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Route Optimization for Solid Waste Collection & Management in Ward no. 23 of Yavatmal City

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Abstract: ***In today's world waste management is a very significant problem. In many cities, most of the waste is disposed without proper segregation which has lead to both economic and environmental sufferings. Due to rapid industrialization, the population of Yavatmal city is increasing due to which solid waste generation is also increasing. It has been estimated that the average waste generation from the Yavatmal city is approximately 312 Grams per capita per day and daily around 56.5 Metric Ton of waste is dumped in a dumping site. Thus the management of solid waste is now becoming a serious issue to keep the city environmentally healthy and clean. GIS is one of the new technologies which has contributed a lot in a very less period to the waste management society. In the present paper, the Q-GIS software is introduced for route optimization of solid waste collection and management in ward no, 23 of Yavatmal city. This paper aims to optimize the routes of ward no.23 of Yavatmal city for solid waste collection and management. The main objective is to obtain maximum efficiency of solid waste collection and transportation, to reduce time consumption for solid waste collection, and to reduce the cost required for the collection of solid waste and its transportation. To use the route optimization process, firstly data such as population density, waste generation, total vehicle details, the present expenditure required for solid waste collection and transportation, conditions of roads were collected and were analysed. For the demonstrative purpose, only one ward i.e. ward no. 23 of Yavatmal city is taken. This paper attempted to optimize the routes of ward no. 23 by using Q-GIS software. The routes of ward no. 23 are optimized using the ORS tool plugin. Finally cost is compared for solid waste collection and transportation using this technique with the existing municipal solid waste collection and management system, as a result, the cost saved after optimization is around Rs.77,562 which is equivalent to 31.25% of saving compared to existing expenditure spent on ward no. 23 for solid waste collection and transportation. This fact is main that a small percentage improvement in the collection operation can affect a significant saving in the whole cost. From the analysis and results, it is concluded that for optimization of routes the Q-GIS software gives better accuracy and can be used as a decision-making tool by municipal authorities for the efficient management of solid waste collection and transportation.***

Keywords: Route optimization, Solid waste collection and transportation, Ward no. 23, Q-GIS software, ORS tool, Municipal Corporation (MNC).

I. INTRODUCTION

The study is conducted in the ward no. 23 of Yavatmal city, Maharashtra, India. The District lies between 19° 26' and 20° 42' north latitudes and 77°18' and 79° 9' east longitudes. It is surrounded by Amravati and Wardha District to the north, Chandrapur District to the east Andhra Pradesh State and Nanded District to the south and Hingoli and Washim Districts to the west. Yavatmal is around 90 km away from divisional headquarters, Amravati while it is 670 km away from the state capital Mumbai. The municipal area of Yavatmal is approximately 81.5 Sq. Km i.e. 8150 Hectare. Considering the census data of 2011, the Population Density is approximately 31 Person per hectare. At present, the town has 63804 residential households / premises distributed into 28 wards.

In Yavatmal total solid waste generation is 56.5 MT/day out of which 24 MT/day is from domestic sources, 20 MT/day is from commercial sources and remaining 12.5 MT/day is from other sources which include education institutions, hotels and restaurants.

The city consists of total 28 number of wards out of which ward no 23 is taken for route optimization purpose. One of the reasons to take this area under considerations to study is that, it has about waste generation of about 7.46 metric ton per day which is about 13.2% of total MSW generated in the city. According to current situation the ward no 23 has a population of 10567 people and no. of houses are 2449.

The selection of this ward for the study is mainly motivated by the introduction of waste-collection services to households in the urban area more efficiently as it has complicated routing and it was difficult for waste collectors to navigate through this route without use of GIS as compared to the other wards that presently exists in the city. As the waste generated in this area is of various types it also helped in exploring the different aspects for collection.

This area consists of various elements such as domestic houses, educational institution, hospitals, hotels and restaurants which allowed us to explore problems that were arise during collection of the waste due to the various aspects associated with it.

Reducing the expenses and economic budget was another principal which resulted into selection of the area for the study as it has a crowded density of domestic houses and most the route are not connected which causes in increasing the transportation expenses.

II. DEFINATION OF MUNICIPAL SOLID WASTE MANAGEMENT

Municipal solid waste (MSW), also called Urban Solid Waste, and is a waste type that includes predominantly household waste (domestic waste) with sometimes the addition of commercial wastes, construction and demolition debris, sanitation residue, and waste from streets collected by a municipality / ULB within a given area. They are in either solid or semisolid form and exclude industrial hazardous wastes and bio-medical waste.

MSW can be broadly categorized into four broad categories such as:

1) *Biodegradable Waste:* food and kitchen waste, green waste (vegetables, flowers, leaves, fruits), paper (can also be recycled).
2) *Recyclable Material:* paper, glass, bottles, cans, metals, certain plastics, etc.
3) *Inert Waste:* construction and demolition waste, dirt, rocks, street sweeping, drain silt, debris.
4) *Domestic Hazardous waste (Also Called "Household Hazardous Waste") & Toxic Waste:* medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish.

III. GAP IN EXISTING SWM OF YAVATMAL CITY

A. Collection and transportation system is incompatible, therefore manual and multiple handling becomes inevitable.
B. The quantity of waste transported as well as the operation hours of each vehicle is not measured.
C. Size and location of Bins are not decided appropriately.
D. Waste through open vehicles and mixed form is transported.
E. Crews have not assigned route boundaries.
F. Crews maps are not been updated in past two years.
G. Collection services supervisor doesn't know how many stops and containers are included in each individual route.
H. Collection services supervisor doesn't know how long each route should take.

These above all points gave us a good indication that operations are not efficient and optimizing the waste collection routes could be beneficial. A municipal solid waste management system, which consist of 50 to 60 % of total solid waste collection & management expenditure, can be reduced by carrying out route optimization only. If route optimization is performed in solid waste collection process, total expenditures will get decreased.

IV. WHY Q-GIS

The use of the GIS allows the user to create, arrange, treat and analyse the geographical information. Geographical Information Systems enable the reader to visualize, and interpret data for a better understanding of relationships, trends and patterns. Massie (1995) adopted GIS for improving MSWM programs.

Q-GIS is a free open source software, designed to allow users to collect, manage, analyse and retrieve large volumes of spatially referenced data.

The use of the GIS allows the user to create, arrange, treat and analyse the geographical information. Q-GIS is an open source software and it is user friendly. Doesn't need higher configuration and also gives faster output.

Best possible routes for solid waste collection were identified based on the information obtained with the help of the Q-GIS regarding the possible routes, and having taken into account the restrictions to the road conditions and topography. The routes were chosen in a way that the resources used for the collection, the length of the route and the time taken to complete the collection is minimized.

For generating the optimal routes for the solid waste collection, the following data were required:

1) Study area boundary.
2) Name of the roads and their width.
3) Traffic volume details.
4) No. of storage bins and their location.
5) Capacities of the bins.
6) Time taken for collection of solid waste per bin.
7) Type of vehicles used and its capacity.
8) Existing run routes for the compactor vehicles.
9) Fuel consumption of the compactors.

V. METHODOLOGY

A. Locating the Boundary of Ward-23

In order to get the entire idea about the boundaries of all the wards present in the city, firstly we get a ward map of our city from the local Municipal Corporation (MNC). Then we selected a particular ward for which we have to optimize the routes. After selecting a particular ward, we drawn the boundary of that particular ward in Google Earth software and save it in KML file format.

B. Installing Required Plugins in Q-GIS Software

1) *Quick Map Services:* A plugin that makes work with web-based base maps easy. This plugin provides convenient list of services plus search for finding datasets and base maps.
2) *ORS Tools:* ORS Tools provides access to most of the functions of openrouteservice.org, based on Open Street Map. The tool set includes routing, isochrones and matrix calculations, either interactive in the map canvas or from point files within the processing framework. Extensive attributes are set for output files, including duration, length and start/end locations.

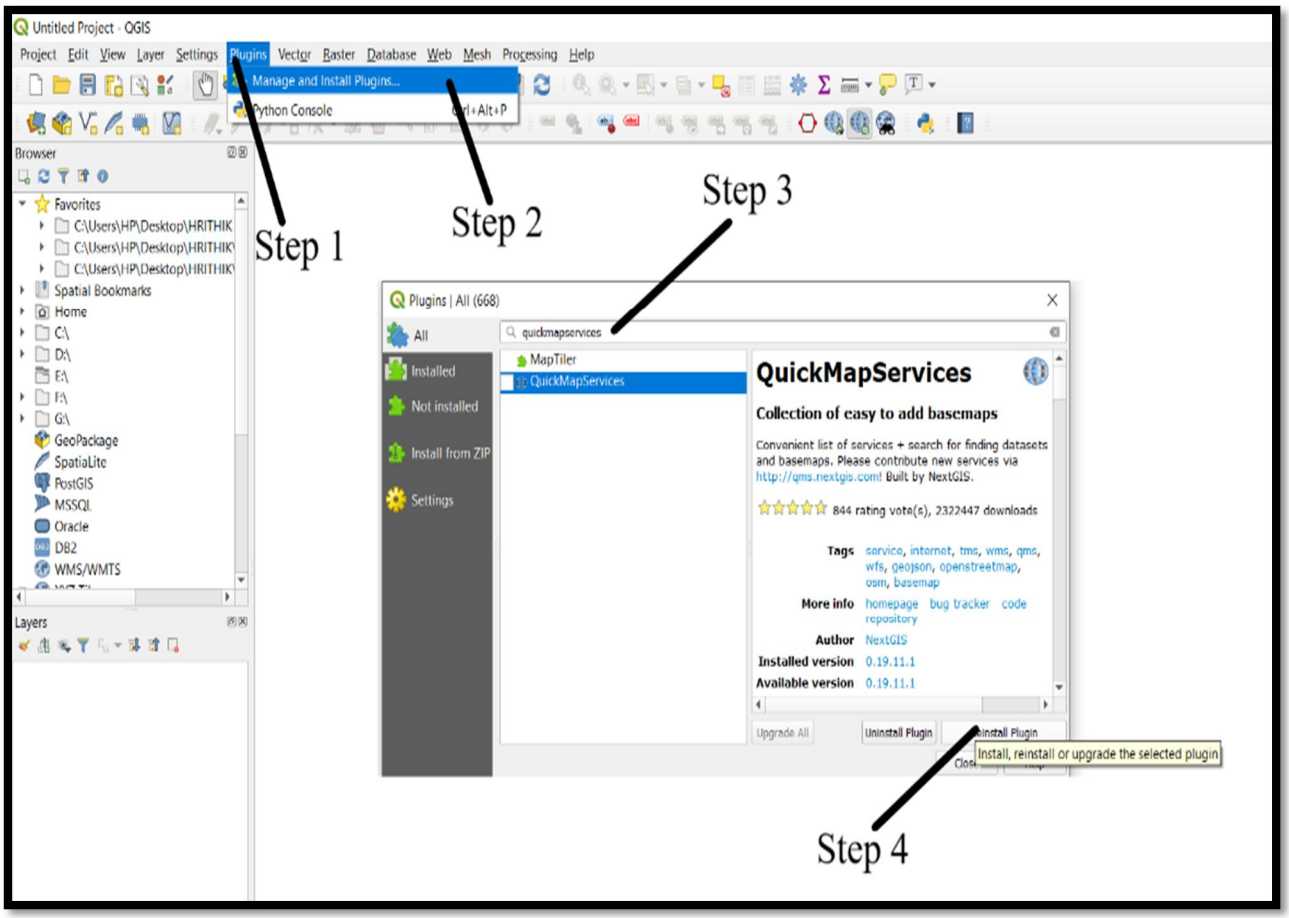

Fig. 1 Installation of Plugins

C. Importing KML File in Q-GIS Software

The KML file in which we have drawn the boundary of particular ward that KML file we need to import in our software called Q-GIS 3.10.

1) Steps to Import KML File

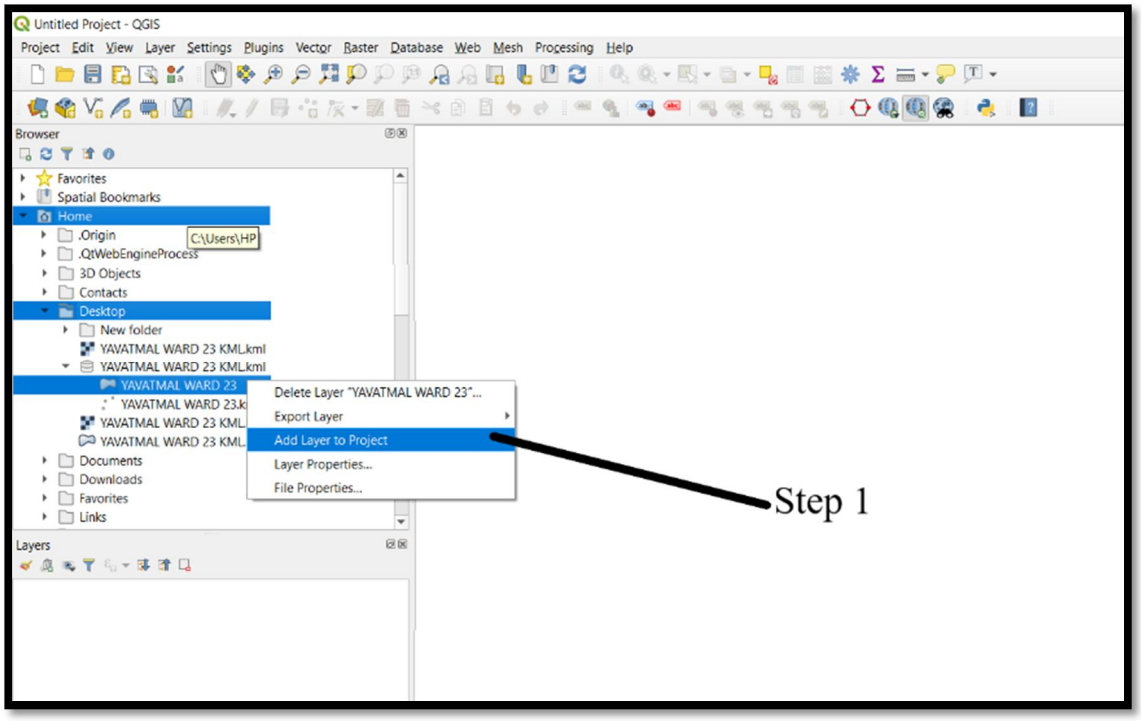

Fig. 2 Importing KML File in Q-GIS Software

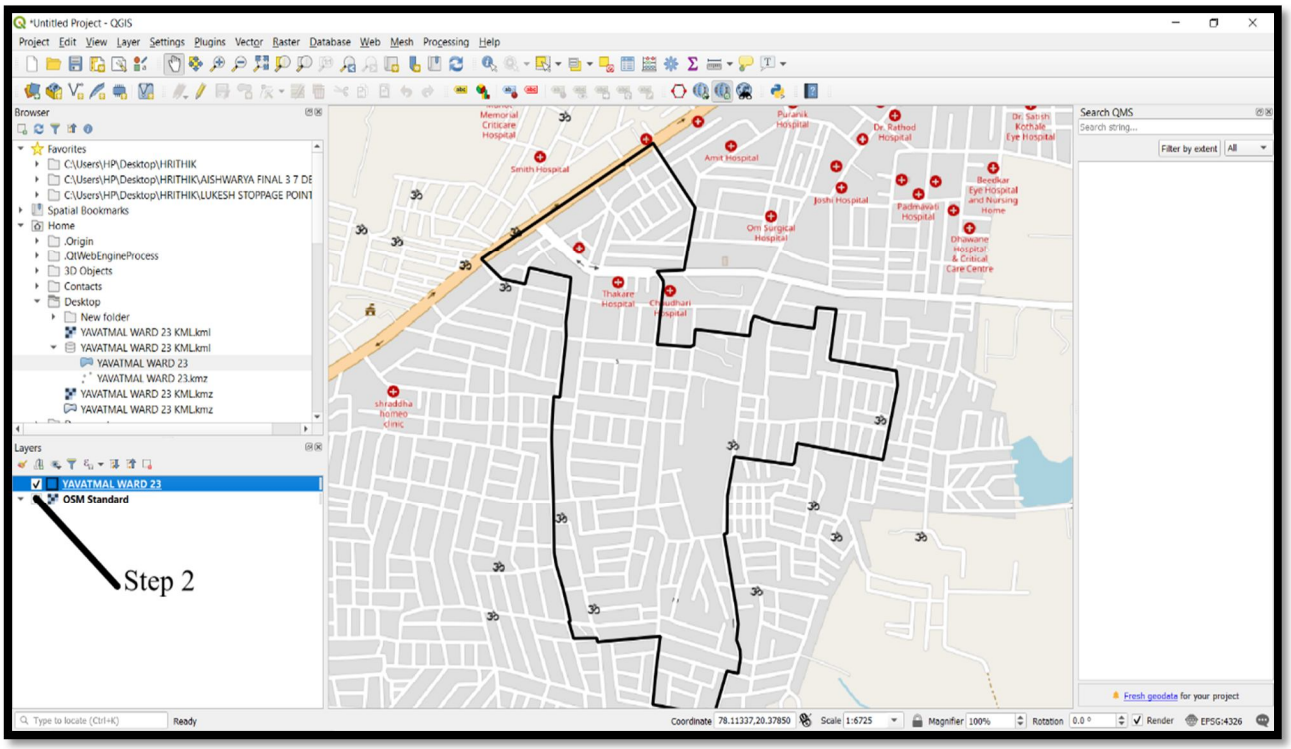

Fig. 3 Turning on Layer of Imported KML File

D. Dividing Particular Ward in Two Parts

As per the information that we got from local MNC, two vehicles are provided in each ward for the solid waste collection purpose. As two vehicles are going in ward, we need to divide the particular ward in two parts so that both vehicles will have their own boundaries in that ward.

The division of a particular ward is done in two parts manually by using line layer in Q-GIS software itself, keeping in mind that both the vehicles should cover same distance in that particular ward.

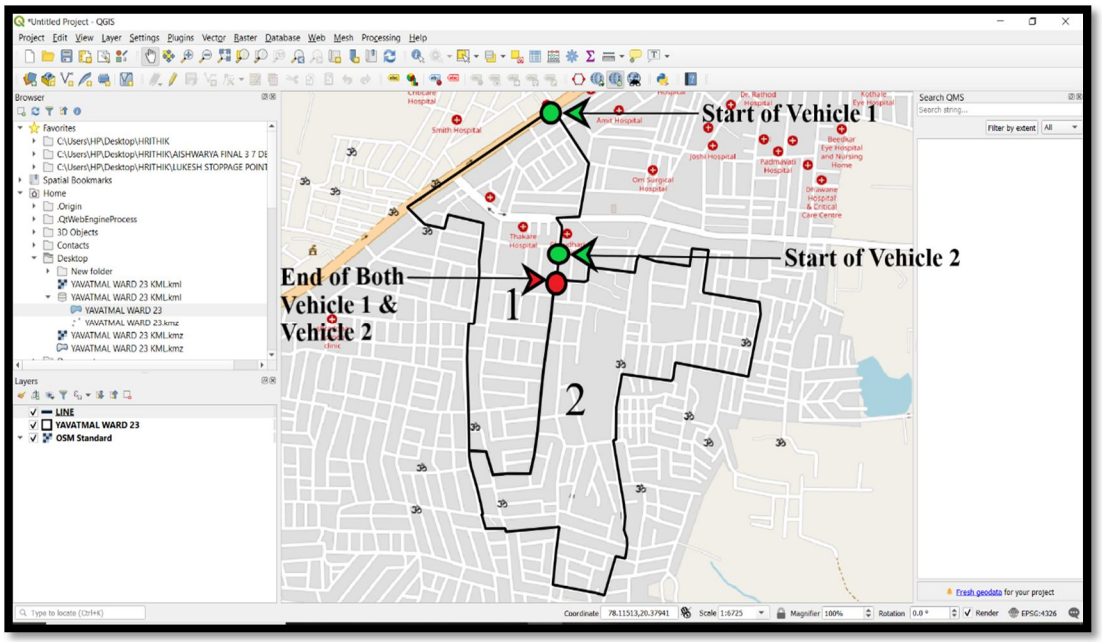

Fig. 4 Division of Ward in Two Parts

E. Optimizing Routes of a Ward by Using Plugin

ORS Tools is the best plugin that we get in Q-GIS Software, which allows us to select maximum 50 points on the routes and by running that plugin it gives us either shortest or fastest route with directions according to our choice.

1) Steps for Optimizing Routes

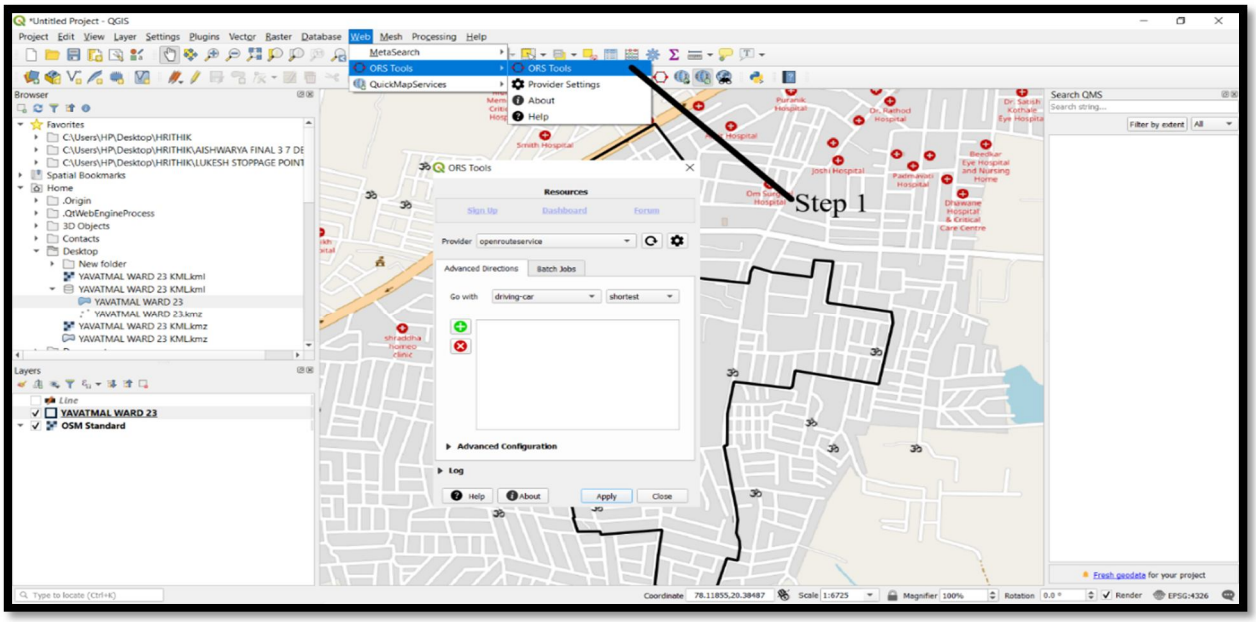

Fig 3.5: Selecting ORS Tool Plugin from Tool Bar

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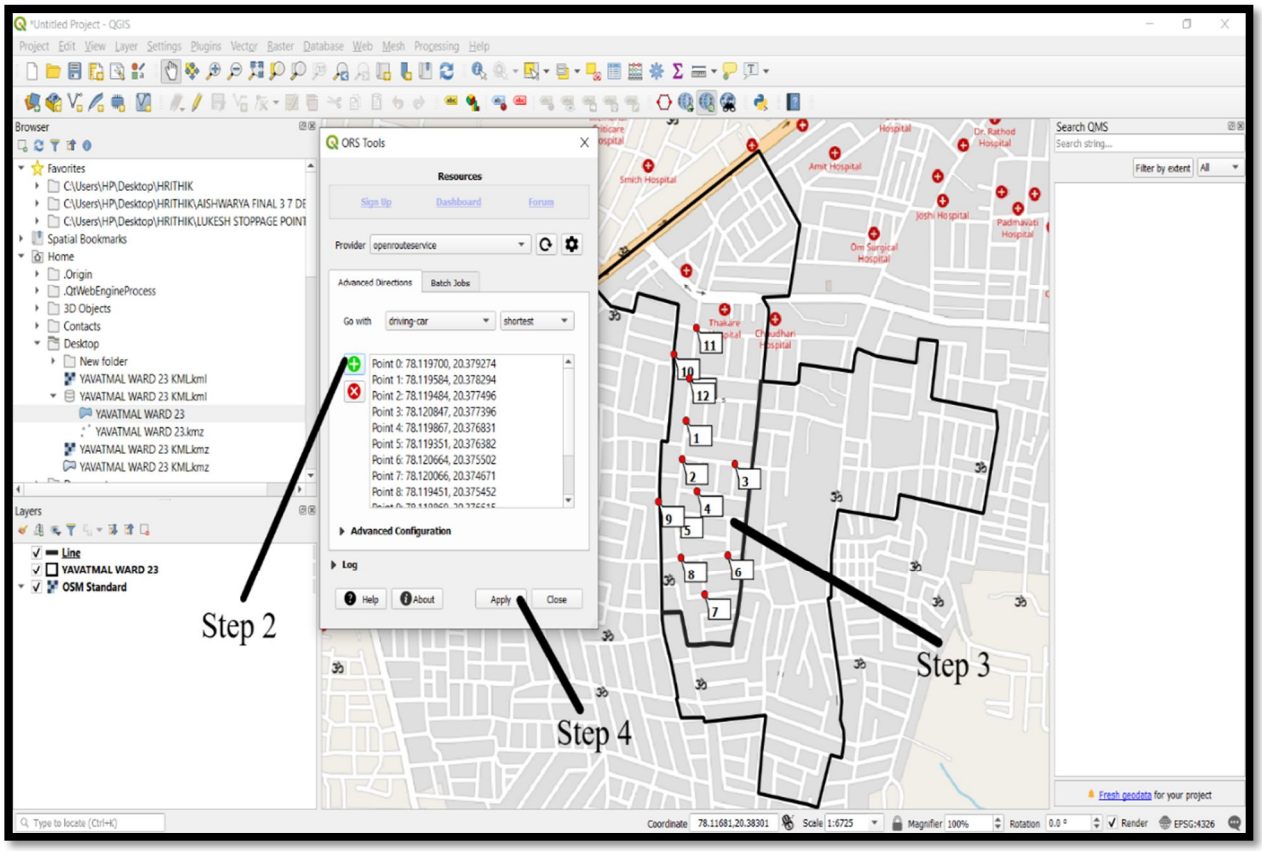

Fig 3.6: Selecting Different Points on Route Using ORS Tool

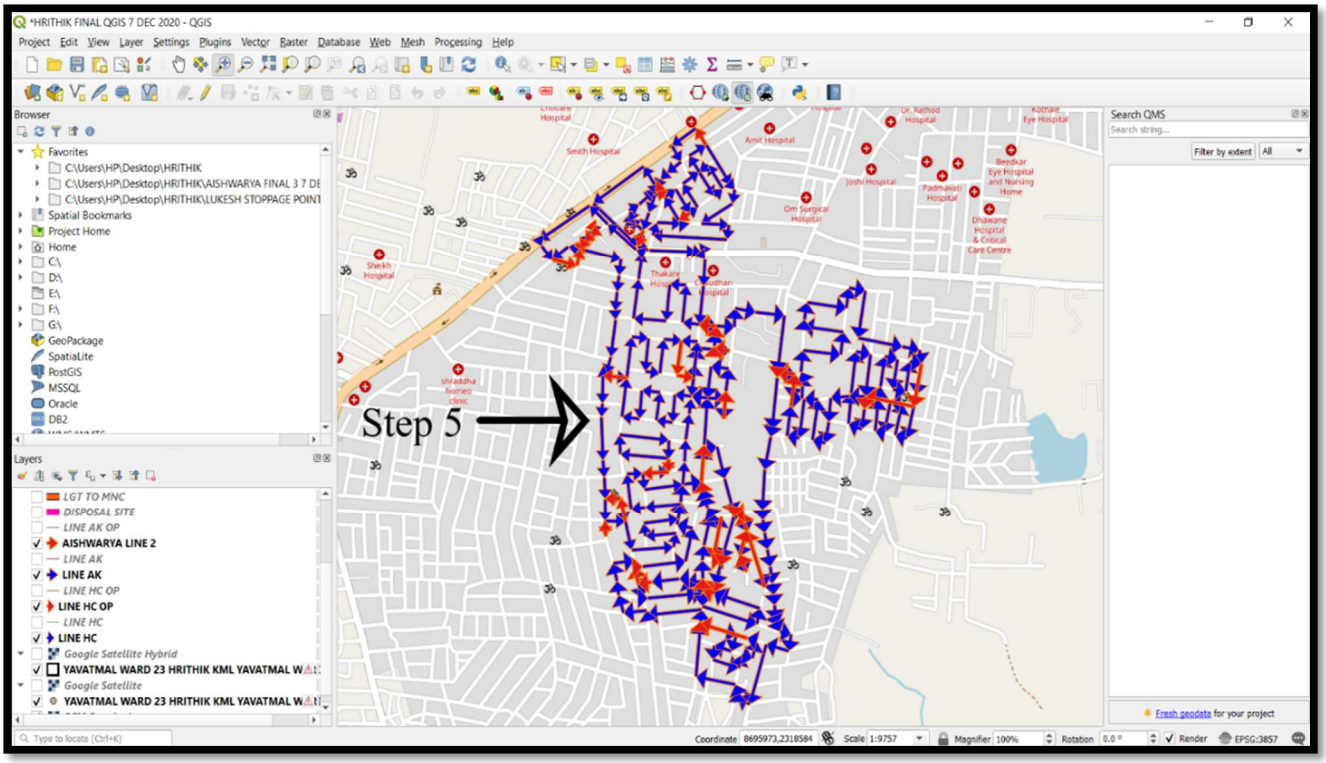

Fig 3.7: Optimized Route Find Out by Q-GIS Software Using ORS Tool

F. Locating Stoppage Points

Stoppage points are created in Q-GIS software by creating a new shape-file layer in it. With the help of new shape-file layer we can create point geometry type layer, with the help of which we can locate points on routes which are considered to be stoppage points for two vehicles in that particular ward.

1) Steps for Locating Stoppage Points

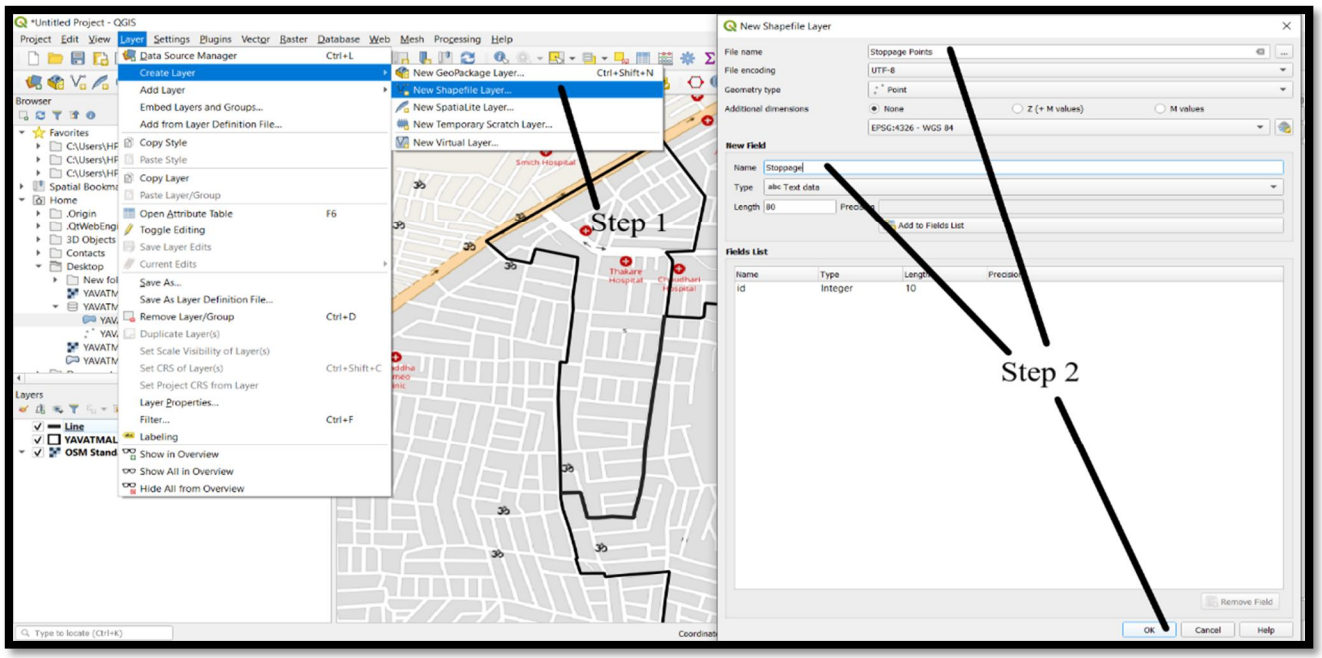

Fig 3.8: Creating New Shape File Layer of Point Geometry Type

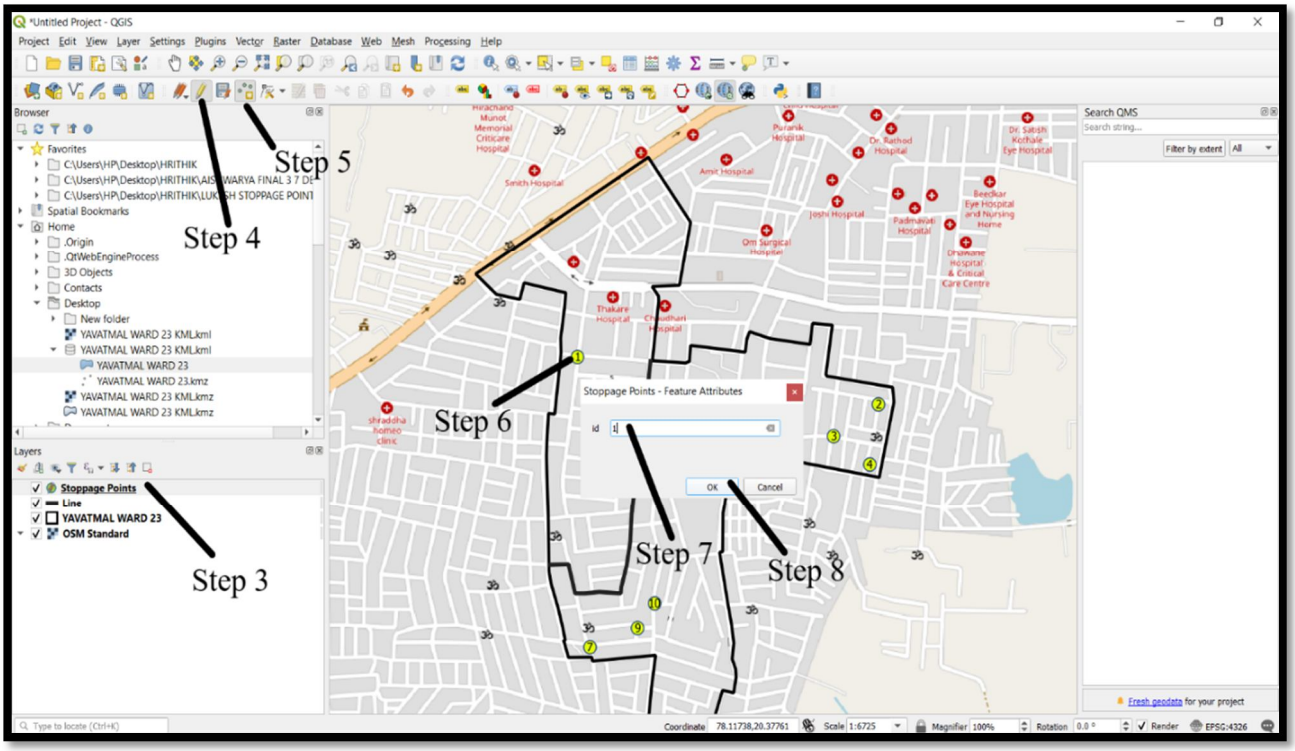

Fig 3.9: Creating and Locating Stoppage Points

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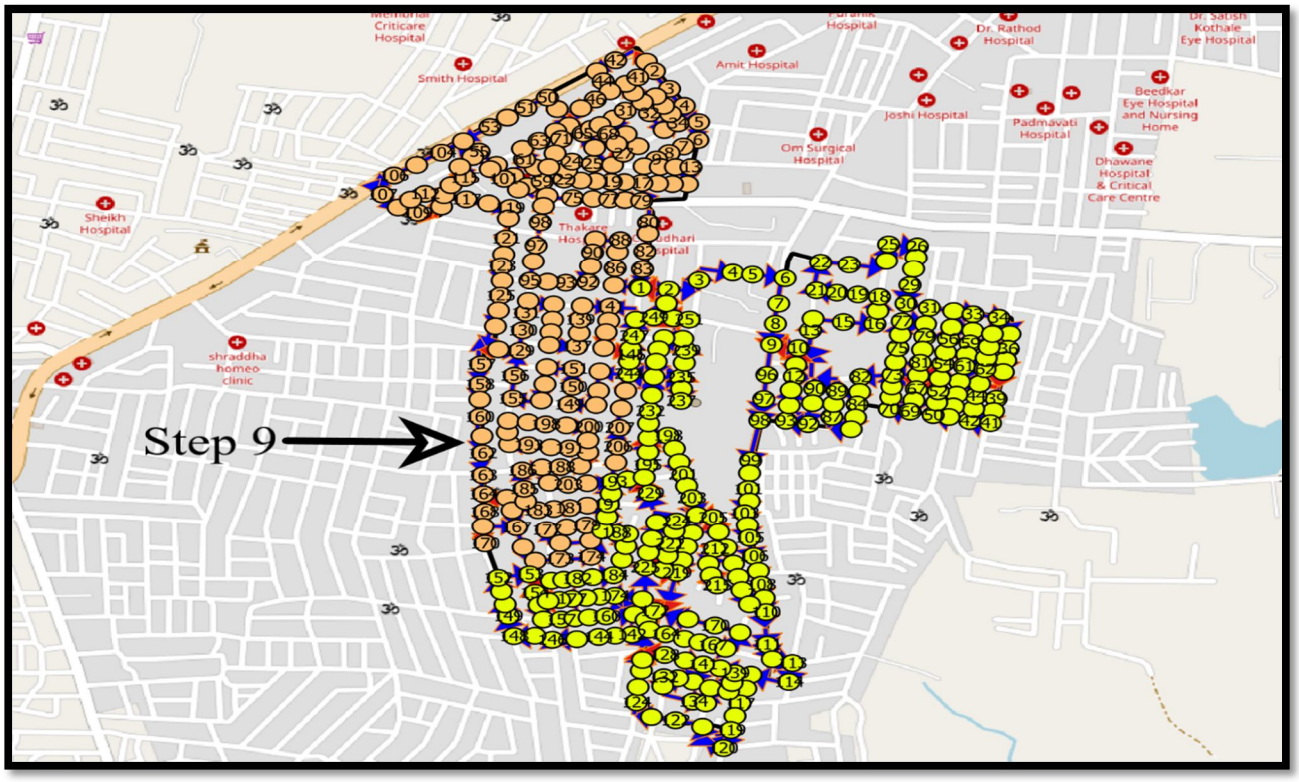

Fig 3.10: Locating Number of Stoppage Points

G. Creating Attribute Table

Attribute table is a table in which both distance that should be travelled by a vehicle and the corresponding cost is given. Steps to create Attribute table for Calculating Distance:

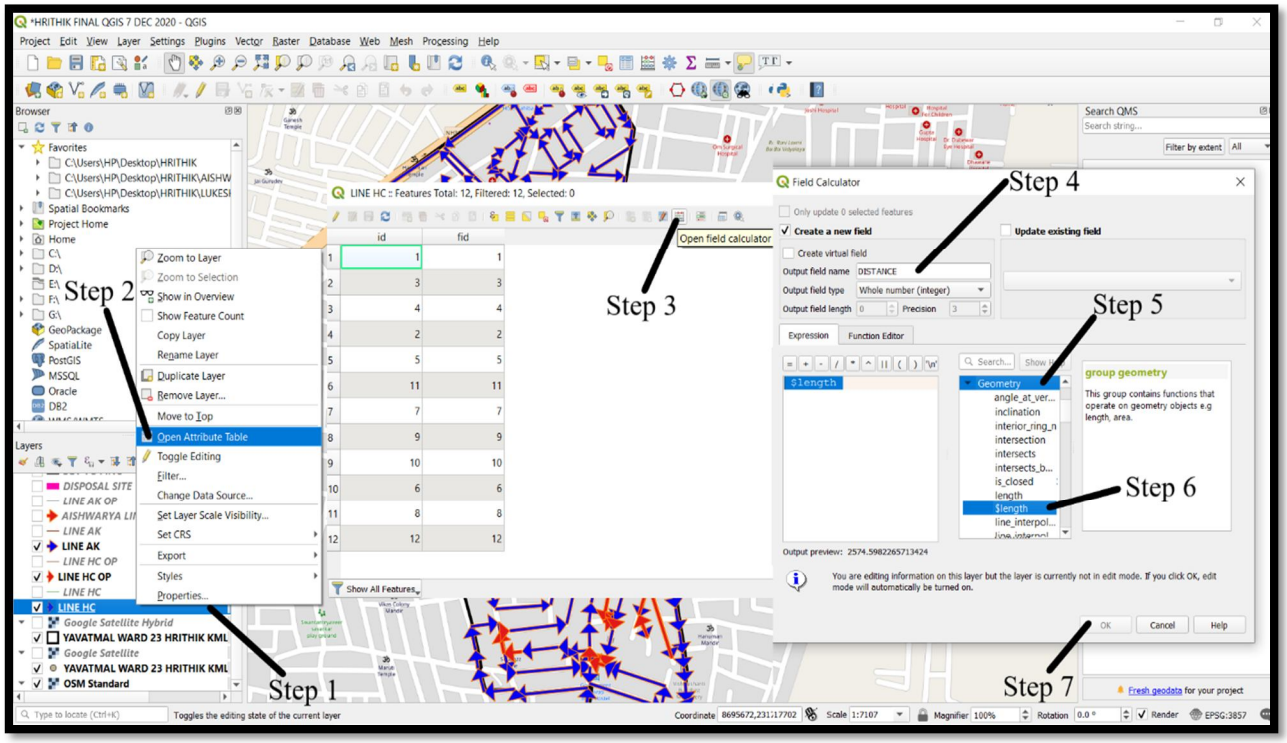

Fig 3.11: Creating Attribute Table for Calculating Distance of Each Route

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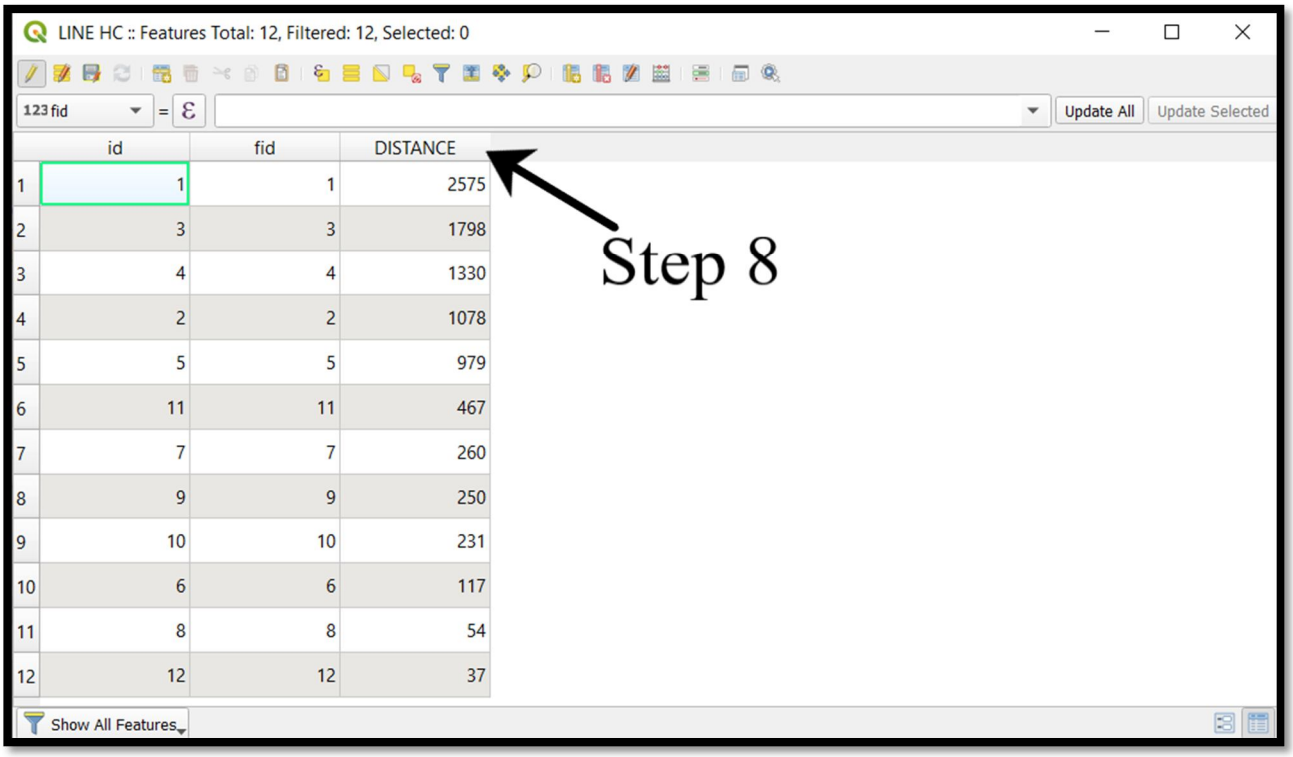


	id	fid	DISTANCE
1	1	1	2575
2	3	3	1798
3	4	4	1330
4	2	2	1078
5	5	5	979
6	11	11	467
7	7	7	260
8	9	9	250
9	10	10	231
10	6	6	117
11	8	8	54
12	12	12	37

Fig 3.12 Formation of Table of Distance

1) Steps to Create Attribute Table for Calculating Cost

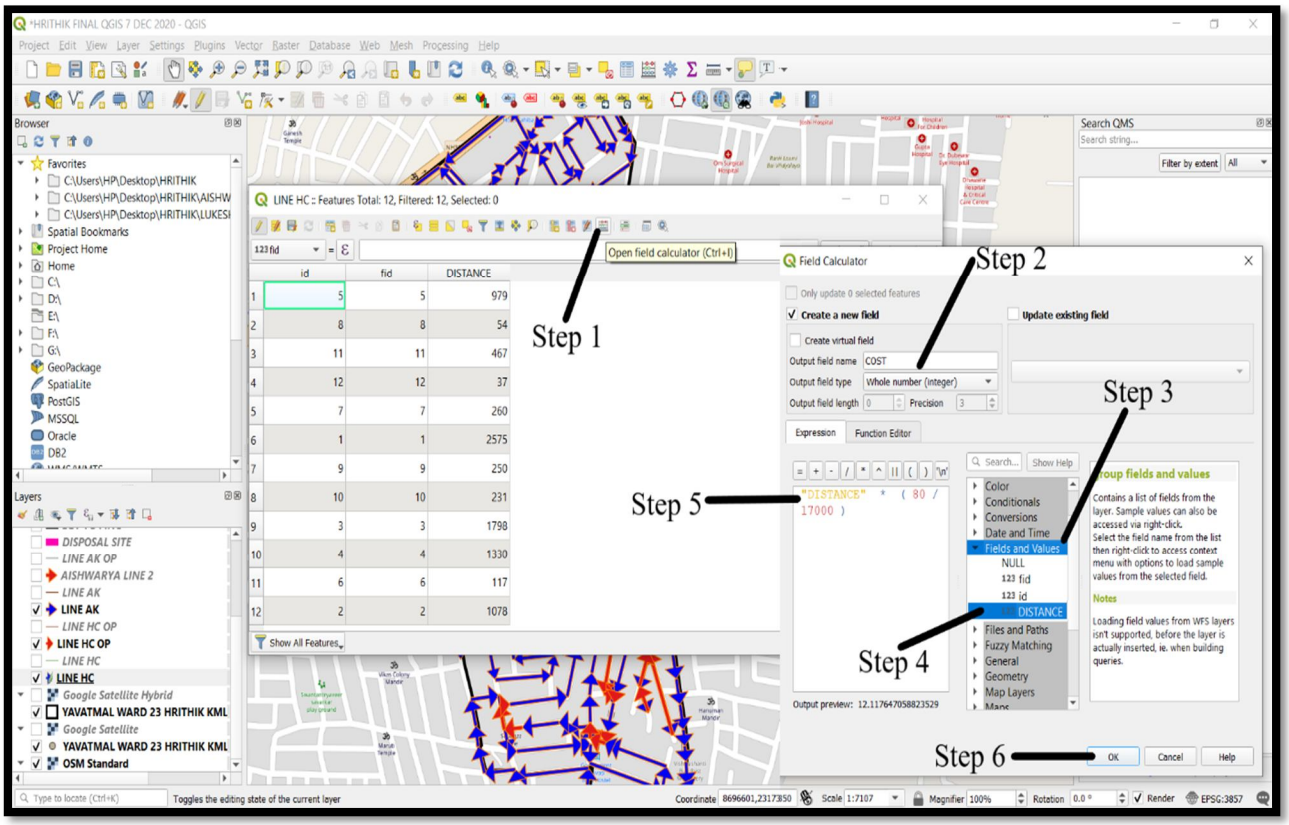
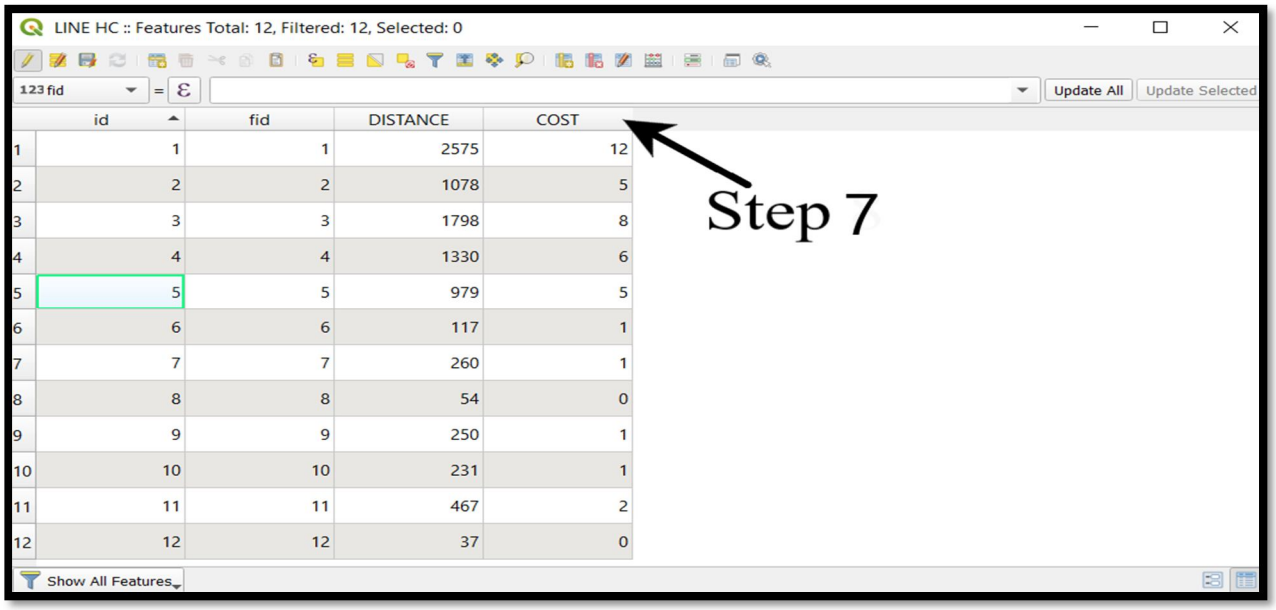


Fig 3.13: Creating Table of Cost Required



	id	fid	DISTANCE	COST
1	1	1	2575	12
2	2	2	1078	5
3	3	3	1798	8
4	4	4	1330	6
5	5	5	979	5
6	6	6	117	1
7	7	7	260	1
8	8	8	54	0
9	9	9	250	1
10	10	10	231	1
11	11	11	467	2
12	12	12	37	0

Fig 3.14: Formation of Table of Cost Required

This is how we carried out our methodology to optimize the routes of ward no. 23 of Yavatmal city for solid waste collection and transportation. Based upon the outputs that we got from the Q-GIS software, we calculated distances and the corresponding cost required for those optimal routes for solid waste collection and transportation by preparing an attribute table.

VI. RESULTS

With this GIS technique, optimum route was identified which found to be cost efficient when compared with the existing run route. The optimal route obtain by Q-GIS for both vehicle 1 and vehicle 2 are 29 km and 31 km. The cost for these operation for both vehicle 1 and vehicle 2 are 6,885 rupees per month, 83,768 rupees per year and 7,140 rupees per month, 86,870 rupees per year respectively. The cost is save up to 31.25 % per year. The software based analyses is quick and easy to understand as compared to manual analyses. So software based analyses also the good option for these type of study.

PARTICULARS	VEHICLE 1	VEHICLE 2
No. of Stoppage Points	209	252
Travelling Distance to Cover Up Entire Ward	9.2 Km	10.8 Km
Total Travelling Distance from start to End	29 Km	31 Km
Diesel Required	2.7 litres/day	2.8 litres/day
Monthly Cost	Rs.6,885	Rs.7,140
Annual Cost	Rs.83,768	Rs.86,870

PARTICULARS	VALUES
Present Annual Cost	Rs.2,48,200
Annual Cost After Optimization	Rs.1,70,638
Cost Saved	Rs.77,562
Saved Cost Percentage	31.25%

The above result that we got, demonstrates the effectiveness of GIS technology in optimizing the waste collection and transport routes to achieve time and distance savings, eventually resulting in a most economic transport model.

VII. CONCLUSIONS

The present study clearly explain the approach followed for the optimization of routes in ward no. 23 of Yavatmal city for solid waste collection and transportation. GIS has proven to be a powerful tool for the route optimization for solid waste collection and transportation. The study confirm the choice GIS provides an unbiased methodology and has the ability to optimize and change relevant variables in solving such problem. It demonstrates the effectiveness of GIS technology in optimizing the solid waste collection transport routes to achieve time and distance savings eventually resulting in a most economic transport model. As a result the cost saved after optimization is around Rs.77,562 which is equivalent to 31.25% of saving compared to existing expenditure spent on ward 23 for solid waste collection and transportation. The results obtained from this pilot study are encouraging to expand the scope to cover entire city for optimization of the routes for solid waste management and collection. In addition to cost deduction, as more and more communities are moving toward mandatory recycling of materials, the route optimization will provide opportunities for separate collection of recyclable waste using same logistic and equipment. This will reduce the reliance of city councils to disposal sites and increase disposal sites operational life. The GIS network analysis proved to be powerful tool in determining the economical routes for waste collection. The results are in easily understandable format, this will help the local municipal authorities in implementing this kind of project for their solid waste management system. The local authorities can carry out solid waste collection and transportation management efficiently with the help of Q-GIS software.

VIII. ACKNOWLEDGMENT

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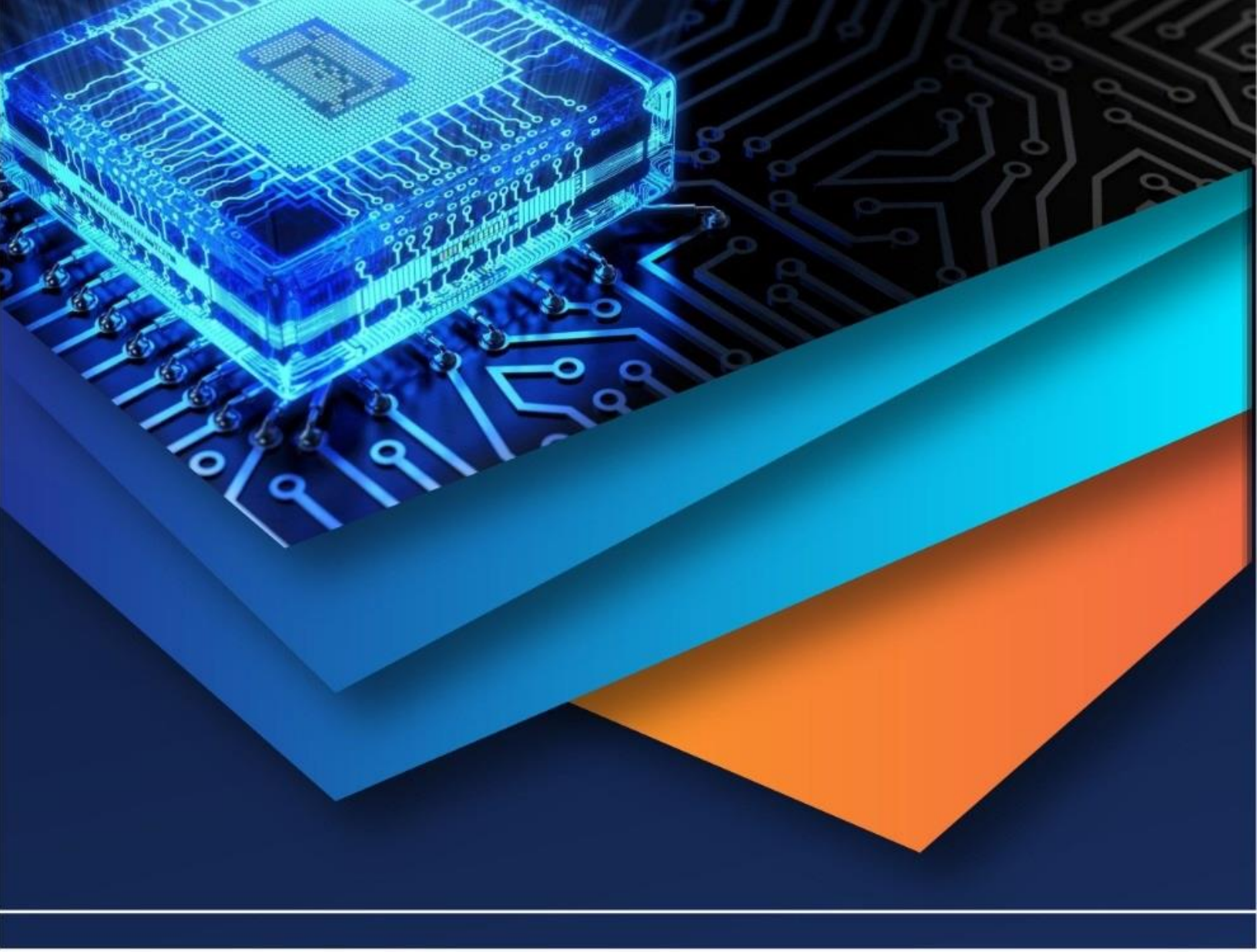

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