Network-level Inconsistency based Models for Macro-level Safety Evaluation

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INTRODUCTION

- Geometric design inconsistency – defines the non-conformance of road geometry with driver's expectation
- A popular approach of inconsistency measure is operating speed based inconsistency (Lamm et al., 1999;Garcia et al.,2003; Polus et al., 2004; Llopis-Castelló et al., 2018)
- Previous studies have focused on inconsistency at local scales
- A network level safety analysis using inconsistency is yet to be analyzed
- A few studies have used density of inconsistency in three consecutive segments (Wu et al., 2013)
- Propose the analysis of spread of inconsistency over a regional network

CHALLENGE

- Aggregation of inconsistency to macro-level spatial unit
  - ✓ Heterogeneity of variable within spatial unit – ecological fallacy (Wang et al.,2020)
  - ✓ Need of a spatial clustering algorithm with contiguity constraints

OBJECTIVES

- Define spatial regions with homogeneity ensured w.r.t inconsistency
- Define network-level inconsistency measure for crash analysis

Methodology

- Road network segmentation based on curvature criterion
- Operating speed-based inconsistency measured as **Δ**V at every tangent-curve transitions
- Clustering segment using Spatially Constrained Hierarchical Clustering (SCHC) imposing contiguity constraint
    - ➢ Clustering logic is to merge two entities i and j if the dissimilarity value d_{ij} is the smallest compared to all other entities, constraint to $w_{ij} = 1$
    - ➢ The dissimilarity matrix is calculated using the inconsistency measure (**Δ**V) in the network
- Aggregation of cluster specific variables such as inconsistency measures and network features
- Crash modelling using cluster specific variables

- Network-level Inconsistency Measure
  - Average of inconsistency as a network-level inconsistency measure

$$\bar{I} = \frac{\sum_{i=0}^{n} I}{n}$$

I =the inconsistency measure assigned to each road segment
n = the number of road segments clustered to form the region

  - Inconsistency density

$$ID_{10} = \frac{N(\Delta V > 10)}{L}$$

ID_{10} = density of speed variation greater than 10 kmph in the region
N (ΔV >10) = number of segments in the region with speed variation greater than 10 kmph
L = length of road network in the region

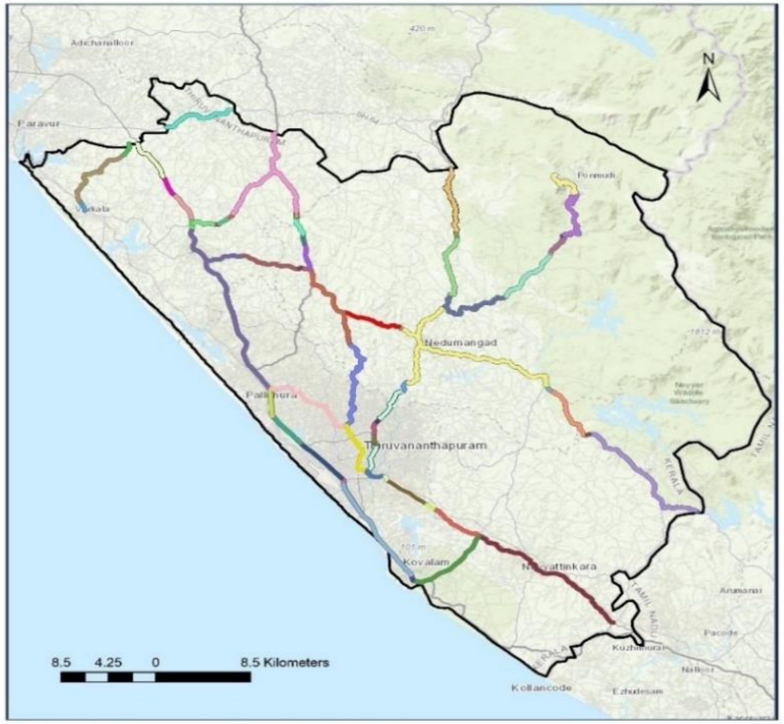
- Network Features
  - Centrality measures quantify the property of a network component (node or link) based on the aspect of “being central”, being intermediate” and “being accessible”.
  - Edge betweeness centrality (C)

$$C_i = \sum_{j,k \in G, j \neq k \neq i} \frac{n_{jk}(i)}{n_{jk}}$$

  - To incorporate accessibility condition, edge betweenness was modified as $\overline{C.A}$ where C is the edge betweenness and A is the number of access roads in the clustered region.

Analysis and Results

- **Data Description**
  - Road network consisting of National and State highways of Thiruvananthapuram district in Kerala, India.
  - Road is segmented into 1429 curves and 745 tangent segments using GIS-add in toolbox ROad Curvature Analyst (ROCA) (Bil et al., 2018)
  - Estimate of operating speed – Google crowd-sourced speed at some peak and non-peak hours of a weekday and weekend were taken
  - Geocoded crash location (Kerala Road Safety Authority) – (n



- **Network Regions Resulting from Spatial Partitioning**
  - Speed inconsistency as the homogeneity criteria
  - 64 network regions
  - Moran's I value – 0.66 with p value of 0.001

Analysis and Results (Cont.)

- **Preliminary Analysis**

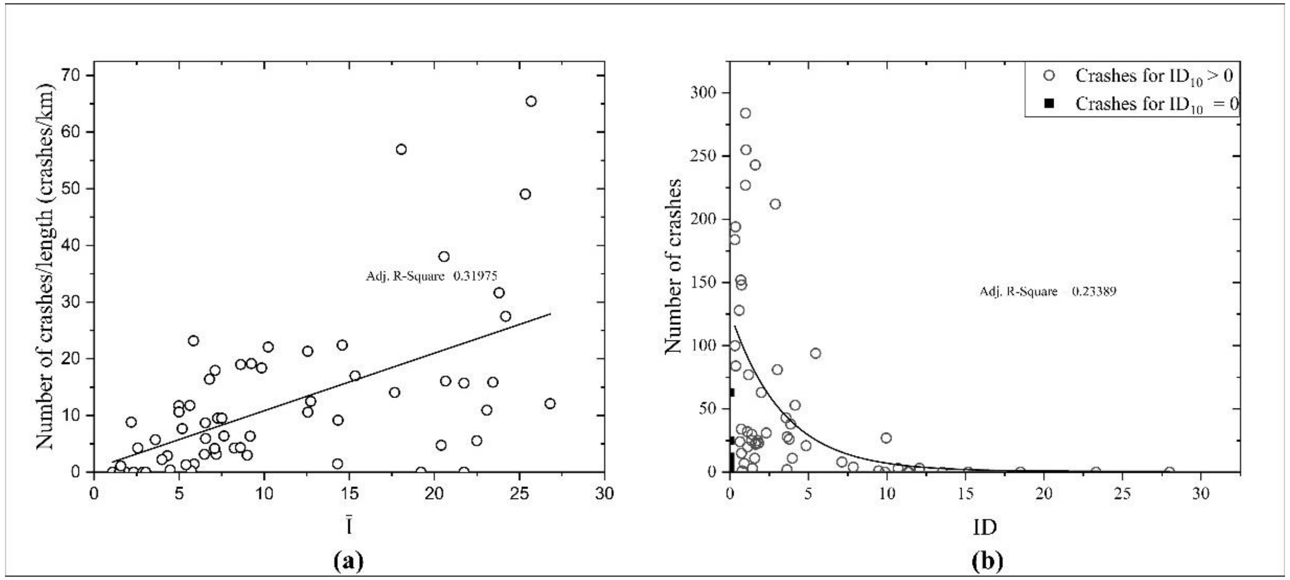


Figure 2. Scatter plots of crashes in network regions against: (a) average inconsistency and (b) inconsistency density

- $\bar{I}$ presents a positive trend with the crash occurrence
- Inconsistency density inverse relation with crash occurrence
- Both scatter plots indicate the presence of unobserved error

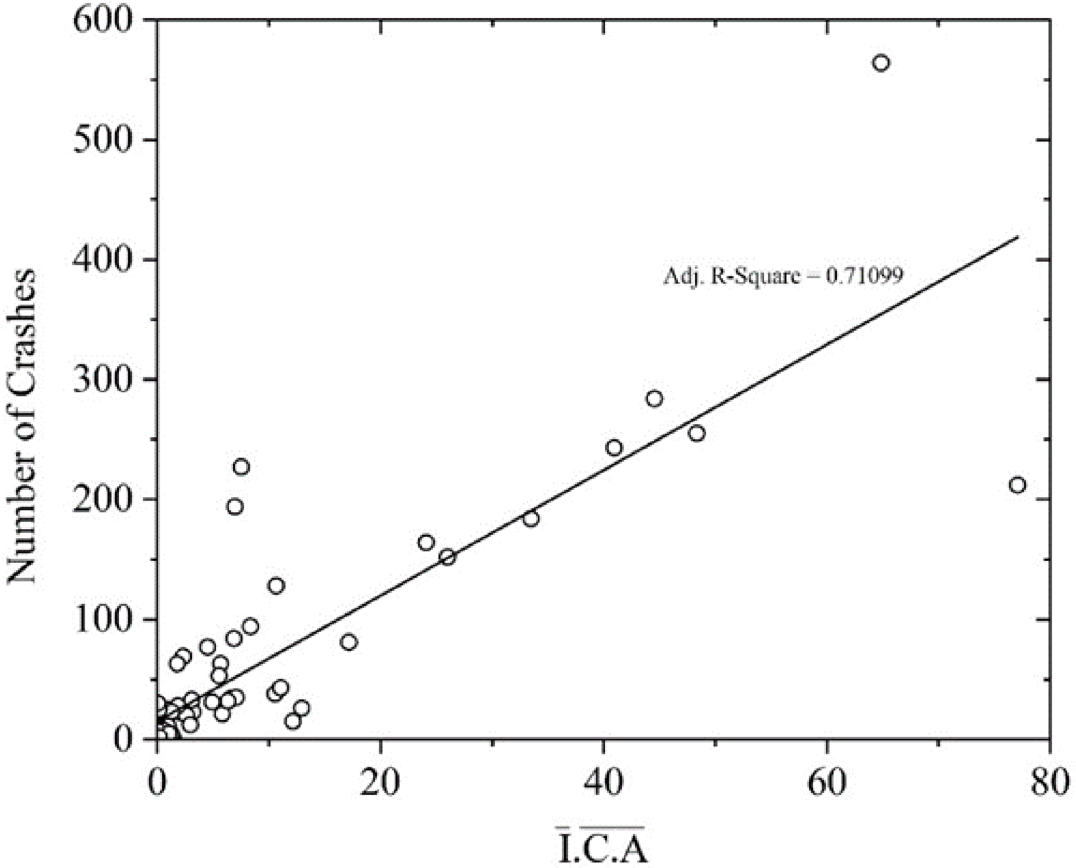


Figure 3. Combined effect of inconsistency ($\bar{I}$) and weighted centrality ((C.A)) on crash frequency

- Modified inconsistency with incorporation of road centrality and accessibility shows better relation with crash frequency.

Table 2: Crash frequency models with network-level inconsistency variables

Model I :	$Y_i = e^{\beta_0} . e^{\beta_1 . \bar{I} . \overline{C.A}}$	
Variable	Estimates	Sig.
(Intercept)	3.064	0.000
$\bar{I}.\overline{C.A}$	0.063	0.000
Pearson χ^2	93.071	
$\chi^2_{(0.001)}$	102.15	
Log-likelihood Chi-square	61.269	0.000
Log-likelihood	-295.885	
AIC	595.769	

Model II :	$Y_i = e^{\beta_0} . e^{\beta_1 . ID_{10} + \beta_2 . \overline{C.A}}$	
(Intercept)	4.115	0.000
ID_{10}	-0.276	0.000
$\overline{C.A}$	0.376	0.000
Pearson χ^2	81.549	
$\chi^2_{(0.001)}$	100.881	
Log-likelihood Chi-square	94.818	0.000
Log-likelihood	-281.145	
AIC	568.290	

- Developed two set of models with each of the proposed inconsistency measures.
- Pearson's χ^2 statistics, log-likelihood measures presents significant goodness of fit for both
- Incomparison, model with inconsistency density and modified centrality measure perform better.
- Inconsistency density presents inverse relation with crash frequency, whereas, modified average inconsistency with network feature shows positive relation

Discussion

- Driving instances with high variations in speed on a highly central road with frequent potential collision points (access points) bear high chances of crash

- Inconsistency density appears to be inversely related to crash occurrence; this might be due region specific driving behavior.
  - ✓ As inconsistency density increases, the drivers might get habituated to the variation of speed, thereby tending to be more cautious
  - ✓ Rare instances of high-speed variations might influence the driver expectancy making the driver less vigilant while traversing that region

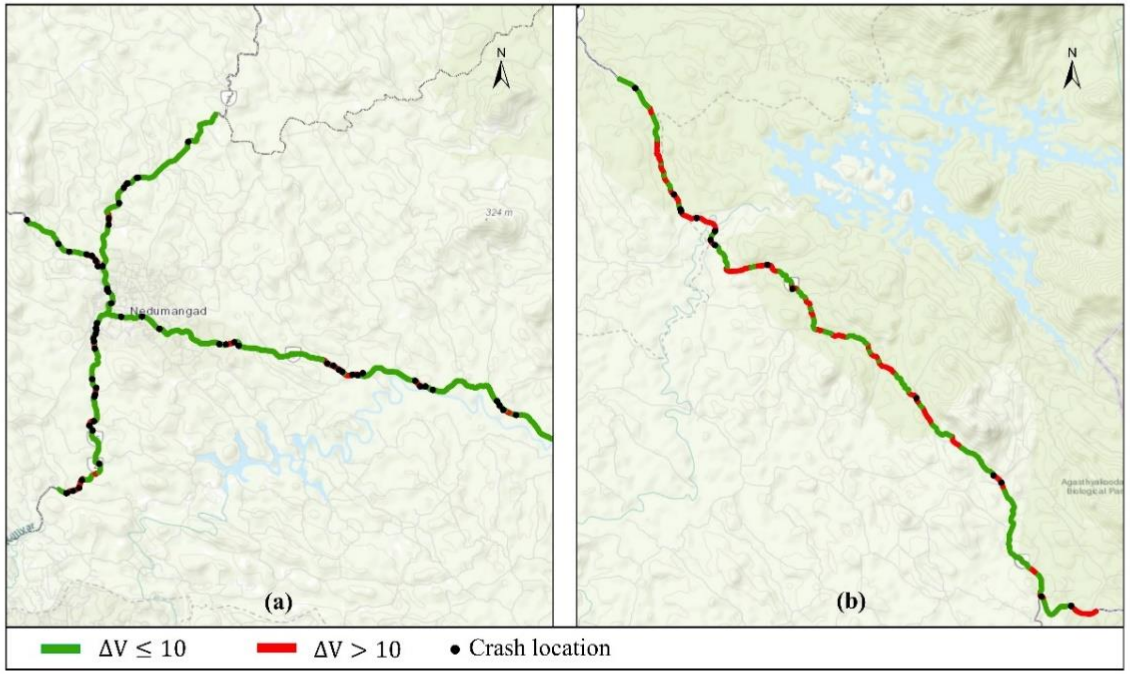


Figure 4. Effect of inconsistency density on crash: (a) a region with lower ID_{10} but higher crash rate and (b) a region with higher ID_{10} but lower crash rate

Conclusion

- Study presents a macro-level safety evaluation considering network-level design inconsistency measure
- Study considered two objective;
    - Defining a spatial unit with homogeneity of variable ensured – Spatial clustering
    - Define network-level inconsistency measure for safety evaluation – aggregation of segment inconsistency in cluster
- Crash model suggests that;
    - All instances of speed variation need not be crash inducive.
    - Relation of speed variation with crash is region specific
    - High variation of speed across segments of highly central road with high accessibility increases the crash risk
    - Inconsistency density is inversely related to crash occurrence
    - Inconsistency density reflects the driver expectation acquisition phenomenon at a macro scale

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Reference

1. Lamm, R., Psarianos, B., Mailaender, T., 1999. Highway Design and Traffic Safety Engineering Handbook. McGraw-Hill Companies, Inc.
2. García, A., Llopis-Castelló, D., Camacho-Torregrosa, F. J., & Pérez-Zuriaga, A. M. (2013). New consistency index based on inertial operating speed. Transportation research record, 2391(1), 105-112.
3. Polus, A., & Mattar-Habib, C. (2004). New consistency model for rural highways and its relationship to safety. Journal of transportation engineering, 130(3), 286-293.
4. Llopis-Castelló, D., Bella, F., Camacho-Torregrosa, F. J., & García, A. (2018). New consistency model based on inertial operating speed profiles for road safety evaluation. Journal of transportation engineering, Part A: Systems, 144(4), 04018006.
5. Wu, K. F., Donnell, E. T., Himes, S. C., & Sasidharan, L. (2013). Exploring the association between traffic safety and geometric design consistency based on vehicle speed metrics. *Journal of transportation engineering*, *139*(7), 738-748.
6. Wang, C., Liu, L., & Xu, C. (2020). Developing a new spatial unit for macroscopic safety evaluation based on traffic density homogeneity. *Journal of advanced transportation*, *2020*.

Thank you