17th Urban Mobility India Conference cum Exhibition 2024

Evaluating Spatiotemporal Transit Accessibility based on Gravity Model: A Novel Framework Using Big Data

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WHY ACCESSIBILITY ?

❑ When the Public Transport Becomes Choice for Users' as a Transport Mode ???

SPATIAL AVAILABILITY – ORIGIN & DESTINATION

- Is there a transit stop within walking distance of the trip origin?
- OR Is a car available AND a Park & Ride facility located along the way?
- OR Is a bicycle available AND are bike storage facilities available?

NO

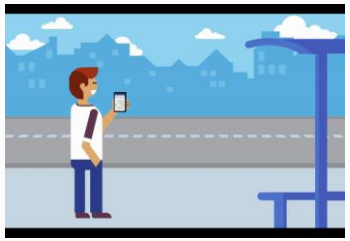
YES

TEMPORAL AVAILABILITY

- Is service at or near the time required?

NO

YES



INFORMATION AVAILABILITY

- Are the schedule and routing known?
- OR Is telephone or Internet information offered, the information line not busy when customers call, and the information accurately provided?

NO

YES

CAPACITY AVAILABILITY

- Is space available on the transit vehicle at the desired time?

NO

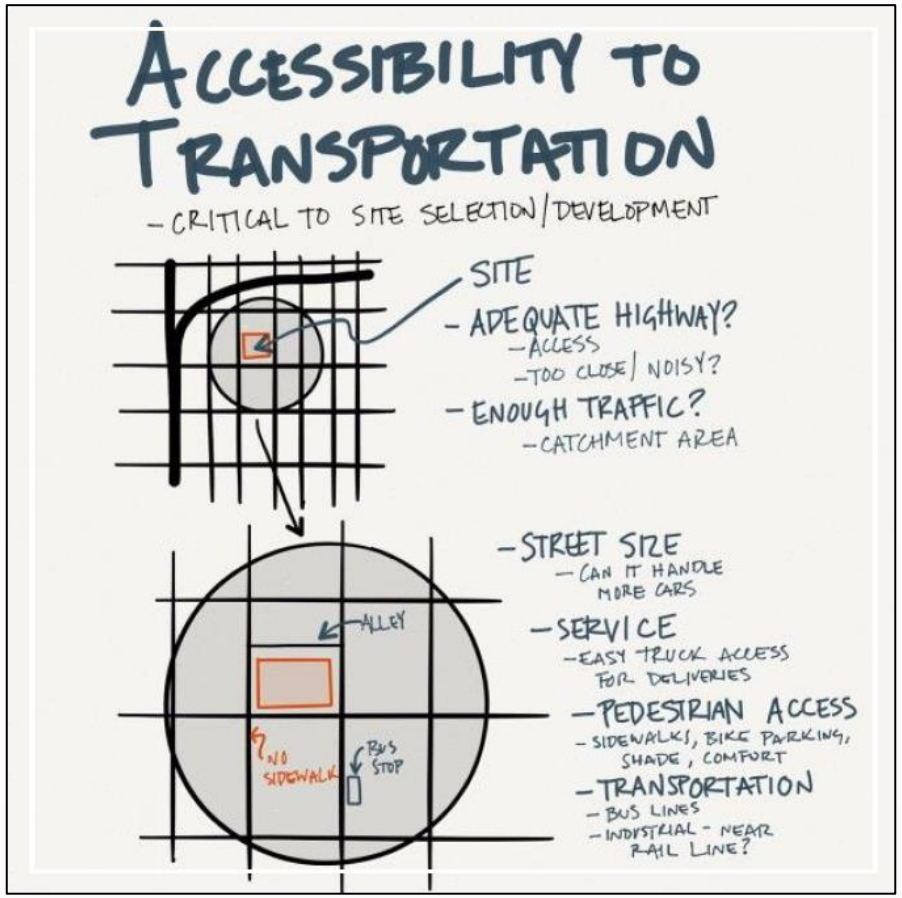
YES

Transit is an option.
(Traveller may choose transit if the quality of service is good.)

Transit is NOT Available.
(Traveller may choose another mode or the trip is not taken.)

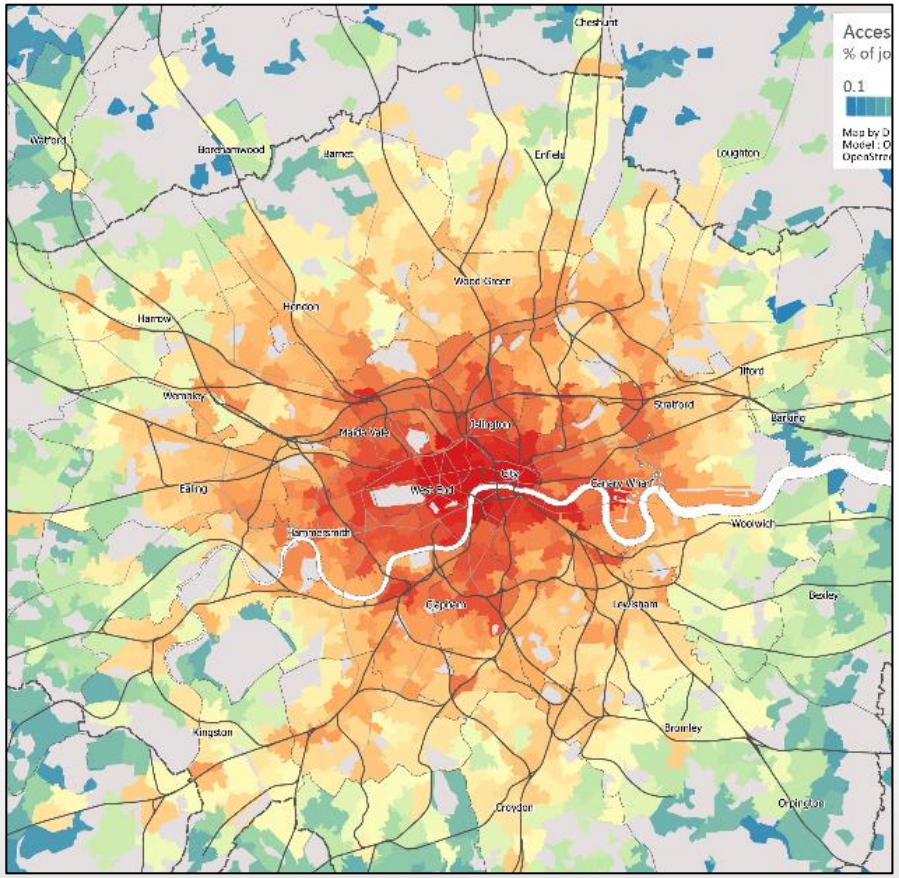
(Source: Transit Capacity and Quality of Service Manual, 3rd Edition, 2013)

WHAT IS ACCESSIBILITY ?

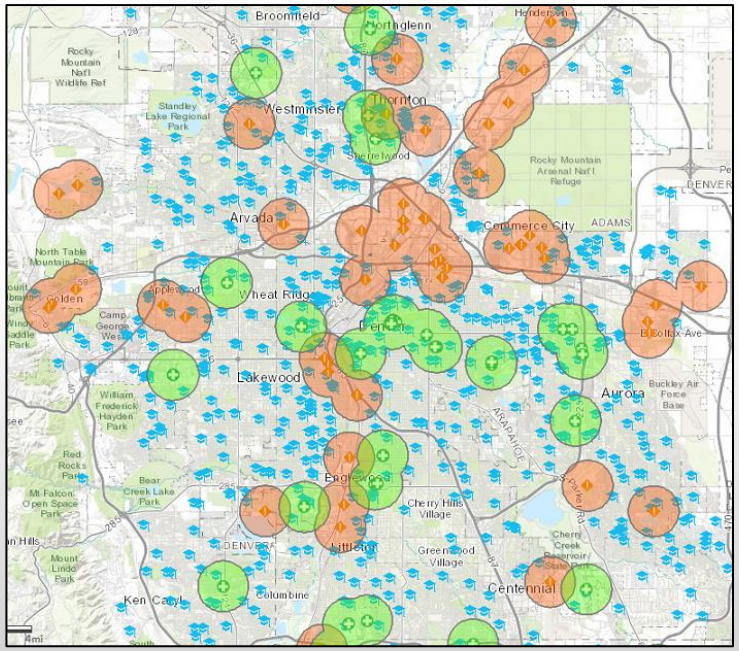


- Relative ease of reaching a particular location or area. (Litman, 2021)

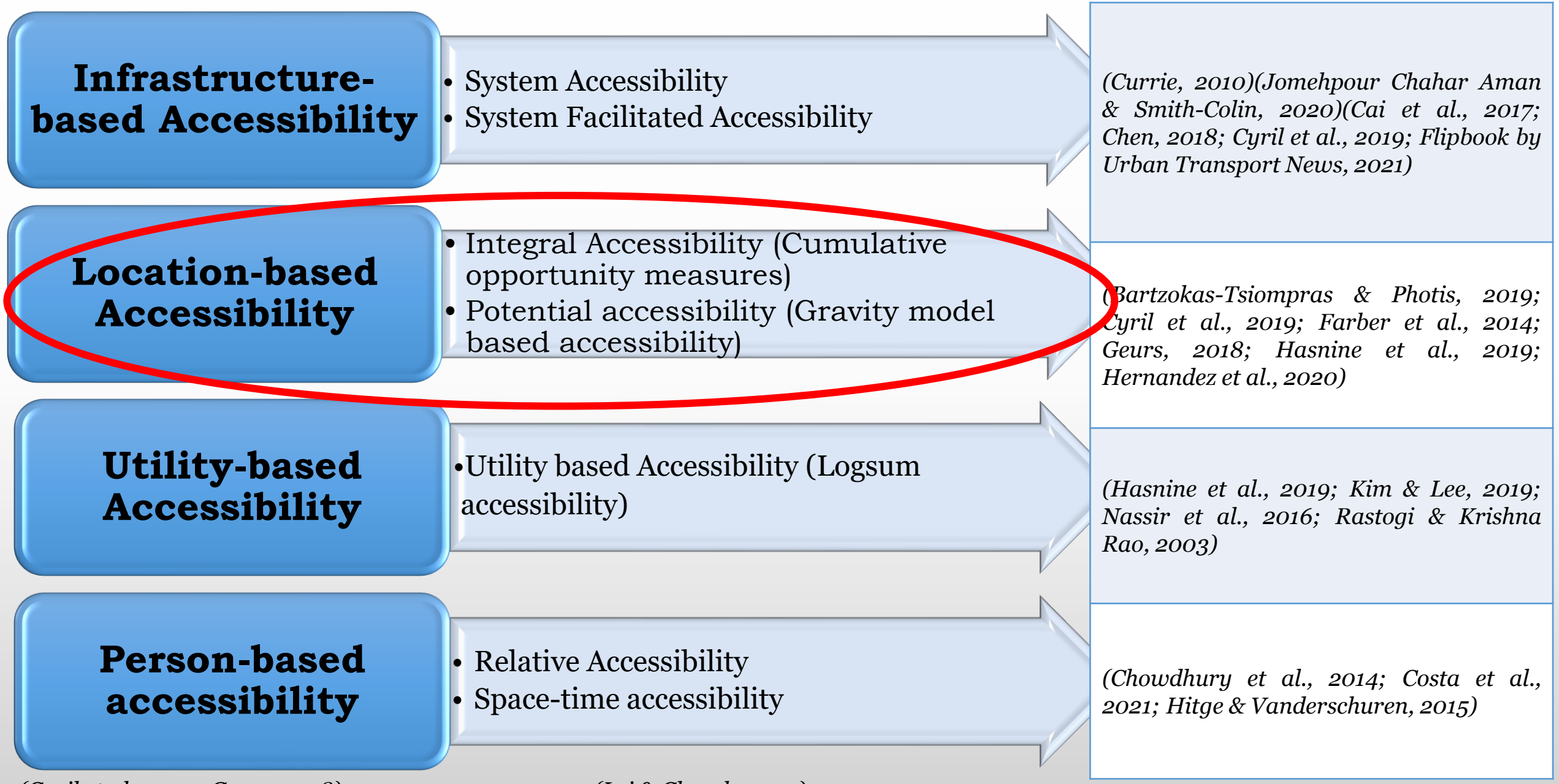
- Potential of opportunities for interaction. (Hansen, 1959)



- Accessibility (or just access) refers to the ease of reaching goods, services, activities and destinations, which together are called opportunities. It can be defined as the potential for interaction and exchange. (Engwicht, 1993; Hansen, 1959)



ACCESSIBILITY MEASUREMENT CLASSIFICATION



(Cyril et al., 2019; Geurs, 2018)

(Lei & Church, 2010)

LOCATION-BASED ACCESSIBILITY

- This category is associated with calculating a measure of **overall access associated with a number of possible destinations**.
- Cumulative sum of **opportunity** under **travel threshold of time, cost, distance or efforts**. *(Geurs, 2018)*

a) Integral Accessibility (Cumulative opportunity measures)

- The simplest integral measure is a **count of the number of opportunities** of some type of activity within a **reasonable travel distance or time of a particular location**. *(Lei & Church, 2010)*

- **Threshold time consideration**:
- 20 min *(Farber et al., 2014)*
- 30 min, 60 min *(Lee & Miller, 2018)*
- ✓ 10 min, 20 min, 30 min, 40 min, 50 min, 60 min *(Owen & Murphy, 2019)*
- ✓ 15 min, 30 min, 45 min, 60 min *(Cyril et al., 2019)*

b) Potential Accessibility (Gravity-based measures)

- ✓ It estimates the accessibility of opportunities in zone ith to all other zones (n) in which **smaller and/or more distant opportunities provide diminishing influences**. *(Geurs, 2018)*
- The impedance of **time, distance, cost or efforts** were considered in different forms: **Exponential form, Power function form, Inversely proportional, and Derived deteriorated functions**. *(Bhat et al., 2000)*

LOCATION-BASED ACCESSIBILITY

Proposed modifications in past studies for Location-based Accessibility calculation

❑ **Base Equation** *(Bhat et al., 2000; Lei & Church, 2010)*

$$A_{ik} = \sum_{j \in M_{ik}} O_{jk}$$

➢ **Opportunity/ Activity types** *(Bhat et al., 2000)*

Employment, Public and Private Facilities, Regional Malls, Non-work, Healthcare, Airport, Recreational and Educational Facilities

❑ **Introduce Travel Threshold** *(Bhat et al., 2000; Cyril et al., 2019; Farber et al., 2014)*

$$A_{ik} = \sum_{j \in M_{ik}} d_{ij} O_{jk}$$

➢ **Limitation of Opportunity model** *(Bhat et al., 2000; Hansen, 1959; Lei & Church, 2010)*

1. Selection of Travel threshold
2. Equal importance is given to all distanced opportunities

❑ **Introduce Travel Impedance** *(Bhat et al., 2000; Casas, 2003; **Hansen, 1959**; Hasnine et al., 2019; Lei & Church, 2010; Yang et al., 2019)*

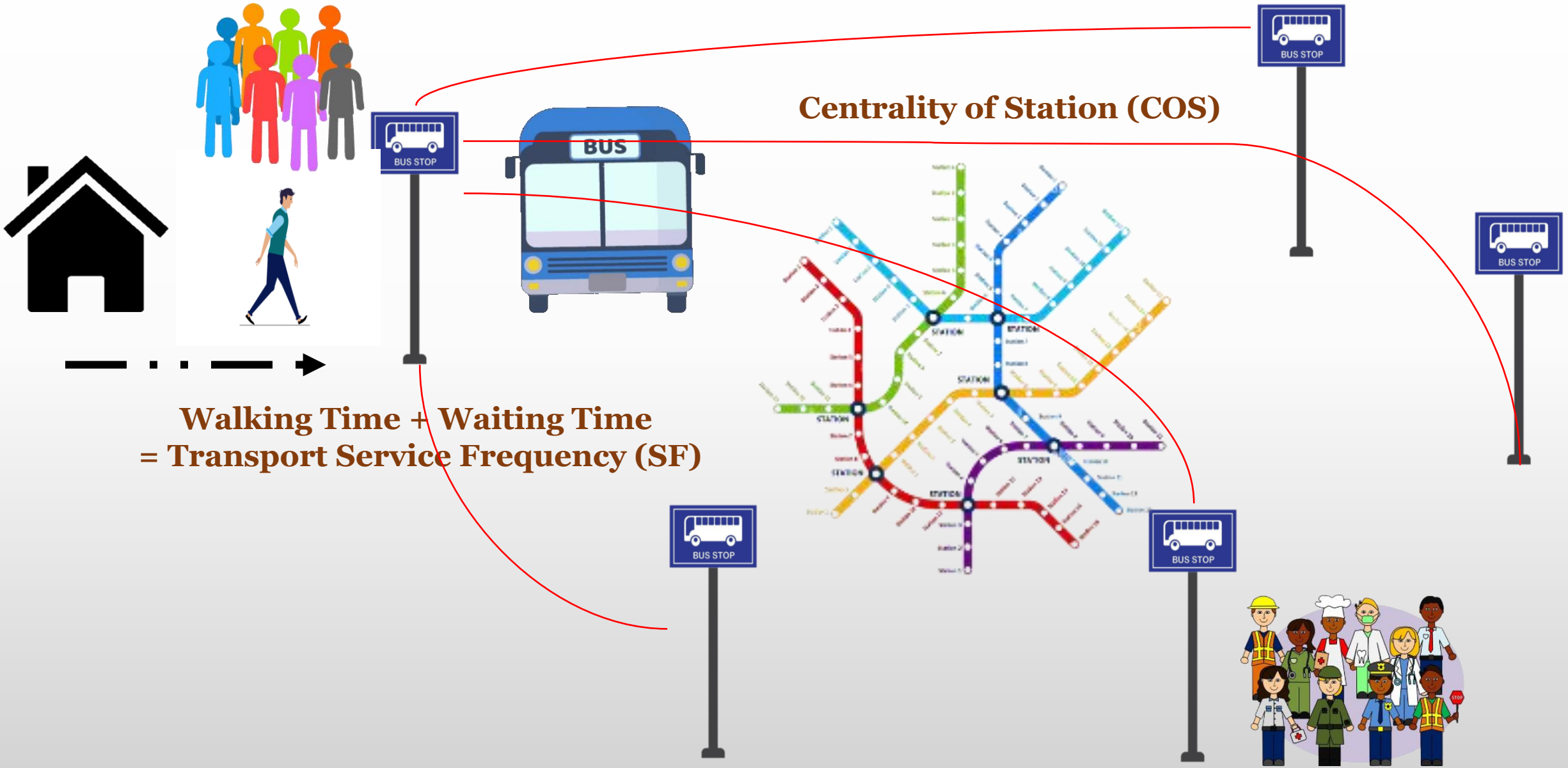
$$A_{ik} = \sum_{j \in M_{ik}} d_{ij}^{-\beta} d_{ij} O_{jk}$$

➢ **Considered Travel Impedances** *(Bhat et al., 2000)*

1. Euclidean Distance
2. *Actual Network Distance*
3. *Travel Time*
4. *Combined Measure of Time and Distance*
5. *Perceived Distance and Cost*
6. *Generalized Cost*

ACCESSIBILITY MEASUREMENT

❑ Comprehensive Public Transport Accessibility Index (CPTAI) (Yang et al. 2019)



Centrality of Station (COS)

Walking Time + Waiting Time
= Transport Service Frequency (SF)

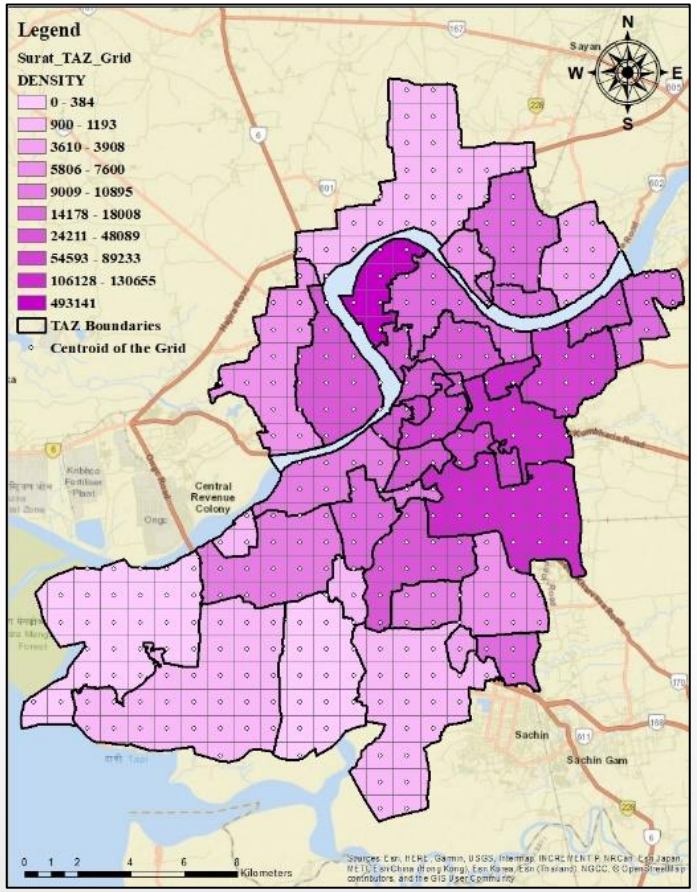
STUDY AREA

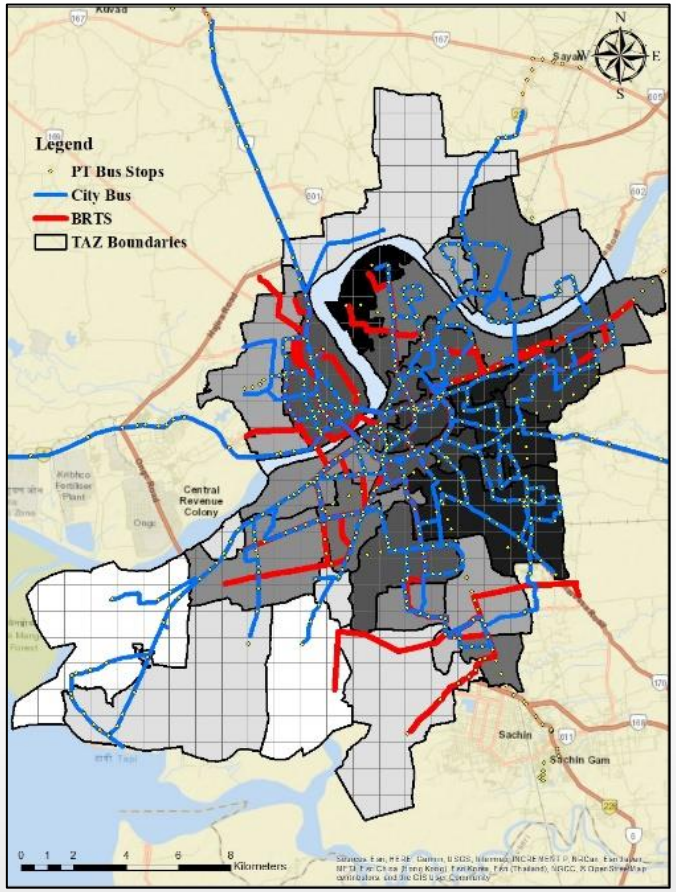
Area= 426 km² (2024)

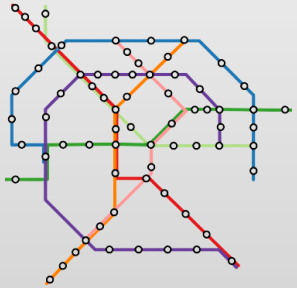
Population= 8 million (2024)

Average Annual Household Income = 10.80 Lakhs INR (2018)

Minimum 2 Vehicle per HH (2019)



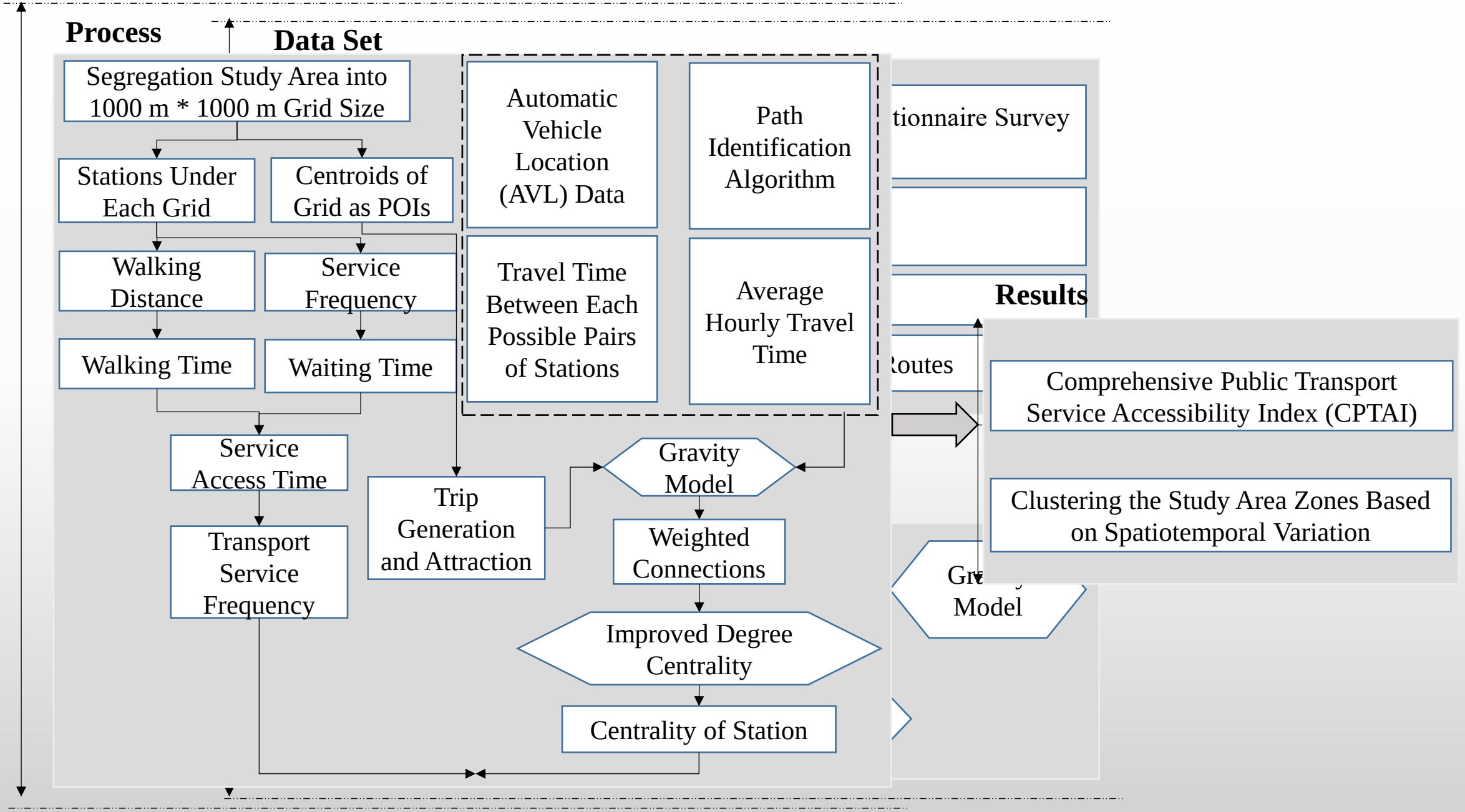




- 12 Bus Rapid Transit System (BRTS) routes and 46 city bus routes
- 500 km transit network
- 0.275 million avg. daily ridership
- 2.5% public transport mode share

(Source: Surat Municipal Corporation, Surat Sitilink Limited 2024)

METHODOLOGY



WALK SPEED AND WAITING TIME ESTIMATION

❑ Descriptive Statistics of Revealed Preference Data

Total No. of Samples = 1123			
Trip Pattern (%)		Age Group (%)	
Trips without transfer	51	0-15	4
Trips with one transfer	44	16-30	81
Trips with two transfers	5	31-45	10
Trip Purpose (%)		>=46	5
Work	57	House Hold Size (%)	
Education	31	1-2	6
Recreational	4	3-4	48
Shopping	3	5-6	40
Social	5	>=7	6
Fare Type (%)		Ave. Monthly Income (%)	
Single journey ticket	69	<20000	85
Smart card	18	20000-40000	12
Multiple journey ticket	10	>40000	3
Daily pass	3	Vehicle Ownership per Household (%)	
Use in a Week (%)		Bike	51
1 to 5	16	Car	6
6 to 10	20	Cycle	7
11 to 15	62	Other	1
>=16	2	No Vehicle	35
Access Mode (%)		Average Access Distance	560 m
Walk	94	Average Egress Distance	420 m
Auto	4	Average Access Time	5.5 min
Drop-off	1	Average Egress Time	4 min
Others	1	Average Walking Speed	**1.69 m/s (6.11 km/h)**

❑ Walking Speed

- Sample Avg. = 1.69 m/s (6.11 km/h)
- Population Avg. = 1.38 m/s (5 km/h) *(Murtagh et. al. 2020)*
- Sample SD = 1.52
- Number of Samples = 1123

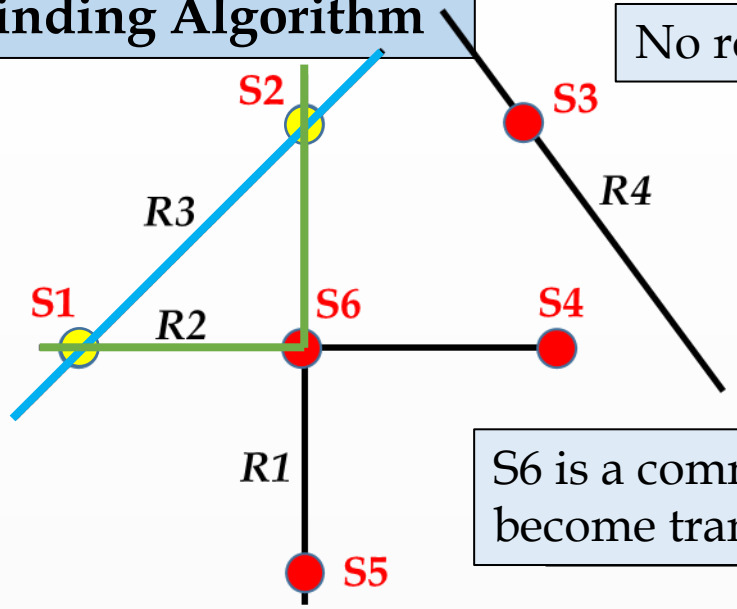
@ 5% significance level the sample mean is significantly differ from population mean.

❑ Waiting Time

The waiting time at each transit stop has been identified by considering the half of the frequency *(Surat Sitilink Limited, 2022)* of all passing routes at given location. *(Yang et. al. 2019)*

ACTUAL TRAVEL TIME ESTIMATION

Path Finding Algorithm



No route between S1 to S3

S6 is a common stop on these routes and become transfer points (S1-> S6 -> S2)

How many route have bus stops S1 and S2?
S1 – R3 and R2
S2 – R3 and R1

Generation Date	Service Type	Service	Processing Date	Origin	Destination	Route No
01/01/2022 06:01	QR Issue	QR Ticket Sales	01/01/2022 06:02	KOFS	KHBR	16U
01/01/2022 06:02	QR Issue	QR Ticket Sales	01/01/2022 06:03	ADGA	SANP	17U
01/01/2022 06:02	QR Issue	QR Ticket Sales	01/01/2022 06:02	DAGA	PANG	16U
01/01/2022 06:02	QR Issue	QR Ticket Sales	01/01/2022 06:01	PAPJ	SWSO	17EU
01/01/2022 06:02	QR Issue	QR Ticket Sales	01/01/2022 06:06	GAJC	*****	12U
01/01/2022 06:02	QR Issue	QR Ticket Sales	01/01/2022 06:05	UNNA	RAST	12U

ACTUAL TRAVEL TIME ESTIMATION

302VUP	302VUP TT	305DN	305DN TT
KHARWARNAGAR BRTS	2.00	UNN INDUSTRIAL ESTATE BRTS	2.00
UDHANA DARWAJA BRTS	5.00	UNN NAKA BRTS	5.00
UDHANA DARWAJA	4.00	BH	
RUSTAMPURA SWIMMING POOL	6.00	BH	
JANTA HOSPITAL	8.00	BH	
NAVSARI BAZAR	6.00	SC	
GOPI TALAV MARKET	1.00	PR	
GOPI TALAV	5.00	PR	
WADI FALIYA	4.00	PR	
KOT SAFIL ROAD	6.00	GANE	
BHAGAL CHAR RASTA	5.00	VADO	
BHAJIWALI POL	2.00	MAAK	
KASKIWAD	6.00	BHAG	
SAIYEDPURA VEGETABLE MARKET	8.00	KV HA	
PUMPING CHAR RASTA	9.00	BHAG	
HODI BUNGALOW	1.00	CHIKU	
MAKBARA MASJID	3.00	SMC C	
SANT JALARAM SOCIETY	1.00	SHIV E	
NANI BAHUCHARAJI TEMPLE	5.00	VEER S	
PANDOL POLICE CHOWKI	9.00	ASHANAGAR SOIETY	1.00
AKHAND ANAND COLLEGE	4.00	GAYATRI SOCIETY	5.00
VAADINATH CHOWK	1.00	JHANSI KI RANI GARDEN	4.00
GOPAL NAGAR	6.00	SMC SOUTH ZONE OFFICE	6.00
SHREE SWAMINARAYAN MANDIR	4.00	PANDIT DINDAYAL UPADHYAY BHAVAN, SATYANAGAR BRTS	12.00
DABHOLI CHAR RASTA	8.00	KHARWARNAGAR BRTS	15.00
PRAMUKH SWAMY CHOWK	8.00		

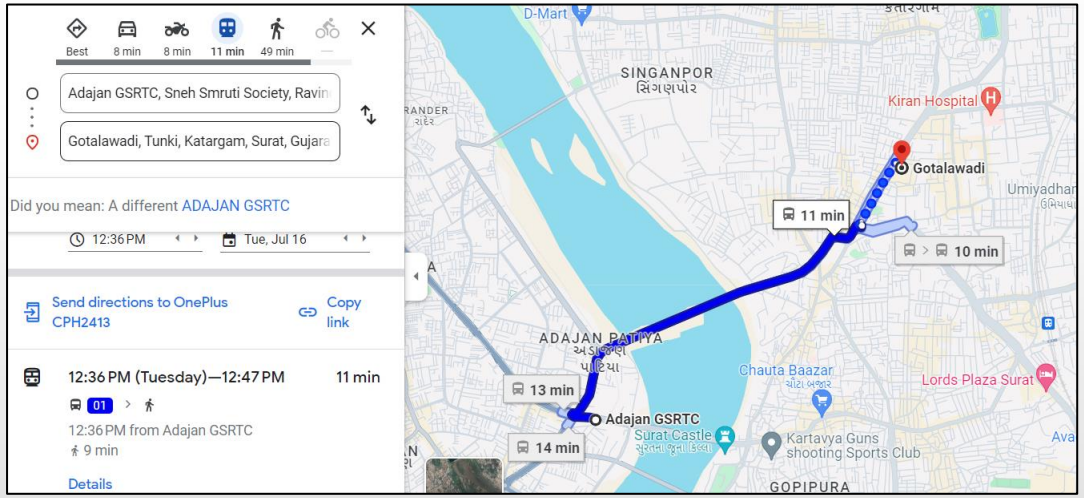
Origin	Destination	Travel Time	Transfer Count	Origin TAZ
PGAA	PGAA	0	0	8
CICY	PGAA	77	2	26
LAXN	PGAA	61	2	23
GANG	PGAA	64	2	26
DGAP	PGAA	76	3	32
GASA	PGAA	75	3	36
BHBA	PGAA	NRF	NRF	35
ECWA	PGAA	NRF	NRF	35
GABC	PGAA	NRF	NRF	32
BUGC	PGAA	78	3	32
SKBA	PGAA	90	3	29
GOKU	PGAA	89	3	29
PANC	PGAA	87	3	29
TAAR	PGAA	85	3	29
ISMA	PGAA	56	2	9
SRNA	PGAA	72	3	2

ACTUAL TRAVEL TIME ESTIMATION

Path Finding Algorithm- Validation with Google Map Data

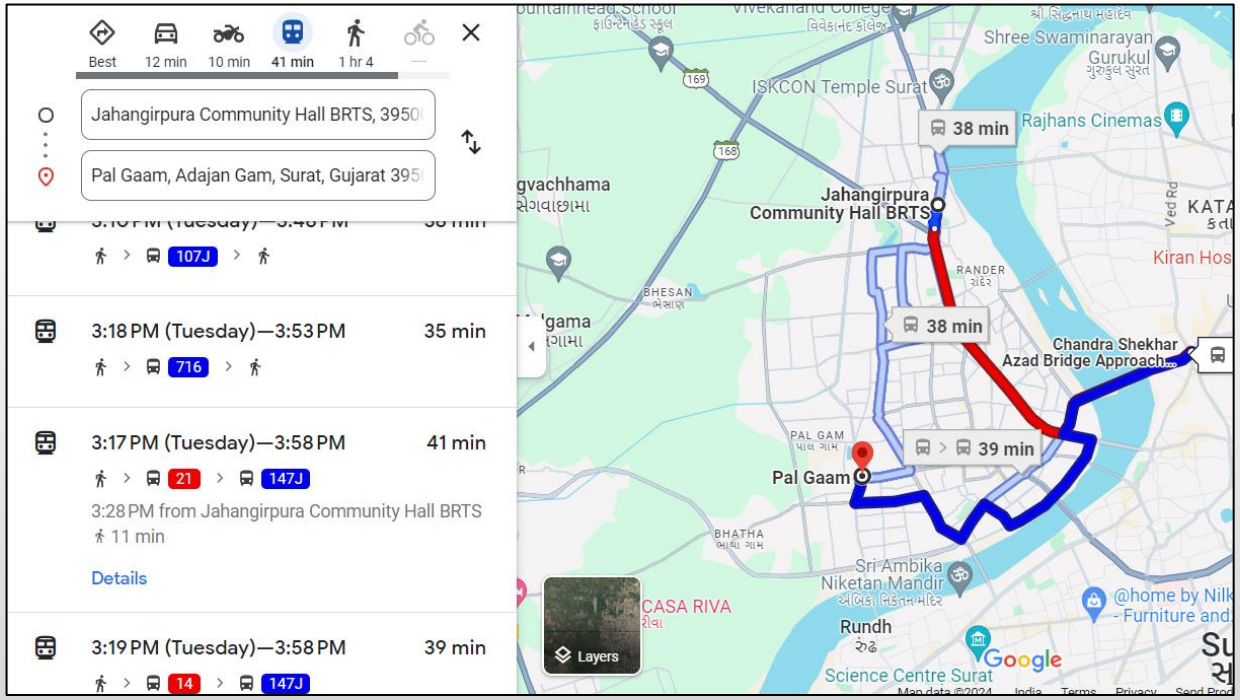
```
# Print the results
print_path_results(results)
```

```
Optimal path from ADAJAN GSRTC to GOTALAWADI (Transfer route):
Total time: 7.0 minutes
Transfer Count: 0
Route details:
From ADAJAN GSRTC to GOTALAWADI via route 01UP
```

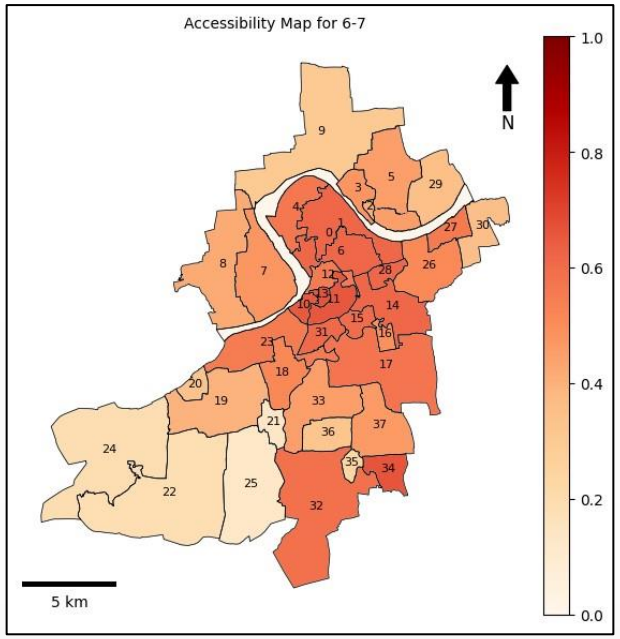


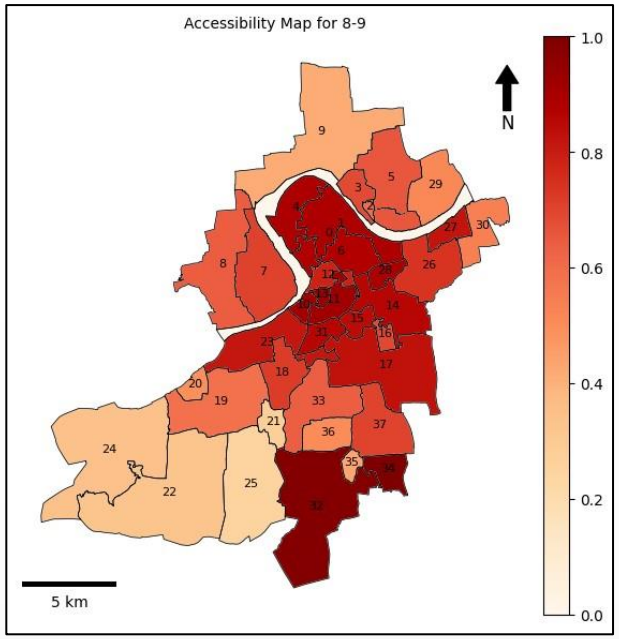

```
# Print the results
print_path_results(results)
```

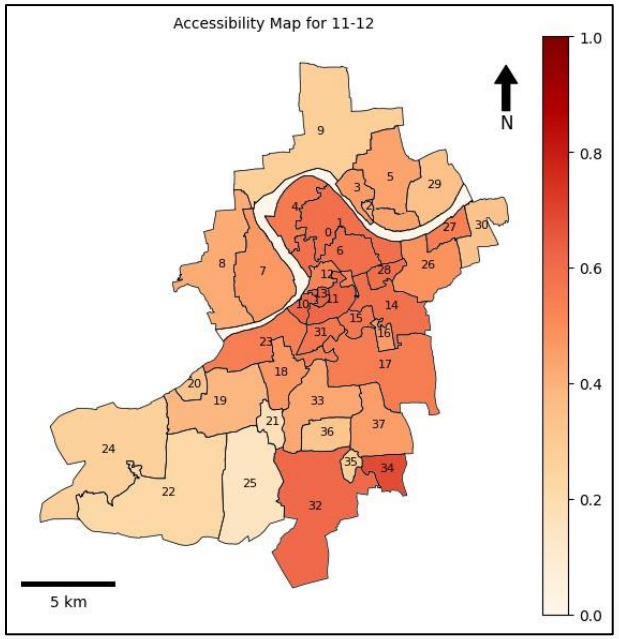
```
Optimal path from JAHANGIRPURA COMMUNITY HALL BRTS to PAL GAAM (Transfer route):
Total time: 45.25 minutes
Transfer Count: 1
Route details:
From JAHANGIRPURA COMMUNITY HALL BRTS to TRINITY BUSINESS PARK via route 716UP
From TRINITY BUSINESS PARK to PAL GAAM via route 147UP
```

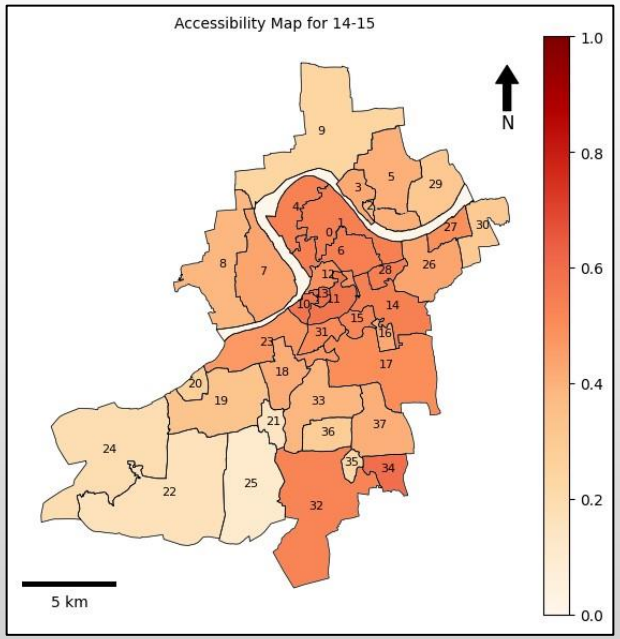


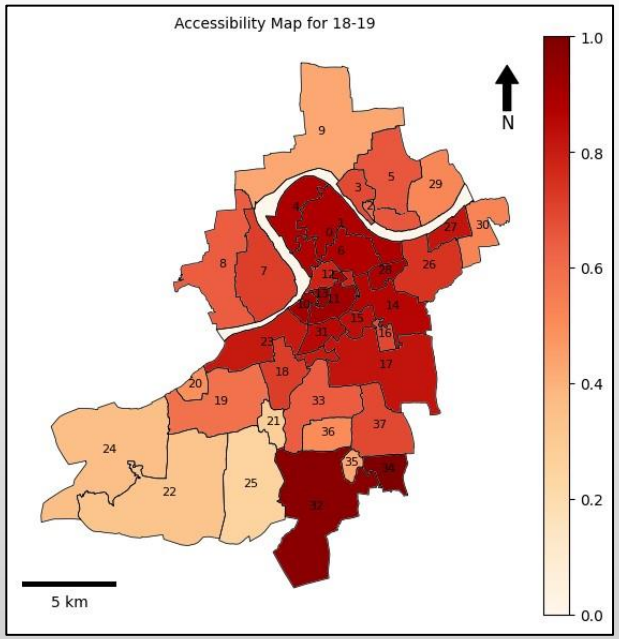
COMPREHENSIVE PUBLIC TRANSPORT ACCESSIBILITY INDEX (CPTAI)

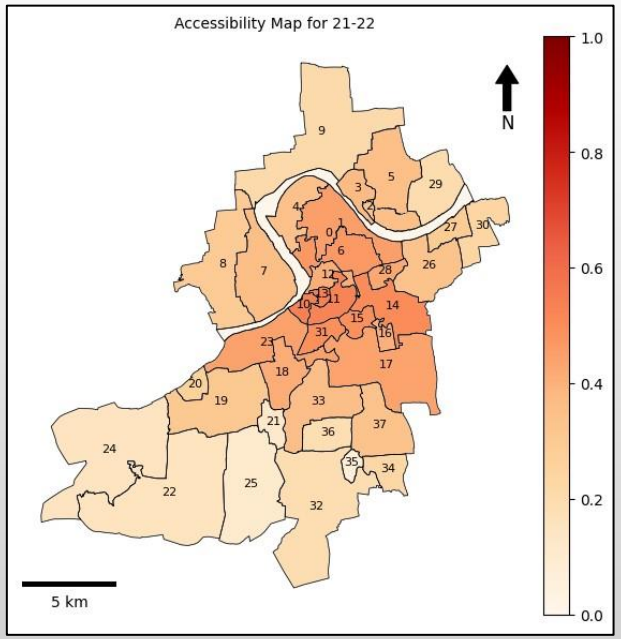




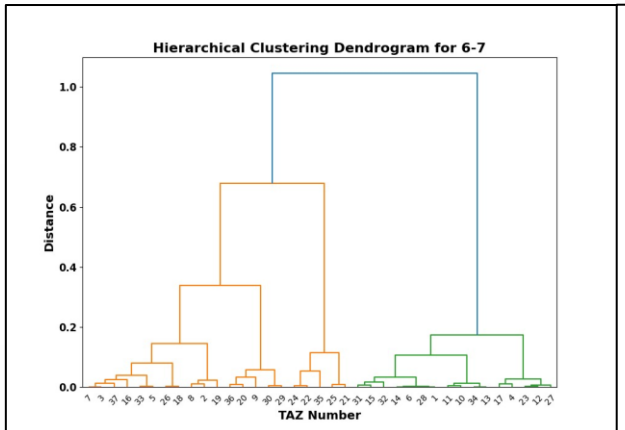


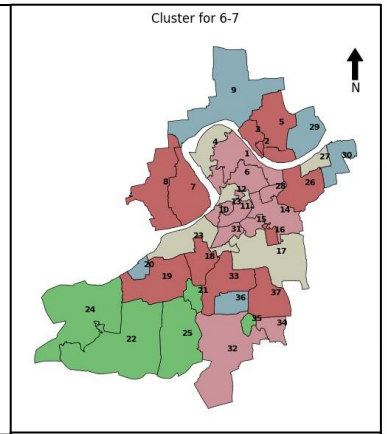


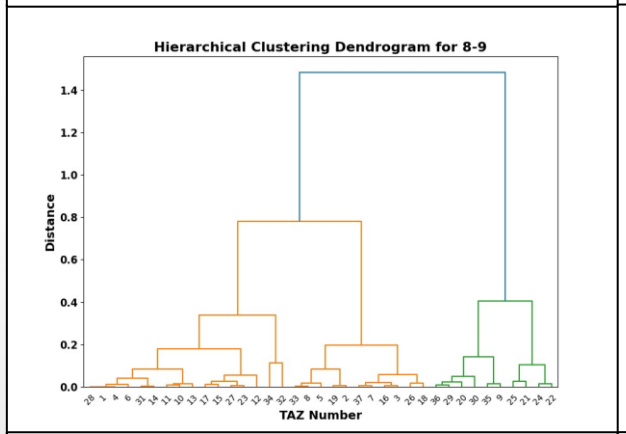


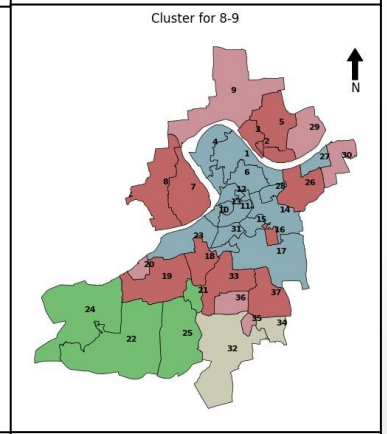


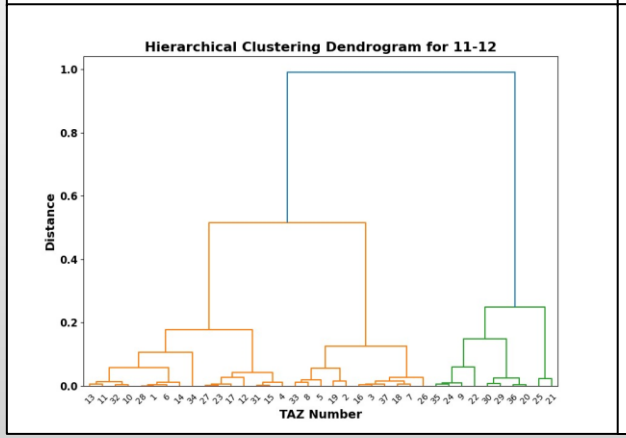
HIERARCHICAL CLUSTERING ANALYSIS

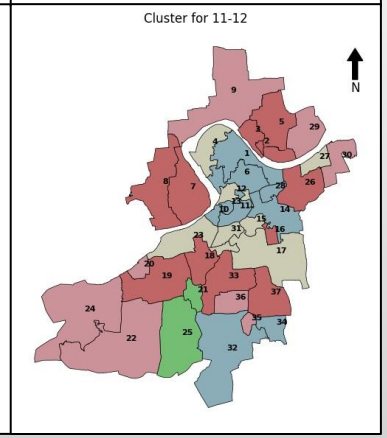


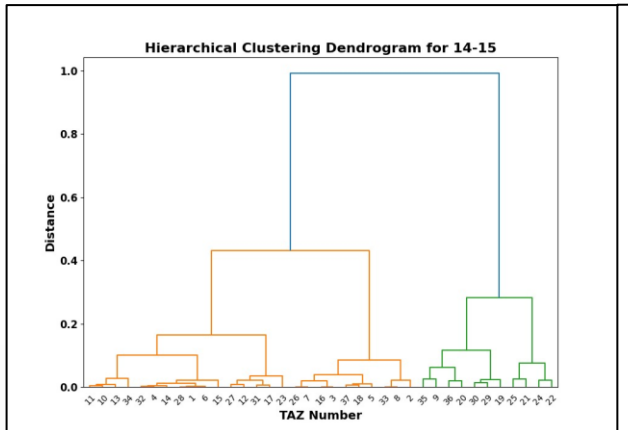


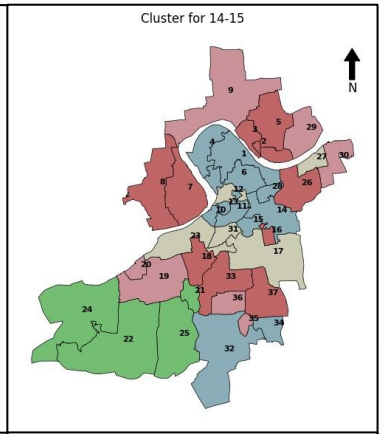


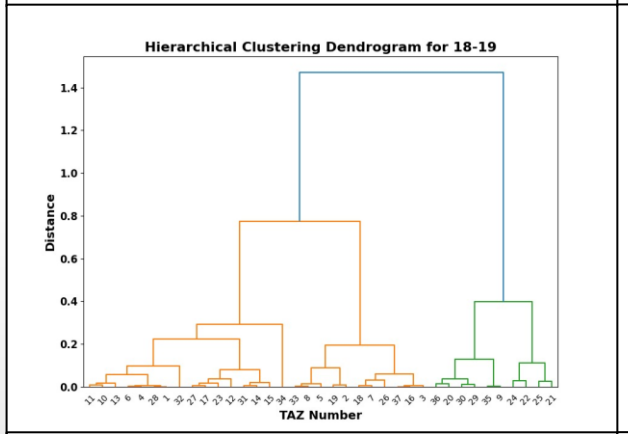


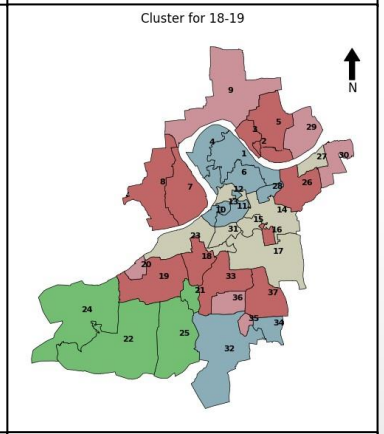


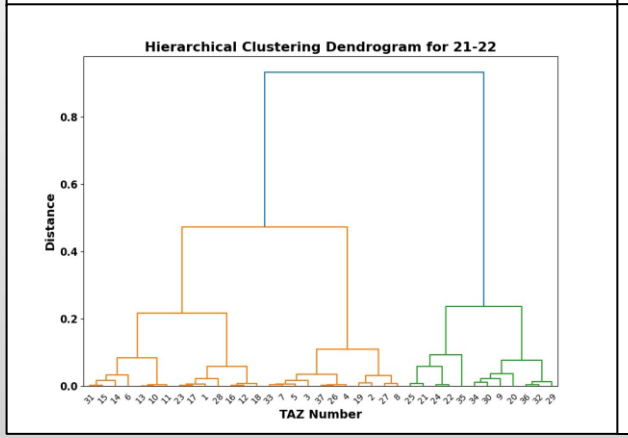


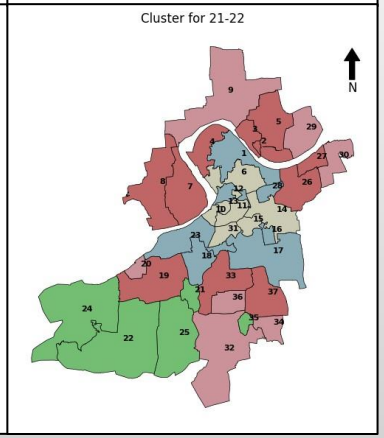




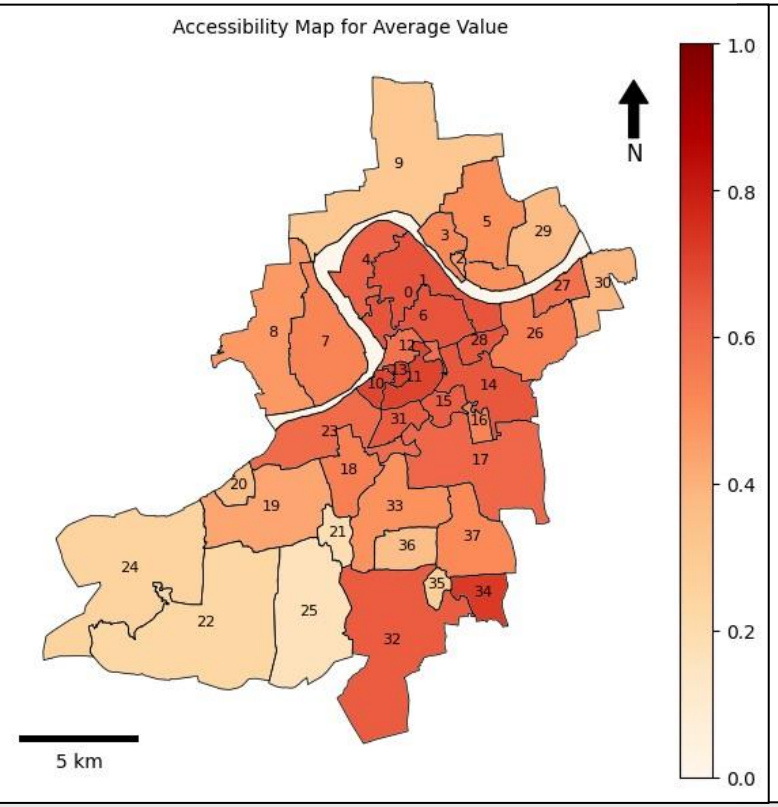


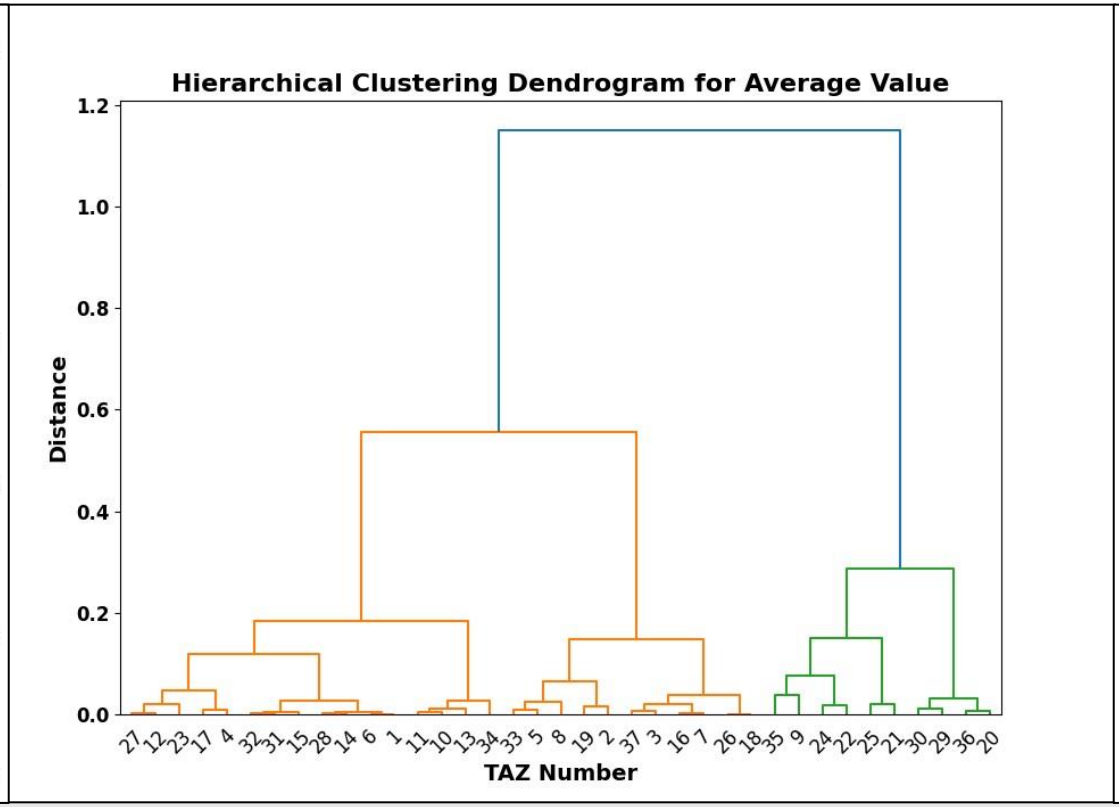


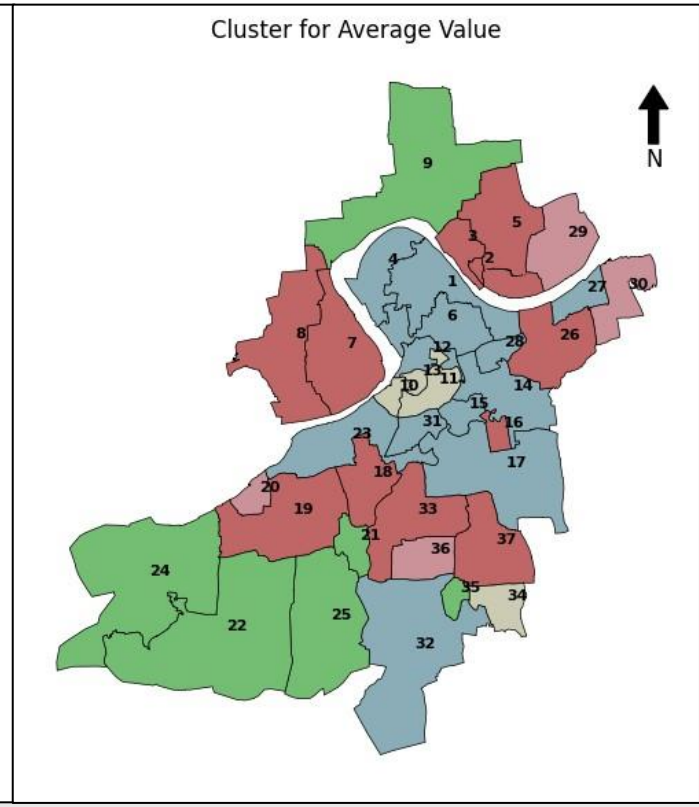




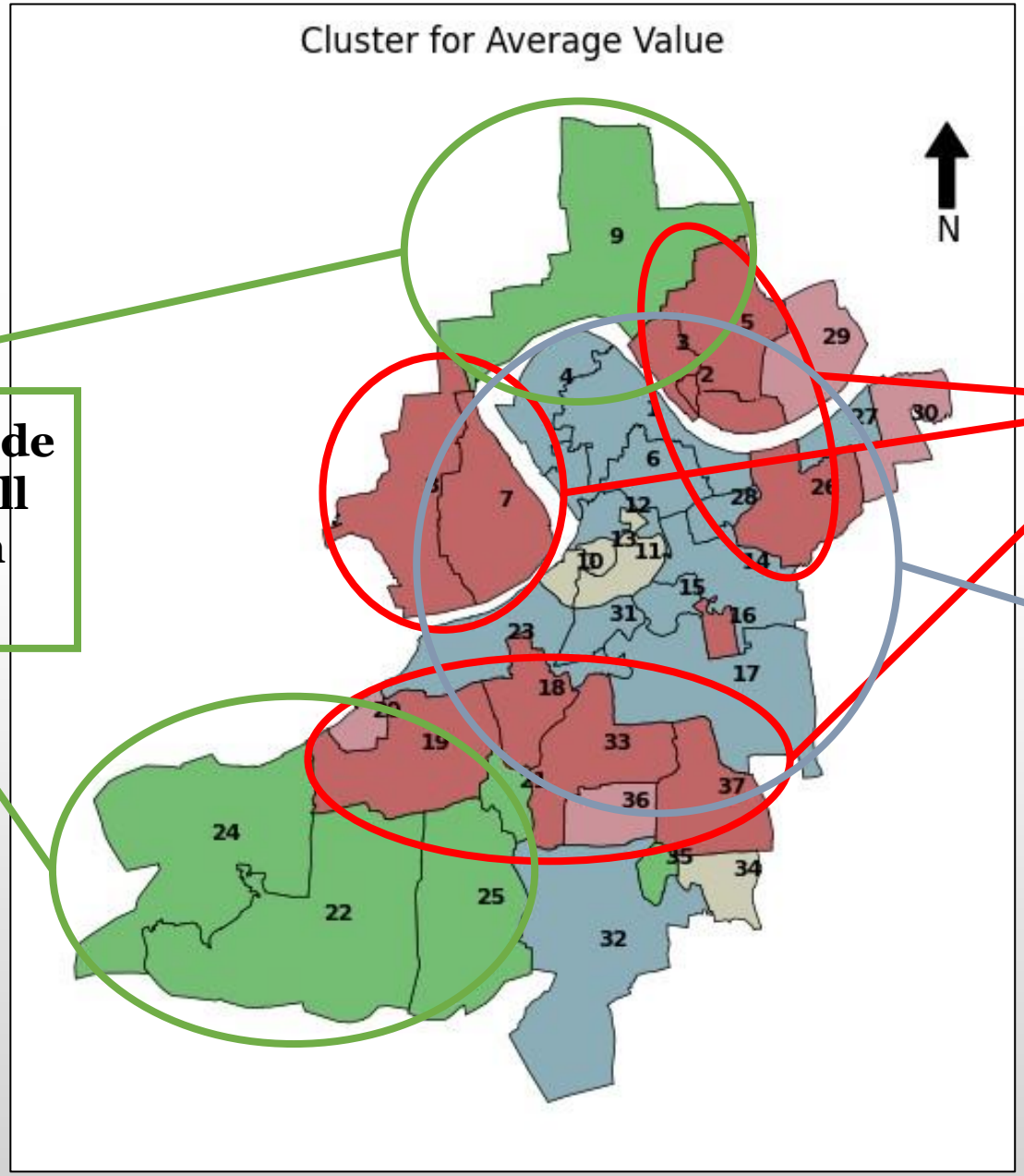
HIERARCHICAL CLUSTERING ANALYSIS







POLICY RECOMMENDATIONS



- **Motorized feeder mode integration for overall travel time reduction**
- **Network expansion**

- **Network expansion and operational enhancement**
- **Maintain travel time reliability and on time performance operational aspects**

- **Increase quality of service to attract more ridership**

CONTRIBUTION OF THE WORK

01

Consideration of walking speed based on revealed preferences for calculating stop-level accessibility.

02

Utilization of end to end AVL and GTFS static data to calculate actual in-vehicle travel time.

03

Inclusion of operational (actual) time instead of scheduled time for the calculation of impedance factors.

04

Frequency based hierarchical clustering of the zones considering the hourly travel time variation driven accessibility measurement.

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Thank you!