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Household Renovation Waste in the Netherlands: Mapping the Social Side of Waste Flows

Daan Schraven, Kai Vaessen, Zhaowen Liu, and Tong Wang

Abstract The transition to a circular economy necessitates cities to effectively manage their waste flows by capturing and redirecting them within the municipal domain. Traditional approaches to controlling waste flows have primarily relied on quantitative methods, such as material flow analyses. These methods excel in mapping the quantitative aspects of the materials and visualizing their sequential movements. However, recent advancements have highlighted the significant role of human behavior in shaping waste flows. For example, the way that citizens sort their waste determines the components and calorific value of the flows and directly impacts the circular rerouting challenges within the city. This paper argues that enhancing waste management practices in a circular economy requires analytical tools capable of incorporating the social dimension. Based on this premise, a novel approach termed the Waste Journey is developed and tested using a case study on household renovation waste in the Netherlands. Various methodological options to map the case are discussed and an initial framework for the Waste Journey is then proposed. The study emphasizes the influence of social processes on waste handling and offers a comprehensive means in which these processes can be mapped to effectively address challenges toward zero-waste cities.

Keywords Waste management · Circular economy · Social engagement · Waste journey

D. Schraven (✉) · T. Wang
Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, The Netherlands
e-mail: D.F.J.Schraven@tudelft.nl

K. Vaessen · Z. Liu
Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

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1 Introduction

Besides greenhouse gas emissions, it is forecasted that cities will contribute to 50% of global waste generation by 2050 [4]. Next to the forecasted urbanization of 68% of the world population living in an urban area by 2050, the infrastructure that needs to handle and cope with the city waste collection will be overburdened and inadequate [60]. In response, among others, to this global societal challenge, the United Nations formulated the Sustainable Development Goals (SDGs) in 2015, as a global call to action. Within this grander scheme, the Dutch government formulated their strategic ambitions to a full-scale transition to a Circular Economy (CE) by 2050 [34]. In this CE strategy the Dutch government gives waste management a crucial role, through the publication of the National Waste Management Plan 3, or NWMP3 in short. In the NWMP3 the Dutch government seeks to (1) limit the generation of waste, (2) restrict the burden of production chains on the environment, and (3) optimize the use of waste materials [44].

To date the academic literature has been addressing a wide variety of problem domains on waste management in a quantitative fashion. For example, Wang et al. [65] studied the flow of waste from decorations and renovations from the generation of waste to the end-state (e.g., recycling or land-filling) and estimated the different waste generation rates for different materials. This quantitative approach can also be seen in the study of Ding et al. [8], in which the waste generation rates of renovation waste are determined based on the reasons for renovating a house (e.g., carpentry or painting). Other studies focus on the role of informal waste collectors in a material flow analysis of the television waste management process [56]. Other topics seen in recent studies are waste generation rates, waste collection methods, waste management, sustainable development goals, and waste composition studies [22]. As these studies primarily focus on quantitatively addressing how the waste follows a specific stream from generation to its end-state, they generally lack attention on the social side. As a result, they miss out on the role and impact of different actors as they interact with waste, which has become the key of realizing the objectives proposed by the NWMP3. In this plan the Dutch government emphasizes waste prevention and reuse, and it requires the broad participation of actors, such as households and businesses, to change their production and consumption behaviors at early stages. Thus, the management of the waste stream is no longer only about the quantity, but also the "quality" of the waste stream (i.e. how well it is separated for further treatment). Furthermore, waste treatment has been recognized not only as an environmental challenge, but a complex economic-social and systemic issue [28]. Therefore, an actual focus on the inclusion of actors in the waste management process is needed to unlock the opportunity for shifting perceptions of the overall performance of the waste management system [68], most notably on the aspects of circularity and inclusiveness.

This chapter aims to address this issue by answering the question: *"How to identify barriers and opportunities for realizing inclusiveness and circularity in a waste management process?"* As Chapter 2, 3 and 4 of this book elaborated, in the context

of waste management, we define inclusiveness as "everyone in the society can fully participate in and benefit from waste-related activities equally", and circularity as "using R-strategies in the socio-economic system to replace the linear economy". In the following sections, the state of the art in methodologies for waste management, circularity, and inclusion are reviewed in Sect. 2, and an approach—Waste Journeys—is proposed. After the methodology is developed in Sect. 3 it is applied to a Dutch case of household renovation waste (HRW) in Sect. 4. Section 5 discusses the implications of this method and Sect. 6 offers generic conclusions.

2 Theoretical Underpinnings

In this section of the paper, we develop the theoretical framing regarding the needs of capturing data on the social side of a waste management process. First, we review the generic background to CE. Then we review the generic inclusiveness background and inclusive waste management. Thirdly, we discuss the generic traits of material flow analysis (MFA), their shortcomings in light of inclusiveness and how new traits from the customer journey and other theoretical underpinnings can offer a new way to make waste flow analysis more inclusive by focusing on the social side. Finally, we finish with a conceptualization of this method, which we coined the Waste Journey.

2.1 General: Circular Economy Background

Some materials that are commonly used are depleting. In fact, the extraction of these materials should be limited to zero [23]. Until recent days, most economies in the world are still operating based on linear principles in which raw materials are used to produce products, which are then disposed of as waste at the end of their life. This linear economy is also known as the "take, make, and dispose" economy and has many negative effects on different aspects (e.g. environment) that, in the end, can threaten the survival of humanity and needs to change fundamentally [17]. A consensus is reached that a more sustainable economic model is needed.

Within this overarching debate, the CE concept gained much momentum in the academic literature in recent years [27]. The concept itself originates in different scientific disciplines, such as environmental economics and industrial ecology [33]. In environmental economics, Pearce and Turner [38] described that a transition would at some point take place from an old open-ended economic system to a CE system, following the laws of thermodynamics. In this field, some economists described three economic functions of nature (providing resources, life support system, and placing waste and emissions), which would come at a price and market, and therefore needed reflection in economic terms like the price of a product [5, 38]. Notably, pricing nature's products is an incomplete approach that does not account for the intricate,

interdependent dynamics among the single subsystems of the larger human–environment ecosystem. In industrial ecology, the CE system stems from the examinations of the industrial system and its environment, making up a coupled ecosystem which can be described by flows of material, energy, and information [17]. Against these backgrounds, the CE is positioned as a holistic view of processes and systems.

In practice, many regions have recognized circular economy transition as one of the key strategies for sustainable development. In 2008, the Chinese government released the law of "Promotion of Circular Economy", defining CE as the practice of reducing, reusing, and recycling in production, distribution, and consumption [30]. The European Union followed in 2015, in their action plan describing CE as "an economy where the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste minimized" [11, p. 2]. In March 2020, the European Commission embraced a new Circular Economy Action Plan (CEAP), a pivotal component of the European Green Deal, which outlines Europe's blueprint for sustainable growth [12]. This shift towards a circular economy within the EU not only alleviates the strain on natural resources but also fosters sustainable economic expansion and job creation. Moreover, it stands as a fundamental requirement for attaining the EU's 2050 climate neutrality objective and reversing the trend of biodiversity decline. This new action plan introduces a series of initiatives spanning the entire life cycle of products. To realize these goals, the new action plan incorporates a blend of legislative and non-legislative measures, pinpointing areas where EU-level intervention offers substantial added value.

Kirchherr et al. [27] analyzed 95 definitions and found that the core principles of the circular economy include the R-framework, waste hierarchy, and systems thinking. The 10R framework developed by Potting et al. [40] presents ten strategies (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover) in a hierarchical order that contribute to the CE. In the European waste directive, the Waste Hierarchy set a top-down prioritization of waste treatment strategies: prevention, preparing for reuse, recycling, recovery, and disposal [10]. The final core principle is systems thinking, which underscores the necessity of a comprehensive system overhaul to transition to a circular economy. A circular economy involves a complex system in which individuals, businesses, and ecosystems are interconnected [28].

2.2 General Inclusiveness Background and Inclusive Waste Management

Inclusiveness is a recent term that is derived from inclusion. As the concept of inclusion is difficult to define, one could also look at what is not inclusion. Its antonym, exclusion, could be defined as 'a state in which individuals cannot fully participate in their political, economic, and social lives' [59]. A former minister from the

government of France spoke about exclusion as "mentally and physically handicapped, suicidal people, aged invalids, abused children, substance abusers, delinquents, single parents, multi-problem households, marginal, asocial persons, and other social 'misfits'" [42, p. 162). This term emerged after the European social welfare crisis and formed the basis for social studies on exclusion.

The UN coined the term inclusive society as a "society for all" (United Nations, n.d.) and described it as a society providing mechanisms for people so that they can actively participate (in all political, economic, and social dimensions) and are assured that they receive the same opportunities, regardless of their background (United Nations, n.d.). According to a study by Gerometta et al. [16] inclusion in social relations is formed by interdependence (in the form of division of labor and social networks) and participation (in the form of ability to consume, political power and education).

In the city context, inclusiveness is adopted in the thought of the inclusive city. The World Bank conceptualizes that an inclusive city exists "in a complex web of multiple spatial, social and economic factors." Chapter 3 of this book gave six interwoven dimensions of inclusion in the city context, namely the:

- spatial dimension, which ensures equal access to housing, services, and infrastructure;
- social dimension, which focuses on equal access to social resources and creates ownership of these social resources;
- economic dimension, which allows everybody, especially the disadvantaged, to share in rising prosperity, including labor and welfare services;
- environmental dimension, which addresses the current generation's environment and natural resource demands without sacrificing future generations' interests;
- political dimension, which grants citizens equal political rights and obligations and ensures a non-discriminatory relationship between the state and citizens;
- cultural dimension, which means cultural heterogeneity and diversity of cities should be taken into account in the urban policy-making process, so that personal cultural belonging can be respected in a society where ethics and common values are guidelines.

To summarize, it can be conceptualized that inclusiveness is the degree to which all people, including the most disadvantaged, can actively participate in, make use of, benefit from, and are affected by various aspects of their lives within spatial, political, economic, environmental, social, and cultural dimensions. In this way inclusiveness is also affecting the waste management as this is an important service in cities. It requires participation and cooperation between the different actors, which includes the households, recycling companies, and waste collectors, among others. If any of these actors does not experience the same level of inclusiveness as others, it can disrupt the balance and functionality of the system.

More specifically, in less developed countries, inclusiveness in waste management is regarded as the incorporation of traditional informal waste collectors in the system [7, 12, 19–21, 32, 37, 46, 49, 51, 54]. Most of these studies observe that many cities around the world are modernizing their waste management system, and that the

technocratic approach actually undermines the role of informal waste pickers and collectors [69], since these actors are neither included nor intended to participate in these modernized processes for various reasons.

To alleviate this, the design of a waste management system needs to include these actors in the decision-making process and ensure that the design can create mutual benefits for all these actors. In doing so, qualitative indicators were constructed for user and for provider inclusiveness [57]. User inclusiveness can be defined as: "the extent to which users have a say in the waste management services in a city" [3, p. 257]. Provider inclusiveness is "the degree to which service providers are involved in waste management planning and implementation processes" (ibidem, p. 257).

Making the waste management process and system inclusive ensures that various actors can play crucial roles in effective waste management by cities, supporting related circular economy ambitions [24]. In that sense, informal stakeholders should be seen as part of an inclusive circular system, contributing to long-term urban sustainability [62].

2.3 The Analytical Traits of Methodologies for Inclusive Waste Flow Analysis

One of the methods that is used most often in waste management studies is the Material Flow Analysis [14, 68]. MFA is an accounting approach to substance flows entering, remaining within, and leaving a defined socio-economic system. The quantification focuses on the waste flows and their trajectory through various parts of the waste management process. Such a quantification is particularly useful for assessing the level of circularity of a flow/system, by quantifying which flows remain within a system vis-a-vis which leave it, indicating the extent of circularity of that very system [14, 68]. One notable shortcoming of MFA is its limited emphasis on the role and the interaction of actors in the waste management process. This neglect can result in an incomplete understanding of the complexities and challenges associated with waste management practices. For instance, MFA may not adequately capture the role of informal waste pickers who are often marginalized and operating outside formal waste management systems, but still contribute to the recycling process [52]. In addition, MFA misses qualitative features of waste systems that make the MFA happen, i.e., routines and exchanges between stakeholders as well as their value ideals and norms that motivate them to engage in any consumption, recovery, or disposal pattern.

Next to MFA, there is a method called the Wasteaware benchmark. It can be used to identify weak spots in a solid waste management system of a city [3], as well as to measure the performance of a waste system allowing for a comparison between cities [66]. The data that feed the indicators of the benchmark are intended to be easily usable. However, conclusions regarding the results are limited to merely comparing the quantitative features between processes. It lacks a proper qualitative interpretation

and the role of actors (users and general public) have with the performance of the waste management system. Still, the Wasteaware benchmarks can be used as criteria for the degree of user and provider inclusiveness.

Clearly both MFA and Wasteaware benchmark have some limitations when it comes to the social side of a waste flow analysis. A recently applied method managed to take on board inclusiveness and circularity in waste management through the theory of planned behavior [39]. This is a framework explaining how intentions and behavior play a crucial role in a person's decision-making process. The behavior of an individual is formed through different constructs like attitude, subjective norm, and perceived behavioral control [2]. Pongpunpurt et al. [39] extended the theory by adding a situational and knowledge factor and therewith used it to capture people's intentions for household separation at the source. With this, the researchers set up hypotheses about the factors to explain the intention of waste separation by an actor, and found that residents in Bang Chalong, Thailand, were positively and most significantly influenced in their waste separation by their knowledge and subjective norms.

Figure 1 shows the schematic representation of the theory of planned behavior and its behavioral factors. In this theory, attitude is used for arguments that relate to the attitude the actor has towards separating or recycling waste. The subjective norm is used for arguments that relate to any form of social pressure, like separation is desired by the community. Perceived behavioral control refers to the reflection of an actor on their own ability and willingness to perform a given behavior, like easy or hard to separate waste. The situational factors relate to the elements that form the actor's contextual situation, for example, the location or facilities that allow or compel to separate waste. Finally, knowledge refers to the actor's knowledge of sorting waste, like knowing how to separate paper from a bottle.

Interestingly, this study by Pongpunpurt et al. [39] set up an attractive way to include the social side of the waste management process, however, it only went as far as targeting one node, whilst the waste management process consists of multiple nodes through which waste flows. This insight therefore gives a few implications for a theoretical development for inclusive waste management. First, it is observed here

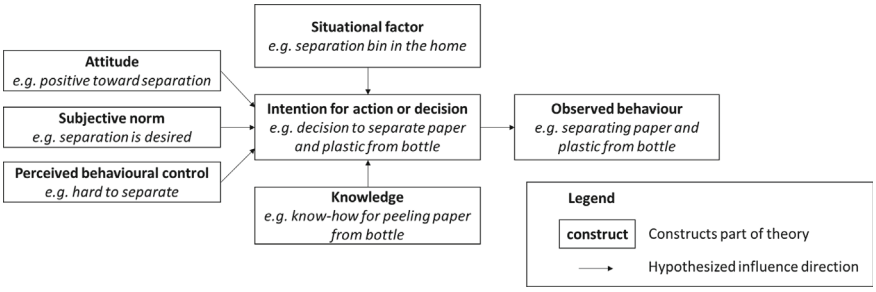

Fig. 1 Schematic representation of theory of planned behavior with examples inspired by Pongpunpurt et al. [39]

that this theory could serve as a basis to extract the social engagement of one actor in a chain of multiple nodes. Second, it shows the potential of the theory of planned behavior to describe the nodes along a waste flow as the parts where actors' decisions and behavior will influence the path of the waste through the system. Thirdly, this level of analysis could unlock the potential barriers and opportunities that these decisions cause in the system to realize inclusiveness and circularity.

Following from the aforementioned implications, it is clearly shown that experiences of an actor have a strong impetus on how decisions are made, but usually at just one place in the flow of the waste. However, in order to improve the waste management at a system level, an effective analysis would have to rely on methods that can (1) view the underlying behavioral factors of the theory of planned behavior and also (2) analyze this across the entire path of multiple places in the flow that waste is travelling, (3) and therefore be flexible enough to follow the direction of the decisions by each of these individual actors. In this sense, measures for improving the circularity would have to be understood during the entire flow, whilst the screws to turn would have to be understood through the inclusive actor level. Therefore, a method which is able to follow the actor involvement from the point of view of the waste would have to be facilitated to analyze actor-level measures for system level problems.

This extraordinary set of criteria challenged the researchers to think beyond the usual methodology repertoire in waste management studies. As a matter of mere unconventional interest, it was taken as a challenge to look for a method that would fit well inside these set criteria. Following from that it is argued that the design sciences offered an unconventional approach, called the Customer Journey, that suits the needs for the requirements as described above.

The customer journey knows various definitions. It is referred to as a process that a customer goes through, where the stages and touchpoints collectively make up the customer experience [55]. Also, Terra and Casais [53] define it as a sequence of events in which the customer goes to look for information and interacts with a product or a service. It looks at the complete sum of the customers' experience on interactions with a brand or product [41] including the pre-purchase, purchase, and post-purchase stages [14].

A few analytical traits are noteworthy here. The focus is on the sequence of events, also called points of interactions, from mostly the customers' perspective [13, 50]. At these interaction points, the analysis looks at how the customer acts and makes decisions regarding the use of the product or service and treats these as separate event stages [48]. In this way the journey that a customer goes through can be evaluated retrospectively [47] and can be used to understand where the product or service creates value for the customer [61]. This way the customer journey helps to identify barriers and opportunities that can help to improve the process of the customers experience along the journey. It should be noted that the customer journey, in some instances, can also be focused on the perspective of the product or service provider to identify certain issues.

Although the customer journey is not used in waste management studies, it proves to be useful for evaluating the experience of actors (in this case customers) in a

(business) process [55]. This focus can resemble the evaluation of the experience of actors in a waste management process. We therefore make a cautious flip in the customer journey thinking that can unlock the systemic view on waste management processes (Fig. 2).

In essence, the flip entails changing the customers' perspective to the waste perspective. This means that the analytical ideas of a journey are now used to follow how the waste goes through the process of human-to-human handling and interacts with each of them at sequential points across the journey. The idea is that at these points of interaction, the analysis looks at different actors' intentions and behavior. This helps to establish a detailed overview of the waste management process by evaluating the interactions, relationships and arguments for actions and decisions.

Essentially, we define a Waste Journey as the process that waste goes through, across a sequence of events interaction points (made up of actions and decisions with regards to the handling of the waste) of actors that make up the waste management process. In the next part, the methodological components for this concept are synthesized with useful building blocks from the reviewed literature.

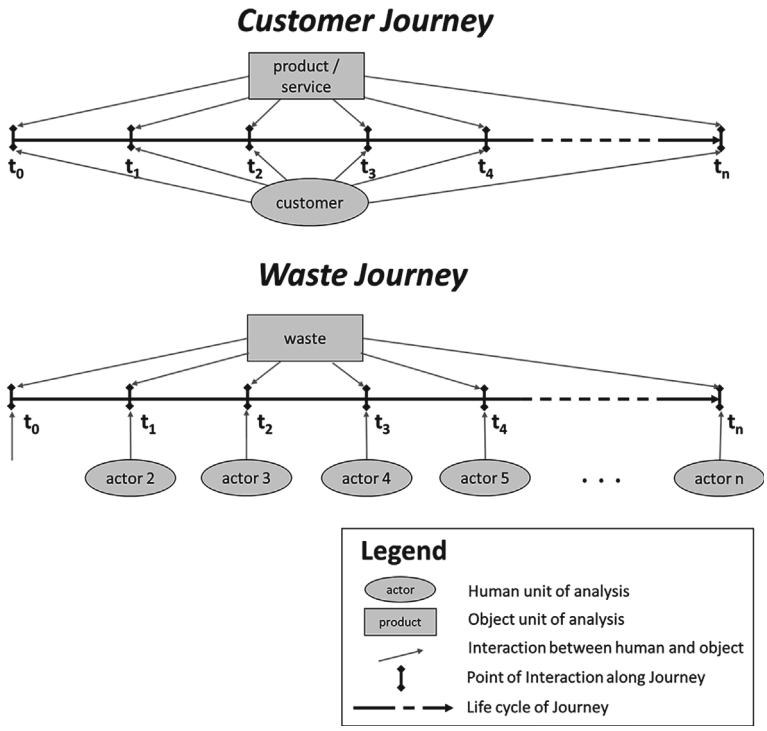

Fig. 2 Waste Journey conceptualization inspired by Customer Journey

3 Waste Journey Methodology

For a waste journey to work, choices need to be made regarding its set up, empirical data collection and analyses. First, we describe the setup of the Waste Journey concepts' goal and analytical components, as it is inspired by the customer journey. Next, we suggest the data collection, analysis, and visualization tools for implementing the Waste Journey method in real cases.

3.1 Waste Journey Setup

The goal of the waste journey is to identify barriers and opportunities for realizing inclusiveness and circularity in the waste management process. This implies an open research approach in which the waste is simply followed as it moves from actor to actor, starting at the point where resources have been discarded and enter the waste management process. By mapping the sequence of this process, the realization of the circularity and inclusiveness can be qualitatively analyzed. This is where the theory of planned behavior can help in identifying the underlying arguments for certain decisions and actions of the different actors can unveil experienced barriers and opportunities by these actors.

In the process, actors can act and decide in ways in which the waste process is performed in a circular way or not. For example, the waste can go to certain circular end-states across the journey and points where various actors interact with it. Therefore, the circularity of the waste journey can be defined by the end-state of the waste, like the preparation for reuse or incineration. The analysis observes the reasons for people to generate waste and how they will prepare themselves for this generation. Furthermore, people will take steps after the waste is generated and then the waste will go across different actors as it is picked up, processed, and distributed onto other locations, until a certain end-state. In the process the different actors can also interact with each other while handling the waste, for example, when waste is moved from hand to hand. Certain behavior will describe the actions that have led actors to behave in that way. The arguments behind this behavior can be clarified by using the theory of planned behavior, which can help to explain the potential origins of certain desired or undesired outcomes.

Figure 3 shows the graphical representation of the waste journey. In this scheme, each point of interaction represents a step in the waste management process, where one actor handles the waste and then leaves it or hands it over toward the next point of interaction. Within the point of interaction, the waste journey considers that these actions can be observed, and that the underlying planned behavior constructs (i.e. attitude, subjective norm, situational factor, knowledge, perceived behavioral control and intention) can be discerned. As the action or decision can help to understand the circular performance, the constructs of planned behavior help to understand the reasons of why these occur. Examples of these insights could be that an actor separates

waste in a certain fashion because his neighbor does this too, or she has a positive attitude toward a certain decision.

Also, the theory of planned behavior can help to describe the inclusiveness of the waste management process. An example of this can be someone does not separate plastic waste, because there is no plastic container nearby. This way, it could for example be learned that some structural aspects, like accessibility of facilities, could be an underlying reason for certain circular performances not to be realized in the waste management process. This can then point to improvement suggestions.

A sensible method also has a clear demarcation of its system boundaries before it can be applied. Therefore, the waste journey has a clear start and end allowing the analysis of its circularity and inclusiveness. The start of the journey is when an actor decides that a resource is discarded as unusable. At this moment waste is generated. Then a varying number of steps could be taken by various actors in the journey that the waste undergoes. These steps can be circular and inclusive or the opposite of these. At some point the waste gets to an end of the journey. This happens when the waste has found a new stationary function (e.g. reused), dysfunction (e.g. at a junkyard) or in some other way eliminated (e.g. incineration).

The sequence of the data collection is chronological, i.e., starting at the closest actor to the start of the journey. This way the study can remain open to any direction that the waste is taken on its journey. This facilitates a detective type of study of the waste flow. It will also remain possible to prepare the study of a waste journey by sequencing the expected processing phases of the journey beforehand. The data can be collected at the points of interaction where an actor during an interview can describe the way they approach the waste action and decisions along the lines of the underlying constructs of the theory of planned behavior. This can be repeated for all actors until the end of the journey is reached.

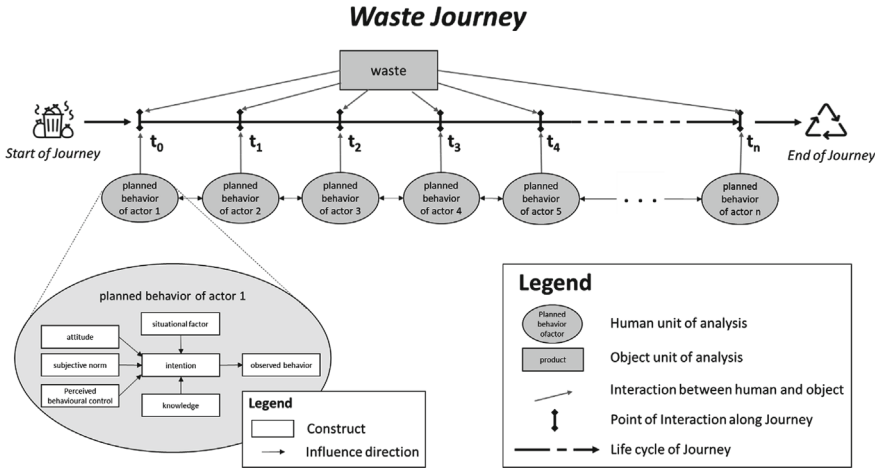

Fig. 3 Graphical representation of Waste Journey setup

An important sidenote about the data collection is also that waste at a certain point can be split into multiple follow-up waste items which receive their own continued journey. If this happens, then the approach faces a methodological choice to either continue with all journeys or with a prioritized one. Having a clear answer to such a query beforehand helps to avoid stalling the data collection.

The full data that can be used for further analysis in the end are the interviews about the constructs with the actors. The quality of the data set will depend also on the cohesive following of the actual journey of a waste item. This means that a physical type of waste can be used as actual flow to go to interview the actors that have handled it. This would, however, be quite restrictive. A more practical way would be to apply a snowballing technique in an interview to learn about the next actor that a certain focal waste item would be transferred to. The outcome of the full set of data can help generate an understanding of the waste as it has travelled and the why of it. This can lead to the detection of gaps and opportunities for intervention to achieve inclusiveness and circularity in the waste management process.

3.2 Data Collection

The waste journey is set up as a case study focusing on one waste stream. A frequently used method for data collection in case studies is interviews [26]. This helps to understand the perspective of a respondent and the how and why of that perspective. Interviews can be held both face to face or through an online platform, like Microsoft Teams. These can also be performed in various forms, like semi-structured, exploratory, or unstructured. The semi-structured approach is known for its flexible and versatile qualities during the conversation with a respondent [25]. This is an especially useful approach to gather perceptions and opinions from respondents, like on inclusiveness and circularity.

The interviews aim to reveal the waste journey as these are carried by the actors, who have been selected as the interviewees. Therefore, the interview questions target to map the process (sequence of decisions and actions) of the actor. Collecting a sequence like this is often helped by asking respondents to write the actions and decisions on cards, e.g. post-its, and then ask them to place these in front of them on a table. As decisions and actions are added on the surface, the chronological sequence of all these events can be constantly reflected on by the respondent to represent the process as accurately as possible.

The interviewer can then ask about the motivations behind each action and decision placed on the cards, allowing for inquiry into the reasoning behind the actor's behavior. This approach enables the collection of different inputs from the actors without needing to have them written down beforehand. A face-to-face interview provides the opportunity to also gather non-verbal communication with the respondents. This can be useful when interpreting whether a follow up question on their intentions, or other behavioral constructs could reveal additional insights form their perspective.

The interview protocol is made up of three parts. First, there are more generic questions which intend to obtain background information about the start of the waste journey and the self-described role and scope of experience of the waste journey of the actor. This is important to understand, because each actor forms a part of the waste journey but will probably not possess full knowledge of parts that occur before or after their involvement. Second, there are specific questions that one wants to ask with regards to the specific actor-role and phase that the individual performs. In this part it is useful to ask about the key arguments of the interviewees and their interactions with the direct actors before and after them in the journey. Regrading the waste flows, both quantitative and qualitative elements will be collected. For quantitative data, we focus on the amount and composition of generated waste flows. For qualitative data, we collect norms, value ideals, drivers, and routines of transactions.

3.3 Data Analysis and Visualization

The analysis of the data can be conducted in different ways, depending on the way that data was collected. First, a sequence of decisions and actions is mapped by an actor (which can be by post-it notes or on a Mural/Miro board canvas). The maps from individual actors can then be stacked up to reconstruct the collective waste journey. This can be visually represented through Draw.io or some other diagramming software application. Second, the interview texts can be coded along the planned behavior constructs (attitude, perceived behavior control, and so on) to help describe the arguments for actors' decisions and actions. The coding itself can be done by data-driven coding, i.e. coding with an open mind and no starting list of codes, or concept driven coding, i.e. coding along predefined categories or concepts [18]. A waste journey benefits from concept-driven coding because, if an actor's underlying motivations are already theorized under an umbrella like the theory of planned behavior, then concept-driven coding helps to gather evidence on these factors.

To enhance the understanding of the behavioral background behind waste flows the analysis should be presented in a narrative or textual manner and a graphical representation. A narrative representation entails the advantage of addressing the actor's underlying motivations and arguments. The graphical representation of a waste journey depicts waste flows from one actor to another. In each step actions of individual actors and the drivers behind these actions are provided. This representation gives a detailed overview of the actors' actions and the arguments they had for their actions but lacks details in all the steps in the waste management process. A swim lane diagram facilitates the visual insight by allowing a flowchart for the actions and decisions to unfold. Swim lane diagrams have this quality because it clearly presents which actor takes which action and the interactions between the actors (Lucidchart, n.d.). In addition, the swim lane diagram provides a degree of detail that helps in identifying potential bottlenecks (Lucidchart, n.d.).

4 Implementing the Waste Journey on Household Renovation Waste

In this part we report on the case of the HRW journey. First, we introduce the motivation of selecting HRW for our case study. Then we describe the context of the HRW in the Netherlands and the theoretical overview of the case-specific waste journey. Subsequently, we present and analyze two cases of HRW journeys. Finally, we describe patterns and revealing insights from these two cases.

4.1 Case Selection

For a proper empirical study on the applicability and academic novelty of the waste journey method, construction waste is a typical waste stream that has a lot of potential, because of its oftentimes job-based waste generation, and thereby organic manifestation of the eventual waste handling. For example, it is mostly generated through construction and demolition projects. This offers the opportunity to test the method to see how it helps to trace this waste handling and actors' behavior in it.

Construction waste in general is a critical waste category, which also performs quite well in terms of circularity in the Netherlands. The recycling rate of construction waste in the construction projects in the Netherlands is more than 95% [34]. In addition, quite some research is performed into this type of waste [36, 64, 67].

Within this major category, renovation waste is generally unknown regarding its degree of circularity. In this subcategory, single-house renovation projects are characterized by a high degree of decision-making due to the demolitions, which are more unpredictable for the actors involved. For example, there are typically small renovations of a bathroom, living room, or complete house for which the type of tiles, cabinets or other stuff inside the building can be quite hidden before waste is generated. The waste related to these projects is called Household Renovation Waste (HRW).

A standard waste management process can be understood in the following stages [7]: collection, transport, sorting, treatment, and final disposal or reprocessing. The customer journey informs that this overview misses a preparation and a generation stage. Therefore, as a matter of theoretical comprehensiveness, for the case it is decided to incorporate a preparation and generation stage in the standard waste management process.

Figure 4 represents the theoretical overview of the case-specific waste journey. The stages are used to check the journey completeness of the empirical study. It starts with the preparation, where waste could be generated, for what reasons, and inform on different routes. For example, a household during their renovation project could involve hiring a contractor to do the renovation for them. The different decisions made in this phase will have an impact on the remaining waste journey. Next, in the generation stage, the waste could either be generated by the household itself or

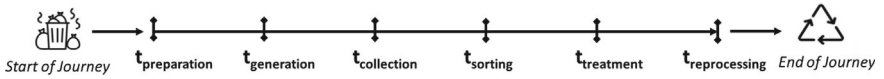

Fig. 4 HR waste journey stages derived from theory

by a professional organization. Different decisions could be made that influence the remainder of the waste journey, such as separating each tile with care, which makes them reusable, or by braking the tiles off the wall making them not reusable. In the collection stage, people can bring their waste to the municipal recycling center themselves, or the waste will be collected by a recycling/waste disposal company. In the sorting stage the waste is sorted and prepared for future purposes. In the treatment stage, the waste is processed for an end-purpose. In the disposal / reprocessing stage the waste is either disposed or reused, recycled, or repurposed.

4.2 Case Background and Contextual Assumptions

HRW can enter the waste journey through two optional routes. First, HRW can be brought to a municipal recycling center and will then be considered as Construction and Demolition waste or as bulky waste [45]. Another option for this waste to be managed is by using a container that is placed in front of the house. In this instance, there are containers in different sizes and for different materials, like wood, metals, bulky waste, and construction and demolition waste (Bouwbakkie.nl, n.d.). Insofar, neither of these options helps the separation of the HRW.

The actors in the HRW handling are represented in Table 1. It starts with citizens who own a home that they want to partly renovate. Once this is decided, citizens then make use of municipal recycling centers, contractors, and professional recycling companies for processing their waste. This makes the role of citizens in the HRW system quite big, and they need to be included in the system for it to function at its full potential.,

The HRW is expected to grow in the Netherlands in the period 2020–2030, based on a government goal aiming to insulate 1.5 million houses for realizing the energy efficiency in old homes [43]. Earlier estimates show that HRW after a home renovation project varies between 5 to 10 percent of the total construction and demolition waste [31, 35]. In these estimates, it is unclear if this includes only necessary retrofits or also esthetical renovations (Wang et al., 2020).

In the academic literature, it is hard to find studies that treat HRW as a separate waste stream, but as a part of the total construction and demolition waste. A few exceptions have studied renovation waste as a separate waste stream, and these note the importance to do so, because of the need to improve the reuse and recycling potential of HRW [8, 31, 35, 65].

Table 1 Overview of HRW actors

Actors	Roles
Household	Tend to generate waste by renovating something in their house. Can generate the waste themselves or hire a contractor. Can transport the waste to a municipal recycling center
Contractor	Generate HRW. Can do the transport, but not necessarily
Municipality	Set regulations for the waste management process. Supply the municipal recycling center
Waste disposal company	Offer containers for HRW collection and trans-ports them to the sorting facility. Can do the sorting itself but not necessarily
Waste sorting company	Treat the waste into different waste streams for the purpose of recycling. Can also do the collection of waste
Household	Tend to generate waste by renovating something in their house. Can generate the waste themselves or hire a contractor. Can transport the waste to a municipal recycling center
Contractor	Generate HRW. Can do the transport, but not necessarily

Among this small set of studies, two different definitions of HRW can be recognized. First, HRW is defined as waste that is related to "the modification or improvement of the residential building" [8, p. 1]. Second, HRW is defined as "waste that is related to the work needed in the building due to obsolescence or deterioration of some of its elements" [31, p. 392].

Ding et al. [8] defined six stages of HRW generation: layout transformation, installation engineering, mason engineering, carpentry engineering, paint engineering and related installation. Each of these stages all relate to a reason for a certain type of waste to be generated. Ding et al. [8] estimated that for their study about 75% of the waste was generated during the layout transformation stage, which mostly consisted of rough stony materials, like bricks, concrete and tiles.

Specific data about HRW can be collected using a variety of techniques, like site inspections, interviews, and literature studies [8, 68].

4.3 Mapping HR Waste Journey

Here we will report on the HR waste journey. In the Dutch context it was found that there are two different routes for citizens to handle HRW. Therefore, two separate waste journeys were mapped: direct municipal offering (WJ1), or on-site container (WJ2).

4.3.1 Waste Journey 1: Direct Municipal Offering

WJ1 started with a homeowner who decided on a renovation project himself in his house in Rotterdam. As the HRW was followed, it went to a recycling center and then to a sorting company for construction and demolition waste. An overview of interviews is offered in Table 2.

Figure 5 offers a visual representation of WJ1. It started with a homeowner (interviewee WJ1-1) who removed a wall to connect a living room with an old bedroom. He reasoned that it would be cheaper to do it himself. The homeowner created a plan from old pictures and asked a handyman for advice and quality check. After this was confirmed, the plan was executed, with first cutting the power and then a careful test. Then the wall was demolished entirely. The wall had a wooden frame with insulation material, closed with an oriented standard board and gypsum panels. This material was turned into smaller pieces and placed in bags for easier transport. The homeowner brought this to the recycling center himself since his municipality offered this as a free service. He used his own car and rented a trailer.

The recycling center inspected the waste but did not inspect his credentials as a citizen of the city. The operator at the recycling center (interviewee WJ1-2) said this should be done. After the waste inspection it was indicated where the waste should be brought on the premises. The homeowner regretted not separating the waste more thoroughly, as he put the wooden beams and panels together that had to be sorted in the wooden container and contaminated gypsum container. This separation was not checked by a supervisor at the recycling center (interviewee WJ1-1). In the background the recycling center representatives (interviewee WJ1-2, WJ1-3, and WJ1-4) elaborated that the check could have been done without the homeowner knowing about it.

Up until this point the homeowner was able to indicate the waste journey directly. Thereafter the waste flow became less clear, without direct accounts of the waste. This is where the accounts from the recycling center representatives provide more

Table 2 Overview interviewees of WJ1 about direct municipal offering

Actor	Representative interviewees	Action/role in WJ1-DMO
Homeowner	Interviewee WJ1-1	Remove a wall in a house in Rotterdam
Recycling center	Interviewee WJ1-2	Operate a municipal recycling center and trade waste
	Interviewee WJ1-3	Operates a commercial recycling center and trade waste
	Interviewee WJ1-4	Operate 12 recycling centers in Noord-Holland and trade waste
Construction waste sorting company	Interviewee WJ1-5	Sort construction and demolition (C&D) waste

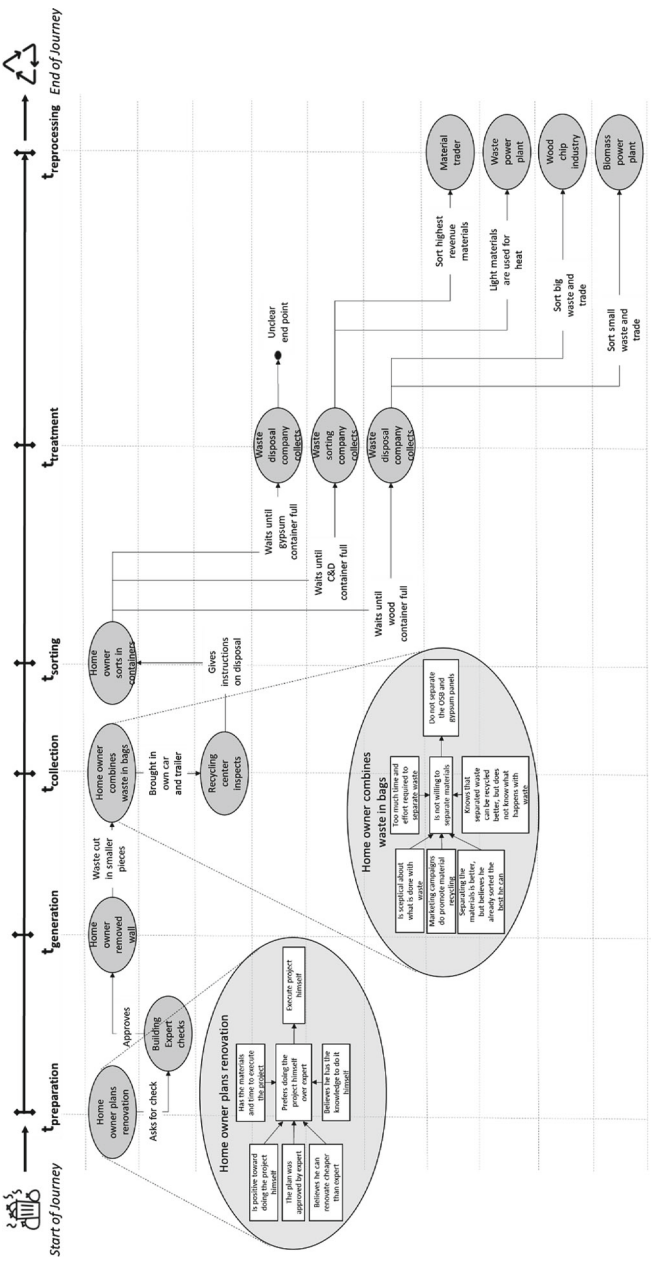

Fig. 5 Observed behaviors in Waste Journey 1

insights. These indicated that when the container is full, it will be collected, inspected, and weighed by a waste disposal company.

The wood container is sorted into different sizes. The bigger pieces can be used for woodchips in chipboards. The wood can also be compressed for pellets which will then be used in biomass power plants or for heating in houses.

The C&D container has a variety of materials due to its function as a residual bin. Also, this container is collected, inspected, and weighed by a waste disposal company. After the company accepts the container, it will pick the most valuable materials from its contents, like metals and chunks of wood. The remaining waste is then prepared to be sorted by a C&D waste sorting machine (interviewee WJ1-5). Once the waste arrives at the waste sorting company, it is specifically inspected for contamination and dangerous materials that can harm the machine, like gas cylinders, batteries, and video decks (which can strap around the machine).

Before the waste is inserted into the machine, a gripper picks up the biggest wooden and metal materials out of the waste pile. The waste sorting machine makes use of different techniques to automatically sort the waste. First, the waste is sorted into different sizes by using different sieves. Then high-caloric materials are sorted by wind shifters, i.e. automated machines which blow light materials away from stream. These materials are traded in different sizes, mostly as fuel for industries with a need for high, like the cement industries. After the wind shifters, the near infra-red (NIR) sorting machines separate wood materials out of the stream automatically. The different sized streams go into a handpicking station. Here, 8 to 12 people sort the waste by hand into containers underneath them, which are sorted for different purposes.

The rubble waste of wood comes out of these sorting processes and will be shredded. If the quality is good enough, then the shredded wood is traded as granulates or otherwise immobilized. Plastics are traded in the high caloric waste fraction or traded by plastic waste materials. The waste is traded as scrap metal.,

The contaminated gypsum container that comes from the recycling center was not mentioned during any of the other interviews. Therefore, it was not recorded in this waste journey what happened to this container.

In waste journey 1, we also aimed to capture the arguments of the observed behavior by actors in the journey. Given the challenges with the interviewees in this journey, we wanted to focus on two decisions from the homeowner that we could map in the best detail.

The first decision that the homeowner made was about performing the project himself. The main reason appeared to be the fact that doing the project himself would be cheaper than hiring an expert. He also had a positive attitude toward doing it himself, as he saw it as a fun challenge: “I found it a fun challenge, and it costs me a lot less money that way”. Closest to the situational factor, the homeowner mentioned that he has the materials and time to do the renovation himself: “I started by drilling a small peephole in the wall to see……”. The homeowner relied on the opinion for his plans from a known expert, which can be interpreted as a subjective norm.

The second decision that the homeowner made was about separating materials that were used from the wall. He decided that he did not want to separate the composite

gypsum and OSB panels from the wall. This disables the circular potential of recycling both gypsum and OSB panels for reuse. Interestingly though, he was aware of this potential and the complications for non-separation: "I would suspect, it would be better to separate plaster and wood from each other as much as possible……but that would have taken me a lot of time and a lot of screwing". Yet, the homeowner was discouraged by the time and effort it would take to separate the two panel types. Also, he noted that gypsum would create a lot of dust: "And a lot of mess because that plaster, it's going to swirl everywhere". In addition, the homeowner was uncertain about what would happen to his waste thereafter: "I do not know what they are going to do with it. If it all gets flicked into the incinerator anyway." This created a certain skeptical attitude about sorting the waste: "I do not know how useful the work (waste separation) would be to me". A municipal marketing campaign did not convince him to separate it, because it did not tackle the concern about the time and effort: "If it all does end up going up in flames, I will have spent eight hours there screwing out screws for nothing and my whole house will be one big white dust mess".

4.3.2 Waste Journey 2: On-Site Container

WJ2 started with a contractor who completely renovated an apartment in Amsterdam. The contractor was willing to participate in the interviews. As HRW was followed we encountered a container broker, waste sorting, and a collection company. An overview of interviews is offered in Table 3.

Figure 6 offers a visual representation of WJ2. It starts when the contractor starts a complete renovation of an apartment in an old building complex in the center of a big city. The homeowner just bought the apartment according to the contractor (interviewee WJ2-1). The contractor and the client meet to align expectations and plan for the renovation work to commence.

The contractor prefers to completely strip the apartment and not reuse materials, because the quality of these cannot be guaranteed and preparing materials for reuse is costly and labor intensive. In addition, the contractor receives a margin on new materials, which incentivizes this procedure over reusing materials. For the renovation itself a permit was required, which included a reservation for a parking spot for

Table 3 Overview interviews of WJ2 about on-site container

Actors	Representative interviewees	Action/role in WJ2-OSC
Homeowner	No interview	Owns home to be renovated
Contractor	Interviewee WJ2-1	Completely renovate a house in Amsterdam
Waste sorting and collection company	Interviewee WJ2-2	Pick up containers, sort waste, and trade waste
Container broker	Interviewee WJ2-3	Arrange the container for the contractor

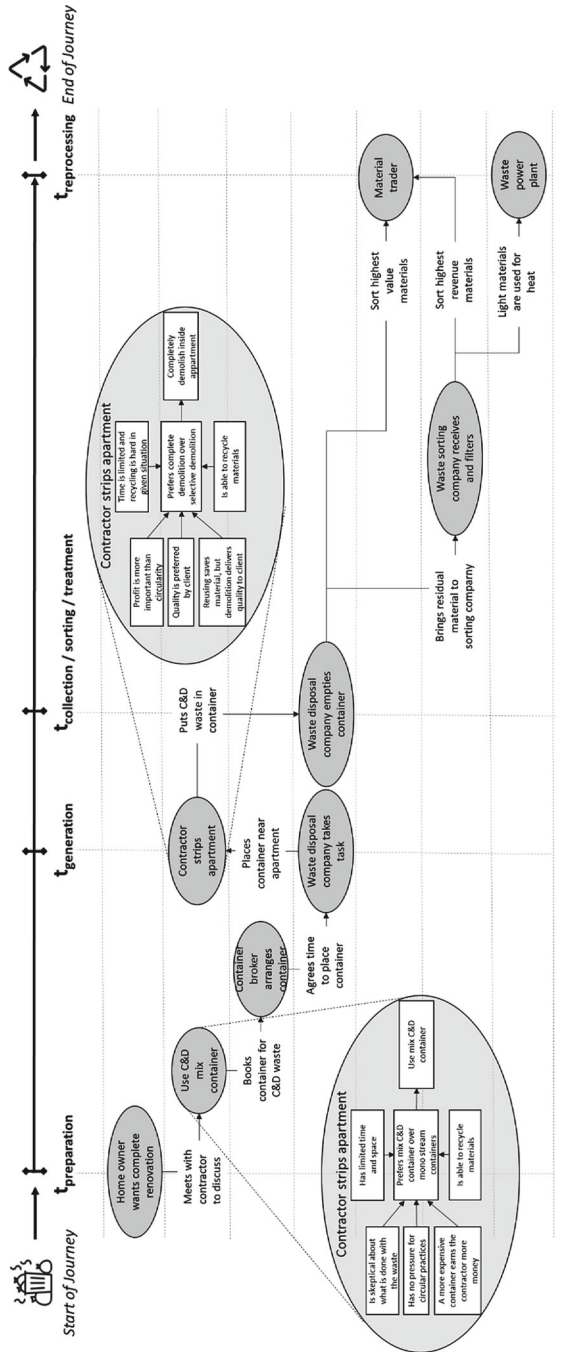

Fig. 6 Observed behaviors in Waste Journey 2

a container. This permit is requested and acquired by the homeowner at the municipality. After the permit was granted, the contractor contacted the container broker for arranging a container. The contractor prefers to use a mixed C&D Waste container, because sorting waste is more costly and laborious for their workers. The contractor also is skeptical about the waste sorting performed by the sorting companies.

The container broker guarantees the handling service for the container for the contractor and the waste disposal companies. The container broker finds communication between the parties important in his line of work, because of a general negative attitude and language barrier between the contractor and disposal companies. They communicate between the parties about the timely placement for the contractor and pick up for the waste disposal company. The waste disposal company is a separate company and has a waste sorting machine. The installation was not described.

In waste journey 2, we also aimed to capture the arguments of the observed behavior by actors in the journey. In this waste journey we had a contractor (interviewee WJ2-3) who could make multiple decisions that influenced the circular performance of the project. Therefore, we took the two key decisions from the contractor that we could map in the best detail for the observed behavior.

First, the contractor decided to not separate C&D waste, and instead opted for one on-site container for C&D mixed waste. One reason for this is also that sorting waste within the center of a big city is time consuming. Also, the contractor showed a skeptical attitude toward waste sorting: “I got a question about that the other day for a permit, some things are separated in there but to what extent is that reused. They say some things are recycled there. But I don’t believe it that much”. Furthermore, the contractor earns money on the price of the container, and even more importantly, the contractor takes a margin in the more expensive mixed C&D container than a wood container: “I would rather if we just look at the money, have one container that I can throw everything in than have a container that I can only throw wood in”. Finally, the contractor feels no pressure from the client or other outside influences to focus on material circularity in the project.

Second, the contractor decided to completely demolish the interior of the apartment instead of applying a selective demolition: “Our preference is to take an apartment or a house/building completely empty, so that then we’re not building on someone else’s work”. This decision was made to accomplish a higher quality end result for the client: “If you put plaster against it, you must plaster very thickly to get it straight again. That’s just not possible, we don’t do it like that”. Selective demolition was unattractive here because preparing for reuse was considered quite laborious and costly: “You could reuse those battens that are often on the ceiling, but then you must take them all out in one piece, which will already be a challenge”. Also, it was expected that the client would prefer to receive a high-quality project: “The customer expects that (buying new materials) and pays for it”. In addition, in its attitude the contractor did acknowledge that circularity would be better, but that the business case is not right for this project: “If we can make more money by separating waste, and recycling or reusing most stuff then we will, yes”. In the end, it is striking to see that the contractor decided to strip although he was aware and still unwilling to pursue the saving potential with selective demolition because of

the clients unwillingness to pay otherwise "So, then it becomes unattractive to the customer very quickly, because then they must start paying an awful lot of money to have old materials back in there that in themselves are just as good as the new materials".

5 Discussion

In this section we discuss added value and implications of the proposed waste journey method based on the results of the two applied waste journey cases. In so doing, we first discuss the critical notes from the two HR waste journeys. Next, we lay out how the innovative ways of data collection and analytics have contributed to revealing these findings. Finally, we reflect more broadly on the meaning of these points for the waste journey method and its future use.

5.1 Critical Notes

The two waste journeys revealed a few remarkable findings. First, it showed some patterns regarding the non-transparency of the information of a waste journey. This manifested itself in different reasons for the start and end of the waste journeys. Close to the start of the journey some actors were observed as unwilling to participate in the research. For example, the homeowner in WJ2 did not want to be interviewed. Closer to the end of the journey, some actors did not want to openly speak about their activities or journey follow-ups. For example, in case of the recycling center in WJ1, there was an unwillingness to share specific follow-up partners in the journey because of certain commercial interests that were at play. These particular observations about the household renovation waste reveals how data inaccessibility in diligent and systematic data collection can actually qualitative lay bare the lack of inclusiveness in the waste management system because of hidden actions and motivations to general inquiry and potentially between actors.

Another core finding was related to the explicitly described circular behavior and underlying intent in the waste journeys. There were a few instances where the lack of circular actions was laid bare in the open where also the underlying planned behavior constructs helped in locating the specific reasons that prevented circular behavior from occurring. For example, in waste journey 2 the contractor clearly prioritized full demolition because he considered profit more important than circularity, despite his awareness of societal arguments in favor of the opposite. Another example, in the same light, was the shared motivation not to decide for circular actions, because of skepticism about the in-transparency of the waste treatment higher up in the waste journey.

Both findings lay bare a critical catch 22 about these waste journeys. First, the waste journeys were not regarded inclusive because of the unwillingness from actors

at the start of the journey to share the reasons for their decisions due to a lack of understanding about what happens further along the journey. This all the while circular actions actually seem to be dislodged because of this exclusive attitude of actors between each other and in general to begin with.

5.2 Added Value of the Analytical Properties of Waste Journey Findings

The observations could be made as a result of analytical properties in the design of the waste journey methodology. First, the type of visualizations of Fig. 5 and 6 have been specifically designed to show the combination of action flows and underlying behavioral drivers. This was done in response to a lack of methods standalone not able to show both a clear disentangling of the total range of activities between the actors along the journey, and the complex motives for these actions and decisions. Oftentimes underlying motives can be shown in a narrative style, by events analysis and underlying constructs [63], but this generally lacks the ability to place these narrated actions and reasons into overall system of actors. On the contrary, flow-oriented diagrams, like Swimlane diagrams (Lucidchart, n.d.), are used to show this overall system, but fail to clearly outline the behavior between actors through the journey. This is where we conceptualized a combination of the Swimlane diagram, events analysis, and underlying constructs in Fig. 5 and 6 as a sort of relay diagrams. Here we define relay diagrams as the ability to explicate the interactions between actors through arrows, but separating them in lanes, as they shape the waste journey as if they run a relay race. In this way, a story board for the waste journey is visualized and explained with underlying behavior constructs.

Another methodological trait that helped uncover the findings in the waste journey was related to the potential of detecting underlying motivations for actions and the potential to identify the source of incentive propositions to curb the undesirable ones. For example, the homeowner in waste journey 1 did not want to separate the gypsum from the OSB panels because it was too much effort. The deeper reason for this appeared to be the skeptical attitude about what happens with waste further into its journey. This therefore revealed that a potential incentive to curb this behavior could be to be more transparent about the way in which waste is processed later into the journey. Also, in waste journey 2 the contractor preferred to completely demolish the interior of the apartment, instead of sorting waste on site. His motivation was both client-driven and financially driven, although he was aware of the circularity potential. This clearly showed the system-based incentives that play part into his decision, and the inevitable implications this had for the following journey.

5.3 Power of Waste Journey

The waste journey method was intended as a detective-like approach to follow waste from actor to actor, to understand the actual processes that specific waste undergo in a local setting. The set up and first application of this method on two HR waste journeys has uncovered a few notable contributions. First, it was found that currently no method is targeted to the empirical interplay between inclusiveness and circularity. Waste journeys have unlocked the observational capability in its systemic line of enquiry at flow and underlying actor behavior level to find relations between inclusiveness and circularity in the two cases. More specifically, it helped to observe that certain circular actions were not taken by actors at the start of the journey due to a lack of inclusiveness of what happens to their waste toward the end of the journey. In essence, this could help in finding the key barriers and opportunities for local waste management practices and inform local and regional authorities on how to curb undesired circularity effects with inclusive-triggering incentives.

A second contribution is the very fact that the setup itself allows to empirically collect data about actor behavior in a supply chain through a relay function. It thereby goes beyond the work of Pongpunpurt et al. [39] who focused on the applicability of the theory of planned behavior on the motivations of individual actors on waste-related decisions. A specific insight about the importance of this supply chain orientation was also unveiled in the set-up of the household renovation waste journeys. Specifically, it appeared that the preparation phase proposed by Buch et al. [7] was very crucial for this type of waste stream, because of the laborious process that demolition brings for the start of the HR waste journey. It was also empirically confirmed, due to the crucial decisions at the start that influences the journey in terms of who becomes involved and what types of underlying motivations are leading the next journey stages.

A final contribution lies in the versatility and openness of the waste journey method. As it tries to map waste flows by following the waste on its path through the waste management process, the snowballing technique makes it possible to identify the inclusiveness of actors about their role and decisions. In this way, the blank responses along the journey also become a potential indicator about the transparency of actions and decisions in the actual waste management process. Even more so, in cases the waste sorting company revealed that there are instances where the interviewed representative of the actor does not make the decisions, potentially revealing more complex internal organizational structures of why certain activities are taken. Also, the study did not particularly underscore any methodological limitation prohibiting it from following other waste streams.

6 Conclusions

In this paper the waste journey method was developed and tested in response to the question: *How to identify barriers and opportunities for realizing inclusiveness and circularity in a waste management process?* The waste journey method was shown to identify potential barriers and opportunities by looking at the actor interactions in the waste handling, their motivations for making decisions, overseeing its journey implications and the systemic mishaps that poor inclusion and circularity in a journey can unveil.

In a practical sense this study offers a method that could be of direct value to waste management practitioners and related policy officers in a city. The direct value would manifest itself in the identification of observed behavior of actors in the waste chain and their underlying motives for that behavior. It was shown through two cases on household renovation waste how the inclusion and circularity can interact between the actors in the waste chain, and how these hold each other hostage in undesirable behavior if not targeting the underlying reasons for stalling behavior. The novelty lies in both the unconventional approach of reconfiguring a design-based tool called the customer journey by flipping units of analyses and the introduction of the relay diagram to visualize the actor interactions and motives in a system process.

The waste journey method has a few observed limitations. First, the waste journey in its proposed form is mostly able to address single waste types and heavily contextualized (in terms of location and time) at a high-quality detailed level. There are reasonable expected modifications needed before it could be entertained for entire waste systems in a city or even comparability between two single waste types. Second, the waste journey in its proposed form still is a time-consuming approach to track and trace the waste. This is especially limiting when the researcher is not able to immediately access the relevant actors through the snowballing process. This could potentially be resolved through more closed and mass-oriented data enquiries like surveys. Thirdly, although the systemic approach allows to learn about the transparency of actors about their role in the waste chain, it still makes the journeys' continued enquiry dependent on a positive willingness for the next actor to share their actions, decisions and follow up partners. Potentially, more detailed and preplanned versions of a waste journey could mitigate this dependency.

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