Teaching & Learning 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



Amila Jayasinghe Nawoda Jayarathna Samith Madusanka **Teaching & Learning 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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# PREFACE

This book serves as open educational material 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 book, 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 book 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 mediumsized cities, a teacher looking for robust educational tools, or a practitioner in need of refining your technical expertise, this book 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.

# TABLE OF CONTENTS

LIST OF TABLES	. viii
1. INTRODUCTION	1
Graphical representation of the facility to population Dispersion in a medium-sized city (Fi Result)	inal 2
2. OVERVIEW	3
3. Required Tools / Software	3
4. DATA COLLECTION AND METHODOLOGY	4
4.1 Data categorization and collection	5
4.1.1 Data Categorization	5
4.1.2 Data Collection	6
4.2 Preparation of the Data Layers	. 19
4.2.1 Insertion of the population data into the project	. 19
4.2.2 Insertion of the Road data into the project	. 22
4.3 Summary	. 23
5. Application Section - Medium-Sized City's Service Profiling	. 24
5.1 Deploying Network Analyst Tool	. 24
5.1.2 Creation of New Network Data Set	. 27
5.1.3 Creation of the service Area and Set properties	. 29
5.1.4 Incorporating population data	. 30
5.1.5 Pixel Value concern to calculate population density of separate zones (Isochrones),	. 31
5.2 Graphical representation of the details (Population Density vs. distance) of Service Categories.	. 34
5.3 Distance from POI to the nearest facility POIs considering proportions	. 35
5.4 Deploying ORS Tool	. 38
5.5 Defining Equation & the Calculations	. 45
5.5.1 The Alpha Parameter,	. 45
5.5.2 The Beta Parameter	. 47
5.5.3 The Omega Parameter	. 47
5.5.4 Calculations of the City Attractiveness (services) Index:	. 48
6. ANNEXURE	. 50
6.1 Questionnaire to derive omega values	. 51
6.2 Summary of the Responses	. 52
6.3 Preparation of maps	. 54

# TABLE OF FIGURES

Figure 1:The proximity of residents to various facilities in Kurunegala city (starting from services)	n categorized 2
Figure 2: Entire process in a flow chart	3
Figure 3:Python code & API key prepared to obtain POI data from Google API	14
Figure 4: Insert CSV files to ARC Map	16
Figure 5: Displaying Population Density	20
Figure 6:Mapping population Density.	21
Figure 7:Split Road layer.	23
Figure 8:Steps to create Network data set.	27
Figure 9: Insert Insertion of data into Excel.	33
Figure 10:The proximity of residents to various facilities in Kurunegala city (s categorized services)	starting from 34
Figure 11:Entering proportional data into excel for processing	37
Figure 12: The Proximity of people to various facilities in Kurunegala city (S Administrative points	Starting from
Figure 13:Creating an account in open route service	
Figure 14:Utility Curve11. Organize spreadsheet as given for the easy calculations	45
Figure 15:Utility Curve	46
Figure 16: Survey results	47
Figure 17:Incorrect formats of mapsCheck the text given in the legend	55

# LIST OF TABLES

Table 1:POI Data Categorization and Sources.	5
Table 2 : Derived alpha values after giving weights to identified prioritized fields accordingly	46
Table 3:Derived Omega values after identifying prioritized field results from the survey conducted	47
Table 4:Calculations of the city attractiveness Index	49
Table 5:Comparison of the Index values.	49

# **1. INTRODUCTION**

This training book offers a comprehensive guide to analyzing whether Sri Lankan cities qualify as 15minute cities, using software ARC GIS can substitute with open-source software QGIS and the Open-Source Data usage Google (OSM). The book 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 book is designed to be both expandable and replicable, allowing for the inclusion of more indicators to refine each city's index.

The book is structured into three chapters:

- Chapter 2: Introduction to the book
- Chapter 3: 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 4: 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	<ul> <li>ARC MAP / QGIS PRIZREN 3.34 (Installed ORS Plugin)</li> <li>Google Colab / Pycharm</li> </ul>
DATA COLLECTION	Web pages	Google Cloud platform

# 4. DATA COLLECTION AND METHODOLOGY

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

- 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 book 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 book 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 &	Public parks & Playgrounds					
Entertainment	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

← → C 😑 consc	ole.cloud.google.com/freetrial/signup/tos	☆ む   🤨 🗄
<b>S</b> T	ry Google Cloud for free	
Step	o 1 of 2 Account Information Access to all Google Cloud products	$\sim$
g	Get everything you need to build and run your apps, websites and services, including Firebase and the SWITCH ACCOUNT Google Maps API.	
	\$300 credit for free	$\langle \cdot \rangle$
Countr	ry Put Google Cloud to work with \$300 in credit to	$\sim$
Sri La	nka v spenover me next so days.	
D	No autocharge after free trial ends	
Supple of Serv	ng this application, you agree to the <u>coogle cloud Platform</u> (2, emental Free Trial (2, and <u>any applicable services and APIs</u> Terms vice. We ask you for your credit card to make sure you are not a robot. If you use a credit or debit card, you won't be charged unless you manually activate your full account.	
AGRE	EE & CONTINUE	

• Select the option Try "Google Cloud Free" select "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.

✓					
← → C S console.cloud.google.com/freetrial/signup/billing/	LK		*	ជ	
Try Google Cloud for free					
Step 2 of 2 Payment Informatio Your payment information helps us reduce fraud and us debit card, you won't be charged until you manually ac Payments profile Your payment information is saved in a payments pro your Google Account and shared across Google acro poyments profile Payment method Add payment method	on Verification         Access           use if using a credit or         Add payment method           Add payment methods are based on your currency (USD) apament setting. Learn more about payment methods         (USD) apament setting. Learn more about payment methods           +         Add credit or debit card         (USD) apament setting.	and here the set of th		•	
SUBMIT		•			

• The window will appear like this,



• Enter the legit data for the following questions, And click the Button "Done"



• You will open into window like this, and click the icon at the upper left corner,

Come – My First Project – G × +			- Ø X				
← → C 😄 console.cloud.google.com/welcome/new?p	roject=polar-decorator-422112-t3		☆ む   🤨 🗄				
■ Google Cloud String My First Project ▼ String	Search (/) for resources, docs, products, and more	Q Search 🔶 🛌	1 🤉 ፣ 😗				
Pre-built solution templates 🛛							
Summarize large documents u Generative AI Generative AI, summarization, machin	e learning Create a data warehouse with BigQuery Data warehouse, dashboards, ETL, analytics, data analysis	Create an analytics lakehouse Data science, IOT, streaming analytics					
View all Solutions							
Train and host ML models Vertex Al	View and use notebook data Vertex Al Workbench	models (Analyze and manage data BigQuery					
Process batch data Cloud Dataflow	Organize business data	speech (i) Convert speech to text Speech-to-Text API					
View all products View all APIs Compare with AWS and Azure							
Interactive tutorials							

• 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".



- 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,

•	RPI Places API – APIs & Ser	vices-N × +						-	٥	×
÷	← → C 🛱 console.cloud.google.com/apit/library/places-backend.googleapis.com?project=polar-decorator-422112-t3									
=	Google Cloud	🔹 My First Project 💌		Q	+	>-	2	0	: (	g
÷	Product details									
	OVERVIEW	Places API Google Enterprise API Get detailed information about 100 million places MANAGE  API Enabled DOCUMENTATION SUPPORT RELATED PRODUCTS								
	Overview Get data from the s over 100 million bu frequently through of Place search (2 Ret string. Place details (2 Ret user reviews.	ame database used by Google Maps. Places features sinesses and points of interest that are updated owner-verified listings and user-moderated contributions. um a list of places based on a user's location or search um detailed information about a specific place, including	Additional details Type: <u>SaaS &amp; APIs</u> Last product update: 9/28/22 Category: <u>Google Enterprise APIs</u> , <u>Maps</u> Service name: places-backend.googleapis.com							

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".

:=	$  \forall \land \rangle$	🗸 Draw 🗸 🎸	2   ①   A <sup>®</sup>   a	あ Ask Cop	ilot –	+ 🕶   9 of 30   🥥		Q
			Opent	StreetMap Data in L	iyered GIS Format // Version	n 0.7.12	\$	
			4.2	Points of	Interest			
			This	layer has an a	associated area laye	er (see section 2.8).		
			The	following feat	ure classes exist in	this layer:		
			cod	e layer	fclass	Description	OSM Tags	
			20xx	public				
			2001		police	A police post or station.	amenity=police	
			2002		fire_station	A fire station.	amenity=fire_station	
			2004		post_box	A post box (for letters).	amenity=post_box	
			2005		post_office	A post office.	amenity=post_office	
			2006		telephone	A public telephone booth.	amenity=telephone	
			2007		library	A library.	amenity=library	
			2008		town_hall	A town hall.	amenity=townhall	
			2009		courthouse	A court house.	amenity=courthouse	
			2010		prison	A prison.	amenity=prison	
			2011		embassy	An embassy or consulate.	amenity=embassy or office=diplomatic	
			2012		community_centre	A public facility which is mostly used by local associations for events and festivities.	amenity=community_centre	
			2013		nursing_home	A home for disabled or elderly persons who need permanent care.	amenity=nursing_home	
			2014		arts_centre	A venue at which a variety of arts are performed or conducted, and may well be involved with the creation of those works, and run occasional courses.	amenity=arts_centre	
			2015		graveyard	A graveyard.	amenity=grave_yard or landuse=cemetery	
			2016		market place	A place where markets are held.	amenity=marketplace	

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,

← → C 😁 colab.google		☆ ⊉
Google colab	Blog Release Notes Notebooks Resources	ab New Notebook Sigr
	Google Colaboratory Colab is a hosted Jupyter Notebook service that requires no setup to use and provides free access to computing resources, including GPUs and TPUs. Colab is especially well suited to machine learning, data science, and education.	
		~

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.

← → C 🔩 colab.research.google.com/drive/1qrF0tFc_VLr_Y5XHkL0jGuhbNylx7hXT?authuser=0#scrollTo=8cvjVWzuaOav						
CO ▲ Untitled1.jpynb ☆ File Edit View Insert Runtime Tools Help	E Comment	🚉 Share 🎄 g				
+ Code     + Text       Q     Ipip install googlemaps       Inin.install.vlswmitar       {x}     Run cell (CH+Enter)	Ipip install googlemaps pip install xlsxwriter					

• 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 dfl.empty:
    df1['url'] = 'http://www.google.com/maps/place/?g=place id:' +
df1['place_id']
if not dfl.empty:
    if 'geometry' in df1:
latlong = dfl.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 dfl.empty:
    df1['latitude'] = lat.astype(float)
    df1['longitude'] = lng.astype(float)
dfl.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 (<u>https://download.geofabrik.de/osm-data-in-gis-formats-free.pdf</u>).

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,

A	utoSave 🤇		15° C	- <del>-</del>	dataset	<ul> <li>Saved to</li> </ul>	this PC 🗸	<i>,</i>	) Search						0	nawoda ja	iyarathna 🚺	D lä	æ	- 0	_/×	4
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8	{'location	https://i	m #909CE1	https://m	Elimount	[{'height':	ChIJS36IH	ChIJS36IH	GOOGLE	['lodging'	, VJCX+894	OPERATIC	NAL	3.3	12				http://ww	7.870758	80.64	
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10	{'location	https://i	m #909CE1	https://m	Hotel Kiya	[{'height':	ChIJb_fUe	ChIJb_fUe	GOOGLE	['lodging'	, No, 102 K	OPERATIC	{'compour	3.6	41				http://ww	7.858444	80.6	
11	{'location	https://i	m #909CE1	https://m	Sayare Inr	[{'height':	ChIJ8fJ9R	ChIJ8fJ9R	GOOGLE	['lodging'	, No. 545, L	OPERATIC	{'compour	4.8	95				http://ww	7.867555	80.63	
12	{'location	https://i	m #909CE1	https://m	Green Vie	[{'height':	ChIJRd0DI	ChIJRd0D	GOOGLE	['lodging'	, No 05 Silv	OPERATIC	{'compour	5	9	{'open_n	ow': False}		http://ww	7.874391	80.64	Ш
13	{'location	https://i	m #909CE1	https://m	Marcopol	[{'height':	ChIJRTXQ	ChIJRTXQ	GOOGLE	['lodging'	, 624 anura	OPERATIC	{'compour	4.1	10				http://ww	7.878163	80.65	
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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 these layers as CSV files to the project and convert them into point layers by following

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 the following popup menu,

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• 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.

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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.

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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 bookly 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:

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.



• Check the box,



## 5.1.1 Creation of Impedance in the Attribute Table

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





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### Note:

Set the speed according to requirement. This study focus on walkability I use 1.34 ms<sup>-1</sup> as the average walking speed of a person.

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## 5.1.2 Creation of New 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,

K New Network Dataset X						
Do you want to model tums in this network ? No © Yes Tum Sources: C Clabela Tump b						
<ul> <li>Obvior Julio*</li> </ul>						
2 - You will open to this window						
Click "Yes" and go ahead with						
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<book net=""> Cancel</book>						
X New Network Dataset X						
How would you like to model the elevation of your network features?						
Using 2 Looranate values inton Geometry Using Bevation Fields						
Source End Field Kurunegala_split_layer From End						
Kurunegala_split_layer To End						
4 - You will open to this window.						
Click your preference and go						
ahead with "Next" button.						
< Back Next > Cancel						



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

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.



Layer Properties					×					
Line Gen	eration	Accum	ulation		Network Locations					
General	Layers	Source	Analysis Se	ttings	Polygon Generation					
Generate Polygo	ins			L						
Polygon Type		Multiple Facilitie	s Options							
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Opetailed		Create polygons for each facility. These								
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Meters	~	Join polygons of multiple facilities having the same break values.								
Excluded Source	es	Overlap Type								
C Kurunega	ala_split_layer	Rings     Do not include the area of the smaller breaks.								

17. In "Polygon Generation" tab, put "200m" asthe "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.



19. Service Buffers output is here. Follow same process for each category (11<sup>th</sup> step to 18<sup>th</sup> 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.





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

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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.







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.



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

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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,





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.



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 bookly, 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.

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4	Recreationa	200	2	0.054054		Railwaysta	200	7	0.466667		Shopping	200	60	0.38961		Commerc	200	75	0.471698	
5		400	10	0.27027			400	2	0.133333			400	51	0.331169			400	53	0.333333	
6		600	7	0.189189			600	3	0.2			600	20	0.12987			600	20	0.125786	
7		800	6	0.162162			800	1	0.066667			800	4	0.025974			800	4	0.025157	
8		1000	2	0.054054			1000	1	0.066667			1000	8	0.051948			1000	3	0.018868	
9		1200	2	0.054054			1200	1	0.066667			1200	4	0.025974			1200	3	0.018868	
10		1400	1	0.027027			1400	0	0			1400	2	0.012987			1400	0	0	
11		1600	3	0.081081			1600	0	0			1600	1	0.006494			1600	0	0	
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21						800	6	0.088235			800	6	0.074074			800	10	0.147059		
22						1000	9	0.132353			1000	2	0.024691			1000	7	0.102941		
23						1200	5	0.073529			1200	7	0.08642			1200	4	0.058824		
24						1400	8	0.117647			1400	0	0			1400	4	0.058824		
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26						1800	2	0.029412			1800	1	0.012346			1800	0	0		
27						2000	4	0.058824			2000	2	0.024691			2000	1	0.014706		
28							68					81					68			
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Figure 11:Entering proportional data into excel for processing.

			Admi	nistrative Serv	rices			
Distance	Recreational	Railway	Shopping	Commercial	cial Cultural Health c		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.



 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.

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

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 <u>https://openrouteservice.org/dev/#/login</u> this link and create an account.

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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."

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

openrout service	P v Donate	Services	Tools	Examples	Ask Us!	Plans	Jobs	API Playground	Dashboa, G	shboard	
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6. Open QGIS software and check whether the ORS plugin is available or not,



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

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Not installed Not installed Upgradeable Install from ZIP	Adjust Style Censo IBGE Clip Multiple Layers Cronometro DataExplorer: Data Analysis and Visu Dataforsyningen ExcelSync Extractor FIM GeoData C7/SK	All Plugins On the left you see the list of all plugins available for your QGIS, both installed and available for download. Some plugins come with your QGIS installation while most of them are made available via the plugin repositories. You can temporarily enable or disable a plugin. To <i>enable</i> or <i>disable</i> a plugin, click its checkbox or double-click its name Plugins showing in red are not loaded because there is a problem. They are also listed on the 'Invalid' tab. Click on the plugin name to						
<b>~</b>	<ul> <li>Geobald C2 Six</li> <li>Geometry Checker</li> <li>Geosearch DK</li> <li>GEOSYS Plugin</li> <li>GNAVS</li> <li>Instituto Canario de Estadística (ISTA</li> <li>MISLAND</li> <li>Monokai Code Editor Color Scheme</li> <li>movecost</li> <li>Nimbo's Earth Basemaps</li> <li>OpenQuake Integrated Risk Modellir</li> <li>ORS Tools</li> <li>PgVersion</li> <li>PolSAR tools</li> </ul>	<ul> <li>see more details, or to reinstall or uninstall this plugin.</li> <li>2. Type ORS in the search bar and check is it already installed, otherwise install it clicking "Installed, otherwise install it clicking "Install".</li> <li>Upgrade All</li> <li>Uninstall Plugin Reinstall Plugin</li> </ul>						

8. Insertion of the POI data into the project.



#### 9. Go to the ORS tool.



#### 10. Window of the ORS tool

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Go with driving-car  fastest  fastest	<ul> <li>✓ d</li> <li>API Key</li> <li>Enter API Key here.</li> <li>Base URL</li> <li>http://localhost:8082/ors</li> <li>Request timeout in seconds (1 - 3600)</li> <li>60</li> <li>Add Remove OK Cancel</li> </ul>
Advanced Configuration  Log  Help About Apply Close	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.

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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.

🔇 Matrix From Layers			×
Parameters       Log         Provider       openrouteservice         Travel mode       foot-walking         Input Start Point layer       * Kurunegala Bus stand [EPSG: 32644]         Selected features only       Start ID Field (can be used for joining) [optional]         Input End Point layer       * Admin [EPSG:4326]	· · · · · · · · · · · · · · · · · · ·		Matrix from Layers         The Matrix algorithm returns a duration and distance matrix for multiple source and destination points.         You need to have a valid API key (Web' menu > 'Configuration') or sign up at https:// openrouteservice. org/sign-up/.         Travel Mode: determines the profile used.
Selected features only End ID Field (can be used for joining) [optional]	8. Enabling option "O Algorithm", Run the to	pen output file pol.	after running
Advanced * Run as Batch Process	0%	Run	Close Help
14 Running process			
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15. Repeat this for other services as well,



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

Fi	le Home	Insert	Page Layout	Formulas	Data	Review	View	Automate	e Help								F	<sup>1</sup> Comments
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1	А	В	с	D	F	G	н	1	J	к	L	М	N	0	Р	Q	R	S
5	Service points	Bus station			1													
7	FROM ID	TO ID	DURATION H	DIST KM														
8	0		0 0.285188889	1.42596														
9	1		0 0.321408333	1.60706														
10	2		0 0.278058333	1.3903														
11	3		0 0.055113889	0.27558														
12	4		0 0.085944444	0.42972														
13	5		0 9.079202778	0.39602														
14	6		0. 0.257133333	0.33567														
15	7		0 0.110941667	0.55471								1						
16	8		0 0.146169444	0.73086														
17	9		0 0.201683333	1.00842														
18	10		0 0.263802778	1.31903														
19	11		0 0.244466667	1.22234														
20	12		0 0.315488889	1.57746														
21	13		0 0.480869444	2.40437														
22	14		0 0.0981	0.49051														
23	15		0 0.082355556	0.41678														
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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

$$SCORE_{city} = \sum_{k} \omega_k \sum_{i} (n_k)^{\alpha} * \exp(-\beta * GC_i)$$

- $n^{\circ}$  service  $k^{\prime}$  = 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.
- $\alpha$  = weight to be calibrated.
- $\beta$  = weight to be calibrated.
- $\omega_k$  = weight based on the relevance of the service of type *k* among the other types.

## 5.5.1 The Alpha Parameter,

The alpha ( $\alpha$ ) 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  $alpha(\alpha)$  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 ( $\beta$ ) parameter indicates the decrease rate of the impedance function as the distance from the city increases. A smaller  $\beta$  value leads to a lesser damping effect on each service's score contribution, whereas a larger  $\beta$  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  $\omega k$ ) 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,





Service	Omega Ω values given.						
Recreational	2						
Shopping	5						
Commercial	10						
Culture	2						
Administrative	4						
Health	5						
Table 2: Derived Omega values after identifying prioritized field results from the survey conducted							

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

	А	В	С	D	E	FG HI					
1	Ω	4			B4	POWER(B3,B2) * SUM(E7:E29) * B1					
2	α	0.2			1 Ω	4					
3	n	23	4		2 α 3 n	Formulea used					
4	Partial Score	71.16937	<b>_</b>		4 Pa	rtial 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	12. Partial score of every					
24	17	0	0.073291667	0.36646	0.693184	service of the city must be					
25	18	0	0.104083333	0.52042	0.594271						
26	19	0	0.349233333	1.74618	0.174439	calculated and sum of that					
27	20	0	0.277269444	1.38636	0.249984	would be the city index					
28	21	0	0.747108333	3.73557	0.02386						

# 5.5.4 Calculations of the City Attractiveness (services) Index:

					Dambulla			Kurunegala			Kegalle			Kalutara		
Service	ω	α	β	n	Σ exp(-β*GC)	partial score	n	Σexp(-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 <sub>sity</sub>						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.)

 $\alpha$  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 <sub>city</sub> =  $\Sigma$  (partial score <sub>k</sub>)



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.

1	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











#### 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 the 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 the correct units at the legend.
- 9. Check the text given in the legend.
- 10. Mention the correct sources.





Check the units of the scale bar.

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# AFTERWORD

Medium-sized cities play a pivotal role in achieving national sustainability targets, yet often lack the analytical tools to evaluate urban service accessibility. Rooted in Urban Informatics, this guide presents a systematic, spatially-explicit approach to assessing progress toward the 15-Minute City concept, integrating Google API data, GIS, and accessibility metrics.

By highlighting service equity and spatial justice, this book contributes to a deeper understanding of urban function and livability in secondary cities. It is our hope that this work supports both local planning efforts and broader urban policy frameworks, making cities more inclusive, walkable, and resilient.







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