IIT Ropar
CP301: Development Engineering Project

END SEM REPORT 2021

Improving Waste Management through Efficient Collection, Intelligent Disposal, and Live-Tracking

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Acknowledgement

We highly acknowledge the support of our supervisor - Dr. Harpreet Singh. He has been very supportive throughout the project. Although the times are tough due to the global pandemic, we were able to complete the project timely and in a better manner than expected. This was made possible through Harpreet sir's motivation, our regular meetings without fail and the support we received throughout the semester from our faculty advisors- Dr. Sachin and Dr. Devranjan.

We would also like to acknowledge the IIT Ropar's support for giving us the opportunity to realize this dream through this course. We also thank our family members and friends for providing us their support to complete our project from our homes.

Abstract

Over the past 30 years, India tipped to double the amount of waste it generates.[1] And the rising amount of waste has been a topic of debate over the past decade. The government usually encourages initiatives, such as 3R's - Reuse, Recycle and Reduce. The focus is generally on reducing the waste generation. Government has successfully capped the amount of waste upto some extent, but with the rising population, stopping the rate of waste generation is impossible.[2] Hence, with the initiatives to control the waste generation, it is high time to search for opportunities in the same. Tonnes of 'garbage', which everyone thinks of as useless, is a source of unlimited potential for us.

The conventional methods of 'waste management' won't be able to sustain the current rate of garbage production. Hence, in this project, we have focussed on the whole supply chain of waste, from its collection to disposal site (collection of waste, organising the data for municipal corporations, understanding the pain-points of users and finally optimising the garbage disposal recommendation system through data analysis and data processing). This project focuses on making the whole process of waste management more efficient, and transparent. Overall, the project focuses on connecting the loose ends and generating employment from this particular supply chain.

[1] https://timesofindia.indiatimes.com/india/in-30-years-india-tipped-to-double-the-amount-of-waste-it-generates/articleshow/74454382.cms

[2] Kumar, Akhilesh, and Avlokita Agrawal. "Recent trends in solid waste management status, challenges, and potential for the future Indian cities–A review." *Current Research in Environmental Sustainability* 2 (2020): 100011.

Chapter 1: Introduction & Problem definition

India generates the most waste in the world and it is expected to increase more till 2050. This huge waste consequently gives rise to the problem of proper waste management in India. Government has taken strict measures for proper discharge and disposal of solid waste but they need to be improved on the ground level.

The problem starts right from the collection of household waste, and continues till the post processing of the collected waste. **Our project focuses on the whole supply chain (for Chandigarh) and makes this waste management supply chain more efficient and suggests multiple ways to make it more profitable for Govt/ municipal council.**

Fig 1.1: Top 5 municipal solid waste generators annually

The key to efficient waste management is to ensure proper collection and segregation of waste at source and to ensure that the waste goes through different streams of recycling and resource recovery. Technology needs to participate in this step to ensure fast, accurate, easy and user friendly waste collection and segregation at large scale.

Chapter 2: Literature survey

2.1 Dataset on investigating an optimal household waste management in GIS environment and quantitative and qualitative analysis in Bumehen city, Tehran, Iran

We read the research paper and analysed it thoroughly:
Purpose: the purpose of this research was to optimize the waste collection and transportation system in Bumehen city in Tehran, Iran.
Data Collected: the average weights of municipal solid waste, time taken for collection and transportation of municipal solid waste (MSW) was measured.
The environmental and time perspectives under the current management system were used to calculate the criteria in the paper. Identification of general characteristics of the region and the type of waste management were recognised through field studies.
Based on information such as **density, population, waste generation capacity, available routes and existing route types, number, type and capacity of tanks, the site of temporary transfer stations** was determined and the appropriate routes were designed for the garbage trucks.

The collection system was designed based on population density, road width and accessibility, the shortest travel route from homes and per capita waste generation. The present state of the waste collection tanks placement in the city's neighborhoods is completely traditional. However, as the Experts stated, maps should be designed considering tanks spacing and road width of at least 100 and 4m, respectively.

The waste transport routes were selected on their proximity to the main roads (the shortest); Quicker access to the transfer site and the road leading to it, as well as only one-time passage through the road.

2.2 Chandigarh Government report analysis:

We read government reports based on waste management in Chandigarh and searched for answers to the following questions:

1. What are the methods being employed currently to handle waste in Chandigarh?
2. What are the major problems faced by the municipal corporation in collecting and disposing of waste?
3. What are the major prevalent problems in Chandigarh related to overall waste management? What are the loopholes in the current waste management system?

An average of 370 tons/day of solid waste is generated in Chandigarh. The entire solid waste is handled by the municipal corporation of Chandigarh. The following steps walk us through the entire waste collection process:

1. **Primary Collection:** Every day roads are swept and waste is collected between morning 6 AM to 4 PM in the evening. The sweepers are provided with handcarts or 'redis' and brooms to clean the roads properly, to clean the open drains, to collect the waste and load it into the carts provided and then they transfer them to the primary collection points. These handcarts/redis also visit every house and collect waste from them. These primary collection points have huge dumpsters and are called 'Safai Kendras'.

Fig 2.1: Redi or handcart which collects waste and dumps it in the primary collection points: Dumpsters

2. **Storage:** At these Safai Kendras, waste is collected and stored by rag pickers. Then they segregate the waste before it is sent off to the disposal site. Trucks or dumpers then enter these Sehaj Safai Kendra's and transfer the waste from these storage sites to the disposal site.

Fig 2.2: Storage and segregation of waste at Sehaj Safai Kendra's in Chandigarh

3. **Secondary Collection:** Waste is transferred by trucks. This part has a lot of problems as the collection routes, collection times and quantities are random and haphazard.

4.  

Fig 2.3: Transportation of waste

5. **Final disposal of Municipal Solid waste:** There is only one dump yard that has been designated for this purpose consisting of 45.11 acres of land and it is situated in Sector38 near Dadu Majra labor colony.

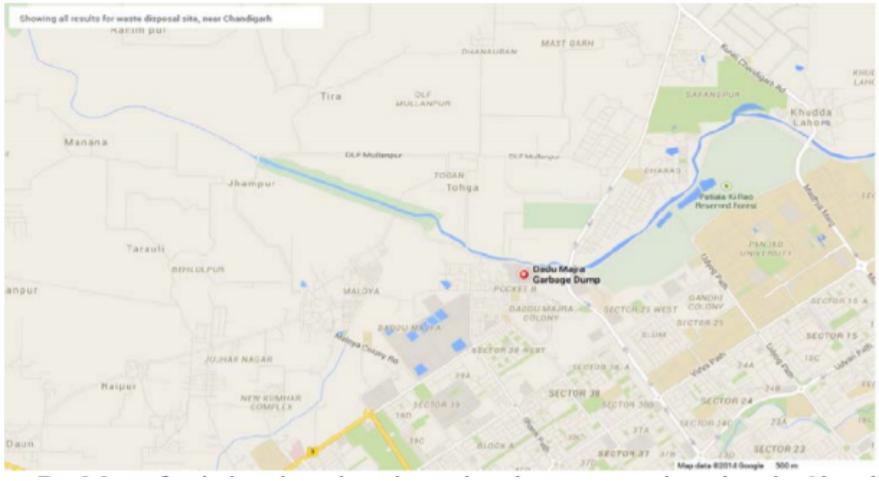

Fig 2.4:. Map of existing dumping site and garbage processing plant in Chandigarh

Fig 2.5: The main dumping site

6. **Processing of Solid Waste:** Waste is processed at Refuse Derived Fuel Plan in Chandigarh.

Fig 2.6: Processing of waste at Refuse Derived Fuel Plant in Chandigarh

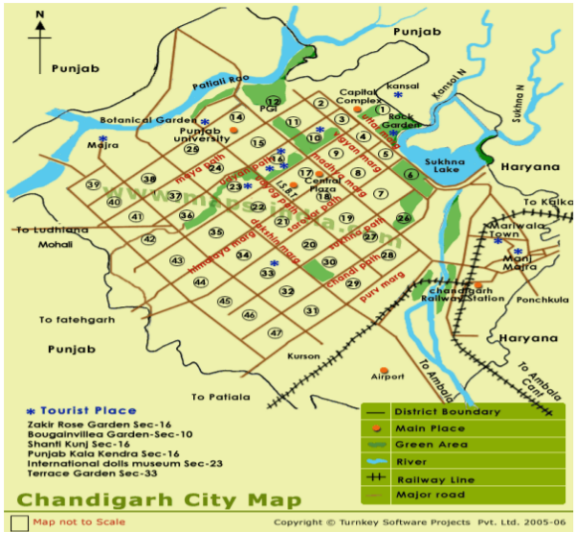

Fig 2.7: Map of Chandigarh city

Prevalent Problems related to waste management in Chandigarh and other tier-1/tier-2 cities:

1. **Bad Conditions of Collection Containers and surrounding areas**
2. **Poor Working Conditions: Waste is segregated manually leading to hazardous conditions for the front line waste management workers**
3. **Limited Resources, less capacity of processing plant and disposal site almost full**
4. Old collection vehicles are not replaced timely
5. **Waste is not separated at source**
6. **Inefficient Waste Collection System**
7. **Waste Disposal Methods are not upto the mark. Many unsuitable methods are used for the same**

<u>We will be targeting most of these 7 problems in our development engineering project.</u>

Chapter 3: Methodology

In the mid-sem report, the step by step for methodology was defined. Hence, we will draw a parallel comparison between targets set and how many of them we achieved. This section will be followed by a detailed explanation of code, which we deployed in our algorithm. Finally, we will define the limitations of our project.

3.1: Data Collection

The grievance portal on our website and app deals with this part. Any resident of the city could log in and submit a simple google form regarding the waste near his/her surroundings. The UI (User Interface) is simple and could be used by anyone. The mobile application makes this part even more convenient for users.
The information collected from end-user is about:

1. Name of User
2. Contact number
3. Image of garbage
4. Location / Address
5. Date and Time
6. Quantity of garbage
7. Is it toxic or not?
8. Description

3.2: Data Processing

We were able to achieve most of our set-targets. If multiple requests are made for the same site, the code will handle it and consider it as a single location.
If a location is invalid, a notification will be generated signalling the invalid input location.

3.2.1 Prioritizing the data

The toxic waste is given priority over biodegradable / non-biodegradable waste. Those locations will be treated separately and all other garbage sites planning will be pushed by a day or two, depending on the requirement.

3.2.2 data modelling

Data modelling was performed in python (LINK to google colab). The data was filtered and processed to identify the locations on a map. Invalid locations were accompanied with an error message. How we modelled the data is explained in a detailed manner in the code section.
'Clean' data was available with us post-processing.

3.3: Marking on Map

All the locations were marked on a map, using Folium library in python. The output map is depicted below:

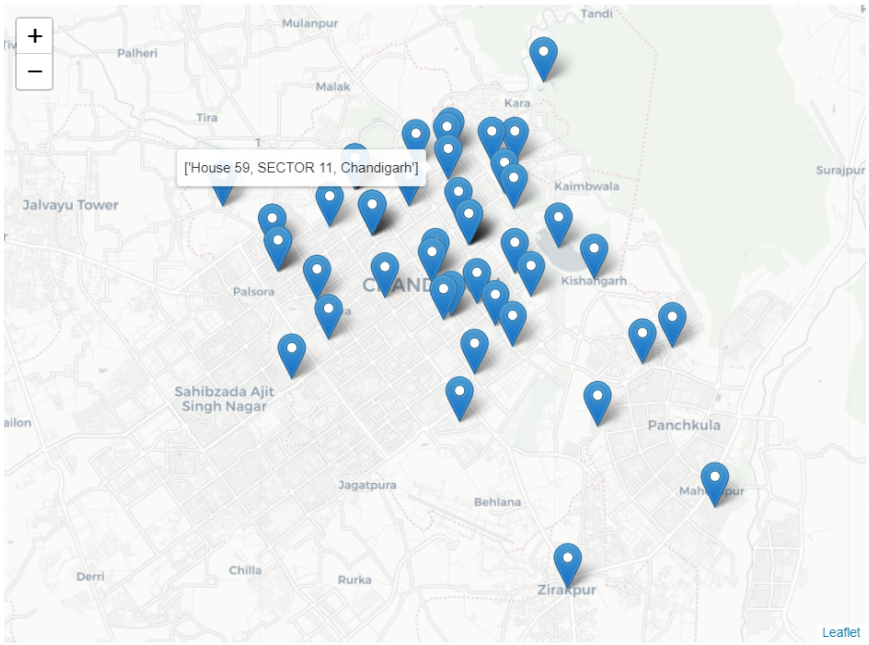

Fig 3.1: Marking on map

3.4: Conclusion

After marking all locations on map, we found the most optimal path for a garbage van (assuming constraint is on daily travel of the vehicle). Once the locations were cleared, the clearing date and time were stored in the database. This data was further used to compute the overall cleanliness index of the city.
This data was used to analyse the status / pattern of waste generation in a particular city. These patterns were used to install / adopt different waste management techniques, as explained in this report. Observing this data, we would be able to locate the potential sites for installation of a new biogas plant or placing a new dumpster.

3.5: Feedback

Users have been provided a provision of submitting feedback about their request. If the garbage removal process is delayed / not done properly, citizens can rate the services of municipal corporations / garbage collection companies. This feedback will ultimately reflect in the cleanliness index of the city.

Overall, we have covered all the aspects of this project, as promised in the mid-sem report and went ahead to cover more things like the website and the app, which were previously not in our list. The impact of this project is huge, and future possibilities are limitless. The methodology / flow of the project can be revised in future, depending upon the personal preferences of the Garbage collection and management body.

Chapter 4: Website Walkthrough

Website Link: https://sites.google.com/iitrpr.ac.in/waste-disposal-and-management-/home

The website connects various parts of the project together and displays dome parts of our work to the audience. More importantly, it serves as the source of data on which the municipal corporation acts, as the citizens can fill the form on the website to convey their grievances/complaints to the municipal authorities. The website is divided into the following pages and sections:

4.1 Home Page

The Home page displays some essential parts of the project. It also contains the live dataset which the citizens can keep track of, to check the status of their complaints

4.1.1 SCHEDULE AND MANAGEMENT PLAN

The Schedule is set by the Municipal Corporation and the route for each day is marked and added to Google Maps and Google Calendar. Also, the method which is to be used to handle a particular type of waste at a particular location is also added in Calendar. The best part is, that the Calendar is open to the general public to view. In this way, the citizens can keep track of which locations will be cleaned today and what would be the route number for the day. The locations along that particular route can be checked via the locations marked on Google map in the Code section.

4.1.2 Location wise Images

The images that are uploaded by citizens will be publicly available in this section along with the location where that image was clicked.

4.1.3 DATA Collected (Power BI Visual)

The PowerBI visual is a **live dashboard** which is synced with the live data collected through the Google Form in the Grievance Section. This visual has slicers/filters which can help anyone on the internet to check a particular grievance/complaint, its status, and other details corresponding to that grievance. The various filters are:

- Quantity of waste (Low/Medium/High)
- Type of waste (Biodegradable/Non-Biodegradable/Mixed)
- Date
- Method deployed to handle waste
- Current Status

Other details which can be seen here are:

- First Name of the user
- Address/ Location of waste
- Date on which waste was spotted
- Description

We could not publish the dashboard on the Microsoft PowerBI platform- because we required a company domain to do so and the iitrpr.ac.in domain has restricted functionality in this regard. This would have enabled anyone on the internet to use the live features of this dashboard, whereas now, only our team can use the live functionality. We have also uploaded the link to the pbix PowerBI file on the website, in case anyone who has PowerBI installed wants to interact with the live dashboard. Nevertheless, we have shown the complete live functionality in the recorded video presentation.

Data Section: this is a static section which displays the following:

- CLEANLINESS INDEX OF CHANDIGARH
- Kgs of waste collected this month
- Number of Locations which have been furnished with new dumpsters
- Kgs of waste recycled this month

4.1.4 Workflow of our Project

It is a brief workflow of the project and mentions the main parts of the project.

4.1.5 Shortest Routes

This section explains how we have calculated the shortest path for the locations to be covered everyday by the municipal van.

4.1.6 Methods to Handle Waste | Suggestions for Municipal Corporation

This section mentions the methods that will be used to handle waste and gives a brief description of each method, along with an explanatory picture. The various methods which we believe are suitable for waste management and disposal in Chandigarh are:

i. Disinfection and Sterilization

ii. Biogas Plant

iii. Placing Dumpster

iv. Automated Dustbins

v. Coconut Shells

vi. Landfill

vii. Incineration

viii. Waste compaction

ix. Composting

x. Vermicomposting

4.1.7 Outline and Live Dataset

This dataset includes a Google sheet which is in live synchronization with the dataset and the form responses. It also shows the other parts of the project like: Master sheet (contains the entire workflow), week by week Progress of the project, some Links used, outline of business model, sheet for calculation of cleanliness index, Colab notebook data for Developers and some other details about the project.

4.1.8 Live Map

Helps track locations on the map. It also contains a static map of Chandigarh city

4.1.9 The Team

Includes names of team members, supervisor and instructor

4.1.10 Contact Us Section

This section helps citizens to contact us. We have created a dedicated email ID for this purpose. This is where we collect feedback from users which is later also used to calculate the Cleanliness Index.

4.2 Grievance Section

Has the Google Form which citizens can fill to send their grievances. Link to form: https://forms.gle/iEQtu7QcKed1fpzNA. The responses are in live-sync with the Google sheet displayed on the home page and with the PowerBI Dashboard.

4.3 Cleanliness Index

Explained in the Cleanliness Index Section of this report.

4.4 Business Model

Explained in the Business Model Section of this report.

4.5 Code

Explained in the Code Walkthrough Section of this report.

4.6 Documentation

This page of the website shows all the documents that were written by us. These documents do not have Open Access - only people with iitrpr email ID can view these documents. We have restricted access in order to prevent others from copying and using our original idea, and this has been done on the suggestion of our supervisor- Dr. Harpreet. These documents include:

1. Mid-sem report
2. End-sem report
3. Path Planning Algorithm
4. Central Database and Project Sheet
5. Collection of information and research

This section also has some of our meeting pictures displayed in an image carousel. We have also displayed some images of the PowerBI dashboard in this section.

Chapter 5: App Walkthrough

App Link:

Download Android APP:
https://s3.amazonaws.com/gonativeio/static/6098048e67ede04b52559192/app-release.apk

Source Code Android:
https://s3.amazonaws.com/gonativeio/static/60976a5e67ede04b5255894f/android_source.tar.gz

Source Code iOS:
https://s3.amazonaws.com/gonativeio/static/60976a5e67ede04b5255894f/ios_source.tar.gz

To play app on website (Android):
https://appetize.io/app/r0m3g9ueckue9nc2erd6jgnzmw?device=nexus5&scale=75&orientation=portrait&osVersion=8.1

To play app on website (IOS):
https://appetize.io/app/x92rc4xf1aqecgn1hu5t8njrem?device=iphone6s&scale=75&orientation=portrait&osVersion=13.7

NOTE: We have provided the complete code for android and IOS source code for application. We haven't published it on google play store due to the following reasons:

1. We need to take the google console subscription to publish it on play store.
2. We have used some tools for google map APIs that we haven't subscribed to. Publishing it to the general audience might be an issue at this point of time.
3. We used certain tools to make sure the UI of the app and web is the same. We can't publish it on play store without taking the commercial rights from them. Again that includes some costing $700-$1000.
4. As per our limited knowledge we need to be a registered entity to publish an application nowadays as per new consol rules.

Also, we can go through the complete application directly on the web. We can play the application on the web and that will give the same user experience when someone uses it on mobile. Links are provided above.

Chapter 6: Code Walkthrough

Link to Google Colab:
https://colab.research.google.com/drive/1gaBPETdd5Nk6upd-6JRdh3iXf8VDLJ2k?usp=sharing

For simplification purposes, the code is divided into 7 parts. The basic python libraries used in this project were geopy, geopandas, numpy, pandas, folium, pydrive, branca, dijkstar and gmaps. All these parts are explained below:

6.1: Loading the Dataset

In this part, we imported the data from google spreadsheet to google colab. We used the pydrive library. The dataset imported was stored as a dataframe (df). Finally, this data of 53 addresses was converted into an array of size 53.
The subset of this section included filtering of the data. If any invalid location was entered into the system, the system will display a message - 'Invalid Input Address!!'.

```
array([['Municipal Corporation, Chandigarh'],
       ['Sector 40A, Chandigarh'],
       ['Rajindra Park, Sector 1, Chandigarh'],
       ['Chandigarh Club, Sector 1, Chandigarh, 160001'],
       ['Chandigarh university, Sector 6, Chandigarh'],
       ['House 22, SECTOR-7, Chandigarh'],
       ['SECTOR 27, CHANDIGARH'],
       ['House 32, SECTOR-15, Chandigarh'],
       ['House 25 ,SECTOR 21, Panchkula.'],
       ['House 14, SECTOR 39-B, Chandigarh'],
       ['House 1000, SECTOR 38-B, Chandigarh'],
       ['House 13, SECTOR-24, Chandigarh'],
       ['House 2294, SECTOR 23-C, Chandigarh'],
       ['Industrial area, phase 2, Chandigarh'],
       ['rock garden, Chandigarh'],
       ['MANIMAJRA complex, CHANDIGARH'],
       ['Sukhna Lake, Chandigarh'],
       ['Delhi Public School, Sector 40B, Chandigarh'],
       ['Maloya, CHANDIGARH'],
       ['Hockey Stadium, Sector 42, Chandigarh'],
       ['Highland Park, Zirakpur'],
       ['Paras hospital , PANCHKULA .'],
       ['Sector 44D MARKET, Chandigarh'],
       ['Bus stand sector 43 , Chandigarh'],
       ['House 2, SECTOR 26, Chandigarh'],
       ['House 59, SECTOR 11, Chandigarh'],
       ['House 14, SECTOR 39-B, Chandigarh'],
       ['MAULI COMPLEX, Chandigarh'],
       ['sector 30A, Chandigarh'],
       ['Government Museum and Art Gallery, sector 10C, Chandigarh'],
```

Fig 6.1: Array of Addresses

6.2: Visualizing all Locations on Map

We used the Folium library for this purpose. The Map generated was customizable. The map with all addresses marked is depicted below.

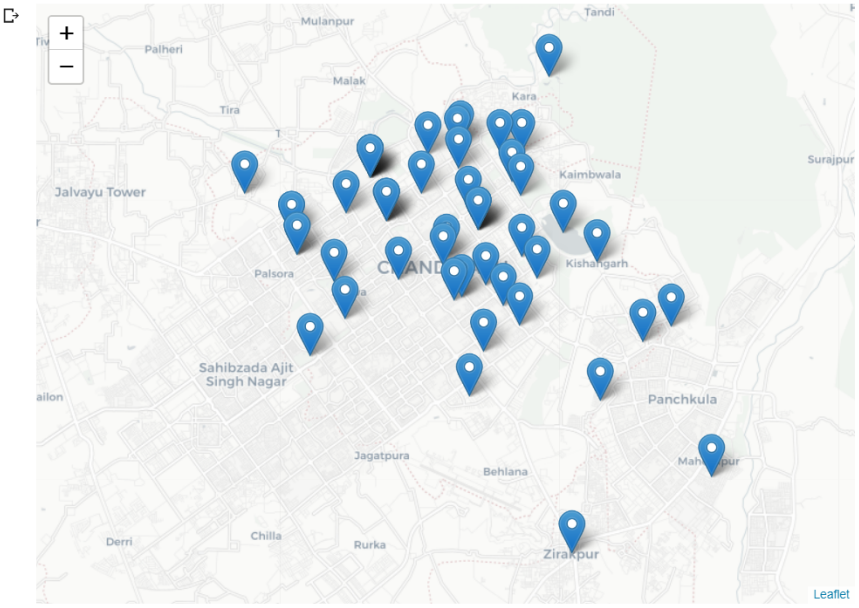

Fig 6.2: All locations marked on Map

6.3: Finding Coordinates of all Locations

After we visualized the distribution of addresses, we built two arrays, lats[ ] and longs[ ], to store the respective values of latitude and longitude of each location. These latitudes and longitudes were used for computation purposes in further code.

6.4: Constructing a Graph with nodes and edges

An exemplar graph is displayed below.

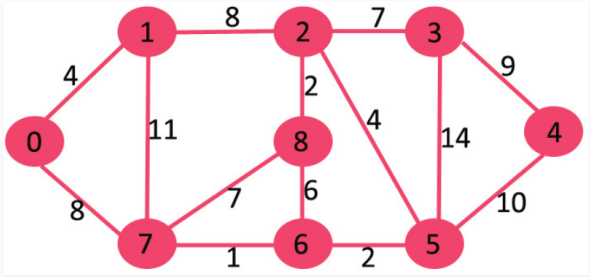

Fig 6.3: Constructing a Graph with nodes and edges

The idea was to construct a similar graph, where each location was depicted by a particular node and each edge represented the on-road distance between the two nodes. Since we had directed graph in our case, we used 53 nodes (for 53 addresses), and 53 x 53 edges (one for each possible path between two locations). These edges had edge weights, giving the value of on-road distance.
For determining the on-road distance, json library was used. 53 x 53 requests were sent to osrm.org, and the graph was finally completed.

6.5: Using Dijkstra's Algorithm

Till now, we had a graph, and a source node (node number 0), representing the municipal corporation office. Our target was to find the shortest path to each node, from this source node. We used the famous Dijkstra's algorithm for this purpose. Hence, we generated the optimal path from source node to each location. For example:

```
PathInfo(nodes=[0, 51, 20], edges=[3633.3, 7490.6], costs=[3633.3, 7490.6], total_cost=11123.900000000001)
PathInfo(nodes=[0, 31, 6, 21], edges=[3290.5, 816.5, 6606.5], costs=[3290.5, 816.5, 6606.5], total_cost=10713.5)
PathInfo(nodes=[0, 22], edges=[6323], costs=[6323], total_cost=6323)
```

In the above figure, we can observe that if we want to move from node 0 to node 21, we have to pass through node 31 and node 6. The shortest path would look like 0 => 31 => 6 => 21, and the total distance travelled (given by total_cost) will be 10713.5m or 10.7km approximately. Similarly, we found the shortest path for each case, considering every node as a source node, once.

6.6: Tracing the Optimal Path

Finally, we had the graph sorted, and we moved to the final stages of code. The first node in our path was 0 (municipal corporation office). In the first case, we kept our source node as 0, and moved to the most nearest location. In our case it was node 42. Then, we kept the source node 42 and travelled to the nearest node.

In the optimal path configuration, we put the contarint on the daily travel limit of the garbage collection van. Suppose, in a particular case the collection company wants to limit the daily distance travelled by the van as 20 Km or 20,000m. 'Permit' variable defines this limit in the code.
We repeated the process until the distance travelled by the van reached its limit.

```
[0, 42, 11, 46, 50, 52, 1, 22, 38, 48, 49, 7, 45, 0]
20159.2
```

In the figure above, we can observe the optimal path of the van, as 0 => 42 => …… => 45 => 0. And the distance travelled by the van is 20159.2m.
The nodes versus locations to be cleared are shown below:

```
0  -  ['Municipal Corporation, Chandigarh']
42  -  ['Dakshin Marg, 35A, Sector 35, Chandigarh, 160036']
11  -  ['House 13, SECTOR-24, Chandigarh']
46  -  ['House 2, SECTOR 24, CHANDIGARH']
50  -  ['House 13, SECTOR 24, CHANDIGARH.']
52  -  ['Santokh Hospital Chandigarh']
1  -  ['Sector 40A, Chandigarh']
22  -  ['Sector 44D MARKET, Chandigarh']
38  -  ['SECTOR-20C CHANDIGARH.']
48  -  ['House 197, SECTOR 25, Chandigarh']
49  -  ['House 1336, SECTOR 25, Chandigarh']
7  -  ['House 32, SECTOR-15, Chandigarh']
45  -  ['PGIMER, Sector 12, Chandigarh']
0  -  ['Municipal Corporation, Chandigarh']
```

The aerial view, connecting all of the above locations is shown below:

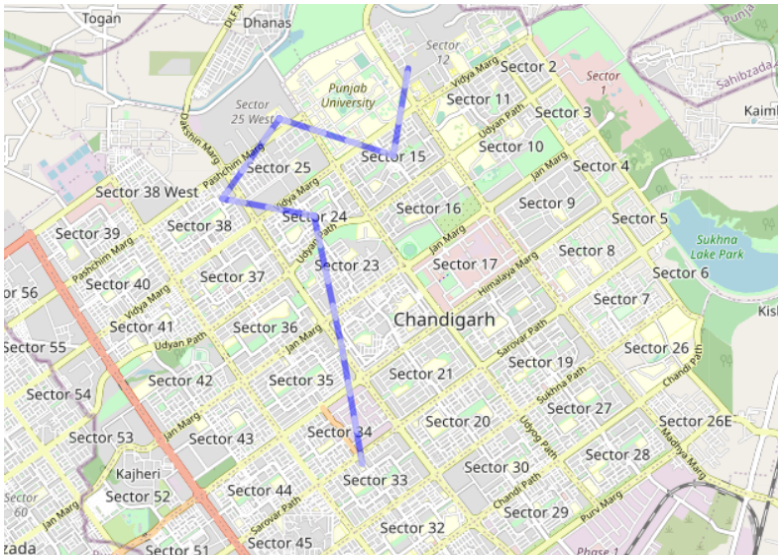

Fig 6.4: Aerial view of optimal path

6.7: Marking the Optimal Path on Map

For plotting the shortest route between two locations on a map, we used google maps service. An API key was generated from our google account. Google usually charges $300 for it's services. But since our account was unpaid and the trial version, we couldn't access the full version of google maps. But the code part is completed and once we activate the google services, we can

observe the path plotting live (in-time shortest path, considering traffic conditions also) on google maps.

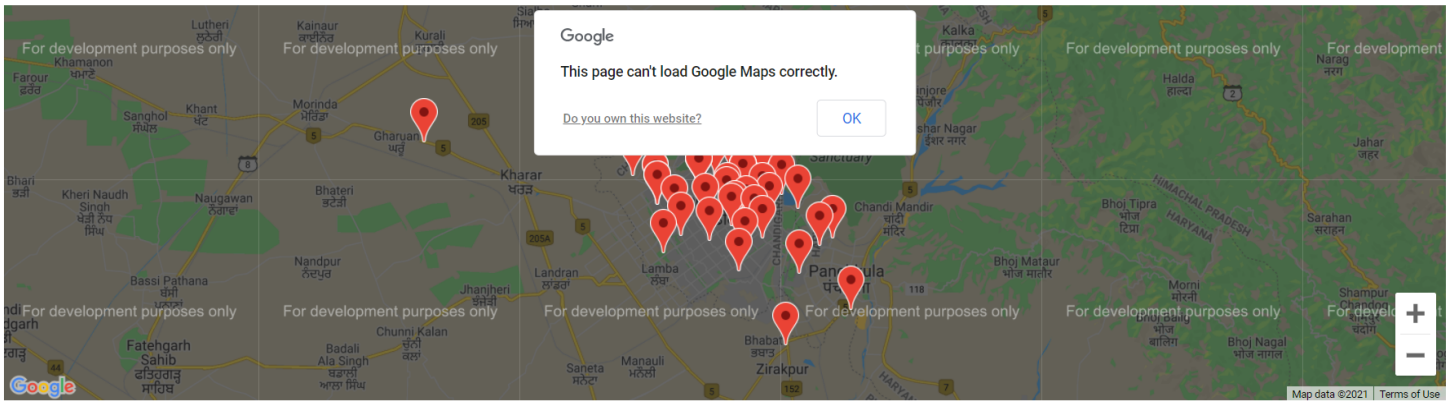

Fig 6.5: Marking the Optimal Path on Map

Chapter 7: Cleanliness Index

7.1: Division of ranking factors (swachhsurvekshan2021)

7.1.1 Service Level Progress (SLP)

Data provided by ULBs

7.1.2 Certification

Based on GFC Star rating, ODF+/ODF++/Water +

7.1.3 Citizen's voice

5 components - Feedback, engagement, experience, Swachhta app, Innovation

Fig 7.1: Weightage overview

7.2: Our model ranking factors

We are considering only 2 dimensions due to unavailability of data from users or we can say we can only make sure only 2 dimensions from users side other is from Municipal corporation side.

Table 7.1: Formulation of cleanliness index

Service Level Progress 1600 marks	Type of Waste (800)	Biodegradable - 800 Mixed - 400 Non-biodegradable - 100	*Quantitative Formulation:* ***800*[Type of waste/3] + 800*[Quantity of waste/3]***
	Quantity of Waste (800)	High - 3 Medium - 2 Low - 1	
Citizens Voice 1800 marks	Current status (900)	Resolved - 3 Processing - 2 Unresolved - 1	*Quantitative Formulation:* ***900*[Current status of waste/3] + 900 [rating/10]***
	Feedback (900)	Based on 10 star rating	

7.3 Net Quantitative Formulation:

800*[Type of waste/3] + 800*[Quantity of waste/3] + 900*[Current status of waste/3] + 900 [rating/10]

Chapter 8: Methods to Handle Solid Waste

8.1: Disinfection and Sterilization:

Places near hospitals and laboratories require disinfection and sterilization. These places generate biomedical waste like “discarded blood, sharps, unwanted microbiological cultures and stocks, human or animal tissue/waste, used bandages and dressings, discarded gloves, other medical supplies that may have been in contact with blood and body fluids, and laboratory waste.”
Places which have parameters in the data like the following:

1. **Location**: Location is close to hospitals/laboratories/medical centres
2. **Type**: Non-Bio/Mixed
3. **Description**: containing keywords like “harmful/infectious/dangerous”
4. **Class**: Biomedical waste

8.2: Coconut Shells:

Coconut shell based activated carbon

Activated carbon is produced from coconut shells in a two-step process.

1. The first step in activation is to carbonize the shells to drive about two-thirds of the volatiles out of the shells, creating a carbonaceous mass full of tiny pores.

2. In the second stage, this carbonized base material is activated at high temperature (1,100°C/2,012°F) in steam. Activation temperature and the amount of activation time are important to create the internal pore networks and to impart certain surface chemistries (functional groups) inside each particle.

Coconut shell-based activated carbons are the least dusty. Predominantly microporous, they are well-suited for organic chemical adsorption. Coconut shell-based carbon has the highest hardness compared to other types of activated carbons, which makes it the ideal carbon for **water purification**.

Source:https://www.watertechonline.com/home/article/15538115/coconut-shell-based-activated-carbon-with-no-greenhouse-gas-emission

8.3: Biogas Plant:

Almost all forms of organic material can be used to produce biogas. However, wastewater, manure, energy crops and organic industrial waste are the most common feedstocks.

Biogas is produced using organic material, which is broken down with the help of bacteria in an anaerobic (oxygen-free) environment. The anaerobic digestion process is a natural process that

often occurs in nature. In a biogas plant, this process takes place in an anaerobic digester and is accelerated by creating the best possible conditions for microorganisms and bacteria to multiply, which leads to a highly efficient breakdown of materials.

The small plant can handle the effect of variation in pH, temperature, and humidity and provides a continuous supply of biogas to fulfil the daily needs of around 5-6 people, with a set up cost of around 10,000 Rs.

8.4: Placing Dumpster

Small or middle sized dustbins can store only a small amount of garbage and also large cardboard pieces can't be placed in it. So, after identifying the places where the average amount of garbage is more, the dumpster can be placed instead/in addition to the garbage bins.

The dumpster has a sturdy base which allows it to stand against strong winds as well from the stray animals. So, places that are quite open or experience strong winds, the dumpsters can be placed. Due to its large size, the dumpster can be modified in such a way that it can store both biodegradable and non-biodegradable garbage in separate compartments which can later be processed by different methods according to the need.

8.5: Automated Dustbins

It's main job is to automatically segregate the garbage into different categories like metals, plastics, papers or recyclable/non recyclable material with the help of machine learning and computer vision. So, it can be installed in the recycling plants or garbage collecting area in order to separate useful materials from the waste. Recyclable materials like metals, polythene bags, papers etc can be sent to recycling centers and organic materials like vegetable/food waste can be used to make manure. Similarly, other materials can be processed according to their nature. It can also be used to separate harmful materials like batteries, medicinal wastes etc from the garbage. Else these types of waste can harm the environment as well as humans.

8.6: Landfill

In this process, the waste that cannot be reused or recycled are separated out and spread as a thin layer in low-lying areas across a city. A layer of soil is added after each layer of garbage. However, once this process is complete, the area is declared unfit for construction of buildings for the next 20 years. Instead, it can only be used as a playground or a park.

8.7: Incineration

Incineration is the process of controlled combustion of garbage to reduce it to incombustible matter such as ash and waste gas. The exhaust gases from this process may be toxic, hence it is treated before being released into the environment. This process reduces the volume of waste by 90 per cent and is considered as one of the most hygienic methods of waste disposal. In some cases, the heat generated is used to produce electricity. However, some consider this process, not quite environmentally friendly due to the generation of greenhouse gases such as carbon dioxide and carbon monoxide.

8.8: Waste Compaction

The waste materials such as cans and plastic bottles are compacted into blocks and sent for recycling. This process prevents the oxidation of metals and reduces airspace need, thus making transportation and positioning easy.

8.9: Composting

All organic materials decompose with time. Food scraps, yard waste, etc., make up for one of the major organic wastes we throw every day. The process of composting starts with these organic wastes being buried under layers of soil and then are left to decay under the action of microorganisms such as bacteria and fungi.

This results in the formation of nutrient-rich manure. Also, this process ensures that the nutrients are replenished in the soil. Besides enriching the soil, composting also increases the water retention capacity. In agriculture, it is the best alternative to chemical fertilizers.

8.10: Vermicomposting

Vermicomposting is the process of using worms for the degradation of organic matter into nutrient-rich manure. Worms consume and digest the organic matter. The by-products of digestion which are excreted out by the worms make the soil nutrient-rich, thus enhancing the growth of bacteria and fungi. It is also far more effective than traditional composting.

8.11: Recovery and Recycling

Recycling is the process of converting waste products into new products to prevent energy usage and consumption of fresh raw materials. Recycling is the third component of Reduce, Reuse and Recycle waste hierarchy.

The idea behind recycling is to reduce energy usage, reduce the volume of landfills, reduce air and water pollution, reduce greenhouse gas emissions, and preserve natural resources for future use.

8.12: Plasma gasification

Plasma is primarily an electrically charged or highly ionized gas. Lighting is one type of plasma that produces temperatures that exceed 12,600 °F.

With this method of waste disposal, a vessel uses characteristic plasma torches operating at +10,000 °F which is creating a gasification zone till 3,000 °F for the conversion of solid or liquid wastes into a syngas.

During the treatment of solid waste by plasma gasification, the waste's molecular bonds are broken down as a result of the intense heat in the vessels and the elemental components.

Chapter 9: Business Model

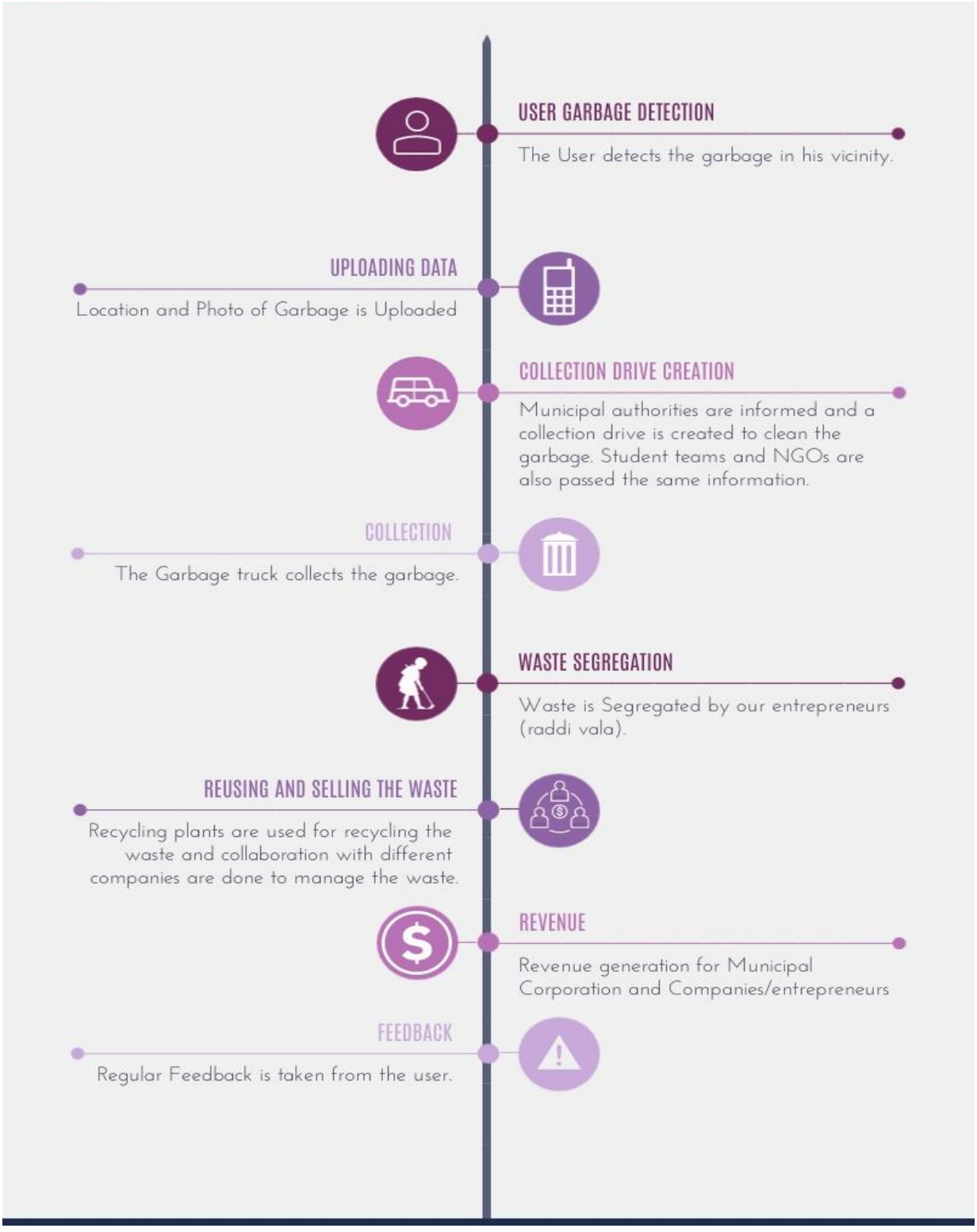

Fig 9.1: Business model

Our business model starts from the User garbage detection. It involves various stakeholders at various stages. We have tried to make our model self sustainable and revenue generating, so that the supply chain is completed and ultimately the cost of operation is incurred from the waste itself. The collection drive is generated from the algorithm discussed above and the garbage is collected from the Municipal Council's waste collection truck. If various NGOs and student communities want to volunteer, the information can also be shared with them as well.

After the collection, the waste needs to be segregated into various categories eg. Biodegradable, Plastic, Electronic etc. This segregation would involve various entrepreneurs including '*Raddivalas*' as well. Each of these stakeholders would be given the profit share that would be generated by the recycling and reusing of the segregated waste. Apart from various methods already discussed above, Biogas plants could also be set up by the municipal council for generating extra revenue. Ultimately this revenue generating model will close our supply chain and would become self-sustaining. Further we plan to include various other methods to handle the waste so that our process becomes more efficient, leading to profit generation.

Chapter 10: Conclusion

This project is just a baby step towards a broader dream. The most beautiful part of this idea is its novelty- it's a unique idea which will benefit all stakeholders- the municipal corporation and the citizens. This idea can actually prove to be useful for managing waste.

The possibilities of expansion are limitless. We modelled our project according to Chandigarh. However, the specifics of this project will depend on geographic and demographic conditions and may vary from state to state. The technology that we are implementing here has not been used till date. However, there are several similar products available in the market, currently used by the Ministry of Housing and Urban Affairs, India. But the features that we have included in this project are surely an upgrade to the current version and there are many additional features as well like the dashboard, shortest path calculation and marking on map, website, live dataset etc.

Apart from features, there are several limitations of this project, such as access to google services, and we haven't used it on masses. As we observed in the business plan, the model is scalable, and could also generate employment. Once we carry this model forward, we believe that we could easily overcome these limitations.

Moreover, we have followed the Swachh Bharat path set forth by our Prime Minister. Our product is directly solving the problems that **Swachh Bharat Abhiyaan** is aimed to solve. Some inspiration has also been derived from the same.

Overall, this project carries a huge potential to improve the existing system, and replace it with a more dynamic and vibrant one, where every aspect of public work is accessible and transparent. This project truly upholds the basic values of our constitution ~ ***'to the people, for the people and by the people'***.

Chapter 11: Individual Contribution

11.1 Aman Goyal (2018meb1206):

I Started with the **problem validation** then identifying the **different use cases**. Then I did **Market research** to check whether competition products exist for the same need. Checking the **tech feasibility** for the problem considering we have limited knowledge. So it was very important for us to get a fair idea whether we can work on the targeted solution or not.

Later comes the **execution of ideas.** Entire team divided the suitable task as per their skills and interest. I was **collecting the database** (decided location- chandigarh). Next flow was to develop a website and Application to ensure that it can be taken to each user. I was contributing a major role in **website development**. Later it was kept in mind website development should be such that we can easily make an **application** out of it for the same UI. So editing a website and making it functional for mobile was another task to be kept in mind.

I was able to manage and **develop (convert) the application** from the website for both Android and Mobile. Later we made links that could run mobile screens UI on the computer only. This was necessary to ensure that the mobile application was working fine on laptop screens and could be compiled later.

Harpreet sir suggested a new dimension of the project that was **cleanliness index calculation.** I took the responsibility for the same. I did the research and collected factors on which swachh bharat ranking is decided and later formulated those factors based on our data provided by users. At each step, it was my responsibility to check the feasibility and accessibility of the product. I ensured that we are moving in the right direction from a product point of view. The primary objective of this whole project was to develop a product that will **align to users' needs** and **address the pain points** of the end user.

11.2 Aman Saraf (2018meb1208):

Our project tries to improve the whole supply chain of Waste Management. Our work started with **identifying a common problem** in our nearby area. After brainstorming we came up with the idea of making the waste management supply chain more efficient and profitable. Each one of us contributed to the refinement of this problem statement.

Further it was important to **collect databases** for understanding the current scenario of Chandigarh. This included interviews of local residents and data provided by government websites. I had my contribution in collection of this data which helped us in analyzing the

current situation. This part also included the database of Addresses of local residents of chandigarh, which helped us in the programming part of the project. I also helped in **web scraping** the garbage image database, which was used to train our waste segregation model. The major source of these datasets were websites such as kaggle and github repositories.

The most important part after this was to set up the whole **Business Model of our project**. Our operation cost was high and we needed to figure out ways to incur it. We had to include different stakeholders in the supply chain to make it profitable and self sustaining. This part was led by me which also included different Methods to handle waste. This included the idea of segregation in sub categories. We expanded our project by introducing the idea of collaboration with various companies that can buy the segregated waste from the municipal council to generate profit thus increasing revenue. Our project also generates Jobs for the community and also takes note of the UN sustainable development goals. The business model sums up this project and provides a long run solution for the same.

Lastly I also contributed to **Website and App development**, where we used Google sites for the development. This also included the Schedule and management planner on the site. I used the software *Vizme* to **prepare various infographics** for our Website and report to showcase our project. My contribution also included the compilation of our final presentation Video.

11.3 Ankur Khosla (2018meb1211):

The project has a substantial **tech stack**. I managed the **python programming** part of the project. The **data collection**, **processing** and **analysis** was performed in the python. Marking of **location on maps**, **designing an algorithm** for figuring out the **optimal path** was all part of it. Finally, the algorithm produced the most optimal path. Although we were stuck at plotting the route on google map, the code was built for the same. As soon as this project is hosted on any online server, this algorithm could be automated and used at the back-end.

While designing the algorithm, there were several options, such as clustering of locations on map, or using the greedy approach (travel to the nearest place, then move to next nearest and so on). But there was an issue with such approaches, that very few of them gave **real time idea about the roads** between the two locations. And among those few algorithms, very few took into account the complete picture. We could also use the concept of **Minimum Spanning Tree** here. This part of ***Network Optimisation*** was an integral part of manufacturing technology 2 course, and the path planning problem could be considered as a practical example of the same.

Apart from the path planning algorithm, I also set up the **google console** and added the **API** to the python program. And I, with my other team members, designed the **workflow /**

methodology of the whole system. The code section on the **website** and **app** is a reflection of this part.

This whole project was developed with an idea of '*transparency and transformation*'. The most interesting part of this project was long brainstorming sessions. Irrespective of online mode, we tried to create something of real value to the society.

11.4 Ashwin Goyal (2018meb1214):

We are working on a project which aims to help municipal corporations and NGOs to efficiently clean the waste in the society. I was the one who gave this idea- I had thought this out in the first year, but never got the time, resources and the team to work on it. I pitched the idea to the team and everyone liked it. It is a very novel idea which is one of the reasons it has been appreciated by everyone. Also, the team needed someone to **lead** them, otherwise things would get unorganised, so I took up the initiative of the same.

I **explained the idea** to the team and we accordingly modified it to make it more practical and implementable. I **analysed** various **research papers** in which something related to waste management was being done and got some ideas from there as well. I further studied the report of waste management in **Chandigarh** and I have presented it in the Research section of this report. Since I am a resident of Chandigarh, it became easy to understand the prevalent problems related to waste management.

Once we achieved significant progress and had automated the collection of waste through efficient algorithms and maps, I went ahead and **created a website**- this was not on our mind previously but as we were really enjoying the project- we made the website and later, an app also. I was just exploring Google Sites and within 7-8 hours, I had the first version ready, which includes most of the part which is visible in the current version of the website. Later we added some more functionalities to it. I also had some past experience with **PowerBI**, so I also created the live dashboard which is visually very appealing and was praised for, by Harpreet sir.

Also, I set **the parameters/data fields** that were to be used in the entire project. Some of these were: quantity of waste, quality of waste, uploading images of waste (which would help the garbage collection van to collect that waste easily), addresses (based on which the code is suggesting feasible routes) etc. Also, I **collected** the **actual addresses of Chandigarh** for our dataset so that we could train the model. All in all, it was a great learning experience for me.

11.5 Dev Pardesi (2018meb1220):

My main contribution in this project is to **analyze the problem** of waste management and disposal **in various cities** of our country and shortlist them to a few in order to further investigate the waste problem as well as the management system in these cities. I also helped in **collecting the dataset** by floating a **google form** among various persons residing in different sectors of Chandigarh and making a **mail id** so that the persons using the site or application can reach out to us to share their views as well as waste problems among us. I made different sections in the **website**, like the waste disposal section and linking the different images of waste with their corresponding sectors using the backend. I also searched for a way to convert the **google site into an application** that can run in both IOS and android platforms.

Our project also deals with the various **waste disposal techniques** currently being used/ can be used by municipal authorities. I found various techniques for waste disposal and the amount of different types of waste generated in different sectors. This information can be used to opt for suitable waste disposal methods for particular places and also to find an optimal route to save time and effort.

I took the responsibility to check whether all the steps and efforts are done in the right way to create an effective product so that the problem of both public and municipal corporations is handled. I ensured that the product, including the website and the application, is user-friendly and incorporates all the necessary things.

Chapter 12: Other Deliverables

Google Drive link:
https://drive.google.com/drive/folders/1uxaYvfZRJo5dwP-aNBUZ-2cDyxhHoalT?usp=sharing
Dataset published on web as webpage:
https://docs.google.com/spreadsheets/u/1/d/e/2PACX-1vSdqThE7RRi6CA2H7SfRGTrOA6N3jm1OGsWxVP_C3xjNa0PxR2AZ1ZbBnyM0X8WGzX6Kb6bFOCPKqFJ/pubhtml?gid=1429579793&single=true
PowerBI Dashboard Link:
https://drive.google.com/file/d/13YoOZHLediwPH6a-kCwW55hUkVlX29MH/view?usp=sharing
WEBSITE: https://sites.google.com/iitrpr.ac.in/waste-disposal-and-management-/home
App: given above
Video Submitted Separately

References

Research Part:

1. Research Papers: https://www.sciencedirect.com/science/article/pii/S2352340918308588
2. https://www.sciencedirect.com/science/article/abs/pii/S0959652620336027
3. Chandigarh Waste Management Report: http://www.ejge.com/2015/Ppr2015.0229me.pdf
4. Chandigarh's Waste processing Plant: https://www.hindustantimes.com/chandigarh/chandigarh-s-dadumajra-waste-plant-can-perform-at-40-capacity-at-best-iit-roorkee/story-p6XzNAWEuzR1MPq8kk1PDJ.html

Cleanliness Index:

5. https://swachhsurvekshan2021.org/ and http://swachhbharaturban.gov.in/sbmdocumentfile.aspx?DOCTYPE=9999&DOCID=5&id=6agge2yk2fd38k87

Code Part:

6. Physical address to latitude, longitude https://towardsdatascience.com/geocode-with-python-161ec1e62b89
7. Latitude, longitude marking on map https://towardsdatascience.com/plotting-business-locations-on-maps-using-multiple-plotting-libraries-in-python-45a00ea770af
8. Folium library - marking locations https://www.analyticsvidhya.com/blog/2020/06/guide-geospatial-analysis-folium-python/#:~:text=Markers%20are%20among%20the%20most,add%20it%20to%20the%20map.
9. Folium Library - marking path https://stackoverflow.com/questions/60578408/is-it-possible-to-draw-paths-in-folium
10. geopy distance between 2 points https://kanoki.org/2019/02/14/how-to-find-distance-between-two-points-based-on-latitude-and-longitude-using-python-and-sql/
11. complete folium library https://medium.com/image-vision/folium-all-you-need-for-map-visualization-206e88c8ac

12. folium plugins
https://stackoverflow.com/questions/48085110/no-module-named-folium-plugins-python-3-6
13. Path Planning
https://towardsdatascience.com/driving-distance-between-two-or-more-places-in-python-89779d691def#1c17
14. Path plotting on road
https://towardsdatascience.com/find-and-plot-your-optimal-path-using-plotly-and-networkx-in-python-17e75387b873
15. Github Gist code addition
https://gist.github.com/azam/2e35a393ee2425f40c6d04de4ce5926b
16. Github gist for collab notebook:
https://gist.github.com/ankurkhosla199/a5bda22cefa5d682b7bad6e7d67260f9
17. Google Maps
https://medium.com/future-vision/google-maps-in-python-part-2-393f96196eaf
18. gmaps python documentation
https://jupyter-gmaps.readthedocs.io/en/latest/api.html

Waste disposal methods:

19. Waste disposal methods
    a. Waste Disposal Methods - Types Of Waste Disposal | Solutions (byjus.com)
    b. Waste disposal methods (admin.ch)
    c. 7 Waste Disposal Methods | Compactor Management Company (norcalcompactors.net)
    d. waste disposal | Types & Methods | Britannica
20. Coconut shells
https://www.watertechonline.com/home/article/15538115/coconut-shell-based-activated-carbon-with-no-greenhouse-gas-emission

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