Creating a sustainable and centralised internal waste logistics system for Oslo Airport

Master thesis Strategic Product Design TU Delft

Thomas van der Helm

Author
T.T.L. van der Helm

Master thesis
MSc. Strategic Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

Supervisory team
Chair: Dr. ir. Dam, S.S. van
Faculty of Industrial Design Engineering TU Delft
Department of Circular Product Design

Mentor: Ir. Mulder, S.S.
Faculty of Industrial Design Engineering TU Delft
Department Methodology and Organisation of Design

Company Mentor: Jonyer, R.
Circular Economy, Avinor Oslo Airport

PhD mentor: Tschavgova, E.

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TU Delft

Preface

Dear reader,

The realisation that you are reading this right now is very exciting. It means that this master thesis is finished and with that my study time has comes to an end. This thesis is the final deliverable of the master Strategic Product Design at Delft University of Technology, which I carried out from September 2022 until July 2024. It has been an exciting and educational journey and I proudly conclude it with this final project.

I want take the opportunity to express my gratitude towards my supervisors, to start off with Sonja and Sander. Sonja, as my chair, thank you for this opportunity and for your feedback, expertise and knowledge on circularity. Sander, as my mentor, thank you for your feedback, sharp questions and also your support, not only regarding my thesis but also support in my wellbeing and future career.

Next, I would like to thank Avinor. Rita, thank you for all the arrangements you made that made it possible to visit Oslo three times, to do research behind security at the airport and for your feedback and enthusiasm on my project. Also, Anette, thank you for your positivity, feedback and insights into Oslo Airport.

Also, I would like to thank Elisabeth. You acted as advisor, but also as a second mentor to me. You gave me a lot of good feedback, arranged a lot to make things happen and were always positive.

Then, I want to express my gratitude towards all involved stakeholders and specialists in this project. The employees from Avinor, the managers from the food & beverage operating companies, recycling company A, waste processing company A, security company A, the people from TULIPS and the employees from Rotterdam Central Station, Utrecht Central Station, The Mall of the Netherlands and Zuidplein shopping centre. Thank you all for taking the time and effort to share your experiences, insights, knowledge and collaborations.

Last, I want to take the opportunity to thank all the people that stood close to me during this project. First, I want to thank you, Maria and Sophie. It was great to do this graduation project alongside each other, share knowledge, travel to Oslo and do interviews together. Second, I want to thank my girlfriend for always being there and offering me the love and support, sharing thoughts and provided me comforting moments and joy. Third, I want to thank my parents, brother and the family of my girlfriend for the support during my study time, the brainstorming on ideas and sharing thoughts when needed.

All that remains is to wish you a pleasant reading of this thesis.

Thomas van der Helm
July 2024

Summary

This master thesis explores the design and implementation of a sustainable, centralised waste logistics system at Oslo Airport. The project aims to address the challenges of waste management in a high-traffic environment by creating a comprehensive product-service system. The focus is on enhancing waste disposal efficiency, ensuring proper waste separation, reducing waste and promoting circularity within the airport terminal.

The literature review, including qualitative research articles and other published texts, established a theoretical foundation for the project. Key themes from the literature include the importance of centralised waste management systems, the role of technology in waste logistics, barriers to keep in mind that could hinder the transition towards circularity, and the significance of stakeholder involvement in designing sustainable solutions. Semi-structured interviews and observations were conducted to gather insights from various stakeholders, such as food and beverage managers, waste collectors, and store employees at Oslo Airport. And also at other, similar locations. These findings underlined the critical need for a streamlined, efficient waste management system that can adapt to the operational complexities of a major international airport. The identified main problem area's at Oslo Airport were sub-optimal information provision regarding waste management, a lack in motivation among the people to reduce waste and recycle properly and logistical constraints within the airport infrastructure.

The primary research question guiding this thesis is: "How can a comprehensive product-service system be designed to establish a sustainable and centralised internal waste logistics system at Oslo Airport terminal?"

The design outcome of this project is a conceptual service design tailored for Oslo Airport. The proposed service includes a centralised waste disposal intervention in the form of container hubs placed throughout the terminal, a feedback system for improper waste separation, and a weighing solution for waste measurement, supplemented with a financial disincentive mechanism to stimulate waste reduction. The design leverages advanced technologies such as QR codes for traceability of the waste, cloud data storage, and Automated Guided Vehicles (AGVs) to enhance operational efficiency. The developed service provides a detailed visualisation of the service and its touchpoints, although further physical development and elaboration of certain components are required.

In conclusion, this thesis presents a strategic and innovative solution for waste management at Oslo Airport, emphasizing sustainability and efficiency. The findings highlight the need for further research to generalise the results across different contexts. Future work should focus on the scalability of the proposed system and addressing the technological dependencies to ensure robust and continuous operations. The project demonstrates the potential of a holistic, centralised waste logistics system to transform waste management practices in the aviation industry.

List of definitions

Term	Definition
Airside	Airport zone that is security controlled (also referred to as red zone)
AGV	Automated Guided Vehicle (a system of autonomous driving vehicles)
CE	Circular Economy
Commercial unit	An entity in the terminal hall that is used for business purposes (e.g. restaurant, shop, kiosk)
Compactor	A container that compresses waste into convenient bundles
SWMS	Solid Waste Management System
MSW	Municipal Solid Waste
EU	European Union
F&B	Food and beverage
Landside	Airport zone before the security check (also referred to as white zone)
PANT	Deposit on plastic bottles in Norway
PAYT	Pay As You Throw (a usage-pricing model for disposing waste)
Rp19	Returpunkt 19, one of the three waste stations at Oslo Airport
Rp20	Returpunkt 20, one of the three waste stations at Oslo Airport
Tenant	A business entity that rents space from Oslo Airport. See commercial unit
UNSØ	One of the three waste stations at Oslo Airport
Waste bin	Smaller waste collection units used at the commercial units
Waste stream	A specific waste type (e.g. residual, paper, organic, plastic)
WCA	Waste Composition Analysis
Wheelie bin	A container for waste bags that has wheels so that it can be moved easily
WP	Work package

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1 Introduction

The first chapter introduces the topic of this thesis, together with its objective. Also the main research question, the sub-questions and the project scope are defined.

1.1 Growing aviation sector

Back in 1903 the Wright brothers wrote history by creating and flying the first successful airplane (National Park Service, 2015). From that point onwards, aviation has grown enormously and has become a mature sector. The aircrafts today are better when it comes to fuel efficiency, comfort and quietness (Hinninghofen & Enck, 2006) and the aviation sector is fostering global connectivity. (McManners, 2015).

Commercial aviation is a global industry and is experiencing continued high growth. Many regions have aviation sectors that are growing rapidly, such as the Asian market. (Bows-Larkin et al., 2016; Grupo One Air, 2024). Besides, the air passenger demand is also growing (ICAO, 2023). The global aviation industry will continue to grow in the future. Likewise, Oslo Airport estimate that their number of passengers will increase from 20,1 million in 2022 to 29 million in 2030 (Avinor Oslo Airport, 2022). Initially, Oslo Airport already had 28 million passengers in 2019, but this decreased to 20,1 million passengers due to the Covid pandemic. Since the pandemic, passenger numbers are rapidly increasing again.

For that first flight in 1903, pollution barely mattered. However, the tide has turned and sustainability in aviation is more important than ever. Actions to innovate and implement sustainable practices in aviation must be taken to reach the sustainability goals for 2030 and 2050, as outlined by the European Green Deal (2023). The aim is to set the EU on the path to a green transition and achieve climate neutrality by 2050.

1.2 TULIPS

The EU funded TULIPS consortium, consisting of 29 parties led by the Royal Schiphol Group, contributes to the green transition by developing and implementing innovative solutions on airports. Together with its partners as shown in Figure 1 - knowledge institutes, airports, airlines and sector partners - TULIPS focusses on seven main challenges. Each challenge features one or more demonstrator projects, resulting in 17 demo's in total (TULIPS, 2022; Barras-Hill & Barras-Hill, 2021).

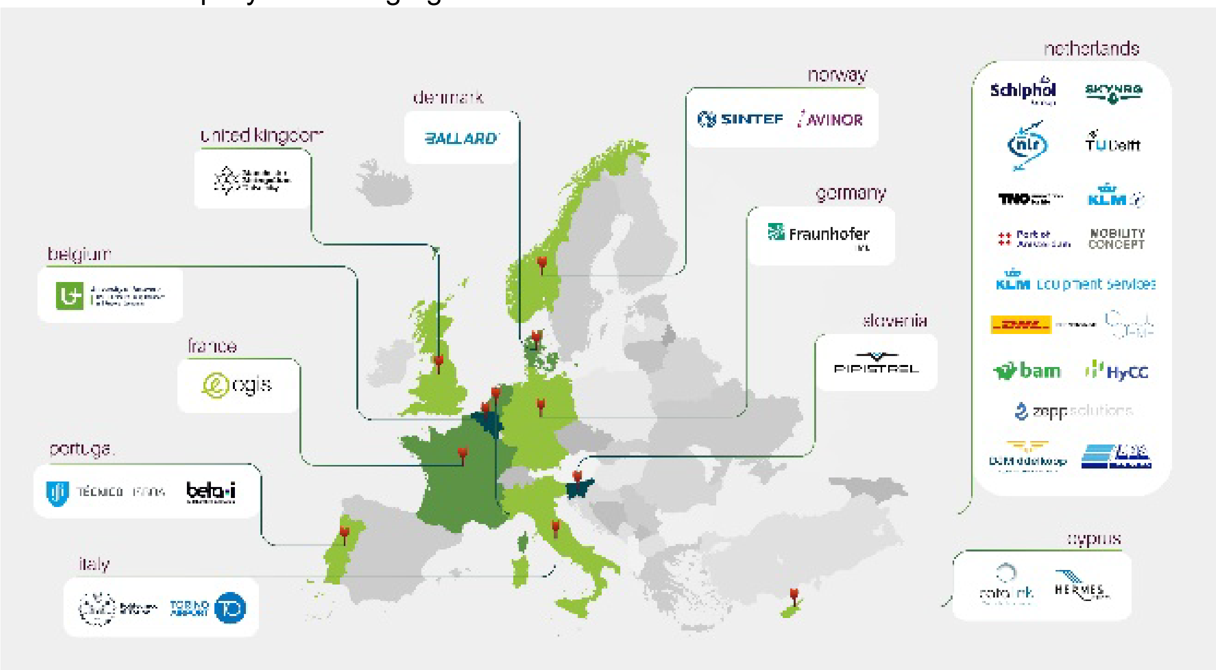


Figure 1: Partners from the TULIPS consortium (TULIPS, 2022).

The activities are organised in 12 WP's (work packages). This research project focuses on WP6: circular airports. Within WP6 there are three tasks defined:

1. Create a high-tech circularity measurement system in terminal to obtain reliable and detailed data.
2. Design waste out of terminal environment taking into account passenger behaviour.
3. Re-use secondary materials through the application of circular building principles.

WP6 has two focus areas, the operational material stream and the construction material stream. As mentioned, this research project focuses on WP6, but more specifically on the first focus area; the operational material stream. With its main objective being to reduce waste per passenger by 20% by 2024 in comparison with 2019 baseline (TULIPS, 2022).

It is inevitable to ignore waste reduction, because airports in general can be seen as big polluters, generating as much waste as small cities (Rizaldy et al., 2018).

According to Sebastian & Louis (2021) the increase in passenger quantity and the expansion of airport activities cause a rise in the waste that is generated and also the different types of waste. So, it is important that the passenger waste is not only reducing compared to the current context, but also reducing even more with the future growth of airports in mind. In fact, the goal for TULIPS is to move from 'reducing waste' (horizon 1: 2019-2025) towards 'zero waste' (horizon 2: 2025-2030) and eventually to a circular economy (CE), which is horizon 3 (2030-2050) (TULIPS, 2024). Also, see Figure 2 below for a visualisation of the 3 horizons from TULIPS.

Figure 2: The 3 horizons towards a circular economy. (Own figure, adapted from TULIPS, 2024).

1.3 Oslo Airport

Oslo Airport (IATA code: OSL (World Airport Codes, n.d.)), alternatively referred to as Oslo Gardermoen Airport is Norway's largest airport, located 35km northeast of Oslo. Oslo Airport is the designated location regarding WP6. This research project is focusing on a case study about the research and design of a sustainable internal waste logistic system for Oslo Airport.

Oslo Airport is operated by Avinor, which is a state-owned company that operates most of Norway's civil airports (The Avinor Group - Avinor, n.d.). More than 13.000 people work at Oslo Airport, employed by over 300 companies, of which 100 companies are operating in the terminal. Regarding Oslo Airport's zero waste ambitions, the aim is to reduce the total amount of waste by 50% by 2030 related to the daily operations, compared to 2022 (Avinor Oslo Airport, 2023).

In order to increase their circularity in waste management Avinor Oslo Airport applies the R9 framework (Avinor Oslo Airport, 2023). This framework helps Avinor determining which circularity strategies are more appropriate to reduce the consumption of resources and materials and the generation of waste (Potting et al., 2017). This framework is also adopted by TULIPS. A visualisation of this framework is shown in the Figure 3.

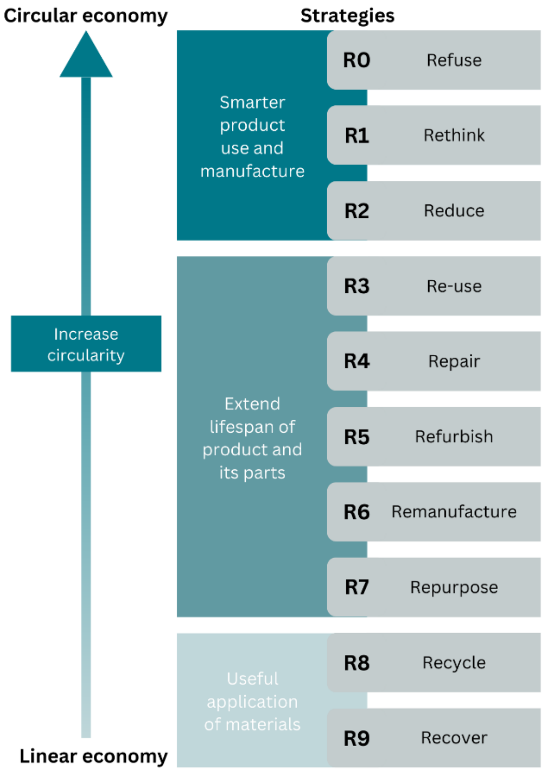


Figure 3: The R9 circularity framework. (Own figure, adapted from Potting et al., 2017).

1.4 Design brief

To conclude the introductory part of this research, a design brief is set up. The problem definition, project scope and research questions are part of the design brief.

1.4.1 Problem definition

The current waste management system at the terminal of Oslo Airport is marked by fragmentation, involving over 100 actors across more than 60 commercial units. This leads to inefficiencies, frequent changes in transporters, and a lack of standardised procedures. Further, there is an unequal distribution of waste collection personnel to collect the waste of the commercial units; for some units their waste gets picked up and some units are on their own when it comes to bringing their waste to the waste station.

Furthermore, according to the defined waste targets by the European Commission (2023) and the EU waste laws (EUR-Lex, 2022) all the waste reduction is going to be measured by weight. Adapting to these new legal requirements, such as weighing specific waste fractions per unit, arises questions like how will weighing technology be implemented and how will waste weighing fit in the operational procedures. These requirements should be taken into account when a comprehensive and centralised service is designed.

Next to that, the working conditions and job appreciation of waste collectors and handlers should be taken into consideration. Despite the great social and environmental relevance of waste collectors, they have been historically marginalised for exercising a profession associated with low educational levels and economic status (Belarmino et al., 2022). People looking down on waste collectors can indicate exclusion and devaluation, which could eventually lead to undermining the effectiveness in creating moral worth and maybe also the disruption in work practices (Hughes et al., 2016).

1.4.2 Project scope

In order to set the scope for this project, it is good to understand airport terminology. The terminal building is divided into a part for arrivals and a part for departures. Next to that, there is a separation into the white and the red zone. The white zone, or landside, is the side of an airport terminal to which the general public has unrestricted access. The red zone, or airside, is the security restricted area of the terminal (Westwood, 2024).

Since the commercial units at the terminal are on both sides of the security check, both zones are within the scope. The white and red zone together can be treated as 'the terminal'. Also, no distinction is made between arrivals or departures.

As mentioned in paragraph 1.2, the focus of TULIPS WP6 lies on two material streams; one operational and one construction.
Only the operational material stream is within the scope of this project. To further define the scope, this project focuses on the terminal building, not the material streams coming from aircrafts or other buildings at the airport. The reason for this is because approximately 64% of all airport waste comes from the terminal (Kadibu & Jonyer, 2022), so making impact there is considered most valuable.
To conclude, the scope of this project is defined as: waste generated by commercial activities by the commercial units in the entire terminal building.

1.4.3 Stakeholder overview

In addition to the project scope a stakeholder overview is made. This project is complex due to many involved stakeholders in the waste management at Oslo Airport. Figure 4 below gives an overview of all the relevant stakeholders in this project, together with their power and interest.

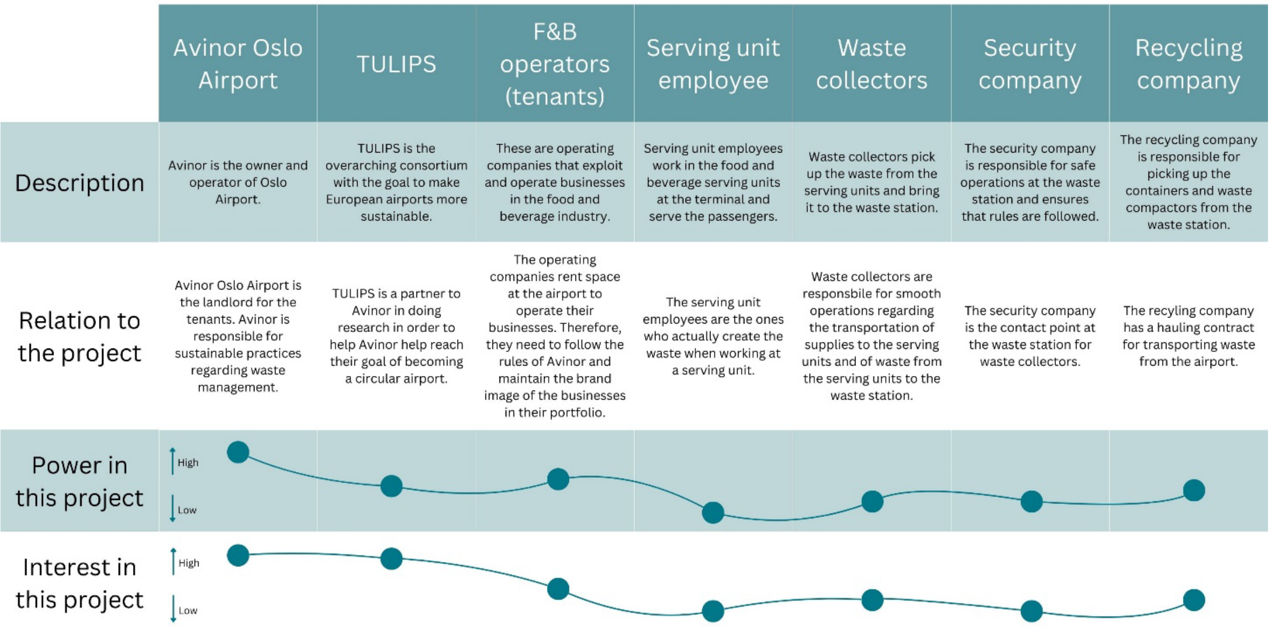


Figure 4: Overview of the relevant stakeholders in the waste management at Oslo Airport. (Own figure).

1.4.4 Project aim

Since this project is complex due to the many involved stakeholders, as described in paragraph 1.4.1, this design challenge asks for a strategic solution. A solution that not only suits the current problems, but one that is also sustainable and future-proof.
The aim for this project is to investigate and design a functional, centralised waste logistics system for Oslo Airport, that ensures proper waste disposal and separation, a feedback system for improper waste separation and a weighing solution to weigh the waste. In addition to this, the aim is also to provide a service blueprint for educating the involved stakeholders in the waste management and emphasis on circularity.

1.4.5 Research questions

This graduation project focuses on sustainable internal waste logistic system at Oslo Airport terminal by mapping the complex stakeholder environment and designing a product-service solution for circular operations of the waste management. The main research question for the project is defined as follows:

"How can a comprehensive product-service system be designed to establish a sustainable and centralised internal waste logistics system at Oslo Airport terminal?"

In addition to the main research question, seven sub-questions are defined to help answer the main research question:

1. How can a centralised service function in the daily operations, including pickup times and routes?
2. What do commercial units need in terms of waste disposal and warehouse logistics?
3. What is the necessary equipment for the waste management system?
4. How can a human-centred approach break the siloes of the current logistical process?
5. How can design contribute to emphasizing and elevating the significance of waste handlers' roles?
6. How can a feedback system be integrated to test the effectiveness of the designed waste logistics system?
7. How can the insights from this project be applied to realise and implement the proposed outcome?

2 Approach

This chapter describes the approach for this project. The overarching framework, together with the main design principle and used methods are highlighted.

2.1 Overarching framework

In this project, a triple diamond framework will be used as overarching framework, because this is a clear, comprehensive and visual description of the design process. This framework helps exploring the context deeply (divergent thinking) and then taking focused action (convergent thinking) (Design Council, n.d.).
A triple diamond model is an iteration on the existing double diamond model. The double diamond model, adopted from Design Council, n.d., is a helpful framework to guide the co-creation process by separating the work into four distinct phases:

1. Discover: problems are explored, insights and user needs gathered and ideas generated.
2. Define: problems are defined and refined, providing a framework.
3. Develop: solutions are created and explored.
4. Deliver: the service is tested and evaluated, rejecting parts that do not work and improving on those that do.

The discover and develop phase are divergent thinking, while the define and deliver phase are convergent thinking. See the figure below for a visualisation of the framework.
The triple diamond introduces a new diamond in between the two existing diamonds: solution discovery. With that, the discovery phase in the double diamond is split up into two diamonds as follows:

1. Problem discovery: problems are explored and opportunities are defined.
2. Solution discovery: solutions are explored and the objective is framed and refined if needed.

At the beginning of the project, before going into the problem discovery, the scope of the problem is set. And in the end, after the development phase, the solution is finalized and possible recommendations are made. A visualisation of the triple diamond framework is shown in Figure 5.

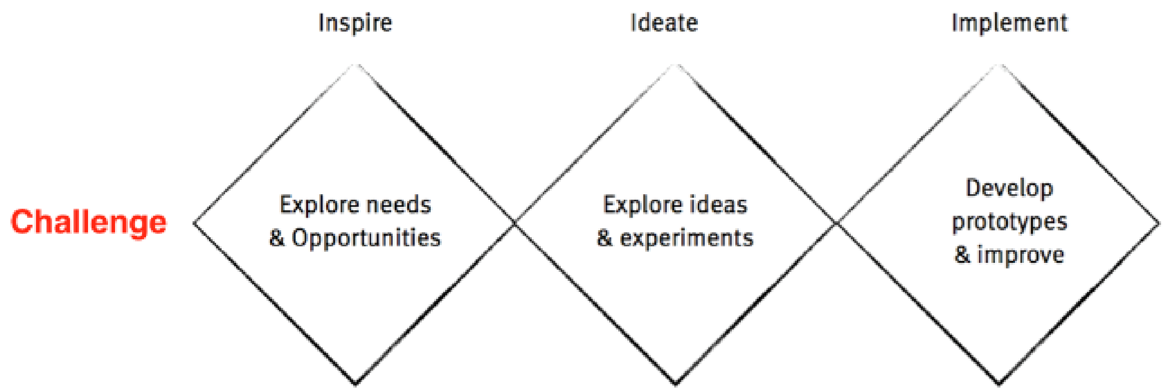


Figure 5: Visualisation of the triple diamond model (Design Thinking by Doing, 2018).

2.2 Design strategy

The design strategy, applied in this project so called co-creation. Co-creation is a principle that uses the perspectives, creativity and knowledge of the stakeholders during the process (Ramaswamy, 2014). By doing that, the design outcomes meet the needs and wishes of the stakeholders and the designer is able to gain a more holistic view of what the solution should include ((Interaction Design Foundation - IxDF, 2021). Stakeholders can be users of a product or service, experts or other non-designers (Van Boeijen et al., 2021). Co-creation will be woven into this graduation project at all stages, from research and exploration, to designing and testing.

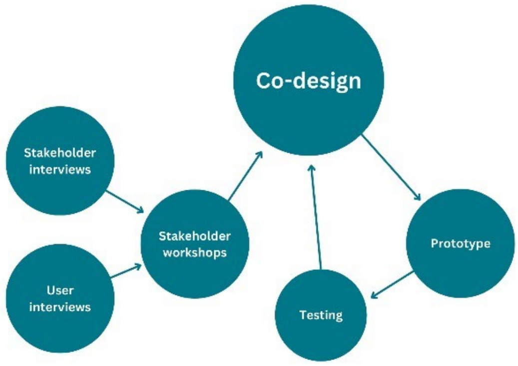


Figure 6: Co-design approach visualisation. (Own figure, adapted from Van Boeijen et al., 2021).

As shown in Figure 6, stakeholder interviews and user interviews will act as input for stakeholder workshops. Those workshops, together with the testing feedback of a prototype, will be the fundament of co-creation.

2.3 Methods

In order to implement the overarching triple diamond model and give substance to co-creation, various methods are used.

2.3.1 Literature review

To be able to define the scope and to get an understanding of this project, literature review is one of the used methods. An integrative approach is used within the literature review. Which means, according to Snyder (2019), that the main purpose is to assess, critique, and synthesise the literature. To elaborate further on this, the aim is to gain an overview of the knowledge base, to critically review and potentially re-conceptualize, and to supplement on the theoretical foundation already existing. The literature will be extracted from (qualitative) research articles, books and other published texts. The insights from the literature review can be found in chapters 2 (the project context) and 3.7 (the project exploration).

2.3.2 Semi-structured interviews

In addition to literature review to define the scope, interviews with stakeholders are used as method for this. Semi-structured interviews are also qualitative research and help discovering the occurring problems and user needs, and to gain insights.
Semi-structured interviews are used for data collection, using questions within a fixed theme, but the phrasing or order of the questions are not fixed (George, 2023). By doing this, the interviews can be used as an explorative tool, which helps investigating different parts of the research question.
Using semi-structured interviews makes it possible to cover relevant topics, while maintaining an open style of conversation with the interviewees. An overview of the details of the interviews can be found in Table 1.

Table 1: Overview of conducted interviews.

Organisation	Function	Duration
F&B operator A	Food & beverage manager	1 h.
F&B operator B	Quality & sustainability manager	1 h.
Oslo Airport serving units	Store employees (35x)	5-10 min.
F&B operator B	Waste collector	10 min.
Serving group A	Waste collector	5 min.
Waste processing company A & Recycling company A	Sales manager & account manager	1,5 h.
Rotterdam Central Station serving units	Store employees (5x)	5-10 min.
Rotterdam Central Station ICS group	Waste collector	20 min.
Westfield Mall of the Netherlands serving units	Store employees (6x)	5-10 min.

Zuidplein shopping centre serving units	Store employees (4x)	5-10 min.
Utrecht Central Station	Store employees (3x)	5-10 min.

The insights of these semi-structured interviews can be found in chapter 4, the explorational phase of this project, while the transcripts can be found in appendix B.

2.3.3 Observations

Next to interviews, several observations were performed. While an interview is a good method to discover what people think and say, observations are a real good qualitative method to discover what people actually do. Observing users of products or services and operational systems can highlight intended and unintended scenarios, which can lead to better understanding of what makes a good service experience (Van Boeijen et al., 2021). The observations also help in the discovery of user needs and challenges in the user context. The outcomes of the observations can be found in chapters 2 (the project context) and 3.7 (the project exploration).

2.3.4 Best practices

In addition to literature review, an analysis of best practices will serve as qualitative research method in this project. Using best practices as a method will enable the generalisation of findings across various cases, thereby enhancing the understanding of phenomena. In this graduation project, best practice analysis is used as method for exploration of existing interventions and contexts. Such as, waste management at other airports, at other public places, and also designed interventions related to centralised waste management.

Ultimately, the aim is to derive insightful conclusions coming from empirical evidence and practical examples (Heale & Twycross, 2017).

2.3.5 Co-creation workshop

Within the main approach of this project, being co-design, co-creation workshops will serve as a specific method to strengthen the co-design approach. Since co-creation will be integrated into the whole graduation project, a specific workshop will serve as a self-contained method that can serve as an accelerator or pressure cooker environment. A co-creation workshop is a session where relevant stakeholders are provided with (design)exercises to gain insights, understanding and to build a fundament towards a solution.

2.3.6 Customer journey map

The aim of this project is the creation of a service blueprint and to develop a product-service system. For that reason it is evident to make use of customer journey mapping. This method is an appropriate way to discover and map the user experiences and stakeholder needs at every action, experience or touchpoint in the system.

2.4 Argumentation

In considering the approach and methods as described above, it is important to recognise potential limitations that may arise. While involving stakeholders in the entire process through co-creation is beneficial for gathering diverse insights and perspectives, it can be time-consuming and resource-intensive. Conducting co-creation workshops and ensuring meaningful participation from the relevant stakeholders can be challenging due to the international character of this project and in addition, not being present on site at all time.

However, despite these potential challenges, the chosen approaches and methods are considered as suitable for this project due to their strengths. Co-creation methodologies are crucial for creating relevant outcomes and solutions, and effective by incorporating insights from diverse stakeholders. The triple diamond framework offers a logical structure for navigating the design process systematically. In addition, the combination of methods such as literature review, interviews, observations, case studies, co-creation workshops, and service blueprint design ensures a comprehensive approach for this project.

To conclude the approach section of this project, an overview is shown in Figure 7. This overview shows the overarching triple diamond framework with the co-creation methods woven into it.

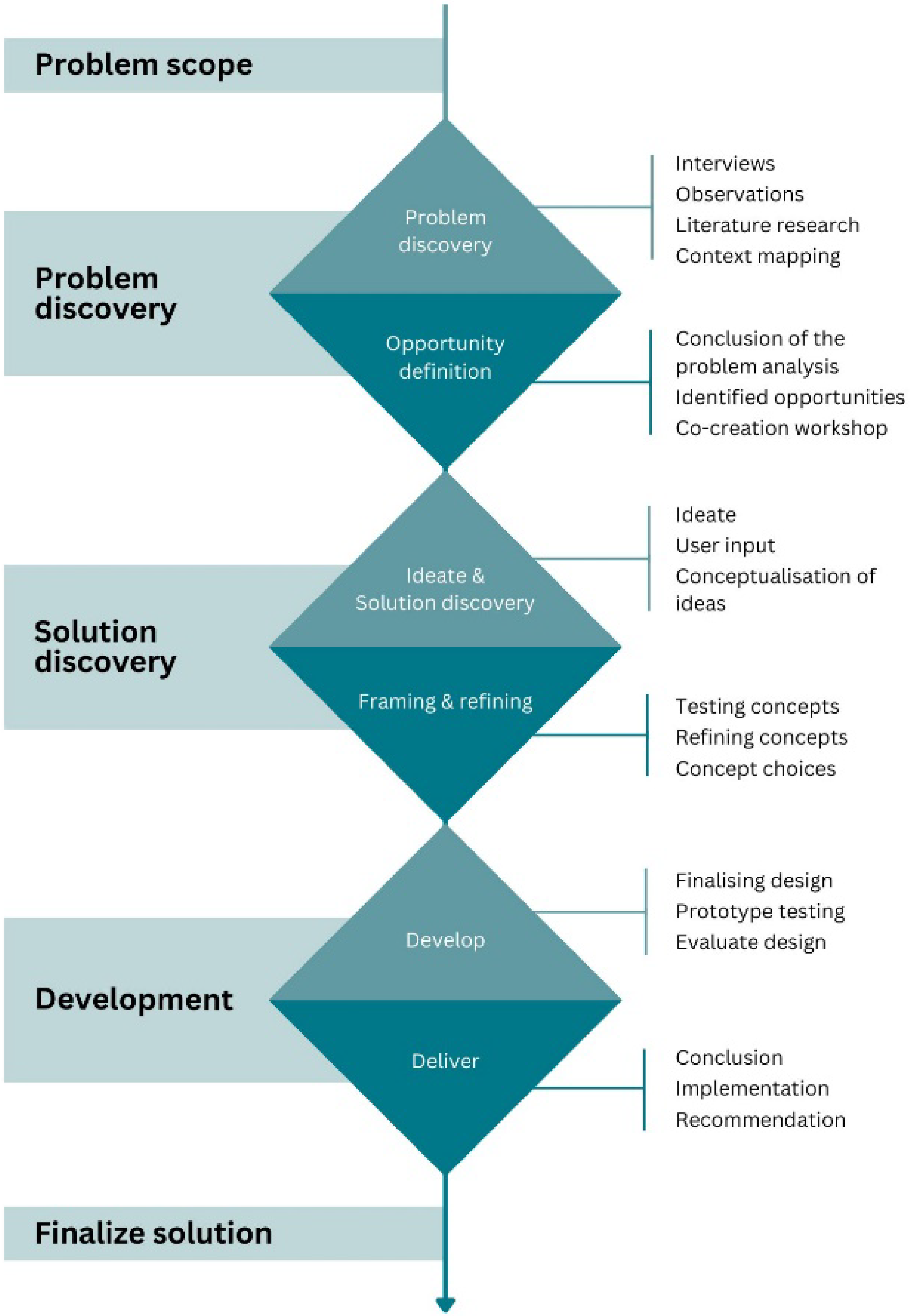


Figure 7: Triple diamond framework applied to this project. (Own figure, adapted from Design Council, n.d.; Design Thinking by Doing, 2018).

3 Context

In this chapter, the context of the project is discussed. To understand a centralised waste system, the definition of waste management will be elaborated and the details of waste management at Avinor will be highlighted. Also, the organisational structure with involved actors in the waste system at Oslo Airport will be analysed, as well as the organisation of the terminal and the composition of the waste.

3.1 Waste management

First, the waste management will be discussed. A waste management system in general involves overseeing all responsibilities, practices, procedures, processes, and resources to establish a system that effectively manages waste and complies with environmental regulations (Elsaid & Aghezzaf, 2015). Moreover, according to Elsaid and Aghezzaf (2015) 'A solid waste management system (SWMS) includes the generation of waste, storage, collection, transportation, treatment, processing, recycling and final disposal of garbage, sewage and other waste products.'

Airports, as substantial waste generators, ought to establish a comprehensive waste management system, encompassing waste reduction, reuse, recycling (3-R), as well as treatment and disposal (Dimitriou & Voskaki, n.d.).

3.1.1 Barriers

In order to design and implement a waste management service at a terminal or to implement circular economy practices at an airport, it is important to know the barriers or retentions. Kirchherr et al. (2018) describe the limited progress regarding implementation of the CE concept, despite its attention by the EU. Currently, CE is still a concept only being discussed by sustainable development experts and because of that it is missing the momentum it needs. The reason for this is that there are barriers, or certain retention points, that hinder CE. Kirchherr et al. (2018) discovered four main overarching barriers on CE, being: cultural, regulatory, market and technological barriers. While, against the expectations, technological barriers are not the most critical barriers. "We find that cultural barriers, particularly a lack of consumer interest and awareness as well as a hesitant company culture, are considered the main circular economy barriers by businesses and policy-makers" (Kirchherr et al., 2018). To extend to this, Salmenperä et al. (2021) also state that CE, specifically in waste management, is mainly hampered due to cultural, regulatory and market factors and not because of technological barriers.

Cultural related barriers

Company culture revolves around shared beliefs, values and practices of the people within an organisation (Hernández-Mogollón et al., 2010). Grugulis and Bevitt (2002) state that barriers in company culture must be resolved if a company want to innovate. Cultural barriers can be caused by lack of training, lack of motivation, lack of ability or other underlying problems (Grugulis and Bevitt 2002).

This can result in lack of communication and cooperation between key stakeholders (Salmenperä et al., 2021).

Regulatory related barriers

According to Allah Rakha (2023) lack of development of a circular economy can also be caused due to regulatory barriers.

Those barriers are about lack of clear policies and regulations, limited incentives for waste reduction and recycling, inconsistent standards for waste management, legal and financial barriers and lastly the difficulty in tracking and measuring waste. Overcoming these retentions is crucial in order to develop sustainable practices and a circular economy.

Market and economic related barriers

Next to cultural and regulatory barriers, market or economic barriers can also impact the development of circular economy. Market and economic barriers entail market uncertainty, high investment costs, the lack of economic incentives (Salmenperä et al., 2021). In addition to this, there is often a lack of data that can facilitate the calculation of economic benefits.

Main takeaways

- A waste management system should be a holistic system that includes generation, storage, collection, transportation, processing and recycling of waste. The service at Oslo Airport should also be approached holistically.

- The waste management service should tackle the circular economy barriers. Those barriers include the lack of training or motivation (cultural), the lack of clear regulations or incentives (regulatory) or high investment costs (market).

3.2 Current waste practices at Oslo Airport

To gain insights in the operation efficiency observations were done and interviews were conducted at the terminal of Oslo Airport and waste station Rp19.

In order to design a service blueprint and to create a centralised waste system, it is important to understand the journey of the waste. Where, how and by whom is waste created? Where and how is it stored? When, how and by whom is it transferred? These questions mainly look at the current situation at Oslo Airports waste management. The current flow of waste that is created by the commercial units is mapped in a flowchart and can be seen in Figure 8.

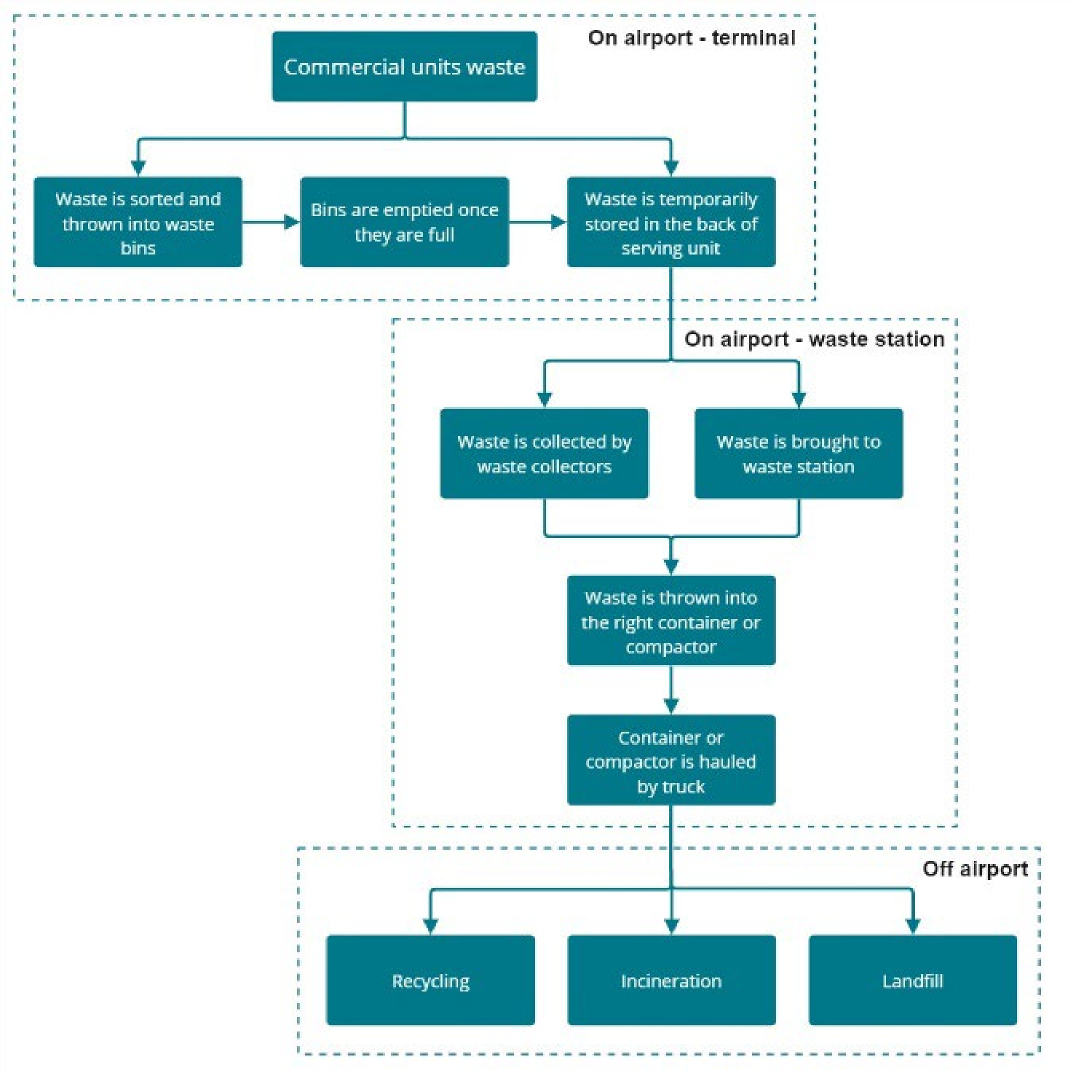


Figure 8: Flowchart of the waste coming from commercial units at Oslo Airport. (Own figure, adapted from Kadibu and Jonyer, 2022).

One step in Figure 8 is the waste being picked up by waste collectors. In Figure 9 one of the inventions that is used for this can be seen. In Figure 10, other self-created solutions are shown. The options that are currently used to transport waste from the commercial units to the waste stations, are using motorised pump trucks with either a pallet, crate, box or cage on top of it. It can be concluded that a standard configuration, product or invention is missing to collect waste at Oslo Airport. This should be taken into account when designing a centralised waste management system.

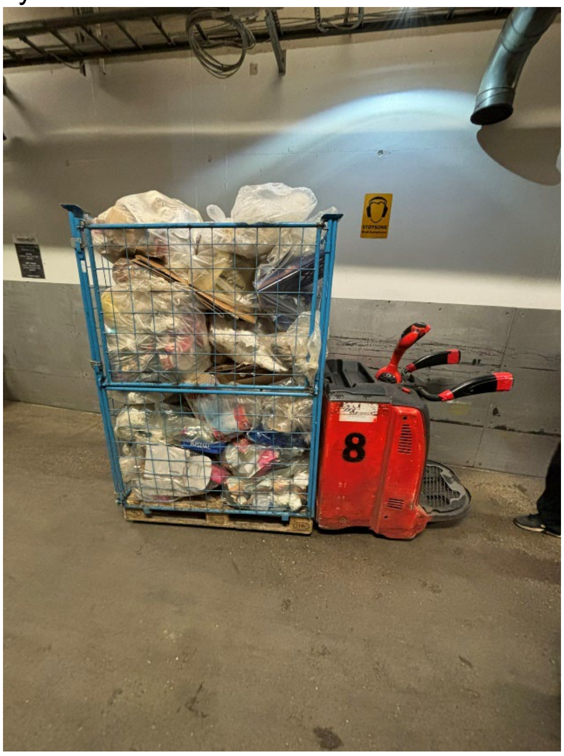


Figure 9: A motorised pallet truck that is used to transfer waste from the commercial units to the waste stations. (Own figure).

Figure 10: Other motorised options to transfer waste from the commercial units to the waste stations. (Own figure).

Another remark in the current waste flow is about separating the waste. The commercial units are expected to separate the waste at their units into bins that contain waste bags. Next, when the waste collectors from the F&B operators come by, the bags of the different types of waste are collected into one of the pallet trucks, as described above, altogether. Subsequently, the waste is separated again at the waste station to throw it into the right container.

According to Avinor's circular economy analyst (personal communication, February 27, 2024), Oslo Airport used a vacuum system for the transportation of waste from the terminal hall to the waste stations in the past, however the system is not in use anymore. The reason for this is occurring maintenance, due to misuse and the old age of the vacuum system. Another reason

are the high costs of electricity to keep the system running.
Figure 11 shows the endpoint of the vacuum system, connected to a container where the waste ends up.

Figure 11: The endpoint of the vacuum system that was used in the past at Oslo Airport for waste collection and transportation (Avinor Oslo Airport, 2024)

The vacuum system is only suitable for closed waste bags. When staff throws in other types of waste, the chance of malfunctioning is high. The hatches where staff could throw the waste is displayed in Figure 12. These hatches are located throughout the terminal and are connected to the system. Additional images, including the whole tube network, can be found in appendix H.

Figure 12: Hatches of the vacuum system that was used in the past for waste transportation at Oslo Airport. (Own figure).

Regarding solution exploration, it is good to keep the vacuum system in mind for a centralised waste management system. The infrastructure for the vacuum system is already existing and can therefore act as part of the waste management at Oslo Airport.

Main takeaways

- A standardised solution for waste collection and transportation at Oslo Airport is lacking and should be designed.
- The service should prevent that waste is being separated at the commercial units, then collected and transported altogether and in the end separated again at the waste station.
- Despite its challenges, the vacuum system remains a potential component for a centralised waste management system, leveraging existing infrastructure for enhanced efficiency.

3.3 Organisation structure

The terminal of an airport is a small city on its own with multiple operations happening and a diverse range of shops and restaurants. The landside of the terminal accommodates ticketing offices for airlines, check-in counters, packaging counters, restaurants, cafés, retail outlets and more. On the airside of the terminals, beyond the security checkpoint, there are duty-free shops, break rooms for airline and airport staff, eateries, and restrooms. (Sebastian & Louis, 2021).

To get a better understanding of the organisational structure of the commercial units at Oslo Airport terminal, the current structure is elaborated below.

In total, the waste management system at Oslo Airport includes more than 100 actors in 60 commercial units, consisting of 22 shops, 44 serving units & kiosks and 1 service provider (Avinor Oslo Airport, 2023). The entity commercial unit is being used as all-encompassing term for all the restaurants, kiosks and shops. The direct contact between employees and passengers happen at the commercial units.

To operate a commercial unit at the terminal at Oslo Airport, a place can be won by bidding on a tender round and winning the tender contract. These tender rounds are being held every five years. The terminal, therefore, can be seen as a landlord that rents out the available space.

The entities that are bidding on those tenders can be individual entities, but can also be F&B (food and beverage) operating companies. An F&B operator exploits and operates 'brands' from their portfolio at the airport. Brands in this context can either be restaurants, kiosks or other serving units. Once an F&B operator wins a tender contract, they can fill up their won terminal space with their brands. These are serving units that they operate under franchise (for example serving unit 31 is part of F&B operator B's brand portfolio), as well as their own brands (L. Thoresen, personal communication, March 22, 2024).

It is also possible for individual businesses to enter the tender rounds. They are not part of an F&B operator and they are therefore responsible for supplying their own store and bringing their waste to the waste stations, while the F&B operators have personnel to do this for the commercial units. In Figure 13, the structure between the airport and tenants, together with the revenue streams, is visualised. This visualisation is displayed enlarged in appendix D.

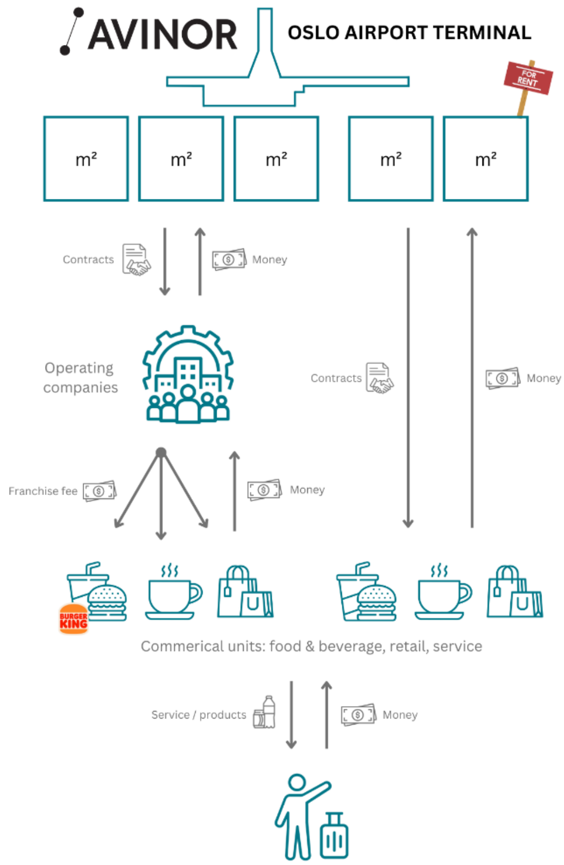


Figure 13: Revenue streams and organisational structure of tenants at Oslo Airport. (Own figure).

As mentioned, there are 70 commercial units currently. Almost two-thirds, 57 shops, are being operated in groups, while the other 14 shops are operating on their own. Within the groups, F&B operator A, B and C are F&B operating companies who operate brands from their portfolio, while the other groups are branded stores.

The groups are composed as follows:

- F&B operator B: 28 commercial units
- F&B operator A: 9 commercial units
- Serving group A: 4 commercial units
- F&B operator C: 3 commercial units
- Serving group B: 3 commercial units
- Serving group C: 2 commercial units
- Serving group D: 3 commercial units
- Serving group E: 5 commercial units

Below, in Figure 14, a map of the arrival hall in the terminal of Oslo Airport can be found with the locations of commercial units from F&B operators A and B.

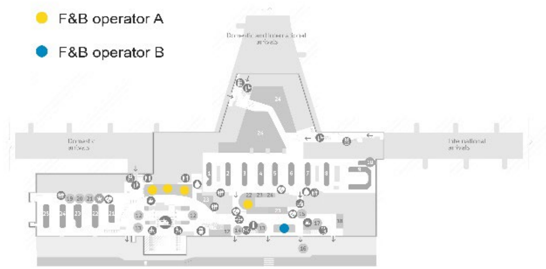


Figure 14: Commercial unit locations of F&B operators A and B in the arrival hall. (Own figure, adapted from Avinor Oslo Airport, 2024).

In Figure 15 below, the same overview can be found for the departure hall. In the departure hall, F&B operator C is also active as operator. See confidential appendix B for a full-size version and additional maps in which each F&B operator is highlighted separately.

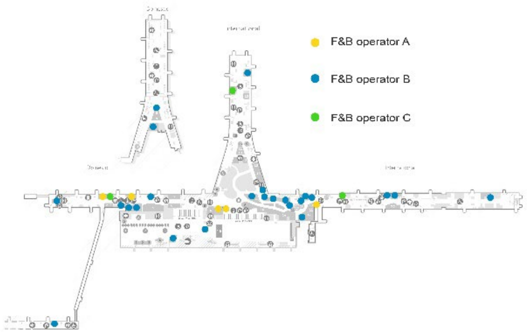


Figure 15: Commercial unit locations of F&B operators A, B and C in the departure hall. Own figure, adapted from Avinor Oslo Airport (2024).

The F&B operating partners are, especially in the departure hall, spread out. F&B operator B for example, operates commercial units in every corner of the terminal; from the international wing to the domestic wing and even a kiosk in the south pier that contains the B-gates.

When looking at the powers and responsibilities, it is important to keep in mind that the involved actors must work collaborative and that the responsibilities are clear. According to F&B operator B Group plc (2023), they make use of the waste facilities at the airport, but do not have the ownership. "As a business operating within client locations, where we do not have direct control over (food) waste collection systems and waste management facilities, this work requires close collaboration with our airport clients."

On the other hand, Avinor is concerned with reducing its own environmental impact and sharing knowledge and best practices with partners and tenants (Avinor Oslo Airport, 2023). By stating that Avinor and the tenants can contribute together to a more sustainable circular future, it indicates that Avinor Oslo Airport provides the guidance and tools that the tenants need in their waste management.

In addition to this organisation structure paragraph, an overview of the stakeholders is provided in paragraph 1.1.

Main takeaways

- The waste management system at Oslo Airport involves many actors which should all be taken into account when designing the service.
- Avinor, as owner of Oslo Airport, can be seen as the landlord. The space for commercial activity is rented out to tenants every 5 year via a tender round.
- Of the 70 commercial units at the terminal, 40 are operated by F&B operating companies. The others are operating individually or in groups when a company has multiple locations at the airport.
- Collaboration between Avinor and commercial tenants is essential for effective waste management. The responsibilities and powers should be clearly defined in the waste management service.

3.4 Terminal structure

In addition to the organisational structure, it also important to understand the structure and physical routings of the terminal. By analysing this, an overview where waste is created is provided. As mentioned in paragraph 1.4.2 the scope that is used for this project is the waste stream coming from the tenants in the terminal.

The terminal of Oslo Airport consists of three main floors: the parking area, storage rooms, corridors and waste stations are in the basement, the arrival hall is on the ground floor and the departure hall is on the first floor. As shown in Figure 16, the terminal is made up of three main piers (north, east and west) and a smaller south pier. The west and south piers are used for domestic flights, while the east pier is used for international flights. The north pier can be configured to accommodate either domestic or international gates. An enlarged image of this overview of the terminal structure can be found in appendix E.

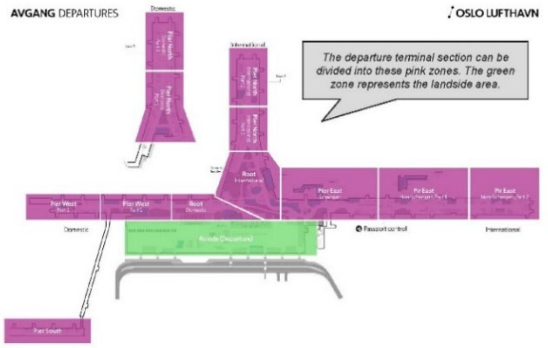


Figure 16: An overview of the departure hall of Oslo Airport (Avinor Oslo Airport, 2022).

Basement of the terminal

In the basement, connected with goods elevators to the other floors, three stations for bringing waste and goods receival are situated. These waste stations, the so called Returpunkten, are the designated connections between the tenants and the 'outside world' for supplies and waste. At those places waste containers are picked up and hauled by trucks and supplies (food, beverages and other non-food items) are delivered.

A map with the goods elevators and the three waste stations can be seen in Figure 17.

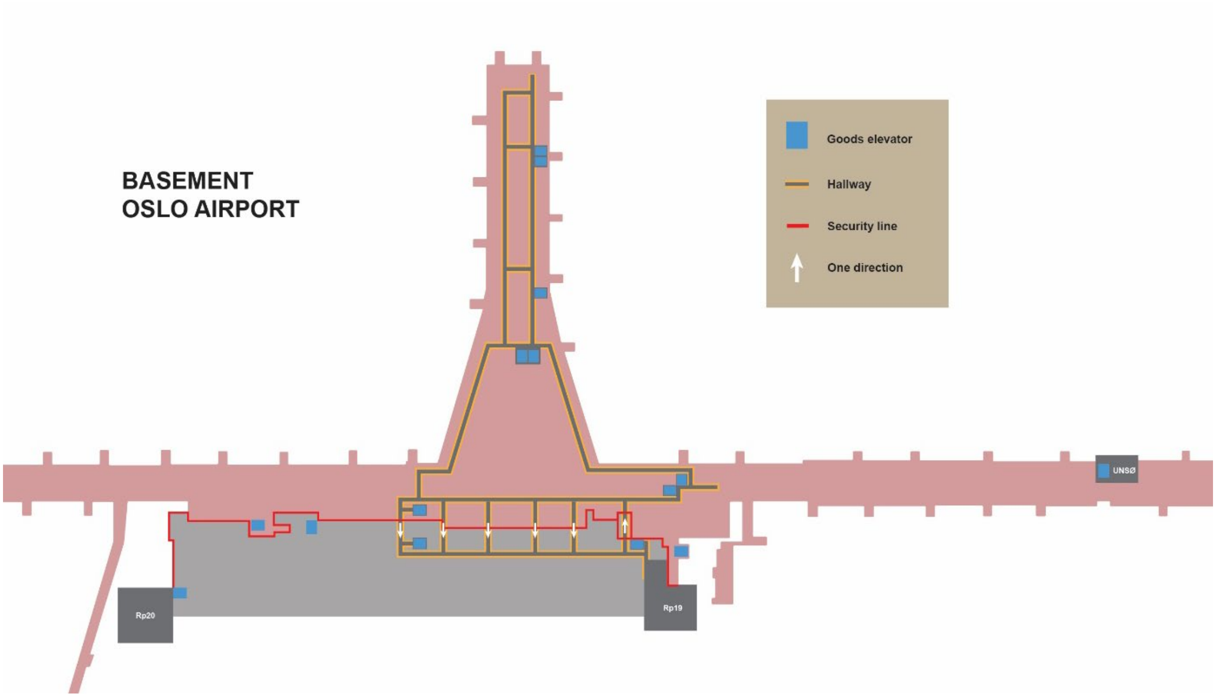


Figure 17: Overview of the waste stations and goods elevators at Oslo Airport terminal. (Own figure, adapted from Avinor Oslo Airport, 2024).

According to Avinor's Circular economy analyst (2024) the three waste stations differ in size and usage:

- Rp20 is mainly used for construction waste. Around 12% of all waste is collected here.
- Rp19 is the most used waste station, as around 85% of all waste is collected here.
- Rp19U (UNSØ) is a small waste station, behind the security border. Around 3% of all waste is collected here.

According to a waste collector from F&B operator B (personal communication, April 4, 2024) there are several reasons why Rp20 and UNSØ are used less to collect waste than Rp19:

- There are not as many waste separation possibilities as in Rp19, this is especially the case for UNSØ. At that waste station it is only possible to bring PANT bottles, residual waste, paper waste and food waste.
- Rp20 and UNSØ are not connected to the basement hallway system and therefore do not include a security control point where incoming goods can be checked. An overview of this hallway system is displayed below in Figure 17**Fout! Verwijzingsbron niet gevonden.**.
- Rp20 and UNSØ are only accessible by one elevator. If that one elevator is out of order then you can not get to the waste stations. Rp19 is reachable via multiple elevator, since these are connected to the hallways in the basement.
- Rp19 is seen as the centre of the terminal, while Rp20 and UNSØ are seen as 'far away'.
- Rp19, but especially UNSØ , are not known well by tenants and the waste collectors.
- The elevator going to Rp19 is only reachable via the white zone in the departure hall. That means that staff with a forklift needs to drive through passengers, this is forbidden during working hours or busy moments during the day. This means that the accessibility with a forklift is inconvenient.
- UNSØ lies in the Non-Schengen area of the airport, which means that staff needs to go past passport control with their employee card. This barrier makes UNSØ less accessible.

For commercial units close by a waste station, it can already be a 10 minute walk to and from the waste station. If a tenant is operating individually it means that they have to miss someone of their own personnel for 20 minutes (Avinor's Circular economy analyst, personal communication, February 27, 2024). Let alone if a commercial unit has to bring waste multiple times per day to the waste station or if a commercial unit is located further away from a waste station and the walk takes more time.

Main takeaways

- Oslo Airport's terminal comprises three floors, with the waste stations in the basement, and three main piers. The elevators should be taken into account in the service for transportation of waste downstairs.
- Waste disposal primarily occurs through three waste stations, with Rp19 being the most utilised, because of goods delivery and accounting for 85% of waste collection. Rp20 and UNSØ are used less for waste disposal, due to limited waste separation options, accessibility issues, and lack of awareness among tenants and waste collectors.
- Challenges, such as distant locations from waste stations and time-consuming walks pose operational inefficiencies for individual commercial units and should be fixed with the help of the waste service.

3.5 Waste station structure

The waste stations, especially Rp19, are places with their own structure. These places are logistics hubs where waste is collected in containers, supplies are delivered and checked by security and containers are picked up by trucks. Rp19 is a real bustling environment during peak moments when supplies are delivered by several trucks from F&B supplier A on Monday, Wednesday and Friday mornings. In fact, Monday mornings can be real chaos, due to the delivery of goods and the collection of accumulated waste from the weekend (Circular economy analyst Avinor, personal communication, March 1, 2024). Also at peak moments for the airport, such as summer, Easter and Christmas, the amount of created waste can double (Serving unit 29, personal communication, February 29, 2024). This results in more activity in and around the waste stations.

At Rp19 there are 15 different waste separation possibilities; big containers for plastics, wood, food, paper, residual, glass and metal. Next to that, there are smaller containers for other types of waste, such as clear plastic foil, hazardous materials, electronics and oil. A map of these waste containers can be found in Figure 18.

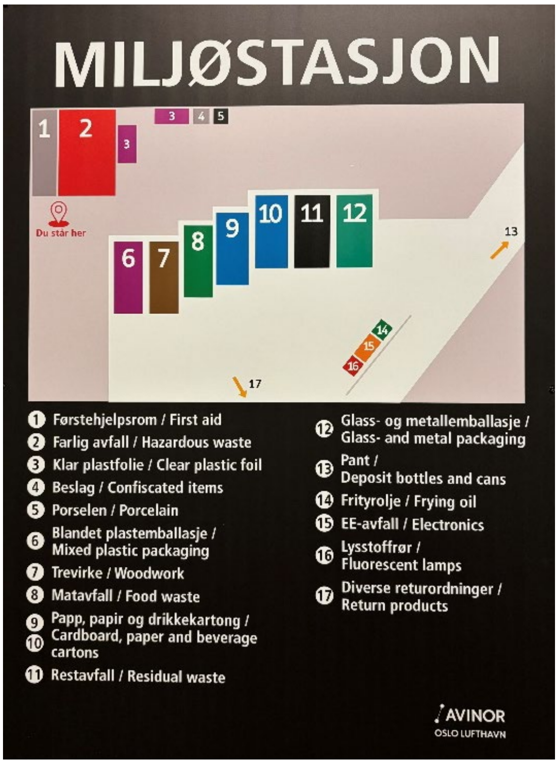


Figure 18: An overview of the different waste disposal options at Rp19 (Avinor Oslo Airport, 2024).

At Rp20 the focus lies more on construction waste. Next to the residual waste and paper waste containers there are also containers for metal, plaster and isolation materials. While at UNSØ (and Rp19 as well) the more common waste types can be collected. UNSØ is much smaller in size than the other two waste stations and can house only containers for residual, paper, plastic foil, bottles and food waste. The difference between the waste stations size lies in the fact that Rp19 and Rp20 can accommodate multiple trucks inside at the same time, while at UNSØ trucks can only pick up a container through a roller shutter directly in front of the container, as shown in Figure 19.

Figure 19: Containers behind a roller shutter at waste station UNSØ (R. Jonyer, February 28, 2024).

Main takeaways

- The three waste stations Rp19, Rp20 and UNSØ differ in waste separation possibilities, accessibility and space. The service should align with the separation possibilities.

3.6 Waste composition analysis

Within airports different types of waste are generated: municipal solid waste (MSW), construction & demolition waste, hazardous & industrial waste and lavatory waste. See Figure 20 for a visual overview of these streams. MSW, more commonly known as trash or garbage, consists of everyday items we use and then throw away (US EPA, n.d.). As mentioned in chapter 1.2, the other waste streams are out of scope in this project.
In airports, this MSW typically originates from various sources, including terminal areas, tenants within the airport premises, airlines, and cargo operations. The waste generated from public areas, office spaces, and other similar locations collectively contributes to the terminal waste. (Sebastian & Louis, 2021).

Kadibu and Jonyer (2022) conducted a waste safari, as part of the TULIPS project, to discover the distribution and amount of different types of waste, a so called waste composition analysis. A waste composition analysis, as the name suggests, is a process where waste is being separated, weighed and categorised (Comission for Environmental Coorperation, 2023).
According to Kadibu and Jonyer (2022) the amount of waste coming from the terminal at Oslo Airport for 2023 was 3402 tons, which is 64% of the total waste generated at Oslo Airport. The remaining percentage of the total waste comes from aircrafts (15%) and other buildings (21%).
A significant 54% of that terminal waste is considered as residual waste. But interestingly, because of improper waste sorting, half of that residual waste is not separated properly and could be recycled into existing waste streams, according to Kadibu and Jonyer (2022). Next to residual waste, paper waste (18,8%) and plastics (9,5%) are also substantial categories.

Furthermore, metal & glass, wood and masses (e.g. stone), all contribute with 5% to the total waste. Lastly, there are other small categories that contain less than 1% of the total waste, such as hazardous waste, electronics and fat and frying oil. In .

Figure 22, a pie chart with the composition of the waste can be found.

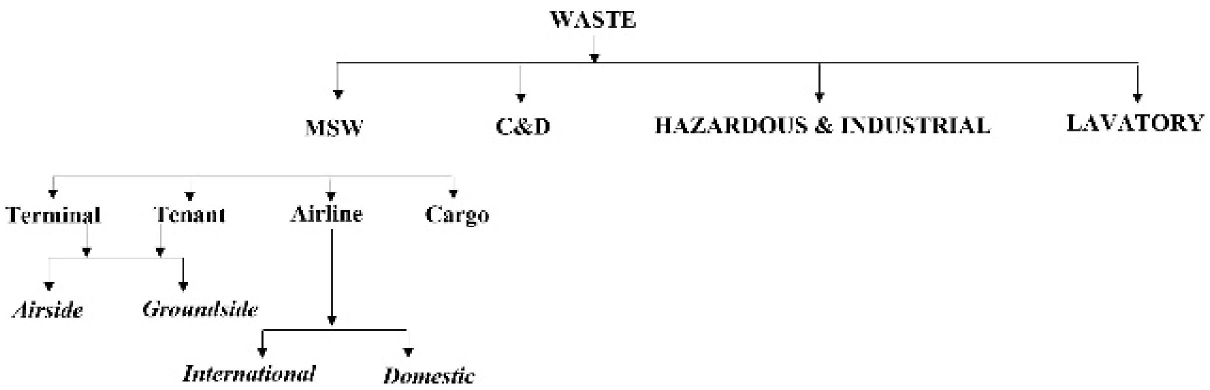


Figure 20: The different types of waste streams at an airport (Sebastian & Louis, 2021).

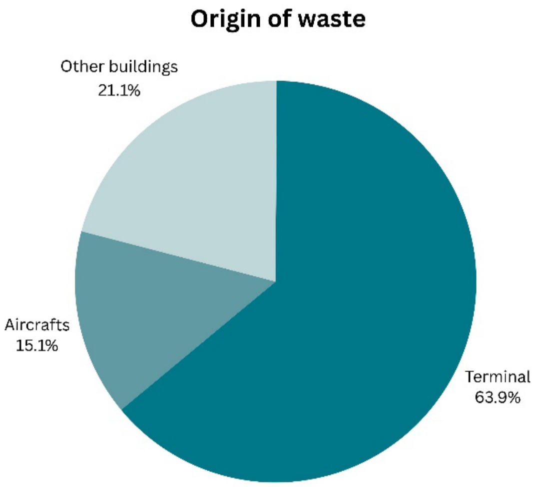


Figure 21: Origin of waste at Oslo Airport. (Own figure, adapted from Kadibu and Jonyer, 2022).

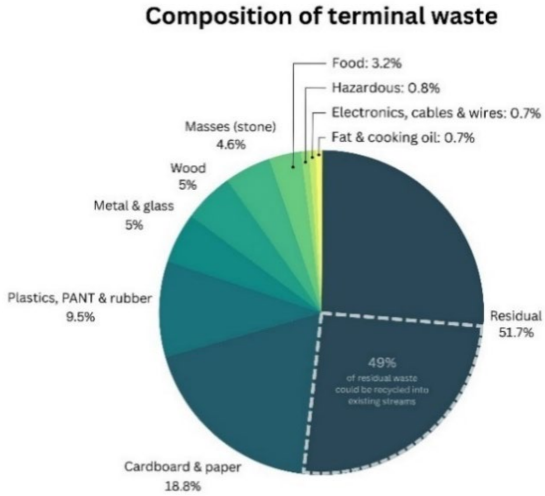


Figure 22: Composition of waste at Oslo Airport. (Own figure, adapted from Kadibu and Jonyer, 2022).

The waste coming from the terminal also includes food waste. Airports produce compostable and green organics through their foodservice operations. Substantial quantities of food waste are generated from discarded food and food preparation in airport restaurants and other eateries (Sebastian & Louis, 2021). At Oslo Airport, over a third from all food waste generated by the commercial units is edible food. Due to improper waste sorting, 16% of the residual waste consists of food waste (Kadibu and Jonyer, 2022). Together with the 3,2% of the total waste that is actually sorted as food waste, makes food waste accountable for 19,2% of the total generated waste.

For the five biggest waste streams, a composition of waste items per waste stream can be seen in Table 2.

Table 2: Waste composition per waste stream coming from the commercial units at Oslo Airport. (Kadibu and Jonyer, 2022).

Plastics	Paper	Metals	Organics	Other
• Plastic bottles • Plastic cups, cup lids, hard plastic • Plastic bags & soft plastic • Other undefined plastics (hard	• Packaging paper (made without or with “grease-proofing agents”) • Packaging cardboard/hard paper • Drinking box • Paper cups • Napkins and disposable cleaning paper • Other paper (receipt, flyers, magazine, etc.)	• Aluminium packaging (foil/cans) • Other metal	• Food waste (EDIBLE) • Organic waste (INEDIBLE) • Compostable serving tools (bamboo cutleries, etc.)	• Hybrid packaging (paper-plastic mixed) • Unclassified residual waste

Main takeaways

- A waste composition analysis at Oslo Airport revealed that terminal waste accounted for 64% of the total waste generated.
- Of that terminal waste, 54% is residual waste
- Half of the residual waste is improperly sorted. The solution should be designed accordingly so that sorting rates are improved.
- Cardboard/paper (18,8%) and plastic (9,5%) are also two prominent waste streams and should be taken into account.
- Food waste is accountable for 19,2% of the total waste, however 16% of that ends up in the residual waste stream. A third of the food waste is edible food.
- The plastic, paper, metal, organics and residual waste streams are accountable for the most waste, so it is plausible to focus on those streams when designing the service.

3.7 Conclusion

The study on the context of the waste management system at the terminal of Oslo Airport, highlights the importance of considering the entire waste management process, from creation to recycling. Overcoming obstacles to establishing a circular economy, such as cultural, regulatory, and market challenges, is crucial for sustainability efforts. Currently, Oslo Airport lacks a standardised waste collection and transportation solution. Also, effective collaboration between Avinor and commercial tenants is key. Clearly defined roles and responsibilities are essential for success. Challenges like varying waste separation options and accessibility issues at different waste stations must be addressed with tailored strategies. Additionally, the analysis of the waste composition reveals areas for improvement, especially in reducing residual waste and enhancing separation efforts.

4 Exploration

In this chapter, the waste management at Oslo Airport is further explored. This is done through the mapping of stakeholders and their relations, conducting interviews with stakeholders to explore their needs and by organising a co-creation workshop.

4.1 Stakeholder relations

In addition to paragraph 1.1, where the organisation structure is highlighted, below a visual overview of the involved stakeholders can be found in Figure 23. This figure gives an overview of the relations between the stakeholders that are involved in the waste management at Oslo Airport. These relationships can indicate use, contribution, support, managing, setting rules or engagement between stakeholders. The map is divided into three levels: A being the subject or core of the project, B being the direct stakeholders and C being the indirect stakeholders. Direct stakeholders are entities that are in direct relation with the waste system at Oslo Airport. For example, waste collectors that use the system or the waste station that contributes to the system. Indirect stakeholders are entities who have a relation or influence on the waste system via an indirect way. For example, Norwegian regulations that influence Avinor or passengers at the airport that engage with commercial unit employees. An enlarged visualisation of this stakeholder map can be found in appendix F.

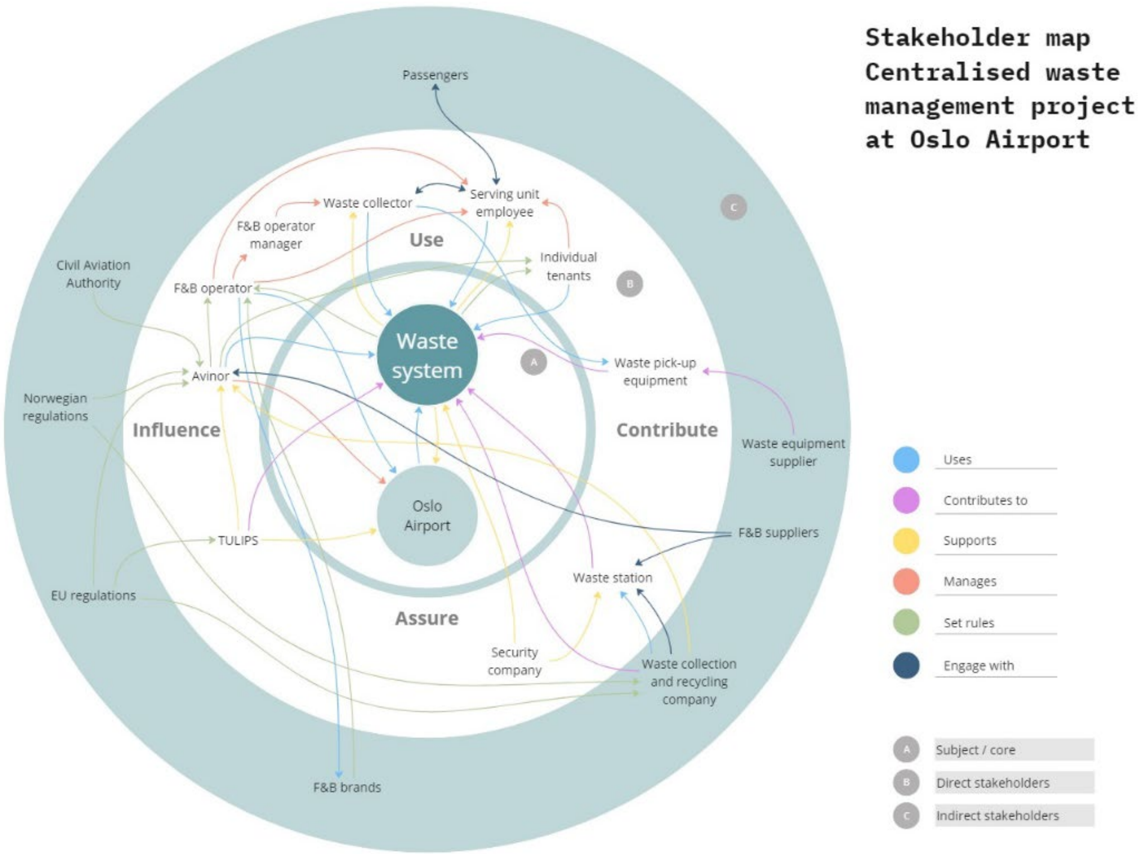


Figure 23: Stakeholder map with the relevant stakeholders in the centralised waste management project at Oslo Airport and their relations.

In the map, only stakeholder roles are described. Below in Table 3, an overview with the description falls within a certain stakeholder role is given. To see the concerned company, see confidential appendix A.

Table 3: Companies that belong to the stakeholder roles.

Stakeholder role	Entity
F&B operator	F&B operator A F&B operator B F&B operator C
Waste collector	Employee of a F&B operator who collects the waste
Individual tenants	All commercial units that are not owned by a F&B operator
Waste pick-up means	Equipment/tools that are used by waste collectors
Waste processing company	Waste processing company A
Waste collection and recycling company	Recycling company A
Security company	Security company A
F&B suppliers	F&B supplier A
Waste station	Rp19

4.2 Stakeholder needs

To get a better understanding of those involved stakeholders in the waste management system at Oslo Airport, deepening semi-structured interviews were conducted. These interviews were conducted with staff working at the commercial units, waste collectors and F&B operators. The objective of the interviews was to explore the needs and underlying problems of stakeholders and also to gain insights into the current waste management at Oslo Airport. By exploring these perspectives, the aim was to gather comprehensive data, including information on challenges faced, stakeholder perspectives and relations, areas for improvement, and potential opportunities for innovation.

An overview of the interview details can be found in chapter 2.3.2, semi-structured interviews.

4.2.1 Commercial units

As described in paragraph 3.2, the commercial units are the places where the interaction with the airport guests happen and where 82% of the total waste is created (Kadibu & Jonyer, 2022). After interviewing almost every commercial unit (except for duplications of units of which there are several present in the terminal that had already been interviewed and the airport lounges), the most important insights can be described as follows:

- Different approaches: commercial units differ in waste management strategies. Some use self-collection, but most use waste pickups by external personnel.
- Frequency of waste collection: waste collection frequency varies across tenants, ranging from multiple times a day to once or twice a week. The vast majority has daily waste collection.
- Limited space: the majority of the commercial units don't have much space to store waste or multiple waste bins. This leads to strategic unpacking and storage practices to optimize space utilization.
- Lack of knowledge: there's a lack of information and awareness about waste separation protocols among the personnel. This leads to waste not ending up into the right waste stream.
- Use of Too Good to Go: several commercial units utilize the Too Good to Go concept to minimize food waste.
- Lack of resources: besides the lack of space and information, there is also a shortage of time and personnel. Because of that, waste separation is not prioritized in the daily operations; waste removal is.
- Commercial unit want to be able to deposit their waste at the waste station after closing time.

The interview guide and interview notes can be found in appendix B. The mapping of waste practices of the commercial units can be found in appendix C.

One insight that is clearly visible, also for the passengers, is the lack of space in the commercial units. In Figure 24, waste being temporarily stored next to commercial units or behind them, can be seen. This temporarily storage of waste is due to missing of storage space inside the commercial unit.

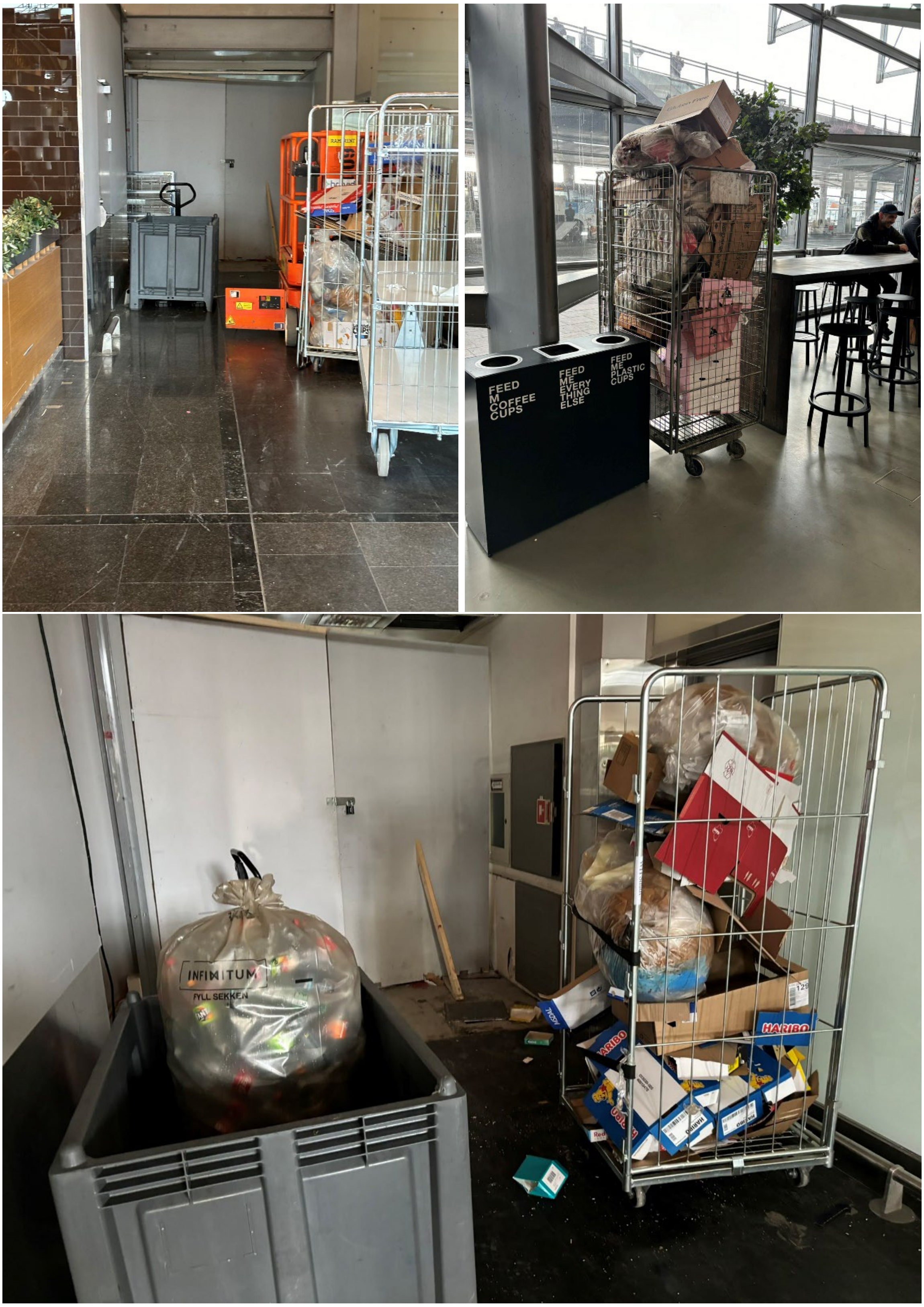


Figure 24: Three example situations where waste is being temporarily stored next to, or behind, commercial units due to the lack of space. (Own figure).

Also, regarding waste sorting, a higher error in sorting occurs when done by passengers. From the observations being done at the terminal, the conclusion can be made that the few commercial units that have waste separation possibilities for passengers in their guest areas experience a high sorting error in those waste bins.

This is also highlighted by the account manager of the hauling and recycling company (personal communication, March 14, 2024), mentioning that it is better when the staff of commercial units do the waste sorting themselves instead of the passengers.

Main takeaways

- Commercial units have varying frequencies of waste collection and storage space. The system should be centralised but also align with individual differences.
- Proper waste sorting and recycling efforts should be stimulated.
- Waste is better separated when done by staff instead of passengers. Therefore, public accessible bins should be excluded from the service for now.
- Also, commercial units experiment with new concepts (like Too Good To Go) to reduce food waste.

4.2.2 Waste collectors

The waste collectors are the people providing the commercial units with supplies and collect their waste. They are, because of that, the bridge between the commercial units and the waste stations. The most important insights from a waste collectors perspective:

- Waste collection: different types of waste are collected in one roll container. The bags are sorted at the waste stations.
- Morning rush: the busiest time for waste handling stations occurs in the morning between 6:00 and 8:00, as the accumulated waste from the previous day comes in.
- Poor information flow: information does not flow sufficient from management or policymakers to the waste collector. The waste collectors do not always know in which container the waste should be. When extra signs are added to the container, it is still unclear or ignored.
- Accusations: waste collectors claim that personnel from the commercial units do not sort waste properly, because they do not care about recycling.
- Lack of responsibility or motivation: the waste collectors do not feel the urge to reseparate waste bags when not sorted properly. Resulting in a bigger amount of residual waste. In addition, they feel more responsible for the delivery of supplies to the commercial units and see waste collection as a 'side business'
- Staffing: waste collectors work in two shift per day, so the morning until evening is covered.

The interview guide and interview notes can be found in appendix B.

The poor information flow, as described above, has resulted in a few short term solutions. These solutions are mainly information provision in the form of signs with warnings or information. For example, to make clear for the waste collectors in which container waste needs to be thrown. These signs are often low-tech and short term solutions. Examples of the current situation and the situation before can be viewed in appendix N.
And still, even with a warning being displayed three times, from own observations it is clear that the signs are not read. This shows that the information flow, or at least obeying the rules and information, is poor.

Main takeaways

- The fact that information does not always reach waste collectors and waste they need to pick up is not always properly sorted should be tackled in the service.
- The lack of responsibility and/or motivation regarding proper waste separation should be improved.

4.2.3 Operators

As described in paragraph 1.1, the F&B operators are companies that exploit and operate 'brands' from their portfolio at the airport. From interviews with F&B operators A and B (see appendix B5 and B6), the following insights are found:

- The operators need to follow the rules of their contracts with Avinor, including rules regarding circularity.
- Within the rules of Avinor, the F&B operators are both free and fully responsible to operate their businesses.
- The brand images of brands from their portfolio need to be maintained.
- The rent at the terminal and personnel costs are high, therefore earning revenue is an important driver for the F&B operators.
- In addition is cutting costs also important.

Main takeaways

- F&B operators are in a difficult position as they operate within contractual obligations with Avinor, balancing responsibilities for circularity, maintaining brand images and generating revenue.
- The responsibility should therefore be clearly defined in the service.

4.2.4 Avinor

Lastly, besides the commercial units, waste collectors and operators, there is Avinor as important stakeholder. Avinor is the client in this graduation project, but also a stakeholder with needs and wishes, which are represented by Avinor's circular economy analyst. Besides the objectives from chapter 1, additional wishes and remarks are as follows:

- A centralised waste pick-up team (referring to Schiphol) that operates 24/7 is too expensive.
- Avinor has the wish to profile themselves as a modern airport. Therefore, modern, automatic and/or high-tech solutions are desirable.
- In addition to modernity, it is also desirable to have a solution that aligns with the luxury and overall appearance of the airport.
- Cost reduction is a great motivator to have a certain solution adopted.
- In terms of safety, operations does not want waste collectors to drive in the terminal hall during peak hours.

Main takeaways

- The solution should include modern, automatic elements.
- The service should reduce costs if possible.

4.3 Waste weighing

In the introductory chapter the aim for Oslo Airport to reduce the total amount of waste by 50% by 2030 related to the daily operations, compared to 2022 is highlighted. Organisations in Norway have the duty to report on their waste practices and their efforts on waste reduction. In these reports the weight of the total waste must be indicated as well as the change percentage in relation to the year before (Norwegian Environment Agency, 2020). Due to this, post recycling solutions are out of scope, because by doing that, waste registration per waste type and per tenant is not possible. Weighing of waste has become unavoidable, therefore Oslo Airport should be prepared and designed accordingly.

In the past, Avinor has experimented with a waste weighing system at waste station Rp20, as shown in Figure 25. People bringing the waste to Rp20 were able to scan the machine next to the container with a personalised card and then throw away their waste in that container. The data of the throwing activity is not registered, because the system for that was never set up. This intervention for waste weighing is not ideal, because of two main reasons. First, the people using the containers forgot their cards multiple times when coming down to the waste station. Therefore, the key lockers were installed next to the container to store the personal cards. Second, it is time consuming to weigh and register all the waste coming in. This can result in traffic jams in the waste station, especially during the morning peak hours as described in paragraph 4.2.2.

Figure 25: Current waste weighing device at Rp20.

Also at waste station Rp19 and UNSØ an attempt was made to weigh residual waste, see Figure 26 (Circular economy analyst Avinor, personal communication, February 28, 2024). However, this device is half-ready and not in use.

Figure 26: Waste weighing intervention at UNSØ.

While these solutions may not have been the most optimal implementations, it is still important to stress that waste regulations change annually. Due to this, it is needed to adapt to the regulations that occur and be prepared for the future (B. Nielsen, personal communication, March 14, 2024).

In addition to waste weighing, the account manager of the hauling and recycling company (personal communication, March 14, 2024) highlights the importance of compacting the waste. Compacting waste and reducing manual handling are effective methods for decreasing emissions, as well as, proper sorting of waste into different streams.

Main takeaways

- Waste weighing is an unavoidable requirement in order to facilitate accurate waste tracking per type and tenant and should be included in the design.
- Post-recycling solutions are excluded in this project.
- The design should tackle challenges regarding weighing the waste such as, time-consuming processes, leading to congestion during peak hours and accessibility of the weighing system.

4.4 Co-creation workshop

In order to include relevant stakeholder in the design process, a co-creation workshop was organised, see Figure 27. At the session, four participants were present.

An overview of the participants can be seen in Table 4. The setup of the co-creation workshop and used slide deck to guide the session can be found in appendix G.

Figure 27: Co-creation workshop.

Table 4: Overview of participants at the co-creation workshop.

Participant	Function	Organisation
1	Circular economy analyst	Avinor
2	Waste collector	F&B operator B
3	Manager of the waste collectors	F&B operator B
4	Commercial unit employee	F&B operator B

The main objective of the workshop was to discover different interpretations of the problems and challenges regarding waste management at Oslo Airport. And subsequently to get everybody on the same page, so that a proposed intervention will be seen as a satisfying solution by all stakeholders. Additionally, the objective of this workshop was to create solutions for the problem statement.

Main problems

Below the main problems, as a result from the session, are listed in order from most recognised to less recognised by the participants.

1. The security control at the waste station closes earlier than the serving units do.
2. Money is seen as more important than the environment.
3. Hundreds of people throwing waste daily means more chance of somebody not caring or being morally wrong.

4. It is difficult to create a sense of responsibility.
5. There is a lack of time.
6. There is no dedicated place for solid metal at Rp19.
7. Rules are not thought through.

Solutions

For problem statement 1 to 4, solutions were created. Solutions were created via a brainwriting carousel, in order to let every participant think of solutions for every problem statement. The solutions that got the most attention are listed below:

1. One waste management team, dedicated to sorting and throwing waste in the correct container.
2. Introduce rewards/punishments on a personal level.
3. Allocate money for keeping the security control open longer.
4. Have a module in the ID card that teaches and motivates people about waste reduction, recycling, looking at waste as a resource, etc.
5. Put on a big fake camera with a sign. Play on peoples 'fear'.

Main takeaways

- The service should focus on three main problem domains, being operational and infrastructural problems, information flow problems and human behaviour or cultural problems.
- Operational problems are mainly about infrastructure and practicalities, such as an early closing time of the waste station, lack of time and space, long distances or the missing of a solid metal container.
- Problems in information provision are due to the many stakeholders involved in the process, the missing of a communication channel and of a training program.
- And there are cultural challenges, which mainly revolves around the lack of responsibility. For this, both short term and long term solutions were initiated.
- A centralised waste management team that is fully responsible for, and dedicated to the waste is desired to include in the service.

4.5 Conclusion

In this chapter, the context of this project was explored. This was done by conducting interviews, analysing best practices and the mapping of current practices. From this exploration, it can be concluded that the waste management landscape at Oslo Airport is complex due to many involved stakeholders, but without one dedicated responsible entity for the waste management.

An important conclusion, that is underlined by the commercial units, the F&B operators and the waste collectors, is that there is a sense of a principal-agent problem taking place at Oslo Airport. The principal–agent problem refers to the conflicting interests and priorities that arises when one person or entity (the “agent”) takes actions on behalf of another person or entity (the “principal”) (Wikipedia contributors, 2024b). In the context of this project, Avinor is the principal who delegates their authority to the agent. The tenants (both F&B operators and individual operating tenants) are the agents, who acts and make decisions. This is visualised in Figure 28.

Furthermore, it can be concluded that there are three main problem areas in this project. First, operational problems that include lack of time, space and implementation of a weighing solution. Second, information provision is a problem. Information does not reach all the stakeholders, or is not clearly communicated. Third, culture or human behaviour causes problems in the lack of responsibility and conflicts of interest.

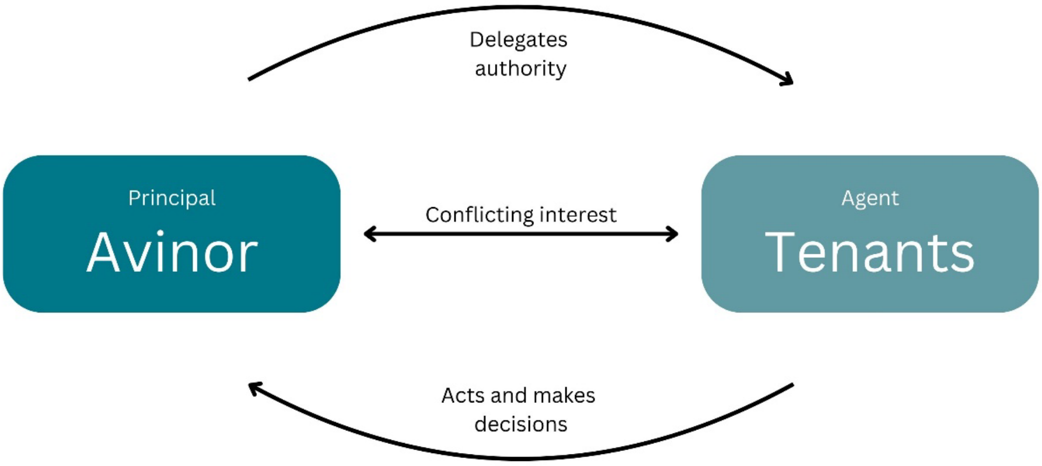


Figure 28: Principal-agent problem regarding waste at Oslo Airport. (Own figure, adapted from Investopedia & Jiang, 2023).

5 Interventions

Following up on chapter 4 where the topic of this thesis is further explored by conducting interviews and observations, this chapter continues on this exploration. Existing design interventions and similar contexts to Oslo Airport are discussed and best practices are analysed. This forms a bridge towards the design phase of this project.

5.1 Best practices

First, in order to learn more about centralised waste management, sustainable waste practices, waste separation, waste reduction and to discover possible (parts of) solutions to implement at Oslo Airport, best practices are analysed. The intention is to investigate other, comparable phenomena and to generalise the insights.

Therefore, airports around the world, that have sustainable practices, are investigated.

Schiphol airport

Schiphol is the biggest airport of the Netherlands, containing a centralised waste pick-up team that collects waste of 125 to 150 commercial units. With a team of 30 collectors in total they collect waste between 05:00 and 23:00 with approximately 7 persons per day. For Schiphol, the main reason to implement a centralised service was so they could provide a service to the commercial units so they can focus on sales and also to increase proper waste sorting. The service not only involves waste transport and sorting but also offers guidance to commercial unit employees, immediate feedback on sorting errors, and verbal communication with units regarding sorting issues. Overall, the service has been positively received by commercial units, leading to improved waste sorting rates and supporting Schiphol's sustainability goals. Besides, the feedback system from waste collectors towards the commercial units is experienced as supporting instead of blaming.

These insights come from a conducted interview with Schiphol, which can be found in appendix B8.

Changi Airport

Located in Singapore, Changi Airport implemented several features regarding sustainability. First, the airport has an automated pneumatic waste conveyance system that sorts and transports dry and wet waste to recycling and composting facilities (De Guia, 2023). This reduces the use of bin trucks or waste collectors. Second, they have a food digestion machine, which can transform food waste into water. Microbes break down the food waste and produce water as a by-product (Changi Airport Group, n.d.). Third, Changi Airport has adopted a Rotary Waste Drum (RWD), a new version of a conventional waste compactor. By combining compacting with rotating the waste, the volume of waste can be reduced. This resulted in a halving of waste hauling trips (Changi Airport Group, n.d.-a). The Rotary Waste Drum is displayed in Figure 29.

Figure 29: Rotary Waste Drum at Changi Airport, Singapore. (Changi Airport Group, n.d.-a).

San Francisco Airport

The airport of San Francisco is progressive when it comes to sustainability, with their statement to become the first airport in the world to become carbon neutral. They have a recycling and composting program. With this program, the aim is to recycle, compost or reuse 90% of the airports total waste. (CBS News, 2022). Also, they banned the sale of plastic water bottles at the airport.

London Gatwick Airport

In 2016, London Gatwick Airport opened its waste-to-energy system. By doing this, the airport was the first in the world to convert waste into energy onsite. This system makes it possible to convert organic waste into biomass fuel that is used to power the processing plant and to heat a part of the terminal. The environmental-related benefits from this system include a reduction in truck vehicle journeys to external waste plants, which has resulted in lower vehicle-related CO2 emissions, lower vehicle noise levels, and less vehicle congestion. Besides, the water that is created as by-product is used to clean waste bins located throughout the airport (Baxter & Srisaeng, 2022).

Atlanta International Airport
At Atlanta International Airport, tenants are restricted to use single-use plastics and are stimulated to use compostable alternatives. If tenants do not oblige this rule, their leasing contract is suspended after a third violation (Sebastian & Louis, 2021).

Naples International Airport
In 2017, Naples International Airport took steps to improve waste management by introducing sorted waste collection. This resulted in 62% of all waste being sorted for recycling, while the remaining 38% was used for energy production by third parties. To support these efforts, modern waste management facilities were constructed, and programs such as door-to-door waste collection were implemented throughout the airport buildings. The airport also launched an information and awareness campaigns to engage airport stakeholders and passengers in recycling initiatives (Miedico, 2018).

Main takeaways
In order to reach a circular economy, there need to be:

- Regulatory measures
- Increased awareness and responsibility among tenants
- Increased sorting rates
- The fostering of cooperation between stakeholders.

5.2 Similar contexts

Next to other airports, it is interesting to look at similar contexts. Public places, such as train stations and shopping centres with multiple serving units have similar operations and characteristics as an airport and therefore interviews and observations are conducted to learn from other waste management systems.

5.2.1 Train stations

Waste management practices at two big train stations at the Netherlands are observed and interviews with commercial units are conducted.
Both stations have a centralised waste pick-up team (one is from the station itself and one is outsourced to a cleaning company). Also, the maximum amount of different waste streams is two or three (residual, paper and sometimes organic), which keeps waste management simple for users to understand. However, this is dependent on legislation and is therefore different per country. Interestingly, there are few to no remarks on current practices.
A full overview of the data from the conducted interviews can be found in appendix B.

5.2.2 Shopping centres

Other similar environments to an airport are shopping centres. Interviews were conducted with commercial units at two Dutch shopping centres. Again, similar to the train stations, there are few waste separation streams. Neither of the shopping centres have a centralised service for collecting waste. The staff of the commercial units is responsible themselves to collect the waste in the containers and compactors. A full overview of the data from the conducted interviews can be found in appendix B.

In Figure 30, insights regarding waste management at the Dutch train stations and shopping centres can be found. This overview highlights the different types of waste, as well as the separation possibilities, the way waste is collected and how often and also a short description on the practices regarding their waste management.
An enlarged visualisation of this overview can be seen in appendix I.

	Rotterdam Central Station	Utrecht Central Station	Westfield Mall of the Netherlands	Zuidplein Shopping Centre
Type of waste collection	Centralised, outsourced by a cleaning company.	Centralised, done by the NS (the operator of the station).	Self by the staff of the commercial units.	Self by the staff of the commercial units.
Amount of times per day	Two times per day.	Multiple times per day.	When needed or at end of the day.	When needed or at end of the day.
Waste practices	Waste is collected at the back of the commercial units, connected to a passenger-restricted hallway behind the commercial units. And waste is then brought to a waste station at the back of the trainstation.	Waste is collected at the front of the commercial units in the passenger area. And waste is then brought to a waste station under the train station.	Staff of the commercial units brings waste to the waste station that they can access with a card. The waste station is positioned at the front of the Mall.	Staff of the commercial units can throw residual waste into shafts connected to containers in the basement. Cardboard waste is brought to the compactors downstairs outside.
Generated waste types	PLASTIC, PAPER, REST WASTE, ORGANIC	PLASTIC, PAPER, REST WASTE	PLASTIC, PAPER, REST WASTE, ORGANIC, GLASS	PLASTIC, PAPER, REST WASTE, ORGANIC
Separation options				
Payment	Included in rental agreement as a fee	Included in rental agreement	Included in rental agreement	Total fee is divided by the amount of square meters

Figure 30: Overview of insights regarding waste management at Dutch public places. (Own figure).

Main takeaways

- In order to satisfy the stakeholders, especially the tenants, the waste management should be made as easy as possible.

5.3 Waste pick-up and weighing

In addition to chapter 4.2.4, where waste weighing is elaborated, this chapter highlights a practical interpretation of a waste collection and weighing solution.
An interview was conducted with a waste processing company from Norway. This company is involved in this centralised waste management project as partner to develop a solution for the waste pick-up intervention. Proposed solutions include a municipal-style waste collection system approach, in which trucks will drive past the commercial units to collect one type of waste per pick-up round. Instead of trucks, forklifts or small carts equipped with tablets for waste registration, are proposed. Mobile compactors from a Dutch container company, are being considered for this, with a focus on compacting plastics, cardboard/paper and residual waste. These three types are the biggest waste streams and compacting food waste is challenging as the food waste is dense and gets moist inside the compactor.
Challenges for this intervention include ensuring operator safety, efficient operation of the compactors, and elevator weight limitations and regulations.

Safety concerns

Ensuring safety in waste management operations, particularly with forklifts carrying mobile compactors, is essential, especially in bustling terminal environments during peak moments like summer, Christmas, and Easter. The substantial size of these machines poses significant risks when navigating through crowded areas. Operator visibility is

therefore crucial. Additionally, incorporating sensors or warning lights onto the compactors can provide feedback and alerts, further enhancing safety measures and minimizing the risk of accidents.
In addition, comprehensive safety training is probably necessary for operators. Integrating this training into existing e-learning modules would streamline the process and ensure that safety protocols are effectively communicated and understood.

Efficiency
A mobile compactor takes around 20 seconds to compact waste when the container is empty and around 30 seconds when the container is almost full. In order to operate as efficient as possible, it would be beneficial to drive the forklift to next tenant during this compacting timeframe.

Weight limitations
The terminal of Oslo Airport consists of three floors, including waste stations in the basement, see paragraph 3.4. This means that an elevator is an obvious transportation method. The volumes of the accumulated waste in the mobile compactors are not going to be a problem. However, its weight can become a problem, especially when using a 3,5 cubic meter compactor. When it is fully filled it becomes heavy and the elevator can only handle up to 4 tons of weight.

Main takeaways

- Safety is a big concern, especially in busy areas in the terminal and should be taken into account.
- Efficient operations are needed to save time.
- The maximum weight in the elevators should be taken into account when designing the waste service.

5.4 Pay As You Throw

Following up on paragraph 4.2.4 about waste weighing, this paragraph elaborates on PAYT (Pay As You Throw). The PAYT model is an initiative with financial disincentive that discourages people to throw away waste. In this model, designed for municipalities, a person would pay for the amount of waste that is being thrown (Wikipedia contributors, 2024). The aim of this initiative is to let citizens take responsibility and to encourage them to sort their waste correctly in the separated waste streams (Jones, 2021). According to Morlok et al. (2017) financial disincentives in the form of TAX are effective when it comes to recycling, but they seem to be less effective when it comes to reducing waste. PAYT has been attempted or implemented in different forms, mainly by municipalities as waste prevention strategies. Research from Jones (2021) elaborates on the PAYT model in Flanders, Belgium. They use waste bins that contain electronic chips that charge a fee according to the weight or volume of a certain type of waste. The highest fee is applied to residual waste, followed by greens (biodegradable waste). A high fee on biodegradable waste is meant to stimulate citizens to do home composting. Plastic bottles, metal and drinking cartons (PMD) were classified as a low rate fee and paper, glass and textiles would be free. In this system, citizens are encouraged to sort their waste as much as possible, as they would pay more for the amount of residual waste.
Although, the PAYT model was initiated at a municipal level, meant for citizens, lessons can still be learned from it for this project. It sheds light on a different approach to commonly separate and reduce waste. The commercial units at Oslo Airport could be seen, in this case, as 'the citizens' and would pay per amount of waste. With this, the commercial units are confronted individually with financial disincentives.

Main takeaways

- Pay As You Throw is a financial disincentive model regarding waste. By increasing the fee on residual waste, the urge to proper separate residual waste into other waste streams is created.

- This approach could be adapted to the commercial units at Oslo Airport.

5.5 Principal-agent problem

Following up on the conclusion from Chapter 4, where a principal-agent problem is discovered between Avinor and its tenants, this paragraph elaborates on this phenomenon. As mentioned, Avinor and its tenants have a conflicting interest when it comes to circularity and sustainable waste practices. For tenants getting rid of the waste is priority, while the priority for Avinor proper waste separation and reducing waste is.

According to Miller (2005) there is not one perfect solution to principal-agent problems, but rather multiple solutions. One of those solutions is the implementation of incentives for the agents (the tenants in this context). Incentives, rewards or punishments that impact human behaviour, could be money, status, company advantages, etc. These incentives for the tenants should align with the incentives of Avinor (Waschenfelder, 2023). When a monetary incentive model does not work properly, another solution should be implemented. According to Miller (2005), good corporation between teams is beneficial in fixing the principal-agent problem. The individual efforts of the team members (the tenants) contribute to the total output, which creates a special form of moral hazard. It results in having no risk in the formal sense on a individual level. To prevent this, monitoring individual team members is a possibility (Miller, 2005).

It is also possible to monitor the agent more intensive. By giving the agents direction and monitoring them closely, programmed behaviour and a hierarchical authority occurs. However, this can result in a more bureaucratic system.

These findings are underlined by Rameezdeen et al. (2019), who state that a strong incentive gap and information asymmetry between principal and agent results in agents acting on their own self-interest rather than the interests of the principal. Goal alignment between the principal and agent is hereby necessary to fix the principal-agent problem.

Main takeaways

- The principal-agent problem between Avinor and its tenants highlights conflicting interests regarding sustainability.
- The service should therefore provide a solution to this principal-agent problem.

5.6 Automated Guided Vehicles

Automated Guided Vehicles (AGV's) are vehicles that are self-driving with navigation through wires, radio waves, magnets, sensors, camera's or lasers (Wikipedia contributors, 2024c). According to Moshayedi et al. (2019) an AGV is a robot that can be used as automated transportation method, due to their high efficiency, flexibility, reliability, safety and system scalability. AGV's are commonly used in warehouses, but can also serve in hospitals for medical service such as delivering food and drugs and collecting medical and biological waste and serve in airports for baggage transport (Moshayedi et al., 2019). Moreover, hospitals in Norway already implemented AGV systems for different purposes, under which waste transportation (Avinor Oslo Airport, 2024).

Implementation of AGV's is in line with the wishes of Avinor Oslo Airport, as described in chapter 4.2.4 and can therefore be considered as a desirable part of the service blueprint. In addition, from the mapping of the terminal and its basement, which can be found in chapter 3.4, attention has already been paid to AGV's by Avinor in the past. There are (warning) signs regarding AGV's, as shown in Figure 31 and Figure 32, but AGV's are currently not involved in the waste management system at Oslo Airport.

Figure 31: Attention sign for an AGV station in the basement of Oslo Airport terminal. (Own figure).

Figure 32: Warning sign for AGV's in the basement of Oslo Airport terminal. (Own figure).

Main takeaways

- Automated Guided Vehicles are a realistic option for automatic waste transportation at Oslo Airport.
- The possibilities for AGV implementation should be explored when designing the service.

6 Scope

In the previous chapters the current waste management context at Oslo Airport is analysed, the stakeholder needs are discovered and best practices are explored. Since time and resources within this graduation project are limited, a scope is defined in this chapter with an overarching problem statement and a breakdown of problem domains. From these problem statements, a design challenge is formulated and is outlined in a design roadmap.

6.1 Setting the scope

6.1.1 Overarching problem statement

The waste management system at Oslo Airport Terminal presents a complex set of challenges that hinder the establishment of a sustainable circular economy. The current landscape is characterised by fragmented practices and a lack of cohesive management. This fragmentation is compounded by various factors, including cultural norms, regulatory constraints, and market dynamics, which collectively hinders the progress towards sustainable waste management goals.

A critical issue is the absence of a standardised waste collection and transportation solution, resulting in operational inefficiencies and suboptimal resource utilisation. Moreover, effective collaboration between Avinor and the tenants is hindered due to a principal-agent problem, where conflicting interests and priorities undermine collective efforts regarding waste management.
The identified problem areas can be broadly categorised into three main domains: operational challenges, information dissemination and cultural and behavioural factors.

6.1.2 Operational challenges

Operational challenges within the waste management system at Oslo Airport that are echoed by all stakeholders include logistical constraints such as limited time and space, long distances from the commercial units to the waste stations, as well as the absence of an effective weighing solution and the accessibility of the waste stations. These operational challenges hinder proper waste collection and separation. Therefore, the first design challenge is: "improve the ability of proper waste collection and separation".

6.1.3 Information provision

There is a notable gap in the provision of information, with key stakeholders lacking access to crucial data or receiving unclear instructions or the ability to understand the provided information, and staff is not trained sufficiently to operate in a waste management system accordingly. Also, new rules or regulations are not always thought through before implementation. This leads to the following design challenge: "increase the awareness and consideration of proper waste separation".

6.1.4 Cultural and behavioural factors

The third problem area is within human behaviour and organisational culture. These factors play a significant role in shaping waste management practices. The lack of a shared sense of responsibility or a dedicated entity with ownership results in a conflicting interest among stakeholders regarding waste management practices. Also, waste is still being seen as dirty and not important. Motivation among stakeholders is needed in order to see waste as valuable raw material. This results in the following design challenge: "improve the motivation of proper waste separation and reduction".

6.2 Design challenge

The overarching problem statement, supplemented with the sub-problem domains, allows to form an overarching design challenge:

“Design an integrated waste management service for Oslo Airport Terminal that tackles operational inefficiencies, improves information provision and encourages responsibility and motivation among stakeholders regarding waste, ultimately facilitating the transition towards a sustainable circular economy.”

7 Design

This chapter shows the design solutions for the set design challenge. The design opportunities are explored in a process of ideation. Subsequently, from the created ideas concepts are developed and evaluated.

7.1 Introduction and approach

In chapter 6, the main problems are highlighted and a design challenge for this project is formulated. This chapter uses the design challenge as guideline in the design of solutions. In order to design solutions and translate those solutions into concepts, several methods are used:

Brainwriting

Brainwriting is a method for generating a great number of ideas with the assumption that quantity leads to quality. Brainwriting is a method that makes it possible to speed up idea generation, by letting individuals writing down their ideas on their own and subsequently share their thoughts with others and reflect on them (Van Boeijen et al., 2021).

How-Tos

How-Tos are problem statements written in the form of a question that support brainstorming and idea generation (Van Boeijen et al., 2021). With this method ideas can be explored with an open and non-judgmental view. Using How-Tos is a diverging method and can be helpful to create many ideas in the beginning of the ideation phase.

Morphological chart

A morphological chart is a design tool which can be used for exploring and generating potential solutions to design challenges (Van Boeijen et al., 2021). It's a methodical way of breaking down a problem into parts and enables to describe possible principal solutions by combining solutions for each sub-function.

C-box

A C-box stands for creativity, and the paradox of creativity. According to Van Boeijen et al. (2021) it is a method that uses a matrix with two axes and four quadrants. The generated ideas can be mapped along the axes, creating an overview. This makes it possible to start converging towards concepts or to elaborate on ideas by moving an idea to a different quadrant.

Harris profile

A Harris profile is a graphic representation of the strengths and weaknesses of design concepts in relation to the design criteria. A Harris profile is a visual evaluation of concepts and is not a precise, calculated method. This is a convenient method, because exact properties and characteristics of design concepts might not be not defined yet (Van Boeijen et al., 2021).

Impact feasibility matrix

The impact feasibility matrix assesses the concepts on its impact and the feasibility. According to Beekast Inspirations (2020) This method provides an approach to choose those actions that can have the biggest impact on the problem and that are most likely to get accomplished. This matrix consists of two axes, impact and feasibility, from low to high. By ranking the concepts on this matrix, an overview is created which concepts create the most impact and the ease of implementation. This can help in decision making.

7.2 Brainwriting

To start off the ideation process, the method brainwriting was used. This method was incorporated in the co-creation session, which can be seen in chapter 4.4. The results of this brainwriting session are displayed in appendix G4.

7.3 How-Tos

Subsequently, a brainstorm took place with the help of 'How-Tos'. The three main challenges with the sub-challenges, which can be seen in chapter 6, acted as the 'how-questions'. For example, the question 'how can awareness be created regarding proper waste sorting?' was used to generate ideas for this specific challenge. The ideas were sketched and written on paper and can be seen in appendix J.

7.4 C-box

The ideas generated during brainstorming and brainwriting were supplemented and mapped on this C-box matrix based on feasibility and user value and can be viewed in Figure 33. For feasibility (Y-axis), one end represents 'difficult to implement' and the other end represents 'easy to implement'. For user-value (X-axis), one end represents 'creates high value to the user needs' and the other end represents 'creates low value to the user needs. The post-its, with each post-it containing one idea, are divided into three colours, which relate to the three main problem domains.

- Black: improve the ability of waste collection and separation.
- Blue: solutions to cultural and human behaviour problems.
- Yellow: improve information provision.

The ideas in the upper right quadrant are both high in user value and in feasibility. Therefore, these ideas are mainly incorporated into the concept creation.
An enlarged visualisation of the C-box can be seen in appendix K.

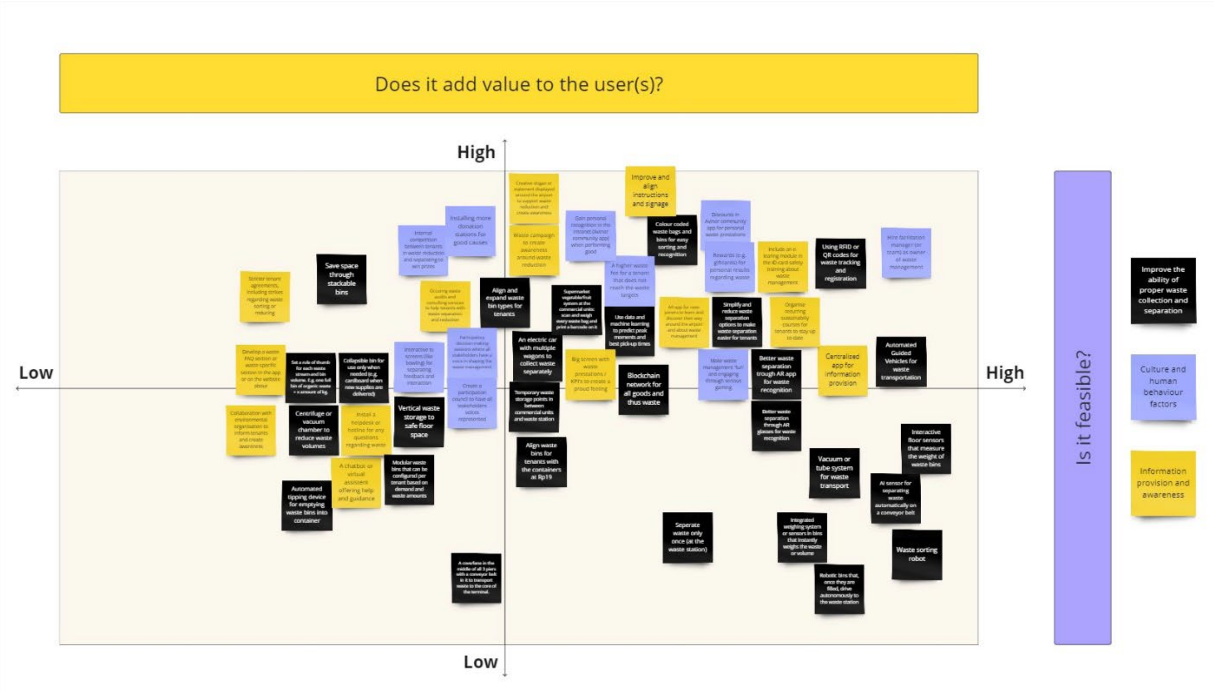


Figure 33: C-box feasibility and user value (Own figure).

7.5 Morphological chart

According to Van Boeijen et al. (2021) a morphological chart helps creating solutions or eventually concept from ideas. This is done by deconstructing the overall function of a service into sub-functions. Again, the sub-functions in the morphological chart are the challenges formulated in chapter 6.

For every sub-function, multiple options are formulated as solutions written on post-its. This can be seen in Figure 34. The sub-functions all serve as part of the proposed service for the internal waste management at Oslo Airport.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11
Making waste separation easier	Improve and align instructions and signage	Interactive tv screens (like bowling) for separating feedback and interaction	Align and expand waste bin types for tenants	Colour coded waste bags and bins for easy sorting and recognition	Align waste bins for tenants with the containers at Rp19	Simplify and reduce waste separation options to make waste separation easier for tenants	Seperate waste only once (at the waste station)	Waste sorting robot	AI sensor for separating waste automatically on a conveyor belt	Better waste separation through AR glasses for waste recognition	Better waste separation trough AR app for waste recognition
Waste transportation	Automated Guided Vehicles for waste transportation	Vacuum or tube system for waste transport	A cove/lane in the middle of all 3 piers with a conveyor belt in it to transport waste to the core of the terminal.	Robotic bins that, once they are filled, drive autonomously to the waste station	An electric car with multiple wagons to collect waste separately						
Saving space / waste storage	Save space through stackable bins	Centrifuge or vacuum chamber to reduce waste volumes	Modular waste bins that can be configured per tenant based on demand and waste amounts	Vertical waste storage to safe floor space	Collapsible bin for use only when needed (e.g. cardboard when new supplies are delivered)	Temporary waste storage points (e.g. a hub per pier) in between commercial units and waste station					
Weighing waste	Using RFID or QR codes for waste tracking and registration	Integrated weighing system or sensors in bins that instantly weighs the waste or volume	Supermarket vegetable/fruit system at the commercial units: scan and weigh every waste bag and print a barcode on it	Set a rule of thumb for each waste stream and bin volume. E.g. one full bin of organic waste = x amount of kg.	Interactive floor sensors that measure the weight of waste bins						
Training employees	Collaboration with environmental organisation to inform tenants and create awareness	Include an e-learing module in the ID-card safety training about waste management	AR app for new-joiners to learn and discover their way around the airport and about waste management	Organise recurring sustainabilly courses for tenants to stay up to date							
Information provision	Waste campaign to create awareness around waste reduction	Centralised app for information provision	Develop a waste FAQ section or waste specific section in the app or on the website about	Install a helpdesk or hotline for any questions regarding waste	A chatbot or virtual assistent offering help and guidance	Reccuring waste audits and consulting services to help tenants with waste separation and reduction					
Motivating staff	Internal competition between tenants in waste reduction and separating to win prizes	Creative slogan or statement displayed around the airport to support waste reduction and create awareness	Gain personal recognition in the intranet (Avinor community app) when performing good	Discounts in Avinor community app for personal waste prestations	A higher waste fee for a tenant that does not reach the waste targets	Rewards (e.g. giftcards) for personal results regarding waste	Big screen with waste prestations / KPI's to create a proud feeling	Make waste management 'fun' and engaging through serious gaming			
Ownership of waste management	Hire facilitation manager as coordinator and owner of waste management	Hire facilitation team to take over all waste related activities	Participatory decision-making sessions where all stakeholders have a voice in shaping the waste management	Stricter tenant agreements, including strikes regarding waste sorting or reducing	Create a participation council to have all stakeholders voices represented						
Other	Automated tipping device for emptying waste bins into container	Use data and machine learning to predict peak moments and best pick-up times	Installing more donation stations	Blockchain network for all goods and thus waste							

Figure 34: Morphological chart. (Own figure).

7.6 Concepts

Concepts are created by combining sub-functions from the morphological chart into a comprehensive whole. In total, six concepts were created from this. For each concept the main process is elaborated with a front-end and a back-end flow, as well as an overview of the touchpoints.

7.6.1 Concept 1: Trashbot

This concept consist of several sub-functions from the morphological chart (Figure 35) and focusses on taking away the responsibility of proper waste sorting from the commercial unit employees by reducing human error or lack of motivation. The separation of waste is automated with the help of a robot that recognises waste with AI technology and develops its accuracy overtime through machine learning. The process of the concept together with the touchpoints can be seen in Figure 36 and Figure 37.
Below the advantages and disadvantages will be highlighted for concept 1.

Advantages

- Aligns with the wishes of Avinor to be an innovative airport.
- Takes away the waste separation responsibility from the commercial unit employees.

Disadvantages

- High investment costs to place a trash robot at every commercial unit
- Lack of space to place a trash robot at every commercial unit.

Figure 35: Morphological chart sub-functions concept 1. (Own figure).

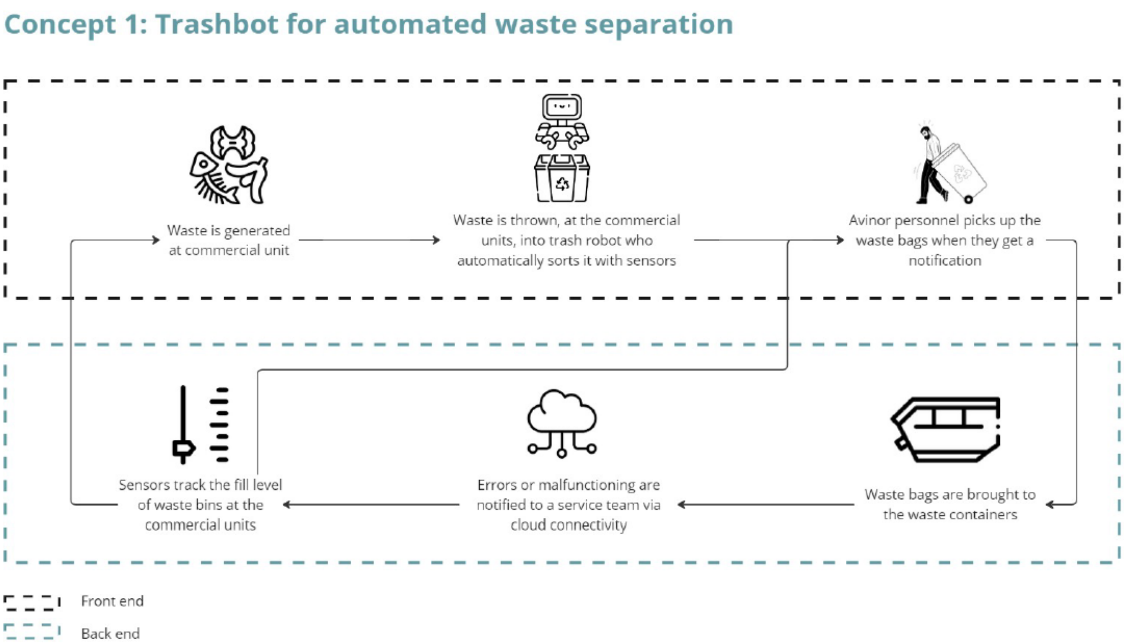


Figure 36: Main process concept 1. (Own figure).

Figure 37: Touchpoints concept 1. (Own figure).

7.6.2 Concept 1.2: Trashbot with AGV

This concept is in its core the same as concept 1 (Figure 38), however this concept has a more futuristic character and thereby focussing on a later stage in the design roadmap formulated by TULIPS, see Figure 2. The separation of waste at the commercial units is done in the same way, but the transportation to the waste station is fully automatic. By implementing an Automated Guided Vehicle system the trashbots can drive on its own to the waste station after closing time. This can happen overnight so that passengers are not hindered and the commercial units can start their day with empty waste bins.

The process and the touchpoints can be seen in Figure 39 and Figure 40.

Below the advantages and disadvantages will be highlighted for concept 1.2.

Advantages

- Aligns with the wishes of Avinor to be an innovative airport.
- Takes away the waste separation responsibility from the commercial unit employees.
- The AGV system saves time, because employees do not have to walk to the waste station in the basement.

Disadvantages

- The mapping of tenants waste practices showed that most tenants bring their waste, or let it collect, two times per day or more. Therefore, emptying the waste bins only once overnight is not desired.

	Option 1	Option 2	Option 3
Making waste separation easier	Improve and align instructions and signage	Waste sorting robot	AI sensor for separating waste automatically on a conveyor belt
Waste transportation	Automated Guided Vehicles for waste transportation	Robotic bins that, once they are filled, drive autonomously to the waste station	
Saving space / waste storage	Modular waste bins that can be configured per tenant based on demand and waste amounts	Temporary waste storage points (e.g. a hub per pier) in between commercial units and waste station	
Weighing waste	Integrated weighing system or sensors in bins that instantly weighs the waste or volume	Interactive floor sensors that measure the weight of waste bins	
Training employees	Include an e-learning module in the ID-card safety training about waste management		
Information provision	Waste campaign to create awareness around waste reduction	Centralised app for information provision	Develop a waste FAQ section or waste specific section in the app or on the website about
Motivating staff	Big screen with waste prestations / KPI's to create a proud feeling		
Ownership of waste management	Participatory decision making sessions where all stakeholders have a voice in shaping the waste management	Create a participation council to have all stakeholders voices represented	
Other	Automated tipping device for emptying waste bins into container	Use data and machine learning to predict peak moments and best pick-up times	

Figure 38: Morphological chart sub-functions concept 1.2. (Own figure).

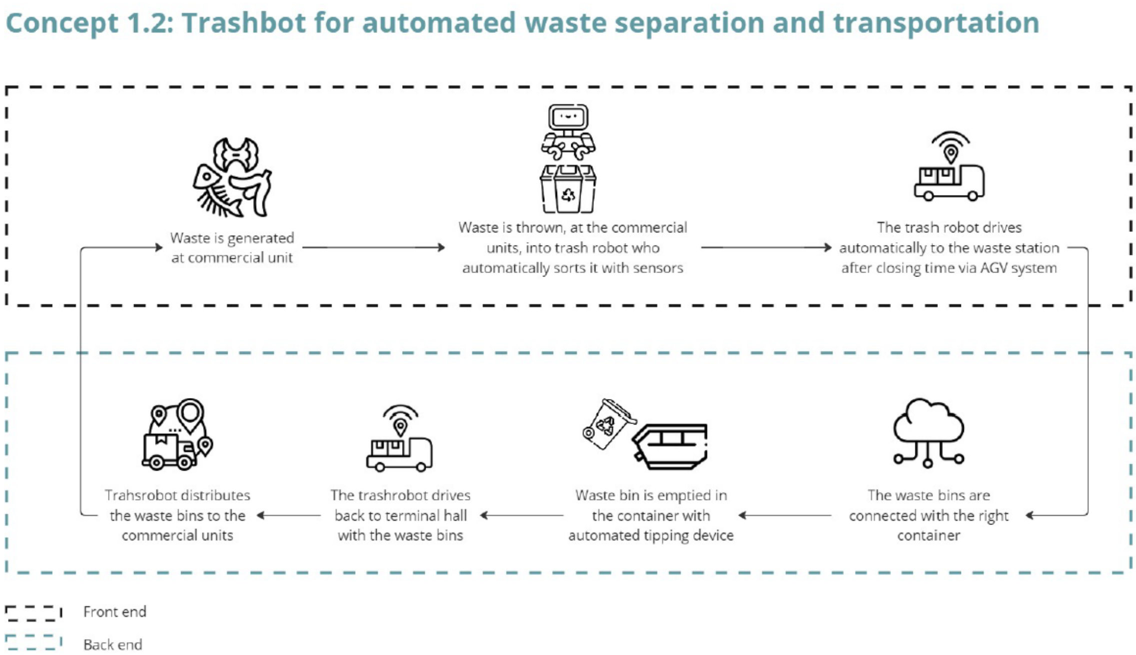


Figure 39: Main process concept 1.2. (Own figure).

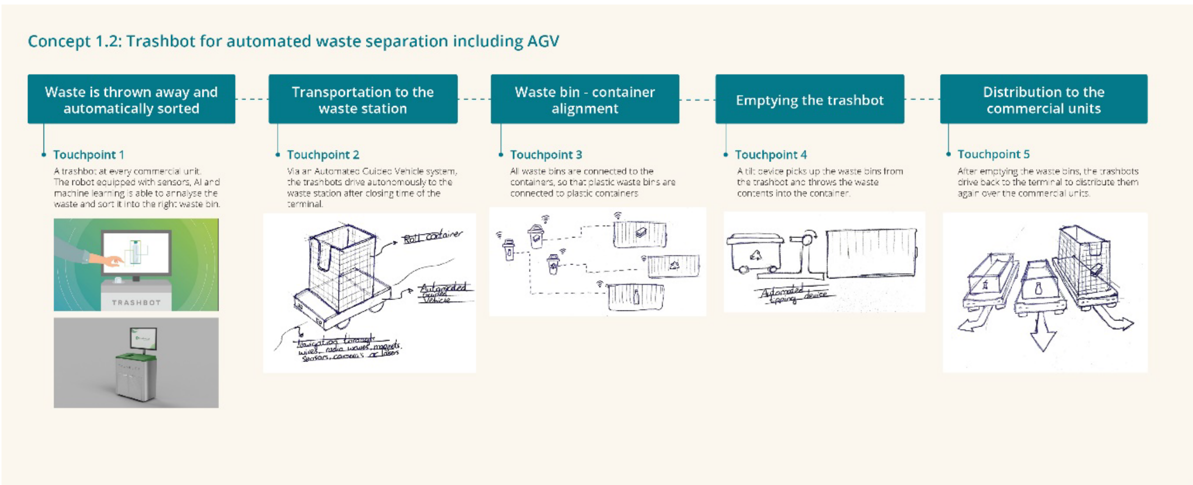


Figure 40: Touchpoints concept 1.2. (Own figure).

7.6.3 Concept 2: Personal motivation through air miles

This concept focusses on tackling the human behaviour aspect by motivating on a personal level. The combined sub-functions are displayed in Figure 41. Staff of the commercial units are clearly instructed on waste separation through improved signage. At the waste station, in front of every container, the waste will be assessed on a conveyor belt with sensors equipped with AI technology. The better the results, the more points are earned. These points are assigned to the employee of which the ID card is scanned and can be used for several (sustainable) incentives, such as public transport tickets or higher discounts in the Avinor community app.
For this concept, the main process with its touchpoints can be seen in Figure 42 and Figure 43. Below are the advantages and disadvantages listed.

Advantages

- Tackling the human behaviour problem by motivating the employees to properly sort the waste is beneficial.

Disadvantages

- Implementation costs of a conveyor belt equipped with AI sensors are presumably high.

	Option 1	Option 2	Option 3	Option 4
Making waste separation easier	Improve and align instructions and signage	Interactive tv screens (like bowling) for separating feedback and interaction	Align waste bins for tenants with the containers at Rp19	AI sensor for separating waste automatically on a conveyor belt
Waste transportation	An electric car with multiple wagons to collect waste separately			
Saving space / waste storage	Modular waste bins that can be configured per tenant based on demand and waste amounts			
Weighing waste	Integrated weighing system or sensors in bins that instantly weighs the waste or volume			
Training employees	Include an e-learing module in the ID-card safety training about waste management	AR app for new-joiners to learn and discover their way around the airport and about waste management		
Information provision	Centralised app for information provision	A chatbot or virtual assistent offering help and guidance		
Motivating staff	Discounts in Avinor community app for personal waste prestations	Rewards (e.g. giftcards) for personal results regarding waste		
Ownership of waste management	Stricter tenant agreements, including strikes regarding waste sorting or reducing			

Figure 41: Morphological chart sub-functions concept 2. (Own figure).

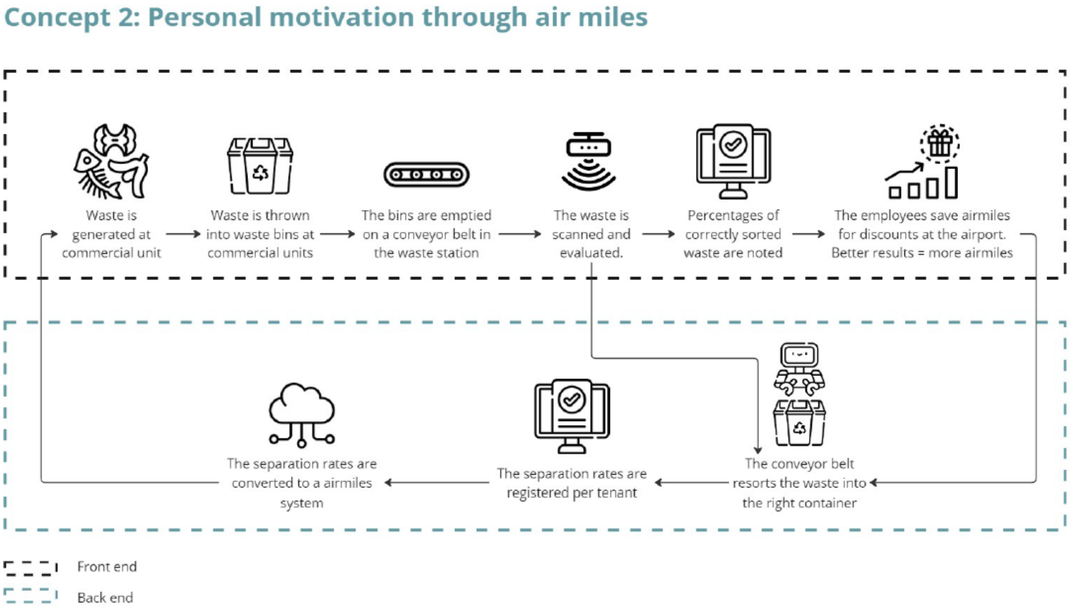


Figure 42: Main process concept 2. (Own figure).

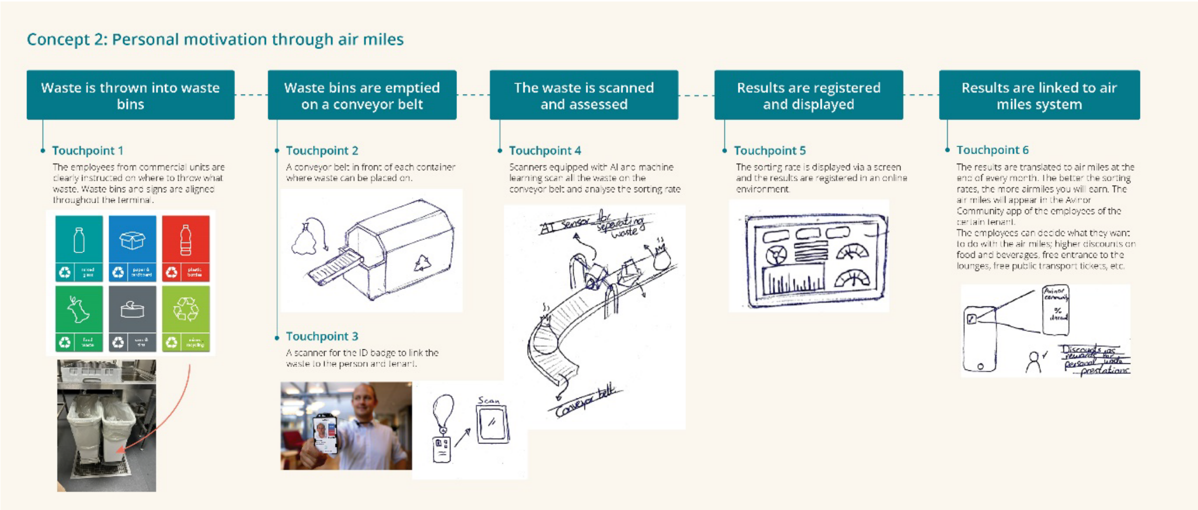


Figure 43: Touchpoints concept 2. (Own figure).

7.6.4 Concept 3: Pay As You Throw

From the sub-functions (Figure 44) concept 3 is created. This concept focusses on tackling the human behaviour aspect by motivating on a management level. Staff of the commercial units are clearly instructed on waste separation through improved signage. At the waste station, waste is placed on a big scale, which can be accessed by scanning the personal ID badge. Like a scale for fruit and vegetables in a supermarket, it automatically prints a barcode sticker to place on the waste bag. Then, before throwing it in the right container, this barcode is scanned at that container. By doing this, it is clear per tenant how much waste they threw away per waste type. The tenants are billed based on their amount of waste, with the highest fee for residual waste to stimulate good sorting.
For this concept, the main process and the touchpoints are displayed in Figure 45 and Figure 46.
The advantages and disadvantages of concept 3 are listed below.

Advantages

- By introducing a waste fee, tenants will be stimulated to sort the waste better.
- Targeting the tenant with the waste fee will create manager support. With that, waste sorting probably does not become optional, if compared to concept 2.

Disadvantages

- Pay As You Throw can be viewed as a negative intervention, because the rent is already experienced as relatively high.

	Option 1	Option 2	Option 3
Making waste separation easier	Improve and align instructions and signage	Colour coded waste bags and bins for easy sorting and recognition	Align waste bins for tenants with the containers at Rp19
Waste transportation	An electric car with multiple wagons to collect waste separately		
Saving space / waste storage	Modular waste bins that can be configured per tenant based on demand and waste amounts		
Weighing waste	Supermarket vegetable/fruit system at the commercial units: scan and weigh every waste bag and print a barcode on it		
Training employees	Include an e-learing module in the ID card safety training about waste management	AR app for new-joiners to learn and discover their way around the airport and about waste management	
Information provision	A chatbot or virtual assistent offering help and guidance		
Motivating staff	A higher waste fee for a tenant that does not reach the waste targets	Big screen with waste prestations / KPI's to create a proud feeling	
Ownership of waste management	Stricter tenant agreements, Including strikes regarding waste sorting or reducing		

Figure 44: Morphological chart sub-functions concept 3. (Own figure).

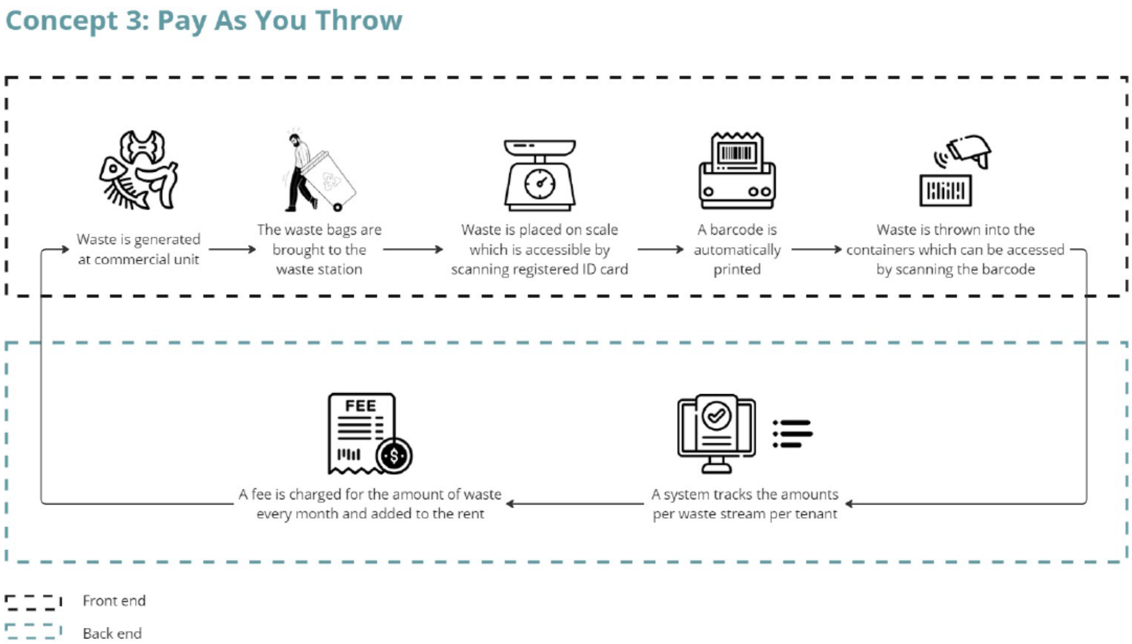


Figure 45: Main process concept 3. (Own figure).

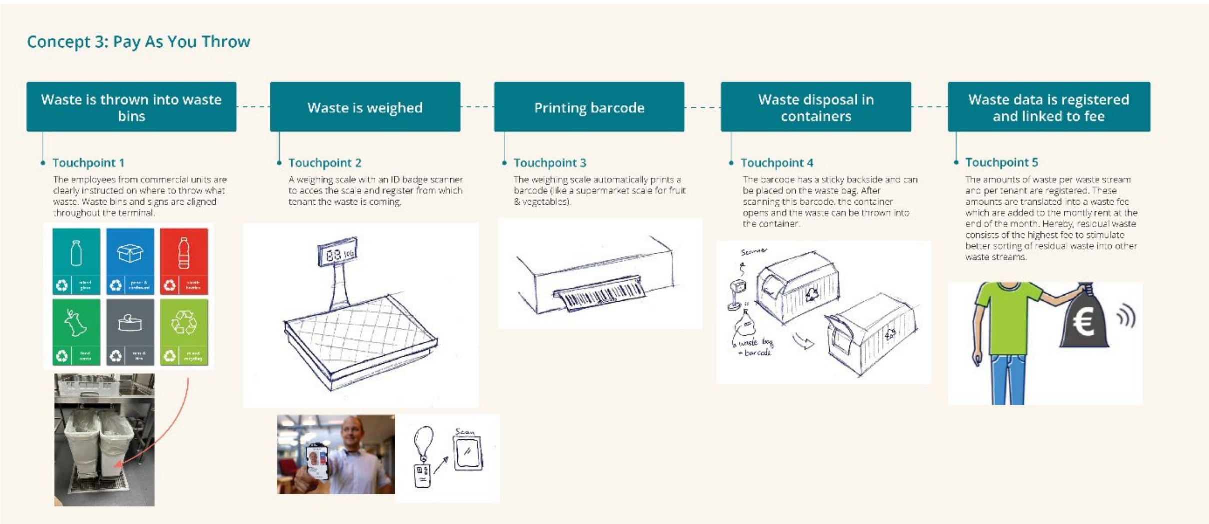


Figure 46: Touchpoints concept 3. (Own figure).

7.6.5 Concept 4: Waste footprint

Sub-functions from the morphological chart are combined and form concept 4, as seen in Figure 47. This concept approaches the waste problem from a new perspective; with the idea that everything that comes in, also goes out. By setting up a waste footprint for every article tenants purchase, insight will be created in the total amount of waste in the whole chain. The tenants will be billed for all materials that come in. This means that it is beneficial if a certain product contains as little packaging as possible. With this concept, waste reduction is tackled at the root/beginning of the chain. It also gives tenants bargaining power over their suppliers to use less packaging materials.

Figure 48 and Figure 49 show the main process and the touchpoints of this concept. The advantages and disadvantages for this concept are listed below.

Advantages

- This concept focuses on the prevention of the waste problem. In the end, the goal is to have zero waste and become circular. This concept tackles this problem from its root.

Disadvantages

- This concept knows an intense implementation, both financial and operational, due to it’s large network of involved stakeholders.

	Option 1	Option 2	Option 3
Making waste separation easier	Improve and align instructions and signage	Align waste bins for tenants with the containers at Rp19	Colour coded waste bags and bins for easy sorting and recognition
Waste transportation	An electric car with multiple wagons to collect waste separately		
Saving space / waste storage	Modular waste bins that can be configured per tenant based on demand and waste amounts	Collapsible bin for use only when needed (e.g. cardboard when new supplies are delivered)	
Weighing waste	Set a rule of thumb for each waste stream and bin volume. E.g. one full bin of organic waste = x amount of kg.		
Training employees	Include an e-learing module in the ID-card safety training about waste management	AR app for new-joiners to learn and discover their way around the airport and about waste management	Organise recurring sustainabiliy courses for tenants to stay up to date
Information provision	Centralised app for information provision	Reccuring waste audits and consulting services to help tenants with waste separation and reduction	
Motivating staff	A higher waste fee for a tenant that does not reach the waste targets	Big screen with waste prestations / KPI's to create a proud feeling	
Ownership of waste management	Hire facilitation manager as coordinator and owner of waste management	Hire facilitation team to take over all waste related activities	
Other	Blockchain network for all goods and thus waste		

Figure 47: Morphological sub-functions concept 4. (Own figure).

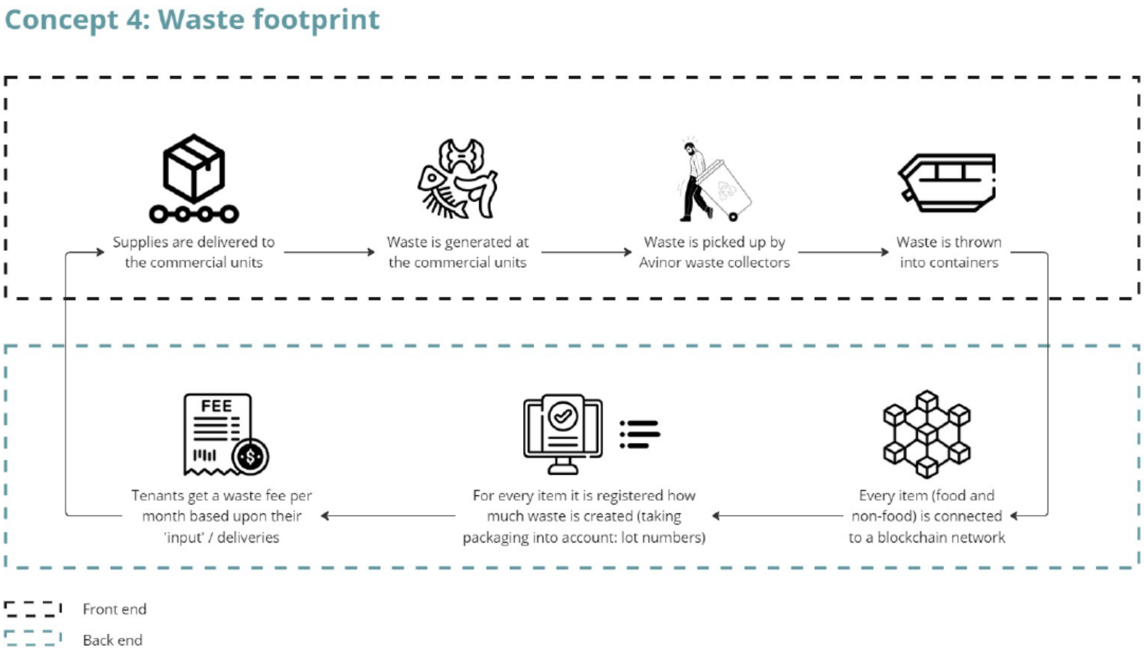


Figure 48: Main process concept 4. (Own figure).

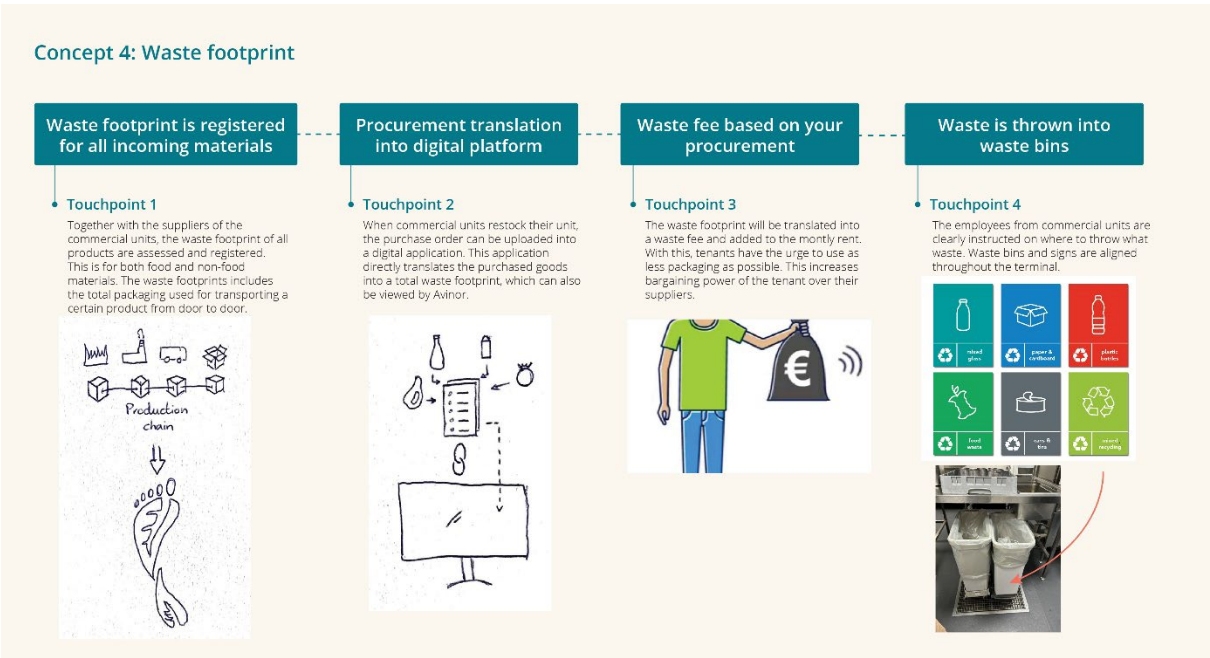


Figure 49: Touchpoints concept 4. (Own figure).

7.6.6 Concept 5: Waste management team

This concept fixes the principal-agent problem that exists at Oslo Airport between Avinor and its tenants. Figure 50 shows the sub-functions from the morphological chart for this concept. Tackling the principal-agent problem is done by assigning a waste management team that has full ownership and responsibility over the waste management. This team will assess every tenants waste, collects it for them and brings it to the waste station.

The process for this and its touchpoints can be seen in Figure 51 and Figure 52. Below are the advantages and disadvantages of this concept listed.

Advantages

- The desirability of this concept is high, because both the tenants, F&B operating companies and waste collectors indicate that a waste management team is desired.

Disadvantages

- This is a short-term concept, which will probably not be a sustainable and future-proof solution.
- The operational costs of a dedicated waste management team are high.

	Option 1	Option 2	Option 3
Making waste separation easier	Improve and align instructions and signage	Align and expand waste bin types for tenants	Align waste bins for tenants with the containers at Rp19
Waste transportation	An electric car with multiple wagons to collect waste separately		
Saving space / waste storage	Modular waste bins that can be configured per tenant based on demand and waste amounts	Collapsible bin for use only when needed (e.g. cardboard when new supplies are delivered)	
Weighing waste	Using RFID or QR codes for waste tracking and registration	Supermarket vegetable/fruit system at the commercial units: scan and weigh every waste bag and print a barcode on it	Set a rule of thumb for each waste stream and bin volume. E.g. one full bin of organic waste = x amount of kg.
Training employees	Organise recurring sustainability courses for tenants to stay up to date		
Information provision	Recurring waste audits and consulting services to help tenants with waste separation and reduction		
Motivating staff	A higher waste fee for a tenant that does not reach the waste targets		
Ownership of waste management	Hire facilitation manager as coordinator and owner of waste management	Hire facilitation team to take over all waste related activities	
Other	Use data and machine learning to predict peak moments and best pick-up times		

Figure 50: Morphological sub-functions concept 5. (Own figure).

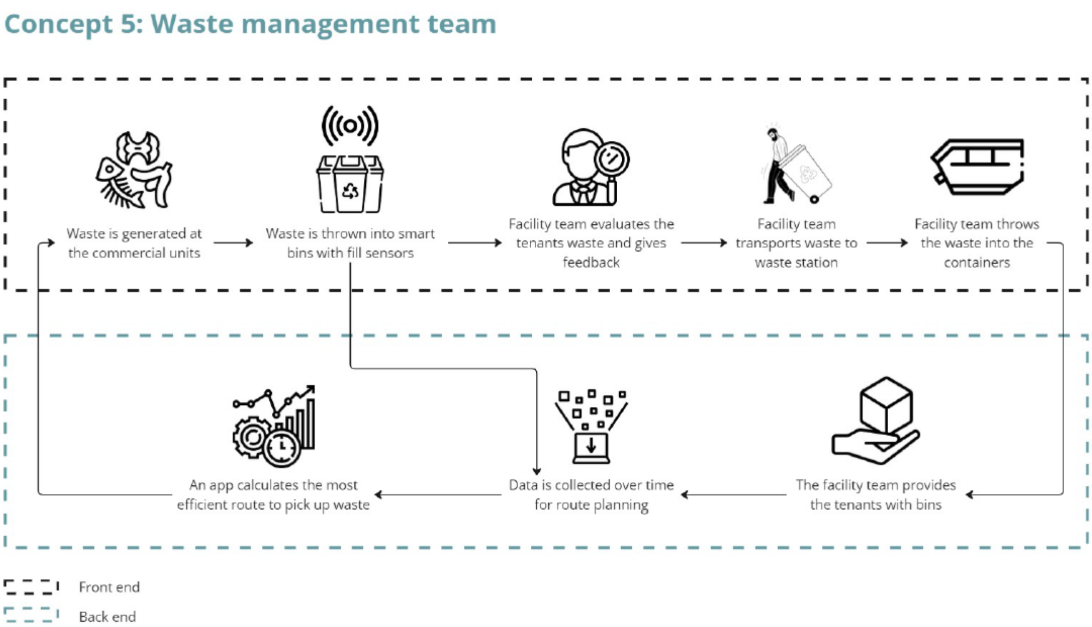


Figure 51: Main process concept 5. (Own figure).

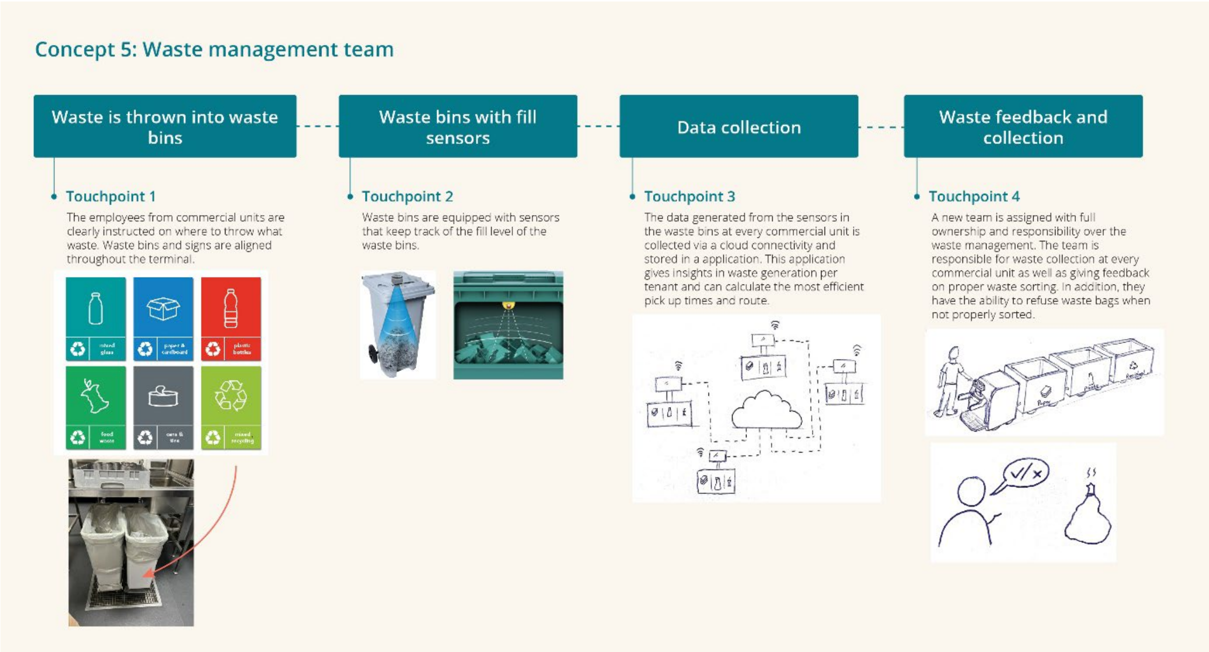


Figure 52: Touchpoints concept 5. (Own figure).

7.7 Concept evaluation

Two methods are used in order to evaluate the six concepts, a Harris profile and an impact-feasibility matrix. To be able to use a Harris profile, the main takeaways from the previous chapters need to be formulated into design evaluation criteria.

7.7.1 Evaluation criteria

To assess the concept, the four pillars of design are used as main categories in the evaluation criteria: desirability, viability, feasibility and sustainability. Evaluating a product or service continuously through these different lenses helps mitigating the risk and having a desired, feasible, viable and sustainable outcome (Werdmuller, 2018).

Feasibility: are the people, time and resources available in order to make the proposed solution happen? The feasibility evaluation criteria come from the observational research, interviews and literature review in chapters 3,4 and 5.

Viability: can the proposed solution be profitable or can it help growing the organisation? For this, investments costs, operational savings and eventual revenue generation are taken into account.

Desirability: is the proposed solution meeting the needs of the users? Do the users really want it? The desirability criteria are derived from chapter 4, where stakeholder needs are defined.

Sustainability: does the proposed solution have a non-negative, or preferably a positive, social and environmental impact. The sustainability criteria come from the circularity targets set by TULIPS in chapter 1.2 and interviews with stakeholders, which can be found in chapter 4.

By assessing the concepts through these different lenses, an optimal solution can be derived from the concepts. The criteria's are a direct translation coming from the main takeaways.

7.7.2 Harris profile

The Harris profile, shown in Figure 53, is used as method to make a visual evaluation of the six concepts. The concepts are evaluated based on the criteria as described in chapter 7.7.1. Appendix M6 includes an enlarged figure of the Harris profile.

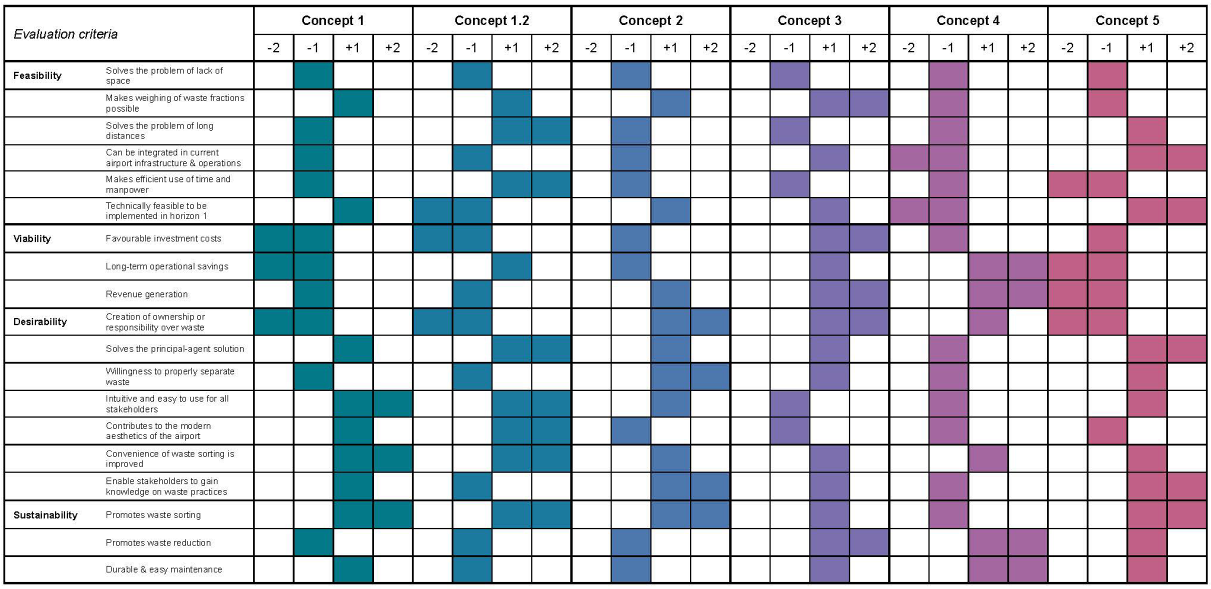


Figure 53: Concept evaluation through a Harris profile. (Own figure).

From the Harris profile it can be concluded that concepts 1.2, 2, 3 and 5 perform the best regarding feasibility. Concepts 1 and 1.2 also score good on desirability. Regarding viability, concept 3 performs the best. For sustainability, there is not one concept that performs significantly better than other concepts, however concept 4 can be considered as the preferable solution.

7.7.3 Impact-feasibility matrix

In order to substantiate the assessment an impact-feasibility matrix is used. With this matrix the concepts are evaluated on two axes. First, the feasibility, in terms of how easy the concept can be implemented in the current operations of Oslo Airport. Second, impact, which can be seen as the degree to which a concept makes reaching targeted goals possible (Beekast Inspirations, 2020). Like the Harris profile, this matrix is not a calculated evaluation, but serves as a visual assessment.

The matrix in Figure 54 shows that concept 5 has the highest evaluation on feasibility, because of the ease of implementation on short-term and the absence of high investment costs for new technologies. However, having a costly waste management team is not desirable (chapter 4.2.4) and therefore does concept 5 score average on impact.

Concept 2 and 3 both have a high evaluation regarding impact, since those concepts tackle the human behaviour problem, which is one of the three main problem domains as described in chapter 6.1.4. Concept 2 is evaluated lower on feasibility than concept 3, because of the implementation of the conveyor belt with AI sensors. This is presumably more difficult and costly to implement than a weighing solution, as described in concept 3.

Concept 1.2 scores equal on impact to concept 2, 3 and 5, but especially lower on feasibility. The automated sorting and time saving through the AGV system will have a high impact, however these systems are significantly more difficult to implement than the other concepts.

Concept 1 is comparable with concept 1.2, however less decorated due to not having the AGV system. This will result in a higher feasibility score, but lower in impact.

Lastly, concept 4 scores the lowest on both feasibility and impact. In this concept the whole chain, including the suppliers, needs to be restructured. This results in the low feasibility. Regarding impact, this concept does not relates back to one of the main problem domains and is therefore assessed low on impact.

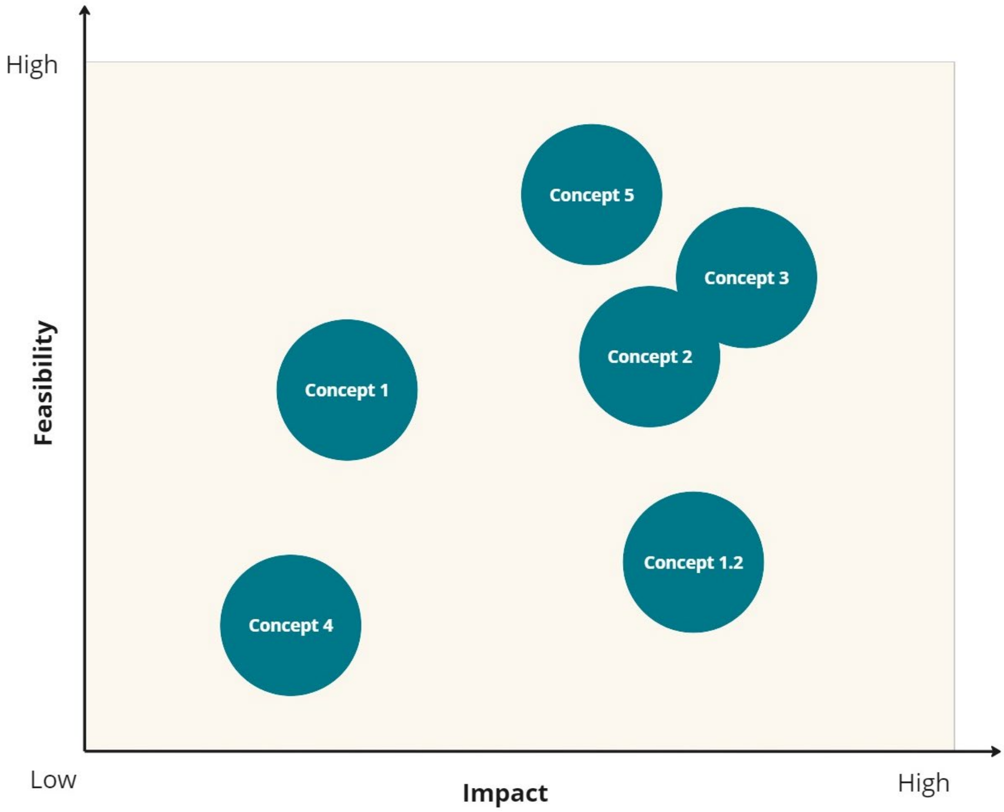


Figure 54: Impact-feasibility matrix. (Own figure).

7.8 Concept elaboration

From the evaluation through the Harris-profile and the impact-feasibility matrix, it can be concluded that there is not one concept significantly more feasible, desirable or viable. Every concept has its advantages and disadvantages. In order to develop a final concept, sub-solutions or parts of the five concepts need to be combined into one concept. Additional literature and elaboration is needed for this to assess certain technologies or interventions.

7.8.1 Incentive versus disincentive mechanism

Concept 2 and 3 are comparable in a way that both concepts stimulate proper waste sorting through implementing an intervention to change human behaviour. Concept 2 uses a financial incentive for this, while concept 3 uses a financial disincentive.

Financial incentives and disincentives are good instruments to change human behaviour or stimulate desired behaviour and are gaining popularity in environmental policy (Thøgersen, 1994). When putting economic incentives in a sustainability perspective, the intended purpose is to achieve proper waste sorting and waste reduction. According to Goetz (2010), incentive programs should meet the user needs. Financial incentives can be applied for reaching better sorting rates, but can have a by-effect resulting in the stimulation of waste creation. Incentivising waste creation is the opposite of the intended purpose of Avinor (becoming circular).

By implementing financial disincentives, users are stimulated to reduce and properly sort their waste. Money can work as a pressing tool by having users pay for the amount of waste that they generate. The concept Pay As You Throw (chapter 5.4) can be used as a financial disincentive program. By doing that, the tenants at Oslo Airport will pay a fee over their generated waste. This will stimulate, especially the management layer in the organisations, to create as less waste as possible. In addition to this, different fees can be used to stimulate proper sorting as well. For this, residual waste should contain the highest fee. In conclusion, financial disincentives are more suitable when it comes to sustainable waste practices at Oslo Airport. Therefore, concept 3 is preferred over concept 2.

7.8.2 Automatic waste sorting

Concept 1 and 1.2 both include an automatic waste sorting robot. This intervention makes it possible to automatically sort the waste more accurately than humans with the help of sensors. The Trashbot (Figure 55), for example, is able to sort waste with a 96% accuracy (CleanRobotics, 2023).

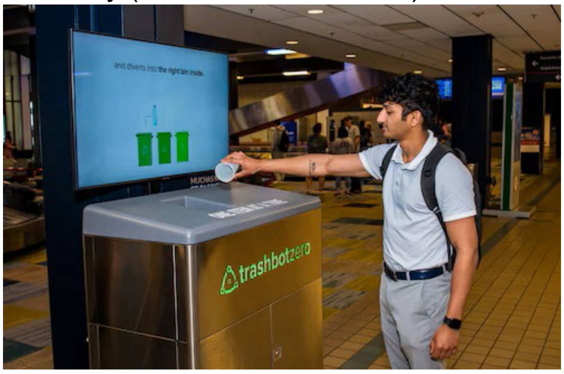


Figure 55: Trashbot for automatic waste sorting. (CleanRobotics, 2023).

The machine is able to sort two to four different waste streams, performs on demand audits and automates the waste data. The current technology contains many disadvantages:

- Time consuming, as it takes 4 to 6 seconds to sort an item,
- Amount of waste streams, as there is a maximum of only 4 waste streams,
- Size of the items, since the maximum size is 3,6 kilograms or liters.
- Multiple items at the same time are still difficult to detect.
- Investment costs, as these machines can cost up to 5000 euros per unit. The total costs will be

significant when placing a sorting robot at every tenant.
- Space is scarce the commercial units at Oslo Airport, so not every tenant will have the space to implement such a machine.

In conlcusion, implementing an automatic waste sorting robot is not yet a feasible and viable addition to the waste management service.

7.8.3 Automated Guided Vehicles

As proposed in concept 1.2, the waste would be transported from the tenants to the waste station after closing time so that the passengers and AGV's not hinder each other. However the mapping of waste practices from tenants (see appendix C) show that most tenants currently bring their waste, or have it collected, more than two times per day. With that knowledge in mind, it is necessary to either have larger waste bins for waste storage or transport the waste to the waste station more often, with the condition to have a location where the AGV's not hinder the passengers. Since larger waste bins are not feasible due to space limitations at the commercial units, the latter is preferred. By letting AGV's drive only at the hallways in the basement, passengers in the terminal hall are not obstructed.

7.8.4 Waste weighing location

One condition to be able to implement Pay As You Throw is to have a back trace, so that it is registered which waste comes from which tenant. This is because, with the PAYT system, a fee will be charged per tenant. By linking the ID badges of Oslo Airport employees to the waste weighing activity, it is possible to register which waste comes from which tenant. For this, it is necessary to have a location for weighing the waste at the terminal (instead of at the waste station, see chapter 4.3), because many tenants do not come to the waste station themselves but have their waste transported there by waste collectors.

Main takeaways

- Financial disincentives are preferred over incentives as they stimulate not only waste sorting, but also waste reduction. Financial disincentives should therefore be included in the design.
- Automatic waste sorting machines are not feasible and viable to implement into the complex waste system at Oslo Airport.
- Automated Guided Vehicles are desired to integrate in Oslo Airports waste management system. This will eventually reduce personnel costs to pick up and transport waste. For the final concept the system should only be considered at locations where passengers are not obstructed by the AGV's.
- In order to comply to the rules regarding waste weighing (chapter 4.3), waste weights should be registered per tenant. In order to do this, employee ID badges can be used to link the waste throwing activity to the tenant. Preferably, waste is measured early in the process, at the terminal, to be able to register waste per tenant.

7.9 Concept combining

In conclusion, each concept has its own strengths and weaknesses, but the best approach for improving the waste management at Oslo Airport is to combine the most effective elements from several concepts. This includes focusing on financial disincentives to encourage waste reduction, using different rates for this to also stimulate better waste sorting, using Automated Guided Vehicles (AGVs) for efficient waste transport and implementing a system for tenant-specific waste tracking. In chapter 8 a final concept is developed.

8 Develop

In this chapter evaluation results of the concepts are taken into consideration and the concepts will be combined and further developed into one concept.

8.1 Concept development

Based on the outcomes from chapter 7, a testable concept is developed.
This concept offers a solution to the three main problems, being infrastructural hurdles, changing human behaviour to achieve responsibility regarding waste and information provision.

This is achieved by having improved signage for waste sorting at the commercial units, employees are better informed on where to throw what waste.

Also, there will be multiple container hubs placed throughout the terminal where the tenants can bring their waste instead of having to go to the waste station in the basement. These container hubs are in-between stations between the commercial units and the waste station and are equipped with 660L wheelie bins on weighing scales. These container hubs are only accessible through scanning the employee ID badge, which makes it possible at the same time to register the amount of waste per tenant. According to the research from Kadibu & Jonyer (2022) an Airport employee suggested that the waste sorting rates will be higher if each unit disposed of the waste itself, because currently neither the employees of the serving units have any connection with waste disposal, nor the waste collector crew has connection with the production of waste. These container hubs provide a solution to this problem.

Further, this concept includes Pay As You Throw to fine tenants for their generated waste with residual waste containing of the highest fee in order to stimulate proper sorting. Lastly, Automated Guided Vehicles will transport the waste from the container hubs to the waste station autonomously.
The touchpoints of this concept can be found in Figure 56.

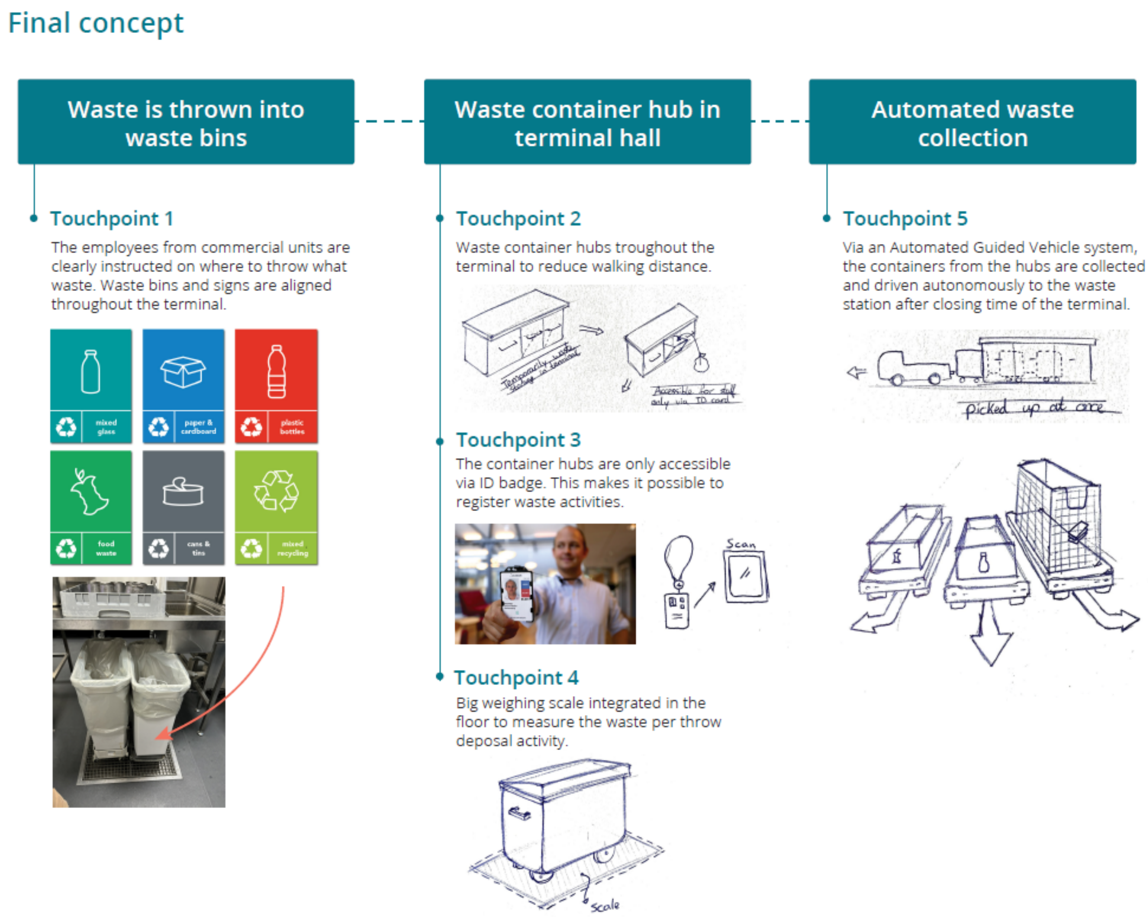


Figure 56: Touchpoints testable concept. (Own figure).

In addition to the touchpoints of the concept, a visual overview is created. In this overview, the solutions to each aspect of the main problems are elaborated.

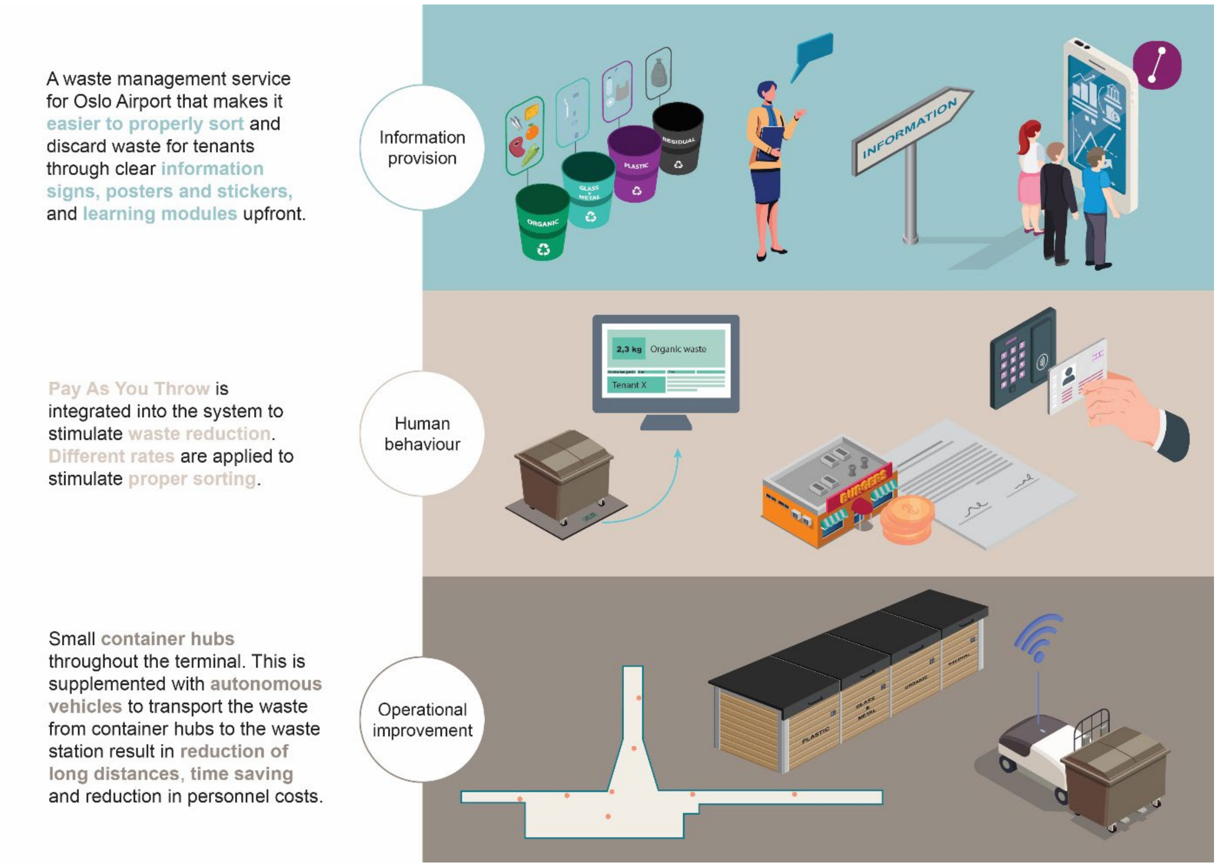


Figure 57: Overview testable concept. (Own figure).

8.2 Service storyboard

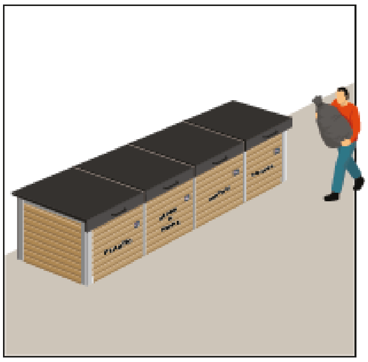
To explain the process of the service of the final concept and in order to evaluate this concept, a service storyboard is created (Figure 58). This storyboard is a visual overview of the scenario what the service will look like, containing every step in the service.

Waste is generated at the commercial units in the terminal.

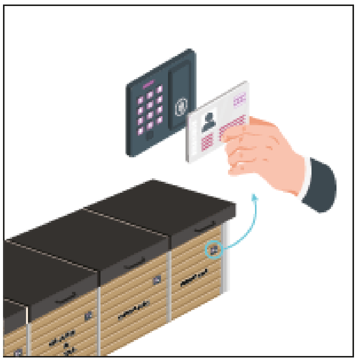
Waste is thrown into the right bin which is stimulated by improved signage and online learning modules.

When a bin is full, an employee empties the waste bin.

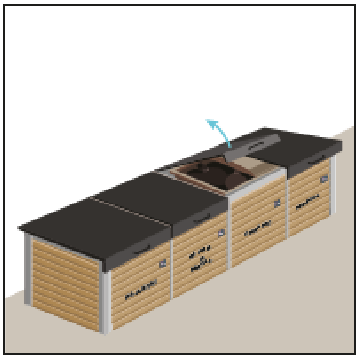
The waste is brought to a terminal waste container hub. Directions can be found at every commercial unit.



The employee arrives at the waste container hub. There are multiple hubs in the terminal hall.

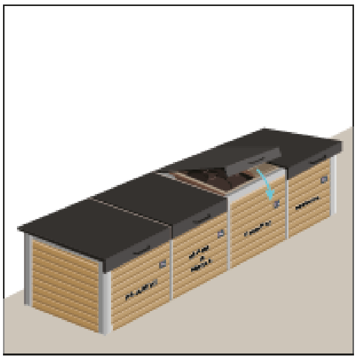


At the waste container hub the employee scans his/her ID badge to open the desired container.



A lid opens and the container is accessible.

The employee can throw the waste bag(s) into the container.



The lid can be closed again.

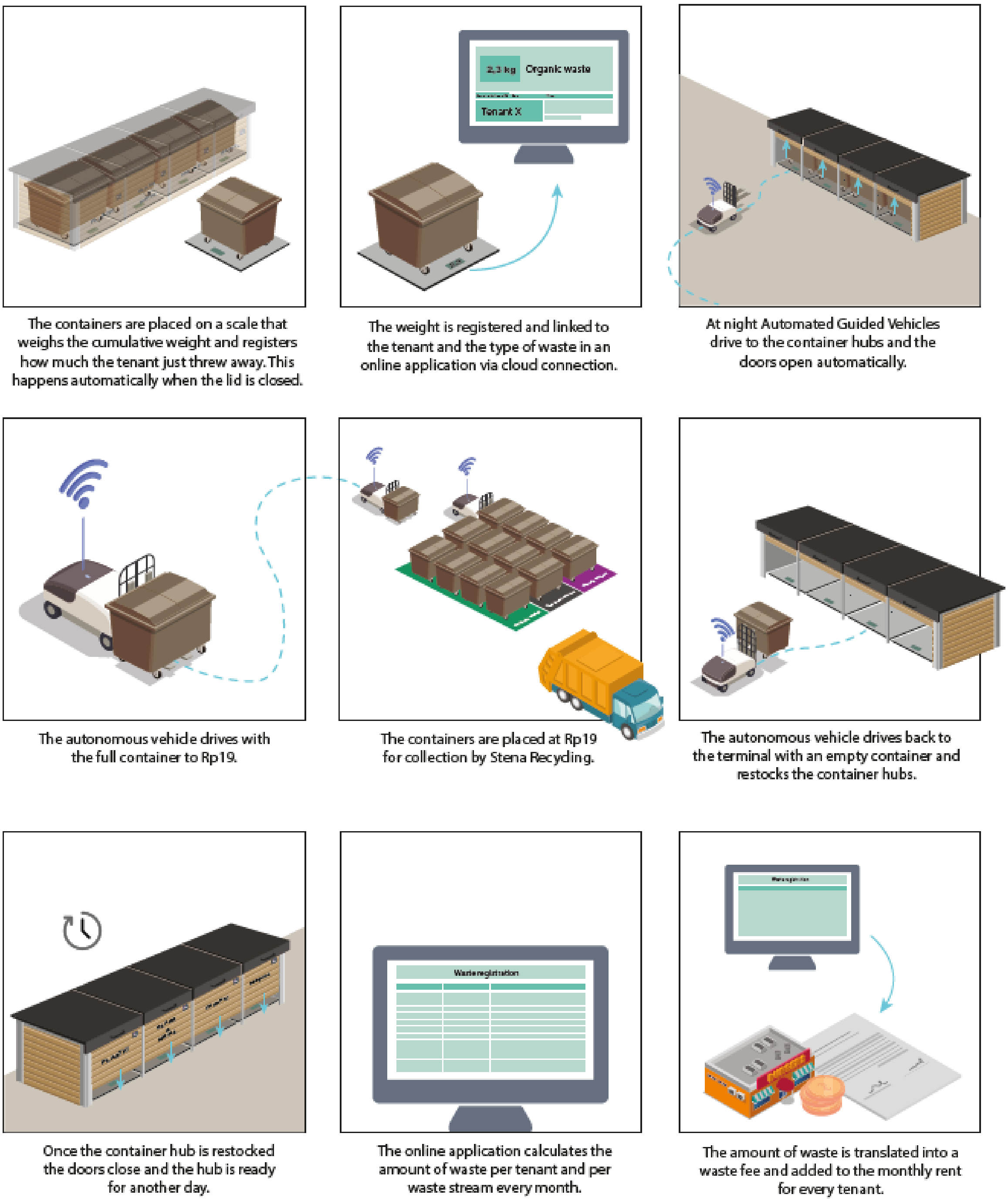


Figure 58: Service storyboard testable concept. (Own figure).

8.3 Container hub locations

An important aspect of the concept is the integration of the so called container hubs. These eleven hubs will be distributed throughout the terminal and serve as the designated places for tenants to throw away their waste. When determining the locations, three aspects are important to keep in mind:

1. Supply and demand. The hubs should be located at places where adequate waste volumes are created and thus consists of a high demand for waste containers.
2. Even distribution. Evenly distributing the hubs throughout the terminal will result in reduced walking distances being almost the same for every tenant.
3. Connection with AGV system. In order to collect waste and transport it to the waste station through AGV's. It is beneficial to, when possible, place the container hubs near elevators. By doing this, the AGV's do not have to drive through the passengers in the terminal hall and the distances to the basement are shortened.

Below in Figure 59 and Figure 60 proposed locations for the container hubs can be viewed in yellow.

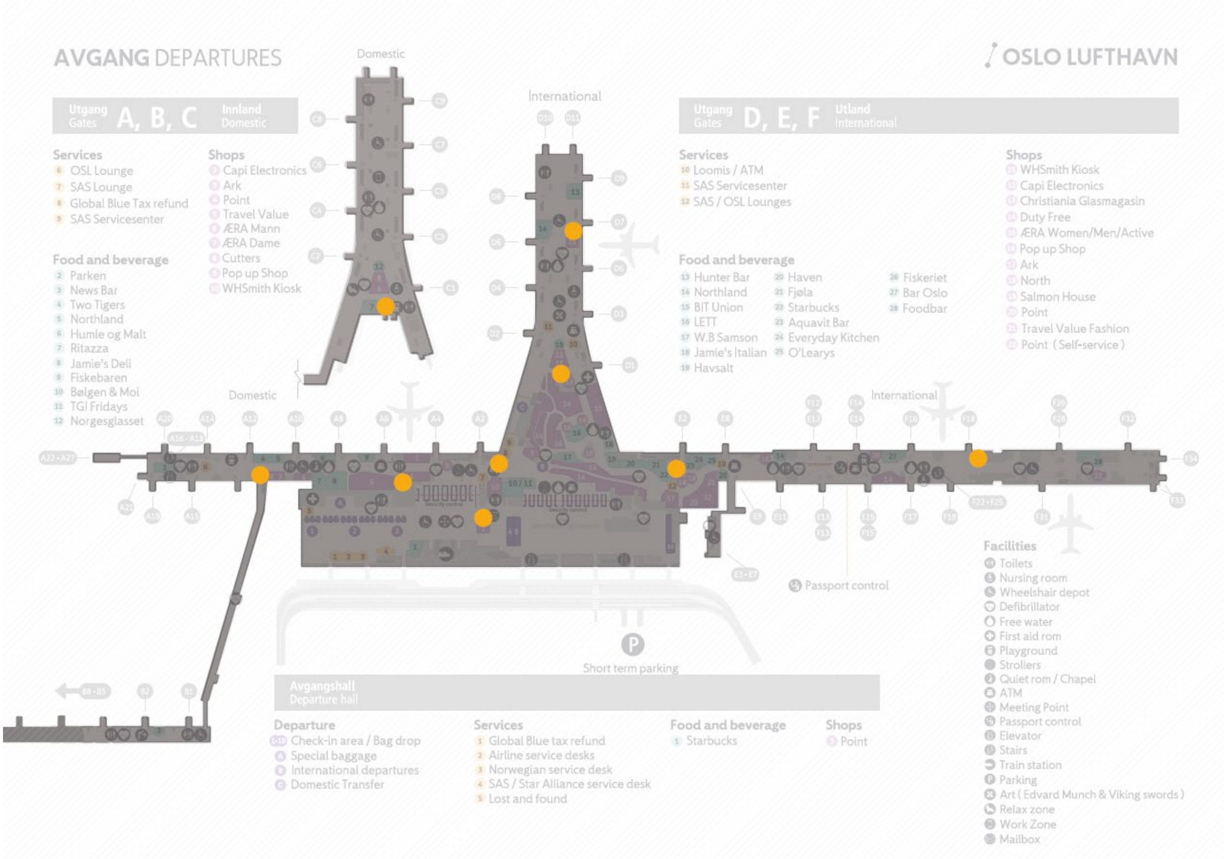


Figure 59: Container hub locations departure hall. (Own figure).

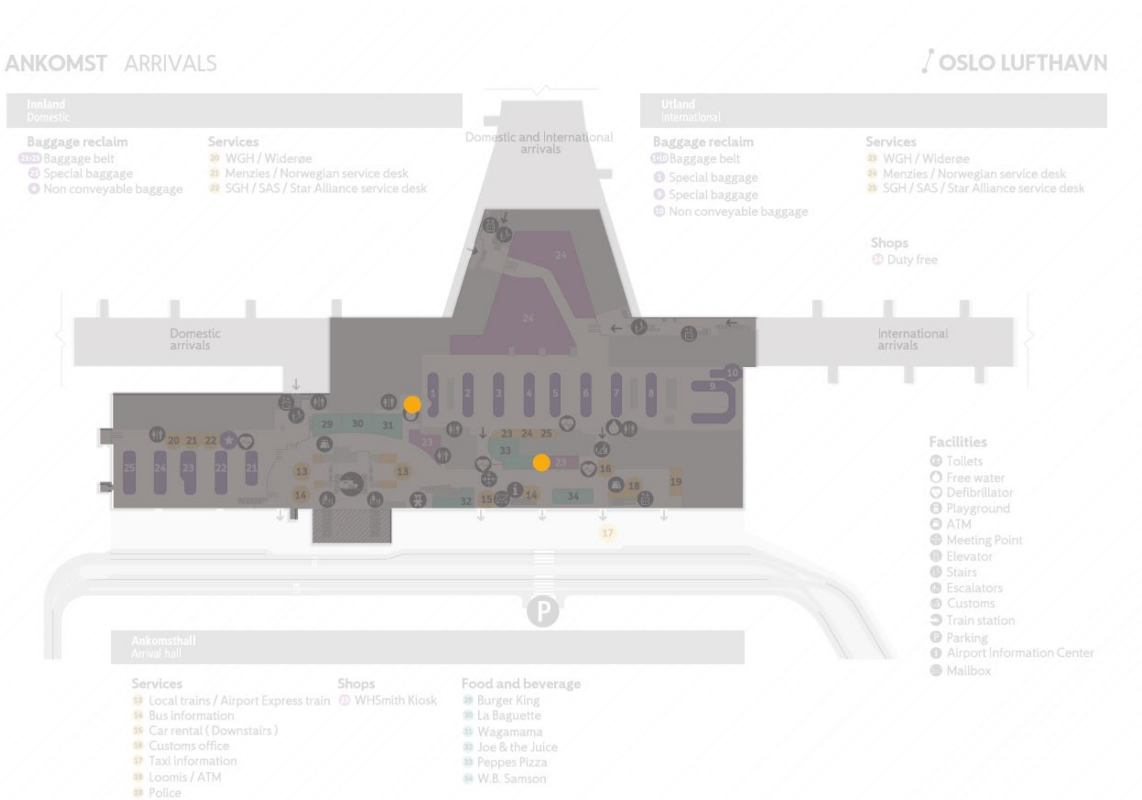


Figure 60: Container hub locations arrival hall. (Own figure).

8.4 Investment costs

Regarding viability, investment costs are calculated. By doing that, an estimated guess is made and provided to Avinor Oslo Airport, the client. Included in the costs estimation are all aspects needed to make the waste management service operational.

COST PRICE ESTIMATION waste management service Oslo Airport					
Item	**Desciption**	**Units**	**Price per unit**	**Total price**	**Source**
Information posters/stickers	Posters and stickers explaining what to throw where	350	€ 1,00	€ 350,00	https://www.printsafari.com/blog/how-much-does-poster-printing-cost/
Waste bins	Providing the tenants with missing bins.	35	€ 30,00	€ 1.050,00	https://www.amazon.com/AmazonCommercial-Gallon-Commercial-Wastebasket-Recycle/dp/B08PDQDBFL
Online learning module	Integration of a new module in the safety course about waste recycling	1	€ 1.000,00	€ 1.000,00	
Container hub framework	Building material for the apearance of the container hubs	11	€ 1.000,00	€ 11.000,00	
Waste container	The waste containers being used at the container hubs	55	€ 300,00	€ 16.500,00	https://www.salesbridges.eu/en/4-wheeled-collection-waste-bin-1100l-black.html
Weighing scale	Scales measuring the weight of the containers	55	€ 2.000,00	€ 110.000,00	https://www.mhaproducts.com.au/floor-pallet-scales
PAYT system	An IT application for registering the waste and linking it to the tenants	1	€ 20.000,00	€ 20.000,00	https://reliasoftware.com/blog/app-development-cost
ID card scanner	Installation of ID card scanners for accessing the container hubs	55	€ 100,00	€ 5.500,00	
Automated Guided Vehicle	The costprice of the actual autonomous robot	4	€ 20.000,00	€ 80.000,00	(Kubasakova et al., 2024) / (AGV network, n.d.) / (Weyers, 2024)
AGV infrastructure	The infrastructure to guide and connect the robots	1	€ 40.000,00	€ 40.000,00	(Kubasakova et al., 2024) / (AGV network, n.d.) / (Weyers, 2024)
			Total	€ 285.400,00	

Figure 61: Investment costs estimation. (Own figure).

8.5 Evaluation

To test the design challenge set in chapter 6.2, validation with all important stakeholders was carried out.
Table 5 shows the involved stakeholders, the goal of each validation and the setup of each validation. The validations are elaborated in the next chapters. Each chapter highlights the most important insights.

Table 5: Validation overview.

Stakeholder	Goal	Setup
Tenants at Oslo Airport	Validate the storyboard, together with the location map on their opinions and implementation in daily operations.	Tenants were visited and asked if they were willing to give feedback on a service concept. Then the storyboard and location map were shown and followed by asking semi-structured interview questions.
Circular economy analyst Avinor (Client)	Validate the storyboard, location map, implementation roadmap and price estimation from a client perspective.	A meeting was scheduled where the storyboard, location map, implementation roadmap and price estimation were shown. Semi-structured interview questions were asked.
Recycling company A	Validate the storyboard, together with the location map on practicalities.	An online meeting was scheduled. During this meeting a small presentation was presented to introduce the graduation project and the main problem. Followed with an explanation of the storyboard and location map. Semi-structured interview questions were then asked.
F&B operator A	Validate the storyboard, together with the location map on their opinions and implementation in daily operations.	An online meeting was scheduled. During this meeting a small presentation was presented to introduce the graduation project and the main problem. Followed with an explanation of the storyboard and location map. Semi-structured interview questions were then asked.
F&B operator B	Validate the storyboard, together with the location map on their opinions and implementation in daily operations.	An online meeting was scheduled. During this meeting a small presentation was presented to introduce the graduation project and the main problem. Followed with an explanation of the storyboard and location map. Semi-structured interview questions were then asked.

8.5.1 Tenant validation

The first validation session was carried out with 20 tenants at Oslo Airport. The main insights are listed in Table 6 below. These insights are clustered in themes, including the key insights per theme and quotes as argumentation.

Table 6: Tenant validation results.

Theme	Key insights	Quotes
Feasibility and desirability	• The concept is clear and easy to understand. • The concept is perceived positively	"Concept is clear." "It seems quite nice. I don't know if it is doable for Avinor. But it is awesome to have a place close by to throw away the waste." "Your concept is quite good." "I think it's a smart concept."
PAYT (Pay As You Throw)	Opinions on PAYT vary, with some seeing it as a useful motivator and others concerned about additional costs.	"The reason is good, but generating the waste in the restaurant is controllable, but not for passengers. So it needs to be separated." "PAYT is very useful." "Not really an opinion on it. At least not negative thoughts about it." "It helps getting a better understanding in waste and in my opinion it is not a bad thing to do this." "Avinor just wants more money."
Container hub location	• Location of the container hubs is crucial for feasibility and ease of use. • The proposed locations are perceived as good options.	"It would be awesome to have a hub close by. That saves a lot of time." "Container hub location is good." "Container hub close by is really beneficial." "The container hubs shouldn't be visible for passengers in my opinion." "Location of the container hub is amazing – this is your selling point."
Training and navigation	• Proper training and clear navigation are necessary for successful implementation. • Additional navigation is unnecessary if it is included in the training upfront.	"Navigation to the hubs should be in the training upfront." "Directions to the container hub are not necessary for us, but otherwise I think it can be included in the safety training." "Every business should have this map you made. It is a clear overview of the locations." "Just teach new joiners the waste locations. We have trainers that navigate new joiners through the whole business."

System implementation	The system needs to be easy to implement and use, with some tenants already seeing benefits.	"It can be easily adopted if Avinor implements it." "Implementation shouldn't be a problem I think." "It is easy to implement, because it is close by and currently we also have to dispose our garbage ourselves." "In my opinion this service will be easy implementable, because we are used to the vacuum system and this service is comparable."
Waste sorting	Proper sorting of waste is a concern, with suggestions for making it easier for staff and ensuring compliance.	"Staff can be lazy so it needs to be easy." "How to assure proper sorting? That is the only thing that might go wrong." "Think about the PANT, because the deposit needs to be returned to the business." "It is easy for an employee to mess up."
System reliability	Concerns about the reliability of the system, particularly the IT and robot components.	"What if the IT system goes down or there is no connection." "What will happen if the system with the robots is down?"

8.5.2 Client validation

The second validation was carried out with Avinor’s circular economy analyst, who is also the company mentor in this graduation project. The main insights are listed in Table 7 below. These insights are clustered in themes, including the key insights per theme and quotes as argumentation.

Table 7: Client validation results.

Theme	Key insights	Quotes
Feasibility and desirability	Positive reception but questions about container hub appearance and logistics.	"The idea is very good." "This concept also solves the issue with security control." "The challenge with this concept: how exactly will the container hub look like."
Investment and costs	High initial costs with future savings; test plan needed for cost allocation.	"Investment costs are quite high, however personnel costs will be saved later." "A test plan is needed to allocate money."
Location and logistics	Placement needs careful consideration to avoid traffic obstruction and ensure efficient waste collection.	"Logistics is key." "Placement on the first sight seems okay." "Is it a place that can be sold for commercial purposes? Then a container hub cannot be placed there probably." "It shouldn’t obstruct traffic or hinder passengers”
Residual waste and compactors	Consider making residual disposal harder; compactors might be needed for certain waste streams.	"Should there even be a residual container? Maybe a higher fee is not enough to reduce residual waste." "Think about compactors for high-volume waste like paper and PANT."
Pilot testing	Emphasis on a pilot phase to determine feasibility and gather data.	"Need to think about how to test this concept. For example, a pilot phase with 1 container hub." "This test plan is needed to allocate money." "Waste processing company A could probably help with customising container hubs or set up a test hub."
System reliability	The system should be easy to understand	"Key point in this concept: it should be really easy to understand."

8.5.3 Recycling company A

The third validation was carried out with two people from recycling company A, the company that hauls and recycles the waste for Avinor. The main insights are listed in Table 8 below. These insights are clustered in themes, including the key insights per theme and quotes as argumentation.

Table 8: Recycling company A validation results.

Theme	Key insights	Quotes
Feasibility and desirability	The overall concept is appreciated and seen as promising.	"Really like the idea of the concept"
Smell management	Effective smell management is crucial to avoid unpleasant odors from waste.	"How is the smell managed? Because waste can become smelly"
Waste sorting control	Ensuring proper waste sorting is a challenge and needs addressing.	"There is no control in waste sorting in your concept. People can still throw everything in one waste bag or in the wrong container."
Compaction of waste	Waste needs to be compacted before transportation to enhance sustainability.	"Compacting the waste is necessary, either at Rp19 or at the container hubs... Only glass & metal doesn't have to be compacted. The other waste streams should be compacted."
Cost considerations	Calculating costs is essential as that can determine the feasibility of the concept.	"Costs are important to calculate. This is a make it or break it aspect for this concept to make it work."
Container hub design	• Recycling company A can provide the necessary infrastructure for the container hubs. • Using 600 L containers is a practical suggestion.	"We are able to provide the container hubs... they have a big network of suppliers in order to make the framework, include the weighing scale, etc." "The suggestion to use 600 L containers in the container hubs is good... These can be easily emptied into the bigger containers/compactor at Rp19... There are already solutions for this."
Service responsibility	A designated team or individual should be responsible for the service and its management.	"There should be one responsible team, company or person for the service and also at Rp19."
User experience for passengers	Passenger experience should be unaffected by container hubs or unrelated information.	"You don't want to bother passengers with container hubs or with information signs that are not for them."

8.5.4 F&B operating companies

The fourth and fifth validation were carried out with managers from F&B operators A and B. The main insights are listed in Table 9 below. These insights are clustered in themes, including the key insights per theme and quotes as argumentation.

Table 9: F&B operating companies validation results.

Theme	Key insights	Quotes
Feasibility and desirability	• The concept is appreciated • The concept is seen as a positive solution • There are no significant issues or missing elements.	"I really likes the concept" "I think your concept is a great idea. It’s a good solution." “I don’t see big problems in the concept or aspects that are missing. ‘This is a system that could work’." "There is nothing missing or there are no recommendations to improve the service." "Time saving and the ability to keeping the airport clean are the most beneficial points of this service." "It’s also a really sustainable solution."
Container hub locations	Having multiple, convenient waste disposal locations is appealing and practical.	"The most appealing is having several locations in the terminal where you can deposit waste close by." "As long as you don’t have to walk far, it’s good."
Registration and accountability	Registering waste by unit rather than by operator can promote competition in waste reduction.	"Register the waste per unit to create a healthy competition between the units in reducing waste." "Specify (e.g., through ID card changes) from which unit the waste comes."
Pay As You Throw (PAYT)	PAYT is a positive and smart approach, though opinions differ on how to structure the fees.	“This is the only way to do it. I am positive about this." "You should only have a fee for residual waste and not for the other streams." "This is smart to do... But different tariffs per waste stream will lead to faulty throwing."
Implementation feasibility	Implementation is seen as straightforward, providing operational freedom and efficiency.	"Implementation will be easy. I don’t see obstructions in this." "It’s easy to implement... easy for people to shift to a way of working that makes it easier for them."
Practical considerations	• Using trolleys for waste transport • Placement of high-waste units are important.	"It depends on the next tender round where the big restaurants with a lot of waste will be located... this may affect the placement of the hubs." "I would use trolleys for the transport of waste bags to the hubs... food waste is heavy." "Avinor should provide small trolleys or cars for this transport."

Avinor's role and engagement	There are concerns about Avinor's commitment to waste management and their support for the concept.	"The only thing is that I am not sure if you'll get Avinor on board." "Earlier there was this vacuum system... Avinor doesn't take any effort for waste management now."

8.6 Refining the concept: feedback integration

Following up on the evaluation results, this chapter elaborates on integrating the feedback into a refined version of the concept and by doing that finalising the concept. From chapter 8.5 the following areas are identified for refinement in the final service:

- Control or traceability on waste throwing in order to improve proper waste sorting.
- For the manual waste transportation from container hubs to waste station on the short term, determine how this will be incorporated into the service.
- Design the system respectively that residual waste will be reduced.

8.6.1 Comparative assessment of waste separation control

A comparative assessment was made to discover the solution that is best suitable to include into the waste service system in order to be assured of proper waste sorting. For this, three steps are undertaken. First, different solutions are created for the question 'how can waste sorting be controlled and eventually improved?' Second, evaluation criteria are established in order to assess the different solutions. Third, a Harris profile with the evaluation criteria is used to compare the different solutions with each other.

Figure 62 shows the different solutions created on the question on how to control and eventually improve waste sorting.

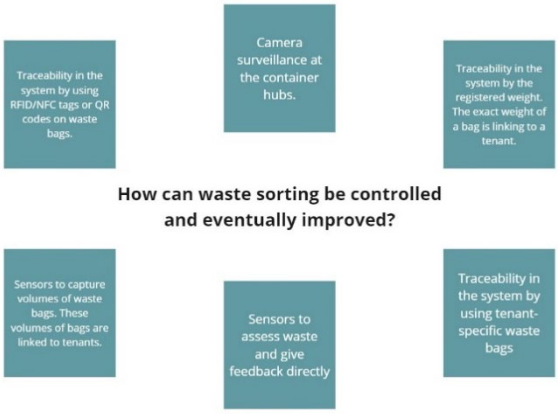


Figure 62: Solution creation for waste separation control. (Own figure).

These six different ideas are compared with each other with the help of a Harris profile. The ideas are assessed on accuracy, costs, user effort, effectiveness, reliability and feasibility. This Harris profile is displayed in Figure 63. From this comparative assessment, it can be concluded that solution 1 and 6 are the most promising, with solution 1 being the preferred option regarding costs and feasibility. Solution 1 includes traceability in the system through RFID tags or QR codes on the waste bags. When doing waste audits, the auditor can easily backtrace a faulty sorted waste bag to the tenant that deposited the waste bag. Appendix M7 includes an enlarged figure of the Harris profile.

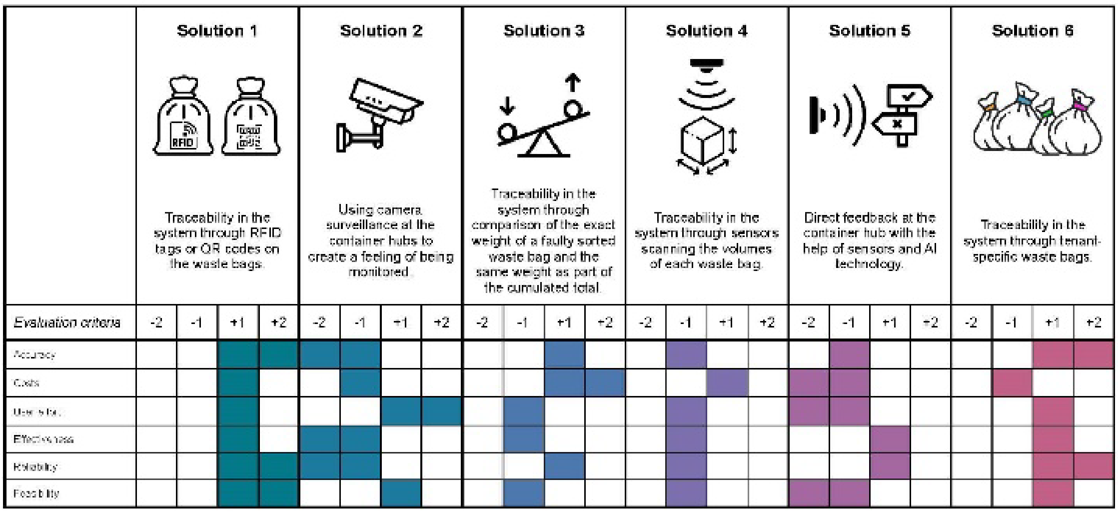


Figure 63: Comparative assessment waste separation through Harris profile. (Own figure).

According to Tavares et al. (2012) RFID technology has limited acceptance and high costs. Quick response code, also known as QR-code, is seen as a less complex and cost effective alternative for RFID in supply chain traceability. Also, regarding sustainability RFID technology uses physical printed tags, while QR-code technology works with a 2D image of the code. Since Avinor has the goal to become a circular airport, it is important not to create extra potential waste such as physical tags. Research on environmental RFID tags, or 'green tags' is still in an early stage and is therefore more difficult to implement than QR-code technology (Voipio et al., 2021).

8.6.2 Manual waste transportation

The proposed waste management service is not a concept that is fully implementable on a very short term, especially not the automated guided vehicle system. The concept therefore needs to contain an implementation plan or design roadmap, which will be elaborated in chapter 9. In order to implement the service on a short term, waste transportation from the container hubs to Rp19 needs to be done manually. This transportation can either be established by enabling the current waste collectors from F&B operating companies or by hiring a new dedicated waste management team.

Waste collectors F&B operators

The first option is to make contractual agreements with the F&B operators to let the waste collectors transport the waste from the container hubs to Rp19. This could be advantageous for cost efficiency. Utilising the existing workforce can reduce costs related to hiring and training new employees. Also, they are already familiar with the airport environment and the terminal layout. However, chapter 4.2.2 showed that the F&B operator waste collectors lack responsibility. They see restocking of the commercial units as their main task and waste collection is less of a priority. And, by letting the current waste collectors transport the waste, the principal-agent problem is still in place as described in chapter 5.5, since this new proposed waste service will be owned by Avinor.

Dedicated waste management team

The second option for transporting waste from the container hubs to Rp19, is through hiring a new dedicated waste management team. By hiring a dedicated team, the disadvantages from the F&B operator waste collectors are tackled. Responsibility will probably be higher, because waste management will be the main task for the waste management team and by employing them through Avinor, there will not occur any principal-agent problem. In addition, Taylor (2023) states that a dedicated waste management team can improve waste

handling, reduce errors, increase recycling rates and might lead to waste reduction.
Besides transporting waste, this waste management team can also include the waste audits (as discussed in chapter 8.6.1) in their daily work activities. By doing that, the desirability of having one entity responsible for waste management (both transport and feedback), as discussed in chapter 4.4, is met.

8.6.3 Reducing residual waste

One of Avinor's objectives is to reduce residual waste, since half of that could be recycled into existing waste streams. In chapter 7.8.1 an financial disincentive mechanism was already introduced in the system in order to reduce the overall waste. However, from evaluation (chapter 8.5) it can be concluded that refinement is needed in order to stimulate waste sorting and to reduce residual waste. Residual waste is also a costly fraction to handle (Kadibu & Jonyer, 2022).
A case study in Germany shows a reduction of residual waste of 71% in a period of five years after introducing a certain Pay As You Throw scheme (Morlok, Schoenberger, Styles, Galvez-Martos, et al., 2017). Although, this study focussed on household waste, it is possible to apply the scheme to the waste management service of Oslo Airport. This scheme is displayed in Figure 64.

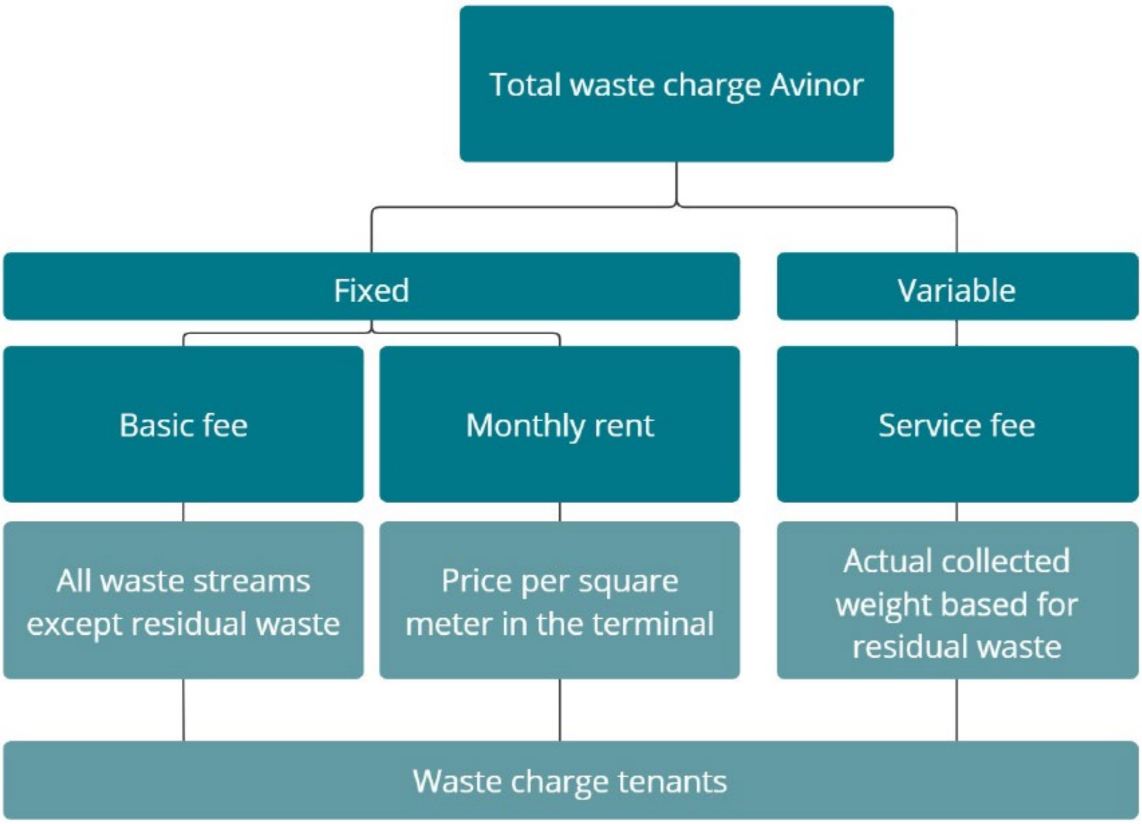


Figure 64: PAYT scheme to reduce residual waste. (Own figure, adapted from Morlok, Schoenberger, Styles, Galvez-Martos, et al., 2017).

The waste fee consists of two parts, a fixed fee and a variable fee. The fixed fee will contain the monthly rent as well as a basic fee for all tenants and covers the recyclable waste streams. The service fee covers the residual waste and is based on the actual collected weight at the container hub per tenant. Card and Schweitzer (2017) also underline that a PAYT scheme based on weight is the most effective compared to volume based or frequency of collection.

PAYT tariff

The available literature about implementing PAYT focuses solely on municipalities and household waste. In the case study from Morlok, Schoenberger, Styles, Galvez-Martos, et al. (2017) a weight fee of 0,18 EUR per kg was applied, while in the study of U.S. EPA Office of Solid Waste (1999) a rate of $1,50 per waste bag was set. Another example in Finland shows a fee of 0,27 EUR per kg (Ukkonen & Sahimaa, 2021).

It is suggested that Avinor decides on the rates for the PAYT scheme with the waste charge they get from recycling company A in mind.

8.7 Final concept

This paragraph concludes this chapter with an elaboration of the final concept and with that the overall design of the waste management service. The waste management service of Oslo Airport includes the container hubs throughout the terminal and aligned waste signs, as developed in chapter 8.1. Next to that, waste bags with QR code technology for traceability, a waste management team and a PAYT scheme with a fee for residual waste is implemented. Below, the final concept is visualised with an overview of the service (enlarged version in appendix O), a service scenario to explain all the steps in the service and renders to create an image of the container hubs.

Figure 65: Final concept: overview of the service. (Own figure).

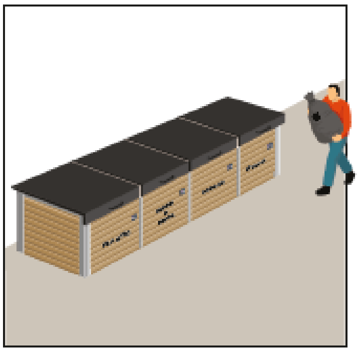
Waste is generated at the commercial units in the terminal.

Waste is thrown into the right bin which is stimulated by improved signage and online learning modules.

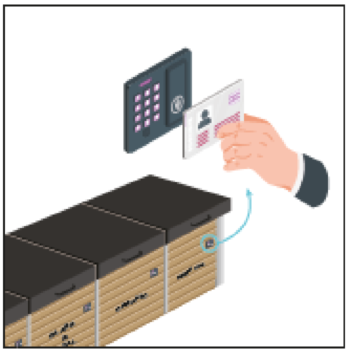
When a bin is full, an employee empties the waste bin.

Every waste bag is tagged with a QR code that is tenant-specific.

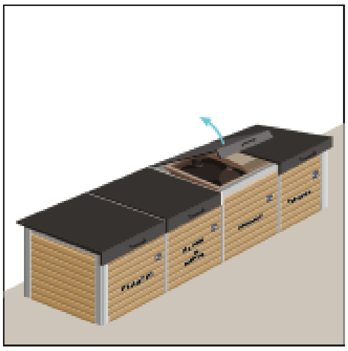
The waste is brought to a terminal waste container hub. Directions can be found at every commercial unit.



The employee arrives at the waste container hub. There are multiple hubs in the terminal hall.

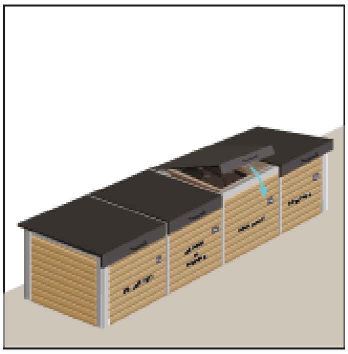


At the waste container hub the employee scans his/her ID badge to open the desired container.

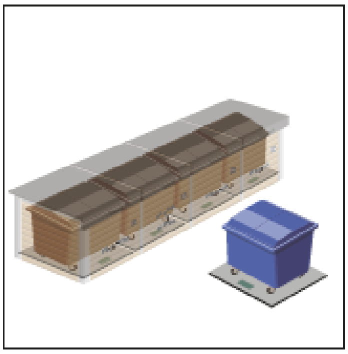


A lid opens and the container is accessible.

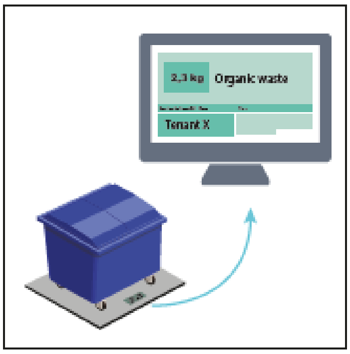
The employee can throw the waste bag(s) into the container.



The lid can be closed again.



The containers are placed on a scale that weighs the cumulative weight and registers how much the tenant just threw away. This happens automatically when the lid is closed.



The weight and type of waste is registered and linked to the tenant in an online application via cloud connection.

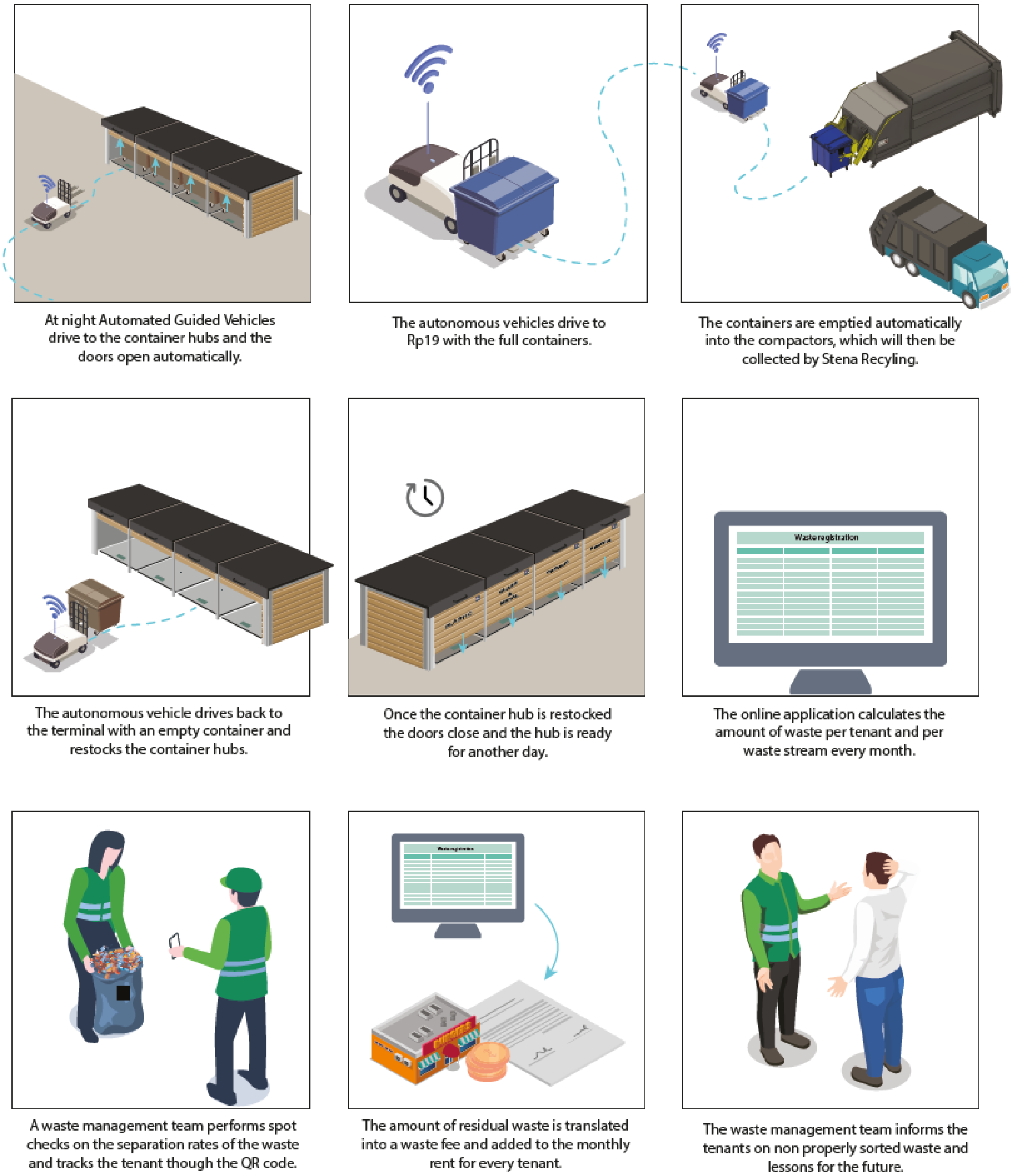


Figure 66: Final concept: service scenario. (Own figure).

Container hub mock-up

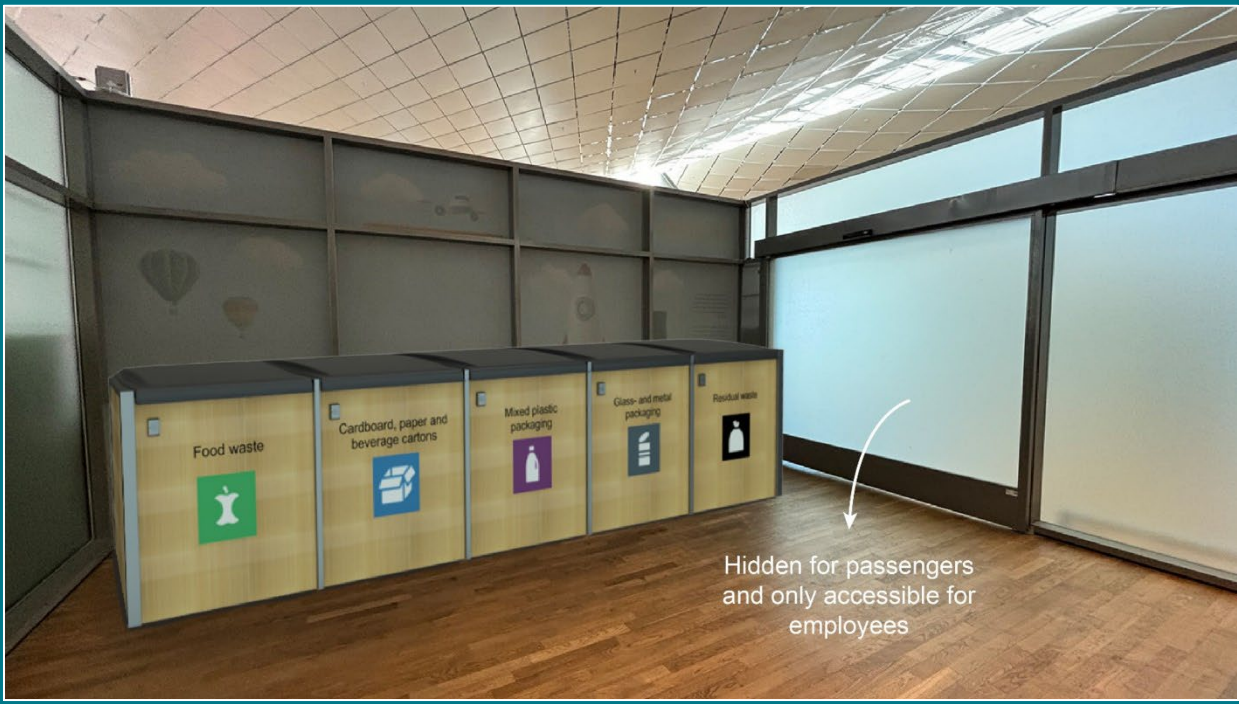
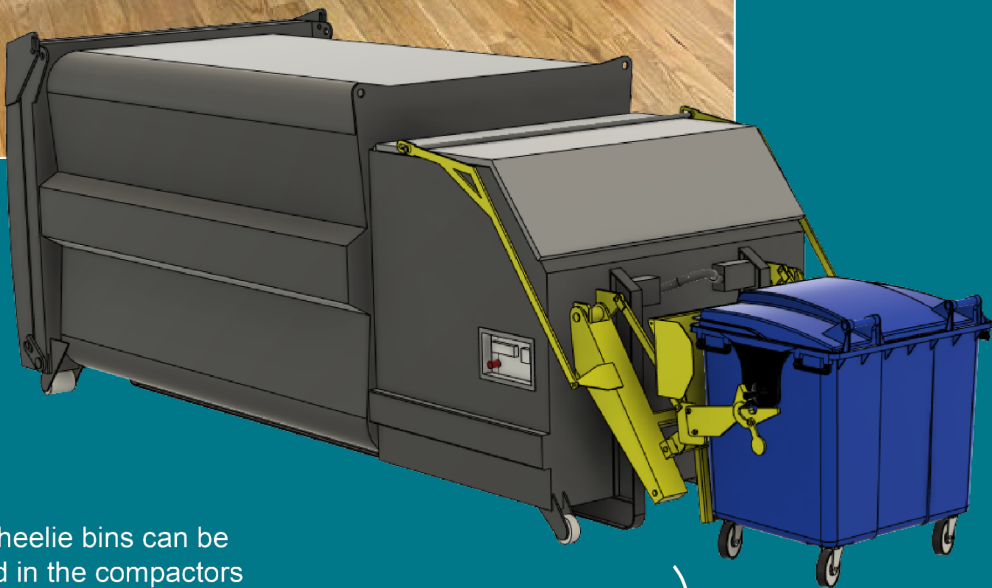


Figure 67: Final concept: container hub mock-up front. (Own figure).

Figure 68: Final concept: container hub mock-up entrance. (Own figure).

Figure 70: Final concept: container hub mock-up side. (Own figure).



The 660 L wheelie bins can be easily emptied in the compactors in the waste station

Figure 69: Final concept: emptying of the wheelie bins. (Own figure).

9 Deliver

This chapters focusses on delivering the service solution to the client. For this, a design roadmap is created to serve as guideline for the implementation plan and a test plan is created to structure the pilot phase.

9.1 Strategic roadmap

Avinor is working, together with TULIPS, towards a circular economy. In order to reach this, TULIPS has created a roadmap with clear horizons in order to reach their objectives. In Figure 71, a roadmap especially for this graduation project can be seen. Here, the horizons and goals are adopted from TULIPS, but the drivers, service touchpoints and triggers are customised towards the waste management system. This strategic roadmap acts as a long term vision and roadmap towards horizon 3. An enlarged version can be viewed in appendix P.

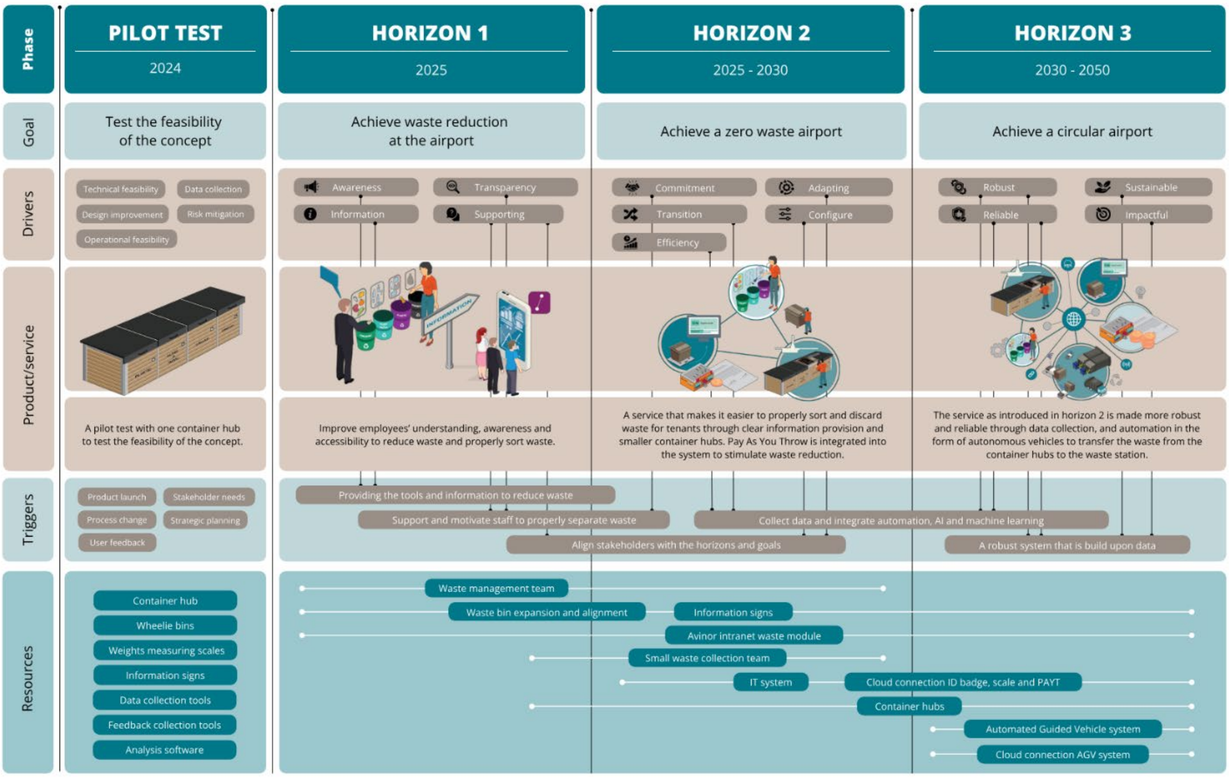


Figure 71: Strategic roadmap waste management service at Oslo Airport. (Own figure).

9.2 Implementation strategy

In addition to the design roadmap, which is a long-term outline towards the future, an elaboration on the short-term implementation and test plan is needed. The desirability of the waste management service is tested through stakeholder validation, see chapter 8.5. But before being able to implement the new waste management service, the design needs to be tested on its feasibility. This chapter outlines the implementation strategy. Part of this implementation strategy is a pilot test. The implementation strategy, including the pilot test will be elaborated.

Preparation phase

This phase bridges the gap between the ending of this project and the first realisation of the service. A pilot test will be conducted at the terminal with one container hub. The preparation phase entails the design for this hub, the selection of the location and setting up the finances. This phase will take three months to complete.

Baseline phase

The baseline phase is the phase to gather baseline data. Currently waste related data is only available for the terminal as a whole, but not per tenant or smaller part of the terminal. Since the pilot test will be conducted with only one container hub and only five targeted tenants, the baseline data for those specific tenants needs to be collected. This baseline monitoring and data collection will take one month to complete.

Implementation phase

The implementation phase covers the same location as the baseline phase. That means that the same five tenants are targeted, but this time with the container hub in place. This phase includes informing the five tenants on the change for their waste activities, observing the day to day waste management and collecting data on separation rates and user feedback. Again, this will take one month to complete.

Comparative analysis phase

After sequential testing two months after each other, there will be an analysis phase. This comparative analysis will take two weeks to complete. In this phase, the separation data and user feedback from the baseline phase is compared with the data and feedback from the implementation phase.

Reporting phase

Following up on the analysis phase, the results will be translated into findings and conclusions. And subsequently presented to the management of Avinor. With that, the pilot test is completed and eventually the implementation strategy could continue after a positive outcome of the pilot test. Again, this reporting phase covers two weeks in total.

Introduction phase – H1

After a successful pilot test, which can be completed in 2024, the waste management service can be introduced throughout the terminal from the beginning of 2025. In this first phase, all tenants and involved stakeholders will be informed about the results of the pilot test and the upcoming changes in the waste system. Also, all container hubs will be build throughout the terminal hall. And all waste bins and signs will be aligned at the commercial units.

Development phase – H2

Following up on the introduction phase, the development comes in place. This phase will mark the start of the actual commissioning of the waste service. The tenants will deposit their waste at the container hubs, a waste management team will transport the waste from the hubs to Rp19, conduct spot checks and provide feedback on sorting to the tenants. The waste fee for residual waste is also introduced in this phase.

Maturation phase – H3

In the last phase the waste transportation from the hubs to Rp19 will be automated by implementing the AGV system. Also, by collecting data in the development phase, it is possible to pivot the service slightly if needed. For example, adding more container hub locations, changing the proposed locations or including other waste streams. Through this learning and development, a robust system will be created and the service will mature.

A visual overview of the implementation strategy can be found in Figure 72.

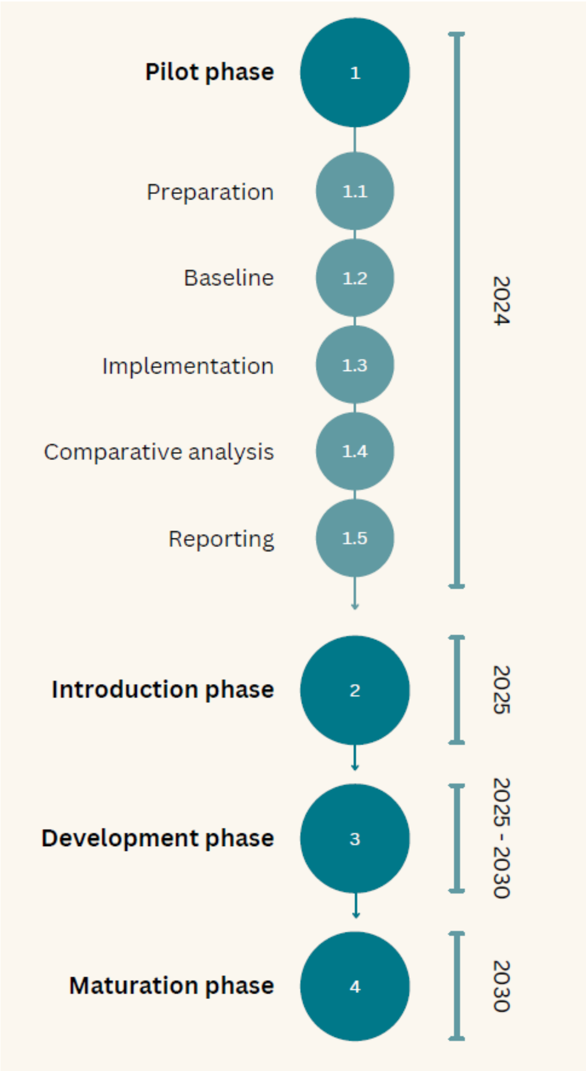


Figure 72: Implementation strategy waste service. (Own figure).

9.3 Pilot test

The first step in the implementation strategy is the pilot phase. In this phase the design proposal, more specifically the feasibility of the container hub, will be tested. For this, a test plan is developed.

Required resources

The following resources are required for the pilot test:

- Container hub and five 660L wheelie bins
- Weight measuring scales
- Signage and informational materials
- Monitoring and data collection tools
- Feedback collection tools (surveys, interview guides)
- Analysis software (for data analysis and reporting)

Description of the pilot test activities

Baseline phase (without hub):

1. Observation and monitoring: monitor and record waste disposal practices, volumes, and separation rates in the area without the hub for one month.
2. User feedback: conduct surveys and interviews with tenants to gather feedback on current waste management practices and challenges.
3. Data collection: collect quantitative data on waste volumes, types, and separation rates. Record operational metrics such as collection frequency.

Implementation phase (with hub):

1. Hub installation: installation of the container hub in the selected area.
2. Training and communication: inform tenants about the hub, its purpose, and how to use it effectively. Provide training sessions if necessary.

3. Observation and monitoring: monitor and record waste disposal practices, volumes, and separation rates in the area with the hub for one month.
4. User feedback: conduct surveys and interviews with tenants to gather feedback on the new hub and its impact on waste management practices.

Proposed location

A central point in the terminal, and located next to two elevators, is chosen for the pilot test. This location is marked with a blue circle in Figure 73. There are several tenants close by which could be selected to take part in this pilot test.

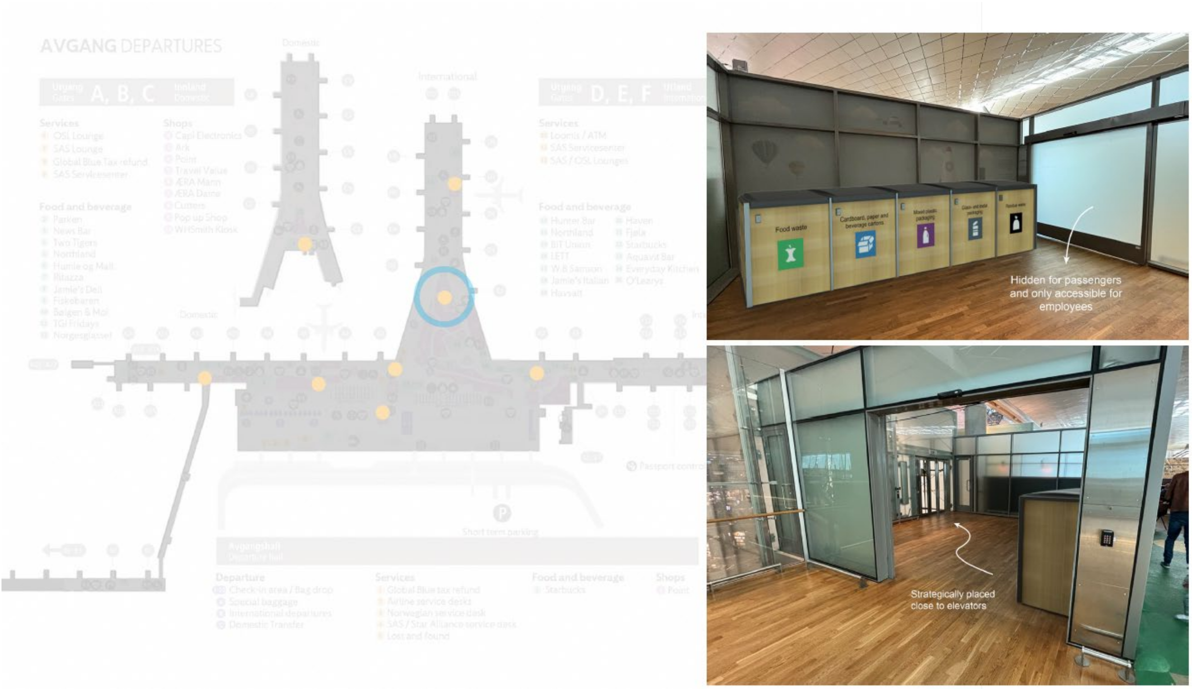


Figure 73: Proposed location pilot test. (Own figure).

Finances

An indication is made for the costs to set up the pilot plan, which can be seen in Table 10.

Table 10: Costs estimation pilot test.

COST PRICE ESTIMATION pilot test container hubs				
Item	**Description**	**Units**	**Price per unit**	**Total price**
Information posters/stickers	Posters and stickers explaining what to throw where	5	€ 5,00	€ 25,00
Container hub framework	Building material for the appearance of the container hubs	1	€ 1.000,00	€ 1.000,00
Wheelie bin 660L	The waste containers being used at the container hubs	5	€ 300,00	€ 1.500,00
Man hours	The hours needed in order to conduct the pilot test	167,5	€ 70,00	€ 11.725,00
			Total	€ 14.250,00

Timeline

Below in Table 11, a timeline is described for the pilot test. This timeline includes the activity, description of the activities, who is conducting that part of the test, the duration and required hours.

Table 11: Timeline description of the pilot test.

Activity	Description of activities	Who	Duration	Required hours
Preparation	• Site selection • Hub design • Set up finances	• Recycling company • Thomas • Elisabeth	June - 15 September	60 hours
Baseline phase	• Baseline data collection • Observation • Monitoring • User feedback (without hub)	• Elisabeth	16 September – 15 October **1 month**	22 working days x 1,5 hours = 33 hours
Implementation phase	• Hub installation • Training • Observation • Monitoring (with hub)	• Elisabeth	16 October – 15 November **1 month**	23 working days x 1,5 hours = 34,5 hours
Comparative analysis	• Data analysis • Performance metrics evaluation	• Elisabeth • Sonja • Rita	16 November – 30 November **2 weeks**	20 hours
Reporting	• Findings compilation • Recommendations • Presentation	• Elisabeth	1 December – 15 December **2 weeks**	20 hours

10 Conclusion

In this chapter, the results of the project are concluded. It assesses the design on the set design criteria and the main research question is answered by answering the formulated sub-questions.

10.1 Feasibility

Can it be done?

The final design of a new waste management service proposes the introduction of a logistical improvement, information provision improvement, as well as a motivation improvement.
To improve logistics, a container hub as 'in-between' waste station is designed to reduce walking distances. Information is improved by having a waste management team that serves as feedback mechanism. Aligned waste bins and signs at all commercial units should also improve information regarding waste management. Motivation is improved by introducing a 'Pay As You Throw' disincentive mechanism, which stimulates tenants to reduces and properly sort waste. On a conceptual level it can be concluded that the overall service design is feasible. Relevant stakeholders were asked to validate the concept and it turned out that the service does not obtain significant challenges or hurdles in order to realise it.
A pilot test is going to take place to test the concept in reality on its feasibility.

10.2 Desirability

Do the users want it?

Avinor has the objective to go from reducing waste to zero waste and in the end become a circular airport. This goal can be achieved, among other things, by introducing the proposed waste service. Avinor, as client, is positive about the design proposal and wants to proceed with the pilot test. Next to Avinor, other relevant stakeholders in the system were taken into account during the design of the service and were asked for their opinions. The tenants, the food & beverage operating companies and the recycling company were optimistic and showed positive validation results. Therefore, it can be concluded that the design proposal is a desired solution.

10.3 Viability

Does it contribute to long-term growth?

Looking at Avinor's future goal to become a circular airport, together with the constant changing regulations regarding waste, a robust and sustainable solution was needed. By introducing container hubs in the system with a weighing solution, the service complies with the regulations. Also, tenants are stimulated to reduce waste, properly sort the waste and waste management is made easier. Together with the extra income for Avinor, coming from the Pay As You Throw fee and the relatively low investment costs, this service proposal provides a future-proof solution. And with that, it can be concluded that the design proposal is viable.

10.4 Research questions

The main research question "How can a comprehensive product-service system be designed to establish a sustainable and centralised internal waste logistics system at Oslo Airport terminal?" is answered by answering the sub-questions.

How can a centralised service function in the daily operations, including pickup times and routes?

Observations and interviews at Oslo Airport showed that tenants operating commercial units differ from each other. The commercial units include restaurants, bars, kiosks, as well as non-food units. Because of that, the amount of waste between the units and also the desired amount of times per day that waste is being picked up or brought to the waste station differs. In addition, tenants indicated that current waste collectors often come by too late or too little. An important condition to have a service functioning in the daily operations is to extend the 'opening hours' of the security control at waste station Rp19. Then, waste can also be deposited after closing time of the commercial unit. For those reasons, it is important that the commercial units have the freedom to deposit their waste on their own, so that they can deposit their waste on a time that is the most convenient for them. The implementation of container hubs, which function as little ‘in-between’ waste stations in the terminal hall, makes this possible.

What do commercial units need in terms of waste disposal and warehouse logistics?

Analysis showed that there are several aspects that the commercial units need in terms of waste disposal. Logistical constraints such as limited time and space, long distances from the commercial units to the waste stations, as well as the absence of an effective weighing solution and the accessibility of the waste stations make it difficult for commercial units to properly dispose their waste. Also, regarding information provision, commercial units are not always (motivated to be) up to date regarding waste management.
The commercial units indicated that they need an ‘easy to understand’ solution. The logistical constraints can be resolved by the implementation of the container hubs. Also, clear and aligned communication and signs are needed in order have commercial units understand the waste disposal practices.

What is the necessary equipment for the waste management system?

The new, proposed service for the waste management system has an approach that includes container hubs as in-between stations to deposit waste. These hubs, eleven it total, together with five 660L wheelie bins per hub can be seen as equipment that is needed to make this waste management system functioning. Next, mechanical equipment to empty those wheelie bins into the bigger waste compactors is needed. Other, desired equipment that is needed, but not mandatory to have a functioning system are Automated Guided Vehicles to automate waste transport from the hubs to the waste station. Also small carts or trolleys are desired to transport heavy waste bags from the commercial units to the container hubs.

How can a human-centred approach break the siloes of the current logistical process?

Analysis showed that the current system is siloed with some commercial units operating on their own, while others are operated under bigger food & beverage operating companies. This also effects the waste management, with some units have their waste picked up, while others deposit waste themselves. This is resolved by the implementation of a dedicated waste management team and the container hubs. By doing this, all commercial units are treated equally since they all have to deposit waste on their own. This empowers the employees and creates a sense of responsibility. The waste management team serves as a human communication and feedback system towards all stakeholders. Also, during this project, stakeholders were involved in the process. For example, through a co-creation workshop. This results in a service design that meets everyone’s needs.

How can design contribute to emphasizing and elevating the significance of waste handlers' roles?

From interviews it appears that there is not a sense of insignificance towards waste collectors or handlers. However, the waste collectors do see restocking and distribution of food and supplies as their primary job, but do not see waste collection as their primary job. The design of the new proposed service therefore excludes the waste collectors from waste management system for collecting waste.

How can a feedback system be integrated to test the effectiveness of the designed waste logistics system?

Integrating a feedback system in the waste logistics system is realised through a technology and a human aspect. The technology aspect contains tenant-specific waste bags including QR code technology in order to trace back waste bags to the tenant. The human aspect in the system is the waste management team, employed by Avinor. This team conducts spot checks on the separation rates of the waste and provides feedback to the corresponding commercial unit if needed.

How can the insights from this project be applied to realise and implement the proposed outcome?

In order to implement the proposed service, an implementation strategy is designed and proposed to the client. This strategy consists of four phases. The first stage is a pilot test to test the feasibility of the new service on a low scale. After a successful pilot, the introduction phase begins. Followed by a development phase and subsequently the last phase, the maturation phase.

11 Discussion

To follow up on the conclusion of this thesis, this chapter provides a discussion. This chapter includes the recommendations for the future, implications or limitations that might have obstructed this project and a personal reflection.

11.1 Recommendations

This graduation project has provided valuable insights and addressed the research question effectively. However, to further enhance the waste management system and ensure its long-term success, several recommendations are proposed. These recommendations aim to build on the findings of this project and identify areas for future improvement and research.

Testing

While the proposed service offers a great solution to the logistical constraints, explained in chapter 6.1.2. The actual feasibility needs to be tested through the pilot test. Due to changing regulations regarding waste, the system needs to be flexible and constantly developing. It is recommended that the proposed waste management team gathers data and feedback so that the system can evolve over time into the most feasible, desirable and viable solution.

Reducing waste

Introducing the Pay As You Throw mechanism improves waste sorting and waste reduction. While this proposed design will increase the recyclable waste streams and reduce residual waste, it is still recommended to look into additional solutions and interventions as well. For example, the redistribution of surplus food waste through the TooGoodToGo app is already being used by some commercial units, but the amount or participating users could be increased. Additionally, exploring other waste reduction initiatives, such as composting organic waste or partnering with local charities for food donations, can provide more interventions for minimising waste.

Choice in waste streams

Because of space limitations, the container hub only contains five waste streams: residual, paper & cardboard, glass & metal, plastic and organic waste. Those streams are accountable for the biggest part of the total waste. Waste coming from the commercial units that is categorised as any other stream still needs to be thrown away at Rp19. During the pilot test, but also afterwards, this choice needs to be evaluated. Eventually, desired waste streams need to be added to the container hubs or a redesign is needed.

Circularity initiatives

In chapter 5.1 best practices from other airports around the globe are analysed. Several solutions to become a circular airport are discussed, such as a composting program, converting organic waste into biomass fuel and a rotary waste drum to reduce waste volumes. It is advised to look into these best practices and see whether certain solutions are feasible to implement at Oslo Airport. By doing that, the route to becoming a circular airport might be even accelerated.

Principal-agent problem

The last recommendation is about the principal-agent problem, as discussed in chapter 5.5. This chapter describes the relation between Avinor and its tenants. Avinor is the principal who delegates their authority regarding waste management to the agent. The tenants are the agents, who acts and make decisions. The design outcome of this project provides a solution to the conflicting interest (since Avinor and the tenants have different interests and priorities), because with Avinor as owner of the service and also as provider of the waste management team, the principal does not delegate responsibility but takes responsibility. To further mitigate the principal-agent problem, it is recommended to establish a collaborative framework that includes regular communication, feedback mechanisms, and joint decision-making processes between Avinor and its tenants.

11.2 Limitations

This graduation project has given valuable insights and gave an answer to the research question. However, this project knows limitations. These limitations could be used to define future research possibilities.

Generalisability

The first limitation in this project is generalisability. This project and the research were conducted for a specific client, Avinor Oslo Airport, which means the proposed design is a tailored intervention suited specifically to the context and needs of Oslo Airport. Factors such as the airport's size, layout, waste generation patterns, and stakeholder engagement practices were all considered in the design process, making it highly specific to this environment.

To generalise the findings and contribute to the broader literature on centralising a waste logistic system, independent research is needed across different airports and contexts. Comparative studies involving multiple airports of varying sizes and operational models would help identify common principles and adaptable strategies. Without such independent and varied research, the applicability of this project's findings to other settings remains uncertain, limiting its broader impact on waste management practices in the aviation industry.

Detailing

This master thesis is a 100-day project, which means that time is limited. Limited time means a limitation in elaborating on the design. The design outcome of this project is a service concept on paper with visualisations of the service and its touchpoints. However, the touchpoints of the service are not developed physically or elaborated thoroughly. For example, the container hub is rendered to create a visualisation of the hub, but the exact dimensions or appeal are not designed. This means that design improvements are still possible for the waste management service.

Dependence on technology

The proposed waste management system at Oslo Airport relies on advanced technology like QR codes, cloud system for data storing and PAYT administration and the Automated Guided Vehicles. This dependence presents several challenges. Any technological failures, maintenance issues, or problems with integration could disrupt the entire waste management process. Consequently, this reliance on technology introduces the risk of system downtime and incurs additional costs for troubleshooting and repairs. Therefore, while these technologies can enhance efficiency and accuracy, they also bring vulnerabilities that need to be managed to ensure smooth and continuous waste management operations.

Scalability

Scaling the proposed waste management system from a pilot phase to cover the entire airport presents additional logistical and operational challenges. While initial trials might yield promising results, expanding the system will require careful planning to handle the increased volume and complexity. Ensuring that the proposed solutions remain efficient on a larger scale is crucial to avoid potential inefficiencies and disruptions. This scalability requires detailed consideration to maintain the system's effectiveness as it grows.

11.3 Reflection

This is it, the final chapter of this master thesis and the end of a twenty week graduation project. This provides a good moment to look back on the past weeks and reflect on my work, personal experience and development.

At the beginning of this project, I noted down my motivation and personal ambitions in the graduation brief. An important objective for me was to gather a good understanding of waste logistics, but also in logistical thinking and system thinking. Also, I wanted to make an impact in the real-world with my graduation project. And lastly, the ambition to become an exemplary service designer.

When I was in high school, I would never have thought that one day I would obtain a Master of Science. After four years of VWO (pre-university education) my mentor and I concluded that I did not have the full capacity to succeed, resulting in going to HAVO (senior general secondary education) and leaving my friends behind. Logically, after I graduating I started a university of applied science studies. At Hogeschool Rotterdam I finished industrial product design. I thrived during that bachelor, gained personal development, made friends for life, met my girlfriend there and graduated cum laude with a thesis rewarded with a 10.

Ambitious and dedicated as I like to try to be, I wanted to start the strategic product design master at the TU Delft. I was expecting a hard time, thinking the gap between Hogeschool Rotterdam and TU Delft was big. However, this master went smoother than expected. Especially this thesis went smoother than I could have ever imagined.

Although I had some beginner mistakes, such as not being aware to make a presentation for the midterm meeting or not knowing that I was the one in charge for weekly meetings and setting the agenda’s. But from that, the only thing I could do is learn.

Learning and developing myself is something I did for sure. I received great feedback from my supervisors, conducted interviews, did field research, managed stakeholders, gained rich insights. Furthermore, working with a real-life client really developed my project management and communication skills. Although it was not the first time for me that I worked with a real-life client, the great size of the company and the international aspect was a first. I think it is very valuable that I have gathered those insights on working in an international context and having to manage flights and security documents besides my thesis.

Looking back on my personal ambitions for this graduation project, I can conclude that is has been successful. I managed to gain a lot of insights into logistics, circularity, waste management and service design. Also, the plans of the client to test my design in a pilot mean a lot to me. It gives me recognition for the work I did and also feedback that the client is satisfied with the outcome.

The past weeks were both very exciting and educational and I am proud on the result.
“What we learn with pleasure, we never forget” – Alfred Mercier

Thomas van der Helm
July 2024

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