

Modern AIML application in Transport Emissions in India

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.....Science

“The air pollution is not restricted to geopolitical boundaries and can travel long distances”

STRATEGY QUESTION:

In an era of rapidly changing climate–
“Shouldn't we shift from location-specific and emission-centric to larger meteorological and climatological process-based approach”?

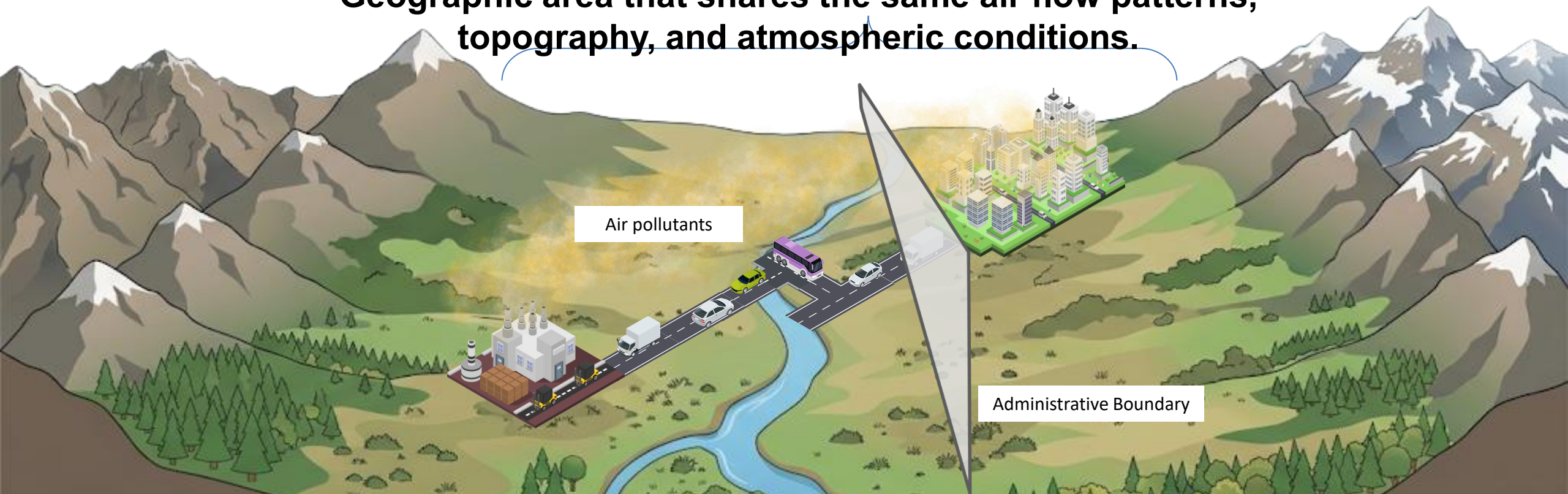
ORIGIN OF “AIR-SHED CONCEPT”

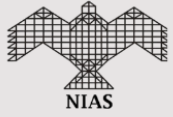
JURISDICTIONAL MISMATCH

Re-thinking Spatial Boundaries

AIRSHED

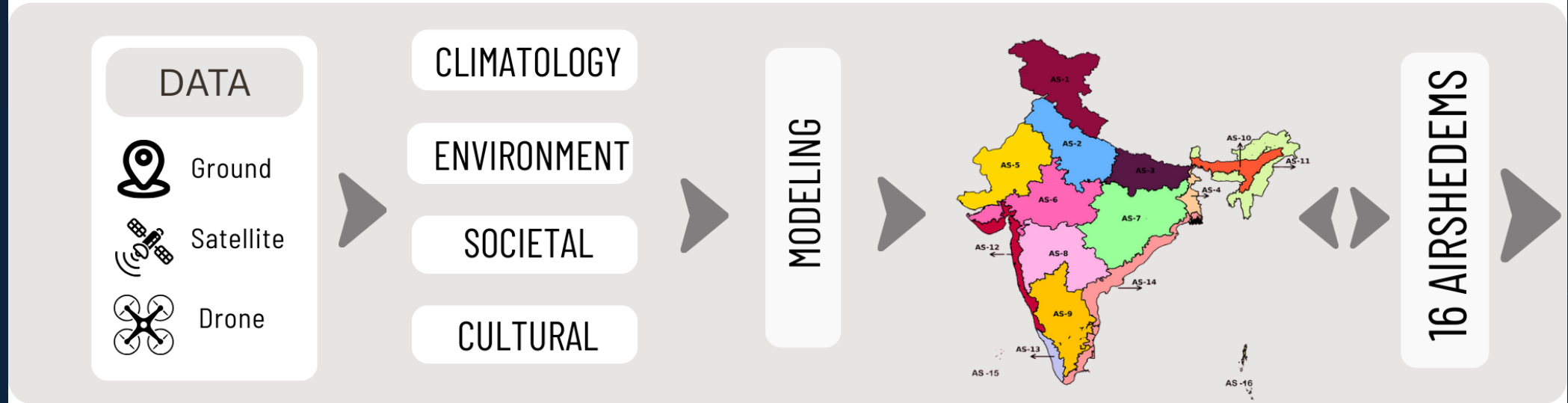
Geographic area that shares the same air flow patterns, topography, and atmospheric conditions.





National Air Quality Resource Framework of India (NARFI)

(An AIRSHED Based Air Quality Management)



Identification of Airsheds in India

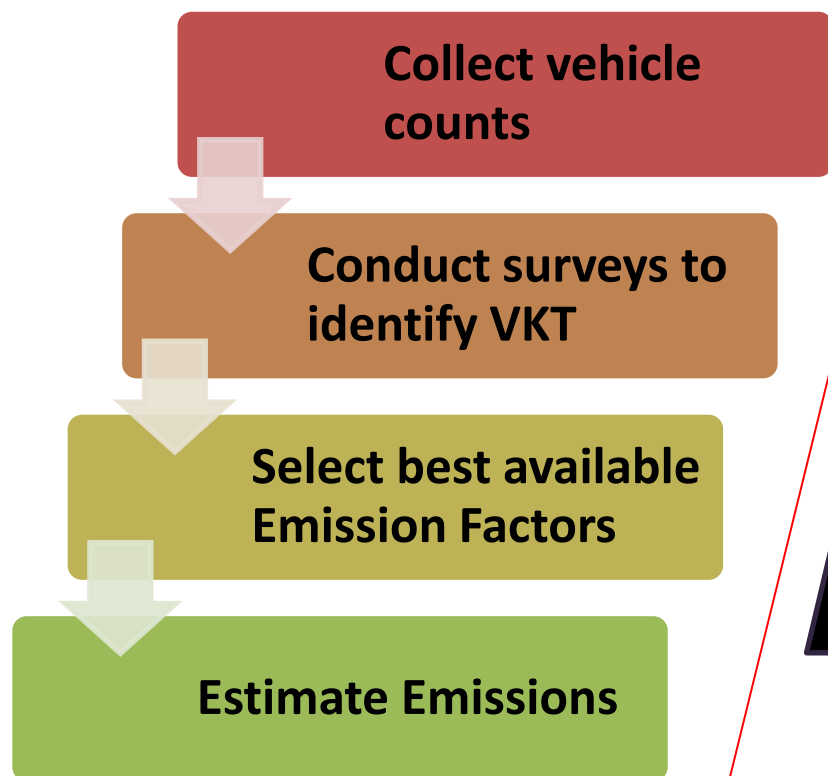
An *airshed* is a geographic area that shares the same air flow patterns, meaning that air pollution generated within this area tends to stay within its boundaries due to prevailing wind patterns, topography, and atmospheric conditions.



Gen-Zee EMISSIONS

IMPROVING ANALYTICAL RIGOR

Current Approach



Critical Limitations



ASSUMPTIONS USED IN PAST STUDIES



Driving cycle

Most inventories use generic urban cycles or no cycles at all (Tier1 methodology) not locality-specific.

Underestimates emissions from congestion



Fuel quality

Most inventories assume compliant fuel quality from all stations.

Causes mismatch with actual emissions due to difference in Emission Factors.



Cold-start / short-trip share

Most inventories assume fixed generic percent.

Underestimates urban CO and VOCs.

SOLUTION: IMPROVING EVIDENCE BASE & ASSUMPTIONS



Driving cycle



Fuel quality



Cold-start / short-trip share

REPLACEMENT EVIDENCE SOURCES

- Fleet composition: RTO / Vahan registration data, refreshed annually
- Driving cycle : Local traffic & telematics studies; city-specific cycles
- Load factors: Freight surveys and targeted primary data collection
- Fuel quality: State Pollution Control Board fuel-testing records
- Trip patterns: Travel-diary or app-based mobility data

Vehicle-Specific Factors

- a.** Engine Technology and Age
- b.** Fuel Type and Quality
- c.** Vehicle Weight and Aerodynamics
- c.** Vehicle Type and Size
- d.** Tyres



Maintenance and Environmental Factors

- a.** Vehicle Maintenance
- b.** Weather and Road Conditions
- a.** Traffic Congestion
- b.** Terrain



Operational and Driver-Related Factors

- a.** Driving Behavior
- b.** Vehicle Speed
- c.** Load Management
- d.** Route Planning
- e.** Idling



Vehicle-Specific Factors

1. Engine Technology and Age

Description of Influence: Modern engines are more fuel-efficient, reducing fuel consumption and emissions. An older, poorly maintained engine would have lower efficiency.

Scenario: A newer truck with a more efficient engine completes the same trip with 10% less fuel.

S. No	Trip Distance (KM)	Fuel consumption (Litres)	Fuel Type	Emission factor (CO ₂ e/liter)	GHG Emission (kg CO ₂ e)
1	500	144	Diesel	2.68	385.92

Maintenance and Environmental Factors

3. Traffic Congestion

Description of Influence: Stop-and-go traffic is highly inefficient, leading to increased fuel consumption and higher emissions.

Scenario: The truck is stuck in heavy traffic, increasing the trip's fuel consumption by 15%.

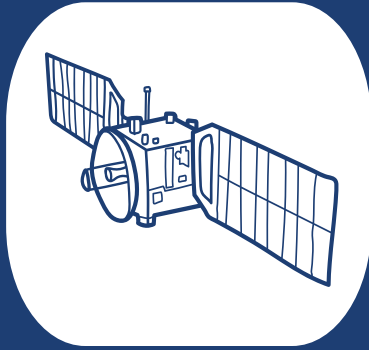
S. No	Trip Distance (KM)	Fuel consumption (Litres)	Fuel Type	Emission factor (CO ₂ e/liter)	GHG Emission (kg CO ₂ e)
1	500	184	Diesel	2.68	493.12

Advanced Techniques

Emission Inventory Development



Drones



Cubesats



Field Survey

The update interval of Indian emission inventories is too slow and need acceleration by modern techniques.



AI/ML FOR EMISSIONS

Intelligent Monitoring & Prediction Systems

Drone Video

Frame Extraction

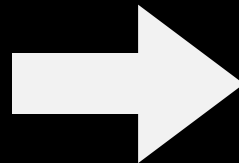
Vehicle Detection

Number Plate OCR

Vahan Query



END-TO-END DATA FLOW



Emission Data

HOW THE AI-MODELS WORK



Convolutional Neural Networks (CNNs) - The Foundation

- CNNs mimic human visual processing - recognizing patterns hierarchically from simple to complex.
- This filter detects vertical edges. Different filters detect horizontal edges, diagonals, curves.

Layer 1 (Early)

Layers 2-3 (Middle)

Layers 4-5 (Deep)

Final Layers

Detects basic features

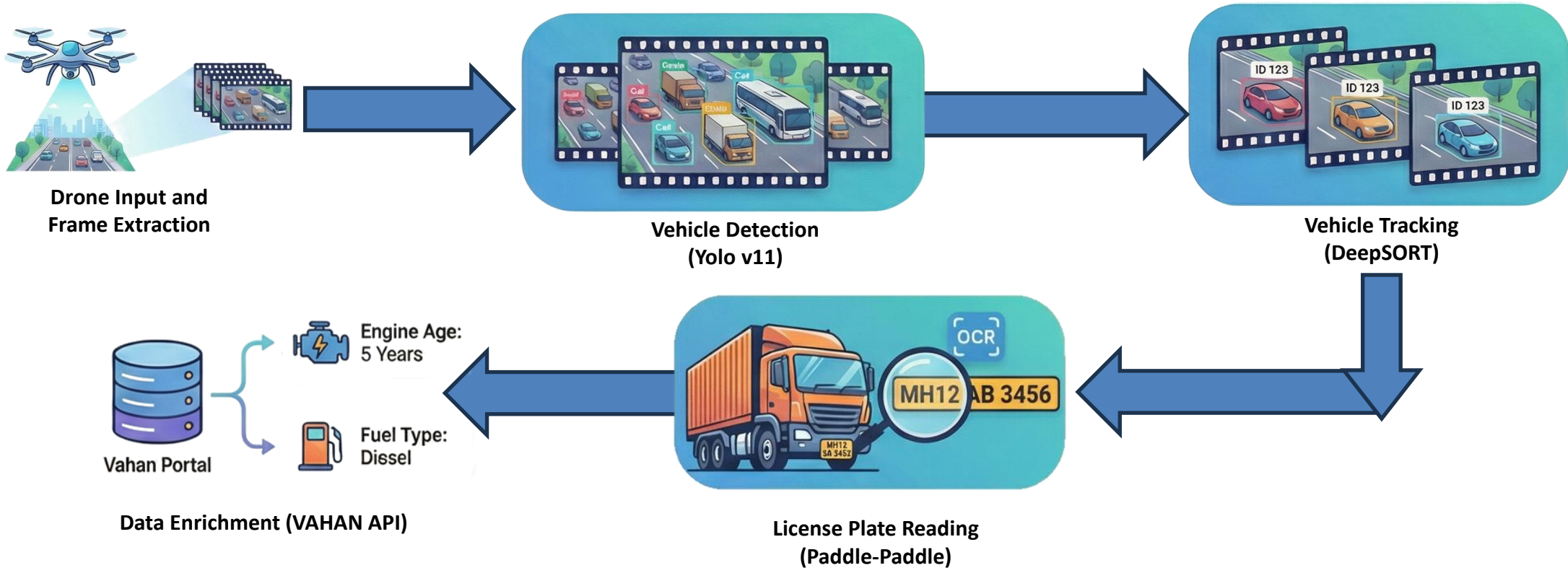
Detects shapes & textures

Detects object parts

Detects complete objects

PLUGGING THE GAPS IN ACTIVITY DATA

USE OF DRONES AND MACHINE VISION TO SPEEDUP DATA COLLECTION



PLUGGING THE GAPS IN ACTIVITY DATA

PUBLIC PARTICIPATION / CITIZEN SCIENCE

Anyone can be an air quality researcher



Information

You received 30% higher $PM_{2.5}$ exposure during your commute than at home.



Risk

Not irreversible but consistent exposure may lead to respiratory issues in $\approx x$ period



Expectation

This could fundamentally change public understanding of air pollution.

DATA Sources



Smartphones

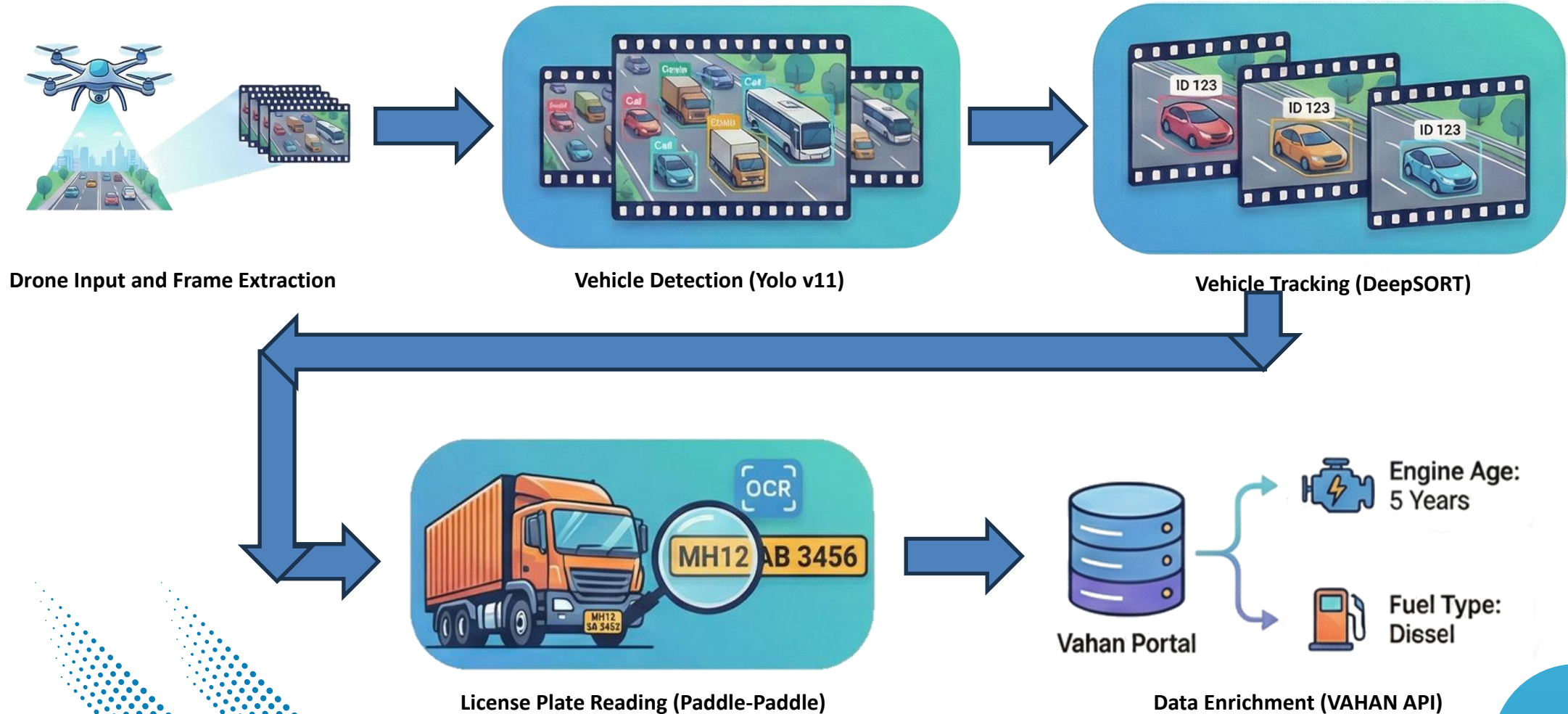


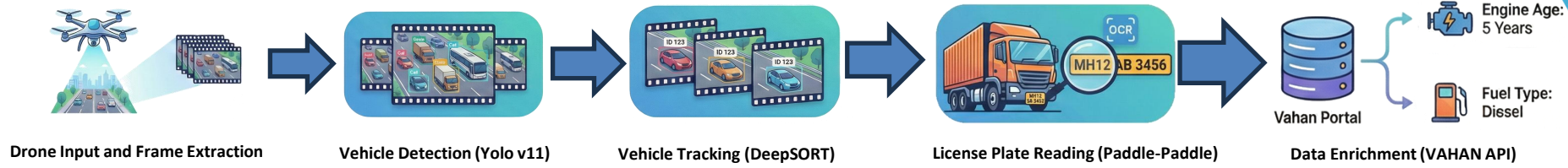
Wearables



Low Cost Sensors

AI-ML WORKFLOW



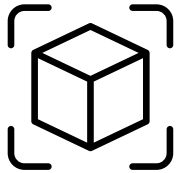


AI-ML WORKFLOW



Vehicle Detection (Yolo v11)

Why YOLO (You Only Look Once)?



YOLOv11 offers improved object detection performance enabling accurate identification of various vehicle types (cars, trucks, buses, motorcycles) even in complex traffic scenes.



YOLO enables persistent ID assignment to vehicles across video frames, ensuring precise vehicle counts by avoiding duplication due to temporary occlusion or motion blur.

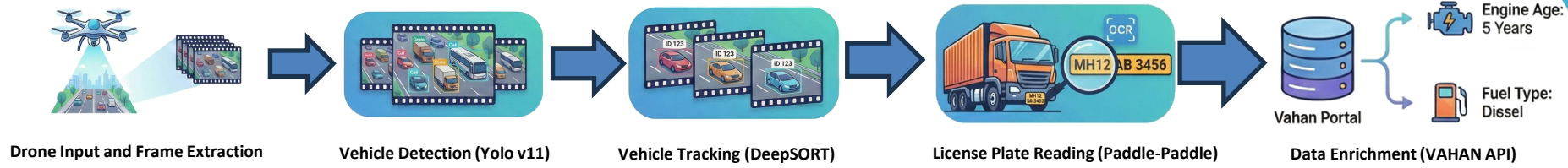




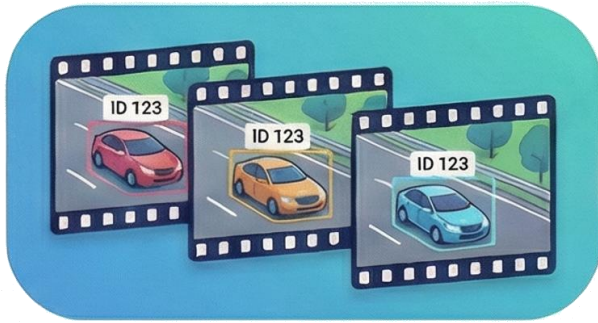
Vehicle Detection (Yolo v11)

YOLO in Action





AI-ML WORKFLOW

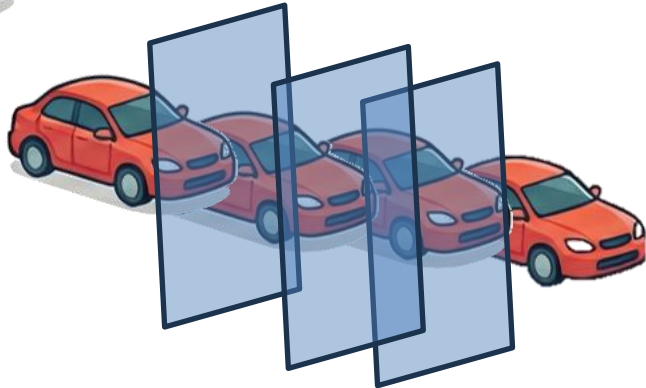


Vehicle Tracking (DeepSORT)

Traditional Object Detection : Double Counting



There is a chance that a single object is repeatedly counted across multiple frames.

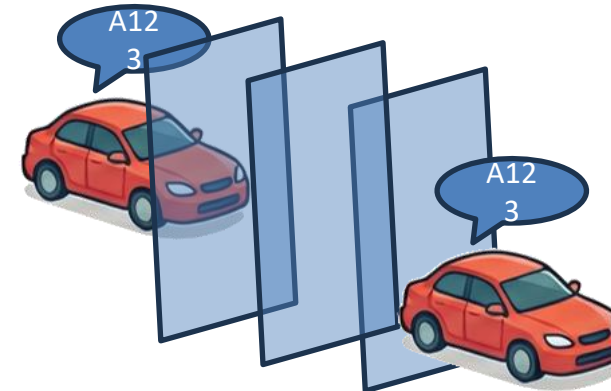


High chance of overestimation of vehicles especially in conditions where occlusion is high

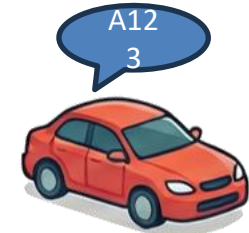
Vehicle Tracking using DeepSORT

Movement Prediction

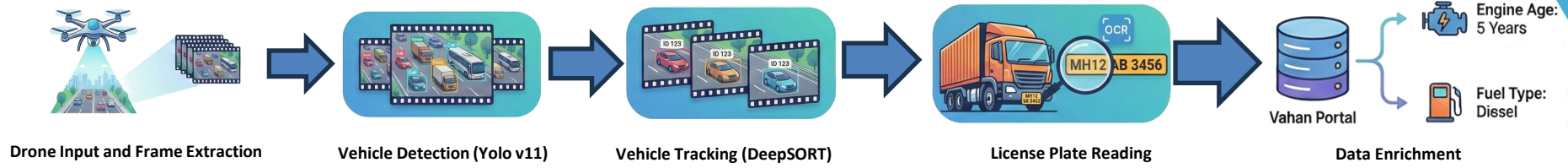
Kalman filtering prediction estimates objects' future position based on current position and velocity



Keeps track of the object even if it is temporarily occluded



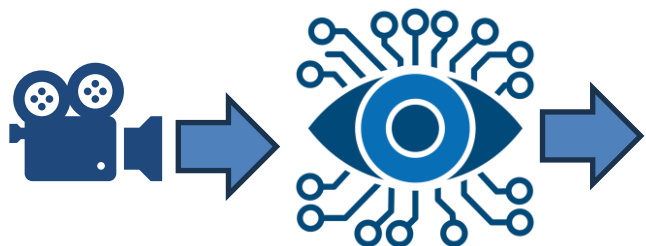
Creates a fingerprint for each object in a frame



AI-ML WORKFLOW



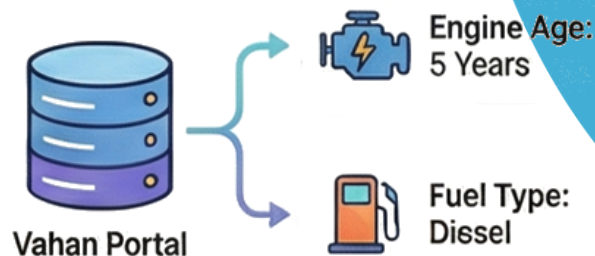
License Plate Reading



MH 12 FQ 3718

License plate text Extraction

This technology can easily handle skewed drone angles and non-standard Indian number plates.



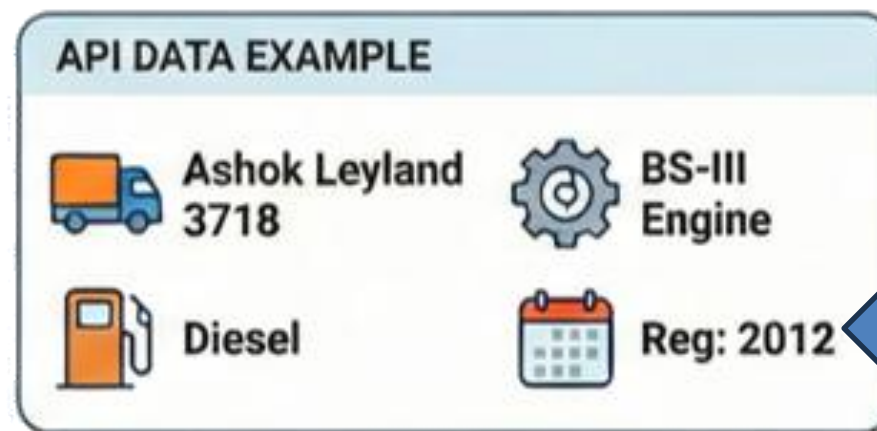
Data Enrichment



.csv input



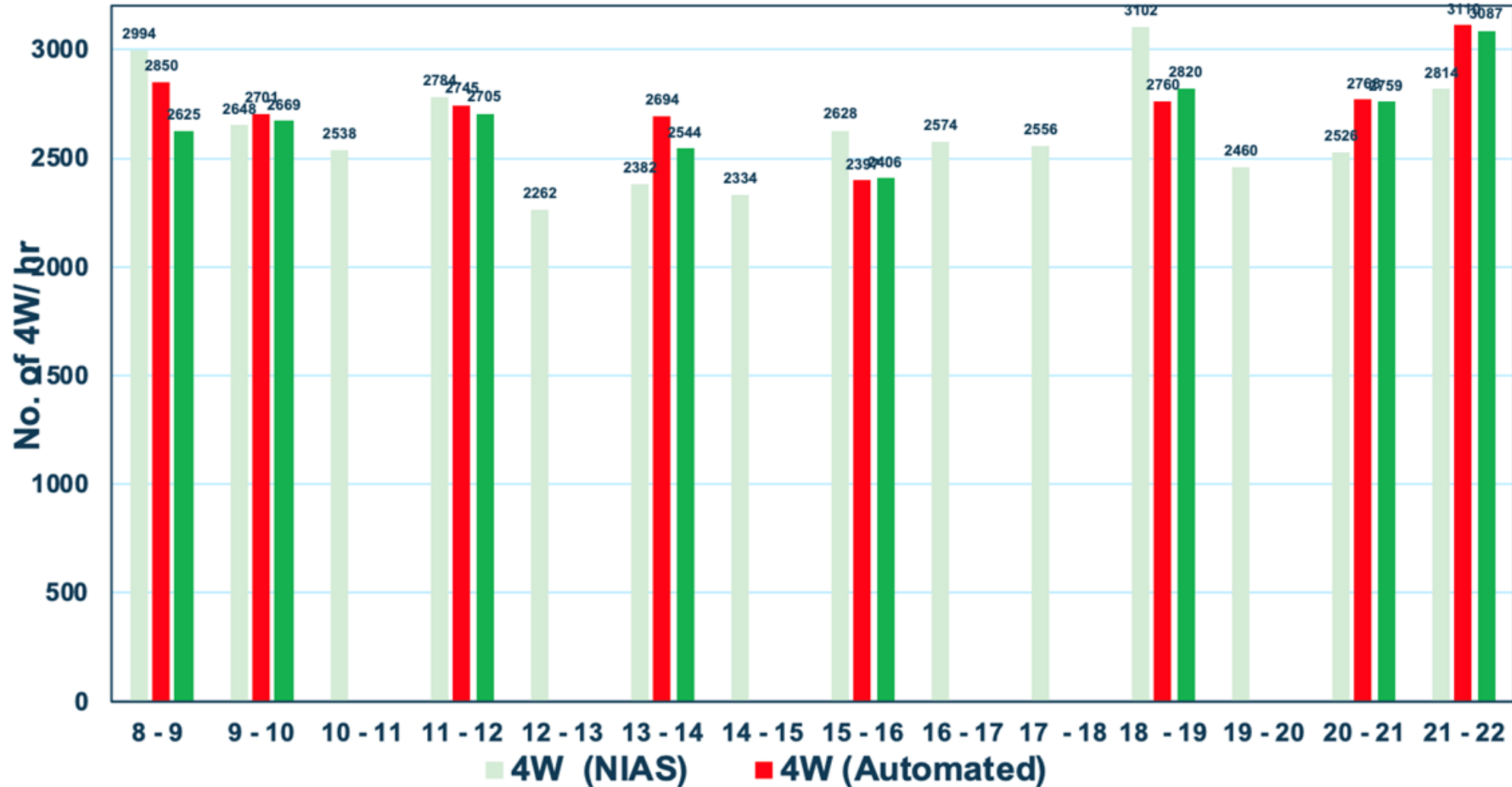
Vahan API



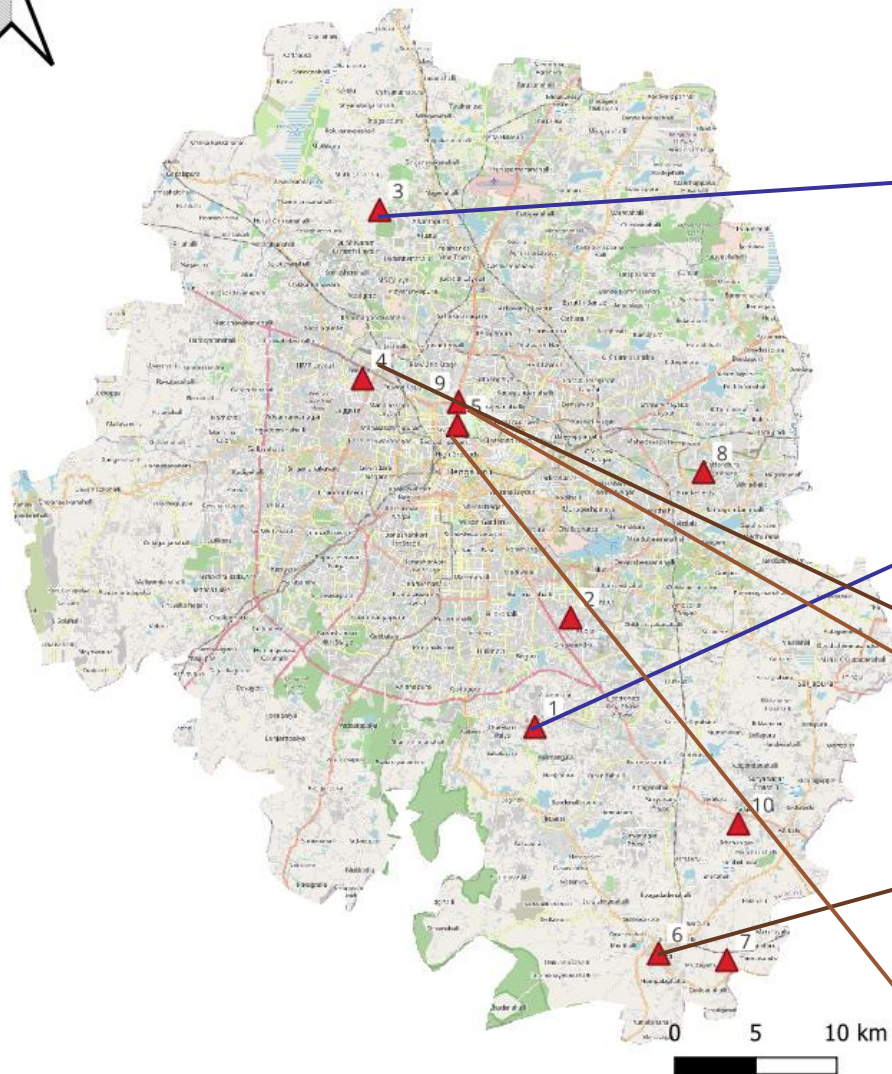
.json output from API call

MODEL VALIDATION - BENGALURU

SARAKKI CIRCLE



Hotspots Identified



Landfills



Industrial Areas



Traffic Junctions

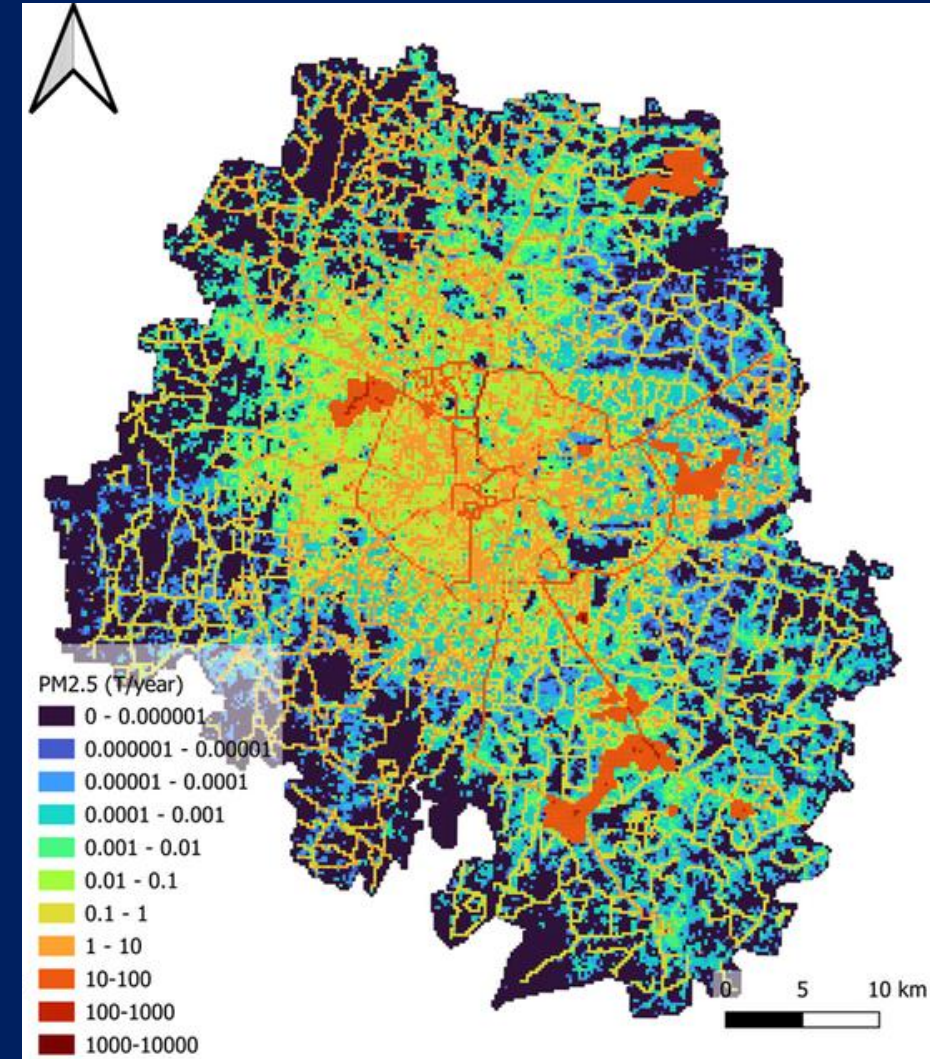
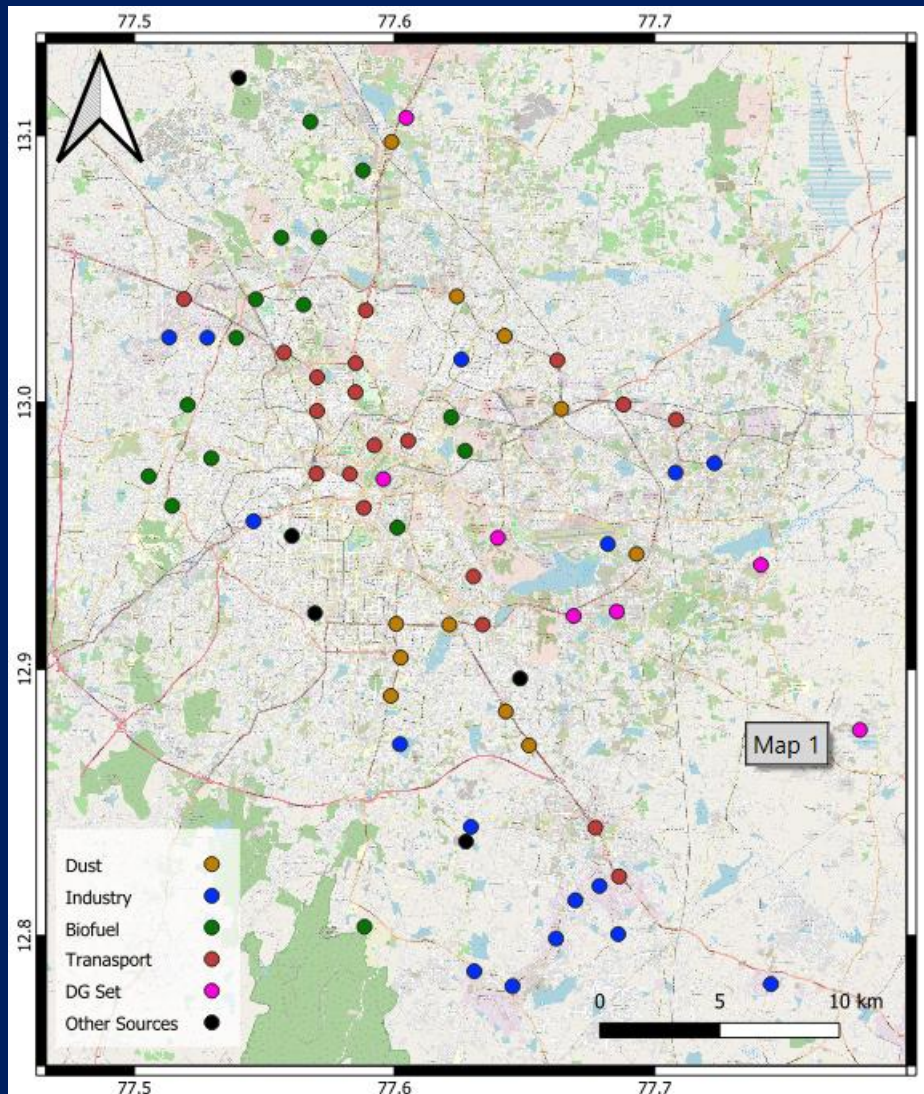


Area **v/s** Emissions

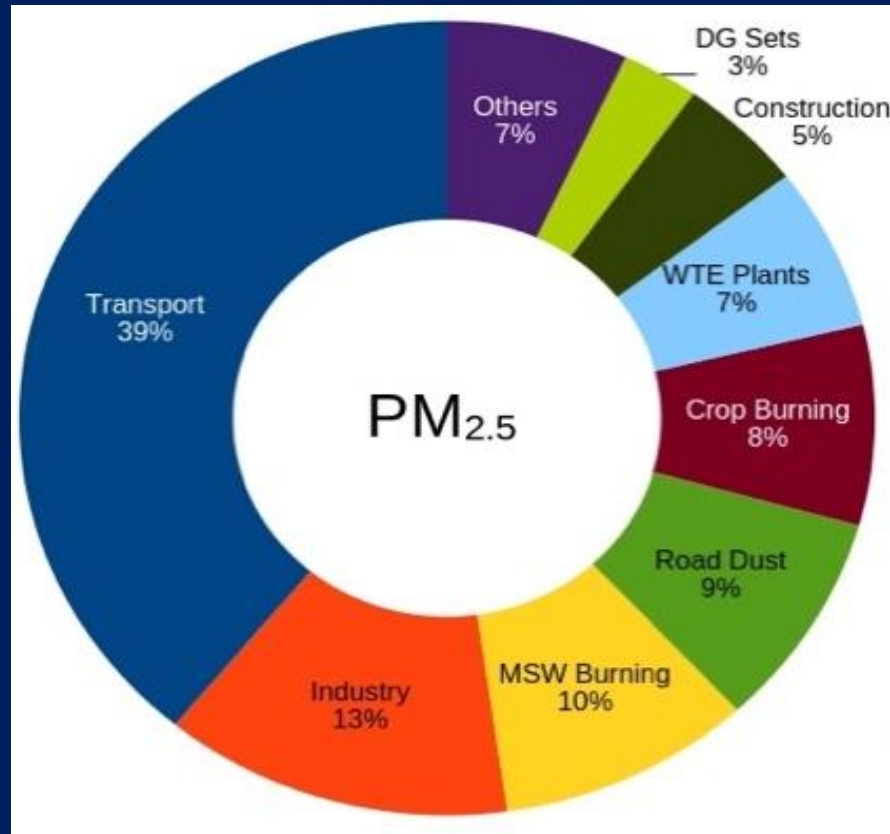
80 -Top Hotspots

21%
Emissions
of $PM_{2.5}$
From

0.28%
of City
area



Vehicle Numbers **v/s** Emissions

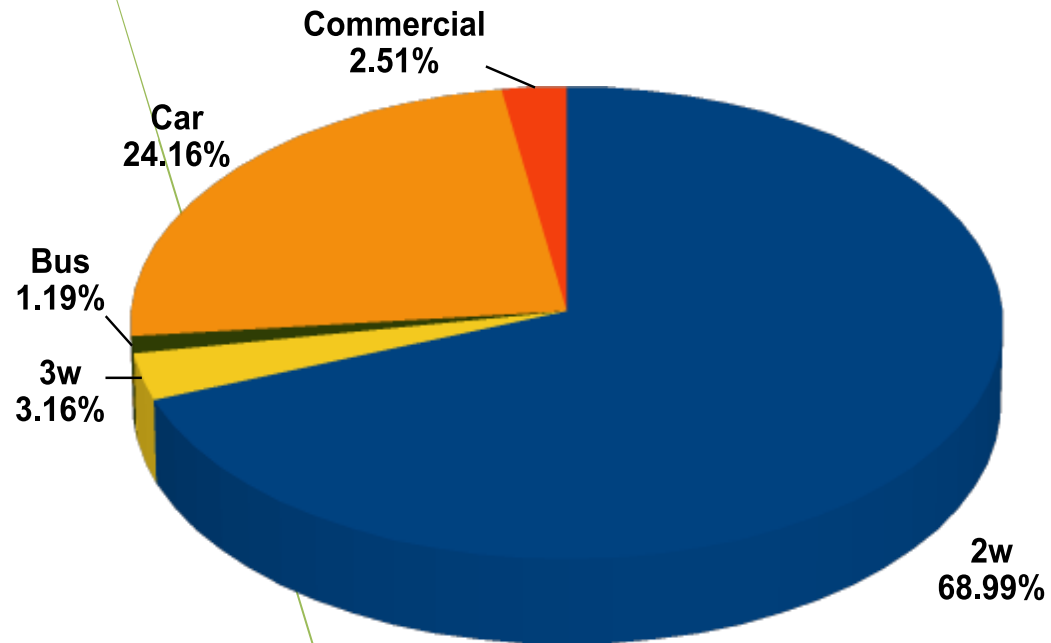


- **40%** of transport PM_{2.5} emissions from HCVs & LCVs, with **~3%** of the total fleet.
- **19%** of transport PM_{2.5} emissions from Buses with **>1%** of total fleet

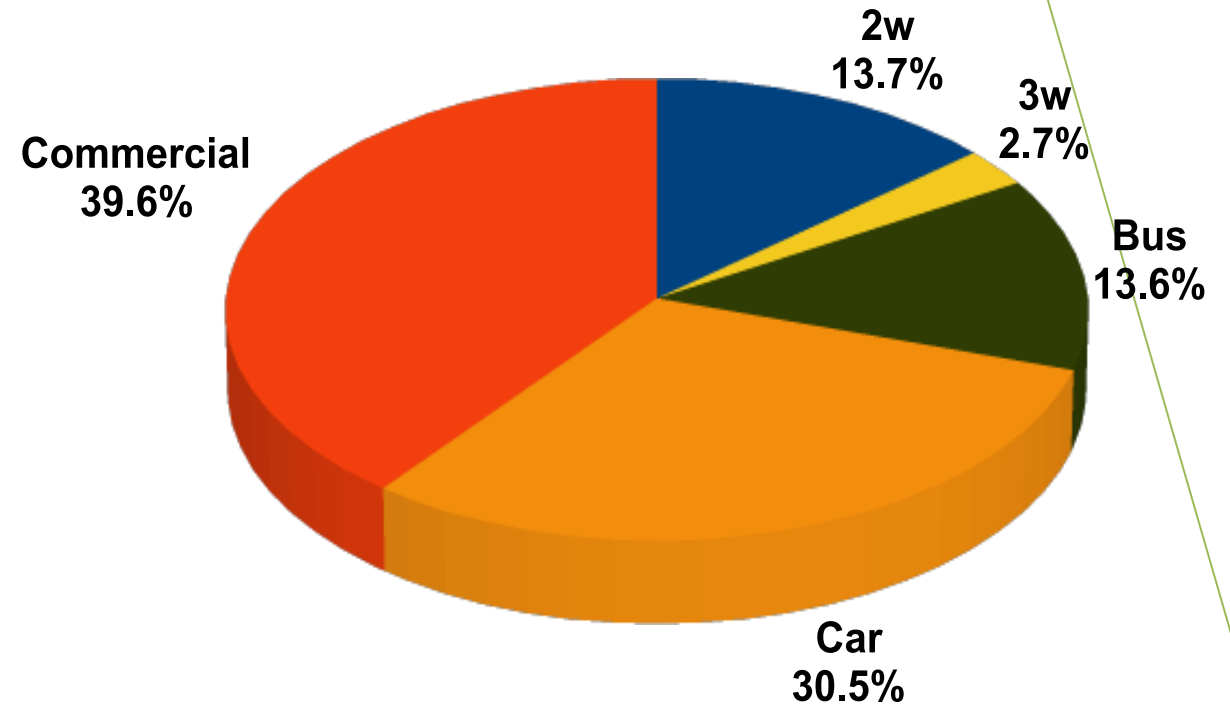
59% Emissions By 4% Vehicles

2W are **70%** but contribute only **11%** of PM_{2.5} emissions, Cars 22% gives 20% emissions.

TRANSPORT PM_{2.5} EMISSION CHARACTERISTICS OF DELHI



Vehicle Types



PM_{2.5} emissions from different vehicle types

ECONOMIC BENEFITS FROM EV TRANSITION

DELHI, INDIA

Interventions	Percentage Reduction in PM _{2.5} Concentration	Benefit from reduced mortality (Crore INR)	Benefit from reduced morbidity (Crore INR)	Reduction in Per capita healthcare cost (INR)
2W & 3W to EV	5.97%	328.00	52.46	291.52
All Cars to EV	11.07%	607.53	97.17	539.96
All HCV to EV	8.80%	483.08	77.27	429.35
All LCV to EV	5.48%	300.84	48.12	267.38
All Bus to EV	4.89%	268.74	42.98	238.85
All Vehicles to EV	36.11%	1982.45	317.08	1761.96

Transition to EV !! Economy !!

Health benefits for different Indian cities from complete transition to EVs



Indian Mega City	% Reduction in level of PM2.5	Benefit from reduced mortality (Crore INR)	Benefit from reduced morbidity (Crore INR)	Reduction in Per capita healthcare cost (INR)
Delhi	39.18%	2151	344	1912
Chennai	43.86%	1585.85	255.36	1001.17
Bengaluru	39.11%	1144.03	334.26	2008.48
Mumbai	29.13%	680.46	226.30	530.92

BIG DATA: NEW-GEN PREDICTION SYSTEM

REALTIME VEHICLE MAPPING

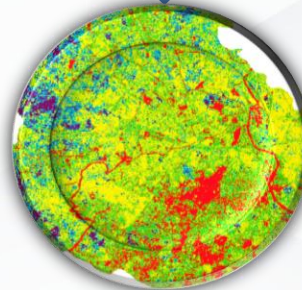


AI-BASED MACHINE VISION



GRIDDED EMISSIONS

CTM-MODEL



POLLUTION CONCENTRATION

AI-SMART

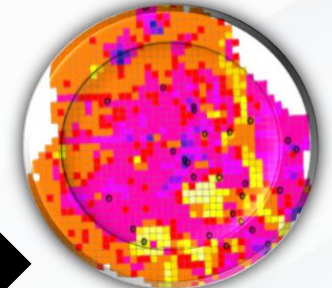


DEEP LEARNING MODEL



AI-FLAKY TEST

HOT FORECAST



TARGETED INTERVENTIONS

THANK YOU



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