Mobility and Vehicle Design Project III

DESIGN OF PUSH CART FOR MUNICIPAL SOLID WASTE COLLECTION IN RESIDENTIAL AREAS

IDC School of Design
अभिकल्प विद्यालय

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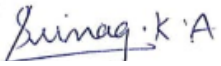
of this project.



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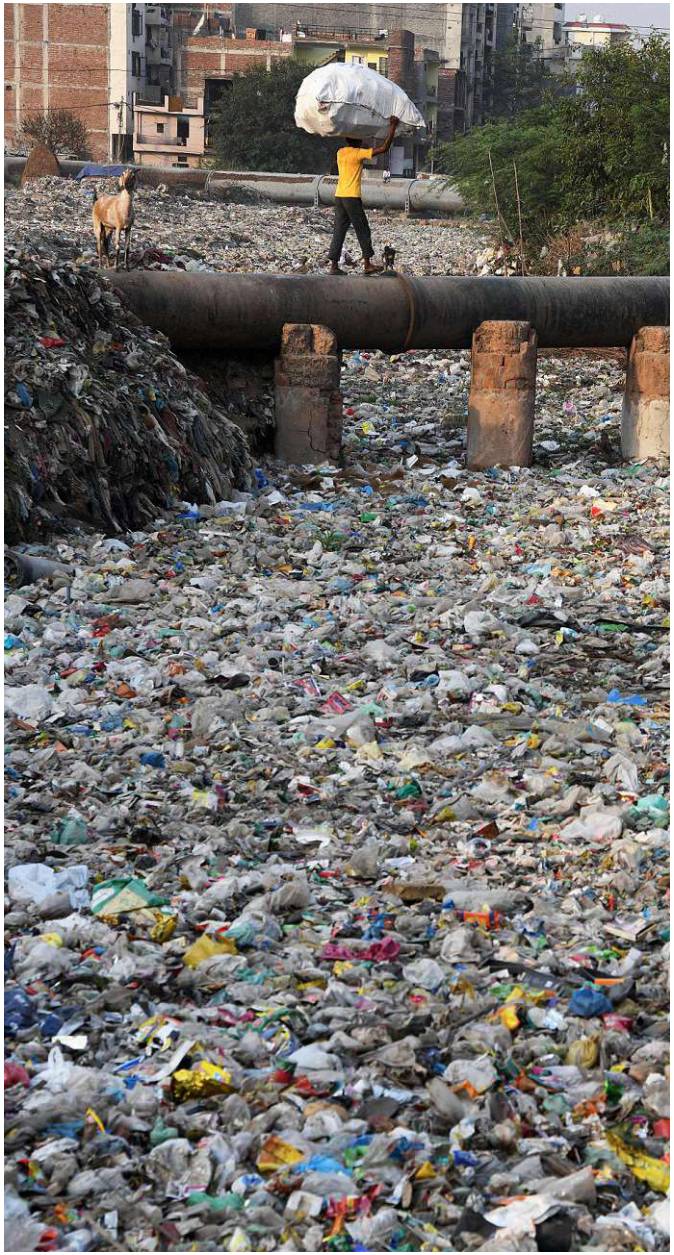
Abstract

India produced around 62 million tonnes of garbage every year and 62% of it ends up in landfills. Since most of the disposed waste is recyclable, it is necessary for the waste to stay segregated till the recycling stage.Unsegregated waste makes it difficult for the derive value out of it during recycling process as waste gets mixed in large quantities during collection process,. Therefore, the problem must be solved at the roots of waste collection and handling in order to prevent the mixing of waste

The pushcarts used by the pourakarnikas (household garbage collectors) of Bengaluru are the first mediums for collection and transfer of waste. Through observation, it was noticed that the cart neither aids the process of carrying segregated waste nor is easy to handle it in terms of moving it, stopping etc. To understand more problems associated with the cart and see it in the perspective of waste management, field studies were conducted in and outside IIT campus. The studies include in understating the way waste is disposed by the consumers, identification and handling of waste by the collectors, transferring the waste and the equipment used to transfer it from the source to the disposal unit. Studies also understanding recycling and disposal of waste based on it's type. Based in the study, the design brief was structured and ideation was done. The ideation included creating scaled mock ups to get a clear understanding of the concept. The agenda during ideation was not only to address the issue but also to make sure that the cart fits into the system. A 1:4 scale mock up model was created to get a better idea on the design of the cart. And addresses all the issues mentioned in the brief.

The cart addresses the problem segregation of waste and it's handling to make it more convenient for the collector to further segregate and generate the value out of waste. It also addresses the issue of handling waste that is hazardous upon it's direct exposure to the collector

Working on this project gave a detailed understanding of the process of waste management and numerous issues associated to it. These issues are opportunities for the designer to design better products or systems for improved functioning. It also gave an understanding on how to design a vehicle such that it fits into the system, address the problem and is also convenient to the user.



1.0 Introduction

Waste management in India falls under the purview of the Union Ministry of Environment, Forests and Climate Change (MoEF&CC). In 2016 this ministry released the Solid Waste Management (SWM) Rules, 2016, these rules replaced the Municipal Solid Wastes (Management and Handling) Rules, 2000 which had been in place for 16 years

Urban India (about 377 million people) generates 62 million tonnes of municipal solid waste each year, of this about 43 million tonnes (70%) is collected and 11.9 million tonnes (20%) is treated. About 31 million tonnes (50%) is dumped in landfill sites.

With changing consumption patterns and rapid economic growth it is estimated that urban municipal solid waste generation will increase to 165 million tonnes in 2030.

India is a rapidly growing economy, but the country is facing a chronic problem of unmanageable urban waste. Landfills in most of the cities are overflowing with no extra space for additional garbage. According to a recent report by the Central Pollution Control Board, Delhi needs 650 acres of landfills (four times more than the existing landfills) to fulfill its present need.

Approximately 9,000 metric tonnes of solid waste is produced daily in Delhi. The city has four dumping sites, but all of them are overflowing. Mumbai produces 6,500 metric tonnes of garbage daily, which is dumped at the Deonar dumping ground. The landfills in Gorai and Chincholi Bunder have been shut down. It is expected that the Deonar landfill site will expire by 2016. It has been found out that landfills are responsible for about 20% of methane gas emission in India. This gas is directly responsible for greenhouse effect. Moreover, these landfills are not built as per accepted specifications. This causes groundwater contamination. Improperly collected and uncollected waste dumped in streets or in drains acts as breeding grounds for insects and rodents.

Image 1.0.1 A sea of plastic is seen spreading through the New Delhi slum of Taimur Nagar.

1.1 Waste generation in India

India is experiencing rapid urbanization while remaining a country with physical, climatic, geographical, ecological, social, cultural and linguistic diversity.

The population of India was 1252 million in 2013, compared with 1028 million in 2001. Population growth is a major contributor to increasing MSW in India.

Census Year	Population (Millions)	Decade growth) Millions)	Average annual exponential growth rate (%)	Progressive growth rate compared with 1911 (%)
1911	252.0	13.7	0.56	5.75
1921	251.3	-0.8	-0.03	5.42
1931	278.9	27.6	1.04	17.02
1941	318.6	39.7	1.33	33.67
1951	361.1	42.4	1.25	51.47
1961	439.2	78.1	1.96	84.25
1971	548.1	108.9	2.20	129.94
1981	683.3	135.1	2.22	186.64
1991	846.4	163.1	2.16	255.05
2001	1028.7	182.3	1.97	331.52
2011	1210.2	181.4	1.64	407.64

Table 1.1.1 Population growth in India

1.2 Growth of mega cities in India

Mega-cities are a relatively recent phenomenon, associated with globalization of the economy, culture and technology. Mega-cities in India include Ahmedabad (6.3 million), Hyderabad (7.7 million), Bangalore (8.4 million), Chennai (8.6 million), Kolkata (14.1 million), Delhi (16.3 million) and Greater Mumbai (18.4 million). These have dynamic economic growth and high waste generation per capita, as shown in table 1.2.

City	Population in 2011 (million)	Total waste generated in tonnes per day	Waste generation (kg per capita per day)
Ahmedabad	6.3	2300	0.36
Hyderabad	7.7	4200	0.54
Bangalore	8.4	3700	0.44
Chennai	8.6	4500	0.52
Kolkata	14.1	3670	0.26
Delhi	16.3	5800	0.41
Mumbai	18.4	6500	0.35

Table 1.2..1 Major cities in India and per capita waste generation data (2010–2011)

1.3 Statistics on waste generation

Estimating the quantity and characteristics of MSW in India and forecasting future waste generation is fundamental to successful waste management planning. The quantity of MSW generated depends on living standards, the extent and type of commercial activity, eating habits and season. India generates approximately 133 760 tonnes of MSW per day, of which approximately 91 152 tonnes is collected and approximately 25 884 tonnes is treated. MSW generation per capita in India ranges from approximately 0.17 kg per person per day in small towns to approximately 0.62 kg per person per day in cities, as shown in table 1.4

Waste generation rate depends on factors such as population density, economic status, level of commercial activity, culture and city/region. Figure 1 provides data on MSW generation in different states, indicating high waste generation in Maharashtra (115 364–19 204 tonnes per day), Uttar Pradesh, Tamil Nadu, West Bengal (11 523–15 363 tonnes per day), Andhra Pradesh, Kerala (7683–11 522 tonnes per day) and Madhya Pradesh, Rajasthan, Gujarat, Karnataka and Mizoram (3842–7662 tonnes per day). Lower waste generation occurs in Jammu and Kashmir, Bihar, Jharkhand, Chhattisgarh, Orissa, Goa, Assam, Arunachal Pradesh, Meghalaya, Tripura, Nagaland and Manipur (less than 3841 tonnes per day).

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Population	Waste generation rate (kg per capita per day)
Cities with a population <0.1 million (8 cities)	0.17–0.54
Cities with a population of 0.5-1.0 million (11 cities)	0.22–0.59
Cities with a population of 1.0-2.0 million (16 cities)	0.19–0.53
Cities with a population >0.1 million (13 cities)	0.22–0.62

Table 1.3.1 Waste generation per capita in Indian cities.

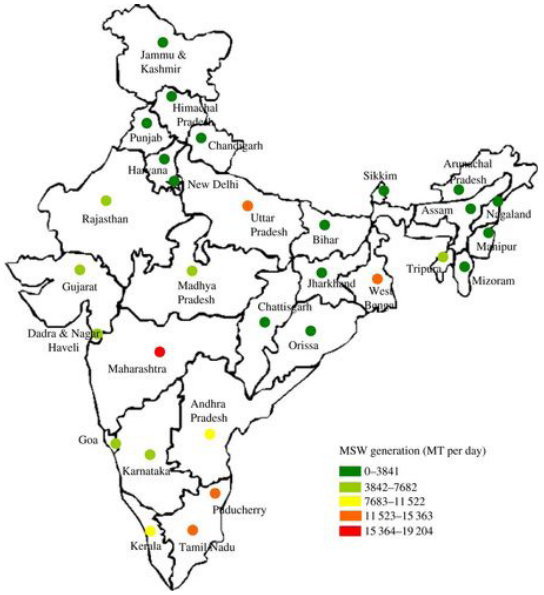


Image 1.3.1 State-level statistics of MSW generation in India

1.4 Waste characterization data

The local economy impacts on waste composition, as high-income groups use more packaged products, resulting in higher volumes of plastics, paper, glass, metals and textiles. Changes in waste composition can have a significant impact on waste management practices. MSW may also contain hazardous wastes such as pesticides, paints, used medicine and batteries. Compostable organics include fruits, vegetables and food waste. Healthcare waste contains disposable syringes, sanitary materials and blood containing textiles and is governed by the Biomedical Waste (Management and Handling) Rules 1998 and the Amended Rules, 2003, and should not be mixed with MSW . The average composition of MSW produced by Indian cities is approximately 41 wt.% organic, approximately 40 wt.% inert, with approximately 19 wt.% potentially recyclable materials, as shown in table . Most organic waste is generated from households, and inert waste is generated from construction, demolition and road sweeping. Waste samples collected from Delhi, Ahmadabad and Bangalore indicate that MSW composition varies between cities.

Percentage (%) by weight

Compostable	Inert	Paper	Plastic	Glass	Metals	Textile	Leather
41	40	6	4	2	2	4	1

Table 1.4.1 Waste characterization in India

1.5 Waste collection and transport

Waste collection, storage and transport are essential elements of any SWM system and can be major challenges in cities. Waste collection is the responsibility of the municipal corporations in India, and bins are normally provided for biodegradable and inert waste. Mixed biodegradable and inert waste is often dumped, with open burning a common practice. Improvements to waste collection and transport infrastructure in India will create jobs, improve public health and increase tourism. Local bodies spend around Rs. 500–1000 per tonne on SWM with 70% of this amount spent on collection and 20% spent on transport.

1.6 Waste Disposal

SWM disposal is at a critical stage of development in India. There is a need to develop facilities to treat and dispose of increasing amounts of MSW. More than 90% of waste in India is believed to be dumped in an unsatisfactory manner. It is estimated that approximately 1400 km2 was occupied by waste dumps in 1997 and this is expected to increase in the future, as shown in the graph below

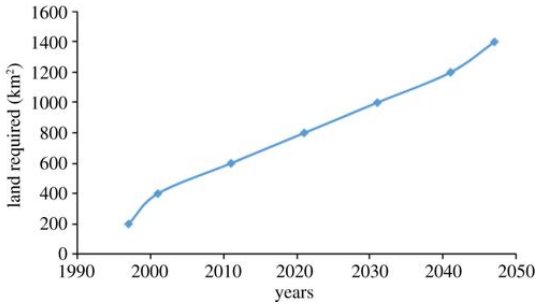


Image 1.6.1 Cumulative land required (km2) for disposal of MSW.

1.7 Current waste management in India

1.7.1 Key waste management legislations in India

The MoEF issued MSW (Management and Handling) Rules 2000 to ensure proper waste management in India and new updated draft rules have recently been published. Municipal authorities are responsible for implementing these rules and developing infrastructure for collection, storage, segregation, transportation, processing and disposal of MSW.

Chandigarh is the first city to develop SWM in a planned way and has improved waste management compared with other Indian cities

1.7.2 Role of the informal sector in waste materials reuse and recycling

The informal sector has a very important role in India and this must be integrated into formal SWM systems. The informal sector is characterized by small-scale, labor-intensive, largely unregulated and unregistered low-technology manufacturing or provision of materials and services]. Waste pickers collect household or commercial/industrial waste and many hundreds of thousands of waste pickers in India depend on waste for an income, despite the associated health and social issues. Pickers extract potential value from waste bins, trucks, streets, waterways and dump-sites. Some work in recycling plants owned by cooperatives or waste picker associations. Waste picking is often the only source of income for families, providing a livelihood for significant numbers of urban poor and usable materials to other enterprises. Waste pickers in Pune collect organic waste for composting and biogas generation. Waste pickers also make a significant contribution by keeping cities clean.

A recent study of six Indian cities found that waste pickers recovered approximately 20% of waste, with 80 000 people involved in recycling approximately three million tonnes. It is estimated that every tonne of recyclable material collected saved the Urban Local Bodies approximately INR 24 500 per annum and avoided the emission of 721 kg CO_2 per annum.

Image 1.7.1 Rag pickers play a vital role in waste management

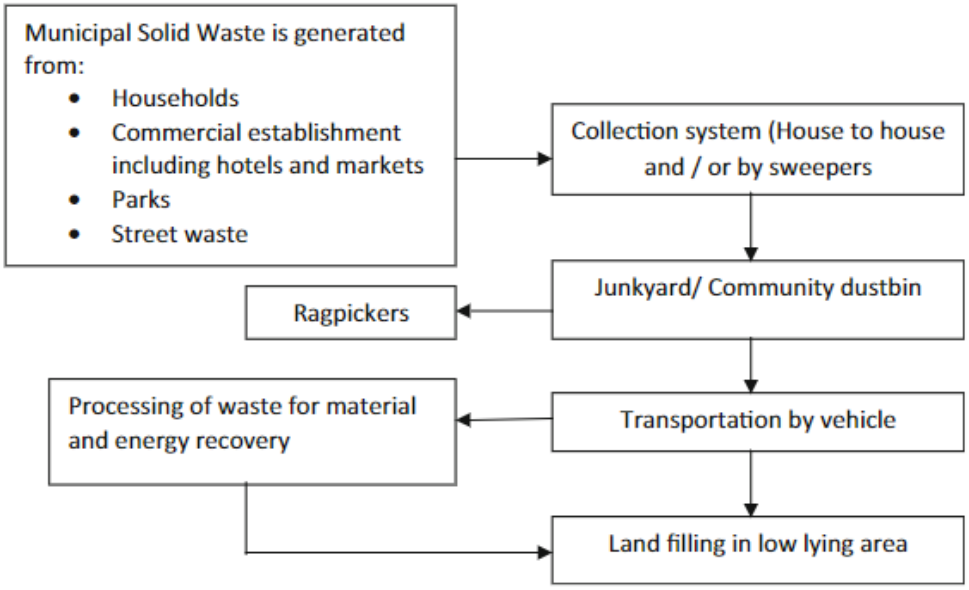


Image 1..2 The flow chart of existing municipal solid waste management system in India

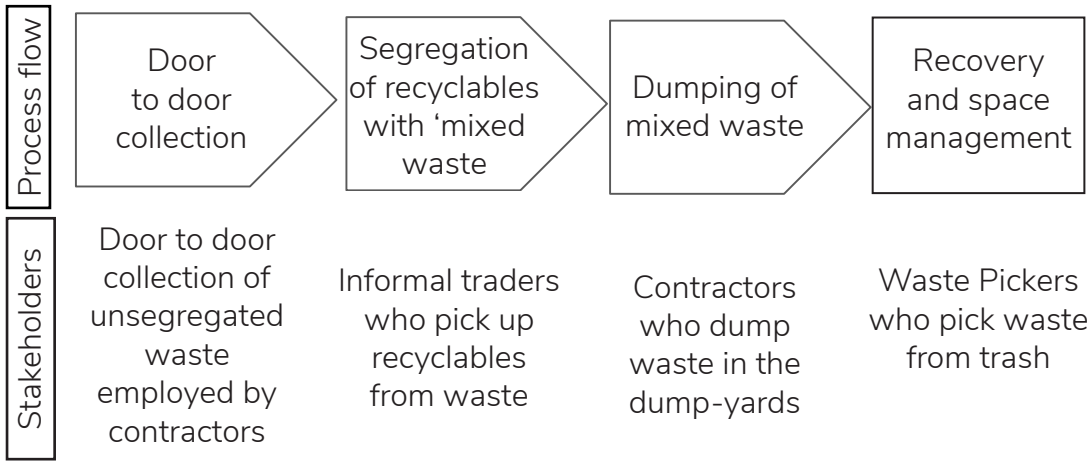


Image 1.7.3 Waste Management Module in India

1.7.3 Municipal waste management mechanism

The solid waste generated is collected from door to door by garbage collectors . These collectors are not only involved in collecting the garbage but also are involved in sweeping the roads . The waste that is collected is transferred to the local dumping grounds or to the transport units such as trucks, tipper autos etc.

Rag pickers play an important role in collecting the items that are recyclable from the garbage and transferring it into recycling centers. The garbage from these points are transferred to the recycling centers where recycling of waste takes places. The waste is usually let out on the conveyor belt and is the items that can be recycled are selected manually. The items that cannot be recycled are further transported to the areas for energy recovery or the landfills. Items that can be burnt in order to get energy out are sent to the recovery centers. Items that cannot be burnt end up in the landfills.

Segregation of waste is usually done in the initial stage and the waste collectors play a vital role in segregating the waste an hence prevent the waste to end up in the energy recovery centers or the landfills

2.0 The Pourakarmikas

Image 2.0.1 Push cart used by pourakarmikas

Image 2.0.2 Pourakarmikas are involved in cleaning the streets

Image 2.0.3 Pourakarmikas are exposed to waste during cleaning process

Image 2.0.4 The overflowing cart with waste must also accommodate the leaves fallen on the road

Bengaluru generates almost 1700 tons of Solid Waste every day. These include waste generated by residential areas, commercial establishments, hotels, hospitals, institutes, etc.20 % of the waste is collected by the Pourakarmikas and tipper autos. 80% of the collection and transportation activities have been outsourced. About 20,000 pourakarmikas are being utilized (by both BBMP and the contractors) in for the door to door collection, street sweeping and transportation of municipal solid waste. The ratio of number of pourakarmikas to the residents is 1:1000. There is one push cart for every 200 households. Though pourakarmikas play a major role in collecting the municipal solid waste and keep the streets clean, the push carts used by them do not help them with their purpose.

Contractors bring in groups of men and women from different villages who are accommodated in temporary tent-like structures in the wards where they work. Women of a particular village prefer to live and work together in the same place. They rarely interact with others, as their dialect or language is different and the city is an unfamiliar place for them. Also, sweeping and cleaning as jobs are something they are familiar with and does not require them to learn something new.

Pourakarmikas toil in working conditions that are far from perfect, as numerous reports and studies have shown. Hired by contractors selected by the city municipal corporation, there have been occasions when they have not received their salary for more than six months. Deep financial distress has even led to an instance of suicide by a pourakarmika.

Many a time, they are paid much less than the minimum salary of Rs 14040, which they are entitled to. Often they are not even aware of the additional benefits like Provident Fund that they should be getting.. Most of the women surveyed said this is the only government job that an illiterate, uneducated woman can get.

2.1 Problems associated with the cart used by the Pourakarmikas

Image 2.1.1 Mixing of collected waste

Image 2.1.2 Waste piled up in the carts

1. Mixing of leaves swept on the road is mixed with both wet waste and dry waste. This hampers the entire segregation process due to the nature of the waste. Unsegregated waste may end up in landfills.

Image 2.1.3 Unsegregated waste dumped at local dumping points

Image 2.1.4 Waste piled up in the carts

2. After door to door collection of waste, the waste is either transferred to trucks, tipper autos or localized dumping units. Current cart designs do not facilitate this process. The waste transfered may mix up during the process and thus hamper the segregation process.

Image 2.1.5 Scavenging by stray animals

Image 2.1.6 Carts left out on the roads

3. After collecting the waste and transferring to further locations for post processing, the cart is left on the roads for rest of the day. Any leftover waste in the cart attracts scavengers and thus makes the cart messy. The filthiness of the cart increases due to rains as the rainwater accumulates in the cart along with the waste.

Image 2.1.7 Extra bins added to the cart

Image 2.1.8 The cart has not changed based on waste segregation rules

5. Not much changes in the design of the cart is witnessed though segregation of waste is made mandatory by the municipal authority on the residents of the city. Apart from adding extra bins to the cart, not many changes are brought up in order to contain the waste

Image 2.1.9 Extra bins added to the cart

Image 2.1.10 The cart has not changed based on waste segregation rules

6. Filled carts demand physical effort to push especially on the slopes

3.0 Observation Study

Studies were done in order to understand the entire system of waste management so that the cart that is designed not only becomes a part of the system, but also plays a vital role in the smooth functioning of the system.

The study was done at 4 places which are as follows:-

1. IIT Campus- The study was done in within the campus of IIT Bombay to understand the journey of waste right from the dust-bin to the exit from the campus. The study was carried out in the hostels, staff quarters, eateries present within the campus. Various aspects such as the handling of wet waste, dry waste, e-waste, bio waste from the labs, hospital and girls' hostel was studied.

2. Great Eastern Apartments- A study was also done at Great Eastern Apartments, Kanjurmarg to understand the system of waste management in an apartment complex. The study included how the wet waste is processed in order to convert it into compost.

4. Ambedkar Nagar- To understand how the waste is disposed outside the homes, a study was done outside the campus at Ambedkar Nagar near the campus.

3. Dharavi- Since plastics are disposed in huge numbers everyday, a study was done at Dharavi to understand how the plastic waste is handled and post processed.

3.1 Study of waste transfer from hostel to the dump-yards

Image 3.1.1 Waste collected in the bins

Image 3.1.2 Unsegregated waste is collected in sacks

Image 3.1.3The sacks are transferred manually to the bins

Image 3.1.4The sacks are transferred to the truck

Image 3.1.5 The sacks are then transferred to the sorting center

Image 3.1.7 Compression of sorted waste

Image 3.1.6 Partial sorting of waste

Image 3.1.8 Cardboard, packaging plastics are few of the items picked during sorting

Image 3.1.9 Sorted waste is transferred to the truck

The truck transfers the sorted waste into recycling units

3.2 Study of waste transfer from mess to the dump-yards

Image 3.2.1 Collection of waste in blue drums

Image 3.2.2 Equal distribution of waste in the drums

Image 3.2.3 Transfer of drums to the truck

Image 3.2.4Transfer of drums to the sorting center

Image 3.2.5 Compression of wet waste in the hydraulic unit

Image 3.2.6 Cleaning of drums with water

Image 3.2.7 Cleaned drums are transferred to the mess

3.3 Study of waste transfer from staff quarters to the dump-yards

Image 3.3.1 Wheelbarrow used to transfer the waste

Image 3.3.2 The waste in the bins is segregated

Image 3.3.3 Dry waste and wet waste is transferred in separate sacs

Image 3.3.4 Plastic carry bags are torn open to transfer the waste

Image 3.3.5 Metal rod is fastened with rope to the wheelbarrow to accommodate the sacs

Image 3.3.6 Sacs are placed in the wheelbarrow

Image 3.3.7 Sacs are transferred to the bins

Image 3.3.8 Sacs are transferred to the truck

Image 3.3.9 Wet waste in compressed by the hydraulic garbage compactor. Dry waste is partially recycled

Compressed waste is transferred to the dump-yards

Recyclable items are transferred in a truck for post processing

3.4 Cleaning of Bin and Transfer of Waste from Bins to the Dump yards

Image 3.4.1 Metal frame around the bin is disassembled

Image 3.4.2 Waste present in the bins is transferred in the sac

Image 3.4.3 and Image 3.4.4 Bin is manually cleaned with water and liquid soap. The frame is later assembled

Sacs are transferred to the van which transfers waste to the segregation unit. Partial segregation is done in the unit.
The remaining waste is compressed in the garbage compactor.

Image 3.4.5 and Image 3.4.6 Similar process is followed in cleaning other bins. The sacs are carried manually. Waste from departments is also collected

3.5 Composting of Organic Waste near the Lakeside Area

Image 3.5.1 Waste collected from the staff quarters is transferred in sacs. The sacks are further transferred in the carts.

Image 3.5.2 Part of dry wet waste and the complete collection of dry waste is transferred to the trucks

Image 3.5.3 Only the waste present in smaller drum is transferred to the truck The waste present in the larger drum is used for composting

Image 3.5.4 The organic waste present in the drum is transferred for composting

3.6 Disposal of E waste in the campus

Image 3.6.1 E waste is collected in the specially allocated dustbins

Image 3.6.2 E waste from hostels, staff quarters, departments are transferred to bins present in the PHO office

The waste segregated on certain basis is given to the vendor for further recycling process

3.7 Disposal of Sanitary Napkins in the campus

Image 3.6.3 Sanitary pads are disposed in red colored bins

Image 3.6.4.-Waste is transferred to the PHO office via a pick up truck

Image 3.6.5 and Image 3.6.6 The waste transferred is stored in yellow plastic bags which is collected by the vendor twice/ week. Since sanitary napkins are not recyclable, the pads are incinerated

3.8 Disposal of Waste at Great Eastern Apartments

Type of waste generated

Image 3.8.1 Inorganic waste

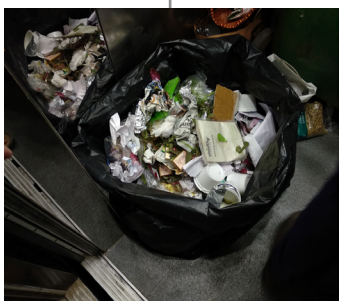


Image 3.8.2 Rejects

Image 3.8.3 Organic waste

Image 3.8.4 Inorganic waste is collected by the scrap dealer

Image 3.8.5 Rejects are disposed by transferring to the BMC collecting units

Image 3.8.6 Organic waste is converted into compost

3.9 Converting Organic waste into Compost

Image 3.9.1 Organic waste collected is transferred to the bins

Image 3.9.2 The waste is shredded manually initially

Image 3.9.3 A shredding machine is used later to shred the waste

Image 3.9.4 The shredder is also used to shred the fallen leaves

Image 3.9.5 The shredded mixture is transferred to the compost tumbler. The tumbler is rotated everyday

Image 3.9.6 It takes approximately 2 months to form compost in the tumbler

Image 3.9.7 Sieve is used to filter the compost

Image 3.9.8 Compost ready to be used.

4.0 Time-line of the journey of waste generated in the campus

To understand the time taken to transfer the waste from one point to another point with in the campus, a time-line was plotted . The graph not only explains the journey of the waste from one point to other point of the campus, but also the time spent by the waste at that point. The time-line also explains how the waste is transferred from one place to another.

Example, the waste is manually collected fro the staff quarters Ananta and a wheel barrow is used to transfer the waste. This waste is transferred to the compression unit using a truck. The sanitary napkins and bio waste collected from the hospitals are transferred to the PHO office and then transferred to the post processing units outside the campus.

The time-line gives information on the time spent by the waste at various points inside the campus

4.1 Time-line for disposal of sanitary pads

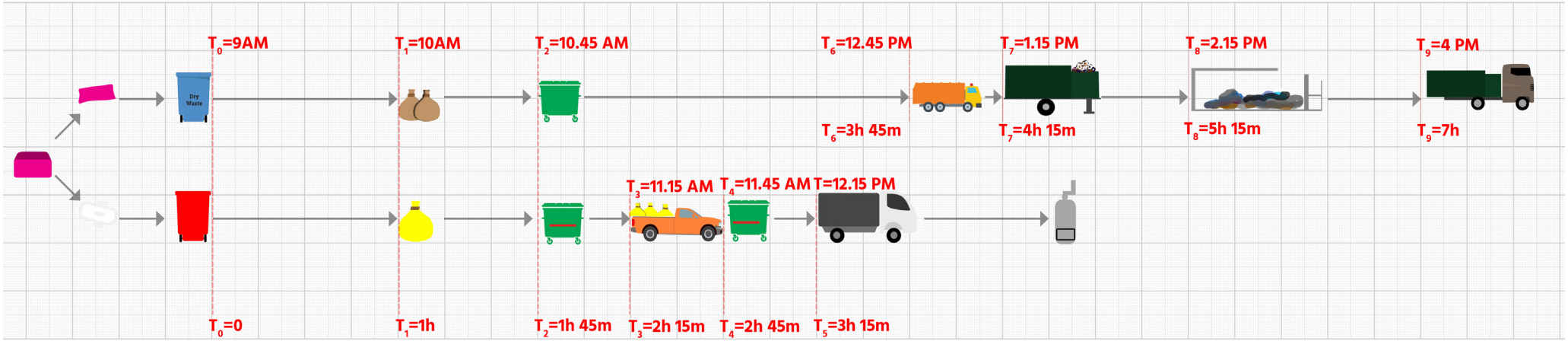


Image 4.1.1 Time-line for disposal of sanitary pads

The packaging cover of sanitary napkins are disposed in regular waste bins. Sanitary napkins are disposed in bins coloured red

T_0- Cleaning of bins begin.

T_1- Regular waste and sanitary pads are disposed in separate bags. Sanitary napkins are transferred in yellow plastic bags.

T_2- The bags are kept in bins specified for the napkins.

T3- A pick up collects the bags.

T_4- The collected bags are transferred to the PHO office and is stored in specific bags.

T_5- The bags are collected by a disposal vendor in contract. The vendor visits the institute twice a week to collect the bags

The pads are disposed by incineration

4.2 Time-line of Disposal of Waste generated in Hostels

Image 4.2.1 Time-line for disposal of waste generated in hostels

T_0- Cleaning of floors begins and the waste from bins are transferred into the sacs

T_1- All the waste from the floors of the wing are transferred into the sacs

T_2- The sacs are transferred to the bins manually. The sacs weigh around 50-50 kg. 2-3 sacs of waste is generated by a hostel everyday.

T_3- The truck collects the sacs from the hostel.

T_4- The sacs are emptied in the hydraulic compressor. Partial sorting of waste manually and compression of waste takes place. The handpicked recycled items are transferred to the truck.

T_5- The compactor truck leaves the campus for dumping the waste in the dumpyards. The truck containing the recyclable items leaves the campus to transfer to recycling units

4.3 Time-line of Disposal of Waste generated in Staff Quarters

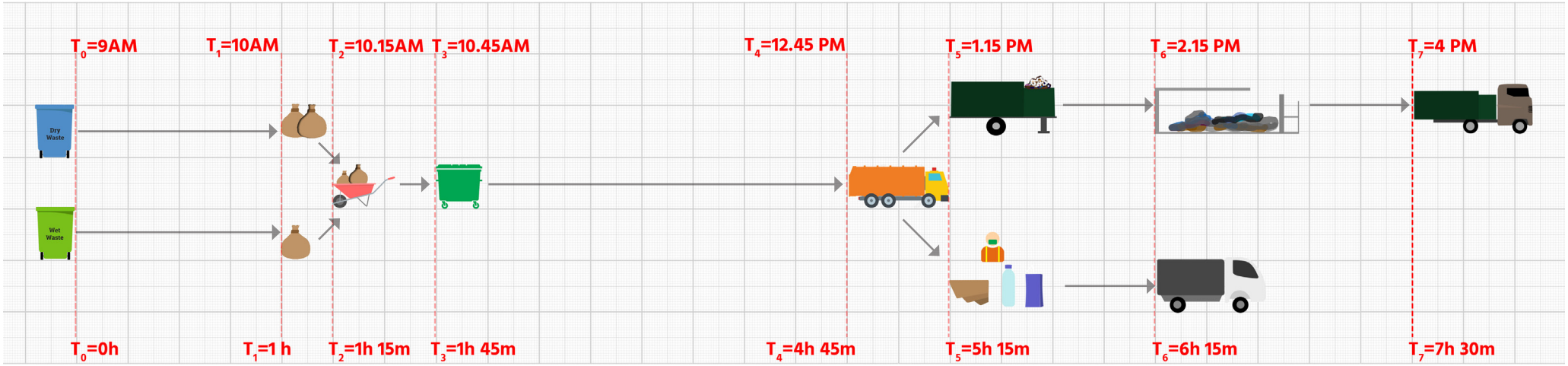


Image 4.3.1 Time-line for disposal of waste generated in staff quarters

T_0- Door to door collection of garbage begins. Wet waste and dry waste are transferred into separate sacs

T_1- The openings of sac are tied.

T_2- The sacs are transferred to the wheelbarrow

T_3- After sweeping the premises, the sacks are transferred to the bins

T_4- Collection of the sacs by truck

T_5- Wet waste is transferred to the garbage compactor. Segregated dry waste is further segregated for further

T_6- Compression of wet waste. The recyclable dry waste is sent to recycling unit

T_7- The compactor leaves the campus for dumping the waste in dumpyard

4.4 Management of waste generated in Great Eastern Apartments

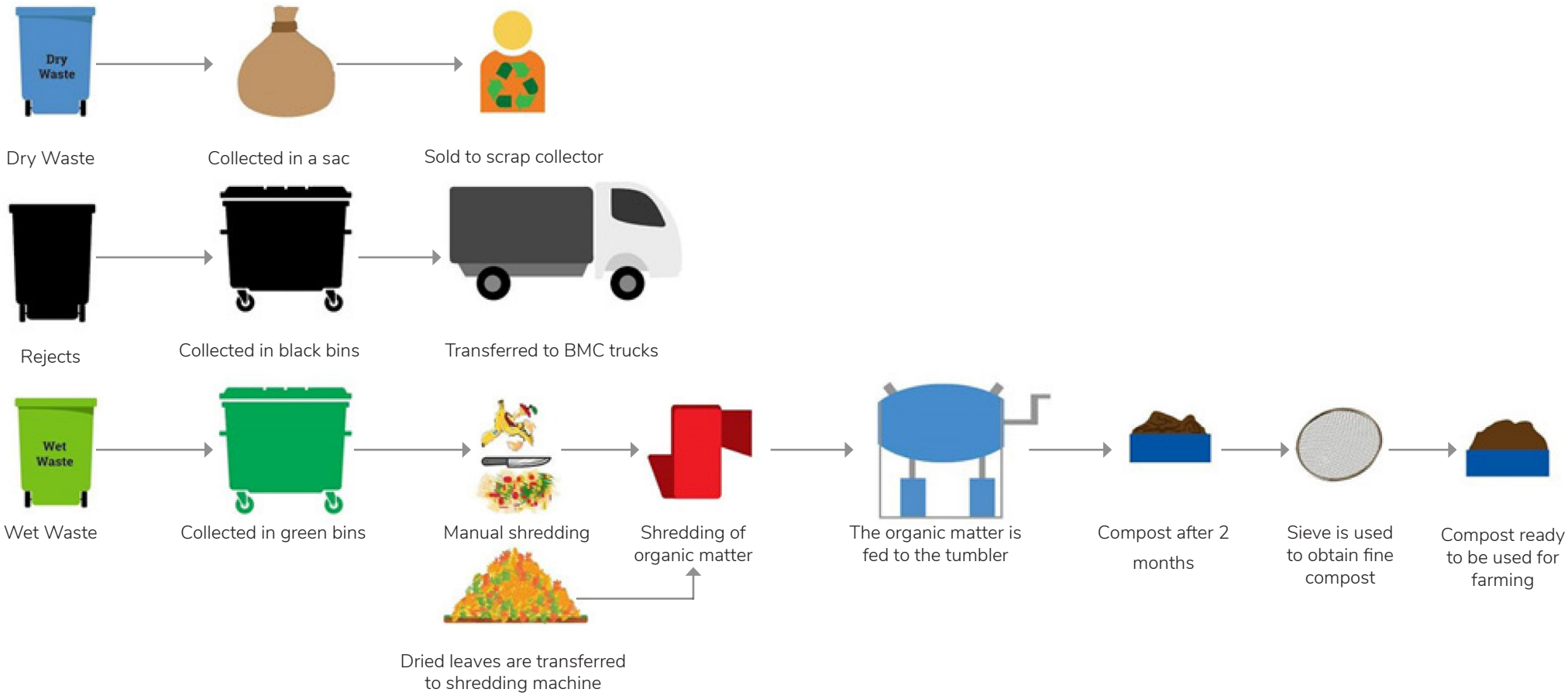


Image 4.4 Waste management in Great Eastern Apartments

5.0 Observation study on handling of waste at Ambedkar Nagar

Image 5.1 Use of sacks avoids direct contact with waste

Image 5.2 Waste is unsegregated and is thrown directly in the truck

Image 5.3 Waste collected by door to door collection and sweeping the roads is transferred to the wheeled bins

Image 5.4 The wheeled bins have a capacity of 240 liters and it takes 3 empty bins of same unit to collect the waste

Image 5.5 Unsegregated waste was also transferred in the collecting unit of the tipper autos by the residents

Image 5.6 A separate sack was hung outside the auto to collect plastic bottles.

6.0 A visit to Dharavi to understand the handling and post processing of Plastic waste

Image 6.1 Dharavi processes around 10000 kg of plastic per day. The plastic is usually purchased by rag pickers. The sacks seen above contain plastic for post processing

Image 6.2 Sorting of plastic happens manually at sorting units

Image 6.3 Plastic is sorted initially in terms of material and later by color

Image 6.4 If the plastic is not sorted terms of colour, the end product may turn out to be grey in colour when the plastic is melted and reformed during recycling process

Image 6.5 The sorted plastic is shredded in pieces for further recycling process

Image 6.6 The shredded plastic is packed in sacks and is ready to be transferred to factories for further recycling process

6.1 Journey of plastic waste collected by scrap dealers

Plastic products instead of its disposal is sold to the scrap dealers

Since selling of waste plastic generates monetary value for plastic rather than disposing, it is sold to the scrap dealers

↓

The scrap dealers sell the plastic to the sorting units of Dharavi

Discarded plastic which can be recycled is sold to the sorting units at Dharavi.

↓

Identification and sorting of plastic based on it's type.

The plastic is identified by various methods such as feeling the texture, breaking it and observing it's composition, the odor of the fumes when burnt, the stiffness of the plastic when it is bent using hands etc.

↓

Further sorting of plastic based on colour

Melting and Mixing of plastic of different colours results in a grey coloured output. In order to avoid this, the plastic is further sorted based on colour

↓

Shredding/Griding of sorted plastic

After the sorting is done, the plastic is shredded in strips or grinded into pieces using machines

↓

Washing of shredded/grinded plastic

The shredded/grinded plastic is later washed and dried. It takes around 4-5 days for it to dry and would take more time during the rainy season. Roughly 10000 kg of plastics is processed at Dharavi per day

↓

Packing and transport of the washed plastic pieces

The dried plastic bits are packed in sacks and are transferred to the manufacturing units to convert it into products. The sacks would contain plastic of one type of material and colour. Around 10000 kg of plastic bits are transferred from Dharavi to manufacturing centers every day

7.0 Design brief

1. The cart must have separate compartments to accommodate wet waste and dry waste.
Since segregation of waste increases the chances of recycling of dry waste and composting of wet waste, the cart must be designed such that wet waste and dry waste can be segregated

2. The cart must be lightweight, easy to turn, easy to push in the uphills and easy to control in downhill.
The carts are pushed using human effort and must be easy for the waste collector to push the cart in uphills, bad roads and must be able to handle the cart at downhills as cart becomes heavy and difficult to handle.

3. The cart must accommodate a compression mechanism to compress wet waste and empty plastic bottles.
Wet waste is generated in huge quantities. This causes spillage of waste on the ground and also makes the cart filthy. Therefore the cart must have a compression mechanism for the wet waste. Empty plastic bottles occupy a lot of space. Hence a compression mechanism for empty bottles is required.

4. The cart must be able to accommodate the transferred waste thus avoiding spillage on waste.
Overflowing of waste makes the cart filthy and also may be hazardous to the health of the collector. Therefore the cart must be designed such that it could accommodate all the waste collected for that particular day.

5. The cart must avoid mixing of wet waste and dry waste during waste transfer.
Waste is usually transferred from the bins to either the local dumping points, tipper trucks or trucks. During transfer process, the waste gets mixed and hence may hamper the segregation process later on. Hence the cart must be designed that no mixing of waste takes place later on during waste transfer.

6. The cart must not be prone to scavenging by stray animals.
The cart is generally left on the roadside after the day's waste collection task is done. The leftover waste in the cart attracts scavengers and hence make the cart filthy. Therefore, the cart must be designed such that it doesn't attract scavengers which make the cart more filthy.

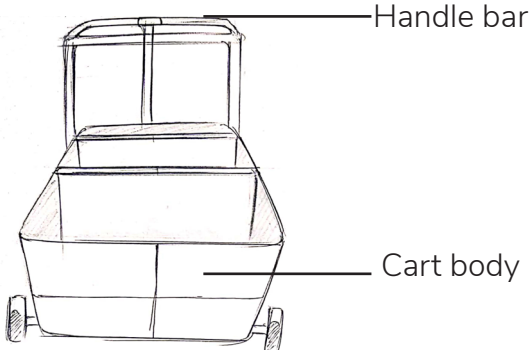
7. The cart must not get filthy during the rainy seasons.
The cart is left out on the road after the collection of waste is completed for a day. Left over wet waste makes the cart filthy during rainy season. Therefore the cart must be designed such that it doesn't get filthy during rainy season

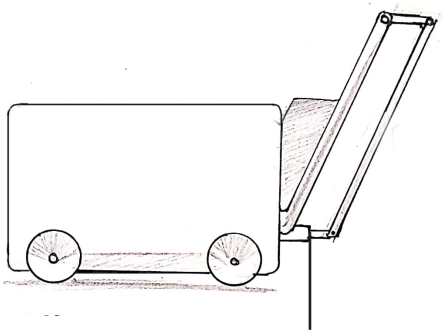
8.0 Ideation

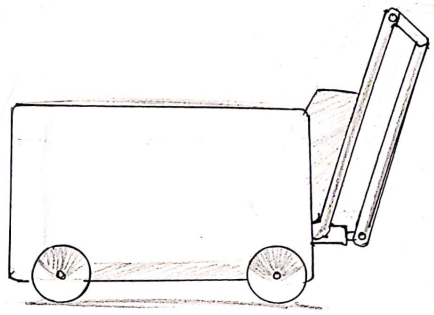
Concepts were created based on the brief which was formulated on the inputs received during observational study. The concepts generated focused on various factors such usability of the cart, segregation of waste, compression of waste etc. Mock ups were created in the subsequent stages for better understanding of the design process.

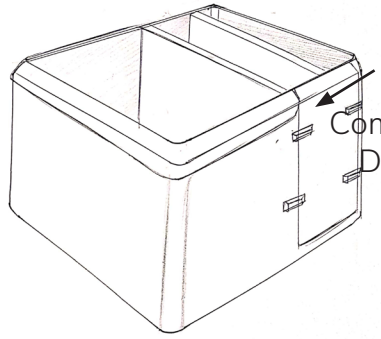
Concept 1

The ideation process started with keeping considering that the wet waste and dry waste is segregated. Focus was on compressing wet waste

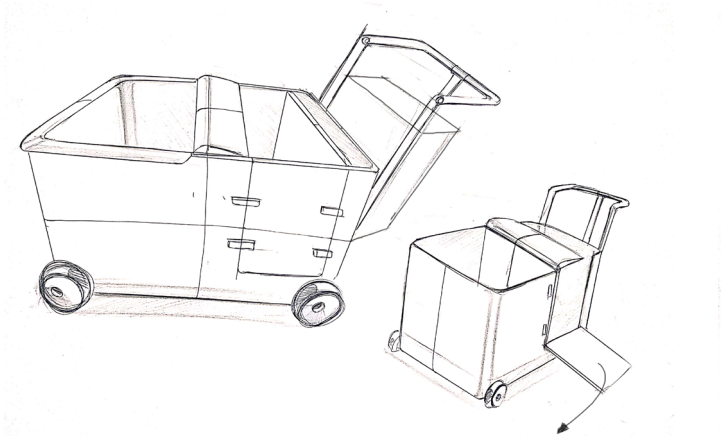


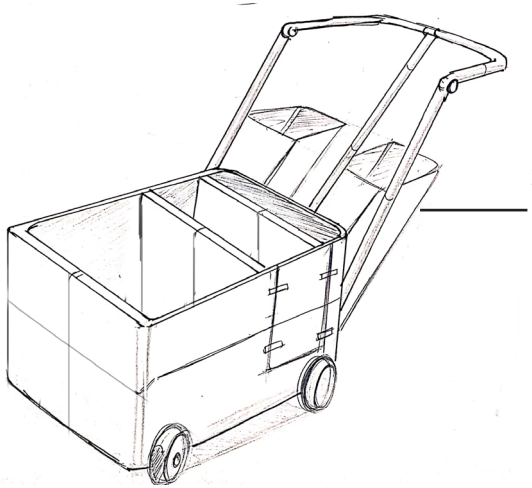

Slider crank mechanism





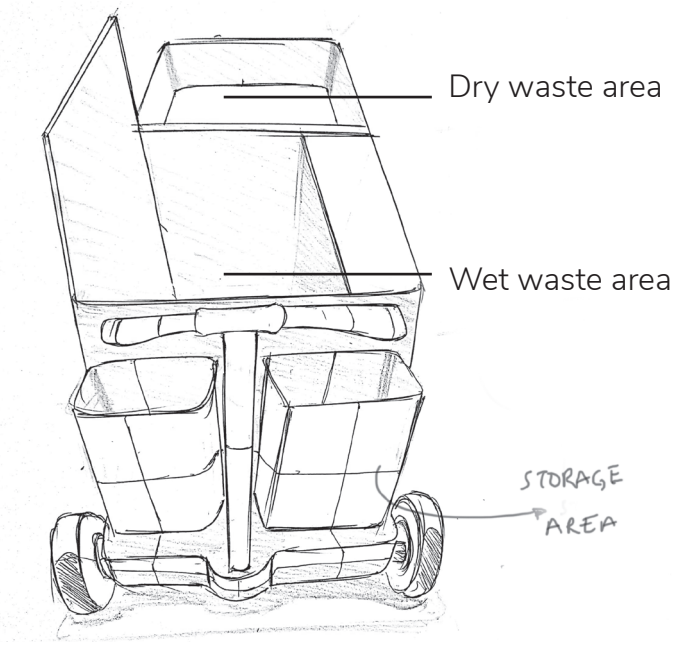
Slider compressing wet waste


Dry waste is transferred to sacks

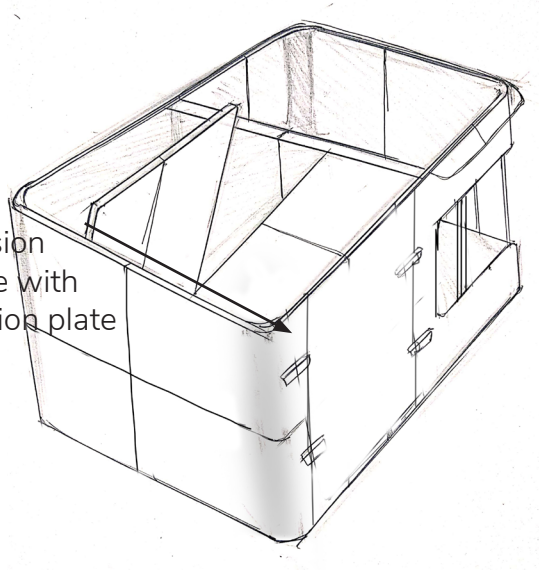


Concept 2

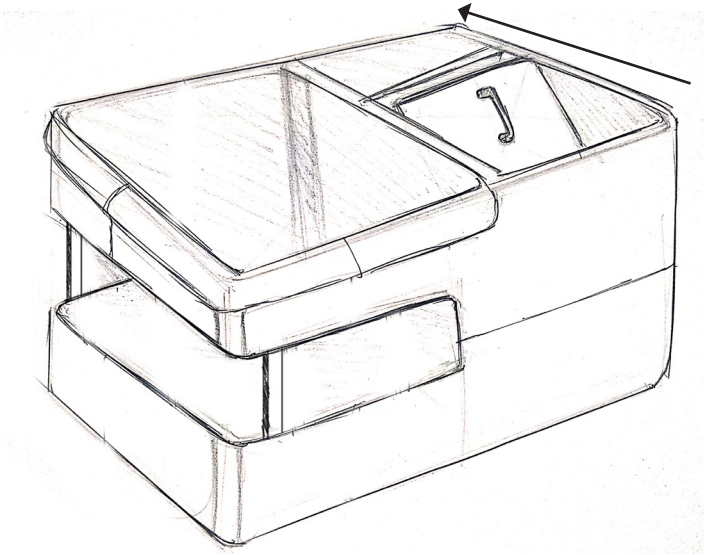
In this concept, the use of sacks was explored. Sacks not only prevent in mixing waste, but also prevent the direct contact of waste



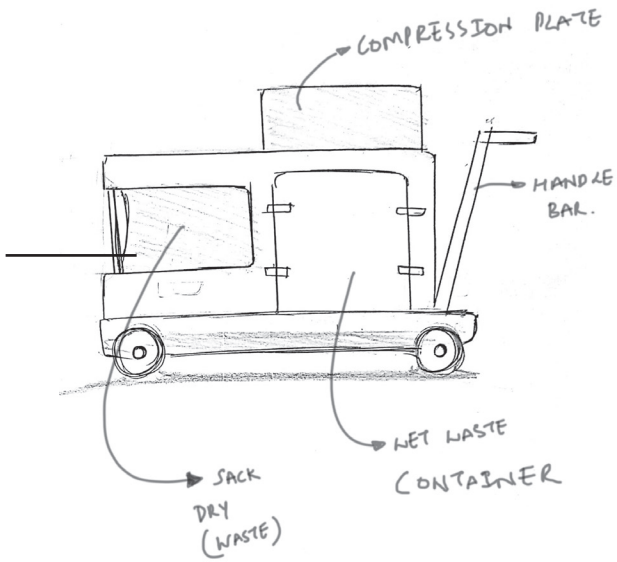
Compression wet waste with compression plate



Compressing wet waste

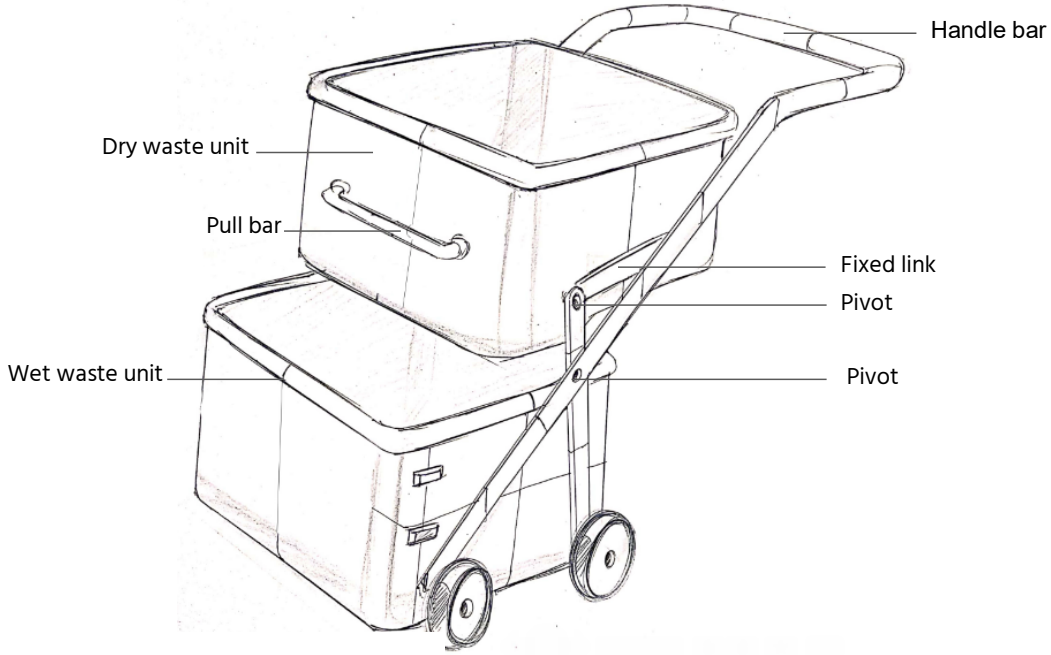


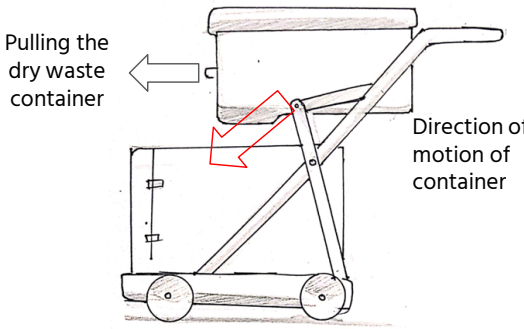
Sack in the front for dry waste can be removed after accumulating waste

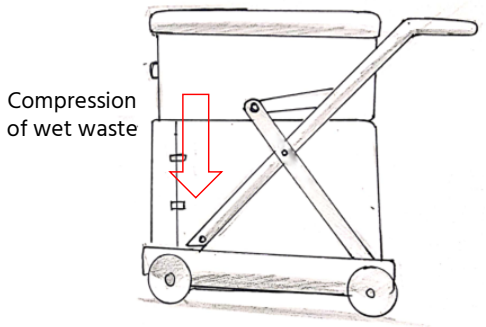


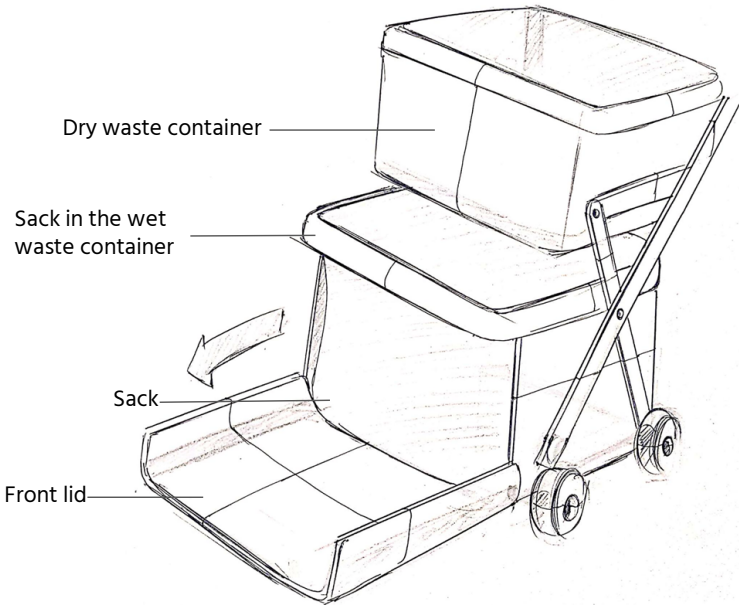
Concept 3

Here, compression of wet waste is in focus. The upper box is involved in compressing the wet waste



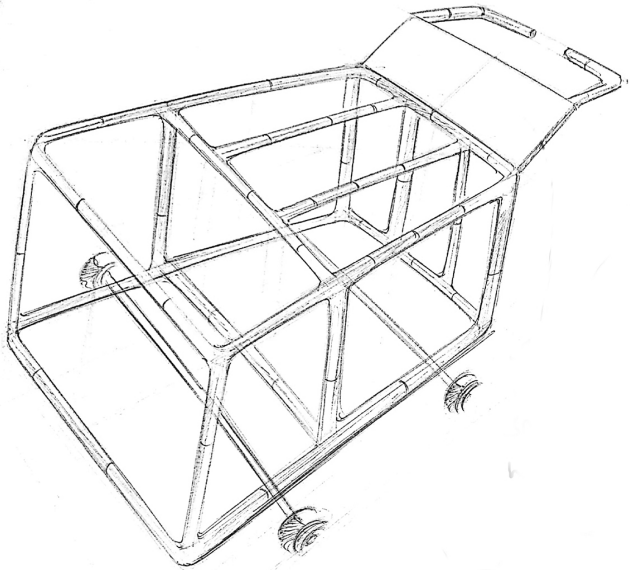


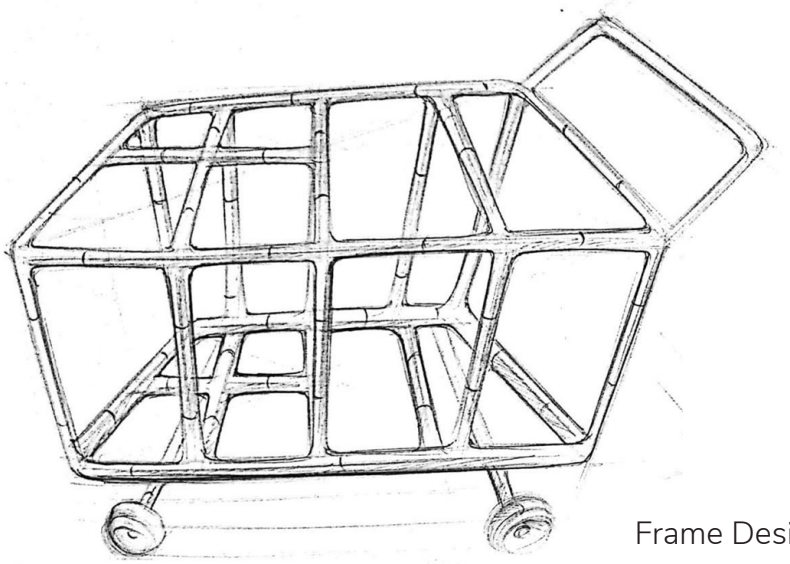




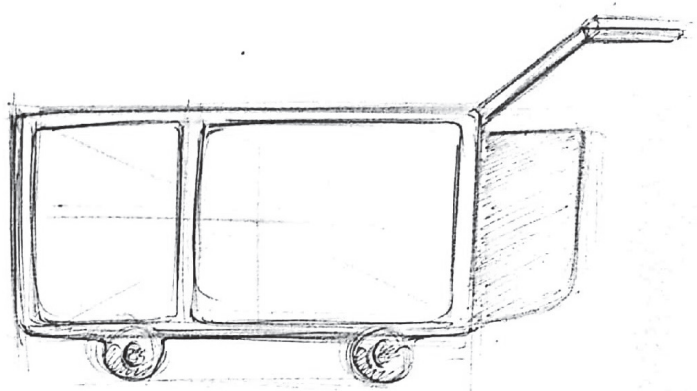
The front lid of the wet waste container is opened in order to remove the sack containing the compressed wet waste

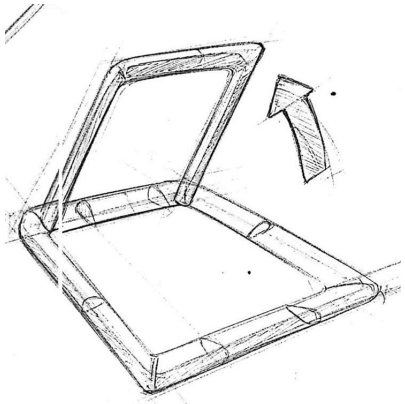
Concept 4. Direction 1- Here, an element of concept 2 is considered. The idea of sack is continued and a new feature of inclined surface is brought into picture



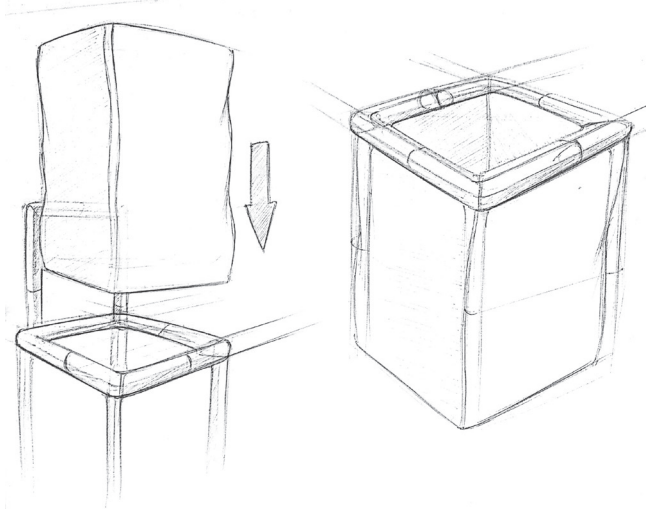


Frame Design

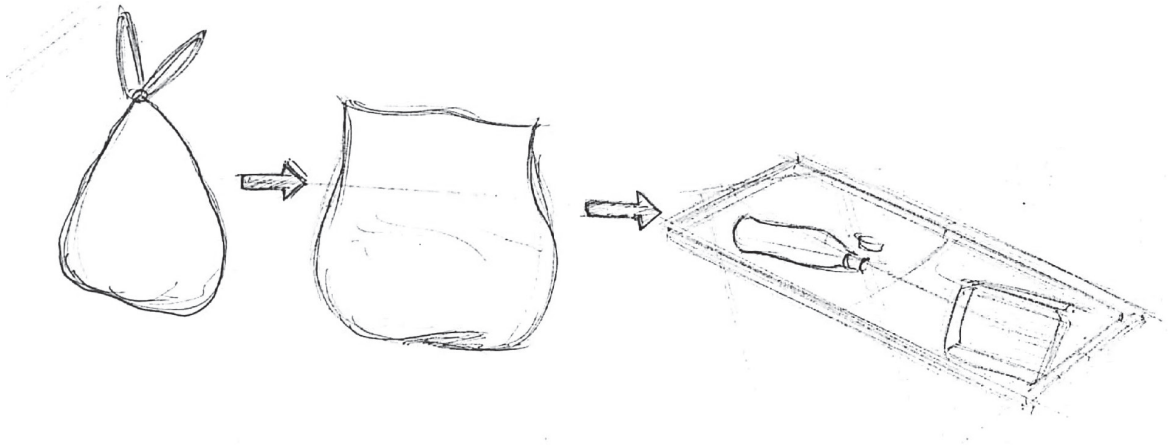




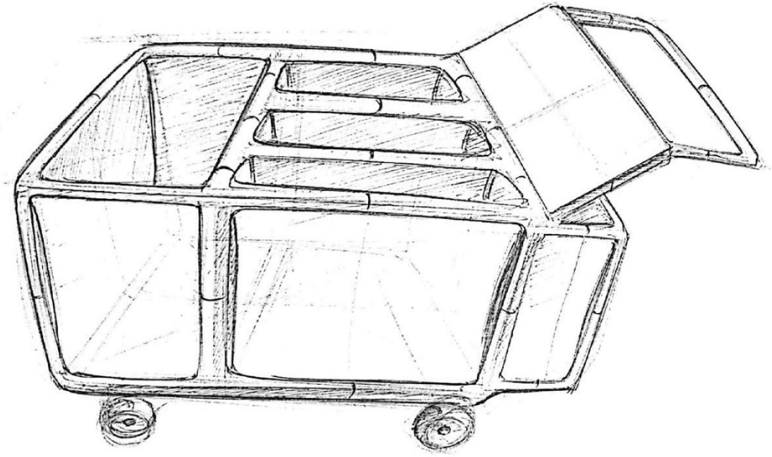
Frame opening

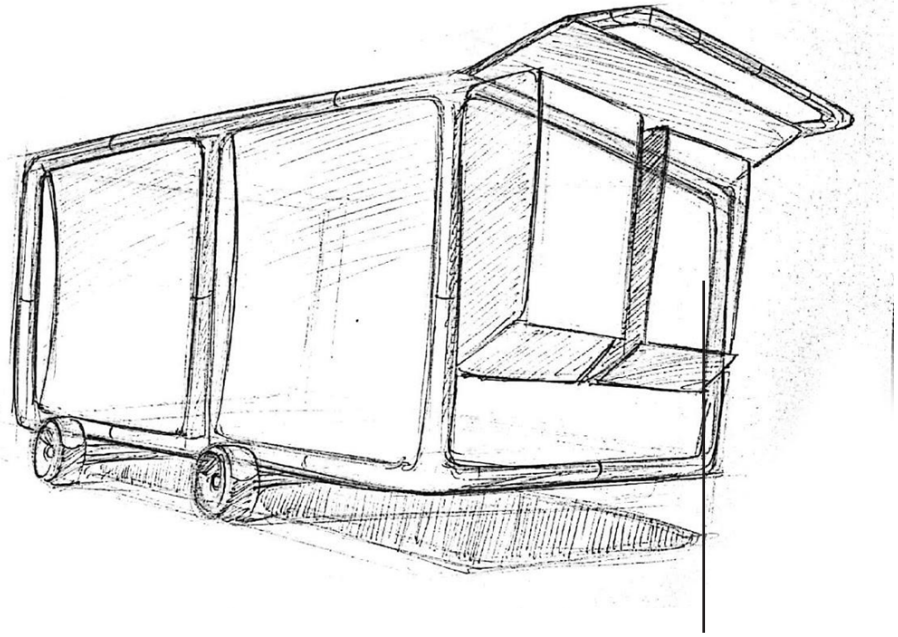


Mounting of sack on the frame



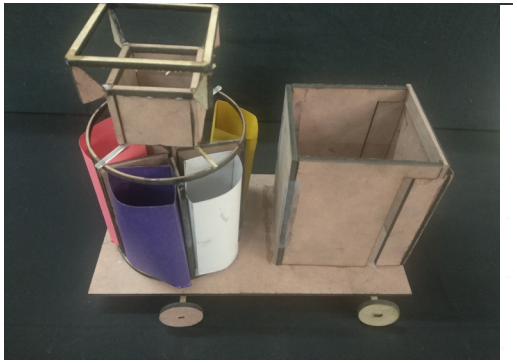
Inclined surface is used for sorting of the waste

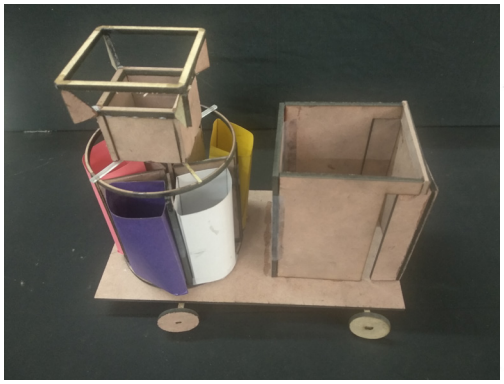


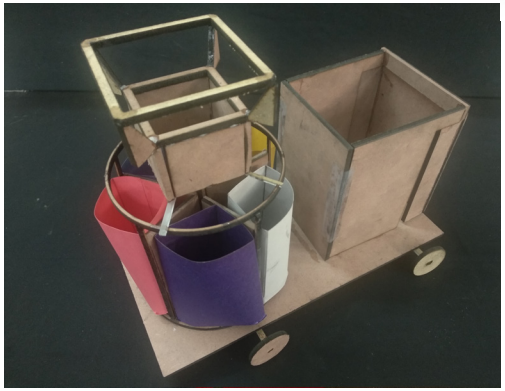


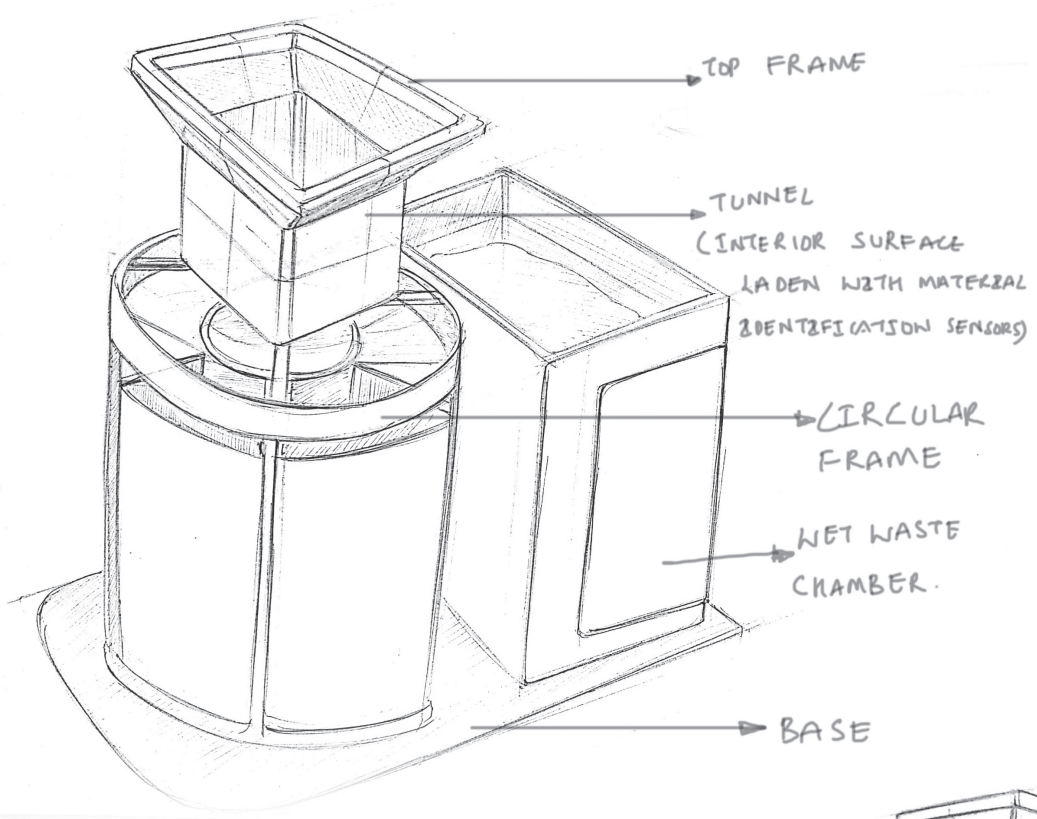
Storage Area

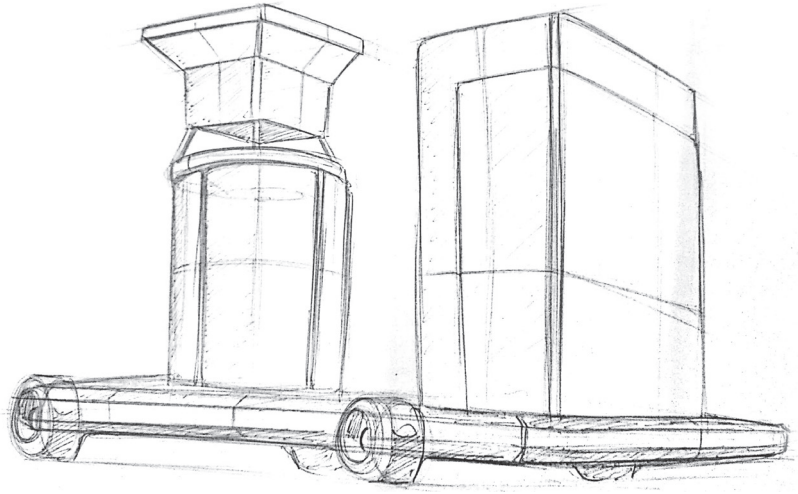
Concept 4. Direction 2- A hypothetical concept where automatic segregation takes place. Here, there is no requirement of segregating wet waste and dry waste manually by the collector

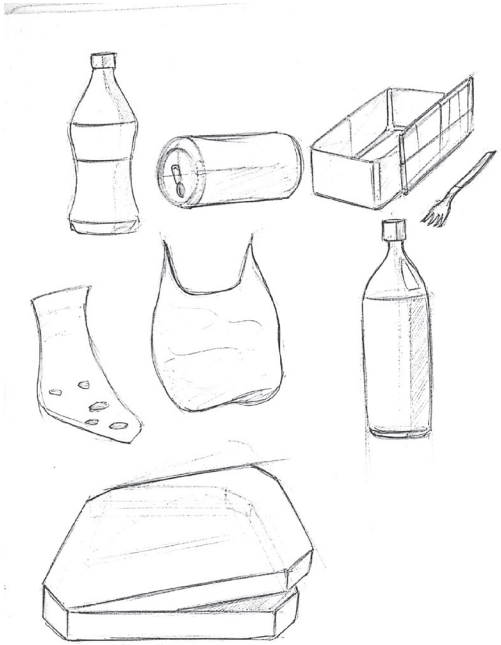






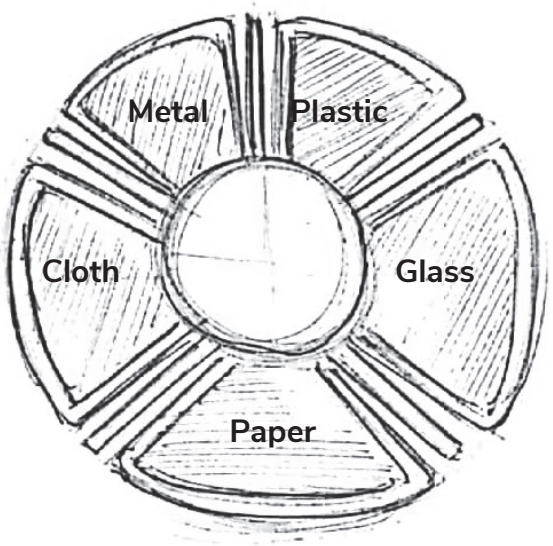




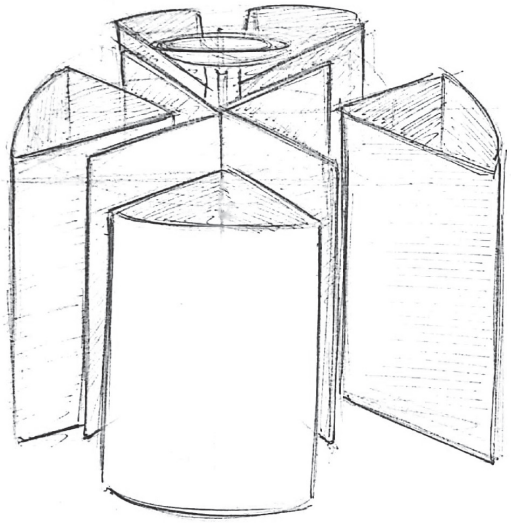


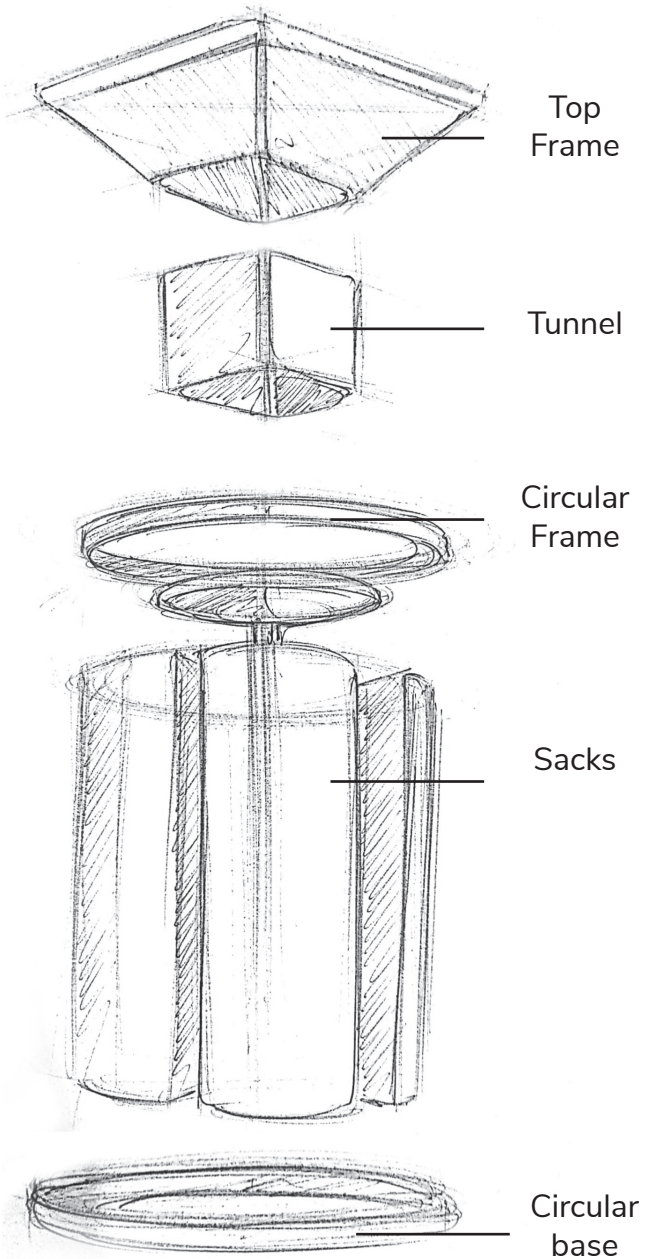
Dry waste is transferred to the dry compartment

Wet waste is transferred to the wet compartment



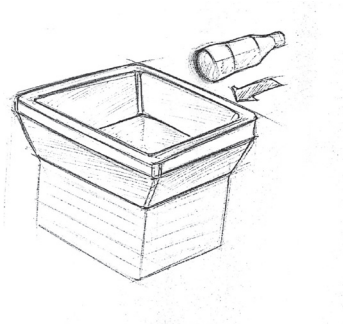
Arrangement of sacks



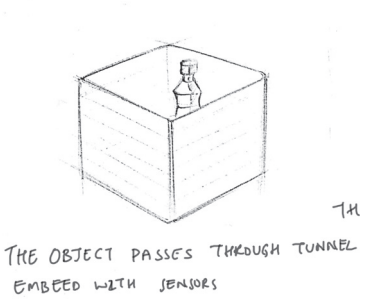


Dry waste segregation unit

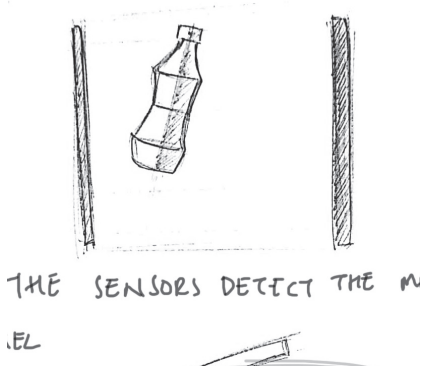
Segregation unit



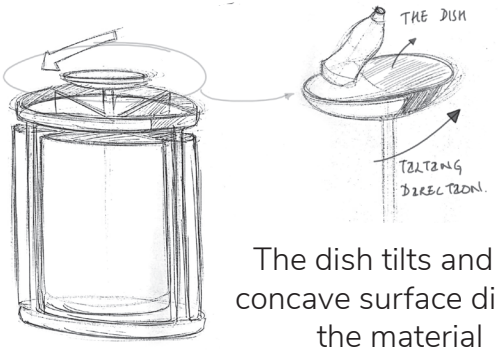
Waste is thrown in the upper frame



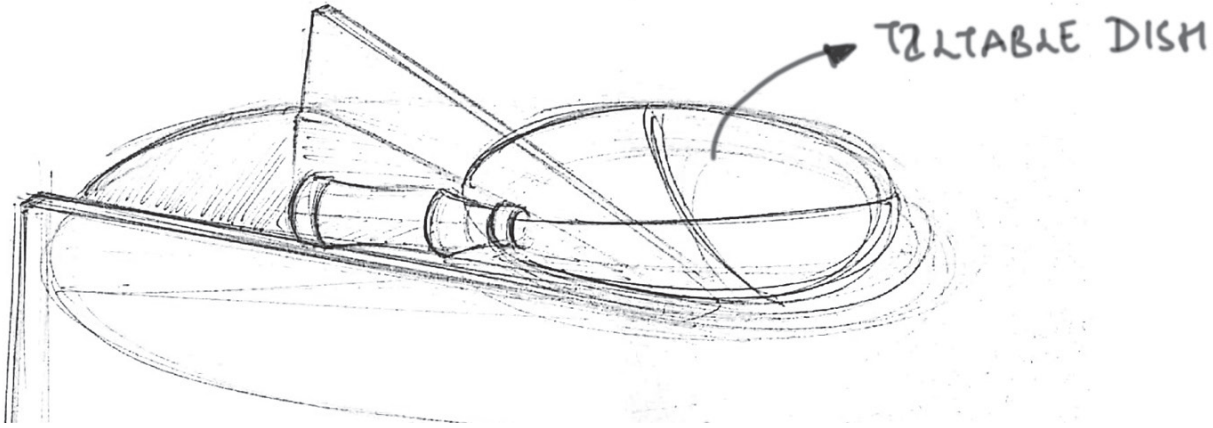
The material of waste is detected by sensors present on the interiors of the tunnel

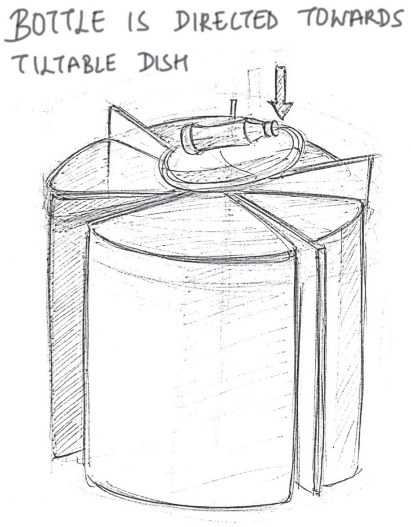


The material is detected by the sensors

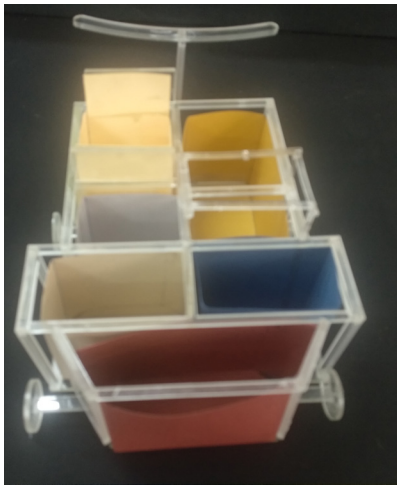


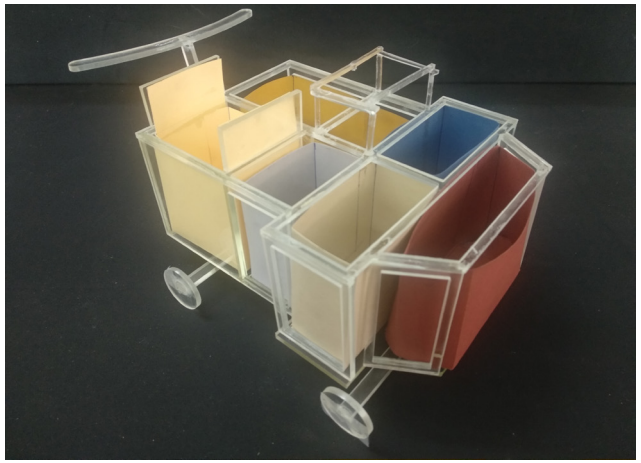
The dish tilts and the concave surface directs the material

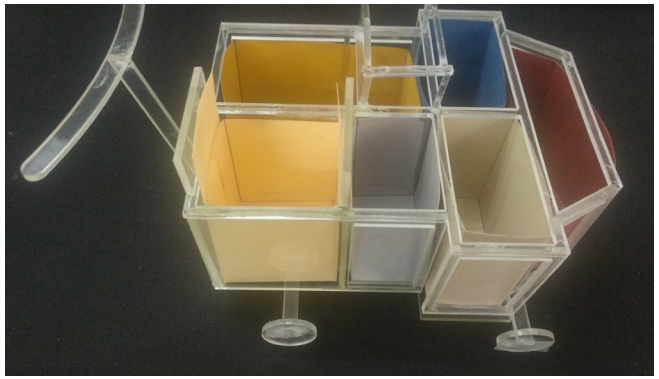


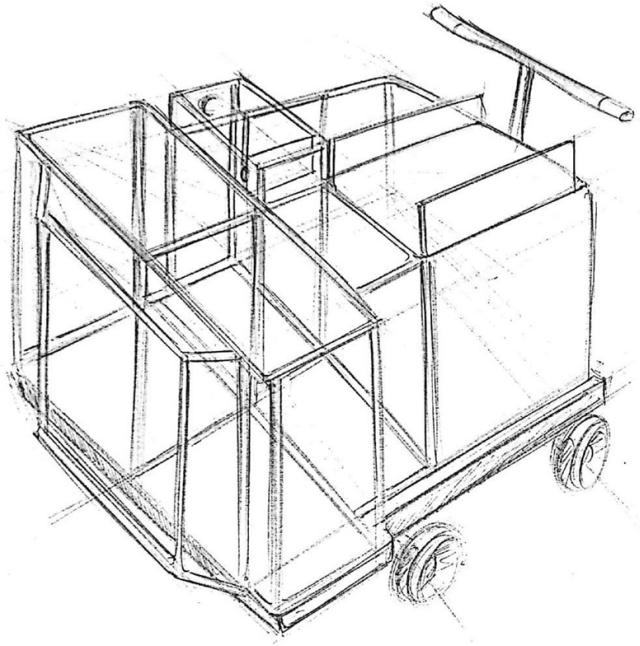


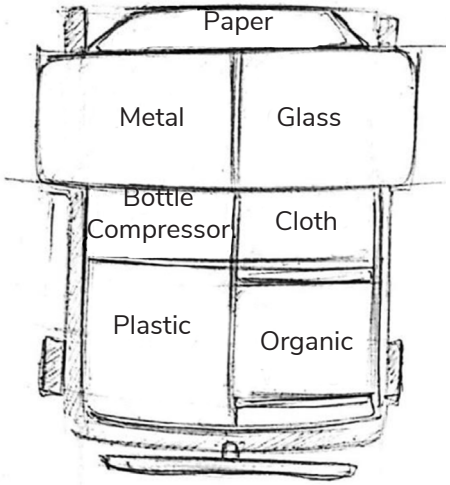
Concept 4. Direction 3- Here, the concept of a segregating surface is included. The frame is divided based on each material

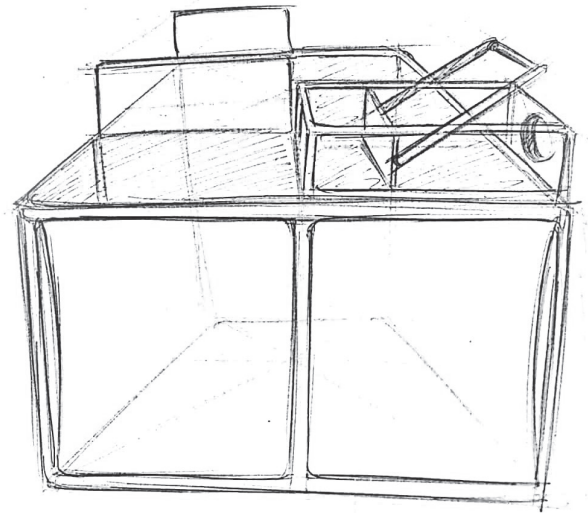




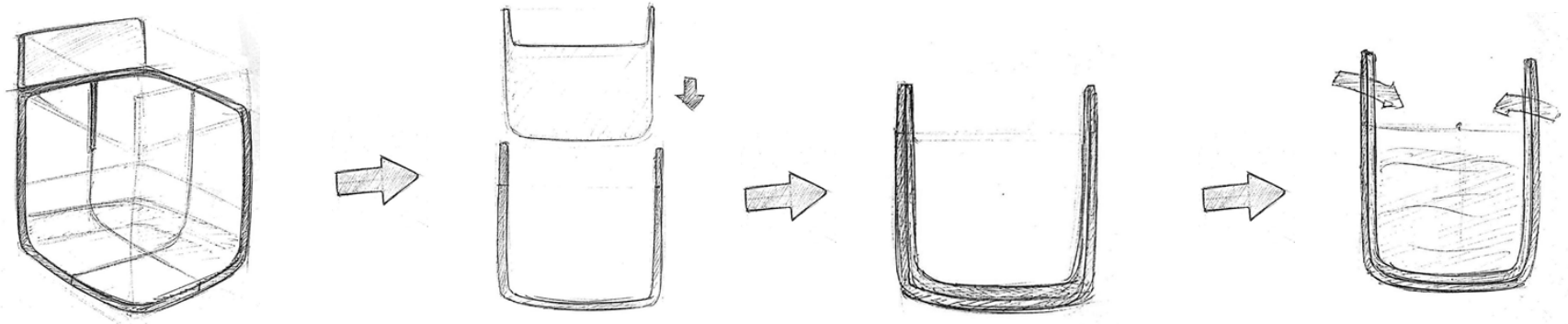








Compression of wet waste

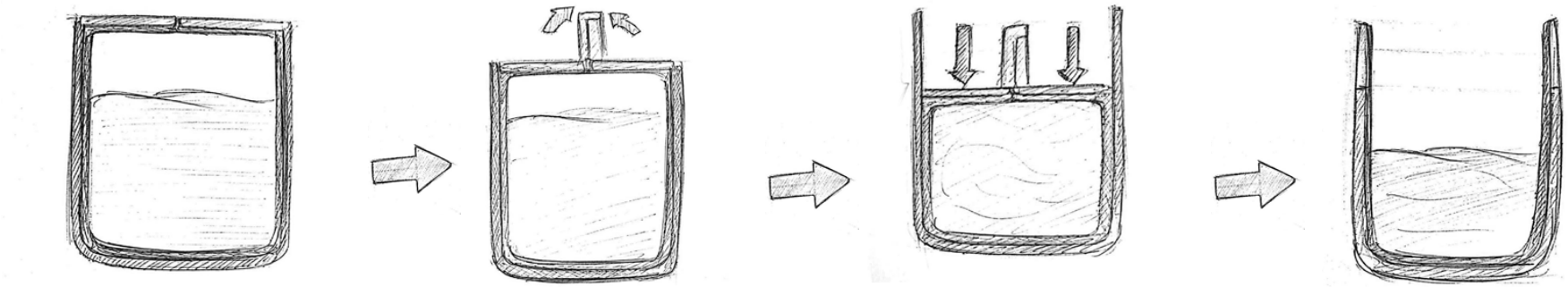


The container has a groove for the vertical motion of the lid for compression action. The base of the container has not sharp turns thus avoiding the tearing of the sack

The sack is transferred to the container such that it covers the inner surface of lid

Wet waste is transferred to the sack

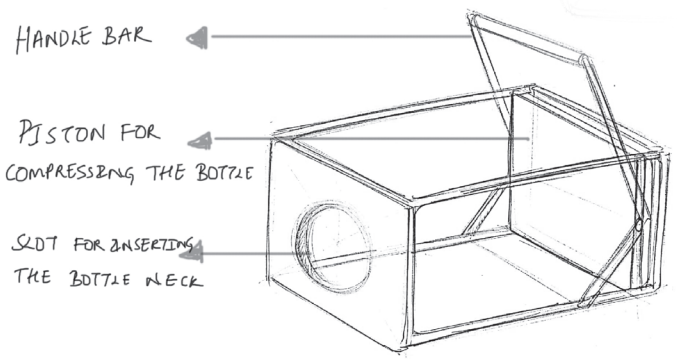
On reaching of wet waste at certain level, the lid is closed. The lower surface of lid doesn't come in direct contact of waste due to presence of sack

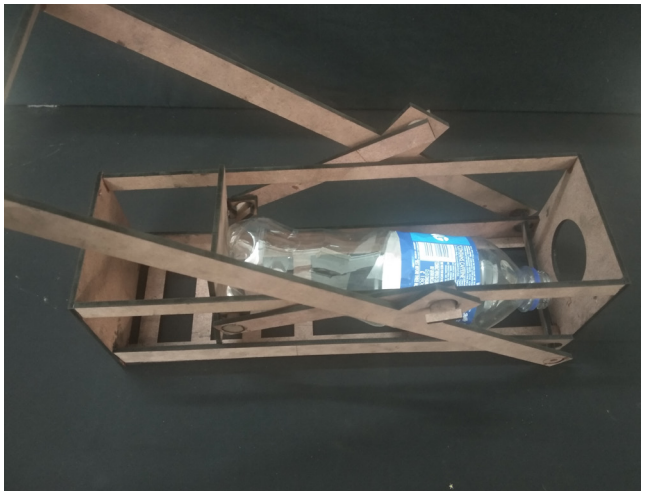


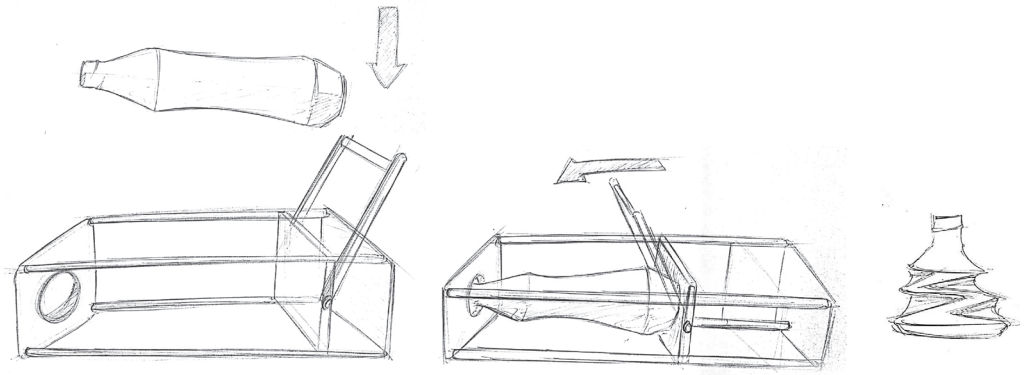
The handle bars present on the lid are used to compress the waste

After the compressing action is done, the lids are back in vertical position

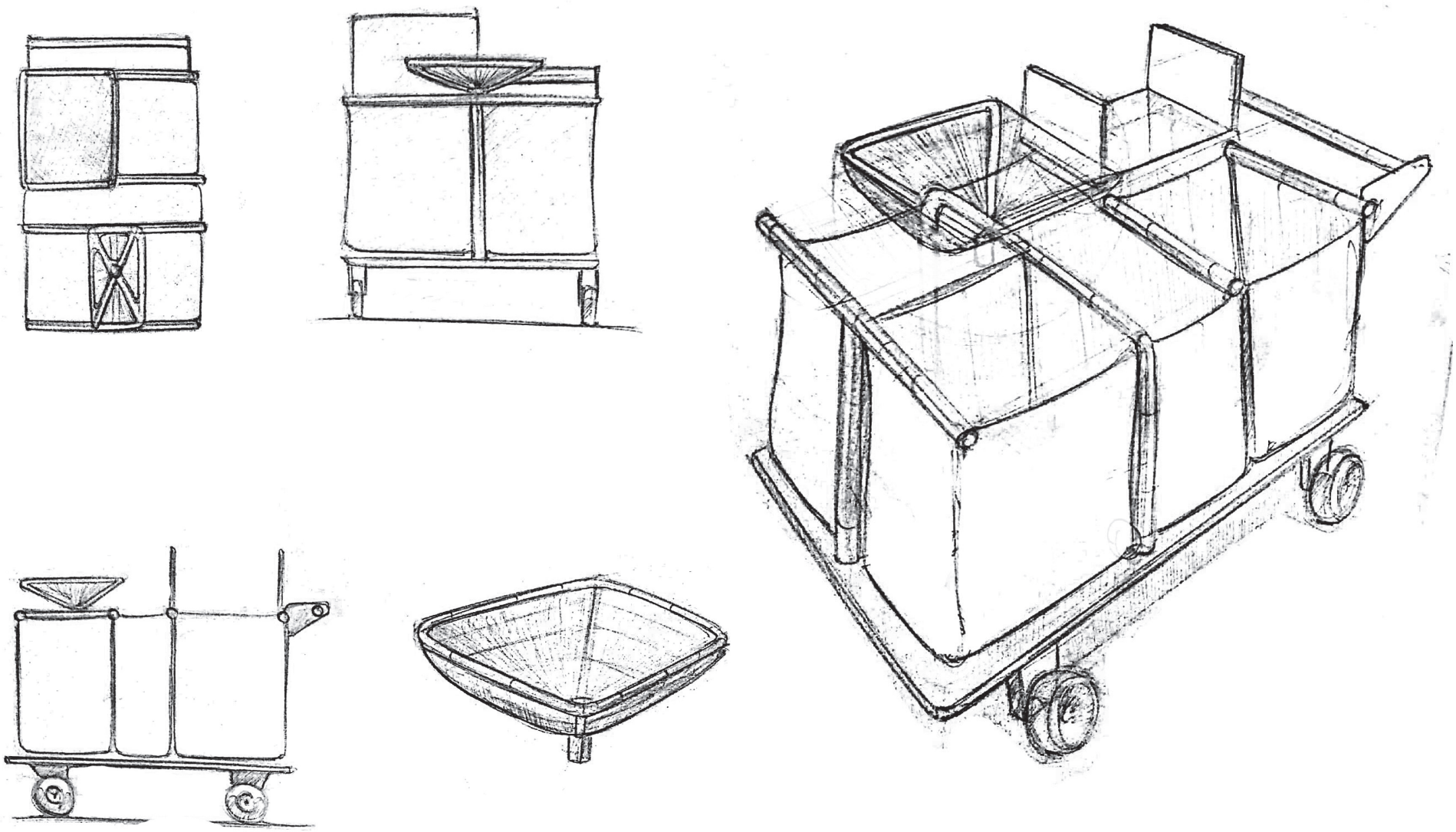
Bottle compression mechanism

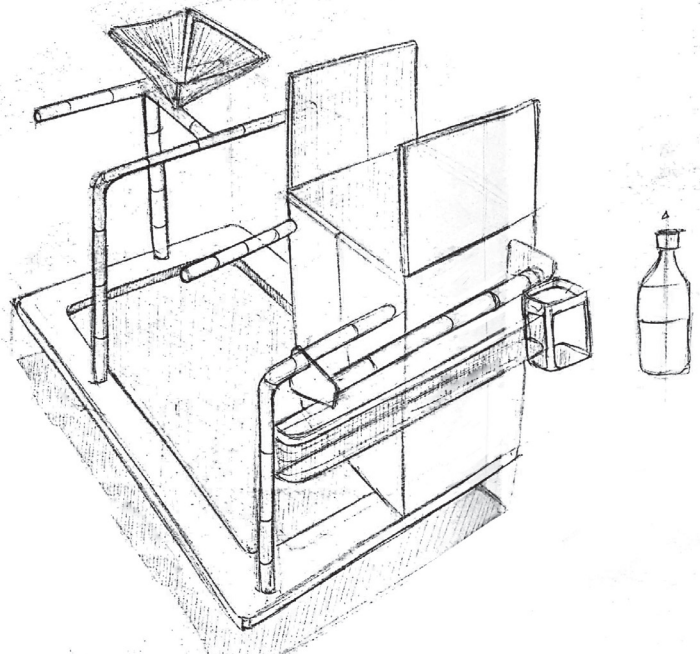




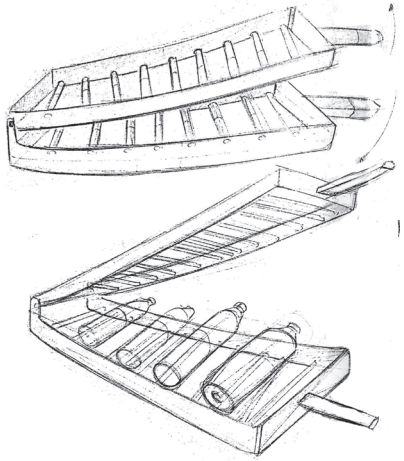


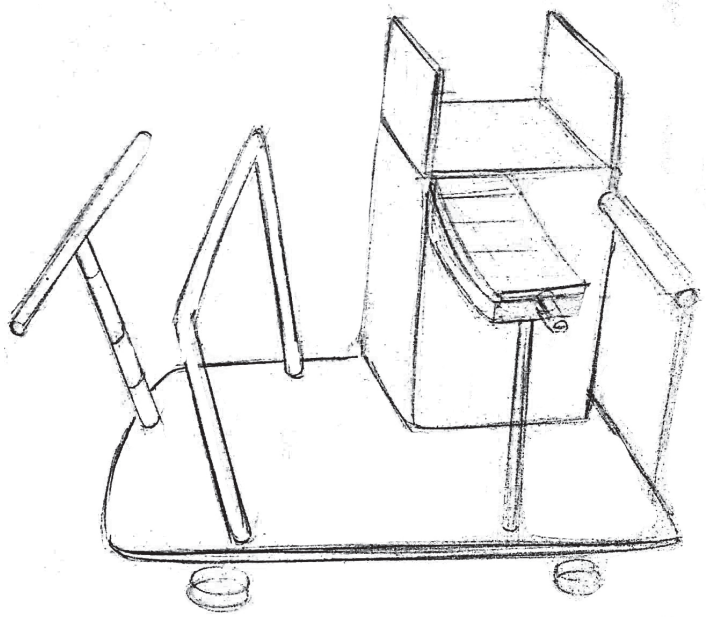
Concept 4. Direction 4- Here, a segregation surface is considered. The frame elements are reduced



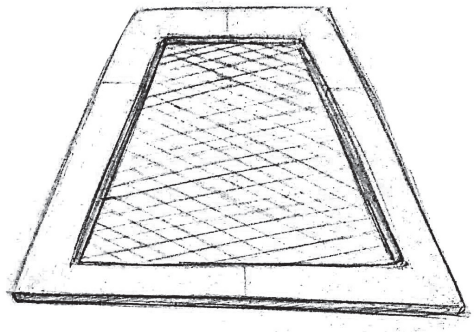


Frame of the cart

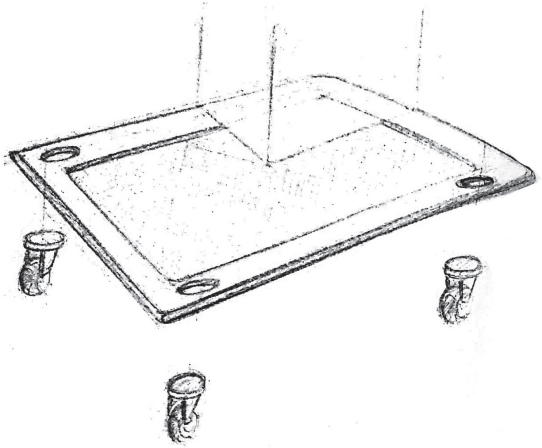




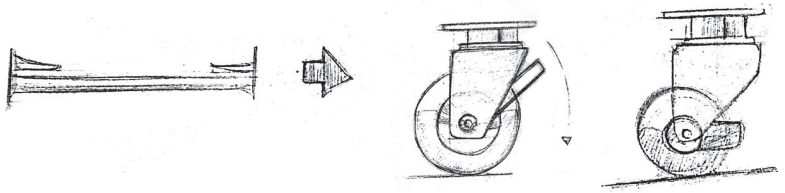
Mechanism for compressing multiple bottles at a time



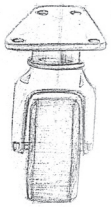
Base is made of mess to reduce weight



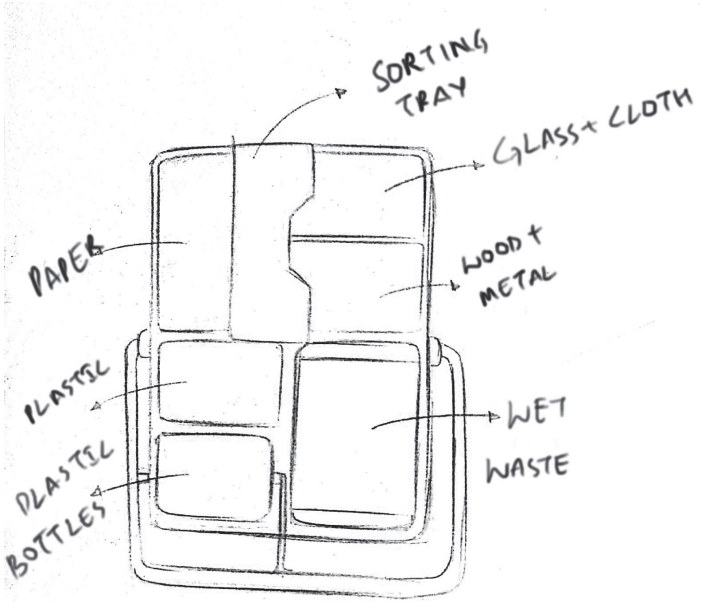
Caster wheels are used for motion

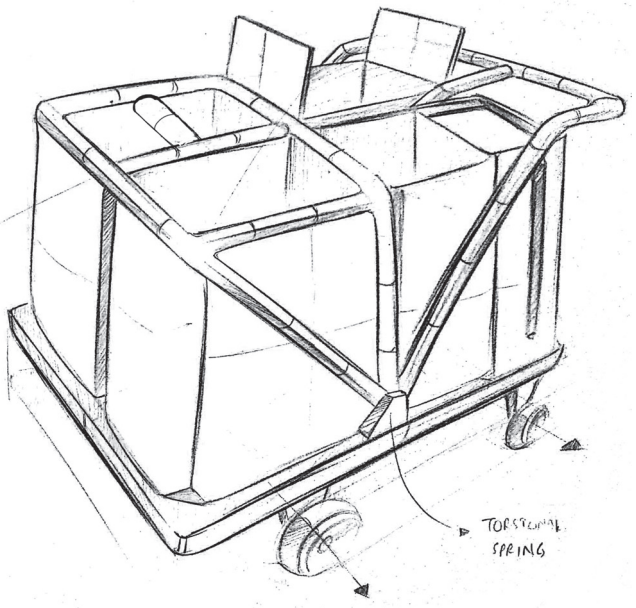


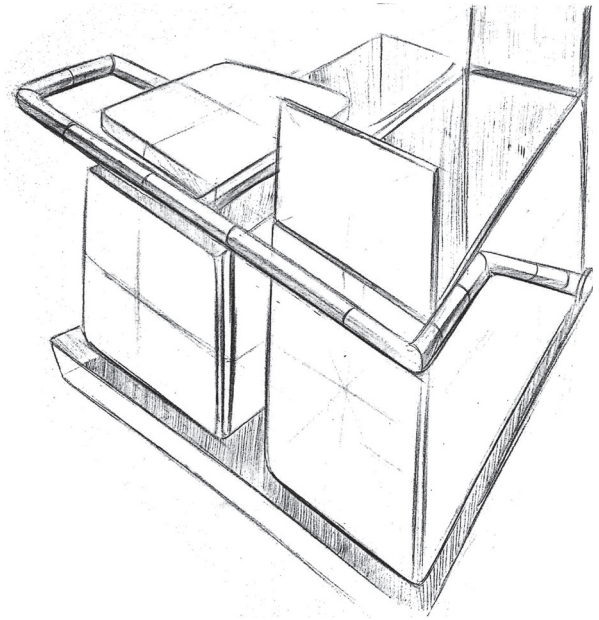
Handbrake is integrated to the caster wheels

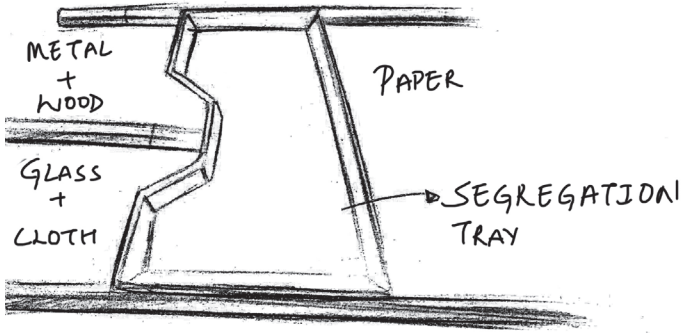


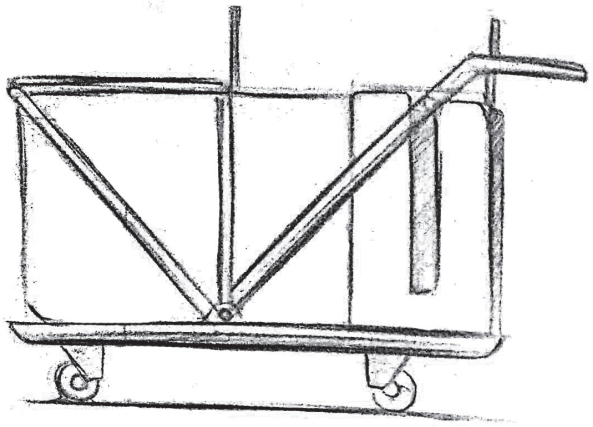
Concept 4. Direction 5- Using handlebar for compressing weight. Use of torsional spring helps in upward motion of the handlebar after compression

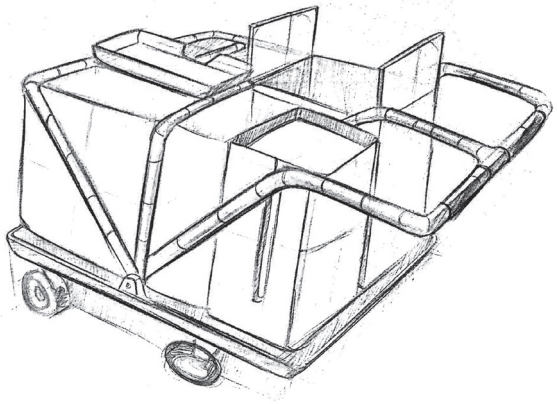


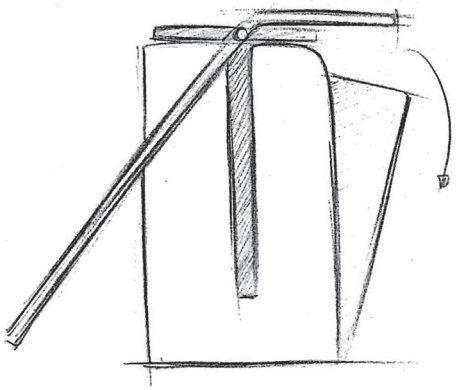




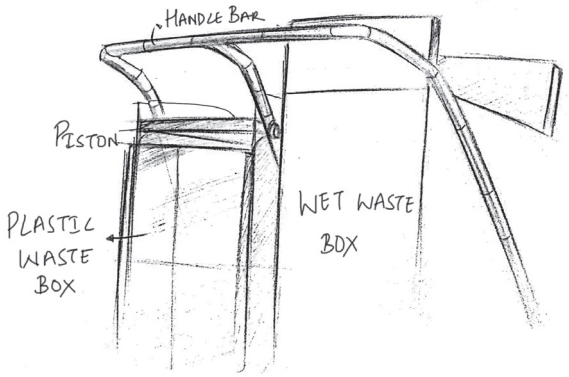


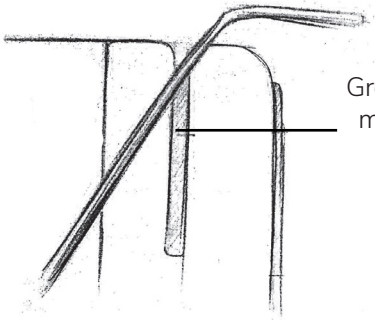






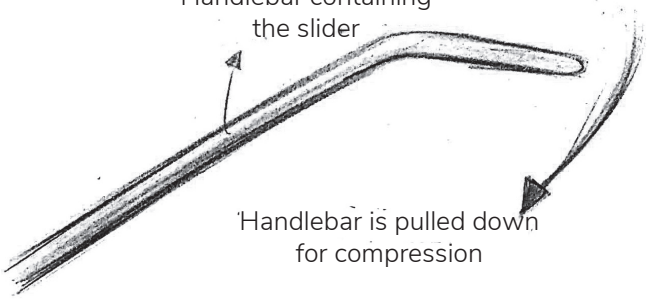
Container is tilted to throw the bottles



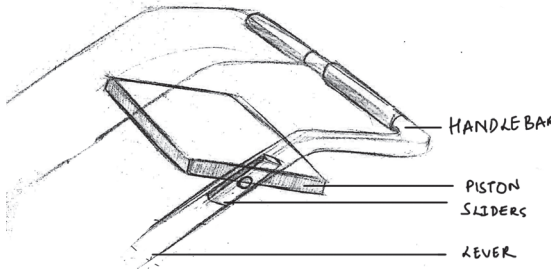


Groove for vertical motion of piston

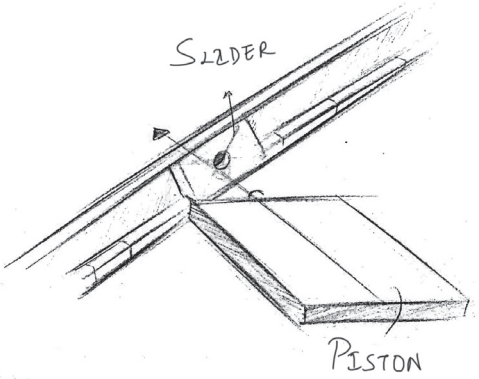
Handlebar containing the slider



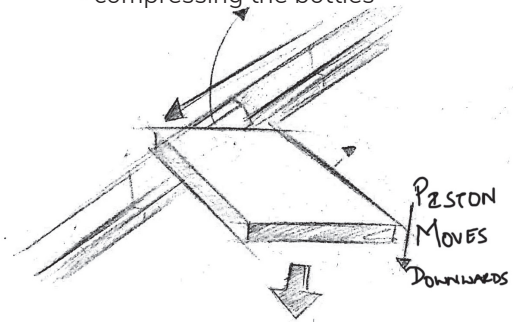
Handlebar is pulled down for compression

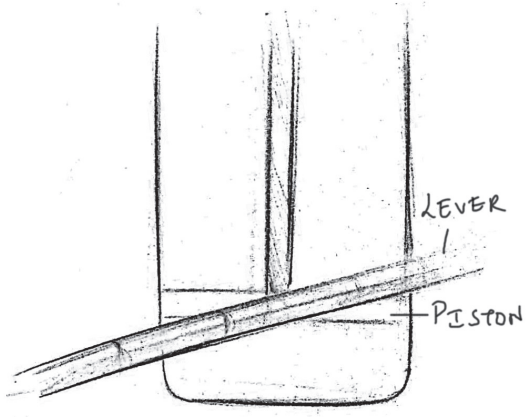


Piston is connected to both sides of lever through sliders

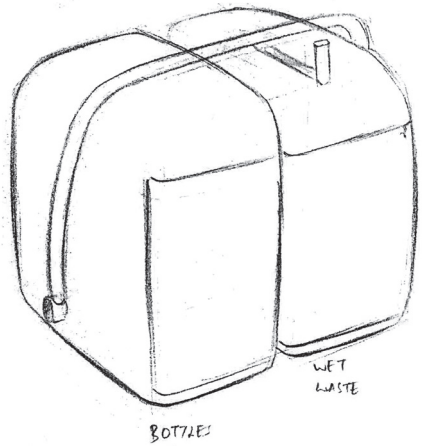


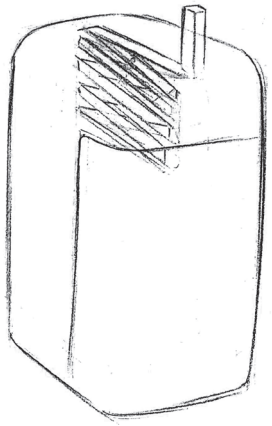
As the sliders move downwards along the lever, the piston moves downwards thus compressing the bottles

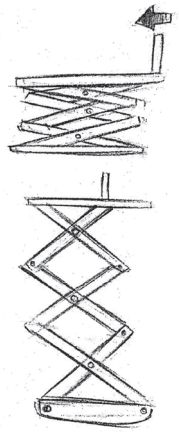


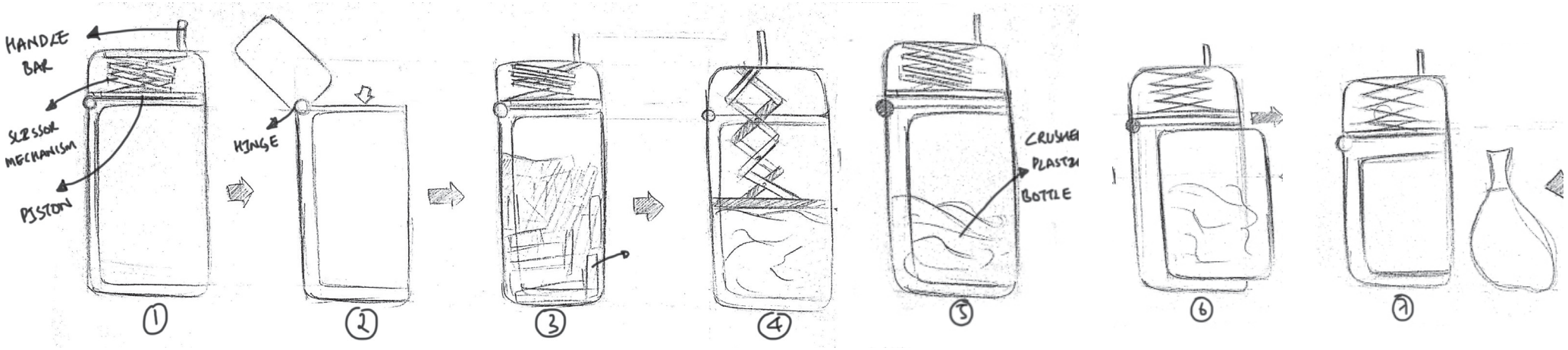


Using scissor link mechanism to compress plastic bottles

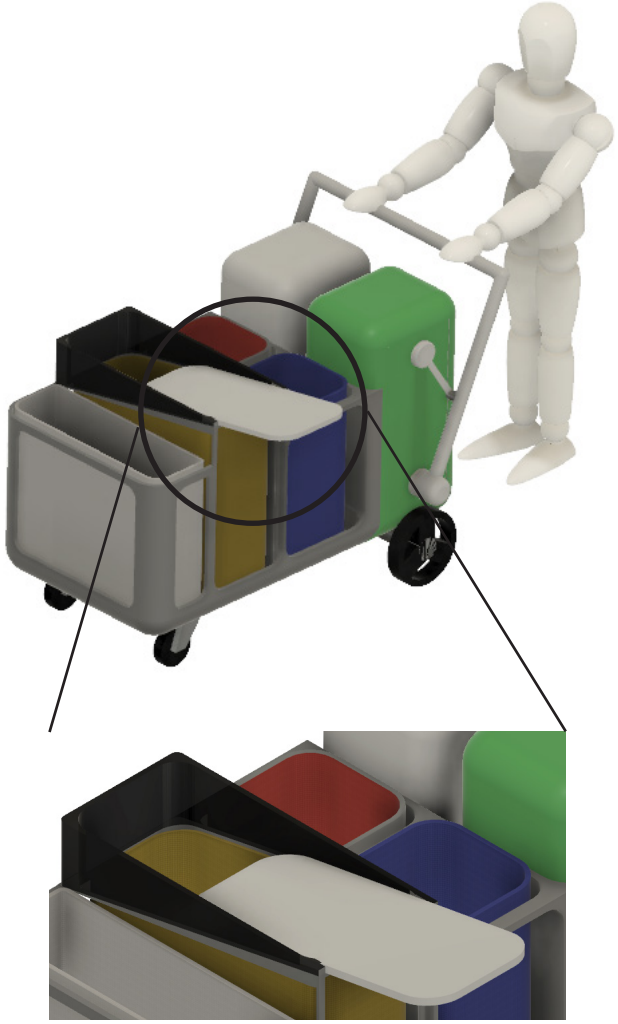


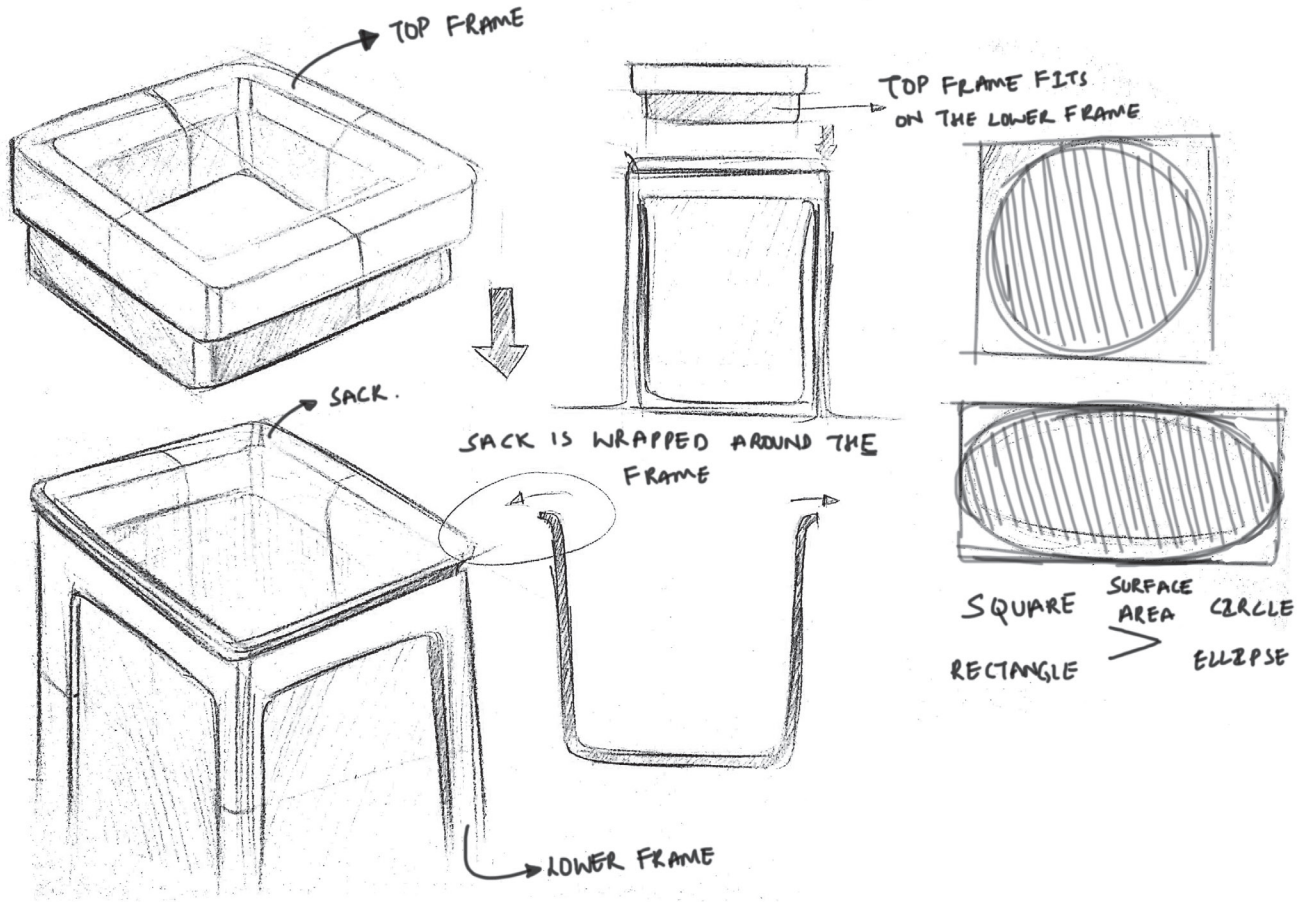


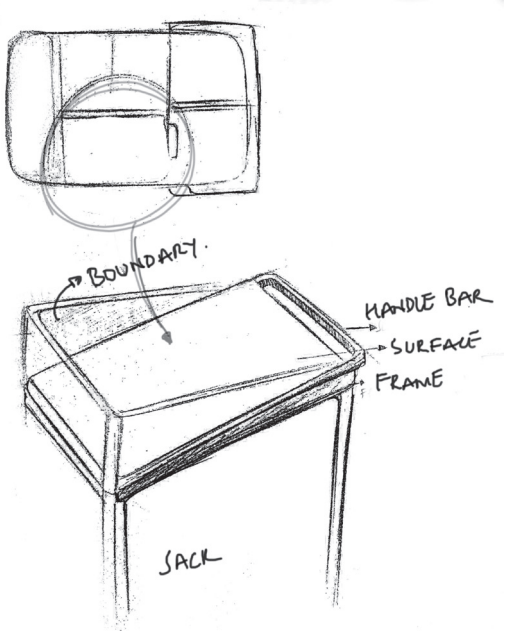




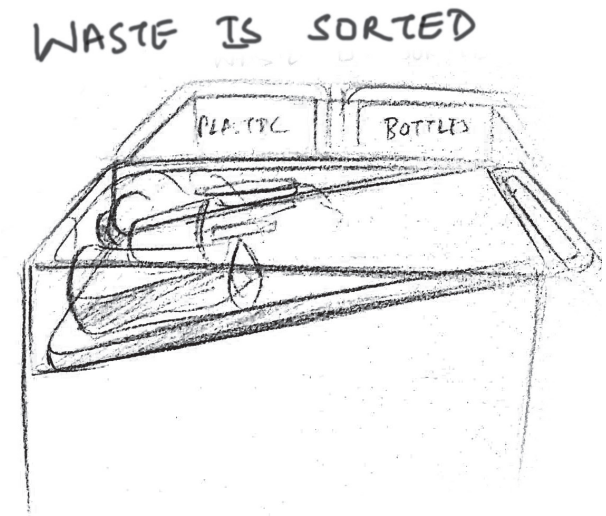
Concept 4. Direction 6- In this concept, an inclined surface is used in order to contain and serrate the waste. Pulling of inclined surface drops the waste in the container

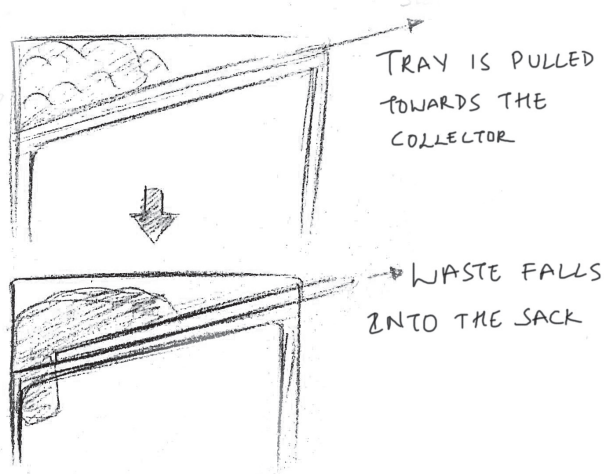




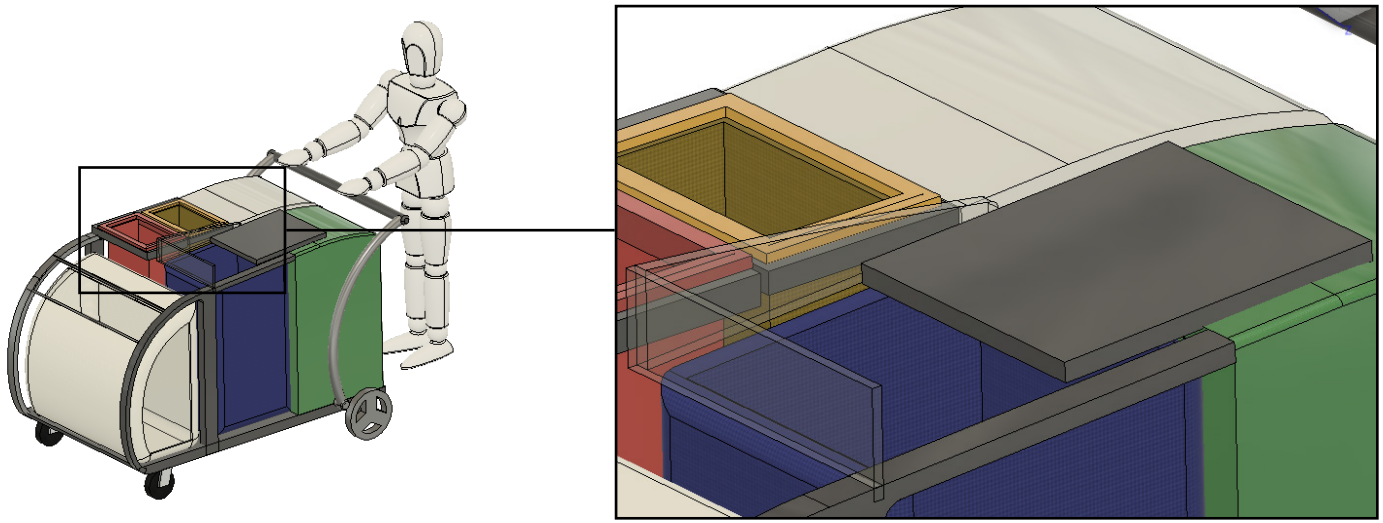

BOUNDARY
HANDLE BAR
SURFACE
FRAME
SACK


WASTE IS POURED ON THE
SORTING SURFACE

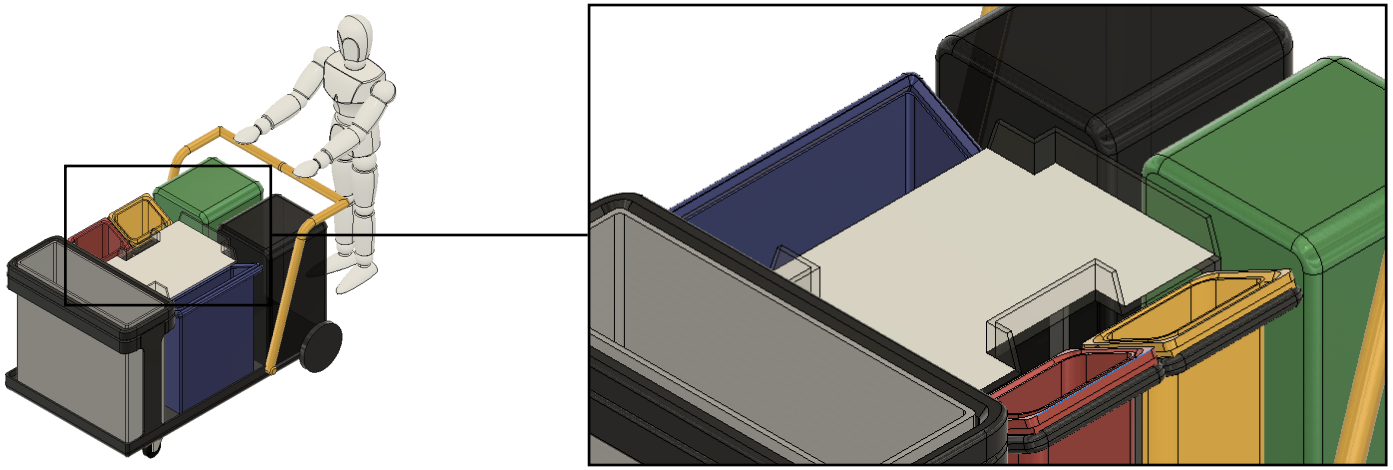

WASTE IS SORTED
PLASTIC
BOTTLES


TRAY IS PULLED
TOWARDS THE
COLLECTOR
WASTE FALLS
INTO THE SACK

The concept was refined with through model. The direction of sliding of lid is changed.
This makes the lid more accessible but reduces the surface area of the lid.



The frame of the lid is inclined. This makes it easy to transfer the waste to the respective bins. The surface is necessary area to transfer the waste to the respective bins



Determining the dimensions

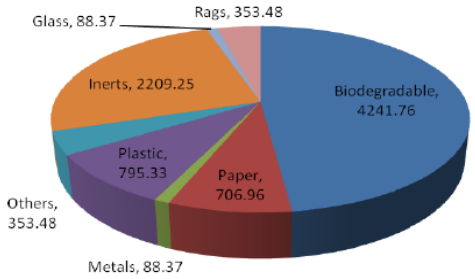


Image Composition of municipal waste in Mumbai (In tonnes/day)

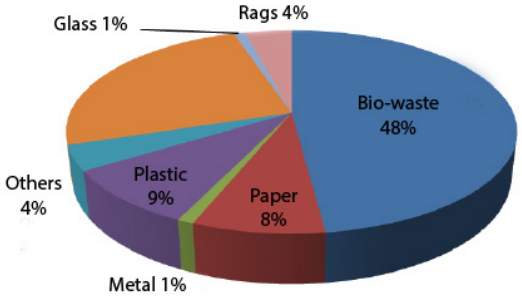
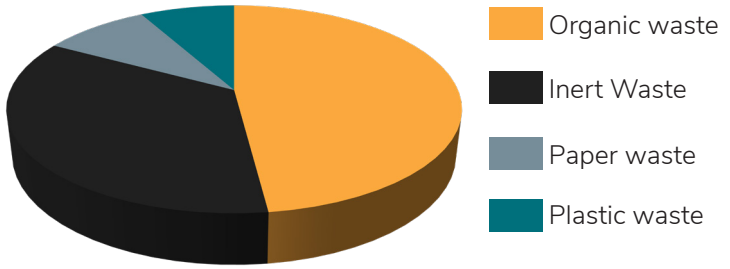


Image Composition of municipal waste in Mumbai (in %)



Distribution of waste when combined (in %)

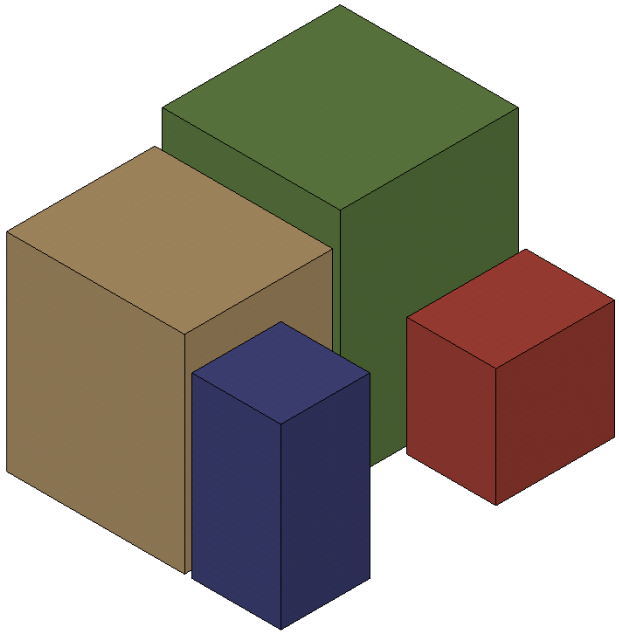
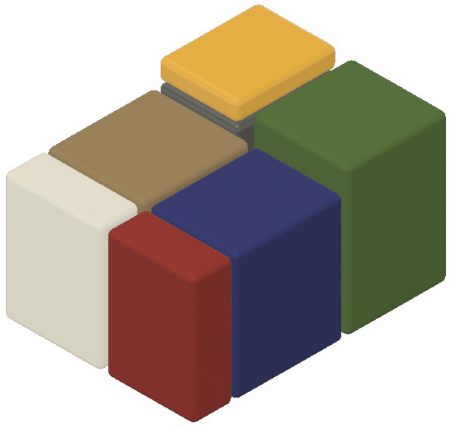


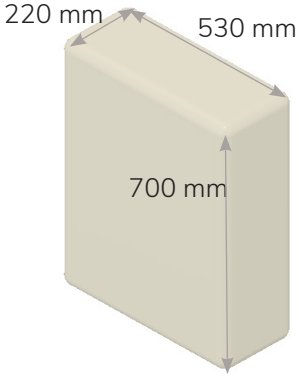
Image Comparision of volume of waste in liters

The charts above show the composition of municipal solid waste generated in Mumbai per day. The figure is converted into percentage. More the number of separating members in the frame, higher is the weight of the frame. Therefore wastes are comparatively generated less i.e., rags, metal, glass and other waste are combined and hence occupy 35% along with inert waste. Similarly, 58% of organic waste is generated, 9% of waste is plastic and around 8% of waste is paper.

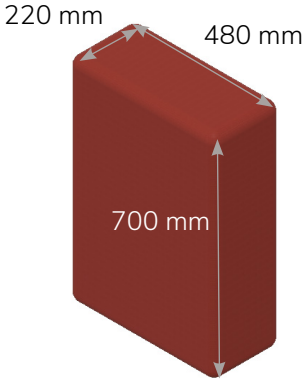
As per the conversation with the collector at Ambedkar nagar, around 2-2.5 wheelie bins are required to collect the waste. 240 liters of bins are used to collect the waste. Therefore, 600 kg of unsegregated waste is collected per day. The 600 kg of unsegregated waste is distributed with respect to the information obtained from the pie charts. The distribution of 600 liters of waste is as follows:-

- Organic Waste-288 Liters
- Plastic Waste- 54 Liters
- Inert Waste- 210 Liters
- Paper Waste- 48 Liters

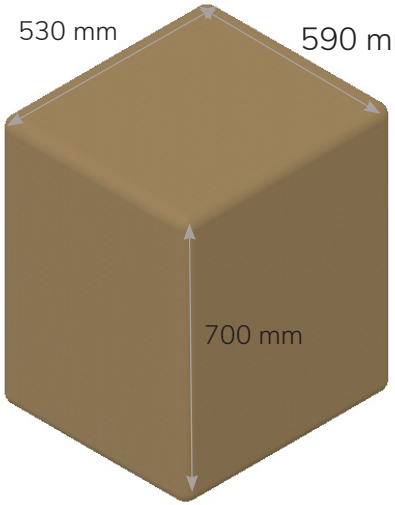




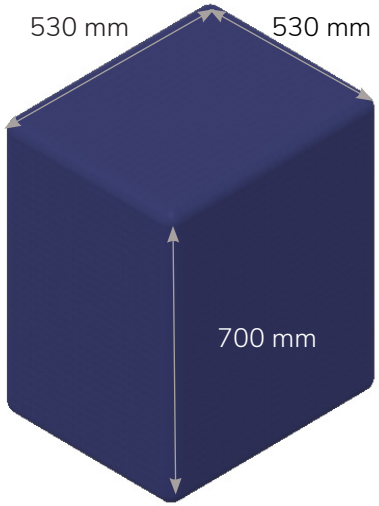
Paper Waste- 81 Liters



WW



Inert waste- 220 Liters

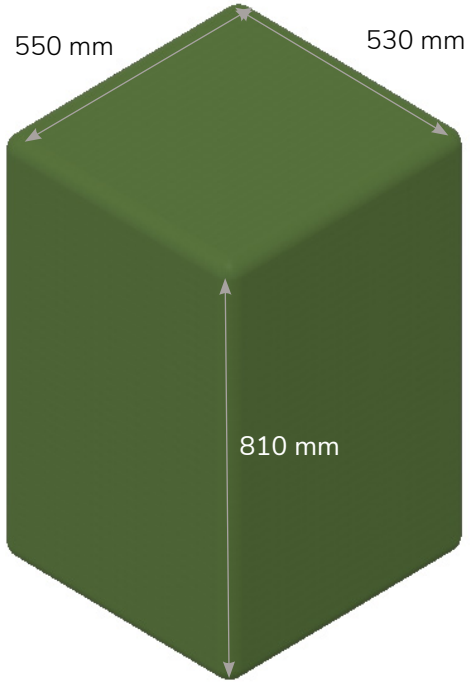


Plastic waste- 220 Liters

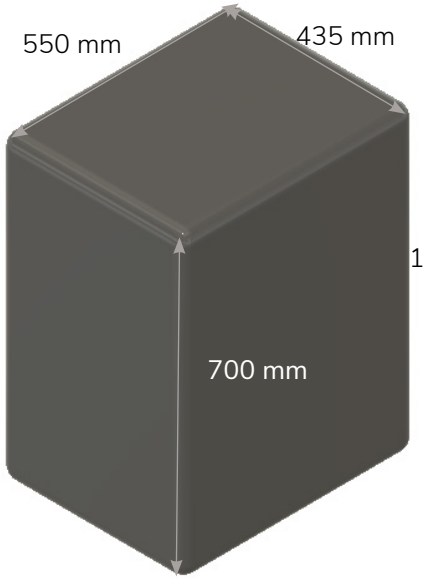
Certain adjustments were made in the volume of the containers such that the edges of the frame match with each other. This was done without decreasing the volume of the containers/ sacks. Since a sack and a container is dedicated for plastic waste and a container is dedicated for compressing plastic bottles, a part of the container is used for storage purposes

The compression mechanism used for plastic bottle waste is the downward motion of piston connected to the handle bar. The compression mechanism used for organic waste is scissor link mechanism which is driven by a handlebar.

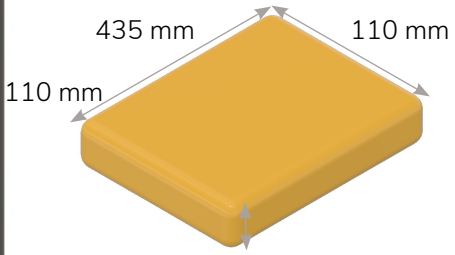
Storage space is necessary to store sack for bottles, cell phones, masks etc.



Organic Waste- 240 Liters



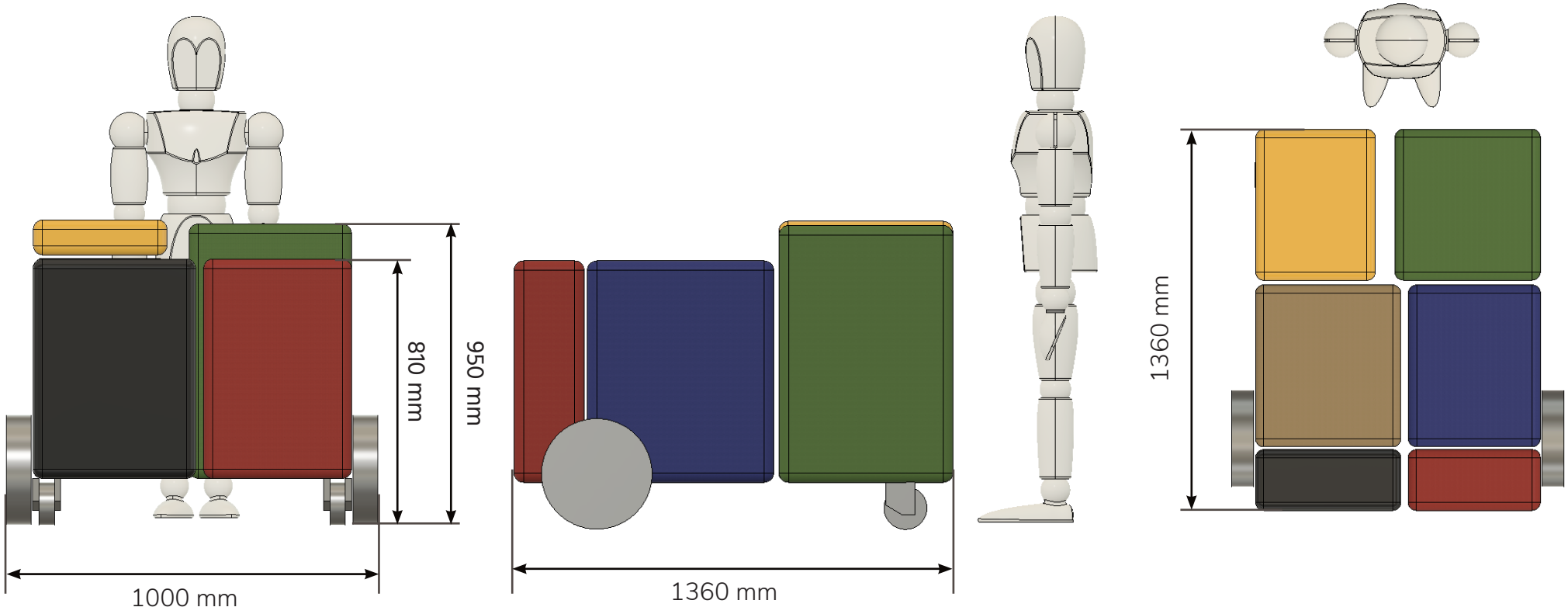
Plastic Bottle- 185 Liters



Storage Area- 25 Liters

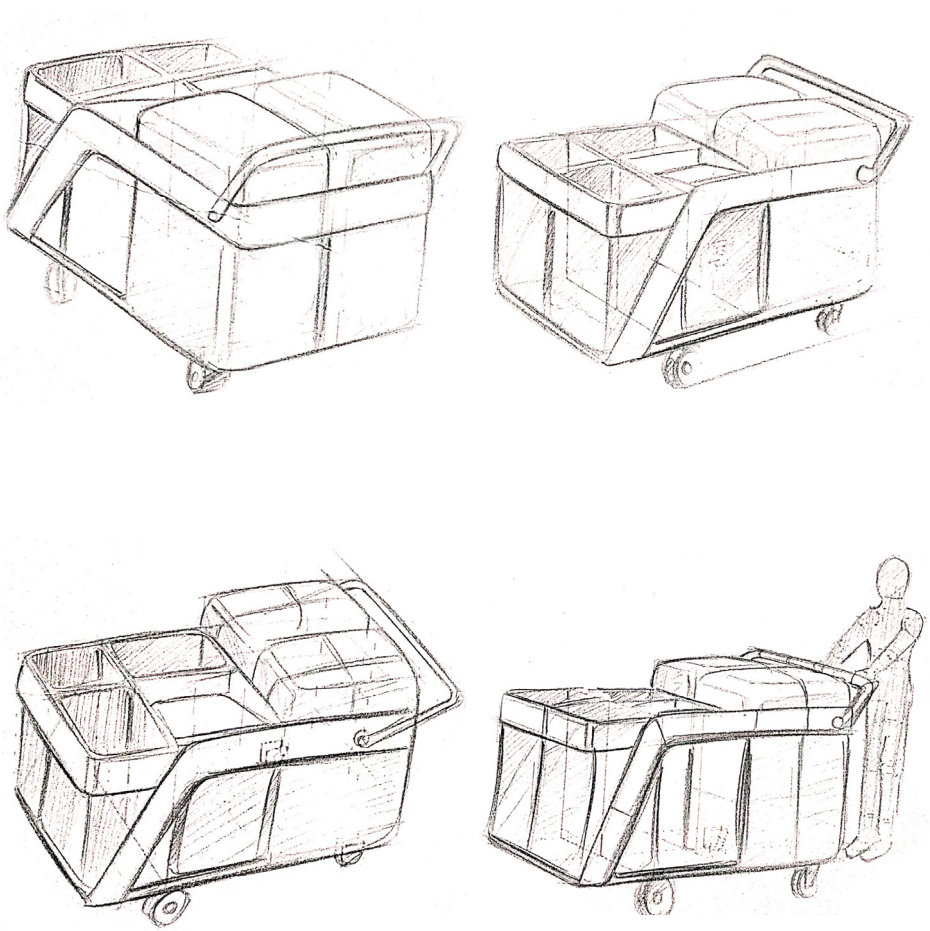
9.0 Fixing the dimensions of the cart

Based on the volume of the containers, dimensions for ideation were obtained. Based on load rating, 100 mm diameter caster wheels were chosen in the rear. The front wheels chosen were such that it doesn't obstruct removing bags from the frame. Since The sacks are tied to the top end of the frame, a frame is connected to the containers. During ideation, care is taken to prevent addition of weight to the frame.

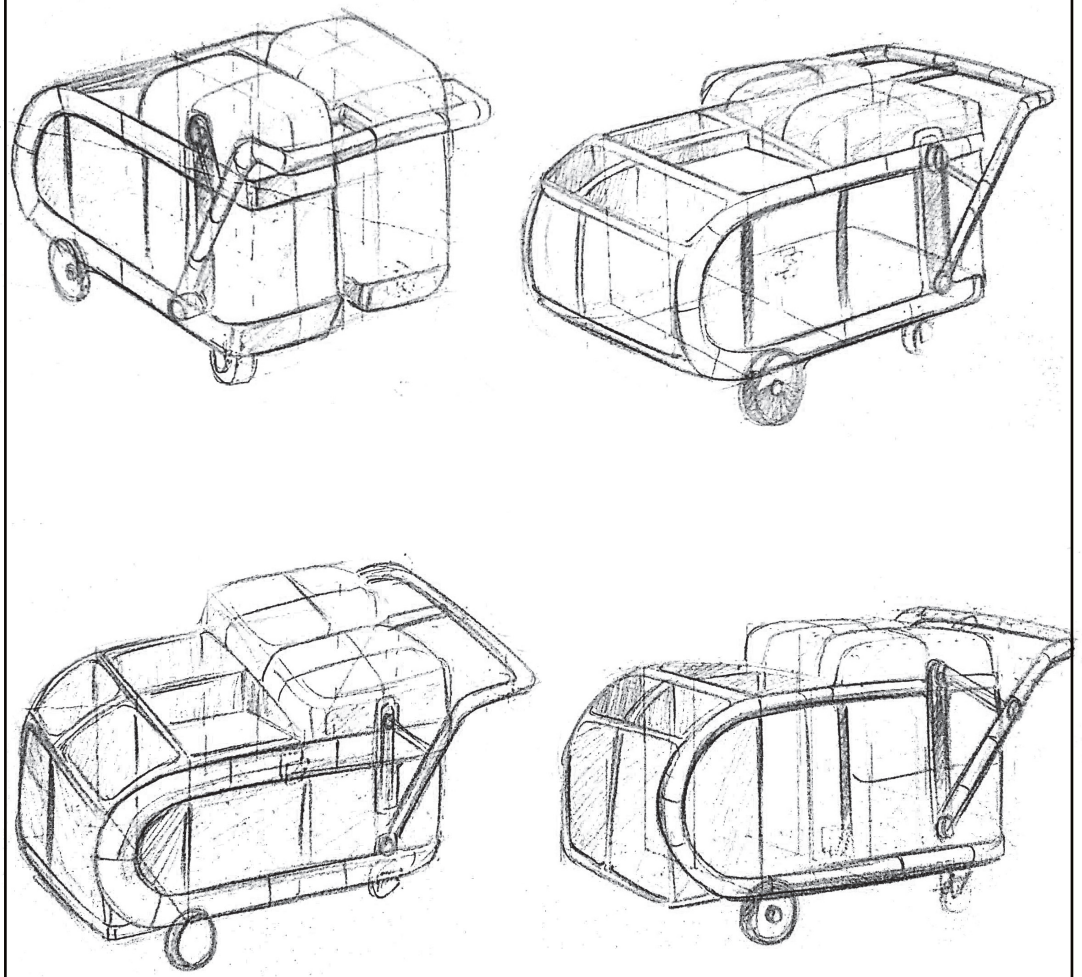

810 mm
950 mm
1000 mm
1360 mm
1360 mm

10.0 Form Ideation

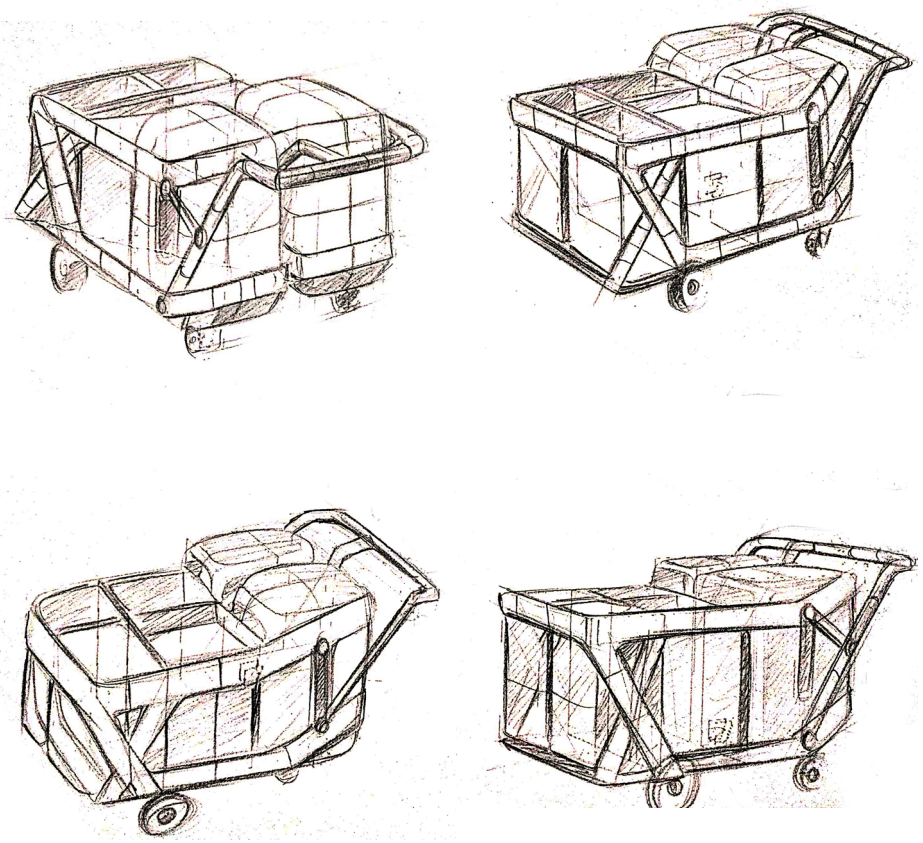
Concept 1



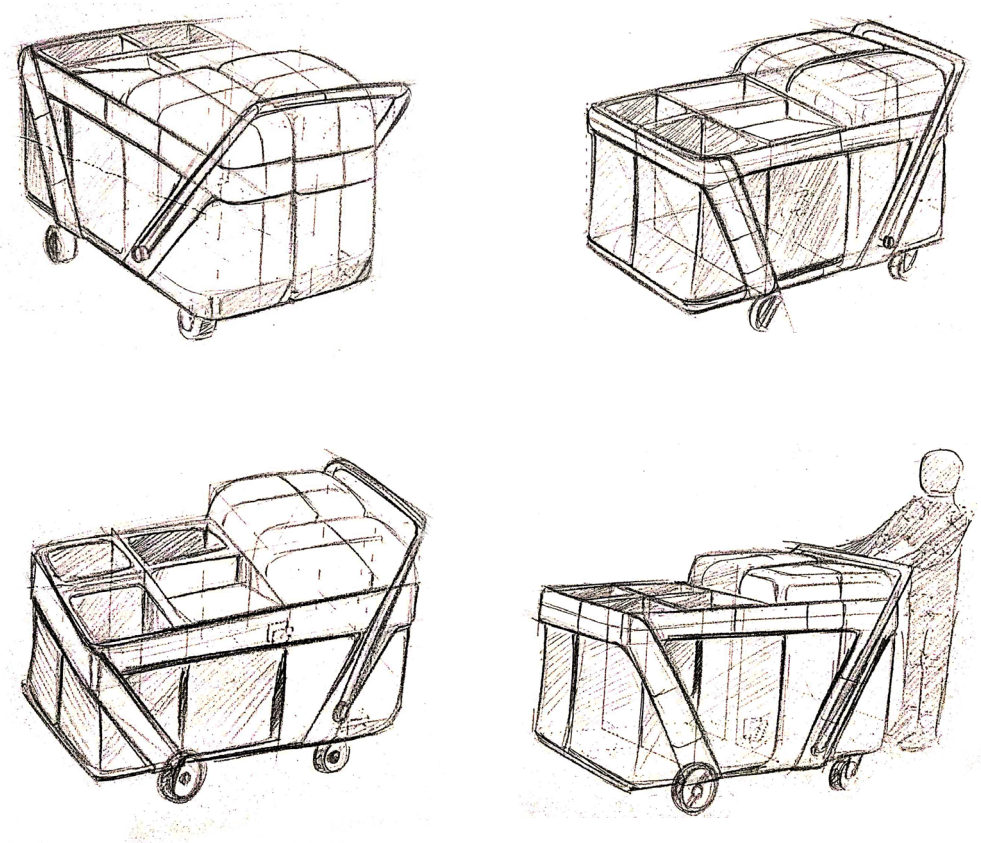
Concept 2



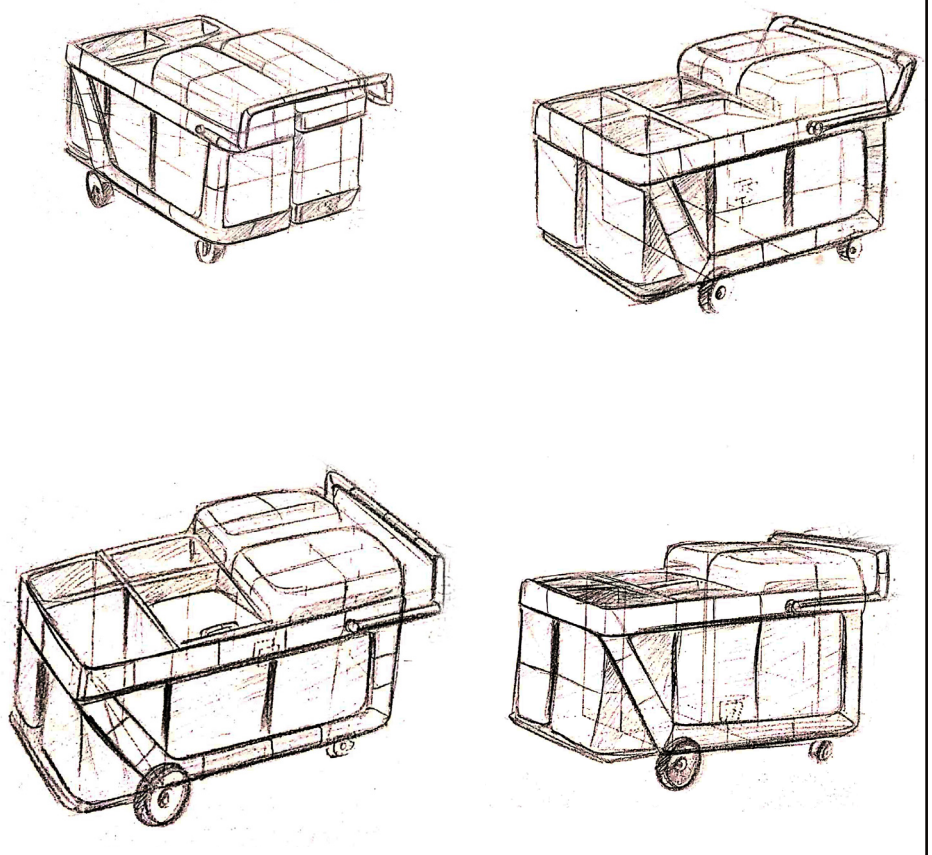
Concept 3



Concept 4



Concept 5



Concept 6

9.0 Final Concept

After freezing the dimensions and the mechanisms, cad model of the final concept is generated. The final concept address the problems mentioned in the design brief. Apart from this, a storage box was dedicated as a temporary storage of collector's wastes.


Handlebar
Wet Waste Container
Link
Plastic Bottle container
Bush with Torsional Spring
Acrylic frame
Inert Waste
Plastic bottle slot
Main body
Front Wheels
Rear caster wheels


Brake lever
Mesh
Reflector
Bio waste
Vertical handle
Plastic waste sack
Rope
Paper sack
Front frame

General process of handling dry waste

Step 1-The sacks are attached to the main body with the help of the frame.

Step 2- The waste is spread out on the mesh. Here manual segregation of waste takes place

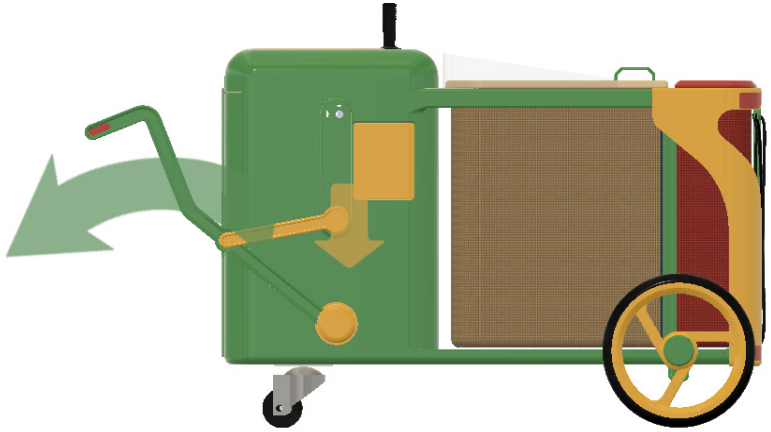
Step 3- The waste is transferred to the respective bags manually.

Step 4- The mesh tilts thus transferring the inert waste into inert compartment

General process of handling empty plastic bottles

Step 1-Plastic bottles are transferred into dedicated slot on the right hand side of the bottle compressor

Step 2- The lid is tilt-able and can easily let through a 2 liter PET bottle



Step 3- The handlebar is rotated towards the user. This leads to pulling of the connecting rod downwards. The connecting rod brings the piston downwards

Step 4- This action compresses the plastic bottles The torsional spring brings back the rod into it's original state

Conclusion

The cart is seen in the perspective of the waste management system. Since the segregation of waste is already done by the collector during the time of collection, segregation is more effective. The waste per person during segregation process is less compared to waste handled in the later stages. Spreading of dry waste enables the collector to spread out the waste clearly and hence help in sorting the waste. The waste is sorted based on the nature and the processing required in further stages. Paper waste collected sold by the collector to the scrap dealer as it would generate incentive and hence would encourage the collector to sort the waste.

Compression of bottles would reduce the amount of space consumed by empty plastic bottles. This increases the efficiency of cart in terns of space. This also holds good for the wet waste compartment as compaction of wet waste is necessary in order to use the space efficiently. This makes the cart efficient. Storage space can be used for storing the gloves, sacks, documents etc.

Four wheels are used in order handle unequal distribution of load. Rear caster wheels help in turning the cart.. Since the cart is left out in the road, reflectors are used at the extremities of the cart for easy visibility when exposed to light in the dark.

Easy removal of sacks from the space underneath the top frame is effortless. It is not necessary for the collector to remove the sack from the top. Use of ropes in the front keeps the sack within the front frame on downslope.

The use of cart also prevents the waste to come in direct contact while handling in the subsequent stages. The sacks are durable as they are made of jute. The sacks also help in preventing the waste to get mixed in the subsequent stages. Thus the segregated waste is maintained in the sacks even in the further stages.

Therefore the cart prevents the mixing of waste in the subsequent stages. Th segregated waste does not mix when it is transferred for post processing. Compaction process improves the capacity of the cart. Features such as brakes at the handlebar region helps the collector to control the cart on downslope. Parking brakes helps in keeping the cart stationary on downslope which enables the collector in easy collection and sorting of waste.

The cart is beneficial in not only collection of waste but also segregation of the collected waste. This aids the further segregation process. The efficiency of segregation is aided by the mesh, separate sacks etc.

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