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LAHORE UNIVERSITY OF MANAGEMENT SCIENCES

LWMC RESOURCE OPTIMIZATION

ANALYSIS REPORT &
CASE STUDY

CLEAN LAHORE
Lahore Waste Management Company
LWMC

INTRODUCTION

This report aims to provide a complete and precise description of the work and analysis performed on vehicle route data provided by the Lahore Waste Management Company (LWMC).

Our goal behind the analysis was to gain insights from data such as vehicle movement routes and container collection patterns and to gain maximum utilization of solid waste resources.

Disclaimer: The data provided for each vehicle type was limited. For example, out of a total of 37 compactors, data was shared for 5 compactors. Therefore, there are limitations, due to missing information, in the insights derived from the data.

DATA OVERVIEW

The data provided by LWMC, using which the analysis was conducted, consists of the following:

- GULBERG TOWN VEHICLE CATEGORIES AND COUNT
- GULBERG TOWN TCP (TEMPORARY COLLECTION POINT) AND PARKING LOCATIONS
- GULBERG TOWN HOTSPOT POINTS AND CONTAINER LOCATIONS
- GULBERG TOWN FUEL REPORT AND STOP REPORT FOR JUNE 2022
- VEHICLE GEO-COORDINATES (ROUTES) FOR JUNE 2022

DATA-TYPE	DESCRIPTION
Containers in Gulberg	942
Unique Container Locations	367
0.8m3 and 5m3 Containers	921 and 21 respectively
Open Heap and Open Plot Locations	26 and 6 respectively
Vehicles in Gulberg Town (Total)	77 mini dumpers, 37 compactors, 11 chain arm role, 6 arm role, 12 dumpers, 11 loaders, 6 pickups
Vehicles for which GPS data provided	10 mini dumpers, 5 compactors, 5 chain arm roles, 4 arm roles

ANALYSIS ON DATA

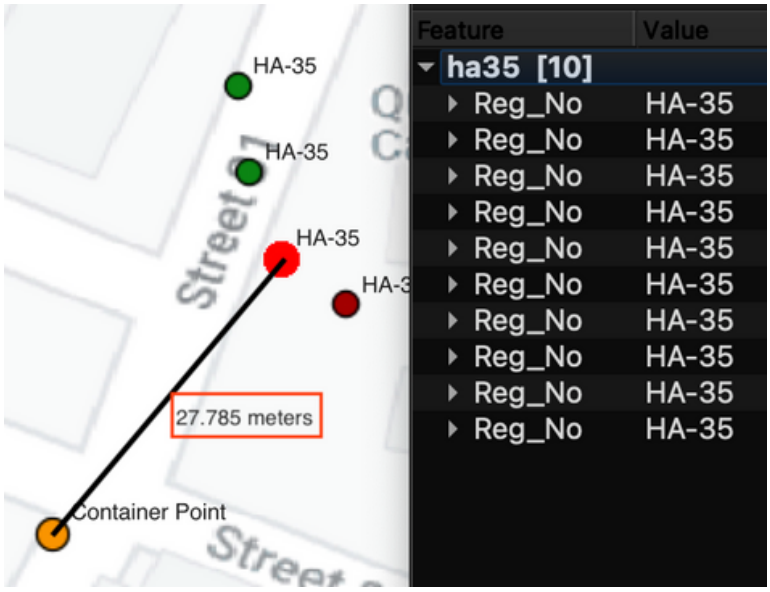
The motivation for analyzing the data was to derive container collection patterns from each vehicle over a period of a month. We conducted a detailed analysis of the routes to see the daily container pick-up trends for each vehicle. The aim is to identify how many times a container needs to be attended by each vehicle to create an efficient operations plan. This is also the first step of the 3 case studies below for identifying if a container was attended.

The following rules are defined to categorize the container into served or unserved categories. Using the routes (vehicle GPS) data, the only way to check whether the container is served by the vehicle or not is by the distance between the container and the vehicle, and by considering the stop time of the vehicle near the container. The applied rules are as follows.

RULES:

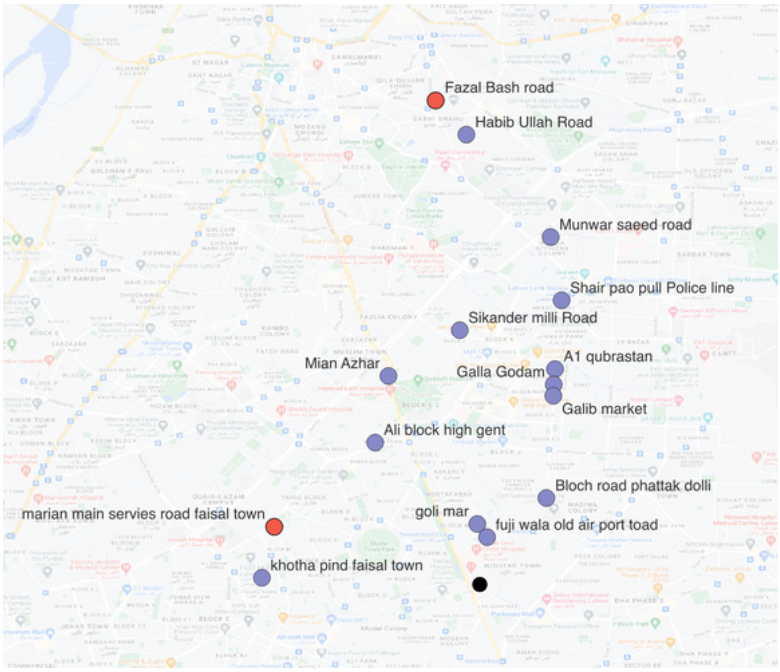
- A buffer of 30 meters is used to check the presence of a particular vehicle near the container.
- Moreover, if the stop-time of a vehicle near a container is more than 20 minutes then the vehicle is considered to be serving a container.

This image shows that there is some noise in GPS points. There also may be difference between given container locations and actual locations. Therefore, a threshold of 30 meters is taken with the probability of many other outliers. This vehicle is idling at one point for more than 10 readings and 20 minutes.

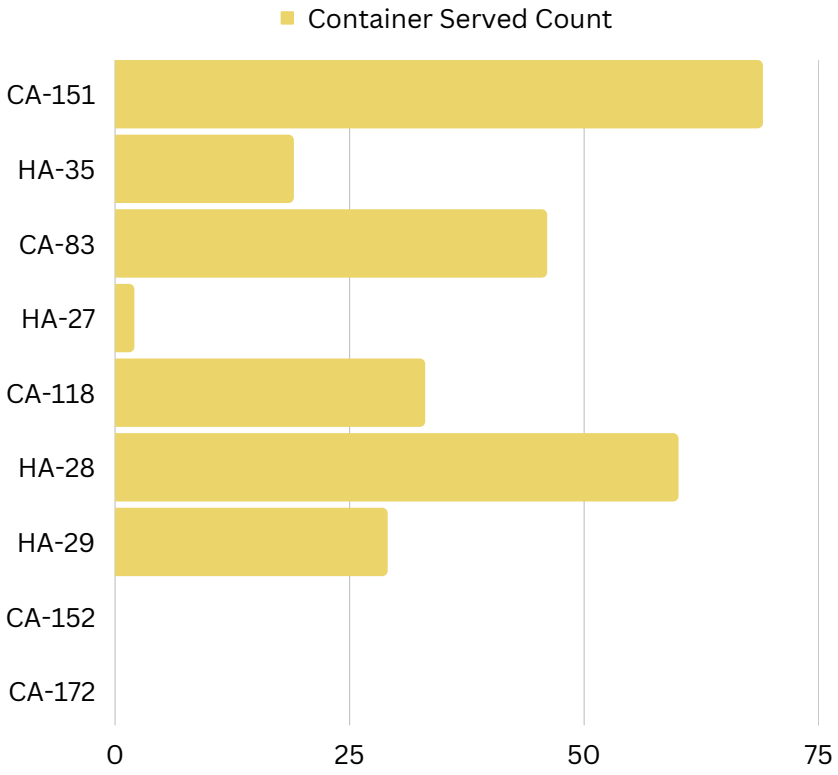


ANALYSIS OUTCOMES

It can be seen, that the containers in purple color are served in the month of June, and the containers in pink shade were not covered by any of the vehicles from the available vehicle data. There might be a possibility that other vehicle might have served that vehicle but nothing can be said as, no data was provided for those vehicles.



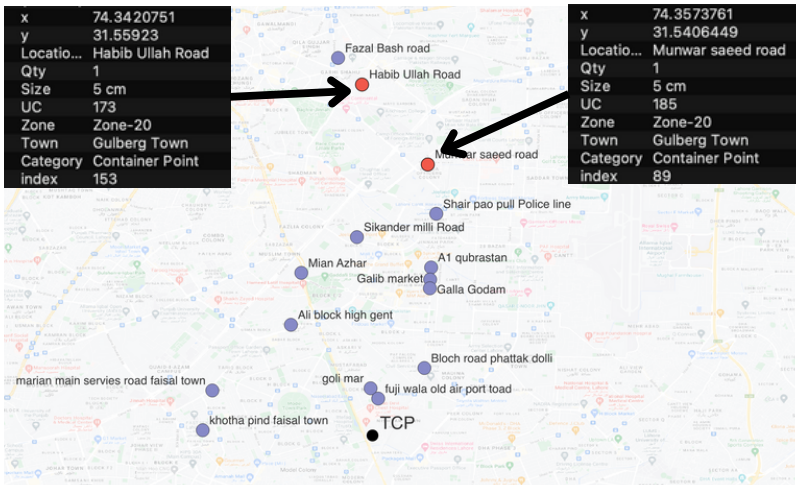
The chart below represents how many containers have been served by each vehicle over the whole month of June:



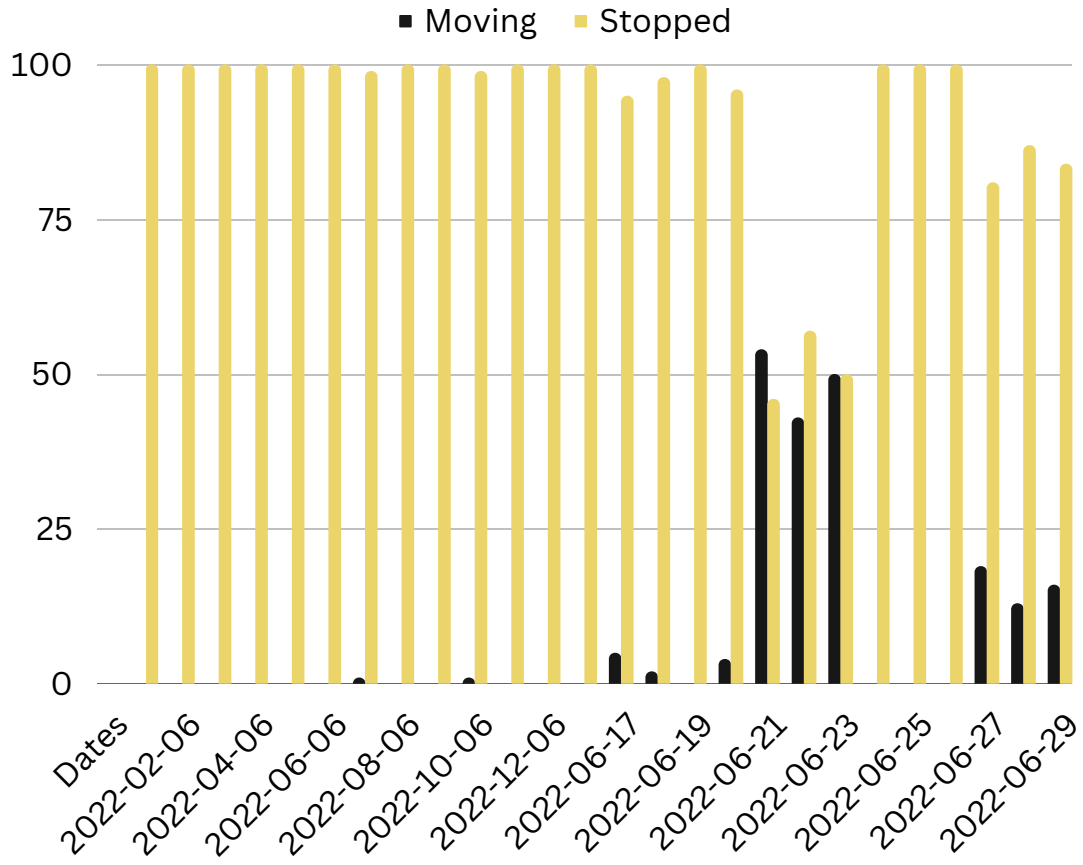
CASE STUDY 1: RESOURCE REALLOCATION

Based on the analysis above, Arm Roll **HA-27** has attended only two containers in June as depicted in the figure below. One container with ID 89 was attended on the 21st of June and placed on Munawar Saeed Rd.

The other container with ID 153 was served on the 23rd of June, placed on Habib Ullah Rd. In terms of overall activity performed, arm roll HA-27 has mainly been in moving state for about 3 days. While on rest the days this particular vehicle was



in idle state (presented in the figure below). Therefore, HA-27 can be reallocated to another town by assigning the containers served by this vehicle to another resource as done in the following pages.



REALLOCATION OF VEHICLES

For the purpose of reallocation, the following criteria have been defined to make the decision of assigning containers attended by **HA-27** to other vehicles.

CRITERIA

1. At time t when HA-27 is serving the container, another vehicle should be at TCP or near TCP.
2. A particular vehicle should be free for time period T, in order to return to TCP after serving the container

VEH-ID	CONTAINER-ID	TIME	LOCATION	LONGITUDE	LATITUDE
HA-27	89	21/06/22 8:16:00	Munawar Saeed Road	74.3572	31.540804
HA-27	153	23/06/22 7:50:00	Habib ullah Road	74.34204	31.559468

CONTAINERS SERVED BY HA-27

The aim is to appoint other less utilized vehicles to serve containers previously attended by HA-27 and to relieve and reallocate vehicle HA-27 to another town.

For container 89, two vehicles CA-118 and HA-35 are available within 1 km of the TCP and both these vehicles served only 1 container on the 21st of June. CA-118 served the container with ID 65 at 10:25:00, while HA-35 served container 365 at 18:55:00.

The average speed for HA-35 from 8:00 to 9:00 is 11.51 km/h and the distance of container 89 to TCP is 9.8 km. So, the average time to serve the container and return to TCP will be 1 hr and 42 minutes. On the other hand, the average speed of CA-118 between these hours was 18.6 km/h. The overall time taken by this vehicle to cover the 9.8 km distance from TCP to container 89 is 1 hr 03 minutes. However, CA-118 is attending container 65 at 10:25:00 which makes it impossible for this vehicle to attend container 89. So, it is better to assign container 89 to HA-35 which is free for much more time in progressing hours.

VEH-ID	TIME	LOCATION	LONGITUDE	LATITUDE
CA-118	21/06/22 8:16:00	at GREEN CNG Ferozpur Road	74.346504	31.468356
HA-35	21/06/22 8:16:00	at BUS STOP CHILDREN HOSPITAL Ferozpur Road	74.341448	31.480452

AVAILABLE VEHICLES TO SERVE CONTAINER ID: 89

After analysis, it was seen that HA-27 served container ID 153 on the 23rd of June at 7:50:00, and CA-118 on the 23rd of June has not served any container and is at the TCP at that time. So, container 153 can be served with vehicle CA-118 and HA-27 can be set fully free of its services within the month of June and it can be reallocated or dedicated to another town.

VEH-ID	TIME	LOCATION	LONGITUDE	LATITUDE
CA-118	23/06/22 7:50:00	at LWMC-WS-ALBAlbayrak Children Workshop	74.34432	31.477792

AVAILABLE VEHICLES TO SERVE CONTAINER ID: 153

CASE STUDY 2: ROUTE OPTIMIZATION

In the previous section, vehicle route optimization was performed on vehicle routes to predict optimized routes for covering the same containers on the same day as served by LWMC vehicles. In this section, we have created a pipeline (data processing model) that takes vehicle types, vehicle capacity, container locations, and the number of containers at each location as input to output optimized routes for vehicles.

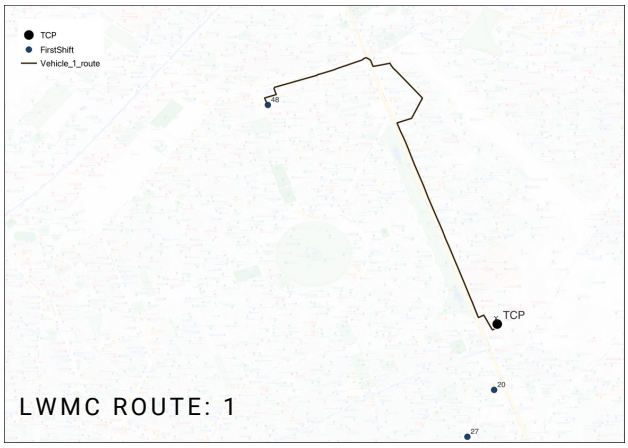
We have performed an analysis in shifts defined by LWMC, and have predicted routes in shifts. First shift:12:00 am to 08:00 am; second shift: 08:00 am to 04:00 pm; third shift: 04:00 pm - 12:00 am.

	Quantity
Container Locations	21
C-13s	4
C-7s	1

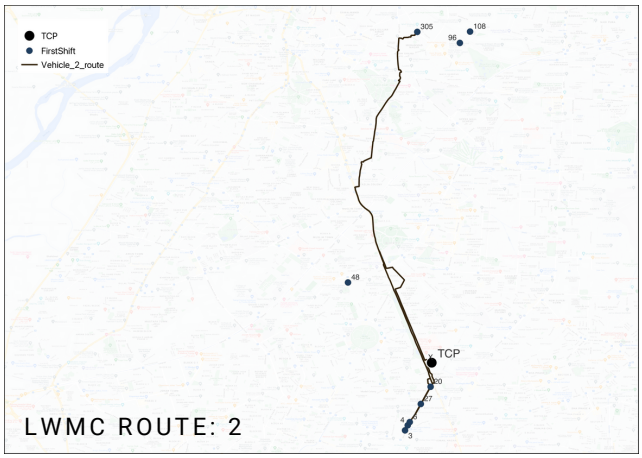
Note: We were provided with data for only 5 compactors; 4 were C-13 and 1 was C-7. Sample analysis was performed for a single day on the 13th of June 2022 since the higher activity was observed on this day. Therefore, we picked data for this particular day and predicted our routes.

ANALYSIS ON FIRST SHIFT:

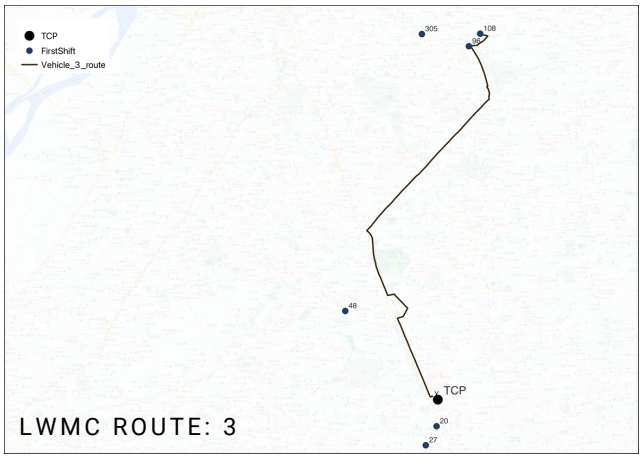
There were 9 containers served on the 13th of June 2022 in the first shift. All these containers were served by a total of 3 vehicles of LWMC as depicted via the vehicle routes. The distance covered by these 3 vehicles is 10.1 km, 29.05 km, and 25.02 km respectively, to cover all 9 containers in the first shift in a total distance of 64.16 km.



LWMC ROUTE: 1

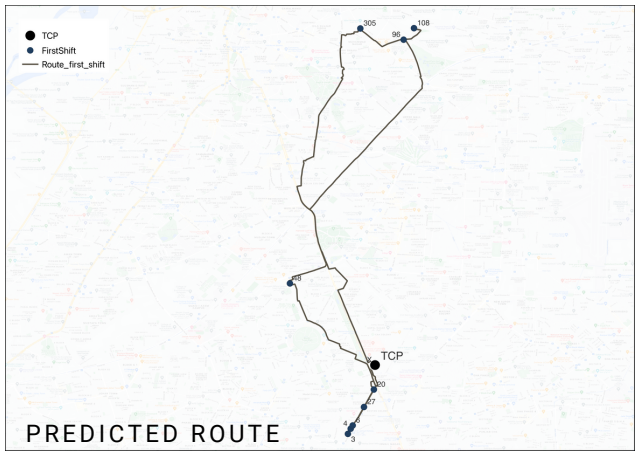


LWMC ROUTE: 2



LWMC ROUTE: 3

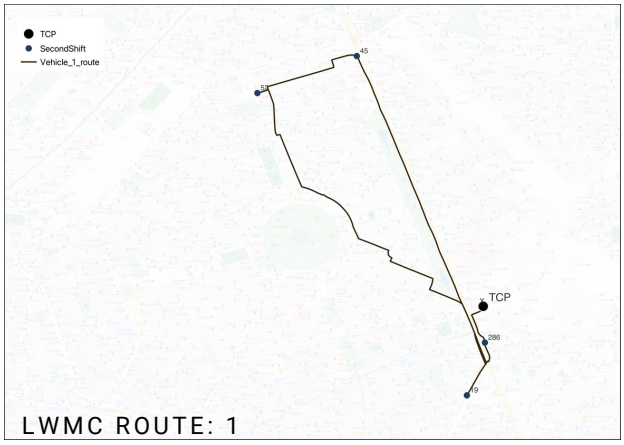
While on the other hand, we have predicted the routes from our own pipeline by attending to and covering the containers served in the first shift. The number of containers at each location, vehicle type, and vehicle capacity was the inputs. Our model predicted one single route for all the given container locations covering a distance of 33.06 km which is almost half of the total distance traveled by 3 vehicles in the case of the LWMC status quo.



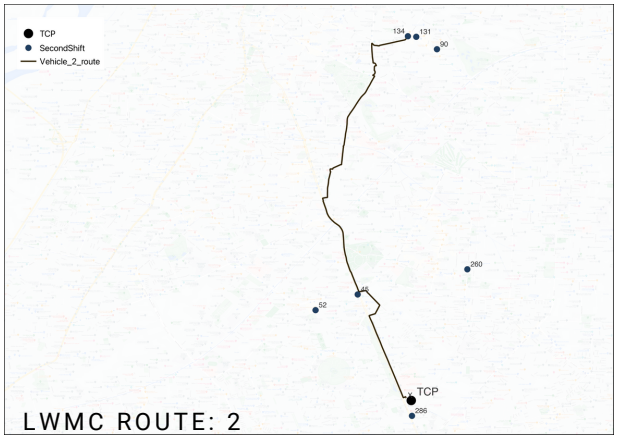
PREDICTED ROUTE

ANALYSIS ON SECOND SHIFT:

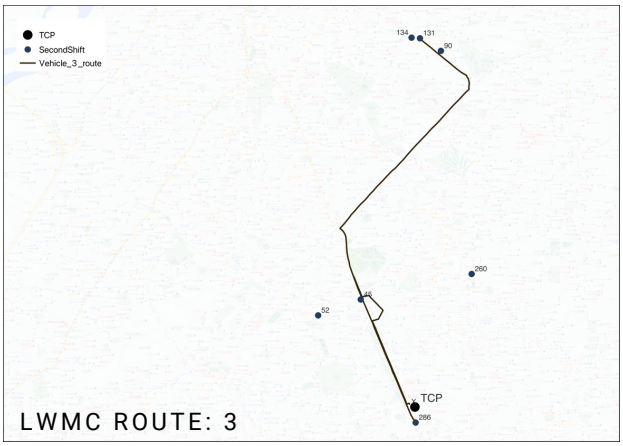
In the second shift, LWMC data shows SMW operational activity by 4 vehicles, and these vehicles attended 8 container locations covering a distance of 11.41 km, 23.91 km, 46.45 km, and 12.95 km respectively for each vehicle. The total distance traveled, in this case, is 94.71 km. The routes of all 4 vehicles are shown below.



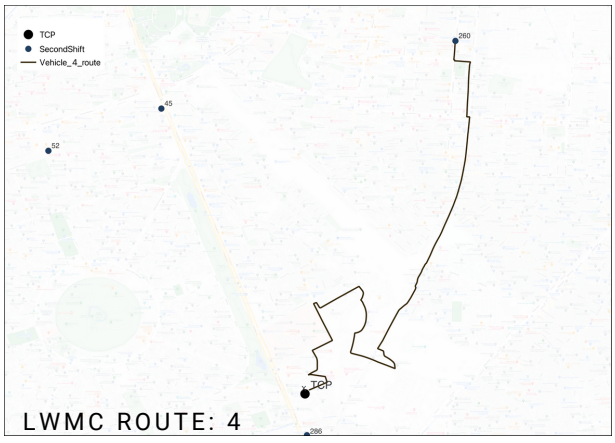
LWMC ROUTE: 1



LWMC ROUTE: 2

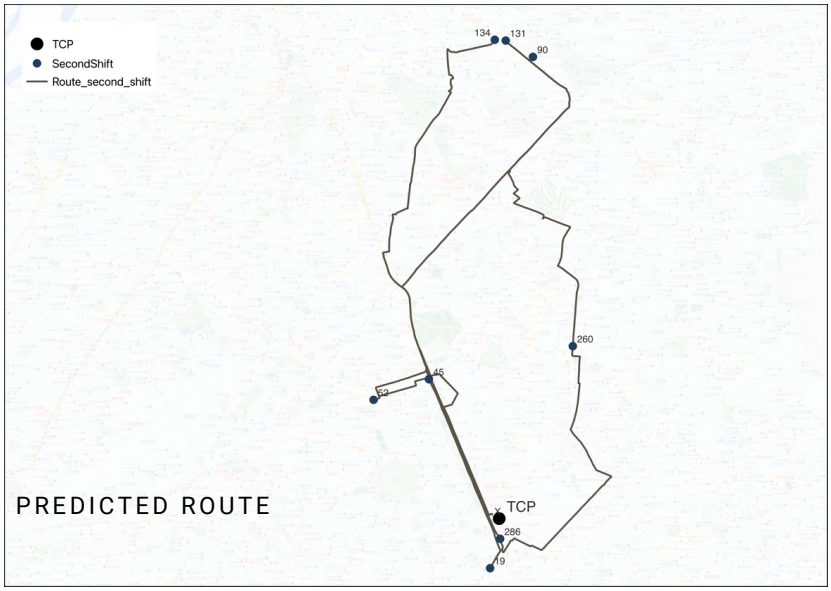


LWMC ROUTE: 3



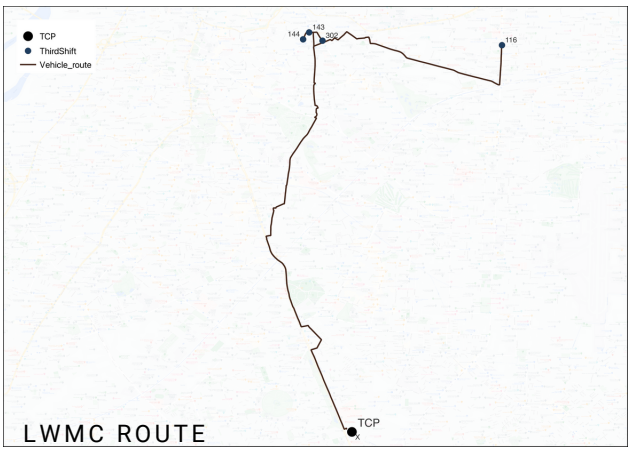
LWMC ROUTE: 4

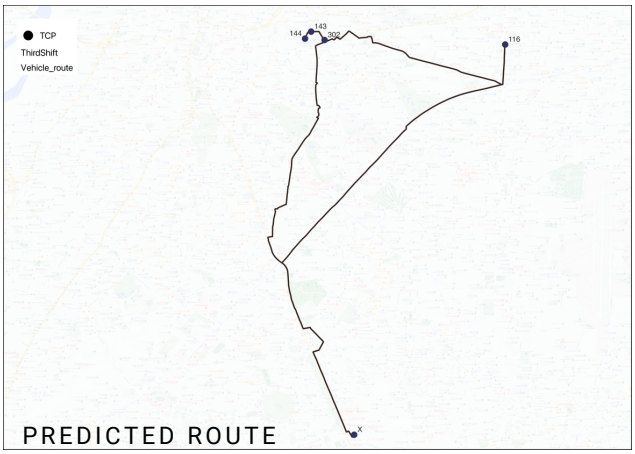
In the second shift, the route predicted by our model covered all 8 container locations in 75.82 km, taking all capacity constraints into consideration. The distance traveled by LWMC's vehicles was more than this distance and also our model has used 1 vehicle instead of using 4 vehicles. The average speed for the C-13 compactor according to the given data is 18.5 km/hr. With this speed, it can travel the stated distance in 4 hours and 30 minutes.



ANALYSIS ON THIRD SHIFT:

As per the data, 1 vehicle of LWMC has served 4 container locations in the third shift of the selected day. All these four containers are predicted to be served by 1 vehicle but in a different sequence for the sake of optimization. Our predicted route shows the total distance traveled is 34.38 km while the route taken by the LWMC vehicle has covered a distance of 37.8 km.





DISTANCE COMPARISON OVER SHIFTS:

		LWMC Routes			Predicted Routes	
	First Shift	Second Shift	Third Shift	First Shift	Second Shift	Third Shift
Vehicle: 1	10.1 km	11.41 km	37.83 km	33.06 km	75.82 km	34.38 km
Vehicle: 2	29.05 km	23.91 km				
Vehicle: 3	25.02 km	46.45 km				
Vehicle: 4		12.95 km				
	64.16 km	**94.71 km**	**37.83 km**	**33.06 km**	**75.82 km**	**34.38 km**
Total Distance:		**196.70 km**			**143.26 km**	

CASE STUDY 3: CONTAINER COVERAGE

Another study that we conducted was that we took the containers of the entire Gulberg town and tried to predict routes for the complete town using 37 compactor vehicles employed in this town. The results obtained show that using only 22 C-13s and 9 C-7 compactors, we can serve all 921 0.8m containers in a single go.

As per LWMC data, there are around 367 unique locations for both 5m and 0.8m containers, and for only 0.8m there are 342 unique locations. In total, there are around 942 containers out of which 921 are 0.8m containers. In order to serve all these 0.8m containers we have 37 compactor vehicles. 28 compactors are C-13's and 9 compactors are C-7's. We passed all container locations, container quantities at each location, vehicle types, and vehicle capacities to plan optimized routes for Gulberg town.

Data Entity	Quantity
Container Locations	342
Total Containers	921
C-13s	28
C-7s	9

PREDICTIONS FOR VEHICLE ROUTES:

Given vehicles, container locations, and container capacities, our pipeline has predicted the following routes for the coverage of all containers in Gulberg town.

Vehicle_No	Vehicle_Type	No.of_Locations	No.of_Containers	Total_Distance
Vehicle_1	C-13	0	0	0
Vehicle_2	C-13	0	0	0
Vehicle_3	C-13	0	0	0
Vehicle_4	C-13	0	0	0
Vehicle_5	C-13	0	0	0
Vehicle_6	C-13	0	0	0
Vehicle_7	C-13	20	35	37.079
Vehicle_8	C-13	11	35	30.033
Vehicle_9	C-13	16	35	31.407
Vehicle_10	C-13	17	35	31.265
Vehicle_11	C-13	14	35	28.393
Vehicle_12	C-13	9	35	25.456
Vehicle_13	C-13	15	35	26.032
Vehicle_14	C-13	18	35	28.39
Vehicle_15	C-13	10	35	22.741
Vehicle_16	C-13	13	35	21.995
Vehicle_17	C-13	17	35	18.304
Vehicle_18	C-13	11	35	16.798
Vehicle_19	C-13	13	35	15.57
Vehicle_20	C-13	8	35	17.866
Vehicle_21	C-13	14	35	14.413
Vehicle_22	C-13	10	35	14.499
Vehicle_23	C-13	11	35	16.369
Vehicle_24	C-13	12	35	14.156
Vehicle_25	C-13	12	34	14.947
Vehicle_26	C-13	21	34	18.276
Vehicle_27	C-13	14	35	13.982
Vehicle_28	C-13	12	35	12.376
Vehicle_29	C-7	7	18	8.562
Vehicle_30	C-7	8	18	9.5
Vehicle_31	C-7	3	14	4.372
Vehicle_32	C-7	5	18	5.007
Vehicle_33	C-7	6	18	5.756
Vehicle_34	C-7	9	18	4.553
Vehicle_35	C-7	7	18	5.906
Vehicle_36	C-7	3	17	4.813
Vehicle_37	C-7	6	14	2.712

CONCLUSION

At the conclusion of this report, we can see that there were a few data limitations.

- We were provided with data for only 5 out of 37 compactors on which we conducted our comparative analysis and generated our own routes. There might be anomalies in the study because we are neglecting the frequencies with which the containers were served. Therefore, this is not enough to propose evident results.

- In our data analysis, we have found some anomalies such as, when the routes of two vehicles, CA-152 and CA-172, were observed on QGIS, the positions of these vehicles were not even closer to 5m3 containers, open heaps, or open plots. However, both of these vehicles carried out vehicle movement throughout the month, according to the route analysis performed on them. It is unclear what actions these two vehicles carried out and impossible to determine from the given data. For a complete analysis and solid conclusion, it is requested provide the complete data.

- From the provided limited amount of data, we have predicted the routes of all vehicles covering all the containers, however, if the data corresponding to all the vehicles is provided, we can verify our optimized routes along with a comparison with existing routes.

REQUEST

If we can obtain data for all Chain Arm Roles and Arm Roles, we can provide more accurate insights on resource re-allocation. A similar study can be done on Compactors' data to obtain comparable insights for them as well. We can also generate more accurate results if provided with the data for all compactors for at least one month.