

Vibration-Aware Traffic Management Framework Based on Vehicle-Induced Emissions and Route Sensitivity Analysis

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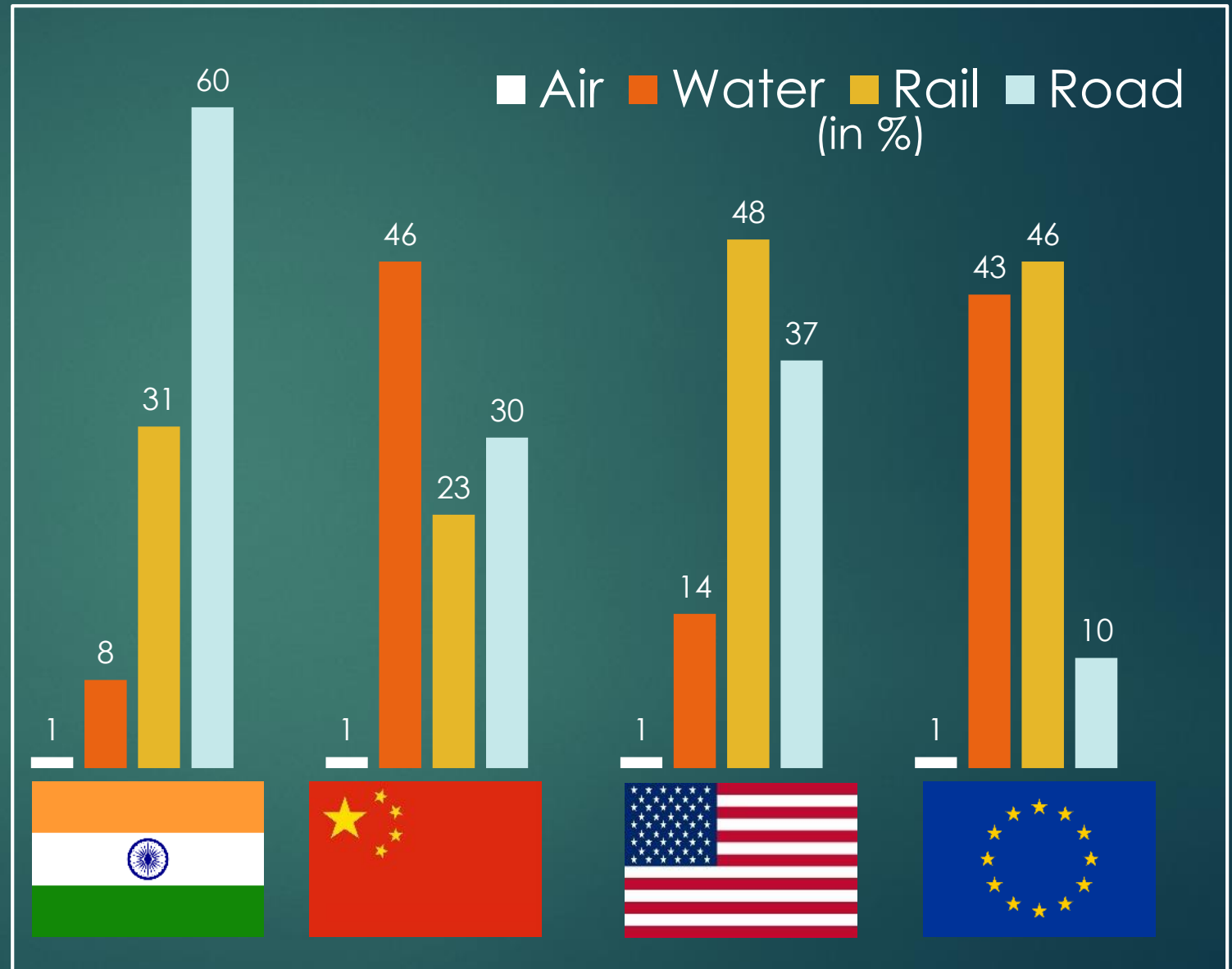
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Introduction

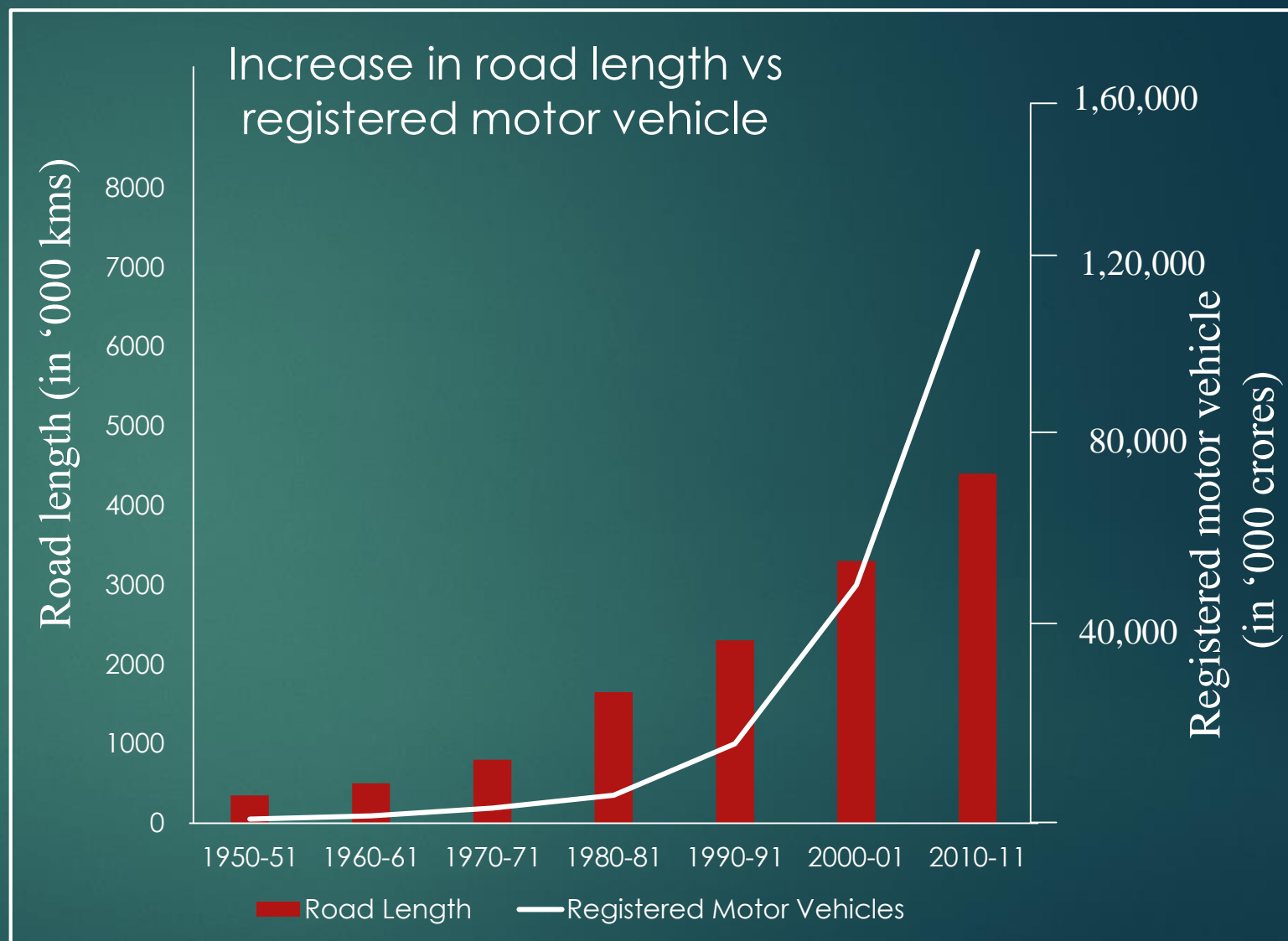
- Three-fifths of transport in India happens through roadways, far higher than developed economies
- In the US, the share of road transport is 37%, while it is far lower at 10% in Europe
- India's reliance on road transport is twice that of China's 30% share



(Source: Nomura Research)

Introduction...

- Road length in India has increased from about 4 lakh km (1950) to about 55 lakh km (2015)
- Since 2000, road network in India has grown by 39%, and the number of registered vehicles has grown by about 158%

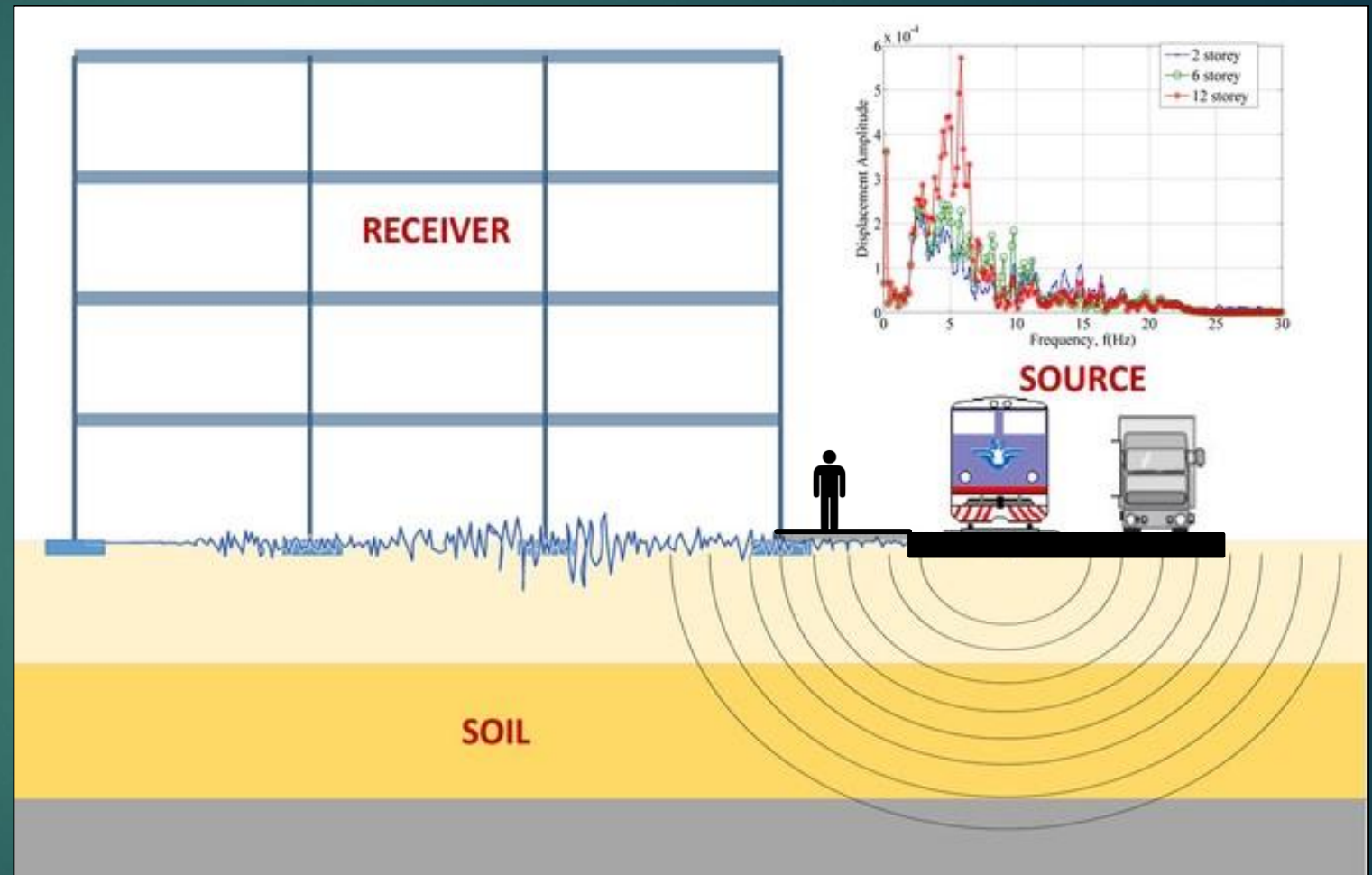


(Source: PRS Legislative Research)

Introduction...

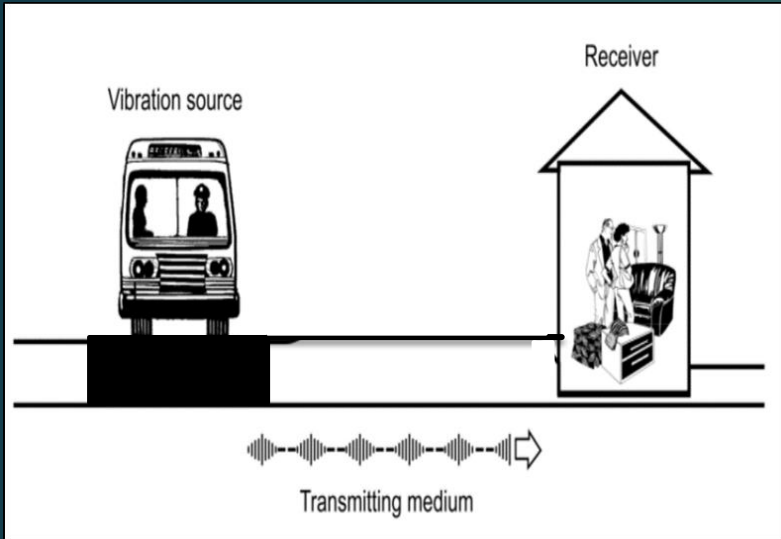
Traffic-Induced Vibrations :

- Major traffic pollutants are noise pollution and air pollution
- According to Hajek (2006), transportation agencies are supposed to receive complaints from road users and residents living near highways
- Further, complaints on vibration caused by highway traffic are less frequent, but they do occur
- Many transportation agencies do not have applicable guidelines for the resolution of complaints due to vibrations



(Source: Marija Nefovska-Danilovic, 2013.)

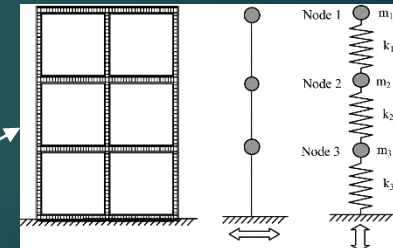
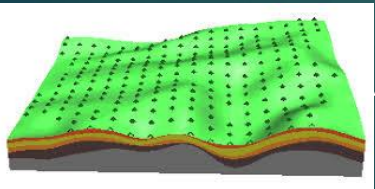
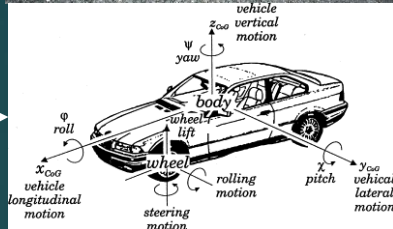
Components of Traffic-Induced Vibration



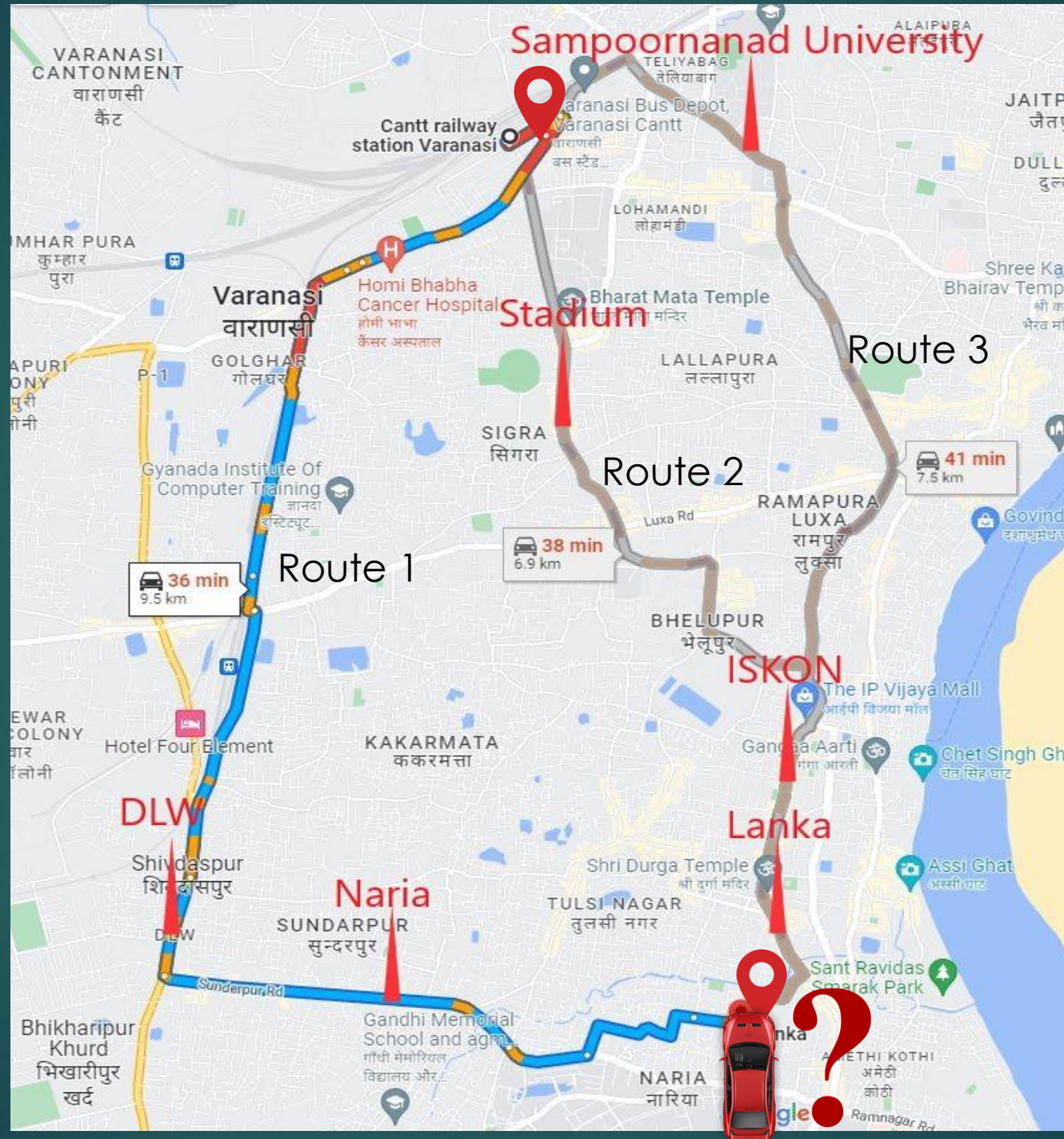
Source

Transmission Path

Receiver



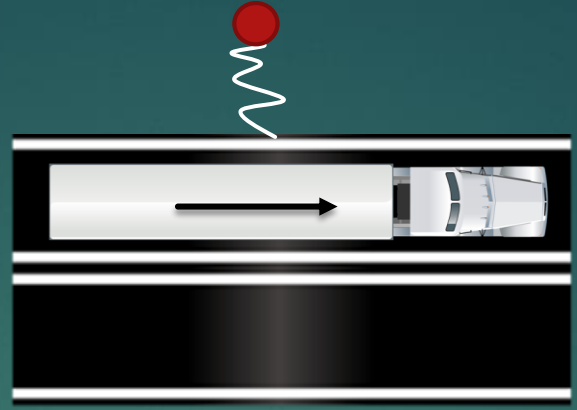
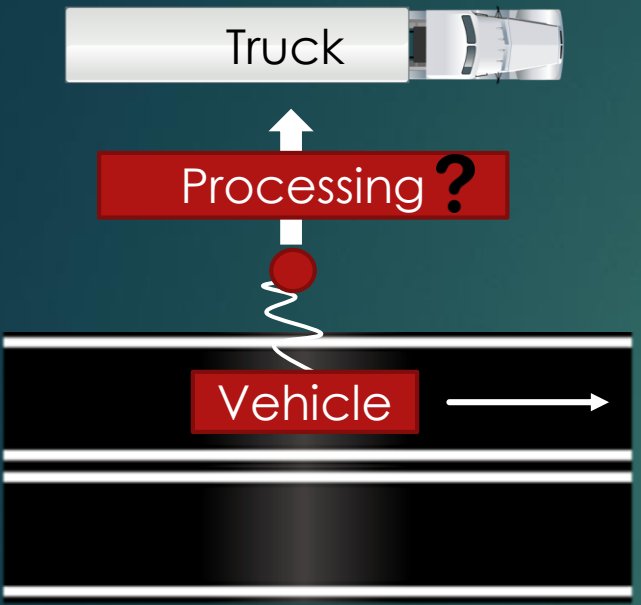
Research Gap



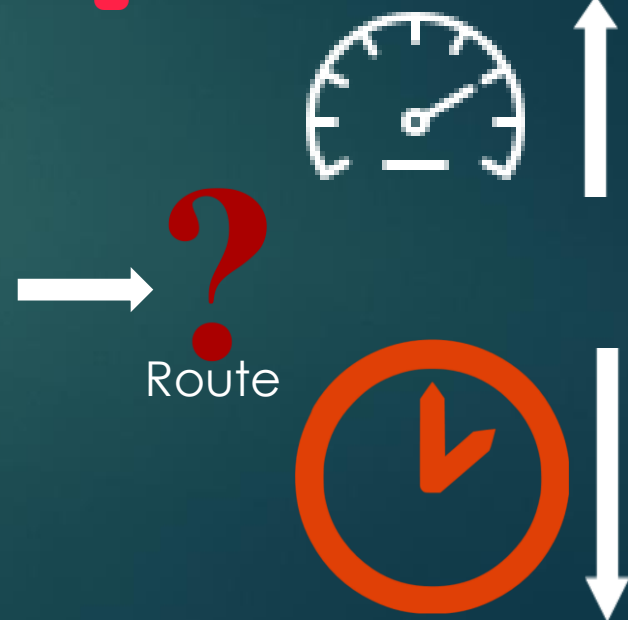
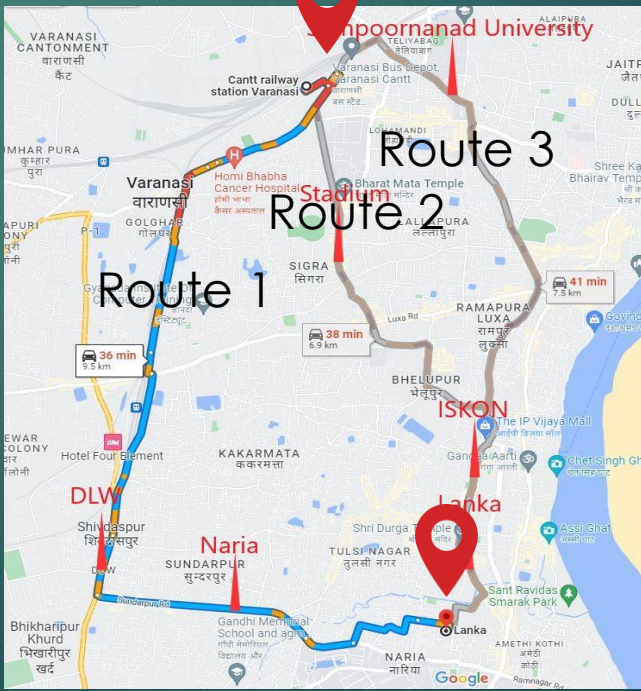
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Lack of a routing framework that enforces corridor-specific vibration limits while minimizing travel time.

Objective



Unified Vibration-Aware
Traffic Management
Framework



Instruments



Accelerometer



Sound Level Meter



Lidar Speed Gun



Camera



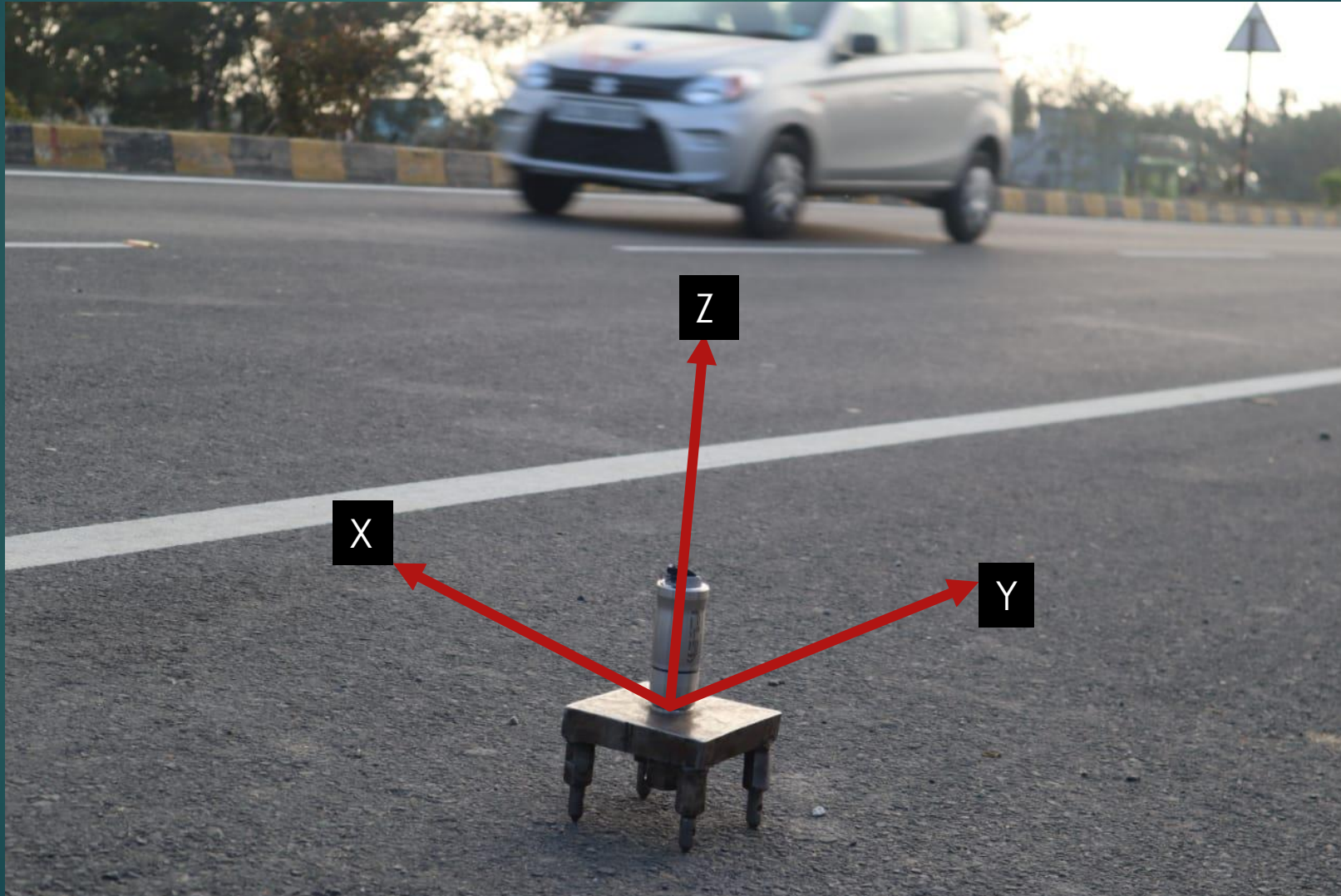
Accelerometer Mounting Device



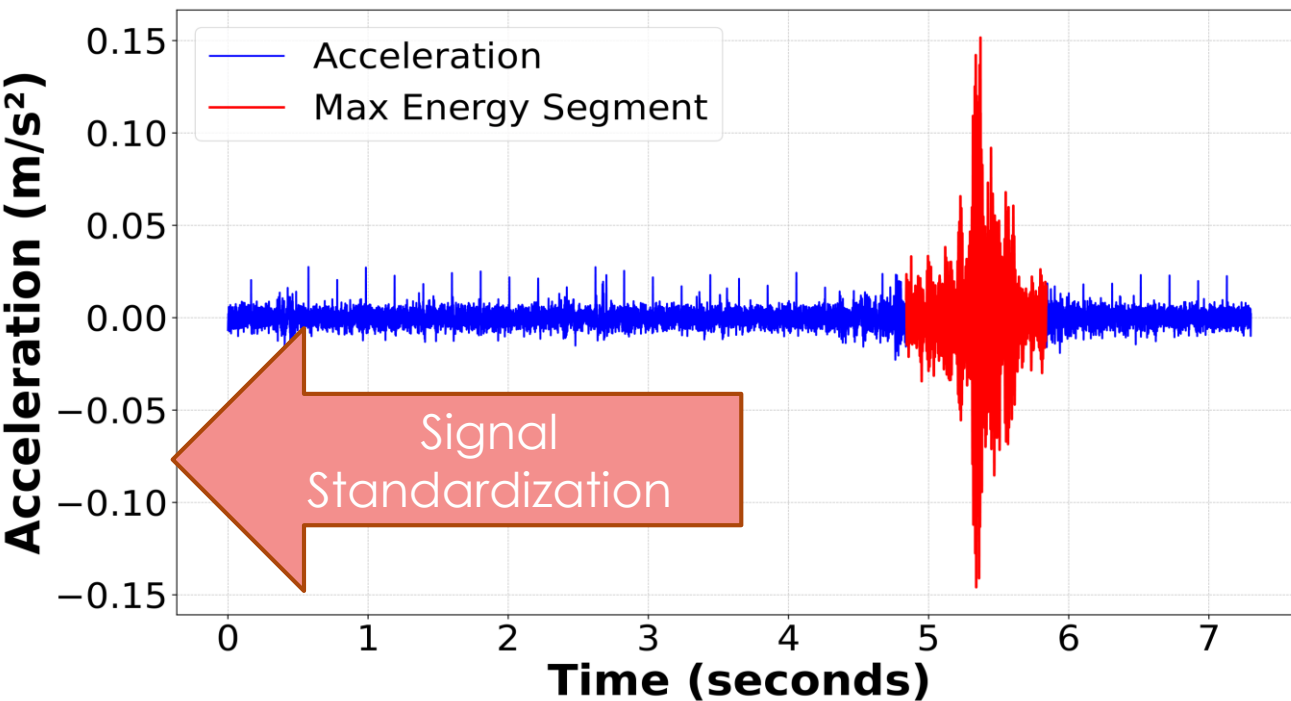
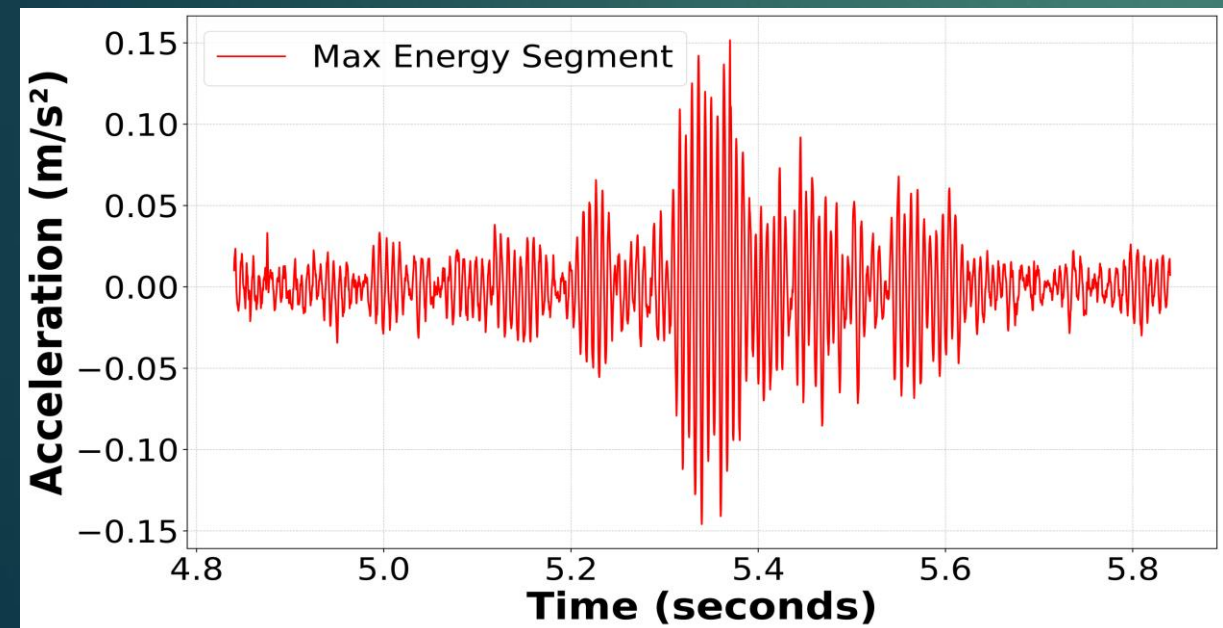
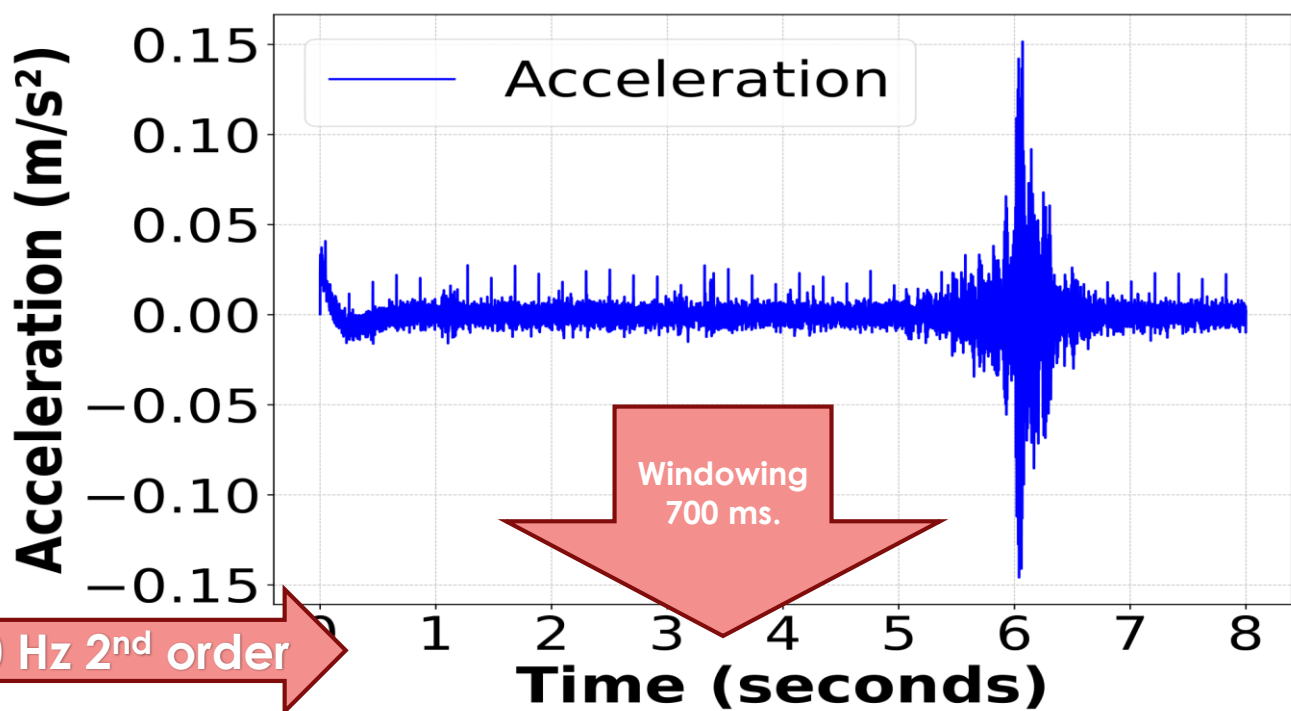
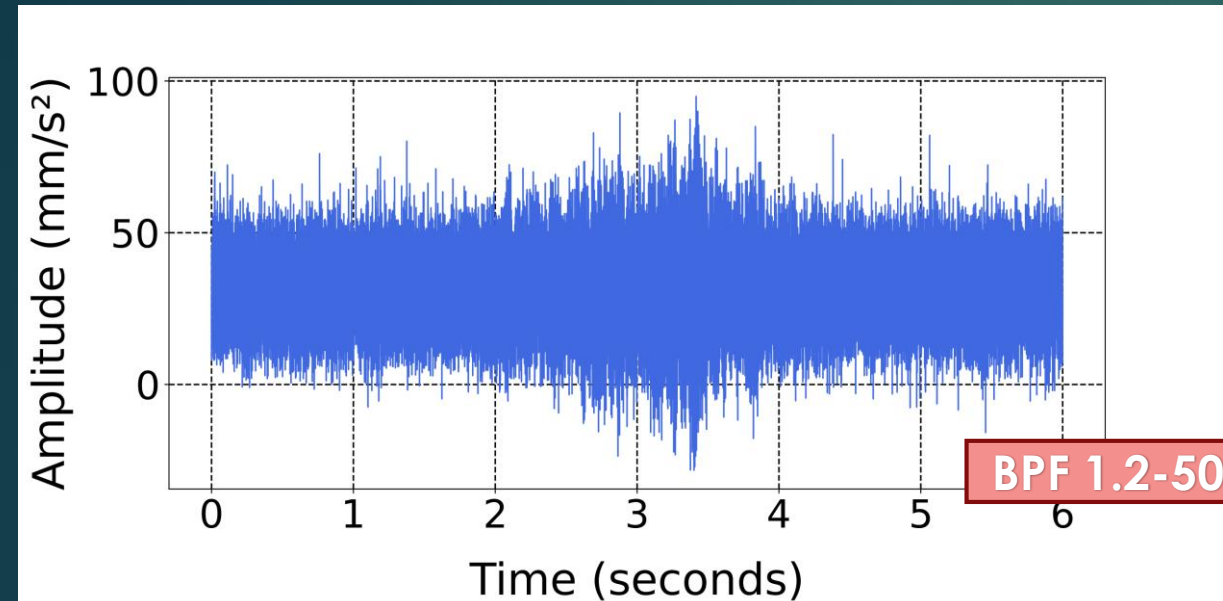
On Site Setup

Accelerometer Mounted on Road Surface

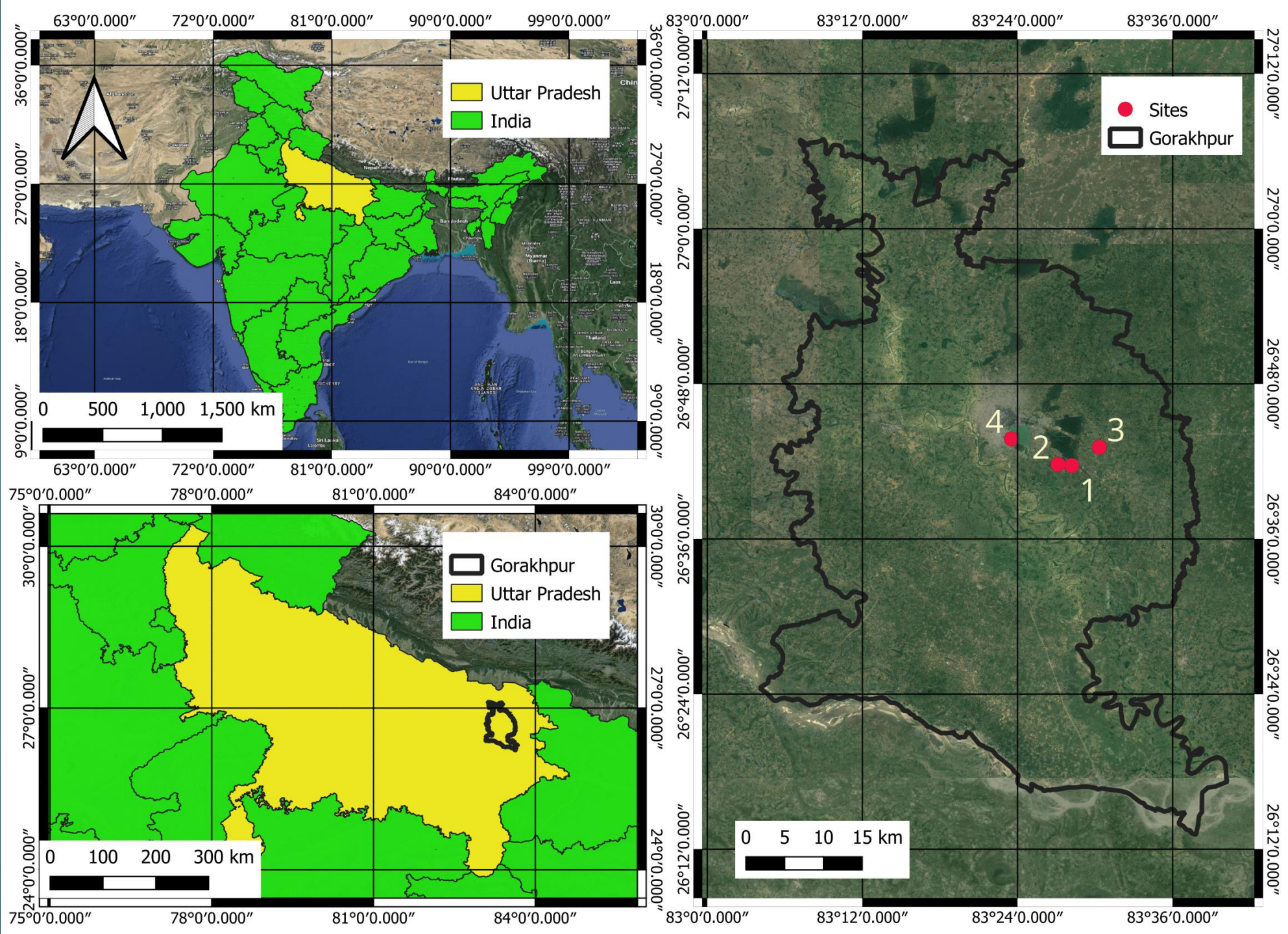
A Patent on an accelerometer mounting device has been filed and published in the Indian Patent Journal



Signal processing

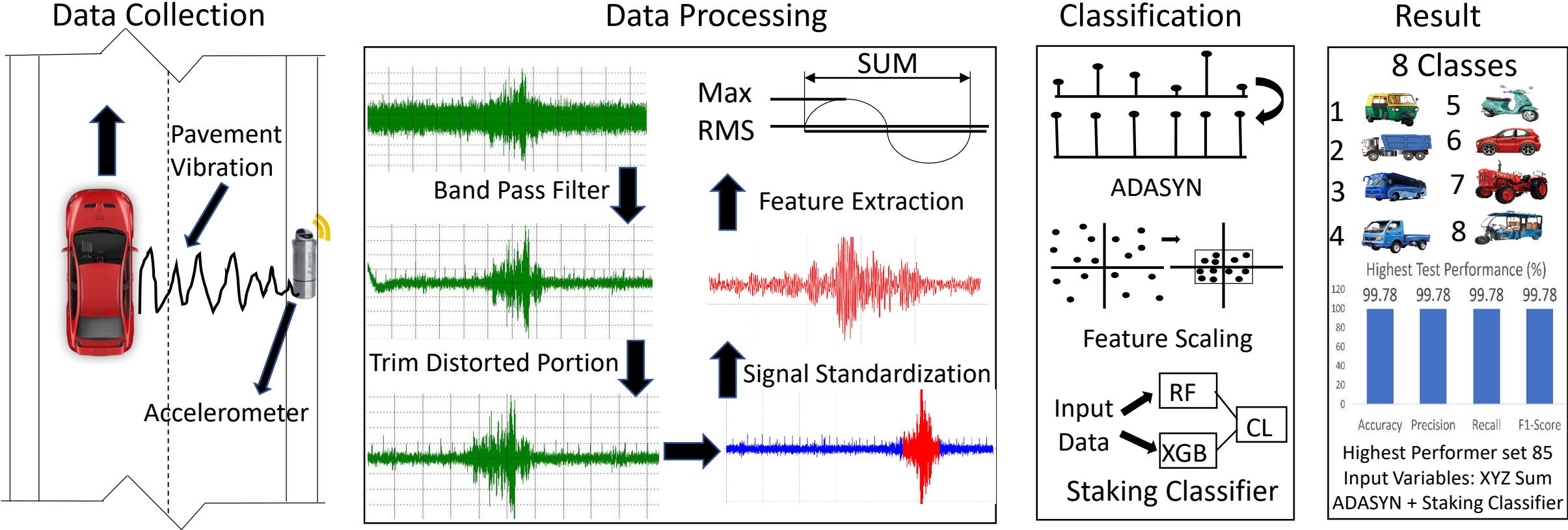


Reference Vibration
Emission Level/
Passenger Car
Vibration
Equivalence and
Vehicle
Classification Study
Sites

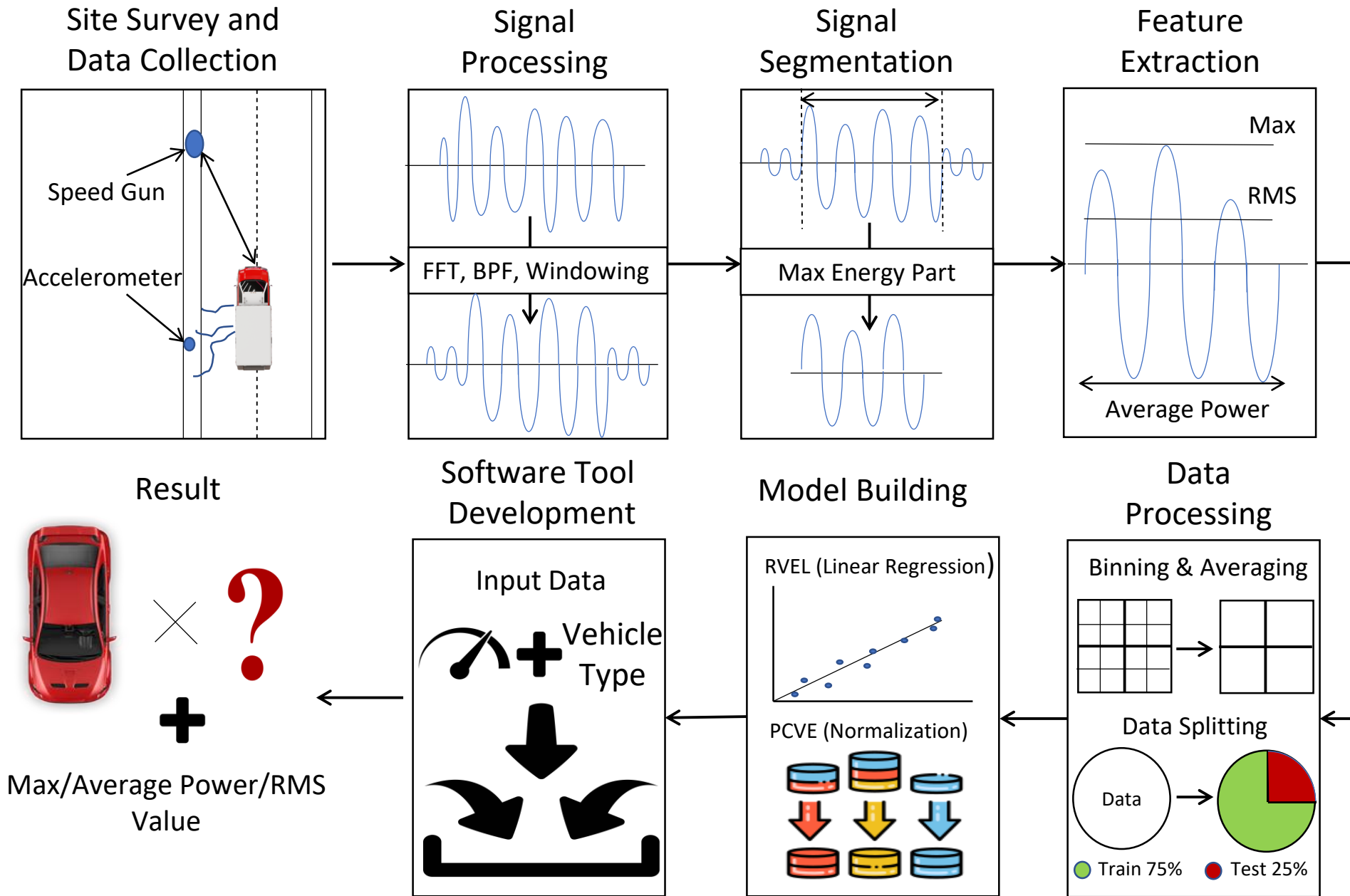


Vehicle classification using Vibration data

Vehicle Classification Using Pavement Vibration Signals



Analytical Pipeline for Traffic-Induced Vibration Evaluation Using RVEL and PCVE



Data Collection site of Route Optimization Study

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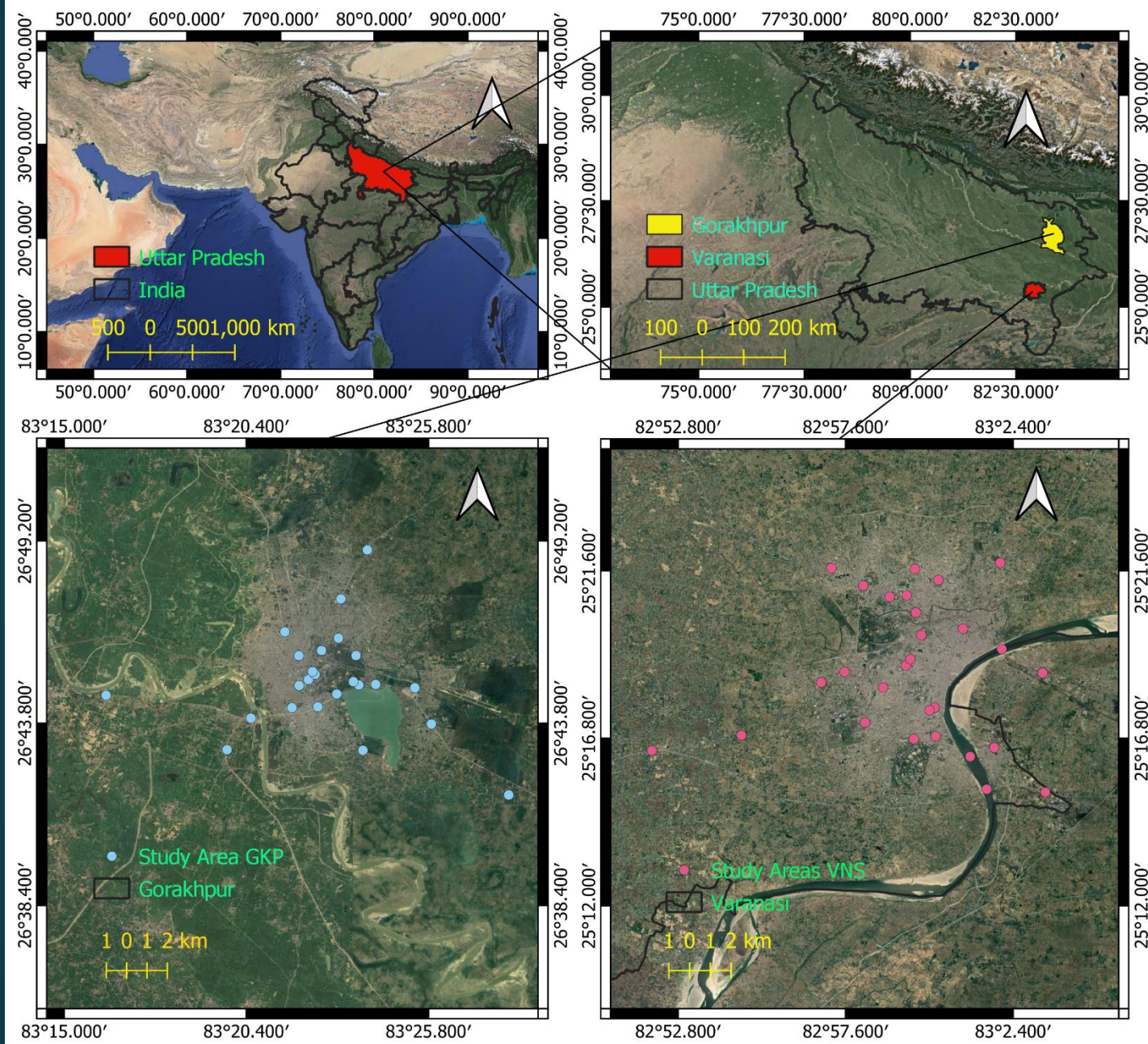
Continuous Monitoring

No of sites selected (Total 6 rounds of data collection done, each round contains 3 hours of continuous monitoring)

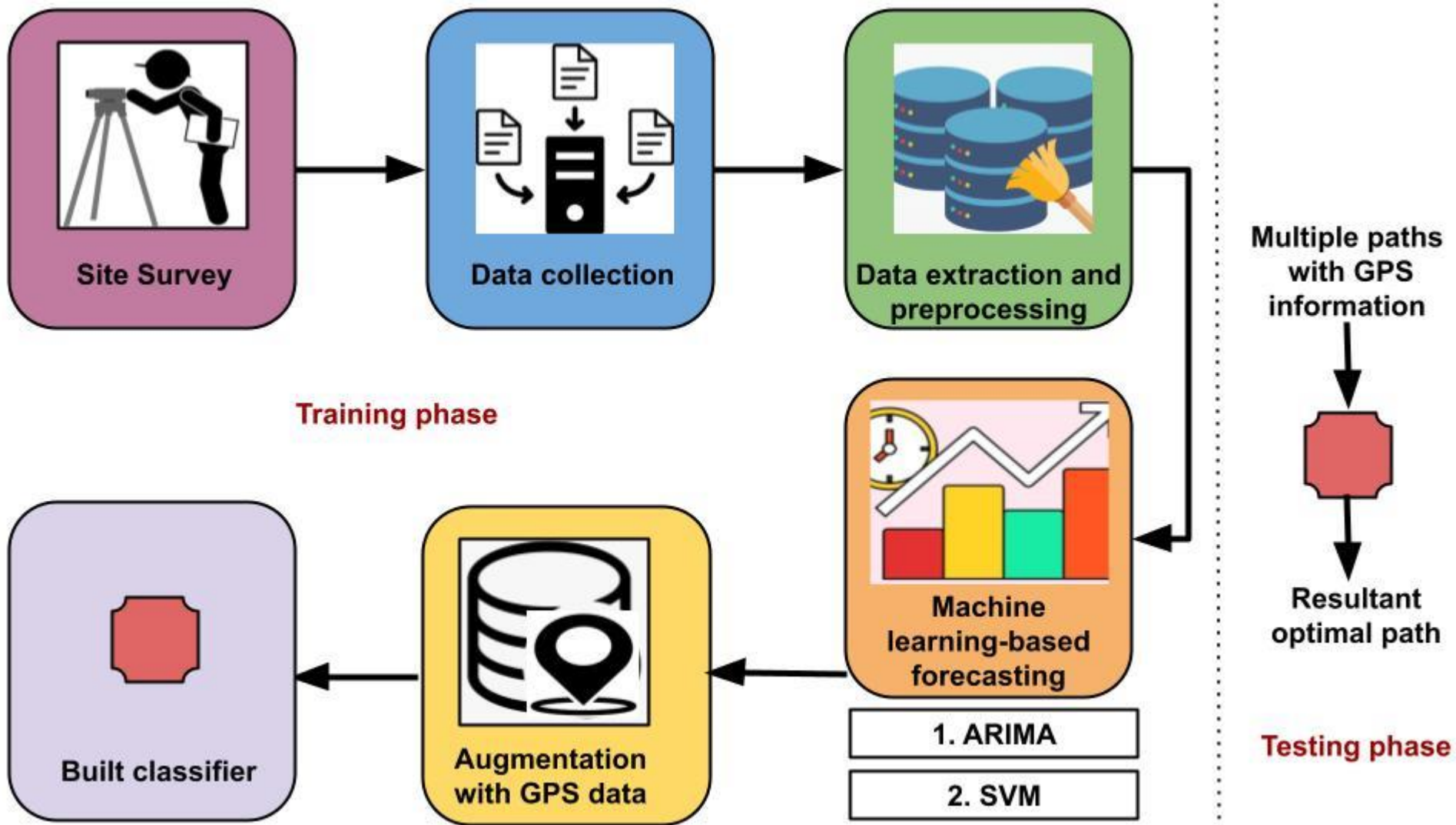
Varanasi – 28

Gorakhpur – 24

This data covers a total of 11 vehicle categories



GPS augmentation and route optimization



Proposed Unified Vibration-Aware Traffic Management Framework

GPS Data



+

Classified Vehicle Volume

Route A /Route B



Cases

Route Evaluation Logic (Three Cases)

Case 3: Both Non-Sensitive Zones

- No RVEL limit needed
- Select route with:
 - Lower PCVE load
 - Lower PCU (congestion)
 - Shorter delay
 - Fewer speed interventions

Case 2: One Route Sensitive, One Not

- For Sensitive Route:
 - Apply RVEL threshold,
- For Non-Sensitive Route:
 - No RVEL threshold, but minimize PCVE + PCU
- Compare both routes
 - Prefer Sensitive Route only if safe & shorter
 - Otherwise, divert via Non-Sensitive Route

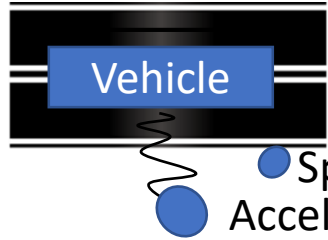
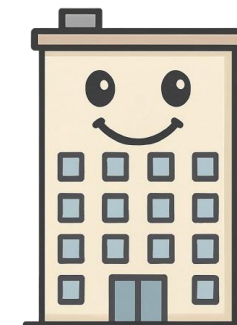
Case 1: Both A and B Sensitive Zones

- For each route:
 - Check RVEL vs. Zone Threshold
 - If RVEL > limit:
 - Try Speed Reduction → Recompute RVEL
 - If RVEL OK → Flag with Speed Cap
 - Else → Try PCVE Substitution (Truck ↔ Cars)
 - ✓ If feasible & PCU OK → Allow
 - ✗ Else → Mark route as infeasible
- Select feasible route with lowest PCVE + PCU + Delay

Decision Module

Compute Final Route
 w_1 PCVE + w_2 PCU +
 w_3 Congestion + w_4 Delay

Recommend Optimal Route
 → Route ID
 → Speed cap (if enforced)



Classification



RVEL/PCVE Module



RVEL = 5.6

3.2

×

Vehicle

Truck

Speed Gun
Accelerometer

- Proposed new indices, PCVE (Passenger Car Vibration Equivalence) and RVEL (Reference Vibration Emission Level) for standardized vibration quantification
- Achieved 99.78% accuracy in vehicle classification using ground vibration signals and machine learning models
- Integrated classified vehicle count data into GPS-based models for accurate traffic forecasting and route optimization
- Combining the above three studies proposed a framework for Vibration-Aware Traffic Management for optimizing the mobility and the permissible vibration level

Thanks

Data without processing is merely noise.

Research without clarity is an undamped vibration.”

— Amar Deep Pandey