Advancing Work Zone Safety with Explainable AI: Evaluating the Effect of Work Zone Presence on Crash Severity

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Introduction

- 891 people died in U.S. work-zone crashes in 2022 (FHWA, 2024)
- Work zones raise crash frequency, but their effect on crash severity is mixed
- Prior ML/SHAP studies explain severity predictions inside work zones, not the effect of work-zone presence
- Unanswered: where and when do work zones make crashes worse?

Objectives

- Measure whether work zones make crashes more or less severe on average, using six different methods.
- Estimate the work-zone effect for every crash, including where it happened.
- Find what drives that effect and map where work zones help or hurt.
- Check that the results hold up, and turn them into simple rules for work-zone traffic control

Methodology

- 934,860 NJDOT crashes, 2019-2025; 14,803 in construction, maintenance or utility zones
- Outcome: any injury (KABC); fatal/serious (KA) and 5-level KABCO as checks
- 425,316 geocoded crashes; overlap sample keeps 97.4% of work-zone crashes

Methodology

1. **COMPARE** Six methods test if work zones change injury risk
2. **ESTIMATE** An effect for every crash, including its location
3. **EXPLAIN** What makes a work zone more or less harmful
4. **MAP** Where work zones help and where they hurt
5. **CHECK** Re-test on newer data and repeated model runs
6. **ACT** Turn results into simple traffic-control rules

Validation & Reliability

- Temporal holdout (zones from 2019-2021, tested on 2022-2025): hot +0.60 pp, elsewhere -1.71 pp, cold -3.82 pp; the ordering holds
- SHAP importance stable across refits (ρ = 0.94); single-crash effects less so (ρ = 0.58)
- E-value 1.39: hidden confounding could shift the small average, so conclusions rest on the pattern

Result 1 · Work Zones Protect, on Average

-1.75 pp
injury probability
(causal forest, doubly robust)

OR 0.82
fatal / serious injury
(adjusted logit)

6 of 6
estimators agree
in direction

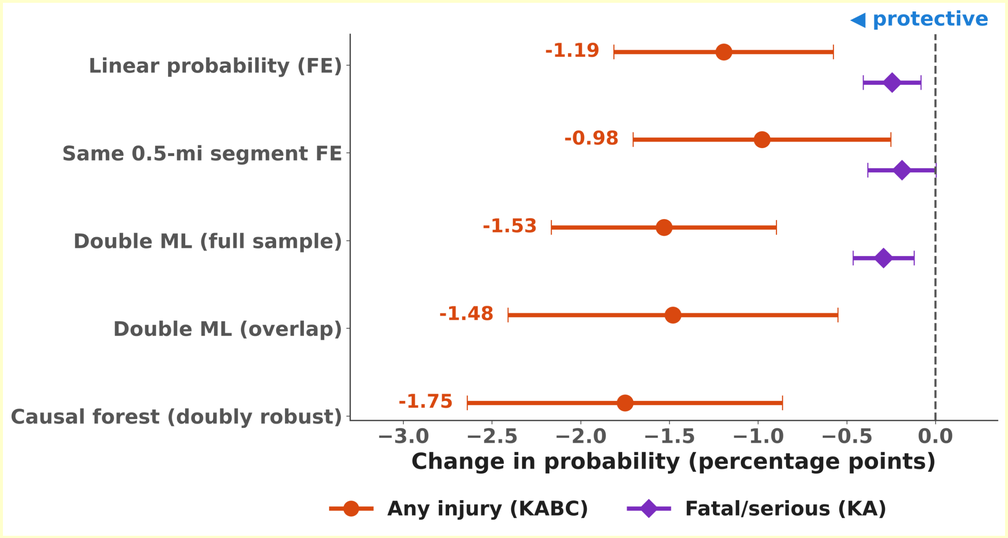


Figure 1. Work-zone effect across estimators (95% CI). Every estimate is below zero.

Result 2 · When Protection Vanishes

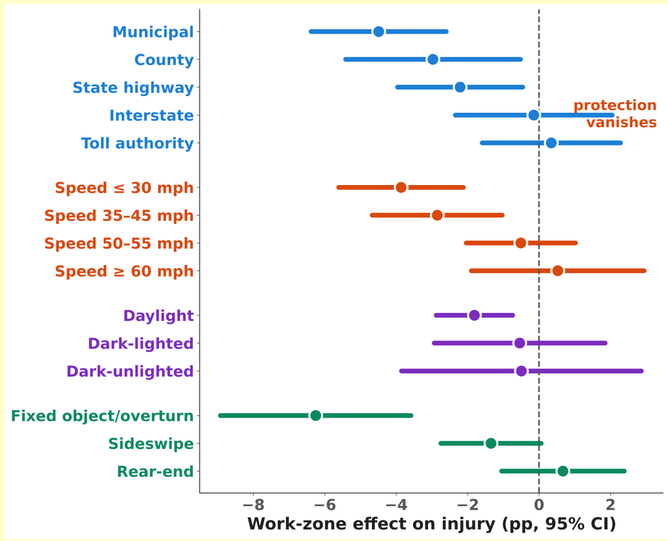


Figure 2. Average work-zone effect by subgroup (double ML)

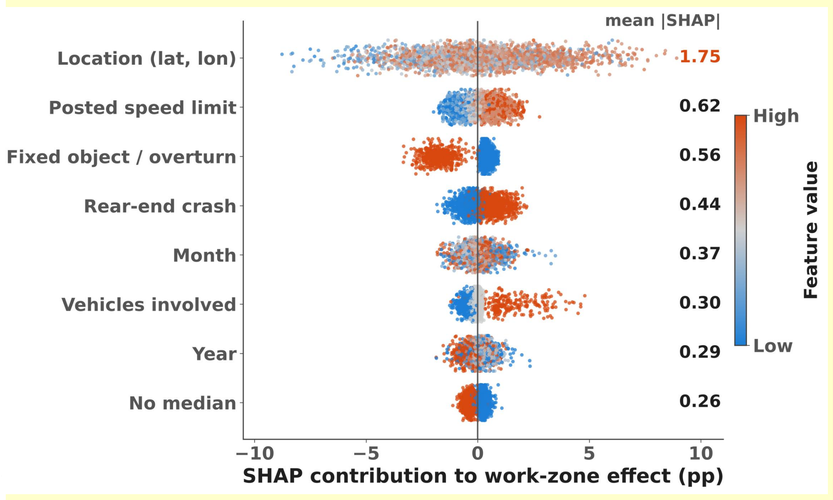
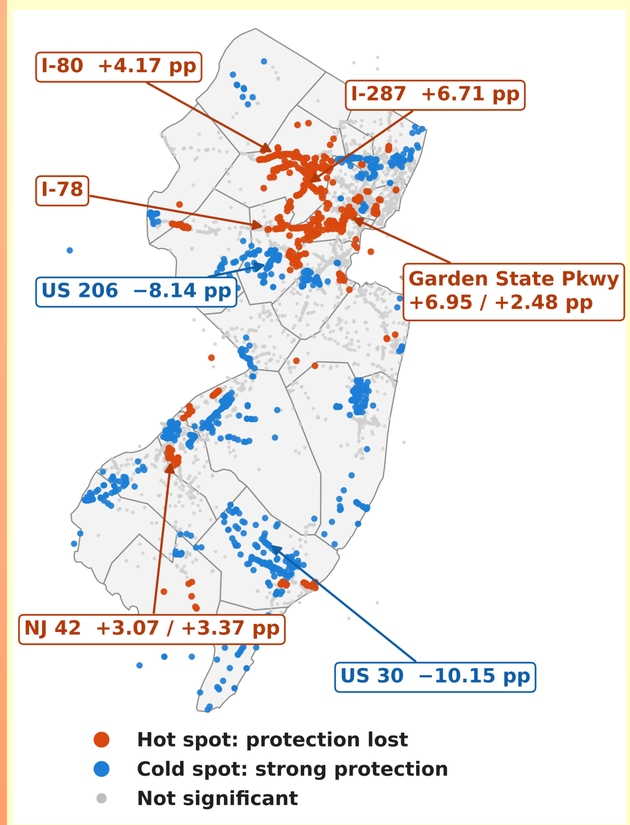


Figure 3. SHAP on the causal effect τ(x): what makes a work zone more harmful

Effect becomes more harmful on **interstate/toll roads (×1.26)** and **after dark (×1.18)**; location is the **#1 driver (29% of attribution)**

Result 3 · Where: GeoXAI Hot Spots



Corridors in significant clusters

Corridor	County	τ(x), pp
Garden State Pkwy	Union	+6.95
I-287	Morris	+6.71
I-80	Morris	+4.17
NJ 42	Gloucester	+3.37
NJ 42	Camden	+3.07
Garden State Pkwy	Essex	+2.48
US 30	Atlantic	-10.15
US 206	Somerset	-8.14
US 46	Passaic	-4.74
NJ 18	Middlesex	-4.22

Hot spots: 52 mph avg., 64% interstate/toll
Cold spots: 44 mph avg., 22% interstate/toll

IF speed limit ≥ 55 mph **AND** a rear-end crash, **THEN** injury risk rises (+1.27 pp)

From Explanation to Action

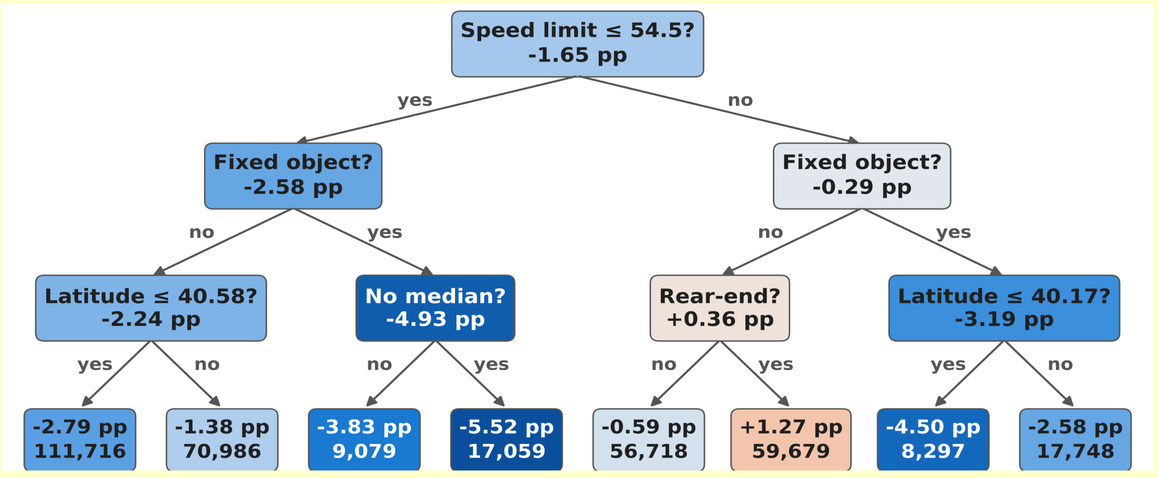


Figure 5. Effect tree. Only harmful leaf: speed ≥ 55 mph + rear-end (+1.27 pp)

- Prioritize **≥ 55 mph corridors**: GSP, I-80, I-287, I-78, NJ 42
- **Queue-end warning** & speed harmonization for rear-end risk
- **Night work:** stronger lighting & conspicuity
- Use hot/cold layers when **scoping projects**

Conclusions

- On average, work zones lower injury probability by about 1.75 pp
- The benefit disappears at ≥ 50 mph, on freeways, at night and in rear-end crashes
- Location matters most: protection is lost on GSP, I-80, I-287 and NJ 42
- Traffic control needs reinforcement on ≥ 55 mph corridors, especially for rear-end crashes and night work
- Limitations: no traffic-volume or lane-closure data used
- Next step: test warning signs and step-down speed limits