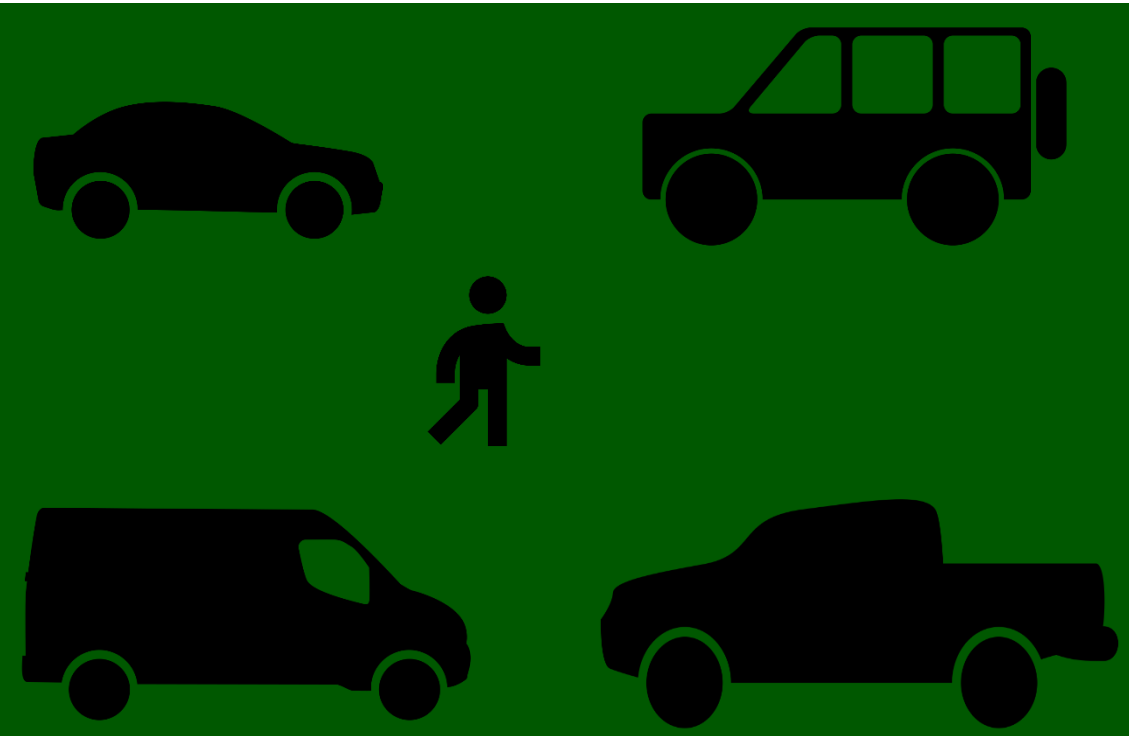
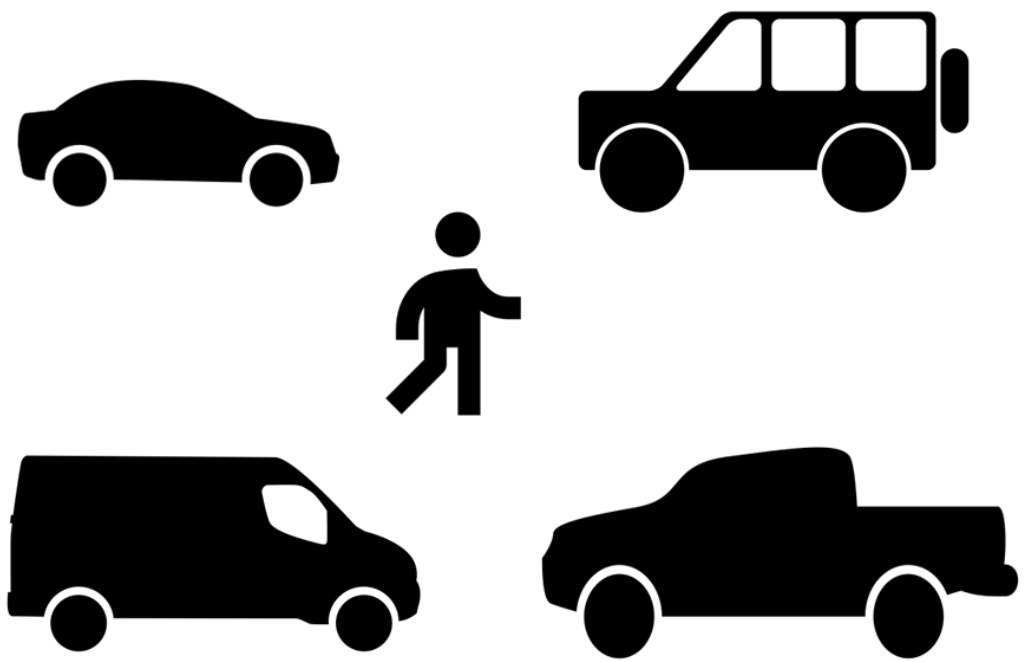
March 5th, 2024



Measuring the Impact of Vehicle Design and Speed on Pedestrian Injury Severity in the Pacific Northwest

Agenda



- **Motivation**
- **Past Research**
- **Data and Methods**
- **Findings**
- **Recommendations**
- **Limitations**

Motivation:

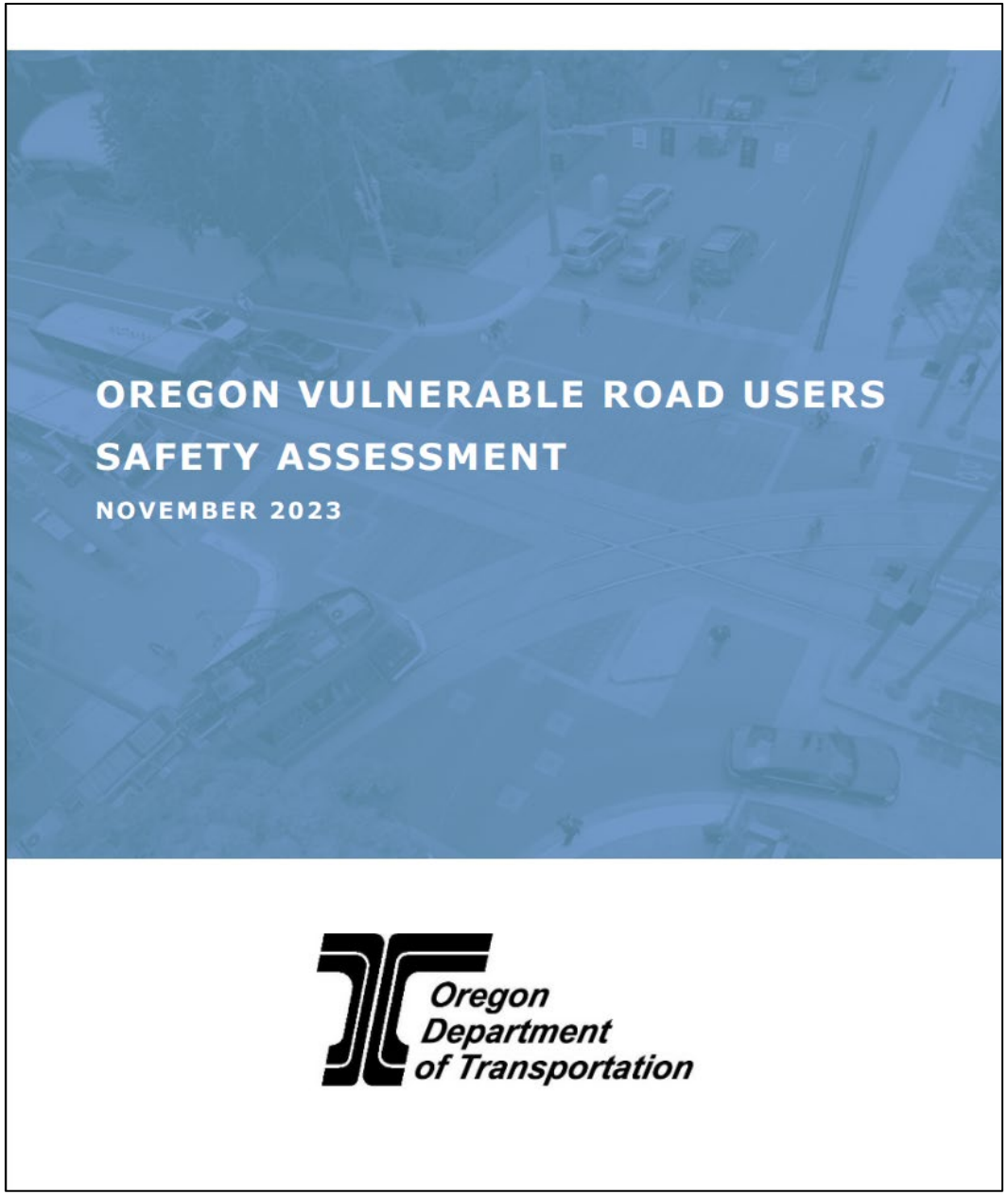
Oregon DOT Vulnerable Road Users Safety Assessment (VRU SA)

VRU Background

- VRU SA required as part of Highway Safety Improvement Program (HSIP)
- Describes the current state of safety for people walking and bicycling

Research Objectives

- Determine vehicle design features that can be measured using state and regional data
- Measure effect of vehicle design features and other important features



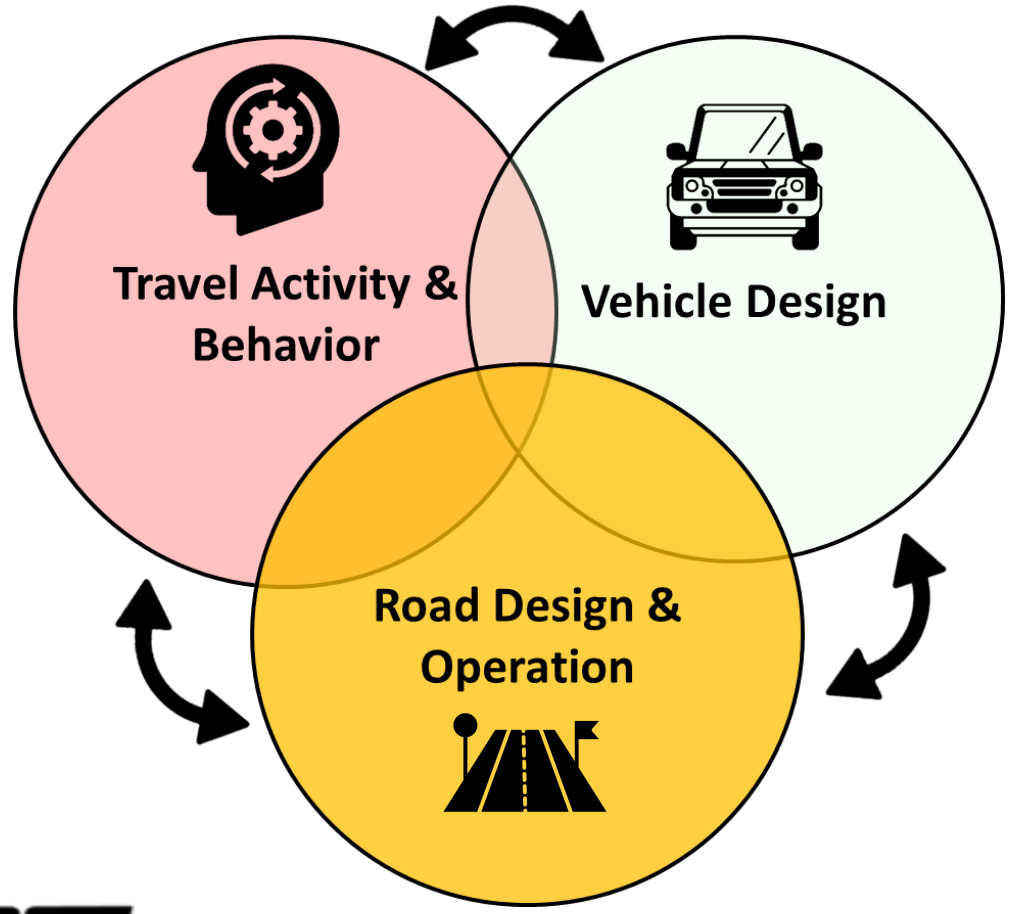
Motivation:

The Safe System Approach

- National Roadway Safety Strategy (NRSS) explicitly calls out *Safer Vehicles*
- Vehicle design typically left out of the safety conversation at state/local level
- To manage we must measure

Motivation:

Inputs to Crash Injury



Travel Activity & Behavior

- More travel increases probability of crash
- Humans make mistakes

Vehicle Design

- Significant improvements in standard/available safety features
- Weight and design becoming a problem for vehicle non-occupant

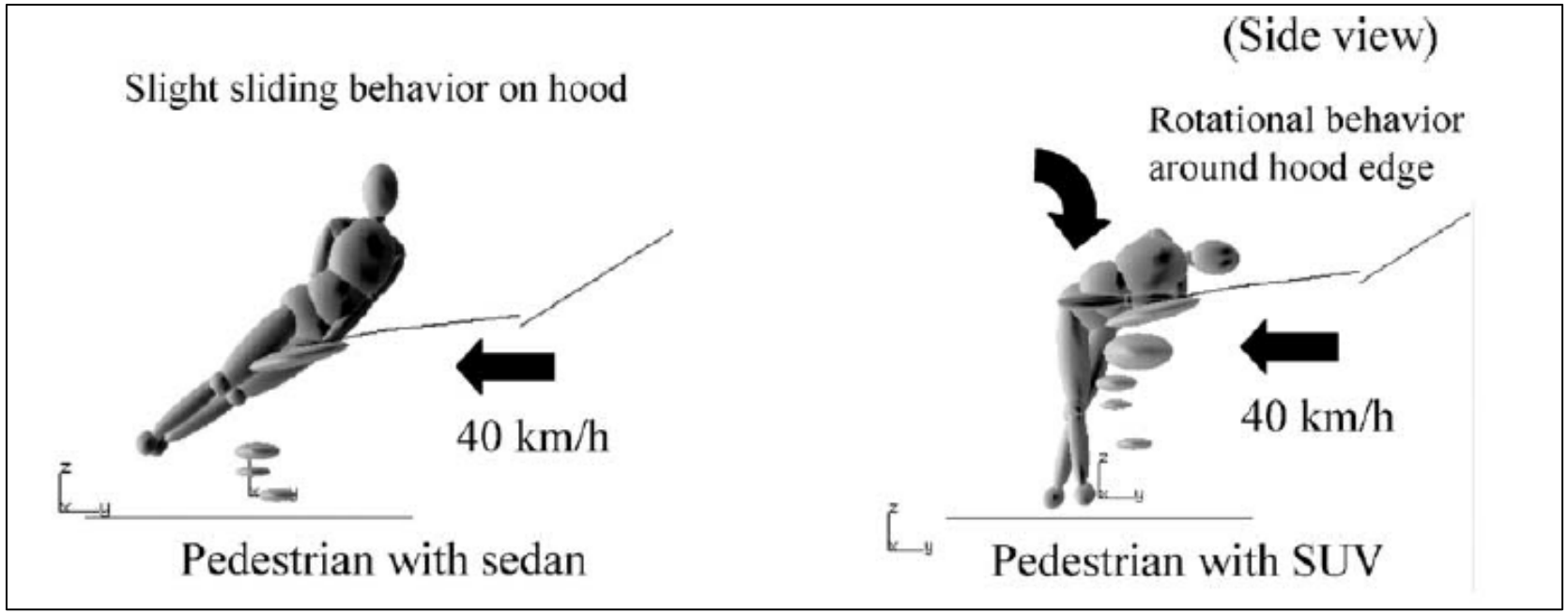
Road Design and Operation

- Influences human behavior
- Design & operation can alter crash risk

Motivation:

Biomechanics of Pedestrian Injury

- Body Type
  - Influences impact area on pedestrian's body
- Vehicle Mass
  - Along with speed, determines impact force
- Vehicle Stiffness
  - Vehicle material determines force transferred to pedestrian



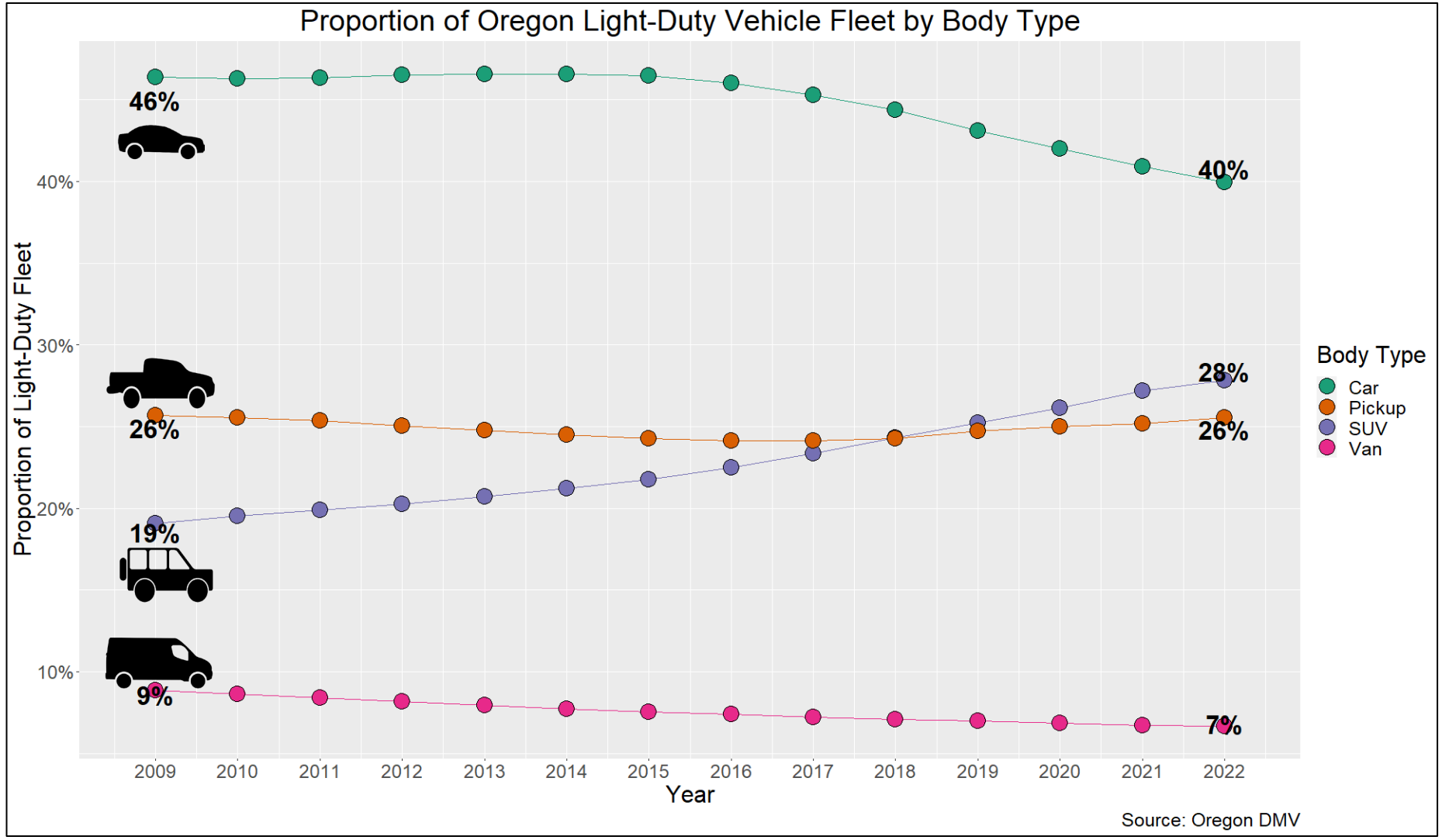
Source: Maki et al. 2002

Motivation:

Changes in Light-Duty Fleet Composition

Oregon

- 430,000+ more SUVs on OR roads compared to 2009
- 100,000+ pickups now compared to 2009
- No change in pickup proportion but…



Motivation:

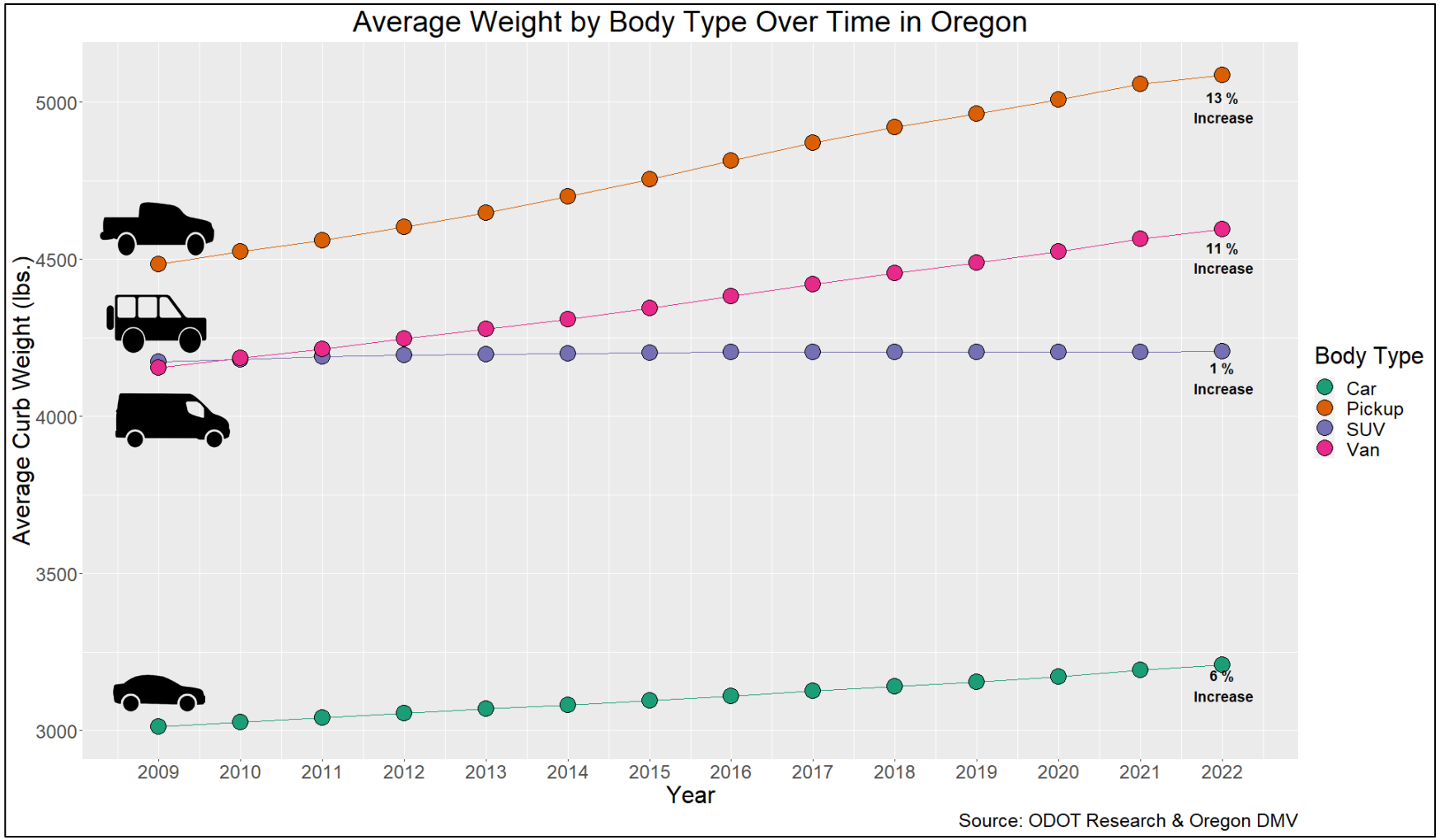
Changes in Vehicle Weight

Oregon

- Vehicle weights are increasing for all body types
- Pickups most significantly

United States

- Pickup weight up 30% since 1975
- Larger SUVs up 7% since 1975



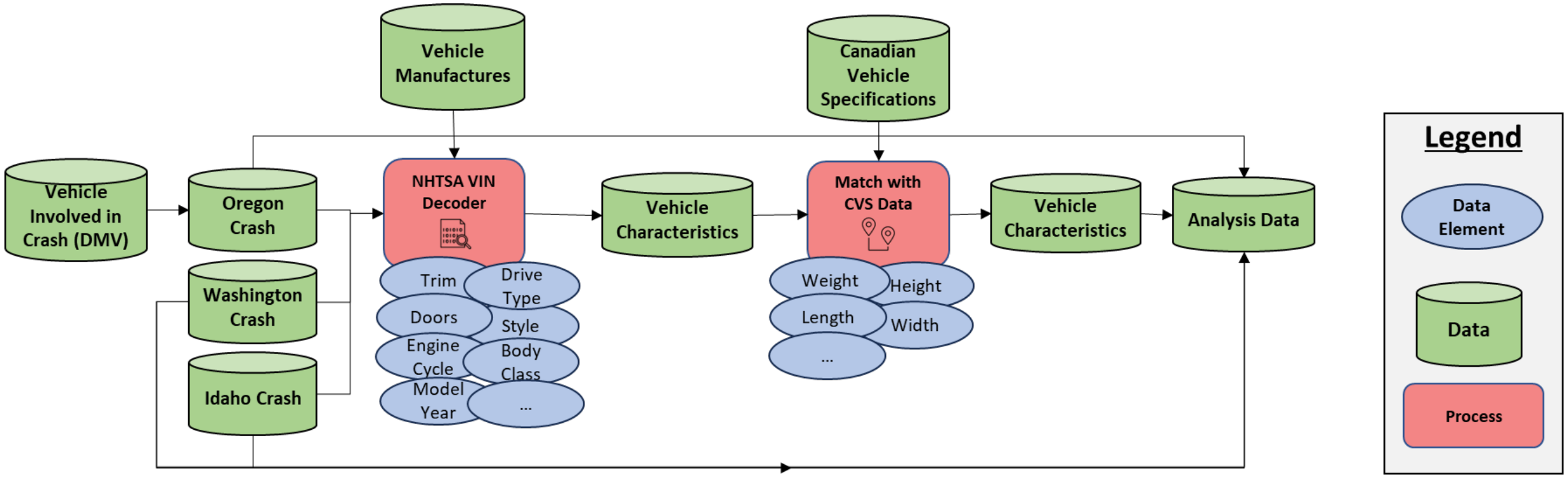
Background:

Past Research

Title	Authors & Year	Bike/Pedestrian/ Both	Method	Sample Size
Using ordered and unordered logistic regressions to investigate risk factors associated with pedestrian crash injury severity in Victoria, Australia, 2022	Nasri & Aghabayk 2022	Ped	MNL and ordered logit	10,040
Prevalence and factors associated with pedestrian fatalities and serious injuries: case Finland, 2020	Malin & Silla 2020	Ped	Geographically Weighted Ordinal Logistic Regression	287
Analysis of pedestrian-vehicle crash injury severity factors in Colorado 2006–2016	Batouli & Guo 2020	Ped	logistic regression	13,856
Exploring the factors contribute to the injury severities of vulnerable roadway user involved crashes, 2019	Dong & Khattak 2019	Both	ordered logit, mult logit, mixed generalized ordered logit	9,180 ped, 1,402 Bike
A mixed generalized ordered response model for examining pedestrian and bicyclist injury severity level in traffic crashes, 2008	Eluru & Bhat 2007	Both	mixed generalized ordered-response logit	3,200
The association of light trucks and vans with paediatric pedestrian deaths, 2006	Dimaggion & Durkin 2006	Ped	logistic regression	18,117
Pedestrian crashes: higher injury severity and mortality rate for light truck vehicles compared with passenger vehicles, 2004	Roudsari et al. 2004	Ped	logistic regression	552
Child and adult pedestrian impact: the influence of vehicle type on injury severity, 2003	Henary & Crandall 2003	Ped	logistic regression	552
Pedestrian injuries and vehicle type in Maryland, 1995–1999	Ballesteros et al 2003	Ped	logistic regression	~2,500

Data and Methods:

Vehicle Data Processing Workflow

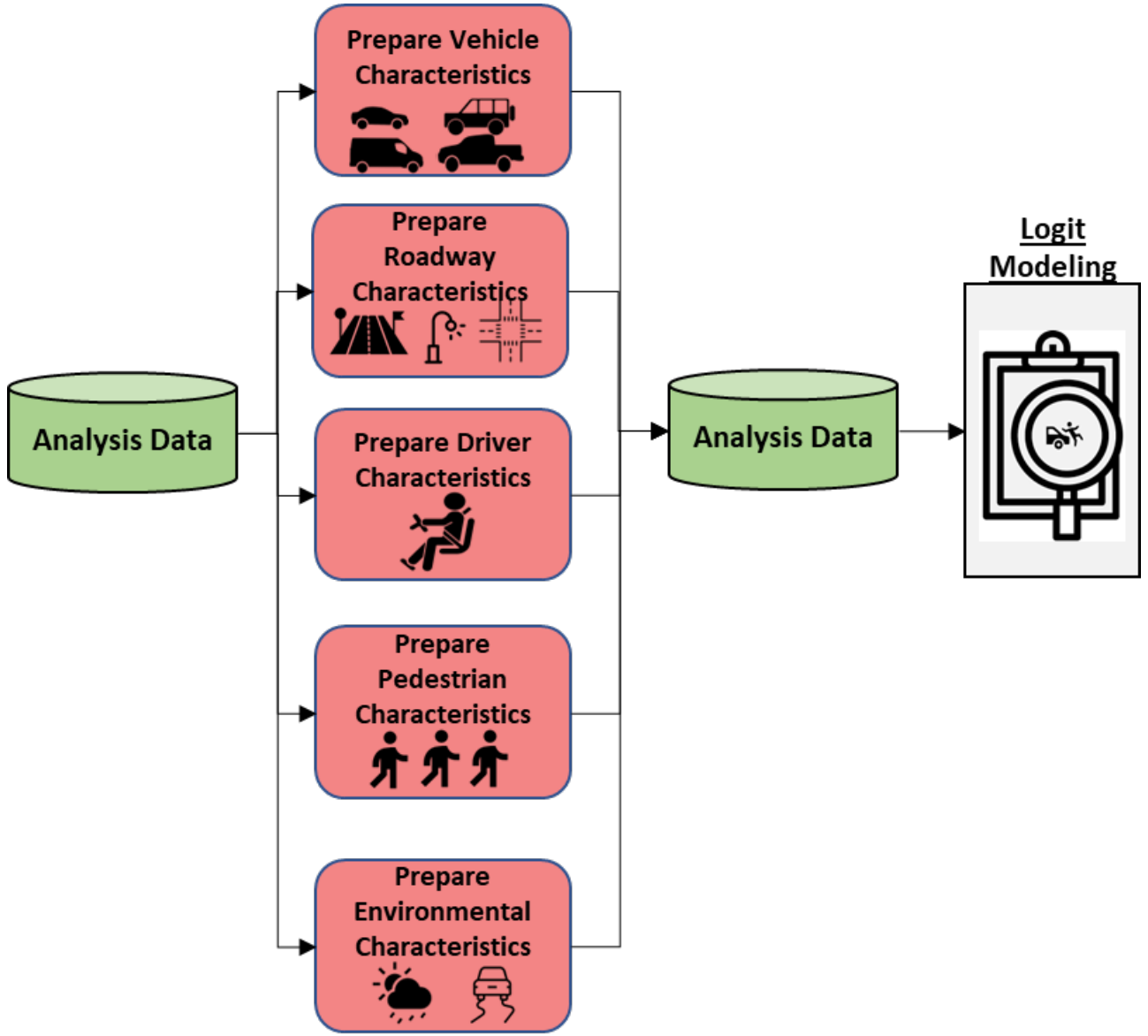


Data and Methods:

Crash Data Processing

Data

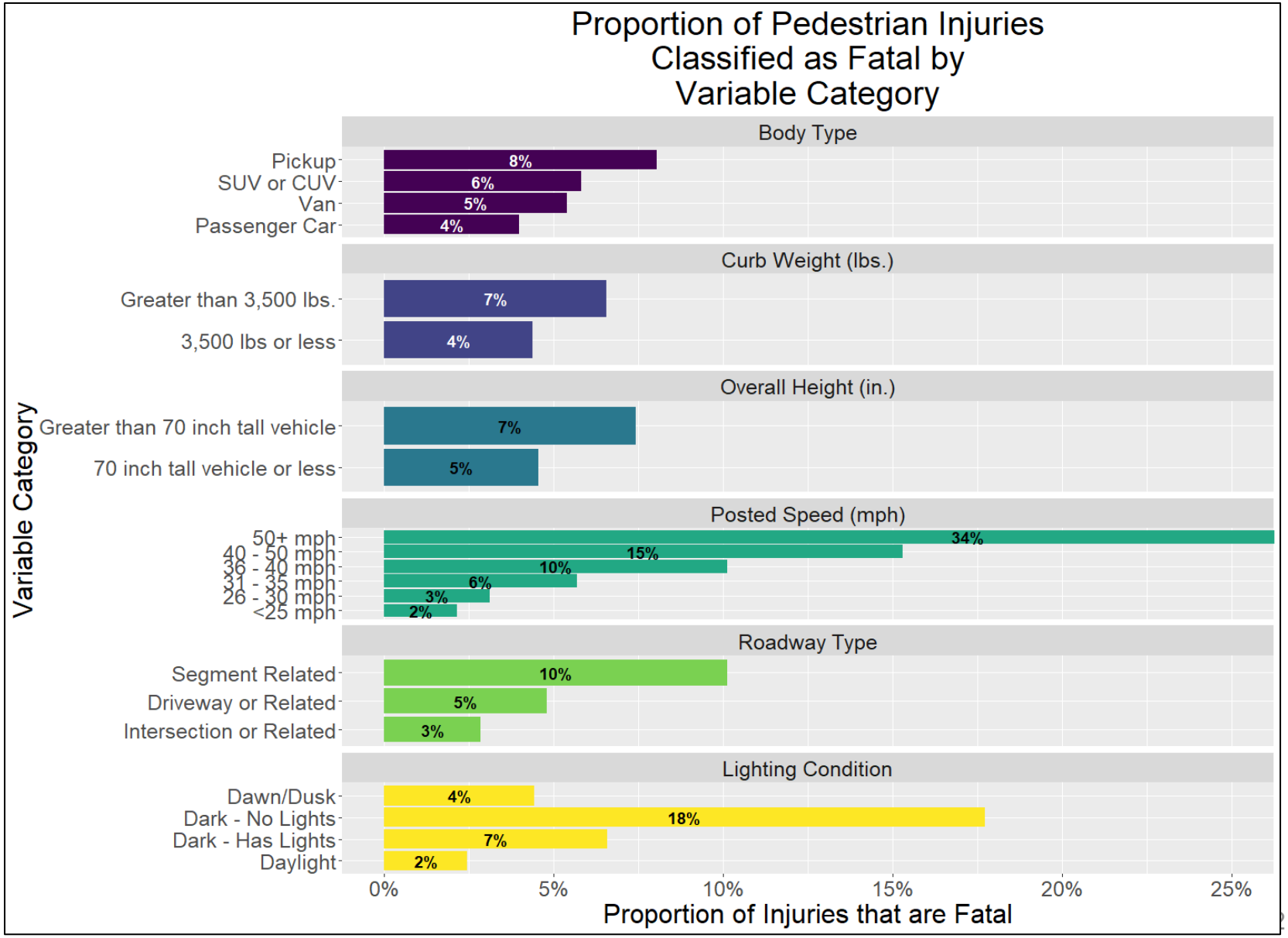
- Single-vehicle pedestrian involved
- Light-duty vehicles involved
- Use posted speed limit for measure of speed
- Four levels of injury severity: fatal, serious, moderate, minor, possible
- Remove some observations in categories with low observations



Data and Methods:

Data Descriptives

- Higher % of pickup/SUV/CUV involved crashes result in fatal pedestrian injury
- Height & weight appear important too
- Speed a clear factor in fatal injury
- Other roadway features important



Data and Methods:

Multinomial Logit Modeling

- Linear-in-parameters function describe likelihood of a given injury severity
- Estimated using R open-source statistical computing package nnet
- Results presented in Odds Ratios (ORs)
  - Values greater than 1.0 indicate an increase odd of the injury type when the given independent variable increases by one unit
  - Value of less than 1.0 indicates a decrease probability of the injury type when the independent variable increases by one unit

Model specification described as follows:

$$S_{in} = \boldsymbol{X}_{in}\boldsymbol{\beta}_i + \varepsilon_{in}$$

where:

$\boldsymbol{X}_{in}$ is a vector of explanatory variables

$\boldsymbol{\beta}_i$ is a vectors of parameters to be estimated

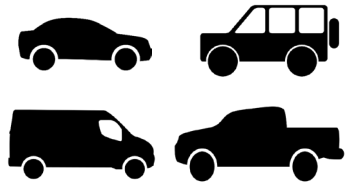
ε_{in} is a Type I Extreme Value distributed error term

Given the error is Type I Extreme the underlying probabilities are computed based on the logit probability of injury severity i for crash n:

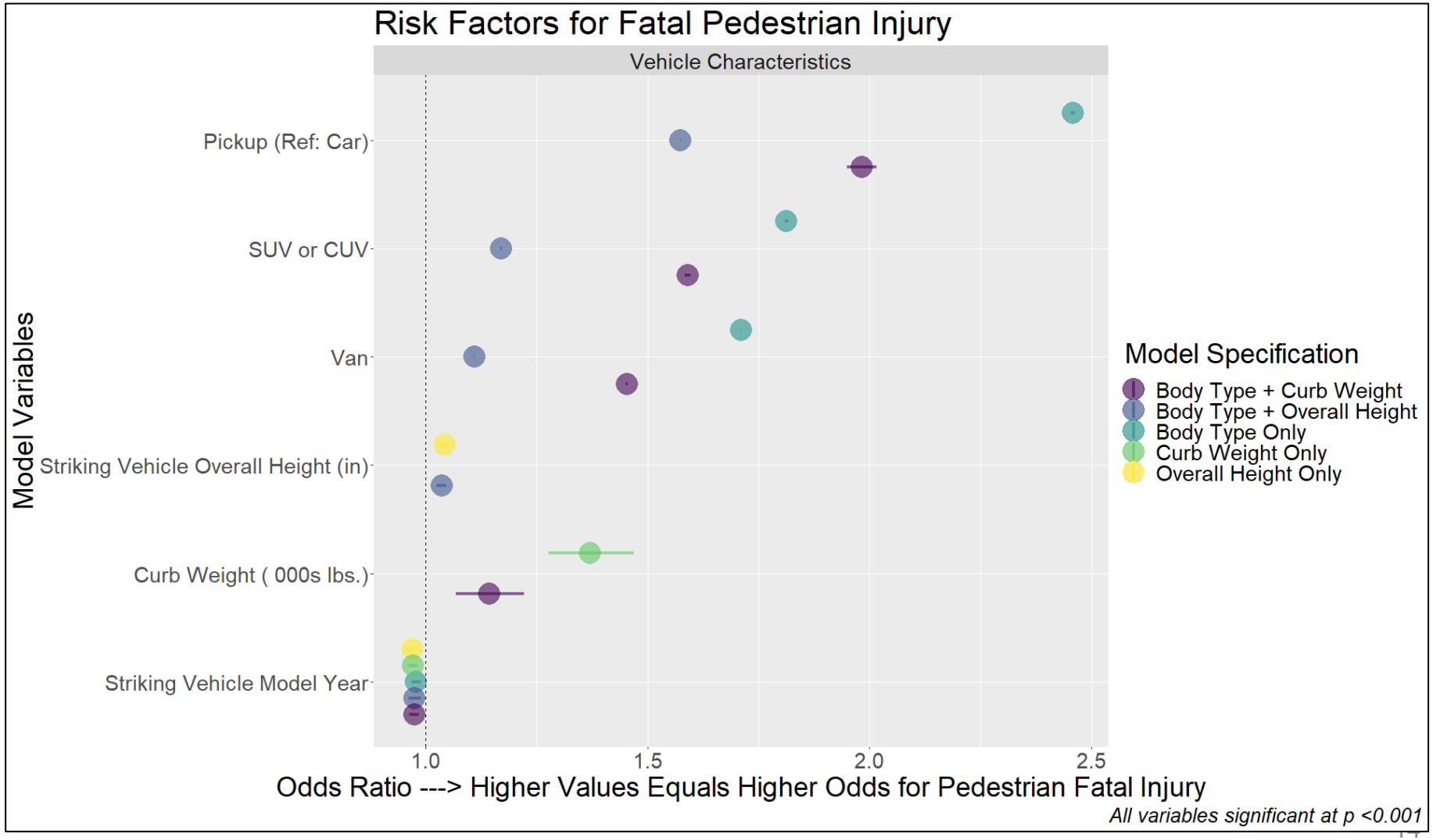
$$P_n(i) = \frac{e^{(\boldsymbol{X}_{in}\boldsymbol{\beta}_i)}}{\sum_I e^{(\boldsymbol{X}_{In}\boldsymbol{\beta}_I)}}$$

Findings:

Vehicle Characteristics



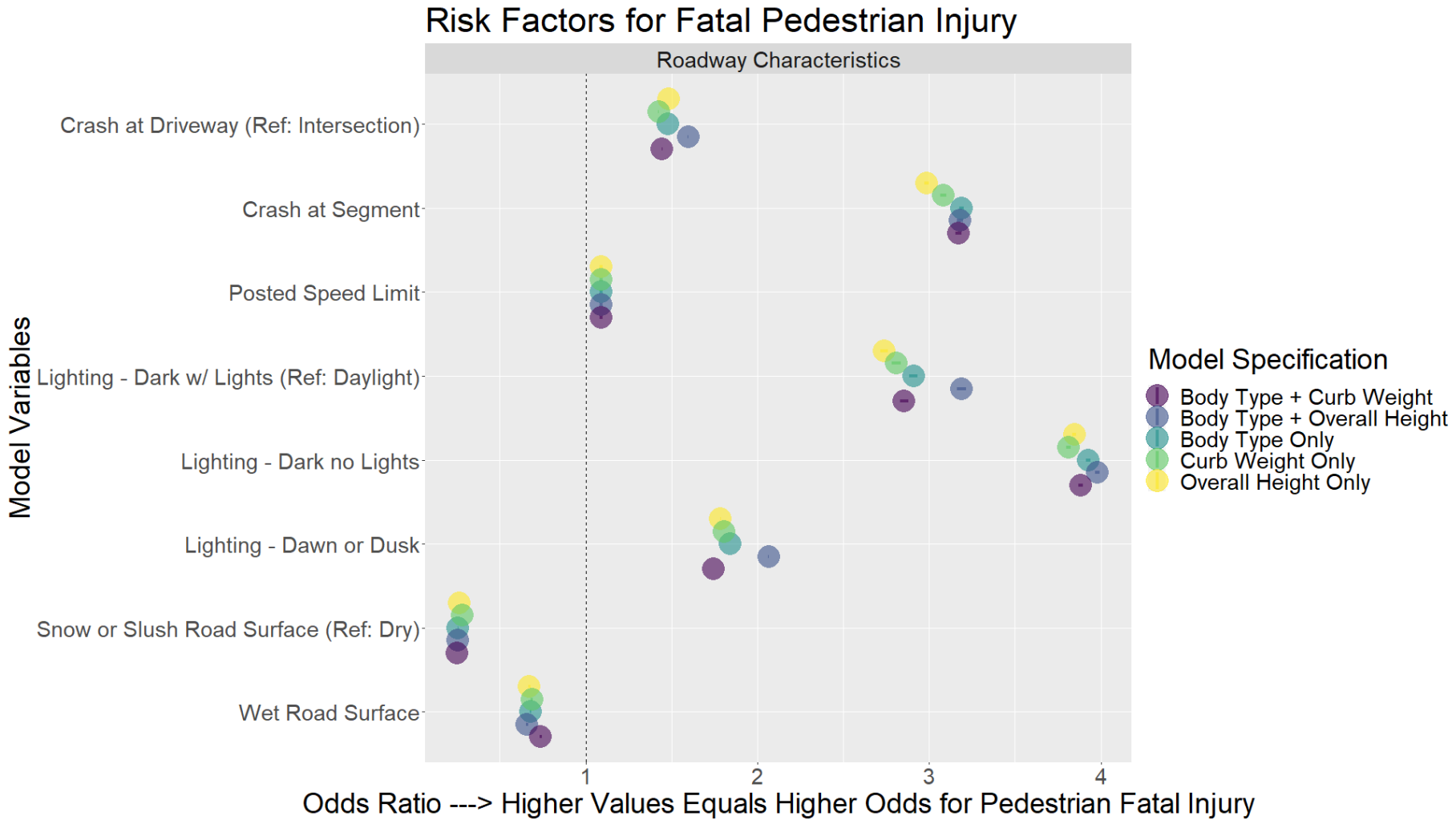
- Five models to assess various vehicle design elements
- Pickup
  - 1.6 to 2.5 higher odds of fatal
- SUV/CUV
  - 1.17 to 1.8 higher odds of fatal
- Van
  - 1.11 to 1.71 higher odds of fatal
- Overall Height (per inch)
  - 1.037 to 1.044 higher odds of fatal
- Curb Weight (per 1,000 lbs.)
  - 1.14 to 1.37 higher odds of fatal
- Newer vehicle decrease odds



Findings:

Roadway Characteristics

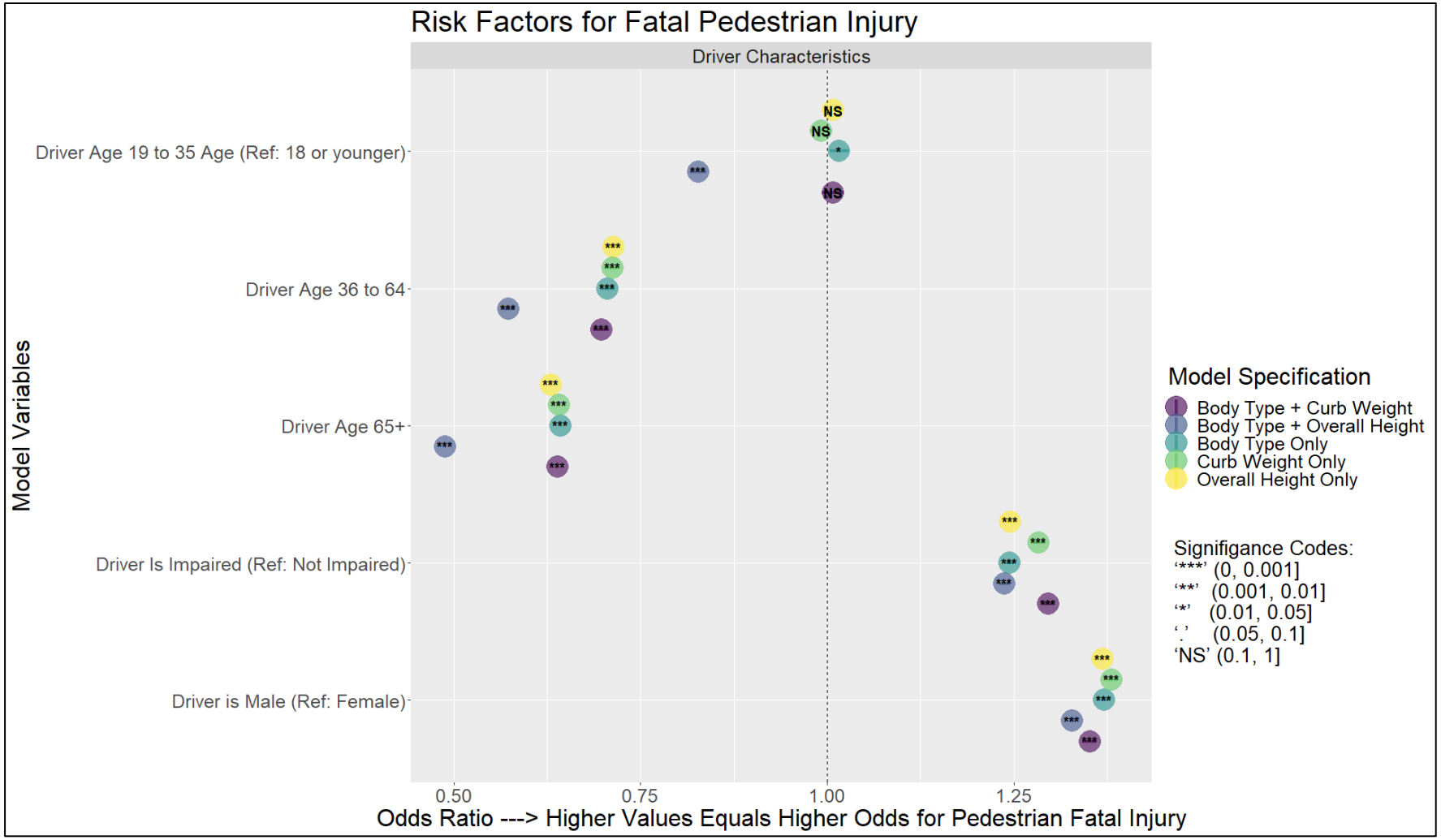
- Crash Type
  - Segments – increase odds by 2.9 to 3.2 (compared to intersections)
- Posted Speed (per mph)
  - Increase odds by 1.09 to 1.092
- Lighting
  - Dark w/ lights - increase odds by 2.7 to 3.2
  - Dark no lights increase odds by 3.8 to 3.9



Findings:

Driver Characteristics

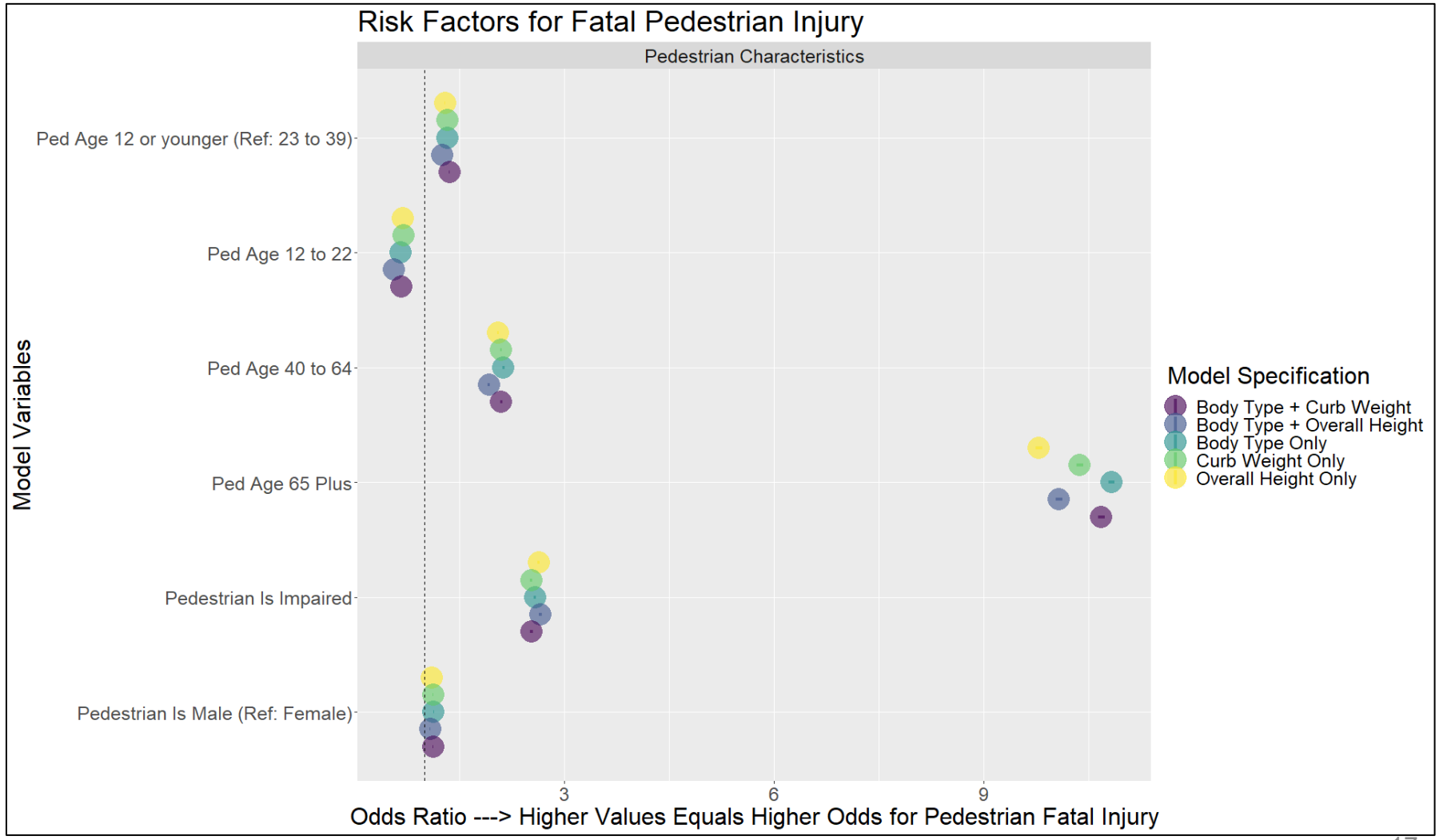
- Driver Impairment
  - Increase odds by 1.24 to 1.30
- Driver Age
  - Older drivers generally reduce odds
- Sex
  - Drivers being male increase odds of fatal



Findings:

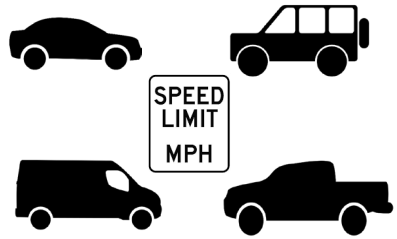
Pedestrian Characteristics

- Pedestrian Impairment
  - Increase odds by 2.5 to 2.6
- Pedestrian Age
  - U-shaped risk profile younger and older higher odds
- Sex
  - Males generally increase odds

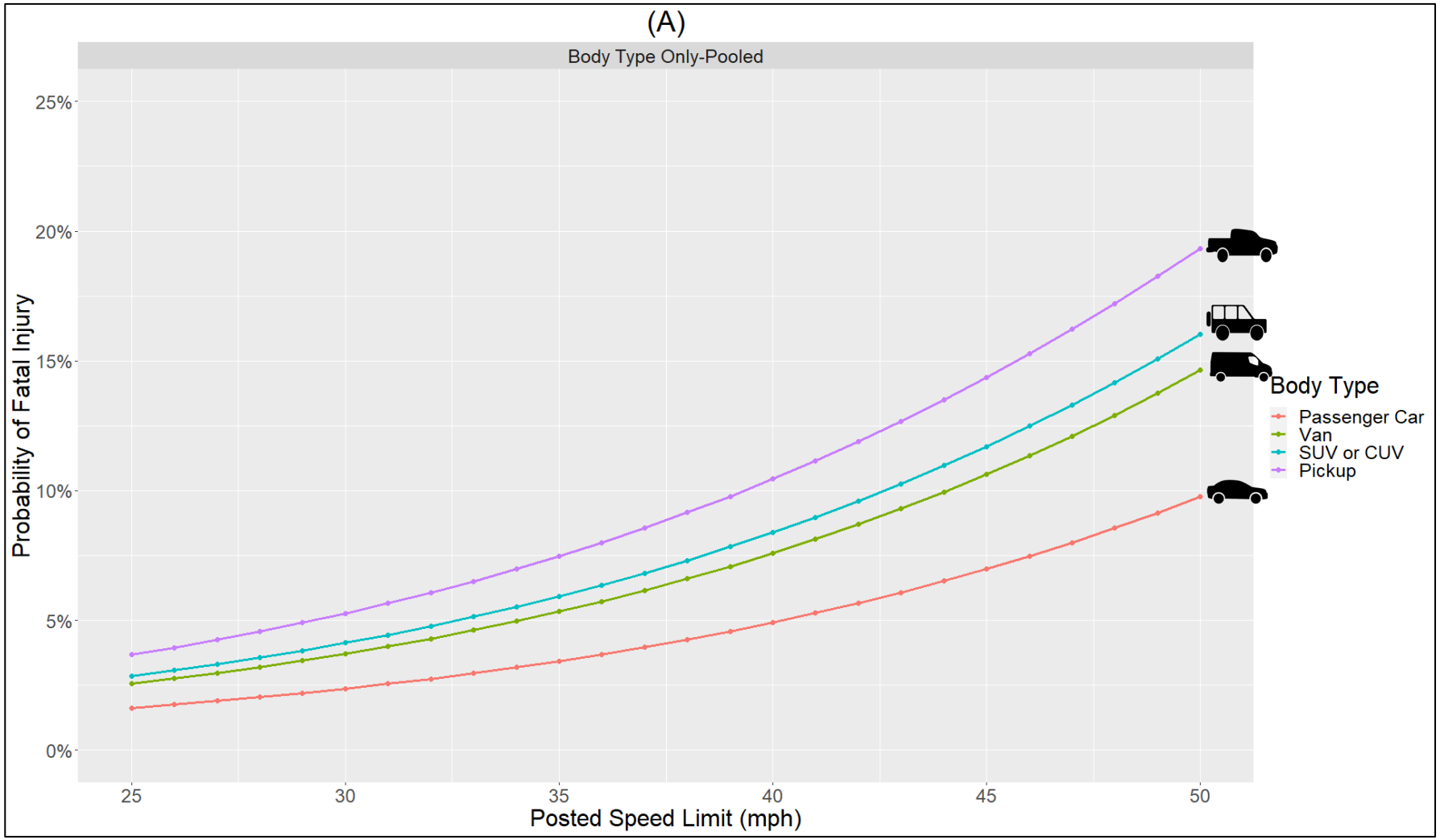


Findings:

Marginal Effects – Body Type and Speed

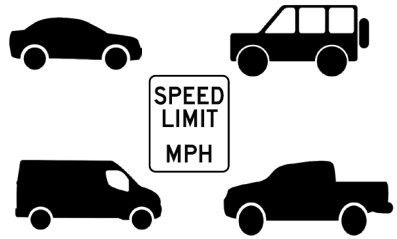


- Apply model to demonstrate changes in likelihood of fatal injury
- Body Type
  - Observable difference in odds by body type
- Speed
  - Obvious contributor to increasing odds of fatal injury

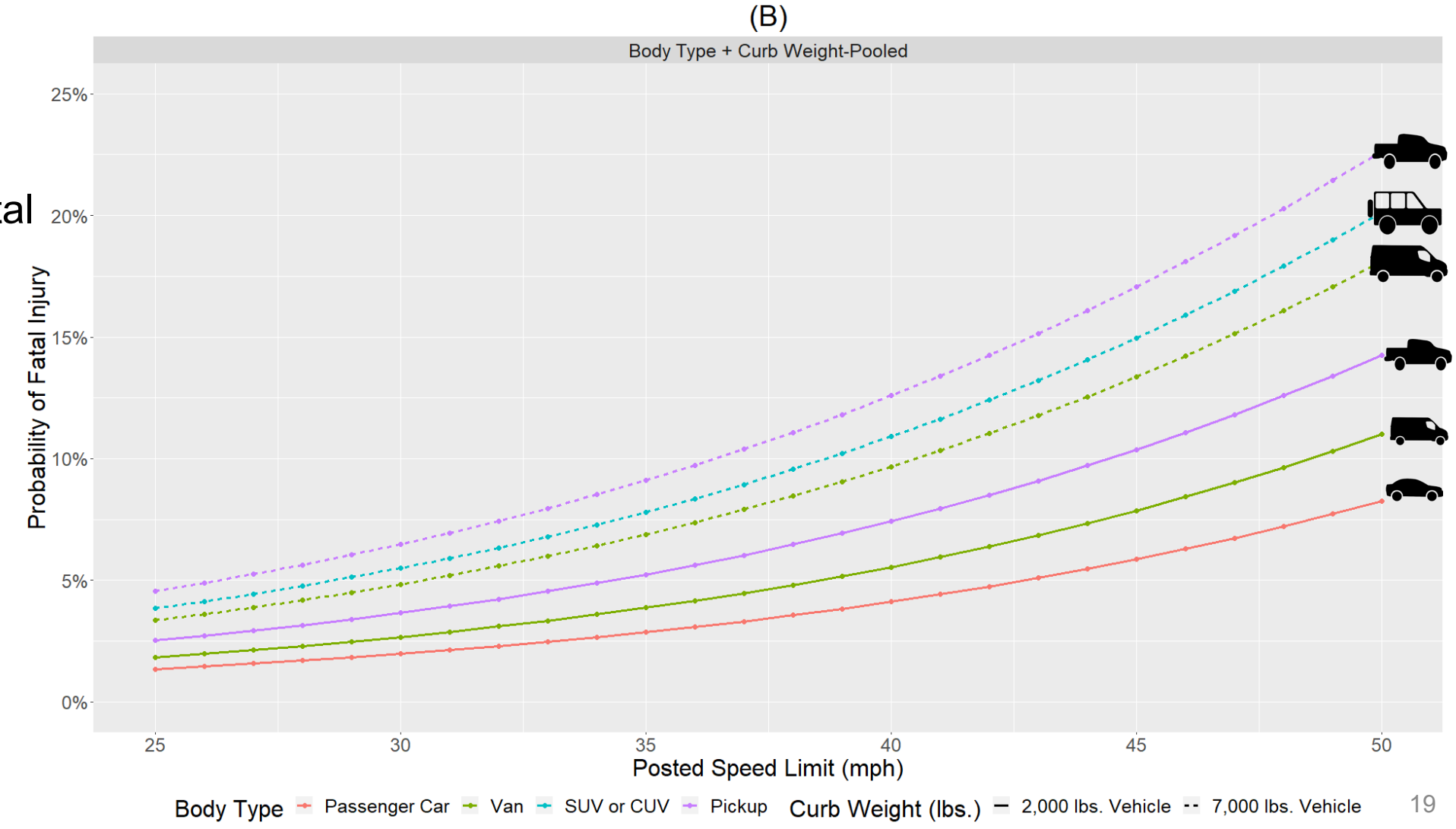


Findings:

Marginal Effects – Body Type + Weight and Speed

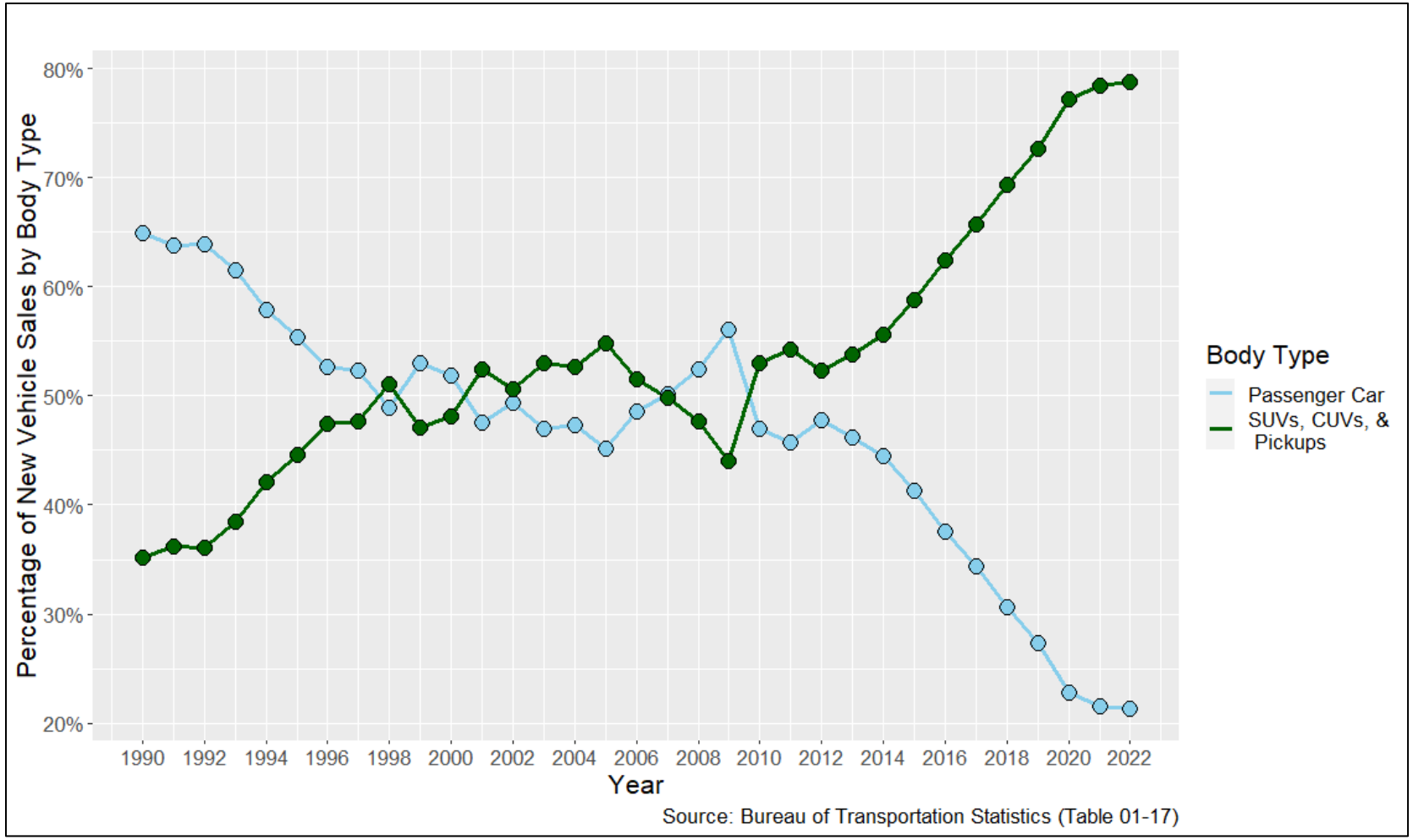


- Body Type and Weight
  - Both vehicle characteristics increase odds of fatal injury
  - No passenger vehicles in highest weight category



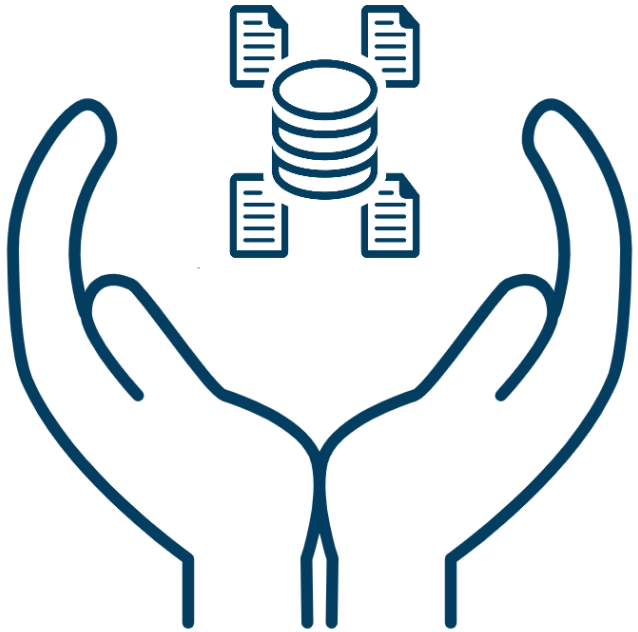
Recommendations

- Consider interventions that reduce adoption of larger vehicles (pricing, education, marketing, etc.)
- Improve agency intelligence on how vehicle design influences injury severity
- Track and monitor impact of vehicle size/design in crash outcomes
- NHTSA – improve vehicle data quality and access



Limitations

- Do not have operational speeds of vehicle
- Do not have all the vehicle characteristics that are likely important
  - e.g. automated emergency breaking, vehicle add-ons, A pillar design, multimedia
- Fewer observations in Oregon than other states
- Could try more sophisticated logit specification (try random parameters or interaction effects)
- Pedestrian characteristics like existing health issues
- EMS response time



Questions and Acknowledgments

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