User centred design and energy efficient packaging collection infrastructure supporting circular future lifestyles

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Abstract. The collection and recycling of packaging and life cycle assessments have traditionally been developed from a technical perspective, not including the actors in the chain. How recycling should be done depends on who you ask, and whether you look at the issue from an energy, material, legal or user perspective. FTI, the Packaging and Newspaper Collection organization is responsible for better circularity and collecting these fractions in Sweden's municipalities. When recyclable materials end up in the wrong place, it causes problems leading to increased energy use in the life cycle. The ongoing project Tjårven, aims to reduce energy use in connection with packaging collection, as well as potential energy gains in the second stage of the packaging life cycle, by redesigning packaging collection from a user centred perspective. To do this, design interventions are developed based on observed and self-reported user behaviour, a literature review of state-of-the-art collection infrastructure and an understanding of the system developed using actor-based LCA methodology. The latter methodology is used to show the energy use in the lifecycle, including the actions of the actors in the chain. The interventions developed will be tested through a case study that will be evaluated to see if it helps to achieve more energy efficient collection infrastructure, allowing for better circularity and therefore more sustainable future lifestyles. The present article presents the first part of the project, summarizing the results from the user centred observations, literature review and initial actor-based LCA model.

1 Introduction

The collection and recycling of packaging and life cycle assessments have traditionally been developed from a technical perspective, not including the actors in the chain [1]. However, recycling behaviour determines to a large extent how well a collection system works and should therefore be included in efforts to improve the recycling of packaging. The ongoing project Tjårven, aims to reduce energy use in connection with packaging

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collection, as well as potential energy gains in the second stage of the packaging life cycle, by redesigning packaging collection from a user centred perspective.

The Tjårven project is a collaboration between Semcon, RISE and FTI, the producer responsibility organization for packaging and newspapers in Sweden. The project started in February 2021 and has since gathered data through on-site observations, user surveys, interviews, waste characterization, a literature review [2] and local waste statistics. The collected data will be used to inform an actor-based LCA model and design interventions aimed at improving the collection of packaging waste. The interventions are to be developed and tested in selected collection stations during the fall of 2021, generating observable results from the project by early 2022. This article summarizes the main results of the project so far. On-site observations (including surveys, interviews, and cleaning shift tour) are described in section 2, the literature review in section 3 and the structure for the actor-based LCA is presented in section 4.

2 On-site observations

Several FTI packaging collection stations were observed at the beginning of the project. Later on, 9 stations were selected for a deeper study. The selection was based on aspects such as placing, densely populated area, as well as stations where users could act "unseen". Three station categories were defined: **1:** Hidden in densely populated area, **2:** Placed at a shopping area and **3:** Visible, in densely populated area. In each category, three stations were chosen, two for interventions and a third to act as control group. The stations considered have at least one container of each fraction, to allow for comparisons, and are all cleaned often: 3 or 6 times/week.

2.1 Surveys

Since it is known that it is hard for people to tell how they actually do things if they get the question, we wanted to try to see if their interview answers matched with a recycling log that they filled in during the two days. The log consisted of rows where the participants filled in four values: kind of product, in what category it was sorted, in which room, and why. This was sent out to eight of the interview participants and we got response from five. This part is yet not analysed.

To see where in the process the user has issues, an emotion survey was sent out together with the log. In this survey, they got to fill in the Self-Assessment manikin (SAM) emotional scale connected to the situation at home, the path to the recycling station and the visit at the station. This was filled in at two different dates of going to the station with recycling. This survey showed that the participants in this small study felt increasingly more negative feelings at the station than at home.

2.2 Interviews

People often think that the stations are good to use, but that they are mis-used by users who dump and litter. They also have opinions about the number of containers and how often these are emptied. Other opinions are regarding the layout of the station, that it can feel cramped (if there are several who sort at the same time), and that the holes for the throw-in are too small. The condition of the stations is sometimes experienced as stale and dilapidated.

People are generally positive regarding packaging collection stations, and a lot of blame is placed on "other individuals": "Those who mess up". Opinions are divided about if the number of containers and collection intervals are adequate or not. Regarding cleaning, people

think it is generally dirty and that the stations could be refreshed. The place itself is described as gloomy.

People would also like the opportunities to leave other things than packaging and papers at ÅVS. Some believe that FNI offers more opportunities for sorting. Some raise the conditions that the home entails. For example, that they do not have much space for sorting at home. Some also believe that the distance to ÅVS affects, as they cannot carry far. ÅVS is not placed evenly and near to where they are needed. Sometimes it can be difficult to use the stations efficiently; when things are dumped, there are difficulties in reaching the containers.

2.3 Cleaning shift

We followed some cleaners at 8 stations in Gothenburg: The working pace was fast. Some stations were heavily littered while some were tidy and needed no action. Some of the problems the cleaners wished to mention were: The big hole in the container where a rubber cover should be placed. They are often missing, and materials tend to fall out of the vessels. They should be made differently, they easily break. It is a stressful workplace, with diapers and leftover food to be cleaned away. Some things are sorted incorrectly by cleaning staff. For example, diapers put in plastic sorting. Glass that cannot be put in the bin is placed on the ground outside. It is thrown away by the cleaning staff in the containers. The fence also causes difficulties in cleaning. Material to the non-packaging containers is not the staffs' job to sort, but they do it. Large packaging is a problem that is pointed out by both cleaners and residents.

3 Literature Review

The literature review can be divided into two sections, the first focusing on household waste sorting behaviour insights, and the second on extended producer responsibility for paper and packaging products (EPR for PPP) and how they contribute to waste collection systems and recycling behaviour. The first section is based on 5 previous literature reviews focused on waste sorting behaviour and the design of waste collection systems [3, 4, 5, 6, 7], while the second section reviews technical reports from EPR branch organizations. The main aspects form these sources were summarized and the most relevant aspects to the Tjårven project were highlighted in an internal literature review report [2].

3.1 Recycling behaviour

Based on the reviewed articles, specifically the one that compared 36 reported interventions and compared their efficiency [5] and the one that categorized good practices to improve recycling performance from 162 articles [6], the review concludes that social modelling (having prominent people describe how they recycle to influence other's behaviour), environmental interventions (physical changes to the collection stations and associated infrastructure) and communication strategies are the types of interventions that obtain the best results in improving recycling behaviour (in that order). Literature also recommends that how such interventions are defined, should be based on the local context and users' circumstances. Therefore, it is important that the user research and data collection presented in section 2 be used as a base to detail the final project interventions.

3.2 EPR for PPP

Extended Producer Responsibility Alliance EXPRA was identified as a relevant international EPR association, influential in the European context. FTI is already a member of this organization; however, much of the available EXPRA content can still be used by the project team as a EPR for PPP specific benchmark. Looking at fellow EXPRA member organizations for inspiration with regard to how they communicate and relate to other stakeholders in the Waste Management branch, should be seen as a reminder that the ways the PROs for paper and packaging are currently defined in Sweden is only one way of operating within this legal form. The Swedish regulations that define how FTI operates might be subjected to change based on shifting criteria at the EU, influenced by other EPR frontrunners.

4 Actor-based LCA model

The actor-based modelling has been used in several ways. The goal was to include a user-based perspective on recycling. The case study includes 3 types of stations and a total of 9 stations within two cities (Gothenburg and Örebro). The households have been selected based on participating observation at the stations. At the stations a large number of screening interviews/surveys (45 interviews) and a minor number of in-depth interviews and recycling behaviour logbook (6 city, 1 hidden, 1 shop) were performed.

In order to learn about the stations, the collection and cleaning frequency have been studied (shown in table 1). In the city of Gothenburg, there are 322 stations to be cleaned and 998 containers to be collected (including plastic, metal, paper, and glass). In the city of Örebro, there are 34 stations to be cleaned and 129 containers to be collected.

Table 1. Collection and cleaning frequency at 9 stations.

	1	2	3	4	5	6	7	8	9
Name	Bagare-gården	Här-landa	Mast-hugget	Lun-den	Bersjön, Kvadrant	Bersjön, Teleskop	Haga	OK	Coop
Station, City	City, Gothenburg			Hidden, Gothenburg			Shop, Örebro		
Metal	1x	1x	1x	1x	1x	1x	1x	1x	1x
Paper/ Carton	4x	7x	5x	2x	2x	3x	5x	3x	6+1x
Plastic	2x	7x	1x	7x	1x	2x	2x	1x	2x
Glass	1x	1x	1x	1x	1x	1x	1x	1x	1x
Container	8	9	6	8	8	6	9	9	17
Cleaning	3x	3x	3x	6x	6x	6x	6x	6x	6x

In order to find out, how households perform their recycling at home, on the way to the recycling station and at the station, an actor-based model for households has been performed. This included storage at home, transport, and the station. In order to identify the actors involved in the activities of sorting and cleaning, some participant observations have been performed on stations, collection and cleaning. The results show that the activity of sorting (and the problem of wrong sorting) has several actors involved, such as the households (for sorting), the cleaners (for after-sorting) and the municipality (for residual waste). The activity of sorting plastic (and the goal of sorting more) has several actors involved, such as households, the cleaners, and the municipality (for residual waste). The activity of cleaning has different actors such as households and cleaners.

The results from the in-deep interviews and recycling behaviour logbooks show that most are satisfied about a simple, control, ordered collection and a short distance. About 20% refer the station as clean and tidy, 20% are stressed at the station because of operators cleaning or

emptying, 40% are irritated due to a messy station, and 20% have nothing to report. The results from the 8 in-deep interviews show hinder for collection, such as full stations (2 of 8), the distance (4 of 8), messy stations (1 of 8), and some do not have any hinder (1 of 8). All interviewees feel irritated about food plastic, but do not see it as a problem. All do have correct sorting behaviour. Most of the interviewees dishwash before sorting at home (7 of 8), while half use cold water (3 of 8) and half use warm water (3 of 8). The results from the 45 screening interviews show that: 24 are walking (apartment), 16 using the car (villa), 1 bicycle and 1 electric bike. Most are walking due to a short distance < 1000m. Most are walking in station (city, hidden) and using the car (shopping area).

In order to find out how the recycled material is handled from the recycling station to the recycling park, an actor-based model for recycling has been performed. This included collection, transports, pressing, transports, and pelletised. The recycling rate for metal packaging is 96% and energy reduction is 75-95% (www.ftiab.se). The recycling rate for glas packaging is 93% and energy reduction is 20% (www.ftiab.se). The recycling rate for paper packaging is 73% and energy reduction is 40% (www.fiskeby.com). The recycling rate for plastic packaging is 44% and energy reduction is 30% (www.ftiab.se/Profu). The total amount of packaging on the market 585 kton paper, 233,6 kton glas, 217,2 kton plast, 36,2 kton metal (www.scb.se). The recycling rate for plastic packaging is 44%, while about 0,63 kg/kg is used as new material and 0,28 kg/kg is used as new energy (Profu, 2021). In the latest mapping of plastic flows in Sweden, the results were 96 kton household packaging (material recovery) and 306 kton household residual waste (energy recovery), 790 kton from shops and 130 kton from industry (energy recovery), in total 1434 kton [8].

Table 2. Recycling statistics and goals for Sweden (FTI, 2021)

	Glass	Paper	Plastic	Metal (steel)	Metal (Alu)	Newspaper	Total
Recycling	94%	77%	**28%**	87%	56%	89%	72%
Household	94%	66%	**15%**	93%	53%		
Industry	94%	84%	**46%**	81%	84%		
Goal Sweden	90%	85%	**50%**	70%	50%	90%	65%

The measuring of plastic recycling (sorting rate) shows how much plastic is collected from a sample of 10 kg sorted material. The results show (before the intervention) how much from the 9 stations under June 2021. The results show also plastic collection in general, such as 80% plastic (40% hard plastic + 40% soft plastic), 10% wrong packaging (paper, metal, glass) and 10% others (wrong sorting). The results show also a pattern for wrong sorting behaviour at different stations, such as no plastic packaging or no packaging. Only 5-10% wrong sorting has been identified in the city which can be explained due to strong environmental behaviour. Slightly more wrong sorting 0.5-20% close to shopping areas and the most wrong sorting 30-50% at hidden stations, for example food residues, sand for pets, or cement products. The latest recycling statistics from 2021 show the need for more recycling for plastic in general. Households do only have a recycling rate of 15%, while the industry's is about 46%, still less than the goal of 50%!

5 Conclusions and future outlook

In order to change collection design and increase the collection of plastic, the design method seems relevant. Previous studies using the design method have shown that it is possible to increase the collection by 30% due to the design of the collection station and information, as well as the design of logistics with a household focus. In the city of Borås, a design-based method has been used that resulted in a closer distance for the stations (www.hb.se, User driven service innovation). The Product Service System PSS method has been used, resulting

in better transport service (www.ri.se, TJAVS). To change household behaviour, the method of Nudging seems relevant. Previous studies using nudging have shown that 65% better cleaning can be reached due to nudging using social norms, funny messages, easy to do the right thing, visible, simple, and inclusive design solutions (www.nudged.se/nudgingsweden). The next step in the project involves a multi-stakeholder co-creation workshop to identify interventions. Under autumn 2021, the interventions with households and stations will be performed and evaluated (sorting rate, reduce transport and energy use). The new combined method (user-centred design, actor-based modelling, and PSS service) will help to identify the best design for households and stations, as well as the best design for reduced energy and transport.

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