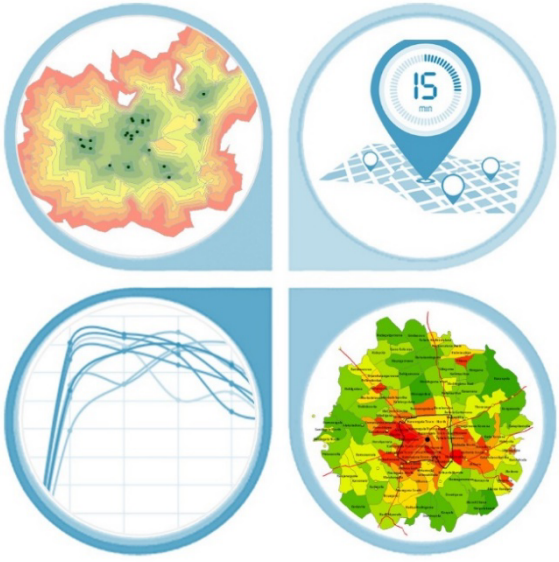
Curricula Enrichment delivered through the Application of Location-based Services to Intelligent Transport Systems

Co-funded by the Erasmus+ Programme of the European Union

Teaching & Learning Manual
Step-by-Step Guide:

Exploring Methodology for Evaluating Medium-Sized Cities' Progress Towards Achieving the 15-Minute City Ideal in Terms of Accessible Urban Services



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Description

This manual serves as an essential educational resource for both undergraduate and postgraduate degree programs, offering a detailed, step-by-step guide to Medium-Sized City's Urban service Profiling Designed to bridge the gap between theoretical knowledge and practical application, this guide is meticulously crafted to meet the needs of students, educators, and practitioners alike.

Within the manual, readers will find comprehensive instructions on using Google API data, employing GIS software to analyze spatial information, and interpreting this data to understand the distribution of city service points of interest (POIs) to pinpoint community-level shortages. It then explores the relationship between facilities and population within specific distance-based isochrones (considering walking distance). The manual not only enhances learning in academic settings but also equips industry professionals with the skills necessary to conduct advanced spatial analysis and contribute meaningful insights in their fields.

Whether you are a student aiming to study the proximity & accessibility of urban services in medium-sized cities, a teacher looking for robust educational tools, or a practitioner in need of refining your technical expertise, this manual offers invaluable guidance and support. It ensures that users at all levels gain proficiency in leveraging modern applications to explore urban service profiles of cities and study them effectively.

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1. INTRODUCTION TO TRAINING MANUAL

This training manual offers a comprehensive guide to analyzing whether Sri Lankan cities qualify as 15-minute cities, using software ARC GIS can substitute with open-source software QGIS and the Open-Source Data usage Google (OSM). The manual provides instructions on how to edit source code used for data extraction and utilize field mapping and graphical interpretations of the results.

The analysis starts by reviewing the distribution of city service points of interest (POIs) to pinpoint community-level shortages. It then explores the relationship between facilities and population within specific distance-based isochrones (considering walking distance). This involves examining the distribution of facilities relative to the population to assess whether the available facilities suffice for the population's daily needs. Measurements of proximity and accessibility are conducted using graph topology, forming the basis for further analysis. An analytical index, unique to each city, is developed to reflect its essential geographical characteristics. This index aids in categorizing cities and identifying potential enhancements to strengthen their regional roles. The manual is designed to be both expandable and replicable, allowing for the inclusion of more indicators to refine each city's index.

The manual is structured into three chapters:

- One: Introduction to the manual
- Chapter Two: Describes the four-step methodology used in the assessment, including examining city-level services with data collection, analyzing the interplay between services and population to identify underserved areas, calculating service availability within each buffer zone around facilities by determining the ratio of the number of facilities to the population and the distance from POI to the nearest facility POIs and evaluating city attractiveness through available categorized services using a gravity indicator, and, taking into account the proportions for each category of facility.
- Chapter Three: Annextures

Graphical representation of the facility to population Dispersion in a medium-sized city (Final Result)

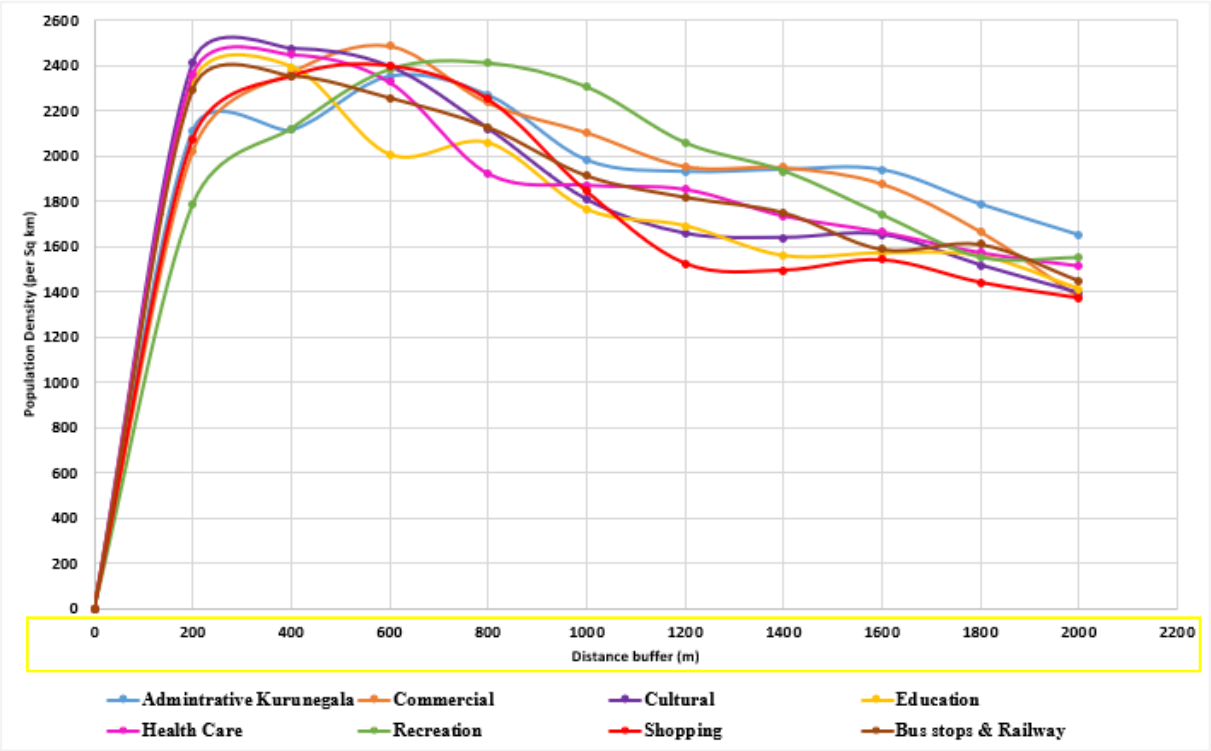


Figure 1:The proximity of residents to various facilities in Kurunegala city (starting from categorized services)

The Network Analyst tool examined service Accessibility of the city, for city residents. And explores the relationship between facilities to population dispersion within specific distance-based isochrones. Which Evaluates Medium-Sized Cities' Progress Towards Achieving the 15-Minute City Ideal in Terms of Accessible Urban Services.

2. OVERVIEW

The overall procedure presented here, provides a clear overview of the methodology and the sequential steps involved in the evaluation process.

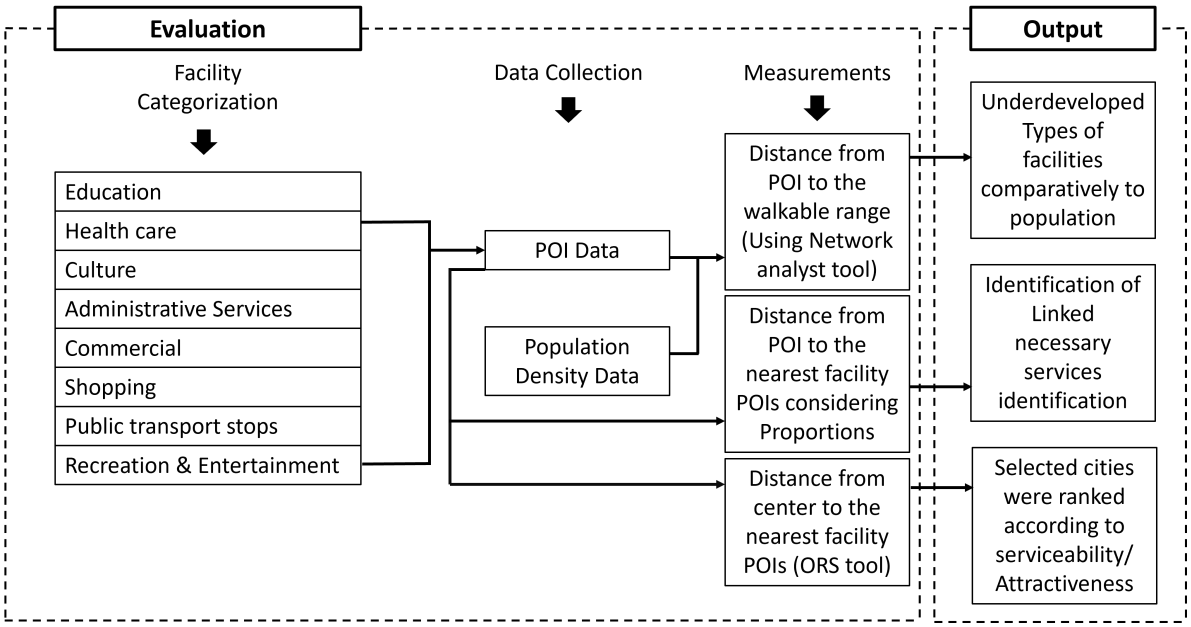


Figure 2: Entire process in a flow chart

3. Required Tools / Software

REQUIREMENT		
APPLICATION	• Softwares	• ARC MAP / QGIS PRIZREN 3.34 (Installed ORS Plugin) • Google Colab / Pycharm
DATA COLLECTION	• Web pages	• Google Cloud platform

4. DATA COLLECTION AND METHODOLOGY

To conduct the analysis, the overall methodological framework follows four basic processes.

I. First, the categorization of the services into eight categories; Administrative services, Commercial services, Cultural services, educational services, Health care services, Recreational services, Shopping services, and public transport services (Table 01), applicable to Sri Lanka referring to applicability and literature.

II. Second, POI data extraction using Google API and Google My Maps. The services available within a 2km radius of the city's major point of insertion have been selected.

III. The third step is to take the measurements of distances (isochrones) and time by considering speed by employing a network analyst tool.

IV. Fourth, calculated the service availability of each buffer zone around the facilities by determining the ratio of the number of facilities to the population, and distance from POI to the nearest facility POIs considering proportions for each category of facility.

V. Calculation of the city’s service attractiveness index.

4.1 Data categorization and collection

4.1.1 Data Categorization

The data categorization model for this manual was established after reviewing various studies on data categorization in cities worldwide that relate to 15-minute cites studies (Literature review). The categories identified can be adjusted based on the unique characteristics of each city or according to local priorities and preferences. The selected categories for this manual are as follows:

Attribute	**Facility**
Educational	Type 1A, 1B: Schools with GCE Advanced Level (A-Level) classes
	Type 1C: Schools with GCE Advanced Level (A-Level) art and commerce classes.
	Other schools
	Tuition classes
	Nursery
Health care	Government hospitals
	Private Hospitals
	Dispensaries
	Pharmacies
Cultural	Religious places
	Library
Administrative	Government institutions
	Administrative offices
	Post offices.
Commercial	Banks
	Financial institutions
	Restaurants
Shopping	Supermarkets
	Clothing centers
	Public markets
Public transport stops	Railway stations
	Bus stands & Nodal Bus stops
Recreation & Entertainment	Public parks & Playgrounds
	Indoor sports complexes & fitness centers
	Cinema halls

Table 1:POI Data Categorization and Sources.

Note: If there are preprocessed categorizations available within your local context, they can be used as substitutes for the current categorization.

4.1.2 Data Collection

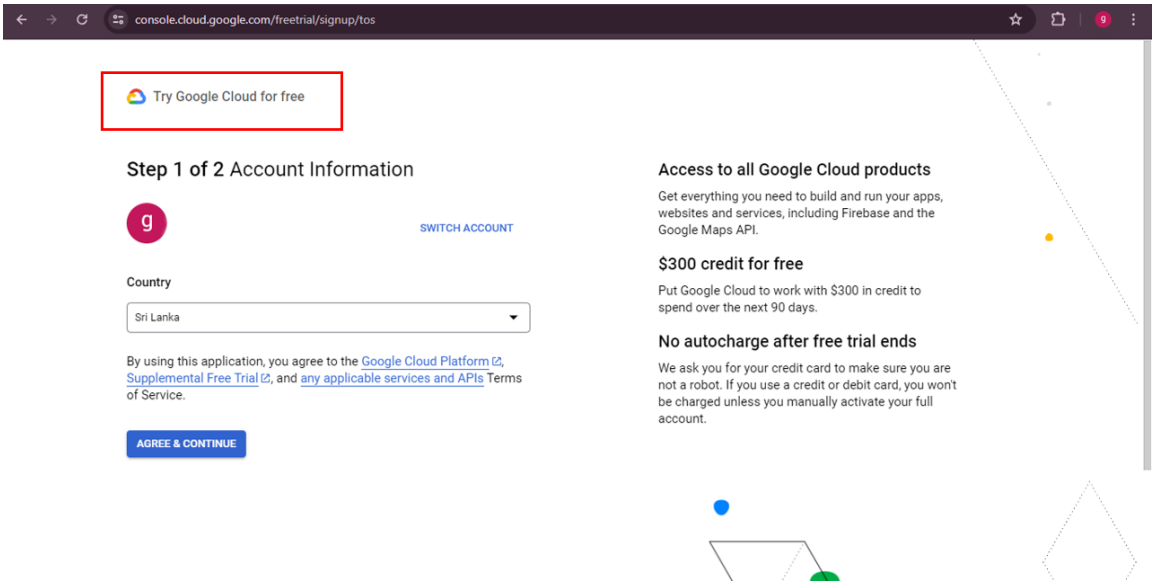
The initial step of the process is to collect the data. This data collection process entailed compiling information on diverse facilities within 2km buffers from the city center and organizing them into eight distinct categories. These included Administrative, Commercial, Cultural, Educational, Healthcare, Recreational, Shopping, and Public Transport services.

To ascertain the number of facilities in each category within a 2km radius, Point of Interest (POI) data and information from Google My Maps were employed. POI data encompasses geospatial coordinates and supplementary details such as names, categories, Coordinates (addresses), and contact information. For this study, POI data were sourced from the Google Maps Places API (accessed in December 2023). Since it's an electronic platform with different and unique features, we must create a unique Python code to extract the data from the website.

Step 01:

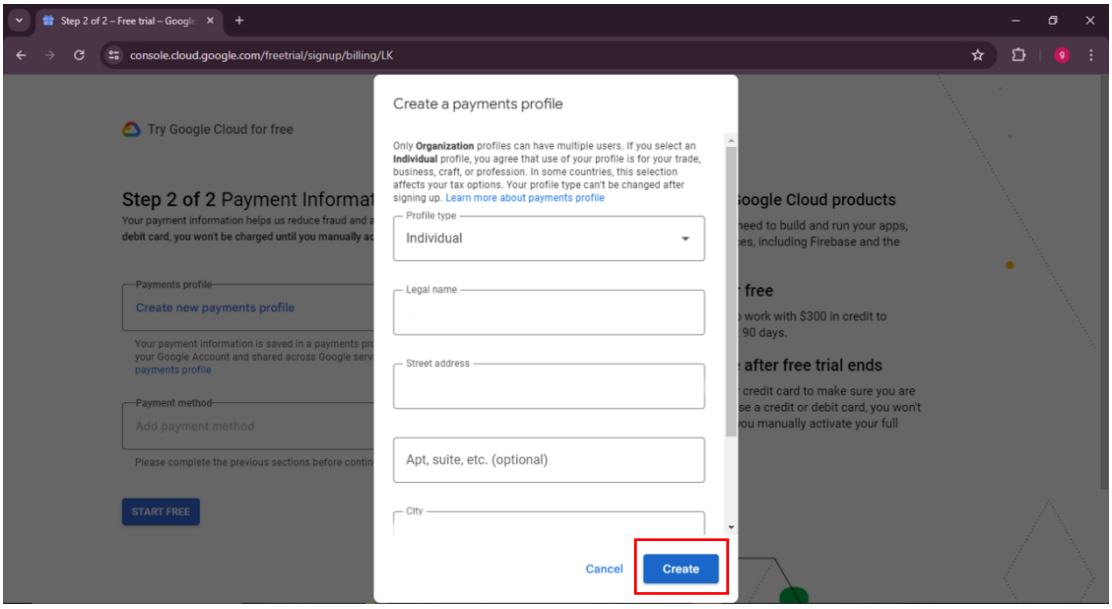
Creation of Google API key

1. Access Google Cloud Console: https://console.cloud.google.com/
   - Navigate to Google Cloud Console
   - Log in using your Google account

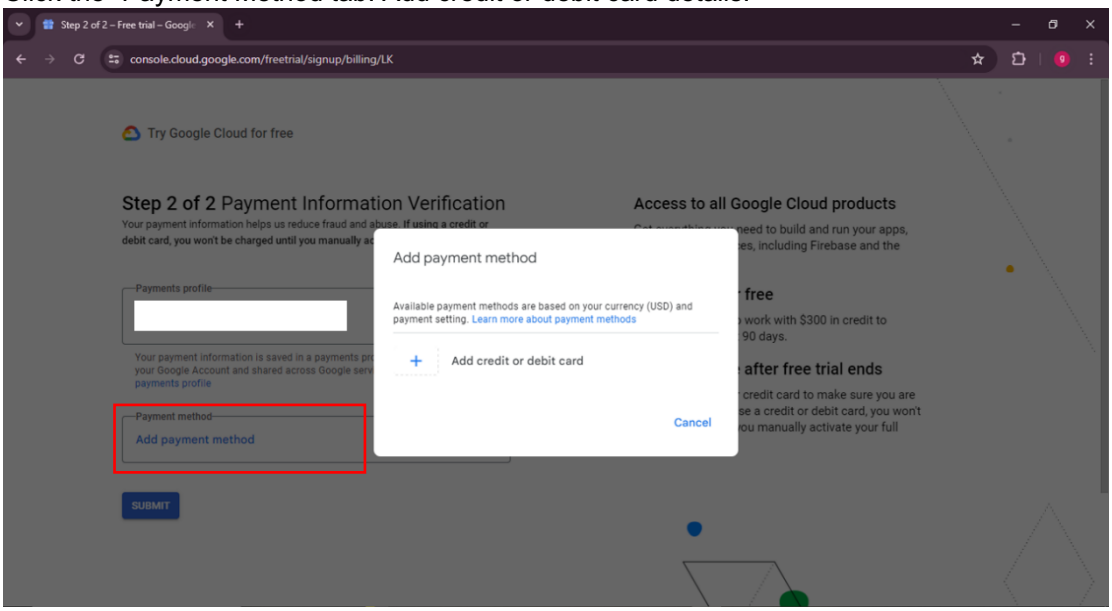


   - Select the option Try “Google Cloud Free” select the “Country” and Click “AGREE & CONTINUE”.

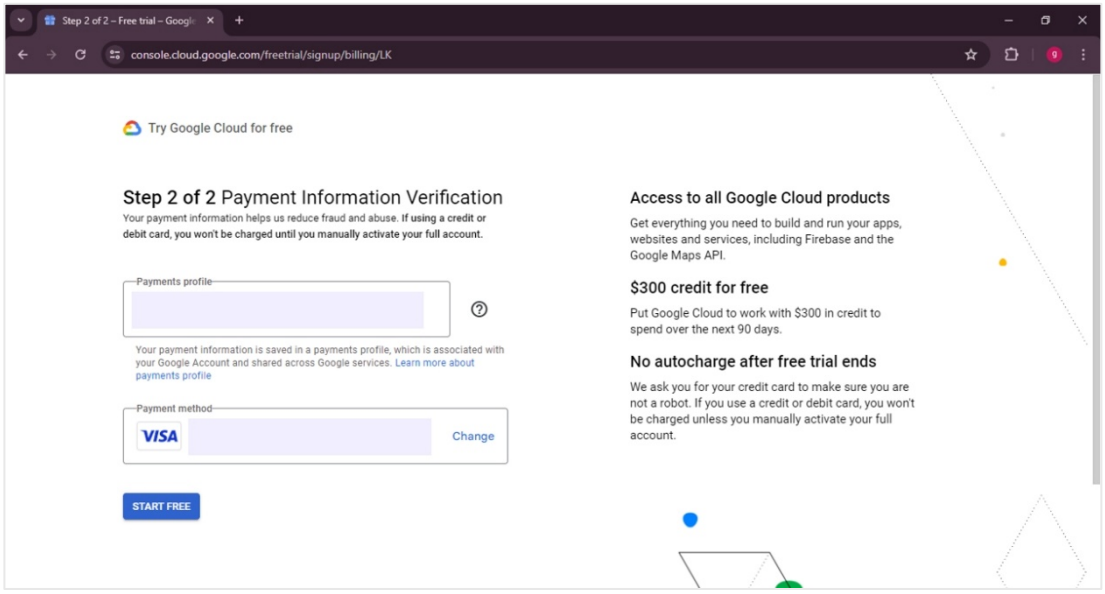
- Enter the legit data for the following questions, And click the Button “Create”



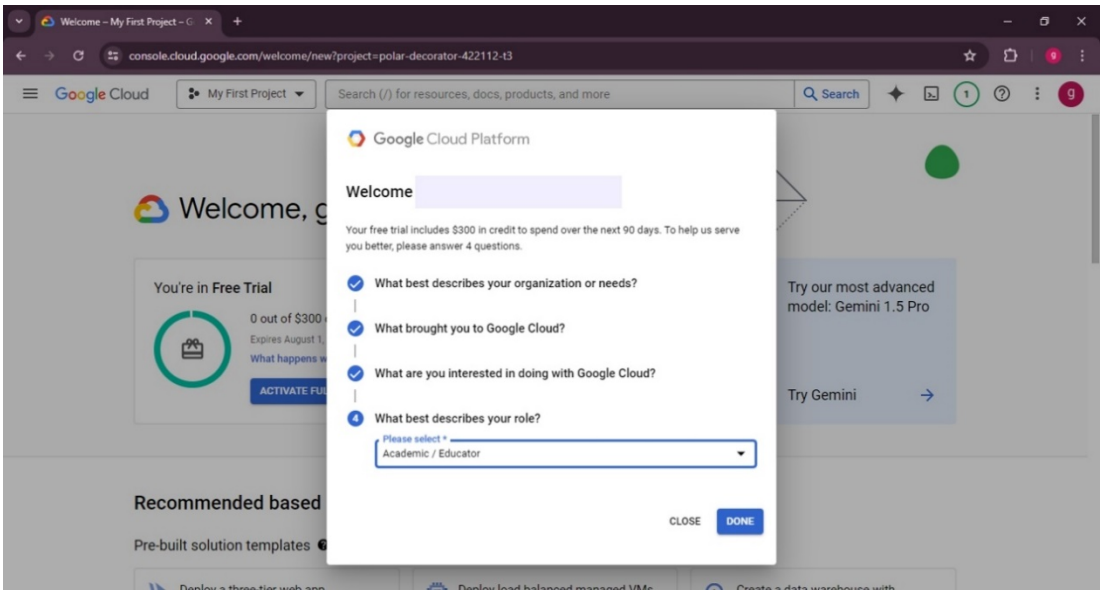
- Click the “Payment Method tab. Add credit or debit card details.



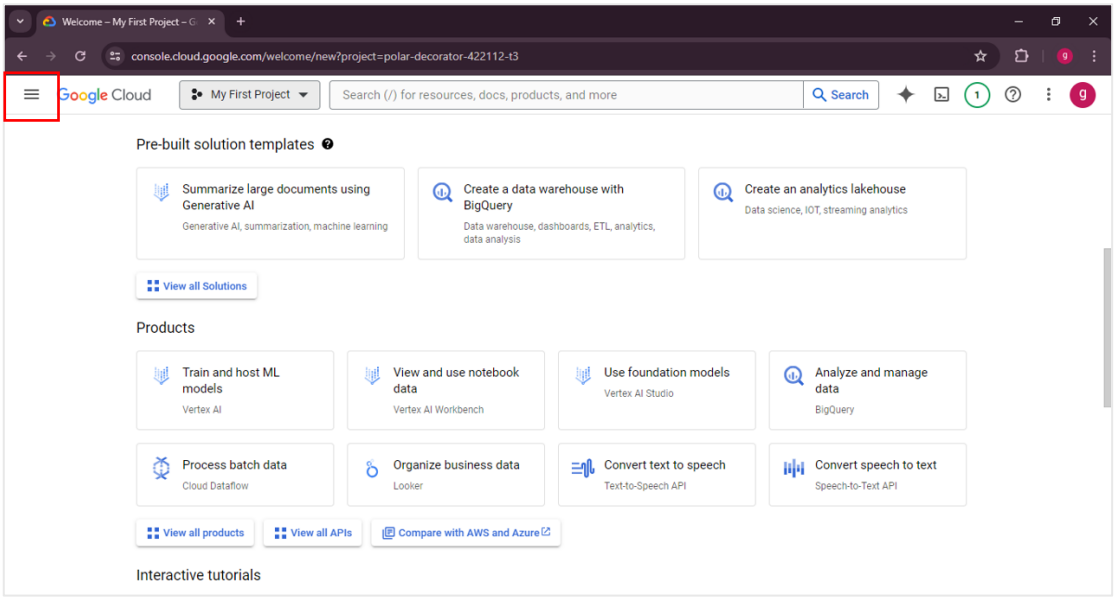
- The window will appear like this,



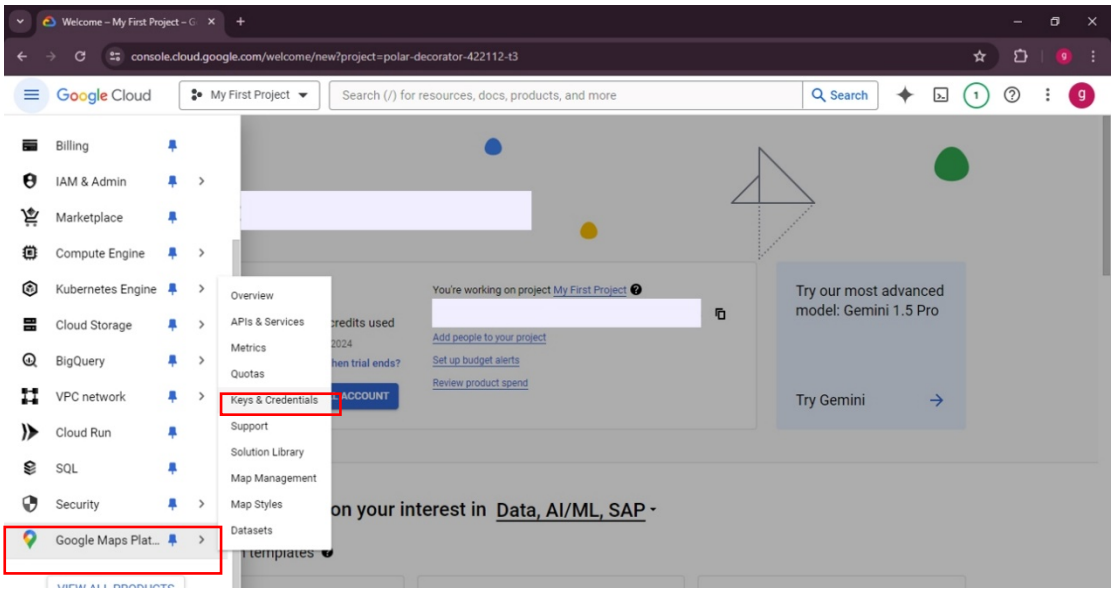
- Enter the legit data for the following questions, And click the Button “Done”



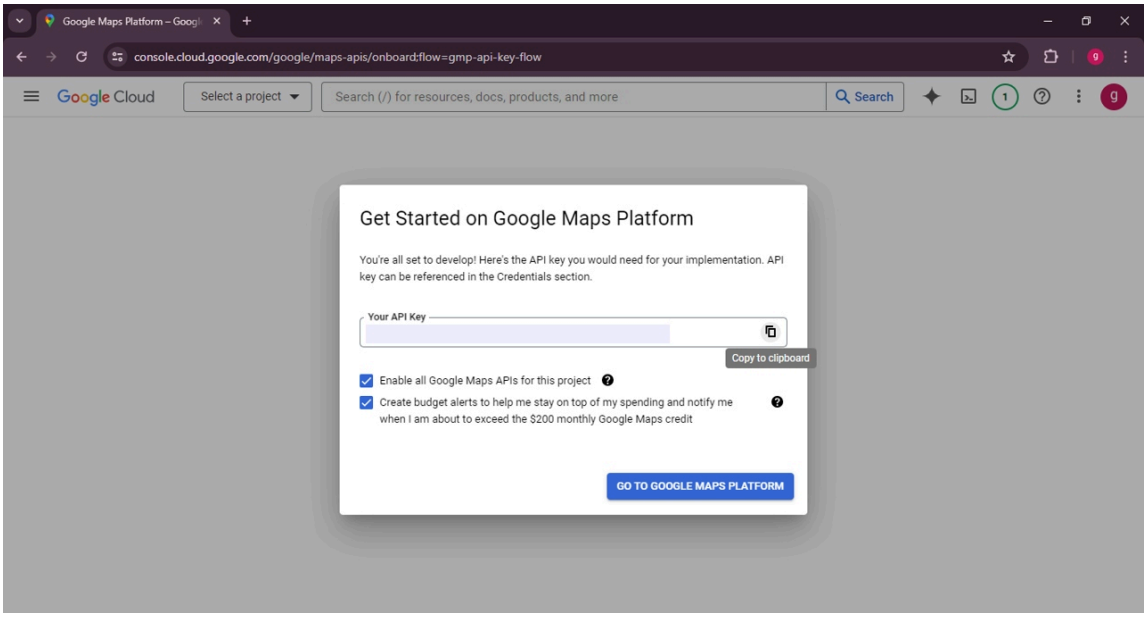
- You will open in to window like this, and click the icon at the upper left corner,



- From this drop down go to “Google Maps Platform” and Select “Keys and Credentials” where you will able to obtain the generated personal “API key”.



- Here copy the API Key on your “Clipboard”.

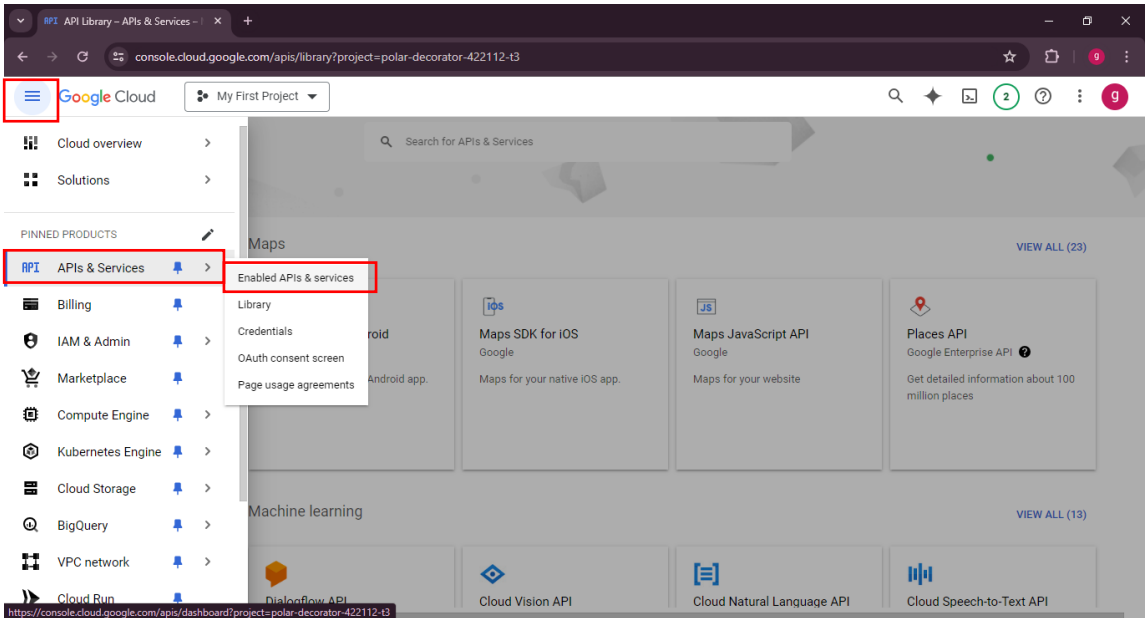


2. Document and Save the Key:

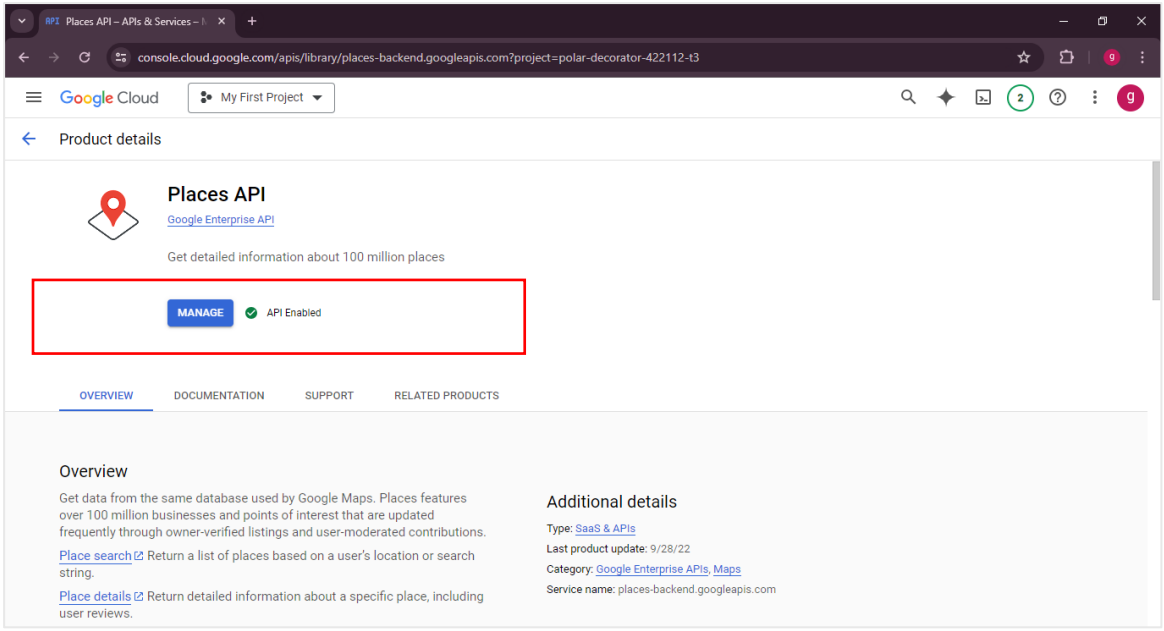
   Note down the key securely in a notepad.

3. Enable APIs:

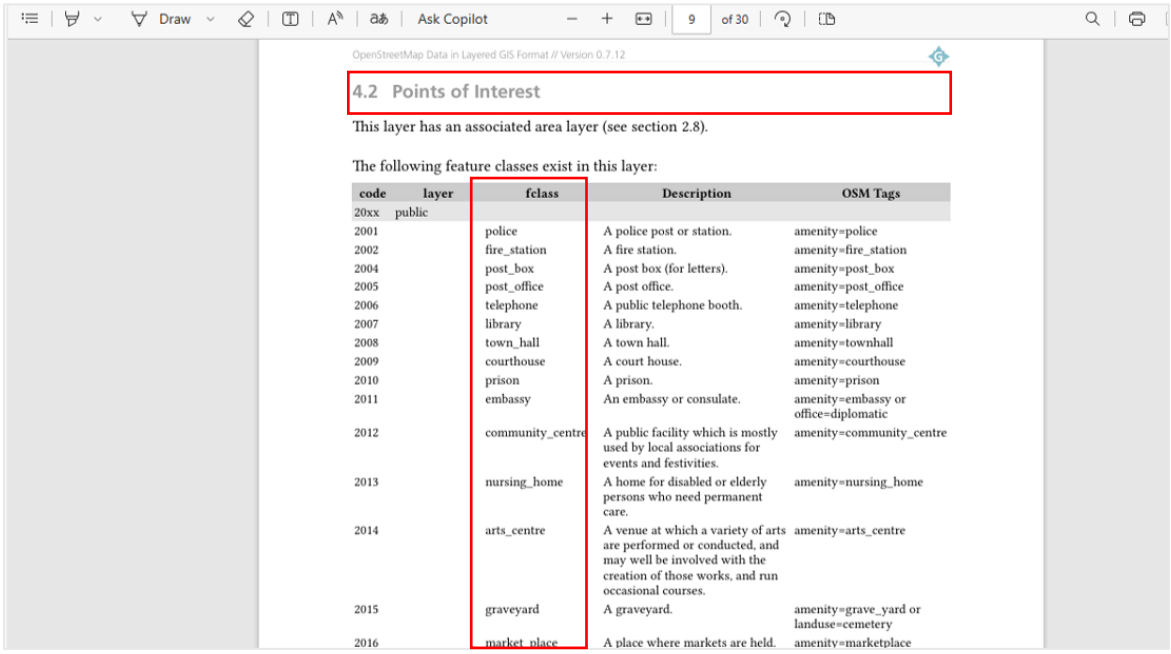
   - Go to “API & Services” in left upper corner drop-down,
   - Click on “Enable APIs and Services” and search for the necessary APIs (e.g., Google Maps) to enable.



4. In here, Enable Places API,



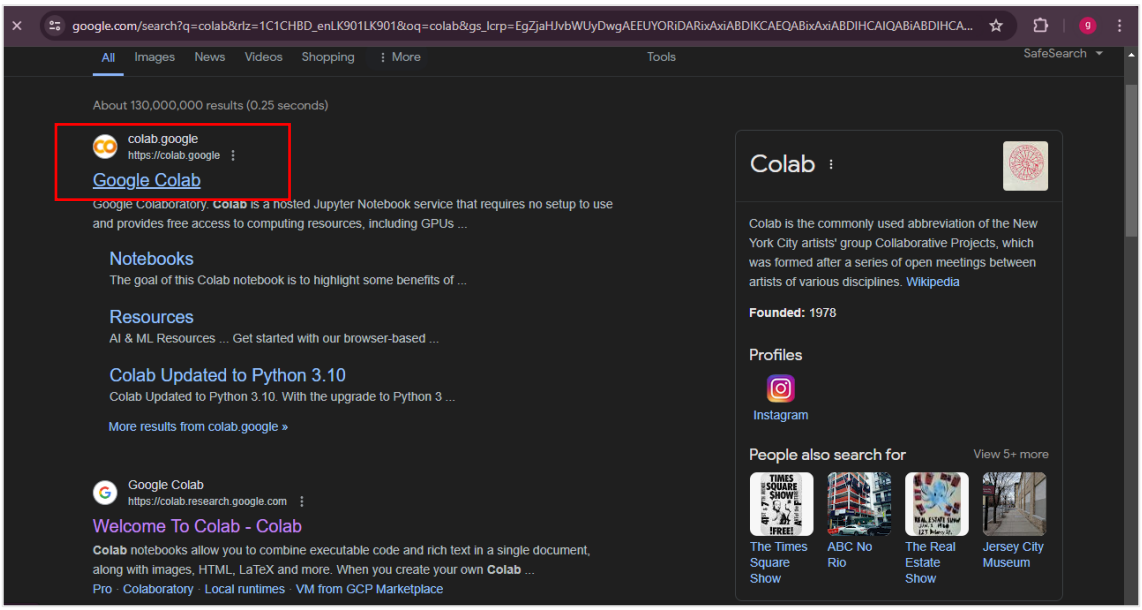
5. Check the places API data compatible with your categorization,
   Go through this link: https://download.geofabrik.de/osm-data-in-gis-formats-free.pdf
   - The next step is to extract the POI data, for that, you need to run a code in Python, before that clarify the available data format and classes you are going to request from the “Google API”.



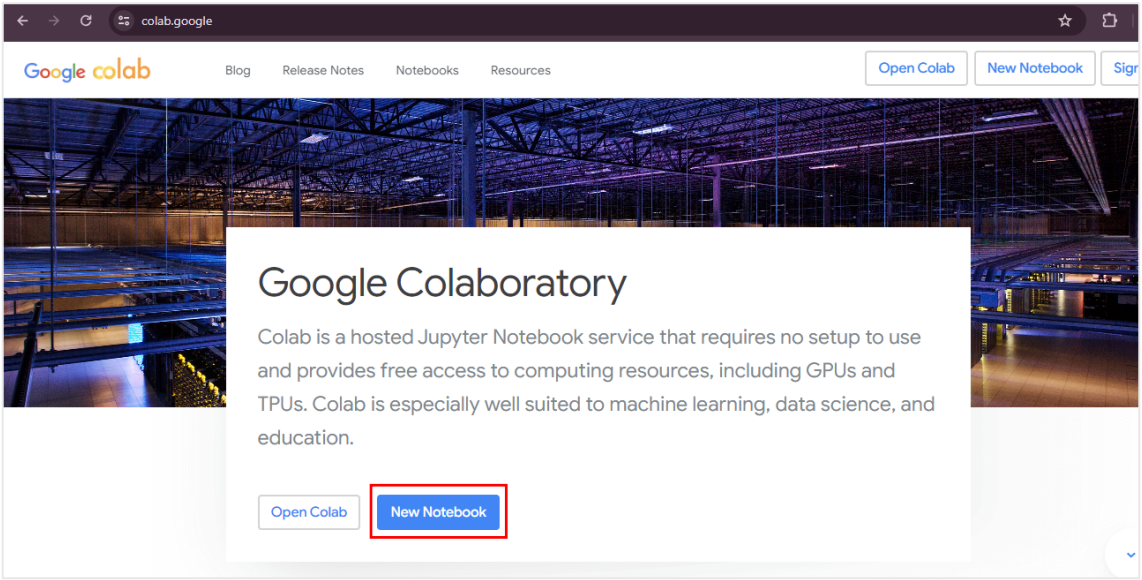
Note: Most Importantly, Billing information (https://developers.google.com/maps/billing-and-pricing/billing) needs to be checked in before any request from Places API using the following Python code.

Step 02:

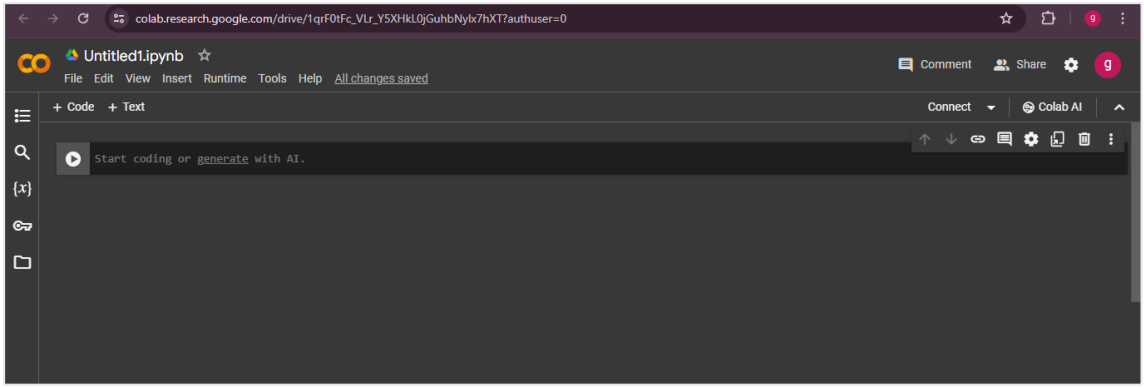
- Open the below code (Figure 01) in a Python notebook (Google Colab preferred), https://colab.google/



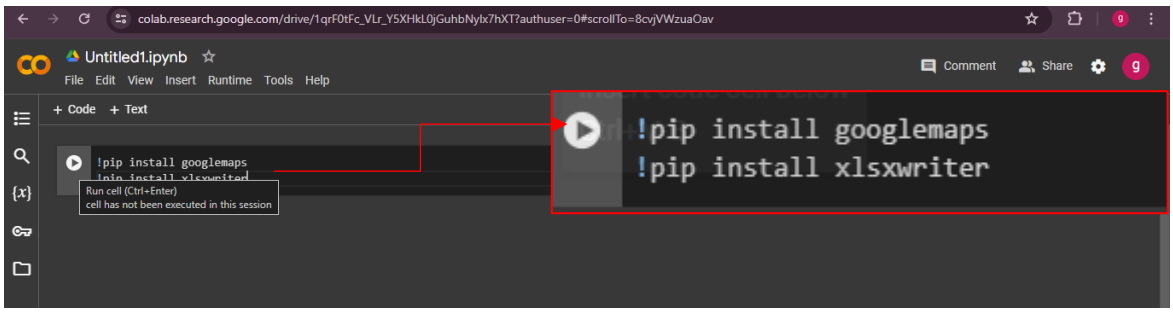
- Then inside “Google Colab” there is an option to go for a “New notebook” Click that option,



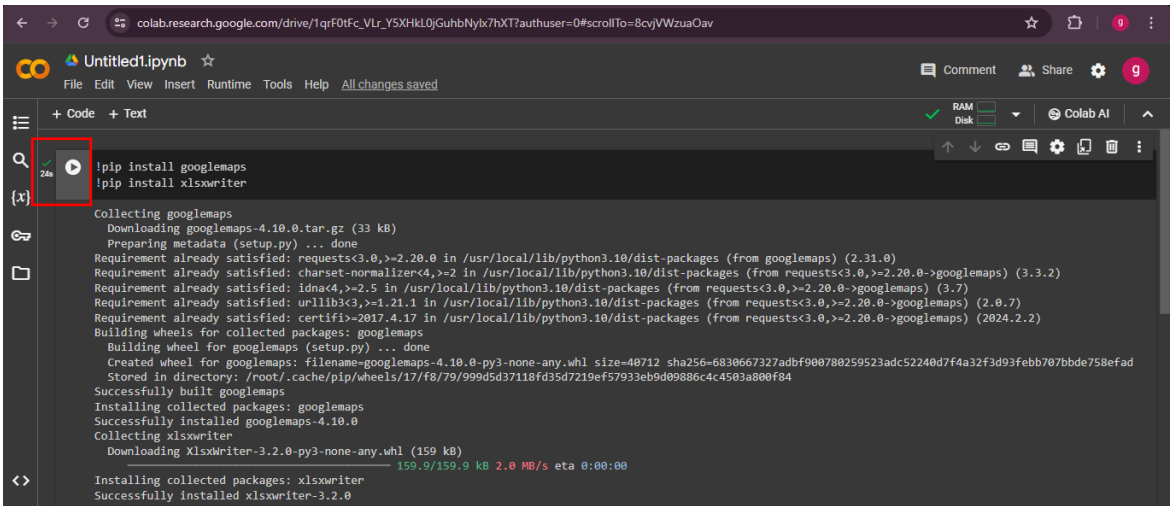
- It will direct you to the following interface,



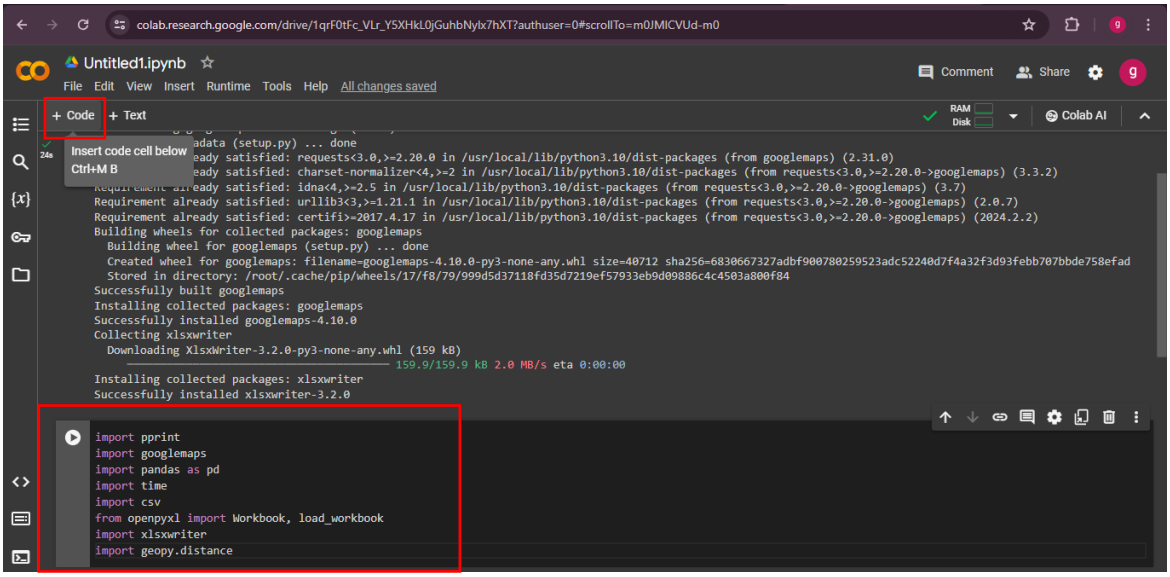
- Now you have to set the Environments of the colab notebook, write the below note in the notebook, and run using the “Play icon” button.



- Output results will look alike as follows,



- Take a new phase using the “+code” icon in the upper tab write the following note and run the code as same in the above step.



- Take a new phase using the “+code” icon and enter the following code,

```
!pip install googlemaps
!pip install xlsxwriter

import pprint
import googlemaps
import pandas as pd
import time
import csv
from openpyxl import Workbook, load_workbook
import xlsxwriter
import geopy.distance

output = pd.ExcelWriter("/content/dataset.xlsx")

location = "7.874126220945256, 80.65109203759063"

API_KEY =

DataList1 = []

gmaps = googlemaps.Client(key=API_KEY)

#1
places_result = gmaps.places_nearby(location = location, radius =2000,
type= 'resturant')

DataList1.extend(places_result.get('results'))
next_page_token = places_result.get('next_page_token')

while next_page_token:
    time.sleep(3)
    places_result = gmaps.places_nearby(location=location,
radius=2000, type='resturant', page_token = next_page_token)
    DataList1.extend(places_result.get('results'))
    next_page_token = places_result.get('next_page_token')

df1 = pd.DataFrame(DataList1)
if not df1.empty:
    df1['url'] = 'http://www.google.com/maps/place/?q=place_id:' +
df1['place_id']

if not df1.empty:
    if 'geometry' in df1:
        latlong = df1.geometry.astype(str).str.strip("
{}").str.split(" ")
        latnew1 = latlong.apply(pd.Series).rename(columns={2: "lat",
4: "lng"})
        lat = latnew1.iloc[:,2].str.replace(',','')
        lng = latnew1.iloc[:,4].str.replace(',','').replace('}','',
regex=True)
```

```
if not df1.empty:
    df1['latitude'] = lat.astype(float)
    df1['longitude'] = lng.astype(float)


df1.to_excel(output,sheet_name='resturant',index=False)

output.close()
```

Figure 3:Python code & API key prepared to obtain POI data from Google API

Before running the code add the saved Google API key (Copied earlier and saved in a notepad), center point (Latitude and Longitude) of your center point, radius, and service type (according to your categorizations).

Note: Things should be subtitled according to the work indicated in red color boxes.

Valid service types are listed in the Google API documentation (https://download.geofabrik.de/osm-data-in-gis-formats-free.pdf).

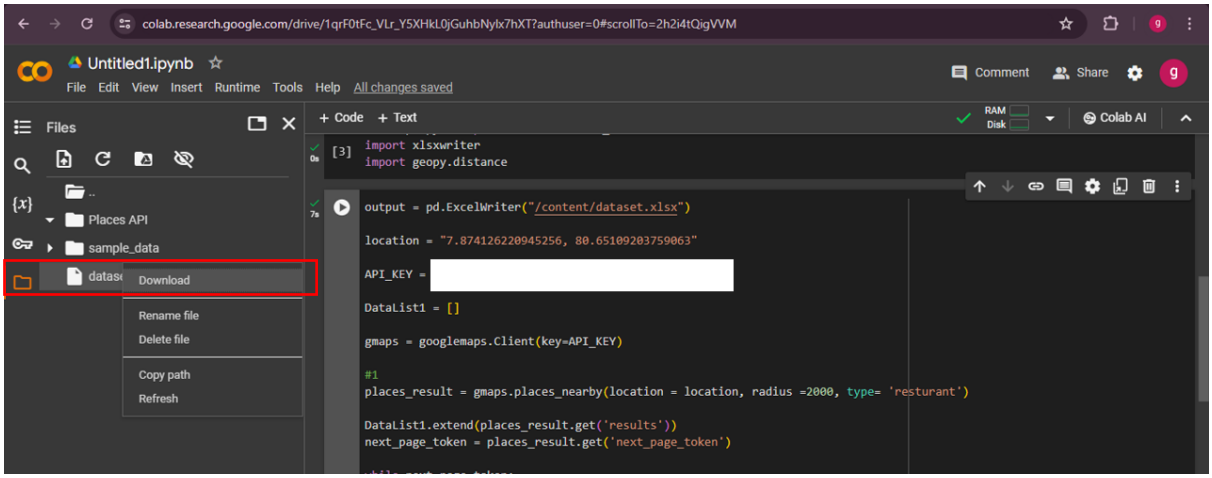
PS: Selected Location for this analysis: "7.874126220945256, 80.65109203759063",

Selected API key: Personal API key

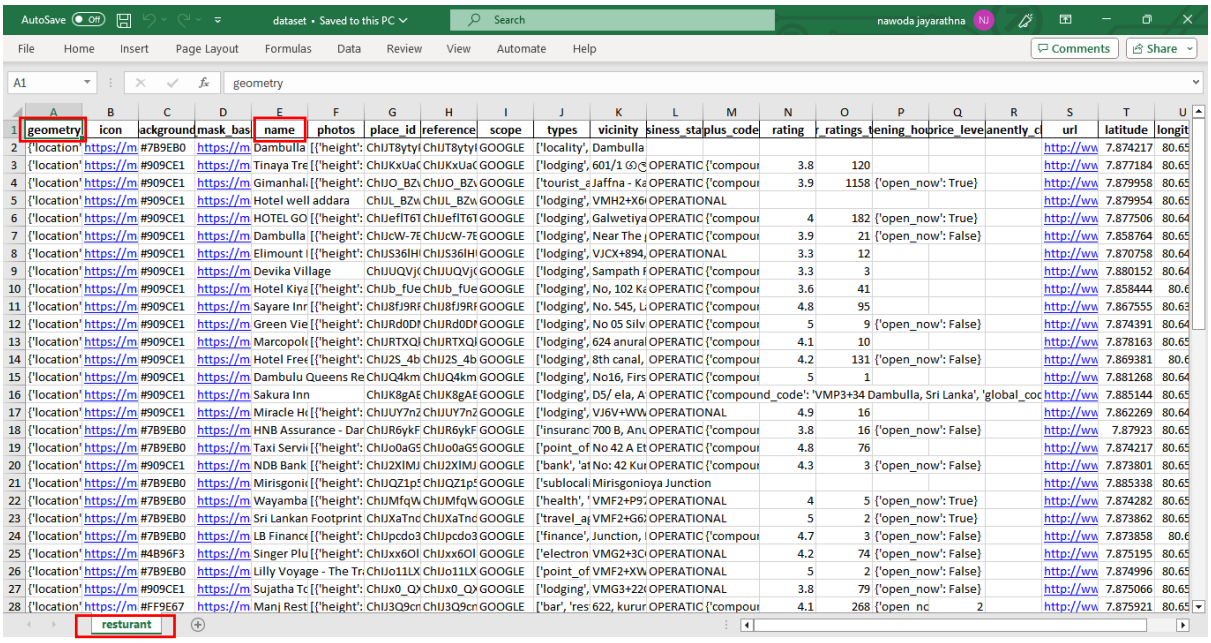
Selected Radius: 2000 meters

Selected Type: Restaurant

- Now you can download the XLSX file following these steps,



- The downloaded data file will look like the following,



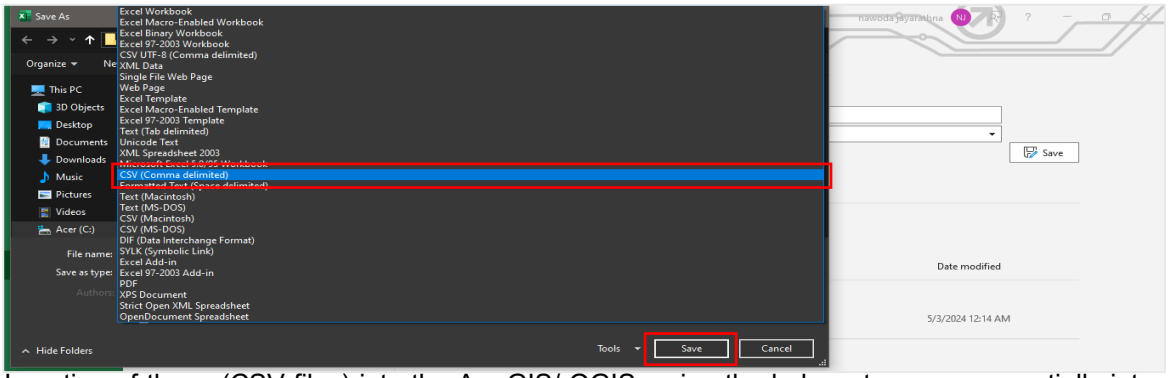
Likewise, needed categories could be downloaded by running the code in Google Colab.

Note: Make sure to check the billing details (Number of Requests)

- Data cleaning (Remove the unnecessary data in CSV and keep data needed for your analysis)
  From this detailed Excel, for this study purpose “Location” and “Name”, other should be removed.

Step 03:

- Convert the XLSX file into to CSV file,
  Open XSLX file > File >Save as > Browse to the location > Select the Save Type as CSV



Insertion of those (CSV files) into the Arc GIS/ QGIS, using the below step we can spatially interpret the Point data into the project. For this example, Bank data of city of Kurunegala has been used.

(1) Open ARC map > (2) Browse the CSV file from “Catalog” > (3) Drag and drop the CSV file into the Project.

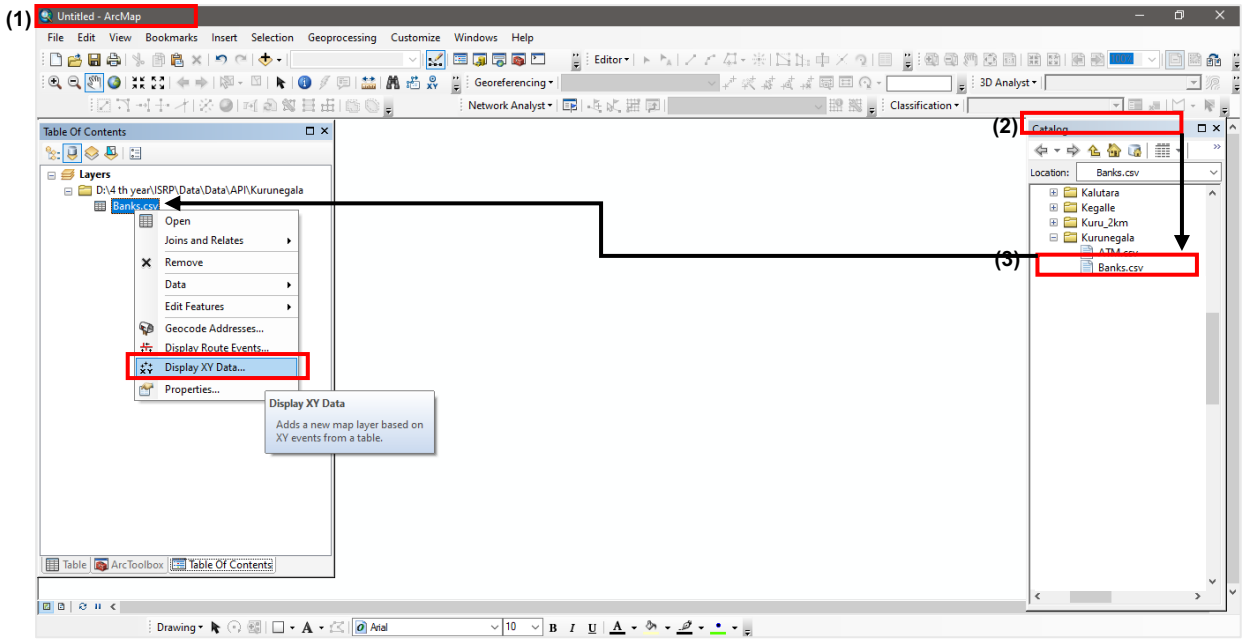
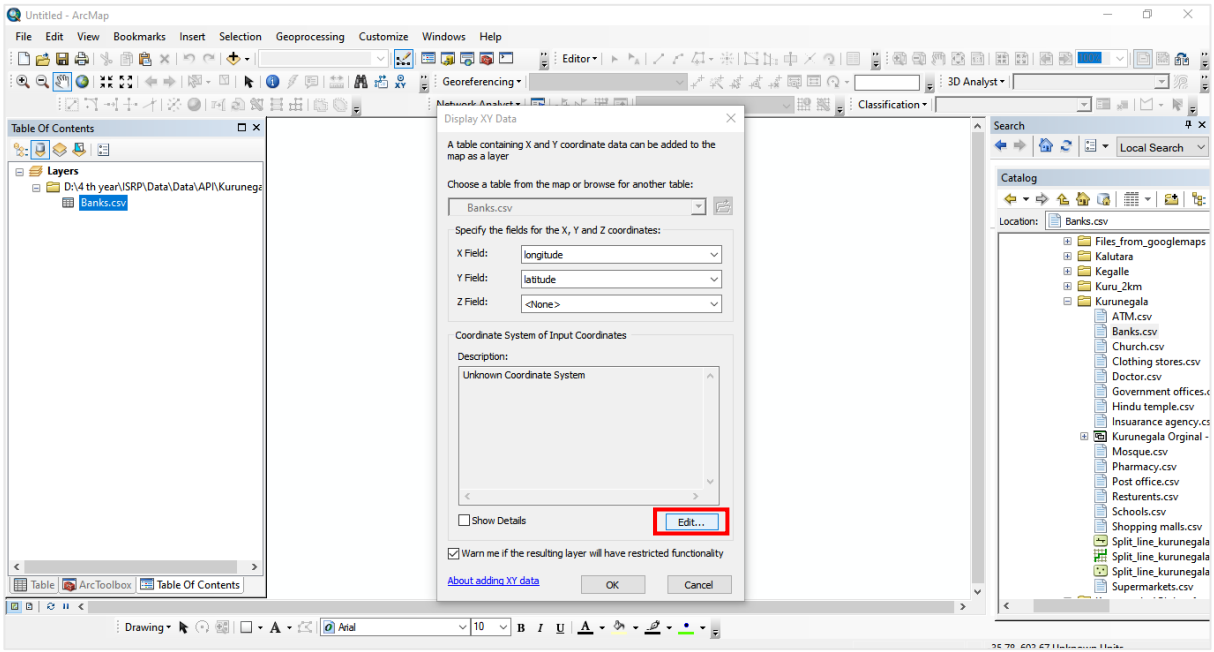
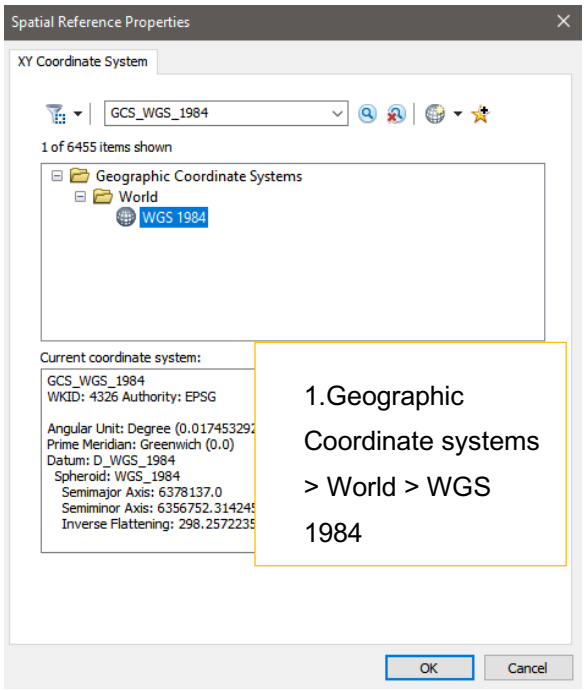
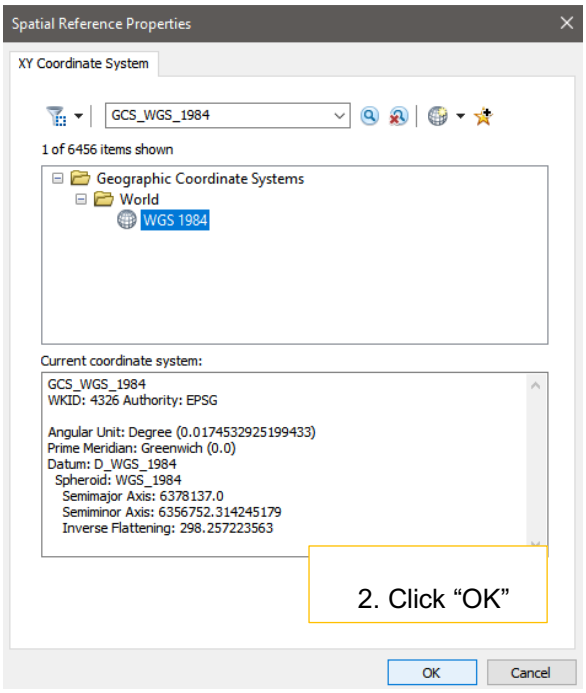


Figure 4: Insert CSV files to ARC Map

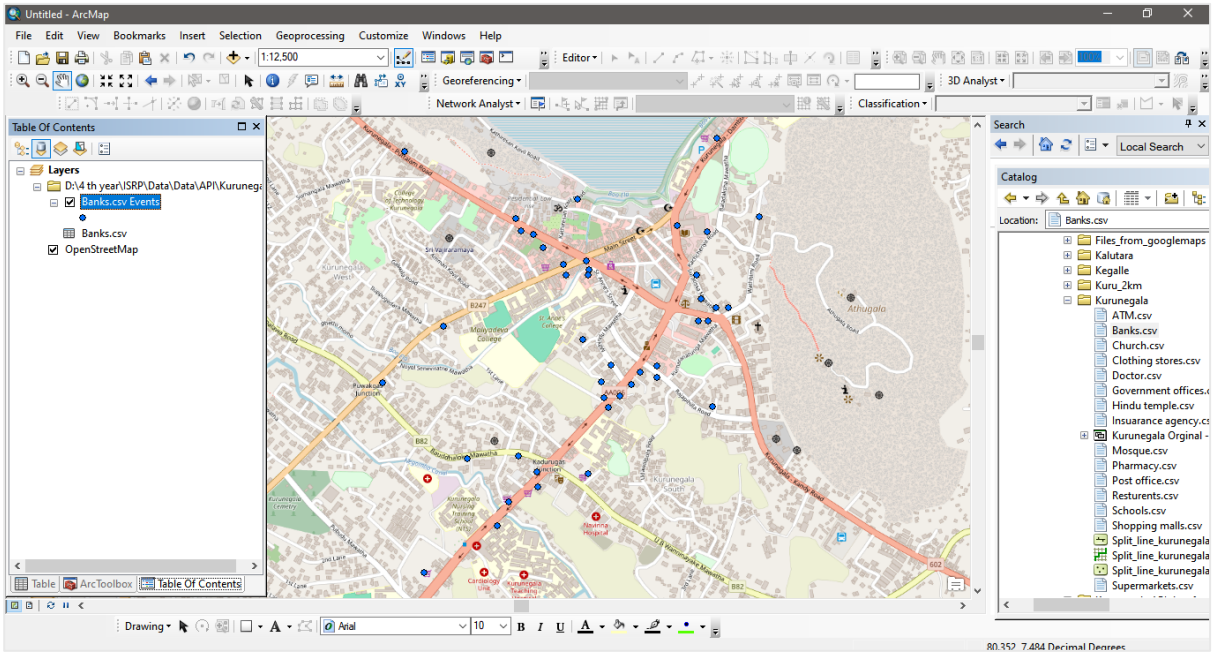
- Right-click on the “Banks” Layer displayed in “Table of Contents”. This popup menu will appear and set X Field as “longitude”, and Y Field as “latitude”. Then click the “Edit” button to set the coordinate system.





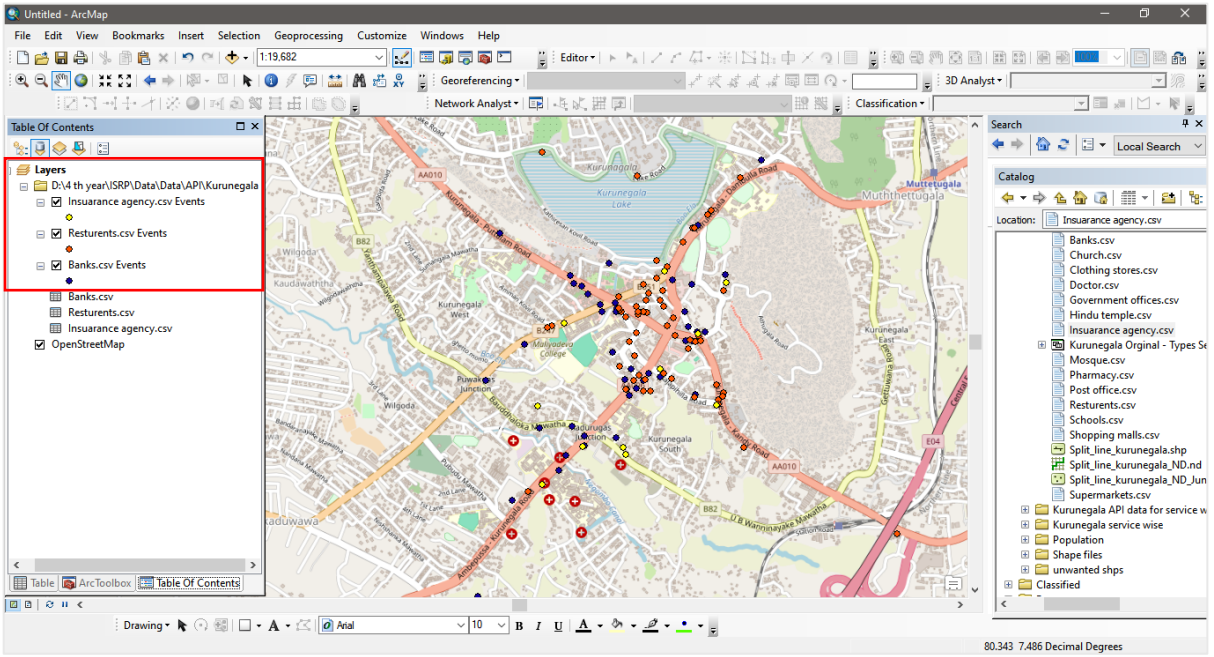


- Spatially, POIs belonging to the CSV will be displayed on the project as follows:



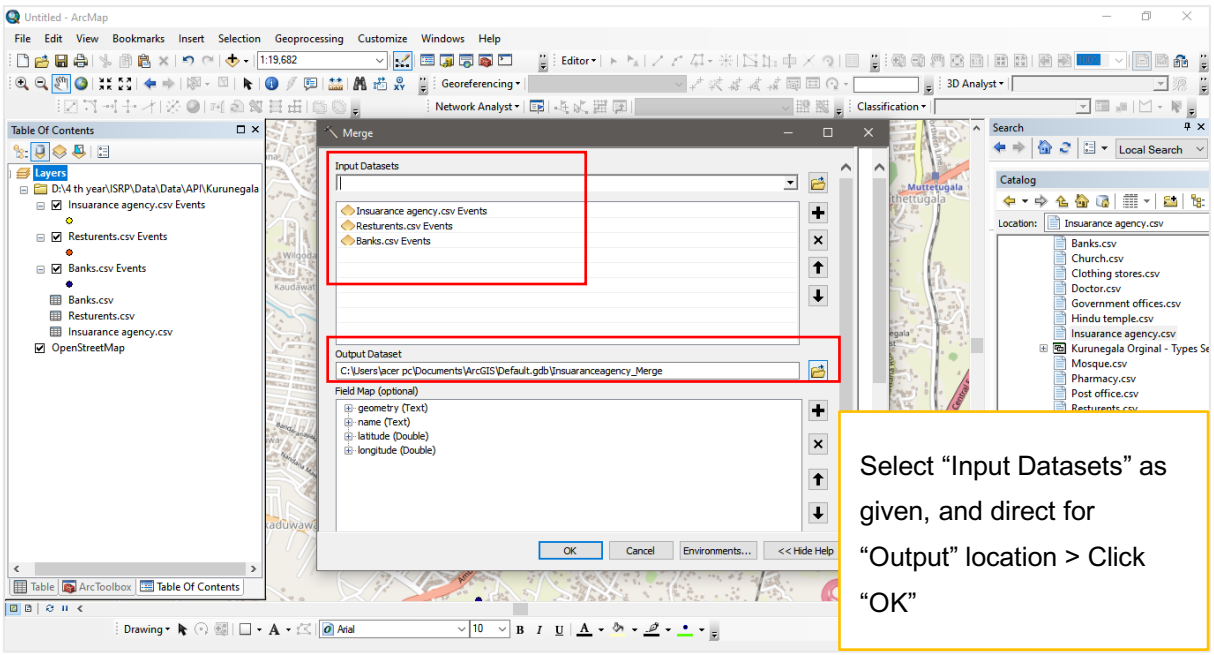
- According to the service categorization (Table 01), Under the “Commercial” categorization there are 3 subcategories; Banks, Financial institutions, and Restaurants.

  Addition of those layers as CSV files to the project and convert them into point layers by following the above steps.

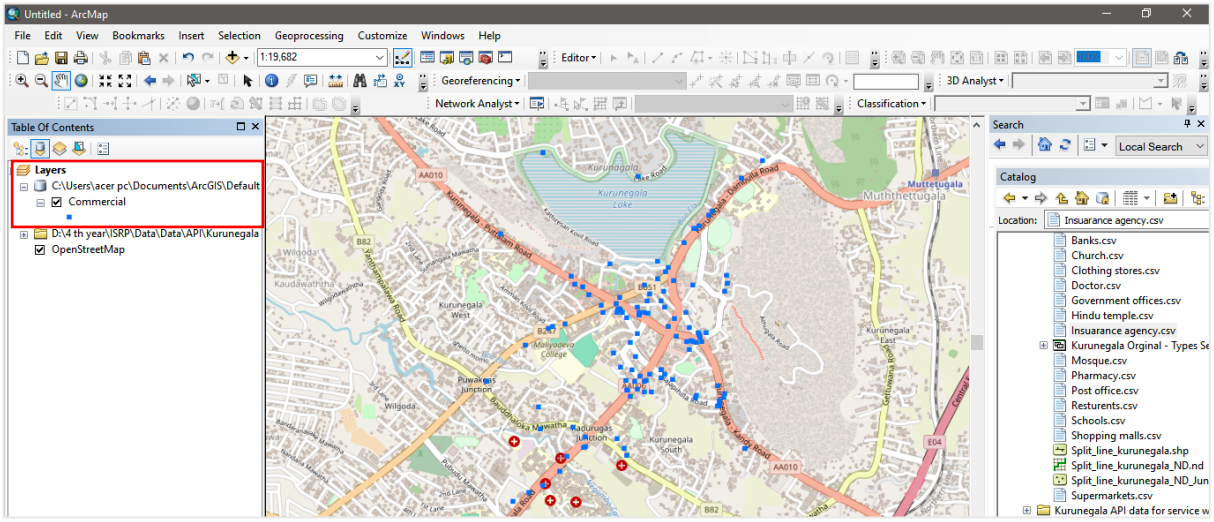


- To set those layers as one layer (Commercial Layer) Merge option in the “Geoprocessing” toolbox should be used.

  Go to Geoprocessing > Click drop-down > Select “Merge” You will open up to following popup menu,



- Now you can obtain commercial category as one layer, likewise, we can formulate other categories as well (Reference with Table 01).

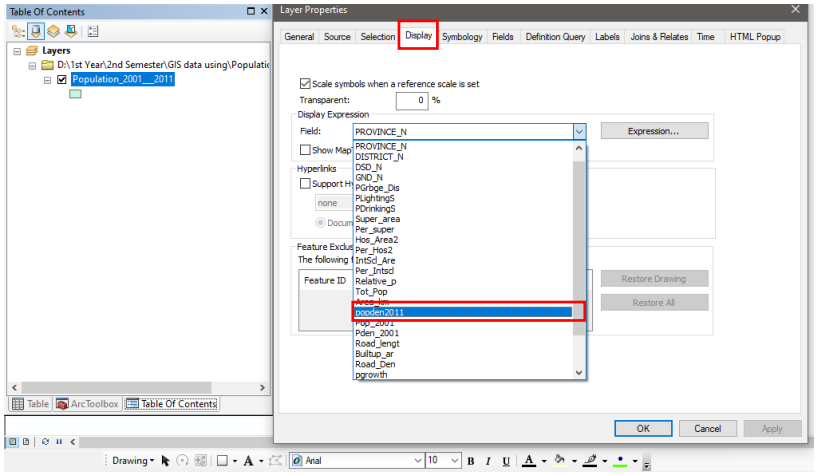


Note: (Location selected to extract API data; major population insertion point to each city has been selected). For example – the coordinates of the bus stand as the center point.

4.2 Preparation of the Data Layers

4.2.1 Insertion of the population data into the project

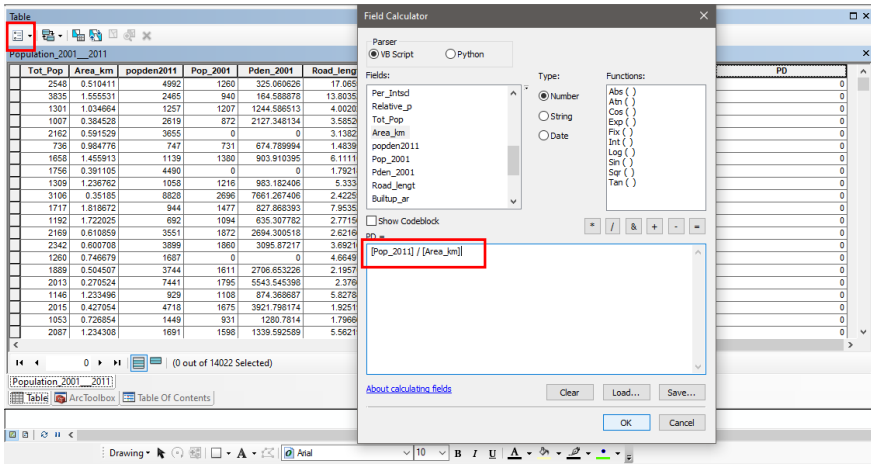
Population data for cities were sourced from the 2012 Statistical Yearbook published by the Census and Statistics Department of Sri Lanka. Enable the population layer into Population density. This can be obtained easily if the population density data is already processed.



1. Right Click on layer > Layer properties > Drop down the Field > Select the population density field.

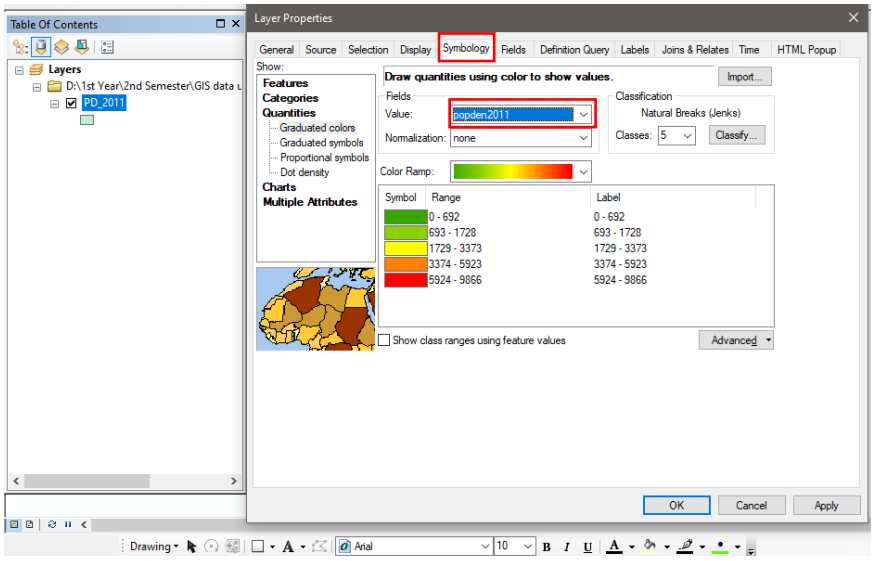
Figure 5: Displaying Population Density.

Otherwise, create a new field in the attribute table and use the calculated geometry in the attribute table. Use the equation (Population / Area) = Population Density.



2. Right Click on layer > Open attribute table > Add a new field > Right click on the new column > Field calculator > Insert the equation > Ok.

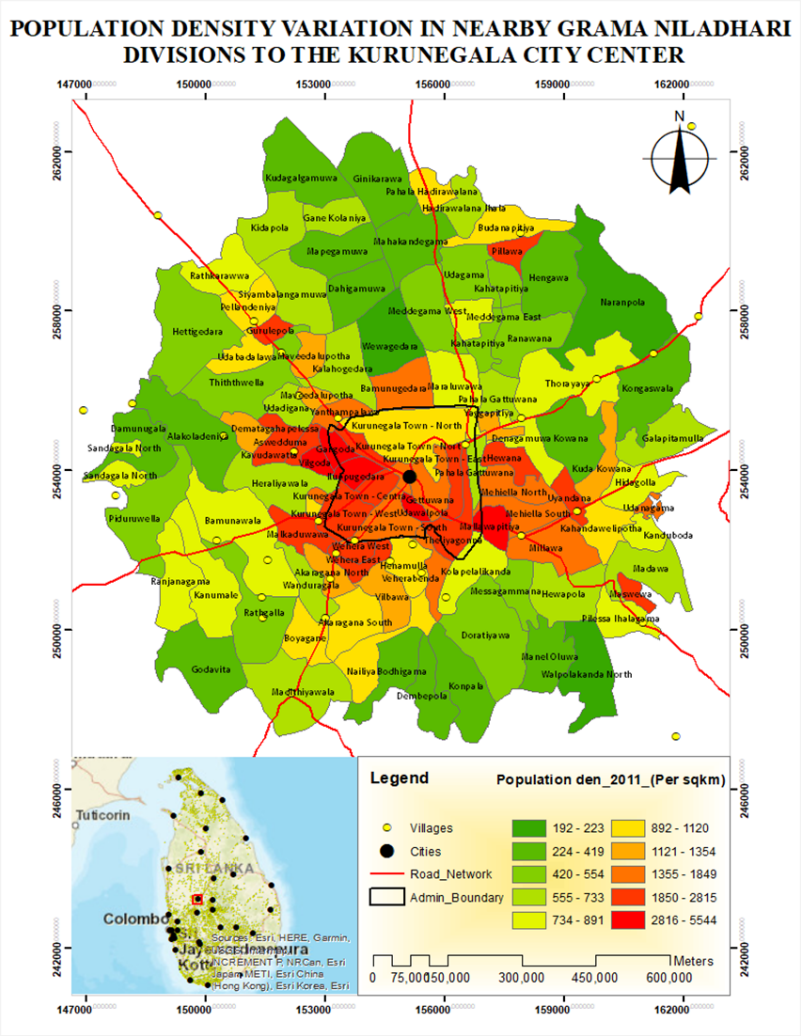
Figure 6:Calculate Population Density



3. Right Click on layer > Open Layer properties > Go to symbology > Select the Quantities option and apply density layer in the value field and classify according to your preference > OK.

Figure 7:Classify Population Data

In here the classification done according to Natural breaks where class quantity is selected as 5. This could be customized according to the preference and the nature of the data inserted.



This Figure shows one of the sample maps for population density distribution in the nearest Grama Niladhari Divisions around the city center (Kurunegala). In this case the population data classified in to 10 classes.

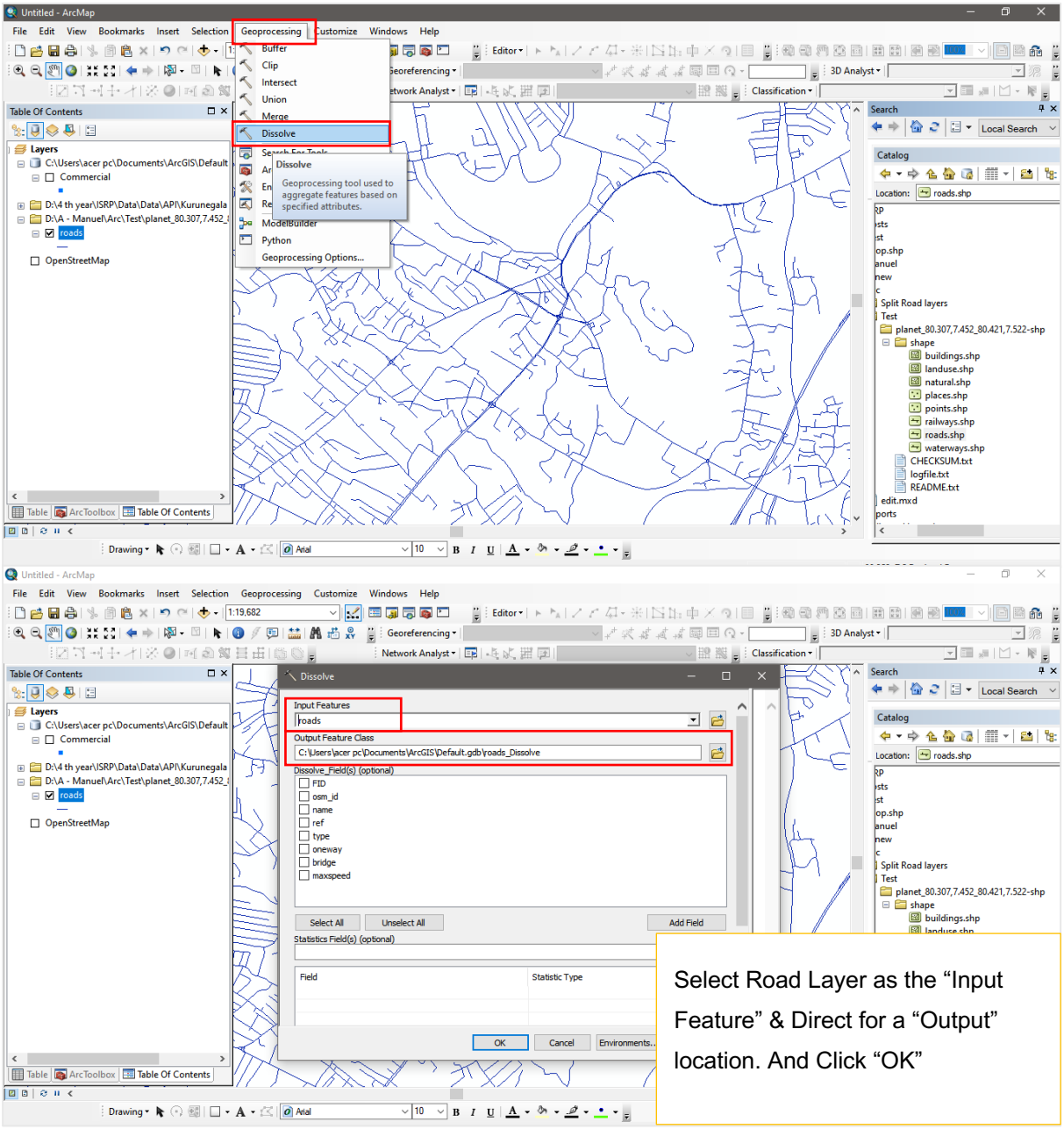
Figure 6:Mapping population Density.

4.2.2 Insertion of the Road data into the project

Note: From this point onward in need of easy demonstration Kurunegala city will be in focus.

Step 01:

- To run the Network analyst tool, a digitized road data layer (Split at vertices) must be prepared. The following steps could be incorporated into the process. This can be done either manually or using the tool “Feature to Line” from the Arc Toolbox.
- Before deploying “Feature to Line”, Go to the “Geoprocessing” tool and Select the “Dissolve” option from the drop-down menu.



The dissolved layer will automatically appear on the project, and then do as follows:

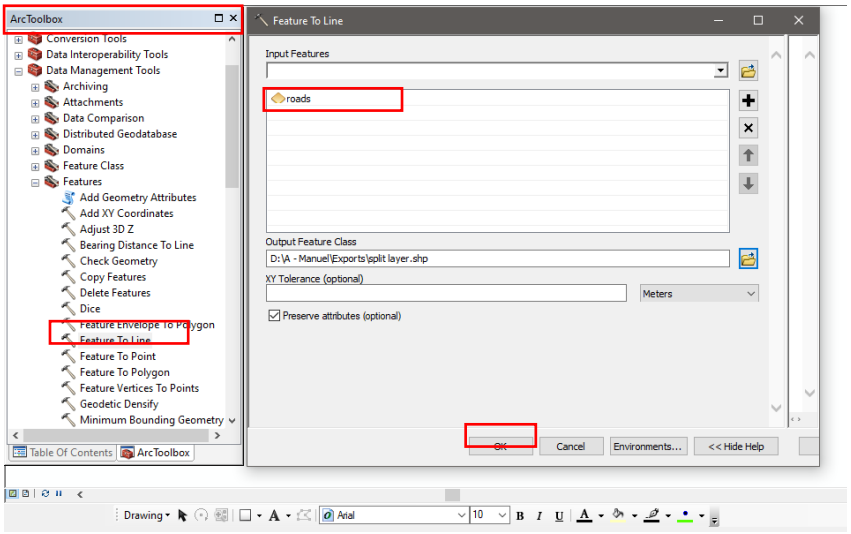


Figure 7:Split Road layer.

Go to Arc toolbox > Data Management Tools > Features and then select "Feature to Line" option.

Select input feature as the Road Layer and direct to Output Feature Class.

Then we can obtain a road layer split at vertices.

4.3 Summary

The ARC GIS software elaborated geo-referenced data. Following the city's geo-localization, the project involved uploading all geo-referenced files related to services from OpenStreetMap (API) and census data (population) from the Census and Statistic Department of Sri Lanka into the ARC GIS project. A maximum observation distance of 2km from the city center was established. Subsequently, the preparation of the road layer entailed digitizing individual road segments and setting up the Network Analyst tool.

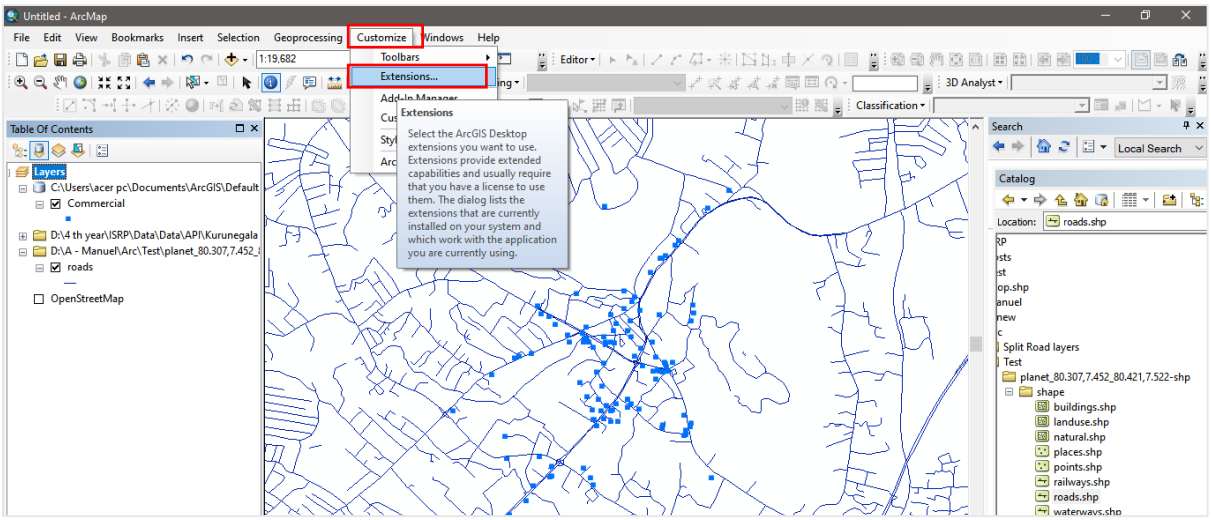
5. Application Section - Medium-Sized City's Service Profiling

5.1 Deploying Network Analyst Tool

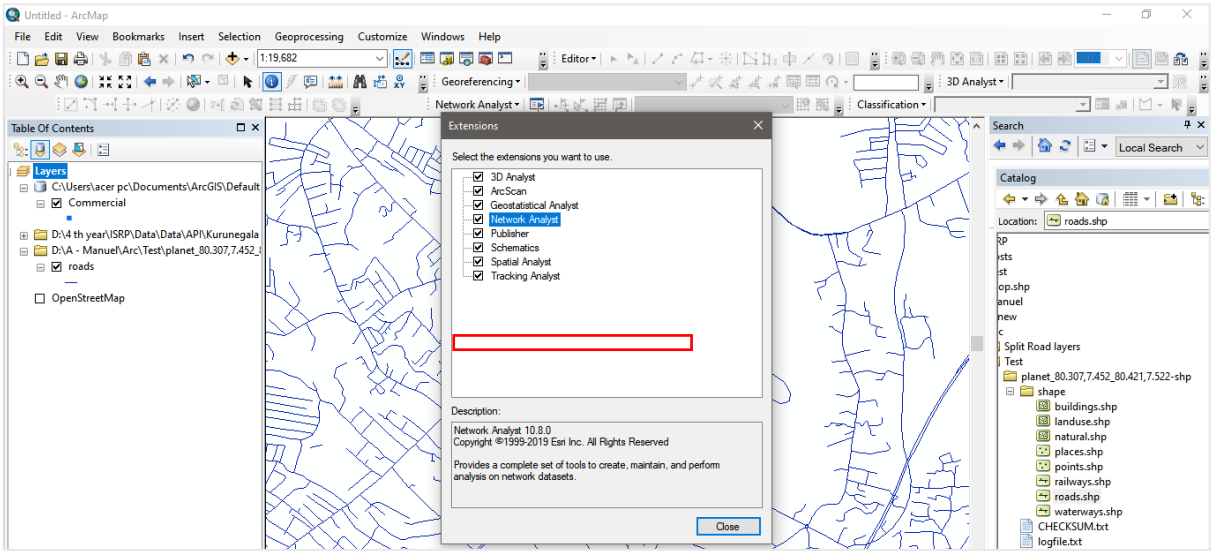
The application section discusses the deployment of two tools in ArcGIS and QGIS software: the Network Analyst tool and the ORS plugin, respectively. Both can be done through QGIS software as there are constraints in loading the data here onward Network Analyst tool will be guided by Arc GIs and steps from QGIS will be mentioned parallelly. Before running the NA tool, you must enable the Extension.

Go to the "Customize" option in the upper of UI and go to "Extensions". Check whether the "Network Analyst" option is enabled. If not, enable it.

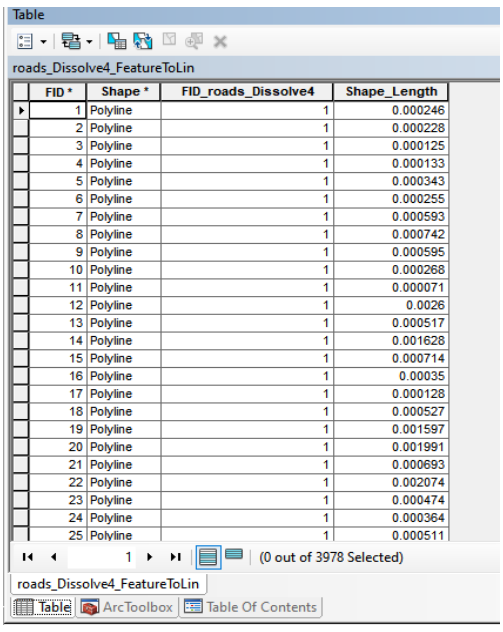
- Enabling Network Analyst tool,



- Check the box,



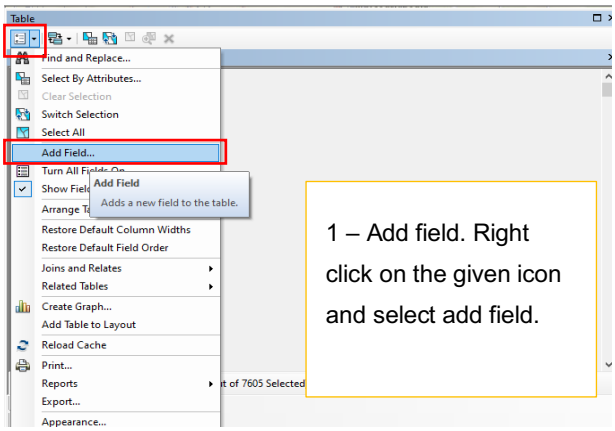
5.1.1 Creation of Impedance in the Attribute Table.



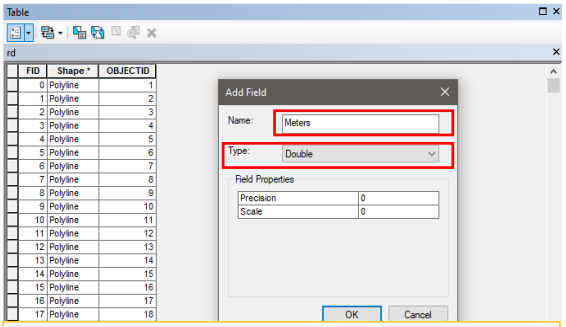
The attributes of the road layer, after deploying "Feature to Line" will appear like this.

(Right click on "Feature to Line" layer > Click "Open Attribute Table")

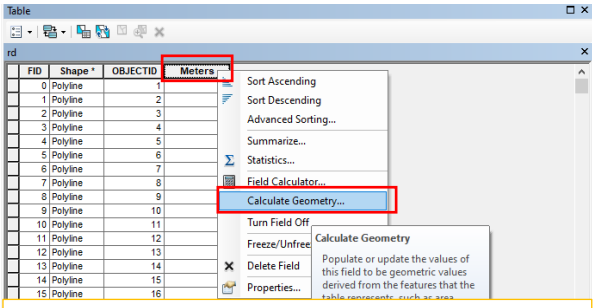
Then you must create the impedance in the Attribute table of the split road layer



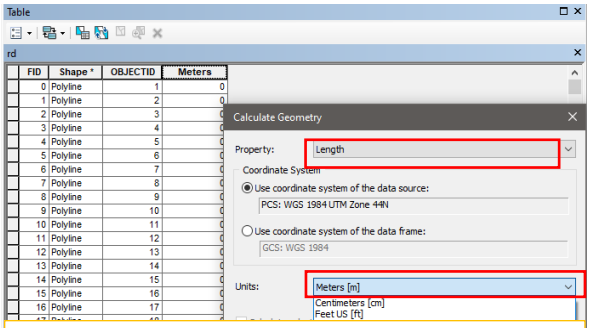
1 – Add field. Right click on the given icon and select add field.



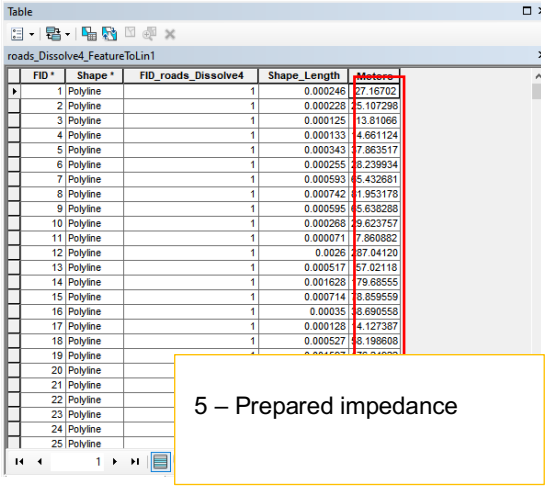
2 – Name the field & select the "Type.**" Note:** Spellings for "Meters" should be exactly the



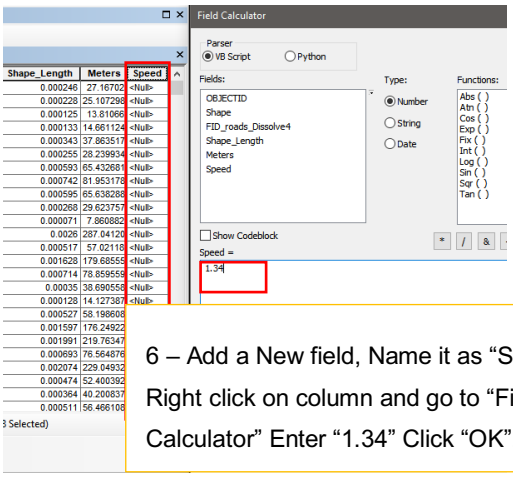
3 – Right click on the added column (Meters) & select "Calculate Geometry".



4 – Select the "Length" from the drop down menue. Make sure to select standard units.



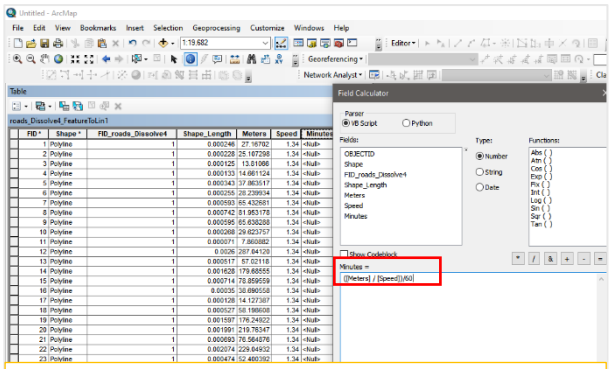
5 – Prepared impedance



6 – Add a New field, Name it as "Speed", Right click on column and go to "Field Calculator" Enter "1.34" Click "OK".

Note:

Set the speed according to requirement. This study focus on walkability I use 1.34 ms^{-1} as the average walking speed of a person.



7 – Use the Formulea “Distance/Speed = Time” Since Network Analyst tool requests Time in “Minutes” formulae should appear as “([Meters]/[Speed])/60”

FID *	Shape *	FID_roads_Dissolve4	Shape_Length	Meters	Speed	Minutes
1	Polyline	1	0.000246	27.16702	1.34	0.337898
2	Polyline	1	0.000228	25.107298	1.34	0.31228
3	Polyline	1	0.000125	13.81066	1.34	0.171774
4	Polyline	1	0.000133	14.661124	1.34	0.182352
5	Polyline	1	0.000343	37.863517	1.34	0.470939
6	Polyline	1	0.000255	28.239934	1.34	0.351243
7	Polyline	1	0.000593	65.432681	1.34	0.813839
8	Polyline	1	0.000742	81.953178	1.34	1.019318
9	Polyline	1	0.000595	65.638288	1.34	0.816397
10	Polyline	1	0.000268	29.623757	1.34	0.368455
11	Polyline	1	0.000071	7.860882	1.34	0.097772
12	Polyline	1	0.0026	287.04120	1.34	3.570164
13	Polyline	1	0.000517	57.02118	1.34	0.709219
14	Polyline	1	0.001628	179.68555	1.34	2.234895
15	Polyline	1	0.000714	78.859559	1.34	0.98084
16	Polyline	1	0.00035	38.690558	1.34	0.481226
17	Polyline	1	0.000128	14.127387	1.34	0.175714
18	Polyline	1	0.000527	58.198608	1.34	0.723863
			0.001597	176.24922	1.34	2.192155
			0.001991	219.76347	1.34	2.733376
			0.000693	76.564876	1.34	0.952299
			0.002074	229.04932	1.34	2.848872

8 – Outlook of the attribute table after calculations

5.1.2 Creation of New Network Data Set

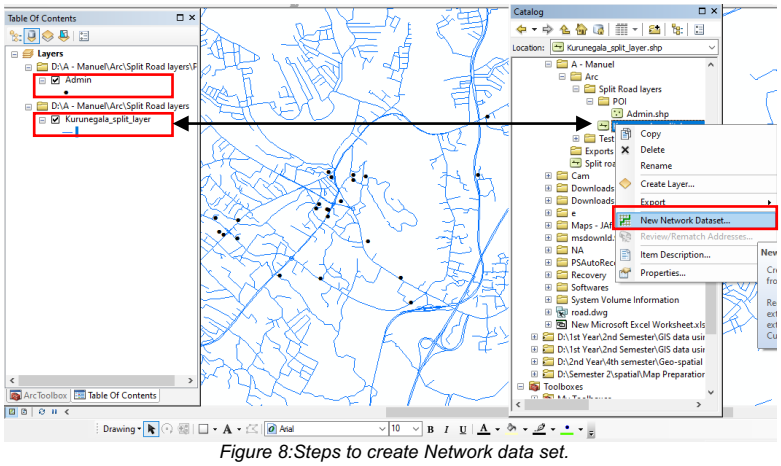
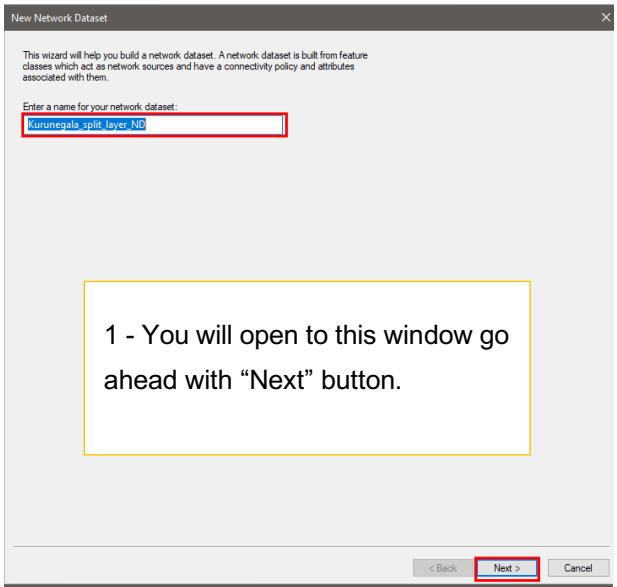


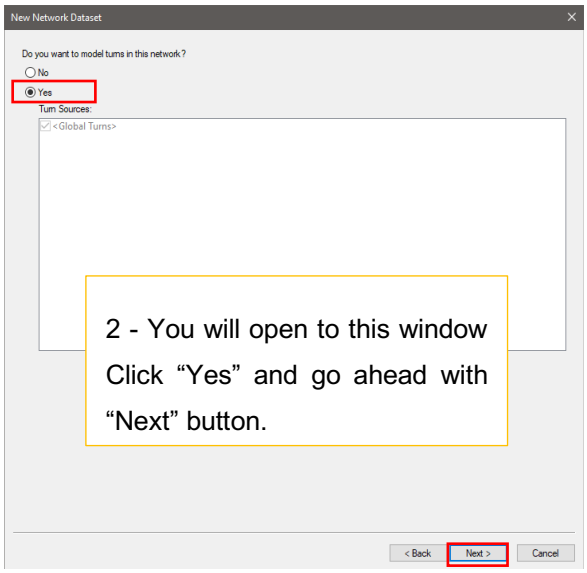
Figure 8:Steps to create Network data set.

Insertion of the point layer going to analyze into the project and then in the catalog right click on the split road layer > go to New Network dataset.

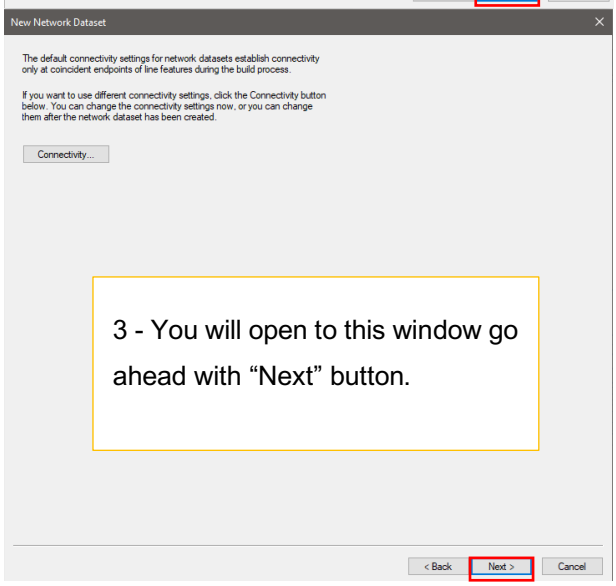
Now this will guide to creation of a New Network Dataset,



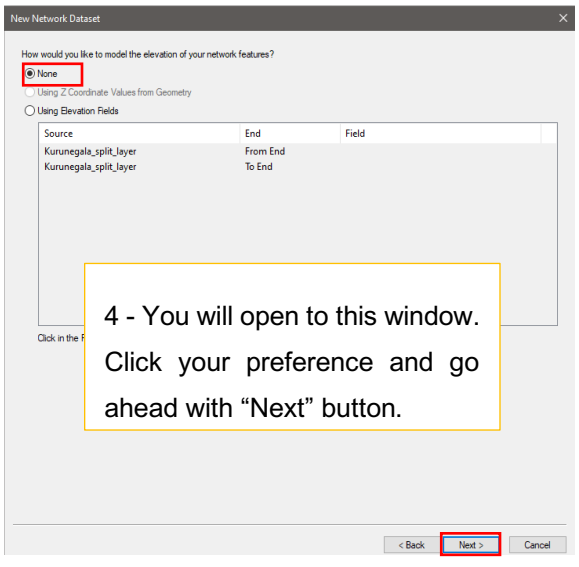
1 - You will open to this window go ahead with “Next” button.



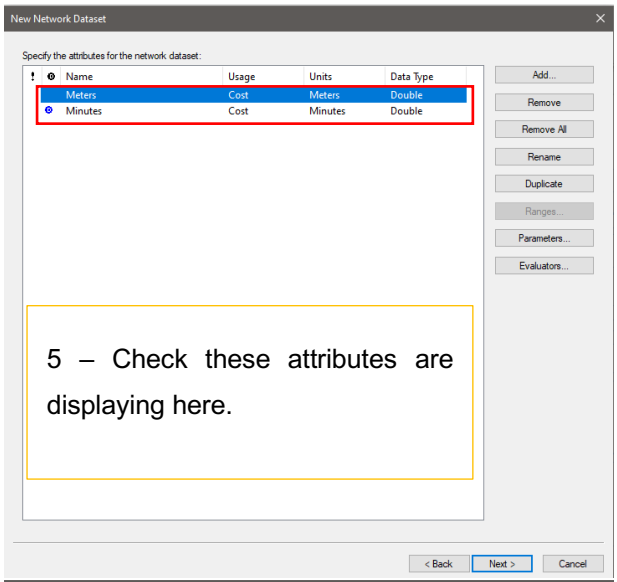
2 - You will open to this window Click “Yes” and go ahead with “Next” button.

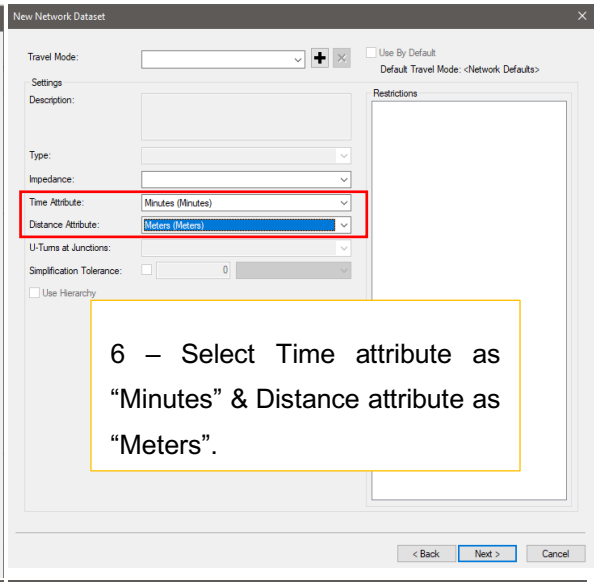


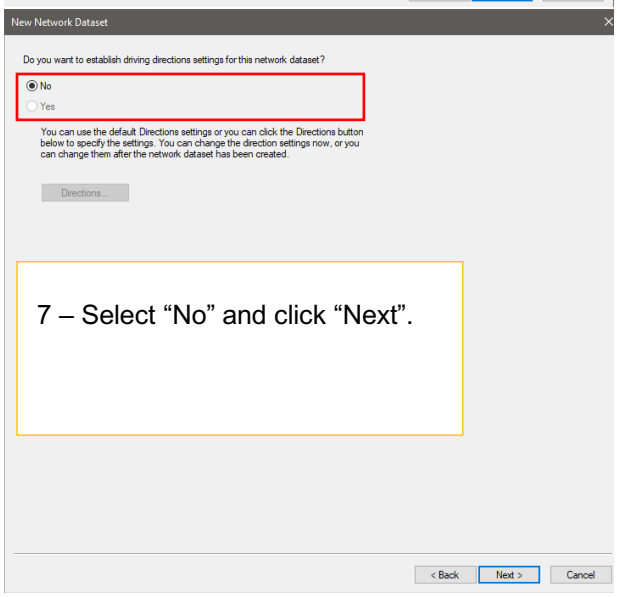
3 - You will open to this window go ahead with “Next” button.

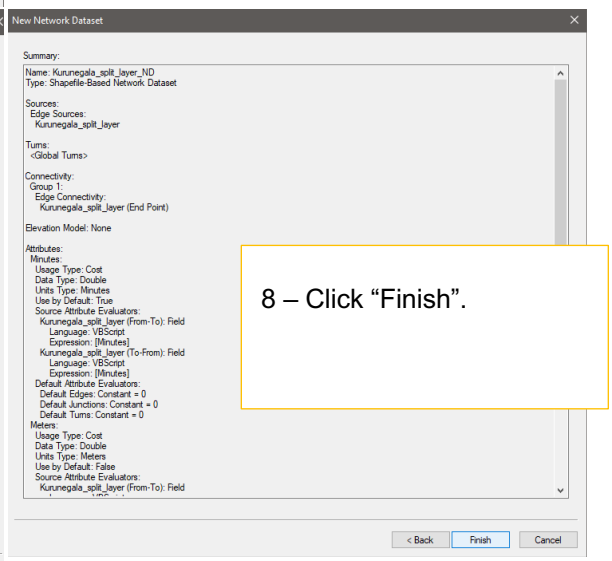


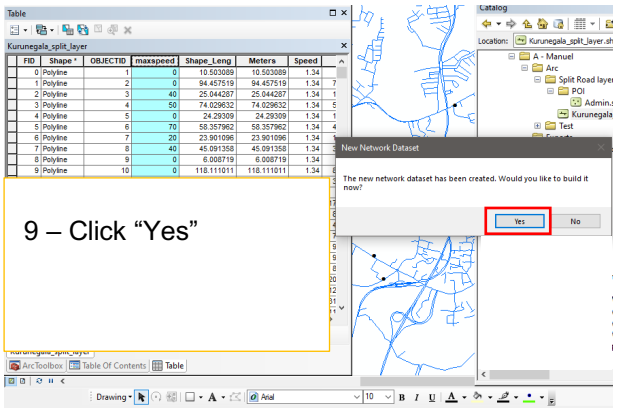
4 - You will open to this window. Click your preference and go ahead with “Next” button.

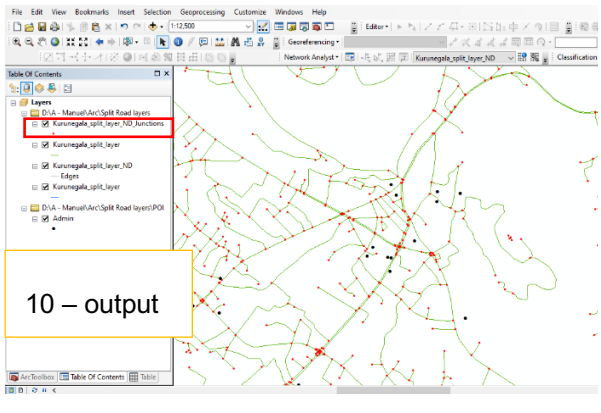






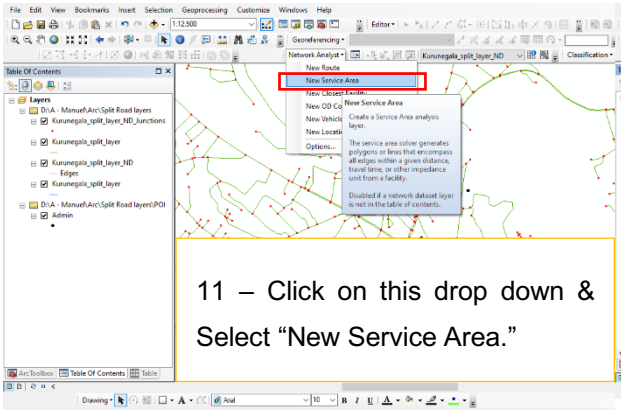




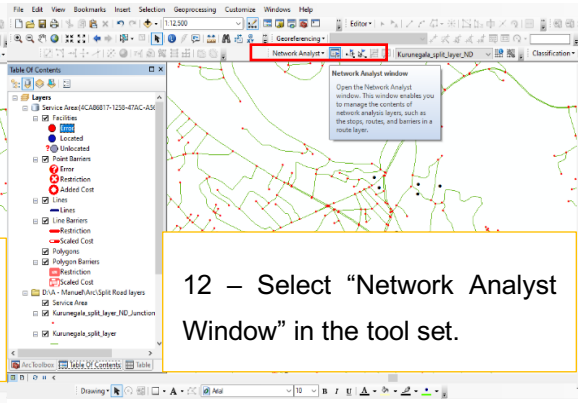


Go to Nework analyst tool in the tab and now the tool is enabled for the work. In the drop-down menu select the “New Service Area” option.

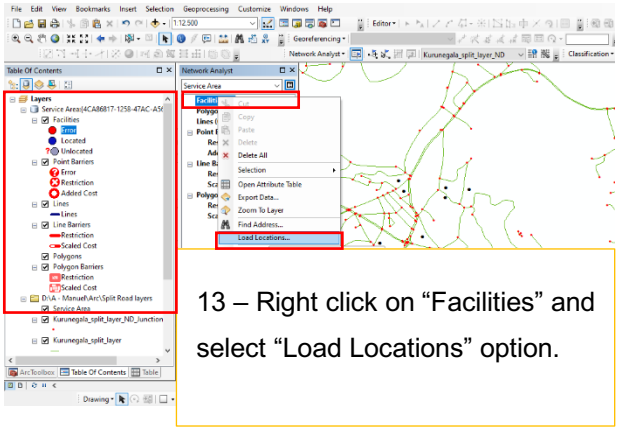
5.1.3 Creation of the service Area and Set properties



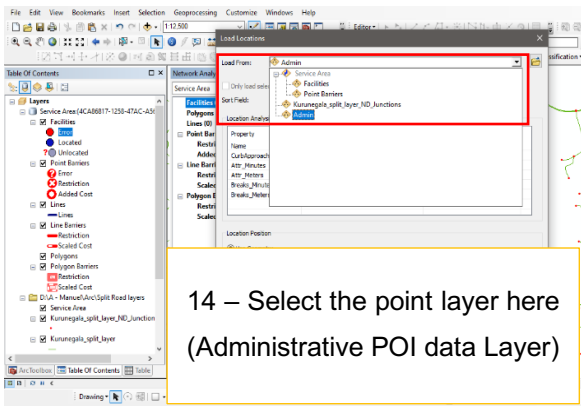
11 – Click on this drop down & Select “New Service Area.”



12 – Select “Network Analyst Window” in the tool set.

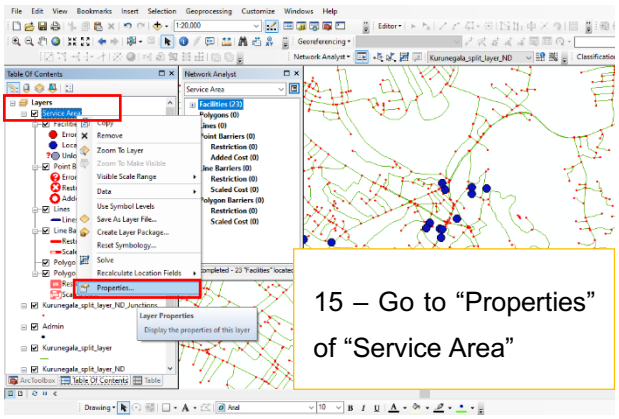


13 – Right click on “Facilities” and select “Load Locations” option.

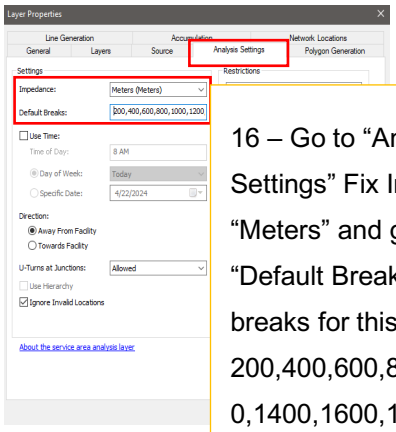


14 – Select the point layer here (Administrative POI data Layer)

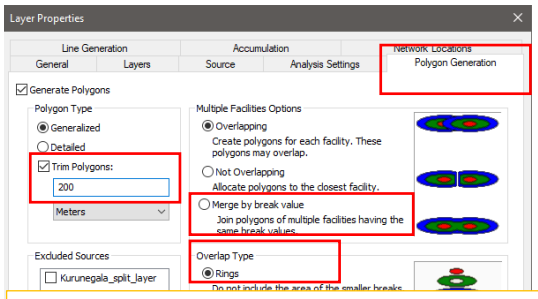
Activating the “Multiple Facility Polygon Generation” feature with a buffer distance set at 200m, thereby plotting a 2km walking isochrone to underscore the services within the walkable radius from the selected facilities.



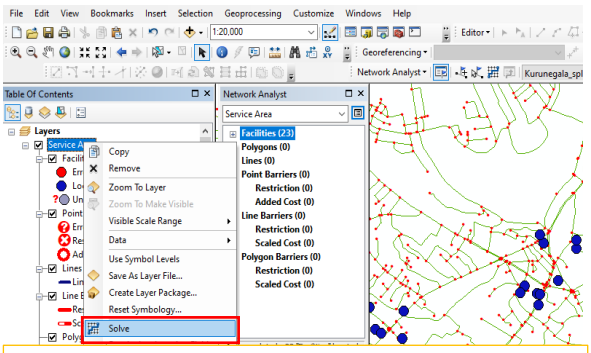
15 – Go to “Properties” of “Service Area”



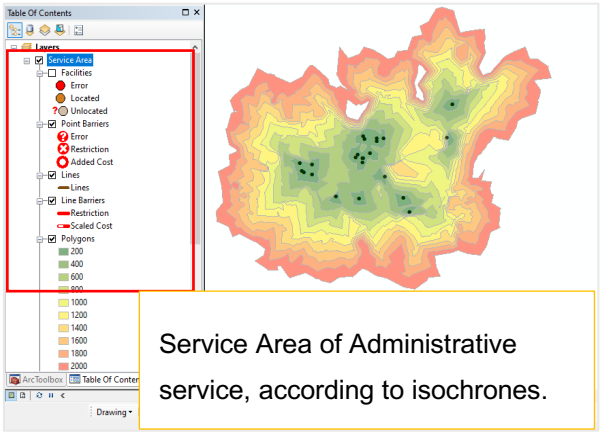
16 – Go to “Analysis Settings” Fix Impedance as “Meters” and give the “Default Breaks”; Selected breaks for this study are 200,400,600,800,1000,1200,1400,1600,1800,2000 in meters.



17. In "Polygon Generation" tab, put "200m" as the "Trim Polygons" extent, while selecting "Merge by break value" Multiple Facilities Option & Overlap Type as "Rings."



18. Use "Solve" option in "Properties". Service Area > Solve.



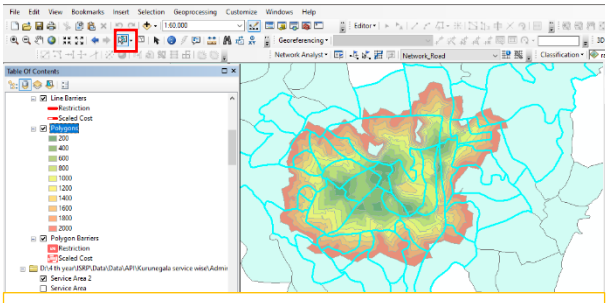
Service Area of Administrative service, according to isochrones.

19. Service Buffers output is here. Follow same process for each category (11th step to 18th Step). This is to identify unique service areas belong to each category.

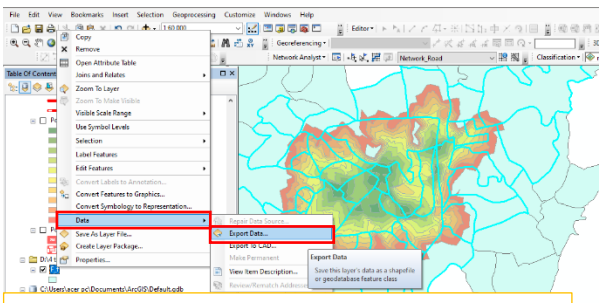
5.1.4 Incorporating population data.

Incorporating Population Data into the Network Analyst, add the population data containing the DSD file (From the Department database) into the project select the area where the network is spread, and export the collection of DSDs as a separate file.

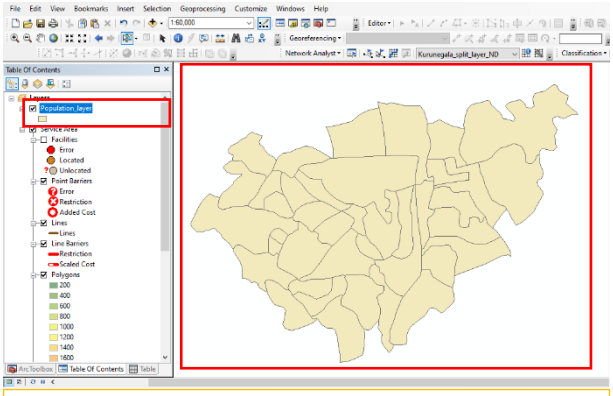
- Go to Catalog > Browse to Population Layer which is pre-processed > Drag and Drop on Project.



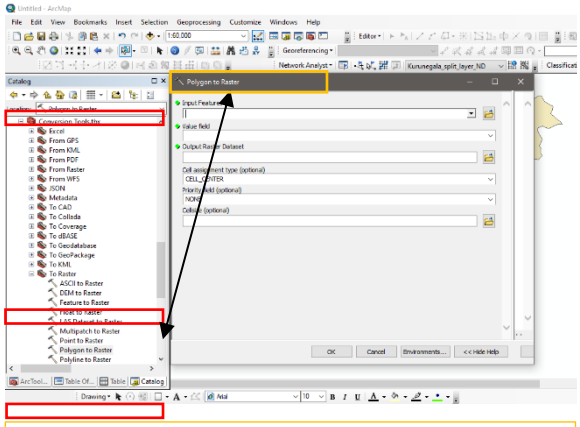
20. Click "Select Feature" icon and select the DSDs within the network service area.



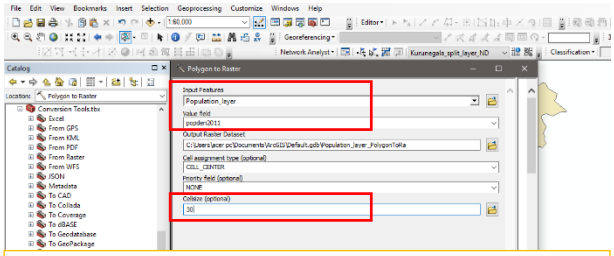
21. Export them as a separate layer. Right click on layer > Data > Export



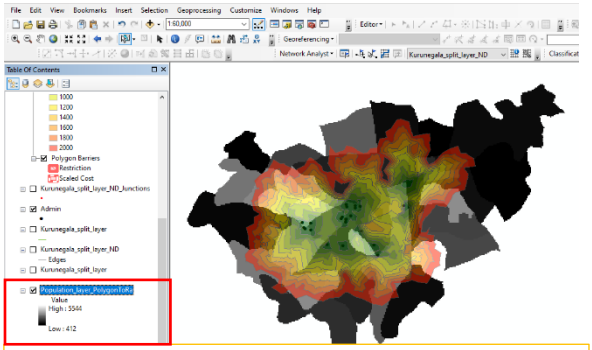
22. Since population data available in DSD wise, this step conducted.



23. Easy of calculation population data will be converted into raster format. Conversion tools > To Raster > Polygon to Raster

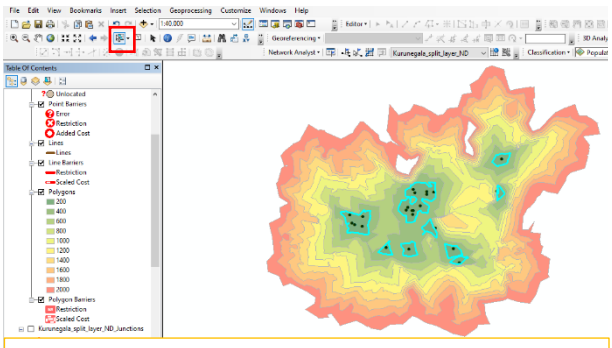


24. Select the Newly exported population layer as the “Input Feature”. Set population density as “Value Field.” Assign “Cell size” according to the nature of the data.

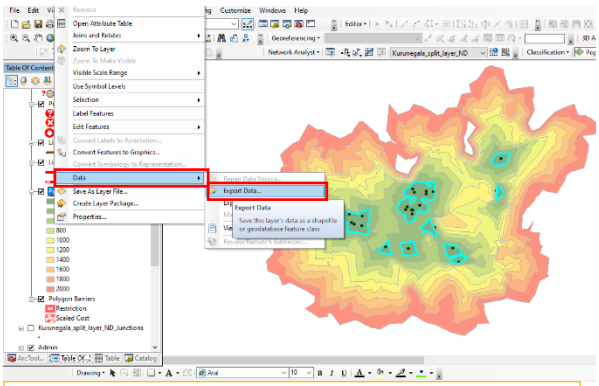


25. Population layer as a Raster layer

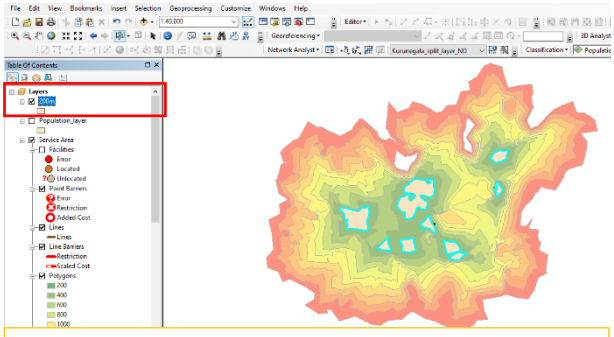
5.1.5 Pixel Value concern to calculate population density of separate zones (Isochrones),



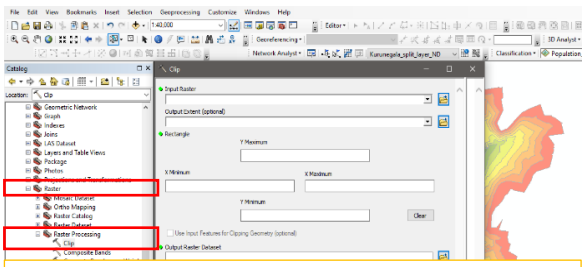
26. Enable “Select Feature” option and select the separate isochrones and export them accordingly. Above example shows the 200m isochrone selection.



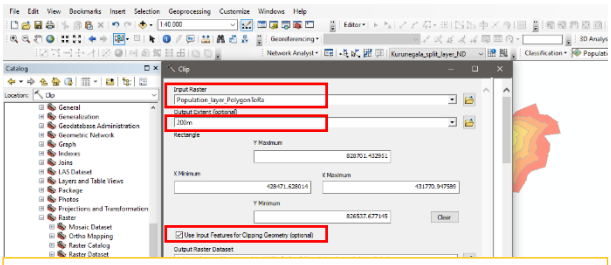
27. Right click on “Polygon” layer and go to “Data” and export it as a separate Layer.



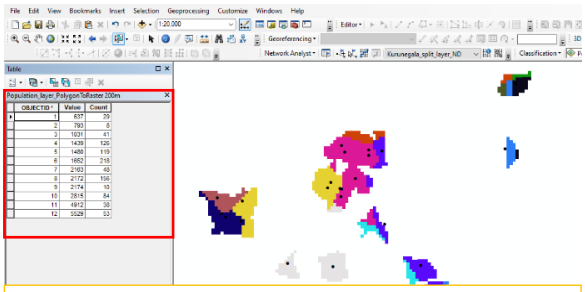
28. Import a copy of export layer in here.



29. Arc Toolbox > Data Management Tools > Raster > Raster Processing.



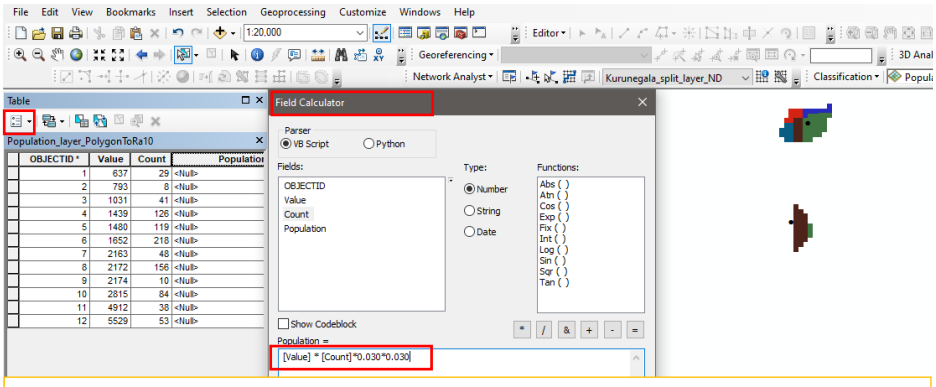
30. Insert converted population raster layer as the “Input Raster”, And select the “output Extent” from exported Isochrones (200m) and make sure to tick the given box (Clipping Geometry”



31. This shows the output raster after clipping 200m isochrone with population data. And attribute table as well.

Graphical representation of population density data with distant buffers,

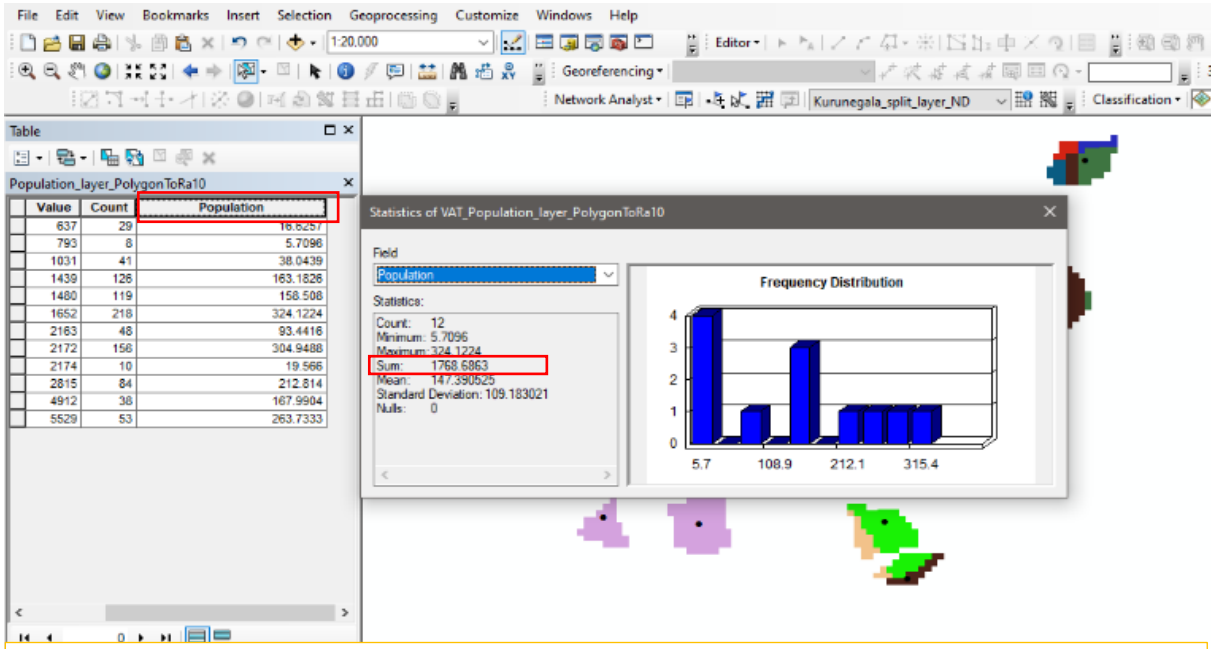
Note: Repeat the same steps for all the 10 isochrones.



32. Add new field. Then right click on new column > select “Field Calculator” from the drop-down menu. Enter the equation [Value* Count* 0.030*0.030]

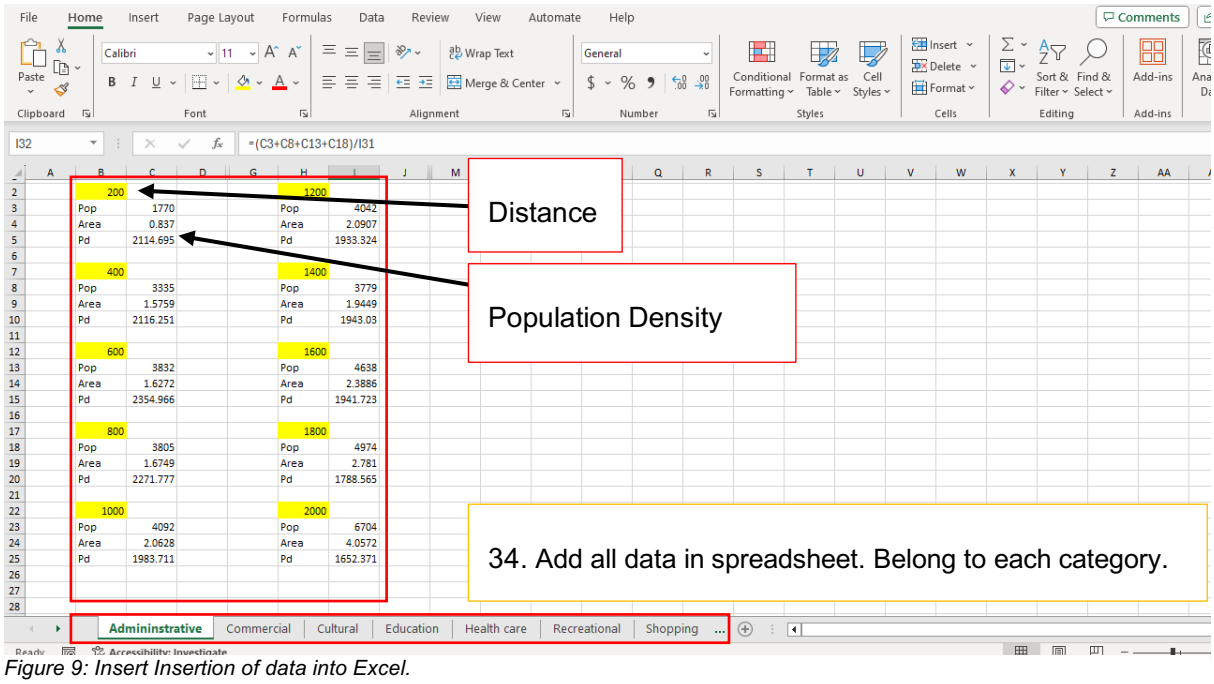
Note: Selected pixel size is 30 meters.

“Count” attribute denotes the number of pixels belong to 200m radius;" “Value” field denote density of the DSD as whole. Population can obtain through the following equation,



33. Right click on population column and note the sum of the population live in that zone (200m).

- Manually enter each data into a spreadsheet and calculate population density using Formulea; ([Population]/[Area] = Population Density).



34. Add all data in spreadsheet. Belong to each category.

Figure 9: Insert Insertion of data into Excel.

5.2 Graphical representation of the details (Population Density vs. distance) of Service Categories.

Plot the details in the corresponding fields accordingly. Using the data in Figure 10.

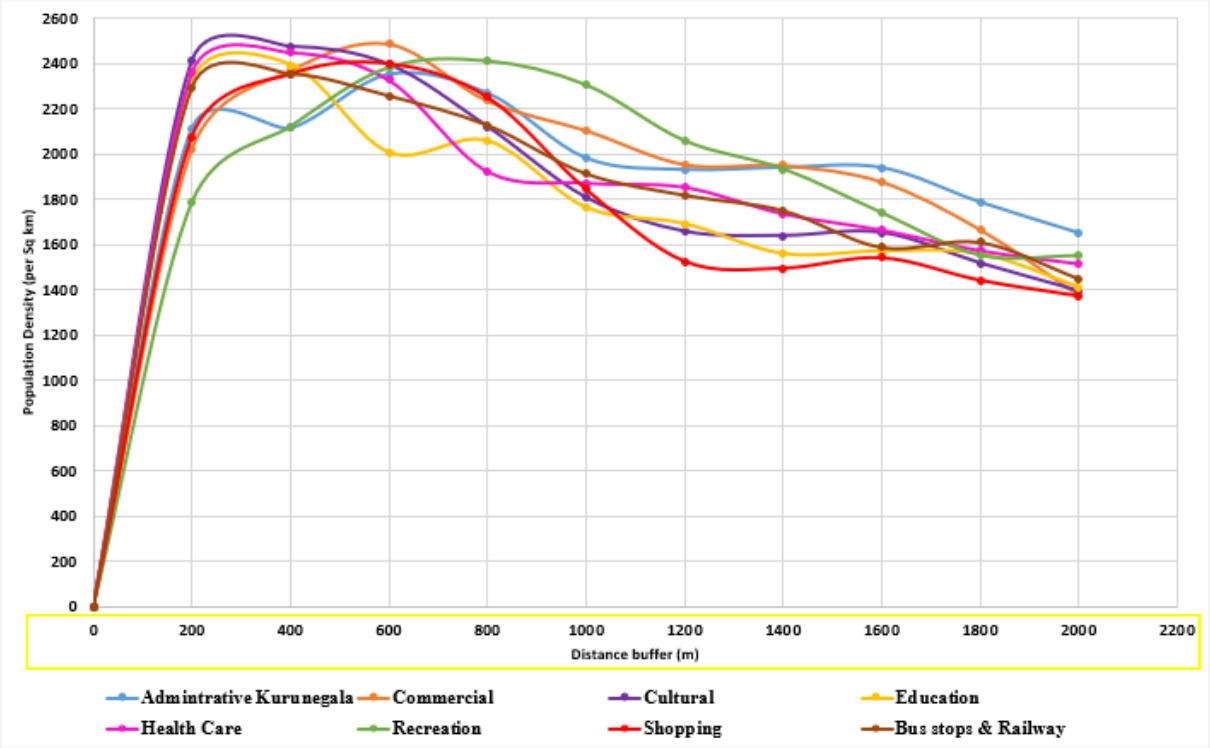
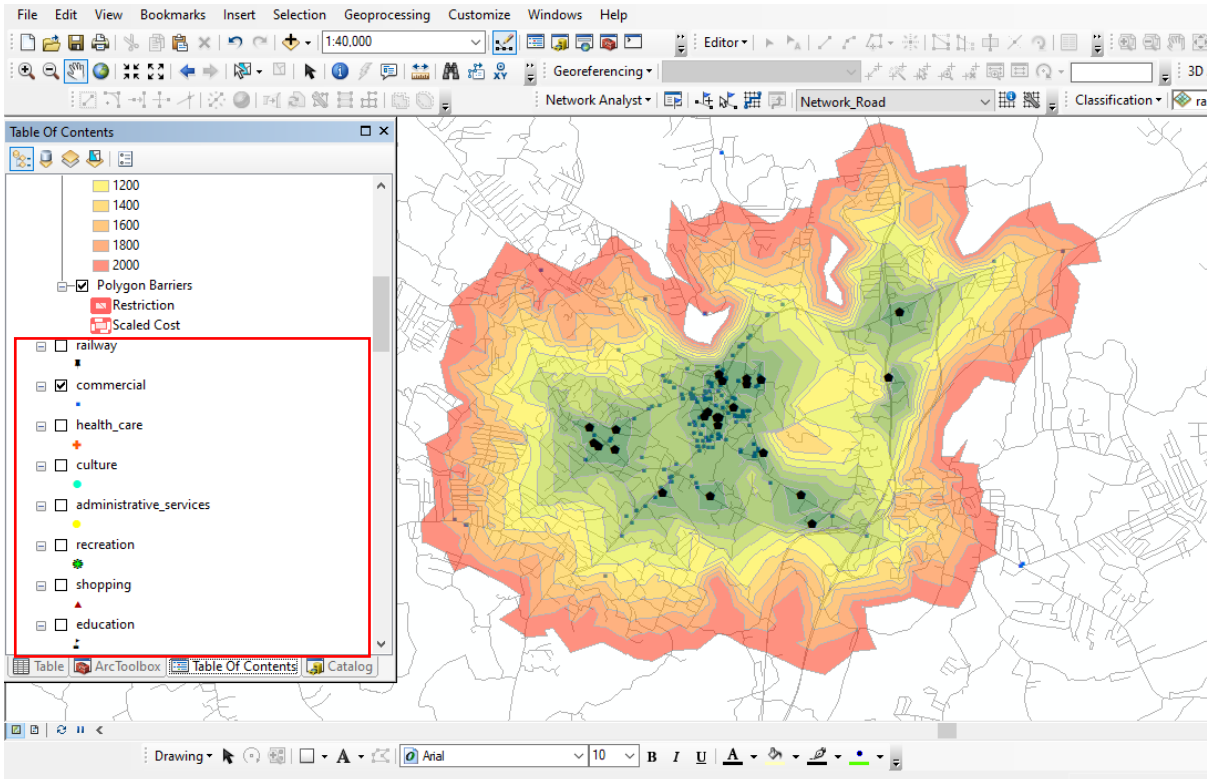


Figure 10:The proximity of residents to various facilities in Kurunegala city (starting from categorized services)

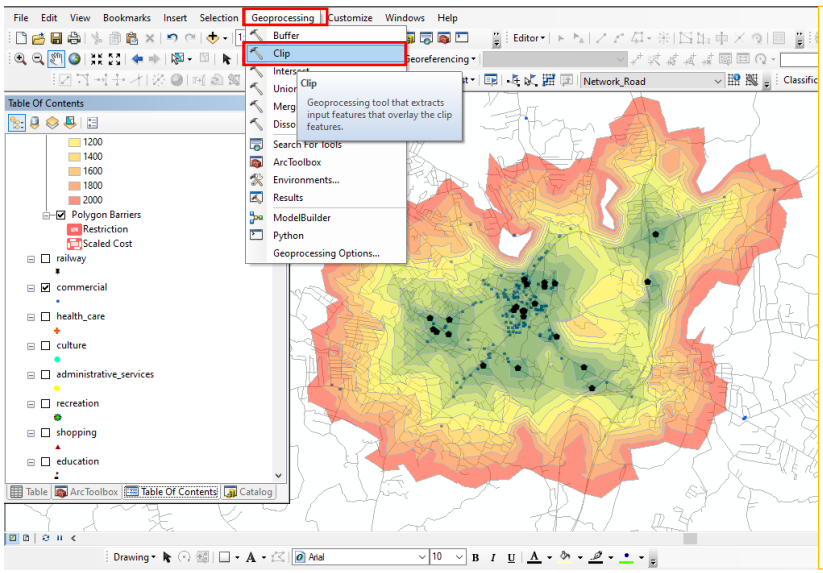
Graphical results are given in the above graph. How the dispersion of facility to population has been identified in the city of Kurunegala. This figure highlights the dense clustering of various facilities within the city, with a maximum observational distance of 2000 meters along the x-axis.

5.3 Distance from POI to the nearest facility POIs considering proportions.

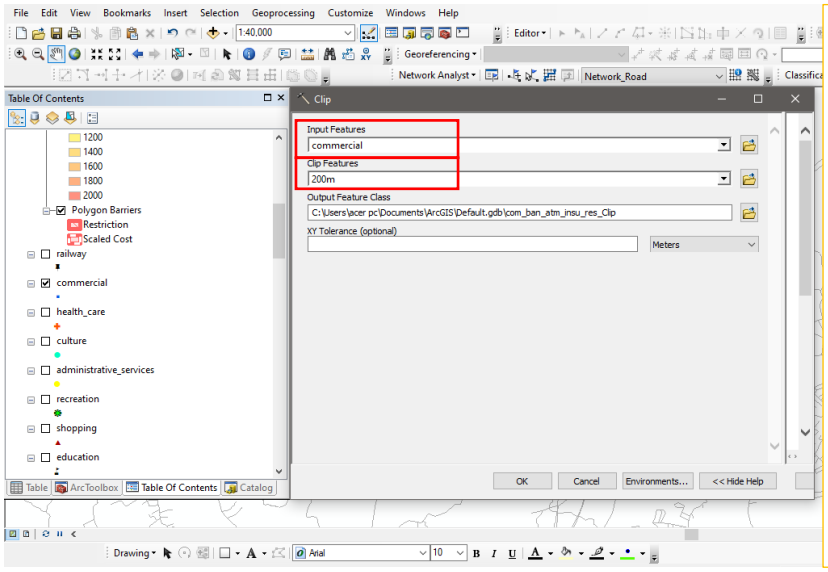
Using the Network Analyst mechanism (output data), the proximity of services to each other can be analyzed to identify the availability of linked services (from one service to other services), considering the number of services within specific isochrones. This analysis can be conducted.



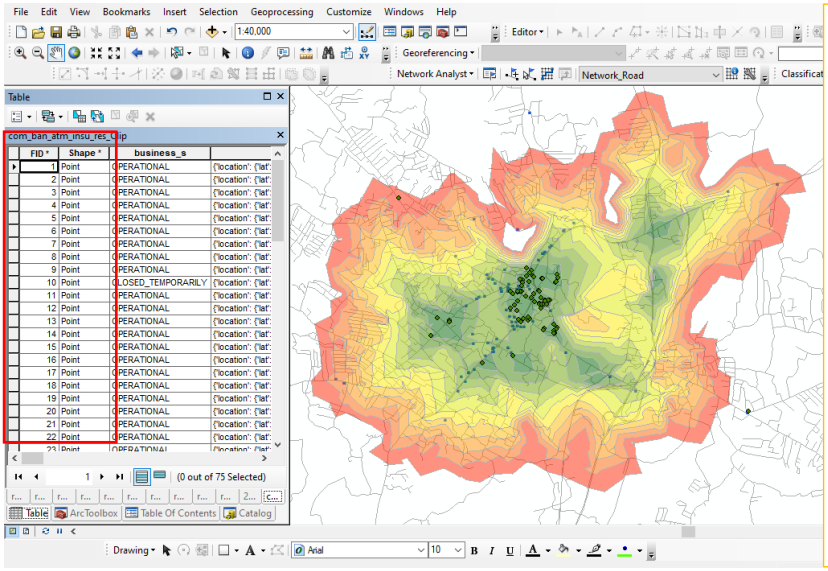
Insert all the POIs belonging to all categories into the project. Let's take the pattern of deviation of commercial Points from administrative service buffers,



1. Go to Geoprocessing tool > select "Clip" in the drop-down menu.



2. Select “Commercial layer” as the “Input Feature and 200m buffer (vector layer) as the “Clip Feature”. Output will be the commercial points which are located within the 200m buffer zone belong to Administrative Services.



3. Number of POIs can count using the attribute table of the created layer. (Clipping Commercial services within the 200m buffer zone of Administrative Services)

Note that a spreadsheet helps to draw a chart compared to the other services, The Above practice should repeat to each category of services, for all 10 isochrones separately.

The below spreadsheet shows the note of data required to check the linked service (7 categories) to the Administrative Service.

- Insert the extracted data into to spreadsheet manually, considering the available number of services within specific isochrones. The density Column shows a proportion of data belonging to each isochrone as a proportion of the same category.

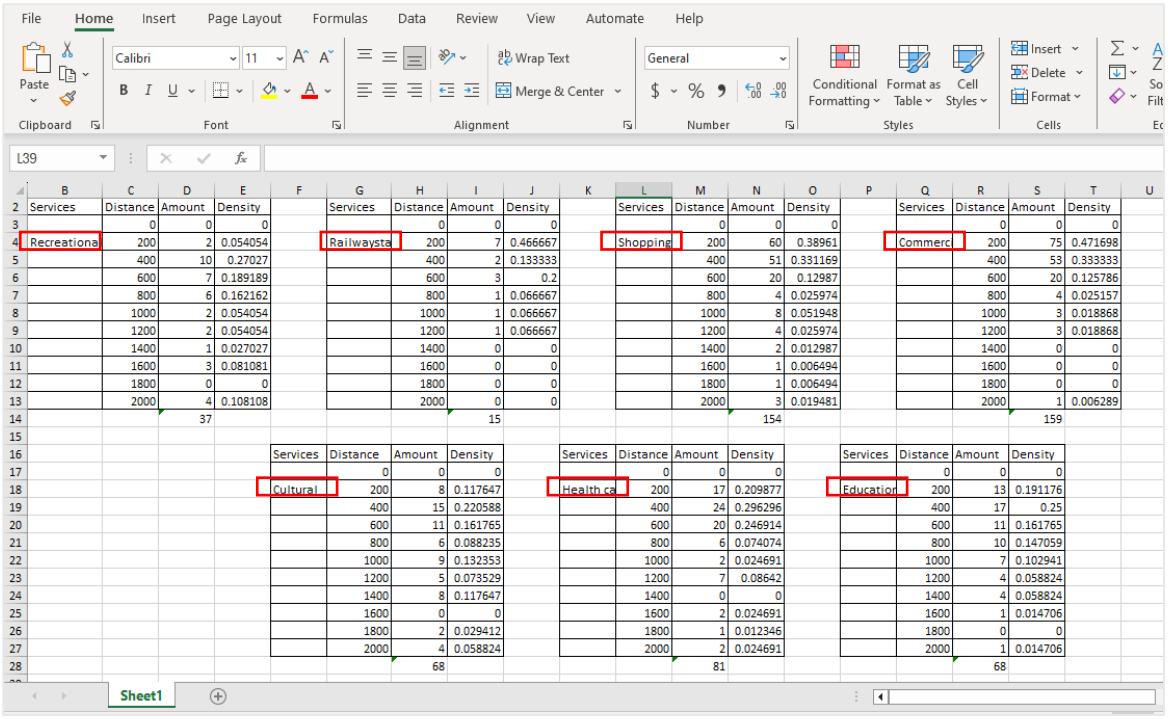


Figure 11:Entering proportional data into excel for processing.

	Administrative Services							
Distance	Recreational	Railway	Shopping	Commercial	Cultural	Health care	Educational	No. of POIs
200	0.05	0.47	0.39	0.47	0.12	0.21	0.19	182
400	0.27	0.13	0.33	0.33	0.22	0.30	0.25	172
600	0.19	0.20	0.13	0.13	0.16	0.25	0.16	92
800	0.16	0.07	0.03	0.03	0.09	0.07	0.15	37
1000	0.05	0.07	0.05	0.02	0.13	0.02	0.10	32
1200	0.05	0.07	0.03	0.02	0.07	0.09	0.06	26
1400	0.03	0.00	0.01	0.00	0.12	0.00	0.06	15
1600	0.08	0.00	0.01	0.00	0.00	0.02	0.01	7
1800	0.00	0.00	0.01	0.00	0.03	0.01	0.00	4
2000	0.11	0.00	0.02	0.01	0.06	0.02	0.01	15

Above is the summarized data (Proportions) which is used to plot the graph regarding linked services.

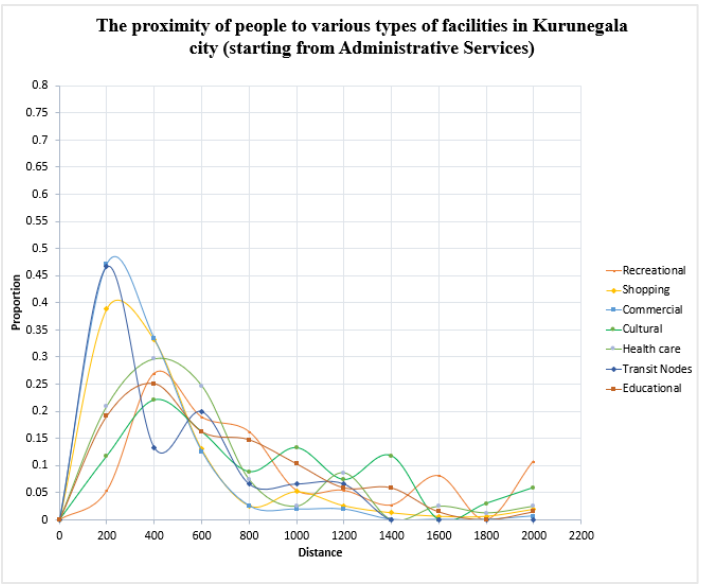


Figure 12: The Proximity of people to various facilities in Kurunegala city (Starting from Administrative points

4. Select the data and go to "Insert" tab in excel > Select "Insert Line or Area Chart".

Note: In this graph, the Y axis indicates the proportion of services available within the considering zone while the X axis indicates the selected isochrones.

Validating the attractiveness of services from the city center: Adapting and applying the gravity-based model.

5.4 Deploying ORS Tool

The ORS (Open Route Service) tool, a plugin in QGIS, integrates the functionalities of the Open Route Service API within the QGIS environment where a separate API key is generated for the Routing service. This versatile online service delivers routing solutions based on OpenStreetMap (OSM) data, enabling QGIS users to access a wide array of services from Open Route Service. These services encompass Routing, Isochrones, Matrix, Geocoding, and Reverse Geocoding.

The Matrix tool within ORS generates a matrix of travel times or distances among multiple points, serving as a key asset for optimizing logistics, analyzing networks, and conducting in-depth accessibility studies. Measuring distances from various points to the city center plays a pivotal role in the creation of a gravity index.

Gravity-based models effectively evaluate a specific zone's accessibility with surrounding zones. Borghetti et al. (2021) adapted the gravity index to measure human attraction. In this study using that index during the validation phase.

To run the ORS tool first, we need to prepare a Routing API Key,

1. Click “open route” service in Google and go to https://openrouteservice.org/dev/#/login this link and create an account.
2. You will be directed to this window,

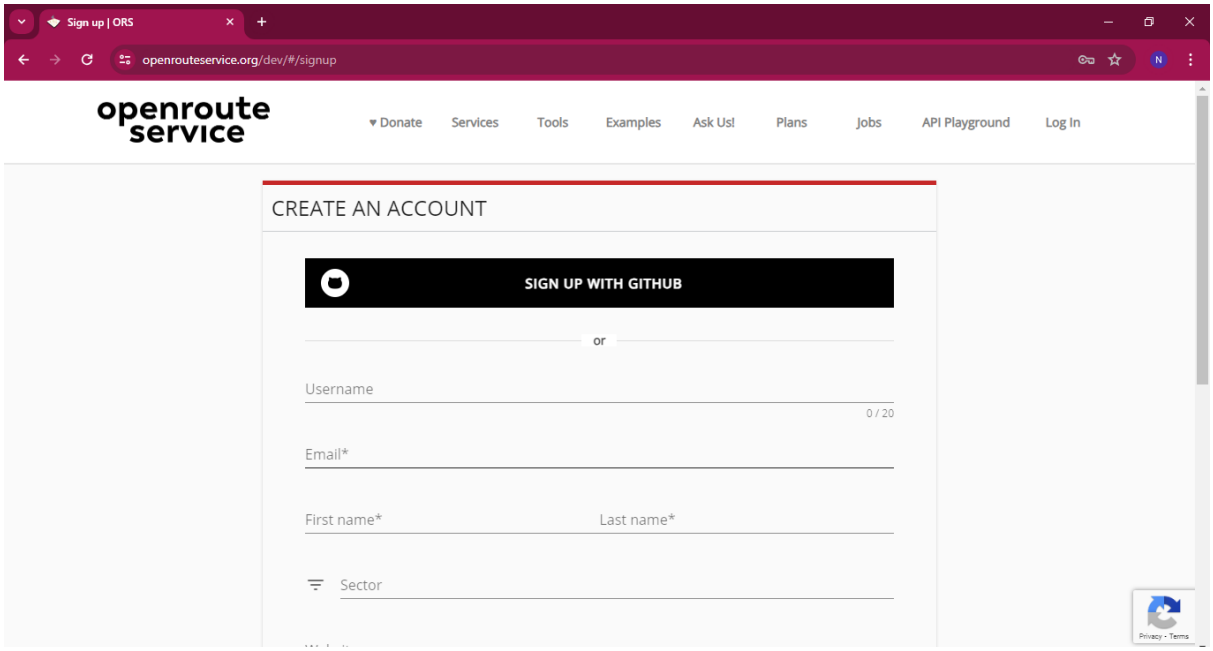
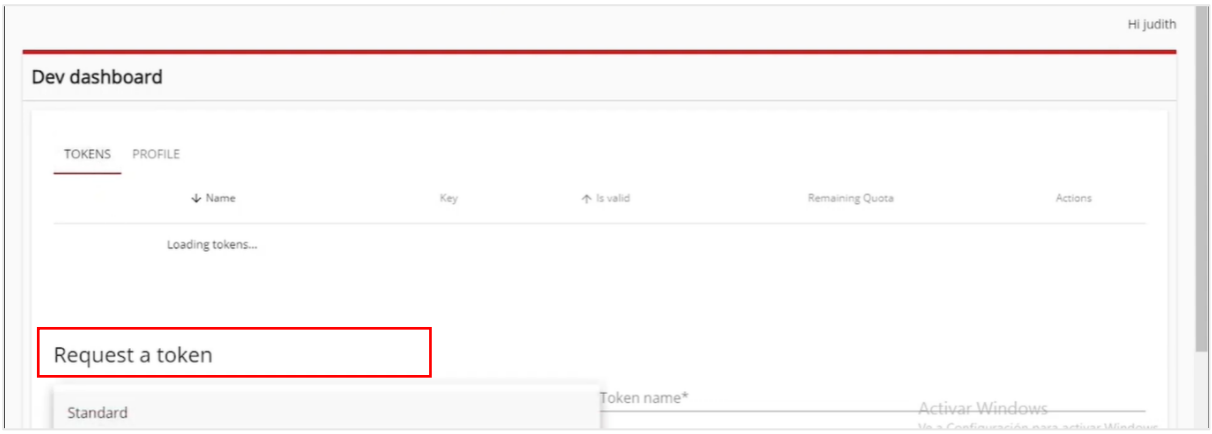
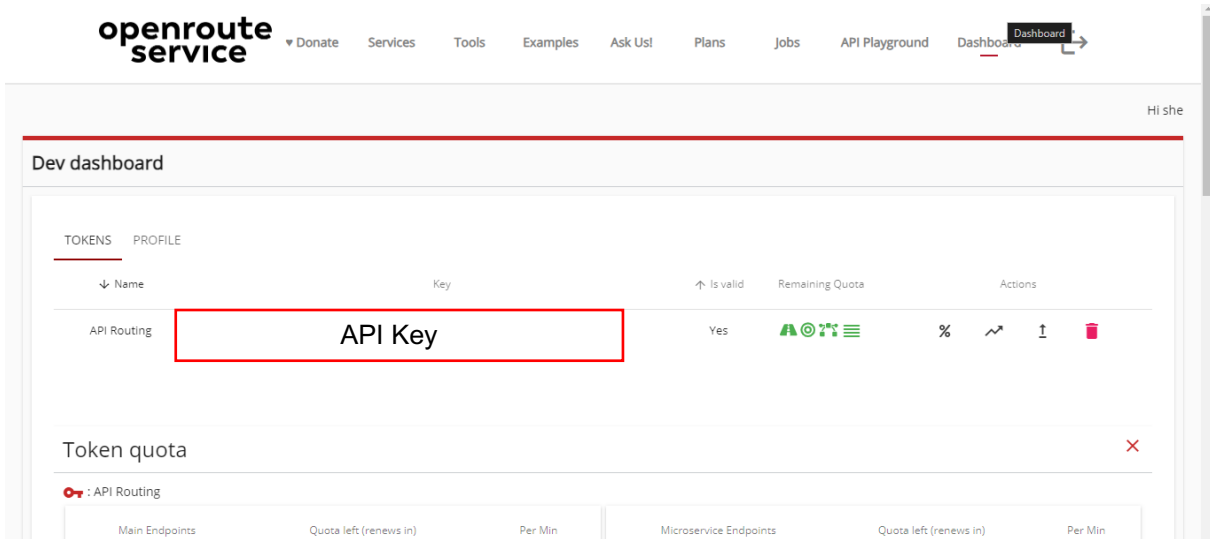


Figure 13:Creating an account in open route service.

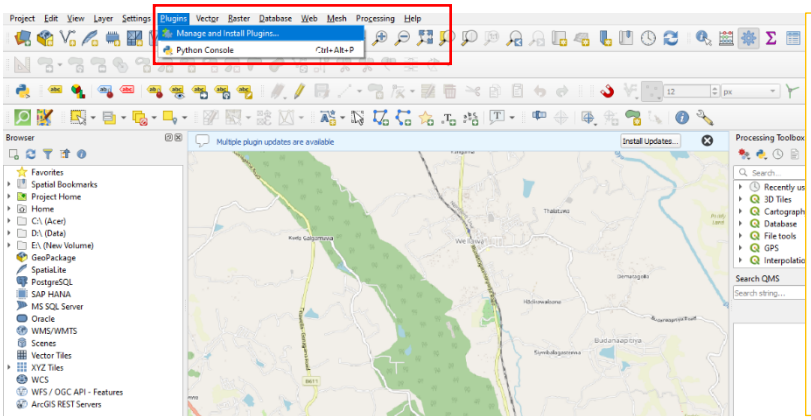
3. Submit it and log in for free use.
4. Request for a token here by entering “Token Type” & “Token Name.” And then click “Create a Token.”



5. It will provide an API key in the given location, which you need to copy for the clipboard.

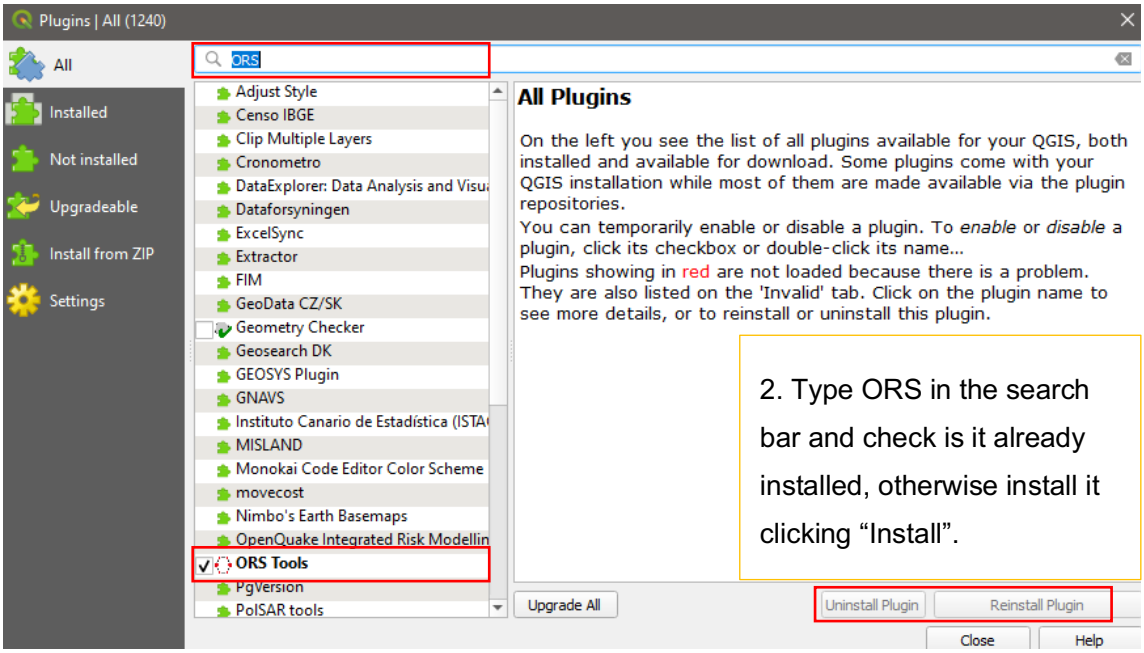


6. Open QGIS software and check whether the ORS plugin is available or not,

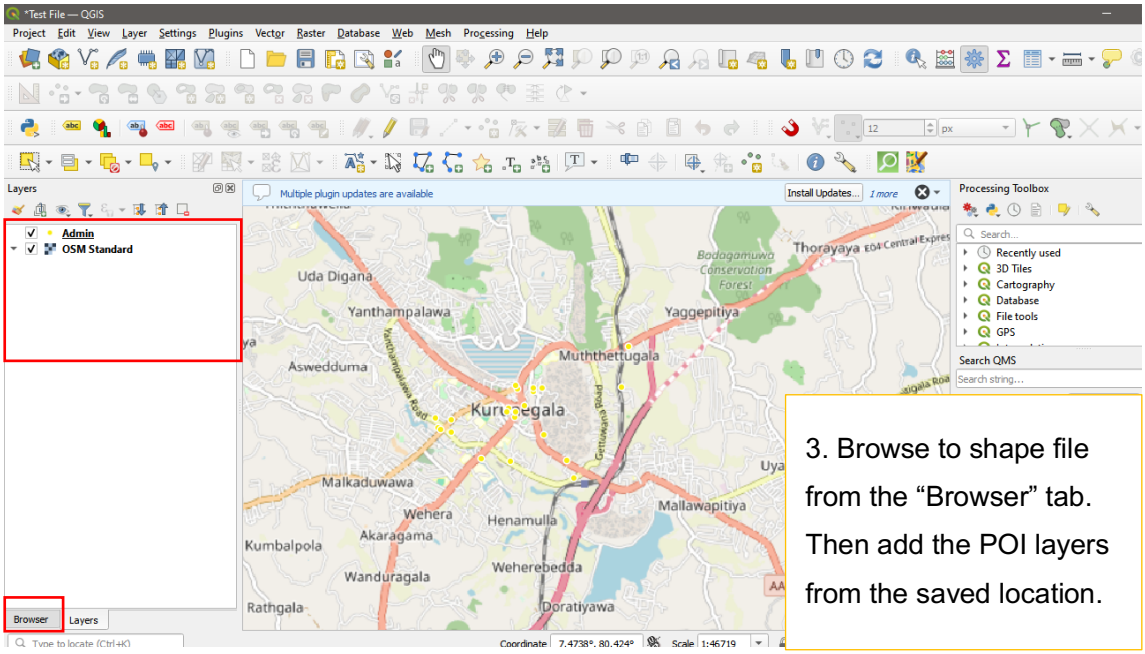


1. Go to Plugins tab and click “Manage and Install Plugins.”
2. Go to Plugins tab and

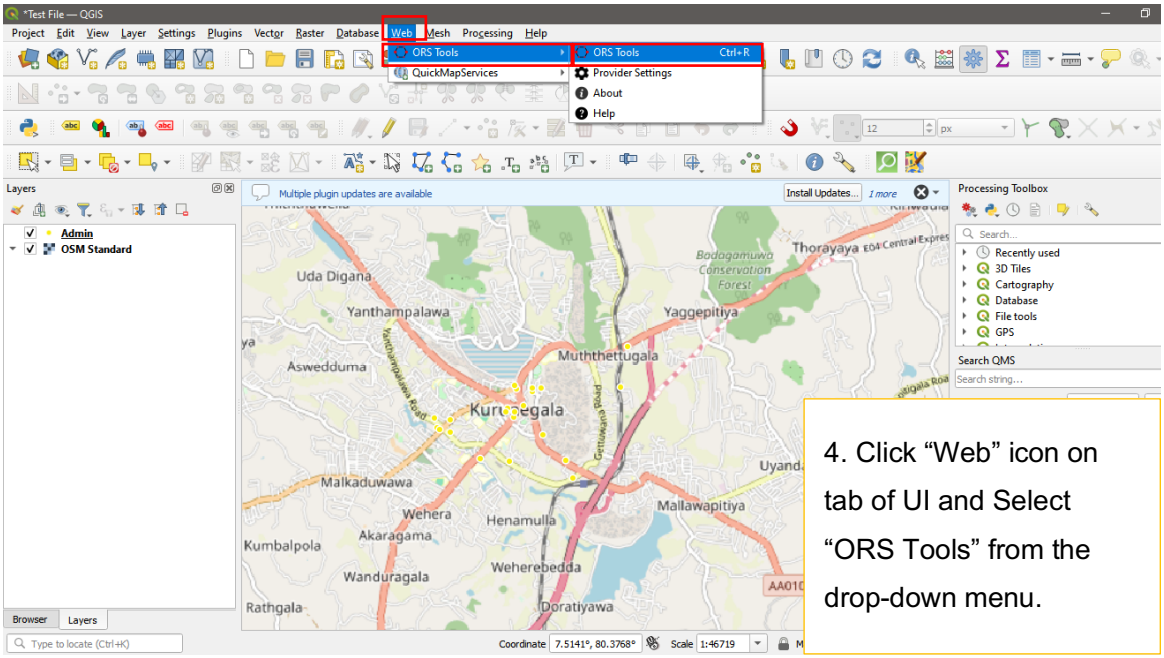
7. Then you will be directed into the following window,



8. Insertion of the POI data into the project.

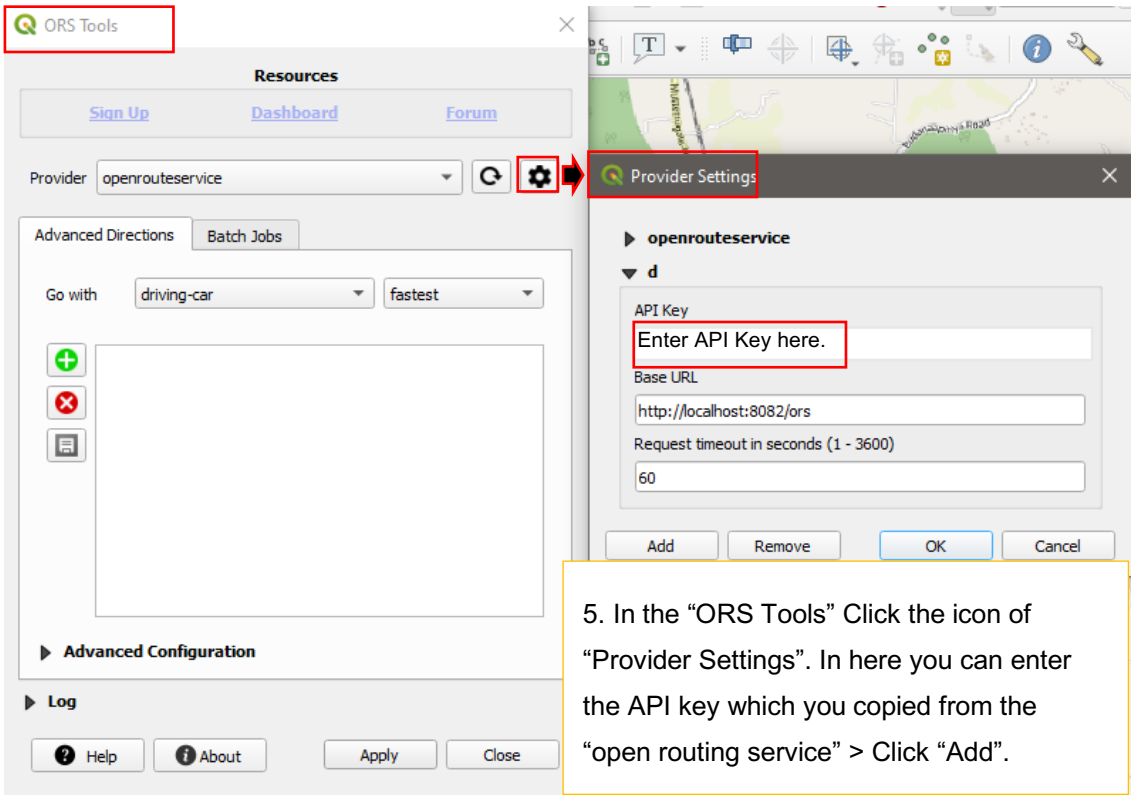


9. Go to the ORS tool.



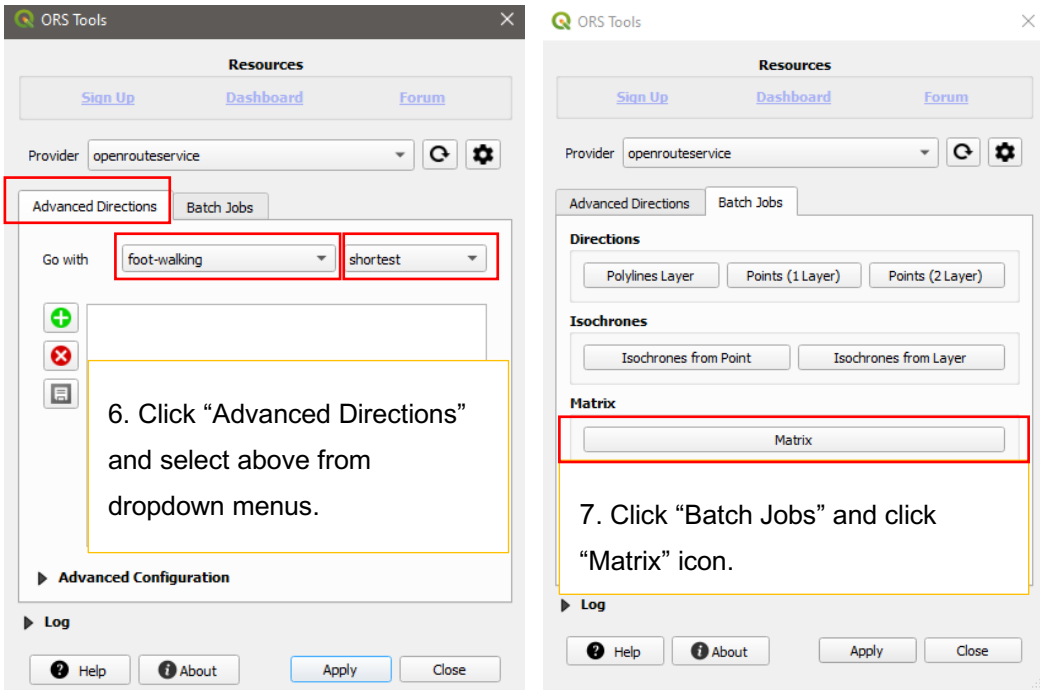
4. Click “Web” icon on tab of UI and Select “ORS Tools” from the drop-down menu.

10. Window of the ORS tool

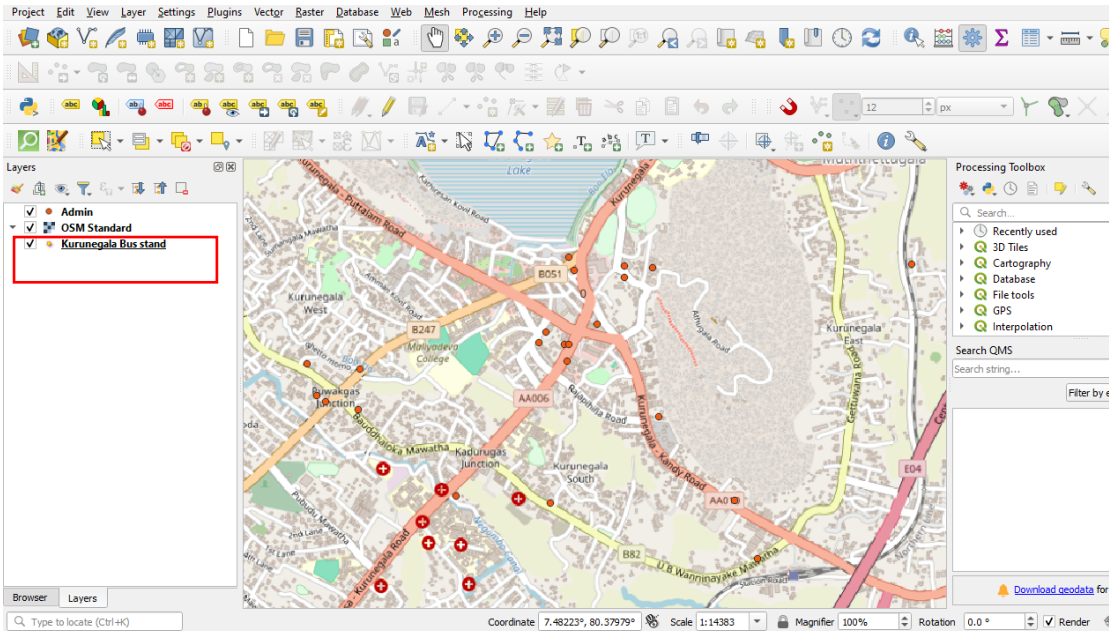


5. In the “ORS Tools” Click the icon of “Provider Settings”. In here you can enter the API key which you copied from the “open routing service” > Click “Add”.

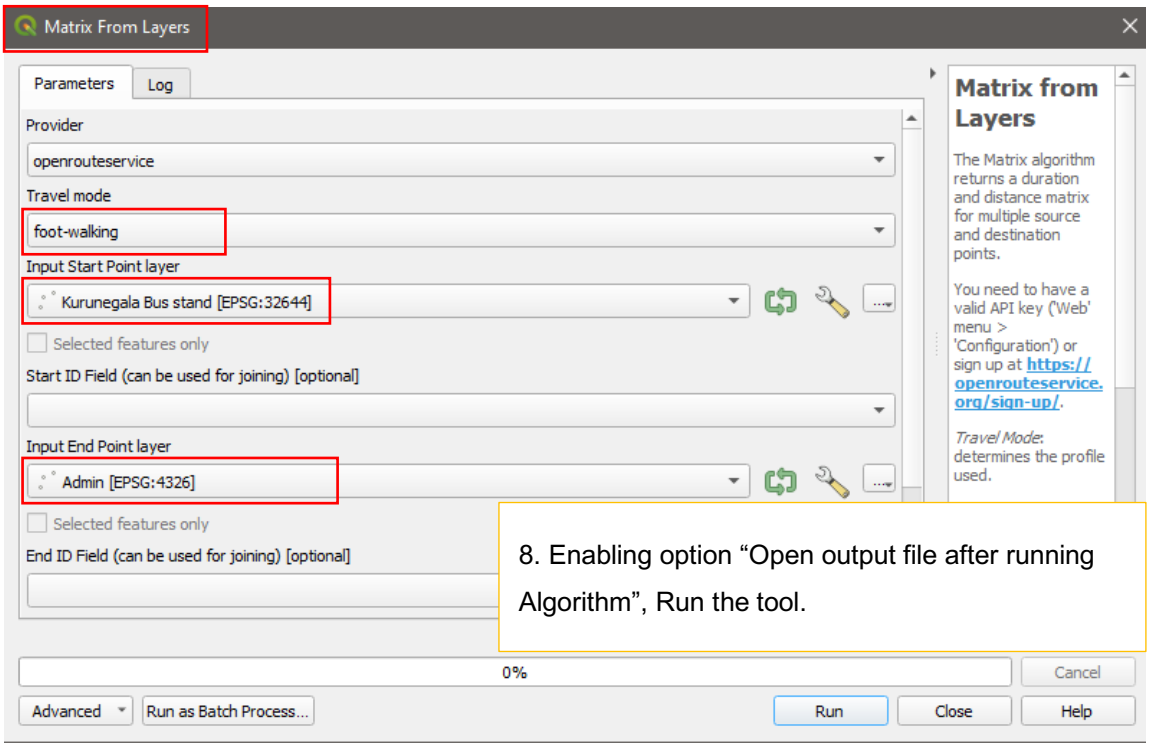
11. Fix the settings.



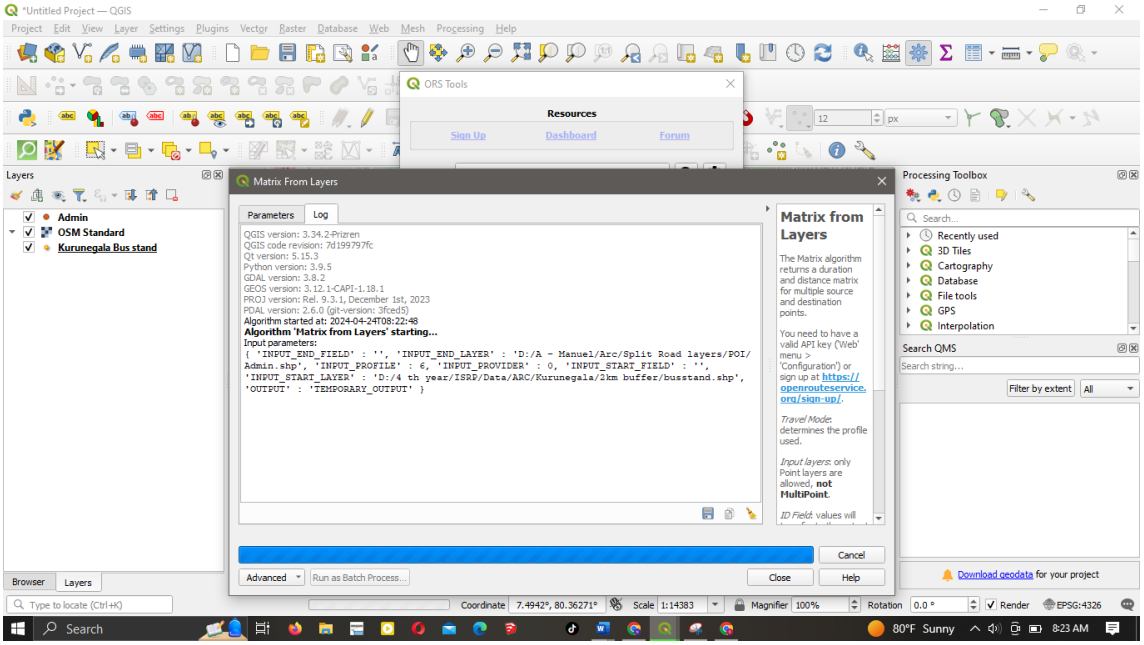
12. Since we are going to measure the city attractiveness index. This study uses insertion points as the Bus station of Kurunegala as the center of services, it varies with the context and the situation. Therefore add the center point of the city to the project as a shapefile. This enables us to calculate the distance from every service administrative point to the bus stand of Kurunegala.



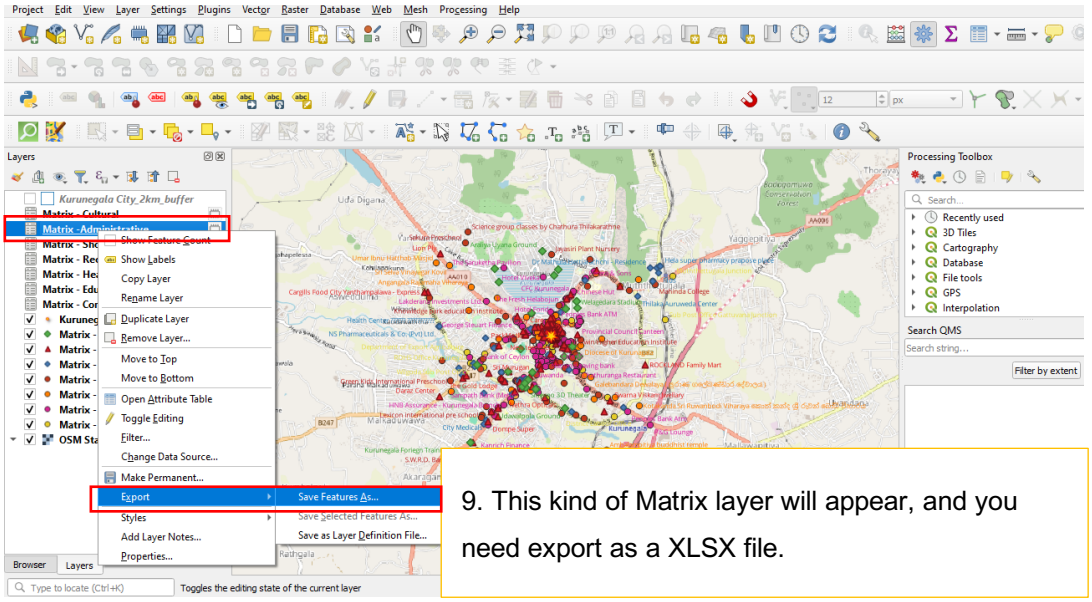
13. After clicking the Matrix button in the “ORS Tool” window, this window will appear, where you need to select the Mode of travel, Input start point layer, and Input Endpoint layer as well.



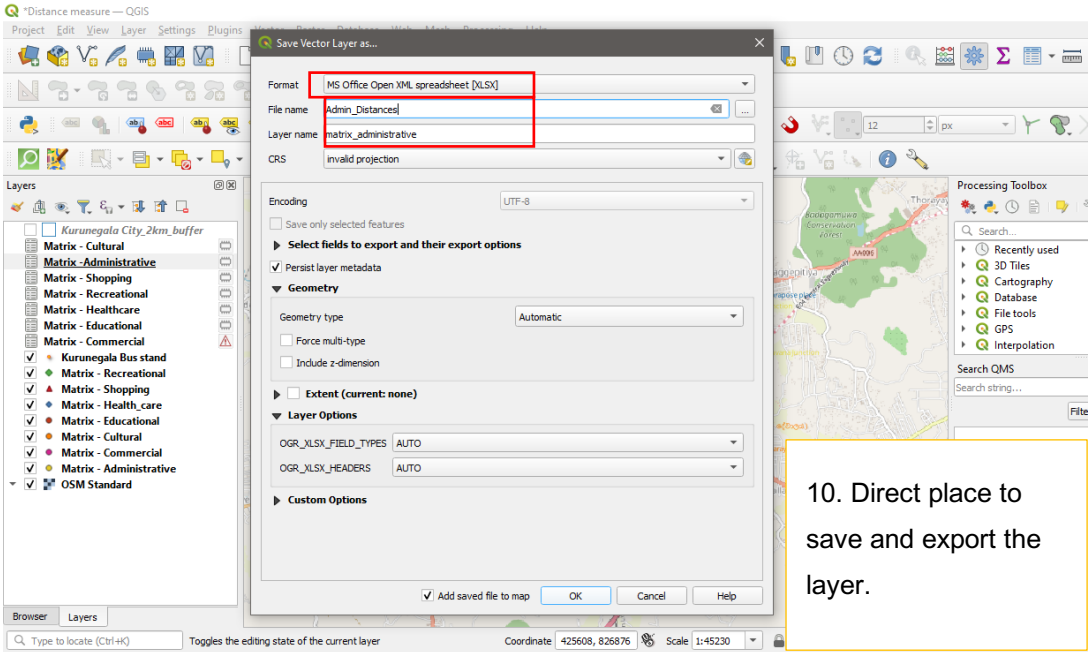
14. Running process.



15. Repeat this for other services as well,

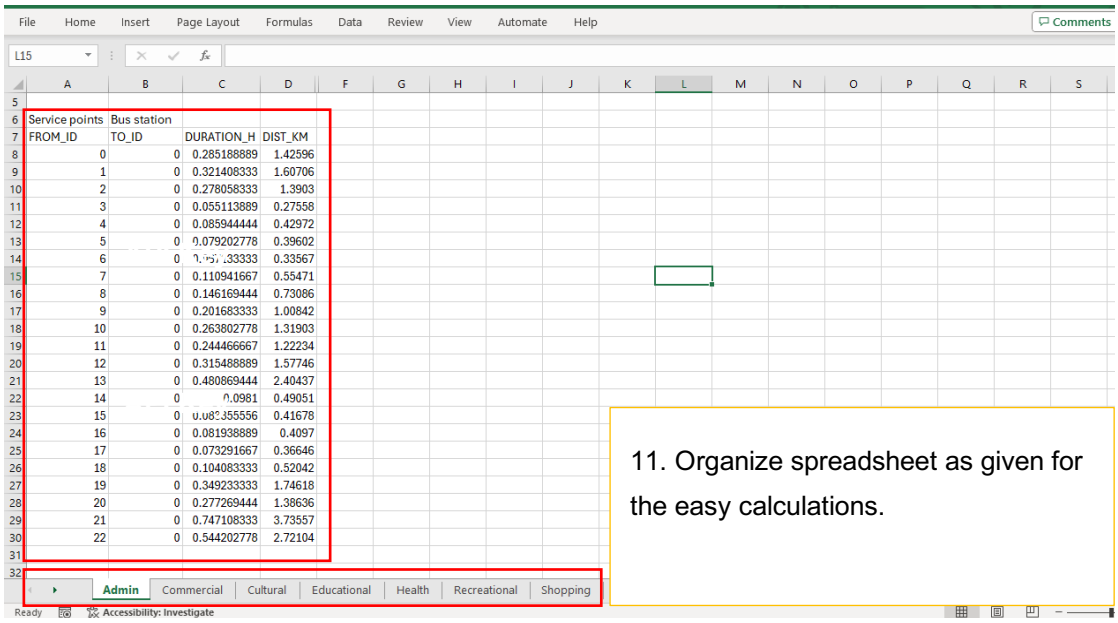


9. This kind of Matrix layer will appear, and you need export as a XLSX file.



10. Direct place to save and export the layer.

16. Generalized Cost in Kilometers from the Point of Consideration to the i th Service Point calculated for each service category in the selected city Kurunegala, The sheet can be organized as follows,



Service points	Bus station		
FROM_ID	TO_ID	DURATION_H	DIST_KM
0	0	0.285188889	1.42596
1	0	0.321408333	1.60706
2	0	0.278058333	1.3903
3	0	0.055113889	0.27558
4	0	0.085944444	0.42972
5	0	0.079202778	0.39602
6	0	[illegible]	0.33567
7	0	0.110941667	0.55471
8	0	0.146169444	0.73086
9	0	0.201683333	1.00842
10	0	0.263802778	1.31903
11	0	0.244466667	1.22234
12	0	0.315488889	1.57746
13	0	0.480869444	2.40437
14	0	0.0981	0.49051
15	0	[illegible]	0.41678
16	0	0.081938889	0.4097
17	0	0.073291667	0.36646
18	0	0.104083333	0.52042
19	0	0.349233333	1.74618
20	0	0.277269444	1.38636
21	0	0.747108333	3.73557
22	0	0.544202778	2.72104

17. Gravity-based models effectively evaluate a specific zone's accessibility with surrounding zones. Borghetti et al. (2021) adapted the gravity index to measure human attraction.

5.5 Defining Equation & the Calculations

$$SCORE_{city} = \sum_{k} \omega_k \sum_{i} (n_k)^{\alpha} * \exp\left(-\beta * \mathrm{GC}_i\right)$$

- n° service $_i^k$ = number of services of type *k* around the city center.
- GC = generalized travel cost: average distance from city center to service *k*. Expressed in km.
- α = weight to be calibrated.
- β = weight to be calibrated.
- ω_k = weight based on the relevance of the service of type *k* among the other types.

5.5.1 The Alpha Parameter,

The alpha (α) parameter represents the exponent to which the number of each type of service is raised. Understanding the logic behind this value requires considering the perceived utility of services surrounding the city from a user's perspective. As the addition of more services occurs, the overall utility begins to saturate, exhibiting a trend that is less than proportional.

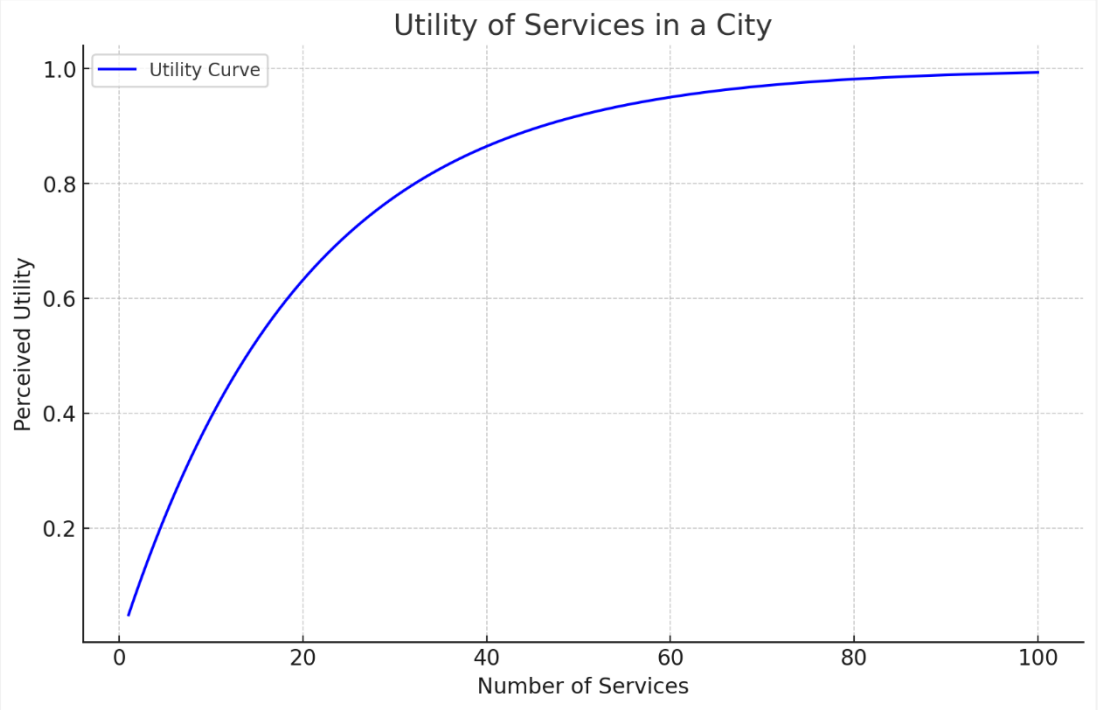


Figure 15:Utility Curve

For this purpose, the study utilized trade data (conducted a trend analysis) acquired from the Account Division of the primary case study city Kurunegala. The Municipal Council provided annual data for the year 2023. We then determined the importance of each category by summing them up. This approach enhanced the clarity of the index. This was conducted in a hypothetical situation where trade tendencies depend on people's needs.

Deriving Alpha values based on trade data Sum of the 3374. Weighed Arithmetic means applied to this in deriving alpha(α) values.

Category	**Number**	**As a percentage**	**α values given.**
Recreational	17	2.5	0.2
Shopping	2186	47	0.45
Commercial	563	40.5	0.4
Culture		0	0.3
Administrative		0	0.2
Health	91	9	0.3
Educational	22	1	0.2

Table 2 : Derived alpha values after giving weights to identified prioritized fields accordingly.

- Weights were given considering percentages. Alpha values are assigned using that.

5.5.2 The Beta Parameter

The beta (β) parameter indicates the decrease rate of the impedance function as the distance from the city increases. A smaller β value leads to a lesser damping effect on each service's score contribution, whereas a larger β value results in greater attenuation. Generally, literature assigns a value of 1 to this parameter (Paez, Scott, Morency,2012).

5.5.3 The Omega Parameter

Further, the weights (each single ωk) serve as parameters that favor the scores of certain types of services over others. The selection of each weight depended on the relevance of each service within the city's context. To achieve this, the study conducted a survey. Omega parameter weight extraction depends on the preference of people on weekdays. A random sample was taken of forty people from the city at peak hour. Based on the majority of service preferences Omega values were assigned,

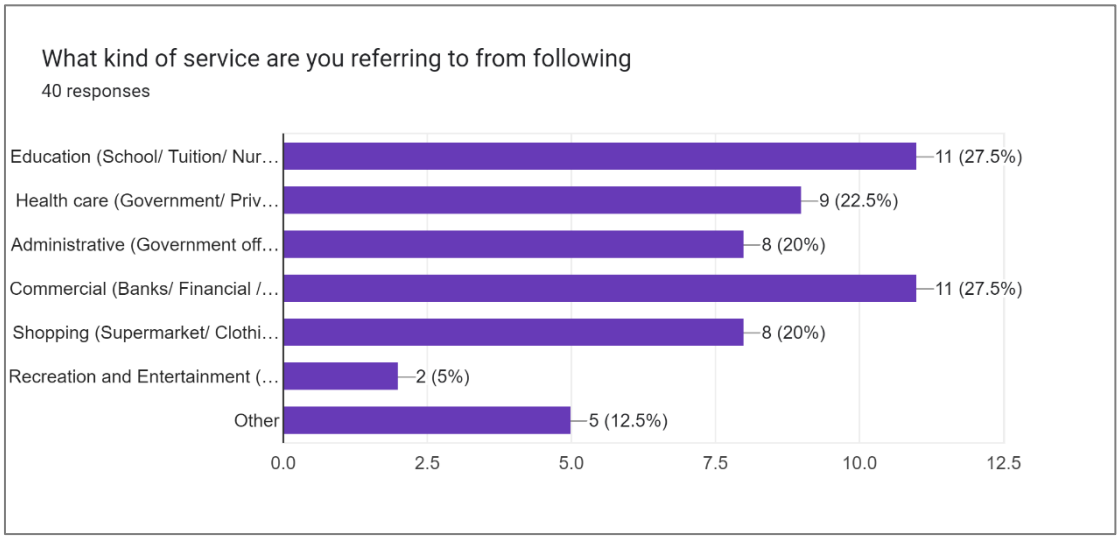


Figure 16: Survey results

Service	Omega Ω values given.
Recreational	2
Shopping	5
Commercial	10
Culture	2
Administrative	4
Health	5

Table 3:Derived Omega values after identifying prioritized field results from the survey conducted.

5.5.4 Calculations of the City Attractiveness (services) Index:

	A	B	C	D	E
1	Ω	4			
2	α	0.2			
3	n	23			
4	Partial Score	71.16937			
5					
6	FROM_ID	TO_ID	DURATION_H	DIST_KM	EXP(-GC)
7	0	0	0.285188889	1.42596	0.240278
8	1	0	0.321408333	1.60706	0.200476
9	2	0	0.278058333	1.3903	0.249001
10	3	0	0.055113889	0.27558	0.759132
11	4	0	0.085944444	0.42972	0.650691
12	5	0	0.079202778	0.39602	0.672993
13	6	0	0.067133333	0.33567	0.714859
14	7	0	0.110941667	0.55471	0.574239
15	8	0	0.146169444	0.73086	0.481495
16	9	0	0.201683333	1.00842	0.364795
17	10	0	0.263802778	1.31903	0.267395
18	11	0	0.244466667	1.22234	0.29454
19	12	0	0.315488889	1.57746	0.206499
20	13	0	0.480869444	2.40437	0.090322
21	14	0	0.0981	0.49051	0.612314
22	15	0	0.083355556	0.41678	0.659166
23	16	0	0.081938889	0.4097	0.663849
24	17	0	0.073291667	0.36646	0.693184
25	18	0	0.104083333	0.52042	0.594271
26	19	0	0.349233333	1.74618	0.174439
27	20	0	0.277269444	1.38636	0.249984
28	21	0	0.747108333	3.73557	0.02386

Formulea used

12. Partial score of every service of the city must be calculated and sum of that would be the city index.

				Dambulla			Kurunegala			Kegalle			Kalutara		
Service	ω_k	α	β	n	Σ exp(-β*GC)	partial score	n	Σ exp(-β*GC)	partial score	n	Σ exp(-β*GC)	partial score	n	Σ exp(-β*GC)	partial score
Recreation	2	0.2	1	5	2.683007307	7.403649527	24	7.330064609	27.68088982	20	8.871813565	32.3034124	13	7.259536883	24.2508844
Shopping	5	0.45	1	57	25.91362083	799.1748152	125	72.87306321	3199.974633	92	47.48140477	1816.34393	98	46.81005465	1842.30227
Commercial	10	0.4	1	110	44.98511876	2948.668467	150	76.36109293	5666.418404	121	60.60839499	4127.11843	108	54.0222252	3515.13469
Cultural	2	0.3	1	14	2.41211695	10.64796872	31	9.461333611	53.01403494	17	6.755347742	31.6091183	23	7.944600352	40.702436
Administrative	4	0.2	1	9	3.332728955	20.68752271	23	9.503586557	71.16936536	13	4.493864345	30.0240048	19	8.505848035	61.3095786
Health	5	0.3	1	20	6.835388177	83.95415329	49	14.59346536	234.5239822	44	14.52686827	226.0361	15	6.058936956	68.2643274
Educational	10	0.2	1	16	3.771209885	65.66057779	43	13.07249888	277.3654131	26	10.07540841	193.311339	23	10.38323897	194.392013
SCORE $_{city}$						3936.197154			9530.146723			6456.74633			5746.3562

Table 6:Calculations of the city attractiveness Index.

- Sample calculation indicated using a black box (Partial score of Administrative services in city Kurunegala.)

α will be the same across the selected 4 cities as all of them are considered Medium-sized cities
partial score = $\omega_k * n^{\alpha} (\Sigma \exp(-\beta*GC))$
SCORE $_{city} = \Sigma$ (partial score $_k$)

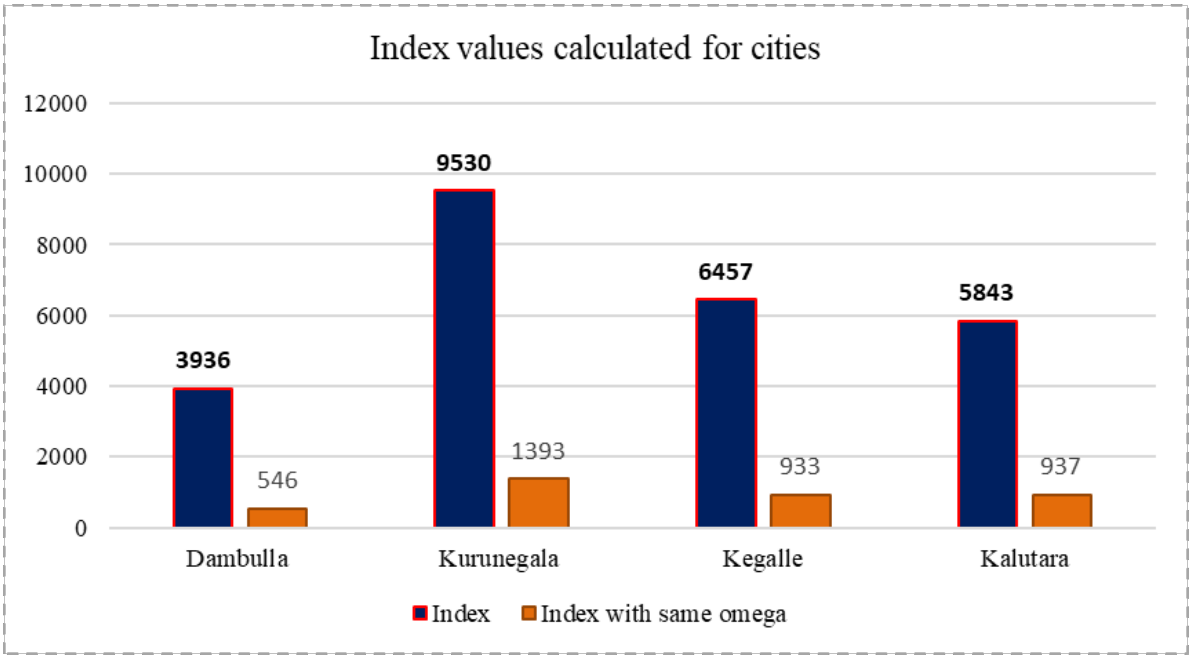


Table 7:Comparison of the Index values.

The gravity index was calculated for all cities, ranking Kurunegala, Kegalle, Kalutara, and Dambulla in order based on their service attractiveness from the city center. This score indicates a city's attractiveness based on the services developed within and surrounding it. The model shows Dambulla city's facilities are lacking, resulting in a low attractiveness index, while Kegalle and Kalutara maintain the same level of attractiveness. In contrast, Kurunegala is identified as the most attractive city, attributed to its superior service provision considering the city center as the nuclei. Deployed the same omega value of Zero indicated that the results would be more or less similar except for the cities Kalutara and Kegalle. Therefore, the preference of people is a fact.

6. ANNEXURE

Field data was collected through Google Forms, employing both observational and questionnaire surveys (on the field). The main goal of this research was to refine the validation methods used to calculate omega values. It also investigated the patterns of movement of people within the primary area of study and considered their service preferences and choices as part of the analysis.

6.1 Questionnaire to derive omega values.

Service Attraction - Weighting

Omega parameter weight extraction depending the preference of people in week days.
Random sample taken from the city.

1. Where are you from?

_____

2. Approximate distance from your home to Kurunegala

_____

3. Which mode of transport you used?

Mark only one oval.

- ◯ Bus
- ◯ Train
- ◯ Private
- ◯ Other

4. What kind of service are you referring to from following

Check all that apply.

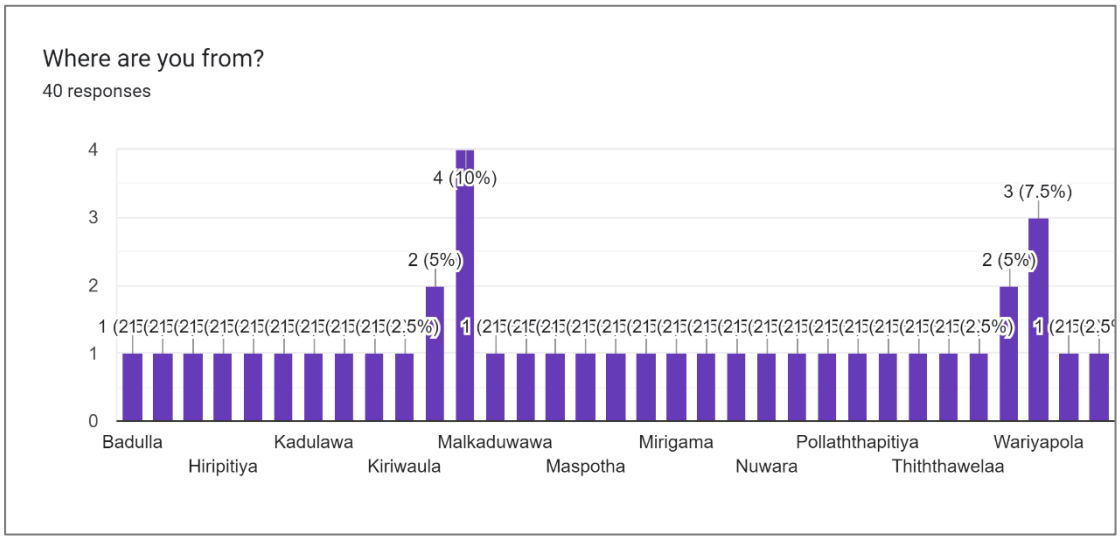
- ☐ Education (School/ Tuition/ Nursery)
- ☐ Health care (Government/ Private/ Dispensaries/ Pharmacies)
- ☐ Administrative (Government office/ Post office/ Sub post office)
- ☐ Commercial (Banks/ Financial / Resturents)
- ☐ Shopping (Supermarket/ Clothing / Public Markets)
- ☐ Recreation and Entertainment (Public park play ground/ Cinema hall / Indoor sport complex or fitness)
- ☐ Other

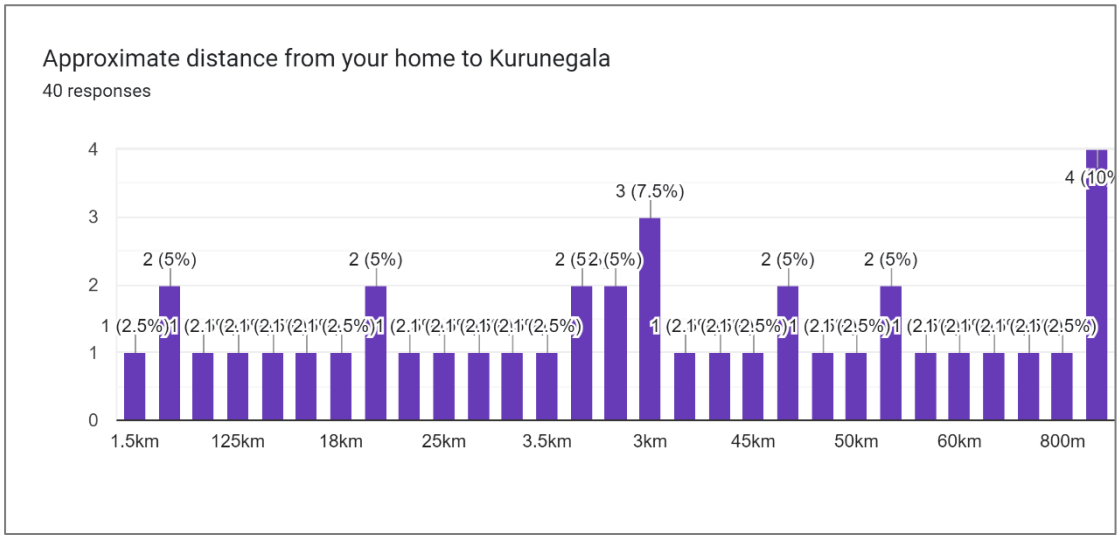
5. Quality and Distance Measure (Assume small Price variations are there)

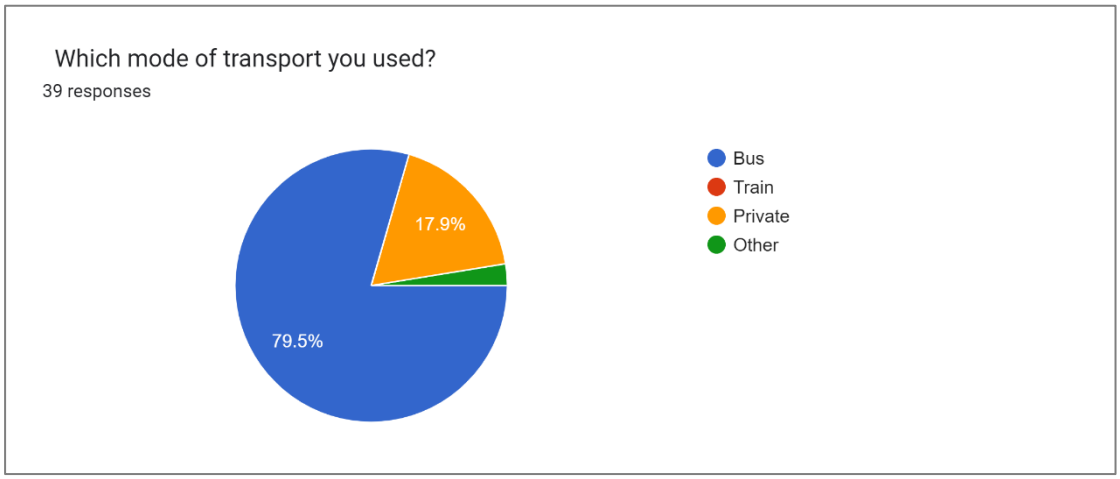
Mark only one oval.

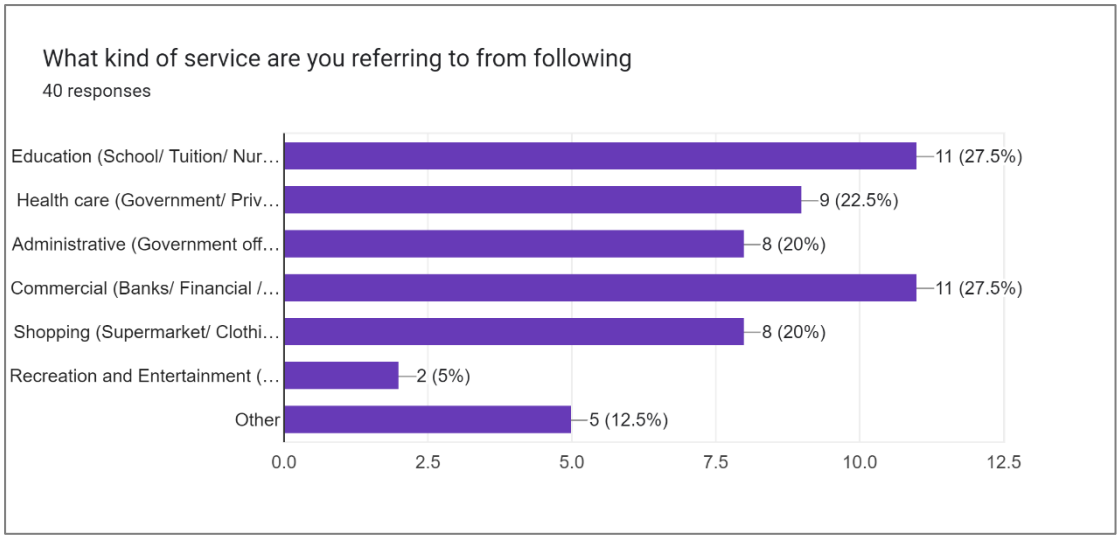
- ◯ A - 200m (Bad Quality)
- ◯ B - 400m (Quality)
- ◯ C - 600m (Good Quality)
- ◯ D - 800m (Supreme Quality)

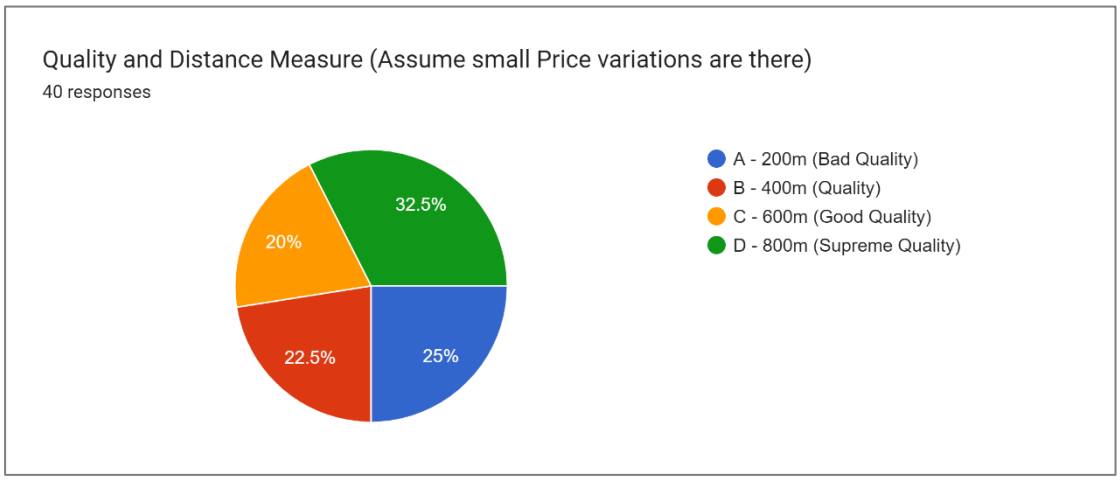
6.2 Summary of the Responses







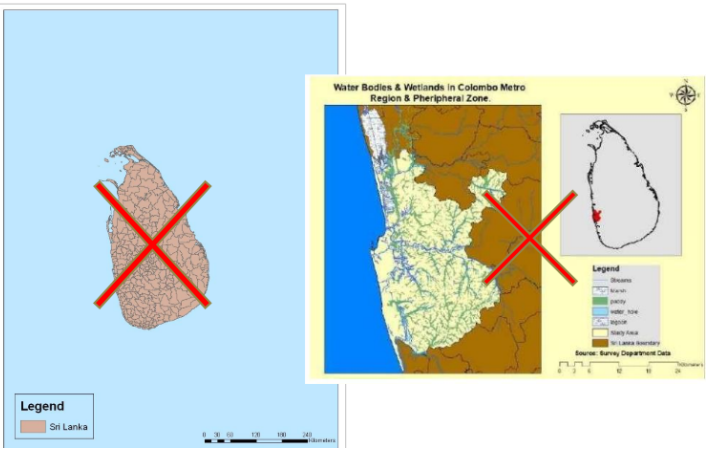

What kind of service are you referring to from following
40 responses
Education (School/ Tuition/ Nur…
Health care (Government/ Priv…
Administrative (Government off…
Commercial (Banks/ Financial /…
Shopping (Supermarket/ Clothi…
Recreation and Entertainment (…
Other
11 (27.5%)
9 (22.5%)
8 (20%)
11 (27.5%)
8 (20%)
2 (5%)
5 (12.5%)
0.0
2.5
5.0
7.5
10.0
12.5


Quality and Distance Measure (Assume small Price variations are there)
40 responses
32.5%
20%
22.5%
25%
A - 200m (Bad Quality)
B - 400m (Quality)
C - 600m (Good Quality)
D - 800m (Supreme Quality)

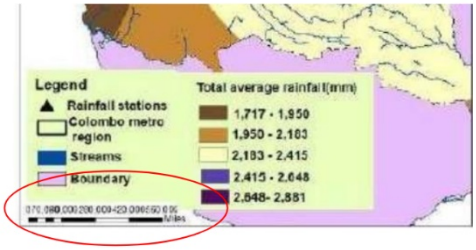
6.3 Preparation of maps

1. Use Suitable Colors & Symbols
2. Show adjacent administration boundaries.
3. Maximum utilization of map space
4. Show the Graticule Network with appropriate grid size.
5. Show the basic elements in the map.
    a. Transportation Networks
    b. Water Bodies
6. Prepare a descriptive map.
    a. Label notable features.
        i. Major Road Types
        ii. Major Rivers
        iii. GN Boundaries
        iv. If needed, show the location of the area in a different data frame.
7. Check the units of the scale bar.
8. Mention correct units at the legend.
9. Check the text given in the legend.
10. Mention the correct sources.

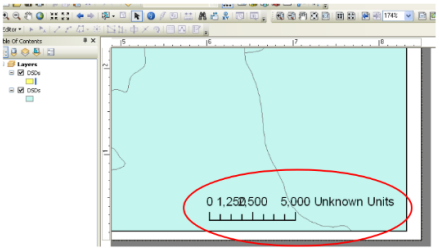
Examples



Maximum utilization of map space



Check the units of the scale bar.



Check the text given in the legend.

Mention the correct sources.

Figure 18:Incorrect formats of maps