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Consumer and Business Barriers to Household Food Waste Solutions

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Consumer and Business Barriers to Household Food Waste Solutions

by

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A DISSERTATION

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Abstract

An estimated 35.3 million tons of food waste are landfilled each year in the United States, causing negative environmental, economic, and social impacts and almost half of that waste is from households (US EPA, 2017). To meet EPA goals for landfill diversion of food waste, the material can be captured as a resource and re-used through methods such as composting. However, participation in household food waste collection programs is lacking; there is a need to understand the interplay between the individuals' responsible for providing the waste stream and the pickup services providing the infrastructure to collect and manage the separated material. This dissertation serves to fill this gap through three steps. First, the Theory of Planned Behavior is used to identify the important factors and beliefs that influence individuals' intention to separate household food waste. Then, semi-structured interviews provide an in-depth analysis of the challenges and operations food waste pickup services face from the entrepreneurs themselves. Finally, the first comprehensive review of food waste pickup services was completed to establish their attributes, like price, and compare them with the preferences of consumers. The findings will provide missing information and identify the barriers and opportunities that stakeholders, municipal and industry alike, can use to support participation in landfill diversion of household food waste through growth and development of food waste pickup services.

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Chapter 1: Introduction

A review of the challenges associated with participation in residential food waste management solutions

An estimated 35.3 million tons of food waste were sent to the landfill in 2018 representing the single largest material stream (US EPA, 2023). As land space for disposal shrinks, the cost to dispose of food waste rises (Musulin, 2018). Landfilled food waste contributes to the 14.1 percent of human-related methane emissions that come from the disposal area (USDA, 2023). Methane is one of the most potent greenhouse gases, with 80 times more global warming power than carbon dioxide (CO2) (EDF, 2023). To address these economic and environmental problems created by food waste, the US has set a goal to reduce food waste by 50% in the year 2030 (Leibrok, 2015). However, this goal cannot be achieved without addressing residential food waste.

Household food waste accounts for 40% of all food waste from commercial and residential sectors that is generated in the US, contributing significantly to the aforementioned economic and environmental challenges (U.S. EPA, 2018). The food waste reduction goal of the EPA is to reduce wasted food to 164 pounds per person per year (US EPA, 2017). However, while reduction is the most important pathway, unavoidable food waste will still exist from activities like cooking (e.g. meat and vegetable trimmings) (National Academies of Sciences, Engineering, 2020) and consumers' conflicting priorities such as the desire to make meals that are fresh (Qi & Roe, 2016). Therefore, there is still the need to establish solutions to handle the persisting residential food waste stream as a resource.

A number of landfill alternatives exist to process household food waste, but consumers face barriers to utilizing those solutions. Home composting, vermicomposting, bokashi composting, and decentralized composting are all options available to consumers (Adhikari et al., 2010). Individuals' barriers to home composting include perceived time required (Wu et al., 2019), knowledge required (Edgerton et al., 2009), a "yuck" or "ick" factor from concerns about pest attraction and odor (Oehman et al., 2022; Pai et al., 2019; Pickering et al., 2020), and situational factors like infrastructure available (Taylor & Todd, 1995). New businesses have emerged to fill a market gap by providing convenient solutions for household food waste management (Layzer & Schulman, 2014). These businesses are sometimes called community composting or curbside composting, or household food waste services. The services aim to

provide household food waste pickup while also addressing the barriers consumers face to separating food waste and composting.

The success of these household food waste solutions relies on consumer participation to supply a reliable waste stream. For example, New York City launched curbside collection and drop-off programs in 2011, but ultimately had to halt service due to lack of participation (Champeny, 2018). In 2017 curbside collection programs served 6.1 million households, but only 6.3% of food waste was diverted from landfills or incinerators (US EPA, 2017). Insufficient participation is reportedly the number one challenge for residential curbside collection programs (Layzer & Schulman, 2014; Pinkerton, 2021).

Targeted intervention strategies have been successful at motivating participation in other waste management behaviors like recycling (Tong et al., 2018), but require a baseline understanding of what individuals think and believe about the specific behavior. To date, research has focused on understanding the behavior of wasting food, citing a lack of meal planning (Neff et al., 2015; Principato et al., 2020; Reynolds et al., 2019). However, this approach has ignored individuals' food waste separation behavior, often referred to as source separation, an action necessary to support downstream landfill diversion solutions. There are also unique aspects of managing household food waste whose impact on individuals' separation behavior has been neglected. For example, decaying food waste has the potential to produce odor and attract pests, but no study has investigated how beliefs about these outcomes impacts individuals' separation intention. A few studies have investigated broad factors that impact people's source separation behavior, but these analyses neglected identifying the important underlying beliefs informing individuals' separation behavior (Ghani et al., 2013; Yuan & Yabe, 2015).

The new residential pickup services are a unique solution because they are independent businesses started by entrepreneurs, aiming to provide convenient household food waste separation infrastructure for consumers. Therefore, there is potential for these services to enable consumers to overcome their separation and composting barriers to participate. However, infrastructure needs to align with consumer needs (Bernstad, 2014; Geislar, 2017; Metcalfe et al., 2012) and there are a host of challenges to implementing composting solutions; operational costs of are typically high (Benyam et al., 2020) and businesses have to contend with established waste management infrastructure (Bruni et al., 2020; Pai et al., 2019). Yet, it is unknown what challenges the food waste pickup entrepreneurs face, and how their business

models are informed by consumer needs. This information is necessary to support this new infrastructure to enable consumer participation in landfill diversion alternatives.

Success of these new food waste pickup services hinges on participation from individuals but consumers are only motivated to use programs that meet their needs and align with their preferences. Factors that influence consumers' participation in recycling programs include distance to recycling drop-off locations (González-Torre & Adenso-Díaz, 2005; Rousta et al., 2015) and frequency of household food waste pickup (Ghani et al., 2013). Price can also impact how consumers interact with food waste management systems (Yuan & Yabe, 2014). However, these studies do not address what US consumers look for specifically in the emerging residential food waste pickup business model solution. Additionally, the features available to consumers through curbside pickup models vary and the emerging business models offer innovative features outside the scope of conventional waste management (Yepsen, 2015). However, research has primarily investigated municipally operated curbside service models (Yepsen, 2015), ignoring the unique details of the emerging business models. Therefore, a comprehensive review of only food waste pickup businesses is missing. This assessment is necessary to evaluate if business' features align with the preferences and convenience priorities of consumers for residential food waste management.

Dissertation Objective

To fill this knowledge gap, this dissertation addresses the following research question:

What are the barriers and opportunities to enabling consumer participation in household food waste solutions?

The research was carried out through three interconnected investigations, which are detailed below and shown schematically in Figure 1.

Objective 1: What are the beliefs individuals hold that influence their intention to separate household food waste?

Approach: Characterize individuals' intention to source separate through the application of the Theory of Planned Behavior

Objective 2: What are the challenges of operating a community composting service and how do consumers inform their service model?
Approach: Evaluate the inner-workings, challenges and operations of the food waste pickup services from their perspective

Objective 3: Do the features of household food waste pickup services align with consumer preferences for those services?
Approach: Characterize the household food waste pickup business sector and establish consumer preferences for the services for comparison

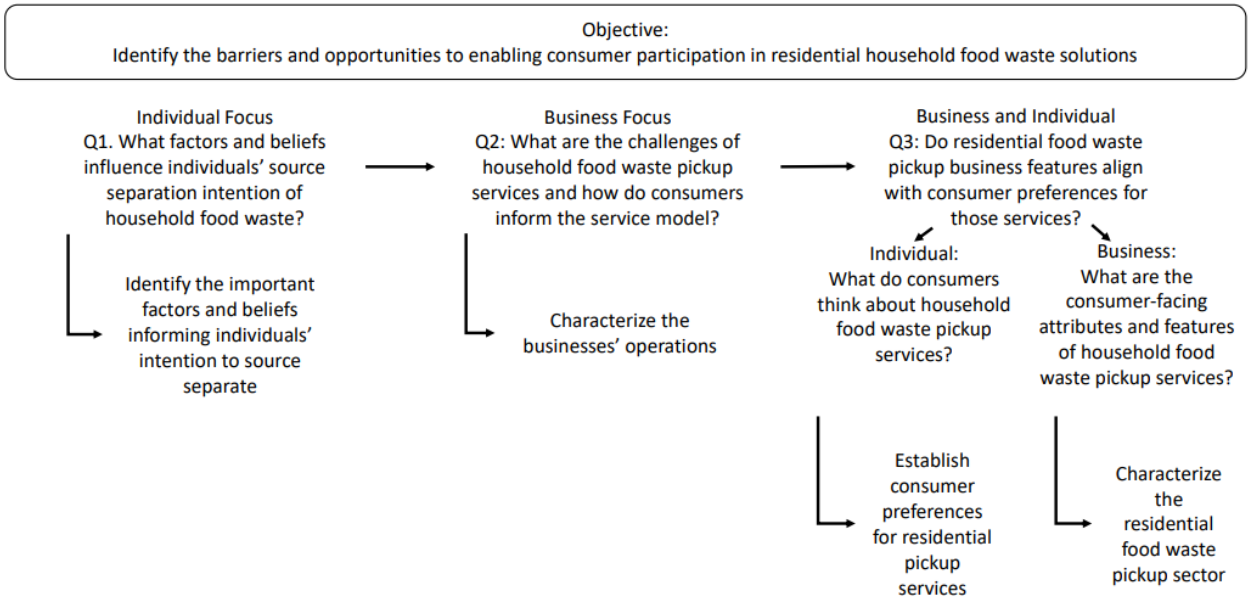

Figure 1. Overview of research structure and approach for this dissertation

The results of this work can support the development of intervention and education strategies for participation in household food waste service and inform the design of existing and future household food waste management infrastructure. Findings provide support for policy initiatives to enable the development of residential food waste infrastructure solutions that meet consumer needs. The information can be used by stakeholders, government and private, to support participation in residential food waste solutions.

Chapter 2: The factors and beliefs informing individuals' intention to separate household food waste

Research question: *What are the beliefs individuals hold that influence their intention to separate household food waste?*

This chapter is part of a published work, "*What predicts and prevents source separation of household food waste? An application of the Theory of Planned Behavior*" (J. M. Oehman et al., 2022) which is edited lightly here.

1. Introduction

A broad body of literature has identified ways to reduce the amount of wasted food generated in households, including meal planning ahead of grocery shopping (Principato et al., 2020), increasing use of foods with cosmetic defects (de Hooge et al., 2017), and extending the useful life of food through proper storage (van der Werf et al., 2019). In addition, educating individuals about the meaning of food date labels could prevent confusion and the discard of food that is still good (Neff et al., 2015; van der Werf et al., 2019). Suggested interventions to reduce household food waste include awareness, technology, managing leftovers, size-portioning, storage, packaging, food risk, policy, regulation, and educational campaigns, which have been the predominant strategy deployed so far (Hebrok & Boks, 2017). In two studies, food literacy messaging campaigns were found to strengthen individuals' perceived behavioral control and decrease household food waste by about 30% (van der Werf et al., 2021; Wharton et al., 2021).

However, even with aggressive waste prevention and reduction strategies, some food waste will still be generated, due to the presence of inedible parts (e.g., bones, trimmings) and due to consumer opinions that some food waste is necessary to make meals taste fresh and good (Qi & Roe, 2016). Consequently, alternative management options are still required to divert wasted food from landfills. Such options available to households include composting, vermicomposting, or backyard digestion systems (Bortolotti et al., 2018; Curtis et al., 2013), which require space and user knowledge but could typically be operated in the privacy of the household (Loan et al., 2019). Recently, however, a new option has emerged for households: services that collect food waste from the residence or accept waste at drop-off locations and

then centrally manage the resource recovery processes. These services are often called community composting (Yepsen, 2015) or residential organics collection programs (Geislar, 2017), and may operate as municipal programs paid for by taxes, non-profit community programs, or private, commercial services paid for by the resident.

However, success of these programs depends on consumer participation, namely through source separating food from other household waste. For example, New York City launched curbside collection and drop-off programs in 2011, but ultimately had to halt service due to lack of participation (Champeny, 2018). Research shows that structural barriers to separating food waste at home include a lack of available space (Gellynck et al., 2011) and lack of knowledge about handling compost (Tonglet et al., 2004). Barriers to participating in local household food waste collection programs include distance to drop-off locations (González-Torre & Adenso-Díaz, 2005), being unaware of existing compost drop-off bins (Sussman & Gifford, 2013), and people's perception of time available in their schedules to dedicate to handling food waste (Wu et al., 2019). Individuals are also concerned that the price of participating in organics collection programs will cost more than they can afford (Refsgaard & Magnussen, 2009).

Beyond structural challenges, individuals may hold deeper beliefs that influence their decision to engage in food waste separation or collection programs. For example, some individuals report negative feelings and emotions if food waste collection containers are perceived to be unhygienic and unsightly (Curtis et al., 2013). Another issue is the concern about what others will think about the behavior (Geislar, 2017; Refsgaard & Magnussen, 2009), like fear of being labeled a "nutty green" by neighbors and friends (Curtis et al., 2013) or getting other members of the household on board with the activity (Goldsmith & Goldsmith, 2011). Even individuals that hold pro-environmental beliefs may not ultimately choose the most environmentally preferred food waste option (Setti et al., 2018), but may be influenced by other factors, such as existing waste management habits in the home or access to facilities and resources to handle the waste (Quested et al., 2013).

To increase participation in food waste separation and landfill diversion, a greater understanding is required of the underlying structural and personal barriers that households face and the enablers that can motivate behavioral change. Individuals' behaviors result from a chain of intention informed by their attitude, the social influence they experience, and their knowledge and personal ability to perform the behavior (Ajzen, 1991). At the root of this chain

are the internal beliefs people hold about the behavior in question: “Peoples’ intentions and behaviors follow reasonably and consistently from their beliefs no matter how these beliefs were formed” (Ajzen, 2015, p. 127). Understanding these beliefs provides greater insight into interventions likely to change behavior (Ajzen et al., 2011). For example, education alone may be insufficient to motivate an individual to recycle materials (de Leeuw et al., 2014), but targeted interventions, such as providing convenient recycling bins, may increase participation because they address fundamental concerns about inconvenience (Bernstad, 2014).

The Theory of Planned Behavior (TPB) provides a framework to identify and understand the beliefs that inform an individuals’ behavior. The theory predicts behavior from intention, which is preceded by three constructs: attitude, “the degree to which performance of the behavior is favorable or unfavorable”; subjective norms, “the perceived social pressure to perform or not to perform the behavior”; and perceived behavioral control, peoples’ “perceived ease or difficulty of performing the behavior” (Ajzen, 1991, p. 188). These core constructs are assessed by measuring an individual’s underlying behavioral beliefs, injunctive and descriptive norm beliefs, and control beliefs, respectively. The TPB has been applied to study a wide array of waste management behaviors and to design intervention strategies. For example, research has shown that subjective norms, convenience, awareness of consequences (Khan et al., 2019) and knowledge (Tonglet et al., 2004) positively influence recycling intention. As a result, interventions, like communicating information about types of recycling containers, the type of waste for each container, and providing a convenient drop-off location improved household waste sorting (Rousta et al., 2016).

The TPB has also been applied to study food waste behaviors, with much of this work specifically focused on interventions that can prevent or reduce wasted food generation. For example, perceived behavioral control was the main predictor of consumption of dairy products that are past their due date but still good (Schmidt, 2019). Attitude, personal norms (Neubig et al., 2020), and subjective norms (Heidari et al., 2020) were shown to motivate household food waste reduction. Further, the core TPB model can be extended to include additional constructs relevant to the behavior. For example, concerns over health risks negatively influence food waste reduction because people choose to avoid the risk associated with eating leftovers or food past its use-by date (Barone et al., 2019). On the other hand, individuals’ experiences and habits related to food waste play a role in informing their attitude and perceived behavioral control of food waste reduction, thus indirectly influencing future intentions (Riverso et al.,

2017). For example, a low frequency of food disposal combined with a low volume of food waste generated in the past correlate with intent to reduce food waste in the future (Russell et al., 2017).

While the TPB has been used successfully for understanding food waste prevention and reduction, it has seen less frequent application to behaviors related to diverting food waste from landfills. For example, the TPB has been used to study home composting (Edgerton et al., 2009; Taylor & Todd, 1995), but not the preceding behaviors involved in source separating food from other household waste. TPB applied to source separation has thus far analyzed cases in China (Xu et al., 2017; Yuan et al., 2016), Vietnam (Nguyen et al., 2015), Iran (Babazadeh et al., 2018), and Malaysia (Ghani et al., 2013). The method has not yet been used to analyze this behavior in the U.S. and findings cannot be generalized because infrastructure, norms, and policy differences vary from one region to the next and have varied influence on human behavior (Ajzen, 1991).

Applying the TPB model to food waste separation may also require expansion to include beliefs that are unique to this behavior. Unlike other forms of recycling, separating food waste requires individuals to handle a material they may believe to have a strong odor or to attract pests (Benyam et al., 2020; Edgerton et al., 2009; Tonglet et al., 2004). Whether this “ick factor” (Pai et al., 2019) is a deterrent to household food waste source separation has not been fully studied. Further, decisions surrounding food are likely to involve moral norms (Graham-Rowe et al., 2015), or feelings of obligation and guilt, which may not be as relevant to other types of recycling behaviors (Khan et al., 2019; Tonglet et al., 2004). Moral norms were found to influence Chinese residents’ attitudes towards kitchen waste separation (Yuan et al., 2016), but have not been fully studied in other regional contexts. Furthermore, because past behavior is expected to influence future behavior (Ajzen, 2002) it has been included in extended TPB models to predict household waste source separation (Xu et al., 2017), but a comparison between consumers with and without food waste separation experience has yet to be made. Overall, it is unclear how these issues individually and collectively inform individuals’ intention to source separate household food waste.

To fill these knowledge gaps, this study applies the TPB to investigate household food waste source separation and to identify the important underlying beliefs that drive the intention to perform this behavior, using New York State (NYS) as a case study. In NYS, more than $1 billion is spent every year to manage solid waste, 18% of which is food waste (M. Brown, 2017).

In New York City alone, residences are estimated to contribute 54% to total food waste generation (Moreno, 2017), but low residential participation in separation programs has stymied collection and composting initiatives (Collins, 2018). While NYS may not represent the full spectrum of food waste systems across the entire U.S., it does provide an effective case study as a region characterized by a diverse array of socio-economic demographics and food production and consumption systems spread across both urban and rural regions. Confining the study to a single state also controls for anticipated variability in state-level food waste policy and infrastructure, which were anticipated to play a role in informing respondents' underlying beliefs (Babbitt et al., 2021).

The study addresses three main research objectives: 1) to determine the TPB constructs that explain consumer's intent to separate food from other household waste, as a first step towards landfill diversion; 2) to identify the underlying beliefs about food waste separation that may be leveraged to change behavior; and 3) to compare how beliefs and intentions differ between individuals with and without experience separating food waste. Ultimately, the outcomes of this study will inform the design of intervention strategies, business models, and education and policy initiatives that may increase consumer participation in sustainable food waste solutions.

2. Methods

The goal of this study was to apply the TPB following the expectancy-value approach (Ajzen, 1991) to determine the factors and beliefs that influence an individual's intention to separate household food waste. The focus on behavioral intention as the dependent variable was largely based on the difficulty associated with directly measuring food waste separation behaviors. Food waste separation is not directly observable, as an action that happens within private homes, and consumers' self-reported measurements related to food are often inaccurate (Quested et al., 2020). While a gap between stated intention and realized behavior is likely to exist, this approach can provide needed information about household food waste separation barriers and enablers, upon which behavioral interventions can be designed and tested by more direct observations.

The methods entailed research design based on literature review and interview-based elicitation, data collection by consumer survey, and data analysis to formulate and evaluate TPB models using confirmatory factor analysis (CFA) and structural equation modeling (SEM)

(Figure 2.1). Because this research involved human subjects, the interview and survey instruments, protocols, and informed consent processes were reviewed and approved by the RIT Institutional Review Board. Each step is described further in the following sections.

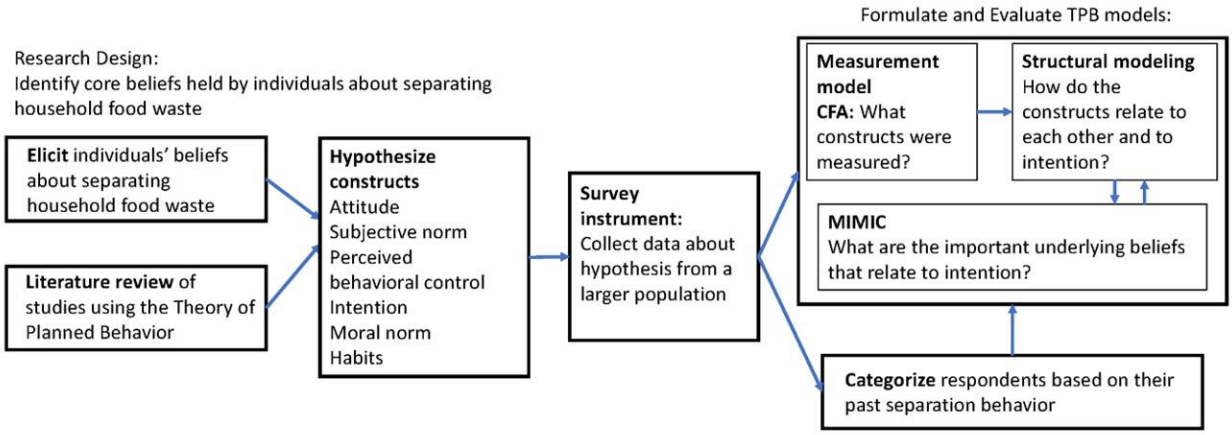

Figure 2.1 An overview of the methodological process implemented in this study to apply the TPB to study household food waste source separation.

2.1 Research Design

The TPB consists of the core constructs of attitude, subjective norm, and perceived behavioral control, which are independent variables expected to influence behavioral intention, the dependent variable. The model includes four underlying belief categories that correlate with independent variables (Ajzen, 2019): attitude is informed by behavioral beliefs, "the subjective probability that the behavior will produce a given outcome or experience;" subjective norm is informed by both injunctive and descriptive norm beliefs, which represent "the perceived behavioral expectations of important referent individuals or groups;" and perceived behavioral control is informed by control beliefs, "the perceived presence of factors that may facilitate or impede performance of a behavior." According to the expectancy value approach, each individual belief is composed of two parts: the expectancy, or the likelihood that the belief will occur, and the value, or assessment of how much that belief impacts the decision to perform the behavior in question (Ajzen, 2006).

The approach to measure these beliefs was based jointly on literature review of past TPB studies, where the behaviors and constructs analyzed could be reasonably extended to food waste separation (as discussed below) and elicitation interviews, to identify and explore

any concepts not yet represented in existing literature. The elicitation process consisted of a series of semi-structured interviews (full protocol provided in the S.I.) that were designed according to Montoya's framework (Castillo-Montoya, 2016). Respondents were recruited at community-focused events (e.g., farmers markets) in Rochester, NY, targeting parts of the community served by a curbside composting program, and via snowball sampling. Respondents were all over 18 years of age, with direct knowledge of household food waste decisions, and included individuals who participated in curbside composting, those that composted at home, and those that did not separate food waste. A total of 14 interviews were recorded, each lasting 10-to 30-minutes. Interviews were transcribed using Happy Scribe™ software and then analyzed line by line with NVivo 12™ software, first through open coding (Strauss & Corbin, 1990), and then according to thematic analysis (Braun & Clarke, 2006). The coding was performed by one researcher, with review and decisions on the use of coding findings made by three researchers.

While interview findings could not be generalized broadly, due to the limited sample size and composition, the identified themes were used to confirm and expand beliefs and constructs found in related literature on food (Russell et al., 2017) or waste management behaviors (Kumar, 2019). For example, individuals expressed concerns about being too busy to separate and the amount of knowledge required to compost separated food waste (perceived behavioral control; Edgerton et al., 2009; Heidari et al., 2018; Nguyen et al., 2015; Wang et al., 2021) and indicated that their behaviors were influenced by the views and actions of other members of their household (subjective norm; Yuan et al., 2016; Zhang et al., 2015). Respondents also discussed their attitudes towards food waste separation primarily in terms of a desire to reduce harm to the environment (Kumar, 2019; van der Werf et al., 2019) or as "a good thing to do" (Khan et al., 2019; Tonglet et al., 2004). These sentiments most closely relate to the instrumental aspect of attitude, which assesses perceived outcomes or consequences, rather than the experiential aspect, which relates to the experiences performing the behavior (Ajzen & Driver, 1991; Ajzen & Fishbein, 2004; Wan et al., 2017). Further, when respondents discussed the experience of food waste separation, they most commonly raised issues of ability. For example, individuals mentioned concerns about odor, messiness, and pest attraction as factors that would prevent them from starting to separate food waste, echoing past studies on household waste (Sidique et al., 2010; Taylor & Todd, 1995). Therefore, these beliefs were

hypothesized to inform perceived behavioral controls, although that was later disproven by the analysis.

Jointly, the literature review and interviews also identified additional factors relevant to source separation behaviors but not fully captured by core TPB constructs. These factors included morality, or a person's sense of obligation to separate household food waste (Botetzagias et al., 2015), experience with curbside recycling of other household materials (Abdelradi, 2018), and household habits related to food, gardening, and natural living (Edgerton et al., 2009; Khan et al., 2019; Kumar, 2019). The literature review was also used to confirm measurement items and scales used in past TPB studies (Ajzen, 2015; de Leeuw et al., 2015; Russell et al., 2017) and operationalize the elicitation interview themes into a survey instrument (Tonglet et al., 2004), as described in the following section. Collectively, the outcomes from the research design (summarized in Tables A1 and A2) formed the hypotheses that attitude, subjective norm, perceived behavioral control, moral norm, and habits would be the primary constructs informing intention, and the core constructs (attitude, subjective norm, and perceived behavioral control) would each be informed by several important beliefs (Table 1).

Table 2.1. Hypothesized constructs, beliefs, and measures based on the literature review and elicitation interview findings. See Tables A1 and A2 for further construct operationalization details.

Hypothesized Construct	**Construct Measurement Definition**	**Reflective and Formative Measures**
Attitude	An individuals' attitude towards separating household food waste	Reflective Measures: Evaluation of separation as bad/good, worthless/worthwhile, unpleasant/pleasant, waste of time/good use of time Behavioral Belief Formative Measures: Potential to reduce environmental harm, landfilled trash, trash cost
Subjective Norms	An individuals' perception of social pressure to separate household food waste	Reflective Measures: People important to me approve, separate their own food waste, think it's a good thing to do Injunctive and Descriptive Norm Beliefs Formative Measures: Family, friend, neighbor approval; Family, friend, neighbor actions
Perceived behavioral control	An individuals' perception of whether or not they have control and the ability to separate household food waste	Reflective Measures: Control of the decision to separate, control over and ability to separate Control Beliefs Formative Measures: Time, space, knowledge and costs of separating; Availability of pick-up and drop-off services; Ability to compost and use compost material; Arguments and support within household; Cleaning required *Potential for pests, odor, and messiness
Intention	An individuals' intention to separate household food waste in the next year	Reflective Measures: Frequency, degree, and determination in planned food waste separation
Moral Norm	An individual's perception of moral	Reflective Measures: Benefits future generations, Right thing to do, Reduces guilt, Duty of a responsible citizen

	obligation to separate household food waste	
Habits	Other behaviors individuals practice which may be related to separating household food waste	Reflective Measures: Gardening, Visiting farmers' markets, Purchasing green cleaning products, Giving money to charity, Eating a vegetarian diet, Driving a hybrid or electric vehicle, Recycling electronics or other household materials

*Interview findings suggested that concerns about pests, odor, and messiness due to food waste separation would be control beliefs; this table reflects that hypothesis, although it was later modified as discussed in the Results.

2.2 Survey Instrument

A survey was developed to gather data to test the hypothesis that the TPB can be used to predict intention to separate household food waste and to identify important underlying beliefs. The survey questions followed the target, action, context, and time (TACT) approach (Ajzen, 2006), in which each question asks the target (NYS resident) about the action (source separating food waste) in a specific context (the household) and time (the next 12 months). Respondents were also asked about their past experiences and practices separating household food waste (from the past 12 months). For each TPB construct, the survey included at least three questions intended to be reflective indicators (direct measurements) (Kline, 2016) and at least three sets of formative indicators (beliefs leading to the formation of the constructs) with questions assessing both expectancy and value (Ajzen, 1991; de Leeuw et al., 2015; Morais et al., 2017).

Following established practices in TPB methodology (Ajzen, 1991, 2006), we implemented validated measurements and scales identified from literature review (see Tables A1 and A2). Direct measures for intention and perceived behavioral control were assessed on unipolar, 5-point scales (Ghani et al., 2013; Heidari et al., 2018). Subjective norm utilized 7-point bipolar adjective scales (Huffman et al., 2014). Attitude followed the TPB questionnaire protocol (Ajzen, 2006), using 7-point, semantic differential adjective scales of good/bad (Russell et al., 2017), worthless/worthwhile (Graham-Rowe et al., 2015), unpleasant/pleasant (Ajzen, 2006) and waste of time/good use of time (Tonglet et al., 2004). Expectancy was assessed on 5-point unipolar scales of likelihood (Ajzen, 2015; Gao et al., 2017; Tonglet et al., 2004) and importance (de Leeuw et al., 2015). Value was assessed on 7-point bipolar scales (de Leeuw et al., 2015) to capture the potential for beliefs to prevent or hinder a behavior (negative) or enable or increase it (positive) (Ajzen & Fishbein, 2008).

The survey instrument (see Oehman 2021 for full text) organized these measurements into six distinct sections that presented questions in a logical order with page divisions and a variety of question wordings, formats, scale anchors, and response set randomizations intended to mitigate common method biases (Podaskoff et al., 2003). Respondents were provided with definitions of key concepts to mitigate ambiguity; for example, specifying that household food waste referred to “any food that is thrown out rather than eaten (things like banana peels, meat trimmings, bones, coffee grounds, old spinach, uneaten leftovers, or plate scrapings).” In addition to the measurements discussed above, respondents were also provided with free text options for open-ended responses and were asked to select three adjectives, from a list of 10 options, that they strongly associated with household food waste separation. The survey also captured standard demographic data, such as age and education level, as well as situational factors, such as owning or renting a home.

The survey was designed and distributed via the Qualtrics platform during September and October 2020, after several months of instrument testing with the general public and implementing feedback about clarity and experience. Qualtrics recruited participants who met the eligibility criteria of being residents of NYS aged 18 years and older. To provide a sample that was representative of state demographics, participant recruitment was continued until quotas approximating the reported 2019 NYS population were met (Table A3) (US Census Bureau, 2019). In parallel, opportunistic sampling by web and social media distribution was carried out to capture additional respondents not affiliated with an Internet panel. A total of 544 reliable responses were received from the Qualtrics panel, and 105 responses were received from opportunistic sampling. The final sample size (n=649) included only those respondents who passed consistency and quality checks, which flagged respondents who “straight-lined” answers across at least three matrices in a row (Vanette, 2018) or straight-lined the matrix of past behavior questions in such a way that would lead to impossible outcomes (e.g., both discarding and separating all of their food waste; see the S.I. for more details). No instances of missing data were found in the finalized data set for the variables required for subsequent analysis.

2.3 Formulating and Evaluating TPB Models

The efficacy of utilizing the TPB model was evaluated through analysis of survey data in two major steps: first confirming the hypothesized constructs through a confirmatory factor

analysis (CFA) and then testing the TPB structural model, including both a baseline and an extended version, to establish relationships between constructs and behavioral intention. A multiple indicators multiple causes (MIMIC) model was used to determine the most important beliefs that underlie the constructs, which were then used to discuss potential interventions. All data analysis and modeling were carried out in RStudio (RStudio Team, 2020) R version 1.3.1093, using custom scripts and the following packages: lavaan (Roseel, 2012), dplyr (Wickham, François, et al., 2020), tidyr (Wickham, 2020), ggplot2 (Wickham, Chang, et al., 2020), RColorBrewer (Neuwirth, 2014), MVN (Korkmaz et al., 2014), psych (Revelle, 2020), semTools (Jorgensen et al., 2022), and the variance inflation factor, vif, function from the car package (Fox & Weisber, 2019). All survey data and model scripts are provided online via figshare (J. Oehman, 2021).

2.3.1 Measurement Model

A confirmatory factor analysis (CFA) (Brown, 2006; Finch & French, 2015) was performed to test the items measured based on the hypothesized constructs according to the TPB (Table 2.1). CFA is used because the data are being tested according to a well-defined theory (TPB), grounded in empirical evidence, which specifies the items and latent variables (Brown, 2006).The initial hypotheses, based on the TPB and literature review, were that attitude, subjective norm, perceived behavioral control, moral norm, and habits would be the primary constructs informing intention. The compatibility of each survey question and adequacy of these hypotheses were assessed through several steps of a CFA: test for multicollinearity and normality, define the constructs per hypothesis, evaluate factor loadings, remove factors and redefine constructs based on subsequent loadings (Kumar, 2019), evaluate convergent and discriminant validity, and test for adequate goodness of fit statistics in the final CFA (Brown, 2006).

Multicollinearity was evaluated by calculating the variance inflation factor (vif) according to Kline's method; all vifs were less than 10, indicating no multicollinearity was detected (Kline, 2016). The CFA used maximum likelihood estimation, which assumes normally distributed data, but robust estimators can be used for data that do not meet the condition of normality (Finch & French, 2015; Kline, 2016). All of the expectancy-value products and construct survey questions were tested for normality using Mardia's test (Finch & French, 2015; Korkmaz et al., 2014) in RStudio via the mvn function from the "MVN" package. All data were found to be non-normal with skew and kurtosis, and therefore, the robust estimator maximum likelihood with Satorra-

Bentler correction (Satorra & Bentler, 2011), mlm, was used for the subsequent analysis (Finch & French, 2015). Harman's single factor test (Harman, 1976) was used to test for common method bias by pooling all latent variable items into a single factor and verifying that the explained variance (0.35) did not account for the majority of the covariance among items (i.e., was less than 0.5).

The CFA factor loadings for each hypothesized construct were evaluated using the following criteria: (1) a loading above a cutoff of 0.4 (Hair et al., 2010; Morais et al., 2018), (2) significance at $p < 0.05$, and (3) consistency in loadings (Kumar, 2019). One question intended to measure attitude (ATT) did not meet these criteria and was subsequently removed, possibly because this item was oriented more towards the experiential dimension of attitude ("separating household food waste would be extremely unpleasant/extremely pleasant"), whereas other attitude measurements focused on the instrumental dimension (Ajzen & Driver, 1991; Wan et al., 2017). Three statements related to habits were removed: NLH5, "following a vegetarian diet" and NLH6, "driving a hybrid or electric vehicle" were not statistically significant and NLH4, "give money to charity" had inconsistently low factor loading relative to other items. Further, the remaining questions related to habits ultimately divided across two factors, one that related to "green" or natural lifestyle habits and one that related more to habits of recycling other materials (see Results and Discussion).

Based on interview findings, one original hypothesis was that the beliefs about odor, pests, and messiness would inform the construct of perceived behavioral control, as respondents mention these issues in the context of their perceived ability to separate food waste. However, these beliefs were found to be insignificant as individual expectancy-value products informing either behavioral control or attitude (see Section 2.3.2), and were instead determined by CFA to be significant only as an independent latent construct. The construct was then termed "yuck factor" to represent individuals' negative disposition to the odor or unhygienic consequences of handling and separating household food waste.

As a result of CFA methods described here, the constructs used in the subsequent analysis included the core TPB constructs: attitude, subjective norm, perceived behavioral control, as well as the additional constructs of moral norm, natural lifestyle habits, recycling habits, and yuck factor. To ensure these constructs were measured well and distinctly from each other, all were evaluated for convergent validity and discriminant validity (Brown, 2006; Kline, 2016) using Chronbach's Alpha (Alpha), construct reliability (CR), and average variance

extracted (AVE) (Kline, 2016). All results indicated that the constructs were measured adequately with Alpha values > 0.7, CR greater than 0.7, and AVE values greater than or equal to 0.5 (Kline, 1999, 2016) (see Tables A3 and A4). Overall, the measurement model met the accepted goodness of fit criteria (Kline, 2016) to continue to the next step of structurally modeling the relationships between the constructs (Figure 2).

2.3.2 Structural Modeling

Structural equation modeling (SEM) was used to test the hypothesized relationships between constructs confirmed by the CFA and the intention to separate household food waste. The SEM process followed three steps: (1) test the baseline and extended TPB models for their efficacy in predicting intention to source separate food waste, (2) determine the most important beliefs underlying the main constructs, and (3) determine differences in beliefs and structural relationships between respondents with and without prior experience separating household food waste. All steps of the SEM were carried out using custom script and the latent variable analysis (lavaan) package in RStudio. All models were evaluated according to the following fit statistics (Table 2): comparative fit index (CFI), Tucker Lewis index (TLI), root mean square error of approximation (RMSEA) and standardized root mean square residuals (SRMR). The percent of variance in intention explained by the model is the R-squared value (x100). All standardized coefficients are reported.

First, the baseline model was assessed to evaluate the relationships between the core TPB constructs and intention according to the TPB (Ajzen, 1991). The baseline model achieved an adequate CLI and TLI score, but had high RMSEA and SRMR values. Based on analysis of the model's residuals (Brown, 2006; Kline, 2016), two covariances were added to the model: one between the errors of two attitude measures (ATT1 and ATT2) and one between the errors of two measures of perceived behavioral control (PBC1 and PBC2). See Table A1 in the Appendix for the specific survey question verbiage. This decision was justified because the corresponding survey questions for both the attitude items and the perceived behavioral control items assessed similar beliefs with very similar underlying distributions. The two attitude items that covaried likely measured a different facet of attitude than the third attitude item (Ajzen & Driver, 1991; Wan et al., 2017). The same is true of the PBC questions where the first two measured control over the decision while the third measured the ability to perform the behavior. Additionally, other studies have likewise found covariates between items of attitude, norms, and perceived behavioral control (Leandro, 2012) and beliefs (Lam & Hsu, 2004). However, given

that removing one of each item is another approach, models were also evaluated in which one attitude and one perceived behavioral control item were removed; the fit statistics did not vary widely and the results of the magnitude, directionality, and significance of the latent variable relationships remain the same. With these covariance adjustments in the model, the baseline model met all required fit statistics (see Oehman 2021 for SEM results with and without the error covariances added and with attitude and perceived behavioral control items removed).

Next, an extended model was built to include the additional constructs discussed above. The TPB allows for additional factors to be added to the model to increase the variance explained in intention, and also states that constructs such as experience may be background factors whose influence on intention may be mediated through the core constructs of attitude, subjective norm, or perceived behavioral control (Ajzen, 2012; Fishbein & Ajzen, 2010). The extended TPB literature review suggested several potential structural relationships wherein the additional constructs directly influenced intention (Graham-Rowe et al., 2014; Khan et al., 2019; Nguyen et al., 2015; Russell et al., 2017; Wan et al., 2012; Xu et al., 2020) or their effect was mediated through the main constructs (attitude, subjective norm, and perceived behavioral control) (Heidari et al., 2018; Heiny et al., 2019; Kumar, 2019; Rathore & Sarmah, 2021; Wei et al., 2021; Xu et al., 2017; Yuan et al., 2016; Zhang et al., 2010).

Because the literature review provided a theoretical basis for both direct and mediated models, both approaches were evaluated based on fit statistics and the proportion of variance of intention explained by each model (Huh et al., 2009). This approach to model comparison is consistent with related TPB literature (e.g., Botetzagias et al., 2015; de Leeuw et al., 2015; Graham-Rowe et al., 2014; Heidari et al., 2020, 2018; Heiny et al., 2019; Wan et al., 2021; Xu et al., 2020). Of the constructs added to the extended model, only yuck factor had a significant direct association with intention, a structure that was tested on the basis of past observations that negative emotions and disgust have a direct relationship with intention (Olsen, 2001; Russell et al., 2017). Conversely, such negative emotions may also be thought to inform the experiential dimension of attitude (Wan et al., 2017), but yuck factor was insignificant when mediated by attitude. All of the other additional constructs were then tested as background factors mediated by the core TPB constructs (Heidari et al., 2020; Heiny et al., 2019). Of all models tested, the baseline and extended models with the best fit statistics and the highest predictions of intention, R-squared value (de Leeuw et al., 2015; Huh et al., 2009) were selected and discussed in the Results (see Oehman 2021 for model comparisons).

Second, a Multiple Indicators Multiple Causes (MIMIC) model was developed to identify the most important beliefs underlying the core constructs of the TPB (Finch & French, 2015; Kline, 2016). MIMIC models are fitting when latent constructs are measured using reflective (direct) and formative indicators (belief expectancy-value products) (Borges et al., 2016). The expectancy-value product was calculated as a multiplicative composite of behavioral beliefs (b_i x e_i) where b_i is the behavioral belief about the expectancy of outcome ($_i$) of the behavior, and e_i is the evaluation of the ith outcome (Ajzen, 1991, 2006; Morais et al., 2017). This same calculation was performed for each belief in the subsequent categories (descriptive norm beliefs, injunctive norm beliefs, and control beliefs).

Following the approach of Borges & Oude Lansink, (2016) and Morais et al. (2017), three individual MIMIC models were tested to determine which behavioral, normative, and control beliefs (as expectancy-value products) had significant correlation (at $p < 0.05$) with ATT, SN, and PBC, respectively. In cases where a belief might theoretically associate with multiple belief categories, they were tested in each of the three individual models, but only retained for relationships that were significant (Borges & Oude Lansink, 2016; Morais et al., 2017). During this process, none of the beliefs related to odor, mess, pests, or container cleaning were found to significantly correlate to their theorized construct (PBC) or any other constructs. This motivated the evaluation of yuck factor as a standalone construct as discussed earlier.

Finally, the models described above were reformulated and tested for respondents that were divided into two groups: those with and without experience separating food waste in the past year (12 months preceding the survey) similar to the approach from Stöckli & Dorn, (2021). This analysis was motivated by the understanding that past behaviors can influence individuals' beliefs and intention (Ajzen, 1991) and because of the opportunity presented by responses that were relatively evenly divided: 307 respondents were "separators" and 342 respondents were "non-separators" (see SI Section 2 for additional details on making this distinction). All of the above modeling steps (CFA, SEM, and MIMIC models) were repeated in the same ways described above, but applied independently to the two data subsets. The models exhibited acceptable goodness of fit statistics, except for the SRMR, which was high for both of the models. Investigation of the models' residuals revealed many underlying relationships between the expectancy-value belief products, which is perhaps unsurprising given the potential for interaction among individuals' beliefs (Ajzen, 1991) and between model constructs (La Barbera & Ajzen, 2020). These interactions were not explored here, both to avoid overspecification of

the model and to focus on the primary goal of assessing utility of TPB for explaining food waste separation intent, but this remains an important area for future study.

In parallel, additional statistical analyses were carried out to test the significance of key differences between separators and non-separators. Wilcoxon rank sum tests (Mann & Whitney, 1947; Wilcoxon, 1945) were used to determine statistical difference between the two groups in their responses to the statement, “I want to separate household food waste but there are reasons why I can’t” and a question as to whether they owned or rented their home. The groups were also compared based on the choice of terms respondents strongly associate with household food waste separation (Figure 5) and their responses to survey questions about whether specific control beliefs make it easier or harder to separate (Figure 6).

3. Results and Discussion

The results presented here demonstrate the efficacy of using the TPB to predict intention to separate household food waste and establish the relationships between key beliefs that enable and hinder separation intent. Results also compare the underlying factors that vary between individuals with and without prior experience separating household food waste (Table 2.1). Discussion of these results focuses on opportunities to leverage beliefs and behaviors to increase participation in food waste diversion efforts.

3.1 Predicting Intention to Separate Household Food Waste

The first goal of this study is to determine if the TPB model could predict individuals’ intent to source separate household food waste. The baseline TPB model accounts for 67% of the variance in respondents’ intention to separate (Figure 3). All three of the base constructs – attitude (Alpha = 0.89, CR = 0.89, AVE = 0.74), subjective norm (Alpha = 0.89, CR = 0.89, AVE = 0.74), and perceived behavioral control (Alpha = 0.82, CR = 0.83, AVE = 0.62) – exhibited good fit and had a significant, positive correlation with intention. However, perceived behavioral control and subjective norm both had the highest correlation with intention ($\beta = 0.39$ for each), indicating that individuals’ behavioral intention is equally linked to their perceived ability to carry out the act of separating food from the rest of their waste and to the social pressure they feel to engage in this behavior. These findings are consistent with other studies that have found the TPB to predict intention to reduce food waste (Russell et al., 2017), separate kitchen waste

(Ghani et al., 2013; Yuan et al., 2016), and source separate municipal waste (Heidari et al., 2018).

However, other studies have found that food waste behaviors were strongly influenced by other constructs, including moral norm (Neubig et al., 2020; Yuan et al., 2016), environmental awareness (Graham-Rowe et al., 2015), and knowledge (Abdelradi, 2018), suggesting that an extended TPB model may offer additional explanatory power. Therefore, we also tested an expanded TPB model that included constructs and background factors verified by the CFA: moral norm, yuck factor, natural living habits, and recycling habits. The expanded model explained 69% of variance in intention, a slightly higher correlation than that of the baseline model (Table 2.2), but with slightly lower fit statistics. The extended model may provide further insight useful for informing solutions and interventions, as it establishes additional factors and relationships that could be leveraged to influence behavioral changes.

Table 2.2. Fit statistics analyzed for the Baseline, Extended, and MIMIC TPB models, for the entire population (first three columns of results) and for the sub-populations divided based on food waste separation experience within the past year (last two columns of results).

Model description	Baseline model	Extended model	MIMIC model	Separators MIMIC model	Non-separators MIMIC model
R-squared of Intention	0.671	0.694	0.680	0.796	0.363
CFI (>0.9)	0.993	0.957	0.957	0.944	0.938
TLI (>0.9)	0.989	0.949	0.951	0.935	0.929
RMSEA (<0.08)	0.037 (p-value = 0.978)	0.052 (p-value = 0.211)	0.055 (p-value = 0.050)	0.064 (p-value = 0.004)	0.064 (p-value = 0.001)
SRMR (<0.08)	0.031	0.054	0.084	0.114	0.119

In the extended model, the construct of yuck factor has good fit (Alpha=0.83, CR= 0.88, and AVE=0.60) and a significant, negative correlation with intention to separate (b= -0.13). This construct captured beliefs that separating food waste will lead to a negative visceral experience or outcome, such as noxious odor, pest attraction, and messiness in the home. While these beliefs were originally theorized as influencing behavioral control, the results of the CFA and MIMIC model (see Section 2.4.1 and 2.4.2) showed a poor fit in that structure. These beliefs were also tested as determinants of attitude, particularly the measurement related to the pleasant or unpleasant experiences of separating food waste (ATT3) but were also found to be insignificant in that structure. However, future study is required to differentiate how beliefs

related to disgust inform experiential dimensions of attitude (Wan et al., 2017) as opposed to behavioral controls or separate constructs that capture negative emotions (Olsen, 2001; Russell et al., 2017).

The importance of the “yuck factor” was consistent with views frequently raised during the elicitation interviews. For example, one interviewee stated, “the odor was just too much” and another, “pricing is not what prevented us from doing it; it was probably habit and concern over smell.” Past work has likewise documented that odor can be a major barrier to participation in curbside collection and organic waste diversion programs (Benyam et al., 2020; Pickering et al., 2020) and that potential for pest attraction may limit municipal recycling (Tonglet et al., 2004). One study assigned beliefs about the outcomes related to odor and bones from seafood consumption to “negative emotions” (Olsen, 2001), but the concept of yuck factor associated with household food waste goes beyond emotion and includes the added physical elements of dealing with food waste, such as physically handling food scraps or spoiled foods. Unappealing appearance, touch, smell, and taste are reasons people throw out food (Andrews et al., 2018) and find leftovers unappetizing (Evans, 2011). This study further adds to this literature by demonstrating how concerns that food waste is “gross” may be a barrier to broader participation in food waste separation and recycling efforts and by highlighting the need for future study to evaluate strategies to overcome these concerns.

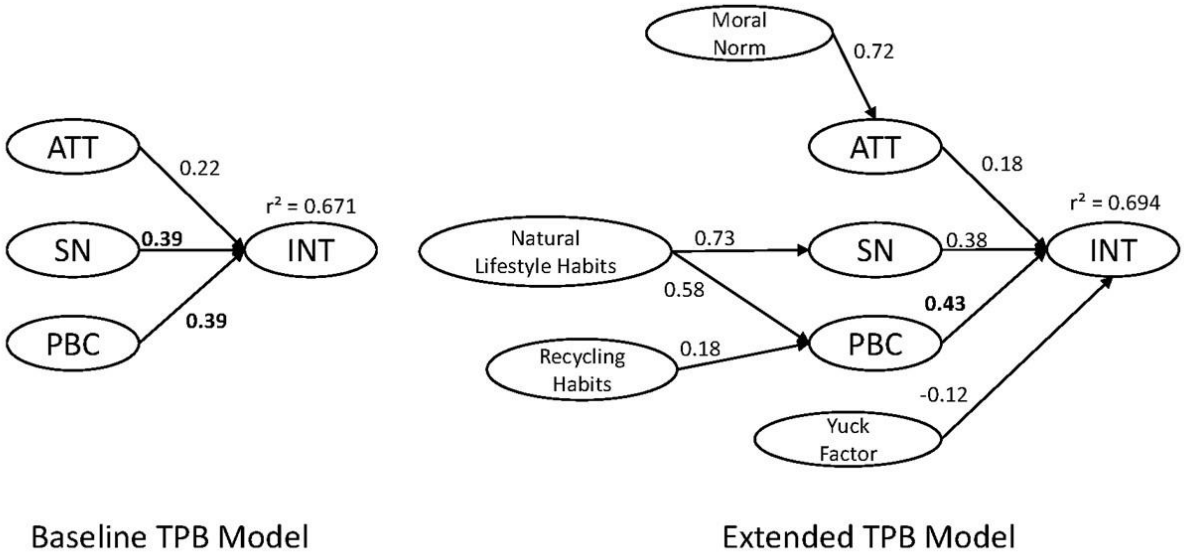

Figure 2.2. Structural models represented the Baseline (left) and Extended (right) TPB models. ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, INT = intention, MN = moral norm; NLH = natural living habits; RH = recycling habits; YF = yuck factor. The values shown on each line are the standardized beta coefficients, or the correlations between the latent variables. The r-squared value for intention was 0.671 in the baseline model and 0.694 for the extended model. All structural relationships shown are significant at $p < 0.05$ (insignificant structural relationships are omitted). The bold type indicates the highest correlation with intention. Covariances between error terms are not pictured.

The extended TPB model also determined that moral norm (β = 0.72, Alpha = 0.88, CR = 0.88, AVE = 0.67) is a background factor mediated by the construct of attitude. Respondents appeared to assign moral value to food waste separation due to feelings of obligation, guilt over sending food to landfill and potentially harming the environment, and a responsibility to recycle food waste as a way of benefiting future generations. Yet even with these strong underlying beliefs, the construct of moral norm did not have a significant direct correlation with intention. This finding is consistent with a comparable study on separating food waste in China, which also found that moral norm informed attitude but did not directly inform intent (Yuan et al., 2016). On the other hand, several studies dealing with food waste reduction have observed a much stronger link to moral norm as an activator of behavior changes that may lead to food waste prevention (Graham-Rowe et al., 2015; Neubig et al., 2020). These differences suggest that morality plays a different role influencing individuals depending on whether they are reducing or separating food waste. In fact, individuals may feel less guilty or responsible for wasting food if they know it is going to ultimately be diverted from the landfill (Qi & Roe, 2017).

The distinction between feeling guilt from wasting food and relieving guilt by separating food from the trash was echoed in the elicitation interviews. One respondent indicated, “I feel good about composting my food scraps instead of throwing them away” and another, “I think just knowing that we’re not putting things in the landfill that we might have put in before makes me feel a little less guilty.” Yet these feelings do not seem to be enough to overcome other barriers that consumers face, including behavioral controls and the yuck factor. One possible explanation is that feelings of morality are warring with feelings of disgust or unpleasantness as this conflict was noted in studies about individuals’ attitudes and causes of food waste (Radzymińska et al., 2016), and safety concerns associated with generating food waste (Watson & Meah, 2012).

These issues are further informed by background factors related to individuals’ lifestyles and experiences with other behaviors that may be connected to food waste separation. For example, one construct emerged, here termed “natural lifestyle habits,” (Alpha = 0.72, CR = 0.73, AVE = 0.49) which included experience with food- and environmentally-related behaviors like gardening, buying foods at local farmer’s markets, and purchasing green cleaning products. This emerged as a standalone construct that was mediated by both subjective norms ($\beta = 0.73$), and perceived behavioral control ($\beta = 0.58$), likely because of the social pressures that drive actions that form how individuals perceive themselves (Fishbein & Ajzen, 2010). Similarly, the expanded model also included the background factor of “recycling habits” (Alpha = 0.67, CR = 0.67, AVE = 0.51) which included past behavior of recycling both municipal household waste and electronic waste. Recycling habits was mediated by a small but significant correlation with perceived behavioral control ($\beta = 0.18$), suggesting that familiarity with other types of recycling may provide a sense of control and ability to carry out food waste separating, similar to a study that found individuals who participated in municipal waste recycling (glass, paper, and plastic) were less likely to waste food (Abdelradi, 2018) and that current food waste habits influence future intentions to reduce food waste (Riverso et al., 2017). Collectively, these habits may be considered “gateway behaviors” (Prochaska et al., 2008; Sheppard et al., 2012) that nudge people towards participating in similar activities through “positive spillover,” which occurs when one pro-environmental behavior increases the likelihood people will perform another (Thomas & Sharp, 2013). For example, household recycling was found to be the initial behavior that motivated consumers to later adopt water and energy conservation behaviors (Berger, 1997). Following this example, food waste separation, collection, and recycling may be more easily

adopted if modeled after the familiar curbside recycling pickup systems. Similarly, positive spillover can be encouraged by co-locating food waste educational activities or drop-off sites at farmers' markets, gardening events, or other locations focused on natural living and green products. The impact of living in urban versus rural areas was not evaluated within the context of this study, but is an additional local infrastructure piece that could impact individuals' intention to separate.

3.2 Identifying Underlying Beliefs that Influence Food Waste Separation Intent

The core constructs comprising the TPB model were further investigated using a MIMIC model to identify the underlying beliefs most strongly associated with behavioral intention (Figure 2.3). The TPB MIMIC model's fit statistics met all of the requirements (Table 2.2). These results show that the most important beliefs informing attitude are those that reflect individuals' concern for the environment and a desire to reduce waste disposal. This finding is consistent with past work linking environmental concerns with attitude regarding source separation of waste (Heidari et al., 2018), kitchen waste separation (Yuan et al., 2016), wasting food (Abdelradi, 2018), and other household waste separation (Nguyen et al., 2015). One challenge, however, is that these beliefs are linked with relatively intangible and uncertain future environmental outcomes, whereas beliefs about the cost, space required, messiness, or anticipated unpleasantness of handling food waste are immediate, tangible barriers that consumers may not be equipped to overcome.

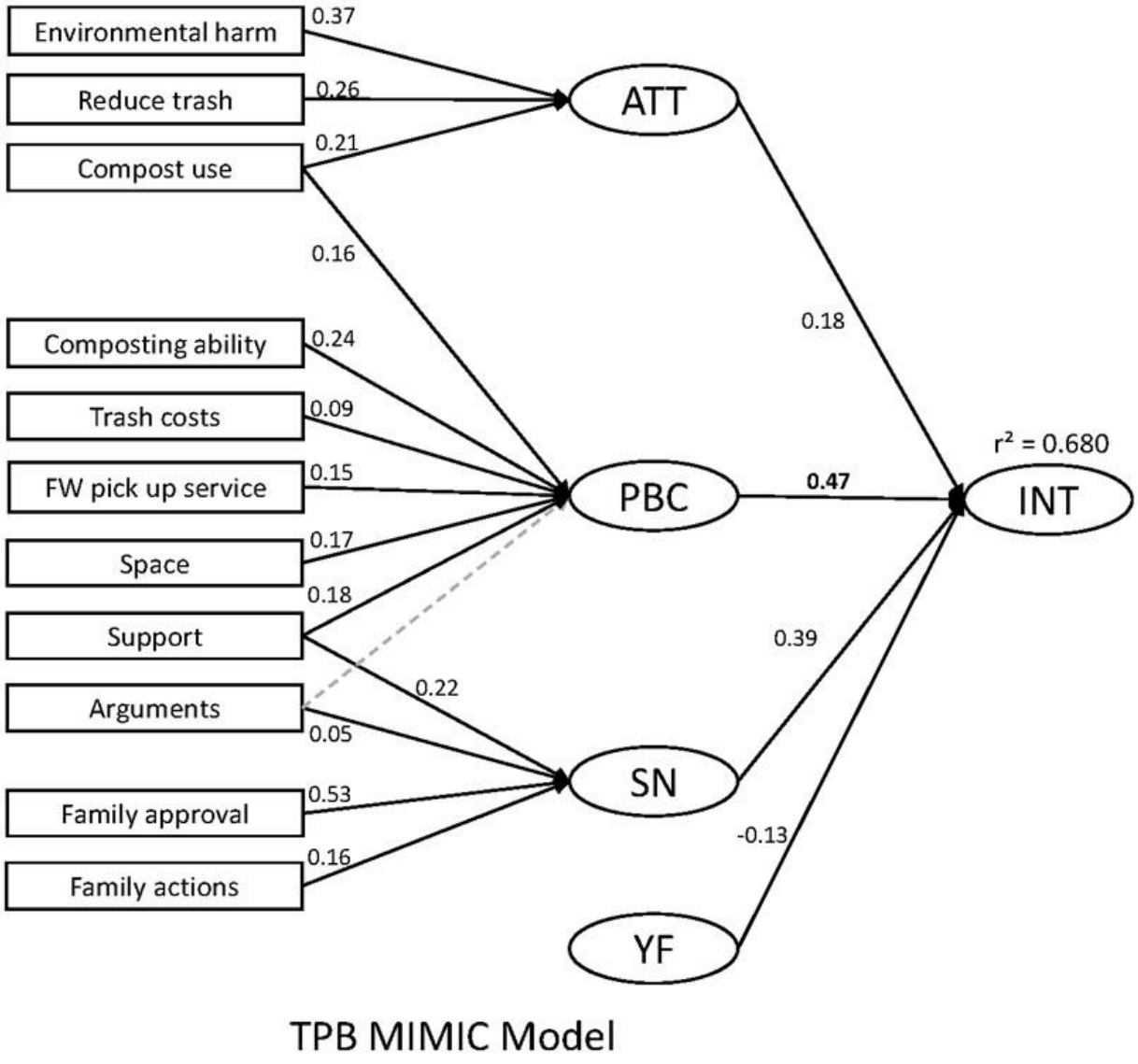

Figure 2.3. The TPB MIMIC model highlighting individuals' important beliefs for each respective TPB construct. ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, YF = yuck factor, INT = intention. The values shown on each arrow indicate the standardized coefficients. Only those beliefs that were significant when tested against each individual construct were carried over to the integrated model shown here; some were then found to be insignificant for the integrated model and are shown here with a broken line. The bold type indicates the highest correlation with intention.

The role of family and other household members also emerged as significant drivers of individuals' behavior. The beliefs with strongest correlations with subjective norm included

having family approval for separating (β = 0.53) and knowing family members who already separate their own food waste (β = 0.16). We also asked survey respondents if they would have support within their household to separate food waste and if separating would lead to arguments in the home (which may not only be comprised of family members). A significant correlation was observed between household support and both subjective norm (β = 0.22) and perceived behavioral control (β = 0.17). In the elicitation interviews, participants often noted the challenge of unsupportive household members: “My family is kind of against it, they reluctantly cooperate” and “I want to do it, but it’s my husband, he’s not on board with the idea.” Overall, the results confirm that individuals experience social pressure to perform a behavior when their respective “in-group” support or also perform the behavior (Cialdini et al., 1990; Terry & Hogg, 1996). These findings suggest opportunities to leverage family relationships and household support, such as marketing household food waste separation as easy, convenient, fun, and feasible for any member of the household.

Many of the strongest correlations were observed for beliefs related to situational factors or food waste management infrastructure. In the MIMIC TPB model, the important beliefs informing perceived behavioral control are related to adequate space for composting, reducing household trash costs, and having access to a food waste pickup service (Figure 2.3). These results suggest that emerging business models that collect food waste from homes can increase an individual’s ability to separate food waste, particularly if space for home composting is limited (Layzer & Schulman, 2014). These services typically provide a collection container, handle the transportation and cleaning, and manage the food waste through composting or other processes, thus eliminating the practical barriers that may arise when setting up a home composting system, as well as the messiness and odor issues associated with cleaning a food waste collection container (Yepsen, 2015). In fact, 94% of respondents indicated that having a food waste service as defined in the study would make it easier for them to separate. The cost of separation was tested as a control belief in the study, but was not significant in the MIMIC model. Future work should specifically investigate consumer preferences regarding the cost to participate in these services relative to the perceived benefits.

3.3 Underlying Beliefs are Different for Separators and Non-Separators

The survey analysis demonstrated that approximately half of respondents had routinely separated household food waste in the last 12 months. This natural division in the data provided

an opportunity to explore how underlying beliefs and behavioral intentions vary between individuals with and without direct experience with food waste. Model construction and analysis were repeated separately for “separators” (n = 307) and “non-separators” (n = 342), resulting in two TPB MIMIC models for comparison (Figure 2.4). The model for separators explained 80% of the variance in intent to separate, while the model for non-separators only explained 30% of this variance.

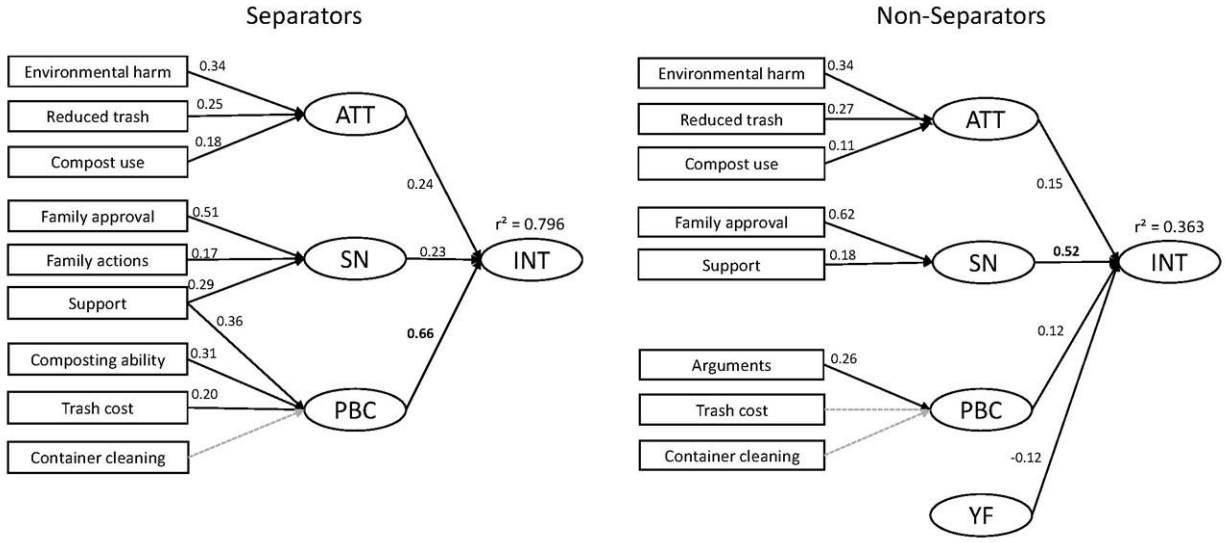

Figure 2.4. The MIMIC models for past household food waste separators (left) and non-separators (right). ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, YF = yuck factor, INT = intention. The values shown on each arrow indicate the standardized coefficients. Only those beliefs that were significant when tested against each individual construct were carried over to the integrated model shown here; some were then found to be insignificant for the integrated model and are shown here with a broken line. The bold type indicates the highest correlation with intention.

One major distinction between these groups was a differing belief in their own ability to separate food waste. Separators have a strong sense of control over food waste separation, and perceived behavioral control is the main predictor of intention (β = 0.66). Having the ability to compost the separated food waste is the most important belief informing this construct for separators (β = 0.32). While the TPB model for non-separators only showed a small correlation of perceived behavioral control with intention (β = 0.12), this construct had relatively low explanatory power (r^2 = 0.06), suggesting that there may be other constructs or underlying beliefs not captured here that influence non-separators. These results also suggest that interactive effects that were not tested in the additive TPB model may be occurring. Recent work has shown that greater perceived behavioral control can strengthen the relationship

between attitude and intention while lowering the relationship between subjective norm and intention (La Barbera & Ajzen, 2020, 2021). Separators exhibit stronger behavioral control and a stronger relationship between attitude and intention compared to non-separators.

To investigate non-separators' perspectives further, we evaluated the differences in responses between the two groups when asked to select terms they strongly associate with household food waste separation (Figure 2.5). Non-separators described the act of separating as "inconvenient" or "difficult" twice as frequently as separators, who more commonly described it as "easy" and even "fun" (Figure 2.5). Further, non-separators had much higher valuations of key control beliefs as making it harder to separate. For example, more non-separators indicated cleaning a collection container and concerns about space, odor, pests, and messiness in the home (Figure 2.5) would make separating a lot harder. These findings mirror a recycling study in the EU, which found that people who did not sort their waste were more concerned about convenience factors (Minelgaitė & Liobikienė, 2019).

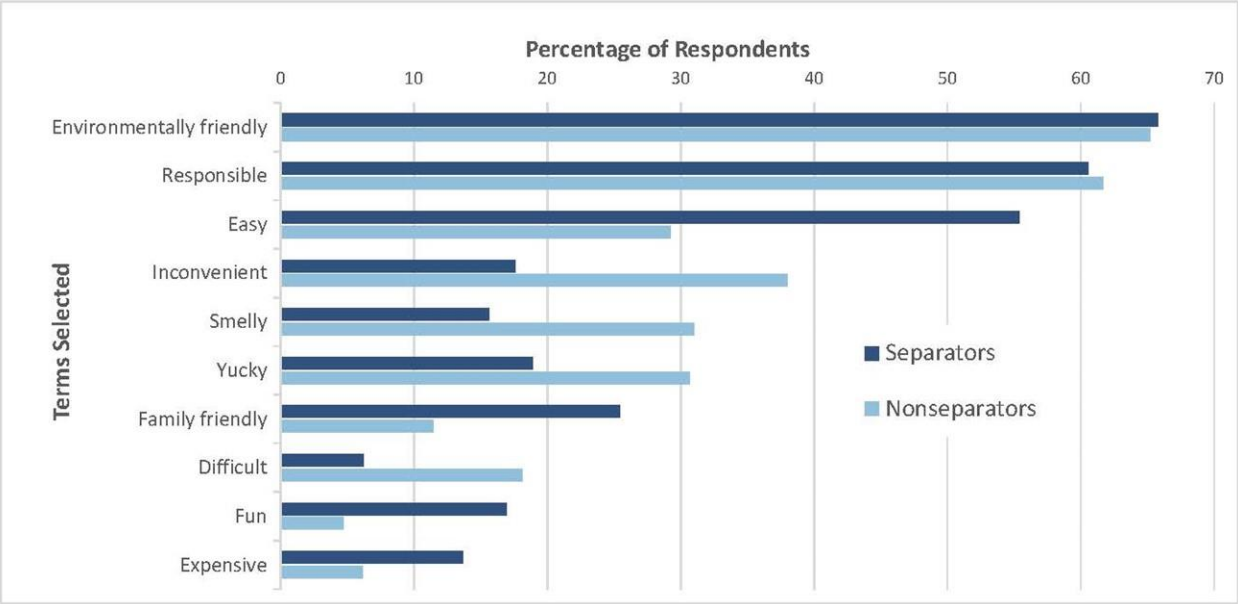

Figure 2.5. The percentage of separators (dark bar) and non-separators (light bar) who selected each descriptive word to describe the idea of separating household food waste. Values reflect the percentage of respondents who selected the descriptor as one of three choices from a list of terms they might associate with food waste separation.

Some initial comparisons may help provide additional interpretation on the differences between the two groups. When presented with the statement, "I want to separate, but there are reasons why I can't," non-separators indicated that this statement describes them significantly

more when compared to those who had source separated food waste in the last year (Wilcoxon rank sum test: w = 58830, p-value = 0.0058, where w is the test statistic and the p-value indicates significance at alpha = 0.05). Thus, non-separators may face different barriers or factors outside of their control. For example, separators were significantly more likely to own their home, and non-separators were significantly more likely to rent (w = 60266, p-value = 2.7E-6). Home ownership may allow separators to have more control over kitchen set-up to collect food scraps or access to outdoor areas that provide space for composting. These differences may also be a consequence of the size and space of the living quarters or the expected concentration of rentals in urban areas with less outdoor areas for composting.
Both separators and non-separators express a positive attitude towards food waste separation as informed by pro-environmental beliefs, but non-separators are far more likely to have negative feelings related to the “yuck factor.” Notably, the yuck factor construct is only significant in the MIMIC model for non-separators (Figure 2.4) and is negatively correlated with intent (β = -0.13). When selecting terms that describe household food waste separation, both groups frequently chose “environmentally friendly” and “responsible,” but non-separators selected “yucky” and “smelly” about twice as frequently as separators (Figure 2.5). Non-separators describe food waste separation as unpleasant at a significantly higher rate than separators (w = 31731, p-value = 2.2E-16) and report that odor, pests, messiness and cleaning a food waste container would make separation more difficult (Figure 7). Non-separators may either have a disproportionate expectation that the behavior is unhygienic because they have never directly experienced it or they have not yet found solutions to manage the challenges of odor, pest attraction and messiness, which separators may have overcome through time and experience.

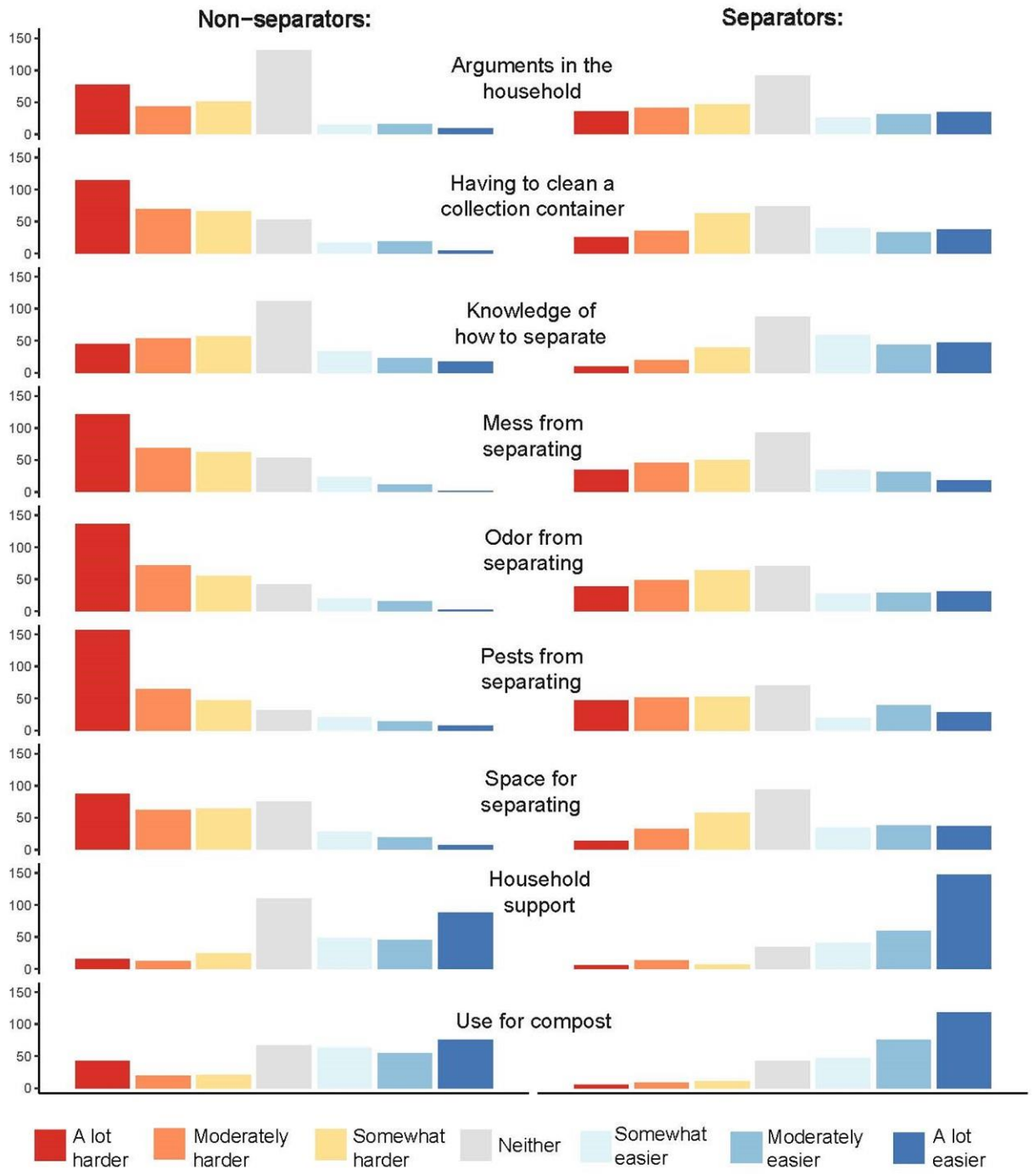

Figure 2.6. A comparison between the control beliefs that separators and non-separators assess to make it easier or harder to separate household food waste. Wilcox tests revealed statistically significant ($p < 0.05$) differences between separators and non-separators for all of the belief categories pictured above, except for “arguments in the household” ($p = 0.057$).

Family is important to both separators and non-separators, but in different ways. For both groups, subjective norm is largely influenced by family approval of separating (β = 0.51 for separators and β = 0.62 for non-separators) and having support in the home to separate (β = 0.29 for separators and β = 0.18 for non-separators). However, the belief about having family members who also separate food waste (family actions) is only important for separators (β = 0.17). Separators were significantly more likely to say that they would separate if their neighbors were doing the same (w = 31996, p-value = 2.2E-16). It should be noted that not all family members are necessarily household members. Therefore, family approval may account for the role of a close type of relationship, but the members may live outside the home. The role support in the home accounts for the role of household members, who may not be relationally close, but are physically close. This finding is consistent with past work that found that individual's involvement in waste separating behaviors could be encouraged by providing information about their neighbors' participation (Ghani et al., 2013). It may also be possible that non-separators know fewer people who actually separate their own food waste: 53% of non-separators reported that they do not have family who separates, and 20% said they don't know if their family separates or not. Since non-separators may desire to change their behavior but lack an example of how to do it, connecting with others who have this experience could provide compelling examples and share best practices and tactics to manage odor and pest challenges.

4. Implications and Extensions

The purpose of this study was to use the TPB to identify the important factors and beliefs that inform individuals' intention to separate household food waste and understand the differences in beliefs held between separators and non-separators. The results point to three areas that might be leveraged to enable food waste separation for landfill diversion: education, business models, and policy. This section further interprets the findings in the context of these potential interventions.

4.1 Potential intervention strategies

Results demonstrate that actions, opinions, and support of family and household members play an important role in shaping an individual's intention to source separate household food waste. Some respondents emphasized their children as inspirations or catalysts for separating food waste, with one interview subject noting "my kids compost at school, so we

do it at home." In fact, households with children in the home were significantly more likely to have source separated household food waste in the past year ($w = 62677$, $p = 3.55E-14$). Thus, educational interventions in primary and secondary schools may present an opportunity to indirectly influence households' food waste practices (Ohshima, 2013) by educating their children about food waste impacts and separation practices (Antón-Peset et al., 2021). Informal education may also play a role to convey the environmental benefits of food waste management as a means to foster participation in pro-environmental behaviors (Lemaire & Limbourg, 2019) as past work has documented correlations between educational efforts and behavior (Aschemann-Witzel et al., 2015). However, education alone is not enough to help people overcome barriers to perform a behavior (Wilson, 1996), rather, informal knowledge sharing through face-to-face interactions (Bernstad et al., 2013) and word-of-mouth (Qi & Roe, 2016), either in person or online (Goldsmith & Goldsmith, 2011; Wharton et al., 2021), may be more effective in increasing engagement and participation. Leveraging these communication practices, while at the same time engaging family and household members, could help non-separators learn methods to overcome the reality of nuisances, like pests and odor.

Results also suggest that the availability of food waste pick-up services may facilitate source separation by increasing individuals' perceived ability to handle wasted food (Figure 3). Residential food waste collection programs remove the responsibility of downstream management of the food waste from the individual and may overcome the beliefs that separation will lead to odor, mess, pests, or having to clean a collection container, all of which are significantly higher for those who do not currently separate food waste (Figure 6). These programs may also address some of the structural barriers noted earlier, like concern over space for separating and ability to separate in a rental home. Thus, there is an opportunity for new circular business models that provide a convenient way for consumers to divert waste from landfill, while at the same time recovering the resources contained in wasted food (OECD, 2018), and creating added value within a community (Bocken et al., 2021). These services, offered by municipal programs and private companies, are available throughout NYS and nationally (CompostNow, 2021). Food waste services are relatively new business models and have a wide array of operational modalities (Yepsen, 2015). Ongoing research is needed to understand how these businesses can contribute towards a circular economy (Närvänen et al., 2021) and if and how their service models are likely to help individuals overcome participation barriers for household food waste separation.

Such services may also enhance consumer participation if they simultaneously provide feedback about environmental outcomes of landfill diversion. Here, we show that pro-environmental beliefs contribute to individuals' positive attitudes (Figure 3), but suggest that these may not be sufficient to overcome practical barriers of handling food waste. Thus, the method and form of conveying information should go beyond environmental messaging. Types of consumer feedback that have been successful at increasing participation in waste management schemes include economic rewards (Xu et al., 2018), technology feedback (i.e. smart bins, bin-cams, and fridge-cams) (Bandyopadhyay & Dalvi, 2017; Comber & Thieme, 2013; Ganglbauer et al., 2013; Lim et al., 2017) and gamification (Soma et al., 2020). Social group feedback, also called norm messaging (Sintov et al., 2019; Thomas & Sharp, 2013), has been effective to motivate consumers to participate in energy saving behavior (Allcott, 2011). This technique may be extensible to food waste behavior if consumers can see how their separation behavior compares to that of their neighbors. Food waste pick-up services may ultimately turn what has previously been a private behavior (home composting) into a more a visible behavior by putting food waste collection containers at curbside for pick up or facilitating drop-off at high visibility locations. Future research should investigate how food waste businesses communicate to consumers and what types of feedback strategies, if any, are most successful.

Circular business models, like food waste pick-up services, have the potential to meet consumer and community food waste management needs, but cost may also be a factor (Figure 3). Past work has shown that the net cost of residential food waste services will significantly decline once a certain density of participation in a city or neighborhood is achieved (Armington & Chen, 2018). But overcoming the initial economic hurdles may require initial government investment or policy support. Currently, however, the majority of policy efforts in the U.S. do not cover residential food waste management. For example, policies including organic waste recovery mandates and landfill bans have been enacted in six states, but these typically only require compliance by large commercial and institutional food waste generators (Leib et al., 2018). However, such policies may indirectly benefit residential service through expansion of transportation and treatment infrastructure that ultimately reduces costs of landfill diversion pathways for households as well. For example, state investment in food waste infrastructure (Shahid & Hittinger, 2021) may reduce costs of currently inefficient hauling and collection systems (ReFED, 2016) and remove regulatory barriers that stunt the growth of businesses and

programs targeting household food waste (Pai et al., 2019). However, more research is required as the impact of government mandates on residential food waste collection and management business and programs in the U.S. has not been widely studied.

4.2 Limitations and future work

One limitation to the use of the TPB model is the focus on measuring behavioral intention rather than assessing the behavior itself, although this approach is typically necessary due to the time and difficulty involved in directly measuring certain behaviors (Ajzen, 1991). Intention is the first precursor to behavior, and here we do see a significant, positive correlation between self-reported separation behavior in the last 12 months and intention to separate food waste in the next year (b=0.89). However, precedent and intention do not guarantee that the behavior will actually be implemented in the future (Sheeran, 2002). Ideally, longitudinal studies would subsequently be conducted to directly assess household food waste separation before and after the implementation of proposed intervention strategies. Further, the results suggest a need for more study specifically focused on individuals with no past experience separating food waste to identify beliefs and barriers not yet captured here. The R-squared value for perceived behavioral control for non-separators was very small, with only one significant underlying belief, suggesting that there are additional or more varied beliefs that inform these individuals' sense of control or ability to separate.

This study investigates the beliefs and factors influencing individuals' intention to separate in a specific region of the U.S., a scope selected to control for regional variability in food waste infrastructure and policy, which may influence how consumers view or experience source separation. However, by focusing on one state, even one as large and as geographically and culturally diverse as NYS, the findings may not be fully generalizable to other regions. Additionally, while efforts were made to mitigate and detect common method biases, some uncertainty is introduced by using questionnaire data collected from common raters, although this too may be addressed through future studies that more directly measure behavior. Survey respondents were recruited through a panel in to fulfill demographic quotas to match reported 2019 NYS percentages (for ethnicity, gender, and age), but opportunistic sampling also took place via social media platforms, which led to a small subset of data that skewed slightly higher than the NYS distribution for non-Hispanic white adults and females and respondents with college education (Table A3). Future work can extend this analysis to evaluate the beliefs and

factors influencing individuals' separation intention in other geographical areas with different policy, infrastructure, and demographics. This could include accounting for the effects of rural versus urban living. Lastly, the issue of food waste separation seems to hit on many different issues for respondents and the covariance between items that we observed seems to suggest that respondents react to different components of attitude when they think about household food waste separation. Future work could validate these and additional measures of the TPB for household food waste separation.

5. Conclusion

Landfilled food waste creates a wide array of social, economic, and environmental impacts that may be mitigated by alternate management pathways. However, landfill diversion hinges on consumer willingness to source separate food waste that can then be recovered either by home composting or by businesses who collect and handle wastes for them. The TPB models presented here provide new insight into individuals' underlying beliefs and the factors that may ultimately help or hinder household food waste separation. The TPB model was found to predict intention to separate household food waste, and provide additional insight by adding the new construct of yuck factor (the unhygienic challenges of food waste separation) and the background factors of moral norm and natural living and recycling habits. When investigating underlying beliefs that inform these constructs, results show that individuals express positive attitudes and a desire for the pro-environmental benefits of food waste separation, but also face situational barriers that limit their perceived practical ability to participate in this behavior. Barriers to food waste separation include structural issues, such as lack of knowledge or space for food waste collection containers, as well as more personal concerns, such as the belief that food waste will lead to odor or pests in their home or arguments among household members. Those individuals with experience separating food waste had a significantly higher sense of control and ability to perform this behavior, suggesting that they have developed strategies to overcome the so-called "yuck factor" or have realized these concerns are not as bad as non-separators may fear. Overcoming these barriers will require intervention strategies that expand knowledge on how to effectively source separate household food waste and benefits of doing so as well as efforts to expand policy and infrastructure to increase collection services and reduce costs of participating. The recent emergence of business and municipal services that provide

household food waste pick-up in the U.S. provide a compelling opportunity to study if these strategies can meaningfully engage consumers in landfill diversion solutions.

Chapter 3: The operations and challenges of community composting business models

Research question: *What are the operations and challenges of residential food waste pickup services?*

1. Introduction

In the last chapter, the important factors and beliefs that influence an individuals' intention to separate were identified. As part of the findings, respondents reported that access to a household food waste pickup service would make it easier to separate their household food waste. In this chapter, the focus pivots from the consumer to the firms providing household food waste collection and management services.

At the intersection of residential food waste solutions and industry is an emerging business model in which residential food waste is collected for composting in exchange for a fee. These businesses aim to collect and compost residential food waste to provide convenience to consumers and have the potential to make it easier for consumers to separate their household food waste (Oehman et al., 2022). Food scraps recovery through private, community composting organizations represents an innovative and growing sector of the circular economy. In 2014 Biocycle identified 198 communities with curbside collection of food waste, noting that many more communities were served by independent organizations contracting directly with households for food waste collection (Pollans et al., 2017; Yepsen, 2015). In 2021, Biocycle identified 124 privately operating household subscription services. However, organics waste recycling has been studied primarily at the municipal level (Parizeau et al., 2015; Pinkerton, 2021; Pollans et al., 2017), with little research to date on the private organizations offering household food waste management solutions direct to consumers.

Resource recovery of food scraps through compost offers a solution to mitigate the environmental effects of food waste while providing economic benefit (Farhidi et al., 2022). All the efforts to reduce wasted food are necessary to minimize the material, but unavoidable residential food waste will persist from vegetables and meat trimmings that are inedible (Pollans et al., 2017). Composting this material as an alternative to landfilling, enables resource recovery, the next step in the EPA hierarchy after food rescue, reduction, and animal feed (US EPA, 2015). Composting organic material creates value by reducing carbon emissions (Farhidi et al., 2022), returning valuable nutrients to the soil (Ayilara et al., 2020; US EPA, OSWER, 2018), and thereby supporting the circular economy (Adhikari et al., 2010; Bekchanov & Mirzabaev, 2018; Farhidi et al., 2022; Tamasiga et al., 2022; Usmani et al., 2021). However,

research has shown consumers face a lot of barriers to composting their own food waste such as a lack of time (Wu et al., 2019), space (Purcell & Magette, 2011), and knowledge about composting (Taylor & Todd, 1995).

Firms, sustainable entrepreneurs, and innovative business models must be implemented to support the circular economy (Bocken et al., 2014; Planing, 2015; Velenturf & Jopson, 2019; Vermunt et al., 2019). Circular business model research has highlighted external influencing factors, internal motivations, and barriers and opportunities to resource recovery models (Vermunt et al., 2019) in construction (Shooshtarian et al., 2022), textiles and clothing (Todeschini et al., 2017) and electronics industries (Kissling et al., 2013), but community composting has not yet been studied. As a result, little is known about the motivations of the entrepreneurs launching the businesses, factors that influence their service models, or the barriers or enablers to implementing their operations. Sustainable business models value social and environmental outcomes (Bocken et al., 2014; Boons & Lüdeke-Freund, 2013), and sustainable entrepreneurs may prioritize these over economic outcomes (Bocken et al., 2014; Millette, 2019) but it is unknown what the goals of community composting operators and their organizations are and how these influence their priorities.

The community composting business model relies on consumers to provide the food waste material stream, but it is unclear how consumer preferences and needs inform these organizations' service models. Participation in composting is necessary for the circular economy, but only 6.3% of food material is currently composted (EPA, 2017). Consumers indicate positive sentiment towards participating in circular economy solutions, but lack knowledge about separating their food waste (Ghani et al., 2013; Li et al., 2021; Pickering et al., 2020) and composting (Edgerton et al., 2009). Organizations such as these that remove the composting responsibility from the individual could make it easier for people to separate their waste (Babbitt et al., 2021; Oehman et al., 2022). Consumer education and interventions like designing convenient infrastructure to align with consumer habits (Bernstad, 2014; Ghani et al., 2013) have been shown to positively influence individuals' participation and help them overcome their barriers. However, it is unclear how these community composting organizations engage with or educate consumers. Furthermore, individuals are not reliable at creating a clean stream of material, a cited issue for household resource recovery (Hoornweg & Bhada-Tata, 2012), but it is unknown the extent to which these organizations deal with this issue, or how they overcome it.

Community composting is a resource recovery business model representing new infrastructure, the constraints, barriers, and enablers of which are unknown. While the

operational challenges of managing compost facilities, like difficulty navigating composting regulations and working within established centralized waste management infrastructure (Pai et al., 2019), and a lack of available land and space for composting (Platt, 2015) have been documented, little is known about the specificities of the collection and hauling portions of these businesses. Residential organics waste collection can face capacity, growth, and equipment use limits (Clark, 2015) and curbside food waste pickup services benefit from efficient routing (Armington et al., 2020; Arribas et al., 2010) but the role these factors play in community composting business operations has not been established. Other circular business models are inhibited by the financial aspects of high up-front investment costs, and high costs of collection and segregation of material (Vermunt et al., 2019), but it is unclear if these business models face similar barriers. Food waste pickup services employ unique features to process and handle the material, but how these models are determined and if they are profitable has not been determined. With the growth and innovations of this business sector in the last ten years (Pinkerton, 2021), it is clear that to some extent these organizations can operate, but it is unclear how they have adapted or innovated to do so.

To understand the underpinnings of these community composting business models, it is necessary to engage with the expert stakeholders in the field by hearing from the founders and operators themselves to learn about the business from their perspective (Salvioni & Almici, 2020). This study is specifically focused on the emerging community composters that are operating as a private business, to understand the drivers motivating the launch of these businesses, the design of their service models, how they engage with consumers, how they've adapted along the way, and what their goals for the future are. Large companies, such as Casella who list residential organics collection as a service on their website were excluded from this study (*Collection | Casella*, 2023). The nature of this type of information is personal and sensitive in nature. Semi-structured interviews are an effective method for data collection when the goals are to: (1) to collect qualitative, open-ended data; (2) to explore participant thoughts, feelings and beliefs about a particular topic; and (3) to delve deeply into personal and sometimes sensitive issues (Harvey, 2011).

Therefore, the goal of this chapter is to identify ways to support further growth and participation in these types of residential food waste pickup solutions. The novelty is that it is the first study to investigate the challenges, operations, goals, and innovations of food waste pickup services from the operators' perspective. In this chapter, the aim is to understand both the internal operations and external constraints that impact these service models.

2. Methods

We applied an exploratory qualitative research approach to understand the motivations, challenges, and enablers of performing and operating residential food waste pickup services. In this case, the underlying factors impacting the organizations' business models, operations, and decisions are required to answer the research question. Qualitative research explores the what, how, or why (Creswell, 2013) by capturing the perceptions of interviewees. Therefore, semi-structured interviews are a well-suited method to collect this information because they create a comfortable, confidential environment for participants to share information they may deem proprietary or sensitive in nature (Harvey, 2011).

2.1 Participant Selection

The geographic area of focus for this study is the United States. The scope of this study is limited to the private, non-profit, or employee owned (co-op) businesses that contract directly with customers in exchange for a fee for their service; municipalities that are offering residential food waste pickup services were outside the scope of this study. To create a sample pool of potential interviewees, a list of community composting organizations was generated in 2021 from the following publicly available websites: CompostNow.org (CompostNow, 2021) and ILSR.org. These two websites yielded a total list of 154 unique organizations in 2021. This list served as the preliminary sample pool to support the interviews, and the starting point for the database for the Market Analysis in Chapter 4, although ultimately the lists in each chapter are different.

For each organization listed on these websites, the individual company's webpage was visited to collect the following descriptive information: (1) active/inactive status, (2) email address to contact (or it was noted if the website only had a form to fill out for contact), (3) if residential curbside pickup was offered, (4) the year the company started (if this information was provided), (5) the state the organization was operating in, (6) if the organization operated in multiple states, and (7) if the website indicated the organization operated using bicycle for pickup.

All of this information was collected and used to inform the interview sampling approach. The list of organizations was filtered to include only organizations offering residential curbside food waste pickup. In total, 149 companies were identified as offering this service, and this list formed the original sample pool (five organizations were removed that did not offer residential food waste pickup). The organizations on the shortened list met the following criteria: (1) provide curbside pickup of household food waste, (2) are geographically diverse throughout the United

States, (3) are representative of operations both new and established, (4) are representative of different sizes of operations (e.g., multi-state versus single-state operations), (5) include some organizations that operate only on bicycles, a feature seemingly unique to these organizations, and (6) are both active and inactive. Some organizations were no longer operating, but these were kept on the list as potential interview subjects as learning why they closed and hearing their perspective about their operations would be applicable to the goals of this research.

The organizational criteria were used to inform a theoretical sampling approach for participant selection. In the analysis method described below, data collection (interviews) and analysis occur at the same time (Figure 3.1). The data is collected and analyzed, and the preliminary emerging themes inform which stakeholders to interview next to achieve adequate data representing the broader sector of interest (Charmaz, 2006). For example, during the data collection and analysis process, few organizations operating in the south were represented in the sample, so, a round of solicitations focused on organizations operating in the southern region of the US was performed (US Census Bureau, 2023). To support this round of solicitations, 12 additional organizations located in the Southern region of the U.S. identified on Litterless.com (*Where to Compost*, 2022) were added to the original sample pool of 149, bringing the final total interview sample pool to 161. This data collection process via interviews continued until information saturation is reached, or no new information was learned through the data sampling and analysis process.

2.2 Interview Protocol

A semi-structured interview protocol was developed to collect information about the business' operations from an interviewee's perspective (Castillo-Montoya, 2016). In this type of protocol, the interview questions serve as a guide to elicit discussion of specific topics, but if and when appropriate, other questions may arise during the course of the interview. The protocol began with a brief overview of the purpose of the research in which the interviewee was participating. The interview opened with asking the participant to describe their title and role with the organization. The remainder of the protocol was structured to address operations in the past, present, and future. The broader questions included: (1) How did the business get started? What challenges did you face when first starting? (2) How does the business operate now and why? (3) What are the biggest challenges faced in daily operations now? (4) How is the price and service model determined? How do consumers affect the service model? What feedback do you get from consumers? (5) How do you educate consumers to encourage participation? (6)

Where do you see the business in the future? What role do community composters play in the grand scheme of food waste solutions? The full interview protocol is provided in the Appendix.

2.3 Interviewee Solicitation

Due to the nature of this human subjects' research, Internal Review Board (IRB) approval from the Rochester Institute of Technology IRB for this project was received. Organizations were contacted via email at the address listed on their "Contact Us" page, or through the contact forms on their websites. Founders and employees of the businesses were solicited. The same message was used for every initial contact, and if no response was received, the organization was contacted again with one follow-up email at a later date. No further attempts were made to recruit an organization after two email requests. The firms were solicited in batches of 7-15 at a time to manage the communication and enable flexibility for scheduling interviews at times that aligned best with the interviewee's availability.

In accordance with the IRB approval, people who agreed to participate were sent a consent form explaining there were minimal risks to participating in the interview. Participants were required to give their consent by returning a signed form or providing verbal consent at the start of the interview. A total of 24 organizations were interviewed, representing a 36% response rate of the 66 organizations contacted and 15% of the 161 organizations comprising the sample pool. The sample size of 24 participants was consistent with other qualitative research studies (Ciccullo et al., 2021; Graham-Rowe et al., 2014; Hull et al., 2021; Shooshtarian et al., 2022). The interviews were conducted from January through August 2022.

2.4 Interview Procedure

The twenty-four interviews ranged between 30 minutes to 75 minutes long. Interviews were performed via Zoom Video Communications™ (*Zoom*, 2022) or telephone, depending on the participant's preference. For interviews performed over Zoom, the auto-transcription from the software was downloaded and analyzed using NVivo™ software (*NVivo*, 2020). The transcripts were edited to match the audio where the transcript missed something. For telephone interviews, the Rev Recorder™ app (*Rev, Free Audio & Voice Recorder App*, 2022) was used to record the interviews, which were then played through Zoom to generate a transcript to download. In accordance with theoretical sampling, data collection was paused after 6 completed interviews to allow for an initial analysis to verify the semi-structured protocol as defined was sufficient, and evaluate the participant sample and emerging codes, categories, and themes. Subsequently, a question was added to the interview protocol to directly probe how

the organizations adapt to consumer feedback and data collection commenced until information saturation was achieved, i.e., the interviews and coding were no longer producing new information (Given, 2012).

2.5 Data Analysis

A constructivist grounded theory procedure was applied to analyze the collected data. It is an emergent bottom-up data analysis process in which the final overarching themes that describe the data are constructed from the data itself, not a preconceived hypothesis. It is a multi-step process used to categorize and compile the data multiple times to form larger themes and relationships from which conclusions are drawn about the community composting business model and operations. In this way the researcher is actively involved in the data analysis process (Charmaz, 2006).

Coding is the data analysis activity defined as “organizing participant responses under common conceptual themes” (Hull et al., 2021). The process began with line-by-line coding, assigning a descriptive phrase to each line of the transcript. In step two, this large amount of information was reduced down through focused coding, whereby “the most significant and/or frequent earlier codes” were selected and categorized into subcategories that make the most analytic sense (Charmaz, 2006). During this stage, we applied the constant comparison method to compare codes from different transcripts to each other and adapt them as needed. In this way, codes must earn their way into the overarching themes. In the third step, axial coding, the categories and subcategories were related to each other to form the final overarching themes that describe the data collectively. An example of these steps is provided in Figure 3.1, which shows larger themes emerging from a portion of a transcript through the application of the grounded theory analysis procedure.

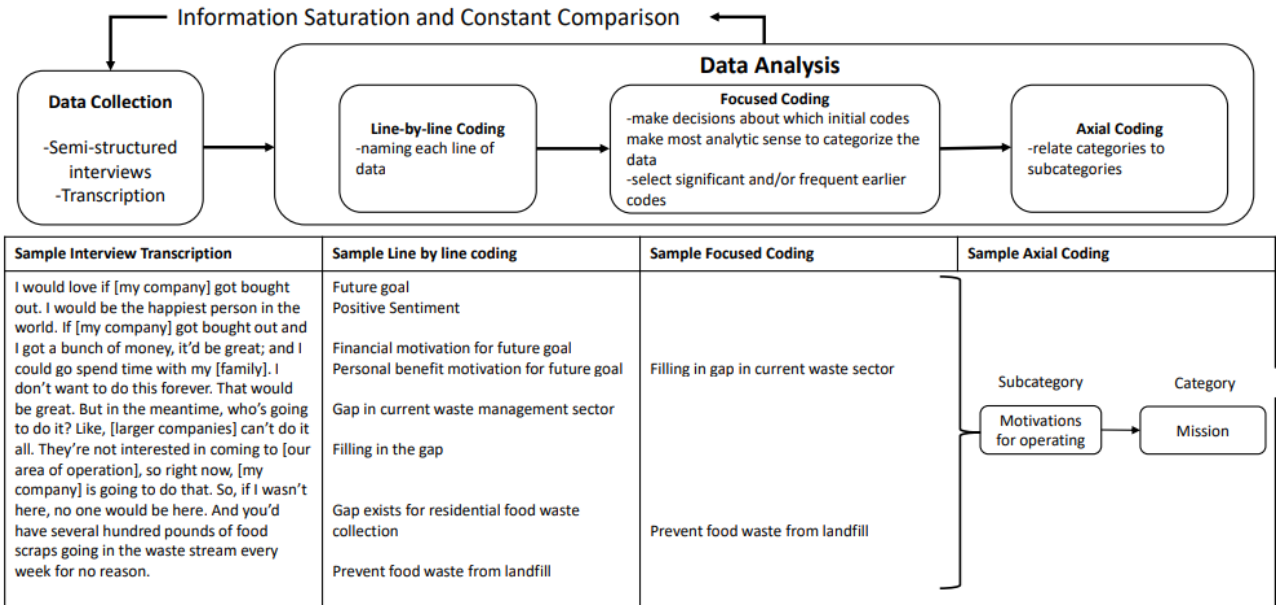

Figure 3.1. An overview of the applied constructivist grounded theory approach using theoretical sampling in conjunction with constant comparison to analyze the interview transcript data. Data collection proceeded until information saturation was achieved.

In qualitative research, interviewee quotes are the primary source of data. Quotes in the following sections have been lightly edited for readability (Lingard, 2019), and where appropriate, quotes are edited to remove any identifying information to preserve participant anonymity.

3. Results and Discussion

3.1 Participant Sample Overview

We conducted 24 interviews with 16 founders and 8 employees of community composting organizations operating throughout the United States (Table 3.1). The interview sample included business operations ranging from 2 to 10+ years old. Our participant sample included 13 small operations (1-499 households), 5 medium (500-999 households), and 6 larger operations (1000+). Three of the organizations interviewed operate on bicycle. The interview participant demographics are compared, where applicable, to the sample pool of household food waste pickup services. However, the purpose of grounded theory is not to yield a quantitatively representative interview sample, but rather the qualitative theoretical sampling approach until information saturation supports diverse representation.

Table 3.1. An overview of the interview participant sample characteristics. Values reflect the total number and percentage of interviewed subjects within each category of interest. Values in

parenthesis represent the percentage of these interviewed subjects relative to the initial list of 161 organizations from which samples were taken (for categories for which this information was available).

	Interview Participants	
U.S. Region of Operation	*Number*	*Percent*
Midwest	4	17 *(25)*
West	3	13 *(18)*
Northeast	10	42 *(26)*
South	7	29 *(29)*
Pacific	0	0 *(2)*
Operation Type	*Number*	*Percent*
Bicycle	3	13 *(11)*
Participant Position	*Number*	*Percent*
Founder	16	10
Employee	8	5
Duration of operation	*Number*	*Percent*
0 to 4 years	7	4
5 to 9 years	13	8
10+ years	4	3
Number of Households Served	*Number*	*Percent*
1 to 499	13	8
500 to 999	5	3
1000+	6	4

The most common characteristic for founders was the acknowledgement of the quantity of food waste generated from households and the environmental consequences of landfilling it, in conjunction with a lack of infrastructure to support residential composting solutions. Founders also commonly expressed a desire to have a job that they enjoyed, contrary to the position they may have held prior to launching their organization. Many, but not all, had a background, either through formal education or personal experience, in an environmental field or role.

The majority of operations are small in terms of staff. In many cases founders were fulfilling multiple roles themselves at the company. In a few cases, there were no employees at the organization; they are small operations and the founder handles all of the tasks. The participating community composting employees who were interviewed had responsibilities ranging from overseeing daily company-wide operations (collection, hauling, and processing), managing day-to-day customer service, scheduling, and administrative tasks, or landing future

clients. They were informed about the origins of the business, expressed passion for the organizations' goals.

The community composters describe their number one role within the broader food waste system as filling in a gap in the current waste management sector. "Casella and Waste Management…are not interested in coming to (our area of operation)…so if I wasn't here…you'd have several hundred pounds of food scraps going in the waste stream every week for no reason" (P20). Beyond the goal of reducing food waste in the landfill, there is also demand for this service. One interviewee explained their perspective this way: "probably the biggest reason to keep going, is the feedback has been so positive, right? The people that want composting, and know about composting, or even learn about composting, and understand the importance of it have been so appreciative, so thankful, and so supportive of what we're trying to do here." (P24). Other interviewees echoed this sentiment stating that customers give "nothing but positive feedback" (P18) and are "extremely thrilled with the finished product" (P21). One interviewee described the following encounter with a client, "My last stop the guy shook my hand. He said, 'I've been composting with you for three years and it's a lifesaving event for me. I couldn't believe we were wasting all this stuff and now it has a purpose and I garden with the soil and get the food back in fruits and vegetables grown from the same stuff'" (P13).

In addition to filling a niche, the businesses' mission includes the broader contributions to their community. For example, they value "community engagement," (P8) and "creating jobs" (P11 and P16). One participant explained that "hyper local [business] models are the most sustainable models…because we're keeping resources local", with another emphasizing similarly that they could keep [the food material] in the city, turn it into compost, and get so many benefits out of that" (P6). Another interviewee explained their role in the community was more "food systems" focused, stating, "I really wanted to enable more [food] to grow" (P12). Participant 11 echoed this sentiment adding that a benefit was "soil remediation" to aid people who wanted to grow food in their urban area. Therefore, the organizations aim to meet the environmental, social, and economical needs of their communities through the operation of their business to collect residential food waste.

3.1.2 Explanation of the varying business models

Participant input shed light on a core, overarching community composting business model consisting of four operational phases: (1) customer engagement, (2) food waste collection, (3) food waste hauling and (4) food waste processing. In general, the businesses

sign-up consumers, provide them with a collection container, collect their food waste, and haul it to a facility for processing to compost. Yet, the organizations implement these four steps in varied ways, thus leading to variability in their business models. Figure 3.2 provides an overview of the four steps of the core business model, and the variability in the service models identified during the interviews.

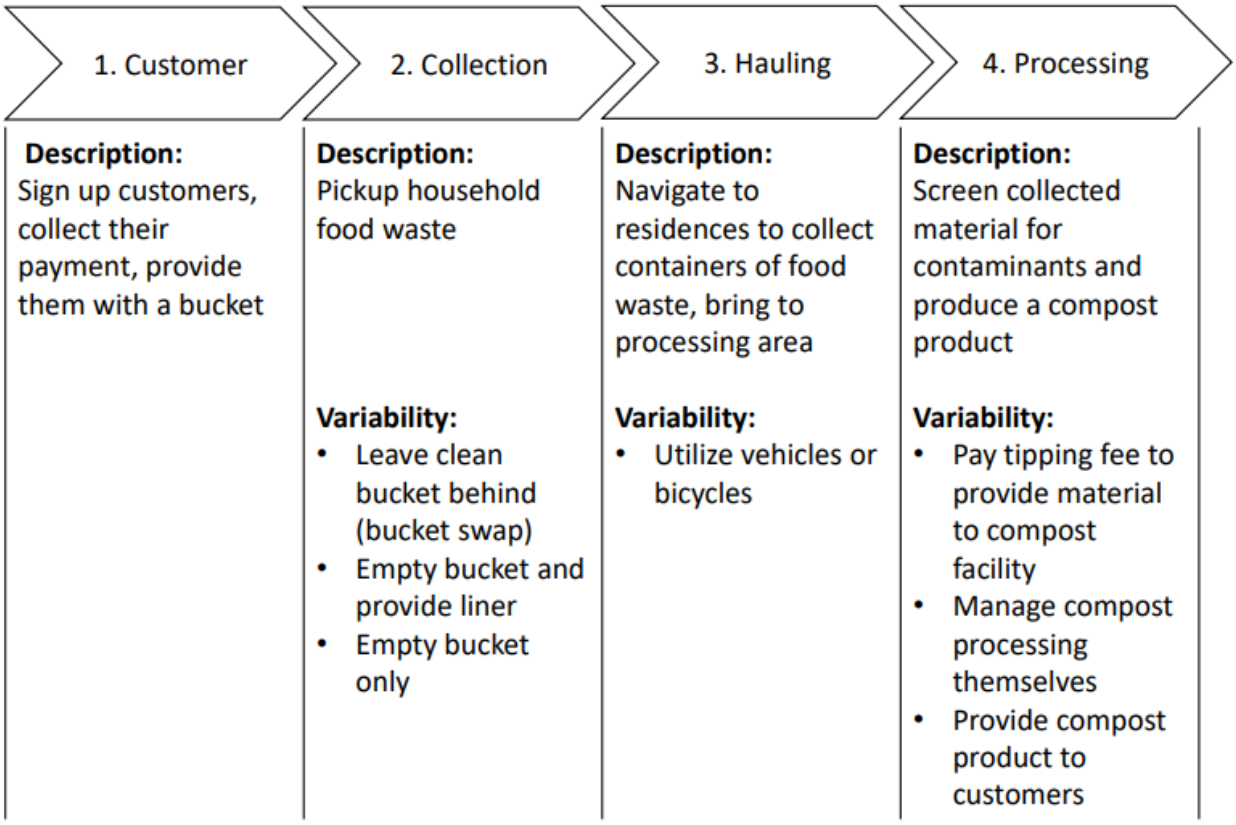

Figure 3.2. Reference framework of the core community composting business model with characterization.

Through the grounded theory analysis, three overarching themes of challenges for the community composters were identified: unique costs associated with each phase of the core business model, the challenge of achieving profitability, and external policy and infrastructure constraints limiting the growth and broader goals of the sector. These themes will be explained and discussed in the following sections.

3.2 Unique Costs and Challenges Associated with the Community Composting Business Model

There is a cost of doing business at each phase of the process involved in the operation of these business models: customer, collection, hauling and processing. Here, the term cost is expanded beyond a direct financial expense to include an exertion, or effort, that ultimately results in a financial impact on the organization. These issues will be explained using each phase of the core business model (Figure 3.3).

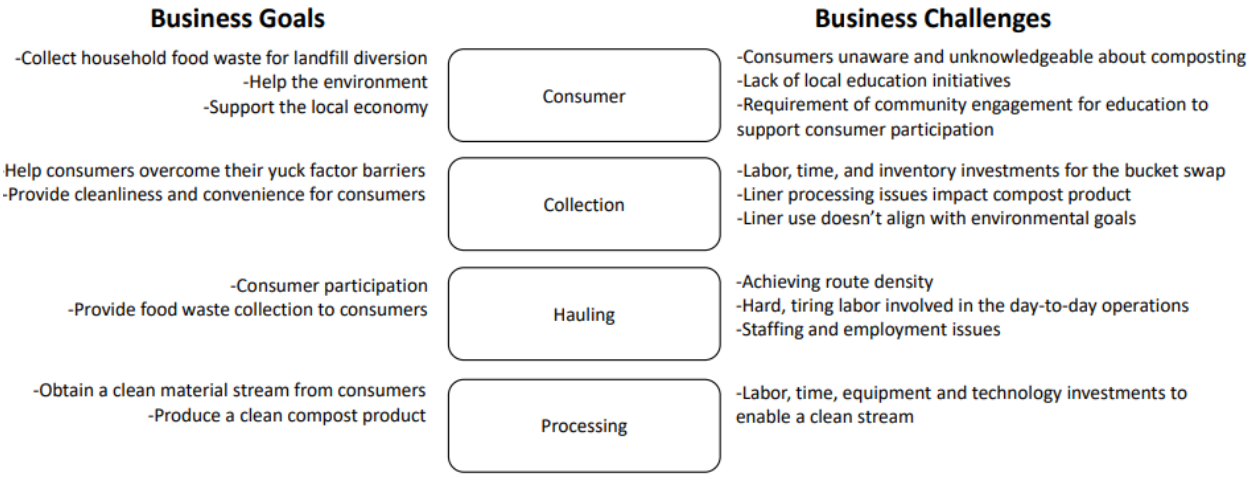

Figure 3.3. An overview of the business goals and challenges for each phase of the core business model and flow of operations.

3.2.1 Customer

One of the main costs of operating a community composting business is consumer engagement, defined here as community outreach to educate consumers about composting food waste and its benefits. One challenge for community composters is that “people are not always aware of compost and how capable they are at contributing to it” (P5). Consumers’ choices are tied to their values and beliefs (Setti et al., 2018), but interviewees reported that “people here just don’t know what composting is” (P24) because “there’s been no public education campaign…no, you know, municipal push, to have composting become normalized” (P1). As a result of this lack of awareness, interviewees reported, “Our initiatives focus on engaging [consumers] in the process of composting. We also get a lot of interest from people wanting to come to our actual facilities and see the operation in person and see how [the] processing works” (P5). Out of necessity, the businesses emphasize community outreach and engagement to educate consumers about composting and its benefits. One participant described it this way, “We do a lot of legwork when it comes to compost education, meaning, not only the science of composting and how it works, but, you know, why compost, why does that matter” (P16). Interviewee 18 confirmed saying, “the role of the community composters is very much educational.” Another participant explained the connection between this community

composting sector, and their role in approach to education through community engagement this way:

"Through the community composting process people learn a little bit, and then they also see it happen. I think that is key to changing the way that people want their food to be not only taken away but grown and given to them, but also how you know their state or their community or all of the above handle more environmental issues. I think community composters are at the forefront of education and behavior change" (P17).

These results show how community composting business models are responding to the challenge of consumers not having the needed knowledge to support their business. Educational initiatives are needed to encourage sustainable behavior (Pickering et al., 2020), but the results provide a missing perspective on how the lack of consumer composting understanding and awareness shapes the role of these organizations. Typically governmental organics curbside programs emphasize the logistical aspects like deployment of curbside carts and collection fleets, ignoring the role that household-behavior change plays in the success of these programs (Gellynck et al., 2011). Yet, knowledge and awareness positively influence household source separation and recycling (Lozano Lazo & Gasparatos, 2022). Additionally, education at the implementation stage combined with local resident involvement can lead to positive organics separation behavior and sustainable waste management strategies (Ezebilo & Animasaun, 2011; Ladele et al., 2021). An added societal benefit is that education campaigns can inform future initiatives and may lead to positive spillover for other types of waste management which is when knowledge about one sustainable aspect promotes sustainable behavior in another way (Ek & Miliute-Plepiene, 2018; Xu et al., 2018). In this way, a new business model may fill an educational role to support a circular solution like residential resource recovery of food scraps.

3.2.2 Collection

The results show that the businesses' goals of providing cleanliness as a service to consumers creates a financial burden for the organizations. One of the reasons hypothesized that these businesses might be key to household food waste management is because they provide a service to help consumers overcome the perceived practical barriers to handling and storing food waste (Oehman et al., 2022). The issue of cleanliness was an important factor influencing the service models; providing this as a service fulfilled the organization's goal to overcome consumers' negative dispositions to the odor or unhygienic consequences of handling and separating household food waste. Participant one explained that "in order to be a successful

business, people need to not think of compost as gross and dirty and so it was highly valuable for us to be able to do a full [bin] swap" (P1). On the one hand, "many companies find that this is a way to entice and to convince people to get into composting" (P11) and the organizations believe it's important to consumers: "I believe it's a reason people choose (our company)" (P12). On the other hand, there's a limit to which the organizations can accommodate what the consumers want.

Out of the 24 interviews, 18 subjects indicated that their organization provides a cleanliness feature in their service model, either through a bucket swap or by providing a removable liner that is collected with the food waste, leaving a clean bucket behind. However, 4 participants indicated their organization does not provide any such service to their customers. Rather, "it's up to the customer to clean it," (P13) elaborating that this was based on a financial decision: "I know there's the bucket swaps…it's hard…you don't make any money that way."

The financial implications of providing a cleanliness service to consumers include increased operational costs in the forms of labor and dedicated time: "the swap is much more labor intensive" (P14), and P4 "we have a whole staff dedicated to washing buckets," and inventory investment, "it just would have been way too expensive to have 2 for every customer" (P6). Other issues arise from the use of liners because there is a cost to purchasing them, they often cannot be included in the material used to produce certified organic compost and some food waste processors will not accept them due to the nature of their composting process.

These results provide support for already established ideas about the challenges consumers face when it comes to separating household food waste (Oehman et al., 2022), but provide the missing implications for the businesses. Infrastructure and intervention strategies should align with consumer needs to influence their behavior (Bernstad, 2014; Geislar, 2017). Therefore, we would expect a business to preserve their longevity in the market by ensuring their services align with consumer needs. Instead, there are tensions in the operations, and these organizations have to make different decisions to survive financially. It is clear that the cleanliness feature is important to these businesses, but it is unclear what features constitute a minimum acceptable service model in the perspective of consumers.

3.2.3 Hauling

The third major cost of doing business is hauling collected food waste from residences to the facilities where it is composted, which leads many companies to try to limit customer expansion within a constrained geographic area that doesn't significantly increase hauling costs. Twenty interviewees reported vehicle fuel is the main operational expense, explained by Participant 14,

“the biggest expense, by far, is travel, even before the price of gas got out of hand, it was travel and now it's that much more”. The cost of pickup is exacerbated by the wet, heavy nature of the food waste material being moved (Hall et al., 2022) and current national rising fuel prices. Route density (defined as customers located geographically close to each other) was the number one reported challenge in the hauling phase of the core business model. The results show how this challenge has direct financial, consumer, and operational implications:

> “Route density is the most important thing to any hauler or any delivery person; you want route density. Amazon, I think there's like 160 packages a day. I think our most dense route is 70 stops. So, you know, the denser the route, the more profitable each stop is, [the] more profitable each stop is, the more I can pay my employees, [the] more capital I can have…so I would say route density is the thing I'm always looking at.” (P2)

> “I needed…to build density while also not leaving people on a three-year waitlist before I could actually come to them. So, it's been a balancing act throughout the life of the business…defining our service area, expanding it as aggressively as we can, without getting into a place where we're regretting it because we have people who are too spread out.” (P10)

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These results show how community composters add consumers and expand their service areas has direct business financial implications, a cited circumstance for residential food waste haulers (Armington & Chen, 2018). Unlike conventional waste management services, the community composters are predominantly operating in markets where their service is not mandated or required; Vermont and California mandate household food waste separation for landfill diversion (California, 2023; *Food Scraps | Department of Environmental Conservation*, 2020). Therefore, they need consumer participation but must balance it with route efficiency to limit their operational costs and environmental sustainability impacts associated with vehicle emissions.

An additional cost of operating a community composting business is the hard nature of the work involved. Food waste is a wet and heavy material, making the job of moving it difficult. The day-to-day operations rely on manual labor for collection, hauling, and processing. Some organizations utilize bicycles to haul, supporting larger environmental goals to reduce their carbon footprint (Clark, 2015). An interviewee described their experience hauling via bicycle, “I can't believe people get up and do this like days in a row, because it can be really intense. So, I

think that's something that we're navigating now is how can we make sure that we are, you know, sustaining ourselves in all the ways…are we sustaining our physical health" (P16).

The results show how the difficult nature of the work translates into staffing challenges for the organizations: "Staffing is the biggest challenge. The work is hard, it's tiring, and right now … there's three drivers plus one office driver combo and they're all part-time; none of them want to be full time because it's too tiring. So that makes hiring hard, because people are usually looking for full time work" (P10). Another interviewee explained that as a result of the work involved, they "do get turnover" (P5).

3.2.4 Processing

The fourth major cost of operating is in the processing phase. Results show that the cost to the community composting business is the time and labor investments required to remove contamination, defined as any material put into the collection container that is not accepted by the composting facility. When asked about contamination, Participant 8 said, "I will say it's not a problem, but it takes a lot of work." The businesses need consumer participation, but they also require a clean material stream to convert into "the best possible soil free of contaminants" (P8). However, individuals struggle to source separate household waste properly (Li et al., 2021). Interviewees explained how they manually manage contamination: "So if I find something I say something, hey this is unacceptable. It's easy to find it because I've got eyes on every bucket I put on my truck," (P13) and "I try to [remove contamination at pickup] if I see it, but you don't see everything and so when we're screening at the end, is where we get it out" (P14). Our results also showed that the direct-to-consumer subscription business model enables lower contamination rates, because "people who pay for this, they do not want to mess up. They're not forced to do it. Everybody is incentivized…residential people can ask right away about what goes in. They usually ask before they put in because they care about it. That model works very well" (P13). This is in contrast to other approaches, such as when governments pay for and provide the service to citizens which may incentivize consumers to participate but compromises the material stream quality: "There's a balance there with free service, because the town is paying for it. So, then participation still occurs but the varying attention to it can change, so you end up with dirtier material" (P12).

Enabling a clean waste stream is a cited challenge for the e-waste industry (Wang et al., 2011) and the clothing industry (Cuc & Vidovic, 2014). The findings from this study confirm this issue in the community composting sector but expand to show how contracting directly with consumers as part of the business model supports a cleaner material stream, a factor especially

important in the community composting business. A number of states have standards for the composition or quality of waste that can be composted, and standards for the quality of compost intended for different applications (Yesiller et al., 2011). Curbside service infrastructure needs to apply individuals' recycling behavior effectively and households may be better served by structural improvements rather than through the implementation of financial incentives (Shaw & Maynard, 2008). These food waste pickup organizations have established and proven systems and channels to incentivize consumers to separate their household food waste appropriately. These methods can inform the adaptation of conventional waste management services and design of new household resource recovery systems to enable consumers to separate their wastes appropriately and provide a clean resource stream.

3.3 Profitability is a Challenge

These businesses began with goals to help the environment, but achieving profitability is a challenge (Figure 3.4). Participant 8 described, "most people [are] getting into it of course, to help the environment, maybe to make a little money, but it is not profitable." While the general sentiment was that it is hard to be profitable, only one interviewee (P15) indicated not yet breaking even. The majority noted issues that make it difficult. For example, setting a price that covers operational expenses while leaving enough of a margin is a challenge: "our pricing, I think, is actually reasonable to maybe a bit too low because the margin is quite tight" (P10). The price is subjected to external systemic factors like "inflation, that's killing us right now" (P15) and rising fuel prices have led to higher subscription fees for consumers: "the fuel prices have really made a dip in our profit, and so we did raise everybody's [prices] a little bit…but it's hard to raise very much at one time," (P18) and "we had to raise our price in February. You know I'm not expecting to make a huge amount of money on this, but I can't lose money doing it" (P14). Charging a fee that covers operational expenses is a basic requirement of a successful business model (Teece, 2010), and a challenge specifically impacting these community composters due to the previously described unique complexities driving costs of the operation.

Consumers are a major factor contributing to the profitability challenge because many are unwilling to pay for these services. Twelve interviewees indicated the cost to consumers is a challenge: "Cost is always important. They would prefer it were free" (P12) and participant 22 described it this way: "The big issue that we're seeing the push back is in the cost, you know, [the amount we charge per month] for an average family, it can be a little bit pricey, you know. Unfortunately, that's the cost that we have to go with, but that seems to be the number one push back" (P22). The reason cost is such a challenge is because people are confused as to why

they would have to pay for this service, explained by Participant 1, “There are also people who have laughed at me when I told them that they have to pay for us to take their food scraps away. And there have been people who have done it in a rude way. They're like, why do you have to do that? I already paid for trash.” One consumer perspective that emerged from the interviews is how the production of a sellable product, compost, leads consumers to believe they shouldn’t have to pay for the service explained by Participant 5 in this way, “[people] know that we're making a product so they're like shouldn't you pay me for taking this? And so that's kind of just like the misconception” (P5). Participant 7 elaborated, “when people think that you're collecting food waste, immediately they’re thinking that you're creating this product that you got to be reselling back so they almost have this feeling that, well aren't you making profit on this?”

These results show the cost individuals are willing to bear is low in comparison to the operational expenses of the business, a cited problem for residential curbside organics solutions (Benyam et al., 2020). The easiest way for consumers to transition to a new circular system is if it’s similar to something they are familiar with (Tunn et al., 2019), but often, people are not willing to pay more for green solutions because the value is unclear (Couto et al., 2016). A challenge of these business models is the perceived similarity between these new food waste pickup services and conventional trash services; the infrastructure is similar but the value propositions for consumers are different. Business models need to be attractive to consumers while also economically viable for the firms (Bohnsack et al., 2014), but it is unclear how consumers value these services, or what cost they are willing to pay to participate.

A number of policy solutions may be applicable to the profitability challenge faced by these food waste pickup organizations. For example, if a municipality were to leverage solid waste payment structures, such as pay as you throw (PAYT), or weight-based pricing for solid household waste, consumers may see greater value in reducing, separating, and recycling materials in the home (Hong & Adams, 1999, p. 199). Sacramento, CA raised solid waste disposal costs for residents in order to cover the cost of the new organic waste collection services for its citizens (*Council Approves Solid Waste Fee Increase to Pay for New Food Composting Program, Higher Costs*, 2022). Therefore, there are options for municipalities to enable economic incentives to support these organizations and encourage their residents to participate in these services.

While the focus of this study was on the businesses’ residential operations, results showed that commercial clients play a role in the financial viability of the operations. All but one of the participating organizations had commercial clients of some type (e.g., restaurants, schools, offices, etc.). The participants cited financial benefits to having commercial clients: “we

have the higher profitability and also like consistency and commitment from commercial customers" (P19) and "we've really focused on the commercial just because it's a lot more profitable" (P18). In this way, the results show how diversification of revenue streams by including commercial food waste collection has the potential to enable a more sustainable financial picture.

While the general sentiment from the interviewees was that it was difficult to achieve profitability, the majority find success and continue operating. One interviewee expressed that, "we are very happy with our pricing structure" (P5), and there are a number of organizations that have been operating for 10 or more years (Table 3.1). This indicates that the firms are able to achieve financial sustainability despite navigating tight margins and covering their operational costs while also charging a fee that consumers find reasonable. Beyond commercial clients, some firms utilize other revenue sources like managing zero waste and food waste diversion efforts for events or selling products like high value compost or zero waste lifestyle products. However, some firms in this sector have closed, for reasons that include financial costs as well as the time commitment required (C. Smith, 2021), and the desire to pursue other ventures (*Suncoast Compost by Renuable, About Us*, 2022).

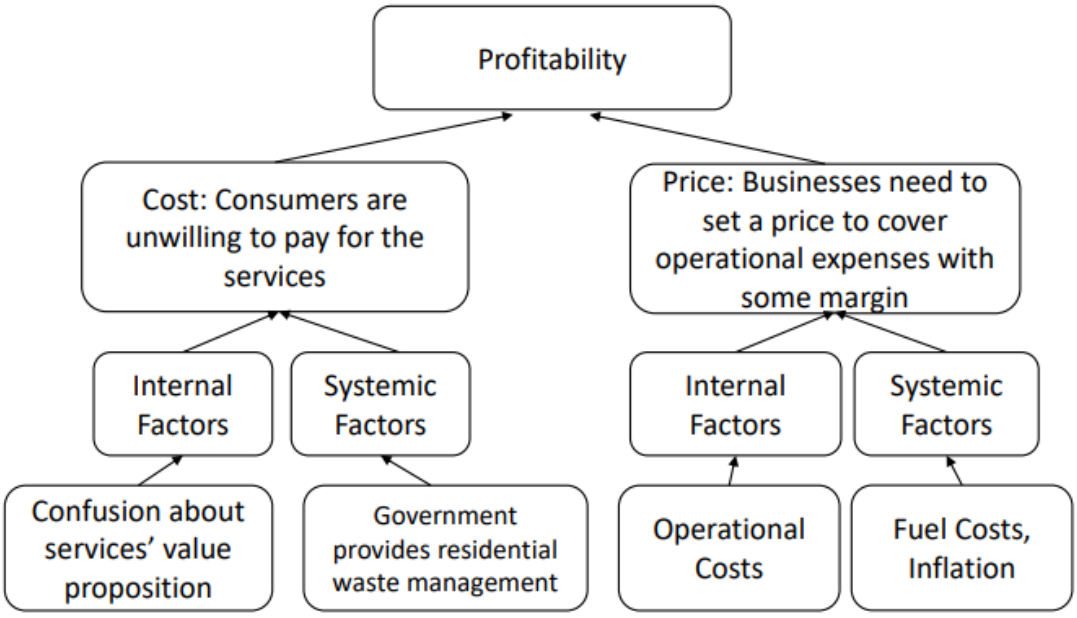

Figure 3.4. An overview of the cost and price challenges limiting community composting businesses from achieving profitability.

3.4 External Constraints

Because of the financial challenges discussed above, it may seem that scaling up to the size and reach of conventional waste companies could be a viable solution. However, existing policy and a lack of infrastructure constrain the expansion of the community composting sector. In order to take on more consumers, the organizations require adequate processing capacity for the additional material collected: “If we're going to keep growing like this, capacity in the state is a challenge to manage food waste. Yeah, there's just not that many places to bring food waste to” (P23). In total, 10 interviewees mentioned regulatory challenges with permitting, and 8 described infrastructure limitations as factors impacting household food waste processing capacity.

3.4.1 Policy Constraints

The community composting sector is constrained by existing policy frameworks. Due to the high moisture content of the food waste material, special permits are required for composting. The nature of the permitting process is “a big challenge” because the requirements for composting vary at the local level, “every city is different, every situation is different" (P17). A complicating factor is that “there’s no specific category for what we’re trying to do” because organic waste management “doesn’t exist in their coding,” so the solution is to “catch the system up to the revolutionary style of composting” (P9). The consequence of the lack of regulatory framework to support new business models elongates and complicates the compost permitting process, explained by Participant 13: “So I had to do the permitting in place with the (state regulating body), it took a year and half. Yeah 70 pages of permit, several of us working on it, a lawyer pro bono. I understand (their) reasons. There are no other…permits (nearby) me so it’s rare; everyone [was] learning along the way” (P13).

Participant 8 expressed similar sentiments about the length of time and effort required from them to comply with regulators regarding their new business model: “So (the city regulators) came back and they wanted to review everything, and now they want to create an ordinance. How long is that ordinance going to take? Nine months. Yes, so I am trying to put together a 50-page document where I'm explaining how different we are (from conventional commercial composting).”

These results show how a lack of a regulatory framework creates challenges for community composters (Pai et al., 2019; Platt, 2015). On the one hand, solving the food waste problem requires innovative business solutions (Bocken et al., 2014), but on the other hand, the current array of state policies can constrain broader circular economy goals, potentially limiting

new business models and stakeholder participation (Pollans et al., 2017; Ryen & Babbitt, 2022). Ultimately, additional composting capacity requires permits. Broad policy efforts to incorporate community composters' experience and knowledge could support the formulation of regulatory solutions that will strengthen and support the resource recovery and recycling sector.

3.4.2 Infrastructure Constraint, Lack of land and space

Contributing to the capacity challenge is the lack of infrastructure to accommodate the specific goals and needs of the community composting sector. To support their broader environmental goals, interviewees described a preference for a decentralized approach to composting, saying "we want our facilities to be as close as possible to residential areas, so we like to have small to medium sized scale operations" (P8) to avoid "shipping this material all around" (P19). However, these firms often operate in dense urban and suburban environments, where "land has continued to be one of our big challenges, other than financial," (P6) a common issue limiting decentralized solutions (Bruni et al., 2020; Pai et al., 2019). Interviewee 11 explained how the land constraint impacts the organization's growth: "I do not do marketing…I have very limited land capacity, so I know that if I promote this on a major basis I run into trouble, you know. So, I can only grow so far." Results also show the consequence of this infrastructure constraint on the overall mission to divert more food waste from landfills: "We want to be diverting as much organic material from landfills and incinerators, as we can, but we're really limited…because public space is really hard to come by and a green space that is welcoming of you know, thousands of pounds of organic waste is also a rare find" (P16).

These results show how a lack of residential food waste composting capacity is constraining the goals and growth of the sector. In order to grow these types of business models for greater resource recovery, engaging with local stakeholders will be required. Social networks can help members get resources that would otherwise be outside their reach (Mortensen & Kørnøv, 2019) and the circular economy requires engaging stakeholders who are often disconnected, from across the food sector (Singh et al., 2021). Connecting with other stakeholders locally to reimagine current land and space may support the growth of residential food waste diversion efforts.

An alternative option is leveraging other food waste treatment technologies that could provide more capacity while avoiding the subsequent land and space issues (US EPA, 2021). Two interviewees expressed positive sentiment towards the alternative technologies, which were described as a biodigester and an aerobic digester. Yet one interviewee indicated they ultimately decided not to purchase these technologies, citing purchase price and reliability as

their concerns. The other explained that the type of output product, opportunities for the product's use, and environmental impact of the output were the main motivators for their choice to use composting instead. However, it is unclear if composting alternatives would be broadly accepted in an industry whose value proposition includes creating compost.

4. Limitations and Future Work

This study investigates the motivations and challenges of community composting business models using semi-structured interviews in conjunction with a grounded theory approach to analysis. Through the nature of the interview procedure, it is possible responses may have been influenced by participants' desires to present themselves in a positive light (Tseelon, 1992), and by the status, age, race, or gender of the interviewer (Charmaz, 2006).

The scope of this study was limited to private community composting businesses operating throughout the United States. There are other private businesses operating within the broader context of North America, but a geographical limit was selected to control for cultural, infrastructure, and policy implications which may influence the design and execution of these service models. One limitation of the participant sample is that there was less representation in certain regions of the United States where organic curbside recycling is predominantly municipally managed. These are areas where composting businesses exist, but they primarily contract with cities to provide the service to citizens, rather than contracting directly with consumers themselves. While interviews were performed until information saturation and the sample size met requirements for qualitative studies, a potential limitation is the sample size compared to the number of currently operating organizations. Future work might extend this analysis to evaluate the motivations and challenges of government managed programs and engage with the stakeholders involved in municipality managed operations, particularly the government representatives, haulers, and processors. Furthermore, this work focused on the household pickup operations of the organizations, yet future work might investigate the role of the commercial clients and operations.

Similarly, the purpose of this study was to focus on the community composting business models, but results show these models rely on other actors in the food supply chain. Future work should explore stakeholders outside the scope of this work to establish missing perspectives about the challenges to broadly implementing these circular business models. Examples include consumer perspectives of these services, stakeholders that interact with these businesses like conventional waste management firms who may be impacted by the growth of these alternative circular economy solutions.

5. Conclusion

Resource recovery of household food waste via composting supports the circular economy and broader sustainable goals of diverting food waste from landfill. Community composting business models provide a service and infrastructure to collect residential material and compost it. However, these businesses rely on consumer participation to provide the material stream, and participation is typically lacking. This paper is the first of its kind to assess the challenges of gaining consumer participation and operating a food waste pickup service from the perspective of the expert stakeholders, the business founders and operators themselves. The results provide new insights into the motivations and challenges driving new community composting business models. This study highlighted a number of unique costs of doing business at each phase of the process and provided additional insight about the tension between striving to meet consumer needs for knowledge, convenience, and cleanliness while still maintaining financial viability. Because consumers are cost sensitive, business must limit the fees charged for food waste pickup in order to have an adequate margin. Additionally, the expansion of the sector as a whole is constrained by a policy framework that is designed for existing large scale MSW solutions and that struggles to adapt to new business models. This study also showed how a broader lack of food waste treatment infrastructure inhibits the growth and broader goals of community composters, and thereby resource recovery and landfill diversion of household food waste.

The findings reported here contribute to the existing literature by providing in-depth insight into household food waste pickup operations from the perspectives of the founders and employees themselves. This information can be used by municipal, business, and governmental stakeholders across the U.S. to support sustainable expansion of composting infrastructure and consumer services. This information can be used to move society one step closer to a circular economy through the support of residential resource recovery community composting business models.

Chapter 4: A review of household food waste pickup services for consumer needs

Research Question: *How do household food waste pickup services align with consumer preferences for the services?*

1. Introduction

An increasingly important piece of infrastructure required to divert residential food waste are organic curbside collection programs. These have been implemented in Australia (De Silva & Taylor, 2022) and Korea where food waste separation is required (Ju et al., 2016). In the U.S. some municipalities have implemented organics curbside programs following mandates to separate household food waste (*Council Approves Solid Waste Fee Increase to Pay for New Food Composting Program, Higher Costs*, 2022; Yepsen, 2015). However, in other areas of the US where food waste separation remains optional for the consumer, entrepreneurs have launched community composting businesses which contract directly with consumers to collect and compost their food waste in exchange for a fee (Pinkerton, 2021). Unfortunately, despite these efforts, participation rates in these organizations have waned, and only 6.3% of food waste in the US is composted (EPA, 2017).

In the last chapter we investigated the challenges and operations of community composting business models through the perspective of the founders and employees. The results showed variability in the execution of the core business model features and highlighted the costs of doing business in each phase of the process. We found a tension between the business goals of providing a cleanliness service method to consumers, while striving to maintain financial stability, and highlighted how consumer unwillingness to pay contributes to the challenge of profitability. However, it remains unclear how the features of the residential food waste pickup business model align with consumer needs.

In order to be effective at collecting household food waste for landfill diversion, infrastructure needs to align with the priorities and preferences of consumers. The food waste pickup services aim to provide convenient household food waste solutions (Clark, 2015), yet, little is known about what specific features consumers desire. Consumers desire to be provided with food waste bins, have food waste collected separately and more often than other types of waste (Ghani et al., 2013) and to be close to drop-off locations (González-Torre & Adenso-Díaz, 2005).There is some evidence that smaller curbside containers are appropriate for food waste only, while larger are necessary for food waste and yard waste collection (Yepsen, 2015). Other features important to successful waste management solutions are collection method and pickup

frequency (Gellynck et al., 2011). Conveniently providing and placing receptacles in individuals' for homes improved their separation behavior (Bernstad, 2014). In the last chapter we found that many consumers are unwilling to pay for household food waste pickup services, but it remains unclear if there are ways to design such systems to actually overcome this financial hesitance.

Consumers make different choices based on price (Lavee et al., 2009), a known factor influencing consumer participation in waste management solutions like recycling (Hong & Adams, 1999) and curbside composting solutions (Benyam et al., 2020; Yuan & Yabe, 2014). Consumers are also typically willing to pay less than what is needed to cover operational costs for curbside solutions (Benyam et al., 2020). Yet, the food waste pickup services charge a fee for household pickup, but the price that US consumers are willing to pay for a food waste pickup service has not been identified. Further, it is not yet understood how such a price might be influenced by features that are unique to food waste pickup, such as the cleanliness service method discussed in the previous chapter.

To fill this knowledge gap, the goal of this chapter is to compare consumer preferences regarding food waste pickup services with the actual service models that are emerging across the U.S. The novelty of this study is that it is the first to collectively address the attributes of private food waste pickup service models and to compare them with the preferences of consumers. This information will inform future implementation of these solutions.

2. Methods

To understand if the food waste pickup service models align with consumer preferences, a two-part approach for data collection and analysis was used (Figure 4.1). First, an exploratory study of the household food waste pickup sector established the common attributes and features of residential food waste collection services in the U.S. Then, consumer preferences for the identified features of these services was characterized. Finally, this information was analyzed for points of comparison and differences.

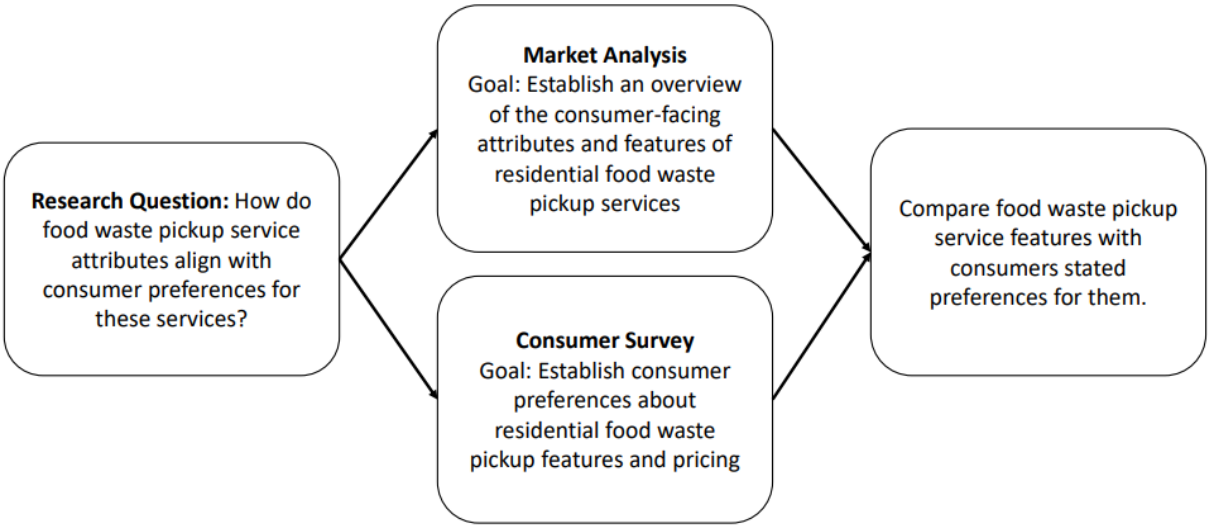

Figure 4.1. An overview of the two-part methodological approach consisting of a market analysis and consumer survey.

2.1 Market Analysis Data Collection

A comprehensive market analysis of household food waste pickup service models was carried out to establish the scope of consumer-facing attributes and features offered across the entire sector. Directories of organizations offering residential food waste services throughout the US are available on three websites: CompostNow.org (CompostNow, 2021), ILSR.org (ILSR, 2022), and Litterless.com (*Where to Compost*, 2022). These databases were used to create a master list of household food waste pickup organizations in order to identify which organizations to include in the final market analysis. In Chapter 3 both the CompostNow.org and ILSR.org website databases were used to create a list of 154 total community composting organizations in 2021. In 2022, this list was expanded to add 114 organizations from the Littereless.com website, bringing the total number of organizations on the master list from these three websites to 267. The scope of the analysis was limited to organizations within the United States to control for policy and infrastructure variability. Therefore, organizations included on these websites but operating outside of the U.S. were not included in the data collection process or analysis.

Data were collected for each organization from each of the food waste pickup services' websites. A literature review combined with results from the previous chapters served to guide what data to collect from the organization websites. Table 4.1 provides an overview of the data collected and a description of the information. The attributes were evaluated based on 1) results of Chapter 2 regarding the impact of convenience and yuck factor on individuals' separation

intention, 2) what the businesses revealed in the semi-structured interviews, and 3) other related literature. General information needed to characterize the organizations was also gathered (Table 4.1). Only information as it pertained to residential services was collected. For example, many organizations offer commercial food waste pickup in addition to residential; information about the details of the commercial operation were not collected. The data collection process was carried out through August and September 2022. All 267 organizations identified from the three databases were characterized through the data collection process. For quality control purposes, this master list was re-evaluated independently by two researchers to verify any outliers.

The organizational websites vary in the type and format of information they provide. The data collection process was structured to accommodate the varying formats. When appropriate, information from the website was transposed to fit the most common format in the database. For example, organizations provided pricing in a variety of units including $/month, as a bulk-rate (total dollars for 3-month, 6-month, 12-month subscription), and in $/week. In some cases, no exact number was given for a price, rather it was defined as “location dependent” meaning the price was determined based on the neighborhood the participant lived in. In the data collection process, all pricing was recorded as $/month, and notes were added if the recorded value for pricing had been transposed from $/week, or $/6 months, etc. Location dependent pricing was listed as “location dependent.”

In many cases, the information desired was not provided on the website. In these scenarios, information not given (ING) was utilized to indicate that the website was searched for the information but it was not there. Not applicable (NA) was used sparingly and only where it was appropriate. For example, if pickup was not a feature offered by the organization, then weekly, biweekly, and monthly pickup pricing is NA. If an organization offered weekly pickup but not biweekly or monthly, “not offered” was used to indicate that those features specifically were not offered.

Table 4.1. A summary of the data collected from each organizations' website.

Consumer-Facing Feature	**Description**	**Data Collection Description and Format**
Food Waste Collection Methods Offered	Some businesses offer pickup and dropoff options	Pickup Offered: Y/N, Dropoff Offered: Y/N
Pickup Frequency Offered	Some businesses offer weekly, biweekly, and/or monthly pickup frequencies	For each pickup frequency offered, the price was documented in $/month. If the price was transposed, it was noted. Location dependent pricing was noted as "location dependent." Weekly Pickup: Price ($/month), Location Dependent, Not Offered Biweekly Pickup: Price ($/month), Location Dependent, Not Offered Monthly Pickup: Price ($/month), Location Dependent, Not Offered
Collection Container Size and Quantities Offered	In addition to the main collection container provided to consumers, some businesses offer other sizes as well, or multiples of the size (e.g., 2x5 gallons)	Sizes in gallons were listed as given on the website: 1, 4, 5, 6 If multiples of a size were offered it was entered in the following format: 2x5, such that the firm offers two 5-gallon buckets
Cleanliness Service Method Offered	Some businesses use a bucket swap, some use liners, and some don't provide any such service	Bucket Swap Offered: Yes/No If No, and they utilize liner, then this is listed as "N, Liner."
Household food wastes accepted	Some businesses accept certain food wastes, others do not	Text, the list of accepted materials as given on the website was collected.
Compost made available for customers	Some businesses make the compost product available to their customers as part of the business model	If the website indicated that finished compost is made available to consumers: Yes/No
Pest/Odor Mitigation Strategy	Some businesses provide information on their websites to address odor and pest concerns	Text, information collected verbatim from the website about pest and/or odor management
Discount offered	Some businesses provide discounts to their consumers	Text, information verbatim from firm website, or "not offered"
Active/Inactive Status	Some businesses are no longer operating	Active/Inactive based on website status
State of Operation	Geographical state in which the business operates	State abbreviation

2.2 Market Analysis Framework

The purpose of this study is to begin to characterize the broad sector of household food waste pickup services. After all the data described in Table 4.1 were collected for the 267 organizations on the master list, some organizations were determined to be outside the scope of the analysis. Therefore, this master list of organizations was screened further to align with the stated scope of residential food waste pickup services. This screening process removed 4 organizations that offered commercial pickup only, 18 which were inactive, and 52 that could not be confirmed as collecting food waste at a volume scale expected for typical residential situations. Specifically, the majority of residential operations offer 4-6 gallon buckets for waste collection, which is typical for household food waste generation (Metcalfe et al., 2012; Pinkerton, 2021); some companies offered only much smaller (1-3 gallon) or larger (32 gallons and greater) containers, which would be more typical for non-residential settings or when yard waste is included with the food waste collection from residences (Geislar, 2017; Layzer & Schulman, 2014). These organizations (n = 23) along with those who did not provide volume collection information (n =29), were removed from the data to ensure that the analysis focused on the most common modalities of residential offerings. The final dataset for analysis included information for the remaining 165 companies, all of which met the following criteria (Figure 4.2): (1) functioned as an independent business (i.e., municipally operated programs were not included), (2) had an active status, (3) served residential consumers (i.e., businesses serving only commercial food waste generators were not included), (4) offered household food waste pickup, and (5) utilized collection containers within the size range of 4-6 gallons.

From a comparative perspective, the final data set analyzed in this chapter (n = 165) is similar in size to the sample pool discussed in Chapter 3 (n = 161). However, it should be noted that these two pools are not identical. While some organizations appear on both lists, many are not overlapping as the two datasets were compiled at different times, using different web resources, and screened with distinct criteria according to the purpose of the study. A similar analysis was performed by Biocycle in 2021 examining operations of 124 organizations (Pinkerton, 2021), suggesting that our sample size is consistent with what industry experts have independently analyzed, but this prior work is also likely distinct in composition due to differences in companies operating and available information at the time of each study.

The final dataset (n = 165) was analyzed in Microsoft Excel using tables, graphical analysis and descriptive statistical analysis like mean, median, range, and mode (Holcomb, 2016). Companies often vary pricing by number of collection containers collected. For example, an organization may charge $30 per month for weekly pickup of one 5-gallon container, and $35

per month for weekly pickup of two 5-gallon containers. For the analysis, pricing that was for the most observed single offering, i.e., one 4-, 5-, or 6-gallon container was used. The analysis served to establish the scope of service attributes and most common features across the sector. These results were compared with the NYS consumer survey results to establish how household food waste pickup service features align with consumer preferences.

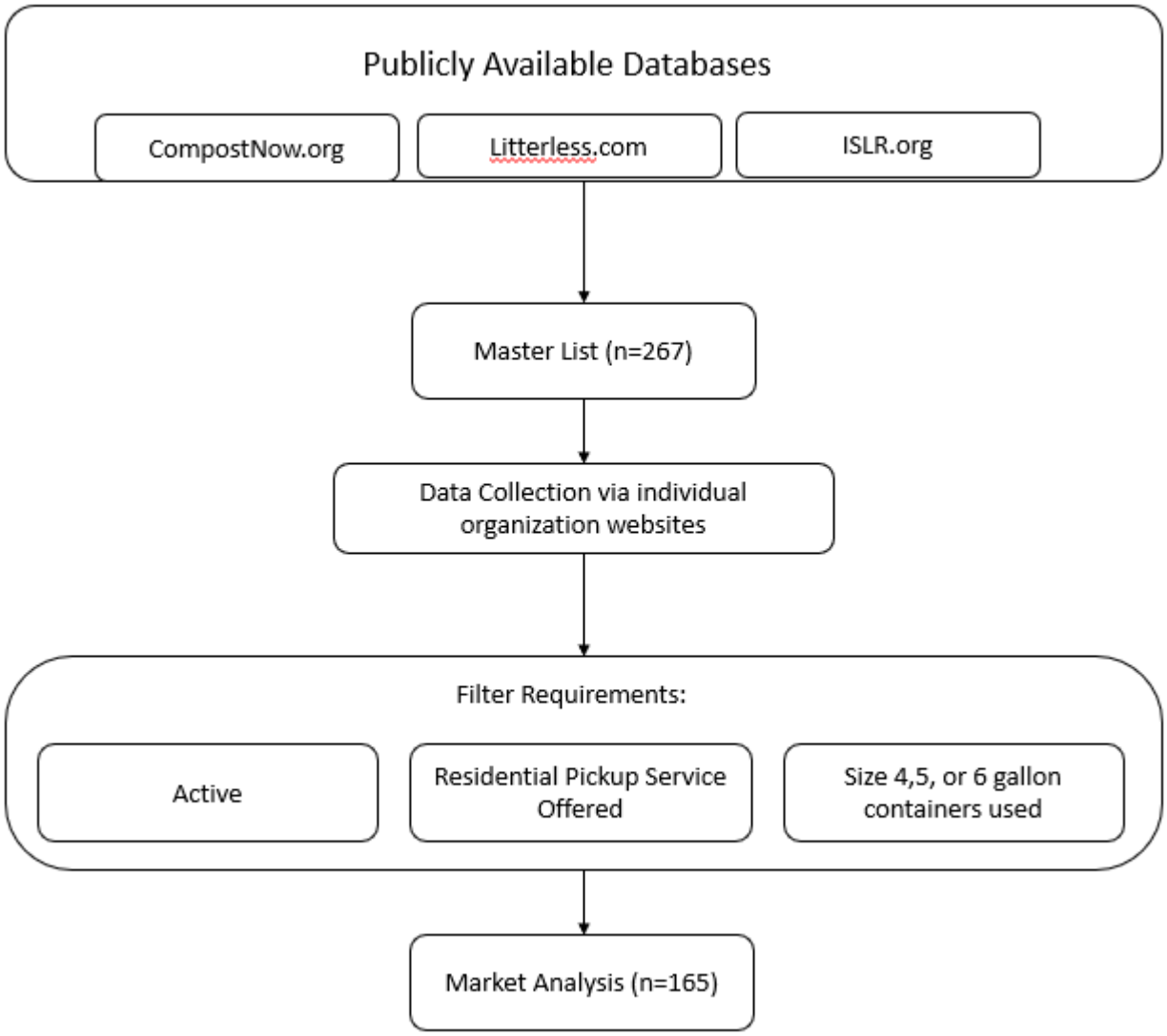

Figure 4.2. An overview of the market analysis approach to generate a final market analysis database of household food waste pickup organizations operating throughout the U.S. This market analysis was used to establish a broad overview of the attributes and features of these pickup services.

2.3 Consumer Survey Design

The survey described in Chapter 2 contained several questions designed to gain insight into consumer preferences for food waste pickup service infrastructure. The purpose of the survey questions was to establish a set of priorities of preferences from consumers when they think about these curbside composting service models. Consumer preference questions included in the previously described survey are outlined in Table 4.2.

One of the challenges with developing the questions was that the household food waste pickup services we were asking participants to evaluate are relatively new, and not everyone may be familiar with the service, its features, and its cost. Another challenge was that there is no information about what consumers think about the varying attributes of the services. Additionally, compared to conventional household waste management services, these household services have unique features, such as cleaning the container for consumers. Therefore, we combined the cost of household food waste management solutions with descriptions of the main attributes in order to provide all survey participants with the same information available to evaluate the questions asked. To evaluate stated preferences between these household food waste management solutions, three survey questions were designed. Each question required the participant to select their preferred method from two food waste management options: home composting vs. a food waste service requiring consumers to dropoff the food waste nearby their home, home composting vs. a food waste service offering curbside pickup at their home, and dropoff vs. pickup.

Household food waste solutions such as dropoff and pickup services offer some convenience, but also include a cost. Home composting is a free management option but requires more effort and time investments from the individual (Curtis et al., 2013, p. 201; Edgerton et al., 2009). Home composting was defined based on literature (De Silva & Taylor, 2022; Edgerton et al., 2009; Loan et al., 2019). A combination of literature (Czajkowski et al., 2014; Dusoruth, 2018; Ku et al., 2009; Yepsen, 2015; Yuan & Yabe, 2015) and the market analysis results were used to inform the attributes and prices to describe the dropoff and pickup options (full details of the questions are provided in the Appendix). For example, in the market analysis, $25/month is a common price for weekly pickup, and a common dropoff price is $10 per month, so dropoff was set at a price of $3 per week (the $10/month was divided by 4 for a weekly rate, which is $2.5, which we rounded up to avoid decimals which may make the information more difficult or confusing to the participant). Weekly pickup was set at a price of $6 per week (which is $24/month) in the stated preference questions (Table 4.2).

In order to compare the price the organizations were charging with the price consumers were willing to pay, a question about consumers' stated preference was utilized in the survey. Stated willingness to pay was selected for this study as opposed to a choice experiment for revealed preferences because a choice experiment requires knowledge of what consumers think about the service attributes and pricing (Blamey et al., 2000; Lancaster, 1996), which is currently unknown for household food waste pickup services. Therefore, this study serves to establish a descriptive overview of consumer perspectives about household food waste pickup services for future work to build on. Participants were asked to select a price they would be willing to pay in $/week for a pickup service. The unit $/week was used because individuals were thought to be better able to relate to the concept on a per week basis. A sliding scale with options ranging from $0 to $10 was used.

Table 4.2. An overview of the survey questions about consumer stated preferences for household food waste pickup services. These questions were included in the same survey described in chapter 2. See Chapter 4 Appendix for full survey question details.

Consumer Survey Question	**Options**	**Supporting Information**
If both of these options were available to you, which would you prefer?	Multiple Choice: Home Composting (free) or Dropoff ($3/week)	(Czajkowski et al., 2014; Dusoruth, 2018; Ku et al., 2009; Yepsen, 2015; Yuan & Yabe, 2015)
If both of these options were available to you, which would you prefer?	Multiple Choice: Home Composting (free) or Pickup ($6/week)	
If both of these options were available to you, which would you prefer?	Multiple Choice: Pickup ($6/week) or Dropoff ($3/week)	
If a food waste pickup is available to you, what is the most you would be willing to pay per week?	Sliding scale, $0-10 ($/week)	(Benyam et al., 2020)
If your city were designing a food waste service, which of the following attributes would be the most important to you to have?	Multiple choice, select one from the list: low weekly cost, service picks up at my home, nearby location for dropoff, takes container and replaces with clean, accepts all food waste, provides free or low-cost compost back, offers education, other	(Yepsen, 2015)

The data were collected within the same survey as described in Chapter 2, which is briefly summarized here. An internet-based survey was administered September through November 2020. A portion of the data was collected from local distribution of the survey through social media and personal emails provided at community events. The survey was also distributed to a survey panel in order to achieve an adequate sample size congruent with NYS demographics for ethnicity, race, and gender. These individual data sets were combined to generate one large data set to move forward with the analysis. The survey design and recruitment methods were reviewed and approved by the RIT Institutional Review Board.

2.4 Consumer Survey Data Analysis

The survey responses were extracted from Qualtrics™ software (*Qualtrics*, 2020) to Microsoft Excel™ software (Microsoft Corporation, 2021) and evaluated following the same methods outlined in Chapter 2 but summarized here. The data set was cleaned to remove participants who “straight-lined” answers to three or more matrices in a row and those who provided contradictory answers to the survey questions about past behavior, indicating a lack of engagement with the survey. In total, after cleaning there were 649 participant responses for analysis.

In the survey, participants were asked about their past behavior (within the last 12 months) of household food waste separation. In Chapter 2, this information was used to establish two groups from the survey participants: Separators (those with past experience separating using home composting, a dropoff service, or a pickup service), and Non-Separators (those with no prior experience in separation). These two groups were again used for comparison of results, with one additional distinction: separators were further disaggregated into those who routinely used a food waste service in the past year and those who did not. This portion of the analysis was carried out using ggplot2 (Wickham, Chang, et al., 2020) in R Studio (RStudio Team, 2020). The remainder of the consumer survey data was analyzed in Microsoft Excel™ using tables and graphical analysis.

3. Results and Discussion

The following section presents the results from the market analysis and the consumer survey. First, the results of the broad market analysis overview of the residential food waste pickup service features are presented. Then, the results of the survey showing consumer preferences for household food waste pickup services are presented. Last, the results indicating how the features of the service align with consumer preferences are shown and discussed.

Chapter 4

3.1 Market Analysis Results

3.1.1 Variability in household food waste pickup services features

A total of 165 household food waste pickup services were analyzed in the market analysis, which established an overview of the attributes and features of household food waste pickup service organizations. The results show that there are core attributes the firms have in common but variability in how these attributes are implemented across the sector (Table 4.3). The variability of the business models was noted in Chapter 3, but here this result is expanded to show the variability across the entire residential food waste pickup sector. For example, the results show that some organizations implement one pickup frequency, while others multiple, some offer one size of collection container, others multiple and some offer only pickup, while others also offer dropoff. These findings show the sector has explored a variety of features and combinations to meet consumer needs, a common and necessary strategy for businesses (Nair & Paulose, 2014; Teece, 2010). Yet, as a whole, the household food waste pickup service industry is still fairly young, with new operations emerging every year (Pinkerton, 2021) and it is unclear if more features enable consumers to participate in these business models, and if they would be willing to pay for those features.

Table 4.3. An overview of the range of attributes and implementation features offered by household food waste pickup services in the US. Bucket swap means the container of food waste is taken and replaced with a clean, empty container. Where percentages do not add up to 100 for certain categories, the difference represents instances in which the information was not provided on the organizations' website.

Food Waste Pickup Service Attributes	Implementation Features	Percent of Organizations	Most Common Feature
Household Food Waste Collection Method	Pickup Only	64	Pickup Only
	Pickup and Dropoff	36	
Pickup Frequency	Weekly (once a week)	87	Weekly
	Biweekly (once every two weeks)	58	
	Monthly (once a month)	14	
	1 pickup frequency option	46	1 pickup frequency option
	2 pickup frequency options	40	
	3 pickup frequency options	10	
Collection Container Size Offered	5 gal	81	5 gallon
	4 gal	16	
	6 gal	2	
	Offer 1 bucket size	70	Offer 1 bucket size
	Offer 2 bucket sizes	21	
	Offer 1 size, but multiples of them	10	
Cleanliness Service Method	Bucket swap only	49	Container Swap
	Bucket swap with liner	14	
	Provide liner only, no bucket swap	12	
	No cleaniness service provided	4	
Household Wastes Accepted	Vegetables	78	Vegetables, Fruits, Meat
	Fruits	75	
	Meat	57	
	Eggs/Eggshells	56	
	Dairy	52	
	Grains	47	
	Bones	45	
	Compostable Products	35	
	Nuts	28	
	Newspaper	19	
	Cardboard	18	
	Seeds	15	
Compost Made Available for Customers	Yes	62	Yes
	No	18	
Consumer Discount Offered	Yes	50	Yes
	No	41	
Pest/Odor Information Provided	Yes	37	No
	No	64	

3.1.2 Dominant features within the broad household food waste pickup service sector

The market analysis revealed there are dominant implementation features across the sector (Table 4.3). The core attributes of the residential pickup business models are the main services offered to consumers: collection method, pickup frequency, collection container sizes, cleaning service, compost product availability, and accepted materials. However, food waste pickup services implement these core attributes differently, and we termed those differences implementation "features" in the following discussion. For example, in the attribute category collection method, there were two different features identified in the analysis: offering pickup only, or both dropoff and pickup. The results show that the dominant feature in this category is pickup.

Across the entire sector of residential food waste pickup services in our market analysis list, the dominant features are offering pickup only; weekly pickup frequency; providing only one

pickup frequency option (e.g., only weekly or only biweekly or only monthly); using a 5-gallon collection container; offering only one bucket size; providing a container swap; accepting vegetables, fruits, and meats; and giving compost back to consumers. While there is much variability observed, these results show certain features are more common than others. It is common for dominant business models to emerge over time in a sector as businesses adapt and figure out what consumers will pay for and what their operations and finances can handle (Teece, 2010).

Fruits and vegetables are the most commonly accepted materials by the organizations. The results are based on accepted materials data as listed and collected from the organizations' websites, but not all organizations included in the analysis provided this information on their websites; some do not provide any information about accepted materials, and others listed that the information is provided to customers when they sign up for the service. These scenarios were not included in the reported results. Therefore, while it may seem that 100% of the community composting organizations evaluated should accept fruit and vegetable material, these results only account for organizations that specifically listed fruits and vegetables as accepted materials on their websites.

3.1.3 Most organizations offer cleanliness as a service

In the previous chapter, the interviews with founders and employees revealed that doing a container swap created several added costs for the business, and that providing bucket liners instead could avoid those financial implications. The market analysis results show that while the household food waste pickup service sector has adopted a few ways to provide cleanliness to consumers, container swap is the most common method. Some organizations clean the bucket and provide a liner, and a number of businesses utilize liners only. Broadly, these results indicate that a cleanliness feature is a common attribute for community composting business models. Given the business challenges of profitability, combined with higher operating costs from the cleanliness service identified in the previous chapter, one option is for the organizations to charge more for this cleaning service. In the market analysis data, two companies specifically noted that while they do provide a cleanliness service, customers must pay extra to receive this service. In this way, their business model provides a low cost for individuals who prioritize that, while ensuring profit when signing on customers who prioritize cleanliness.

3.1.4 Some organizations address pest and odor management

In Chapter 2, concerns about odor and pests were found to inhibit individuals' intention to source separate household food waste. In Chapter 3, helping consumers overcome yuck factor-type barriers was a goal of many businesses, leading them to provide a cleanliness feature. Therefore, to understand other ways organizations help consumers overcome yuck factor concerns, any advice about pest or odor control that was included on the organization's website was included in the market analysis data collection process.

The results show that 37% of the organizations included in our market analysis provide some type of advice or recommendation about how to minimize these issues on their websites. Common strategies to control odor included keeping the provided container tightly sealed, storing the waste in the freezer until collection, and adding sawdust to the bucket. One organization indicated that biochar was added to the bottom of the buckets to help fight odor. For pest management, the common recommendations included storing the bucket indoors with a tightly fastened lid.

3.1.5 Pricing ranges for varying pickup frequencies

The market analysis results show a broad range in pricing for weekly pickup (Table 4.4). Weekly pickup is the dominant pickup frequency feature across the household food waste pickup sector (Table 4.3), but some organizations do offer biweekly or monthly pickup. On average, the organizations charge a lower monthly price for biweekly and monthly pickup (Table 4.4). However, there is a broad range of pricing for each pickup frequency. The purpose of this study was to describe the state of these businesses that operate across the country and these results indicate how they vary by geographic location, potentially due to cost of living differences between the areas of operation. Seemingly, certain urban locations can demand a higher weekly price due to higher living expenses (*Cost of Living Data Series | Missouri Economic Research and Information Center*, 2022). For example, in the market analysis, a company located in the Boston, Massachusetts area charges $44/month for weekly pickup of a 5-gallon collection container, and an organization operating in Washington state charges $60/month. On the low end, a company operating in Knoxville, TN charges $9 per month for weekly pickup of one collection container. Urban areas are also more dense, with most residents living in small spaces that often prevent home composting as an option (Carrie Roble, 2018; DiGiacomo et al., 2018; R. M. Smith et al., 2005).The effect of urban density or multi-family high rise living on pricing was not accounted for in this study.

Table 4.4, The range, median, and mode of pricing in $/month of all three pickup frequency options offered by household food waste pickup services in the market analysis.

Pickup Frequency	Range ($/month)	Median ($/month)	Average ($/month)	Most Common Price ($/month)
Weekly	9-60	30	30	30
Biweekly	12-50	20	22	20
Monthly	8-30	15	16	15

To understand what, if any, other factors impact the total cost consumers pay to participate in these household food waste services, information about any additional fees listed on the organizations' websites was collected. The analysis results show that there are other pricing components involved for consumers beyond just the monthly subscription fee. Results show 28% of companies charge a one-time subscription fee to consumers upon signing up. On the organization websites, this fee was often indicated to cover the cost of the bucket and other company expenses associated with signing up a new customer. Therefore, there are other factors that can influence the final price a consumer would pay to participate in a household food waste pickup service.

On the other hand, it is common for these businesses to offer some type of discount to consumers to entice participation in the service. Therefore, any information offered on the website about discounts was collected and analyzed. The results show 50% of organizations offer a discount to consumers, the most common being for a customer referral. Other discounted options included military or student discounts, bulk subscription discounts (e.g., reduction in price for a 12-month subscription), and a free trial period. One of the challenges of the organizations identified in Chapter 3 is route density, or obtaining consumers that are located geographically close together. Therefore, there may be an opportunity for these organizations to leverage neighbor referral discounts in a way that also promotes route density.

3.2 Consumer Survey Results

This section provides an overview of the main findings from the consumer survey questions. These questions were intended to gauge how consumers prioritize household food waste pickup service features. Defining attributes from the consumers' perspectives is a necessary first step to understanding consumer preferences (Blamey et al., 2000; Lancaster, 1996). Therefore, the purpose of this section is to begin to lay the groundwork of the household

food waste pickup service attributes that are important to consumers such that future work can build on it. Overall, consumers were found to prioritize low-cost options. This result will be explained in more detail in the following section.

3.2.1 Consumers prioritize low-cost options

The results of the exploratory study reveal consumers' stated preference for a low weekly cost for a household food waste service (Figure 4.3). Survey participants were presented with a list of service features and asked to select the one most important factor in their decision to participate in a food waste service if it was offered in their area. The most commonly selected feature was having a low weekly cost, aligning with other studies that highlighted the importance of waste management costs to consumers (Benyam et al., 2018, 2020). This result also echoes the findings in Chapter 3, where interviewees indicated that getting consumers to pay the price they charge for the service was a challenge.

The second most commonly selected feature was having the food waste picked up from their home, a finding similar to a study which found that frequency of waste collection was not a significant factor in the choice of an improved waste management program (Ku et al., 2009). Yet, prior consumer stated preferences for residential food waste management have included having their food waste picked up from their home (Benyam et al., 2018), and having it picked up more frequently (Ghani et al., 2013), but these studies did not establish how consumers prioritize these features compared to others.

The third most commonly selected option was for the container swap feature. Overall, about 16% of consumers surveyed indicated the container swap would be the number one desirable feature for them in a food waste service. This result expands on the tension we identified in the interviews which is that while the container swap is a convenience, most consumers do prioritize the cost to them over convenient features. Similarly, individuals have preferences for the cleanliness of waste facilities (Ku et al., 2009). Even if individuals are using a food waste pickup service, their waste separation facility is their home, and involves having the collection container, or bucket, in their home, or somewhere close to it (for example, on a porch or deck). Therefore, it stands to reason that individuals would likewise have preferences for cleanliness of the bucket, the main food waste management item in their home. Respondents placed a lower priority on the service features of "accepts all food waste," "provides low-cost compost back," and "offering education," suggesting that education alone is not enough to meet consumer needs (Neubig et al., 2020).

The aim of this study was to provide a descriptive analysis of consumers' stated preferences for the varying attributes of a residential food waste pickup service that future work can build on. Factors like environmental attitudes, past experience with organics programs, and demographics have been found to impact individuals' perspectives about organics pickup programs (Dusoruth, 2018; Ladele et al., 2021). Additionally, concerns about food safety impact individuals' waste separation behavior, and ultimately may be a factor in their decisions about waste management (Davenport et al., 2019). Yet, the effect of these factors on respondents stated preference for household food waste pickup service features was not evaluated in this analysis.

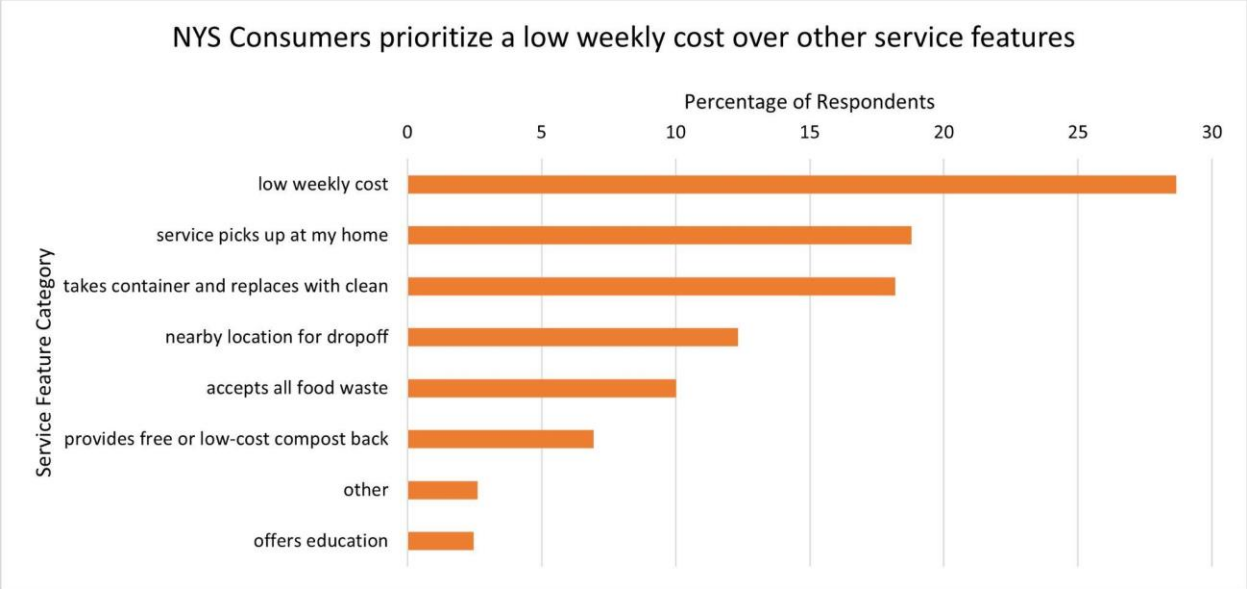

Figure 4.3. Most NYS consumers prioritize a low weekly cost over other household food waste pickup service features. The survey question was exclusive; participants were required to select only one option as the most important feature.

In the survey, consumers were also asked to indicate their preference between three household food waste management solutions: home composting (free), a dropoff food waste service (paid, less expensive), and a pickup food waste service (paid, more expensive). When asked to make a selection between a free food waste management option (home composting), and a paid service (pickup or dropoff), more consumers selected the free option in either case (Table 4.5). Contrary to this finding, residents in Canada had less preference for home composting compared to using a curbside "green bin" option (Ladele et al., 2021). When asked to decide between drop-off and pickup, the percentage of consumers selecting each option was

equal. This result suggests that even given the convenience associated with a pickup option, some consumers still prioritized the lower cost option.

One area of uncertainty is that these findings represent only consumers' stated preferences, whereby their actual behavior, or choice, may be different (Jamieson & Bass, 1989). Additionally, survey participants were required to select one of the given options as a response. Therefore, the results do not differentiate between participants who may prefer neither option. Additionally, choice modeling typically requires knowing what consumers think about these attributes, and which are the most important to them, such that the choices include those attributes (Lancaster, 1996). However, it is unknown what preferences consumers have for the varying service attributes, so literature and the results of the market analysis were used to define the waste management options presented in the survey.

Consumer choices may also be influenced by local organics management programs and policy, which affect participant perspectives about curbside organics collection programs (Ladele et al., 2021). This study did not evaluate for the role that either having a local organics management program available may play, or the role of the type of program. For example, this survey was performed in NYS, and while the percentage of participants from New York City (NYC) is unknown, that region has a history of offering curbside organics pickup and drop-off programs (*Curbside Composting Program Restarts with Low Participation and High Cost*, 2021). Therefore, because NYC residents had access to curbside organics waste services prior to the timeframe of the survey, it's possible that experience influenced their responses. Additionally, demographics, attitudes, and a number of other personal constraints such as housing type or available space can impact individuals' choices and preferences (Chung & Yeung, 2019), but analyzing for all of these factors was outside the scope of this study.

Table 4.5. Consumer preferences for alternate food waste management options. Most consumers prefer a free option when there is a charge for the convenient service.

Survey Question Options	Percent of Respondents
Home Composting vs. Dropoff	
Home composting (free)	58
Dropoff ($3)	42
Home Composting vs. Pickup	
Home composting (free)	55
Pickup ($6)	45
Dropoff vs. Pickup	
Dropoff ($3)	50
Pickup ($6)	50

3.3 Market Analysis Pricing and Consumer Survey Willingness to Pay

The next step of the analysis was to compare the price that companies offer for weekly pickup with the price consumers stated they were willing to pay for the service. As discussed earlier, the market analysis found that companies most commonly reported pricing in $/month. On the other hand, the survey questions were designed with the expectation that consumers might be able to understand a pricing choice based on $/week more easily. Thus, to compare the organizations' pricing ($/month) to consumers stated willingness to pay ($/week), values were related by multiplying weekly price preferences by 4 to approximate results on a monthly basis.

3.3.1 Consumers are willing to pay less than what organizations commonly charge for weekly food waste pickup

There is a discrepancy in the price consumers state they are willing to pay, and what the firms charge for the service. The results of the market analysis show that household food waste pickup organizations most commonly charge $21 to $30 for weekly collection of one container. Yet, most NYS consumers reported they were willing to pay $11 to $20 a month for pickup of one collection container (Figure 4.4).

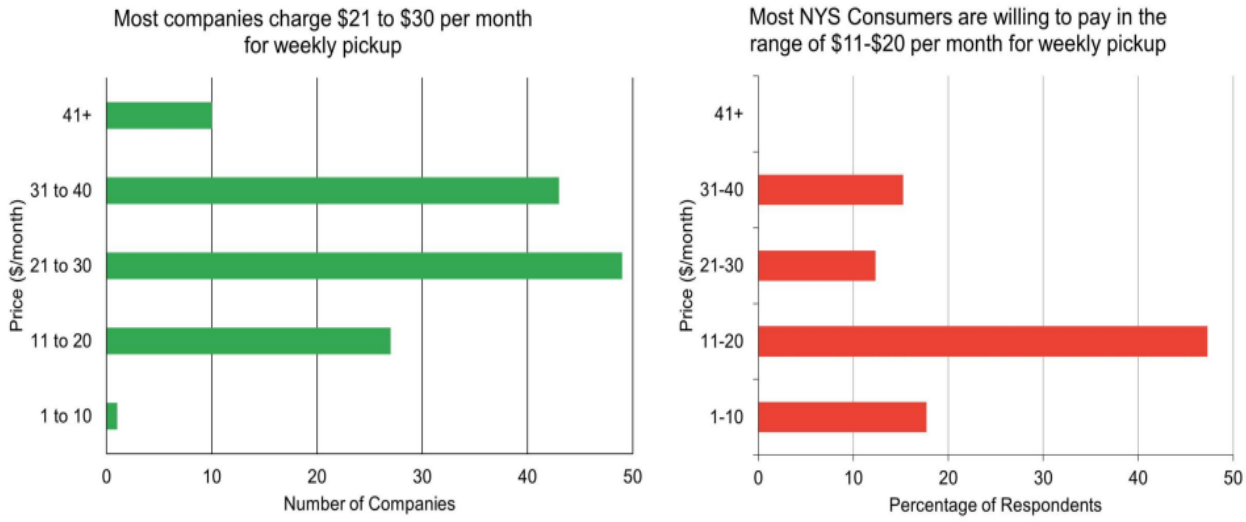

Figure 4.4. Most household food waste pickup organizations charge $21 to $30 per month for weekly pickup of one collection container, but most NYS consumers are willing to pay $11-$20 for the service.

One potential uncertainty is the limitations consumers may have in answering pricing questions on different time scales. Consumers were asked about their willingness to pay on a

weekly basis ($/week), but they might be used to paying bills on a monthly basis. In addition, the study only evaluated consumers' stated preferences, while their actual choices or behavior may be different. and it was not possible to analyze consumer tradeoffs of costs and features, common in waste management literature (Chung & Yeung, 2019).

The consumer survey accounted only for NYS consumer perspectives about willingness to pay, and NYS is a state with a higher cost of living (*Cost of Living Data Series | Missouri Economic Research and Information Center*, 2022). Therefore, the market analysis was disaggregated by state where the business operates, and then pricing was analyzed for services offered in NYS (Table 4.6). These results show that the average price for weekly pickup of one collection container in NYS is $37/month, still higher than the $11-$20/month most NYS consumers said they would pay for this service. The results also show a range of weekly pickup pricing within NYS. Last, the median price in NYS is $30/month, which is still higher than the price consumers are willing to pay.

Table 4.6. An overview of the pricing data for weekly pickup of one 4-, 5-, or 6-gallon container of residential food waste for organizations operating in NYS

NYS Pricing Statistics for Weekly Pickup of One Collection Container of Residential Food Waste			
State	**Range ($/month)**	**Median ($/month)**	**Average ($/month)**
NY	25-60	30	37

3.3.2 Separators and Non-Separators Willingness to Pay

In addition to asking the survey participants about their stated willingness to pay, they were also asked about their past behavior (within the last 12 months) with household food waste separation. Past experience has been shown to impact consumer perspectives about organic waste management programs (Ladele et al., 2021). Therefore, participants stated willingness to pay was evaluated to understand how experience with household food waste separation may play a role in consumers' perspectives.

In Chapter 2, Separators were defined as survey participants with experience separating food waste via any method. Non-Separators were defined as participants without experience separating their household food waste at all. The Separators group was disaggregated further into two groups: Separators (use a pickup service) defined as those who have used a

household food waste pickup service in the last 12 months (n = 158), and Separators (don't use a pickup service), defined as those who have experience separating in the last 12 months, but did not use a pickup service to do so (n = 149).

The results show that Separators who use a pickup service, are willing to pay more than both Non-Separators and Separators who don't use a pickup service. Most Separators who use a pickup service are willing to pay $32 per month, which is more than the $21 to $30 per month most services charge (Figure 4.4), and more than the $20 per month most Non-Separators and Separators who don't use a service, are willing to pay. Typically, support for organics programs is highly sensitive to cost, but other factors, like experience, can play a role in consumers' willingness to pay. This result is similar to a finding where communities that had experience with an organics program exhibited higher support for the program (Ladele et al., 2021). Furthermore, this result provides support for the growing sector of household food waste pickup services (ILSR, 2023); there are consumers who desire and are willing to pay the price to use these food waste pickup services.

Other factors such as available infrastructure can impact consumer perspectives as well (Metcalfe et al., 2012; Sterner & Bartelings, 1998). New composting technologies are available to enable easy in-home management of household food scraps for individuals limited on time and space for traditional composting (Rosner, 2023). This study did not inquire about this type of specific solution in the survey, but focused on home composting in general. It is possible that some survey participants are utilizing these or the availability or knowledge of such solutions may be a factor worth investigating in addition to the impact of other factors such as greenness, attitudes, or yuck factor, on consumer willingness to pay.

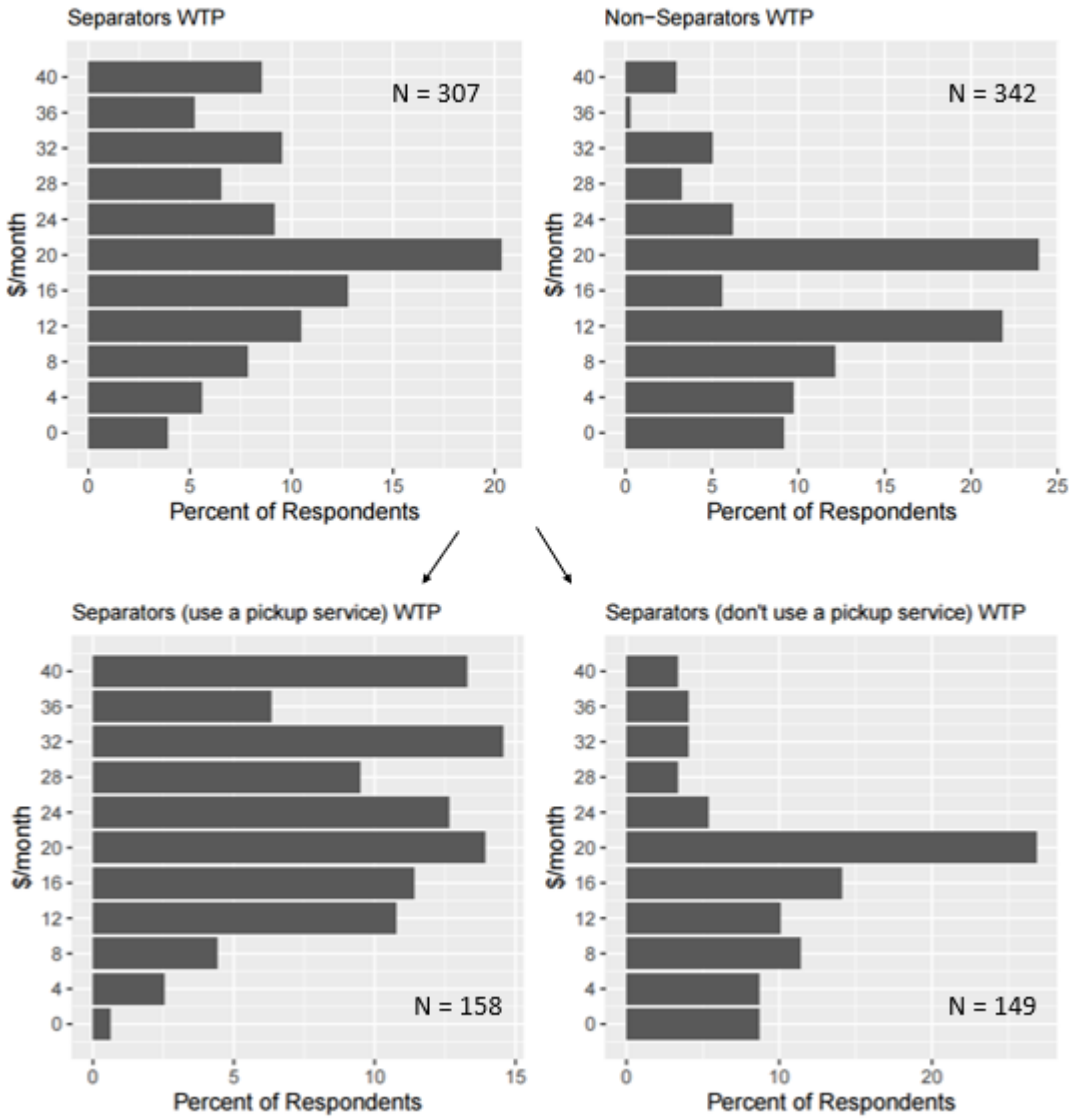

Figure 4.5. NYS consumer stated willingness to pay (WTP) for a food waste pickup service in $/month, broken out based on their experience with separating household food waste (Separators) and those without experience (Non-Separators) in the top row. The Separators were further disaggregated into two groups: those who use a food waste pickup service and those who don't use a pickup service in the bottom row. Weekly pricing preferences from the survey were transposed to monthly ($/month) values for comparison to market analysis results.

Altogether, the market analysis pricing results and consumer survey results indicate a disconnect between the businesses' goals and pricing and consumer preferences, a known issue for organics curbside services (Benyam et al., 2020). The findings show that most consumers may prioritize low cost options over convenience features, aligning with research that consumers are inherently cost conscious about waste services (Gellynck et al., 2011). Yet, the market analysis also shows a number of consumer-facing features are included in the

business model. In this way, the results from the market analysis and consumer survey presented here expand on the interview results in chapter 3, in which participants explained a contributing factor to their profitability challenge is consumer unwillingness to pay and high operational costs from offering cleanliness service features. Business models need to reflect what customers want and how they want it but they also need to be profitable (Teece, 2010). Therefore, these results suggest discrepancy between consumer preferences and business features.

One area of uncertainty is how consumer preferences or willingness to pay may be impacted based on available organics programs or differing waste payment structures. A number of solutions exist in the literature and real-world aiming to address the financial challenges associated with consumer willingness to pay for organics curbside pickup. Weight-based trash disposal models, also known as “Pay as You Throw” (PAYT) have been successful at prompting household food waste diversion (van der Werf et al., 2020). Additionally, a clear-bag policy increased the amount of material recycled and reduced overall municipal waste (Akbulut-Yuksel & Boulatoff, 2021). Another option involves a municipality raising resident waste pricing to cover contracting directly with a pickup service to provide its services to their residents (*Council Approves Solid Waste Fee Increase to Pay for New Food Composting Program, Higher Costs*, 2022). It is unclear how these structures would impact participation in these services specifically.

4. Limitations and Future Work

The goal of the market analysis was to establish a broad overview of household food waste pickup features and attributes. The scope of the market analysis was limited to organizations that contract directly with consumers to provide a household food waste service in exchange for a fee, which excludes municipally operated programs where the cost of using such a service is included in local taxes. Future work may expand to include municipal programs, or to compare the features, attributes, and pricing of municipal programs to those of subscription services.

The purpose of the consumer survey was a descriptive exploratory study to begin to characterize and understand consumer perspectives about emerging household food waste pickup services. One limitation of this study is the total number of survey questions was limited to minimize time and cost of survey response, and therefore doesn’t fully explore the valuation consumers may hold for the different features and attributes of household food waste pickup

services. Additionally, consumer stated preferences for household food waste solutions and willingness to pay were evaluated in this study as opposed to utilizing a choice experiment or other revealed preference model, which would be a logical continuation of this work. Consumers' actual behavior may be different (Jamieson & Bass, 1989), but stated preference was chosen because framing choice models accurately requires knowledge of consumer perspectives about the attributes (Blamey et al., 2000). While this work did not evaluate consumers' tradeoffs of costs and features for the services, future work can use these initial findings to further investigate the attributes consumers prioritize and value in these services and then determine consumers' revealed preferences and tradeoffs

This work did not account for external factors and demographics that may impact results. For example, environmental attitudes or demographics such as education, gender, and income level have been shown to impact individuals' support and perceptions about using food waste curbside collection, as well as the types of waste programs and policy (Ladele et al., 2021). Yet, the role of these factors was not evaluated in the consumer stated preferences. Future work might seek to establish how these variables impact consumer perspectives about household food waste pickup services.

One limitation of the consumer survey is also the timeframe of study and distribution. The survey was distributed in the fall of 2020, after the coronavirus pandemic had altered many lifestyles with more people staying home or working from home, and living different patterns of life. In the fall of 2020, the pandemic was still on-going, with NYS one of the states experiencing severe impacts from the event. However, this study could not account for any impacts of the pandemic on the results, such as if peoples' preferences for home composting versus pickup were impacted by concerns or beliefs about spread of the virus through food material. It is also possible consumers' willingness to pay may have been affected by any personal financial impacts of the pandemic.

This study served to establish a broad descriptive overview of the consumer-facing attributes and features of household food waste pickup services, and consumer preferences for those services. The purpose of this study was to lay the groundwork to begin to understand an emerging business model and consumer perspectives to support future work. More study is needed to evaluate the intricacies of these business models, especially the discrepancy between consumers' prioritization of low-cost options over the features the businesses provide as part of their value propositions. There is a need to understand how these businesses can leverage their features and pricing models to meet consumer needs while supporting their financial stability.

5. Conclusion

Household food waste pickup services represent a new industry able to contribute to broader sustainable goals, yet they rely on the participation of consumers. This study investigates the attributes and features of the broad sector of household food waste pickup services, and how they align with consumer preferences for this type of service model. The purpose of this work was to contribute to existing literature by being the first to establish an exploratory overview of the broad household food waste pickup service sector. The results show variability in attributes across the sector, but some dominant implementation features. A cleanliness service method is a common feature of these business models, with bucket swaps being the dominant choice. There is a range of pricing for the varying pickup frequencies for one collection container, and other factors in the business model that affect the total cost for consumers to participate were highlighted.

This study also serves to establish the first known consumer preferences about these household food waste pickup services, such that future work can build off of the findings. The results indicate consumers state they prioritize low-cost options for household food waste management over other service features, like receiving a clean bucket back. This study is the first to show consumers stated preference for what they are willing to pay for a food waste pickup service. A discrepancy was found between the $11-$20 per month for weekly pickup of one collection container NYS consumers are willing to pay, compared to the $21 to $30 per month most organizations charge for this type of pickup service. Additionally, Separators with past experience using a pickup service are willing to pay more than Separators without past experience with a service, and more than Non-Separators.

As a result of the work laid out in this chapter, a starting point to support future investigation into household food waste pickup service business models is provided. The results provide missing information needed to support further study, and ultimately the growth and establishment of community composting solutions to promote participation in household food waste management.

Chapter 5: Summary, Conclusion, and Future Work

Landfill diversion of household food waste relies on consumers to separate household food waste and provide the necessary material stream, but participation in solutions like home composting, and household food waste pickup services is a challenge. Through an investigation of factors influencing the people responsible for generating the household food waste stream,

identifying pickup services' challenges and operations, a comparison of solutions and consumer preferences, this research aims to fill the knowledge gaps to support consumer participation in household food waste solutions. A summary of the main contributions of this work is provided below:

Chapter 2

- We identified the underlying beliefs and factors that affect individuals' intention to separate their household food waste, including moral norm, and natural living and recycling habits.
- We examined how concerns about odor and pest outcomes negatively impact individuals' intention to separate their food waste.
- We demonstrated how the underlying beliefs informing intention to separate are different for people with experience separating (separators) compared to people without experience separating (non-separators).

Chapter 3

- We established the costs and challenges of community composting operations through the perspectives of the founders and employees who operate the organizations.
- We determined how consumer needs for cleanliness impact the business models.
- We established how consumer unwillingness to pay impacts the pricing of the business models contributing to the profitability challenge.
- We established the external policy and infrastructure constraints limiting the sector and their broader household food waste diversion goals.

Chapter 4

- We provided the first collective state of the market review of food waste pickup services business models.
- We established a broad overview of the varying household food waste pickup business model attributes, and the dominant implementation features.
- We established NYS consumer willingness to pay for household food waste pickup services and priorities for residential food waste pickup business model features.

The results of this work provide outline the barriers consumers and businesses face in household food waste solutions for landfill diversion. This information can be used by multiple stakeholders, municipality officials and business operators alike, to support the implementation and growth of successful household food waste solutions that people will want to engage with. We identified beliefs and factors that support and hinder individuals' intention to separate, such as how the amount of space available within a home is an important underlying belief for separating household food waste. However, this work did not account for how consumer beliefs or preferences for food waste pickup services may vary based on the type of area they live in: urban vs. rural. Future work should investigate how this factor impacts consumer beliefs and preferences for food waste management and pickup services.

We highlighted the challenges in the community composting sector but did not investigate or study the role of commercial clients in the business models. Additionally, the focus of the work was solely on businesses contracting directly with consumers. Future research efforts should expand on this work to engage with other stakeholders involved in municipal programs and broader household waste management infrastructure, including investigating the role of their commercial clients and business.

A noted challenge from the interviews in Chapter 3 is consumers' misconceptions about household waste management being free because it is included in their taxes. However, as noted in Chapter 4, some areas implement PAYT trash payment structures, charging based on either bin size or weight, and yet a third option is that consumers are solely responsible for selecting and paying for their waste management services for the home themselves. The consumer survey did not account for how these varying current waste management payment structures may impact consumers stated willingness to pay. Future work is needed to evaluate how varying policy and payment structures impact consumer perspectives for the services.

This dissertation involved understanding consumer perspectives in NYS, so future work could extend these analyses to include nationally representative populations and explore additional factors surrounding their willingness to separate food waste and/or pay for residential food waste services. Additionally, this dissertation provided a broad overview of residential food waste pickup business models and insights into consumer preferences for these services. Future work should expand on these findings to investigate how consumers value the different implementation features of household food waste pickup services, and the role that environmental attitudes, and demographic features such as income, or gender may play in consumers stated or revealed preferences.

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Appendix

Chapter 2 Appendix Items

Table A1. Representative interview quotes, literature sources, and survey questions that ultimately defined the hypothesized latent variables.

Interview Quotes	Construct	Literature	Survey Question
"But just in general it was just something that we thought was a good thing to do."	Attitude	Barone et al., 2019; Greaves et al., 2013; Kumar, 2019; Russell et al., 2017	ATT1: Separating HFW is…extremely bad/extremely good to do ATT2: Separating HFW is…extremely worthless/extremely worthwhile *ATT3: The activity of separating household food waste is…extremely unpleasant/extremely pleasant ATT4: Separating HFW is…a complete waste of time/a completely good use of time
"My family is kind of against it. They reluctantly cooperate."	Subjective Norm	Barone et al., 2019; de Leeuw et al., 2015; Nguyen et al., 2015	SN1: People important to me…approve of separating HFW (strongly disagree to strongly agree) SN2: People important to me…separate their own HFW (strongly disagree to strongly agree) SN3: People important to me…think separating HFW is a good thing to do (strongly disagree to strongly agree)
"I didn't want to manage the compost myself." "I didn't feel like I had the mental or actual time to invest in the cheaper option." "My wife and I would talk about it first."	Perceived behavioral control	Barone et al., 2019; de Leeuw et al., 2015; Khan et al., 2019; Russell et al., 2017	PBC1: Is it your decision whether or not you separate HFW in the next 12 months? (not my decision to completely my decision) PBC2: How much control do you have over separating the food waste in your household? (no control to complete control) PBC3: Do you have the ability to separate your HFW? (No to completely)
"The intention would be there, the ability to execute I'm not sure."	Intention	Barone et al., 2019; de Leeuw et al., 2015; Heidari et al., 2018	INT1: How often do you plan to separate in the next 12 months? (never to always) INT2: How much of your HFW do you plan to separate in the next 12 months? (none to all of it) INT3: I am determined to separate HFW in the next 12 months (does not describe me, completely describes me)
"I think just knowing that we're not putting things in the landfill that we might have put in a landfill before. And it also makes me feel a little less guilty. I do have some food waste.	Moral Norm	Kumar, 2019; Si et al., 2020; Tonglet et al., 2004	MN1: Separating HFW will benefit future generations (strongly disagree to strongly agree) MN2: Separating HFW is the right thing to do (strongly disagree to strongly agree) MN3: Separating HFW reduces guilt (strongly disagree to strongly agree) MN4: Separating HFW is the duty of a responsible citizen (strongly disagree to strongly agree)
"We would pick those up at the farmer's market and use them in our own garden." "I'm a fairly avid gardener" "We are heavy duty recyclers." "We have one here for newspaper papers and the other one for plastic and metal and glass and I do that faithfully." "We recycle everything we possibly can."	Natural Lifestyle Habits, Recycling Habits	Abdelradi, 2018; Edgerton et al., 2009	NLH1: I garden at my home (does not describe me to completely describes me) NLH2: I visit local farmers' markets (does not describe me to completely describes me) NLH3: I purchase green cleaning products (does not describe me to completely describes me) *NLH4: I give money to charity (does not describe me to completely describes me) *NLH5: I follow a vegetarian diet (does not describe me to completely describes me) *NLH6: I drive a hybrid or electric vehicle (does not describe me to completely describes me) **RH1: I recycle electronics (does not describe me to completely describes me) **RH2: I recycling items such as cans, bottles, paper, cardboard, or glass (does not describe me to completely describes me)

Appendix

*Denotes survey questions that were removed from the respective construct during the CFA (see section 2.0 Methods), and **Indicates survey questions that formed a separate construct during the CFA.

Table A2. Representative interview quotes, literature sources, and survey questions used to assess formative beliefs.

Interview Quote	Expectancy and Value Questions
"I don't know that I enjoy it, but it's important to me to feel like I'm not just sending things off to the landfill, I really hate that." "You know it feels somewhat expensive. It seems like a luxury to me to be able to have that kind of pick up except that we're saving money in that we're doing that every other week trash pickup.	**Behavioral Beliefs** (Responses given on a unipolar scale, 1= not likely to 5 = likely) Question: Separating household food waste would… reduce harm to the environment reduce the amount of trash sent to the landfill reduce my household trash costs **Behavioral Belief Evaluations** (Responses given on a bipolar scale, -3 = extremely unimportant to +3 = extremely important) Question: If the above outcomes happen, how important are they to you?
"I want to do it. But it's my husband." "After we started this my one friend started out. And a woman at work. And my niece is like 'I want to do that.'" "A neighbor a couple of neighbors really were pretty influential in our decision to take it on."	**Injunctive Norm Beliefs** (Responses given on a bipolar Scale, -3 = completely disapprove, +3 = completely approve) Question: In general, would the following people approve of you separating household food waste? Family, Friends, Neighbors **Injunctive Norm Motivation to comply** (Responses given on a unipolar scale, 1 = not motivated, to 5 = completely motivated) Question: When it comes to separating household food waste are you motivated to do what people think you should?
"My son is really good about it. My daughter not so much. She'll do it if I ask her." "It was a mix of independent discovery and then also knowing that other people were using the service." "A neighbor, a couple of neighbors really were pretty influential in our decision to take it on."	**Descriptive Norm Beliefs** (Responses given on a bipolar scale -3 = definitely do not, to +3 = definitely do) Question: In general, do people in the following groups separate their own household food waste? Family, Friends, Neighbors **Descriptive Norm Motivation to comply** (Responses given on a unipolar scale, 1 = not motivated to 5 = completely motivated) Question: When it comes to separating household food waste, are you motivated to do what these people do? Family, Friends, Neighbors
"I guess just not feeling like time-wise it was going to be feasible to do what it took to have a good DIY option." "I thought yeah that's a good idea but I don't have room in my backyard for something like this." "Ok so it's a bit of kind of like a learning curve for composting." "I guess I have one friend that has been kind of like oh yeah this is a good option, I'm glad you have this kind of thing. It hasn't made her decide to do it because of financial constraints but she's in favor of it." "I like the convenience of having someone take it. The convenience factor of having someone pick it up was huge for me." "Pricing is not what prevented us from doing it, it was probably habit and concern over smell."	**Perceived behavioral control beliefs** (Responses given on a unipolar scale, 1 = not likely to 5 = completely likely) Question: Do you think these situations are likely to occur in the next 12 months? I will be too busy to separate food waste I will have enough space in my home to separate food waste I will have sufficient knowledge of how to separate food waste It will cost me money to separate A food waste pick up service will be available to me A food waste drop-off location will be available There would be arguments in my household about separating People in my household would be supportive of separating I would have to clean out a collection container I have the ability to compost food waste I will have a use for the compost (in a garden for example) *The food waste would cause an unpleasant odor in my home *The food waste would attract pests such as insects, rodents, or other animals *The food waste would cause my kitchen to be messy **Perceived behavioral control powers (**Responses given on a bipolar scale, -3 = A lot harder to +3 = a lot easier) Do these situations make it easier or harder to separate household food waste?

*Indicates the three control belief questions which actually formed the yuck factor (YF) construct.

Appendix

Literature used here: Abdelradi, 2018; de Leeuw et al., 2015; Greaves et al., 2013; Heidari et al., 2018; Huffman et al., 2014; Karim Ghani et al., 2013; Khan et al., 2019; Mak et al., 2018; Minelgaitė and Liobikienė, 2019; Nguyen et al., 2015; Russell et al., 2017; Sidique et al., 2010; Tonglet et al., 2004; Wang et al., 2016; Yuan et al., 2016.

Table A3. The Chronbach's alpha (Alpha), average variance extracted (AVE) and construct reliability (CR) of each latent variable as defined as a result of the CFA. NLH was kept because when rounded the AVE value meets the 0.5 cutoff.

	ATT	SN	PBC	INT	MN	NLH	RH	YF
Alpha >0.7	0.89	0.89	0.82	0.95	0.88	0.72	0.67	0.83
AVE >0.5	0.74	0.74	0.62	0.86	0.67	0.49	0.51	0.60
CR >0.7	0.89	0.89	0.83	0.95	0.88	0.73	0.67	0.88

Table A4. Discriminant validity of the latent variables as defined as a result of the CFA. The bold numbers on the diagonal are the AVE. Below the diagonal are the correlations between the latent variables (r). Above the diagonal (italicized) are the squared correlations (r2) of the latent variables. In accordance with Kline's recommendations (Kline, 2016), the r2 values should be less than the AVE to achieve discriminant validity. The variables here reflect adequate discriminant validity.

	ATT	SN	PBC	INT	MN	NLH	RH	YF
ATT	**0.75**	*0.21*	*0.12*	*0.27*	*0.61*	*0.14*	*0.21*	*0.04*
SN	0.46	**0.74**	*0.19*	*0.50*	*0.36*	*0.08*	*0.08*	*0.02*
PBC	0.35	0.43	**0.62**	*0.30*	*0.18*	*0.17*	*0.17*	*0.01*
INT	0.52	0.71	0.55	**0.86**	*0.33*	*0.09*	*0.09*	*0.08*
MN	0.78	0.60	0.43	0.57	**0.67**	*0.23*	*0.23*	*0.02*
NLH	0.37	0.59	0.41	0.64	0.45	**0.49**	*0.12*	*0.02*
RH	0.46	0.28	0.42	0.30	0.48	0.35	**0.51**	*0.00*
YF	-0.20	-0.15	-0.12	-0.28	-0.15	-0.14	-0.07	**0.60**

Table A5. The demographic statistics for the survey data, compared to 2019 NYS statistics where appropriate. The total sample size was n = 649. The data in the NYS column are from (Duffin, 2021; US Census Bureau, 2019, 2015, 2000)

Ethnicity	**n**	**%**	**NYS %**
Non-Hispanic White	435	67.4	62
Non-Hispanic Black	67	10.4	12
Hispanic, Latinx, or Spanish Origin	94	14.6	17
Asian	28	4.3	5
American Indian or Alaska Native	5	0.8	1
Other	16	1.9	2
Prefer not to answer	4	0.6	NA
Gender	**n**	**%**	**NYS %**
Female	370	57	48.6
Male	272	42	51.4
Prefer not to answer	7	1.0	NA
Age	**n**	**%**	**NYS %**
18-24	71	10.9	11.4
25-34	104	16.0	18.5
35-44	116	17.9	15.8

45-54	127	19.6	16.0
55-64	118	18.2	17.0
65+	113	17.4	21.3
Income	**n**	**%**	**NYS %**
Less than $19,999	64	9.9	18.1
$20,000-$39,999	106	16.4	17.7
$40,000-$59,999	68	10.5	14.7
$60,000-$74,999	61	9.4	9.3
$75,000-$99,999	89	13.8	11.9
$100,000-$149,999	95	14.7	14.4
More than $150,000	128	19.8	14.0
Prefer not to disclose	38	5.4	NA
Education	**N**	**%**	**NYS %**
Less than high school degree	12	1.8	6.6
High school degree or equivalent	132	20.3	25.8
Associates (2 yr degree)	83	12.8	8.8
Bachelor's (4 yr degree)	181	27.9	21.2
Graduate degree	221	34.1	16.6
Other	20	3.1	NA

Table A6. Additional demographics collected in this survey.

Residence Type	**n**	**%**
owned by you or someone in your household	453	70
rented by you	190	29
other	6	1
Children in the household	**N**	**%**
Yes	284	43.8
Sometimes	25	3.9
No	338	52.1

Chapter 3 Appendix Items

Interview Protocol

Interviewer will introduce themselves and confirm with interviewee that it is ok to start recording the interview. After verbal consent is received, interviewer will begin the recording over zoom.

–start recording— save it to the cloud

Verbal Consent Script if necessary:
I am Jessica, a student from RIT working on my dissertation. I am conducting a research study to understand how to help households divert food waste from landfills.

Today you will be participating in an interview via Zoom (-or telephone-), which should take less than one hour. Your participation is voluntary. If you do not wish to participate, you may stop at any time. If you have any questions you can ask at any time. All responses will be kept anonymous. There are minimal risks associated with this interview. If you give your consent to participate, please say "I consent".

Overview of myself and research:
Thank you again for agreeing to participate in this interview. Before we start, I just wanted to introduce myself and give a brief overview of my research. I'm Jessica, I'm working to finish my dissertation this year which focuses on helping households divert food waste from landfills. I found out about companies, like yours, that offer food waste pickup as a service and I'm interested in learning more about how this type of service can help people to divert their food waste and also what consumers think about these services.

Review Protocol:
-I will ask questions
-All answers and information will be kept confidential
-We can skip a question at any time, or come back to one if you want. We can stop at any time if you want.

-Do you have any questions before we start?

Opening

1. Can you describe for me your title and role in the company?

Section 1: Background and Start-up

Founder/Employee: First, I'd like to start with learning about the history of the company, can you tell me about how this company was started?
    a. What was the motivation to start this company?
    b. What was the goal? Was there a problem you were trying to solve?
2. Founder/Employee: What challenges or obstacles had to be overcome to start the business and how?
3. Founder/Employee: How long have you been in business?
    a. Potentially: How is it going?

Section 2: Physical operation

1. Founder/Employee: Can you walk me through what a normal day is like in food waste collection and hauling (from picking up food waste, to where it's brought and processed?)
    a. What materials do you accept?
    b. Do you provide a bucket and then replace it (Or whatever you think they do based on market analysis)
    c. Are you only collecting from households or do you also handle food waste from other groups or businesses?

   d. Where do you take the material?
      i. How did you decide to utilize this method (or location) for processing the material?
      ii. (If not shared) What type of facility do you use to process the material? (AD, composting, etc.)
   e. I understand that you collect food waste on bicycles, how does that work? How did you decide to go that route?
   f. It sounds like you would describe the company's primary role as a hauler? Or a hauler and a processor?
2. What are some of the biggest day to day challenges in operations?
   a. How do you overcome these?
   b. Are there any changes in the operation due to seasonality (such as holidays, or cold versus warm seasons?)
3. Founder/Employee: How would you describe the current scale or size of the operation?
   a. How many customers do you have?
   b. Do you track how much material is collected?
4. *Low priority-> Depending on time*: Founder/Employee: What was key to getting you to where you are now?
5. What do you do with the product that is generated from the food waste? (compost or other?)
6. Has Covid impacted your business?

Section 3: Consumer-side of the operation

1. General: Founder/Employee: How has your service been received by consumers?
   a. What kind of feedback have you heard from consumers about your service?
      i. Has consumer feedback led you to adapt your business model or operations?
      ii. How?
      iii. What are some of the main reasons that people have for signing up with you?
      iv. What are the reasons you have experienced that people don't want to sign up?
   b. Price: How did you determine what consumers might be willing to pay for the service?
      i. In general, how do consumers feel about the price for the service you offer?
      ii. Is the price a barrier to getting consumers to sign up with you?
   c. Yuck: In some of our other research we heard that people are interested in participating in this type of service, but think it's gross to separate food waste. Have you heard about this concern from consumers at all? If so, how has that affected your operations?
2. Participation: How do people in your area hear about your service?
   a. Do you use social media (such as Instagram, Facebook, or Twitter) to reach consumers?

    b. (could follow up about word of mouth or discounts/other things we've heard about)
3. Feedback: What kind of information or feedback do you offer to consumers, if any?
4. Education: Founder/Employee: How do you educate or communicate with consumers about what to compost?
    a. What's the craziest thing that someone has put in their collection container?
    b. How are contamination issues handled?
        i. How often do you have problems with contamination?

Future

1. Founder/Employee: What is your vision for this company in the future?
    a. How large would you like to see this company grow?
    b. Do you have plans to offer any additional services or products?
2. Founder/Employee: What are some of the barriers and challenges you face to achieving the goals for the future of the operation?
    a. What do you think would help to overcome these challenges?
    b. How many more consumers or houses would you need to meet the goal?
3. **Companies in states that have passed food waste law: I know that your state has a law that requires commercial food generators to manage their food waste, has that had any impact on your business or operations?
    a. –or generic question– how has waste policy affected your operations if at all? (could put this in operations section as well).
4. Founder/Employee: Businesses similar to yours have started all over the country. Looking broadly, what do you think the role is for community scale composting services in the grand scheme of food waste solutions?
    a. There are similar types of organizations to yours operating throughout the US, do you communicate with other organizations like yours?
        i. Is there a network that you're a part of?

Is there anything that I didn't ask about that you'd like to talk about?

If I think of any follow-up questions would it be ok if I email you?

Chapter 4 Appendix Items

If both of these options were available to you, which would you prefer?

Pick-up Composting

Costs $6 per week

The food waste is picked up at your home

Someone else cleans the container

Also takes meat and dairy

Receive compost back

Drop-off Composting

Costs $3 per week

You drop-off the food waste at a location within 3 miles of your home

Someone else cleans the container

Also takes meat and dairy

Do not receive compost back

Pick-up Composting ○

Drop-off Composting ○

Figure A1. The full details of the NYS consumer survey question asking participants to select their preference for either a dropoff or pickup composting service.

If both of these options were available to you, which would you prefer?

Home Composting

Free

You compost the food waste at your home

You clean the collection container

Takes fruits and vegetables

Compost available to use

Pick-up Composting

Costs $6 per week

The food waste is picked up at your home

Someone else cleans the container

Also takes meat and dairy

Receive compost back

Home Composting ○

Pick-up Composting ○

Figure A2. The full details of the NYS consumer survey question about preferences between pickup and home composting.

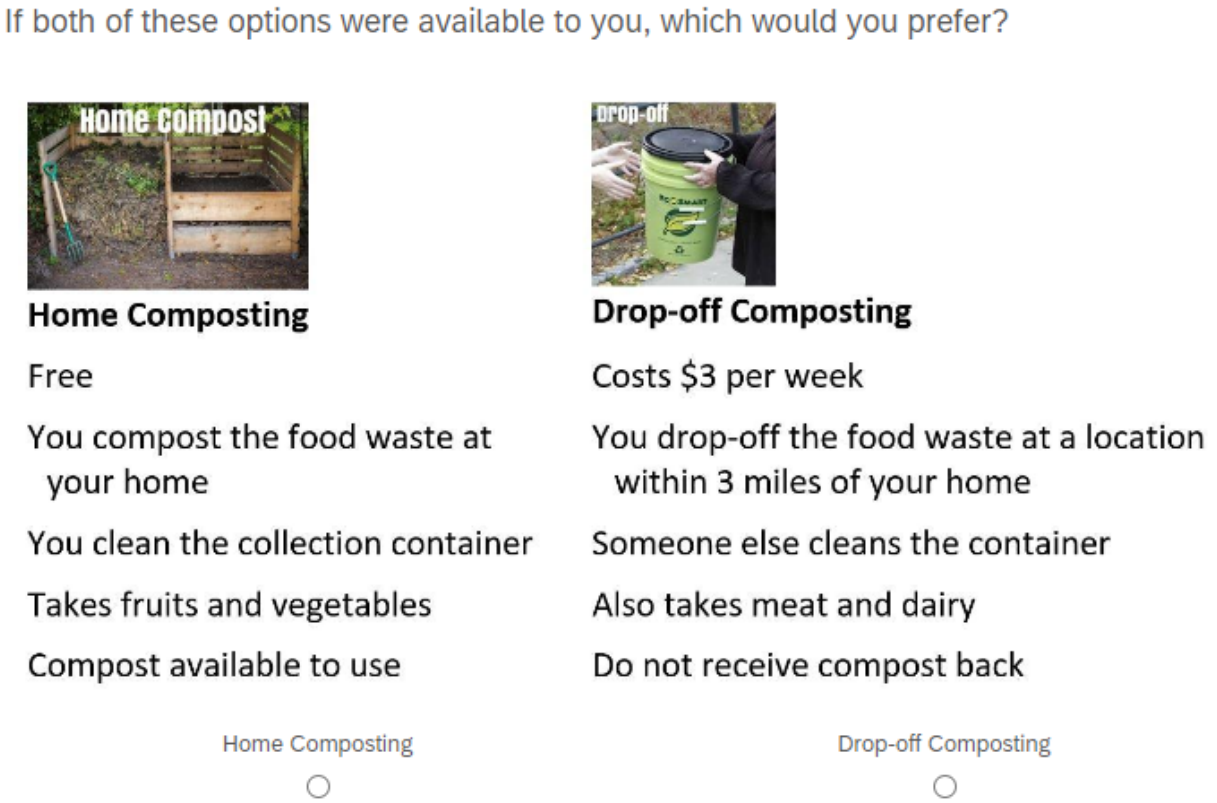

Figure A3. The full details of the NYS consumer survey question asking to select a preference between home composting and dropoff.

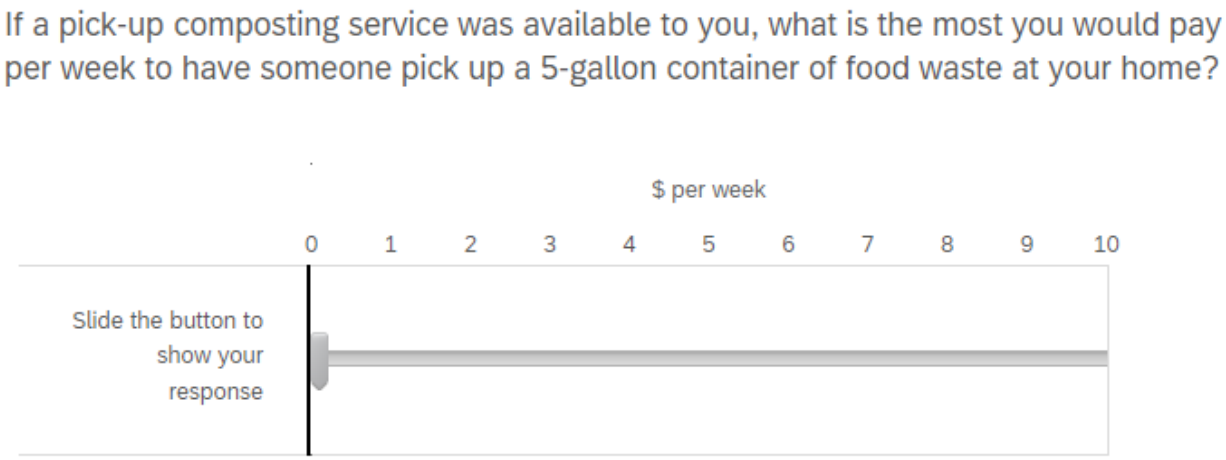

Figure A4. The full details of the consumer survey question asking participants about their willingness to pay for pickup service.

Figure A5. The full details of the NYS consumer survey question asking consumers to select the most important factor in their decision to participate in a food waste service.