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Requirements for a zero-waste zone

Exercising zero-waste within an area, and an example of product design according to zero-waste

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Krav för en zero-waste zon

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Abstract

Waste is a problem that is more relevant now, in the 21st century, than ever before. Waste management is becoming more crucial with more people moving into cities, which demands a fast lifestyle and leading to massive amounts of waste. Managing all the generated municipal solid waste is putting huge amounts of pressure on the infrastructure.

Zero-waste is a topic that has gained popularity as environmental issues have gained attention. The topic has only been around since the late 1990s and without an official governing body the meaning of the topic is diffuse.

The research objectives of this study are to clarify the topic of zero-waste in a way so that it could be exercised within a specified area, as well as bringing forth a concept on how a recycling station within the area could be designed, aligning with the ideas originating from the topic. To achieve these objectives, this study did a literary study on the topic and qualitative research to gain as much understanding over the state of the topic today.

Results from the research conducted during this study concluded that the topic of zero-waste is divided into three different areas, personal, municipal, and business. All areas having their challenges to overcome to achieve zero-waste according to the accepted definitions of the topic. The results derived from the literary study and the interviews concluded into 3 goals, aligning with the principles of zero-waste, specific for an organization or business that wants to define a set physical area as a zero-waste zone. Clarity of waste management, setting a standard of reuse and recycling and monitoring waste, and work towards prevention.

Also, a concept for a recycling station was developed aligning with ideas brought up on the topic to be placed within an area exercising zero-waste.

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Sammanfattning

Avfall är ett problem som är mer relevant nu, på 2000-talet, än någonsin tidigare.

Avfallshantering blir allt viktigare med fler människor som flyttar till städer som kräver en snabb livsstil och leder till enorma mängder avfall. Att hantera allt genererat kommunalt fast avfall sätter enorma belastningar på infrastrukturen.

Zero-waste (översatt: Noll-avfall) är ett ämne som har blivit populärt eftersom miljöfrågor har fått uppmärksamhet. Ämnet har bara funnits sedan slutet av 1990-talet och utan ett officiellt styrande organ är innebörden av ämnet diffust.

Forskningsmålen för denna studie är att klargöra ämnet zero-waste på ett sätt så att det kan utövas inom ett specifikt område, samt att ta fram ett koncept om hur en återvinningsstation inom området kan utformas i linje med idéer som kommer från ämnet. För att uppnå dessa mål gjorde denna studie en litterär studie om ämnet och kvalitativ forskning för att få så mycket förståelse för ämnets tillstånd idag.

Resultat från forskningen som genomfördes under denna studie drog slutsatsen att ämnet zero-waste är indelat i tre olika områden, personligt, kommunalt och företagande. Med alla områden som har sina egna utmaningar att övervinna för att uppnå nollavfall enligt de accepterade definitionerna av ämnet. Resultaten från litteraturstudien och intervjuerna avslutades också i tre mål, i linje med principerna om nollavfall, specifikt för en organisation eller ett företag som vill definiera ett visst fysiskt område som en zero-waste zon.

Mål 1:

Ha ett tydligt sätt för både användare och servicearbetare på hur avfall hanteras.

Mål 2:

Gör återanvändning och återvinning till standarden.

Mål 3:

Övervaka aktivt avfallstillströmningen och vidta åtgärder för att minimera det.

Dessutom togs ett koncept fram för en återvinningsstation för att placeras inom ett område som utövar zero-waste utifrån de principer som tagits upp om ämnet.

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Abbreviations

STHE: Stockholm Tiny House Expo

ZWIA: Zero Waste International Association

MSW: Municipal Solid Waste

1 Introduction

In this section, the background is presented to inform and interest the reader of the topic of the study. Following that, the problems this study is focusing on are described. The section is rounded off by the presentation of the purpose, research questions, and the limitations of the study.

1.1 Background

In large cities, such as Stockholm, the capital of Sweden, where the housing shortage is a major problem that is only growing (Waldfogel, 2018), and the surrounding politics all is general chaos (Blumgart, 2020), one must also keep in mind the environmental impact that it entails. The fact that many people live within a limited area means that the amount of waste increases sharply in that area. Sweden is exemplary in recycling and sorting our waste, but we are not content with that. The city of Stockholm has long criticized the lack of environmental stations in the inner city, six of which are very inconvenient located. (Stockholm Vatten och Avfall, 2019) and the municipality has only developed temporary solutions such as setting up containers at a multitude of locations. Studies have shown that more people would recycle if it were easier and there were more readily available alternatives to recycle in their vicinity (Pietzsch, Ribeiro, & de Medeiros, 2017).

Today, the average human produces 0.74 kg/day of waste (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018), though high-income countries generate 34% of the 2.1 billion tons of MSW annually. To put this from a historical perspective, since 1960 the amount of MSW in America has increased from 88.1 million tons to 292.4 million tons in 2018. Most of the MSW is paper and paper boards originating from the packaging of food and items (United States Environmental Protection Agency, 2020).

The topic of zero-waste is well heard of, often used when talking about waste management. Companies and organizations like to use the phrase freely since there is no general definition known. The phrase is used in different contexts with organizations having different definitions and views of the topic (Hussain, 2021).

1.2 Problem description

There is no one person whom people consider to be the founder of the zero-waste philosophy which has left organizations and communities to come up with different definitions of what they consider the zero-waste philosophy is. The definitions all originate from the same ideas surrounding the elimination of end-of-pipe waste management. One must have in mind that zero waste is a recent concept, thought up in the late 1990s and early 2000s, and is still in the process of being put into action by people and organizations.

The company *Stockholmtinyhouseexpo AB* (STHE) is planning to build a 4500 m² floating artificial island in the heart of Stockholm, during the summer of 2023. The focus of the project is sustainability and alternative housing, they want the island and pier to be a zerowaste zone.

The process of generating requirements for a specific area to be considered as of following the principles of the topic will be difficult since zero-waste lacks an official definition. The reason is that there is yet no official governing body controlling and maintaining a standard of set rules and regulations surrounding the topic.

1.3 Purpose

The purpose of the study is to bring forth the requirements of the floating artificial island Stockholmtinyhouseexpo AB plans build must meet to be considered a zero-waste zone according to the general perception of zero waste and develop design concepts to make it easy to understand, use and manage the recycling stations and the contents for recycling stations used in the zone.

1.4 Research Questions

- What requirements does the island have to meet to be classified as a zero-waste zone?
- What role will recycling systems have for a zero-waste zone?
- How can recycling stations be designed to help the cause of keeping the island a zero-waste zone?

1.5 Delimitations

For the design of recycling stations, this study will only account for physical design, producing low-level concepts, and only give suggestions on materials and manufacturing. Since the earlier work on the topic of zero-waste mostly focuses on MSW.

2 Literary study

Zero-waste is a design principle for solving waste problems within a certain system or area. (Song, Li, & Zeng, 2014) The goal of the zero-waste philosophy is to eliminate end-of-pipe waste management as it is considered a temporary solution to the more permanent problem of a wasteful society (Simon, McQuibban, & Condamine, 2020).

Previous work within the topic has revealed the incoherency of different definitions set by different organizations and companies. Without a governing body to regulate and define the topic, it is left for anyone to interpret and define it suiting their position (Pietzsch, Ribeiro, & de Medeiros, 2017). The multitude of definitions and variants surrounding the topic of zerowaste could be daunting. At first approach of the topic, it seems to be clear what the general definition is, provided by Zero Waste International Alliance (ZWIA) in 2004 and last updated in 2018:

"Zero Waste: The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health." (Zero Waste International Alliance, 2018)

However, this definition is not critically acclaimed and is only used in a few instances by organizations and companies. It should be mentioned that ZWIA is established only in the US, Canada, and Brazil. There are other organizations with similar goals of trying to become the governing body, e.g., Zero Waste Europe, UL, and DCC INFRA PRIVATE LIMITED, all with their definition of zero-waste.

In more recent times the topic of zero-waste has been popularized by influencers and others showing the possibility of living a "zero waste lifestyle" where they put the principles of zero waste into practice and showing it on social media (Leahy, 2018).



Figure 1 Photo of Lauren Singer and her jar (Taha, 2018)

Lauren Singer, shown in figure 1, is a person that has gained a lot of traction online showing her zero-waste lifestyle and introducing millions to the concept. In 2014, she started her blog

"Trash is For Tossers" where she documents the journey of her zero-waste lifestyle she had started 2 years before that. Since the start of the personal blog, she has been given the opportunity to do a TED talk, been interviewed by big newspapers, and starting a company named Package Free. She is famous as "the girl with the trash jar" being that she stored all the non-recyclable plastic she is collected since fully committing to the zero-waste lifestyle in a 16 oz Mason Jar (East, 2016).

Lauren is just one of many influencers who are popularizing the zero-waste philosophy.

2.1 Defining zero waste

When defining zero-waste there is a lot to consider. The definitions by organizations and companies differ, both in the focus of the topic within zero-waste and their phrasing. And the general knowledge of the topic and how it is interpreted is scattered. (Hussain, 2021)

2.1.1 Theoretical zero-waste and its impossibility

The literal theoretical meaning of "zero waste" is impossible. The reason being that waste cannot be avoided. The UN defines waste as:

"Materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded. See also biological waste, solid waste, industrial wastes and household waste."

(United Nations - Department of Economic and Social Affairs, 2016)

And according to the first law of thermodynamics:

Energy can neither be created nor destroyed; rather, it can only be transformed or transferred from one form to another.

Based on these two definitions the only time there is **zero waste** is when the system is empty, total vacuum. On the contrary, there will always be waste within a system, products are produced by a process that is not the main purpose of said process, alternatively, the process not being able to 100% utilize the product, thus leading to waste.

2.1.2 Different definitions of zero-waste

With zero-waste being such a broad topic with no official governing body that must establish and regulate standards and continuously check the authenticity of organizations and/or projects claiming to be working with zero-waste philosophy, one is left with people and organizations defining zero-waste in a way that works for their application (Awasthi, et al., 2021).

When zero-waste is defined for an individual, the focus is mostly on how the individual should both be mindful of the impact on the surroundings which leads towards action.

One of the most famous zero-waste lifestyle influencers is author Bea Johnson. In her book "Zero Waste Home: The Ultimate Guide to Simplifying Your Life by Reducing Your Waste" she introduces the 5 Rs of zero-waste:

- Refuse
- Reduce
- Reuse
- Recycle
- Rot

(Johnson, 2013)

Which is a modified version of the European waste hierarchy given:

- Prevention
- Preparing for re-use
- Recycling
- Other recovery, e.g., energy recovery
- Disposal

(the European Parliament and of the Council on waste, 2008)

This is common when looking at different definitions of zero-waste. The correlation of definitions for personal waste management modified, simplified, and/or a more clarified version of the definition given by governing bodies and businesses.

Different organizations ranging in size, industry, and influence have come up with their definition of zero-waste, e.g.,

"The literal goal of zero waste is to create a waste management infrastructure where everything is recycled, reused, or composted, with nothing remaining for disposal. But most zero-waste advocates are realistic, confessing the unlikelihood that all waste can be eliminated, at least in the foreseeable future. Advocates claim that declaring a zero-waste goal is the most effective way to eliminate the maximum amount of waste, with some residual disposal."

The state of California (O'Connell, 2002, p. 1)

"Zero Waste is a way of looking at the waste stream that goes beyond waste disposal. Instead of seeing used materials as garbage in need of land disposal, discarded items are viewed as valuable resources. Under a Zero Waste plan, "trash" represents jobs, financial opportunities, and raw material for new products. Zero Waste strategies consider the entire life-cycle of products, processes, and systems. Zero Waste represents a fundamentally different approach to waste management, provides sustainable alternatives to landfilling and incineration, and broadens responsibility for solutions."

The island of Guam (Calvo, 2013, p. 101)

2.2 Differences within the topic

The topic of zero-waste could be divided into 3 primary areas,

- Personal
- Municipal
- Business

With each group having its subgroups and challenges striving towards the goal of zero-waste.

This study will only cover the municipal and business part of zero-waste. The reason being that the personal part of zero-waste only affects the individual. It is encouraged to live a zero-waste-inspired lifestyle if one is capable of it, but the way society is today making it time, money, and energy-consuming. Studies indicate that making the changes within people's lives and encouraging the reuse of things is a big contributor in succeeding with a zero-waste plan (Pietzsch, Ribeiro, & de Medeiros, 2017).

2.3 Recycling materials

The first step to take when working within an already established infrastructure and want to implement a zero-waste philosophy is to look at recycling. Recycling looks different in various parts of the world, with regions having split thoughts on what to prioritize (European Environmental Bureau, 2019).

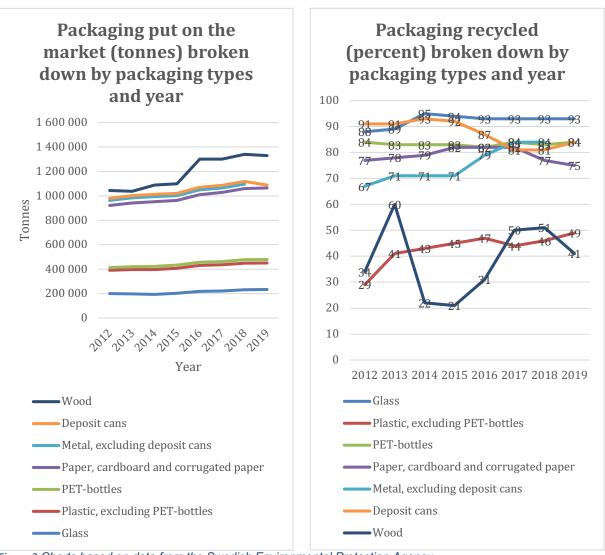


Figure 2 Charts based on data from the Swedish Environmental Protection Agency

As shown in figure 2, statistics from the Swedish Environmental Protection Agency show interesting trends among swedes. Both metal and plastic, excluding PET bottles, have increased significantly over 8 years while the market has not drastically changed the amount of packaging on the market. Research has shown that the reason for this increase in the number of recycled materials is more talk in society about the environmental consequences of not sorting waste and bringing it to public awareness through campaigning (Hinde, 2020).

Some differences are recycling varied materials, some of the recycling processes are harder and costs more for the companies. For example, when recycling plastic it is important to separate distinct types to not lose quality, however, plastic generally loses quality over

recycling cycles. With glass, the quality stays the same when recycling, no matter how many cycles, the tricky part is to not mix colored and non-colored types of glass (Shahbazi, 2015).

When planning recycling tools, it is crucial to find a balance between usability, convenience, and specifying categories.

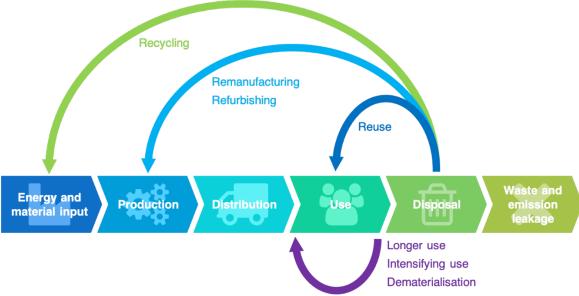


Figure 3 An illustration of the circular economy concept (Geissdoerfer, Pieroni, Pigosso, & Soufani, 2020)

The recycling part of zero-waste parallels with the ideas from the economic system "circular economy", where the goal is to eliminate waste and motivate the continual use of resources.

As seen in figure 3, eliminating the last step is the goal of the zero-waste philosophy. But it is easier said than done, the use and disposal part of the chain is hard to maintain and puts a lot of pressure on the end-user to use and dispose of the product the right way. And this step is also the most crucial to close the loop and make the whole process circular, becoming a cradle-to-cradle process instead of a cradle-to-grave life cycle (Grmela, 2020) (Geissdoerfer, Pieroni, Pigosso, & Soufani, 2020).

2.4 Product design according to zero-waste

When developing and designing a product from a zero-waste standpoint both the design and the manufacturing side of it must be considered. One could argue that if the product does not contribute or promote the already wasteful nature surrounding it that it could be considered zero-waste. But, as previously mentioned in **2.2**, when defining zero-waste, there are two main aspects when dealing with zero-waste.

- 1. Waste management
- 2. Waste prevention

These two areas are the main requirements for a product to be considered zero-waste. And they should always be the philosophy surrounding the requirements hierarchy within product design (Mitchell, 2019) (Grmela, 2020).

So not only should a finished zero-waste product be designed to strive towards the goal of preventing waste, but the entire process also must be working towards minimizing waste in every step. This could be done by either proper recycling or reuse in other ways.

2.4.1 Fundamental rules of zero-waste product design and development

When minimizing waste in every step of the process designers must consider the entire lifecycle of a product. This means that if there is no consideration for a product's life after it has left the manufacturing state it cannot be considered zero-waste (Taherzadeh, Bolton, Wong, & Pandey, 2019).

On the manufacturing side, preventing waste is beneficial, both from an economic and resource standpoint. Manufacturers have for years been working towards optimizing processes to reduce waste. But a thing that one should have in mind is the sourcing of raw materials used in the product, as the obtaining process could generate substantial amounts of waste (P Tamás, 2016).

Unfortunately, less has been researched and brought into practice on the end-of-life side of the product. That part of the lifecycle is less of interest as it requires more data on time, finances, and social (Taherzadeh, Bolton, Wong, & Pandey, 2019, pp. 23-33).

On the manufacturing side of a product, there are well-documented ways and systems for manufacturers to follow to reduce waste in production. (El-Haggar, 2007)

3 Method

In this section, the method of this study is presented. Both the data gathering processes and how the results are concluded will be specified and motivated.

3.1 Design of study

The question regarding the requirements for a zero-waste was answered with help of a literary qualitative study. This method was used to gather information on what has previously been established on the topic and what other similar research has concluded within the area of interest. Different definitions of zero waste that are accepted by people working with questions and projects within the area has be brought forward and the common factors been extracted to produce a list of requirements the island has to meet to be considered a zero-waste zone.

When researching what role recycling systems have within a zero-waste zone a similar approach as with the requirement generation has been conducted, with interviews and literary qualitative studies. Some on-site observations was conducted as well to gather data on how recycling systems work at various locations today.

Data for the design of recycling stations was generated through a research mix of quantitative and qualitative research, including interviews and observations.

The product development process flow that this study follows is:

- 1. Planning
 - a. What are the customer requirements?
 - b. What solutions are available today?
- 2. Concept Development
 - a. Choose concept
- 3. (System-Level Design)
- 4. (Detail Design)
- 5. (Testing and refinement)
- 6. (Production Ramp-Up)

(Eppinger, Ulrich, & Yang, 2019)

This study only covers the two first steps in this process as requested by the company. With the island's focus on sustainability, solutions found today will be compared to suggest ones that align with the goal of the recycle station being easy to understand for the user, have the necessary fractions of materials to sort, and are easy to service by technicians.

This study takes notes from the five-step method for concept generation since it is well known within the industry and widely acclaimed and if needed, do modifications to these steps to fit the requested format of presentation. The five steps are presented in more detail in the book, "Product Design and Development" by Karl T. Ulrich, Steven D. Eppinger, Maria C. Yang.

3.2 Methods of collecting data

Qualitative research was conducted to gain knowledge and understanding of this topic and what has been concluded within this area. Articles, videos, and books on the topic has been thoroughly researched.

Four interviews were conducted with people who work with the topic or similar subjects to get a wider range of information on the topic.

The interviewed people were:

- a professor of Business Administration at the Department of Service Management and Service Studies
- an environmental coordinator
- an environmental manager
- a professor of resource recycling

The structure of the interviews was semi-structured, and the subject of zero-waste was brought up and asked about how the interviewee knows about the subject as well as their perception of what the subject is. The interviews were mainly focused on how the subject is interpreted, presented, and used in different industries. Questions regarding systems for reducing waste will also be brought up since zero-waste is a philosophy emerging from attempts of finding a solution leading to the prevention of waste.

The interviews all were about 30 minutes long conducted in person or over video calls. And after all the four interviews were conducted, enough data was gathered to both support and extend the knowledge this study is researching, as well as providing valuable insights on how established the subject is at this study's writing. The interviewees all had international connection and were familiar with the subject as well as having experience with similar topics. This was well suited and enough to reach the requested level of this study.

For the product design process of recycling stations, following the five-step method, the research was partly qualitative and partly quantitative.

Short interviews with users of various models available today was also conducted. The interviewed people for this part of the study were:

- a service technician working with recycling and maintenance of property
- a worker at a fast-food restaurant that advertises on being environmentally friendly
- a couple of users of different recycling stations while standing next to the station

Each of these interviews were about 20 minutes with straightforward questions about use and suggestions on improvement as well as how the stations are used today. The interviews produced valuable data that gave a good insight in the state of recycling stations today. This method was used to get deeper answers on the use of the products. Indirect observations of users were conducted as well, this method is advantageous as one can analyse the behaviours users tend to use.

3.3 Methods of analysing data

The data gathered from research and interviews about zero-waste was analysed and compared with each other to try to gather a general comprehension of the topic.

For the design part of the study, steps 2-5 of the five-step method, are for the analysis of the gathered data. During the interpreting of the raw data, the method suggests a spreadsheet approach with columns titled Question/Prompt, customer statement, and interpreted need.

When the interpreted need was documented, the next step was to organize the needs hierarchy, this includes combining similar ones, eliminate redundant statements, and reviewing the needs. This was done to narrow down the actual needs (Eppinger, Ulrich, & Yang, 2019).

The goal of this study was not to generate something completely new, but to look at what is available and from that generate a low-level concept of a recycle station based on both customers' requirements and what has been brought up when researching zero-waste. In this study, the already available models of recycling stations were being looked at as a starting point. A useful tool that was used in this study for selecting what models meets the most requirements is a so-called Pugh matrix.

Pugh concept selection is a way to execute a concept screening with help of a matrix. The first step is to list all the requirements the product should meet. Next is to list all the different concepts of the product, in this study's case, the different ones available today. Having a reference model to compare against is crucial. After that, you grade the concepts on how well they match said requirement compared to the reference model. The code used when grading is presented like this: "(+ for "better than," 0 for "same as," – for "worse than")" (Eppinger, Ulrich, & Yang, 2019).

After the grading there are 3 actions to choose between:

- 1. Continue with the concept if it scores high
- 2. Combine multiple concepts if it is possible and worth it
- 3. Discard a concept idea if it scores low

3.4 Validity and reliability

Literary quality research is preferred when finding a definition of the topic zero-waste to be applied over a specified area, this method is preferable since it considers earlier and creditable research on the topic. And to measure the reliability of the conclusions drawn in the research they will be set in comparison to what experts within the area of interest bring up during the conducted interview.

To keep the high reliability within the research the audio during the interviews was recorded, and a requirement was set to a level that the person being interviewed must be working on something regarding environmental issues at the time of the interview. Literary qualitative research is the first step when generating design concepts of this nature. Researching the different models available today and getting data on usage did set up the groundwork for the next part of the research, the quantitative.

The reliability was held on a prominent level by video recording when performing the indirect observations.

3.5 Ethical considerations

ALLEA - All European Academies has presented four principles regarding personal ethics in the pursuit of research:

- "Reliability in safeguarding the quality of the research, which is reflected in the design, method, analysis and use of resources.
- **Honesty** in developing, implementing and scrutinising research, and in reporting and informing others about research in an open, fair, complete and objective way.
- Respect for colleagues, research participants, society, ecosystems, cultural heritage and the environment.
- Accountability or research from idea to publication, for management and organisation, for education, supervision and mentorship, and for their wider consequences."

(ALLEA - All European Academies, 2017, p. 4)

During the entirety of this study, they were a top priority to adhere to and be accountable towards these principles.

When conducting interviews during the research the safety of the person being interviewed was a high priority. To keep the person safe and comfortable the interviewer must be clear on what is going to be recorded and how the information being exchanged will be used.

Also, during the indirect observations involving video recording it is important to follow the laws surrounding these kinds of actions so that everything is clear from the start. This includes the requirement of Information, consent, confidentiality, and utilization to be informed to anyone involved in the research.

4 Zero-waste goals for a municipality, business, or zone

This part of the study summarises the gathered qualitative data from the interviews as well as what was brought forth during the literary study of the subject, and from these two sources combining them toward goals for a zero-waste zone. And as well giving examples of practical ways to exercise zero-waste, both within the zone and in general, based on previous research.

4.1 Development of goals based on literature studies and interview data

When choosing to interpret the zero-waste philosophy within a set physical area one must consider key parameters to work towards. In this section, the goals are to summarize what has been written earlier with a focus on what is possible within the zone, as well as providing a summary on what was brought up during the interviews conducted for this part of the study.

In the first stint of the interview the person interviewed was asked to define what they thought zero-waste was. All mentioned that it was a bit confusing to get an overall picture of the topic since there are so many definitions, but they unanimously concluded that zero-waste is a philosophy regarding waste prevention and management. Theoretical zero-waste and its impossibility due to the general definition of waste was also a common theme brought up and discussed during the interview. Each interviewee agreed that the literary meaning of zero-waste is an impossibility.

When asked about how they have encountered the subject of zero-waste one said that it is more of a frequently used phrase within companies used in newsletters and that it was confusing since there are a lot of similar philosophies striving towards similar things. The rest of the interviewed answered that they had gotten in contact with the topic when researching waste management. Furthermore, the professor of service science brought up the importance of where the delimitations are set when claiming to work with zero-waste since the topic, in its state today, is not properly defined. This has led to companies and organizations having to define what zero-waste is according to their perception of the subject often with limited amounts of research.

Two of the interviewees work at the Uppsala University, and they both mentioned how important the workers cleaning and maintaining the facilities are on the way towards recycling. The reason being that those workers are responsible for the waste getting one step closer to be recycled.

Comparing definitions given by various sources as well as data gathered during the interviews the following about zero-waste could be determined:

- It is a way to emphasize the importance of waste management and prevention (Simon, McQuibban, & Condamine, 2020) (El-Haggar, 2007).
- It is up to the person/company/organization to choose what definition of waste they choose and then work towards minimizing it (Johnson, 2013) (Pietzsch, Ribeiro, & de Medeiros, 2017).
- Prevention is better than management of waste since it that is the root of waste problems (Khan & Islam, 2016) (Ayeleru, Okonta, & Ntuli, 2018).

These core thoughts for zero-waste summarized above will be the foundation when generating specific goals for a municipality, business, or zone to follow if they want to claim to be practicing zero-waste.

Looking at what has already been established within different industries and how they practice zero-waste and aligning it with already established fundamentals for zero-waste three goals were generated shown in table 1.

Table 1 Goals for zero-waste exercising within a municipality, business, or zone

Goal	Requirement to meet	
	Make it clear to both users and	
Clarity of waste management	maintenance workers how waste is	
	managed.	
Setting a standard of reuse and recycling	Make reuse and recycling the standard.	
Monitoring waste and work towards	Actively monitor the inflow of waste and	
prevention	take actions to minimize it.	

With these three goals established within a municipality, business, or zone, it would be considering working towards zero-waste according to what has been claimed to be zero-waste for the time being.

It should be noted that these conclusions are purely a generalization based on different sources' definitions to try to get an overall picture of the topic.

4.2 Practical ways to exercise zero-waste

There are many ways to exercise zero-waste. Depending on the location, setting, and resources the ways could vary. Some factors for succeeding with zero-waste have been earlier been researched, and they all involve practical ways to be done (Pietzsch, Ribeiro, & de Medeiros, 2017). The factors for success that has been brought up by earlier research and how they can be done according to them are as following:

Table 2 Critical success factors and ways of implementing them (Pietzsch, Ribeiro, & de Medeiros, 2017)

Critical Sucess Factors	Ways to Done
Substantial change in the citizens' behavior and consumption	Engage citizens in the activities of reducing and disposing by communication and signaling
behavior and consumption	Create educational programs in schools, communities, and universities
	Provide citizens alternatives for waste disposal
	Promote services/products for collaborative consumption
	Scone inappropriate behavior in relation to disposal of waste
Regulation of rates and financial incentives	Require that consumers pay for the waste they generate
	Cash a rate on each product sold to be paid by manufacturers and importers
	Reduce taxes and fees for cleaner products and processes
	Regulate the import and export of waste
Modifications in the logistics system	Invest in reverse logistics activities
	Prioritize the development of nearby and green chains
	Organization of companies in a cluster or symbiosis
Promote green innovation	Encourage research on new environmentally sustainable technologies
	Develop extension activities to promote innovations created and tested in universities
Products redesigning	Improve the design to extend the useful life of the products
	Eliminate toxicity in the composition of products
	Invest in the supply of products developed through the Design for Sustainable Behavior
	-Prioritize the use of renewable raw material
Qualify infrastructure of industries and municipalities	Use tools to assess the environmental performance
and manicipanties	Invest in labor training
	Invest in new technologies

Table 2 is a compilation of critical success factors when striving towards zero waste according to the authors of the paper. When exercising zero-waste it is important to define what one is capable to be operating on since every case is different. Some of the factors for succeeding with zero-waste will be hard for organizations to meet. But if the initiator of the project makes sure to follow the core ideas and principles and could at any point of time after claiming to work with zero waste show in what way they are following guidelines according to the zero-waste philosophy.

With the goal of zero-waste continuously recycling whilst also working towards the prevention of waste, in many cases the exercising looks different while working towards the same goal (McQuibban, 2020).

An example of such an initiative is the "Zero Waste Family Challenge".

The goal of the challenge could range depending on what the organizers want to achieve, but the main goal is to bring awareness of waste reduction actions.

This initiative has been successful in various locations, from Paris in France to Capannori in Italy. The results being splendid with the recycling rates in those areas growing substantially (Hannon & Zaman, 2018).

Another practical way to promote zero-waste is to remove all-waste bins and making recycling stations the only way of managing waste. This change in infrastructure motivates and brings awareness towards proper waste management. When establishing this it is crucial to research what fractions are possible to recycle close by, since the actual recycling part of the process is the only one that counts. If the waste is sorted but there is no possible way to recycle it and instead everything is incinerated, the entire process of sorting it into different fractions is unnecessary (Hussain, 2021).

5 Product design according to zero-waste with an example of a design for a recycling station

The goal of this chapter is to deal with the design of a recycling station, which will answer the third research question. The design of recycling stations is fundamental to its use. The goal of a recycling station will be to make it as easy as possible for users to sort materials into different sections, but also for those who services the recycling stations and transports the materials to the next step in the recycling process. The parts 5.1-5.4 are a compilation of the empirical data generated for this research question, and 5.5-5.7 shows the process of developing a design of a recycling station that aligns with the zero-waste philosophy.

5.1 Difference between stations and centers

MittSverige Vatten & Avfall defines the difference as, "Det finns stora skillnader mellan återvinningsstationer och återvinningscentraler. Återvinningscentraler är bemannade och du kan lämna till exempel metall, vitvaror, trädgårdsavfall, brännbart avfall och även farligt avfall." (MittSverige Vatten & Avfall, 2017)

[There are major differences between recycling stations and recycling centers. Recycling centers are staffed, and you can leave, for example, metal, white goods, garden waste, combustible waste, and even hazardous waste.] However, at a recycling station, you are only supposed to leave newspapers and packaging. (MittSverige Vatten & Avfall, 2017)

There is a lot of distinctive designs of recycling stations available today.

Figure 4 An example of a common and recognizable design (Recycle Away, LLC, 2021)

As we see in figure 4, there are different concepts and approaches on how to efficiently design recycle stations. In this study, these and other designs are to be compared with each other, listing the advantages and disadvantages. Based on those data based on the comparison will be used in the development of a design concept which will be presented.

5.2 Available on the market today

The market today is wide open with companies that have different takes on what a recycling station could be. More recognizable companies within the industry are, e.g., BigBelly, "the world leader of smart waste & recycling solutions for public spaces. It is a proven solution that is deployed in all 50 states and over 50 countries around the world." (Big Belly Solar LLC, 2021) or lesser-known companies innovating within the area of waste management.



Figure 5 Examples of BigBelly Bins (EWF ECO, 2017)

Companies usually do not sell entire recycling stations but offer waste management solutions, where they establish and maintain stations, e.g., BigBelly. The alternative and more indirect way manufacturers help with waste management is to sell the individual containers that municipalities or organizations put out in groups to make a recycling station. A commonly used and well-known model developed by BigBelly is shown in figure 5.

Waste containers come in varied sizes and variants. They range from including in-built containers for all the various fractions to be recycled to just being one big container for each one, all designed for the same purpose but built for different locations as shown in figure 6 (Burguillos & Caldona, 2018).



Figure 6 Picture of a recycling station designed for indoors usage and an all-in-one recycling station outdoors (SANSAC, 2021)

Factors to be accounted for should be the location, what kind of waste could be recycled nearby, and how the station will be serviced (Burguillos & Caldona, 2018). Figuring out the customer requirements is a key factor when choosing what kind of recycling station should be used.

5.3 Data from interviews and observations about the design of the recycling station

Data was gathered by interviews, direct, and indirect observations at different locations to get a general picture of the usage of recycling stations.

Pictures of different recycling stations were taken to get a visual understanding of variations on different models are presented in figure 7.



Figure 7 Pictures from observations of recycling stations

Also, results were logged, and the following conclusions could be derived:

- The fractions expected in a recycle station are:
 - Glass
 - Plastic
 - Combustible
 - Paper
 - Metal
- The location of the station is crucial for its usage.
- People are good at sorting trash when it is the only option.
- Some categories are more popular than others, plastic and combustible are at the top while glass and metal are less frequent in recycling stations.
- If things are too complicated people tend to throw all their trash in combustible out of laziness.
- There must be a clear plan of where the different fractions are sent to complete the recycling process not too far away from where it was collected and sorted.

5.4 Customer requirements/Product requirements and market analysis

Interviews were conducted with both users and service technicians about how they experience the use of recycling stations today. Shown in table 3 is the interpretation of the raw data in terms of customer needs presented in a matrix.

Table 3 Customer statements and the interpreted need

Question / Prompt	Customer Statement	Interpreted Need
Typical uses	Every time I empty the recycling station, I must use my system of making sure of knowing where to store which bag of waste	Needs a clear system of what is what when emptying the station, a standard system.
Likes – current models	Easy to empty and clean	Ease of use and do maintenance.
	Clear labels on what goes where	Clear and easily interpreted labels showing the various fractions.
Dislikes – current models	Liquids being in the bags lead to stains, odor, and leaks.	Should have a container for liquids.
	Some models had a small drawer for each category of waste, which makes maintenance a lot harder.	Easy accessibility of multiple categories at once.
Suggested improvements	I would like that the container for combustible to be larger because it fills the fastest	Different sized containers depending on waste trends.
	The design should be customizable, so we can adjust what size the container should have depending on its demand.	It should be customizable for different sizes of containers and bags.

5.5 Concept generation

When we now are studying an already well-known product, instead of generating completely new concepts, this study will compare three widely used models on the market.

5.5.1 What was considered when choosing concepts

When deciding what models to use and compare it is important to do thorough market research to find models that are popular but still differentiate from each other, both in design concepts and functionality.

A study was done to find models that are available and are commonly used concluded that most recycle stations have different bins next to one another and the only thing that differentiates them is the labels. The research conducted for this study also indicated that most cases of recycling stations are not customizable, but rather follow a design concept set by standards set by the surrounding infrastructure.

The following three models of recycling stations were chosen since they meet all the requirements set on a modern recycling station, are different from one another, and are used in different environments.

5.5.2 BigBelly High Capacity & Standard Capacity Triple Station

This model was chosen for its high usage throughout the world, being made by a popular and recognizable brand. Often placed outside in parks and public places, this model was a must-have for this study. Figure 8 is a picture of the BigBelly High Capacity & Standard Capacity Triple Station.



Figure 8 Picture of Belly High Capacity & Standard Capacity Triple Station (Big Belly Solar LLC, 2021)

5.5.3 San Sac's Small Package deal

This model was chosen because of its flexibility and San Sac being a well-established brand in Swedish offices. Its ability to be customized to meet set needs and requirements is the strong suit of this model. Figure 9 is a picture of the San Sac's Small Package deal.



Figure 9 Picture of San Sac's Small Package deal (SANSAC, 2021)

5.5.4 UMEA Triple – Slant Hood

This model was selected since it builds on the same design principles as commonly seen in fast-food chains. It stands out and has cutouts in different shapes. All in the same structure. Figure 10 is a picture of the EA Triple – Slant Hood.



Figure 10 Picture of UMEA Triple – Slant Hood (Waste Wise Products LLC, 2021)

5.6 Concept selection

A useful tool to compare different concepts is to use a Pugh-matrix, which is a system where one rates the different concepts depending on listed needs gathered from market analysis, interviews, and observations.

The reference model this study will compare with is the well-known and well-used "Home Recycling Station III" by The Bin Doctor.



Figure 11 Picture of Home Recycling Station II (The Bin Doctor, 2021)

Figure 11 shows is a picture of said recycling station, which consists of the basic functionalities required for a recycling station.

Table 4 Pugh Matrix

Criteria	Reference: The Bin Doctor	BigBelly	San Sac	UMEA
Clear system of different fractions	0	1	1	1
Ease of use and maintenance	0	0	0	0
Clear and understandable labels	0	1	1	1
Container for liquids	0	0	0	0
Easy accessibility of multiple fractions at once.	0	0	-1	0
Different sized containers depending on waste trends.	0	0	1	-1
It should be customizable for varied sizes of containers and bags.	0	-1	1	0
Total	0	1	4	1

The results of the Pugh-matrix results, shown in table 4, concluded that the San Sac solution comes out on top. The reason being that the San Sac model is the only one of the selected models allowing for different sized containers as well as being customizable for varied sizes of containers and bags. The other two models were stronger in one criterion, easy accessibility of multiple fractions, where the winning model lacks. The methods on the other models used to score higher on this criterion will be looked upon when working on improving and modifying the winning concept. The other two models will in this study be discarded for further development since they scored lower, but inspiration will be drawn from them when developing the modified San Sac concept.

5.7 Concept development and adaptation to the remaining requirements

Though the San Sac small package did come out on top, the chosen concept still does not meet all the required needs. With the said model as a basis, this study will try to come up with the changes needed for the model to meet the needs.

5.7.1 Gathering of measurements

San Sac does provide a PDF with measurements written out for a third of the small package shown in figure 12 (SANSAC, 2021, p. 1).

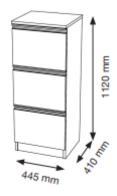


Figure 12 Picture of provided measurements (SANSAC, 2021)

The small package consists of three different models of cabinets shown in figure 13.



Figure 13 Picture of 51-418, 51-417, and 51-413 (SANSAC, 2021)

And the measurements of the different cabinets are provided in a document on their website. In this document, one can read that all the cabinets have the same measurements. Unfortunately, some of the measurements of the finer details are not provided, so this study will have to estimate those, e. g., the small panel at the bottom of the cabinets shown in figure 14. (San Sac AB, 2021)

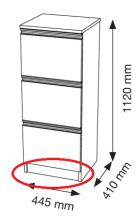


Figure 14 Picture showing the location of the small panel (SANSAC, 2021)

The rest of the measurements were obtained by measuring on a similar model built by San Sac available close by.

5.7.2 Computer-aided design of the chosen concept

To generate a design SolidWorks 2020 by Dassault Systèmes, a computer-aided design program, was used. The first step was to construct the "Small Package deal" with the provided measurements.

Figure 15 is showing renderings of the individual parts, while figure 16 shows the complete "Small Package deal".



Figure 15 Renderings of individual parts in the "Small package deal"

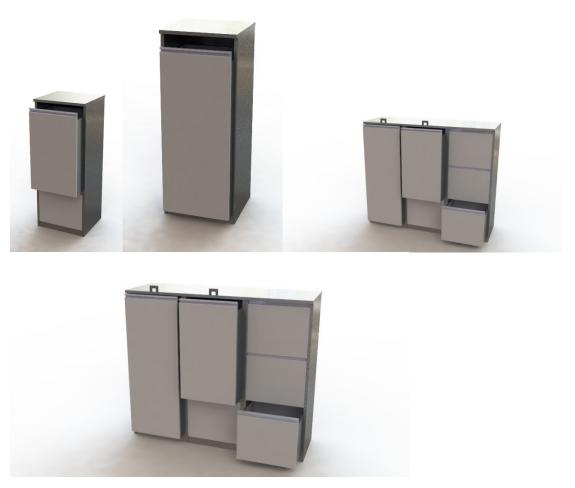


Figure 16 Renderings of the entire "Small Package deal"

Some limitations in the construction made some smaller details not accurate to their real-life counterparts, but the overall design and structure are in line.

The result from the Pugh-matrix¹ shows that, besides aligning with most of the needs, the chosen concept, the "San Sac Small Package Deal", is still lacking in the areas:

- Ease of use and maintenance.
- Container for liquids.
- Easy accessibility of multiple categories at once.

Meeting these needs directly is the main goal of the improvement and modification part of the study.

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¹ See table 5

5.7.3 Improvements and modifications

To meet the need for "Container for liquids" research of similar solutions was conducted. When asked about how they deal with liquids, in an interview with an employee at McDonald's Sweden, the interviewee said that they have a metal funnel that leads to a bucket which is later emptied into a drainage station.

With inspiration from that a solution for dealing with liquids in the current model of the recycling station.



Figure 17 Renderings of the solution for dealing with liquids

As seen in figure 17, the solution is based on the same principle as McDonald's. With a metal funnel underneath the liquid strainer leading down towards a hole in the side of the structure base. The hole leads towards the bottom part of the base, where a box has been designed to hold a bucket that collects the liquid, shown in figure 18. The design also minds maintenance, with the strainer being removable for easy cleaning, as well as having a roof to not collect rain if the station is located outside.



Figure 18 Render of the liquid container box

The discarding of liquids according to zero-waste is an entire area of itself, and most of the research regarding the topic focuses on MSW. So how to correctly dispose of liquids is not a topic for this study.

The remaining two requirements, "Ease of use and maintenance" and "Easy accessibility of multiple categories at once" were combined into one solution.

The changes made to the original concept were:

- Instead of having drawers, they were replaced with holes. The reason for this change was to make it more convenient for people to just insert waste and make the containers inaccessible for anyone except the ones responsible for maintenance.
- The front of each box was color-coordinated with the possibility to add decals to make it clear what fraction goes where making it clear for the user and the people servicing the station.
- The entire station could be opened with two doors at the back, possibly with a lock mechanism (not depicted in the renderings), this makes it possible to service the entire station all at once.

Figure 19 shows renderings of the entire station with the changes made.



Figure 19 Renderings of the station with the mentioned changes

5.8 Research question analysis

The research question that this part of the study was set out to answer is the following: "How can recycling stations be designed to help the cause of keeping the island a zero-waste zone?"

The results of gathered empirical data showed that recycling is a fundamental part of zerowaste and should be prioritised when attempting to exercise the philosophy. When designing a product that aligns with the philosophy there are several things to consider, since zero-waste is such a broad topic. This study concluded that if the product promotes and makes recycling easier, for the person discarding its waste to it being recycled, the product aligns with the ideas behind zero-waste. When re-designing a recycling station to follow these goals, which was further improved with data from interviews and observations, which resulted in a design that follows requirements that both users and service technicians suggested would help the ease of usage and maintaining.

6 Discussion

This part of the study contains reflections of the study and brings up possible sources of error. It answers questions that the reader might have after reading the study as well as bringing up proposals on further improvements and research.

6.1 Discussion of the first and second research questions

The results to answer the first research question regarding what requirements a zero-waste zone should has been summarized into three goals specific to a specified area maintained by an organization or company.

- Clarity of waste management
- · Setting a standard of reuse and recycling
- Monitoring waste and work towards prevention

These goals are based on the results from both the interviews and the literary study, which on its part is based on earlier research on the topic.

Since the results are based on a literary study as well as qualitative data gathering interviews one could argue that they are biased and trying to showcase a negative view of the subject. The goal of the study was to objectively view the subject and present how it is viewed at the time of writing. Whether the results are interpreted as positive, or negative is for the reader to decide.

The second research question regarding the role of recycling within a zero-waste zone showed that it is crucial and fundamental according to every source regarding the subject of zero-waste. The first step towards zero-waste is to bring awareness on how things are at the time being, including recycling. But one much-overlooked aspect of recycling is the step after we sorted the waste, what fractions of waste is possible to recycle in the nearby area. Since if the waste is sorted correctly into different fractions but it all ends up as fuel for incineration due to lack of other recycling options, the sorting was unnecessary in the first place. The different fractions to sort when recycling should be determined after research has been done on what is possible to recycle.

6.2 Discussion of the third research question regarding the design of a recycling station

The third research question was aimed at a design for a recycling station to be used within a zone that practices zero-waste and was conducted to give a brief example of how product design for zero-waste could be conducted.

To gather data for this part of the study, both observations, as well as interviews, were conducted for a qualitative data gathering purpose. This method was beneficial since not only did the data show the quantity of variation the design of a recycling station could have, but it also showed the reasoning why some specific design choices were made.

The finished design brought forth by this study could be found in *figure 19*. This concept was rendered from comparing popular models on the market today and then modify a selected one to meet all the required specifications that were the result of qualitative research on this topic.

6.3 Discussion of the literary study and proposals for further research on zero-waste

The study has, with tools such as a literary study and gathering of qualitative and empirical data, covered and answered the research questions with results that are coherent and are presented in an order that when read should give the reader enough information to understand the basis of the following parts. The topic that has been researched in the study is zero-waste with the goal of at the end the reader leaves with a broader and greater understanding of the topic and kindles a spark of interest of the topic that might lead to further research that could be more specific towards an area within zero-waste.

The gathering of qualitative data for the topic was through interviews. This was a highly effective way to get complementary data for the literary study, which resulted in a deeper understanding of the topic. Although this study tried to cover all bases of the top-level zero-waste thoughts and ideas that are used at the time of this studies writing, since this topic is still under development there is a chance of changes within the topic that would render this study not relevant in the future. Since that might be the case, the reader should have the time of this study's writing and do their own research on the state of zero-waste at that time.

The literary study based its results on research done within the topic earlier. The formats of the information were broad, research papers to books to articles etc., and since zero-waste is a branch out of the "environmental movement", where similar ideas are brought up that in the end work towards the same goal, a cleaner earth with goals of sustainability for generations to come. To keep the literary study within just zero-waste was a challenge, but none the less was it possible to achieve through restraining the subject to only be specifically concerning zero-waste without limiting it by including how the subject affects its surroundings.

7 Conclusions and further work

This part of the study contains the conclusions for the research question this study set out to answer. It also contains proposals on further research within the topic of each research question.

Waste is a growing problem today, especially in bigger cities. The subject of waste management is gaining popularity, and one of the stand-out philosophies within the subject is the one of zero-waste. This study was conducted to bring forth the requirements for a floating artificial island must meet to be considered a zero-waste zone according to the general perception of zero waste, as well as generate a concept for a recycling station to be used within the zone.

7.1 Conclusion of the research questions

To answer the first research question, "What requirements does the island have to meet to be classified as a zero-waste zone?", this study concluded that the requirements needing to be met by a zone claiming to exercise zero-waste to be able to be classified as a zero-waste zone are as follows. First, the important needs have been deemed to be additional clarity of waste management, setting a standard of reuse and recycling, monitoring waste, and work towards prevention. These goals in coherence with making it clear to both users and maintenance workers how waste is managed, make reuse and recycling the standard, and actively monitor the inflow of waste and take actions to minimize it will lead to the first of three goals being accomplished.

The answer to the second research question, "What role will recycling systems have for a zero-waste zone?, it was concluded with this study that the role of recycling systems will have for a zero-waste zone is setting a standard of reuse and recycling, monitoring waste and help work towards prevention of waste. This is a fundamental tool for the managing of waste.

The brought forth concept of a recycling station to answer the third research question, "How can recycling stations be designed to help the cause of keeping the island a zero-waste zone?", was customized according to fundamentals within the subject aligned with qualitative data from interviews with workers to help support the cause of keeping the island a zero-waste zone. This is through keeping the design practical for the maintenance crew and customized especially for keeping the zone a zero-waste zone.

7.2 Proposals of future research on the topic of zero-waste

Since the topic is still under development and is yet to have a governing body at the time of this study's writing, it should be mentioned that this study considers the difference regarding the definitions submitted by various people, organizations, and businesses doing the utmost to generalize impartially, to find commonalities and present them concisely. The results from this study could also be derived into goals regarding other areas concerning zero-waste.

7.3 Proposals of future development on the design of a recycling station according to zero-waste

Since this process was stripped down to essentials, further research is highly suggested to be conducted to generate more reliable results. As mentioned in the method and improvement chapters, the disposal of liquids is not included in this study. So that area could and should be more investigated when trying to get a more general understanding of zero-waste.

The concept brought forth of the design of a recycle station has potential for changes and improvement. Since this study was more about the topic of zero-waste, the product design was done with some estimates that could be replaced with more accurate values with the help of further research. Such research should be more aimed at following the traditional product development steps, to generate meet more needs that this study has brought up as well go through more testing to ensure that the final product both follows the zero-waste philosophy as well as meeting people's expectations on a recycle station.

7.4 Concluding thoughts

The three research questions that this study dealt with, the first two regarding the subject of zero-waste and its real world application, and the third one being a way to integrate the ideas of the subject into a project which in this study was a design of a recycling station, have been thoroughly answered in such a way to cover as much as possible while still leaving room for improvement since the subject is still under development.

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