Vehicle Design and Pedestrian Safety

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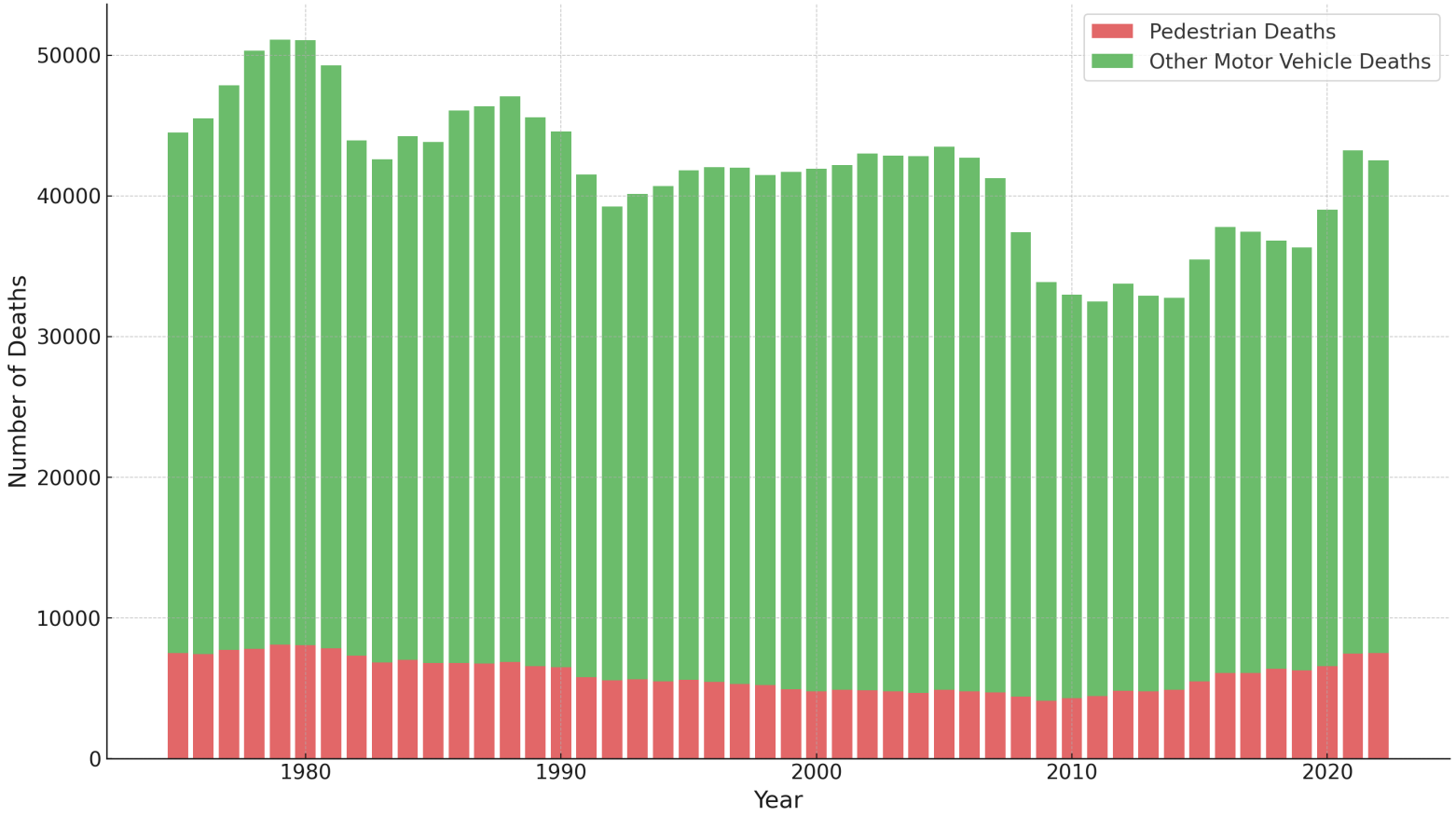
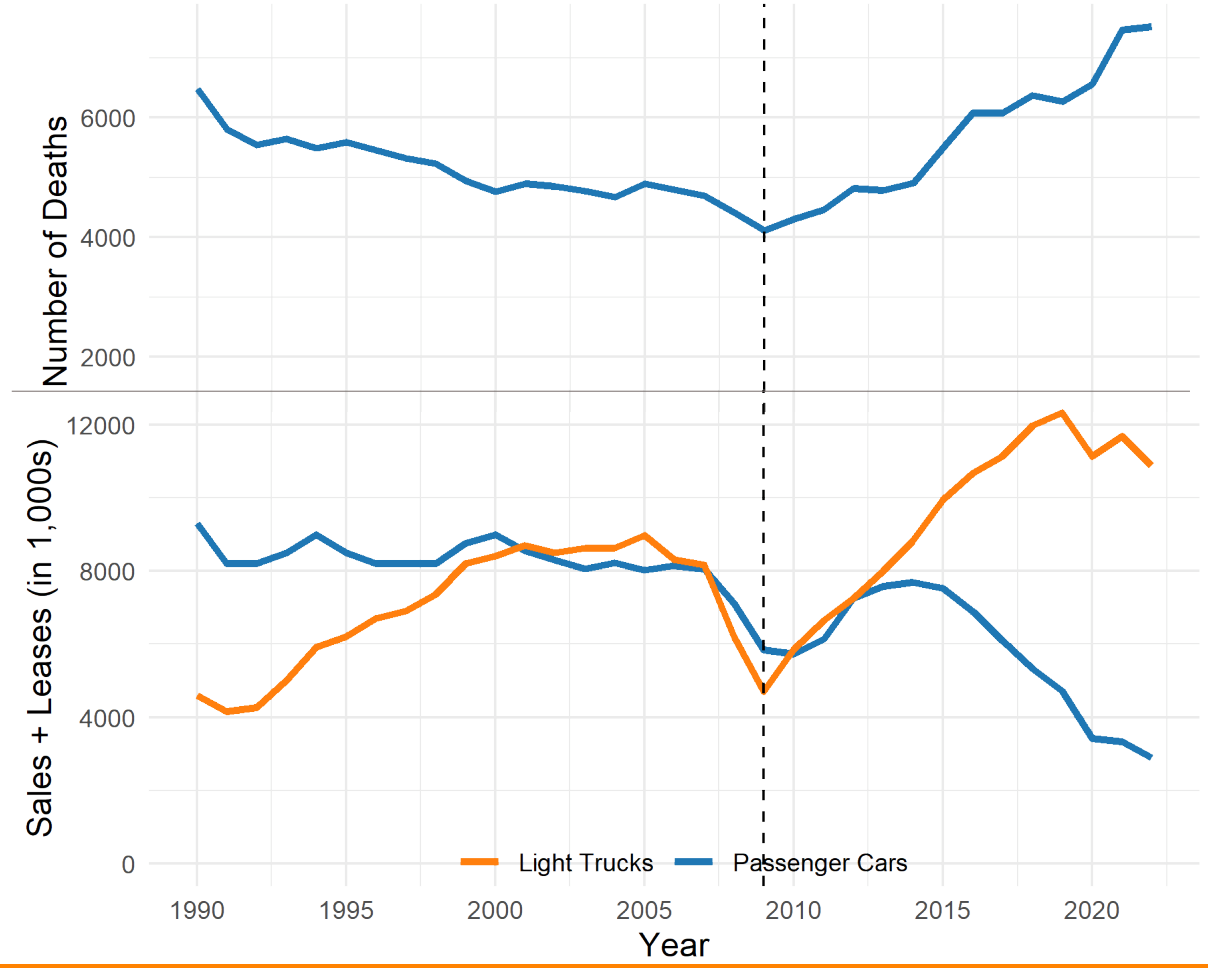
Background: National Crash Trends

- **2000**: Pedestrians made up **11%** of total traffic fatalities
- **2022**: Pedestrian fatalities hit a record high, accounting for **18%** of all traffic deaths
- Pedestrian deaths: **83 percent** increase from 2009 to 2022
- Unique to the US



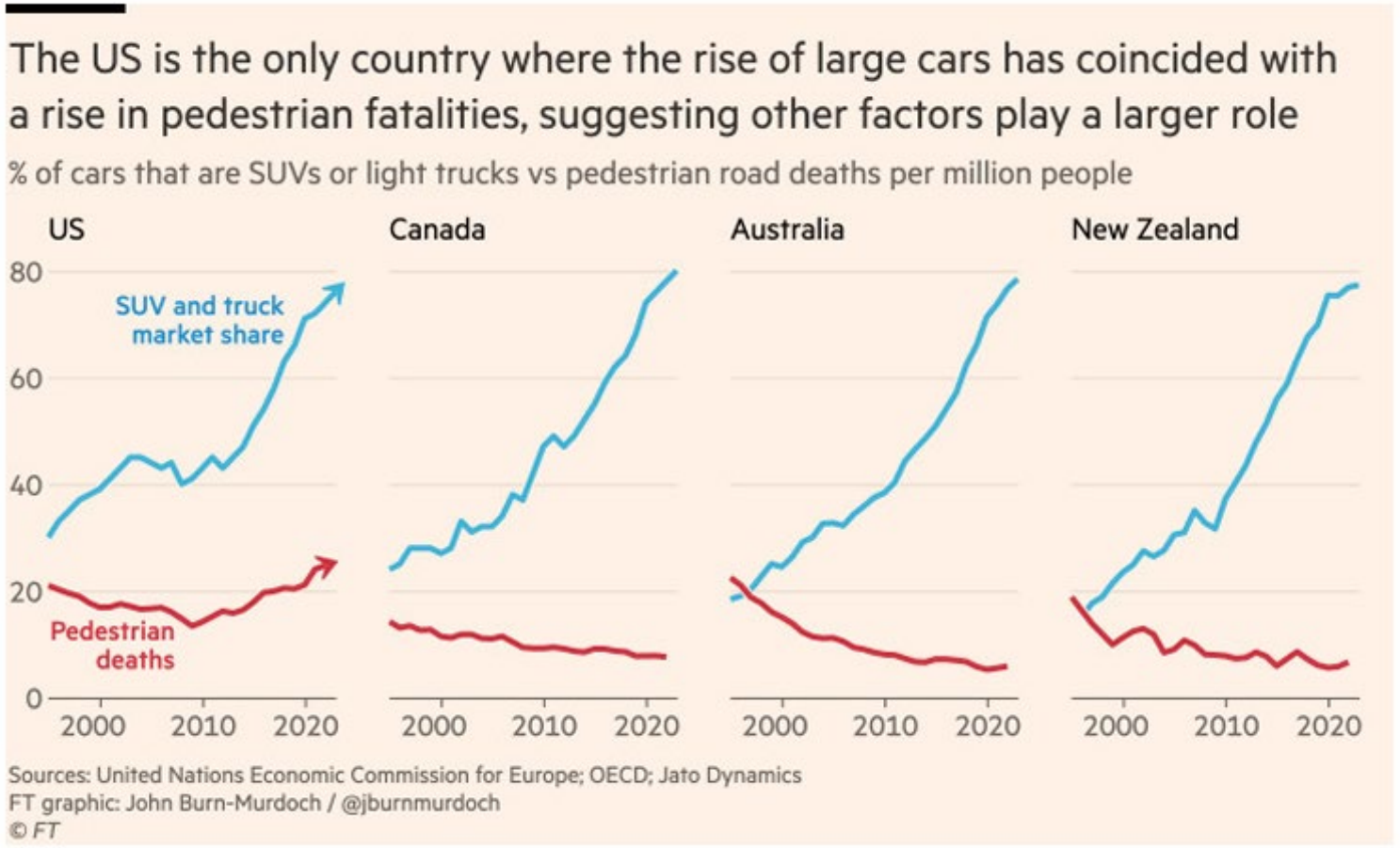
Source: IIHS Fatality Facts 2022 Pedestrian

Large Vehicle Sales vs. Ped. Deaths

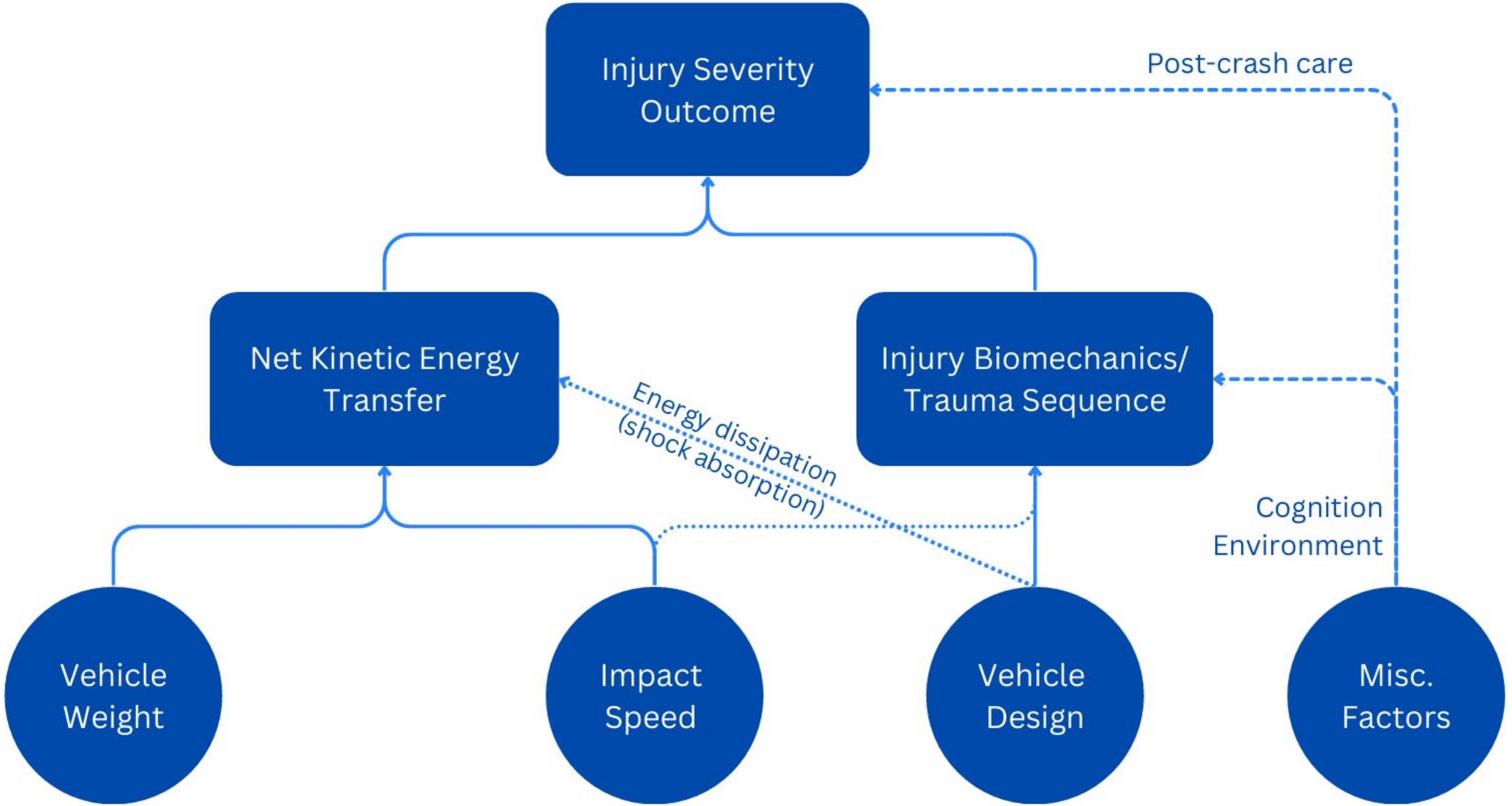


Source: IIHS Fatality Facts 2022 Pedestrian & BTS website

Unique to the US



What causes Pedestrian Injury Severity?


Injury Severity Outcome
Post-crash care
Net Kinetic Energy Transfer
Energy dissipation (shock absorption)
Injury Biomechanics/ Trauma Sequence
Cognition
Environment
Vehicle Weight
Impact Speed
Vehicle Design
Misc. Factors

THE SAFE SYSTEMS APPROACH

PRINCIPLES

DEATH/ SERIOUS INJURY IS UNACCEPTABLE

HUMANS MAKE MISTAKES

HUMANS ARE VULNERABLE

RESPONSIBILITY IS SHARED

SAFETY IS PROACTIVE

REDUNDANCY IS CRUCIAL

ELEMENTS

SAFE SPEEDS

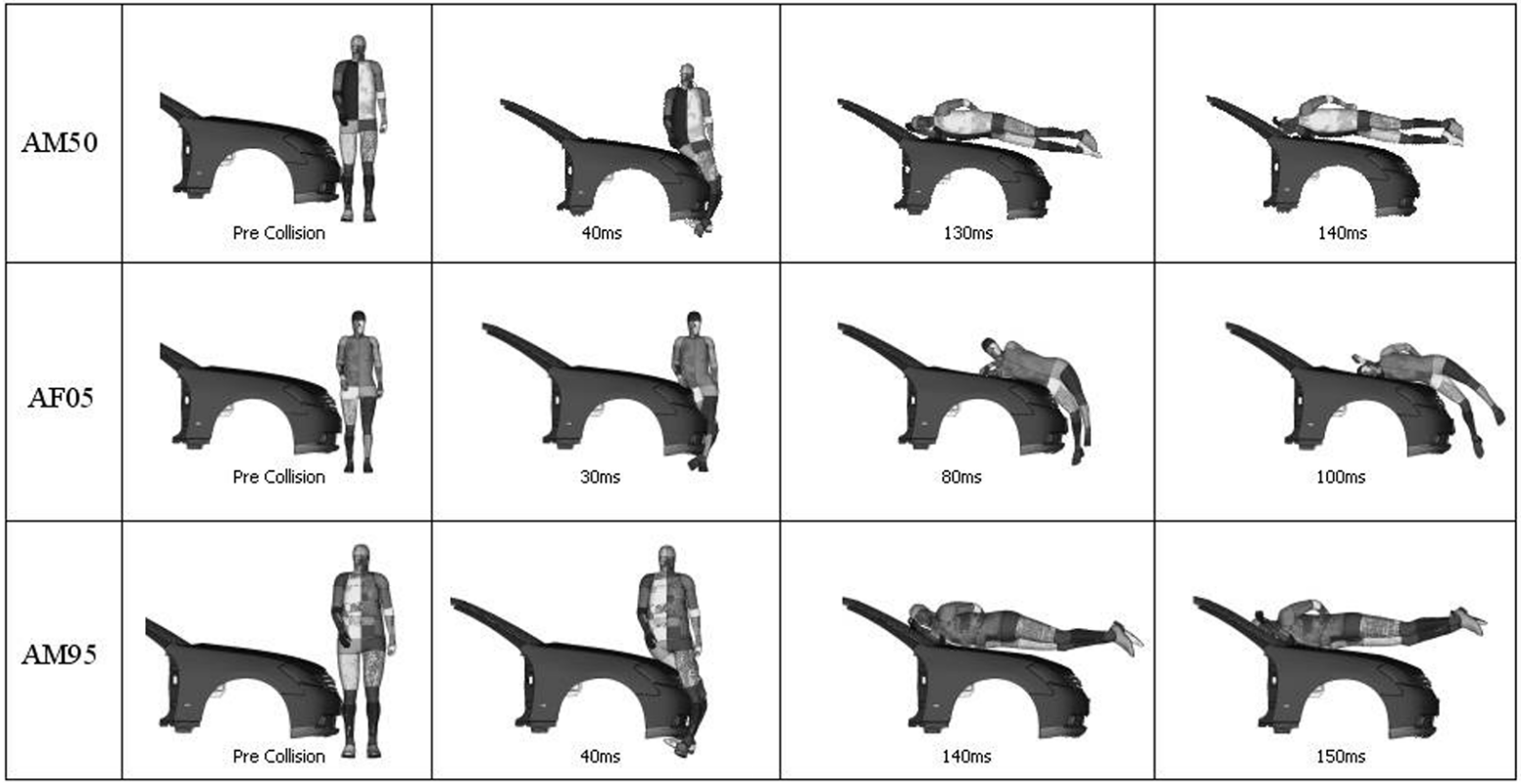
SAFE VEHICLES

SAFE ROAD USERS

SAFE ROADS

POST-CRASH CARE

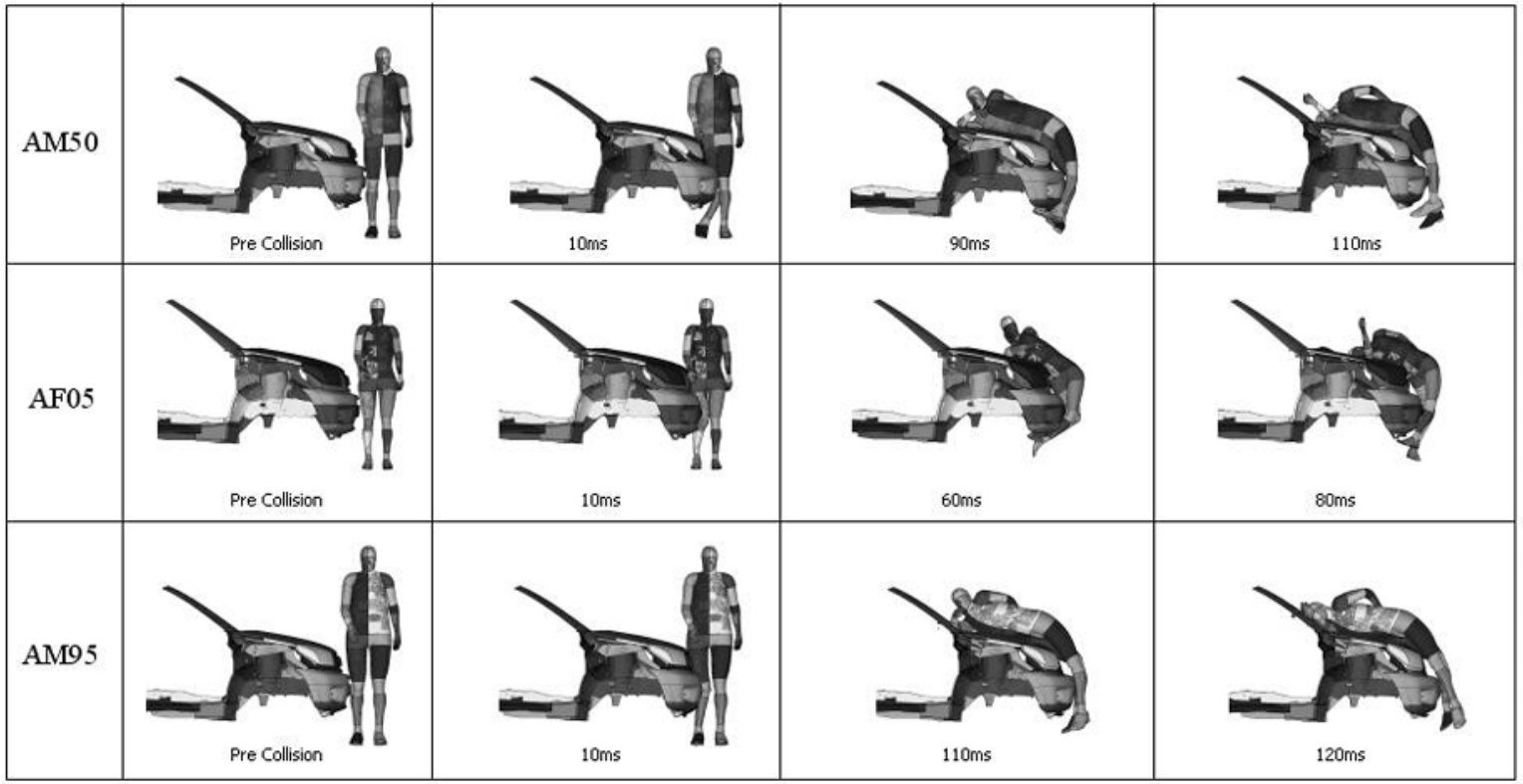
Pedestrian Injury Mechanisms (Sedan)



Impact Kinematics (Sedan, Center Impact, 40km/h).

Source: Research of the Relationship of Pedestrian Injury to Collision Speed, Car-type, Impact Location and Pedestrian Sizes using Human FE model (THUMS Version 4), Watanabe et al. (2012)

Pedestrian Injury Mechanisms (SUV)



Impact Kinematics (SUV, Center Impact, 40km/h).

CPBS Center for Pedestrian and Bicyclist Safety

Source: Research of the Relationship of Pedestrian Injury to Collision Speed, Car-type, Impact Location and Pedestrian Sizes using Human FE model (THUMS Version 4), Watanabe et al. (2012)

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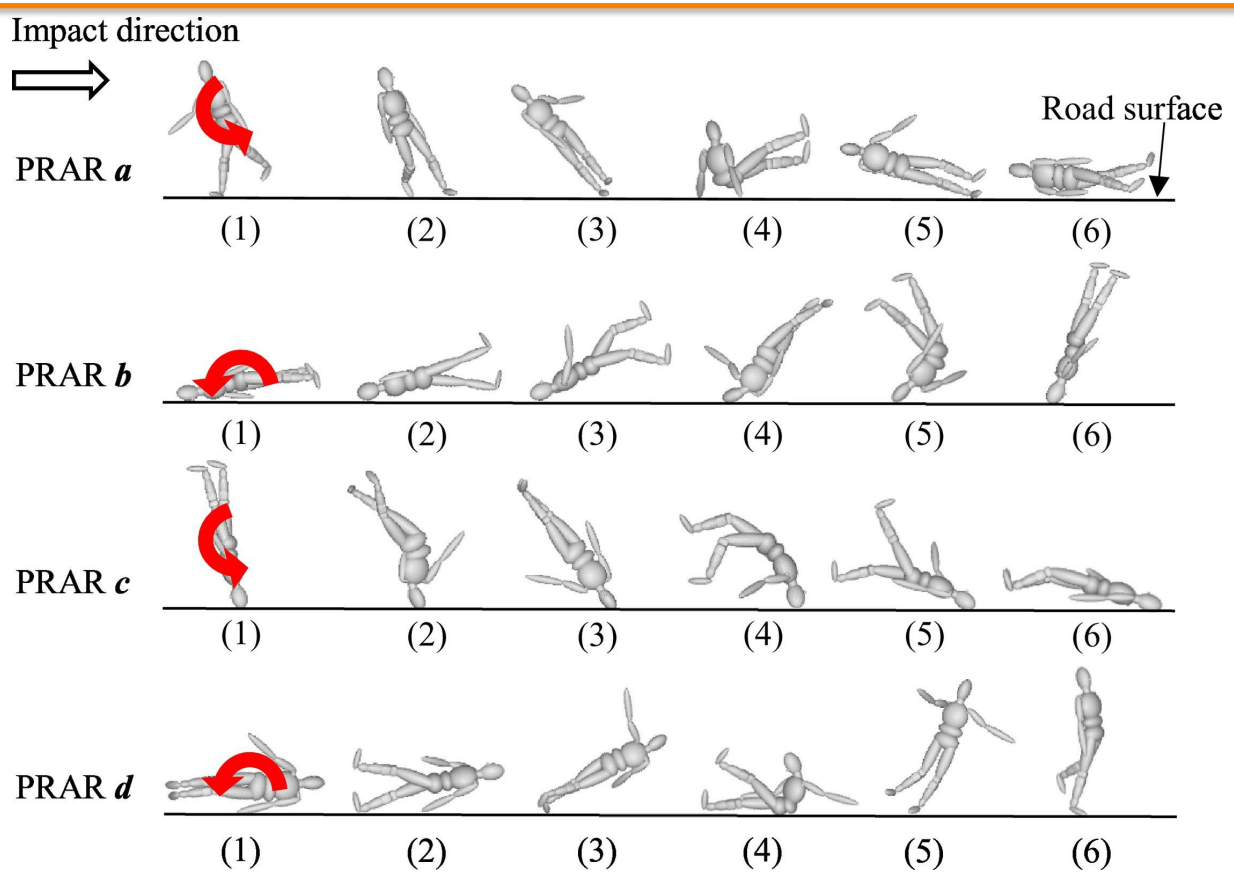
Secondary hits

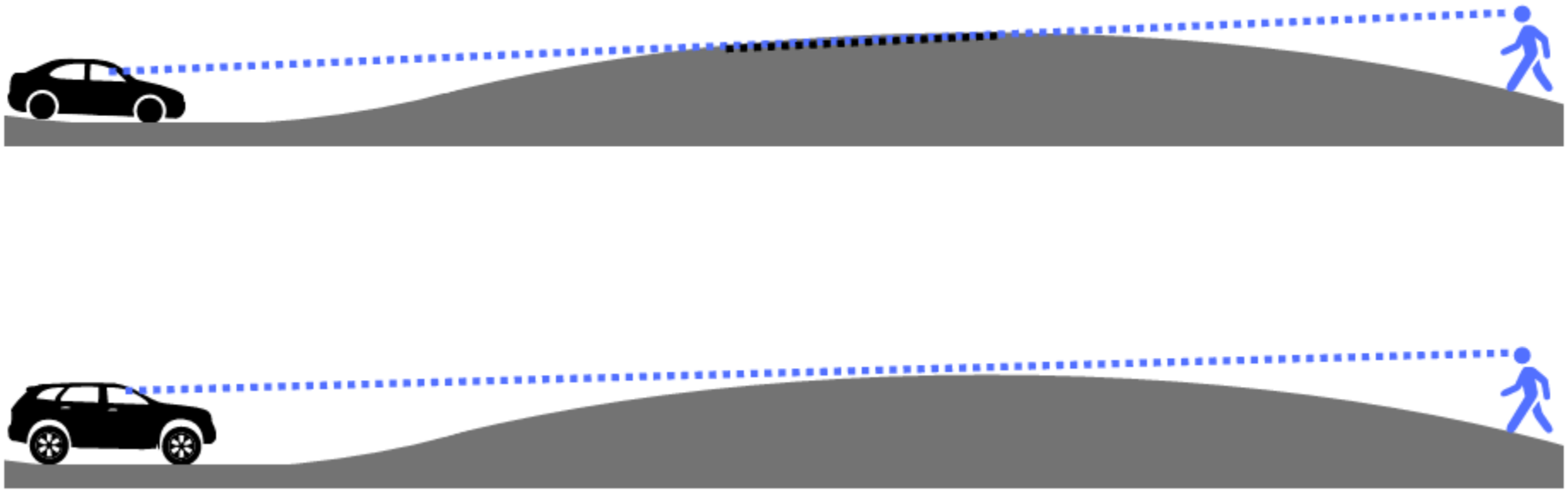
- At low speeds, head injury caused by secondary impact (ground hits) is more dangerous than primary impact
- Brain injury from rapid head movements leading (sideswipe impacts)
- Ground hits are more dangerous in SUVs than sedans with possible chances of runovers



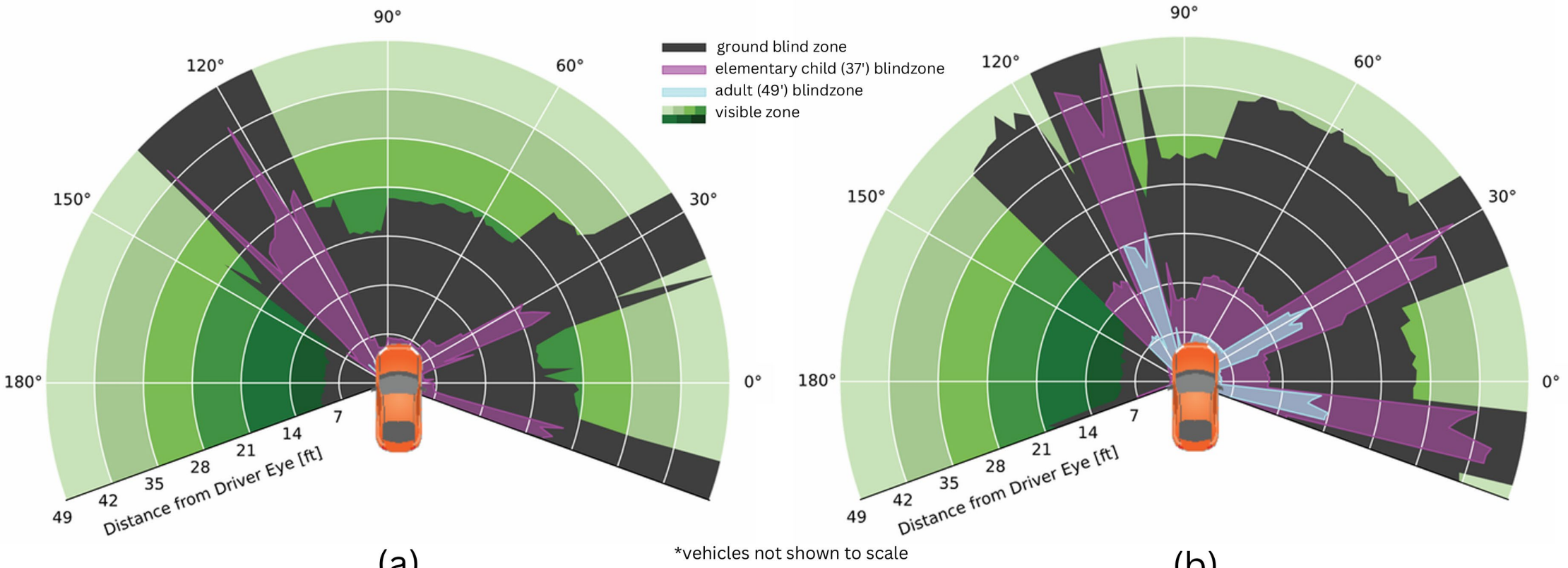
Pedestrian trauma sequence for different rotations (Hamacher et al. (2018))

Source: Tamura, A., Hasegawa, J., and Koide, T. (2018), Hamacher et al., (2012), Hamacher et al. (2018)

Visibility: SUVs vs. Cars



Blind spots (VIEW Blindzone App)



(a)

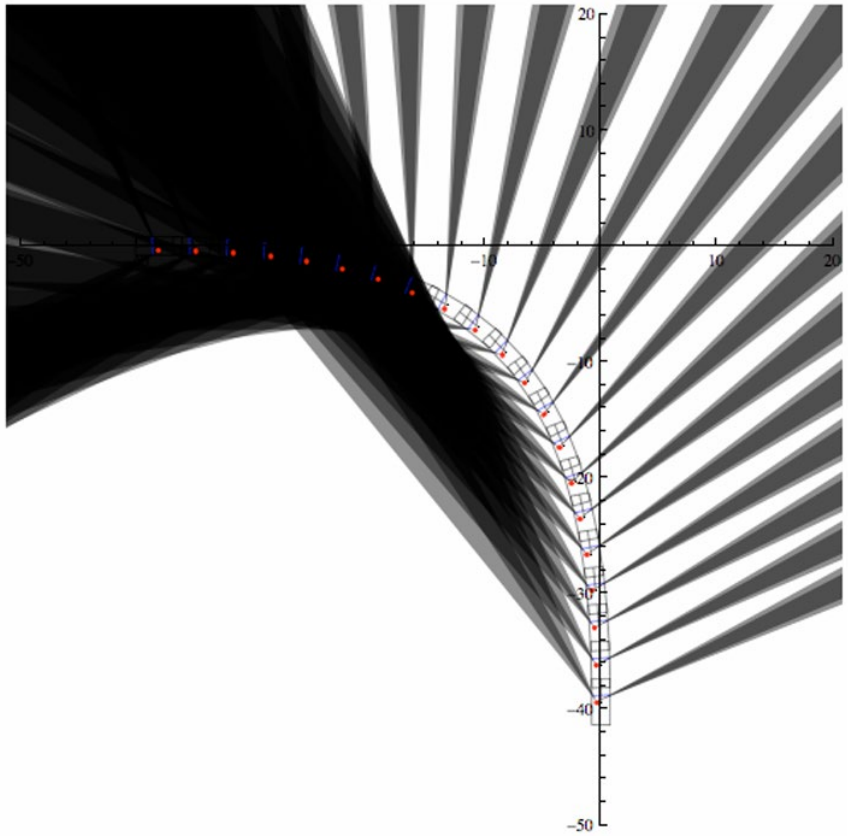
2024 Nissan Altima (Sedan)

(b)

2025 Honda Pilot (SUV)

Source: https://blindzonesafety.org/vehicle_database_table/

A-pillar blind spots during a turn

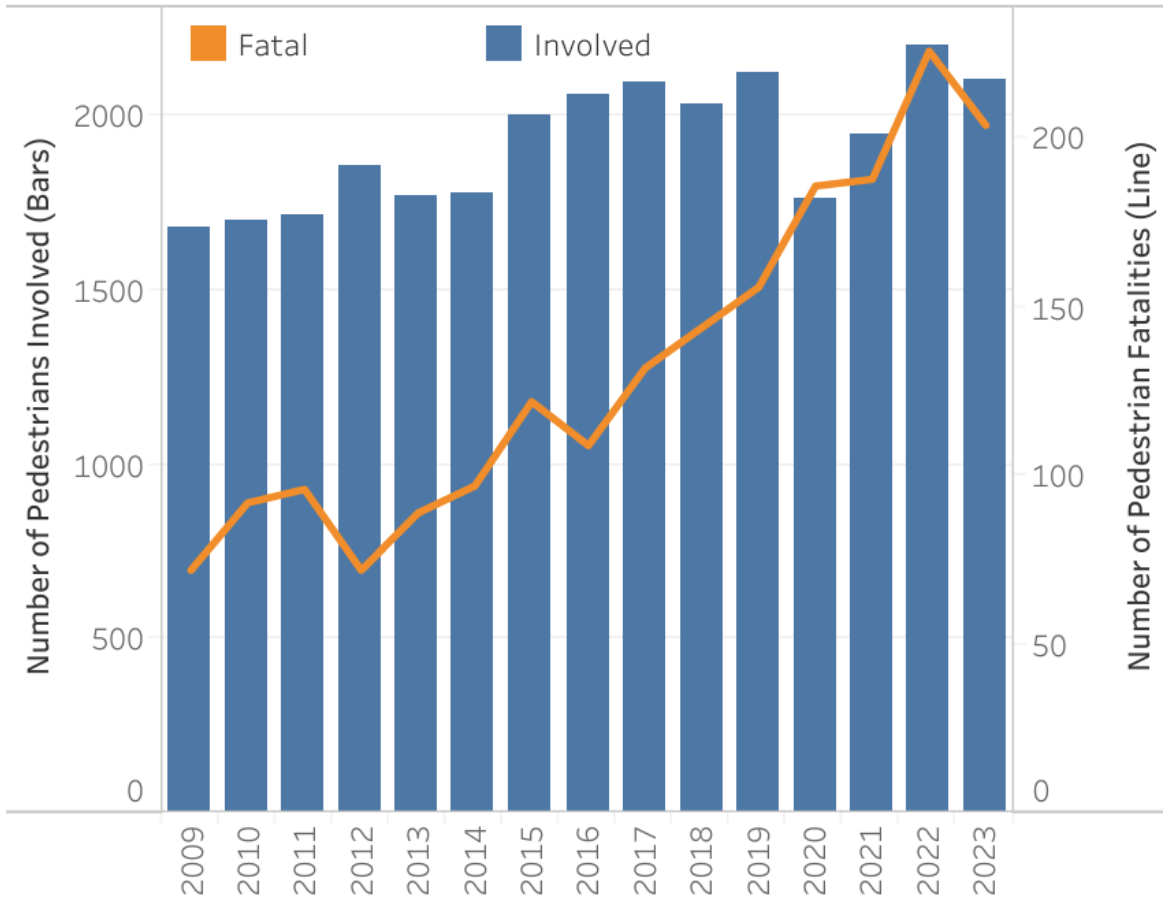


Source: Intersection kinematics: A pilot study of driver turning behavior with application to pedestrian obscuration by A-pillars, Reed (2008)

Pedestrian Crash Trends in Tennessee

Pedestrian Trends in Tennessee (2009-2023)

- Fatality increased by **2.8 times** (max. 3.1 in 2022)
- Involvement increased by 25 percent
- **Fatality rate increased by 126%** (4.30 deaths per 100 involved to 9.71 deaths per 100 involved)
- 75% of total deaths occurred in the nighttime



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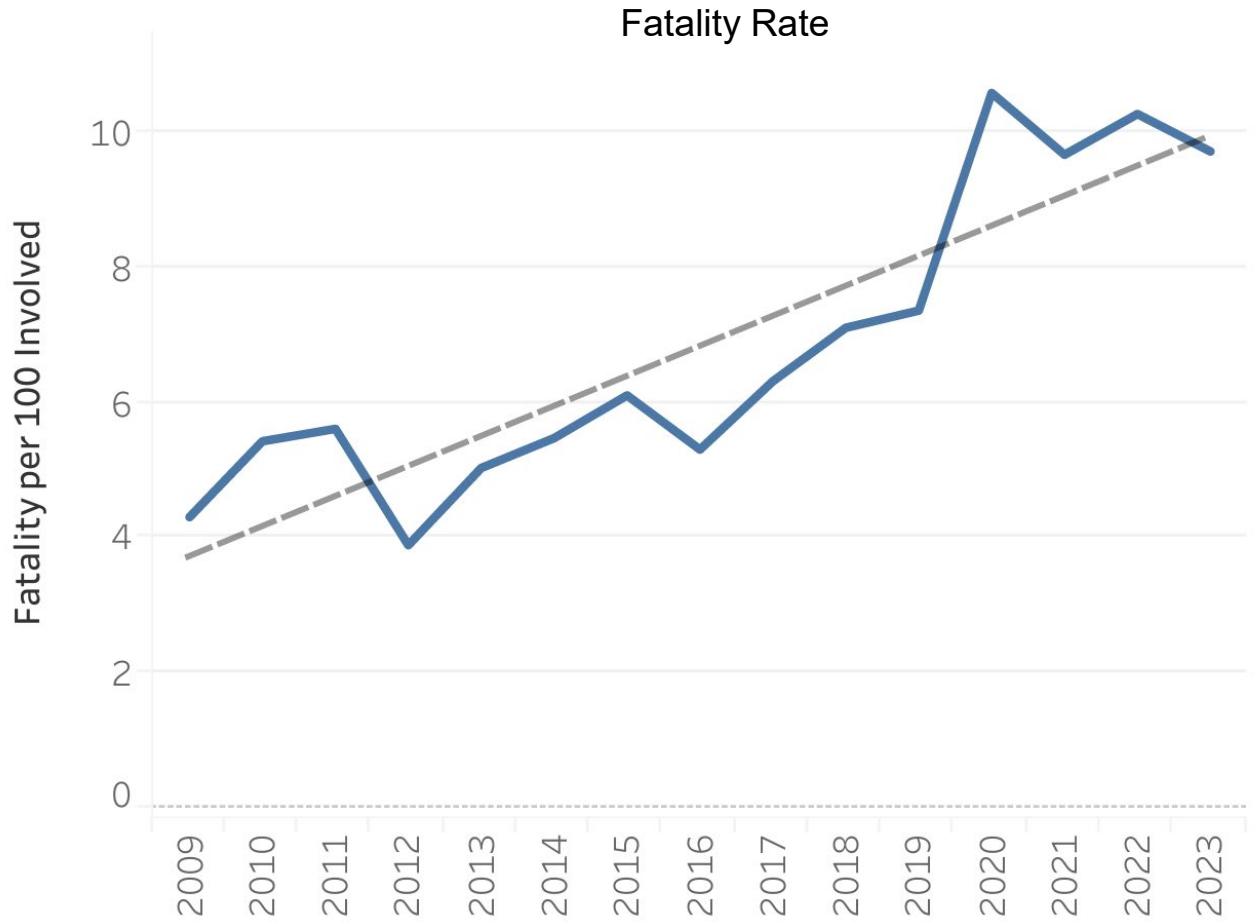

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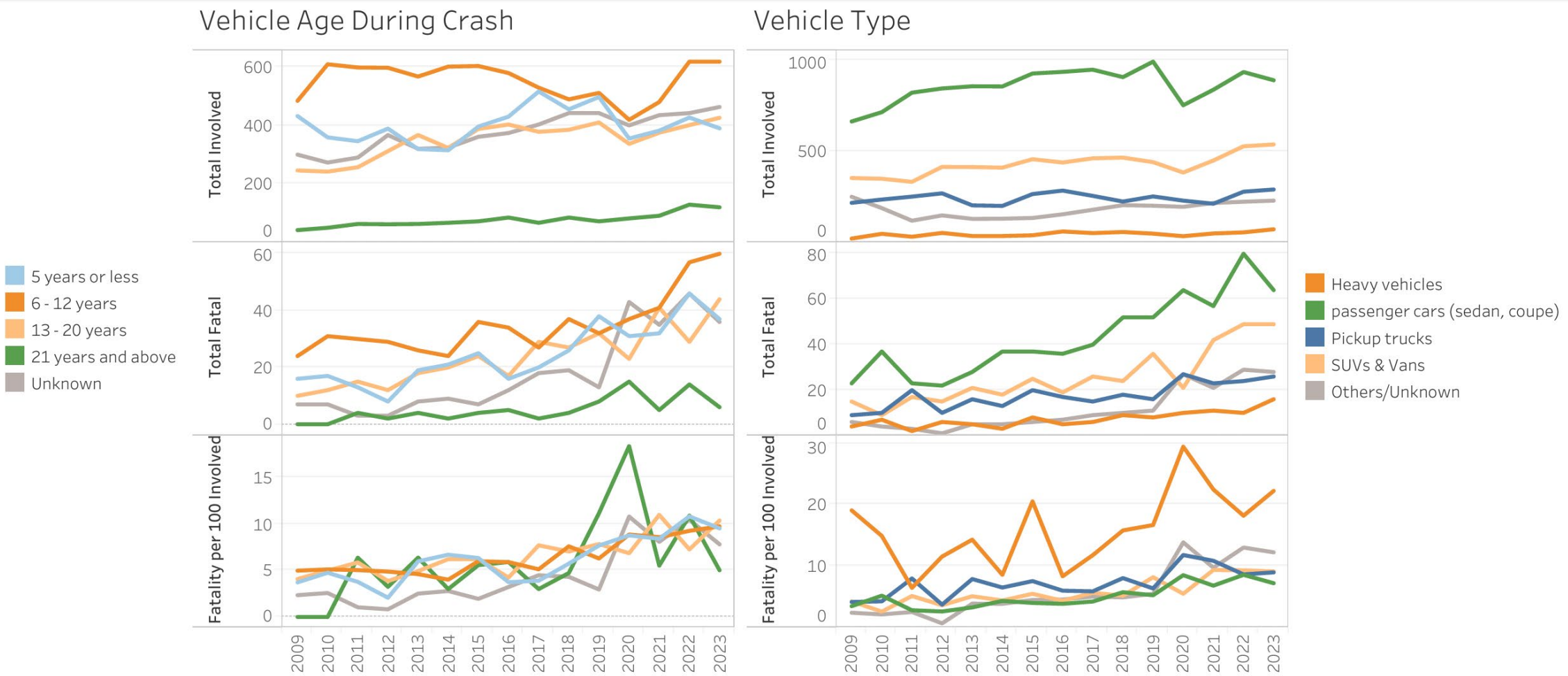

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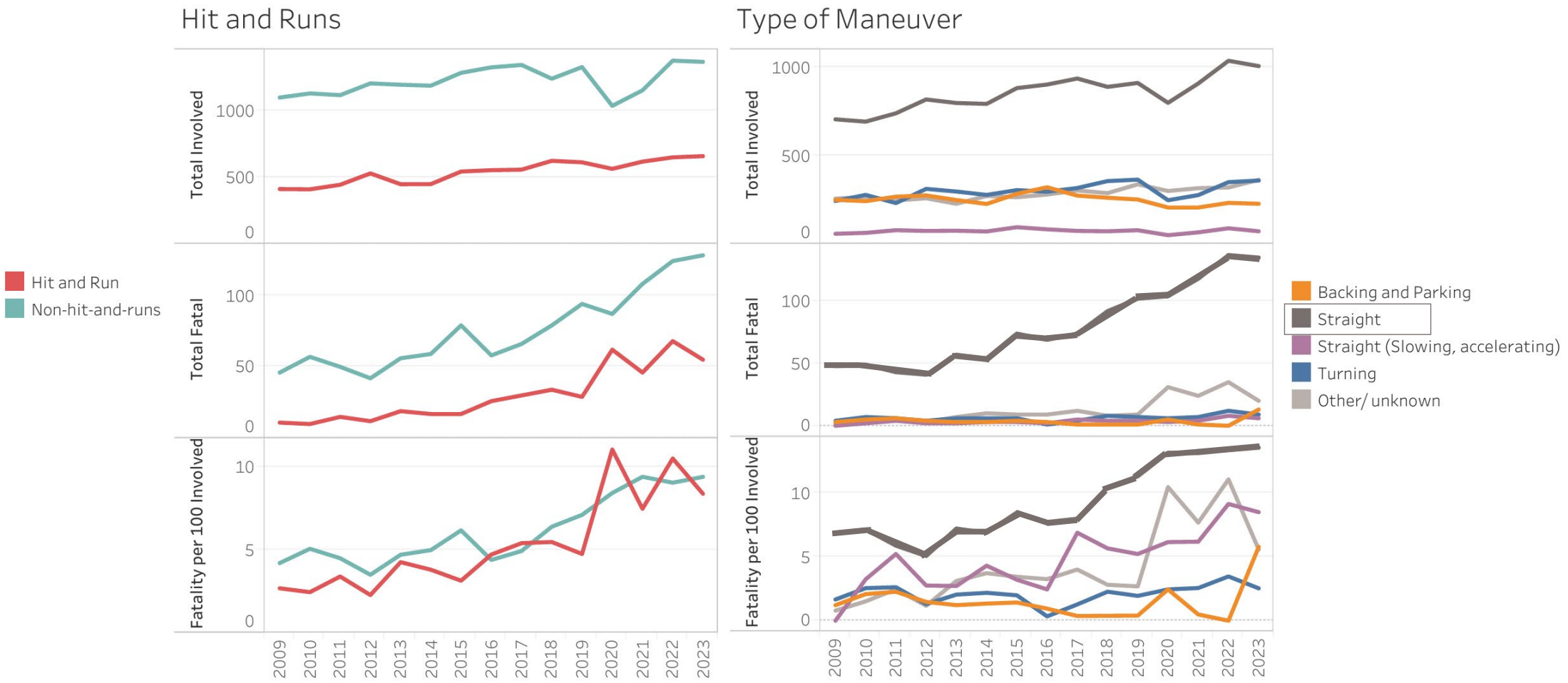

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Using Police Crash Data

- Represents real life crash instances
- Injury severity is reported in a spectrum (KABCO scale) although subjective for non-fatal injuries
- Exhaustive crash analysis (all reported crashes)
- Vehicle dimensions linked from NHTSA's VIN Decoder and Canadian Vehicle Specifications dataset
- Lacks vehicle impact speed details

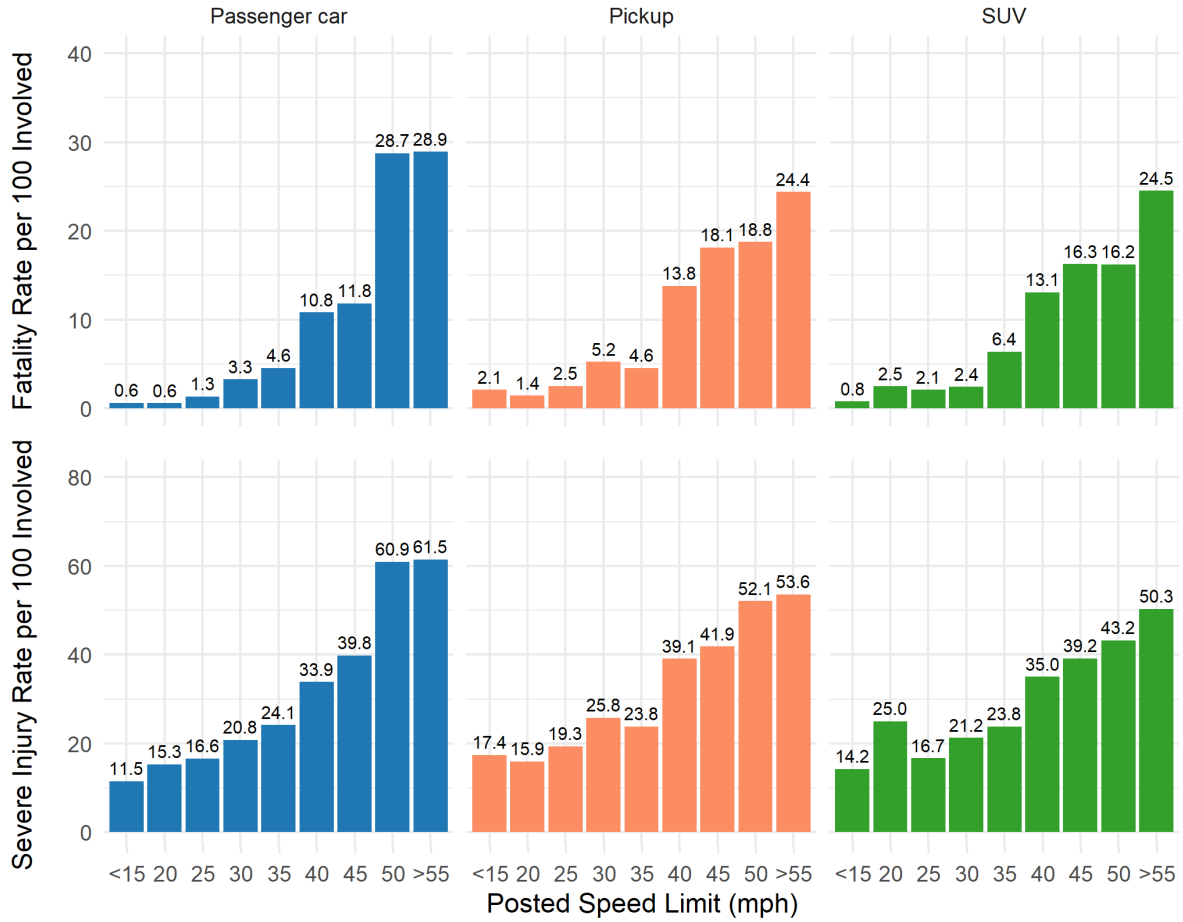
Data

- TN Police Crash Data from 2009 to 2024
- Single-unit non-interstate urban pedestrian crashes
- 16,547 crashes involving pedestrians and consumer vehicles (passenger cars, SUVs, pickups, and sedans)

Proxies for Analysis

- Proxy for Vehicle Impact Speed: Posted Speed Limit
- Proxy for Vehicle Weight: Vehicle Curb Weights
- Proxy for vehicle Design/ Front Hood Height: Vehicle Overall Height
- Vehicle age used as a combined proxy for
  - Vehicle wear and tear effects for older vehicles
  - Impacts of safety technology for newer vehicles

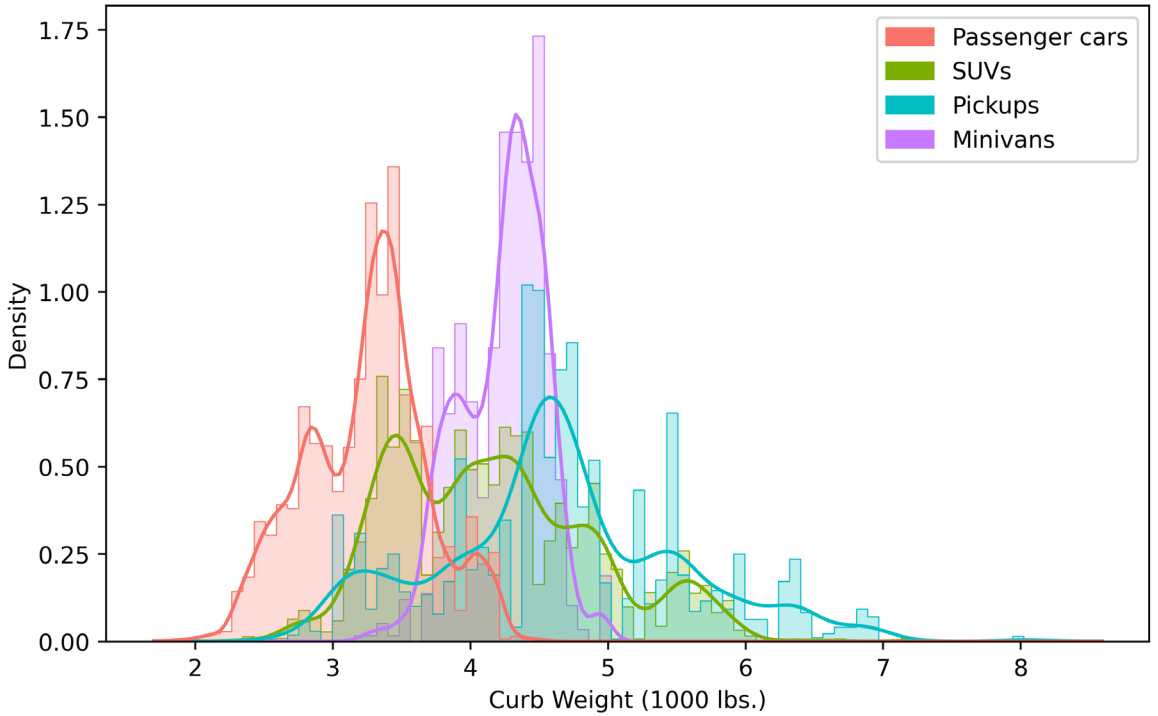
Ped. Injury Outcomes and Vehicle Types



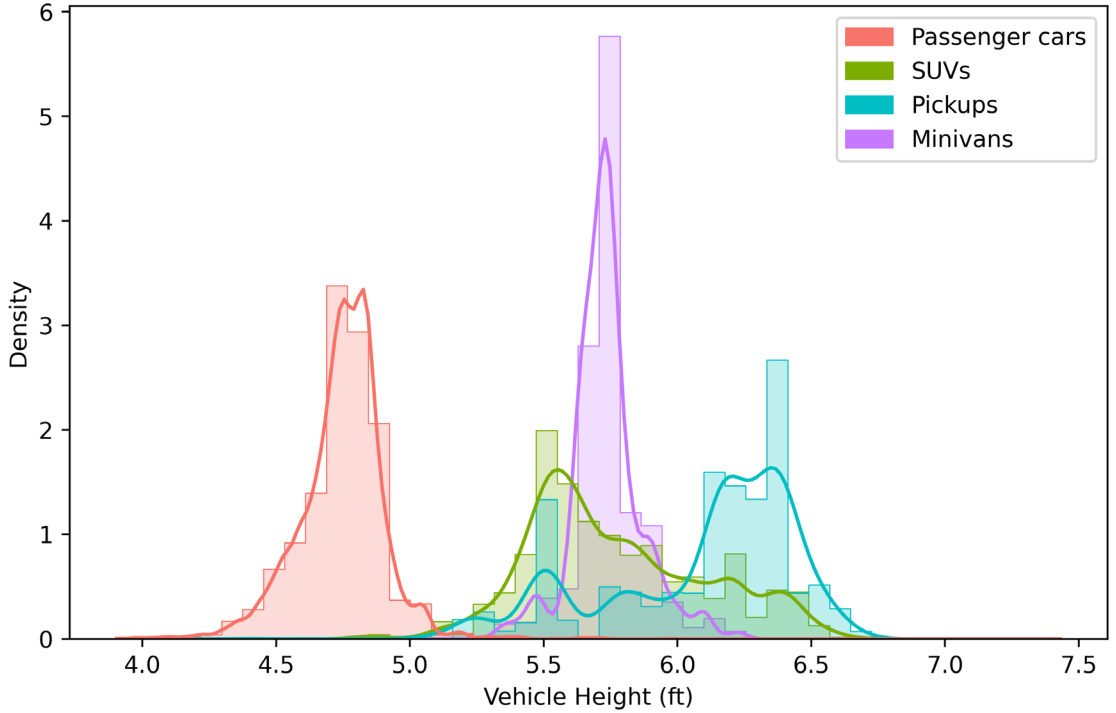
TN Crash data (2009-2024)

Weight and Height Distributions

Curb Weights



Vehicle Height



TN Crash data (2009-2024)

Modeling Approach

- Partial proportional odds model
- Outcome variable
  - 3 levels of injury severity (Fatal, Seriously-injured, and others)
- Independent variables
  - Speed limit, vehicle curb weight, speed-weight interaction, vehicle type/ vehicle overall height, vehicle age, and low-speed manuevers
- Control variables
  - Lighting, crash-year fixed effects, pedestrian features, and driver features

Results

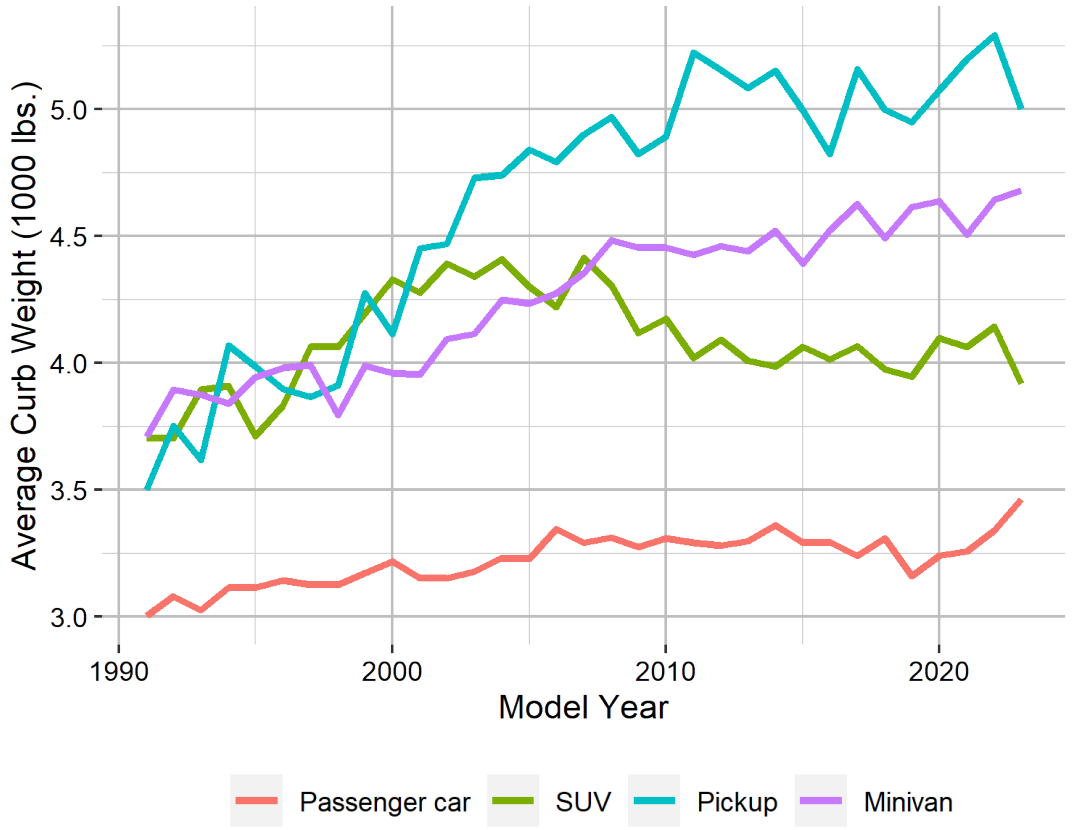
- Speed limit is strongly associated with injury severity outcomes
- Vehicle curb weights and vehicle age are significantly associated with injury outcomes
- Vehicle curb weight and speed limit interaction is significant
- Vehicle overall height is significant for fatal outcomes, weakly significant for severe outcomes

Results

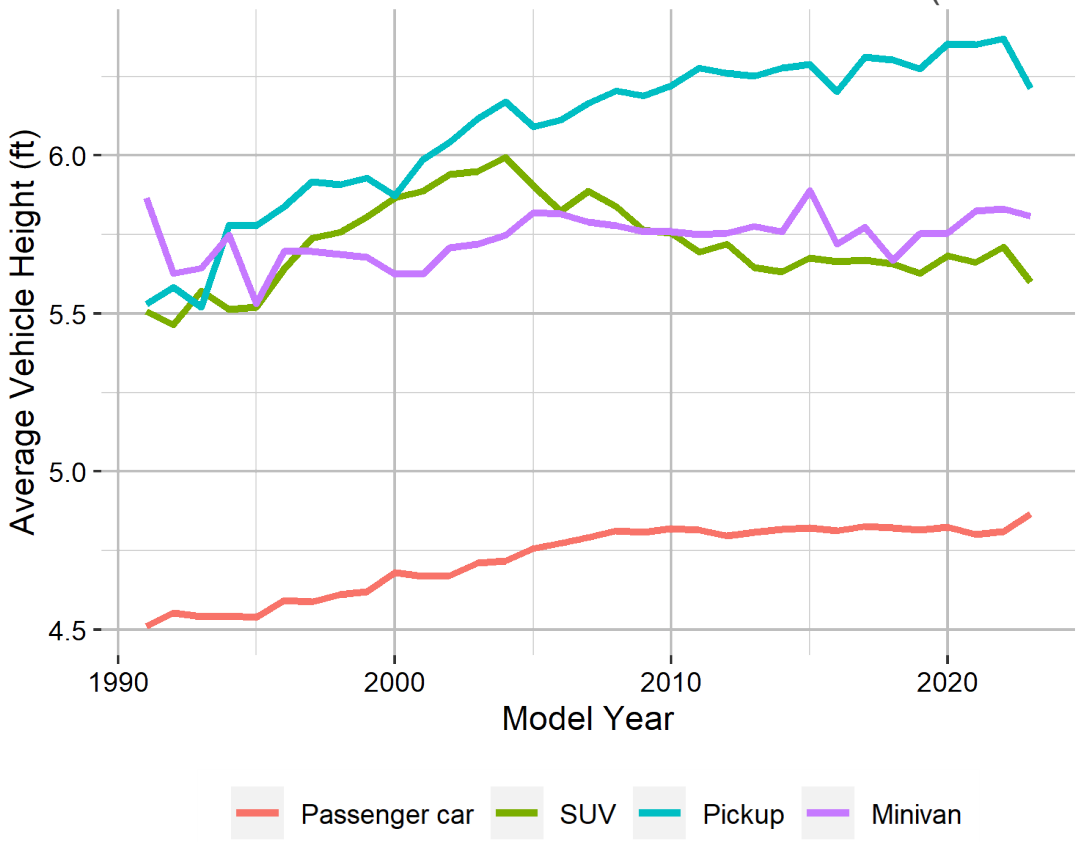
- A 1000 lbs. increase in curb weights raises fatal/severe injury odds by
  - (+)13% on 15 mph (low speed roads)
  - (+)4% on 30 mph roads
- A foot increase in vehicle overall height raises fatal injury odds by 29%
  - Minivans are 29% more likely to be associated with fatal outcomes than cars
  - Compact SUVs are 21% more likely than cars
  - Large SUVs and pickups are 42% more likely than cars
- 11-year-old vehicles are 14% more dangerous than new vehicles controlling for

Vehicle trends

Source: TN Crash data (2009-2024)

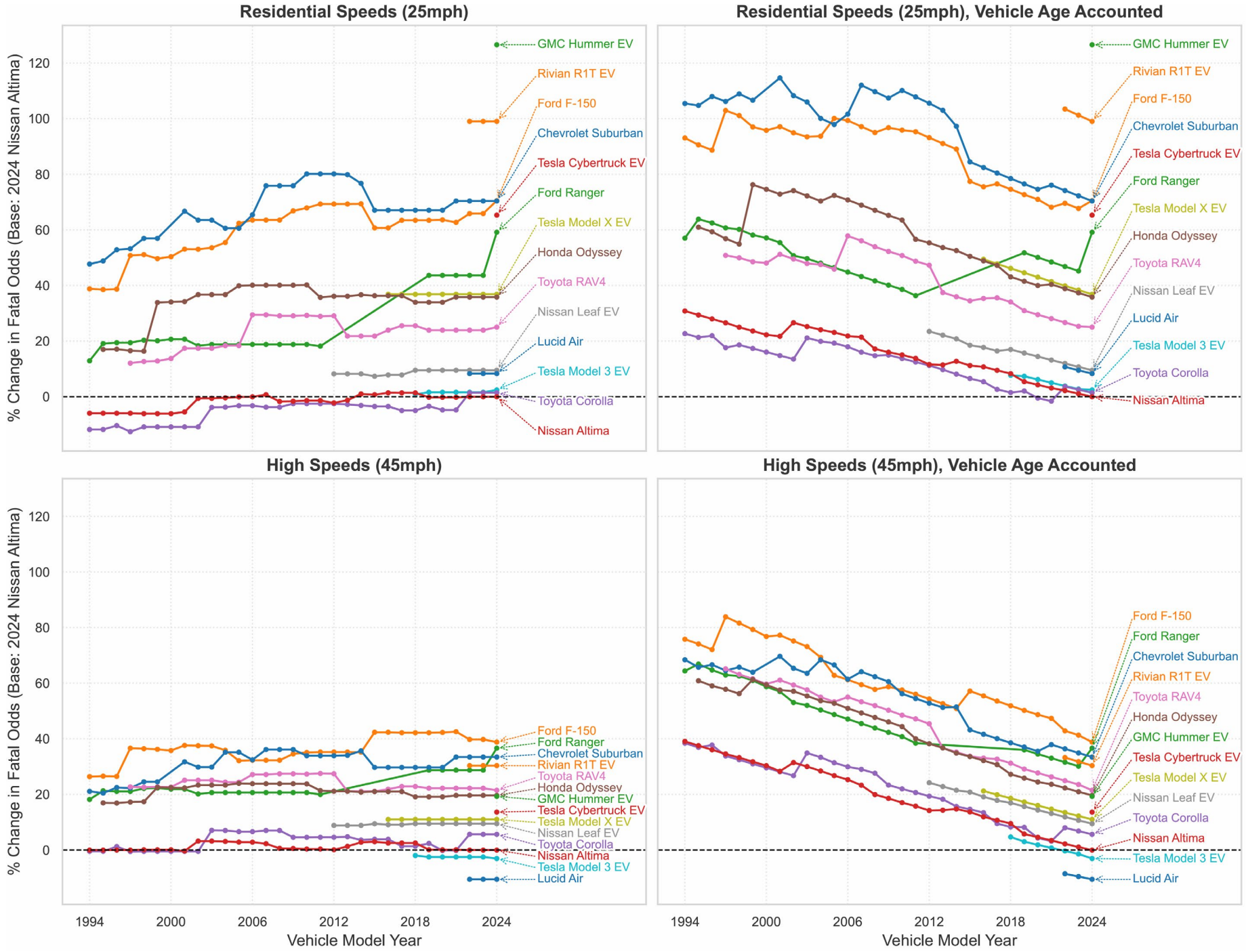


Average Weight



Average Height

Vehicle Landscape



QUESTIONS?

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