



AI-DRIVEN CRASH PREDICTION MODEL FOR HERITAGE CITY ROAD NETWORKS

The Need for Heritage-Specific Safety Performance Functions

Presenter: Ms. Monali bose

PhD Scholar (AcSIR), CSIR-Central Road
Research Institute, New Delhi, India

Co-Author: Dr. Ch. Ravi Sekhar

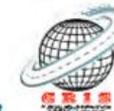
Director, CSIR-Central Road
Research Institute, New Delhi, India

Co-Author: Dr. S. Velmurugan

Head –TES, CSIR-Central Road
Research Institute, New Delhi, India

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1. STUDY CONTEXT AND PROBLEM STATEMENT



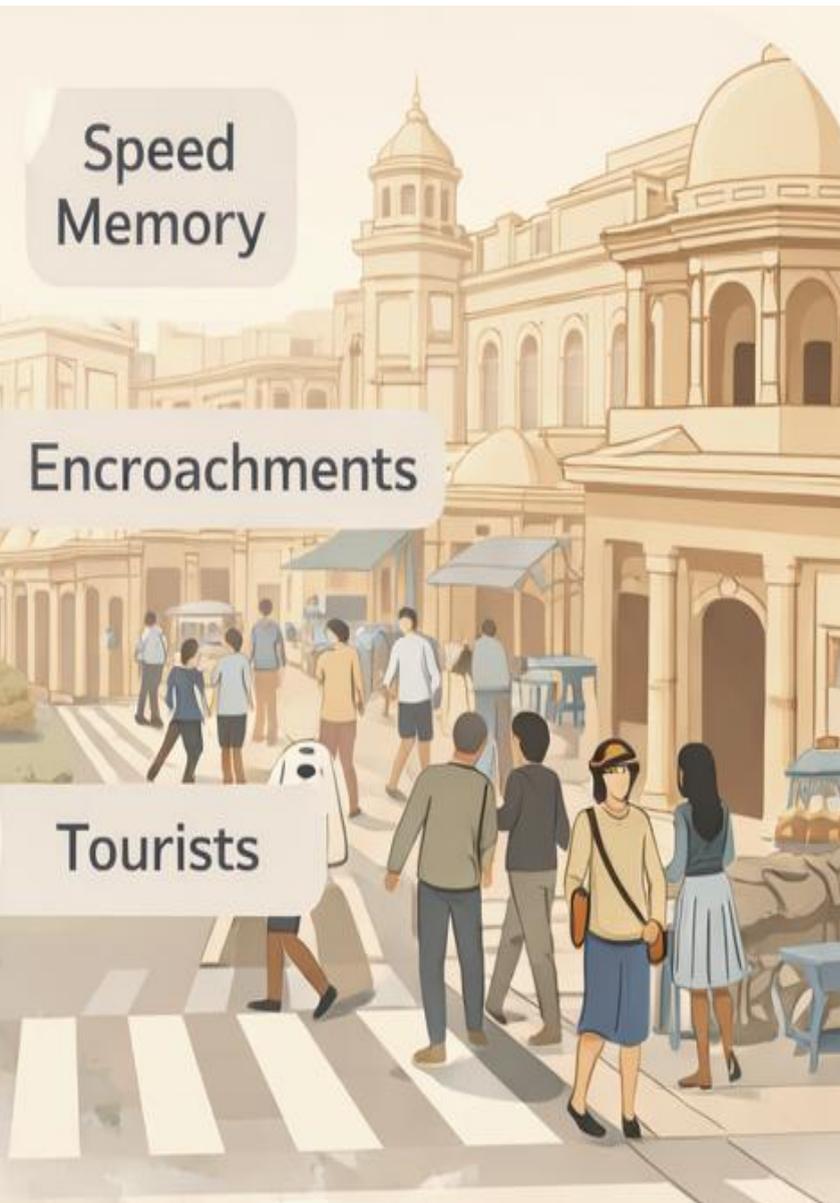
Need of the Study

- Existing SPFs are developed primarily for modern, planned road networks.
- Heritage city roads differ fundamentally in:
 - Road geometry
 - Traffic composition
 - Pedestrian dominance
 - Land-use intensity

Problem Statement

Applying modern-road SPFs to heritage roads leads to unreliable crash prediction and unsafe planning decisions.

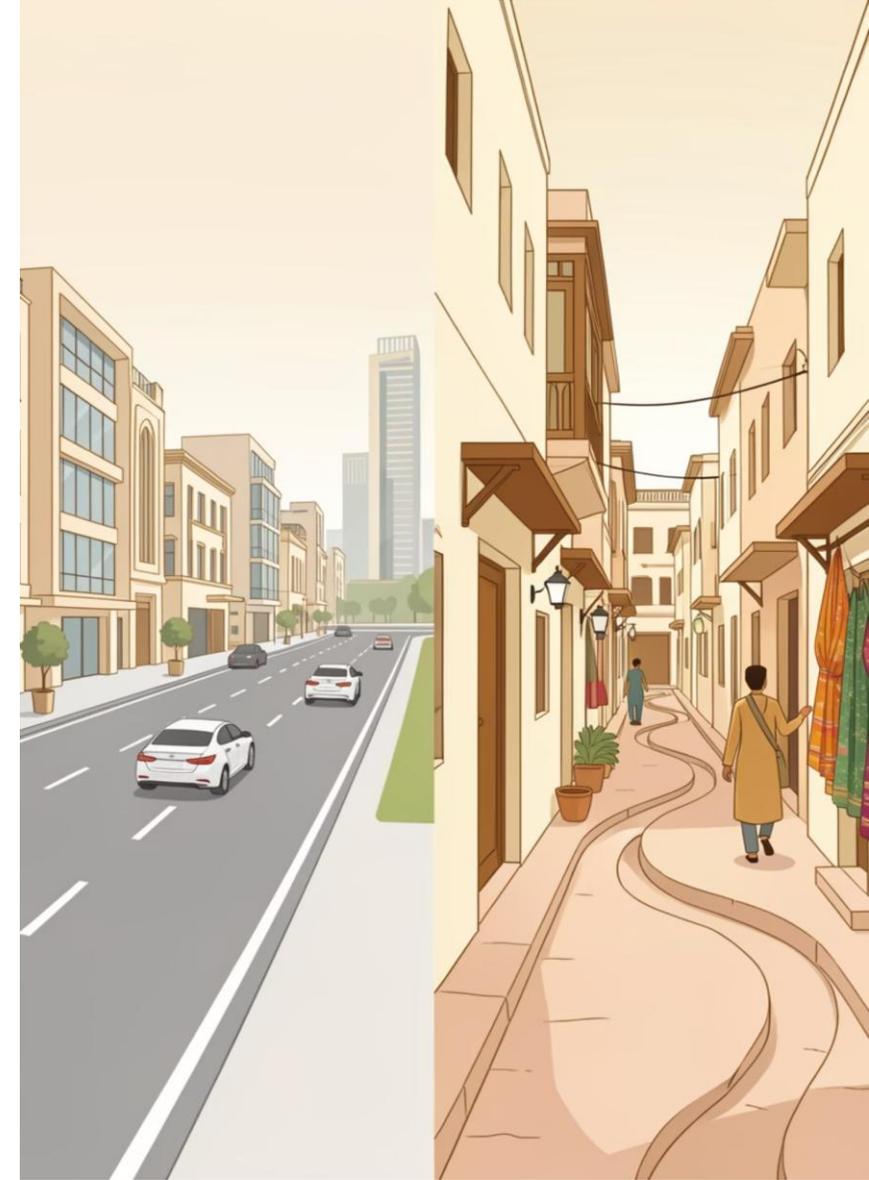
2. RESEARCH MOTIVATION



- Explicitly integrate pedestrian dominance into crash prediction models
- Move beyond exposure-based assumptions toward behavior-driven safety modeling
- Enable evidence-based pedestrian safety interventions without compromising heritage conservation
- Without pedestrian-centric safety models, heritage cities risk designing roads that are statistically “safe” but socially dangerous.

3. RESEARCH OBJECTIVE

- i. Evaluate the predictive performance and transferability of Safety Performance Functions (SPFs) in heritage city road environments;
- ii. Identify heritage-specific crash-generation mechanisms by examining the influence of roadway, traffic, land-use, and pedestrian interaction factors;
- iii. Establish the need for context-aware, AI-driven crash prediction models tailored to heritage city road networks.



4. TWO CITIES, TWO URBAN CONTEXTS



Present Aspect	Bharatpur	Udaipur
Road Width	Mostly Wide, uniform	Mixed wide to narrow, irregular
Geometry	Planned	Planned to constrained
Traffic Mix	Segregated	Highly mixed
Pedestrians	Secondary	Dominant
Parking	Formal	Informal / on-street
Land Use	Zoned	Intensely mixed

Need	Bharatpur	Udaipur
Vehicle-dominated road network	✓	✗
a heritage-dominated network	✗	✓
pedestrian-dominated streets	Moderate	Very high
modern → heritage transitions	Limited	Strong
shared-space behavior	Limited	Extensive

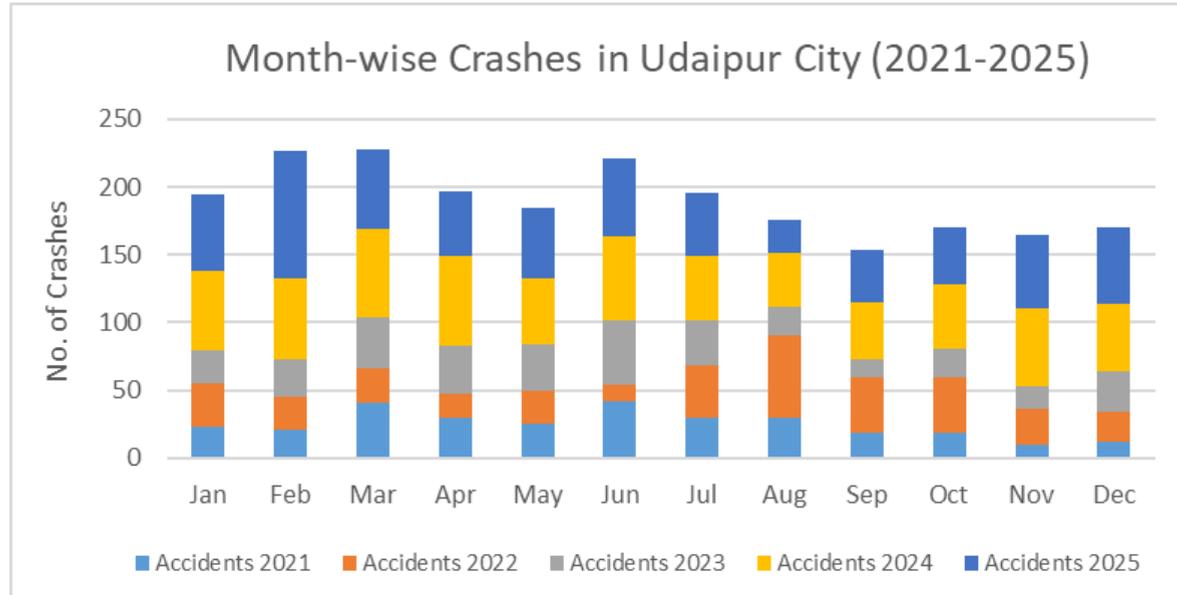
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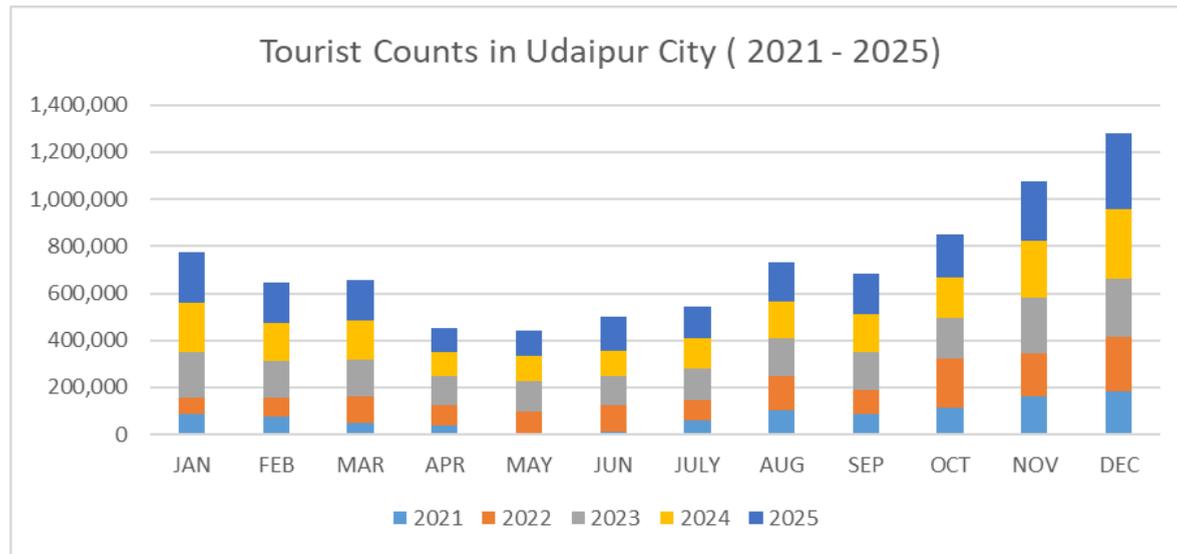
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5. CRASH TREND IN HERITAGE ROAD NETWORK

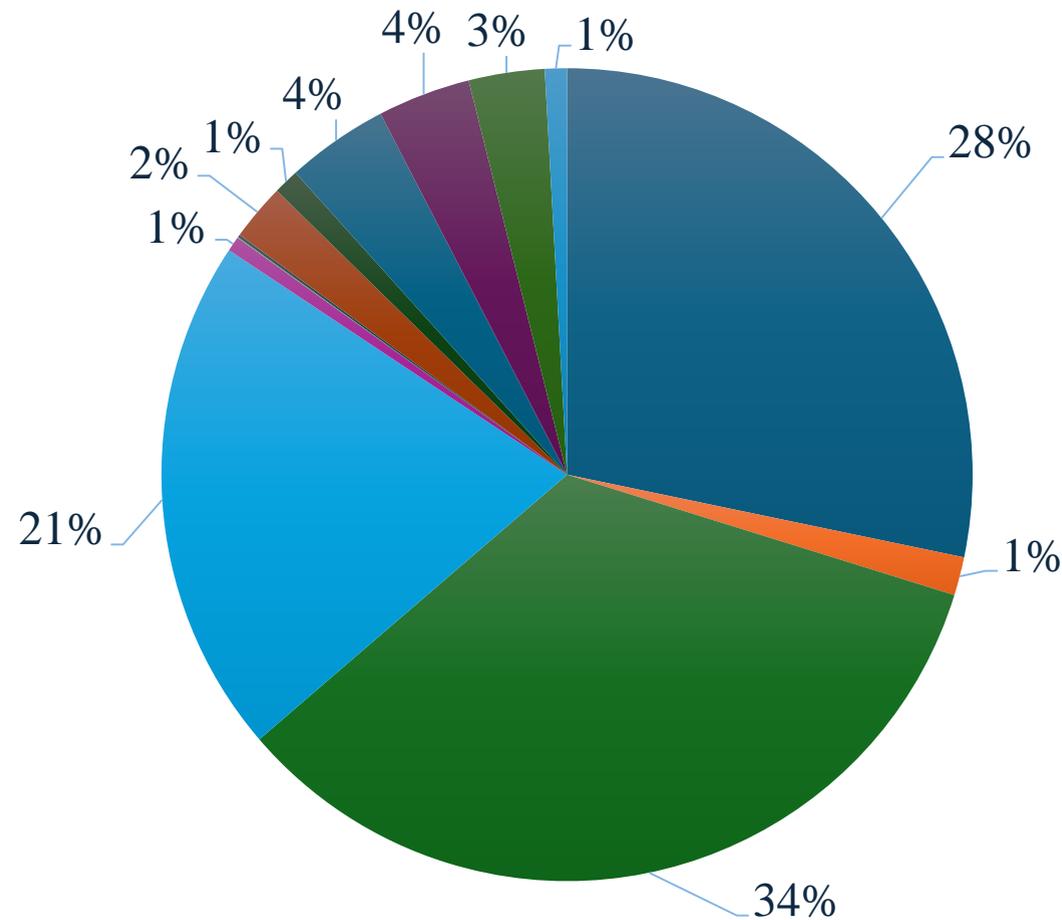


Strong temporal coupling between tourist inflows and crash occurrence in Udaipur heritage core.



Peak crash months align with Winter festival and vacation seasons

5. CRASH TREND IN HERITAGE ROAD NETWORK



34%

Rear-End

28%

Head-On

21%

Side-Impact

Over 80% of crashes fall into three collision types

- Head on Collision
- Hit Fixed Object
- Hit from Back
- Hit from Side
- Hit Parked Vehicle
- Inattentive turn
- Landslide
- No Collision
- Overturn
- Run off Road
- Sideswipe
- Skidding / Overturn
- Vehicle Fell in Gorge

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6. THE HERITAGE SAFETY PARADOX

Heritage areas show a safety paradox where fewer or slower crashes still result in more severe human consequences.



Despite higher overall crash severity on modern roads, heritage roads experience significantly higher fatalities per fatal crash, indicating greater human vulnerability.



7. MODEL VARIABLES AND ARCHITECTURE

Key Variables

Input Variables

- Traffic Volume (X1-X8)
- Pedestrian Volume (X9)
- Road Geometry (X10-X11)
- Operating Speed (X12)
- Safety Audit Ratings (X13-X21)

Intersection Geometry, Lane Markings, Shoulders,
Pedestrian Facilities, Traffic Signs, Roadside
Hazards, Street Lighting, Visibility / Sight Distance ,
Pavement Condition

Output Variable

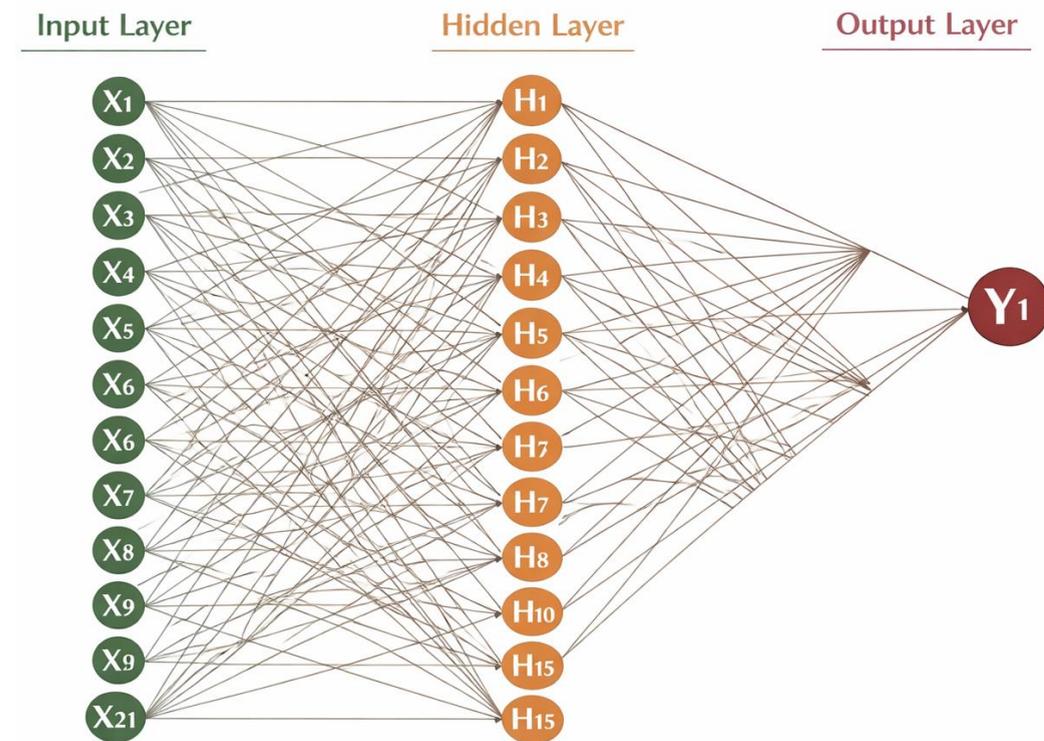
- Total Fatal Crashes for 5 years (Y1)

Data Collection

- iRAD & FIR data (2019-2025)
- Classified Traffic Volume
- Pedestrian Count
- Operational Speed
- Road Safety Audit

Safety Performance Function Model

Artificial Neural Network (ANN)



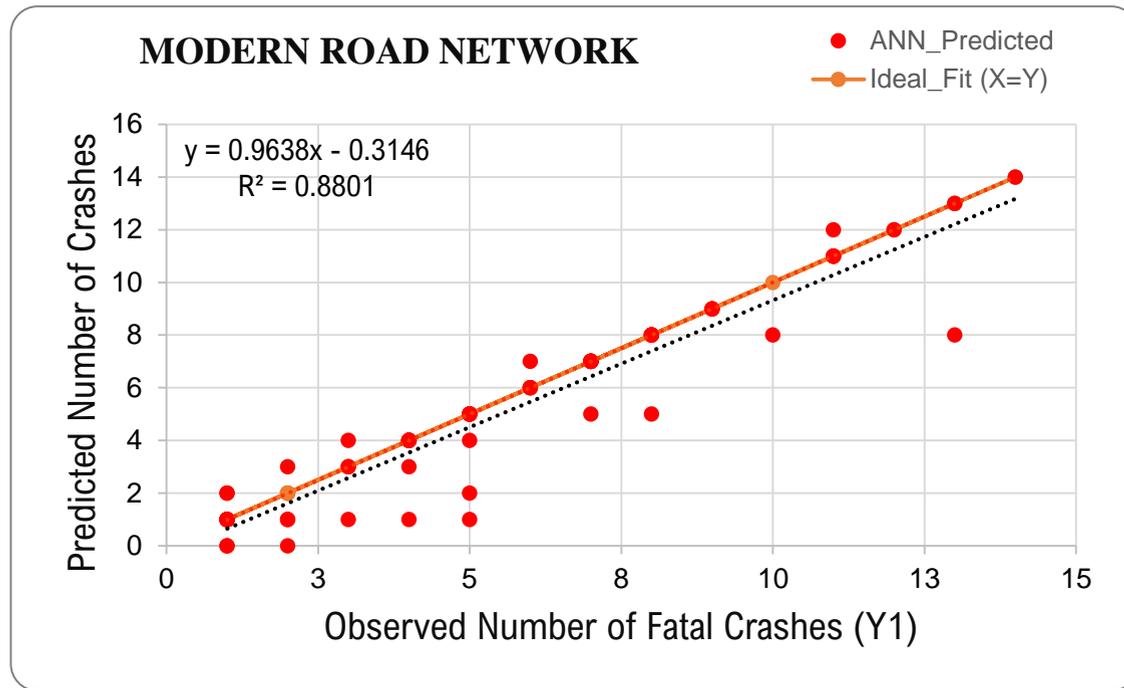
Model Training

80% train, 20% test split

Validation

R², MSE, RMSE metrics

8. MODEL TRANSFERABILITY RESULT

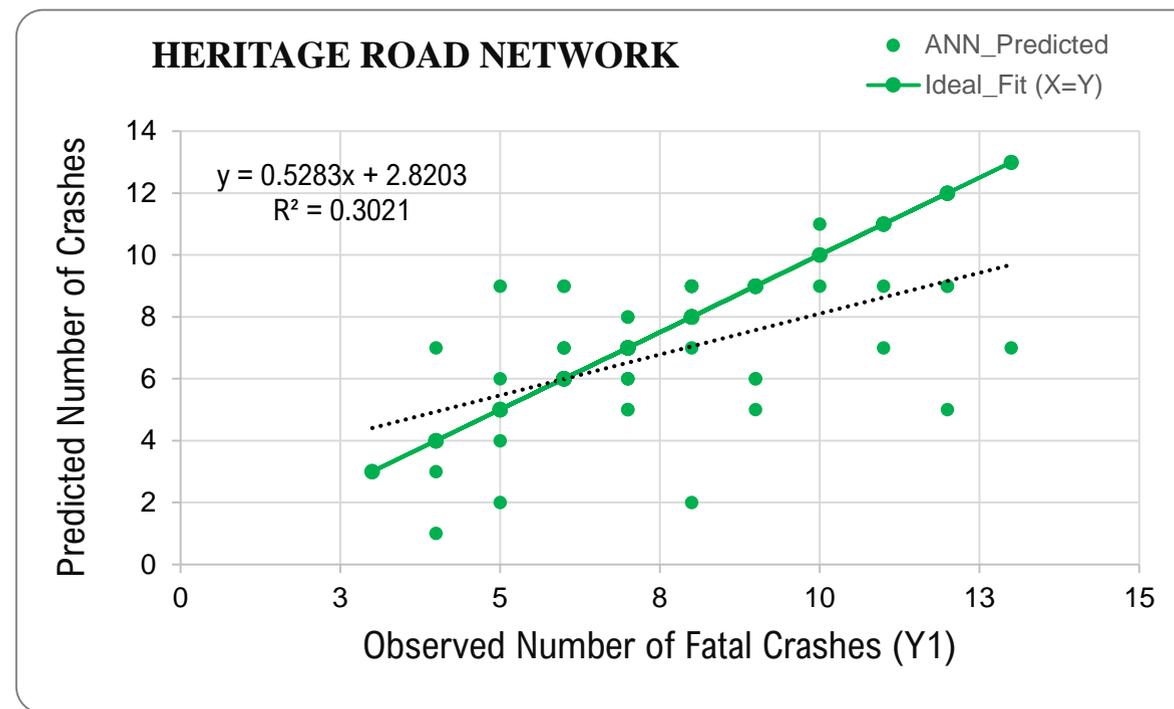


$R^2 = 0.88$ | RMSE = 0.18 | MSE = 0.032

Structured Relationships

Strong positive correlations among traffic volumes, AADT, geometry, speed, and crashes

Exposure-driven crash mechanisms



$R^2 = 0.30$ | RMSE = 0.65 | MSE = 0.423

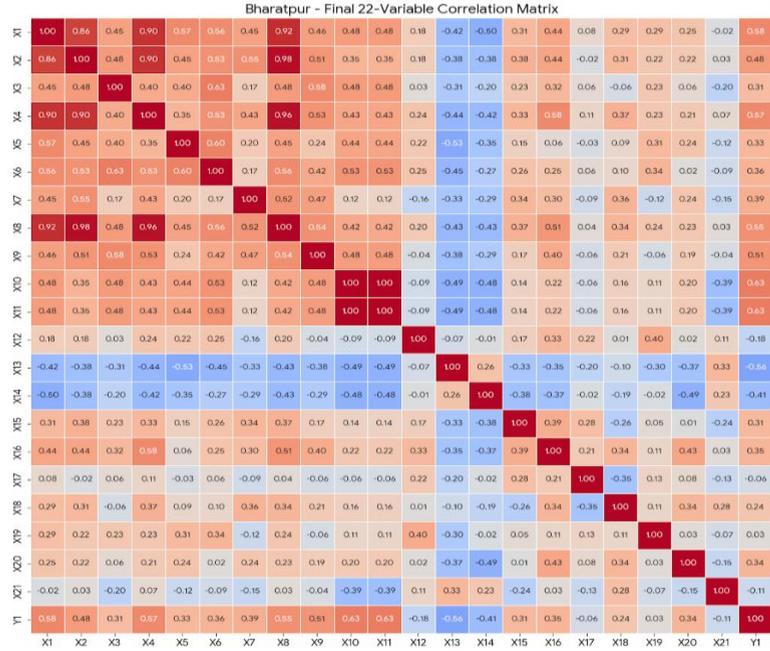
Inconsistent Patterns

Weak associations with conventional variables; strong irregular interactions with pedestrians, NMT, roadside hazards

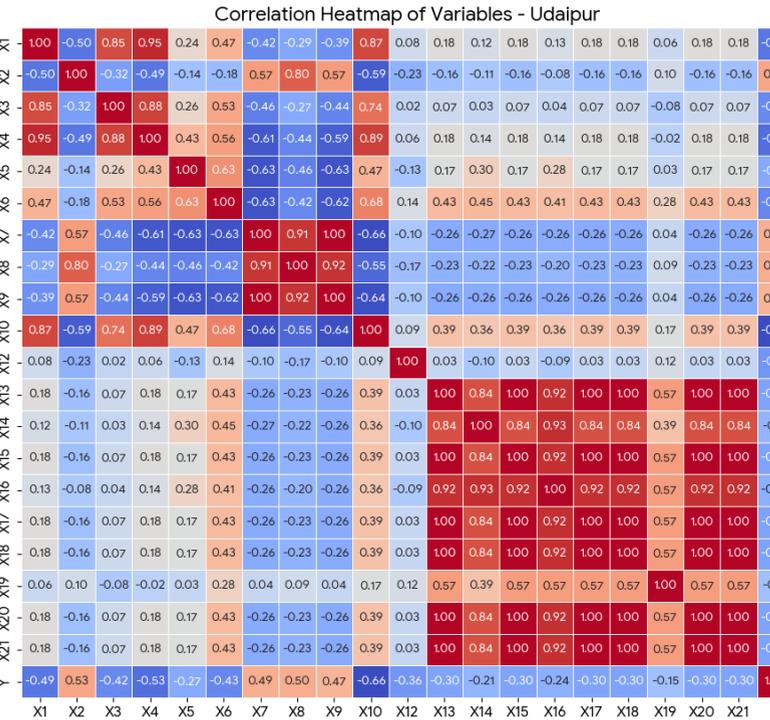
Behavior-driven crash mechanisms

Performance dropped 66%
when transferring model from planned to heritage network

9. CORRELATION CONTRAST: MODERN vs HERITAGE ROAD



Factors	Modern Road Network	Heritage Road Network
Traffic Volume & Width	Strong positive	Weak
VRUs (2W, NMT, Pedestrians)	Moderate positive	Very strong positive
Speed	Strong positive	Weak
Intersection Geometry	Moderate positive	Strong positive
Signs, Markings, Lighting	Moderate negative	Strong positive
Visibility & Roadside Hazards	Moderate positive	Very strong positive



Heritage roads exhibit fundamentally different crash mechanisms, requiring context-specific safety models.

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10. KEY IMPLICATIONS AND CONCLUSION

Key Implications



Poor Transferability

Generic SPF's fail in heritage contexts



Unsafe Policies

Wrong models lead to road widening, increased speeds

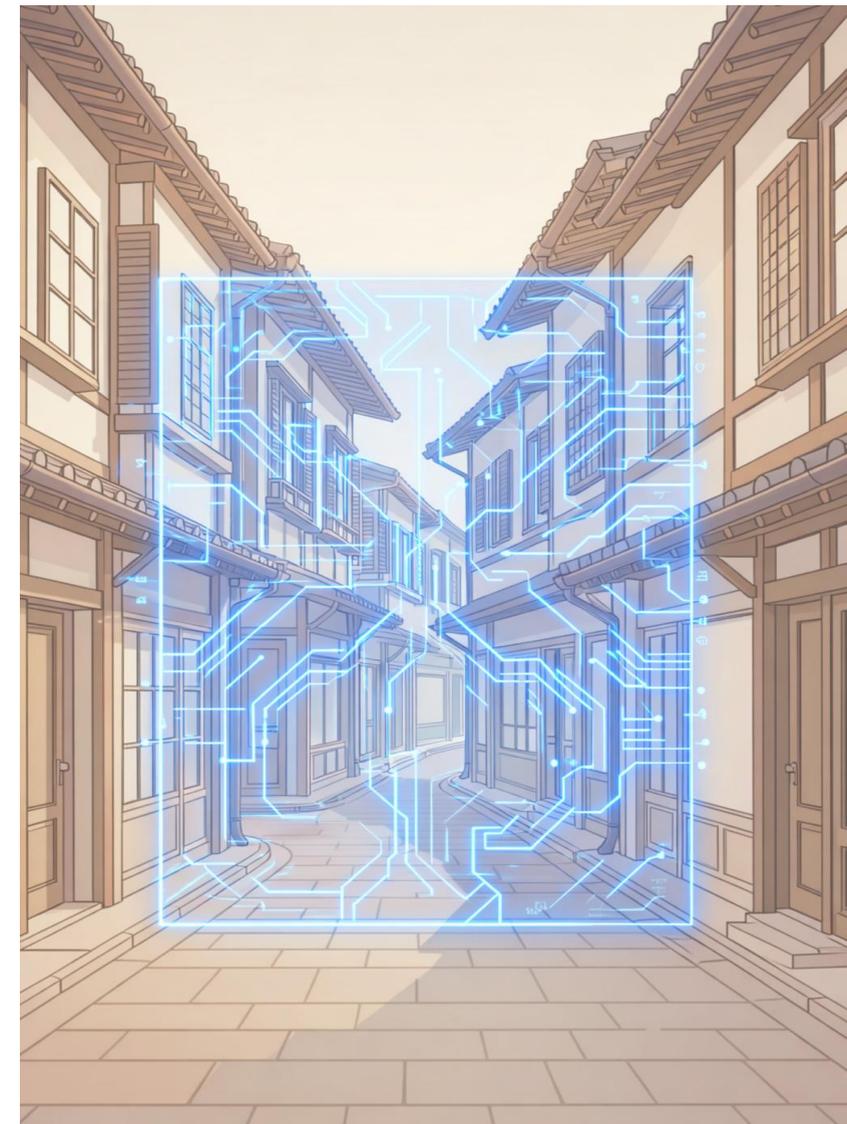


Local Calibration

Heritage cities need specific AI frameworks

Conclusion

Specific AI-driven Crash Prediction Model For Heritage City Road Networks is needed.





THANK YOU

Ms. Monali bose

PhD Scholar (AcSIR), CSIR-Central Road Research Institute, New Delhi, India

Mail id: mona.amit0@gmail.com; Phone: +91 9999895771

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