Ministry of Housing and Urban Affairs
Government of India

16TH URBAN MOBILITY INDIA CONFERENCE CUM EXPO 2023
INTEGRATED & RESILIENT URBAN TRANSPORT
27TH TO 29TH OCTOBER 2023
MANEKSHAW CENTRE, DELHI

INSTITUTE OF URBAN TRANSPORT (INDIA)

COLLABORATIVE GOVERNANCE IN URBAN TRANSPORT

Research Symposium 1: Integrated & Resilient Urban Transport

Paper ID- 21

Exploring Connectivity of Indian Road Networks Patterns and its Classification using Deep Learning Technique

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IISc Sustainable Transportation Lab (IST Lab)

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- Quantification of Transport Networks and urban growth

Literature Review

1

Asami et al., 2001

- **Graph-theoretical and image-analysis based indices** for characterization of network patterns

2

Eriksson et al. (2012)

- Investigated the **associations between three walkability parameters** (residential density, street connectivity and LU mix) **and physical activity**

3

Shi et al., 2013

- Discussed the type of **street network patterns** in urban core area in terms of density, spacing, and the types of street networks.

4

Wagai, J., 2016

- Obtained comparable **street connectivity index** scores

5

Daniel et al., 2020

- **Network topology** determines the shape of a city.
- A **basis** for identifying the network patterns.

6

Li et al., 2022

- Studied physical characteristics of the street network by considering **street length** within the **spatial cell** of the network G (100m x 100m).

Deep Learning Technique

Chen et al., 2021 implemented a deep learning method by generating an image of the street network and classifying it using the ResNet-34 model.

Aim and Objectives

AIM- To quantify, visualize, and compare the road network connectivity of four Indian cities; and to check if unique index ranges can represent road network patterns

Obj 1

To identify and classify the types of road network patterns in India using deep learning technique at micro-level

Obj 2

To find the connectivity of Indian road networks by performing Spatial Network Analysis

Obj 3

To examine the possibility of finding index ranges for Indian road network patterns through graphtheoretical indices

Methodological Framework

Micro level analysis using Grids – (1km x 1km)

Data Collection
- Extraction of Nodes and Edges from OSM in QGIS

Data Preparation
- Formation of Grids
- Sample Images for Classification

Spatial Network Analysis

Correlation Analysis btw Connectivity Indices

Selection of Connectivity Indices

Calculation of Connectivity Indices in each grid

Classification of Road Network using Deep Learning Technique

Annotation

Building and Training the model

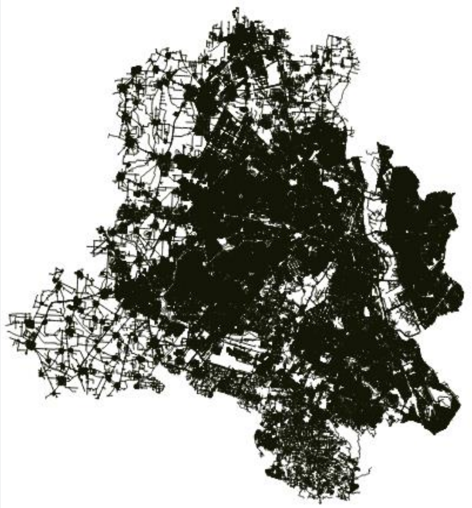
Classification of Road Network Patterns

Classifier Maps representing Road Network Patterns

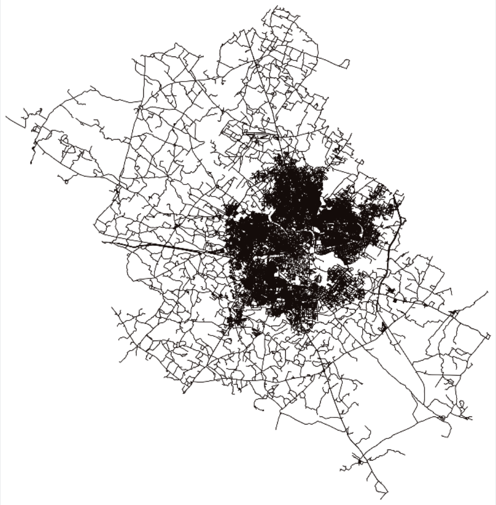
Determination of Connectivity Index Range for each road network pattern

Data Collection

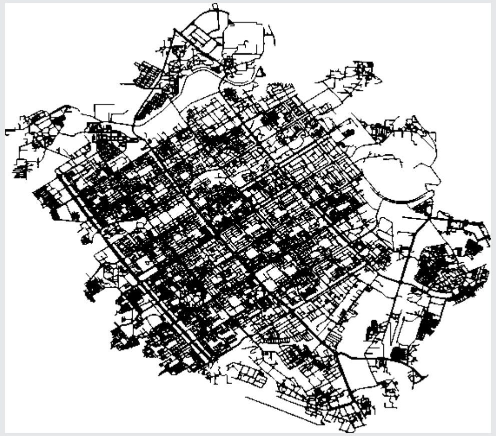
Selected Indian Cities



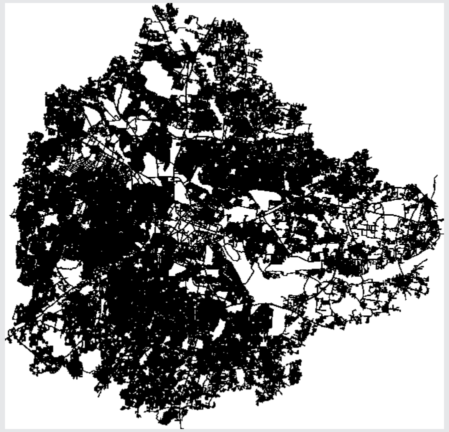
Delhi



Lucknow

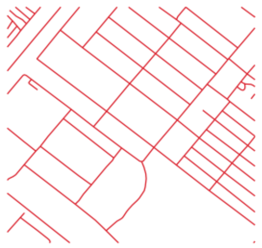


Chandigarh

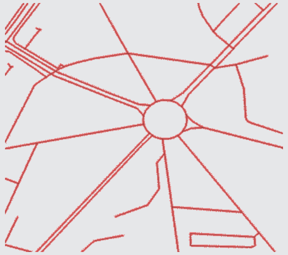


Bangalore

Types of Road Network Patterns



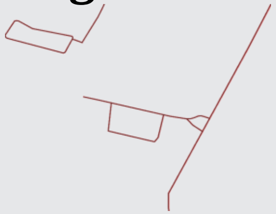
Grid Iron



Ring & Radial

Irregular blocks

Tree & cul-de-sacs

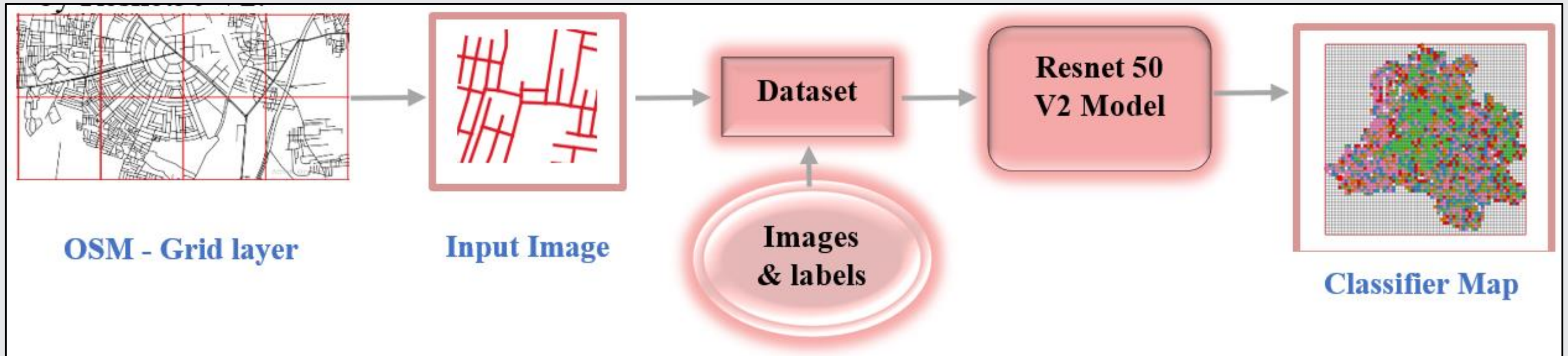


No pattern (Irregular)

Tree & Irregular blocks

Data Preparation

Sample images for classification



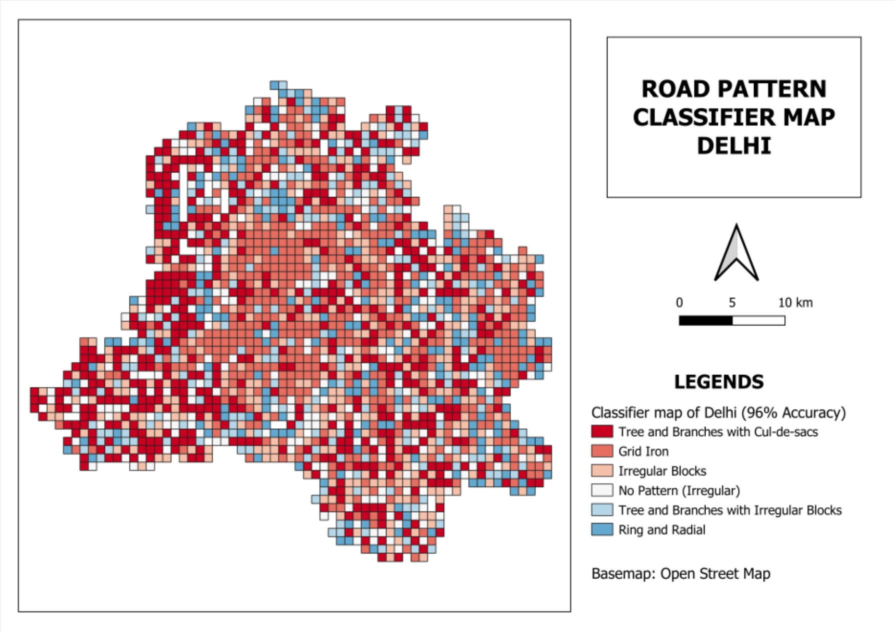
- **Sampling:** Approximately **120** for each class.
- **Input Images:** 764 images which was divided into 611 training images and 153 testing images based on the optimal train-test split ratio of 80:20.
- **Clipping of images:** Manual Classification=5500 images, PyQGIS tool=6561 images.
- **Resnet 50 V2 model** performs better than other variants in the Resnet model with **96.73% accuracy** and a loss value of 0.1655

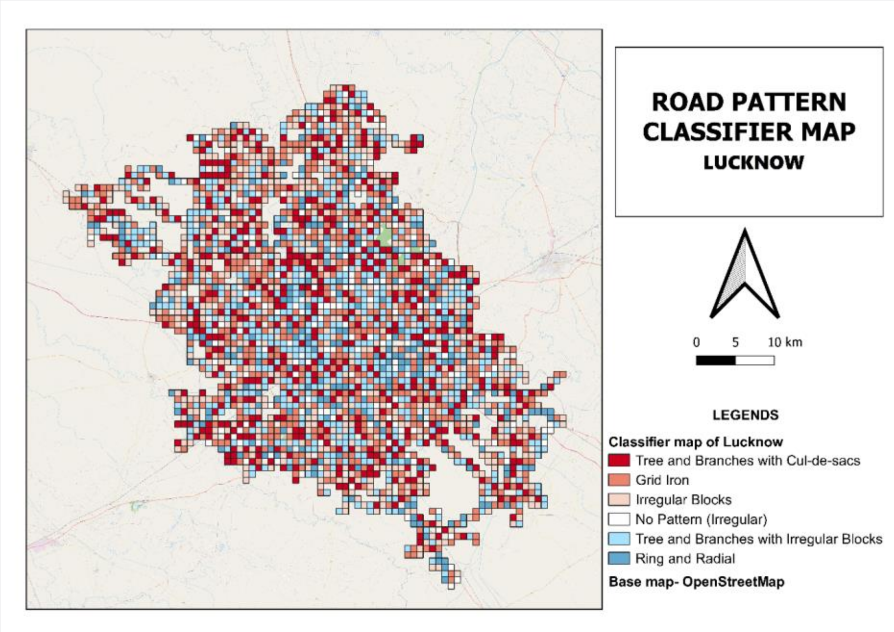
Objective 1

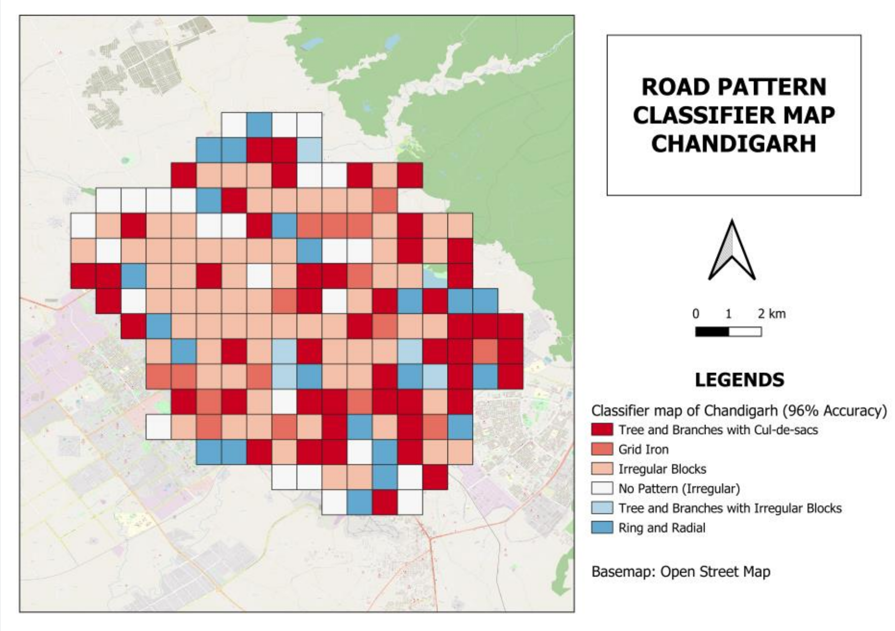
Different types of patterns and its distribution across cities

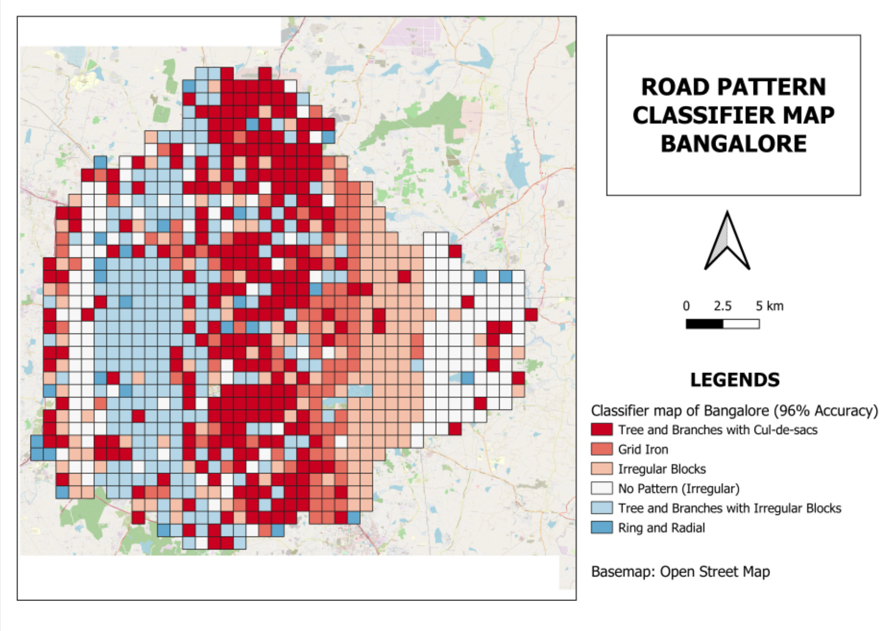
Class	Class distribution			
	Bengaluru	**Chandigarh**	**Delhi**	**Lucknow**
Tree & Cul-de-sacs	27.69	28.41	25.84	19.50
Grid Iron	10.74	9.09	24.69	25.03
Irregular blocks	18.29	38.64	17.36	22.13
No pattern	17.87	8.52	11.28	0.82
Tree & Irregular blocks	22.52	2.84	10.27	23.30
Ring & Radial	2.89	12.50	10.56	9.22

Objective 1- Road Network Classifier Maps









Objective 2- Spatial Network Analysis

Selected Indices

- **Node density:** The number of nodes within a grid cell
- **Intersection density:** The number of intersections within a grid cell
- **Dead-end density:** The number of dead-ends within a grid cell
- **Edge density:** The number of edges within a grid cell
- **Network density:** The sum of the length of the routes considered within a grid cell.

- Beta: $\frac{e}{v}$
- Gamma: $\frac{e}{3(v-2)}$
- Connected Node Ratio (CNR):
  - $\frac{\textit{Total number of intersections}}{\textit{Total number of nodes}}$
- CNR index considers the effect of intersections and dead ends within a grid cell.

Objective 2- Range of alpha and beta index value for different patterns

S. No.	First level	Second level	Third level
1	CULDESAC	-	CULDESAC-IRREGULAR-DISCONNECTED
2	GRID	-	GRID-IRREGULAR-CULDESAC
3			GRID-IRREGULAR-DISCONNECTED

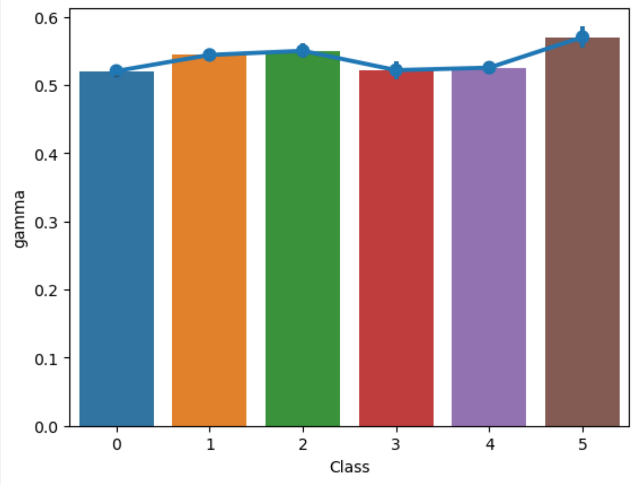
S. No.	Third level	Ranges of alpha	Ranges of beta
1	CULDESAC-IRREGULAR-DISCONNECTED	0.13-0.27	1.25-1.43
2	GRID-IRREGULAR-CULDESAC	0.24-0.307	1.48-1.72
3	GRID-IRREGULAR-DISCONNECTED	0.18-0.32	1.36-1.62

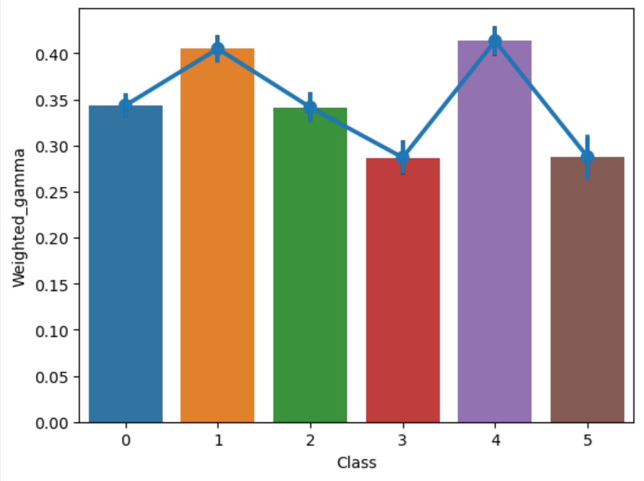
Objective 3- Composite Indexing using Graph-theoretical Indices and GCAR

Index: Grid Coverage Area Ratio (GCAR)

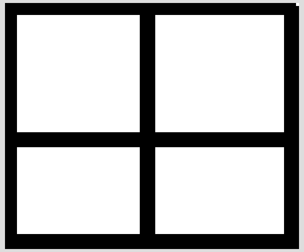
It measures coverage of the network in percentage.

S. No.	Range of Area Coverage (Ac)	GCAR
1	$0 < Ac < 25\%$	0.25
2	$25 \leq Ac < 50\%$	0.375
3	$50 \leq Ac < 100\%$	0.75
4	$Ac = 100\%$	1

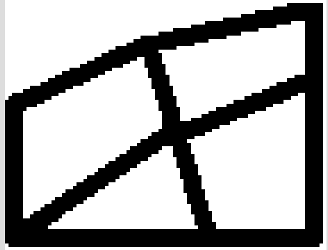




Grid with 100% coverage



Grid with 75% coverage



Equal number of nodes and edges

- In both grid images: $\mathbf{v} = 9$; $\mathbf{e} = 12$
- **Beta:** $\frac{e}{v} = \frac{12}{9} = 1.33$ (**Before inclusion of GCAR**)
- **GCAR100%** = 1 ; **GCAR75%** = 0.75
- **Beta100%** = 1.33 ; **Beta75%** = 0.75*1.33=1

LEGENDS

Class	Name
0	Tree & Cul-de-sacs
1	Grid Iron
2	Irregular blocks
3	No pattern
4	Tree & Irregular blocks
5	Ring & Radial

Summary and Future Scope

SUMMARY

- **Resnet50 V2 Classifier** model classified the road patterns in Indian cities with an accuracy of 97%.
- A **unique index range** can't be found with only by using nodes and edges i.e. just grapg-theoretical indices.

FUTURE SCOPE

- Effects of **urban growth indices** on the connectivity of road network can be studied.
- Combined effect of **land use characteristics, traveller characteristics, travel pattern, route characteristics** and **mode choice** can be studied to understand the **spatial interaction between urban and transportation planning in a** better way.

THANKS FOR LISTENING

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Your best quote that reflects your approach… "It's one small step for man, one giant leap for mankind."

- Neil Armstrong