RETHINK Aging in Place:

An Integrated Indoor Domestic Waste Management System

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In

Inclusive Design

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Abstract

The world's population continues to grow older at an unprecedented rate. In 2015, 8.5 percent of the world's population (617 million) was aged 65 and over. According to the report, "An Aging World: 2015", this demographic group is projected to jump to nearly 17 percent of the world's population by 2050.

Concurrent with this increase in older populations, the 20th century has seen the dramatic increase at the global level in the production of waste. In the past, many societies took an "out of mind" approach to waste disposal issues through the use of landfill waste management, but landfills are now increasingly being perceived as a burden for the whole globe and for future generation.

There is a strong connection between the growing numbers of older adults in North America who are aging independently in their home and their deteriorating behaviors with managing their waste. There are several factors that effect on waste management including changes on shopping habits and related packaging issues as well as a changing population with large numbers of new immigrants who are not used to municipal waste management systems. Prior research indicated the targeting moral obligations, applying planned behaviour programing, and incorporating a positive attitude towards environmentally friendly products can have a positive effect on recycling behaviours. This thesis reports on a study focused on the mature homeowners who are more likely planning to age in place, and desire to understand the limitations of their behavior towards waste management. This study used a qualitative approach, using interviews to understand the views of older adult participants about changes in their home or behavior which

could be compatible with waste disposal. The literature and interviews identified and explored key themes that potentially influenced older adults' attitudes and behaviours related to domestic kitchen waste management: convenience, safety, fits lifestyle expectations and cost. Based on the analysis of the data, two prototypes for an integrated indoor domestic waste management system were designed to encourage older adults to engage in sustainable waste management of garbage and recycling in their homes.

The findings from this study provide useful improvement to the waste management disposal, identifying the mechanisms needed for user's satisfaction for an additional and adequate engagement of domestic waste disposal. The results assure and advocate the use of an accessible, safe, and effective integrated waste management system to domestic waste in terms of ameliorate the behaviors of households towards waste management.

Keywords: Age in place, Waste management, Mature adult's behaviour, Qualitative approach, Convenience, Safety, Fits lifestyle expectations, Cost.

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Finally, I would like to express my deepest appreciation to my family and my friends for being so supportive, special mention to my husband who encourage me and believe in my ability. Great love to my children, I am looking for seeing your work in the future. I dedicate my work to my father who was always my inspiration.

Dedication

The idea of designing an in-home waste management system came to my mind when I moved to live in my house. I lived in an apartment for several years before deciding moving to a house while my children were growing up and needed a bigger place to live in. The move into a detached house required bravery from my side. In the beginning, many things were unusual to me, such as the care of the backyard, cutting the lawn, and the engaging in suburban waste disposal. I was impressed by the waste system offered by the municipal government that helped people live in a clean and healthy community by transferring most waste into beneficial materials. As an interior designer, I was interested to keep the house functional and convenient for each member of my family; I was keen to solve the waste management system inside the home.

I was inspired by Jacquelyn Beth Frank when she mentioned in “The Paradox of Aging in Place in Assisted Living” that “many designers, policymakers, and planners were simply acting on the residents’ behalf, and creating residential environments that they believed would be functional for residents.”

“Aging in place” is an appealing term that I was interested in relatively to - interior design - especially as it applied to senior populations. While Assisted living for seniors were growing significantly, hoping to serve them a better quality of life, most aged people prefer to live and stay in their home and their community independently as much as possible. Thus the potential of designing an in-house waste disposal system suitably designed to assist seniors in their homes in disposal their waste in support of maintaining independent living became a topic for this Inclusive Design Masters Research Project (MRP).

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1. Introduction

1.1. An Aging Population

The world's population continues to grow older at an unprecedented rate. In 2015, 8.5 percent of the world's population (617 million) is aged 65 and over. According to the report An Aging World: 2015, this demographic group is projected to increase by an average of 27 million a year over the next 35 years, reaching 1.6 billion in 2050 (An Aging World: 2015).Figure 1 illustrates that over the next 20 years, Canada's seniors' population — those age 65 and older — is expected to grow by 68%.

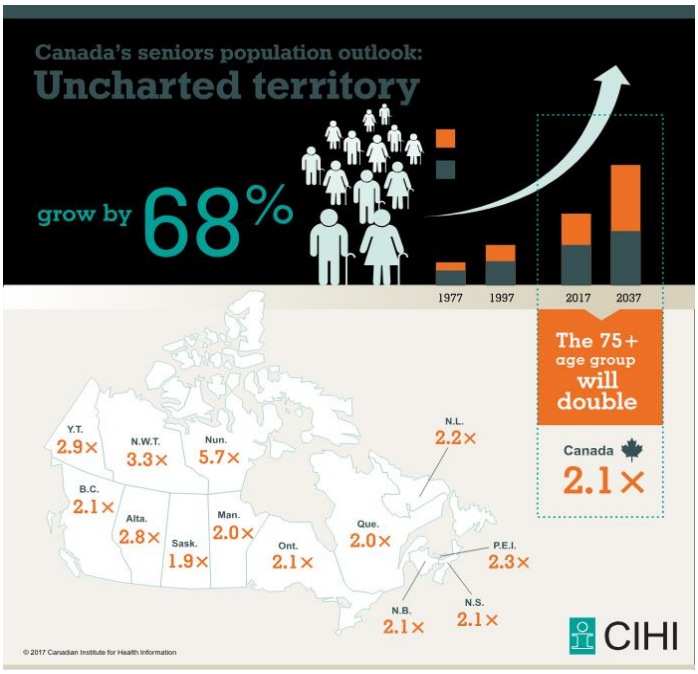


Figure 1 : Growth in the older population in Canada indicates a similar general rate of growth across the ten provinces.

It has been reported by Statistic Canada (2018) that according to demographic projections, the proportion of seniors is expected to increase rapidly until 2031, when all the baby boomers will have reached 65. Seniors could represent between 23% and 25% of the total population in 2036 (Statistic Canada, Seniors, 2018). With continued population growth, the need for building accessible homes will necessarily have to be addressed. There is a high awareness regarding the quality of life in terms of functionality and accessibility among this generation of older people. Consequently, housing design needs to address supportive design and technology especially for people who have physical or other disabilities associated with aging.

According to Statistic Canada, Living arrangements of seniors (2018), The 2011 Census of Population counted nearly 5 million (4,945,000) seniors aged 65 and over in Canada. While 92.1% from this group lived in private households or dwellings (as part of couples, alone or with others), others 7.9% lived in collective dwellings, such as residences for senior citizens or health care and related facilities" (Living arrangements of seniors, 2018).

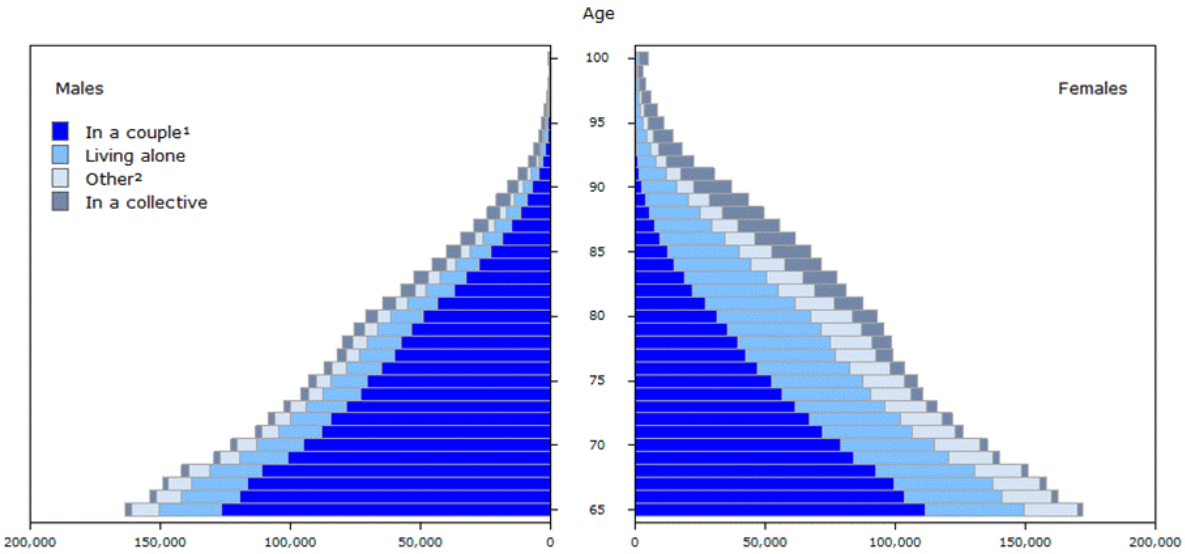


Figure 2: The high percentage of people who are living alone and in a couple according to others from age 65 and older

Figure 2 illustrates the age distribution of the Canadian population aged 65 and over (by single years of age) in 2011 by gender (men and women only) and living arrangement. The categories for living arrangements include living as part of a couple, living alone, other and living in a collective dwelling. Statistics Canada, Census of Population (2011) reported that the categories 'couple,' 'living alone' and 'other' include the population in private dwellings only. The word 'Other' means persons who are lone-parents or an adult children who with relatives and/or non-relatives (Living arrangements of seniors, 2018).

1.2. Maintaining "Aging-in-Place"

It is clearly stated by Davey, Nana, de Joux, & Arcus (2004) the meaning of the term "Aging-in-place" whish is defined as remaining living in the community, with some level of independence, rather than in residential care (Davey & New Zealand Institute, 2004, p.133). "for older

homeowners, remaining at home may depend on their ability to keep their home in good condition, safe, suitable and confortable" (Davey, 2006). In other words, aging in place is a term used to describe a person who lives at their home for as long as they are able, relative to their aging and maintaining independence.

It is important for seniors to consider and plan to accommodate the changes that will occur to them as they get older. Some of the functional changes frequent when people aged are:

- -Reduced vision
- -Decreased muscle strength or endurance
- -Reduced mental processing capabilities
- -Increased risk of falls due to balance
- -Increased risk of illness
- -Reduced hearing
- -Decreased mobility

These conditions may profoundly impact older adults' abilities to function in their daily life activities, such as traveling between the interior and exterior of their home, climbing stairs, performing upkeep and maintenance of the house and other daily activities that involve physical exertion, balance, and ability to carry loads. In the case of typical residential waste management for single family residences, seniors face potential safety issues when transporting waste from the interior to the exterior location of garbage and recycling bins, moving these bins to the street and back to their place. Harsh cold and ice during the winter could affect the potential risk of falls. These challenges can cause older adults to keep their garbage inside their home for extended periods to reduce the number of times they have to travel outside to dispose of waste

into garbage and recycling bins, which is a potential risk factor for health. Thus, providing a convenient method to manage the disposal of household waste from inside the home to garbage recycling bins would be confortable, safe and healthy for older adults.

1.2.1. Dignity and Independence

The concepts of dignity and independence are widely considered as core components of aging well. In a study conducted in The South-eastern United States, where nearly a third of the residents are age 65 and older. Black, Dobbs, & Young (2012) stated that older adults expressed ways in which they enhance dignity and independence for their own contemporaries. Older adults reported that their dignity is based on self-reliance and being self-sufficient and not becoming a burden on or dependent on others, any efforts to assist older adults in maintaining dignity and independence as they age will surely be viewed as welcome relief (Black, 2012). Activities of daily living, including fixing meals, cleaning, grooming, and toileting, need adequate operational space, operational tools/ mechanisms for functionality. Integrating these elements creates a functional system. Creating functional systems within the home of older adults is a crucial factor in staying independent.

This research focuses on the objective for the elderly to live independently and full of dignity. In fact, the “average incomes for people 65 and over are lower than for younger people, related to levels of workforce participation” (Davey, 2004). The financial cost of maintaining a home, especially when one can no longer do household tasks on their own and the associated diminishment of independence within the home environment are important factors related to older adults moving to long term care facilities. However, older adults would prefer to stay

within their own home by making that environment more convenient and safer. According to Etherington (personal interview, November, 2018) the financial cost of living in a long-term care facility is also significant, “When people age, retired, they go to retirement house, this cost between $3000 and $9000 in a month” (Etherington, personal interview, November, 2018).

1.3. Seniors Shopping Behaviors

Seniors shopping behaviors have a profound impact on waste management. Whether from in-store shopping or other shopping methods, people have to be aware of the volume and the material used in the packages left to be disposed after the shopping. When considering the shopping behaviors of older adults, this demographic can be divided into two groups, as stated by Schewe, (1984) who identifies the "young-old," which are aged between 60 and 74, this population can be described as active, vibrant, and healthy, and the "old-old," those who tend to be over 75 and can be described as less healthy, more sedentary, and less sharp in their mental and physical abilities” (Schewe, 1984). Lesakova (2016) introduce his study by stating that seniors have been usually viewed as an unattractive market due to their physical ability and the image of old people being frail. However, Lesakova (2016) revealed in the study that this image has been changed by time, older people consider the social element and experience of food shopping to be a positive factor to this age group and regular social interaction is recognized as a key element in maintaining both mental and physical well-being as people age.

Seniors tend to practice leisure activities that keep them active and socialized such as shopping, gardening, walking, watching television, socializing with friends and family, and reading. Shopping is one of the activities that older people enjoy regardless the methods of shopping used. The attitude of shopping has its impact on seniors' feelings; a research finding by Nuryakin & Farida (2016) had supported a previous research by Ryu (2010) that shopping behavior has significant positive effect of the consumer's satisfaction towards repeat-purchase intention.

Older adults have unique consumption attributes and most seniors have recursive behaviour towards shopping. In order to understand shopping habits and preferences of the elderly, Zalega (2017) analysed the shopping frequency of seniors which revealed that the seniors surveyed were active consumers. As many as 66% of the elderly surveyed were active consumers who systematically visited both small shops and local bazaars as well as shopping malls and shopping centres.

The older adults still have the motivation to shop, but their attitude to achieve their needs are different. As online shopping becomes more prevalent amongst older adults for consumer goods including food products, online product, packaging presents waste management challenges. Online shopping is more accessible than it has ever been to the population at large but especially for older adults with the introduction of tablets, smartphones, easy checkout systems and more secure systems. Impulse buying is an important resource for businesses and an important consideration of older adults who might use shopping to address emotional needs associated with loneliness, boredom, coercive marketing and gaining/preserving identity in retirement. Impulse shoppers buy with no pre-planning at variance to regular shoppers. Providing facilities in shops and online shopping such as free shipping and running sales are effective motivators of impulse buying.

There are some indoor behaviours that are more prevalent in older adults including person-environment relationships, such as possession accumulation “hoarding behaviours” and poor maintenance standards that can produce factors for adverse health effects such as poor air quality, toxic contaminated surfaces, insect and animal infestations.

Barr (2004) noted in his study that individual consumers and households have a vital role to play in achieving sustainable waste management, Barr assured that buying products which will produce less waste, those made from recycled materials, separating wastes for recycling, and composting kitchen and garden waste are helpful in waste management.

While there is no specific requirements to minimize material use in package design, package designers are focused on balancing the need for product protection, material use efficiency and the packaging material’s impact on the environment in the supply chain. A balance in product and packaging material waste can be assessed further to reach an optimal balance of product protection and package use based on waste issues. In regards to package size, some retailer initiatives that are evolving towards healthy environment, such as Amazon, which is trying to ship each order in one correctly sized package instead of multiple boxes, this movement was a response to rising shipping costs and consumers’ concern about the environmental impact and general nuisance of all that cardboard (Stevens& Phillips,2017).

1.4. Initiatives and Services Provided for Aging Population

In a rapidly aging society, many changes can be made to the home to support older adults to live independently. By 2050, seniors will be approaching 20% of the population in developing countries overall. Individual factors contributing to lack of independence, such as decreased mobility, balance, and vision, as well as the effects of some medications, when coupled with external factors in the home, can create risks factors for falls. Household risks such as clutter, uneven floors, inadequate railing or banisters, steep stairs, and slick floor surfaces need to be avoided.

Environmental and product designers can contribute to aging-in-place strategies by creating healthier environments that accommodate people as they age. There are existing devices already available that address mobile impairment including door levers, grab bars, an adjustable-height showerhead with a handheld wand and a walk-in shower/ tubs that incorporate a seating option to extend the ability to older adults with mobility impairments to live independently.

Older adults can experience considerable barriers within both their home and neighbourhood, including barriers and restrictive access to transportation services and other services in the neighbourhood making it difficult to stay active and connected to the society. Some municipal governments provide services for elderly people to minimize the difficulties for citizens such as outdoor services for snow clearing sidewalks. The City of Toronto also provides services for seniors and people with disability residents to help them to get garbage and recycling bins stored outside the home to the curb for pick-up.

However, these services do not address the key component of waste management within the home, especially the sorting of waste as per municipal requirements into the separate garbage, recycling and composting bins.

Collecting waste products and diverting those products that can be recycled into another use is a good ecologic strategy. However, it is not consistently utilized as some people comply with municipal regulations, others ignore good waste management practice and others unintentionally fail to use the correct disposal methods for different types of waste due to unfamiliarity with the regulations.

Education plays an important role with the in-home waste strategies. The methods/protocols of a system must be understood and performed for waste management strategy to function effectively. Municipal governments provide online educational plans to support the waste management and strengthen the ability of people to be more knowledgeable about disposing their waste. However, brochures and online sites that are provided by the government have not been sufficient for many to develop a thorough understanding of municipal waste management regulations and practices.

1.5. Accessibility

Accessibility, in this study, refers to creating a home that functions for people of all ages and abilities.

Why is making a home accessible important? “One in six Canadians (14.3%) lives with a disability and one-third of all Canadians 65 years or over has mobility problems” (Statistics

Canada, 2007). A majority of people would like to live in their homes as long as possible. Today, many single-family homes are unprepared to accommodate accessibility requirements. While building codes include barrier-free design requirements for public buildings have resulted in most public and commercial buildings being designed to be or upgraded to be accessible for persons with disabilities, single-family homes are not required to have the same high standards of accessibility as larger buildings, nor do they address the issue of everyday waste management. Most residential designers and builders do not provide accessible homes that meet the needs of older people with disabilities or are focused on aging-in-place. If designers and developers invested relatively minor resources in the design of new homes, it wouldn't be necessary to make costly modifications to make the home accessible as a homeowner age.

The idea of 'aging-in-place' has become a popular concept for families and individuals who choose to remain in their home and neighbourhood as they age. Planning and implementing features and infrastructural support for additional features that accommodate individuals' needs allows for maintaining their lifestyle as they age reduces the need for future costly renovations. An accessible home supports people of all ages and abilities and is safer and more accommodating to the people who live in these homes. Creating an effective accessible home, also creates the opportunity of aging-in-place for people with disabilities and other family members.

According to many studies, the number of people planning to retire in their current residence is significantly increasing, so it is not a surprise that many home rehab projects focus on accessibility. Popular "age-in-place" renovations include upgraded lighting, wider doors, the addition of elevators or chair lifts and bathrooms with grab bars and walk-in tubs. Kitchen renovations include cabinets and pantry areas, pull-out drawers that provide accessibility at

lower reach abilities, sitting and standing levels are also common. The need of providing a generous circulation and accessible features inside home motivated the author to study and design an accessible "garbage chute" that will assist residents to manage their waste. This innovative designed "Chute" could be effective in sorting the waste effectively and accessibly for older adults in accordance with municipal regulations.

1.6. Waste Management

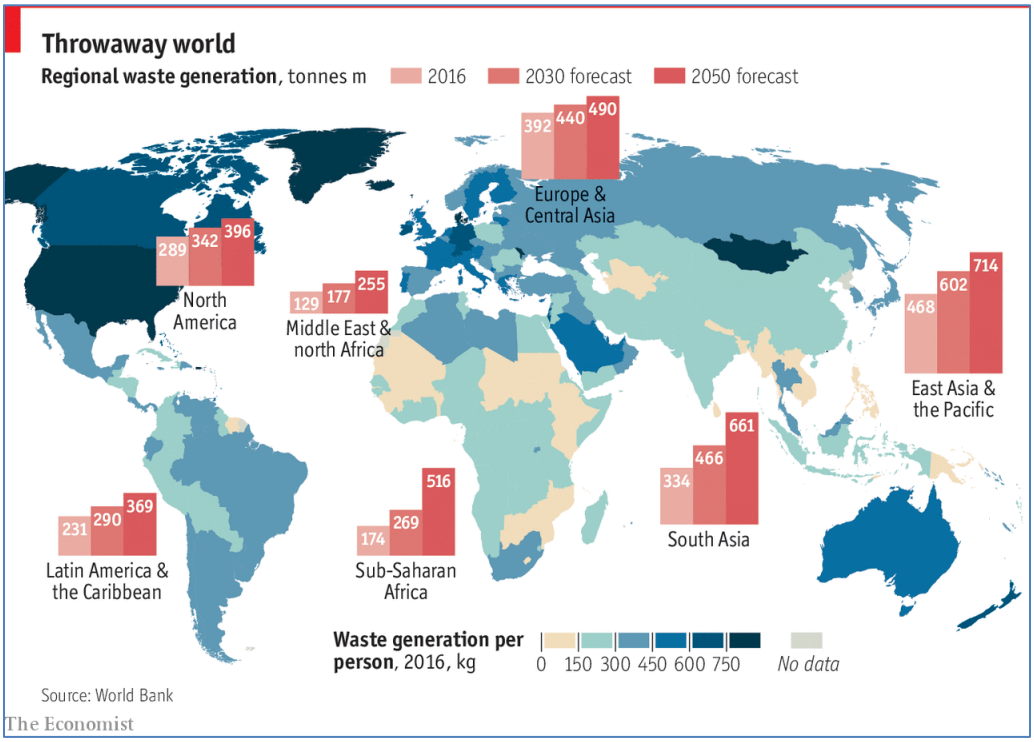


Figure 3: Increasing in waste generation is expected to significantly accelerate through the world (World Bank).

1.6.1. Waste Production

Of all the problems associated with continued rapid growth, waste disposal may be one of the most visible. Cities generate approximately twice as much solid waste as they did before the 20th century and are predicted to achieve higher percentages in the future. In the book WHAT A WASTE 2.0 (2018) it was explained that the "Municipal waste is collected and treated by, or for municipalities". Municipal waste includes bulky waste from households. The economist published in October (2018) that according to the World Bank report, in 2016, the world generated 2.01 billion tonnes of municipal solid waste (household and commercial rubbish)—up from 1.8 billion tonnes just three years earlier. The waste generated equates to 740 grams (1lb 6oz) each day for every man, woman and child on Earth (The Economist, 2018). North America has an established history of producing waste. Despite some societal awareness of the problem, waste generation is still predicted to increase over the next several decades. Figure 3 represents the regional waste generation throughout the world in 2016 and in two different projected years.

CBC news declared (Jan 17, 2013) that Canadians use far too much energy and water, and they produce more garbage per capita than any other country on earth. Canada generates 720 kg of waste per capita per year. The Conference Board of Canada (2019) stated that the increases in waste generation are related to rates of urbanization, types and patterns of consumption, household revenue, and lifestyles. The individual's income and average household disposable income have been steadily increasing since the 1980s which lead to increasing household consumption rates (The Conference Board of Canada, 2019).

Waste disposal is a systematic action for managing waste from its origin to its final disposal. Due to various behaviors of urban residences including shopping behaviours, municipalities are

spending more resources on disposing waste than ever before. Municipal waste management is an expensive public service with municipal governments in Canada spending more than $3.2 billion on waste collection, transport, disposal, and diversion in 2012.

1.6.2. Food Waste

As it is known that separation of waste at the source is admittedly better than the recovery of materials from mixed wastes, the benefit of well disposal of waste reduces the cost of disposal in the long run. Diggelman and Ham (2003) stated that when food waste goes to municipal solid waste systems, it drives collection frequency, making food waste an expensive component of municipal solid waste. Residential food waste is a major issue in many homes, keeping food waste in the kitchen for long time is significantly unpleasant in many sectors. Diggelman and Ham (2003) noted that food waste impacts public health (it rots, smells, and attracts rodents) and costs (it drives collection frequency). The solutions that is most satisfactory for most people; to reduce food waste, to compost it or to get rid of food waste by water such with installing sink grinder.

The future of smart kitchens seems to be working on this global issue, and some brands are creating smart appliances to reduce the production of food waste. Reducing the amount of food used in kitchen is useful but not very reliable as the best solution.

Marinari et al. (2000) noted that home composting can provide a viable alternative for managing organic waste and the compost produced can be added to the soil to improve its characteristics. Using an organic composter help some people to use it for their gardens to grow plants, also the

food waste disposal that is installed in some kitchens is a beneficial strategy to dispose food waste perfectly.

A food waste disposal unit, sometimes referred to a waste grinder, is a kitchen appliance that is mounted directly under the kitchen sink and connected to the sewer pipe. These units are designed to grind biodegradable organics such as meat scraps, vegetables, fruit pits, citrus fruit peelings, coffee grounds and small bones. This use, however, was surrounded by scepticism in certain large cities. New York City for instance, banned food waste disposals for a long time because of concerns that the city's old sewer infrastructure could not handle the additional load. Based on the positive outcome of a study, however, the City lifted the ban and legalized the installation of food waste disposals in residential buildings in 1997. According to Marashlian and El-Fadel (2005), food waste disposals are sold to households under limited or no restrictions in approximately 50 countries including England, Ireland, Italy, Spain, Japan, Canada, Mexico and Australia. Keeping in mind the food waste as an important part of residential waste, it is proposed by the researcher that a potential waste management design that includes food waste disposal will help to create a highly functional waste management system and reduce waste production.

1.7. Shredded Materials:

Most municipal waste systems have regulations on disposing packaging waste to reduce the expenses on sorting and processing. In most cases, packaging requires compaction in size to fit into garbage or recycling bins.

Renee Dello, Project Lead, Waste Management Planning for the City of Toronto, asserted that shredding and compacting materials is not the solution to shrink garbage due to complex process of waste management. “Shredded blue bin recycling materials is problematic for the City of Toronto and this material would not be accepted in our program. Shredded material would cause two issues for the municipal waste operations. Shredded material is harder to contain and is more prone to litter outside on collection days (for example if the winds are strong enough to lift lids or knock bins over). Furthermore, when the material is delivered and tipped onto the floor of a transfer station. Shredded material would be more prone to blowing about and getting tangled in equipment and machinery”.

Additionally, Dello explained that “shredded material would be almost impossible to sort into its constituent parts. For example, while the City of Toronto does collect blue bin materials commingled – it takes them to a material recovery facility (MRF) to be sorted into all the separate streams such as glass, aluminum, steel, paper, cardboard, PET plastic, HDPE plastic and other plastic resins. The City then sells these materials on the commodity market and the revenues help to offset some of the costs of the program. The MRF uses mostly mechanical sorting methods which include magnets, eddy current technology, shaker tables, and optical (infrared light) sorting technology. These technologies work to separate individual items and would not work on materials that have been shredded and jumbled together”.

To achieve lower expenses and more sustainable municipal waste management practices, the challenge will be to reduce the amount of solid waste generated while increasing the potentiality of regular and appropriate waste disposal. This step can be done by providing suitable solutions to integrate in accessible designed home. Including a shredder to the system will be effective to shrink the volume of recycled items and will be acceptable by the city in case of material

separation, in other words, if each material such as paper, plastic and metal are managed in different bags, the materials recycled will be acceptable by the City and consequently the process of recycling will achieve low cost.

1.8. Smart Waste Management:

The global demand of smart waste management through the use of technology in collecting, disposing and managing waste has created a growth industry in residential marketplace especially in urban regions. The development of new services and products is the result of the growing awareness and understanding about the benefits of recycling. Further, the high use of waste as an energy source as an alternative of fossil fuels and the ability to increase the use of recycled materials in other consumer products is estimated to bolster the growth of this segment over next decades. Smart waste management provided the benefits of reduced environmental pollution, employment and revenue generation. Communities, industries, municipalities and various other waste management companies are shifting towards smart waste management in order to cut-down the cost of collection, managing and disposable of waste. Contemporary information technology has been implemented to combine Radio-frequency identification (RFID) technology systems with solar power to create “smart” trash for public waste receptacles. Photopin cc explained the article that adding sensors and compactors to commercial trash cans allow sending real-time data about the “fullness” to web and/or smartphone apps, so waste haulers can make those collections at the time they’re needed, so outdoor bins won’t have overflowed and spilled over.”

All individuals need the freedom and independence to function in their home safely. Technology is one of the features that can be added to enable persons with variables abilities to carry out activities within their home without assistance. Devices such as motion-controlled switches or voice-controlled devices can assist them in opening/closing doors and windows, lighting, home security, appliances, phones etc. Technology assists in improving the safety, usability, and make life easier for many people who are not well served by traditional means.

"The use of technology and automation can create living spaces that are convenient and energy-efficient that minimizes the potential for accidents and result in a home that is adaptable to life's changes". (2008 CMHC, Revised 2016)

As previously mentioned Toronto offers services to seniors and people with disabilities to help them move their garbage and recycling bins to the curb. Providing technological enhancements to the service could improve this essential waste management service. Smart technology can provide a convenient method to minimise common waste disposal mistakes such as incorrect sorting of waste into different curb side bins. Including smart technology into indoor residential waste management environment is a strategy that could assist mature people to live independently in an autonomous, convenient, safe and ecologically responsible manner.

2. Research Design

The goal of this research and design study is to understand and develop a prototype of a system that assists older adults, who live in single family and low-rise multiple units housing, increase their compliance to their local municipal waste management requirements. A qualitative research is indicated as a form of social enquiry that focuses on the way people interpret and make sense of their experience and the world in which they live (Holloway and Wheeler, 2002). Using the qualitative approach, the research explored the behaviour, perspectives, experiences and feelings of people towards residential waste management. The qualitative methods utilized in this study, considering human –centered design approaches to develop a system for residential waste management.

The goals of the study are two-fold. One was to address the following research question:

How can an integrated indoor domestic waste management system attract older adults to engage in sustainable waste management of garbage and recycling in their homes?

The second goal involved the design of a prototype mechanized residential waste management system that could assist older adults better engage in municipal waste management strategies.

2.1. Data Collection

This research and design study was conducted in stages that included three stages of data collection: a literature review, interviews with older adult homeowners that included exploration of their attitudes and behaviours from shopping and managing their waste, and a second set of

interviews with some of the interviewees that participated in the study to gather feedback on two prototypes developed during the design stage of the project.

The literature review was conducted with the goal to understand already identified issues regarding the aging population and its connection to waste management. The background information, which is presented in the previous chapter, informed the development of the interview design and subsequently the design of the prototypes.

The next stage of the study involved interviewing persons between the ages of 40 to 75 years of age, who lived in a single-family housing context. In order to establish a diverse interview group within this relatively small sample size, the researchers focused on recruiting individuals that aligned with one of three distinct population types related to waste management. The first group is represented by people who have a thorough knowledge and experience on how to manage home waste in accordance with expected municipal waste protocols and practice. The second group is represented by people who have lived in the Greater Toronto Area (GTA) for at least 10 years but did not practice or needed more practice to manage home waste in accordance with expected municipal waste protocols and practice. The third group is represented by the people who have immigrated recently to the GTA and lack information about municipal home waste expected protocols and practices. This third group would include persons who are English Language Learners and might not receive municipal information in a language format of their native language.

Participants were recruited using a snowball method where party's that aligned with one of the three groups recommended others to participate. Each potential participant was provided with a representation of a recruitment poster, introductory text and consent form.

A pilot study (pre-exercise), with three individuals not included in the interview population, was conducted to address the design of the interviews in order to address the goal of using inclusive research methods such that members of the community informed the structure, delivery method, content and language of the interviews.

The researcher interviewed five people who represented Group 1, three people who represented Group 2 and three people who represented Group 3. The participant group included three men and eight women. Ages ranged from 40 to 75 years and the mean age was 55.

Each participant was asked to participate in a 45-minute individual semi-structured interview in locations outside their home. This was done to require participants to focus on their general behaviours and avoid bias that might exist should waste issues be present in their home at the time of the interview.

Participants answered semi-structured questions which followed key themes identified from the literature search (convenience, safety, fits lifestyle expectation, and cost) that are structured to meet the conditions of accessibility for people who tend to age in place. (Interview questions are provided in Appendix A).

Data from the literature search and initial set of interviews about the experiences, attitudes and influences that affect kitchen waste management processes was analysed using thematic coding to develop a Thematic Network. Figure 4 below presents the stages of thematic coding method. The technique involved the identification and thematic coding of the key basic experiences identified through the participant interviews, which are identified as Basic Themes for the purpose of establish a Network structure for this study, The next stage of analysis considered how to organize these basic experience into common operational variable identified as

Organising Themes in this study, and then Global Themes that identify the key constructs of an effective waste management system for older adults; safety, accessible, effective, operation, value.

This study was approved and conducted in accordance with the OCAD University REB (No. 101313).

2.2. Data Analysis

Interviews helped to explore specific practical issues and desired outcomes of the identified group regarding their waste disposal needs, opinions or behaviours. The researcher used word and thematic coding to create an affinity diagram of the similar responses and key themes and through multiple iterations of the coding process develop a conceptual for senior adults' waste management in the single-family home context. Martin & Hanington (2012) explained the three steps of Thematic Network. Figure 4 presents the process that involved clustering data step by step which identified Basic Themes, Organising Themes, and Global Themes. The Basic Themes were identified by word analyse with words fitting the themes identified from the literature search (convenience, safety, compatible with lifestyle expectations and cost) and other themes identified as a direct outcome of the interviews. The next step was to examine the relationships of Basic Themes which suggested a set of Organizing Themes. The third step was to identify higher-order Themes or Global Themes that when considered with all the themes provided a conceptual model for the influences of older adult domestic waste management.

Thematic Network

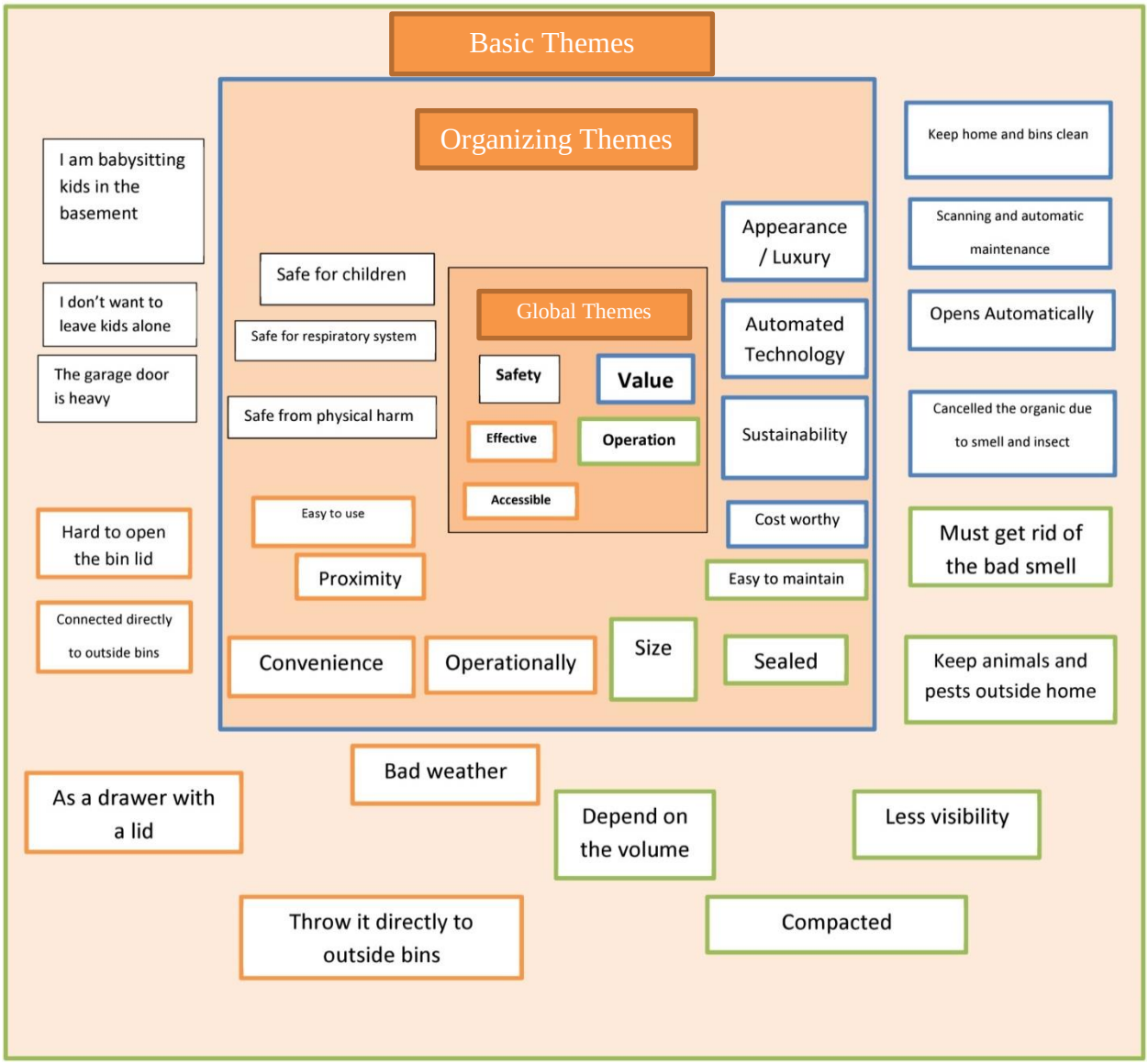


Figure 4: Thematic network used by the researcher to identify Basic Themes, Organizing Themes and Global Themes

2.3. System Analysis and Design Process

In order to design an indoor waste management device/system for older adults living in a single-family home, the design process used the themes of conceptual Network Map illustrated in Figure 4 as operational constructs to analyse the potential key components of a waste management system. The analysis prioritized the global Themes, *Accessible*, *Safety*, *Effectiveness*, and *Value*, in order to understand the advantages and disadvantages of any component of the design iteration of a prototype for a waste management device.

Accessible refers to the "ability to access" and benefit from some system or entity. *Safety* is the condition of being protected from harm or other non-desirable outcomes (Wikipedia, 2019). The meaning in Wikipedia for *Effectiveness* is the capability of producing a desired result or the ability to produce desired output. When a product or system has an expected outcome, it is consider effective, it means it has an intended or expected outcome. *Value* is a measure of the benefit that may be gained from goods or service (Wikipedia, 2019).

The process of designing a waste management system used a de-constructive approach with the elements of potential waste management device deconstructed into the following components: *input, transport, process*, and *output*. *Input* contains the components where a trash enters the system. *Transport* consists of the elements used to provide a movement of items thrown from the input to the output. *Process* is the collection of technologies and methods that the system is depending on to function well. *Output*, which is the other part of the system, includes components where trashes go out from. Table 1 and Table 2 depict the process of deconstructing and analysing.

Mechanisms	Constructs	Target Audience	Analysis
The potential waste management device was deconstructed into the following components: **Input** **Transport** **Process** **Output** Each component included different options.	Accessibility	Children age 5-15 years old	
		Physical disabled	
		Seniors	
	Safety	Children to use	
		Physical health	
		Respiratory system	
	Effectiveness	Maintain	
		Pets and insects repellent	
		Size	
	Value	Time	
		Cost	
		Sustainability	

Figure 5: Template for the Analysis of elements of the Potential Waste Management Device

Mechanisms	Constructs	Target Audience	Analysis
Processing-2- **Shredder/ grinder:** Cut solid items to small pieces. 	**Accessibility**	Children	**Strength:** • The process is fully Automatic, no need to specific knowledge or act.
		Physical disabled	**Limitation:** • It may need additional effort to disrupt waste.
		Seniors	**Limitation:** • It might need additional effort to disrupt waste.
	Safety	Children to use	**Limitation:** • Children may use it incorrectly with throwing wrong items and it could be mess up. • Dangerous if hard items are thrown, ex metal or glass, unless it is installed in proper way.
		Physical health	**Limitation:** • Dangerous in case of misuse it.
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • Needs trainers to maintain. • In case of damage, the whole process is broken.
		Pets/insects repellent	No specific relation to the context
		size	**Limitation:** • The item needs recognizable space.
	Value	time	**Limitation:** • It may need time to wait for the process
		cost	**Limitation:** • Needs a recognizable budget • In case of damage, the whole process is broken and a recognizable budget is needed.
		sustainability	**Strength:** • Reduces large amounts spent on transportation to landfill sites.

Figure 6: Example of System Analysis for an Element of the Potential Waste Management Device

2.4. Ideation and Refinement

In the first iterative of the design process, each of these components were analysed by considering various existing case studies for operation and analysed in relations to the key themes of Accessibility, Safety, Effectiveness and Value. Detailed tables of this process are available in Appendix B.

The analysis informed the design of initial prototypes for the in-home waste management device, one for a gravity-based system and one for mechanical movement system. The goal of these prototypes was to identify basic design; one basic model based on simplest and least costly operations for the simplest home layout situation and one full function model that address a broader range of technical and home layout options.

The second iteration was also evaluated according to Aarron Walter's Hierarchy of user needs; Aarron Walter's hierarchy of user needs defines basic user needs that interfaces must fulfill before more advanced needs can be addressed. Figure 8 shows the four basic of user needs represented by four different colours; each color will be used to identify one basic component. In Aaron' Walter's theory, the superior needs (such as pleasure and delight — at the very top of the pyramid) can only be achieved after more foundational ones (such as functionality and usability) are fulfilled. The study will utilize the colour scheme to identify aspects of the design designed and analysed to address the elements of Aarron Walter's Hierarchy of user needs.

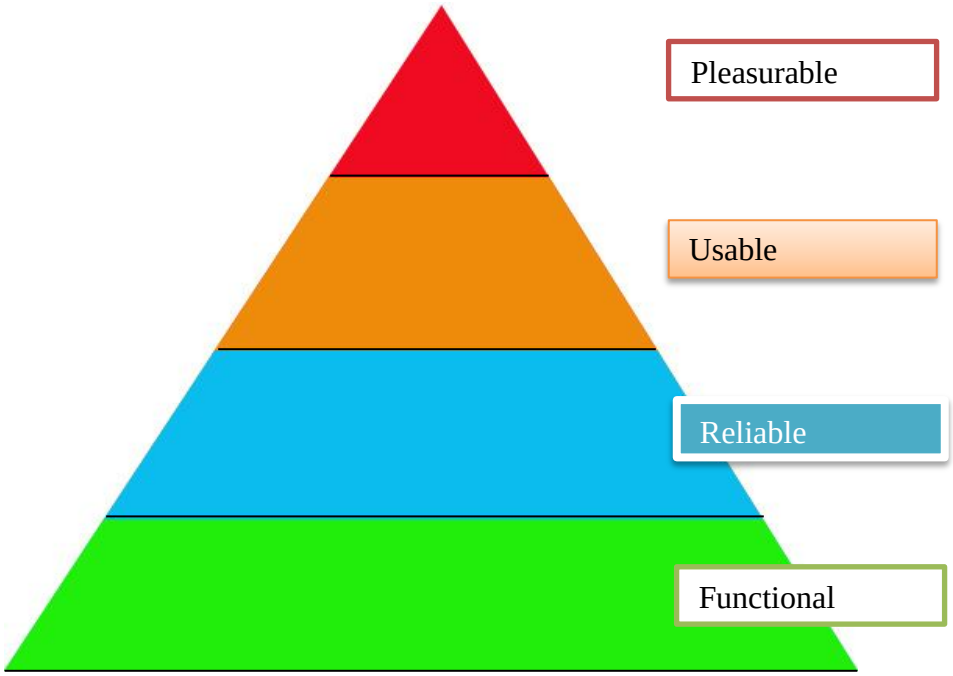


Figure 7: Aarron Walter's Hierarchy of User Needs represented by different colors

The four basic user needs of the Aarron Walter's Hierarchy (functional, reliable, usable, and pleasurable) formed the key evaluation method for the second and third iterations of the design. These user needs were studied with all parts of the deconstructing mechanical devices that the design is consist of.

The third stage of this project involved second meetings with some of participants to gain feedback on the proposed prototypes for a residential waste management system. Participants were shown models of both prototypes to evaluate. Participants were provided with an explanation of the mechanism of both prototypes and they asked to test it and offer their feedback relatively to the constructs that was formed regarding their first interviews.

3. Prototypes for an Indoor Domestic Waste Management System

This chapter documents an analysis of components, which can be used to build indoor waste management systems, derived from deconstructing other mechanical systems that have functions that include input, transport, processing, and output. A system that is mentioned by Meadows and Wright (2008) refers to an interconnected set of elements that is coherently organized in a way that achieves something.

The system consists of three kinds of things: "*elements, interconnections*, and a *function or purpose*. *Elements* are the individual parts of a system which tend to be more visible and easy to recognize. *Interconnections* are the relationships that hold the elements of a system together or describes how elements work together to achieve the systems function/purpose. Meadows (2008) noted that *Function or Purpose* is determined based on the systems behaviour.

The elements in this project are under the titles; Input, Transportation, Process, and Output. The purpose of the potential waste management device is to receive waste and transport it directly to their designated goal.

The potential waste management device was constructed from the components deconstructed from other mechanical devices that include the functions: input, transportation, process, and output. Deconstruction is a qualitative methodology that allows the researcher to analyse the components in order to choose the most appropriate elements to develop a prototype for the evaluation's purpose. Deconstruction means to break down titles into its component parts to inspect them in order to fit the design specifications. Each component has few options to be

considered and criticised under the four title of the constructs (Accessible, Safety, Effective, Value) while designing the prototype.

The design considered the Accessible, Safety, Effective, and Value of each option studied for the four deconstructed parts of the device. The designer analysed each option to determine their potential use in the design of the mechanized system and through multiple iterations of design and analyse produced two prototypes for a potential residential waste management system. The analysis of the constructs and all the components stated below are shown in Appendix B informed the design of two prototype systems presented in this thesis. These two prototypes systems were iteratively refined and evaluated by the research team and by external target audiences.

The mechanisms included under the four categories: input, transport, process, and output in order to improve the analysis process of the potential waste management device were the following:

Input:

- Manual waste divider system,
- High Tech installed door,
- Tip-on door,
- Swing Up flap hydraulic door,
- Flap door,
- Voice and motion control.

Transport:

- Flexible Hose & Flexible Ducting,
- Motorised Conveyor Belt,
- Ventilation,
- Vacuum Pump,
- Vacuum toilet system.

Processing:

- The automated composter for organic,
- Shredder/ grinder,
- Compactor,
- Food Waste,
- Disposers,
- Automated waste sorting machine RFID.

Output:

- positive displacement pump,
- Motorized or a sensor damper.

3.1. Prototyping

3.1.1. Initial Prototype

Figure 8 shows the first sketches of the initial prototype. This idea was created to separate the waste into three different directions by type of waste (garbage, organic, and recycle) and provides them a technique to throw them outside. The design's goal was to provide an accessible opening for all users to easily separate and throw the garbage. Each opening is at minimum width size of 16 inches/40 cm to let user throw big items. The ducts or tubes which connect the input by the other part of the projects were expected to be 8 inches in diameter; to let the waste go through the ducts without any blocking, the system was designed to add a compactor. The design contains an air suction to transport waste through the ducts to the outside part of the system, the air suction motor was located to install in the outside wall, so the noise when the system works will be eliminated.

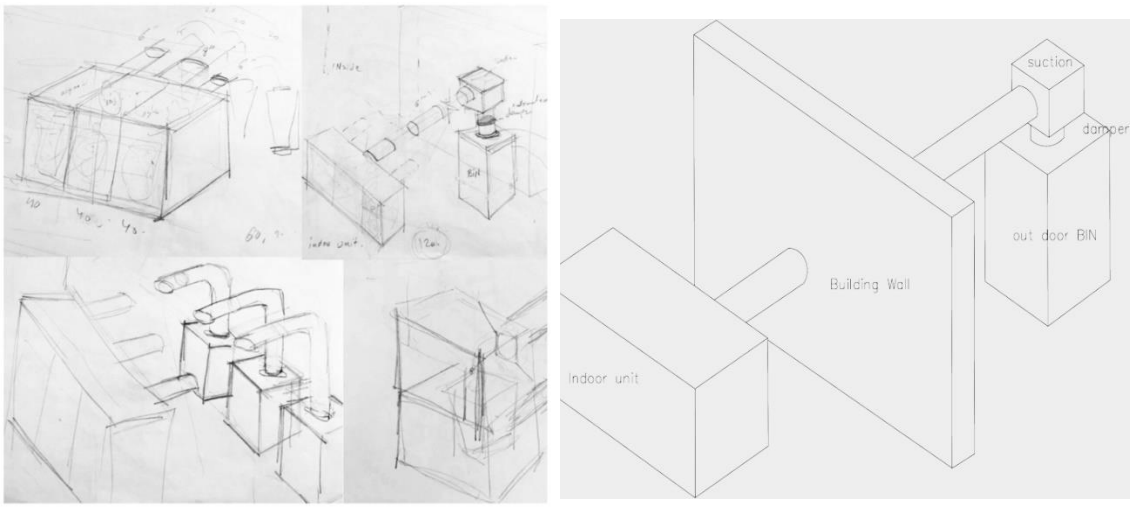


Figure 8: First sketches for Initial Prototype

3.1.2. Initial Prototype Analysis

The researcher evaluated the initial prototype by analysing strengths and weakness in fulfilling four criteria: Accessibility, Safety, Effectiveness and Value:

Strengths of the design:

- The air suction system has the ability to transport trash to long distance.
- The three opening are accessible for all people.
- The openings allow users to easily manage the waste
- Including compactor into the design provide the minimising of the volume of the trash.
- The input and the process of the prototype are working toward the desirable objective.
- The doors are locked to secure safety.
- Ducts are well connected to the outside bins; the trash has its own direction to each bin.

Weaknesses of the design:

- The transportation has a defect, even though the system include a compactor, the compacted items has the possibility to be stuck inside the ducts while transportation.
- The design will take a huge place in the home to be installed.
- The design need to install three air suction motors which is so costly.
- Adding compactors to the design also affect the size of the system; the system includes three separated compactors.
- Actually, recyclable items were the most items to concern about their volume, even though the design includes compactors, clogged ducts are expected.
- In case of malfunction, the system will be down.

Results:

- The idea to design three opening is considered to be addressed.
- The cost is an important issue; re-design the prototype considering the cost.
- The size of the project will be considered to fit most prospected layouts.
- Ducts should be studied to fit the same size of the trash inside the input.
- Include an opening for maintenance.

The results of the evaluation of the initial prototype suggested that the next design iteration should include two different prototypes. One considered to be limited-mechanical depending on gravity to the principle means to provide the most basic functional design. The other one would include more complex technological components to address luxury within its functionality.

3.2. Gravity-based Prototype:

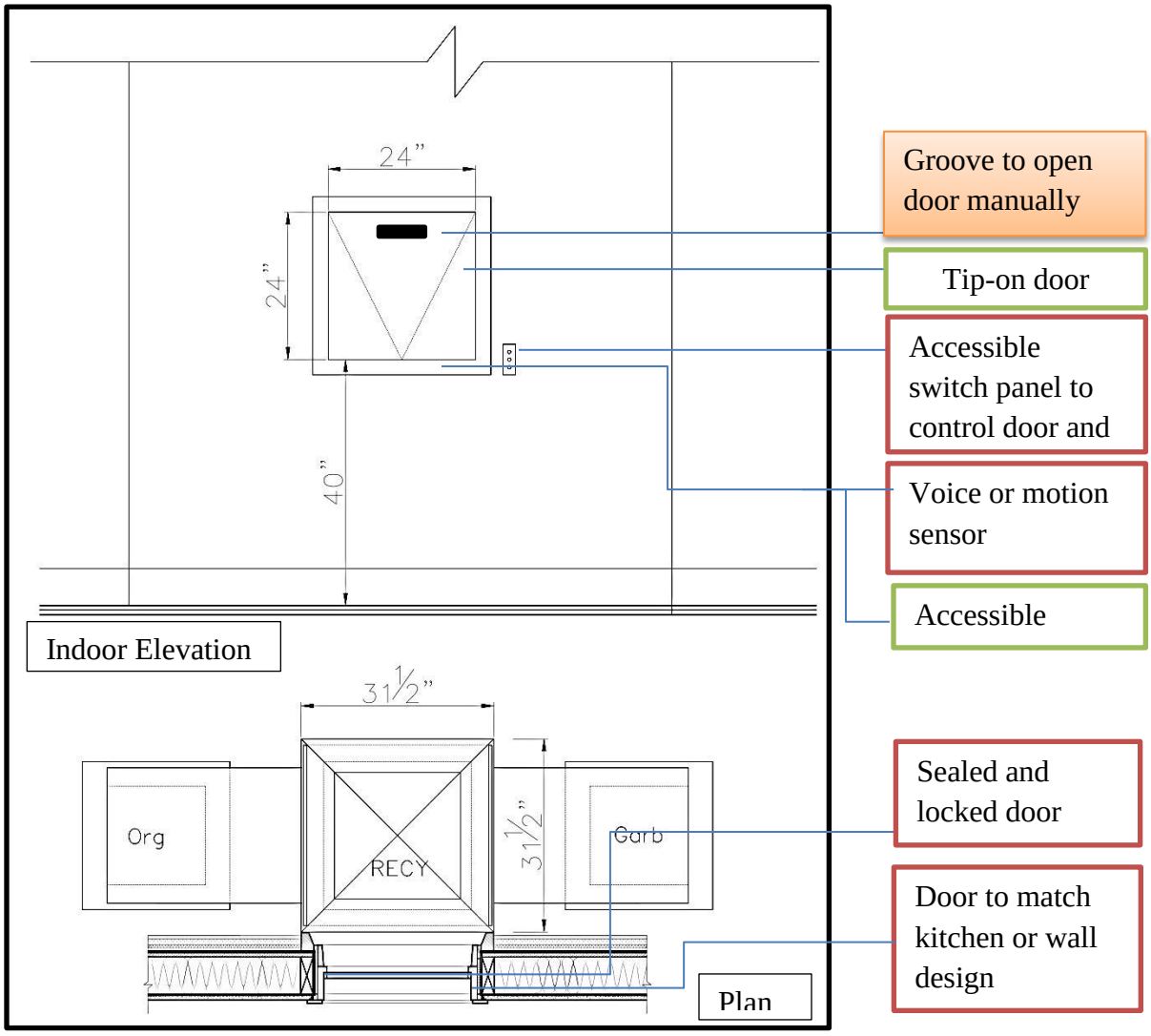
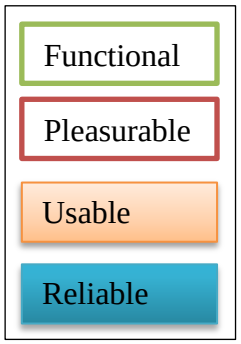


Figure 9: Interior Elevation and Plan for the Gravity-based Prototype



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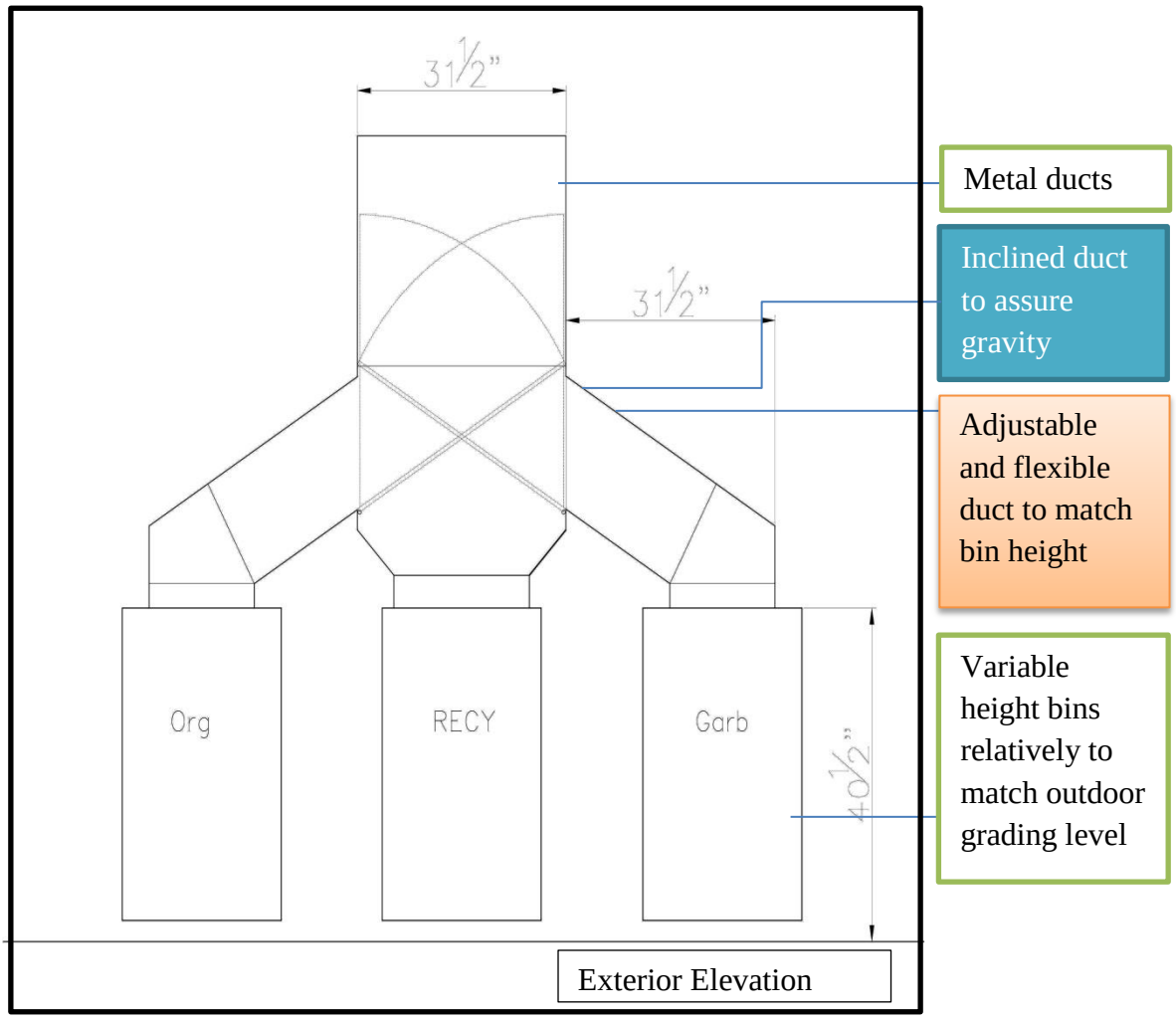
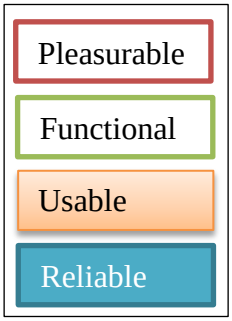


Figure 10: Exterior Elevation for the Gravity-based Prototype



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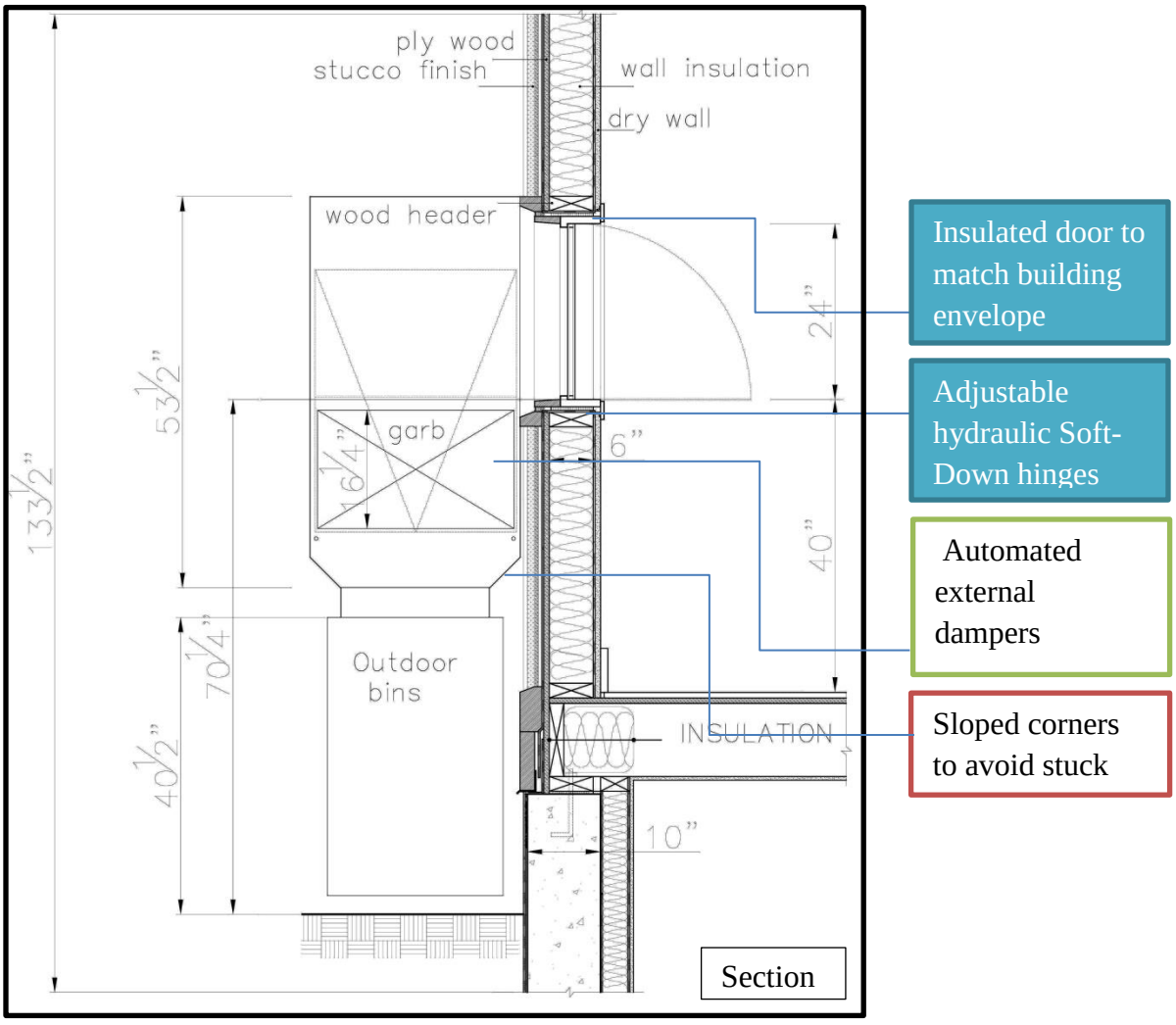
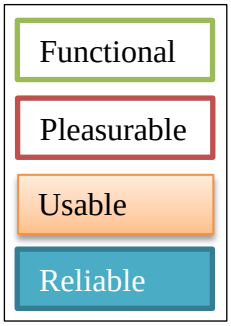


Figure 11: Section for the Gravity-based Prototype



Evaluation Legend

3.2.1. Gravity-based Prototype

The Gravity-based prototype is designed to address a low cost in-home waste management system (Figures 9, 10 and 11). It considers gravity as an essential part of the design. The system is designed to be installed in the wall where the outdoor bins are located. The location of the door is flexible, according to the outside bins. Users will be able to open the door by using several options such as voice sensor or manually by a tip-on system and press the switch on the input panel to function the dampers. There could be an option to add an Ultrasonic Sensors and RFID to the system to help people separating and manage their waste is also an option. In terms of minimizing the size of the design, the prototype includes one opening which receive all kind of waste. The size of the door is considered to fit a large size. The dampers are responsible to direct waste to their appropriate outdoor bin. The outdoor bins are connected by the system with a sealed lock and a damper to prevent bad smell and infestation.

3.2.2. Gravity-based Prototype Analysis

The design was evaluated according to Aarron Walter's Hierarchy of user needs; Tables (1, 2, 3, and 4) show more details about the evaluation.

Table 1: Analysis according Functionality

Functional	The design is expected to assure that each modular part of the system has the responsibility of do its work without affecting other parts of the system.
Input	
strength	• The height of the opening fits the OADA standard. All users can open the door and throw garbage. • Large pieces of trash can fit the door. • The door is operated manually and automated, it fits all needs.
Limitation	• The wall of the kitchen where the waste system is installed should be relatively positioned with the outside bins on the other side.
Transportation	
strength	• The size of the ducts is one size from the chute till the end of the system. • The size of the ducts is wide enough to fit large sizes of trash. • Trash is directed into the desirable bin due to dampers. • Ducts are made from metal material, curved to let objects roll down without any obstacles.
Limitation	• The ducts does not have opening for maintenance
Process	
Strength	• The system depends on gravity base, no need to include complex motors. • Dampers are controlled from the input panel to guide the waste; dampers should be located at their adequate spot before chuting.
Limitation	• The space from the chute to dampers and corners inside the system are crucial to system function.
Output	
Strength	• The external dampers open and close automatically after each chute.
limitation	• Heights of the bins are fixed according to the level of the system • The system does not fit the design of the current bins offered by the city.

Table 2: Analysis according Pleasurable

Pleasurable	The design is expected to provide positive emotional approach and emphasizes aesthetics and enjoyment in user experience, such as to give pleasure; enjoyable; agreeable; pleasant.
Input	
Strength	• The input contains accessible switch panel to control the door. • The door could be related or matched the kitchen design. • The door is sealed and could be locked manually and automatically. • Due to hygiene concerns, user can open the door by voice or motion system.
Limitation	• The door could not installed inside the cabinet • Motion system to open the door could be problematic in case of random movements.
Transportation	
Strength	• Ducts made by metal material. • Ducts are insulated to prevent energy lost and keep inside atmosphere as it is.
Process	
Strength	• The system does not include angles, so trash is not stuck. • The system is sustainable and energy efficient due to its reliance on gravity. • Dampers are controlled to prevent bad smell and infestation.
Limitation	• The system is hard to clean.
Output	
Strength	• The connection between the ducts and the outside bins are sealed and contain locks, so it is safe from animals to enter and easy to unlock.

Table 3 : Analysis according Usability

Usable	The design is expected to refer to the ease of access and use, easy for users to achieve their objective and easy for the user to become familiar with.
Input	
Strength	• The door can open manually and mechanically • The door is accessible to all users • The door will open towards the user so user can put the trash on the bottom of the door and flap it to shoot it outside. • The door is insulated to prevent energy loss. • User can open the door without touching it, in case of dirty or busy hands.
Limitation	• The door takes a specific place, the door opens horizontally.
Transportation	
Strength	• The system depends on gravity, no malfunction issue due to mechanical or electrical shortage. • The ducts are wide and straight towards the outside bins, no blockage flaw. • Due to dampers, each kind of trash goes to its destination. • The waste will end in the outdoor bins and then the dampers will closed to keep the separation from the duct.
Limitation	• The ducts are not rough enough so it can be destroyed. • The system does not have ventilation to prevent bad smell and insects' infestation.
Process	
Strength	• The process depends on the gravity base, the system is energy efficient. • Dampers are controlled automatically from the input.
Limitation	• In case of malfunction of dampers, the system will be down
Output	
Strength	• The final duct that connects the bin is flexible to fit the variable height of the bin.
Limitation	• User should have the ability and the knowledge to unlock the system from the outside bin • In case of fullness of outdoor bin, the system is worthless.

Table 4: Analysis according Reliability

Reliable	The design is expected to refer to the ability of a system to perform its specified function. A reliable design consistently performs according to its specifications.
Input	
Strength	• Using more than one technique fits all needs. • The sides of the door are insulated to prevent loose energy of the heating and cooling system. • The edges of the door are not sharp, not harmful. The closing includes soft closing system.
Limitation	• Huge items such as cardboard are hard to fit without cutting.
Transportation	
Strength	• Non-stick material prevents blockage. • Inclination of the duct and gravity are responsible to direct trash to their destination.
Limitation	• Huge items could be stuck in the duct.
Process	
Strength	• The power of falling is related to gravity, when the position of the input is higher, the chute will be faster; the process depends on the position of the house according to outside bins. • Dampers are automatically controlled from the input board to divide waste. • The diameter of the duct is smooth from the input till the output.
Limitation	• The fullness of the outdoor garbage chute stops the processing of the system.
Output	
Strength	• The outdoor bins are sealed between the connections. • The outside Dampers are responsible to prevent bad smell and insects to go back the home.

Results suggesting adjustments in the following elements:

To develop the design to be more functional ( ), usable ( ), reliable ( ) and pleasurable ( ), the design should consider the following:

- Include an outdoor opening for maintenance
- The system should include ventilation to prevent bad smell and infestation.
- Add a self-cleaning system
- As motion system is problematic for multiple movements, a voice sensor is sufficient.
- The outside bins could include an automated robot to move it to the curb side.
- Make the outside part of the main chamber sloped to prevent snow and leave to stick on top.
- Build ducts from hard materials (galvanised sheet metal)
- Include fullness sensor to the outdoor bins.

3.3. Mechanical-based Prototype

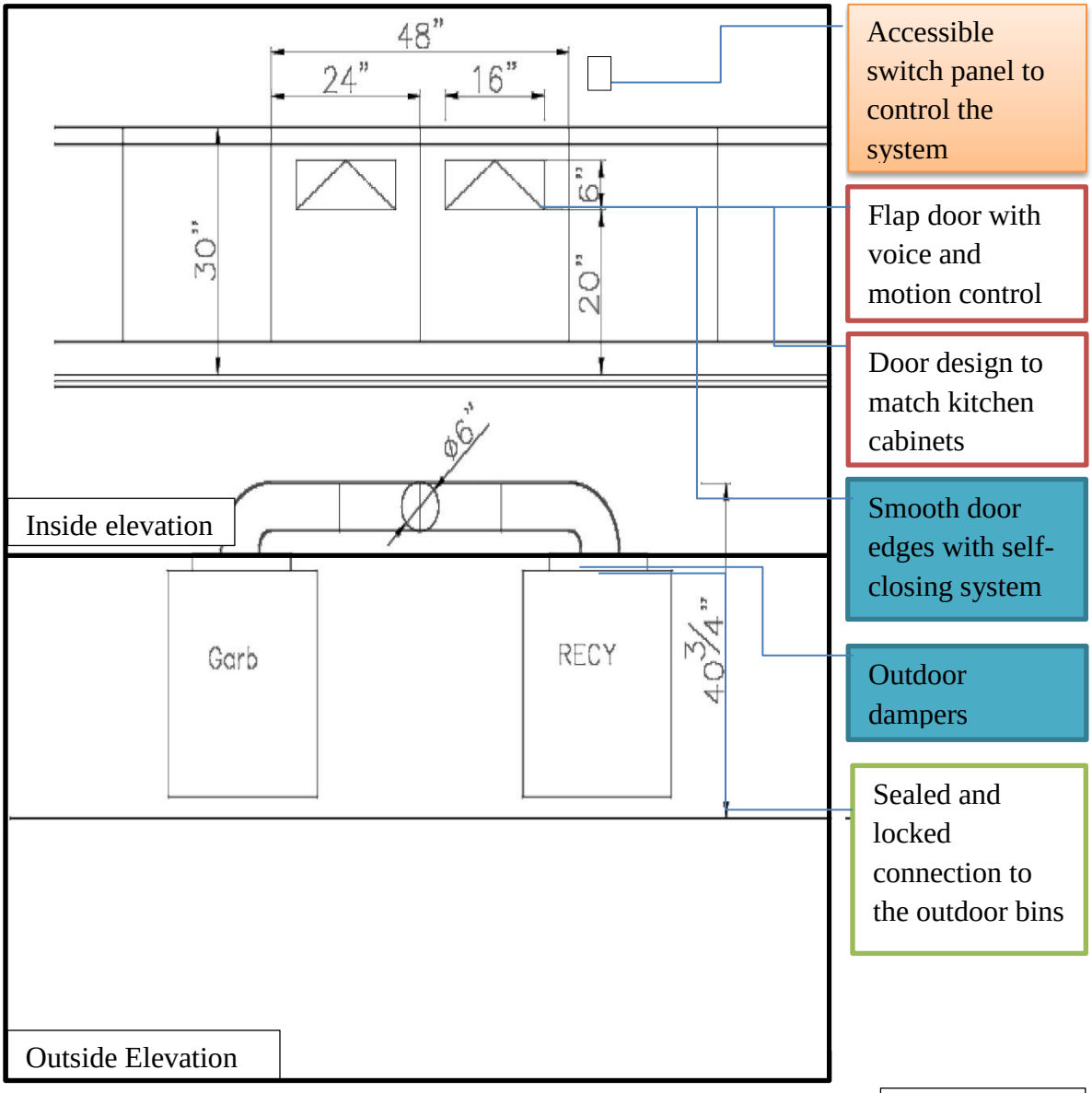


Figure 12: Interior and Exterior Elevations for the Mechanical-based Prototype

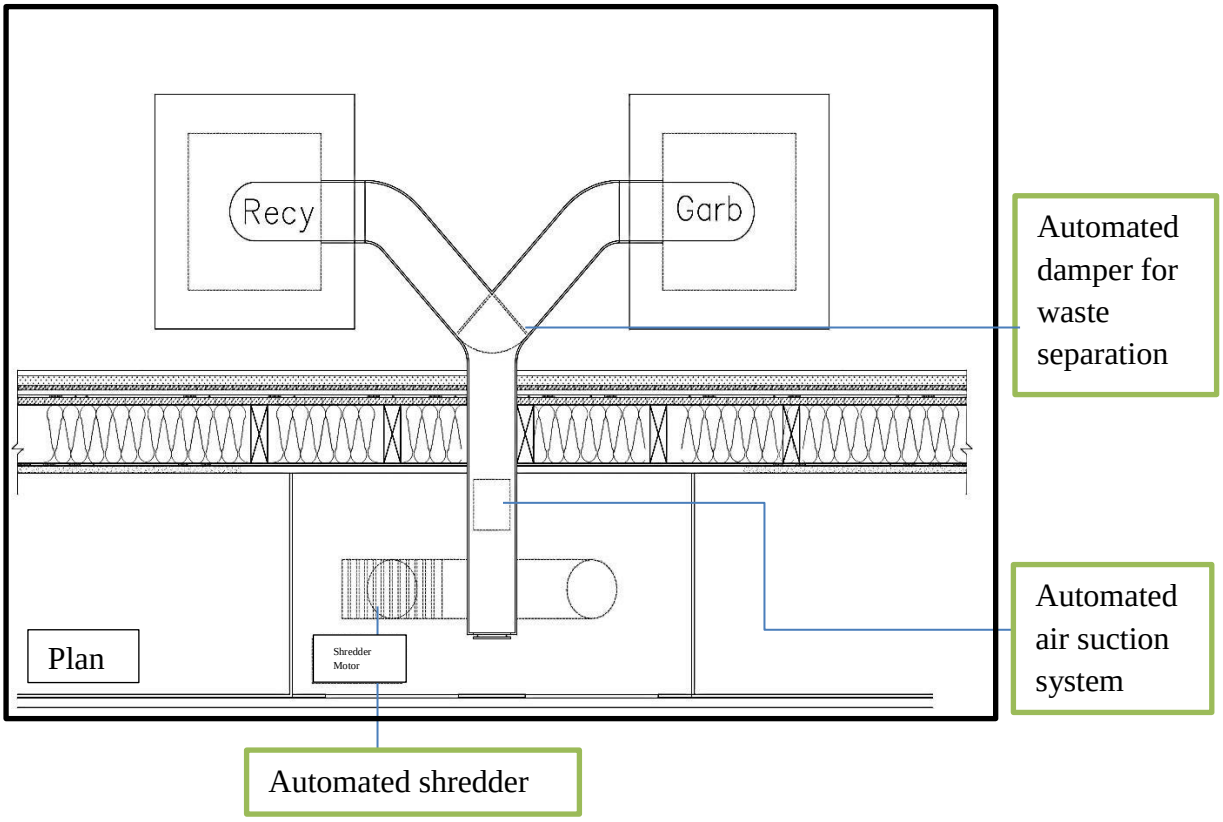
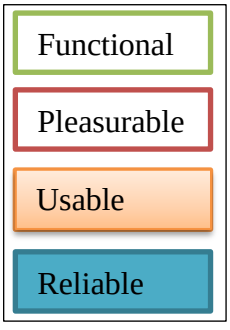


Figure 13: Plan for the Mechanical-based Prototype



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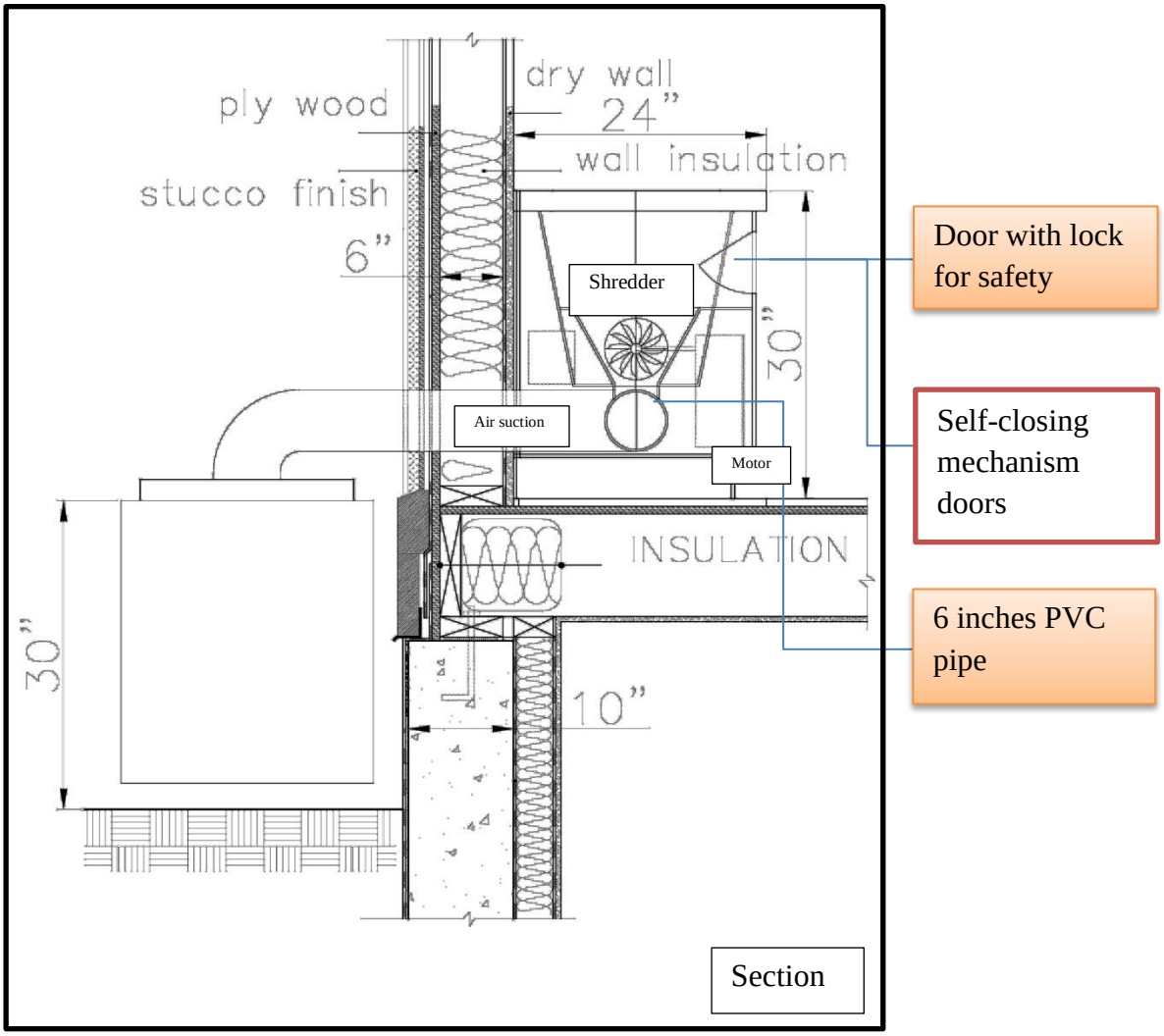
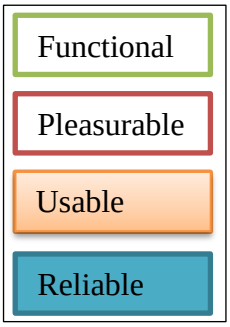


Figure 14: Section for the Mechanical-based Prototype



Evaluation Legend

3.3.1. Mechanical-based Prototype

The Mechanical Base prototype is a deluxe design, the system is designed commensurate with users who search for high quality and deluxe in their home (Figures 12, 13, 14). This prototype is designed to be installed into the cabinet of the kitchen. The device contains mechanical elements such as air suction and shredder. Users will be able to open the door by voice sensor or manually by Flap-door system. Two main doors are installed, one for recyclable material and the other for the garbage. Recyclable items will be shredded and placed in suitable bags. After operating the air suction, the dampers work to lead items to their appropriate outdoor bin. The outdoor bins are connected by the system with a lock and sealed duct and a damper to prevent bad smell and infestation. In this situation, a sink grinder is recommended to install for organic items or an indoor composter, the system does not include a chute for organic.

3.3.2. Mechanical-based Prototype Analysis

The design was evaluated according to Aarron Walter's Hierarchy of user needs; Tables (5, 6, 7, and 8) show more details about the evaluation.

Table 5: Analysis according Functionality

Function	The design is expected to assure that each modular part of the system has the responsibility of do its work without affecting other parts of the system.
Input	
Strength	• Flap doors used with automatic closing system after each use. • Voice and motion are also an option to the system.
Limitation	• The system is installed in the kitchen, a space needed in front of this system as any other machine in the kitchen.
Transportation	
Strength	• The gravity is an essential element to let waste go into shred. • Air suction mechanism functions to transport both garbage and recycle items through the main duct. • The garbage will be transported by PVC pipe to the outside bin directly through the air suction. • The recycle will be transported by PVC pipe to the outside bin after passing the shredder and air suction.
Limitation	• Transportation cannot function for both garbage and recycle at the same time.
Process	
Strength	• Shredder is an essential part of the system, due to the size of the recycle waste, the role of the shredder is to minimise the size of the recycle. • A damper is located on the outside division part to organise the division mechanism
Limitation	• The power of the shredder is not determined.
Output	
Strength	• Sealed and locked connection to the outdoor bins.

Table 6: Analysis according Pleasurable

Pleasurable	The design is expected to provide positive emotional approach and emphasizes aesthetics and enjoyment in user experience, such as to give pleasure; enjoyable; agreeable; pleasant.
Input	
Strength	• The doors follow kitchen design. • According to space and function inside the kitchen, the system and doors are located. • Control buttons are located in a switch panel, accessible for all users and follow kitchen design. • Doors are self-closing mechanism.
Limitation	• The system takes place in two cabinets. • According to the installation location, users are confortable to throw items in standing position and not bend.
Transportation	
Strength	• The ducts take small space comparing to the system. • Dampers provide an adequate separation of the waste to their destination. • According hygiene, tubes are PVC and are able to wash.
Limitation	• Due to hygiene, the system needs a clean system.
Process	
Strength	• Using a shredder, no need for effort to minimize the volume of recyclable items. • Users could choose to turn on or turns off shredder at any time, noise and energy consumption are controlled. • The user is able to throw many items into the recycle cabinet; the shredder machine has a space to enlarge a specific quantity before starting to shred.
Limitation	• The system is costly; it needs a specific budget to install.
Output	
Strength	• Outdoor bins could be wall mounted or built in to provide aesthetic pleasure. • The size of the outside recycle bin are fixed, no need for larger size due to the shred system which minimize the volume of the waste. • Adding additional features to outdoor bins is an option according to users. (Robot and filling sensor).

Table 7: Analysis according usability

Usable	The design is expected to refer to the ease of access and use, easy for users to achieve their objective and easy for the user to become familiar with.
Input	
Strength	• Doors are located in the front side of the cabinet. • The height of the opening follows accessibility standards. • Users are available to choose manual and automated opening(ex: to save energy) • The size of the door can fit big items such as a large box of pizza.
Limitation	• Huge cardboard could not fit
Transportation	
Strength	• Gravity and air suction are responsible to transport material to outdoor bins. • The size of the tube is effective to fit most waste. • A PVC tube is worthwhile to prevent stuck material.
Process	
Strength	• Switch panel are located on the top of the counter to control the system. • Recyclable items thrown are packaged in bags after shredding.
Limitation	• In case of mixed material thrown together, shredder is not affective. Due to city requirements. • Users are responsible to buy recyclable bags to fit the system.
Output	
Strength	• The end of the pipe that connects the bin is flexible to accommodate movement.
Limitation	• User should have the ability and the knowledge to unlock the system from the outside bin

Table 8: Analysis according Reliability

Reliable	The design is expected to refer to the ability of a system to perform its specified function. A reliable design consistently performs according to its specifications.
Input	
Strength	• The edge of the door is studied soft to maintain safety. • Input includes safety lock for kids. • Self-closing mechanism assist safety and functionality of the system. • Doors are accessible for all people. • An opening (from the side) done for maintenance.
Transportation	
Strength	• The container and the duct are large enough to accommodate most waste. • Sealed pipes from the input and the output prevent bad smell and insects' infestation.
Process	
Strength	• The shredder is located at the bottom of the cabinet to ensure safety; the rings are far from the top. • The shredder will not be working if the door is open. • The rings used in the shredder are strong and durable to cut paper, plastic, glass and metal containers. • Air suction is able to work with light and heavy weight.
Limitation	• The power of the shredder is not studied. • The fullness of the outdoor bins stops the processing of the system.
Output	
Strength	• Outdoor dampers provide non-returning waste and prevent bad smell, pets and insects to go through home.
Limitation	• In case of fullness of outdoor bin, the system is worthless.

Results suggesting adjustments in the following elements:

To develop the design to be more functional ( ), usable ( ), reliable ( ) and pleasurable ( ), the design should consider the following:

- Include an additional opening on the top of the counter according to user need.
- Study the cost of the system.
- The outside bins could include an automated robot to move it to the curb side.
- Redesign shredder to be adjustable whenever needed.
- Include an automated packaging system for particles shredded in separate bags to follow city requirements.
- Include another opening for maintenance.
- Study the shredder engine power shredder to match items recycled.
- Include fullness sensor to the outdoor bins.
- Study kitchen layout in terms of location and installation equipment to improve functionality of the system.

4. User evaluation of Scaled Models of Prototypes

Figure 15: Interviews with participants to test and evaluate prototypes

The third iteration of the research stage was conducted with some of the interview participants to test and evaluate the two prototypes, Figure 15 shows the two prototypes and one of the participants during the interviews. People were able to interact with the designs and test it to provide feedback.

Participants were interviewed at different locations and different time to suit their schedule. The researcher explained the details of both prototypes and provides time for participants to test the design. After the observation, the researcher took notes of the participants' feedback.

The researcher met five participants who were available at that time, due to time limitation of the MRP, not all participants could participate. One person from the five participants belonged to the first group which represents people who have a thorough knowledge and experience in managing

home waste disposal in accordance with local municipal waste protocols and practice. Two participants belong to the second group which represent people who have lived in the Greater Toronto Area (GTA) for at least 10 years but did not practice or needed more practice to manage home waste in accordance with municipal waste protocols and practice. The other two participants belong to the third group which represent the people who have immigrated recently to the GTA and lack information about municipal home waste expected protocols and practices.

The Gravity-based Prototype had high satisfaction from all participants, this design met the needs of people who have small space in their house, and they mentioned that the design met their needs due to its flexibility of instalment. This design could be installed inside or outside the kitchen. Participants were satisfied that the system could function safely and efficiently. They emphasized the use of the lock at the input to provide safety for children and prevent any encroach from outside such as thieves, pets, pests or changes in temperature. An additional mechanism, a cutter, was suggested to be installed in the bottom of the door to minimise the huge volume of some recyclable items such as cardboards.

Participants also recommended including additional manual operational system for access in case of a malfunction of ducts, an accessible lock to the outdoor bins for both designs and instructions to unlock the bins.

The Mechanical-based Prototype was appreciated more by participants who belong to the first group and the third group. They were highly satisfied by shrinking the volume of their recyclables; and the deluxe mechanisms of this prototype, which provided richness to the kitchen functionality.. All participants appreciated that the instalment location of this prototype is not related to the outdoor bins. People agreed that this design replaces the need of the existing indoor

bins. Participants had some concerns about the cost related to the shredder system and its accessories, in addition to the maintenance of this system due to its complexity. Some participants worried about the warranty and the maintenance provided for such mechanism.

Participants expressed that both prototypes would provide a positive impact to their attitudes and behaviours related waste disposal. Participants who were not familiar with the municipal waste management practices and protocols, and those who expressed concerns about being able to age-in-place also expressed that they were more likely to adopt and use the system. All participants were delighted by the connection of the system with the outdoor bins.as it addressed the disadvantages of the current issue of the disconnection between the interior of the home and the outdoor bins, such as bad smell, it there attraction to pests, pets and insects. All participants agreed with the potential for the two prototypes to fit all home layouts. One of the participants suggested the idea of mixing both prototypes together to have one single design, which has all these components.

5. Conclusion

5.1. Summary

Older adults tend to seek fewer barriers within home and their community to maintain their quality of life. Disposing waste in a practical, safe and ethical way is a common daily activity that may be affected by several factors related to age including reduction in physical ability to carry containers of waste to outside garbage and recycling bins, reduced understanding of evolving municipal waste management practices, and increased reliance of packaged products, especially food products, that produce extensive waste. This study focused on three groups of mature household adults who are more likely planning to age-in-place within their single family housing and intend to live independently. The study includes literature review to get a profound view of the problem and interviews to fulfill the research of peoples experience and insights. With using Thematic Network method to analyse data, the researcher had the ability to create two different prototypes to accommodate people's need. Both prototypes were evaluated and criticised under many evaluation practices such as Aarron Walter's Hierarchy of User Needs and participants' feedback. Participants responded positively to the benefits of including this system to their home regarding the effectiveness of appropriate disposal of waste. Participants were highly satisfied by the idea although they expressed concerns about the cost, the strength and the ability of the system. Participants agreed that the design could influence the quality of life of wishing to age-in-place including their independency and dignity.

5.2. Inclusivity

This research was formed and evolved in response to The Three Dimensions of Inclusive Design as stated by Treviranus (2018); the designer:

- "Recognize, respect, and design for human uniqueness and variability" (Jutta Treviranus, 2018). Even though the target of this project is mature adult who tend to "age in place" independently, the project is addressing all people who are living in single family home and they tend to be active and positive citizens. The project should be understood and received by everyone in our communities.
- "Use inclusive, open & transparent processes, and co-design with people who have a diversity of perspectives, including people that can't use or have difficulty using the current designs" (Jutta Treviranus, 2018). The interviews were conducted with mature adults who consist of three types of groups, people who live for long time in Canada and they are able to use the current system of waste management and newcomers who are used to the current system and they are facing difficulties to dispose their waste.
- "Realize that the design is in a complex adaptive system" (Jutta Treviranus, 2018). As large wave of Boomers are coming, elderly will be a huge numbers; very specific home modifications needed to permit people to accommodate the process of disposing their waste.

5.3. Limitations of the Study

This research's findings were based on testing and evaluating the prototypes, the process of the study improved along with each stage of the research, the designer evaluation was enhanced by participants' feedback, but the study was limited to the small sample of participants and the time limitation of the MRP. Regarding prototypes, design improvement was expected to be costly, in further studies, prototypes are recommended to be implemented in order to test and get more feedback. Also, the shortage of mechanical experience was an obstacle to improve the deep study of the design; mechanical engineers are recommended to be intended to further development.

5.4. Future Studies

The purpose of the study is to provide an in-home waste management device that can be integrated in the foundation of the house while residents have the choice of choosing the system that meets their needs. This device/system should enable people with different abilities to be more engaged with disposing their waste and to function in their home independently with maintaining their quality of life. A future development could be to include a mechanical robot which will be capable to transfer the bins to the curb when needed.

Research title: An integrated indoor domestic waste management system

Appendix A: Interview's Questions

Constructs		Questions
1. Convenience		
Easy to use		Where is the current location of the outside garbage and recycling bins at your home?
		Do you face any difficulties to transfer waste outside? What are they?
		Would an indoor waste disposal system be more practical and/or convenient for managing waste created in the home? (This question will include several photo of an opening to allow participants rank options relative to practicality and convenience)
		If you have a large item, such as big box from a pizza for example, do you think it would be easier to dispose of it through garbage/recycling chute directly from inside or to personally take it outside to the outdoor garbage bin?
		Concerning inclement weather and the physical efforts of waste disposal, how much more convenient do you think an indoor garbage/recycling chute might be?
Proximity		Where are the main places that you collect garbage/recyclables inside your home?
		How many times during the normal week do you transfer garbage/recycling from inside the house to an outside garbage bin or recycling bin?
Operational convenience		What is your strategy to sort your recyclable and non-recyclable garbage?
		How much more convenient if you have a garbage chute inside your home? (Participants will be provided by a numerical chart from 1 to 10 to answer)

Constructs		Questions
2. Safety		
Safe for children		Would you ever have children under the age of 18 in your home that you would you ask them to take the garbage out to the bin?
		Concerning hygiene and other safety issues (possibility to keep the door open, pinch their fingers, be locked outside home, keep animals and insects to enter home... Is it safer for kids to go outside to throw garbage into the outside bin at your home or do you think it safer for children to use an indoor garbage/recyclable chute inside the home?
		What kind of opening for an indoor waste management system is safer for children? The question will include some pictures to provide the participants many options.
Safe for health (respiratory system)		How long (in days) does garbage and recyclables stay inside home before it is transferred to the outdoor waste bins (ask separate for garbage and recyclables). What determines that schedule?
Safe from personal physical harm		How many steps do you have to travel from the kitchen to the location of the outdoor waste bins?
		How much is safer do you think avoiding taking garbage outside in bad weather would be if you had an indoor garbage chute. (a scale is provided from 1 to 5)

Constructs		Questions
3. Fits lifestyle expectations		
Appearance		Do you prefer to have a garbage chute portal as a feature of your kitchen?
		Can a garbage chute portal be an attractive feature inside your kitchen?
		How much do you think it should be visible? (show example of different approaches to visibility in a kitchen)
Luxury item		Do you believe that an indoor chute is a well-being feature or a luxury feature?
		Is it possible to compare an indoor garbage chute system with any other item inside your home? (Example: trash compactor, dog door, remote control features for lightings or shades)
Technology		Do you look for technology that makes life easier for you?
		What kind of technology should be used in this project? (For examples; such as Automatic chute down opener? Blue box bin full? Scanning waste to see if it is blue box.)
Sustainability		How much does waste disposal factor into your understanding of sustainable environment.(Provide a scale 1 to 5)
		Do you practice sustainability, Reduce, Reuse, Recycle.(Provide a scale)
Aesthetics/Appeal		How might do you enjoy having a well-designed garbage chute inside your home? (Participants will be provided by a numerical chart from 1 to 10 to answer)
		How might a well-designed garbage chute could affect your attitude towards garbage disposal?

Constructs		Questions
4. Cost		
Initial cost		Regarding this project, how much do you expect it is fairly to spend on this design? Participants will have several choices to relate to, for example: A fridge for $2000, a $1000 dishwasher, $500 for a sink...
Time as a cost		How many minutes would you estimate that you spend to collect, sort, and dispose of garbage/recycling each week? Garbage? Recycling?
		For this amount of time (minutes), what other household activities take about the same number of minutes you already gave me?
		Do you think that time saved with this design would be worthwhile?
Resale value		If you decided to sell your house with an indoor garbage chute, do you expect people to recognize the value of this feature?
		Would an indoor garbage chute be a feature that attracts you when purchasing a new house?

Appendix B: System Analysis

<table>
<tr><th>Mechanisms</th><th>Constructs</th><th>Target Audience</th><th>Analysis</th></tr>
<tr><td>Input -1-</td><td rowspan="3">Accessibility</td><td>Children age 5-15 years old</td><td>Strength:
The standard opening of a drawer works(able to use) with children.
Disposing waste in separated spots in a place is easy to be recognised by children.
Limitation:
Objects such as canned vegetables, cardboard milk boxes and used plates at head height or above are a much higher risk of spills.</td></tr>
<tr><td>Manual waste divider system:

A drawer system (box-shaped storage compartment without a lid, made to slide horizontally in and out of piece of furniture). Suitable for indoor cabinet installation. It could be open (Italicaly) as a dishwasher door.

 
Figure 16:Example of manual waste divider system</td><td>Physical disabled</td><td>Strength:
An OADA requirement states the pull or handle should be easy to open with one hand, without twisting the wrist or using any tight grasping or pinching motion.
No need for complex mechanism to use a drawer.
Limitation:
Wheelchair users might have some difficulties to open a drawer that is located in front of them.
The drawer should not be higher than 48 inches or lower than 15 inches from the ground for wheelchair users.</td></tr>
<tr><td>Seniors</td><td>Strength:
No need for complex technology, just simple and easy to open.
No need for hard effort.
Limitation:
The depth and the height of the divider drawer should be studied to meet the level of consideration which can greatly reduce the strain of bending over or stretching.
Needs additional accessory. Such as “D” shaped pulls/handles or other mechanism that allow people of all abilities to open and close the cabinets easily.</td></tr>
</table>

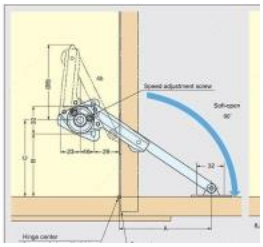
	Safety	Children to use	**Strength:** • Items inside the drawer are not easy to fall comparing to open cabinet. **Limitation:** • Children might not close it tightly unless it has a self-closed system. • Not safe unless it is locked. Children might punch their fingers while closing it.
		Physical health	**Strength:** • No need for hard effort to use it.
		Respiratory system	**Limitation:** • The system should include sealed lid to prevent smell and gas leak.
	Effectiveness	Maintain	**Strength:** • The use a warm rag and some household cleaner to wipe the inside space is enough to clean it. • Maintaining and repairing parts do not need experts, require little maintenance. **Limitation:** • Food particles often stick and lead to mould growth, the use of disposal surrounding is recommended.
		Pets and insects repellent	**Limitation:** • Effective if the organic is maintained well, the organic part should be sealed or covered by lid. • A drawer could be a toy for pets to ruin.
		Size	**Limitation:** • Needs a deep or wide place to fit large items.
	Value	Time	**Strength:** • It will reduce the time of disposing waste because the components are so close to each other.
		Cost	**Strength:** • Do not contain electrical or technical items which require minimum cost.
		Sustainability	**Strength:** • Disuse of electric and technology is a way of sustainability. • The ability of sustain is high in this input.

<table>
<tr><th>Mechanisms</th><th>Constructs</th><th>Target Audience</th><th>Analysis</th></tr>
<tr><td rowspan="1">Input-2-</td><td rowspan="3">Accessibility</td><td>Children</td><td>Strength:
Easy to access, by pressing a button, door will open and children are able to use it.
Minimum needs of technology knowledge which is easy to learn.
Limitation:
Children might forget it open; unless it has self-close system.</td></tr>
<tr><td rowspan="2">High Tech installed door :

The automated door could be open in different mechanism with fixed manual button or a remote.

 
Figure 17: Example of an automated door</td><td>Physical disabled</td><td>Strength:
No need for hard effort to use it.
Could be added by a remote to control it from a distance.</td></tr>
<tr><td>Seniors</td><td>Strength:
So effective for seniors who suffer from physical pain.
No need to use both hands. Light press is enough to open.
Door could be in different material or colour to be more recognised; it could be transparent or colourful, depending on people’s choice.</td></tr>
<tr><td rowspan="3">Safety</td><td>Children to use</td><td>Strength:
The closure method is slow, so it is harmless.
Doors are studied to have soft edges.
The door could be locked if needed.
Limitation:
The size of the door is well thought out so children could not be stuck.</td></tr>
<tr><td>Physical health</td><td>Strength:
No need to bend, or make physical effort to open it.
No need to use both hands to open it, also it can be controlled by a remote.</td></tr>
<tr><td>Respiratory system</td><td>Limitation:
Doors should be sealed to prevent dust and smell infestation.</td></tr>
</table>

	Effectiveness	Maintain	**Strength:** • Easy to clean **Limitation:** • Need experienced and trained people to repair. • If the door broke down, the hall system is down. Unless it is accompanied by manual control.
		Pets and insects repellent	**Limitation:** • Doors should have sealed closure to prevent insects to go through.
		Size	**Strength:** • The size could be variable depending on people's need and matching the kitchen decoration. • The opening could installed in variable shapes. • The opening could be installed inside a cabinet or on the wall. **Limitation**: • The place where the door is installed should include additional space to fit the door when it is open.
	Value	Time	**Strength:** • It will reduce the time to use compared to the traditional bin. **Limitation:** • In case of damage, time to maintain and repair is needed.
		Cost	**Limitation**: • High cost due to technology. • In case of damage, specific budget is needed.
		Sustainability	**Strength:** • Electricity used is higher than a manual opening.

Mechanisms	Constructs	Target Audience	Analysis
Input-3-	**Accessibility**	Children	**Strength:** • Children are able to use this kind of doors easily. • No need for complex or techno mechanism. **Limitation:** • Some children entertained with opening and closing the system.
Tip-on door: Handle-less fronts open at a single touch with the TIP-ON mechanical opening system.   **Figure 18: Example of a Swing Up flap**		Physical disabled	**Strength:** • Easy to open, it can be opened with using any part of the body. • No need for specific touch or a handle to open it. **Limitation:** • The act to close the door might need physical effort depends on the location and the height of the door. • The door could be an obstacle for wheelchair users since it is open toward user.
		Seniors	**Strength:** • Easy to open, it contains simple technology. • No need for hard effort to open it and close it. **Limitation:** • The location of bush button to close it should take into consideration seniors' height.
	Safety	Children to use	**Strength:** • The door contains soft opening system. **Limitation:** • The location of bush button to close it should take into consideration children's' height.

hydraulic door and a detail of the mechanism **Swing Up flap hydraulic door:** Door lift systems which make doors lift up effortlessly, the opening act will create a vacuum that pull the main connector arm in and back into a prone position.		Physical health	**Limitation:** • Opened door could be an obstacle for some users(visual impaired)
		Respiratory system	**Limitation:** • Doors should be sealed to prevent dust and smell infestation.
	Effectiveness	Maintain	**Strength:** • No need for complex maintenance. • Any damaged can occur, the door can be replaced (part of the system can be replaced). **Limitation:** • The system is sensitive and easy to malfunction.
		Pets and insects repellent	**Limitation:** • Doors should have sealed closure to prevent insects to go through.
		Size	**Strength:** • The design of the door is flexible such as a folded door. **Limitation:** • Space should be considered to fit the opening action. • The size of the door is studied regarding the opening,
	Value	Time	No specific relation to the context
		Cost	**Strength:** • Do not contain electrical or technical items, minimum cost.
		Sustainability	**Strength:** • Disuse of electric and technology is a way of sustainability.

<table>
<tr><th>Mechanisms</th><th>Constructs</th><th>Target Audience</th><th>Analysis</th></tr>
<tr><td>Input-4-</td><td rowspan="4">Accessibility</td><td>Children</td><td>Strength:
The design of the door is flexible such as a folded door.
Children are able to use this kind of doors easily.
No need for complex or techno mechanism.
The system could contain a flap button to control access or to close it.</td></tr>
<tr><td rowspan="4">Flap door:

Could be opened in both sides, The door could contain soft plastic(strips) or hard surface. Also it could contain multiple layers, depends on nessecity.

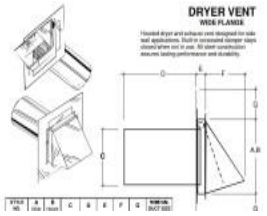
 
Figure 19: Examples of a Flap door</td><td>Physical disabled</td><td>Strength:
It could include PVC strips or flaps are easy to put items through with no effort.
Limitation:
In some cases it requires two hands to open and close.</td></tr>
<tr><td>Seniors</td><td>Strength:
No need for specific touch to use it.
Do not require an extra hand to open and close.</td></tr>
<tr><td rowspan="3">Safety</td><td>Children</td><td>Strength:
Manual opening.
The door could be locked if needed.
The size of the door is well thought out so children could not be stuck.</td></tr>
<tr><td>Physical health</td><td>Strength:
No need for hard effort to use it.
Serves as an excellent temperature sealant.</td></tr>
<tr><td>Respiratory system</td><td>No specific relation to the context</td></tr>
</table>

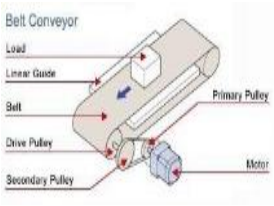
	Effectiveness	Maintain	**Strength:** • No need for complex maintenance. • Inexpensive material could be used.
		Pets and insects repellent	**Strength:** • Prevents insects to go through. • Strip doors close automatically after leaving the space.
		Size	**Strength:** • Possibility of variable size. • No need to extra space, door could be open in many ways.
	Value	Time	**Strength:** • Minimum time to open
		Sost	**Strength:** • Do not need huge budget.
		Sustainability	**Strength:** • Provide temperature control due to fast closing. • Disuse of electric and technology is a way of sustainability.

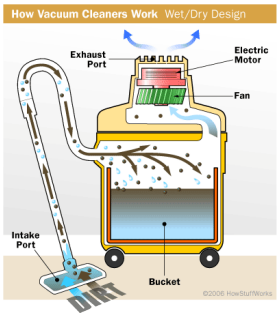
Mechanisms	Constructs	Target Audience	Analysis
Input-5-	**Accessibility**	Children	**Strength:** • Children are able to use this kind of doors easily. • Access is available with no touch, no need for any hand. **Limitation:** • The system could be problematic with many movements and different sounds.
voice and motion control: Acts as a sensor bin, infrared fields sense the area above and in front of the bin so it opens automatically and voice recognition.  **Figure 20: Example of a voice and motion controlled bin**		Physical disabled	**Strength:** • Easy to open and close. • No need for extra accessories such as handles. • Accessible to visual impaired, No need for specific touch to use it. **Limitation:** • The door could be an obstacle for wheelchair users.
		Seniors	**Strength:** • Do not require specific move to open and close, voice or any movement are able to complete the mission. • Accessible to visual impaired, No need for specific touch to use it.
	Safety	Children to use	**Strength:** • The open and close methods are harmless. • Soft opening. • The door could be locked if needed. • The size of the door is well thought out so children could not be stuck.
		Physical health	**Strength:** • Harmless movement, soft opening. • No physical contact needed.

		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Strength:** • easy to clean **Limitation:** • Vulnerable, malfunction can occur easily. • Need experienced and trained people to repair. • If the door is out of service, the whole system is down. Unless it is accompanied by manual control.
		Pets and insects repellent	**Strength:** • Prevents insects to go through since it is controlled.
		Size	No specific relation to the context
	Value	Time	**Strength:** • It will reduce the time to use compared to the traditional bin. **Limitation:** • In case of damage, time to maintain and repair is needed.
		Cost	**Limitation:** • High cost due to technology. • In case of damage, specific budget is needed.
		Sustainability	**Limitation:** • Electricity used is higher than a manual opening.

Mechanisms	Constructs	Target Audience	Analysis
Transport-1-	**Accessibility**	Children	No specific relation to the context
Flexible Ducting: Ducts are conduits or passages for elements to go through  **Figure 21: Example of a duct**		Physical disabled	No specific relation to the context
		Seniors	No specific relation to the context
	Safety	Children to use	No specific relation to the context
		Physical health	**Strength:** • The smoothness of unlocking and displacing the outdoor bins process is connected to this flexible duct.
		Respiratory system	**Strength:** • The duct is treated to ensure air quality • 100% stainless steel door as a standard. This makes for longer lasting, better looking and easier to maintain and clean doors.
	Effectiveness	Maintain	**Strength:** • Stainless steel duct for longer lasting.
		Pets and insects repellent	**Strength:** • Ducts do not include opening or holes
		Size	**Strength:** • Size is flexible
	Value	Time	No specific relation to the context
		Cost	**Strength:** • affordable
		Sustainability	No specific relation to the context

Mechanisms	Constructs	Target Audience	Analysis
Transport-2- **Ventilation:** Hooded dryer and exhaust vent for ventilation.  **Figure 22: Example of a ventilation system**	**Accessibility**	Children	**Strength:** • Automated ventilations or manual ones are easy to use.
		Physical disabled	**Strength:** • No direct interaction.
		Seniors	**Strength:** • No direct interaction.
	Safety	Children to use	**Strength:** • No direct interaction.
		Physical health	**Strength:** • No direct interaction.
		Respiratory system	**Strength:** • Keeps bad smells and microbe outside.
	Effectiveness	Maintain	**Strength:** • Steel construction assures lasting performance and durability.
		Pets and insects repellent	**Strength:** • Release congestion of polluted air, therefore keeps insects away.
		Size	**Strength:** • Does not need a huge place, installed in walls.
	Value	Time	**Strength:** • No direct interaction.
		Cost	**Strength:** • Affordable
		Sustainability	**Strength:** • Made from sustainable material. • Helps to keep a healthy environment **Limitation**: • Materials made from should be durable.

Mechanisms	Constructs	Target Audience	Analysis
Transport-3-	**Accessibility**	Children	**Strength:** • Easy steps to use it.
Motorised Conveyor Belt: A movable belt which help to transport items from a place to another  **Figure 23: Example of a Motorised roller belt**		Physical disabled	**Strength:** • No need for hard effort.
		Seniors	**Strength:** • Easy steps to use it.
	Safety	Children to use	No specific relation to the context
		Physical health	No specific relation to the context
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Strength:** • Cleaning could be by: Garbage Disposal Freshener & Cleaner for organic or monthly regular cleaning with water. **Limitation**: • Needs experts in case of any damage.
		Pets and insects repellent	No specific relation to the context
		Size	**Strength:** • Size depends on the component. **Limitation**: • Needs specific place to install.
	Value	Time	**Strength:** • Manage the time of disposing garbage regarding the speed.
		Cost	**Strength:** • Affordable.
		Sustainability	No specific relation to the context

Mechanisms	Constructs	Target Audience	Analysis
Transport-4- **Vacuum Pump:** Using air stream to suck items and lead it to the exit.  **Figure 24: Example of a vacuum pump**	**Accessibility**	Children	**Strength:** • Easy to use if it is connected with a button on the input.
		Physical disabled	**Strength:** • Easy to use if it is connected with a button on the input
		Seniors	**Strength:** • Easy to use if it is connected with a button on the input
	Safety	Children to use	No specific relation to the context
		Physical health	No specific relation to the context
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • Needs trainers in case of any damage.
		Pets and insects repellent	**Strength:** • Keeps insects away due to the suction
		Size	**Limitation:** • Needs specific place to install.
	Value	Time	**Strength:** • Minimize time of transportation due to suction.
		Cost	**Limitation:** • Needs a specific budget
		Sustainability	No specific relation to the context

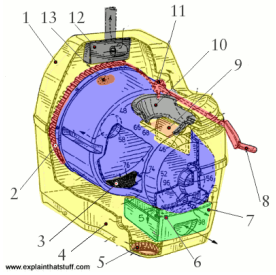
Mechanisms	Constructs	Target Audience	Analysis
Transport-5-	**Accessibility**	Children	**Strength:** • Easy to use if it is connected with a button on the input.
Vacuum toilet system: The vacuum pump sucks the air from the intermediate tank, the valve under the toilet bowl opens and the intermediate tank sucks the waste out of it. The pressurizer blows the waste from the intermediate tank into the main waste tank.  **Figure 25: Example of a vacuum toilet system**		Physical disabled	**Strength:** • Easy to use if it is connected with a button on the input.
		Seniors	**Strength:** • Easy to use if it is connected with a button on the input.
	Safety	Children to use	No specific relation to the context
		Physical health	No specific relation to the context
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • Needs trainers in case of any damage.
		Pets and insects repellent	**Strength:** • Keeps insects away due to the water suction.
		Size	**Limitation:** • Needs specific place to install.
	Value	Time	**Strength:** • Minimize time of transportation due to water suction.
		Cost	**Limitation:** • Needs a specific budget to install.
		Sustainability	No specific relation to the context

<table>
<tr><th>Mechanisms</th><th>Constructs</th><th>Target Audience</th><th>Analysis</th></tr>
<tr><td rowspan="4">Processing-1-

The automated composter for organic:

Aerobic and thermal digestion for food waste.

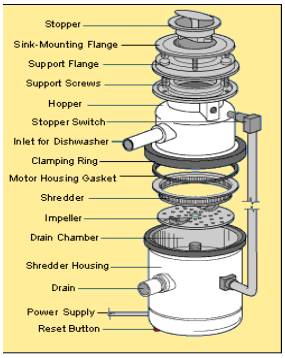
 
Figure 26: Example of an automated composter</td><td rowspan="2">Accessibility</td><td>Children</td><td>Strength:
Children are able and encouraged to throw the left-over of their food.
The process is fully Automatic, no need to specific knowledge.</td></tr>
<tr><td>Physical disabled</td><td>No specific relation to the context</td></tr>
<tr><td>Seniors</td><td>Strength:
The process is fully Automatic, no need to specific knowledge.</td></tr>
<tr><td rowspan="3">Safety</td><td>Children to use</td><td>Limitation:
Children may use it incorrectly with throwing wrong items and it could be mess up.</td></tr>
<tr><td>Physical health</td><td>No specific relation to the context</td></tr>
<tr><td>Respiratory system</td><td>Strength:
It has an air filter, no bad smells or harmful gases.</td></tr>
</table>

composting toilet: Heating element to warm the toilet, encouraging liquid waste to evaporate and solid waste to compost. Composted waste falls through from the drum to the drawer at the front  **Figure 27: Example of composting toilet**	**Effectiveness**	Maintain	**Limitation:** • Needs trainers to maintain. • Needs replacement of air filter. • In case of damage, the whole process is broken.
		Pets and insects repellent	**Strength:** • Depending on the opening, it should be sealed and it should contain air filter to remove bad smells.
		Size	**Limitation:** • The item needs recognizable space.
	Value	Time	**Limitation:** • Recognizable time for the process, minimum time taken for fully-finished compost is one day. • In case of damage, time to maintain and repair is needed
		Cost	**Limitation:** • Needs a recognizable budget to clan it and replace air filter. • In case of damage, the whole process is broken and a recognizable budget is needed.
		Sustainability	**Strength:** • Manages household food and yard waste, transform it into productive resources. • Provides a valuable nutrient-rich medium that can be used in soil. • Volume reduction of organic waste into high quality compost. • Reduces large amounts spent on transportation to landfill sites. • Composting offers a natural alternative to chemical fertilizers.

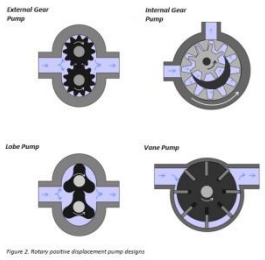
Mechanisms	Constructs	Target Audience	Analysis
Processing-2- **Shredder/ Grinder:** A shredder is machine that is used for reducing the size of all materials. A shredder can be in many different design and many sizes.  **Figure 28: Example of a mechanical shredder**	**Accessibility**	Children	**Strength:** • The process is fully Automatic, no need to specific knowledge or act.
		Physical disabled	**Limitation:** • It may need additional effort to disrupt waste.
		Seniors	**Limitation:** • It might need additional effort to disrupt waste.
	Safety	Children to use	**Limitation:** • Children may use it incorrectly with throwing wrong items and it could be mess up. • Dangerous if hard items are thrown, ex metal or glass, unless it is installed in proper way.
		Physical health	**Limitation:** • Dangerous in case of misuse it.
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • Needs trainers to maintain. • In case of damage, the whole process is broken.
		Pets/insects repellent	No specific relation to the context
		Size	**Limitation:** • The item needs recognizable space.
	Value	Time	**Limitation:** • It may need time to wait for the process
		Cost	**Limitation:** • Needs a recognizable budget • In case of damage, the whole process is broken and a recognizable budget is needed.
		Sustainability	**Strength:** • Reduces large amounts spent on transportation to landfill sites.

Mechanisms	Constructs	Target Audience	Analysis
Processing-3-	**Accessibility**	Children	No specific relation to the context
Zero Waste Sherd: The Zero Waste Monster is a self-contained, hopper-fed liquid depackaging system designed to separate liquids, gels, creams and semi-solids from their plastic, glass or metal containers. It can be used as a depackaging system and also as a food recycling machine.  **Figure 29: Example of a zero-waste recycling machine**		Physical disabled	No specific relation to the context
		Seniors	No specific relation to the context
	Safety	Children to use	**Limitation:** • Not recommended
		Physical health	**Strength:** • No hard effort needed
		Respiratory system	**Strength:** • Depends on items thrown, non-toxically materials are safe.
	Effectiveness	Maintain	**Limitation:** • In case of malfunction, experts are needed
		Pets and insects repellent	No specific relation to the context
		Size	**Limitation:** • It needs a big space
	Value	Time	**Strength:** • Minimize time of manual shred
		Cost	**Limitation:** • costly
		Sustainability	**Limitation:** • Waste management affected by non-separated mixed material

Mechanisms	Constructs	Target Audience	Analysis
Processing-4-	**Accessibility**	Children	**Strength:** • Children are able and encouraged to use it, it may need effort regarding the hook unless it is an automated compacter.
Compactor: Compress material to produce a bale. Machines may operate in a manual,semiautomatic,or automatic mode. In the automatic mode,a sensor inside the compression chamber signals when the chamber is full and activates the compression cycle.  **Figure 30: Example of a manual composter**		Physical disabled	**Limitation:** • It might need effort unless it is an automated compacter.
		Seniors	**Strength:** • Seniors are able and encouraged to use it, it may need effort depending on the hook unless it is an automated compacter.
	Safety	Children to use	**Strength:** • Safe to use.
		Physical health	**Strength:** • No need for harmful movement
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	No specific relation to the context
		Pets and insects repellent	No specific relation to the context
		Size	**Limitation:** • The item needs recognizable space.
	Value	Time	**Limitation:** • It may need extra time to compact material.
		Cost	**Strength:** • Affordable; it contains metal rams which crushes the garbage.
		Sustainability	**Strength:** • Decrease the size of waste in the outside bin and on landfills.

Mechanisms	Constructs	Target Audience	Analysis
Processing-5- **Food Waste Disposers:** A device that is installed under a kitchen sink between the sink's drain and the trap. Its role is to shred food waste into small pieces to pass through plumbing.  **Figure 31:Example and a detail of a sink grinder**	**Accessibility**	Children	No specific relation to the context
		Physical disabled	No specific relation to the context
		Seniors	No specific relation to the context
	Safety	Children to use	**Strength:** • Machine is far from the top
		Physical health	**Strength:** • No need for hard effort
		Respiratory system	**Strength:** • The system is connected with water, no bad smell or gases leakage
	Effectiveness	Maintain	**Limitation:** • In case of malfunction, experts are needed
		Pets and insects repellent	**Strength:** • The system is connected with water which prevents insects' infestation.
		Size	**Strength:** • The system is installed under the sink, no need for a huge place.
	Value	Time	**Strength:** • The process is fast
		Cost	**Strength:** • affordable
		Sustainability	**Strength:** • Grinded food with water do not affect environment

Mechanisms	Constructs	Target Audience	Analysis
Processing-6-	**Accessibility**	Children	**Strength:** • Children are able and encouraged to use it.
Automated waste sorting machine RFID: A machine with Radio-frequency identification that can help to sort waste in different places.  **Figure 32: Example of an automated waste sorting machine included RFID system**		Physical disabled	**Strength:** • physical disabled people are able and encouraged to use it,
		Seniors	**Strength:** • Seniors are able and encouraged to use it,
	Safety	Children to use	**Strength:** • Safe to use
		Physical health	**Strength:** • No need for harmful movement
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • In case of damage, the whole process is broken. • Needs trainers to maintain.
		Pets and insects repellent	No specific relation to the context
		Size	**Limitation:** • The process needs recognizable space, for the input and for the processing.
	Value	Time	**Limitation:** • It might need extra time to separate material; waste component should be thrown separately.
		Cost	**Limitation:** • Vulnerable, low capacity to bear a lot of pressure. Malfunction can occur easily. • High cost due to the technology. • In case of damage, specific budget is needed. • In case of damage, trainers are needed.
		Sustainability	**Strength:** • Manages household food and yard waste,

Mechanisms	Constructs	Target Audience	Analysis
Output-1-	**Accessibility**	Children	**Strength:** • Easy to use if it is connected with a button on the input.
Positive displacement pump: A positive displacement pump is a pump which draws a fixed amount of the liquid from the inlet and discharges it in the outlet at high pressure.  **Figure 33:Example of a displacement pump**		Physical disabled	**Strength:** • Easy to use if it is connected with a button on the input.
		Seniors	**Strength:** • Easy to use if it is connected with a button on the input.
	Safety	Children to use	No specific relation to the context
		Physical health	No specific relation to the context
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • Needs trainers in case of any damage.
		Pets and insects repellent	**Strength:** • Keeps insects away due to the suction
		Size	**Strength:** • Size included to the main component.
	Value	Time	**Strength:** • Minimize time of transportation
		Cost	**Limitation:** • Needs a specific budget
		Sustainability	No specific relation to the context

Mechanisms	Constructs	Target Audience	Analysis
Output-2- **Motorized or a sensor damper:** A damper is a valve or plate that stops or regulates the flow inside a duct, Automatic or motorized dampers may also be controlled by a solenoid.  **Figure 34: Example of a motorised damper**	**Accessibility**	Children	**Strength:** • Accessible if it is connected with a button on the input
		Physical disabled	**Strength:** • Accessible if it is connected with a button on the input
		Seniors	**Strength:** • Accessible if it is connected with a button on the input
	Safety	Children to use	No specific relation to the context
		Physical health	No specific relation to the context
		Respiratory system	No specific relation to the context
	Effectiveness	Maintain	**Limitation:** • In case of malfunction needs trainers
		Pets and insects repellent	**Strength:** • No direct connection, the damper will be located at the opening of each outdoor bin. Waste will fall by the damper to the bin and it closed directly with no letting anything go back again.
		Size	**Strength:** • Variable size, depending on the tube that connect the indoor input to the outdoor.
	Value	Time	**Strength:** • The time will not be affected by the damper.
		Cost	**Strength:** • Affordable cost
		Sustainability	No specific relation to the context

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