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ABSTRACT

Waste management in urban areas is a complex process, encompassing a variety of activities (e.g., acquiring, sorting, disposing), actors (e.g., single individuals, waste collectors, condominium associations), and capacities (e.g., from household recycling stations to physical infrastructures such as recycling and sorting facilities). Whereas previous HCI design research has tackled problems with waste management from an individual, behavioral change perspective, we approach this design space through a feminist ecological design perspective of Digital Environmental Stewardship. Through a combination of qualitative empirical data and materials generated at design workshops, we outline challenges related to waste management in a complex of five multi-apartment buildings. We propose a number of design explorations addressing such challenges, and reflect on the generative role of the DES framework in framing design from a collective and ecological perspective.

CCS CONCEPTS

• Human-centered computing \rightarrow Empirical studies in HCI.

KEYWORDS

Digital Environmental Stewardship; Waste Management; Sustainability; Interaction Design

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1 INTRODUCTION

Digital Environmental Stewardship (DES) has been introduced as a framework to analyze, assess, and design for environmental stewardship practices and sustainable action involving digital and interactive technology [51]. Combining both an ecological perspective on how action is produced and a political economic perspective on the constituents of action, the framework has been applied to the analysis of mobile and web-based applications for waste management. Since waste management in urban areas is a complex process that encompass a variety of activities, actors, and capacities, we see an opportunity in continuing to work with stewarding actions in this context. Although, in this paper, we seek to draw out the generative capacity at the core of the DES framework to design for making sustainable practices actionable in order to foster care for the local environment. As opposed to individualistic perspectives on design which have dominated the Sustainable HCI (SHCI) community [11, 19, 27], the DES perspective aims to scale up [54] the efforts of designing for sustainability by maneuvering on multiple levels and taking into account both the capacities and the motivations that various actors have toward sustainable waste management [51].

In this paper, we draw on four pieces of empirical data, a) exploratory interviews with residents and officials in five housing associations, b) a workshop with residents and officials that focused on problems in relation to actors, motivations, and capacities for waste management, c) anonymous postcards from residents regarding their situated experiences with waste management from the recycling rooms, and d) a design workshop with residents and officials in which concerns and opportunities for interactive technology in relation to waste management were explored. We also draw on observations and reflections from our visits to the buildings and to the garbage rooms. The project activities (i.e., interviews, observations, postcard retrieval, and workshops) were all guided by the DES framework. The paper contributes with (1) an empirical account of how the framework can be used for design and reflections about generative capacities based on our experiences from designing with it including the strengths of considering how designs can become capacities for other actions in a folding in action

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perspective; (2) reflections on the risk of *design death* when having a collective and ecological perspective on designing for sustainability; and (3) discussions around *data as a capacity* in design for digital environmental stewardship.

2 RELATED WORK

Research on everyday practices, waste management, and design that connects to DES can be found in and adjacent to HCI and particularly within the strand of HCI work on sustainability or SHCI. When considering designs of interactive systems there are several works that discuss design particulars in relation to sustainability. In the following, we will present these to situate our endeavors.

2.1 Designing for Sustainable Change-making

Within Human-Computer Interaction, sustainability has been a matter of concern and care for the last couple of decades. A sustainability agenda within HCI (SHCI) has especially grown since the 2007 paper where Blevis [8] argued for principles of renewal & reuse rather than the more popular invention & disposal. From a design perspective, two main efforts toward sustainability have been laid out: sustainability in design and sustainability through design [43]. However, while sustainability through design consists of individual, group, and societal levels of change-making [43], early SHCI work focused predominantly on individual behavior change through persuasive design techniques [19] informed by e.g. self-determination theory [18] and/or the behavior change wheel [44]. Designs for sustainability were heavily influenced by eco-feedback technology (see for example [2, 10, 22, 33, 34, 39, 41, 63]). This has later been criticized for narrowing the scope of sustainability in order to make it a manageable problem to solve through design; however, such designs are susceptible to breakdown (e.g., Jevons paradox) [12]. Instead, there has been calls from the research community to broaden out the scope of sustainability (e.g., [20, 47]) which has led a line of research that focuses on designing beyond the individual [12, 42] by e.g. adopting social practice theory [53, 55, 62] and using it for designing interactive systems for sustainable practices (e.g., [4, 31, 36, 48]). While work informed by social practice addresses the critique of individual behavior change by de-centralizing individuals and individual actions, it is less clear how it can tackle infrastructural issues of sustainable change-making with the generative capacity of practice theory still being developed [30, 52]. Among other things, this has led to calls from HCI to consider positions, outside of western modernist perspectives, which echoes those from outside the discipline for more holistic perspectives grounded in feminist ecological thought [13, 29, 49, 60]. In one such example in environmental studies, Bennett et al. [6] outlines the Environmental Stewardship framework which aims at addressing the change-making attempts in sustainability practices as a complex of relationships among actors (e.g., individuals, collectives), motivations (e.g., moral, monetary rewards), capacities (e.g., infrastructures, personnel), and actions needed (e.g., the introduction of plastic waste sorting). Expanding on the Environmental Stewardship framework within HCI, Rossitto et al. [51] introduces Digital Environmental Stewardship (DES) which also emphasizes 'folding in actions' (i.e., actions should be seen as interconnected, additive,

and generative of other forms of stewardship actions) and reflection in designing for technology-mediated change-making toward sustainability, i.e., how sociotechnical configurations fold into one another and the role of digital technologies in enabling them. Similarly, Cibin et al. [13], through their socio-ecological perspective to design, stressed the importance of considering temporalities and the interrelation between social, technology, and environment as these are always transforming and co-evolving. In this study, we deploy the DES framework in an effort to design for stewardship actions that move beyond the individual behavior change perspectives. The framework guide both our methodological approach by helping us analyze and reflect on how design ideas enable/disable sociotechnical configurations related to household waste management on a local level, and to outline how this might expand into broader sustainability efforts.

2.2 Waste Management in SHCI

One area where methods and techniques from SHCI have been deployed is in waste management. Attempts of tackling issues of waste has aimed to both inform (e.g., [3, 21, 25, 38, 46]) or trigger reflection (e.g., [1, 17, 24, 32, 59]) about the impact of (un)sustainable waste behavior. Farr-Wharton et al. [21], working specifically with food waste, argued for an informational approach where individuals systematize processes related to wasting, such as storage or shopping, to combat avoidable waste in the household. In addition, Thieme et al. [59] showed how social reflections triggered through Bin-Cam failed to change food waste behavior of participants; yet, it motivated self-education and increased perceived behavioral control. Other examples of research are focused around design aspects and thinking about design regarding waste [7, 23, 26, 58]. Grosse-Hering et al. investigated how to design for more mindful and slow interactions to foster appreciation for processes that lead to waste and explore novel ways to think about re-use and re-purpose with respect to residuals [26]. Taylor et al. elaborate on the practice of 'pottering', a kind of activity common in homes which in part is about low key tidying up, cleaning or improving to maintaining a certain level of order [58]. Their research captures rich descriptions of the phenomenon and elaborates on established ways of thinking about interactive system design and use, similar to how our own research tries to frame activities connected to recycling-room use patterns. In their paper on practices around food waste, Ganglbauer et al. [23] bring in an argument for considering the ecological perspective on waste management. In understanding the production of food waste, the authors argue for recognising management of food waste - not as an integrated and recognisable practice, such as cooking or doing laundry - but as a dispersed practice which carries loosely resembling performances of a common activity. Food waste, they argued, is already managed at time of planning and shopping, preparing and cooking meals, and not just when it arrives at the waste disposal. These insights, while gained from studying household food waste, could easily be transferable to more general household waste management and highlight the importance of an ecological perspective to designing for waste management. In line with the move toward an ecological perspective in waste management, Seaborn et al. [54] sought to scale up to improve food waste and recycling rates in a housing estate. The authors

involved multiple actors as part of this effort and stress, based on their experiences, the value of actively imagining their situation and the reasons behind their decisions, opinions, and views in the design process [54].

In this section, we have mapped out perspectives to designing for sustainability within the context of SHCI. Recent research has argued for considering more holistic perspectives to design that are grounded in feminist ecological thought. The DES framework has been proposed as analytical and design lens for such endeavors; however, no previous studies have sought to explore the capabilities of the framework in designing for sustainable change-making. We are interested in how to design for stewardship actions in waste management as this, especially in urban areas, is a complex process, encompassing a variety of activities, actors, and capacities. More specifically, we seek to gain insights about the opportunities and challenges that arise when designing with the increased complexity that the DES framework embraces.

3 METHODOLOGY AND SETTING

The paper builds upon two years of data collection that entails both empirical materials and design explorations around waste management practices in a large multi-apartment complex. In the country where this study was carried out, multi-apartment buildings are generally managed by condominium associations - called bostadsrättsforeningar in the original language - and becoming a member of a bostadsrättsförening is a requirement to own an apartment in these buildings. The apartment complex we investigated entails five bostadsrättsforeningar, each one of them managing one of the five buildings (see figure 1). The complex has four recycling rooms that are shared by the five bostadsrättsforeningar, and managed by a housing community association (samfällighetsförening in the original language; plural: samfällighetsföreningar). A samfällighetsförening typically manages areas shared among households while a bostadsrättsförening is an economic association of residents through tenant-ownership of apartments. Both samfällighetsförening and bostadsrättsförening are legal entities with board members periodically elected by residents. In our case, two board members of each housing association are also part of the samfällighetsförening.

The recycling rooms have different sizes with an average size of 25 m2. Sorting options in the recycling rooms are paper (1-2 bins), cardboard (4-5 bins), glass (3-4 bins), plastic (2-3 bins), and sorting facilities for batteries (1 bin) and small electronic devices (1 bin). In figure 1 top right side, we have sketched up recycling room four (the largest of them) to provide an overview of the recycling options.

3.1 Participants

We explored the problem space of waste management by including residents, and also members of both the bostadsrättsförening and the samfällighetsförening, as these different cohorts of actors reflect the variety of motivations, practices, and resources that are involved in waste management in this setting. We recruited participants from the apartment complex through fliers, message boards, and asking people on site. In what follows, we will refer to each participant as either resident, member of bostadsrättsförening, and/or member of samfällighetsförening although all members of the bostadsrättsforening and the samfällighetsförening also always are residents. This is done to make a distinction between the participants' roles in the apartments complex and thereby give our findings more contextual richness.

3.2 Data Collection

The empirical data has been collected by means of interviews, observations, postcards, and two workshops. We used the DES framework to guide our data collection. In framing interview questions, observational protocols, and workshop activities based on the concepts of actors, capacities, and motivations we were able to get rich empirical data that supported our DES design process. Also, since wasting can be seen as a dispersed practice – a "moment interwoven into other practices and itself arises from multiple other moments of consumption across multiple other practices" [23, p. 21] – we strove to incorporate a diverse set of data collection methods i.e. interviews, observations, postcards, and design workshops.

Interviews and observations. We conducted interviews and observations to generate a rich understanding of the context (including actors, motivations, and capacities), and how household waste practices are managed by single residents but organized through the work of the bostadsrättsförening, samfällighetsförening, waste collection company, and apartment administration company. We conducted a total of five interviews, two with residents (age: 40-50), two with board members of two different bostadsrättsföreningar (age: 50-60), and a fifth with a member of the samfällighetsförening (age: 62). The interviews were about one-hour long and were held in-situ to capture their situated and local knowledge. Besides the formal interviews, residents' experience about the status of the recycling rooms, along with their emotions, and opinions about them, were captured through participant observations which took place on a weekly basis over a period of two years (2020-2022). The observations were all carried out by one the authors who is also a resident. While the interviews were especially beneficial at providing insights into different actors and motivations for waste management and communal care in general, the observations also supported us in gaining a rich understanding of the capacities in the contexts (e.g., amount of bins in each room, the nature of misplaced waste, sorting options in apartments).

Postcards. With the aim of enrolling residents who might not have been interested in participating in interviews, we designed postcards that probed in-situ knowledge about waste management challenges and opportunities from the people coming to the recycling rooms. On each postcard, we had prepared the following questions: 'If you had a magic wand, what would you change in the recycling room?'; 'What is needed of you and other residents to make this change happen?'; 'Who else (residents or other actors) needs to be involved?'; and 'Would any form of technology support the changemaking? Why/why not'. A total of 21 postcards were returned to a postcard box that we had placed in two of the recycling rooms. The postcards activity resulted in data from ten residents mainly concerning radical changes to the use of the rooms. This might reflect the situation that the residents are in when deciding to write a postcard. These contextualized answers were very valuable for us to understand e.g. the motivations for change-making by various residents.



Figure 1: Left: Overview of the apartment complex with roads, apartment buildings (A, B, C, D, and E), recycling rooms (1, 2, 3, and 4) and green areas highlighted. Top right: An example of a recycling room seen from above. Glass containers (G) are placed on the left side; magazines and paper containers (M) in the top; plastic and metal containers (P) in the top right side; cardboard containers (C) in the bottom and bottom left side; and batteries and electronics containers (B) in the bottom right side. Bottom right: The inside of one of the four recycling rooms at the apartment complex

Workshop #1. The first workshop (WS1) was three-hour long and and had two activities. Five participants between 40-60 years old were recruited for the workshop. The first activity was organised to allow the participants to share their experiences of the recycling rooms and the challenges with both sorting and wrongly disposed waste. This activity resulted in three main challenges: collective use of recycling rooms, communication among the different layers of the apartment complex, and the team of residents who, in anonymity, help with waste management activities (called Sopgänget). The second activity was more design oriented. Here, the goal was to collectively discuss ways of addressing the previously identified challenges, as well as considering what this would entail in terms of practical implementation. This discussion was framed by focus points that were directly inspired by the DES framework [51]. As such, we asked participants to identify concrete waste actions that they thought would support them in looking after the recycling rooms but also be perceived as a form of care for all the residents. Participants were also asked to reflect on what concrete capacities would be needed to implement and maintain, why people would be motivated to contribute to the change, and what their own responsibility would be in enacting it.

Gathering and analysis of log data. One point that was extensively discussed during WS1 was the perception that one of the

recycling rooms is used considerably more than the others. This point was then empirically corroborated by log data from the door to each room that we were able to collect. The log data consisted of timestamps displaying when a door was unlocked, the name of the recycling room (1, 2, 3, or 4) and the ID of the RFID key fob used to unlock. After carefully anonymizing the log data to avoid direct connections to the apartment number corresponding to the key fob, the data was visualized to identify patterns and illustrate aspects such as frequency of usage during the five month period which the log data stretched. The data was, then, brought to the second workshop.

Workshop #2. The second workshop (WS2) was a three-hour workshop where seven participants (residents and members of samfällighetsförening) aged 50-75 were gathered to discuss how to address the three challenges that we identified in WS1, along with the interviews and postcards materials. The workshop was divided into two activities.

The first activity consisted of two parts: In the first part, participants explored the log data in plenum. Drawing on Clear et al. [16, p. 2459] who argue that "[...] there is significant merit in making the incompleteness of data a driver for change. Data in this sense becomes a mechanism for identifying gaps in understanding [...]", we brought print-outs of the log data (both aggregated and non-aggregated) to

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WS2 as tangible triggers for reflection and engagement in discussing recycling room use-patterns. In the second part, participants were divided into three groups of 2-3 to collaboratively envision data that they would like to have about the recycling rooms and how to collect it (e.g., sensor technology).

The second activity also consisted of two parts. In the first part, participants were introduced to the three challenges mentioned above. Again, they were split into groups. Each group worked with one of the challenges. They were given twenty minutes to discuss their individual and collective experiences of the challenges. In the second part, the participants, in their groups, went to the recycling rooms. The goal was, here, to brainstorm in situ and contextually explore and practically play-out possible ways to address the respective challenges with support from sensors and other kinds of technology.

3.3 Data Analysis

The empirical data was analyzed using thematic analysis [14] focusing on identifying themes around the challenges and ways of addressing them among the participants. Data analysis entailed familiarization with the data, coding with focus on the identifying actors, motivations, capacities, actions, and the different challenges and opportunities that each of these present for improving waste management. The coded data was clustered into themes that revolved around participant identified problems and opportunities together with how each of these problems and opportunities can be seen in respect to the DES framework. An example theme was 'surveillance in the recycling rooms' which was proposed by a number of participants as a way of combating misplaced waste. This theme relates to the capacity component of the DES framework as it introduces a capacity both in the recycling room and in form of e.g. a server that is needed to store and process the surveillance data. It also relates to the actor component as it introduces one or more actors that need to review the stored data. In addition, it might also change the composition of actors that comes to the recycling rooms e.g. excluding some who do not want to be recorded by a surveillance camera. In the following, we will lay out our findings based on the two major themes that we identified around challenges and opportunities from the participants. In addition, we will lay out our design explorations based on the themes.

4 FINDINGS

The findings are presented in three sections. The first is concerned with the various challenges that the resident experience with the use of the recycling rooms. The second section is concerned with the various opportunities that the residents suggested throughout our studies. The third section unfolds design ideas co-developed with the residents.

4.1 Challenges with Waste Management

The challenges that our participants identified were diverse and sometimes contradictory. In the postcards, we saw examples concerned with frustrations of the behavior of others, whereas, the more dialogical methods provided responses concerned with the shared nature of the challenges and the need to find ways to address them which revolved more around collective care work.

4.1.1 Lack of Communal Care. One theme that recurred in the interviews regarded various aspects of caring for one another. This was often one of the first things that came up when probing the participants on the challenges around the recycling rooms. Several participants would initially claim that the primary reasons for why people did not sort their waste properly or left bulk waste on the floor of the garbage rooms was due to a lack of consideration of others. This was formulated in a range of different ways including "lack of respects of others" (Post Cards = PC), "low morale or lacking solidarity" (PC). While some initially articulated this in rather harsh ways, they often reformulated themselves to bring up other reasons and factors that would make it difficult for people to recycle their waste as they intended, "It is unacceptable when there are shoes, mattresses, water boilers in the rooms but then again some people probably do not have the same opportunities for going to the recycling depot as I do." (WS1).

Several participants noted that they experienced a lack of or unclear information from the bostadsrättsförening and samfällighetsförening regarding how to use the recycling rooms, when they were emptied, what to do when the bins were full, as well as a lack of understanding of how costs are shared for the maintenance for the rooms, "maybe information about the budget and increased costs for waste management should be communicated more clearly" (WS1). This, it was said, could make it so that people did not care for the shared assets. In contrast, one participant claimed that more information should not be needed since it is a matter of solidarity to manage waste properly "I don't know if one should have a compass for how one should think about when or how one should manage waste. It is about solidarity, economy of the förening." (WS1). While some participants saw waste management as a matter of solidarity, others subscribed to a more practical dimension of waste management namely that without proper information and guidelines they could not foresee how their (in)action would impact the actions of others.

While the emotional stress and frustration among some of the residents regarding the situations in the recycling rooms were often connected to issues of morale or solidarity, the participants also pointed to how they experienced that the potential reasons for this was a lack of material capacities for proper use of the recycling rooms "we [in building D] have the largest recycling room. The other one in the end of [building B] is the second largest, the others [recycling rooms 1 and 3] are smaller". (WS1). Waste management is not only a matter of responsibilities and motivations but also of distribution of material capacities in the local ecology.

4.1.2 Invisible Actors and Invisible Actions. At the first workshop, one of the participants who was also member of the board of one bostadsträttsförening mentioned that there was an informal group of people that called themselves Sopgänget (i.e., the garbage crew). This group had voluntarily taken on the task of trying to improve the situation in recycling rooms. They conducted a range of different actions for the upkeep of the recycling rooms and the overall waste management of apartment complex. Interestingly, none of the other participants were aware of the existence of this group or what they were doing. Several participants also mentioned individual residents that on their own initiative regularly cleaned up the recycling rooms, brought bulk waste placed in the recycling rooms

to the municipality recycling centers, and regularly checked that the recycling rooms looked decent.

Importantly, much of the work conducted by Sopgänget and other residents remained invisible to the residents in the different buildings, as well as to the boards of both the bostadsrättsförening and the samfällighetsförening. While the work they conducted is important to the upkeep of the recycling rooms, the fact that their efforts and how they were organized were largely invisible makes it challenging to incorporate their actions in any broader attempts at changing or improving the situation in the recycling rooms. In a sense, the actions of Sopgänget becomes disconnected to that of many other actors in the apartment complex. At workshop two, possible ways of reorganisation Sopgänget were discussed and if the group should become a formalized entity within the samfällighetsförening in order to make their actions visible to other actors and to be able to articulate what actions that they should be responsible for and be provided resources for. "We should maybe choose one from the samfällighetsförening who is representative for waste management. This person could recruit people who would like to be in Sopgänget; somebody who would be engaged in waste management." (WS2). However, this was also problematized since giving the group a formal role and responsibilities would also create expectations and demands as to what actions they should fulfil, "but there is a strength in it [Sopgänget] being an informal entity I think. We would ascribe a different responsibility to the group if it was to be a formal waste management group." (WS2). Potentially, this would make it difficult to recruit people to the group as voluntary engagement was one of their key motivations.

4.1.3 Blurred Understanding of Different Actors. Our findings also showed that there was a variety of ways in how people understood the different roles and responsibilities of actors involved in managing the household waste and the recycling rooms for the apartment complex. While some suggested that the problems primarily stem from the inappropriate behavior of the residents themselves, others would say that the problems occurred because the samfällighetsförening, bostadsrättsförening, apartment administration did not fulfill their responsibilities. One participant mentioned that "Well ... the apartment administration company also have responsibility but it seems that they do not always respond which causes issues because who is then to take responsibility?" (WS2). However, the participants also had different understandings of the various actors involved in managing the waste, what actions each were responsible for, and who should be the one to go about in addressing the various problems that occurred. Some participants proposed that individual residents should be targeted, others mentioned the boards of the bostadsrätts- or samfällighetsförening, the apartment administration company, or the company contracted to collect the waste. Supposedly, several of the problems and much of the frustration that people experienced was due to these organizational uncertainties, making many residents unsure of what to do or where to turn to in order to bring up issues and problems, and even uncertainties in understanding their own role and responsibilities in caring for their shared assets. The participants suggested a range of different ways that they used to take action on problems that they experienced; some sent emails to the board of the bostadsrättsförening or to the samfällighetsförening, some posted messages in the Facebook

group of the bostadsrättsförening, some talked to someone they knew who were part of Sopgänget, some designed their own information signs and posted on the walls of the recycling rooms, while others would on their own initiative clean up a room or take some misplaced bulk waste and drive it to the recycling center themselves.

The uncertainties among residents regarding the range of different actors involved in managing the recycling rooms at the apartment complex made it challenging for residents to understand what could be expected from various actions taken to improve or address the problems that residents experience. Attempts at constructively reaching out or practically addressing the identified problems might go unnoticed or the actors being addressed might lack the capacity to act on the situation.

4.1.4 Infrastructural Limitations. Another challenge that was identified in our data revolved around the infrastructures within and around the apartment complex. Currently, in the apartment complex, there are five buildings and four recycling rooms. Hence, there is not a specific recycling room assigned to each building; each resident has access to all four rooms. The flow of residents in the recycling rooms can therefore be affected by their daily practices such as going to the bus, the grocery store, or taking children to daycare. *"We have come to understand that there are many going to the bus in that direction and take their stuff to the closest recycling room in that direction."* (WS2). This skewed distribution was also observed in the log data of the visits to the recycling rooms. The log data showed that an average of 33 people visited the highest populated recycling room each day and 23 visited the lowest populated one over a six-month period.

Another infrastructural problem that was identified concerned the access of going to the recycling depot with bulk waste. The residents in the apartment complex are of varying ages, from students to pensioners. The students are mainly living in one particular building with smaller apartments (i.e., building C) and often do not own or have access to a car. This, the majority of participants speculated, resulted in them not going to the recycling depot with their bulk waste when moving out etc. "I think that building C is the worst in terms of waste management. They have small apartments with minimal space for storage of recyclable waste and no cars. And when they move out it has to go so quickly that they do not clean up after themselves... They just leave." (WS2) The participants believed that this resulted in them placing their bulk waste in the recycling rooms, expecting that it would be taken care of by the waste collection company. In addition, since the student apartments are smaller in size, those living there might not prioritize a lot of space for recycling.

4.2 **Opportunities for Waste Management**

From the data, we also identified multiple ways of addressing the problems with waste management. These included concrete suggestions by the residents, as well as ones generated from conversations and suggestions from the residents.

4.2.1 Surveillance in the Recycling Rooms. The theme that emerged most immediately from many participants on how to solve the problems with waste management was about finding out who the person

was that misplaced waste and, as formulated by one participant, "get them to fix it" (PC). The idea of surveillance and 'resident policing' was evident in WS1, the post cards, as well as WS2. Especially in the answers to the post cards, three out of ten post cards (from P3, P5, P6, P9) mentioned surveillance of the recycling rooms as a needed action for people not to misplace waste. The suggestion of surveillance was followed by suggestions such as some kind of exclusion from the community of the person littering. For example, "There should be zero tolerance and suspected littering should have immediate consequences. Have in another place scared people about this. It works partially. If they don't follow the rules, just evict them." (PC) and "[what if] everyone that drags stuff to the recycling room that doesn't belong there suddenly disappeared." (PC). During WS2, a participant stated that he looked for address labels on cardboard boxes that were misplaced or that were not folded and sent the boxes to the 'guilty' residents, "[I] look for an address on the box and then we mail it to the guilty and asks them to fold their cardboard box when they go down to the recycling room with it the next time." (WS2). However, other participants raised ethical concerns about this, and noted that such a strategy would not foster a shared sense of community nor security among the residents. Another participant expressed that "I think it becomes very sensitive if you want to know who has misplaced the waste. Then you also need to fix it somehow by going to their apartment and ring the doorbell and say... It is an unpleasant task and it does not foster security among the residents!" (WS2) This strategy to foster a shared feeling of community and responsibility for waste management was touched upon numerous times, especially during WS2. Importantly, expanding the information capacities in the recycling rooms was discussed as having the potential to address these challenges by identifying individual misdoings, while at the same time running the risk of creating new problems when it comes to ethics and to developing a sense of communal care for the shared assets of the apartment complex.

4.2.2 Fostering a Sense of Shared Responsibility. Although household waste management in an apartment complex might seem to concern the residents as individuals or households, we discovered that activities related to waste management bring in a range of different actors (i.e., residents, members of bostadsrätts- and samfällighetsförening, Sopgänget, waste collection company, apartment administration company), who all play a role in making waste management work. From a resident perspective, much of the work that goes into keeping the recycling rooms functional might be invisible. One example from WS2 concerns how a participant from the samfällighet personally took action to install two custom bins in the recycling rooms for batteries and small electronics - items that otherwise often were misplaced: "It did not work as we wanted it to ... So it was me who called [the waste collection company] and got them to put up the two additional bins in here." (WS2). The addition of these new bins was perceived by other residents to have been an initiative and responsibility of the waste waste collection company. This is just one example where we encountered confusion between the roles and responsibilities of the various actors and what actions that need to be taken to change things. From the data, we also identified a number of possible ways to accommodate such challenges by fostering a shared sense of responsibility and an understanding of how the waste management processes are organized.

The first thing needed would be to clarify and/or delegate the responsibilities and mandates of the different actors and to work with fostering an individual sense of understanding of these relations and responsibilities. In the workshops, it was often claimed that this was especially important in relation to building C, which is seen to house mainly young adults who are not living in the apartment complex for as long, and it was argued this made them feel less responsible for the shared assets of the area. One proposal for achieving shared responsibility would be to appoint a waste management responsible in each apartment building, "[...] there need to be one or more people from each building who is responsible for waste management. We need to create a group of people who can meet a couple of times a year to keep all buildings up to date." (WS2). This view was shared by the other participants, "We should have occasional information meetings with representatives from each building as this would get out the information and hopefully also result in the fact that everyone feels a sense of responsibility for the area." (WS2). The ambition that the participants wanted to achieve was that "[...] everyone should have a nice time being here. That is the underlying philosophy and it is necessary that people have this on top of their heads" (WS2). Apart from delegating responsibilities and organizing regular meetings about the recycling rooms, an additional idea was to arrange shared car trips to the municipality recycling depot. A considerable amount of people living in the apartment complex do not have access to a car and this was one of the factors that the participants believed leads to misplaced waste, especially bulk waste that should not be placed in any of the recycling bins, neither in the recycling rooms. As of now, "[...] a lot of old beds and madrases that no one wants are piled up in the basement because people just left them behind when they moved out" (WS2) and a shared car trip to the recycling depot was seen as a way to eliminate some of these bulk waste items that people without a car would otherwise leave behind. Notably, finding ways to make additional physical capital available (such as a car or other means of transportation) to the residents was proposed as a potential way to address some of the problems that people initially would ascribe to a lack of solidarity or respect for others.

4.2.3 Human Sensors and Elimination of Space in Recycling Rooms. During the discussions in WS2 about what sensor technology could bring to waste management, it was challenging for participants to think in terms of what a sensor could realistically measure, despite what was being scaffolded by the workshop facilitators. However, during the hands-on explorations and conversations in the recycling rooms, we discovered that the residents already had ways of sensing the state of the recycling rooms:

Interviewer: How could technology support you with getting an overview of misplaced waste? Participant 1: I think... If we had a sensor that could identify bulk items in the bin room, this would help me with knowing when I needed to go down there and do something about it. Participant 2: But we already have sensors in the recycling rooms... Human sensors

These humans sensors, or natural sensors in the vocabulary of Kuznetsov et al. [37], are residents who move around the recycling rooms on a regular basis to register waste that is misplaced, bins



Pointing to floorspace

Repositioning hin

Figure 2: A sequence of images showing how residents go about rearranging the bins due to there being too much floor space.

that are overflowing, or the bins themselves being out of position. However, opposed to technological sensors, the human sensors are not only registering these issues; they also take action to set things in order, e.g. "Well yes... the [digital] sensors can eliminate the daily trips to the recycling rooms by letting me know where there are problems but they do not take care of the problems. There has to be a human hand ... " (WS2). The participants elaborated that this entails "packing together cardboard boxes that are just thrown into the containers", "taking misplaced travel bags, madrases, and even a cash register to the recycling depot", and "rearranging the recycling bins after they have been emptied so that there are no large areas around them that could be used for dumping things". Tapping into this activity of rearranging bins, we found out that it was something that the residents were very serious about. One participant expressed that "I think a sensor that can detect when bins are emptied would be very beneficial... partly because then I know that I can use the room but also because then I know that I can go down there and check if [the waste collection company] has placed the bins correctly or if I need to rearrange them so that people do not have space for dumping waste between them." (WS2) Later during activity 2 of WS2, the participants showed us how the bins should be placed in the room so that there was the optimal space between the bins to not encourage misplacement of waste (see figure 2). One participant mentioned that "We have figured out approximately how much space is optimal between the bins to avoid misplaced waste on the floor and replacing the bins after they have been emptied has really helped a lot" (WS2).

While the participants thought that technology would not solve all their problems with waste management, they did come up with three ways that technology would assist the 'human sensors' with carrying out their work in the recycling rooms namely by notifying when bins are emptied, when there is bulk waste on the ground, and when especially cardboard bins are full. A notification of emptied bins would let them know when they should go to the recycling rooms to check if the bins are placed properly to minimize misplaced waste; a notification of bulk waste on the ground would help them in knowing when they should inspect what it is and if it is possible to get rid of it; and a notification of full cardboard bins would let them know when to go down to the recycling room to check if it is

just because the boxes are not folded. If it is only the bin closest to the door that is full then they can move this one to the back since people tend to only check if one bin is full before dropping their boxes on the ground or overfilling this one bin. One participant exemplifies that "It is also a reality that people go into the room and to the bin to the right [the one closet to the door]... If this one is full there might be multiple empty bins besides it but still they put their stuff in the full one" (WS2).

Notably, there are a lot of manual work happening in and around the recycling rooms which is conducted by a limited number of residents. This work could not be replaced by digital technologies since it involves physical work such as moving bins around or compacting card board boxes. However, various kinds of sensors could be used to provide information about when this kind of work is needed and it could potentially also engage other residents on the status of the recycling rooms, either to contribute to the manual work conducted by only few people, or to adapt which recycling rooms they visit or which bins they use.

4.2.4 Monetary Costs of Wasting. The consequences of placing bulk waste in the recycling rooms and overfilling of recycling bins are that additional pick ups are needed from the waste collection company and that the samfällighetsförening is invoiced for the extra costs. Ordering more waste pick ups is costly and the bill is distributed between each bostadsrättsförening in the whole apartment complex "One thing is the cost. The more we can pack the cardboard boxes etc. the more we can save on a monthly basis. Right now everyone is paying the same amount of money for ordering more waste pick ups." (WS2) The fact that everyone has to pay for the messiness of a few people leads to feelings of injustice "It is unfair that we, who are already doing the right thing, have to pay the same amount of money as the others when it is them who are making a mess down in the rooms." (WS2) The fact that the costs of waste management are shared equally between all the apartment buildings was a demotivating factor for some of the residents who are thoughtful about their recycling. Some of the workshop participants suggested that the cost of misplacing waste should be moved closer to the people responsible for it rather than putting all costs on the samfällighetsförening. "It is too easy to say that it is the samfällighet that has to take care of the cost... Of course we pay it if there is a bill for all of us, but it should not be that way. We are putting the costs further away from the 'wasters' which means that they can keep doing what they are doing and do not change these bad practices." (WS2) However, moving costs closer to each of the buildings is not straightforward since the capacities of the recycling rooms are unevenly distributed; five building share four recycling rooms. This, and the fact that residents are able to enter all of the recycling rooms, would make the distribution of costs to each bostadsrättsförening challenging.

Another approach revolved around making the costs of misplacing waste and/or overfilling bins more visible for the residents. As of now, the information about costs are sometimes visible in the quarterly newsletters from the samfällighetsförening together with other information. However, the participants saw an opportunity in making information about costs visible in the recycling rooms and showing the overall costs. One participant proposed that "It might not have a big impact for people since the bill for ordering more waste

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pick ups is divided out on every single resident.... If we instead point out that for example in the last month we had 400 EUR in extra costs just from misplaced waste." (WS2). Another related issue concerned the amount of waste being moved to each recycling room, "It is not possible to see how much waste people are taking to the different recycling rooms, and since we also pay based on how much people throw out, it would be good to have some information about the different bins from the different rooms." (WS2) Since the total amount of waste also can result in extra pick ups, the participants agreed that more information about the amount of waste would be needed to adjust the costs. Notably, the waste collection company weighs the waste so the challenge in this case would concern the infrastructural complexities in communicating this between the involved actors, from waste collection company, to the apartment administration company, to samfällighetsförening, to bostadsrättsförening, down to each individual resident.

4.2.5 Information about Status of Recycling Rooms. The idea of having more information about the recycling rooms leads to the last theme - knowing the status of the recycling rooms in order to plan where to go. The activity of household recycling commonly consists of obtaining packaged items (e.g., in cardboard boxes, plastic wrapping, glass bottles), storing the recyclable parts of this packaging in the apartment until these needs to be transported to a recycling room due to various reasons (e.g., making space in the apartment, keeping the apartment tidy). Since waste management is a dispersed activity [23], suggestions from the workshop participants stating that "Is the bin full? Then go to another recycling room" (WS2) often stand in conflict with how waste management is perceived by individual residents, for example, as something that is handled as part of walking to the car when going to work. Because of this, when going to a recycling rooms, residents want to be sure that there is room for their waste so that they do not have to go around multiple rooms with their waste as this would counteract with the activity that recycling is part of, which in this example is, going to work. Overfilled bins and misplaced waste items might be a result of this fracture in the dispersed activity, and at the same time point to a opportunity for supporting residents to avoid such situations. For instance, in WS2, the participants discussed the use of sensor technology to provide an overview of the status of the bins in each recycling room "Would it be possible to use a sensor to get an overview of how full the room is? Then that information could be displayed on a website or something and I could see it before going down there and finding myself in a full room." (WS2) and "We would need a visualization of how full the bins are to get an overview of what room to choose." (WS2). While this seems like an opportunity to address much of the frustration of many of the residents, it is challenging to design technology that could be effectively integrated into the everyday household practices of dealing with waste and other interrelated aspects of family life.

4.3 Design Explorations

The hands-on design explorations in the recycling rooms resulted in a number of ideas and lo-fi mock-ups of how the ideas would fit into the recycling rooms. The ideas ranged from more or less realistic proposals such as information screens and various sensor technologies, to more visionary one involving motorized garbage bins and automatic sorting. Also, they were either 'in the moment' design ideas or ideas to support the planning of actions related to waste management. In the following, a subset of these ideas are presented in more detail and put in relation to the other empirical findings.

One design idea was to add instructional displays in each of the recycling rooms. The displays should provide instructions and information on various aspects of how to properly use the recycling rooms, including instructions such as which kinds of items go where, best practices in relation to waste management, such as how to avoid bins from getting filled too quickly by folding cardboard boxes (see figure 3c). This was argued to be a way of addressing some of the identified issues that occur in the moment of sorting, for instance with cardboard bins getting filled with unfolded boxes or people always choosing the bin closest to the door. Another type of information that was identified as needed in the previous sections, revolved around when the bins were scheduled to be emptied as this would help residents plan their trips to the recycling rooms. Furthermore, sensors for measuring the status of the bins in the recycling rooms could also make use of such displays. As we have noted in our observations of the different recycling rooms, there is extensive use of various signs providing instructions on how to best do the recycling, some of these are provided by the waste collection company, some by the apartment administration company, some by the samfällighets- or bostadsrättsförening, and some by individual residents. This suggests a need for improved information about the recycling rooms.

A second design idea concerned a system for rearrangement of bins to avoid that the bins, after being emptied, gets placed in the wrong position which makes too much floor space available where bulk waste can be placed. The system could track the position of the bins in each garbage room and provide a notification when the bins get out of position. This would allow Sopgänget to go down to the respective recycling room and rearrange the bins so that there is the optimal room between the bins to minimize the space for misplacing waste on the floor. An expansion of this idea was that the bins should be to motorized and be able to automatically reposition themselves after they had been moved around in the room. Although it is possible to use the schedule from the waste collection company to check if the bins are out of position, which is how the Sopgänget manually does it right now, there are occasions when the bins are emptied out of schedule or when the bins are moved by other people in the recycling room without any bins being emptied.

A third idea was a **system for showing the monetary cost of misplaced waste** which would provide an informational approach to showing the impacts from sub-optimal waste management. The system would monitor how many times extra waste pick-ups are ordered and accumulate the cost of extra pick-ups during the previous month to make these visible to the residents, as opposed to the current system where the costs are added to the monthly fee of each household and, therefore, are difficult to see in relation to all other costs of the buildings such as shared bank loans, cleaning, heating, water, etc. The system would show the progression between the previous and current month in order to make the information comparable for the residents.

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Figure 3: From left to right: A cardboard bin with a marble stuck on that represents a distance sensor that tracks how full the bin is. A participant explaining the need for a sensor that track overfilled bins. An imagined information display situated in the recycling room.

A fourth design idea was a **system for providing an overview of status of the bins in each recycling room**. This would be designed to make it possible for residents to plan their visit to the recycling room based on how full the various bins are at each room. A system like this could use distance sensors in each bin (see figure 3a) to measure how full a certain bin is and then display this information to residents before they leave their apartment. This would make it possible to avoid visits to a recycling room where a certain bin is full which would require an additional detour to another recycling room and decrease the risk of overflowing certain bins without checking for space in other bins. The system could potentially also measure the amount of unused space in a cardboard bin so that people could go to the recycling room to fold and stack any boxes that are not put in the bins properly.

These different design ideas are closely tied to the way the individual residents perceive the waste management problems in the apartment complex. As illustrated above, some identify problems as stemming from ignorance of certain individuals, while others point to a lack of information and understanding of the rules and routines that govern the waste management, and others to a lack of infrastructural capacities for waste management. Thus, designing technologies addressing these issues will put the focus on some aspects and leaving out others. Intervening in this kind of relational complexity will, thus, enable certain kinds of actions while not knowing how it influences the various actors being involved.

5 DISCUSSION

The 2022 paper that introduced Digital Environmental Stewardship (DES) as a framework discussed two possible ways of using the framework: as an analytical lens and as a design lens [51]. In the paper, the analytical qualities are highlighted through the analysis of three cases of waste management (see [51]). This paper expands on that work by taking the opportunity to reflect in-depth upon how the framework can be used in a generative manner. In the following, we discuss our experiences with using this framework for design and expand upon how it can be used for addressing design for multi-stakeholder sustainability challenges, contributing to ways of moving from an individual to an ecological perspectives on interaction design.

5.1 Designing for Stewardship Actions in Waste Management

In our study, designing for stewardship actions informed both our methodology, data analysis, and the design responses to the problems that were identified by actors in the context. We found that the DES framework shows both opportunities and challenges when used generatively in a design process. It allowed for the identification of a range of relations that were central to understanding the design space. Particularly interesting were how to design for the invisible actors and actions [56] that emerged from taking an ecological perspective. This emergent design challenge may not have been evident if we had adopted e.g. a user-centred design approach. In addition, the framework supported us in systematically intervening into parts of the context by, for example, introducing data as a capacity in our design efforts. This gave us insights not only on the relations among actors and actions from the point of view of individual residents, but also into the more systemic and temporal levels of the waste management process at the apartment complex and bringing these two perspectives together. As a feminist ecological position, the framework allows us to attend to the multi-scalar nature of environmental care without sacrificing either the individual or the system. Moreover, by bringing in the notion of folding in action [51] we could explicitly consider how opportunities proposed by residents lead to other potential actions and how these actions in turn constitute new challenges or needs for additional actions. Lastly, we also identified a central challenge with taking an ecological perspective to design which relate to the risk of design death due to the entanglement of multiple and conflicting perspectives.

5.1.1 Designing for Visible and Invisible Actors. Our approach to designing for stewardship actions in waste management entailed considerations about which actors are involved in waste management and how these are entangled on multiple levels; their individual and collective capacities for doing waste management work; and their various motivations for doing so.

In the beginning of the project, we identified residents and waste collectors as the main groups of actors that are involved in waste management but as we probed into the residents experiences, a whole palette of actors emerged including samfällighetsföreningen, bostadsrättsföreningen, the accommodation agency, and a number of more or less invisible actors [56] such as voluntary caretakers and Sopgänget.

The analytic framework oriented to action ask both 'what is being done?' and 'who is doing it?' allowing us to see beyond the simplicity of asking 'who is here?'. Each of these actors have different capacities and motivations for action toward improved waste management. For example, Sopgänget moves between recycling rooms on a regular basis as 'human sensors' [37] to gain an overview of how the rooms look and sometimes they bring misplaced garbage from the floor, fold cardboard boxes, or rearrange the recycling bins in order to make each recycling rooms tidy and to improve the chances of people sorting their waste properly (see section 4.1.2). While having a set of well-defined tasks as well as doing open-ended inspection work, Sopgänget did not necessarily want to be a formalized waste management group as it was claimed that this could result in other residents relying on their work and expecting them to be the ones responsible for solving what they perceived as a shared problem - this resonates with the work of Star and Strauss [56, p. 24] stating that "[...] there is "good invisibility" and "bad invisibility," often traced to questions of discretion, autonomy, and power over one's resources." An important design challenge that we took on, therefore, became how to support Sopgänget in doing their daily work task without putting a spotlight on these tasks; thus, maintaining their autonomy. This is a challenge to respect pluralistic forms of work, to not assume a singular value of work and its visibility, nor for a technologically driven formalization and thereby institutionalization of all care works. We sought to overcome this challenge by thinking in terms of actor specific ecologies of action; encapsulating the work of Sopgänget and the other resident groups such as samfällighets- and bostadsrättsföreningen and coming up with design ideas that would assist each of these groups (e.g., the system for rearrangement of bins would address issues that are exclusive for Sopgänget).

Thereafter, we reflected on how each of the design ideas would reconfigure the other actor specific ecologies and the ecology at large (i.e., the multi-apartment complex) by turning to the DES framework as an analytical tool for evaluating designs.

5.1.2 Data as a Capacity in Design. When using the DES framework as an analytical tool, the pillars of the framework (i.e., actors, motivations, capacities) are used to analyze the context and the various actions involved with different practices[51]. However, when using the framework for design, the pillars also become opportunities for intervening into the context in order to trigger new understandings or help shape new practices. We acknowledge here the risk for framings of paternalistic intervention from outside, and emphasize the need for care and ecological framings of design-asaction in itself. That is, design and design interventions can only be understood within the practices of design and the practices in which they intervene.

In our design process, we obtained logged data from each recvcling room which contained timestamp, apartment building id, and event (e.g., door open, door closed). This data was, both in aggregated and atomic form, brought to the second workshop as a capacity related to waste management that was not obvious before [51]. An important distinction, when positioning this intervention as a practice within DES, is that the data is not the solution but a capacity for people to work with. Prior to the design intervention, the actors had a loose idea of how the recycling rooms were used based on their own perspectives of how often each room is full and how many people they meet on average when they go there. However, the logged data helped the actors, during the workshop, in seeing and articulating their situated and local knowledge [28] by providing indications from the recycling rooms that either is compliant or in conflict with their individual and collective perceptions of the rooms - echoing findings from literature on how individuals make sense of data and how data may help them reconsider their understandings (e.g., [40, 42]).

Even though the data was not cleaned up or curated in other ways than some quick and dirty plots, i.e. it was not a robust form of eco-feedback such as previous work [2, 10, 22, 33, 34, 39, 41, 63], it revealed tensions between actors and became part of negotiations about what actions that would need to be taken, reflecting studies of how data may be used as a mediator in considering and negotiating design options [15, 16, 45]. We argue for the strength of using data as intermediate capacities in conversational contexts such as design workshops and co-design activities. These data intermediaries have the strength of challenging understandings and perspectives of the different actors, the actions that could be taken, and the motivations driving these. In addition, they foster new and situated understandings based on both local knowledge and digitally captured knowledge (see section 4.1.4). This was both useful for the researchers and the workshop participants as it highlighted the differences and the tensions in the context and the relational complexities created by the different ways of interpreting the data which resonates with research on the role of data in fostering social negotiations (e.g., [15]) and the need for pluralistic and situated understandings of data and its production [57].

Our work with making data a capacity in design expands on previous work on data-enabled design [9, 45, 61] by suggesting an ecological rather than an individual perspective on how data can support design processes in HCI.

5.1.3 Folding in Actions. A core concept of DES is 'folding in action' which emphasizes the consideration of how outcomes from a DES process circulate and are transformed into capacities for other actions [51]. An example of how the idea of folding in actions can inform design was in section 4.2.1 where one of the solutions from participants was to expand the information capacities in the recycling rooms by adding surveillance cameras. While this addition might solve the immediate challenge of identifying individuals, it may very well hamper the collective motivation to foster a sense of community in the apartment complex or lead to actors using alternative capacities (e.g., garbage disposal facilities at other apartment complexes or local stores) which could result in larger, both ethical and practical, challenges. Here, we can see that designing from within an ecological perspective enables reflections on the potential consequences that may emerge when specific sociotechnical configurations of stewardship are moved across contexts [51, p.14]. In addition, if we consider our design response called System for monetary cost of misplaced waste, it can be argued that a system that communicates the monetary cost of misplacing waste would leverage to people's self-enhancement values [35] by giving an opportunity of building up capital through contributing to the saving of money by avoiding misplaced waste; however, it might also lead to people neglecting the cost when it is spread out over all residents or even lead to more misplaced waste if they happen to recognize that it is more profitable for them to leave their bulk waste in the recycling rooms than it would be to go to the recycling depot on their own. This is an example of the kinds of considerations that has to be made when designing with folding in action in mind, pointing to how, "the relational orientation of the framework lends itself to careful considerations of potentially negative impact of design interventions, and to reflections on the relationships that are endorsed (or disregarded), and of who/what is included, or neglected, in technology-mediated configurations of stewardship actions." [51, p. 14]. It, therefore, suggests future directions for our design efforts where we develop and deploy them for a prolonged period of time, in order to examine immediate as well as long-term changes, together with the possible rebound effects from introducing digital technology into the context. Rather than understanding interventions only as paternalistic externalities, within the frames of techno-solutionism and susceptible to exaggerated effects of novelty as have long and often been criticized [12, 19], we argue that the DES framework attunes us to the slow change that is possible within ecological contexts through adaptations in material and meanings [51]. Here, it would be possible to turn the DES perspective around and use it in an analytical way by investigating which changes in the infrastructure of actors, motivations, and capacities that the intervention fosters.

5.1.4 Risk of design death. With the complexities that arise when designing with a DES perspective, our design process has not led to a singular design that aims to address all the aspects of the context. Instead, we have outlined four different design ideas (see section 4.3) that address specific problems for certain actors in and around the apartment complex. In this perspective, the design ideas become parts of digital ecologies [50]. Rossitto et al. [51, p. 13] stress that "The framework takes attention away from technological solutionism, and the atomization of our being and acting in the world, towards the complex ecology of relationships that constitutes sustainable actions." It is a relational perspective in which the task for the designers is to understand the complexities of the ecology of relations (various actors, capacities, and motivations) and at the same time creatively consider when and what or if to design - it is important when designing technology to "[...] engage in a critical, reflective dialog about how and why these things are built." [5, p. 2274]. Multiple times during the our project, we had to step back to reflect upon if the implication even is to commit to design at all (e.g. section 4.2.3).

This is one of the main challenges with the DES framework; it demands broadening the design space to include actors with different motivations and capacities (e.g., students who might not own a car to go to the recycling depot versus pensioners who have access to a car and time and motivation). There is a risk when taking an ecological perspective in the design process that there is a blurry line between the work of understanding and that of designing; when should one go from one to the other and what differences in perspective does this entail? An excessive focus on understanding can lead to a kind of *design death* where the actors, capacities, and motivations become so complex, entangled, and maybe even conflicting that designing for this ecology of relations would be perceived as impossible by the designer. This is especially true if the designer approaches the challenge with a mindset that a design response has to grasp the whole context. Instead, we teased out design responses that address specific challenges for different actors and viewed these as parts of the larger design intervention.

6 CONCLUSION

Much previous HCI design research into challenges of waste management has sought to tackle the problems primarily from an individual, behavioral change perspective. In this paper, we approach this design space from a feminist ecological design perspective of Digital Environmental Stewardship (DES) in order to explore its generative capacities, as it has solely been used for analytical purposes in the past. Based on studies with a variety of actors, the DES framework allows us to outline challenges related to waste management in a complex of five multi-apartment buildings with four shared recycling rooms and the identified solutions from actors in and around this context. We propose a number of design explorations for addressing the challenges and reflect upon how these might lead to both expected and unexpected actions. The framework has several benefits for design as it allows for identification of the work both visible and invisible actors and actions; taking into account how design interventions can become capacities through the idea of folding in action; and an understanding of how to draw on data as capacity in the design process to reveal tensions and foster negotiations between the abstracted view of the context and actors' experiences of it.

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