are negligible.

To save money when manufacturing the recycling station, coloured and clear glass are collected together. Moreover, there are generally very small quantities of glass in public indoor environments, and few facilities would need more than one container. The result of collecting coloured and clear glass together is that all the collected glass will be recycled as coloured glass.

In this chapter IDA will be described in detail, in terms of construction, usage, and aesthetic expression.

Figure 37. IDA, with standard sized and slim containers together



Standard module with one fraction

"Slim" module with two fractions

Figure 38. Dimensions of the two different types of modules

7.2. CONSTRUCTION

The final construction is a result of the attempts to achieve the desired aesthetic expression and the functionality of the product, as well as to meet technical demands.

7.2.1. Modular system, parts, and sizes

IDA is constructed as a modular system, which allows for a high level of flexibility. The final concept offers different sizes of the outer container as well as the inner container. It is therefore possible for the respective facility to choose both the number and volume of fractions depending on the quantity and type of waste that is generated there.

The recycling station is made up of these main parts:

- The outer container
- The inner container
- The lid
- Collection unit for deposit cans
- Inner construction
- Rails, hinges, and lock

These parts are described in further detailed in the following sections.

The modules should be offered in two different sizes. One "standard" sized module, where each piece contains one fraction, and one "slim" version, where the fractions are placed in pairs (see *Figure 38*). The slim model is in itself wider, nut since the fractions are placed in pairs the total width of the recycling station compared to the number of fractions is slimmer, hence the name.

One piece of the standard sized module is 370 mm wide and 420 mm deep. It has a tilted top surface and a height of 900 mm in the front and 1000 mm at the back (see *Figure 38*). More detailed drawings can be seen in *Appendix XI*. These measurements are the result of several compromises and contradictive demands. Many facilities have limited space in which to put the recycling station. It is therefore advantageous to make each module as slim as possible. On the other hand, the inner volume should be maximized to hold as much waste as possible (the amount is limited to what the collectors can carry), so that the recycling station does not need to be emptied with unnecessary frequency. The height is determined by the anthropometric measurements of the sorters and the collectors (see *"2.1.4. Anthropometric measurements"*). The height is limited upwards by the reach of children and of people in wheelchair, and downwards by the collectors, so that they will not have to bend down when emptying the waste station. The chosen height entails that all sorters included in the user group should be able to reach (see *Figure 39*).

If necessary, it would be possible to increase the depth of the recycling station. This is however not desirable since it would erupt the form, which is currently striving towards a more square shape.

For the slimmer model, each fraction has the width of 260 mm, which means that the outer container is 520 mm wide (see *Figure 38*).

When all seven fractions are put together, the recycling station (with the standard sized modules) reaches a width of about 260 cm. If you put six of the slimmer fractions together (an even number since the fractions are placed in pairs), you have almost as many fractions but it only adds up to a width of 157 cm (see *Figure 39*). Since it is only the width that distinguishes the two sizes (while the depth and height are the same), it is of course possible to combine them in many other ways.

The modules are joined together with screws. The possibility of joining the modules with some type of snapping solution was investigated, but it was concluded from discussion with manufacturers that this would only result in unnecessary tear if the recycling station were to be moved (Olesen, 2013). It could also be an advantage that the recycling station cannot be moved without using tools.

7.2.2. Outer container

The outer container is made of powder coated sheet metal, which is bent and welded together. The sheet steel was chosen for the outer container because the desired aesthetic appearance could be achieved, the material would emphasize the connection with the previous products, the material fulfilled the demands for indoor usage, and the cost of the material and the manufacturing seemed acceptable. The container is perforated and a 1 mm steel sheet is attached on the inside.

The outer container should be offered in the two sizes that are presented in the previous section. The shape of the container does not protrude far from the functional surfaces, but have a wide and inviting radius in the front.

The container is standing on a heel, which has both aesthetic and functional purposes. The heel elevates the recycling station so that it is perceived as lighter, but still stable. To have a heel gives the option of attaching the recycling station to a concrete slab, in order to prevent theft.

The outer container has a top surface that is tilted 14 degrees. This makes it easier to reach for children and wheelchair bound people. It also prevents people from placing waste on top of the recycling station.

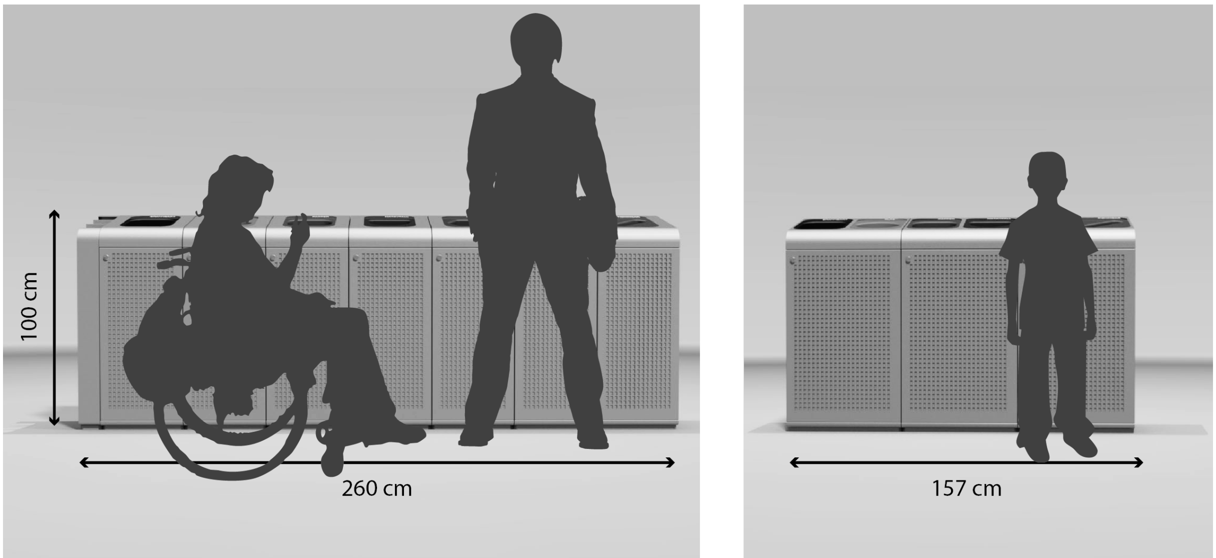


Figure 39. Three representatives of the user group with the wider and slimmer modules

7.2.3. Inner container

The inner container is made of a polymeric material that is vacuum moulded in two pieces along a vertical split line and then joined together (see *Figure 40*). What specific polymer is left to be decided in dialogue with the manufacturer. All three suggested polymers (PBT, PP, and PE) are recyclable and commonly used in the industry. The precise manner of joining the two halves is also left to be decided by the manufacturer, who has expertise in these matters. The demands on the surface quality are quite low, but the inner container needs to be a good fit inside the outer container.

It is suggested that the inner container should be offered in three different sizes, two versions for the standard sized module and one for the slimmer fractions. The three sizes will henceforth be referred to as the "standard", "short" and "slim" model (see *Figure 41*). The three different sizes have the same depth, but differ in width and height. The size of the largest inner container (the standard model) derives from the pursuit to utilize as much of the inner volume as possible. It has a volume of about 76 l and will suite a standard sized plastic bag of 120 l.

A short inner container should also be offered for the standard sized module. The reasons are that less waste is generated for some of the fractions, that you might want to empty some of the containers more frequently, or that you want to use smaller bags (which is especially advantageous for food waste, where the organic bags are troublesome later in the process). To use a smaller inner container would mean that there is space left inside the outer container, which could be used, for example, to store plastic bags (see *Figure 43*). The smaller container has a volume of about 36 l.

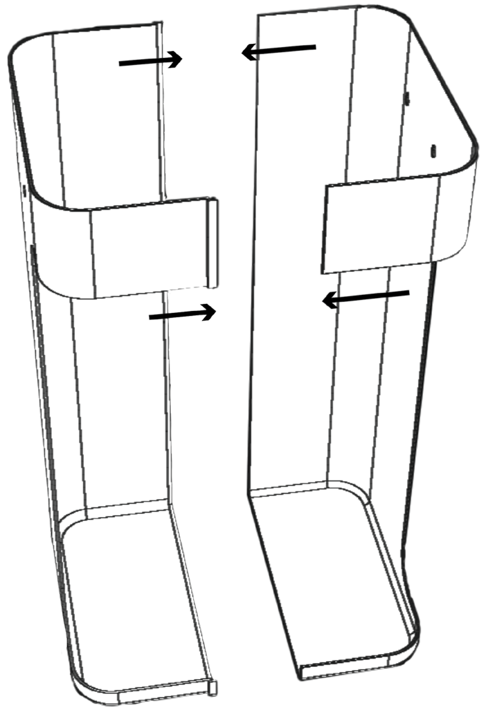


Figure 40. The inner container is manufactured as two parts that are joined together

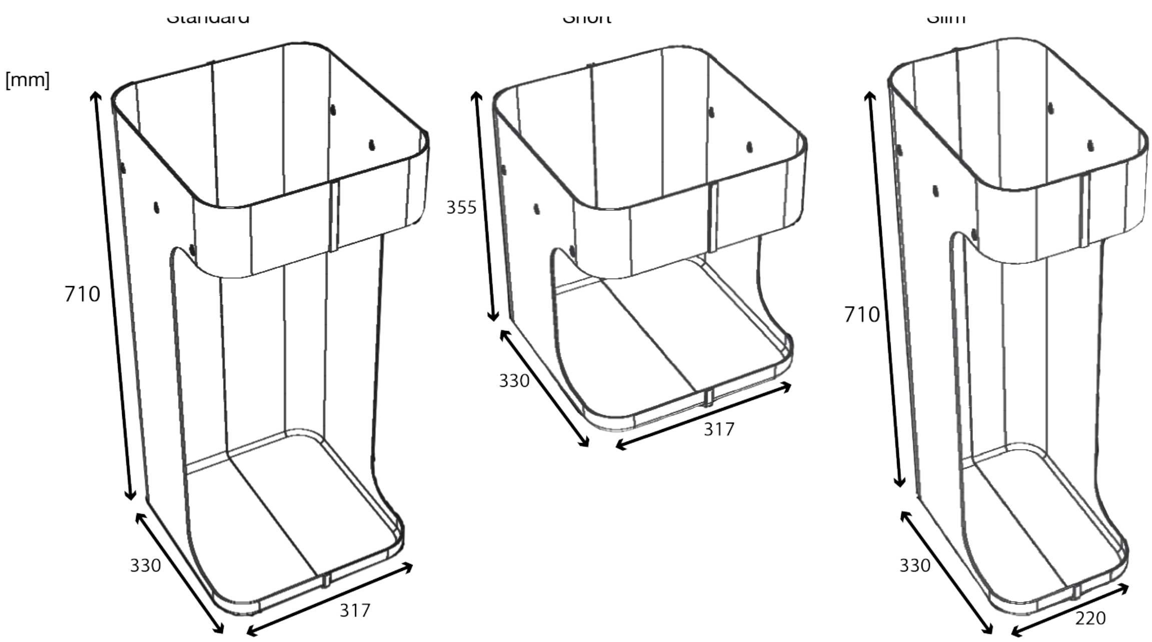


Figure 41. The three different sizes of the inner container

Because the volume of the slim model is already fairly small, it was deemed unnecessary to offer two versions of the inner container in this case. It has a volume of approximately 45 l. The width of this slim model is an estimation based on the assumption that each container is attached to two rails. Since the fractions are placed in pairs, and since it is not necessary to empty each fraction separately, it might be possible to use a single rail in the middle and pull the pair out together. It could also be an option to attach the two containers to each other in some manner. In these cases it might be possible to increase the width of the slimmer container slightly. All three sizes can be seen in *Figure 41*. For more detailed drawings, see *Appendix XI*.

All three sizes of the inner container are open in the front to allow for easy emptying and to avoid lifting above shoulder height (see *"7.4.2. Collectors"*). As requested during the user studies, the inner container has a floor that carries the weight of the waste. The inner floor has a small edge in the bottom to collect fluid and prevent leakage.

The inner container is hitched to the rails by holes in the plastic. This attachment allows for easy fastening and detachment, which makes it possible for the collectors or maintainers to remove the container, rinse it, and clean inside. The holes for fastening the container are shown in *Figure 42*.

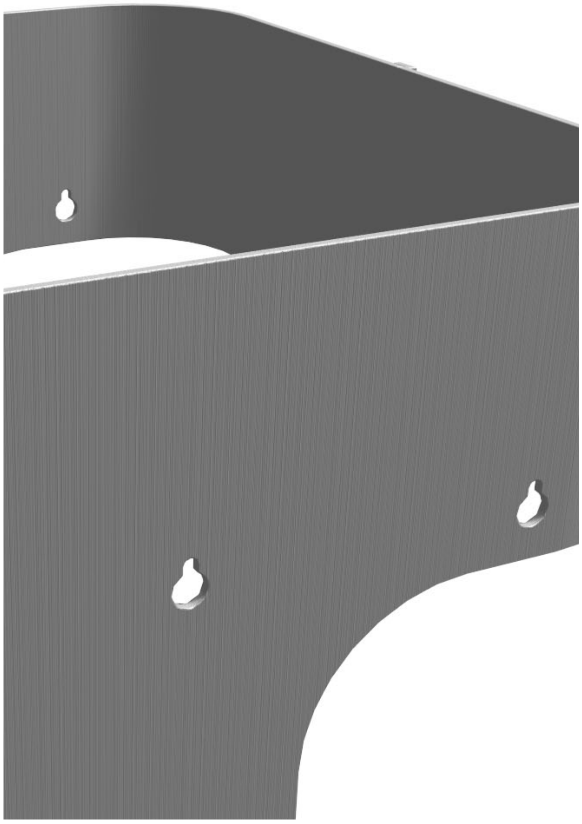


Figure 42. The holes for fastening the container to the rails allow for easy detachment

Figure 43. If a smaller container is used for some of the modules, it is possible to store bags inside the recycling station

7.2.4. The lid

Similarly to the inner container, the lids are made of a polymer that is vacuum moulded.

There are in total seven different types of lids (one for each fraction), with different colours and shapes of the slots. The texts and graphics are printed on a sign that is manufactured separately to achieve tactile letters. The lids are 240x320 mm, with 50 mm radii in the corners (see *Figure 44*).

The different fractions are only distinguished by the lid. This is highly practical both because it means lower manufacturing costs (since there is no need to manufacture different types of containers) and because it adds to the functionality of the product. It is assumed that the lid is the part that will fail first, due to wear and scratches. To make this part easily exchangeable means that the total lifespan of the product can be extended.

Making the lids easily exchangeable also adds to the flexibility of the recycling station. It is possible for the administrators at the facilities to order, for example, 3 units of the modules, but all seven lids, and change them as needed. This is especially useful for event facilities, where the types and quantities change between events.

The lid could be fastened with a grove at the top of the lid and a sprung sprint at the bottom (see *Figure 45*). There might be other solutions to the fastening of the lid, but the important aspect is that it should be easily detachable from the inside, when the door is unlocked, but very difficult to detach from the outside, to prevent stealing.

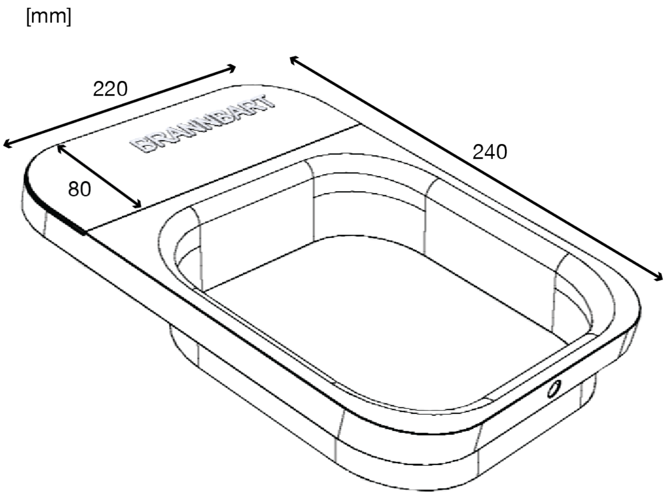


Figure 44. The dimensions of the lid

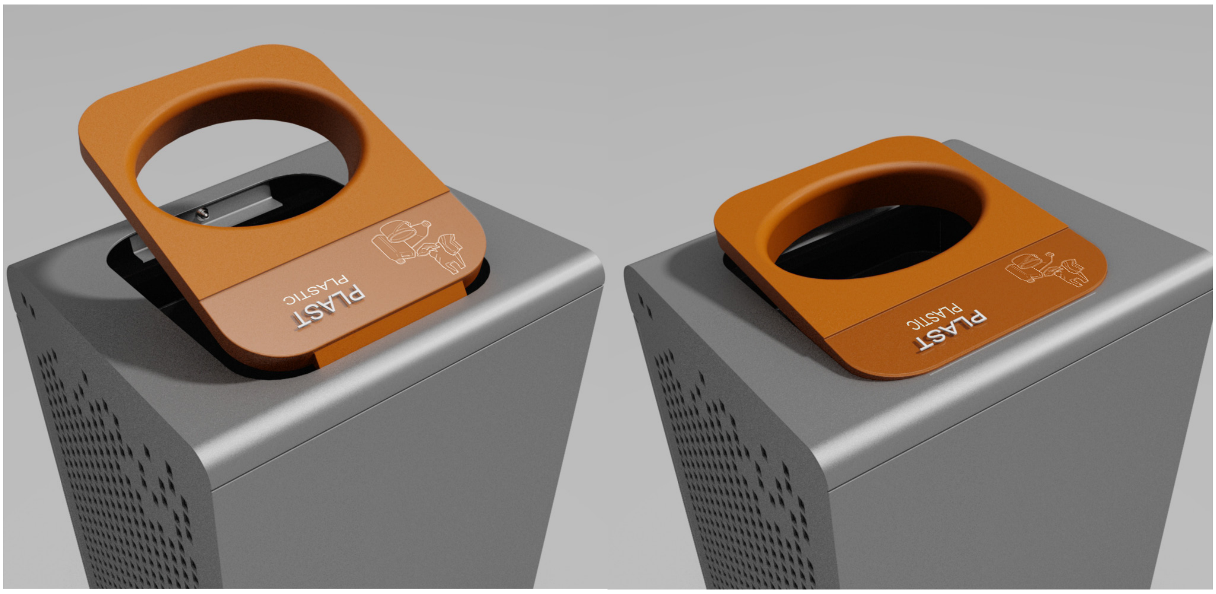


Figure 45. The lids are easily exchangeable

7.2.5. Collection unit for deposit cans

There is a separate unit for deposit cans. The reasons to keep the collection of deposit cans separate are that they are generally quite few and that there are often people who want to collect them. Therefore the collection unit does not need to be as large as the other units, and the deposit cans should be easy to reach. On occasions when there are a lot of deposit cans (for example at some sport events), one of the regular containers could be turned into a collection unit for these. Some facilities would hence benefit from an additional lid for deposit cans.

The separate deposit can unit is made up by pipes where the users put their cans. It holds 12 cans (4 per pipe) or 3 bottles (one per pipe). The design is inspired by the deposit can collection by Nikell and Sundberg (2013), which further emphasises the kinship of the two recycling stations.

The deposit can unit follows the shape of the recycling station, which allows it to blend in and appear to belong, rather then looking as if it has been attached afterwards (see *Figure 46*). For drawings, see *Appendix XI*.

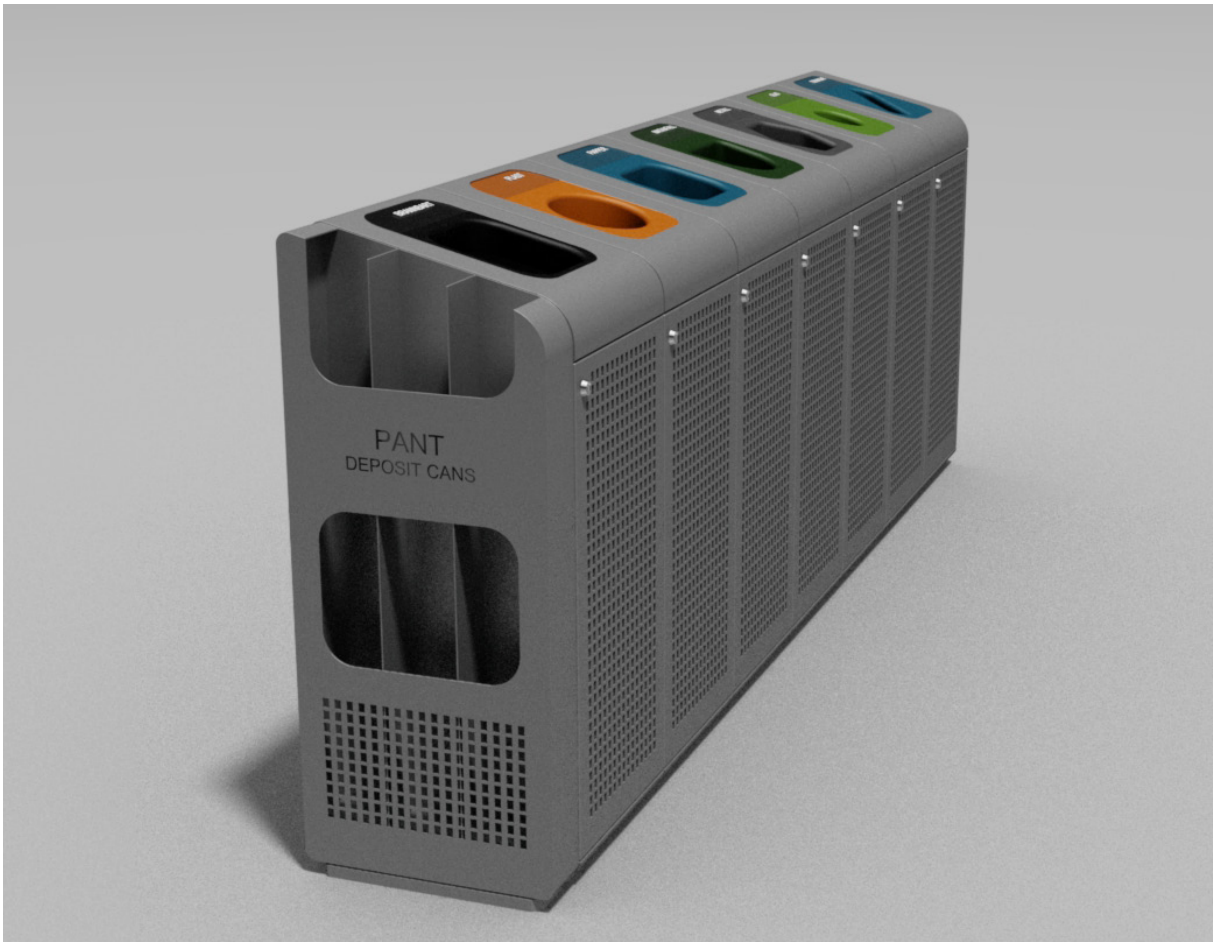


Figure 46. Collection unit for deposit cans

7.2.6. Inner construction

Because the material is quite thin and the surfaces are fairly large, there may be a risk that the sides will bulge (Kardborn, 2013). Therefore an inner structure will be built to stabilize the container. This inner structure can also be used for attaching elements such as hinges for the door and rails for the inner container (see *Figure 49*).

Flat irons build up the inner structure. The dimensions of these flat irons are based on the space required by the hinges rather than what is needed to achieve stability. Depending on the hinges that are used, it might therefore be possible to use slimmer flat irons, which would leave more space for the inner container.

There are four holes in the bottom of the container (see *Figure 47*). These can be used to screw the recycling station onto a concrete slab, or to attach "feet" as are common with dishwashers, for example, to compensate for uneven ground.

Another way to secure the recycling station is to attach a suction cup to the bottom of the outer container. This way of fastening the recycling station can be used on all floors that are sufficiently even, without causing damage. This solution would however further emphasise the importance of an inner structure, because the floor of the outer container would bulge.

In the bottom of the recycling station there is a detachable floor. This is so to prevent leakage, to collect liquid and spillage, and to protect the inside of the container from being exposed to fluids during an extended period of time (see *Figure 48*).

Figure 49. Hinges and rails could be fastened to the inner construction

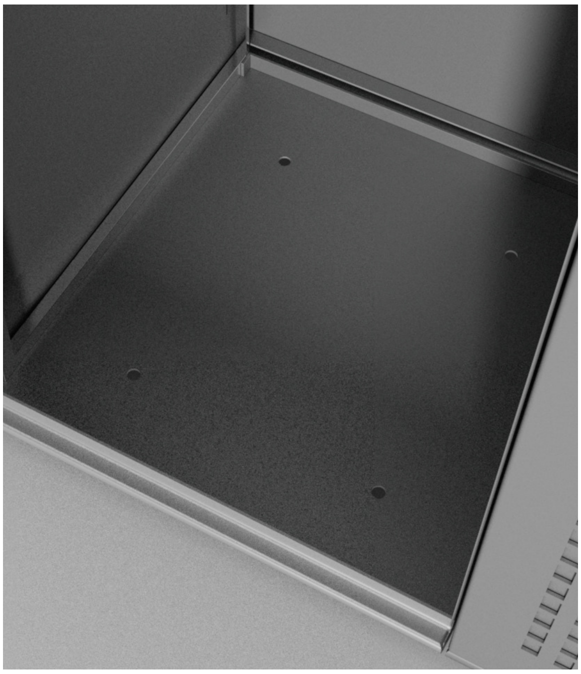


Figure 47. Holes in the bottom to fasten attachments

Figure 48. Detachable inner floor

7.2.7. Rails, hinges, and lock

Rails

The inner container will be attached to telescopic rails. The rails should be dimensioned to carry at least 20 kg, to support the inner container and the maximum amount of waste. From discussion with sales personnel at a company called Rolf Thuresson Trading AB, which deals in component trading for the kitchen, bath, and furniture industries, it was gathered that standard telescopic rails can be found that carry up to 90 kg. However, to over-dimension them like that could mean that the rails will give resistance when pulled, since all the construction elements are coarser (Salesperson at Rolf Thuresson Trading AB, 2013). The project group therefore recommends that telescopic rails dimensioned for 30 or 40 kg should be used.

Telescopic rails can expand to twice the length of their retracted position. Standard rails come in lengths between 250-700 mm, with 50 mm intervals. It would be good to choose a rail that is as long as possible compared to the depth of the container, since this would insure that the space is efficiently utilized. The outer container is constructed for a 400 mm telescopic rail, which reaches 800 mm when fully extended. The inner container has to be built so that some space is left at the back, to provide the possibility of pulling the inner container well out of the outer container (see *Figure 50*). This feature is important, since it makes it a lot easier for the collectors to change the bag (see *"7.4.2. Collectors"*). If necessary it would be possible to extend the depth of the outer container without diminishing the usability of the recycling station. This is however only advisable if it should be necessary to make room for the rails. To extend the depth too much would erupt the form, and the aesthetic expression would suffer.

Hinges

The hinges are put on the inside of the container, and move with an extended arm, as is common, for example, with kitchen cupboards. These types of hinges make it possible to put the doors close to each other and achieve a straight, coherent impression of the recycling station when put together. The disadvantage is that they take up space inside of the modules.

Lock

As requested by some facility administrators during the user study, it is possible to put a lock on the recycling station. There was no extra studies performed to determine what type of lock, but the project group reckon that a standard type would suffice. A common model is used to illustrate (see *Figure 51*). A standard hexagonal key is used to open this lock.

One notion that was expressed was that using a lock with two bars, closing at the top and at the bottom of the door at the same time, would be preferable to a lock with just one bar. This would prevent breaking the door open by bending it.

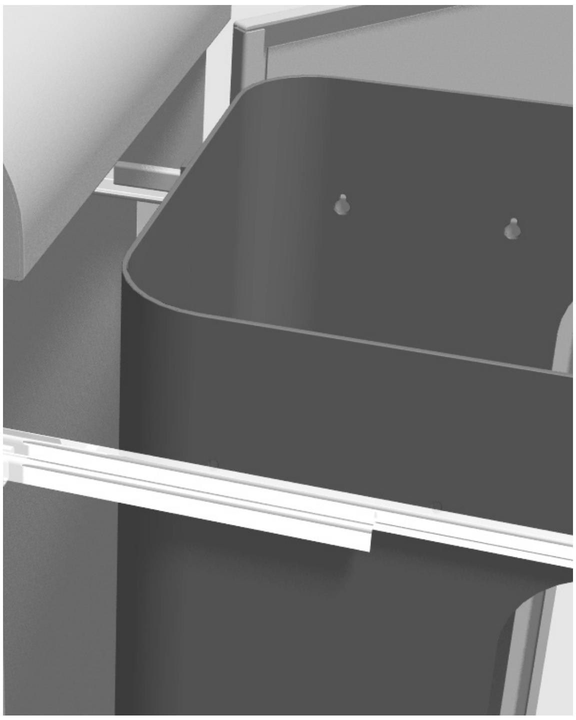


Figure 50. When the inner container can be pulled well out of the outer container

Figure 51. Standard locks can be used

7.3. COMMUNICATING FEATURES AND AESTHETIC EXPRESSION

The following sections present the communicating features (text, graphics, and slots) and the aesthetic expression.

7.3.1. Text and graphics

On the lids there is a transparent sign that contains design features distinguishing the respective waste fractions. *Figure 52* shows an example of these signs. The sign is here presented with a background colour to visualise what it will look like on the recycling station. However, the sign itself should be made transparent and the colour is that of the lid, behind the sign. The text and graphics are printed in white.

The different waste fractions have been written in Swedish as well as in English, to accommodate international visitors. The Swedish text for the seven signs says: papper, plast, metal, glas, tidningar, brännbart and matavfall, with the English translation: paper, plastic, metal, glass, printed material, combustible waste, and food waste. All fonts are uppercase Arial for clarity and consistency with all signs in the municipality of Gothenburg, and the text is white with light grey nuance.

The Swedish words are written with tactile letters and the information is additionally written in transparent braille, printed under the English translation, to include users with visual impairments. The tactile letters have a minimum size of 15 mm and a maximum size of 40 mm and a 1 mm sharp relief. The English letters are not tactile and smaller than the Swedish letters, to prevent confusion.

To the left side of the text, there are graphics of the waste fractions to include users with cognitive impairments and to further clarify the distinction between the waste fractions. The graphics are consistent with those of FTIAB's for paper, plastic, metal, glass, and printed material. For combustible waste and food waste the graphics conform to a national standard (see *Figure 53*).

7.3.2. Slots

The slots on the lids have different geometrical shapes of the slots emphasise the differences between the waste fractions.

Below follow the shape and size of each slot:

Paper: rectangle, 200x160 mm.

Plastic: ellipse, 200x160 mm.

Metal: hexagon, 200x170 mm.

Glass: circle, 110x110 mm.

Printed material: tilted thin rectangle, 230x60 mm

Combustible waste: square, 200x200 mm.

Food waste: half-circle, 200x150 mm.

See drawings in *Appendix XI*.

Figure 52. The sign on the lid contains design features that support the usage

Figure 53. The standard graphics for printed material, plastic, metal, glass, paper, combustible waste and food waste

7.3.3. Colour

The colour of the lids are consistent with FTIAB and national standards for different fractions to emphasise the differences between the waste fractions. However, small adjustment were made to match the colour and material of the outer container. The colours have the following NCS system codes:

Paper: NCS S 3050-B10G

Plastic: NCS S 1080-Y40R

Metal: NCS S 6000-N

Glass: NCS S 1070-G30Y

Printed material: NCS S 3050-B10G

Combustible waste: NCS S 9000-N

Food waste: NCS S 5540-G20Y

The colour of the outer container has the RAL code:

RAL 9006 "White aluminium", for the standard container with the different coloured lids.

These colours were chosen because the recycling station should be discrete and blend into the environment, but still be noticeable when needed. All these different colours of the lids and the steel gray of the outer container could, however, be too much for the most sensitive indoor environments. An alternative colouring is therefore suggested which can be used at facilities such as concert halls or the opera. This "classic" colouring has the following combination:

RAL 7048 "Pearl mousse grey", for the outer container with the consistent black coloured lids.

The classic versions is shown in *Figure 54*.

7.3.4. Aesthetics

The form evaluation showed that concept 3 expressed "friendly", "simple", and "motivating" to the highest degree, and was generally considered to be the most appealing concept (see *"6.3.7. Form evaluation"*). The two features that contributed most to this were the rounded corners of the lids and that the lids were in level with the top surface. These two features were therefore chosen for the final concept.

The perforation has the shape of a rectangle with the dimensions 15x10 mm. The proportions are the same as the previous waste containers in Gothenburg City, in order to create identification. The perforation is laser cut, with a steel sheet in the same colour on the back for a simple and discreet expression. On the side of the container, the perforation has a pattern with a graceful expression with two functions: the graceful expression highlights the module and gives it a stronger identity, and the perforation on the side reduces the risk of graffiti (see *Figure 54*).

The colours of the outer containers have a metallic element which gives it a strong material identity. The connotation of the steel material is strongly related to reliability and stableness.

The expressions "motivating", "friendly", "simple", "identifiable", and "stable" are, with these aesthetic features, accomplished.

Figure 54. Colouring for sensitive indoor environments

7.4. USER PERSPECTIVE

The users were throughout the project divided into two main groups: sorters and collectors (see *"3.3. The users"*). The user experience for these groups is described in the sections below.

7.4.1. Sorters

The sorters' interaction with the recycling station was divided into three steps – Identify, Detect, Assort – that in abbreviated form constitute the product name (IDA). These three steps, which summarize the user experience, are described below.

Identify

The sorter has some type of litter that he or she wants to dispose of. This person scans the surroundings and identifies the recycling station. The classic design and strong product identity of IDA helps to achieve this.

Detect

When reaching the recycling station the sorter discovers that there are different fractions. The sorter needs to detect the fraction corresponding to the litter. The detection is supported by the different colours of the lids, the shapes of the slots, the text differentiating the fractions, and the symbol complementing the text.

Assort

When the correct fraction is detected, the sorter assorts the litter. Hopefully the sorter leaves with a sense of satisfaction from contributing to a cleaner, more environmentally friendly Gothenburg.

7.4.2. Collectors

The process of emptying the waste station is presented in the picture series of *Figure 55*.

The inner container is pulled out, the bag is lifted, then pulled down and drawn through the opening in the front of the container. The bag is then pulled down on to the floor and tied together. When refilling the container with a new bag, the process is simply done in reverse. This way of emptying the recycling station ensures that the collector does not have to lift above elbow height, which according to the theory (*"2.1.4. Anthropometric measurements"*) is ergonomically preferable.

Figure 55. Emptying the recycling station

7.5. ENVIRONMENT AND PLACEMENT

Since the recycling station is based on modules, it allows for many possibilities in terms of placement. The different sizes of modules could be combined to achieve a tailored model that is perfectly suited for each specific facility.

The modules could be placed back to back, in the middle of the room, or (which is probably more common) against a wall. They could of course also be placed by themselves in the middle of a room. This would however require that the perforation cover the back side of the recycling station as well, to discourage graffiti.

There are various options when it comes to placing the recycling station, but some recommendations should be followed.

The recycling station should not be placed on any type of bedplate or step that would increase the height, since this would mean that some of the users would not be able to reach.

The lighting should be sufficient, but not too strong so as to be blinding.

There should be sufficient space in front of the recycling station so that wheelchair-bound people can come close enough to reach.

Since the recycling station is so versatile, it will fit well into the public indoor environments in Gothenburg. *Figure 56* shows an example of how it would look if placed at the event arena Scandinavium.

7.6. RECOMMENDATIONS AND FURTHER DEVELOPMENT

Build a prototype

It was not possible within the time frame of this study to develop a prototype. To do this would answer a lot of questions, and potential areas of improvement would be discovered.

Place the prototype in a public indoor environment

By placing the prototype in a public indoor environment the usability aspect could be evaluated in realistic conditions.

Develop a cover for the slots

Some of the facility administrators requested that there should be an option of adding a cover to the slots. The sorters, however, are in general sceptical towards this suggestion, since it would mean that they would have to touch the recycling station, and this is something they prefer not to do (Bjursten and Mårtensson, 2009). The request for a cover was therefore given low priority.

An advantage of having a lid could be that it works as an "obstacle" that forces the sorters to pause so that fewer errors are made. A lid could also prevent odours (see Requirement 6.7, in chapter *"4.2.5. Specification of requirements"*). The disadvantages of a lid are that the sorters would have to touch the recycling station, that it would not be possible to dispose of waste with one hand, and that it would complicate or obstruct the usage for the visually impaired.

Develop separate unit for collecting fluids

Another request was a separate unit for collecting fluids such as soda or coffee that need to be poured out. This would require some kind of tank that could be emptied in the drain.

Develop bags that do not have to be emptied

One problem with the current solution is that it requires bags to collect the waste. If plastic bags are used, many of the fractions will need to be emptied in the garbage room. This means an extra operation in the work process. This operation could also be harmful since it often requires lifting bags full of waste above the head.

A solution would be to use bags that can be recycled together with the other material in that fraction. Paper or corn bags could be used for the food waste, paper for paper, plastic for plastic, etc.

It would simplify the work for the collectors if the bags were either transparent or marked in some fashion, so that they did not have to remember or check what bag contains what waste when they came to the garbage room. One solution would be to develop specific bags for specific fractions, and distinguish them by using, for example, colour and symbols.

Figure 56. IDA placed in a public indoor environment

8. VALIDATION

In this chapter, the evaluation of the product's validity is described. The validation was performed by means of the Eco strategy wheel and by comparing the result with the demands from the specification of requirements.

8

8.1. ECO STRATEGY WHEEL

The Eco Strategy Wheel is a tool that can be used to stimulate new ideas of how a product could become more environmentally benign (SVID, 2002). The wheel is used to brainstorm around eight different areas (see *Figure 57*):

- Optimise the function
- Reduce the environmental impact during use
- Reduce the amount of materials
- Choose the right materials
- Optimise durability
- Optimise production
- Optimise waste management
- Optimise distribution

The Eco Strategy Wheel was used in this project as a tool for validation in order to examine if the product was achieving sustainability goals. The product's main function – to enable sorting waste in public indoor areas – is in itself contributing to a more environmentally friendly waste management system in the city. However, the product cannot be classified as sustainable if the whole life cycle has not been evaluated through this perspective.

The product's performance was evaluated through questions that highlighted critical issues within the eight different areas.

Optimising the function

Could the product function be optimised so that the environmental impact would be minimized?

The function itself is to reduce the environmental impact of waste. To enhance the product function would primarily require changes of the waste management system surrounding the product. However, once the product has been tested in a real environment, one can see whether there are things to improve with the product itself. For instance, some fractions may need to be more difficult to access, in order to obtain less mixed waste.

Reduce the environmental impact during use

The product requires no power, so the environmental impact during usage is low. Things that are consumed during the usage are detergents and plastic bags.

Is it possible to reduce the use of detergents?

The perforation contributes to reducing the use of detergents, as it impedes graffiti. If the product is looking dull from dirt, it could lead to decreased usage. However, the sheet steel withstands dirt well, because of material properties and choice of colour, and should not need to be cleaned very often. The tactile letters on the plastic lids might make the cleaning more difficult, but the accessibility of the product (which increases with the tactile letters) is prioritised.

The tray in the bottom of the container can be lifted out, debris can be removed, and the tray can easily be rinsed off. This might also decrease the need for cleaning detergents.

Is it possible to reduce the use of consumables?

Even though the energy consumption during use is zero, there is one consumable in the form of plastic bags. Plastic bags contaminate other waste fractions such as paper, metal, and glass in that it is a different material. The waste must therefore be poured out of the bags, and the bags are then thrown away. This could be prevented by using bags of the same material as the content of the respective fraction.

Another way to reduce the amount of bags used and to decrease the contamination of the waste fractions is to use fixed containers.

Reduce the amount of material

Could the material volume be reduced further?

The size of the product is difficult to change since the dimensions are governed by how the product is used (it should be accessible to all users, fit into the facilities, and hold as much waste as possible).

However, thinner material could be tried out, with the risk of causing the product to become dented. If embossing is used instead of perforation it would be possible to reduce the amount of material. This would also make the surfaces stiffer and less likely to bend.

You could leave out the tray in the bottom of the product, which would also reduce the amount of material somewhat.

Choose the right material

In what way do the chosen materials burden the environment?

Sheet steel pollutes the environment when it is manufactured, mined and processed, and when disposed of. However, it is to a very high degree possible to use recycled material. Joints and mountings may usefully be made by soldering, where no new material is added.

The plastic also affects the environment during production and waste management, but it too could be made from recycled material. The sign with the text information includes glued parts and needs to be

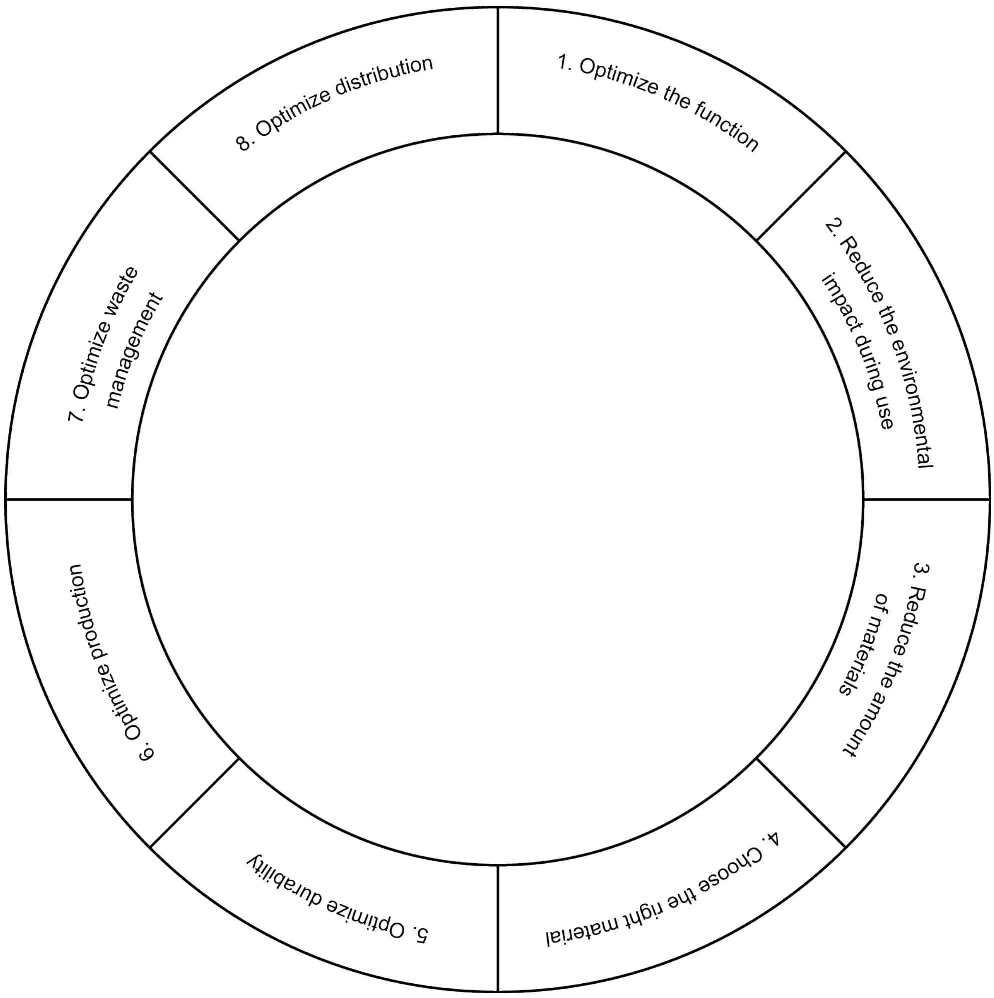


Figure 57. Eco Strategy Wheel

glued onto the lid. If injection moulding were to be used instead of vacuum moulding, it would be possible to have much more detail in the design of the lid. It would then be possible to add a strip in the plastic, under which the sign could be attached. Then no glue would be needed to keep it fixed. The plastic could be coloured instead of painted, which would mean that no extra material would be added and that the lifespan of the plastic parts would be prolonged.

Optimise durability

Could you replace components instead of replacing the whole product? What part of the product will break first? Could this part be replaced/repaired?

Most of the parts can easily be detached from the recycling station. Hinges and rails can be replaced if they break. It is likely that the lid or the inner container (both of which are made of plastic) will break first. However, these are very easy to replace, and this increases the lifespan of the entire product.

By increasing the zinc layer on the sheet metal, the oxidation of the material could be counteracted. Elevating the product by using feet prevents moisture to creep into the bottom. Colouring the plastic instead of painting it would make it more resilient to scratches which would mean that the lids do not have to be replaced as often.

Optimise production

How much energy is used in the manufacturing of the product? Where does it come from?

It is very difficult to analyse the current energy situation since it is not decided who will manufacture the product. However, this is an area where the municipality of Gothenburg may consider imposing energy requirements on the production.

Are waste materials generated during the production of the product?

Yes, for example when the steel is cut to make the perforation. Also the plastic parts often need trimming when manufactured. However, in both cases the waste material is being recycled.

8

Optimise waste management

Can the product be reused?

The function of the product could be altered by changing lids, which would allow the product to be reused. There could also be completely different lids for other purposes. Clothes collection? Disposable cans? The imagination sets the limit for what you could do.

You might also be able to pick out parts of the product and use them in other contexts. The inner container could be used as it is, as a litter bin.

Can the product be recycled?

Both the steel and the plastic components can be recycled.

Can the product be separated into pure materials?

Yes, all components can be separated into pure materials. By deliberately joining and attaching the components to each other by means of design solutions such as snapping functions etc. the amount of heterogeneous materials could be reduced.

Optimise distribution

What transport will be required from primary petitioners to users?

The municipality of Gothenburg could, when procuring the product, impose demands on transportation from suppliers of materials and from manufacturers.

Manufacturing the product in the Gothenburg Region decreases transport, because it will be used in the same geographical location.

8.2. FULFILMENT OF REQUIREMENTS

Below follows the list of requirements along with statements on the degree to which these are fulfilled by the product. *Appendix VI* contains a more extensive table containing the demands and wishes that were gathered during the projects from users and authorities. However, the evaluation below contains only demands because these are the only ones that are necessary to fulfil the functionality of the product.

	Criteria	**Fulfilment of requirements**
1	**Performance**	
1.2	Volume of the inner container	This requirement has specific measurements and it is therefore easily verified.
1.3	Dimensions of outer container	This requirement is based on a compromise between the pursuit of maximizing the inner volume and minimizing the outer volume. As with the previous requirement it is defined by specific measures and hence easily verified.
1.4	Carrying capacity of construction	The most sensitive part of the construction with regard to carrying capacity was deemed to be the rails. As long as these are dimensioned as recommended, this requirement should be fulfilled.
2	**Manufacturing**	
2.1	Minimise manufacturing cost	There is no specific target value for the manufacturing cost, which means that it is not possible to verify whether the requirement is achieved. However, the requirement has been taken into consideration throughout the product development process and it is up to the project initiator to judge whether it is good enough.
3	**Placement**	
3.1	Prevent theft	The recycling station provides fastening possibilities, which means that those who want to entrench it can do so.
3.2	Allow variation of placement	The recycling station is designed so that it can be placed against a wall, in the middle of a room, or back to back. This requirement is therefore fulfilled.

3.4	Allow variation of fractions	This requirement refers to the different needs concerning both the number and type of fractions at the different facilities. It is fulfilled through the application of a module system which provides a high level of adaptability.
3.5	Allow variation of volume	To fulfil this requirement, different sizes should be provided, both for the recycling station and for the inner container.
4	**Usage**	
	Sorters	
4.1	Allow sorting of packaging material	This is part of the main function of the recycling station, and it is fulfilled by providing different containers for different types of waste.
4.2	Allow sorting of food waste	The fractions include food waste, hence this demand is fulfilled.
4.3	Allow sorting of combustible waste	The fractions include combustible waste, hence this demand is fulfilled. If preferred, a unit of the recycling station could be used by itself, as a litter bin.
4.4	Communicate difference between fractions	The fractions are distinguished by colour, graphic, the shape of the slots, and by information written in Swedish, English, and braille.
4.5	Achieve language independence	The written information is supported by graphical information, which is language independent.
4.6	Prevent sorting errors	Sorting errors are prevented by clear and concise information. There are however no particular obstacles in place to prevent the user from sorting errors. One way to reinforce this demand could be to develop a cover for the slots.
4.8	Allow access of slots	The height of the slots is adapted so that all sorters, including wheelchair-bound and children, have access.
	Collectors	
4.9	Allow lifting within the length of the forearm, from the body	The height of the inner container is adapted to meet this demand.
4.10	Limit work involving pushing and pulling	The work involving pushing and pulling is limited to pulling out the inner container, dragging the bag onto the floor, and pushing the container inside. The forces are here estimated to be very low and should not cause work injuries.
4.11	Facilitate emptying	The three sided design of the inner container allows for easy emptying.
4.12	Facilitate the transport of waste at the facilities	Based what the facilities looked like, with obstacles such as stairs and thresholds, the decision was made to use bags inside the recycling station. This is the most flexible solution which allows the personal at the facilities to solve transportation issues by themselves. This is however something that could benefit from additional studies.
5	**System requirements**	
5.1	Maximise the purity of the waste fractions	The combustible waste fraction has the largest slot, based on the assumption that people who do not know or care where they should throw their waste will throw it in this one. One way to reinforce this demand would be to develop a cover. Another way would be to deploy additional units for combustible waste, so that only the sorters prone to recycling would use the other fractions.
5.2	Minimise the contamination of food waste	Food waste is the most sensitive fraction and is therefore the one that would benefit the most from a cover of some sort. Studies could be made of appropriate locations for the food waste fraction in relation to other fractions.
5.3	Maximise the degree of sorting within each fraction	This demand contradicts the two previous ones somewhat, since it would be met by having few and obscured units for combustible waste. As it is, the demand is fulfilled through the clear and concise information explaining each fraction.
6	**Other features**	
6.1	Allow for separate collection of deposit cans	This demand is fulfilled by the separate unit developed for deposit cans.
6.3	Prevent leakage	The inner container has a floor with an edge to prevent leakage. In a addition there is a detachable tray in the bottom of the unit.

6.4	Prevent placing of items on product	The top surface is tilted, so that no items can be placed there.
6.5	Off-load the bag when emptying	The floor of the inner container supports the bag when the recycling station is emptied.
6.6	Enable locking	Some type of standard lock can be added to the recycling station.
7	**Information**	
7.1	Utilise the gestalt laws	The gestalt laws (see *"2.5. Interfaces"*) were utilized when deciding on the design and placement of the information sign.
7.2	Communicate purpose	The expression of the recycling station, the different fractions, and slots clearly communicate the purpose of the product. The design follows the users' mental model of what a recycling station should look like.
7.3	Clarify information	The information is enhanced by being presented in several ways (through text, graphics, shapes, and colours).
7.4	Make the information accessible	The text is written with tactile letters as well as braille, and the contrast to the background is sufficient. The information is also presented with graphics.
9	**Maintenance**	
9.1	Facilitate cleaning	The inner container is detachable. There is also a detachable floor inside the units. The lids can be removed and maybe even put in a dishwasher.
9.2	Allow access for maintenance	Since the inner container and the floor in the bottom of the units are detachable, there should be sufficient access for maintenance.
9.3	Minimise graffiti/posters on product	The perforation make people less prone to put graffiti on the surface.
9.4	Minimise chemical maintenance	The detachable plastic parts make it easy to clean the recycling station without using a lot of cleaning detergents. The sheet metal is resistant to dirt and may not have to be cleaned very often.
9.5	Prevent contamination	The perforation contributes to fulfilling this demand.
10	**Environment**	
10.1	Allow separation of product materials	All main parts are easily detachable from each other.
10.2	Allow replacement of worn components	See above.
10.3	Use environmentally friendly materials	The materials used for this product are recyclable. Additional demands can be imposed on the manufacturers by the municipality of Gothenburg, such as using recycled material rather than virgin material.
10.4	Minimise material usage	The size of the units is optimised, but the material could be reduced, for example, by embossing the sheet metal rather than perforate it.

9. DISCUSSION

9.1. FRAMEWORK

The framework of the study was in many respects the basis of the whole project, in the sense that it covered the complex context of this kind of product.

The system overview (see *"3.1.3. System overview"*) made it easier to understand the relationships between the different actors and how the locations of waste management are connected. However, when creating the system overview, it became increasingly more important to establish a project limit. It became clear that there were room for improvements that could make the system more effective. These improvements concerned the collectors and sorters, as well as environmental aspects. Examples of this are work related issues such as knowing what to expect when handling a waste fraction.

It was beneficial for the project to study the context of the product. It was not possible, however, to go further into possible improvements of the waste management system as it did not fit into the timeframe of the project.

9.2. USER STUDY

The user study focused on two groups: the sorters and the collectors. It was assumed that these were the two user groups who would have most contact with the product. The maintainers have less frequent contact with the product and had therefore lower priority. The product would further not likely be mass-produced and the manufacturers had therefore also secondary priority in the user study.

The most difficult result to analyse from the user study was the different types of waste generated at the respective facilities. Many facilities (cultural facilities, sport centres, and schools) had waste coming from surrounding businesses such as cafes, restaurants, and kiosks on the outside. The waste situation was perhaps easier to analyse at the event facilities than the other three types of facilities, because the waste at events was mainly produced by the restaurants and kiosks inside the facility. The facilities differed in other ways as well, such as in the total amount of waste and the amount of waste within different fractions. This made it difficult to generalise and to select which waste fractions should be available. The final result shows, however, that a modular system, changeable lids, and different colours could solve this difficulty.

The function analysis was helpful in structuring the idea generation, since it provided an overview of all the functions required for the product. Ideas on how to solve the different functions could then be worked out separately, without the risk of some part being forgotten.

The specification of requirements was added to throughout the project. It is the main result of the user study and a tool for validating the product. The municipality of Gothenburg could add their own requirements regarding, for example, transportations and energy consumption during manufacturing, or the amount of recycled materials used.

9.3. CONCEPT DEVELOPMENT

During the concept development the project group tried to stay open-minded towards different solutions, in order to acquire as many ideas as possible. The result was four concepts focusing on functionality. The concepts were deliberately quite different from each other, with different suggestions on how to solve the functions, in order to inspire the discussion. The evaluation and discussion of the concepts were very rewarding, and based on the input that was given, a clear path for the future work could be hewed out.

9.4. CONCEPT REFINEMENT

The concept refinement phase required almost half of the project time and constituted the path between the four functional concepts from the concept development to the final concept. Many different tasks were performed simultaneously during this phase. The shapes and colours were established through form generation and consultation. A material study was performed and the construction was finalised.

It was difficult to perform a material study without any predetermined limitation. To do this properly, and to evaluate the possibility of using less common materials, would require a lot more time, and was therefore not possible in this project. However, the chosen materials fulfil the requirement, since they are recyclable and suitable for indoor usage.

9.5. FINAL RESULT

9.5.1. About the fractions

In Sweden there is usually no material recycling (where all products made of a certain material are recycled) but rather recycling of packaging material (where only products defined as packaging are recycled). It might, therefore, be argued that the fractions should be called, for example, "paper packaging" instead of just "paper". One reason this option was not chosen was that most people do not know what is packaging material and what is not (a paper mug, for example, is not packaging material). It was considered a priority to encourage a new behaviour (to sort waste in public environments) with as little confusion as possible, rather then to teach the distinction between what is packaging material and what is not. It was also a question of accessibility. To write "packaging" on all the fractions would mean much more text in smaller letters. This would result in difficulties for the visually impaired.

The coloured and clear glass fractions are sorted as one. This is because recycling in public environments is meant to be faster than recycling at home, and since there is very little glass waste in the public areas, an additional glass fraction was deemed unnecessary. The whole glass fraction will, then, be recycled as coloured glass.

9.5.2. Some problems that might occur during usage

If the inner container were to get stuck due to torque (because the collectors use one hand at the corner of the container when pulling it out), it could be solved by putting an additional rail at the bottom of the container to absorb forces and steer it. The disadvantages of using an additional rail are that the container cannot as easily be detached and that it must be smaller, to make room for the rail. The volume of the inner container would hence be decreased.

If the bags do not remain around the edge of the container in a satisfactory manner, the problem could be solved by adding some type of spikes to the inner container. Adding spikes would probably require an extra stage in the manufacturing process. According to experiments with models, however, adding spikes will not be necessary. Since the floor of the inner container supports the bag, it is the assessment of the project group that it will stay without slipping down.

9.5.3. Construction

The depth of the outer container is derived from the pursuit of a certain expression. However, to maximise the volume of the inner container it is important to use a 400 mm rail. If it is not possible to fit this length inside the unit, it would be preferable to increase the depth somewhat rather than choosing a 350 mm rail.

9.5.4. Other issues

Plastic bags constitute a problem, especially when used for other fractions than plastic. It would therefore be preferable to use bags in a material corresponding to the respective fraction.

The information should be placed so that persons in wheelchairs could read it. Guidelines for accessibility states that the lower edge of an information sign should be placed at a maximum of 0,8 m above the ground and should have an angle of 45 degrees to the wall. The information on the recycling station is placed 0,9-1 m above the floor at an angle of 14 degrees to the wall. The height of the recycling station is a compromise based on the need of many different types of users. Since it was assessed that the wheelchair-bound would still be able to see and reach, the needs of the collectors were prioritised, so that they would not have to bend when emptying the recycling station.

When the final concept was presented to the municipality, a suggestion was made to add a symbol on the front of the containers to further distinguish the fractions and to make them clearer from a distance. This would be a technical possibility, since the perforation is cut by laser and the symbols for the different fractions could hence be cut into the sheet steel as well. However, this would remove the possibility of using the same unit for different fractions by exchanging the lids. Also, it would be fitting in all environments since the expression would be significantly less discrete.

Before the product is ready to use it needs to be tested as a prototype in a public indoor environment.

10. CONCLUSION

The Master Thesis project "The development of a recycling station for public indoor environments in Gothenburg" has been carried out in cooperation with the municipality of Gothenburg and the organisation for collaboration "Safe, beautiful city". The outcome of this project is the recycling station IDA – Identify, Detect, Assort.

IDA is a recycling station developed specifically for indoor usage in public environments. The environments that have been studied are, for example, stadiums, theatres, museums, public baths, schools, exhibition halls, and libraries. The design and flexibility of the recycling station make it suitable for all of these environments.

The recycling station IDA simplifies and encourages the sorting of waste, through clarity and consciously selected features.

The dimensions of the recycling station are based on physical demands and anthropometric measurements, the amount of waste and the frequency with which it is emptied, as well as the space limitations at the facilities.

Vandalism is impeded by the perforation covering the recycling station. The appearance and shape of this perforation also connect the product with the litter bin and the recycling station from the previous projects (see *"6.3.3. Design format analysis"*).

The ergonomic needs of different types of users have been considered, so that all sorters can reach and see, the collectors do not have to bend or lift above elbow height, and the maintainers and manufacturers have access when handling the product. In addition, users with special needs have been taken into consideration. IDA is accessible to the visually impaired, the wheelchair-bound, and to users with cognitive difficulties.

Throughout the project, environmental concerns have been taken into account. First and foremost, the purpose of the product is to increase the material recycling in Gothenburg, which is an environmental concern. In addition to this, the product itself is made of recyclable materials and has a design conducive to disassembly.

A validation of the recycling station is presented in *"8. Validation"*. In this chapter IDA is evaluated in relation to the demands that were established during the product. However, to fully validate the recycling station an additional user study needs to be performed. Both sorters and collectors will have to voice their opinions and changes may have to be made accordingly.

Design documentation is provided as drawings, but there will have to be some additions and changes to these, since all manufacturing issues are not yet resolved.

It may be concluded that the goal of this project is met, though further studies will have to be conducted to find out how the product is received by the public.

It has been fun and rewarding to work with the municipality of Gothenburg. We, the project group, are very pleased with the result and we hope and believe that the future users of IDA will find the product to their liking.

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12. APPENDIX

APPENDIX I – OBSERVATIONAL GUIDE, SORTERS

Var?____

När?____

- Antal observerade personer:
- Vilket slags skräp slängs?
    - Tidningar — Antal____________
    - Pantburkar och flaskor — Antal____________
    - Engångsmuggar — Antal____________
    - Snus — Antal____________
    - Tuggummi — Antal____________
    - Matavfall — Antal____________
    - Papperslappar (t.ex. kvitton) — Antal____________
    - Matförpackninar — Antal____________
    - Övrigt emballage (t.ex. godispapper) — Antal____________
    - Hygienartiklar — Antal____________
    - Glasbehållare — Antal____________
    - Annat:

      Vad? ____
- Slängs skräp på andra ställen än i sopkärlet?

  Var?
- Finns det möjlighet att sortera skräp?
- Stannar personen upp för att studera skyltarna för att kunna fatta beslut om att slänga i önskad fraktion?
- Slänger de rätt?
- Kommentarer kring skräp eller papperkorg
- Miljö – förhållanden i omgivningen?

Stressigt ____ Lugnt

Trångt ____ Luftigt

Mörkt ____ Ljust

Bullrigt ____ Tyst

APPENDIX II – OBSERVATIONAL GUIDE, COLLECTORS

Var?____

Vem? ______________________________________

När?____

Vad för aktivitet/Vad gjordes?

Tömning av sopsorteringskärl

- Hur stor volym är det på skräpet som töms?
- Vilket slags skräp är det?
  - Glasförpackningar
  - Matavfall
  - Metallförpackningar
  - Pant
  - Pappersförpackningar/kartong
  - Plastförpackningar
  - Tidningar/trycksaker
  - Annat (Farligt avfall, batterier, keramik etc.)

    Vad? ____
- Vad gör de med skräpet?

Tömning av papperskorgar

- Hur stor volym är det på skräpet som töms?
- Vilket slags skräp är det?
  - Glasförpackningar
  - Matavfall
  - Metallförpackningar
  - Pant
  - Pappersförpackningar/kartong
  - Plastförpackningar
  - Tidningar/trycksaker
  - Annat (Farligt avfall, batterier, keramik etc.)

    Vad? ____
- Vad gör de med skräpet?

Tömning av vagn

- Var tömmer de vagnen och hur går det till?
- Hur ofta behöver vagnen tömmas?
- Hur ser det ut i soprummet?

Vad som sades till vem och på vilket sätt

Atmosfär, rytm, och tempo

- Hur är atmosfären? (arbetsmiljö, ventilation, ljus, ljud, stress, varmt, kallt etc.)
- Hur känns tempot/rytmen? (arbetsgång, rutin, stress etc.)
- Hur verkar arbetspositionerna? (lyft, vridningar etc.)

Övrigt

APPENDIX III – SURVEY, EXAMPLE FROM SPORT FACILITIES

Sopsortering

Vi studerar civilingenjörsutbildningen Teknisk design på Chalmers och gör just nu vårt examensarbete i samarbete med Göteborgs stad. Examensarbetet handlar om att utveckla en sopsorteringsstation för offentliga inomhusmiljöer. Exempel på sådana miljöer är skolor, idrottsanläggningar, teatrar, museer, och arenor. Detta kan alltså mycket väl vara en produkt som du kommer att hantera i framtiden! För att ta fram en så bra produkt som möjligt skulle vi behöva ha er hjälp, och vi skulle vara väldigt tacksamma om ni ville svara på några frågor om sopsortering.

Med vänliga hälsningar,
Agnes Lindahl och Anna Johansson

* Required

1. **Din ålder:**

   ....

2. **Kön:**
   Mark only one oval.

   ◯ Man
   ◯ Kvinna

3. **Nämn en idrotts- eller kulturanläggning i Göteborg som du brukar besöka**
   T.ex. ett badhus, sporthall, bibliotek, kulturhus, eller arena

   ....

Hur viktigt tycker du att det är att sortera avfall?
Mark only one oval.

	1	2	3	4	5	
Det är inte viktigt alls	◯	◯	◯	◯	◯	Det är mycket viktigt

Brukar du sortera skräp hemma?
Om svaret på frågan är aldrig, hoppa till fråga 5
Mark only one oval.

	1	2	3	4	5	
Aldrig	◯	◯	◯	◯	◯	Alltid

6. **Vilken typ av avfall sorterar du hemma?**
Du kan markera flera alternativ
Check all that apply.

- [ ] Glasförpackningar
- [ ] Pappersförpackningar
- [ ] Plastförpackningar
- [ ] Metallförpackningar
- [ ] Tidningar och trycksaker
- [ ] Matavfall
- [ ] Grovavfall
- [ ] Elektronikavfall
- [ ] Lampor, lysrör, och batterier
- [ ] Kemikalier
- [ ] Other: ....

7. **Varför sorterar du avfall hemma?**
Du kan markera flera alternativ
Check all that apply.

- [ ] Jag sparar pengar genom att sortera
- [ ] Det gör arbetet lättare för de som hanterar avfallet
- [ ] Det är bättre för miljön
- [ ] Någon har sagt åt mig att göra det
- [ ] Other: ....

Hur viktigt tycker du att det är att sortera matavfall?
Mark only one oval.

	1	2	3	4	5	
Det är inte viktigt alls	( )	( )	( )	( )	( )	Det är mycket viktigt

9. **Vet du vad som händer med matavfall som är utsorterat?**
Mark only one oval.

- ( ) Det används till biogasproduktion
- ( ) Det komposteras
- ( ) Det förbränns
- ( ) Vet ej
- ( ) Other: ....

10. **Vad gör du med skräp, om du inte hittar någon papperskorg?**
Check all that apply.

- [ ] Slänger det på golvet
- [ ] Ställer/lägger det någonstans
- [ ] Ger det till någon annan
- [ ] Tar det med mig
- [ ] Other: ....

11. **Vilken typ av skräp brukar du kasta när du är på anläggningen du nämnde ovan?**
Skriv det du kommer på

....
....
....
....
....

12. **Finns det möjlighet att sortera skräp på anläggningen?** *
Mark only one oval.

- ( ) Ja *Skip to question 13.*
- ( ) Nej *Skip to question 17.*
- ( ) Vet ej *Skip to question 17.*

Det finns möjlighet att sortera skräp på anläggningen

Den anläggning vi syftar på är den du nämnde tidigare i formuläret
Start this form over.

13. **Vad går att sortera?**
Du kan markera flera alternativ
Check all that apply.

- [ ] Glasförpackningar
- [ ] Pappersförpackningar
- [ ] Plastförpackningar
- [ ] Metallförpackningar
- [ ] Tidningar och trycksaker
- [ ] Matavfall
- [ ] Other: ....

Brukar du sortera skräp när du är på anläggningen?
Mark only one oval.

	1	2	3	4	5	
Aldrig	◯	◯	◯	◯	◯	Alltid

15. **Varför/varför inte?**

16. **Om det finns matrester kvar i din förpackning, vad gör du med den då?**
Mark only one oval.

- ◯ Jag kastar den i brännbart
- ◯ Skrapar ur det värsta och sorterar den
- ◯ Sorterar som den är
- ◯ Other: ....

Det finns inte möjlighet att sortera skräp på anläggningen

Den anläggning vi syftar på är den du nämnde tidigare i formuläret
Stop filling out this form.

17. **Borde det finnas möjlighet att sortera skräp på anläggningen?**
Mark only one oval.

- ◯ Ja
- ◯ Nej
- ◯ Vet ej

18. **Varför/varför inte?**

Om möjlighet fanns att sortera, skulle du utnyttja den?
Mark only one oval.

	1	2	3	4	5	
Aldrig	⬭	⬭	⬭	⬭	⬭	Alltid

20. **Motivera ditt ovanstående svar**
Varför skulle du/skulle du inte sortera?

....

21. **Om det fanns möjlighet att sortera, och det var matrester kvar i din förpackning, vad gör du med den då?**
Mark only one oval.

- Jag kastar den i brännbart
- Skrapar ur det värsta och sorterar den
- Sorterar som den är
- Other: ....

APPENDIX IV – INTERVIEW GUIDE, COLLECTORS

Ålder:	Kön:	
10-20	K	M
21-40		
41-60		
60-		

- Sorterar du skräp hemma?
    - Vad sorterar du då?
        - Glasförpackningar
        - Matavfall
        - Metallförpackningar
        - Pant
        - Pappersförpackningar/kartong
        - Plastförpackningar
        - Tidningar/trycksaker
        - Annat (Farligt avfall, batterier, keramik etc.)

      Vad? ____
    - Varför sorterar du/sorterar du inte skräp?
- Finns det möjlighet för besökare på anläggningen att sortera skräp idag?
    - Tycker du att det borde finnas möjlighet att sortera skräp för besökare här på anläggningen? Varför/Varför inte?
    - Vad borde sorteras då?
- Sorterar du själv skräp på jobbet? Varför/varför inte?

- Hur ser sophanteringen på anläggningen ut idag?
    - Hur ofta töms de olika sopuppsamlingskärlen?
    - Hur många kärl töms på samma gång?
    - Hur stor volym är det på skräpet som töms?
    - Vad gör du med skräp som hamnat fel?
        - Låter det följa med
        - Lägger det på rätt ställe
        - Kastar i brännbart
    - Vad tycker du om de sopuppsamlingsenheter som finns idag?
        - Hur är den att hantera?
        - Andra synpunkter?
    - Hur hanteras vandalism? (klotter etc.)
    - Hur tycker du att det fungerar i soprummet?

- Upplever du ditt arbete som fysisk påfrestande?
    - Vilka moment är jobbigast?
    - Har du fått några fysiska besvär på grund av ditt arbete?
- Hinner du med det du behöver på en arbetsdag?
    - Känner du dig stressad medan du arbetar?
    - Belönas ett högre arbetstempo? Kan du gå hem tidigare t.ex. om du utför ditt arbete snabbare?
- Arbetar du ensam, eller jobbar ni i team? Hur ser samarbetet ut?

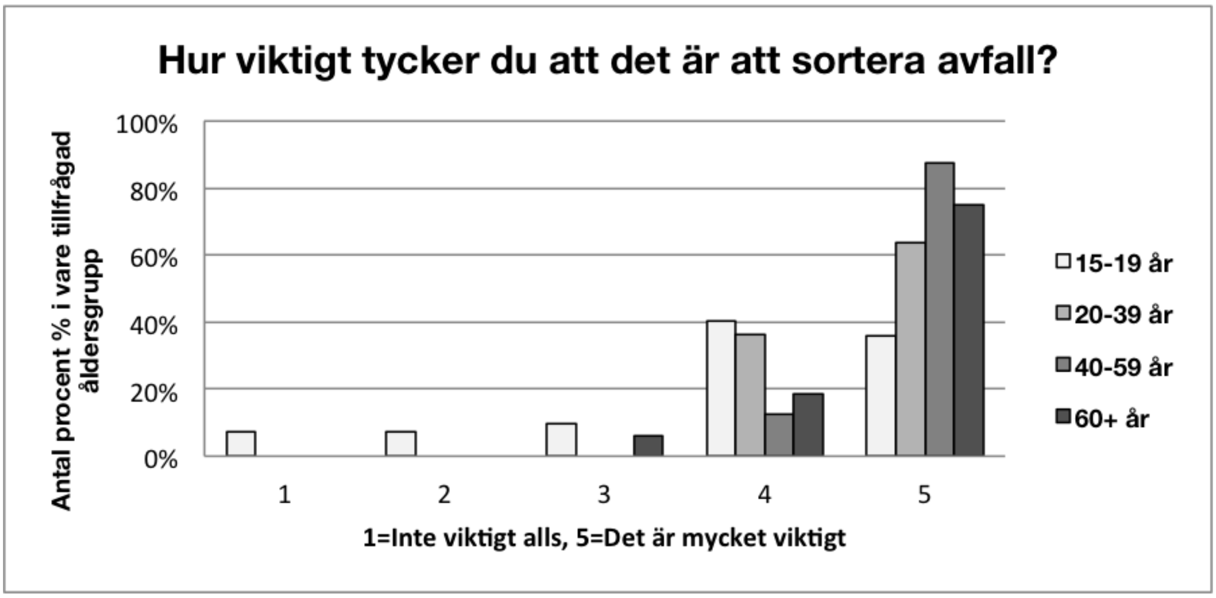
Övrigt:

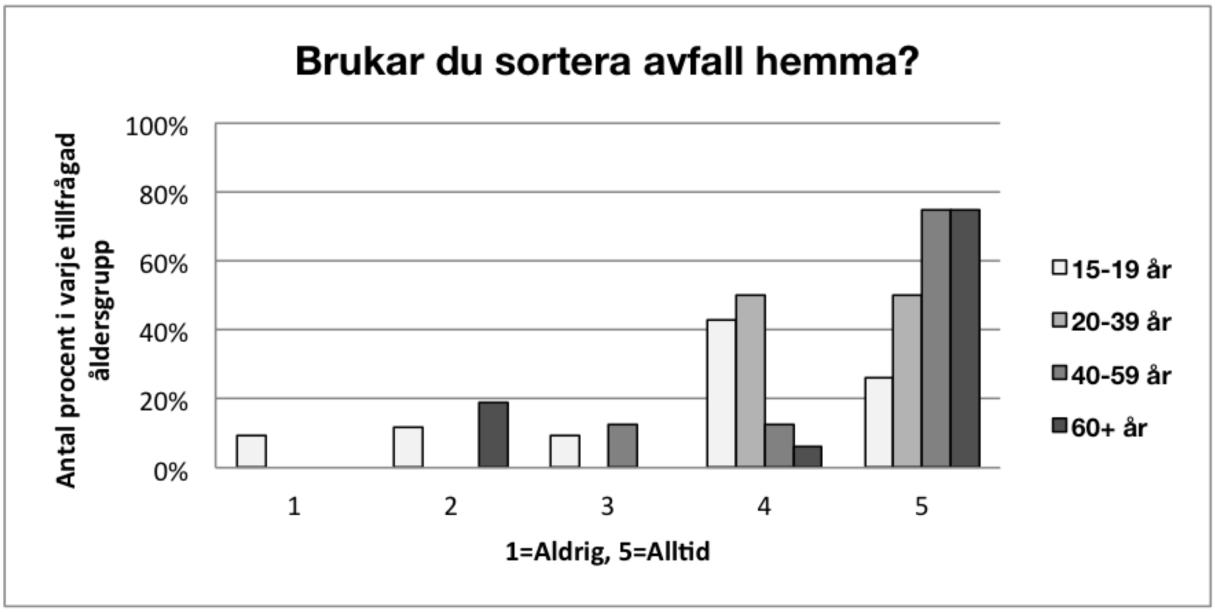
APPENDIX V – QUANTITATIVE EVALUATION

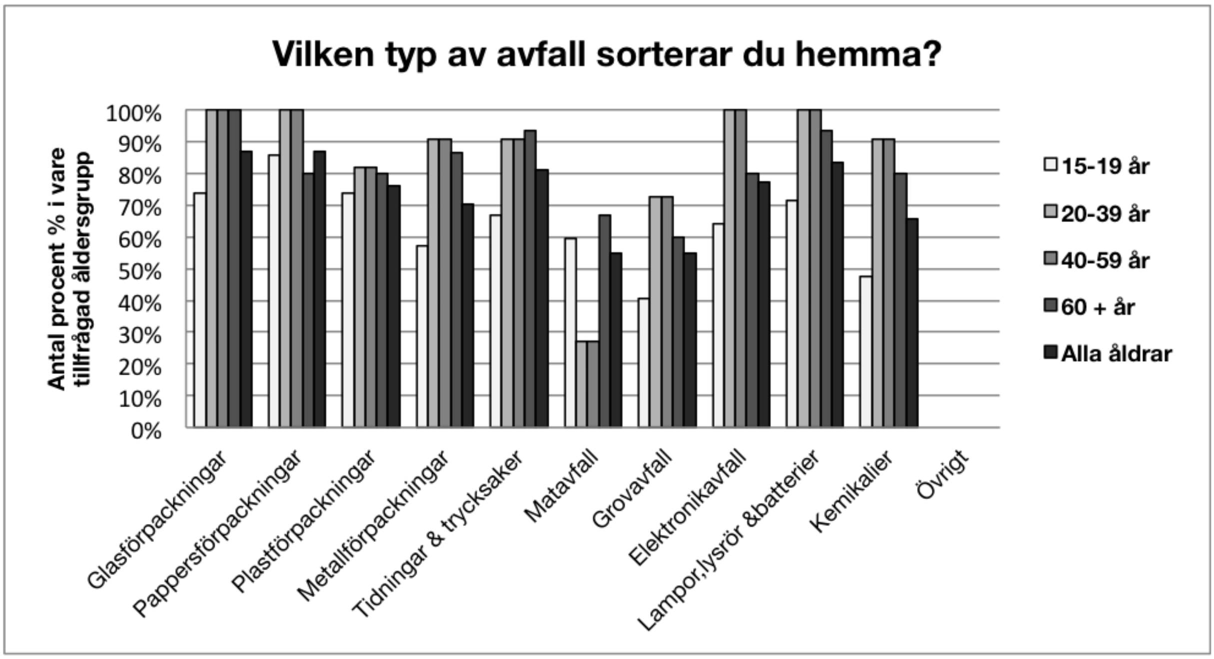
Total number of participants: 84

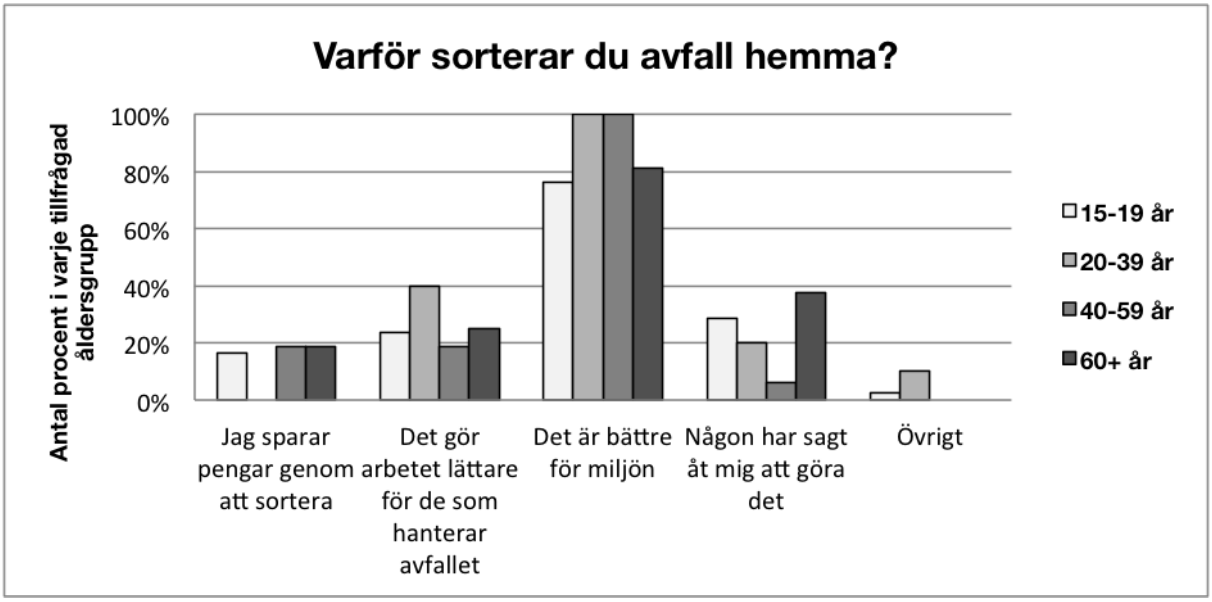
Number within each age group:

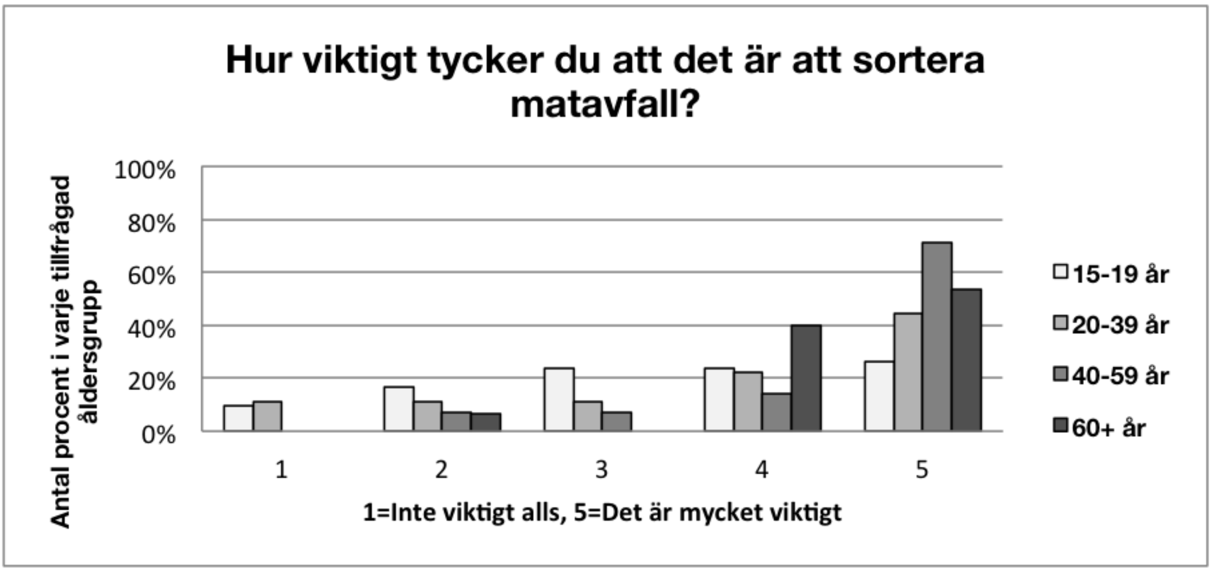
- 15-19: 42
- 20-39: 11
- 40-59: 16
- 60+: 16



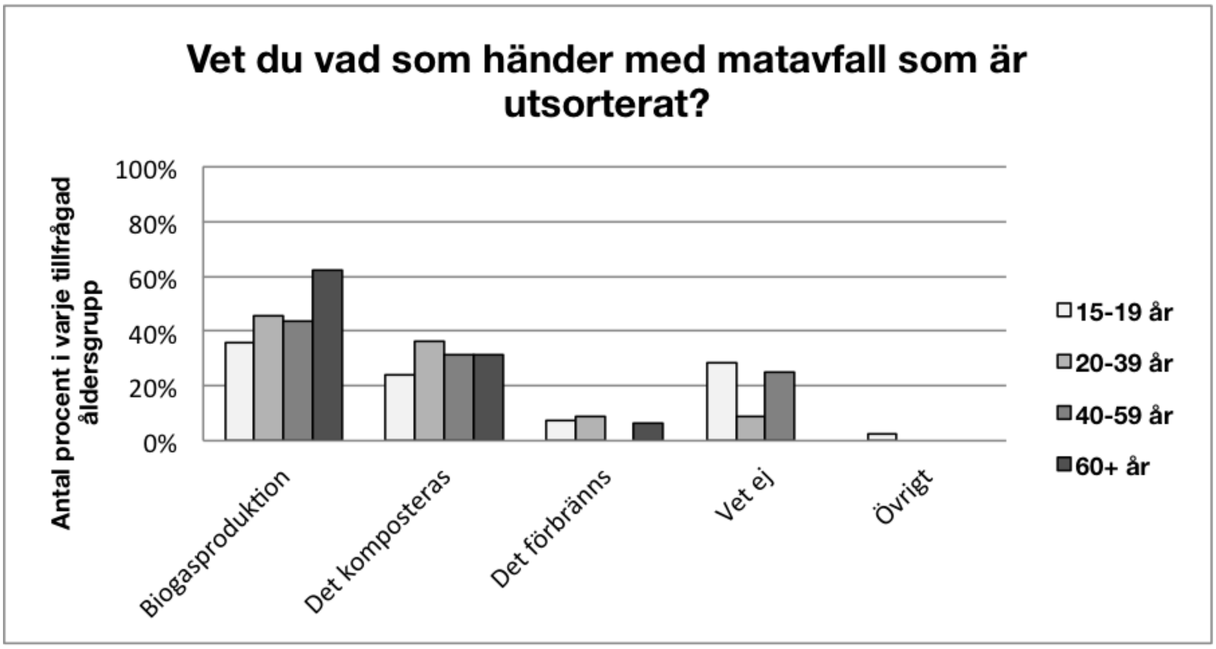


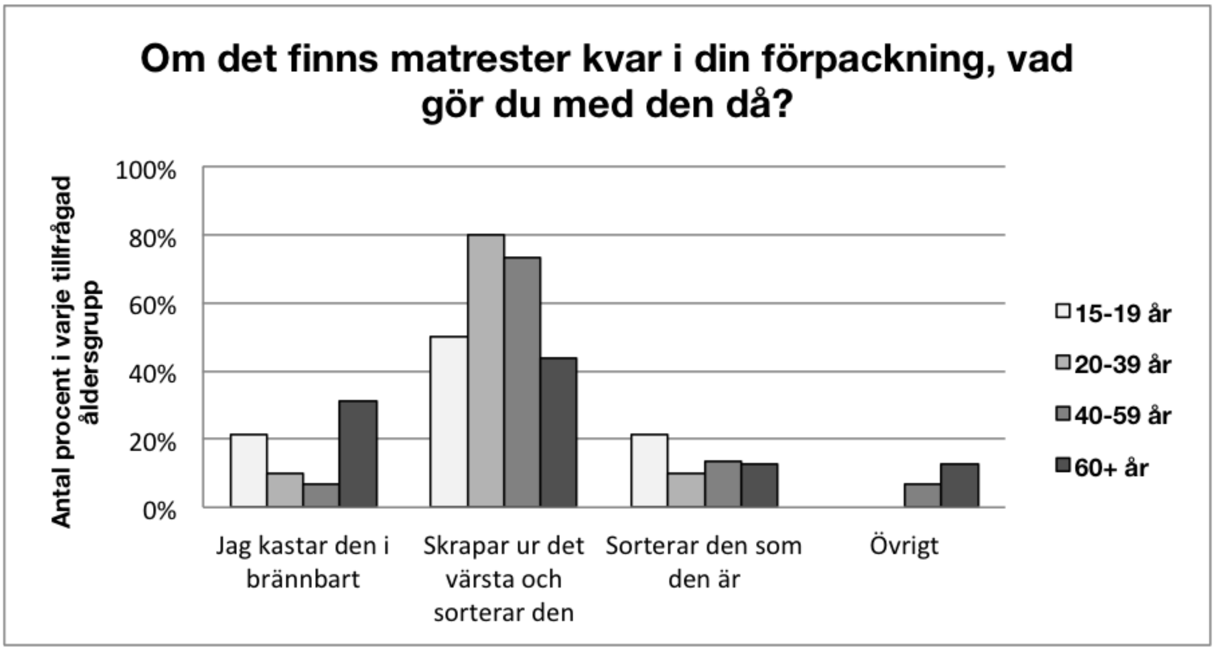

Vilken typ av avfall sorterar du hemma?
Antal procent % i vare tillfrågad åldersgrupp
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Glasförpackningar
Pappersförpackningar
Plastförpackningar
Metallförpackningar
Tidningar & trycksaker
Matavfall
Grovavfall
Elektronikavfall
Lampor,lysrör &batterier
Kemikalier
Övrigt
15-19 år
20-39 år
40-59 år
60 + år
Alla åldrar

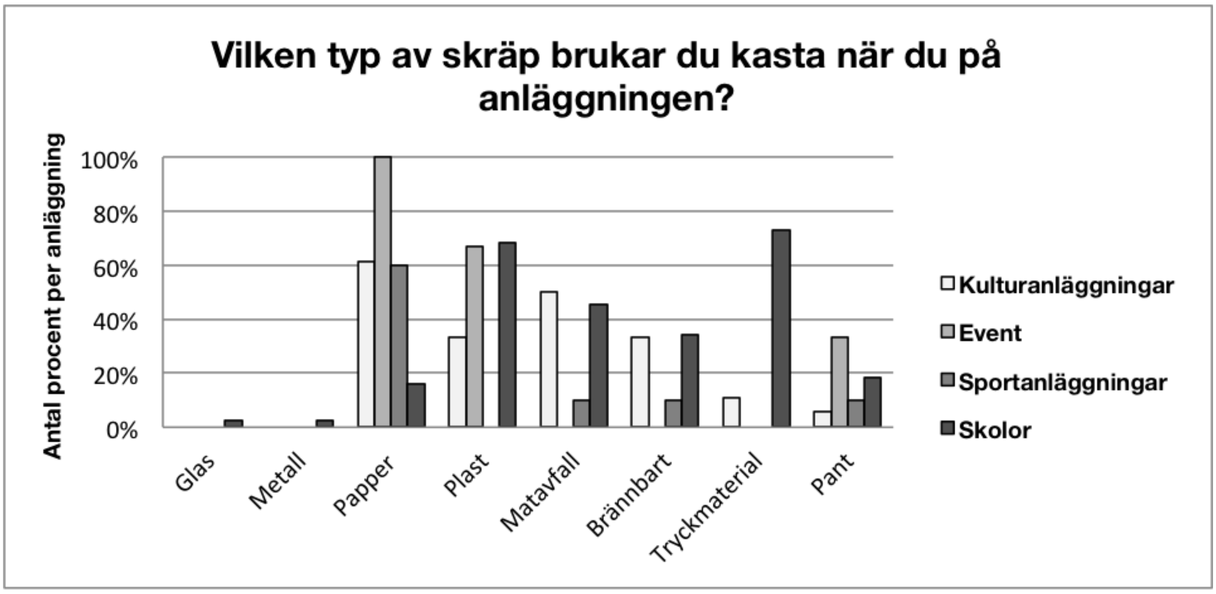

Varför sorterar du avfall hemma?
Antal procent i varje tillfrågad åldersgrupp
100%
80%
60%
40%
20%
0%
Jag sparar pengar genom att sortera
Det gör arbetet lättare för de som hanterar avfallet
Det är bättre för miljön
Någon har sagt åt mig att göra det
Övrigt
15-19 år
20-39 år
40-59 år
60+ år

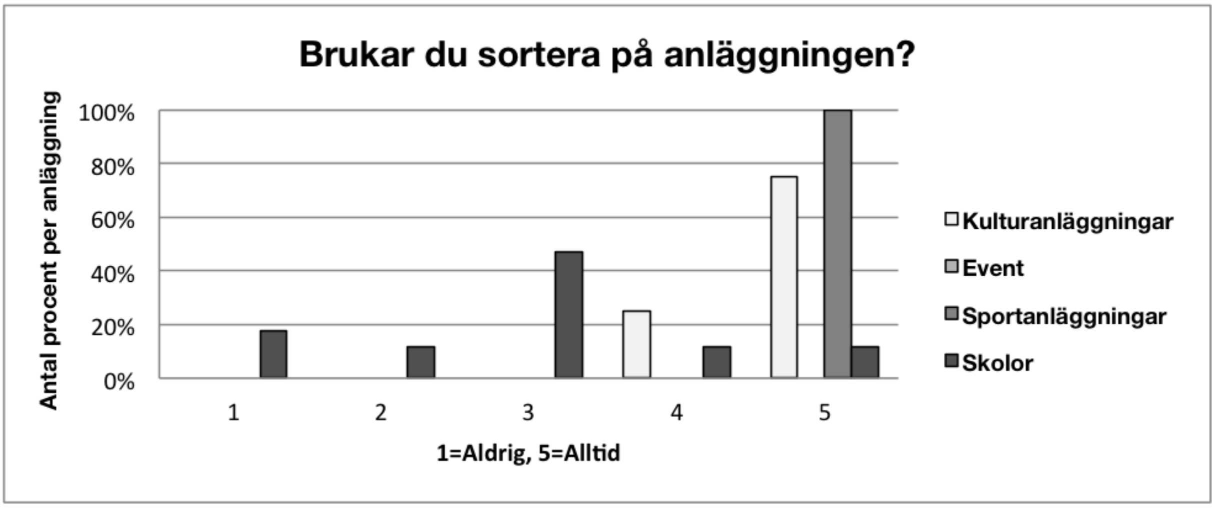

Hur viktigt tycker du att det är att sortera matavfall?
Antal procent i varje tillfrågad åldersgrupp
100%
80%
60%
40%
20%
0%
1
2
3
4
5
1=Inte viktigt alls, 5=Det är mycket viktigt
15-19 år
20-39 år
40-59 år
60+ år

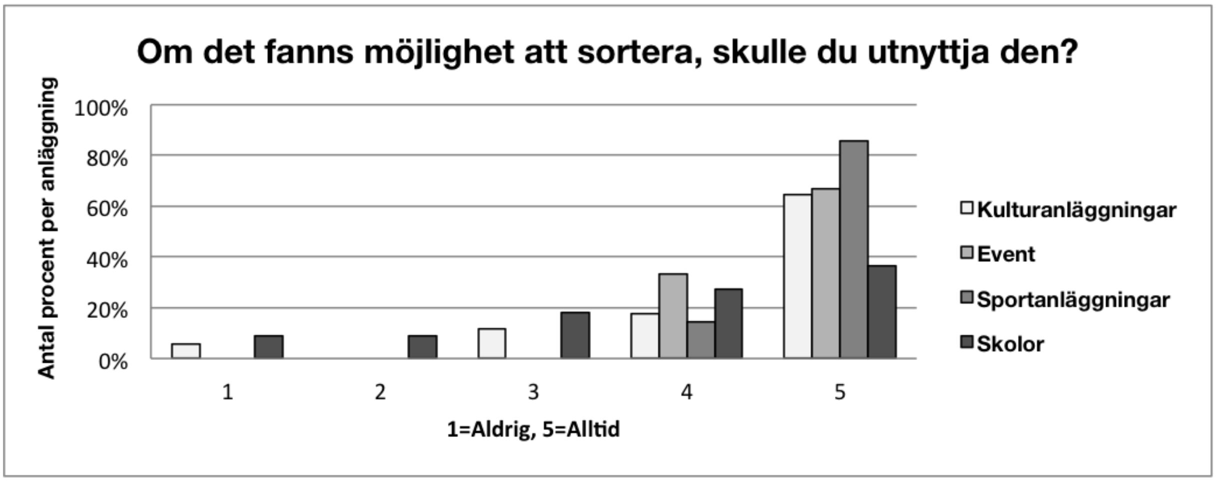

Vad gör du med skräp, om du inte hittar någon papperskorg?
Antal procent i varje tillfrågad åldersgrupp
100%
80%
60%
40%
20%
0%
Slänger det på golvet
Ställer/lägger det någonstans
Ger det till någon annan
Tar det med mig
Övrigt
15-19 år
20-39 år
40-59 år
60+ år


Vet du vad som händer med matavfall som är utsorterat?
Antal procent i varje tillfrågad åldersgrupp
100%
80%
60%
40%
20%
0%
Biogasproduktion
Det komposteras
Det förbränns
Vet ej
Övrigt
15-19 år
20-39 år
40-59 år
60+ år


Om det finns matrester kvar i din förpackning, vad gör du med den då?
Antal procent i varje tillfrågad åldersgrupp
100%
80%
60%
40%
20%
0%
Jag kastar den i brännbart
Skrapar ur det värsta och sorterar den
Sorterar den som den är
Övrigt
15-19 år
20-39 år
40-59 år
60+ år


Vilken typ av skräp brukar du kasta när du på anläggningen?
Antal procent per anläggning
100%
80%
60%
40%
20%
0%
Glas
Metall
Papper
Plast
Matavfall
Brännbart
Tryckmaterial
Pant
Kulturanläggningar
Event
Sportanläggningar
Skolor


Brukar du sortera på anläggningen?
Antal procent per anläggning
100%
80%
60%
40%
20%
0%
1
2
3
4
5
1=Aldrig, 5=Alltid
Kulturanläggningar
Event
Sportanläggningar
Skolor


Om det fanns möjlighet att sortera, skulle du utnyttja den?
Antal procent per anläggning
100%
80%
60%
40%
20%
0%
1
2
3
4
5
1=Aldrig, 5=Alltid
Kulturanläggningar
Event
Sportanläggningar
Skolor

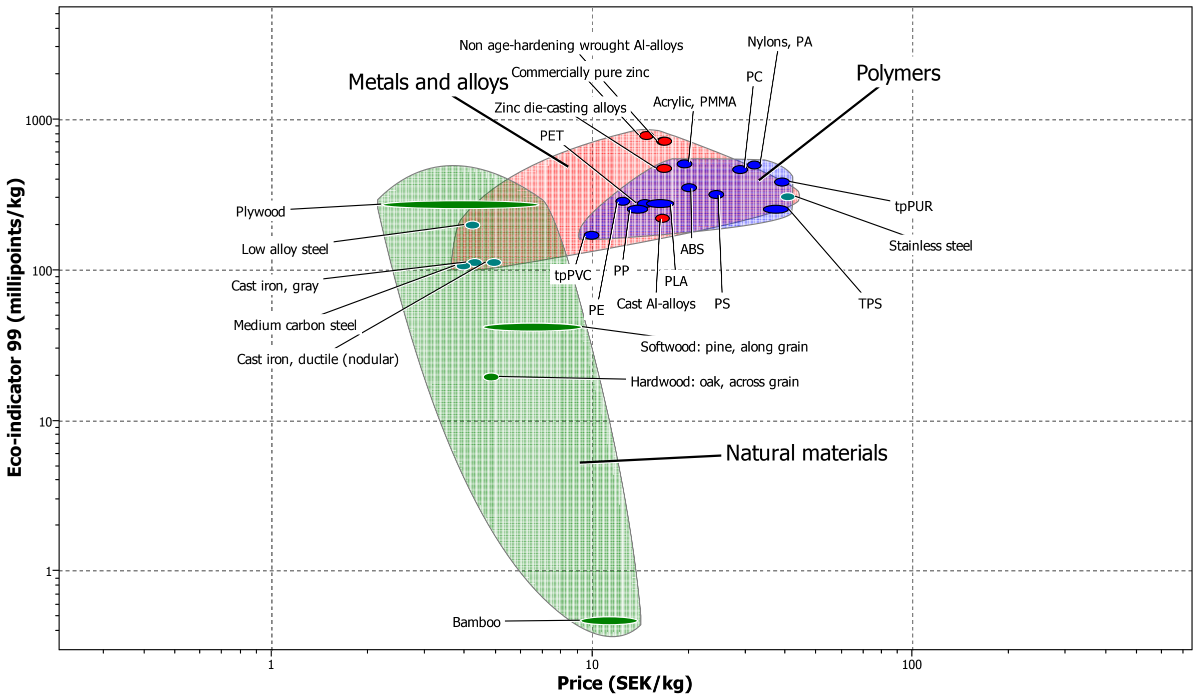
APPENDIX VI – SPECIFICATION OF REQUIREMENTS

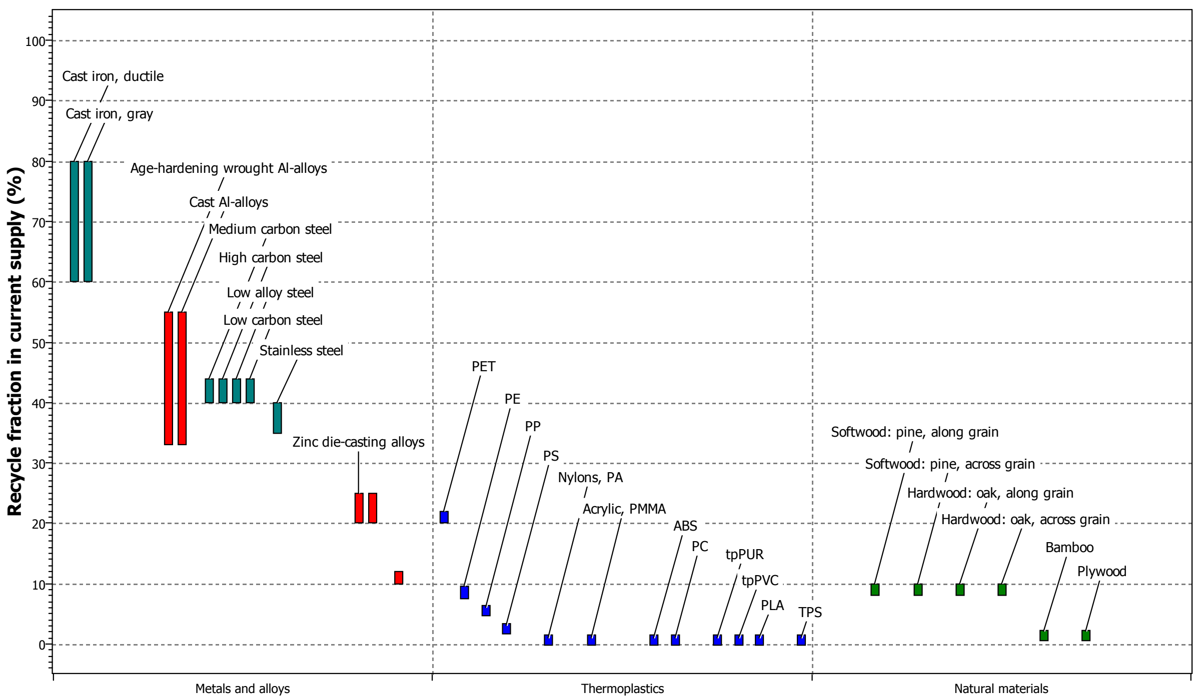
	Chalmers	**Dokumenttyp** *Examensarbete vid institutionen för Produkt- och Produktionsutveckling, Chalmers tekniska högskola*	**Kravspecifikation** **Återvinningsstation för offentliga inomhusmiljöer**				
		Examensarbete vid institutionen för Produkt- och Produktionsutveckling	***Skapad:*** 2014-01-10				
	Kriterier		*Målvärde*	*K/Ö*	*Vikt*	*Verifieringsmetod*	*Referens (kravställare)*
	Funktion						
		Medge sortering av avfall i offentliga inomhusmiljöer		K	5	Prototyp	Göteborgs Stad, Trafikkontoret
1	**Prestanda**						
	1.1	Maximera livslängd	10 år	Ö	4	Materialtest	Göteborgs Stad, Trafikkontoret
	1.2	Volym för innerbehållare	40 l - 80 l	K	4	Mätning	Tömmare
	1.3	Dimension på ytterbehållare	Bredd <400 mm, djup< 450 mm, höjd<1000 mm	K	4	Mätning	Anläggningarna & sorterare
	1.4	Bärkraft hos konstuktionen	25 kg	K	5	Massberäkning	Tömmare
	1.5	Dimensionera efter omkrets på standardpåsar	<1600 mm	Ö	5	Mätning	Tömmare
2	**Tillverkning**						
	2.1	Minimera tillverkningskostnad		K	3	Beräkning	Göteborgs Stad, Trafikkontoret
3	**Placering**						
	3.1	Förhindra stöld		K	2		Anläggningsansvariga
	3.2	Medge varierad placering	Fritt i rummet, mot vägg, i hörn	K	3	Modell	Anläggningarna
	3.3	Medge förflyttning		Ö	4	Modell	Anläggningarna
	3.4	Medge variation av fraktioner	Valfrihet av antal och typ av fraktion	K	2		Anläggningarna
	3.5	Medge variation av volym		K	2		Anläggningarna
	3.6	Tillåt förändring av fraktioner	Möjlighet av att kunna byta ut typ av fraktion	Ö	5		Anläggningsansvariga
4	**Använding**						
		Sorterare					
	4.1	Medge sortering av förpackningar		K	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	4.2	Medge sortering av matavfall		K	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	4.3	Medge sortering av brännbart avfall		K	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	4.4	Kommunicera uppdelning av fraktioner		K	5	Användarstudie	Sorterare
	4.5	Uppnå språkoberoende		K	3	Användarstudie	Sorterare
	4.6	Förhindra felsortering		K	2	Användarstudie	Sorterare
	4.7	Förbered handlande		Ö	5	Användarstudie	Sorterare
	4.8	Medge åtkomst av inkast	800-1000 mm från golv	K	5	Användarstudie	Sorterare

		Tömmare					
	4.9	Medge lyft inom underarmslängd	~300 mm	K	5	Användarstudie	Tömmare
	4.10	Begränsa skjut- och dragarbete	<150 N	K	5	Användarstudie	Tömmare
	4.11	Underlätta tömning	720-900 mm från golv	K	5	Användarstudie	Tömmare
	4.12	Underlätta transport av skräp på anläggningarna		K	4	Användarstudie	Tömmare
5	**Systemkrav**						
	5.1	Maximera renheten hos förpackningsfraktionerna	Avfallet skall vara så rent från organisk material och andra föroreningar som	K	5	Statistikinsamling	FTI AB
	5.2	Minimera föroreningar hos matavfall	Det organiska avfallet skall vara tillräckligr rent för att kunna användas i biogasproduktion	K	5	Statistikinsamling	Göteborgs Stad, Kretslopp och Vatten
	5.3	Maximera sorteringsgraden hos fraktionerna		K	5	Statistikinsamling	Göteborgs Stad, Kretslopp och Vatten & FTI AB
	5.4	Öka förpackningsandelen i förhållande till material		Ö	5	Statistikinsamling	FTI AB
6	**Övriga funktioner**						
	6.1	Medge separat pantinsamling		K	2		Sorterare & anläggningarna
	6.2	Förhindra dålig lukt		Ö	5		Anläggningarna
	6.3	Förhindra läckage		K	5		Anläggningarna
	6.4	Förhindra avställning på produkt		K	3	Modell	Anläggningsansvariga
	6.5	Avlasta säck vid tömning		K	4		Tömmare
	6.6	Möjliggör låsfunktion		K	5		Anläggningsansvariga
	6.7	Tillhandahåll förslutningsmöjlighet		Ö	3		Anläggningsansvariga
	6.8	Minimera glassplitter		Ö	3		Anläggningsansvariga
	6.9	Medge förvaring av säckar		Ö	3		Anläggningsansvariga
7	**Information**						
	7.1	Utnyttja gestaltlagar	Enligt: likhet, närhet, kontinuitet & tillslutning	K	5	Användarstudie	Sorterare
	7.2	Kommunicera syfte		K	5	Användarstudie	Sorterare
	7.3	Förtydliga information	Text, grafik och form	K	5	Användarstudie	Sorterare
	7.4	Tillgängliggör information	Blinda och rullstolsbundna	K	5	Användarstudie	Sorterare
8	**Designuttryck**						
	8.1	Uttryck enkel & diskret	Sorteringsstationen skall passa in i de miljöer där den placeras	Ö	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	8.2	Följa Göteborgs identitet	Igenkänning av tidigare produkter	Ö	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	8.3	Uttryck återvinning		Ö	5	Användarstudie	Sorterare

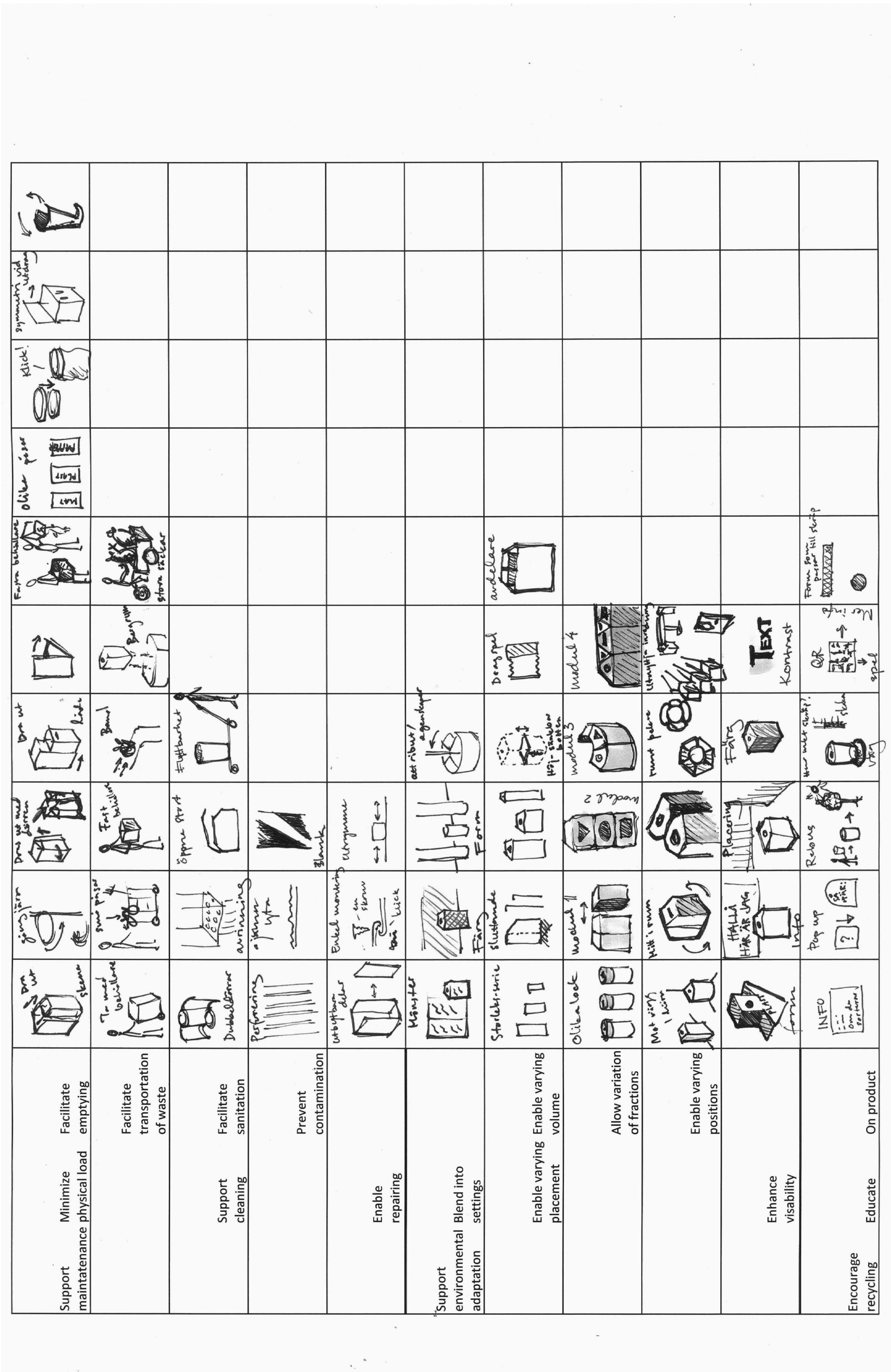
	8.4	Styrk identifierbarhet	Igenkänning av produkttecknet	Ö	5	Användarstudie	Sorterare
	8.5	Uppmuntra till användning	Minska nedskräpning & förstärk miljöengagemang	Ö	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	8.6	Uttryck inbjudande & vänlig		Ö	5	Användarstudie	Göteborgs Stad, Trafikkontoret
	8.7	Uttryck stabil & hållbar		Ö	5	Användarstudie	Göteborgs Stad, Trafikkontoret
9	**Underhåll**						
	9.1	Underlätta rengöring		K	5	Modell	Tömmare
	9.2	Medge åtkomst för underhåll		K	5	Modell	Tömmare
	9.3	Minimera klotter/affischering på produkt		K	3	Modell	Göteborgs Stad, Trafikkontoret
	9.4	Minimera kemikalieunderhåll		K	4		Tömmare
	9.5	Motverka nedsmutsning		K	3		Tömmare
10	**Miljö**						
	10.1	Medge separation av material		K	4	Modell	Göteborgs Stad, Trafikkontoret
	10.2	Tillåt byte av utslitna komponenter		K	4	Modell	Göteborgs Stad, Trafikkontoret
	10.3	Använd miljövänliga material		K	4	Materialstudie	Göteborgs Stad, Trafikkontoret
	10.4	Minimera materialåtgång		K	4	Beräkning	Göteborgs Stad, Trafikkontoret

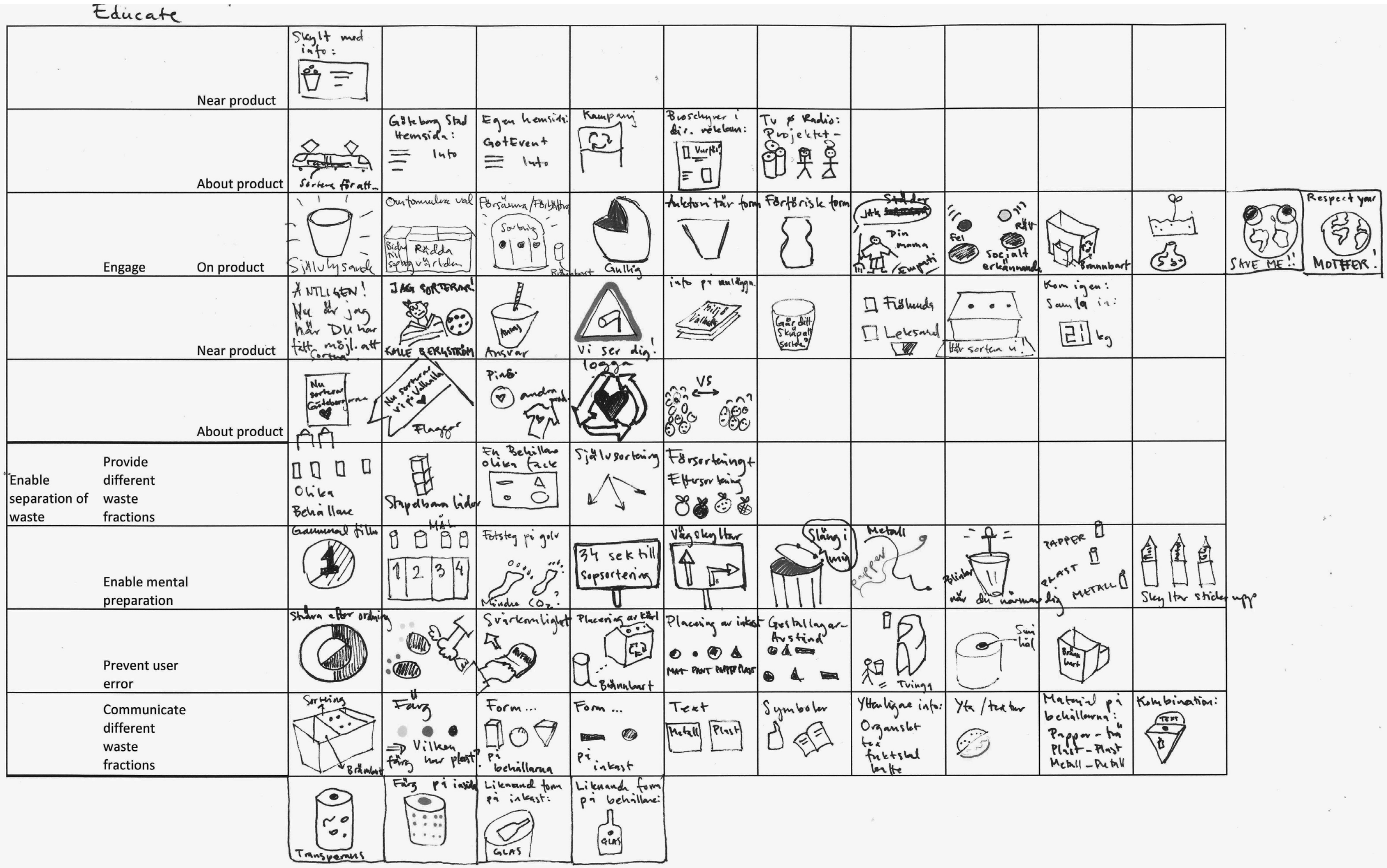
APPENDIX VII RESULT FROM CES





APPENDIX VIII MORPHOLOGICAL CHART

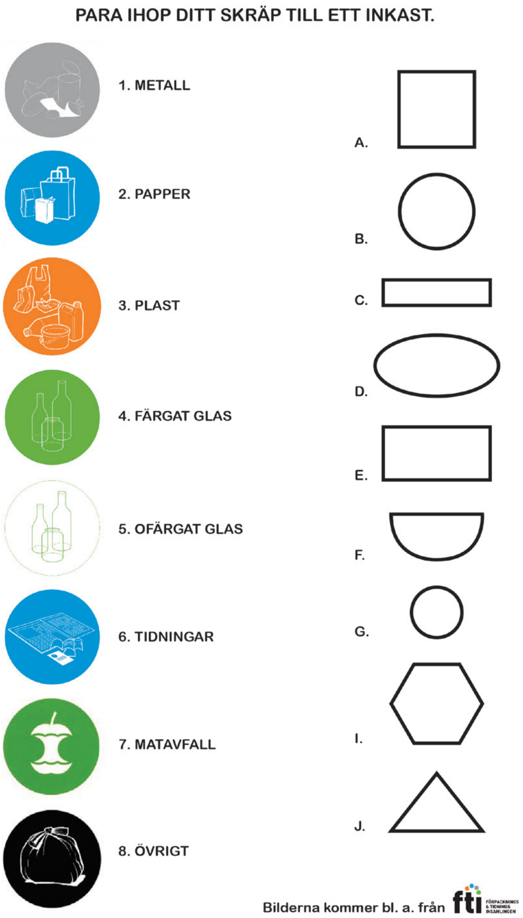




Educate
Near product
About product
Engage
On product
Near product
About product
Enable separation of waste
Provide different waste fractions
Enable mental preparation
Prevent user error
Communicate different waste fractions

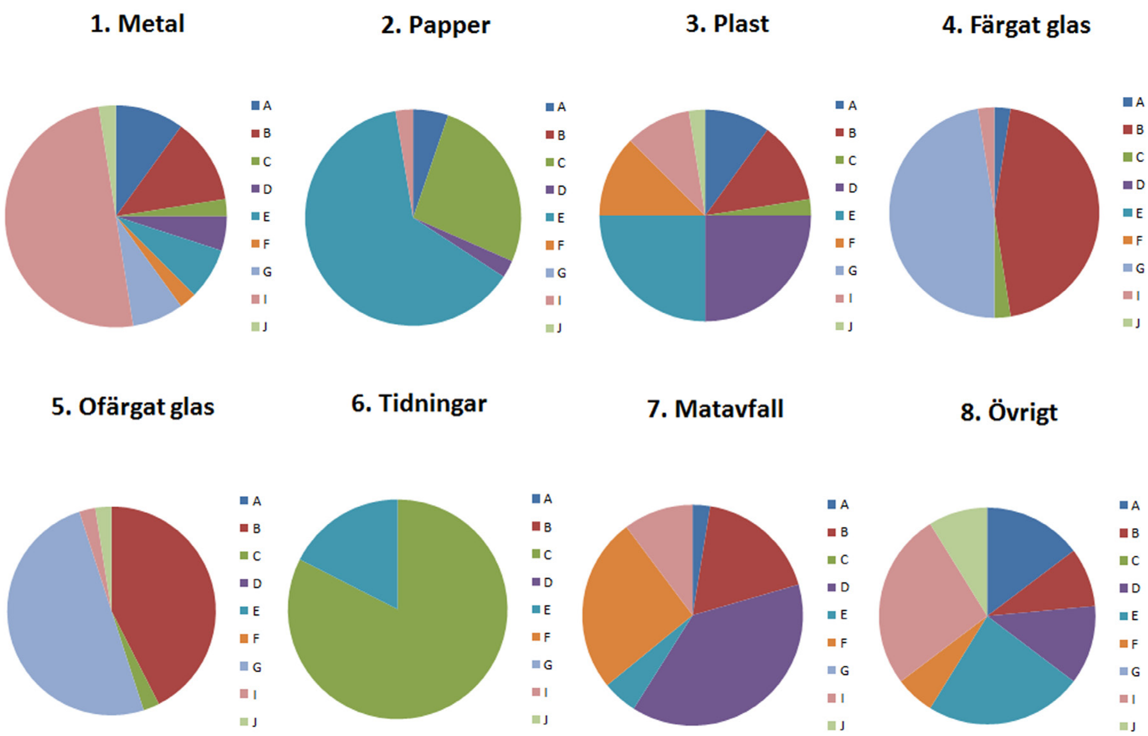
APPENDIX IX SURVEY, SHAPES OF SLOTS

The survey



Total number of respondents: 41

The result



Vad tycker du?

Placera ut koncept 1-4 på skalorna där du tycker att de stämmer in med *uttrycket*.

motiverande ——————————————— tvärtom

motiverande uttryck syftar till det uppmanande och engagerande uttrycket.

vänlig ——————————————— tvärtom

vänligt uttryck syftar till det väna och tillmötesgående uttrycket.

enkel ——————————————— tvärtom

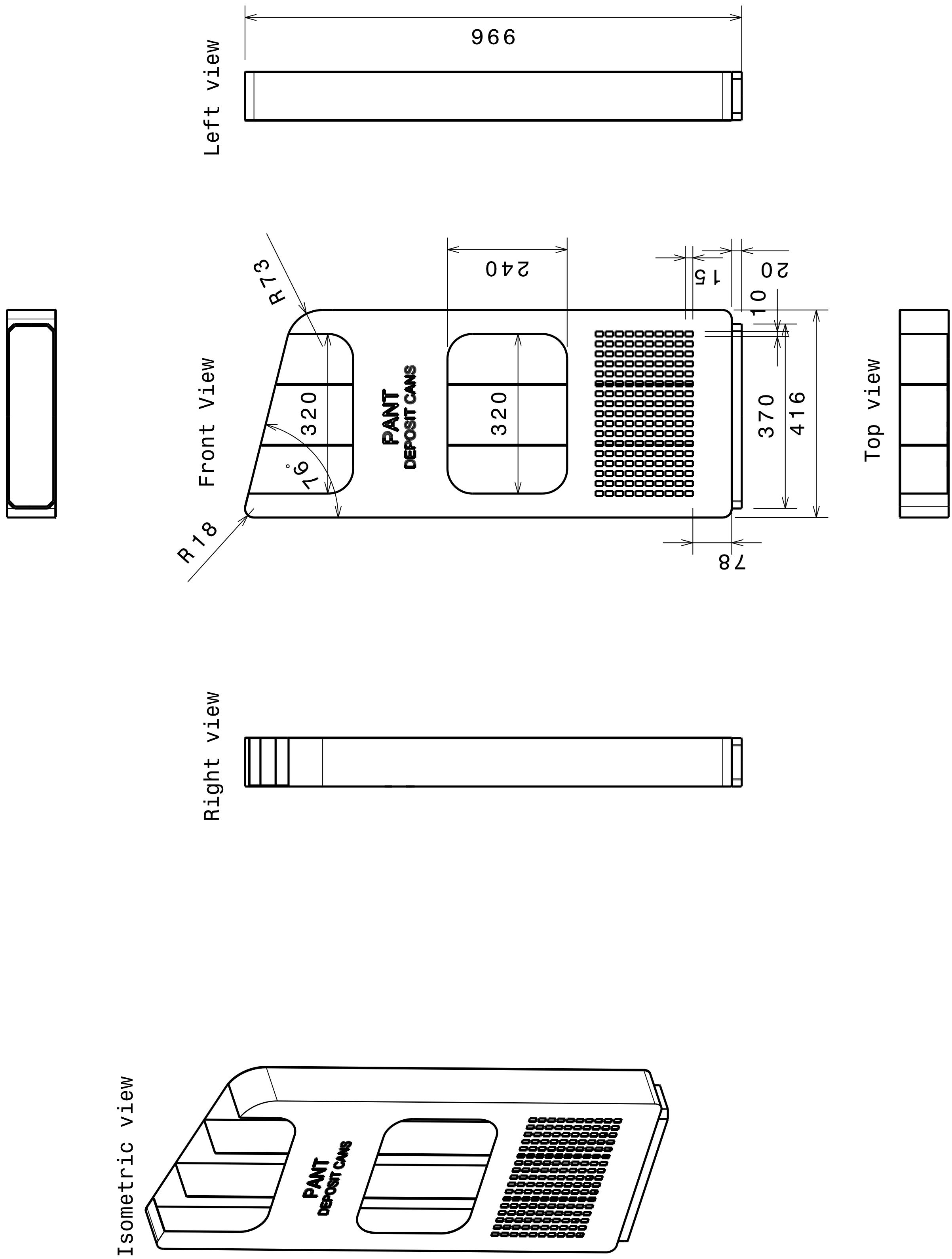
enkelt uttryck syftar till det rena och okomplicerade uttrycket.

identifierbar ——————————————— tvärtom

identifierbart uttryck syftar till det igenkännande och påkallande uttrycket.

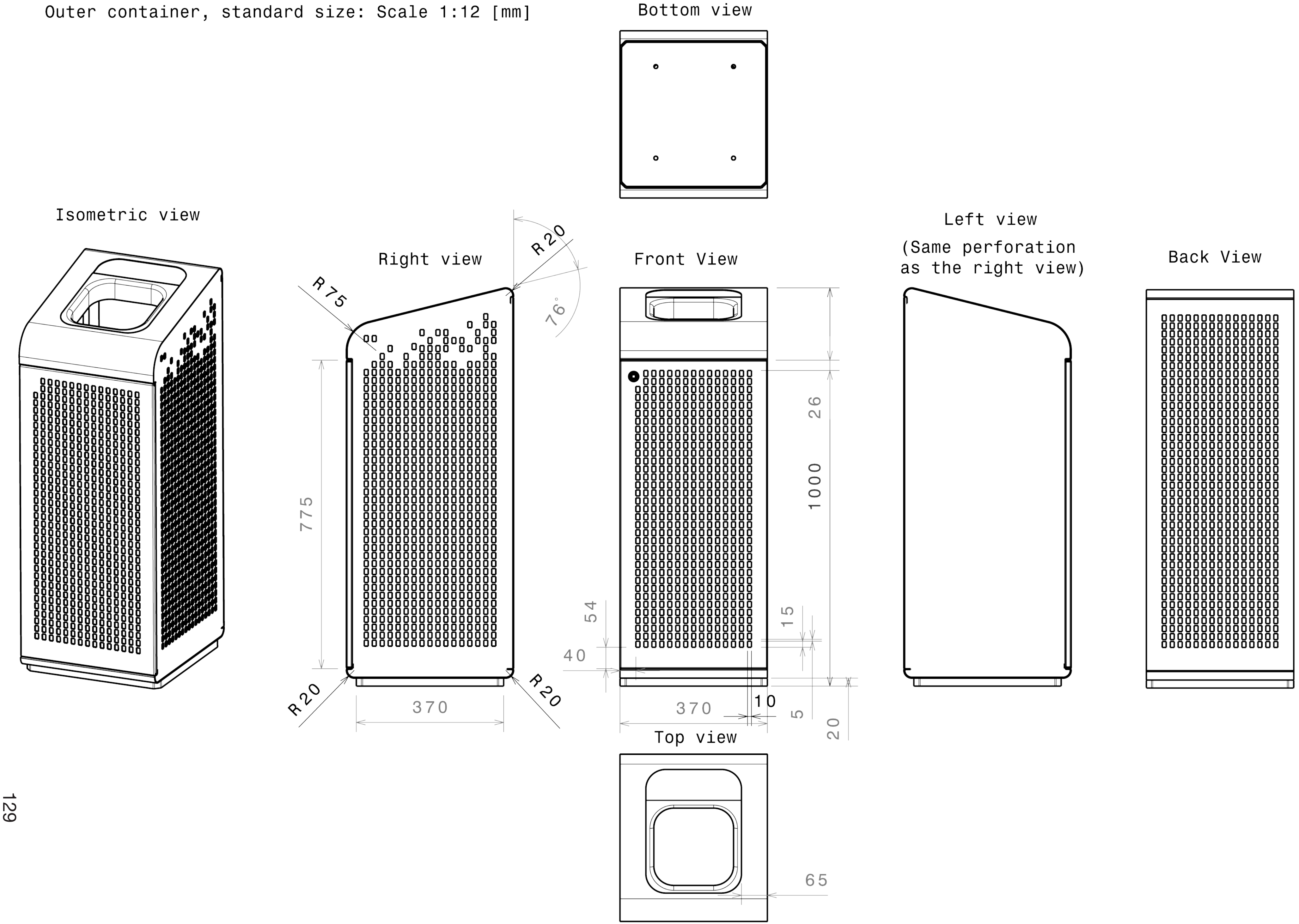
stabil ——————————————— tvärtom

stabilt uttryck syftar till det hållfasta och pålitliga uttrycket.

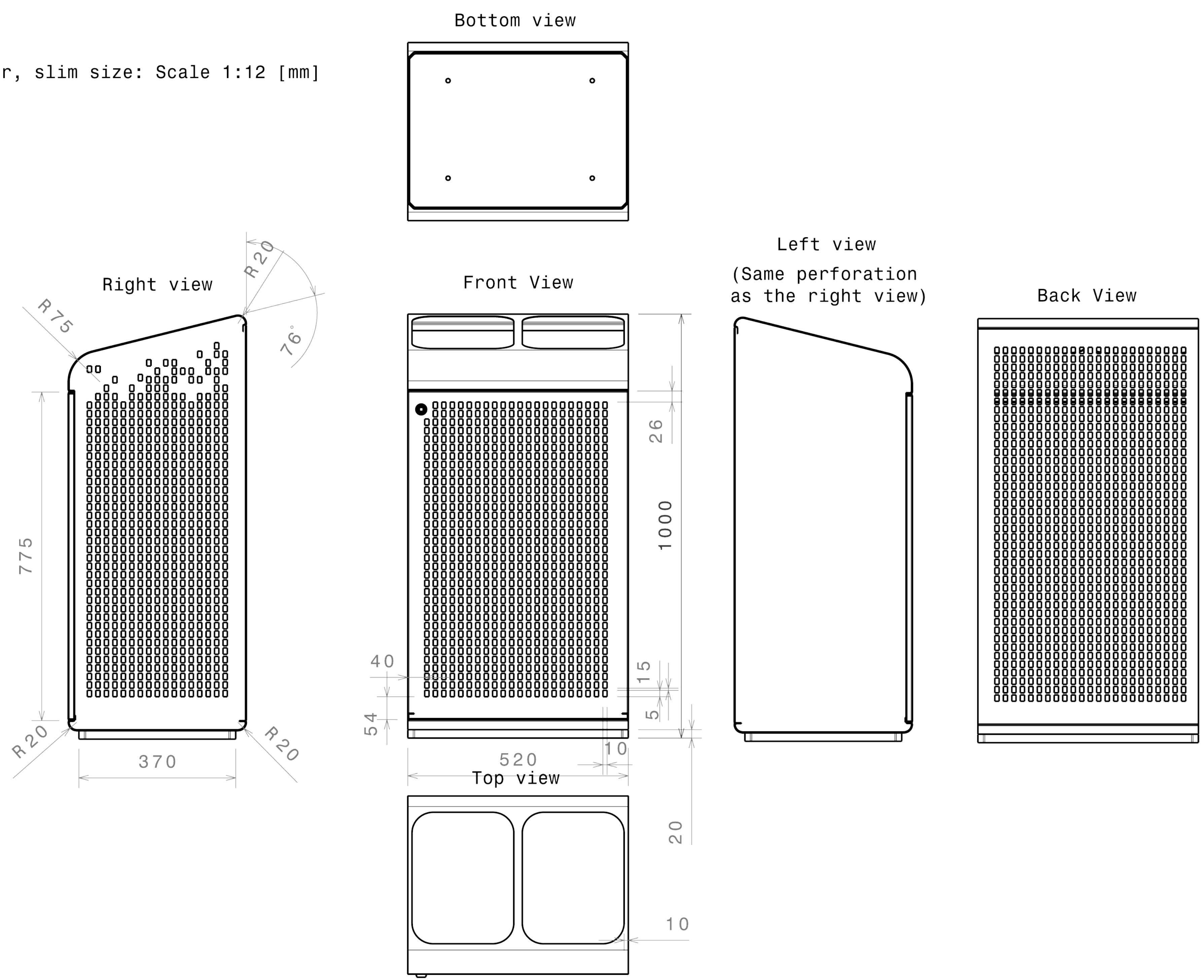


Container for deposit cans: Scale 1:12 [mm]

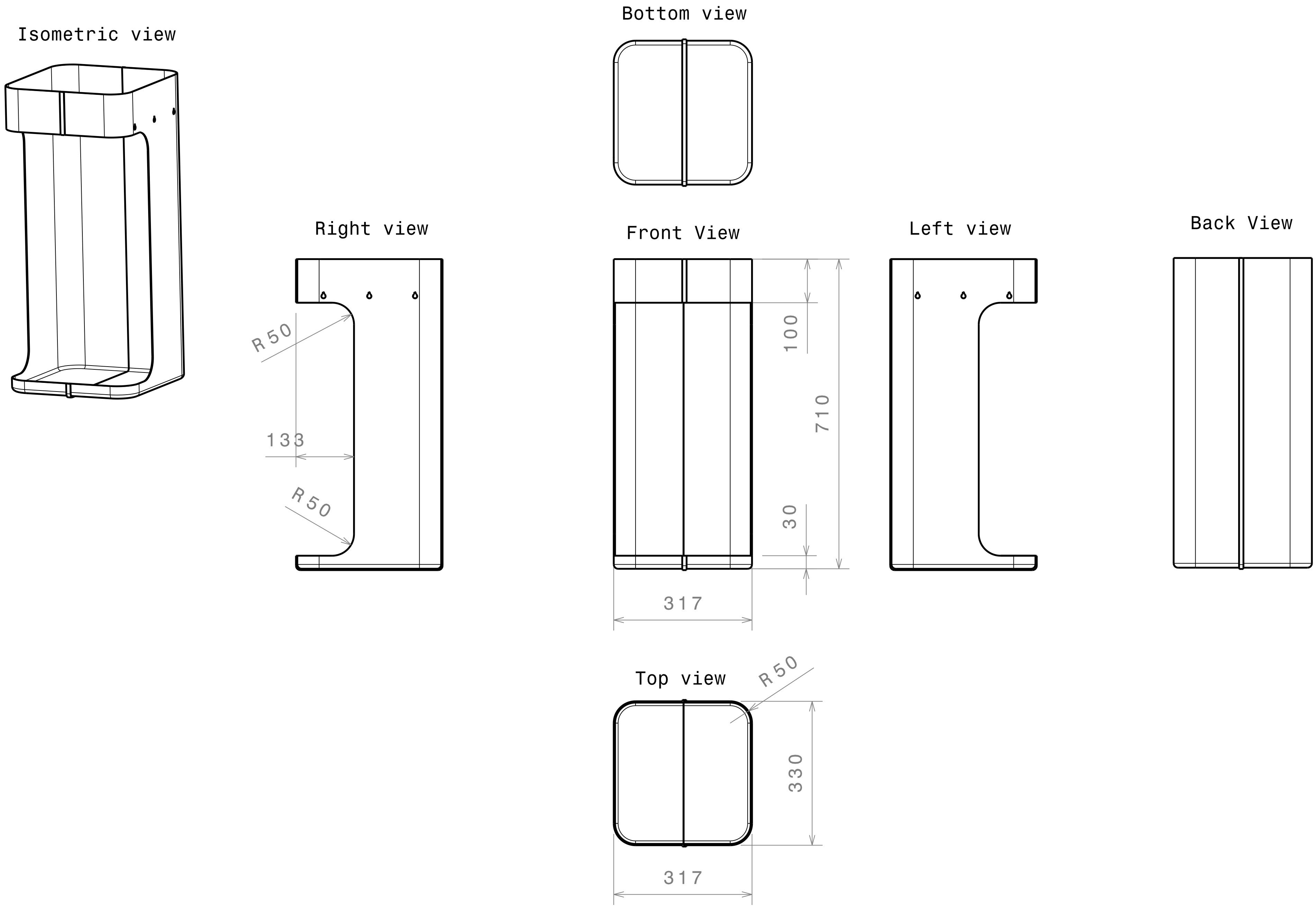
Outer container, standard size: Scale 1:12 [mm]



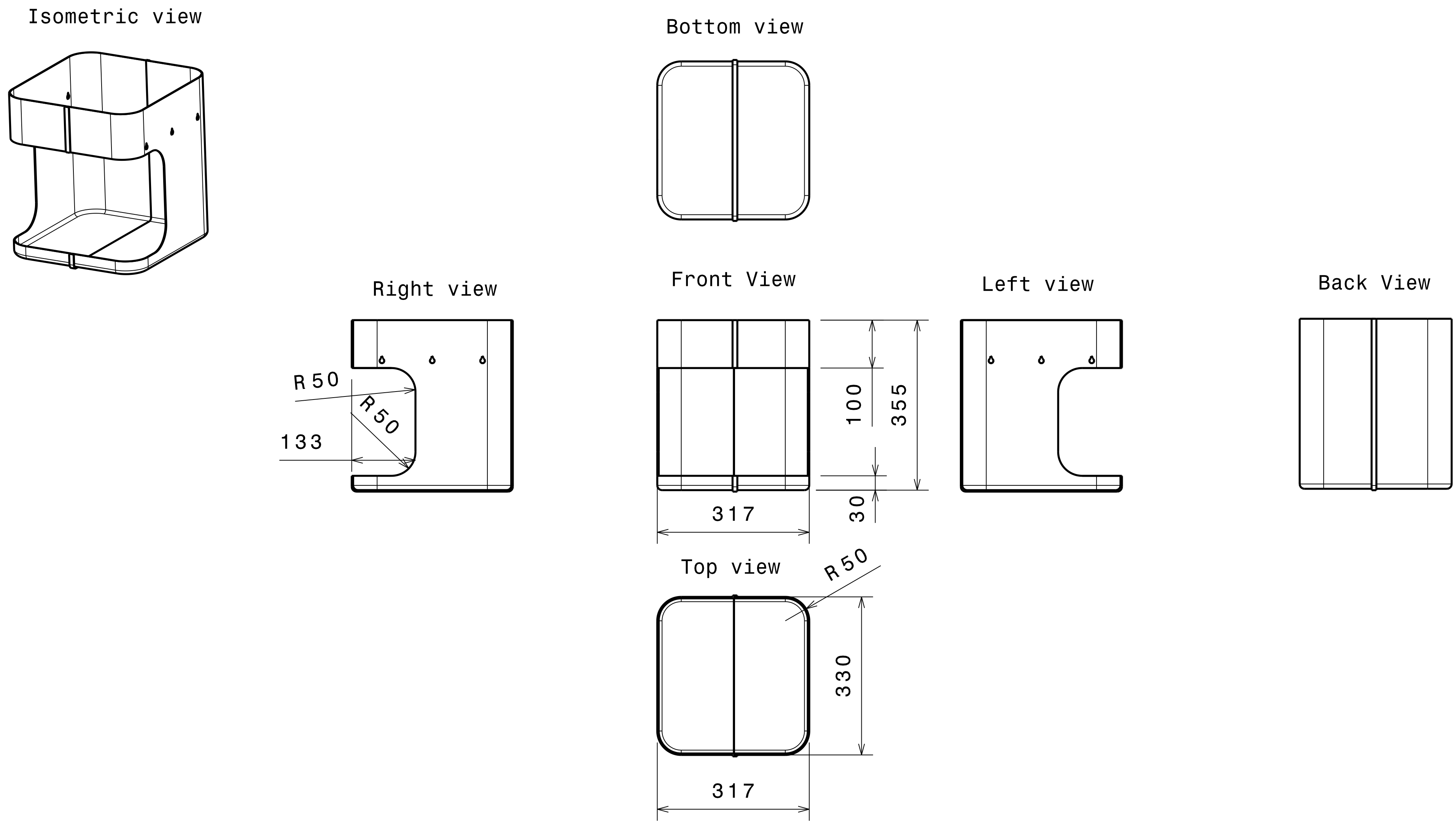
Outer container, slim size: Scale 1:12 [mm]



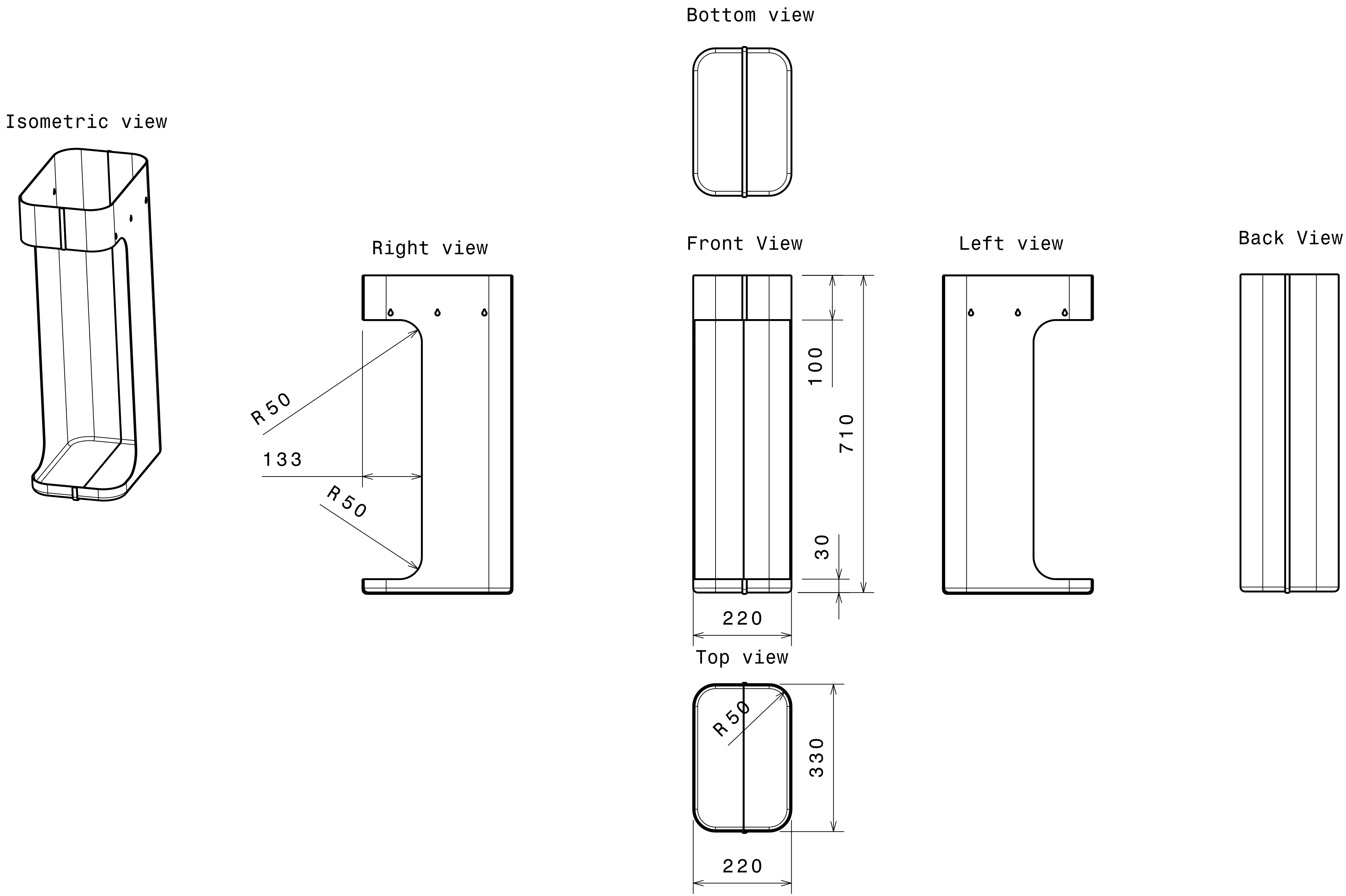
Inner container, standard size: Scale 1:12 [mm]



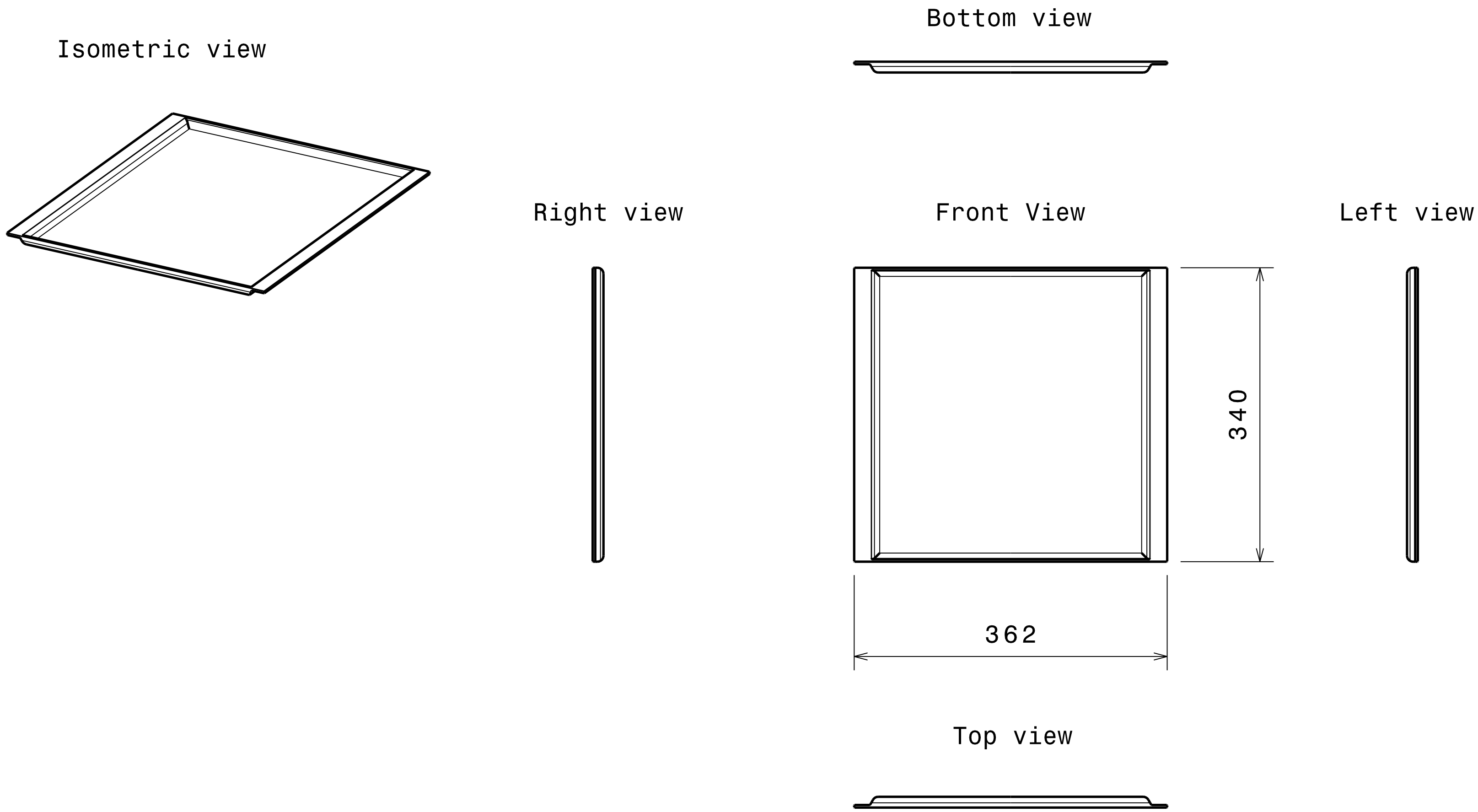
Inner container, short size: Scale 1:12 [mm]



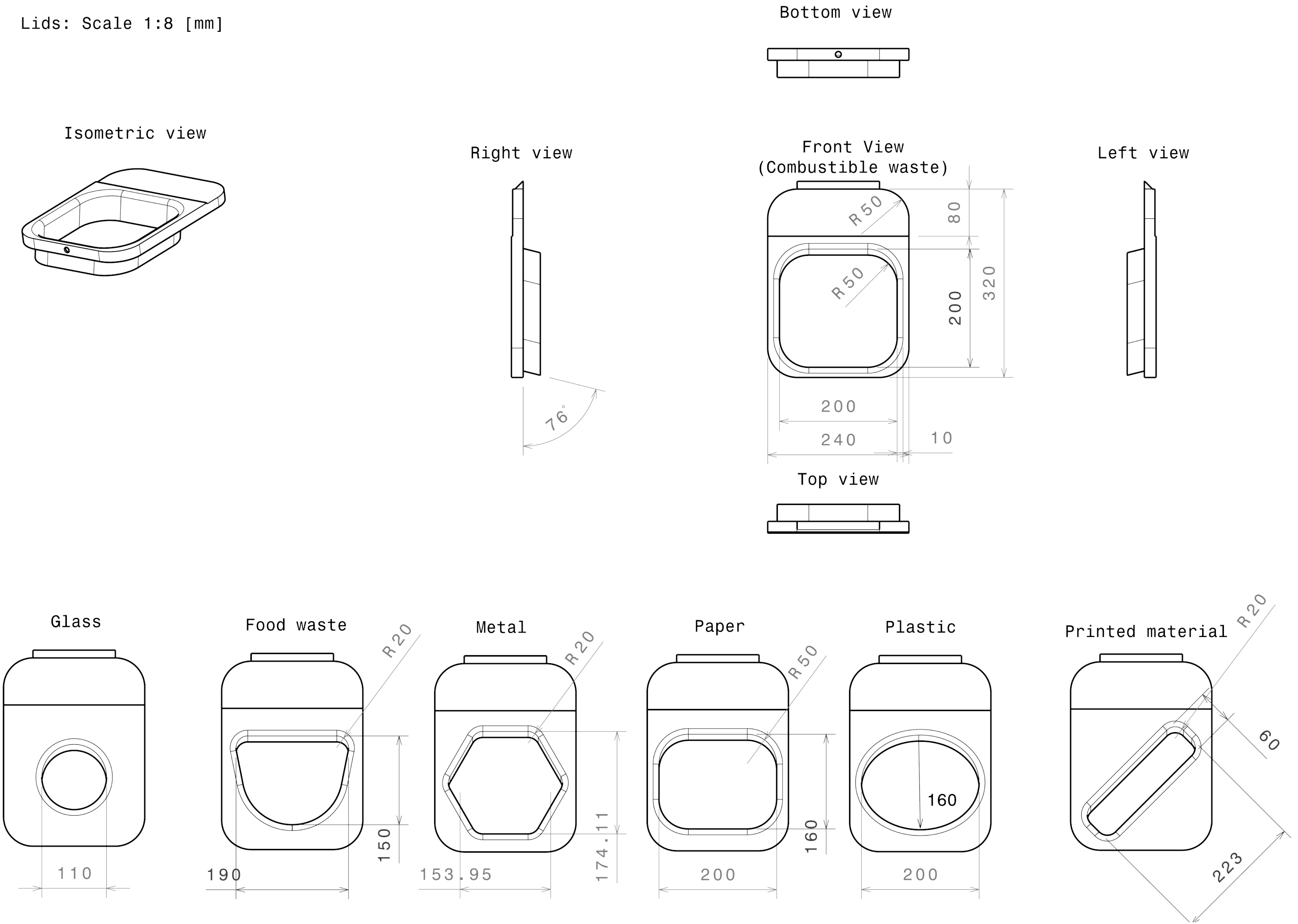
Inner container, slim size: Scale 1:12 [mm]



Inner floor: Scale 1:8 [mm]

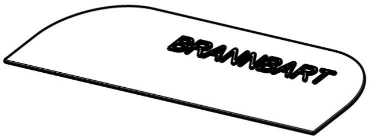


Lids: Scale 1:8 [mm]

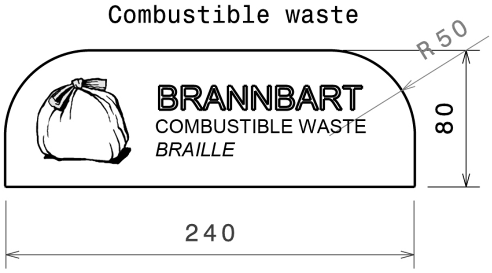


Signs: Scale 1:4 [mm]

Isometric view



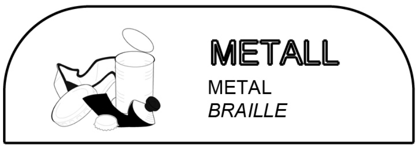
Combustible waste



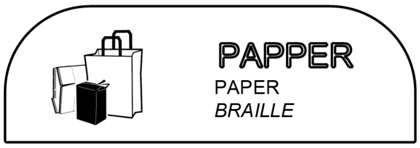
Glass

Food waste

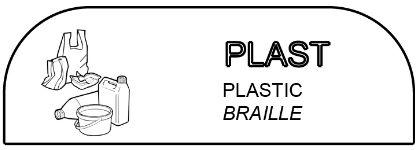
Metal



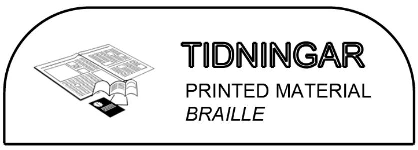
Paper



Plastic



Printed material



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