MF2088 | Innovation and Product Development

A ROADMAP TO A CIRCULAR FLOW OF GLOVES

Project Report
2022

PROJECT TEAM

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Table of Contents

Executive Summary

The project report is structured to cover the work process of the project, followed by research findings and assumptions that have been used to create a proposed solution to the problem statement (See "A Roadmap to a Circular Flow of Gloves" in the Business Plan). The problem statement reads: "How can we reduce the environmental impact of disposable gloves in the public sector of the City of Stockholm?"

The work processes consist of project challenges, roles within the team and innovation processes that have been used to reach the proposed solution. In this project, challenges relate to laws and regulations, the complexity of the stakeholder network and the time frame of the project. In order to find a suitable solution to the problem statement despite the challenges, multiple innovation processes were included. The research findings in this report have been collected by interviews, visits and literature studies. Further, assumptions regarding policies, materials, overconsumption, and commitment to environmental work have been made to create the proposed solutions. Limitations in the project related to the primary estimate for environmental impact, and exclusion of economic figures, customer value, and emissions from transportation are mentioned to clarify the scope of the project. Lastly, conclusions regarding the future potential for creating a circular loop of single-use gloves is presented.

Background

As of today, the City of Stockholm disposes 140 tons of single-use gloves annually from different facilities, being their most consumed type of disposable item. The facilities that are provided with most gloves are pre-schools and elderly care facilities, see *Figure 1*. Since the production and use of plastic gloves follows a linear flow, 140 tons of plastic gloves are also wasted, resulting in approximately 1060 tons of carbon dioxide equivalents (CO2-eq) being emitted every year. Due to the global environmental impact, the Environment & Health Department wants to decrease the emissions of greenhouse gases (GHG) from the public sector and lower their environmental footprint.

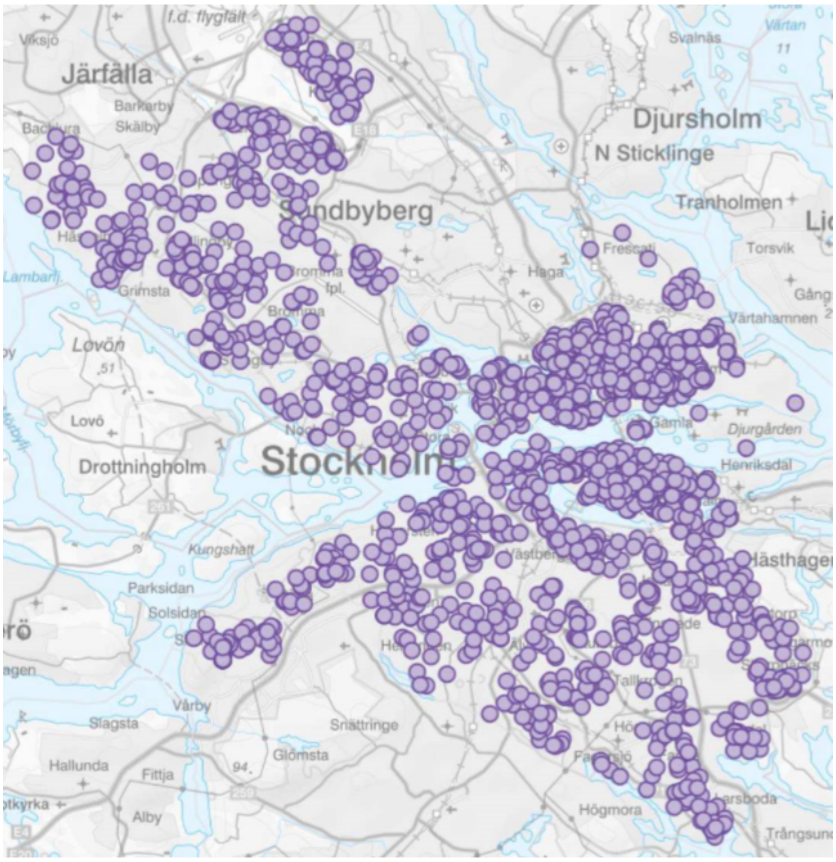

Figure 1. Pre-schools and elderly care facilities in the City of Stockholm

Problem Statement

Given the environmental problems connected to the disposal of single-use gloves, we received a problem statement from the Environment & Health Department which read: "How to reuse the material in 140 tons of disposable gloves and still maintain healthy circular flows?". This problem formulation is quite solution based, implying that the materials in use need to be recycled. To not limit ourselves to specific solutions, the problem statement was reformulated to be more open ended. The reformulated problem statement for the project reads:

> *"How can we reduce the environmental impact of disposable gloves in the public sector of the City of Stockholm?"*

This way, more options are included in reducing the waste, emissions and environmental impact of disposable gloves.

Project Challenges

The problem statement is broken down into smaller problems to develop a deeper understanding of the challenge and find root causes (Stickdorn, et al., 2019). Some of these challenges are presented in a "how can we" manner in *Figure 2* below:

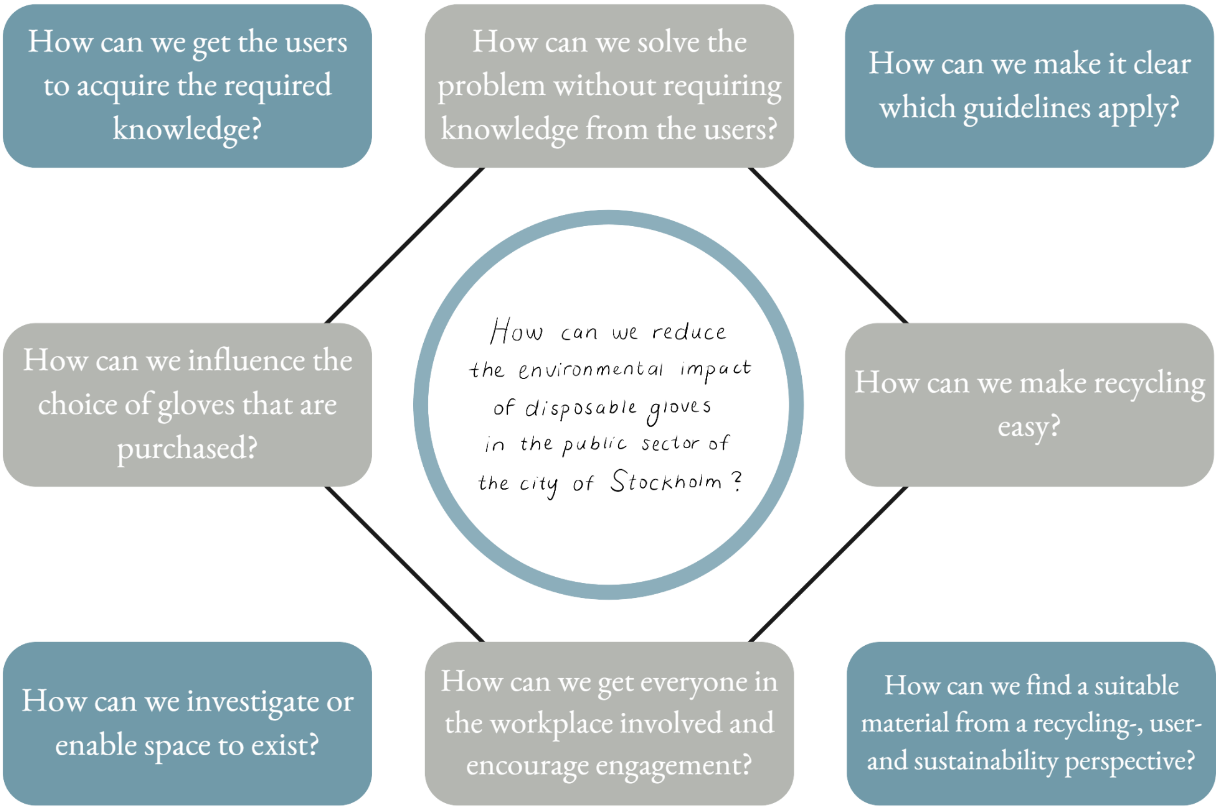

Figure 2. Project challenges

These "how can we"-challenges are created with the circular flow in mind, but also relates to overconsumption. In addition to these challenges, other logistic challenges within our project are being identified. To widen our theoretical base within topics such as polymers, recycling, transports and collection, information from the appropriate stakeholders are gathered. Since disposable gloves are needed in certain occupations to minimise the spread of germs and bacteria, information about different laws and regulations is also gathered in order to learn about the constraints of our possible solution.

The scope of this project is complex due to many factors. Some of these factors include the large number of stakeholders that must be included in any potential solution. With more stakeholders involved, it can be harder to reach consensus and make decisions about the direction of the solution. Also, managing communication and ensuring that all stakeholders are kept informed and engaged can be challenging. With different stakeholders that have different priorities or agendas, it can be difficult to align everyone around a common goal as well as considering all needs and competing interests. Another factor that contributes to the complexity of the project is the rules and regulations to which the solution must conform. The focus of the project was also limited to CO_2-emissions and did not include other consequences such as littering and the release of microplastics.

Since the Environment and Health department is a governing body and is not driven by competition and profit, challenges regarding the Business Plan occurred. These are mainly related to the revenue streams and cost structures since a business plan can be used to detail how a company can gain profit and how they can create value by differentiating themselves from competitors. Because of this, the business plan for the proposed solution needed to take a different approach and look at the problem holistically as a network of stakeholders.

Another challenge of the project is the time limitation. This is difficult since the time frame is very tight and a lot of unforeseen challenges and delays arise during the project. With time limitation comes the challenge of limiting the flexibility of the project team. Since the team is under pressure to complete the project within a certain timeframe, it's more challenging to adapt to changes or change direction of the project in response to new information.

Also, due to the reformulated problem statement, multiple types of solutions are explored during the time frame of the project. All members are responsible for different areas of research in order to manage the time limitation, which consequently creates a knowledge gap between each team member. Therefore, an additional challenge occurs regarding how to inform all members of the knowledge accumulated during the project.

Roles

Internal roles have been distributed within the project team based on the skills and interests of the team members. Team roles are not strictly bound to one person and the team cooperates on many team activities in the project.

Linnea Sundin

Linnea Sundin has the role of **project leader** since she is a person who likes to set up a plan and organise activities. She has the main responsibility of planning the necessary activities needed to reach the goals in time, making sure all deadlines are met and submitting assignments.

Linnéa Lundbäck

Linnéa Lundbäck has the role of **visualisation manager**, as she has a talent for sketching and digital tools. Her main responsibilities are to make visualisations of prototypes and processes from the project work.

Daniel Blomberg

Daniel Blomberg has the role of **analytics manager**. This means that he is responsible for the layout and structuring of the report. Daniel was given this role since he is talented at seeing patterns in information and its relevance to the project.

David Lorang

David Lorang has the role of **executor** as he is a person who makes things happen in a project. He is responsible for making sure the planned tasks are executed in the right way and in time.

Karolina Wassberg

Karolina Wassberg has the role of **sprint master**. She is responsible for managing the sprints, making sure the sprints are planned and that the plan is followed.

Our Innovation Process

The chosen process is a combination of literature and lessons learned. It involves methods such as Design Thinking, iterative prototyping, sprints and the Double Diamond principle. The process is an iterative circular model consisting of five different stages with intermediate decision and evaluation points, which is visualised in *Figure 3.* The different phases of the model should not be used in isolation since the process is meant to be continuously iterated. This includes continuously iterating our challenges and project statements in all phases of the project. The different phases often overlap with each other and ideas from previous stages can be used in all parts of the model if needed.

1. Define problem: The problem can be defined by breaking the problem down to smaller parts and analysing the different components. This allows one to get a more holistic view of the problem so that it can be viewed from different angles.
2. Research: Research is done by interviews, visits, observations and in literature. Research is done to acquire knowledge before the ideation process as well as after.
3. Ideation: In this phase of the process, ideas are generated by using brainstorming activities and other ideation techniques. The goal of this phase is to collect as many ideas as possible to approach the problem from different perspectives. To achieve this, a climate should be created where every idea is valued and should not be criticised. A broad selection of challenges and solutions are mapped out to get a foundation to base the final solutions from.
4. Develop solutions: A solution is chosen for further prototyping. The ideas that were generated during the ideation process are narrowed down and made into a possible solution.
5. Prototype and test: When a solution is generated and developed, a suitable prototype is created for the purpose of testing. If flaws in the solution arise when creating the prototype, it is necessary to go back to the stage of Ideation. If not, testing the solutions with all kinds of users is a way of making flaws appear. The users' inputs are thereafter accumulated in order to continuously improve the solution.

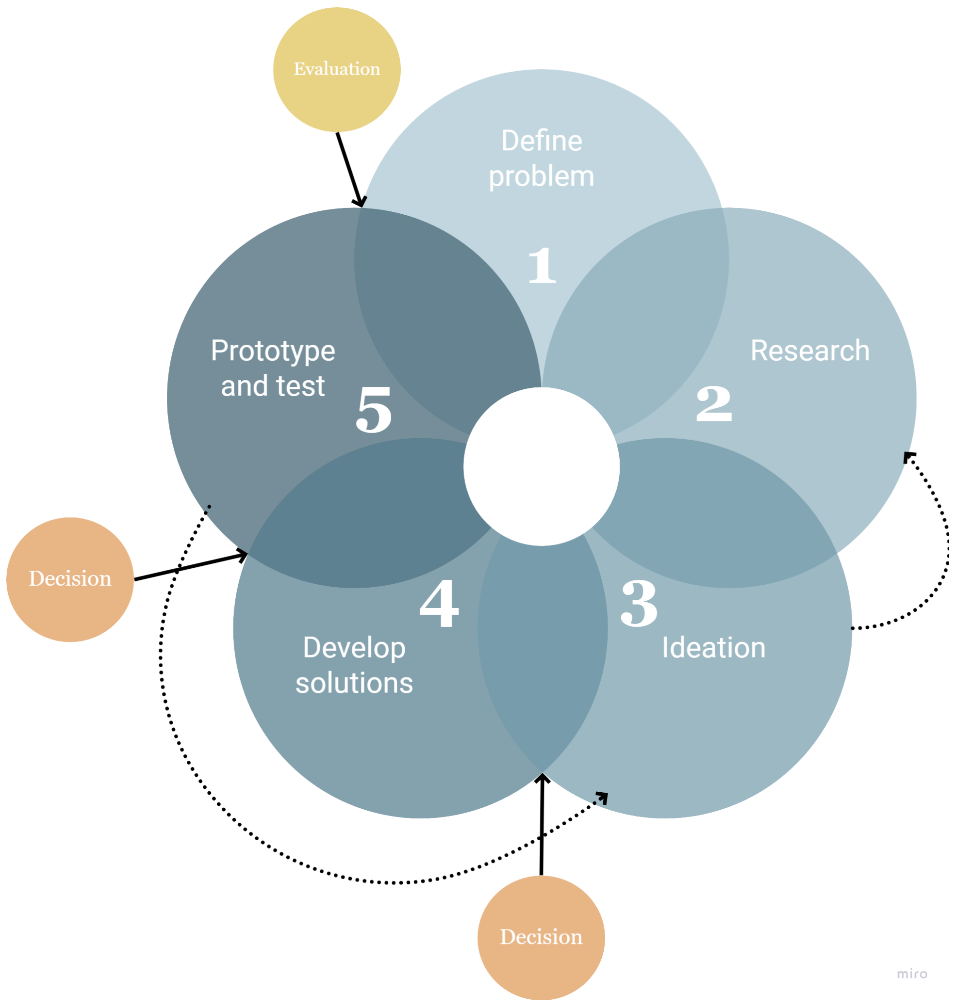

Figure 3. Project process

Design Thinking

This project involves many different stakeholders with different roles and the problem required us to find a solution that was easy to implement and use for all of them. The project also incorporates behavioural aspects that needed to be considered in regards to overuse and the overall attitude towards recycling. Design Thinking is useful since it is centred around the user and their values and needs, allowing us to better create a solution that satisfies all parties (Plattner, 2010). This is applied by visiting the users workplace and everyone that is affected by our proposal and gaining insights of the system as a whole. During visits and interviews, the focus is on open ended questions, observations and asking why in order to find the suitable solution. Design Thinking also describes limitations as something that helps us find a solution that is feasible, desirable and viable (Brown, 2009). Our project is limited in the sense that the problem area is quite big and setting limitations for ourselves as well can be positive. This method helps us focus on that limitation is something that can be useful and constructive for the task (Brown, 2009).

Double Diamond Principle

The Double Diamond principle is an alternate design method which is affiliated with the Design Thinking process (Stickdorn, et al., 2019). However, the Double Diamond process is not user centred, making it suitable for situations where research is required rather than inputs from customers, e.g. deciding an appropriate recycle process for disposable gloves (Stickdorn, et al., 2019). This method is divided into four stages: *Discover, Define, Develop,* and *Deliver* (Stickdorn, et al., 2019). The first diamond, called the problem space, is constituted by sections *Discover,* and *Define*. *Discover* consists of different research methods in order to find inputs regarding the problem. These inputs are later used in the *Define* section to outline all challenges within the problem. The second diamond, called the solution space, consists of sections *Develop,* and *Deliver.* When all challenges are defined, multiple solutions are created in the development stage through prototyping. Lastly, the solutions are delivered to gain inputs from customers/users.

Business Model

Due to working with a project in the public sector, the traditional business model canvas has been neglected. Since the government does not manufacture nor gain profit when distributing plastic gloves to the facilities within the City of Stockholm, a value mapping tool regarding how stakeholders are affected was constructed instead. The stakeholder value mapping displays an overview of how each stakeholder gains or loses economical, social, and environmental value.

Visualisation of Prototypes

Since the prototypes are mostly conceptual and process based, there is a need to visualise them in order for them to be easily communicated. Therefore, an illustration of a product journey map and a future roadmap is made to show what needs to be done in the different parts of the solution scope. A product journey map is a way to illustrate every step of the product life cycle (Stickdorn et al., 2018). Since laws and regulations are continuously changing in regards to disposal of plastics and companies' carbon footprint, the solution has to take into account both the present and the future. Therefore, a future roadmap is used to illustrate the ways of proceeding in the process in relation to changing conditions over time. By visualising prototypes in this way, it makes conceptual, process based solutions more tangible.

Value Mapping Tool

The value mapping tool (see *Figure 4*) visualises value that is missed (and destroyed) and has been used to capture sustainability opportunities (Bocken et al., 2013). Applied to the current value proposition, the value mapping tool is used to visualise the benefits and drawbacks of a linear flow of plastic gloves. Additionally, values that are destroyed or missed are both used to highlight the opportunities for new value creation, visualising the needs for further improvement in the system.

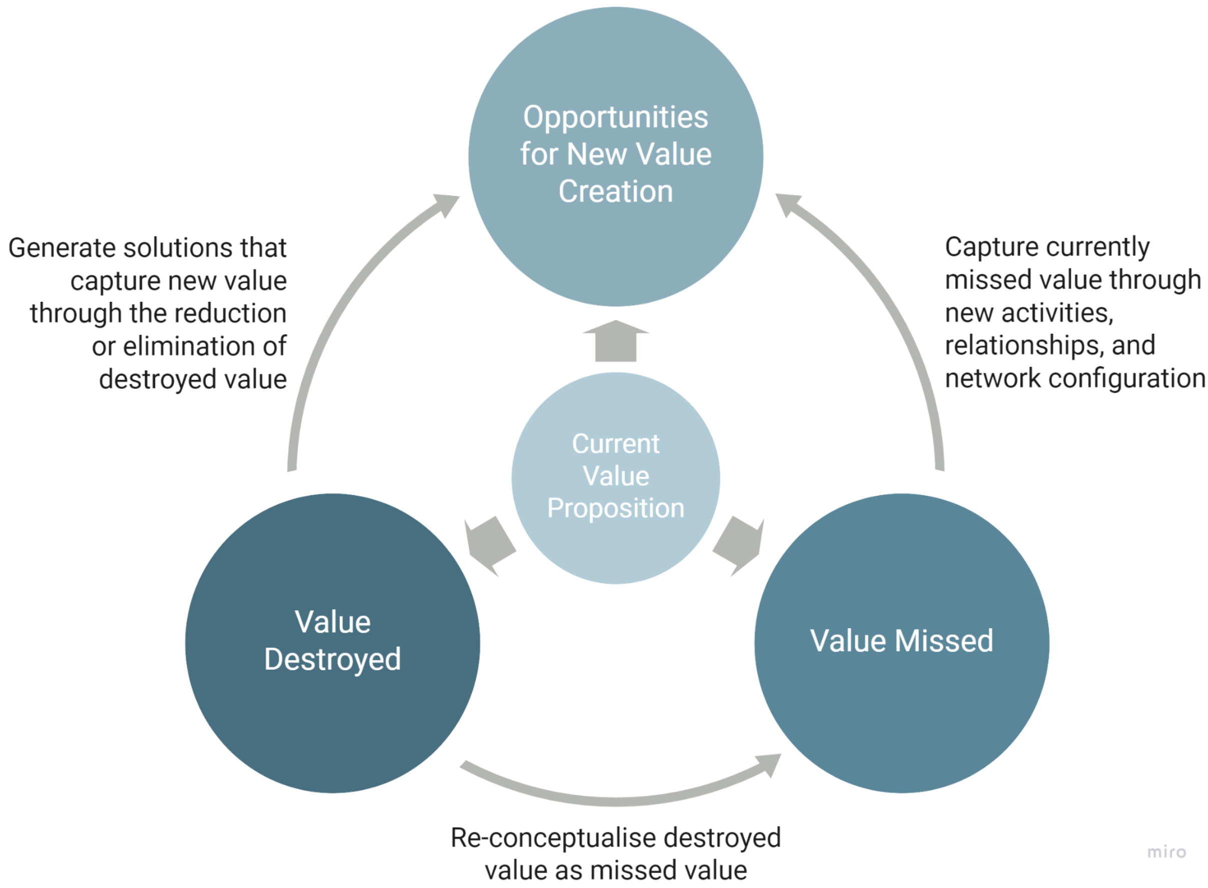

Figure 4. Value proposition (Bocken et al., 2013)

Issue and Hypothesis Trees

Issue trees (also referred to as issue maps, logic trees, et cetera) is used as a method to disaggregate problems or challenges into their component parts to gain better understanding of the main issue. The tool creates a graphical representation of the breakdown, where the main issue is broken down in branches to its sub-issues. Sub-issues can be further broken down until reaching a level where root causes are identified or available knowledge limits further breakdown (Chevallier, 2016; Chia, 2019). From the issue trees, suggestions on actions to solve the subissues are developed. The suggestions form an arrangement of hypotheses on how to solve the main problem referred to as hypothesis tree (Chevallier, 2016; Chia, 2019). Visualisations of both the different challenges and possible solutions are generated from the issue and hypothesis trees. The output from the method is used as proof of concept or to track how ideas have been developed, which is useful when generating ideas as well as when presenting solutions to the Environment & Health Department.

Five Day Sprints

In line with iterative prototyping, five day sprints are used to stay within our project timeframe by limiting the time of the chosen process. Five day sprints are a way of compressing debate cycles and quickly turning difficult decisions into testable hypotheses (Knapp, 2016). The sprints are structured by a "sprint master" in the team that defines and plans a sprint and communicates this to the team. Each sprint has a clear goal and deadlines are set within the team so that the objective is met. However, the length of the sprints in the project is dependent on the field of research and are decided mutually by all members before starting the sprint. Using this way of working effectivizes the design process to quickly prototype conceptual ideas. For the sprints to be achieved, meetings are held before and after each sprint. After a sprint, conclusions are drawn from the previous sprint before starting the next sprint.

Iterative Prototyping

One of our challenges as a team is the time limitation of the project. Therefore, a way to quickly test if solutions or ideas need to be iterated is to begin prototyping as quickly as possible. Prototyping generates results faster and when problems are complex, prototyping will make ideas tangible, making them easier to evaluate, refine and iterate (Brown, 2009). Since the solution refers to a process rather than a product, a way of prototyping involves finding conceptual solutions to different parts of a wider infrastructure, where stakeholders included in the ecosystem are contacted to see if the solutions are feasible or need to be revised. Prototypes should not be near a complete solution because people are more likely not to give their honest opinion or feedback according to Brown (2009). This was applied in the project by presenting early prototypes to the Environment & Health Department in order to "fail fast". The prototypes were made tangible by visualisations of both the product- and the customer journey map, to get a picture of how different stakeholders and different parts of the process are interrelated.

Kanban

To get a better overview of the project and its tasks we used Kanban boards in Miro. Both for the whole project and for weekly tasks. The method is used by creating tasks which are divided among the team members so that all tasks have an assigned task-owner. When a task is in progress it is moved to the "ongoing" column of the board. Finally when a task is finished it is moved to "finished" tasks, which is the last column. It is also possible to set deadlines for each task as well as mark it as prioritised if it is more important for the team to focus on.

To create the weekly Kanban we had weekly meetings where we discussed the tasks and deadlines. We also discussed the process method shortly on these meetings to make sure we were using the methods or that we are revising them if necessary.

Interviews and Visits

The interviews and visits made during the project are presented in *Table 1* below.

Table 1. Interview and visits.

Organisation/ company	Role of respondent(s)	Purpose/theme	Type	Date
Environment & Health Department	Project manager chemical center | Project manager | Project manager chemical center	Project Introduction Project update . . . Presentation	Meeting	5/9 30/9 13/10 7/11 22/11 5/12
Trioworld	Head of sales & marketing (PPE)	Trioworld organisation and TrioCircular	Interview	15/9
Akalla Hill (preschool)	Responsible for purchasing of gloves	Use of plastic gloves in preschool environment	Interview and observations	19/9
ReGlove	Co-founder	Recycling of plastic gloves	Interview	27/9
Naturvårdsverket	Experts from different stakeholder organisations	Sustainable plastic use	Seminar	29/9
Stena Recycling	Expert in plastics	Waste disposal, recycling and transportation	Interview	7/10
Trioworld | Danderyds Sjukhus	Chief Physician & Docent | Head of sales & marketing (PPE), Public Affairs and Regulatory Director, Group Director of Marketing & Communications	TrioCircular - Circular flow of medical aprons (Pilot Project)	Interview and observations	12/10
Väderkvarnen (elderly care facility)	Unit manager	Use of plastic gloves in elderly care environment	Interview and observations	12/10
City of Stockholm	Experts from different stakeholder organisations	Plastforum - Sustainable plastic use in healthcare	Seminar	14/10
OneMed | evercare	Category Manager Business Area Manager	Opportunities and difficulties with recycling of gloves from a wholesaler and manufacturer perspective	Interview	30/11

Project Scope and Limitations

Project scope and limitations are outlining what the project will include and what it will not include. This section will define the constraints and boundaries that will impact the project, such as estimating emissions of greenhouse gases and excluding transportation, customer comfort or convenience and economic aspects.

CO2-eq as Primary Estimate for Environmental Impact

Since the scope of the project refers to lowering the environmental footprint for the City of Stockholm, the focus has been to decrease the emissions of greenhouse gases. Even though carbon dioxide is the most common gas to drive global warming, other gases are contributing to climate changes as well (Brander, 2012). The time duration in the atmosphere for the different greenhouse gases differs and they absorb different amounts of heat, resulting in different global warming potentials for different gases (Brander, 2012). Since the amount of warming a gas causes over a period of time differs, a common unit of measure needs to be established to visualise the total emissions of greenhouse gases. Therefore, carbon dioxide equivalents (CO2-eq) are used to represent a more accurate impact of the total emissions of greenhouse gases, describing the impact different gases have on global warming with a common unit (Brander, 2012).

Excluded Emissions from Transportation

In this project, the emissions of greenhouse gases have been limited to the extraction of raw material, manufacturing and incineration of plastic gloves, since these phases of the lifecycle account for the majority of the emissions (Lindman, 2019). Therefore, the emissions from transportation of plastic gloves have been excluded when creating the prototype. Moreover, aspects like air pollution, increased traffic, and increased noise within the City of Stockholm have been neglected when creating a model which changes the current ways of transportation. Lastly, how the emissions of microplastics change with a circular flow compared to a linear flow of plastic gloves have also been excluded.

Excluded Customer Value of Gloves

When creating a circular flow of plastic gloves, the gloves involved in the circular system may contain different mechanical traits from the ones that are currently used. If the circulated gloves fulfil standards and regulations for use in the health & social sector, their involvement in the system becomes feasible from a legislative standpoint. However, the user experience is equally important as users can choose to use disposable gloves instead if they find them more comfortable and easy to work in. Hence, a limitation in this project is that no customer surveys regarding the feel and comfort of the gloves have been done due to time limitations. Understanding the customer value would be beneficial when developing gloves that can be circulated to make sure that both the user and environmental perspective have been taken into consideration.

Excluded Economic Figures

In this project, no concrete figures of economic profits or losses for different stakeholders have been calculated as this is too difficult to estimate. The cost of the production of the recyclable plastic gloves has also been neglected as it is unclear which material the gloves will use for the solution to be feasible. Instead, it is assumed that the circulated gloves will initially have a higher price than the non-recyclable ones as this is a trend in many other market areas.

Research Findings

The research constitutes the base from which the solution is developed. The most important findings are described in the following sections, where assumptions made based on the research are highlighted.

Organisational Structure of the City of Stockholm

In order to meet our vision, different branches in the City of Stockholm needed to be analysed. This was done to distinguish which departments or committees are involved in the product journey and where. The City of Stockholm is organised in City District Departments, Specialist Departments and City Owned Companies (Stockholms stad, 2020). The departments and committee involved in this project is shown in *Figure 5* below. The Environment and Health Committee is a Specialist Committee that has the political responsibility for environmental issues and is responsible for the Environment and Health Department (Stockholms stad, 2021). The Environment and Health Department is one of the City of Stockholms many Specialist Departments and is responsible for the environment in the City of Stockholm (Stockholms stad, 2022). They create and maintain dialogue with different stakeholders, such as facilities, and coordinate necessary training and information. They are the ones that act on the decisions that the Environment and Health Committee makes. The Service Department is a Specialist Department that is responsible for procurements in the City of Stockholm (Stockholms stad, 2020). This includes contracts with disposable glove manufacturers and recycling contractors.

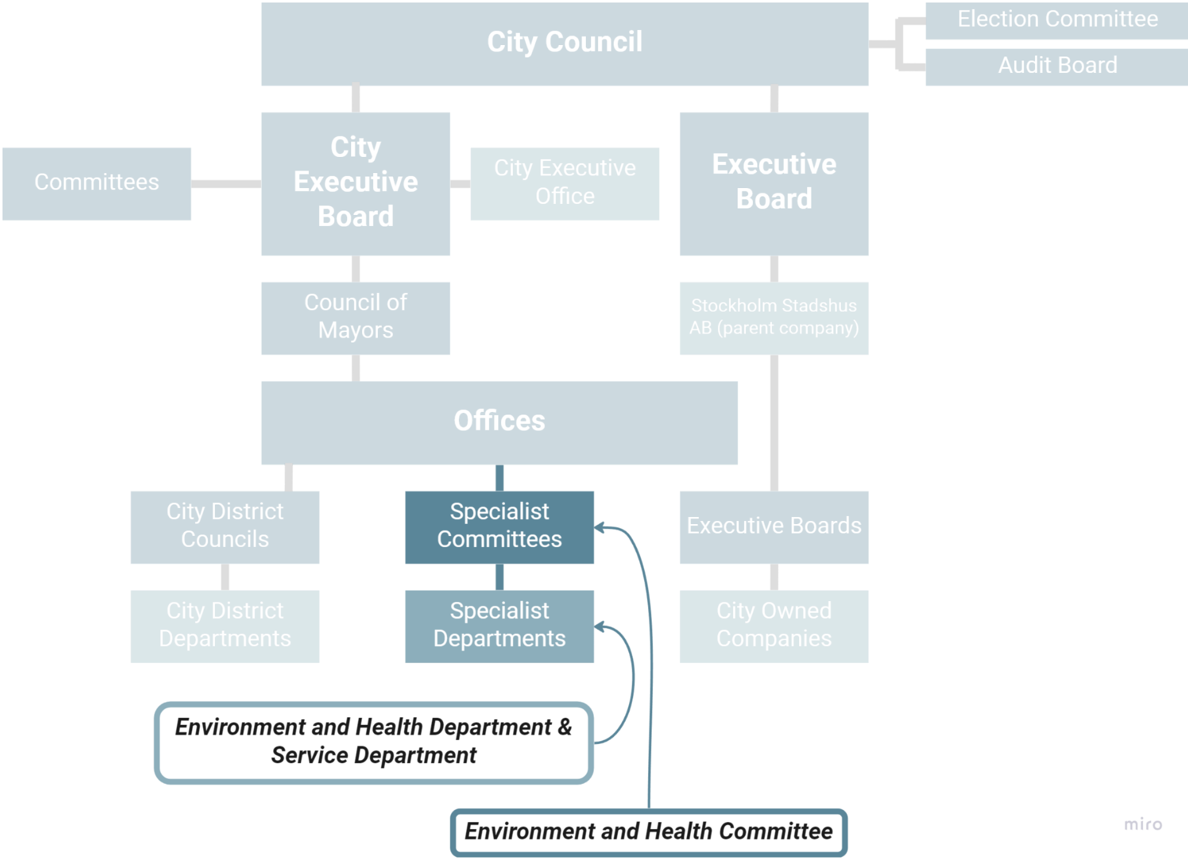

Figure 5. Orgainsation structure of the City of Stockholm (City of Stockholm, 2022)

Policy Approaches Towards Plastics

The use of fossil plastics is related to a number of environmental concerns. As mentioned in the background, a great amount of GHG emissions are generated during the product life cycle of plastic gloves. Most emissions are generated during raw material extraction, production and incineration (Lindman, 2019). Raw material extraction risks having hazardous consequences on marine life and extraction and production are also energy intensive processes that emit pollutants and other hazardous substances. (SOU 2018:84). The increased awareness and knowledge regarding these environmental concerns has led to the development of policies that encourage increased use of recycled plastics. For example, the European Union has developed a plastics strategy and implemented the Directive on Single-use Plastics and the Waste Framework Directive as parts of its Circular Economy Action Plan. The EU plastic strategy partly focuses on making recycling profitable and on efforts to avoid plastic waste (European Commission, n.d.-a). The Directive on Single-use Plastics ban some specific single-use products produced in plastic. The directive claims that the material in these products can be substituted with other materials with lower environmental impact (European Commission, n.d.-b). The Waste Framework Directive includes targets for the recycling and recovery of plastic waste. It also requires member states to take measures to reduce the negative environmental impacts of plastic production and use. Efforts comply with the Waste Hierarchy, illustrated in *Figure 6*, to primarily aim to prevent waste and disposal of waste should be considered if no other step is available. One of the targets is that member states by 2025 should prepare for recycling of municipal waste so that it is "… increased to a minimum of 55 %, 60 % and 65 % by weight by 2025, 2030 and 2035 respectively" (European Commission, n.d.-c).

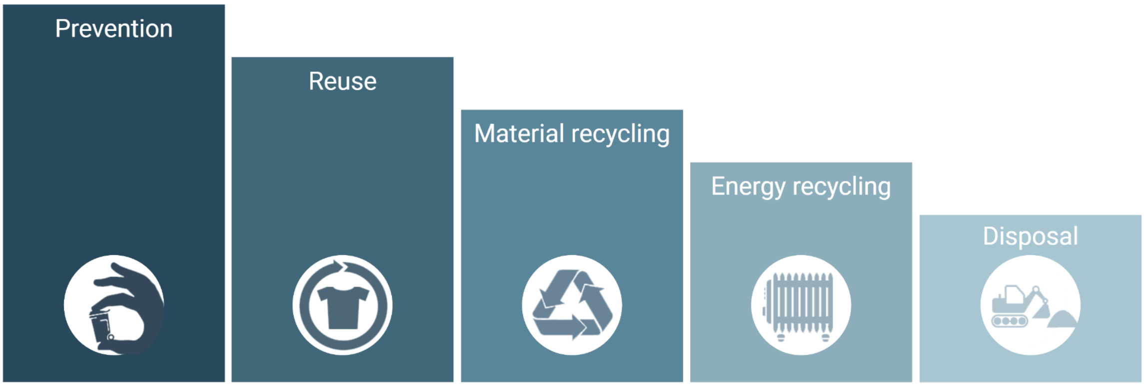

Figure 6. The Waste Hierarchy

Even though there is no specific legislation regarding plastic products in the health care sector, the mentioned directives and regulations concern stakeholders within this area. The directives also suggest that responsibility on producers to design, label, collect and report to ease recycling will increase (Naturvårdsverket, n.d.-a). Furthermore, as more policies are developed, medical equipment will probably be included if feasibility regarding recycling of these products are proven.

Assumption 1 *New policies regarding recycling of plastics will be developed which together with current policies will increase the demand for recycled plastics.* This is based on the increased focus on solving sustainability issues from policy makers and the society as a whole. If specific targets or bans are implemented in regulations, it can make recycled plastic more attractive to both consumers and producers.

Assumption 2 *If there are no policies on the use of recycled plastic, other incentives will be needed to make producers manufacture recyclable gloves and facilities buy them.* This is based on the assumption that recycled gloves are more expensive than gloves made from fossil raw material.

Assumption 3 *To enable policies specifically directed towards PPE such as gloves, the feasibility of recycling must be proven. This can be done through initiating pilot studies with research institutes and other stakeholders.* This is based on the fact that medical equipment made from conventional plastic will not be prohibited until there are alternatives that fulfil required standards.

Procurement to Support Circularity

Procurement of PPE needs to support circularity for a circular flow of plastic gloves to be realised. To support circularity, procurement should include functional requirements related to the needs of the customer, rather than specific products (Upphandlingsmyndigheten, n.d.-a). By using functional requirements instead of having requirements related to specific products, the possibility to develop novel solutions is enhanced as the solution is free from technological boundaries (Upphandlingsmyndigheten, n.d.-b). To further enhance the possibilities of creating novel solutions that cope with circularity, Request for Information (RFI) and dialogs with different suppliers can be used to increase knowledge and find the most suitable solutions (Upphandlingsmyndigheten, n.d.-c). For instance, awareness of material of choice for different products is a prerequisite to control the flow of material towards recyclable alternatives (Upphandlingsmyndigheten, n.d.-a).

As multiple industries in the public sector have requirements regarding traceability of raw material, recycled materials are not allowed in all industries (Upphandlingsmyndigheten, n.d.-a). To be able to implement a circular flow of plastic gloves, the circular flow must be traceable through all phases in the process. Additionally, keeping the material of plastic gloves in a closed loop could benefit the possibilities of establishing a circular flow, since levels of contamination for the medical products can be estimated. Where procurement of recycled material fails to be implemented despite being traceable due to higher contamination levels, considering multi-use gloves as an alternative for disposable plastic gloves can help lower the emissions of greenhouse gases (Upphandlingsmyndigheten, n.d.-a).

Materials

To create a sustainable, circular loop of single-use gloves, there is a need to find a material which can be recycled into new gloves while not requiring processes that make them much more expensive than the gloves that are currently on the market. Therefore, a review of different materials is made to compare the recycling potential, sustainability impact and user-friendliness between the gloves currently used and potential future alternatives.

Latex

Latex is a natural rubber found in trees, but can also be synthetically produced (Guerra et al., 2021). Historically, latex has been a popular material for manufacturing gloves due to its mechanical properties. However, in the City of Stockholm the popularity of latex gloves has decreased over time due to them having allergenic effects on some care recipients. Latex gloves can not be recycled into new gloves due to the polymer chains of the material being cross-linked (Mathew et al., 2001). They can however be downcycled into other products where the same mechanical properties as the virgin latex are no longer needed, thus increasing the material lifetime. A positive aspect of latex is its organic occurrence in nature, making the extraction of the raw material less fossil reliant than other alternatives.

Nitrile

One of the most commonly used gloves within the public sector of the City of Stockholm are nitrile gloves. These gloves are made from synthetic rubber which gives them a higher degree of elasticity than plastic gloves made without plasticizers. Based on visits to Danderyds Hospital and the pre-school Akalla Hill, these gloves have mechanical properties which are appreciated by users and they have also passed the performance requirements listed in standards for use in health & social care sectors (Swedish Institute for Standards, 2016, 2018). However, due to the material's chemical structure, they are not able to be mechanically recycled to new gloves as the polymer chains of nitrile are cross-linked, making them unsuitable to melt down for re-molding (Fortman et al., 2018). There are initiatives today where nitrile gloves are downcycled for use in other applications such as floors tiles and sport court flooring in their second life (Terracycle, 2022), but making a fully circular loop of nitrile gloves is unfeasible in the current scientific landscape.

Polyvinyl Chloride (PVC)

Gloves made from PVC are also used at a high degree in the City of Stockholm, sharing the spot with nitrile gloves as the most used in the sector. PVC is one of the most common thermoplastics used in society today (Omnexus, n.d.-a) and has many areas of application. When manufacturing single-use gloves made from PVC, plasticizers are added to give them their desired elasticity (Kemikalieinspektionen, 2022). Historically, plasticizers that have been commonly used are phthalates, which have been proven to have endocrine disruptive traits (Hlisníková et al., 2020). Therefore, the EU has created a legislation limiting the use of phthalates to not amount to more than 0.1 percent of a products total weight (Kemikalieinspektionen, 2019). While PVC is recyclable in its pure form, the addition of plasticizers make the gloves difficult to recycle as they would need to be separated from the PVC for the plastic not to lose its characteristics in its second life. Heat activation of plastics containing plasticizers also releases hydrochloric acid which can be harmful for humans and equipment used in the recycling process (Michigan News, 2022). However, new research from the University of Michigan has shown the potential of chemically separating plasticizers from the PVC, making it possible to recycle PVC that was previously unrecyclable (Fagnani et al., 2022). Chemical recycling is currently more expensive and the process consumes more energy than mechanical recycling (Lassesson et al., 2021). Furthermore, the process can also include hazardous chemicals (SOU 2018:84). As the technique of chemically separating plasticizers from PVC is currently quite immature, it is unclear how well suited the technique would be for large volumes both in terms of cost and feasibility, but the results of the research shows promising signs for the future recycling potential of the material.

Polyethylene (PE)

PE is also one of the most commonly used plastics in society today (Omnexus, n.d.-b), giving it a large market demand as a consequence. It has a high degree of recyclability and PE-gloves are commonly used in the food industry. The material is not as elastic as rubber-gloves or plastic gloves with added plasticizers, making them less appreciated by users as this is a highly valued mechanical property based on interactions with users. According to standards SIS-CEN/TR 16953:2018 (Swedish Institute of Standards [SIS], 2018) and SS-EN ISO 374 (Swedish Institute of Standards [SIS], 2016), the gloves must contain certain mechanical properties in terms of chemical resistance, penetration time and material strength among other aspects to pass regulations for use in certain application areas. For use in the health & social care sector, PE-gloves do not meet the requirements according to an interview held with glove wholesalers and manufacturers OneMed (Interview OneMed, November 30, 2022). This is especially important in sectors which require protection from bodily fluids and bacteria, and within child and elderly care there are several tasks where this is encountered, i.e. changing of diapers and contact with body orifices. For the gloves to meet these requirements, PE-gloves would have to be manufactured with a thickness that would make them uncomfortable from a user-perspective, according to respondents from OneMed. However, plastic manufacturers Trioworld are investigating the possibilities of using PE-gloves within the sector, and continued research could reveal future potential of the use of the plastic in health & social care. Trioworld have also launched a pilot project in collaboration with Danderyds Hospital where they have successfully initiated a circular flow of medical aprons made from PE, showing that a closed loop system of PE in the health & social sector is achievable for certain products. They are also investigating whether bacteria from contaminated medical equipment can survive the melting temperatures for plastics. If they can not, the regulations for contagious waste management in recycling systems can be changed.

Studies show that using recycled PE would lower emissions by 25 % compared to using fossil PE (Regionledningskontoret Region Stockholm, 2020), and up to two thirds if cycled three times (Interview Trioworld, September 15, 2022). As the material has great recyclability potential, a breakthrough in the research would enhance the possibilities of creating a circular loop of single-use gloves.

Biobased Plastics

There are other types of plastics that are used for medical equipment that could be applied for gloves. Different types of biobased plastics are currently used for personal protective equipment such as aprons. Biobased plastics are partially or entirely based on biological resources (European Commission, n.d-d) and can be produced from cellulose, crops with a high content of carbohydrate such as starch, or residues from industrial, agriculture or forestry processes (SOU 2018:84). Looking at PE, production of biobased products could possibly result in reducing emissions of greenhouse gases by two thirds compared to using fossil raw materials (Regionledningskontoret

Region Stockholm, 2020). An important aspect to consider is mechanical properties as some materials do not possess the same properties as currently used materials do. During the visit to the Trioworld Pilot Study at Danderyds Hospital (October 12, 2022), a Chief Physician claimed and showcased that aprons made from corn starch break more easily than those made from PE. Another aspect to consider is how the raw material is sourced as some biobased materials are made from resources produced with the primary purpose of becoming raw material for bioplastics, whereas others are process residues (SOU 2018:84). Currently, the production rate of biobased plastics is low compared to that of fossil plastics as it is more costly and production capacity low. However, customer demands on "green" products and less use of fossil raw materials among other factors has put pressure to increase production capacity and replace fossil plastics with biobased ones (Lackner, 2015; SOU 2018:84). If production were to shift towards biobased plastics, there would be conflicts over land use with other stakeholders such as food producers. Furthermore, production of biobased materials engender climate issues such as acidification, eutrophication and biodiversity as a result of the way the land is managed (SOU 2018:84). These issues must also be considered when selecting material for the gloves. Lastly, some bioplastics referred to as "drop-in plastics" are of the same polymer structure as their fossil counterparts, making it possible to include them in the same recycling stream (Naturvårdsverket, n.d.-b). In a circular flow with mechanical recycling, a percentage of the material in production must be from raw material in order to maintain desired mechanical properties. Thus, combining drop-in plastics and recycling could be one solution to lower GHG emissions while also pursuing resource efficiency.

Assumption 4 *PE-gloves are not yet suitable for use in the health and social care sector.* This is based on the current standards, research and observations made from the interview held with glove wholesalers and manufacturers OneMed. It is not excluded that these gloves may have future potential within the sector and potential biases from the side of the glove wholesalers and manufacturers have been taken into consideration, but the assumption has been made from the currently obtained information.

Assumption 5 *PVC, nitrile and latex are not yet suitable for creating a circular loop of single-use gloves.* The assumption has been made as nitrile and latex are currently not possible to melt down for remanufacturing of new gloves, and the research for large scale recyclability of PVC-gloves with plasticizers is not yet mature.

Compression of Plastics

To optimise the plastic collection from the facilities, compression of the consumed gloves would make it possible for the trucks to carry higher volumes of material, decreasing the amount of transports needed. The compression can either be done by the facilities themselves or the transportation companies. In Trioworld's pilot project at Danderyds Hospital, the plastic medical aprons were compressed in the hospital recycling room with a pneumatic press which was easy to operate, according to the Chief Physician. However, these types of solutions are only possible in facilities with enough space for pneumatic presses in their recycling rooms, employees with required competency to operate them and with enough cash budget to afford them. It would therefore be unfeasible for most of the elderly care and pre-school facilities in the public sector of the City of Stockholm. Hence, the transport companies would be better suited to compress the plastic gloves in our proposed solution. The National Board of Health and Welfare has a document of regulations for contagious waste SOSFS 2005:26 (Socialstyrelsen, 2021), where it is stated that contagious waste should not be compressed or be included in a recycling system. This is one of the reasons why it is important to inform users of which gloves should be thrown away and which ones should be recycled.

Overconsumption, Behavioural Changes and Nudging

From our visits at facilities and meetings with the Environ and Health Department, we learned that there is an overconsumption of single-use gloves as employees use gloves in situations where they are not needed. To decrease the overconsumption of gloves, information regarding the recommendations and guidelines of when to use gloves, and when the use of disinfectants and hand washing is sufficient to reduce the spread of bacteria, should be made accessible. The National Board of Health and Welfare has a series of guidelines for people working in health and social sectors called *basic hygiene routines* (Socialstyrelsen, 2021). For people to reduce the overconsumption of single-use gloves and improve their application of basic hygiene routines, certain behavioural changes are needed. One approach to tackle behavioural changes is nudging.

Nudging is based on the idea that changes in an environment can influence people's behaviour by making it easier to make certain choices (Mont et al., 2014). This could be done in many different ways, by simplifying information, changes in the physical environment, changing the default options and using social norms (Mont et al., 2014). For instance, facilities should consider placing non-disposable plastic gloves that can be used multiple times for tasks that do not require sterility, simplifying the choice of personal protective equipment (PPE) for the users. The risk of using nudging to change a certain behaviour is that some might feel used or manipulated into making a choice and end up having a negative attitude or behaviour towards the wanted change (Hagman, 2018; Hummel & Maedche, 2019). Therefore it is important to be transparent with the target group and what they value and feel is important (Hagman, 2018).

Feedback

Formative feedback is a type of feedback that aims to reform a particular behaviour or thinking of the recipient by shifting the focus from performance to learning (Shute, 2008). The purpose of formative feedback is to contribute to learning by providing ongoing information and support to the recipient so that they gain a better understanding of the situation (Shute, 2008). This can also provide insight to those providing the feedback as it helps tailor an action plan to the needs of the recipient (Juwah et al., 2004). One form of formative feedback is goal-directed feedback, which is giving information about the current progress toward a specific goal (Shute, 2008). The purpose is to motivate and encourage the recipient with learning oriented goals such as increasing a skill or competence.

Assumption 6 ☐ *Commitment to environmental work will exist in the facilities of the City of Stockholm.* Based on the engagement from staff at Danderyds Hospital regarding the circulation of aprons, the assumption was made that similar commitment will be found in the facilities of the City of Stockholm.

Assumption 7 *Overconsumption occurs in the facilities of the City of Stockholm*. The assumption is based on perceptions by the Environment and Health Department as well as observations at facilities. There are no statistics to show that overconsumption is happening, and therefore, the assumption is made that it occurs at the facilities.

Conclusions

Decreasing the environmental impact of disposable gloves can be approached from many different angles, which consequently creates a large set of challenges. Overconsumption can be worked on today as this does not require new technology or innovation practices, but creating a circular flow of plastic gloves requires socio-technical transitions in terms of the supply network, policy changes and technological advancements. Many areas of the circular system are still being researched, such as the chemical separation of plasticizers from PVC, the bacterial resistance to the melting temperatures of plastics, and the recycling potential of different materials. As research in these areas continue, it will become apparent whether a closed-loop system of single-use gloves is possible. However, a final assumption has been made based on our perceptions of where the research is heading, our visits and observations during the project:

Assumption 8 *There is future potential for creating a circular loop of single-use gloves.* Even though the current scientific progress has not yet reached a point where this is possible with existing practices, there is enough evidence to indicate that the research is headed in a direction where this could be a future possibility.

When the market conditions are mature enough for it to be feasible, the proposition presented in this project work can act as an initial framework for how a circular system of disposable gloves can be facilitated.

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