NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Pedestrian Crash Factors, Trends, and Treatments

June 13, 2023

1:00 – 2:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING RCEP REGISTERED CONTINUING EDUCATION PROGRAM

Purpose Statement

This webinar will examine pedestrian crash trends and analyze various contributing factors. Presenters will also provide recommendations for cost-effective safety improvements throughout the roadway network.

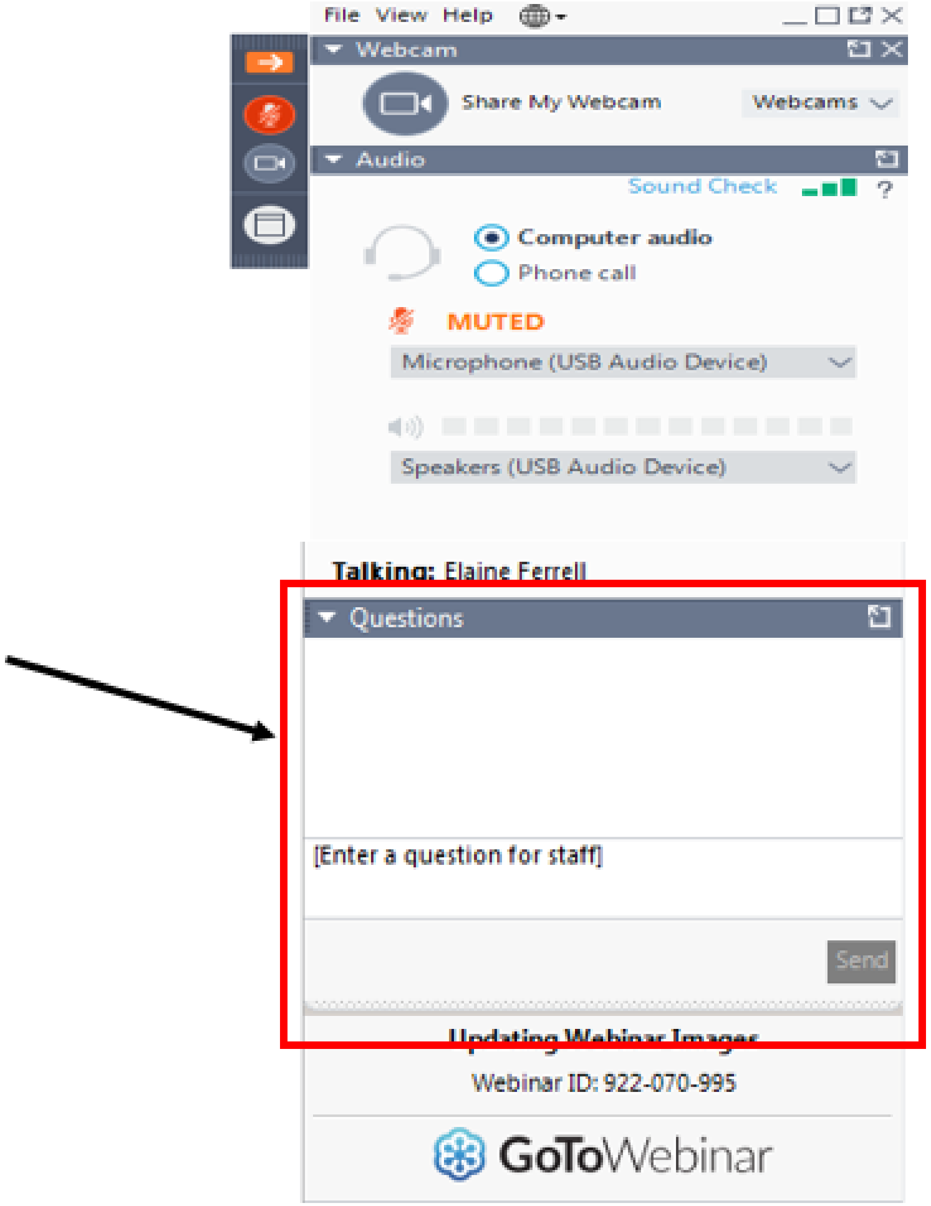
Learning Objectives

At the end of this webinar, you will be able to:

- Identify key pedestrian crash factors
- Predict the benefits and costs of various safety treatments for crashes at and between intersections, along corridors, and at low and high speed
- Ensure the most cost-effective treatments are pursued

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Noah Heath
Noah.Heath@txdot.gov
Texas Department of Transportation

Kara Kockelman
kkockelm@mail.utexas.edu
University of Texas, Austin

Laura Sandt
sandt@hsrc.unc.edu
UNC Highway Safety Research Center

Natalia Zuniga Garcia
nzuniga@utexas.edu
Argonne National Laboratory

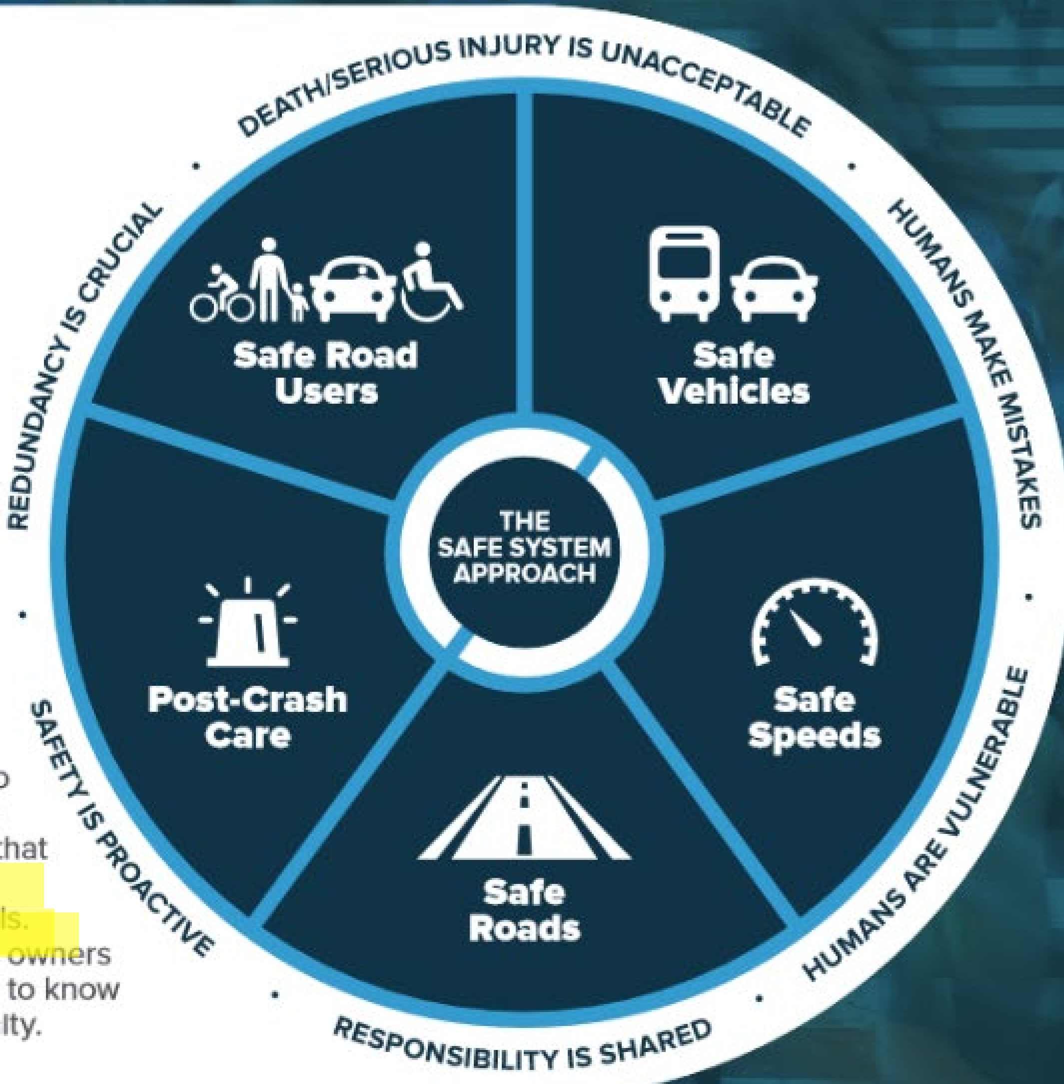
A "Systems" Perspective on Pedestrian Safety Challenges and Opportunities

THE SAFE SYSTEM

APPROACH

Zero is our goal. A Safe System is how we will get there.

Imagine a world where nobody has to die from vehicle crashes. The Safe System approach aims to eliminate fatal & serious injuries for all road users. It does so through a holistic view of the road system that first anticipates human mistakes and second keeps impact energy on the human body at tolerable levels. Safety is an ethical imperative of the designers and owners of the transportation system. Here's what you need to know to bring the Safe System approach to your community.

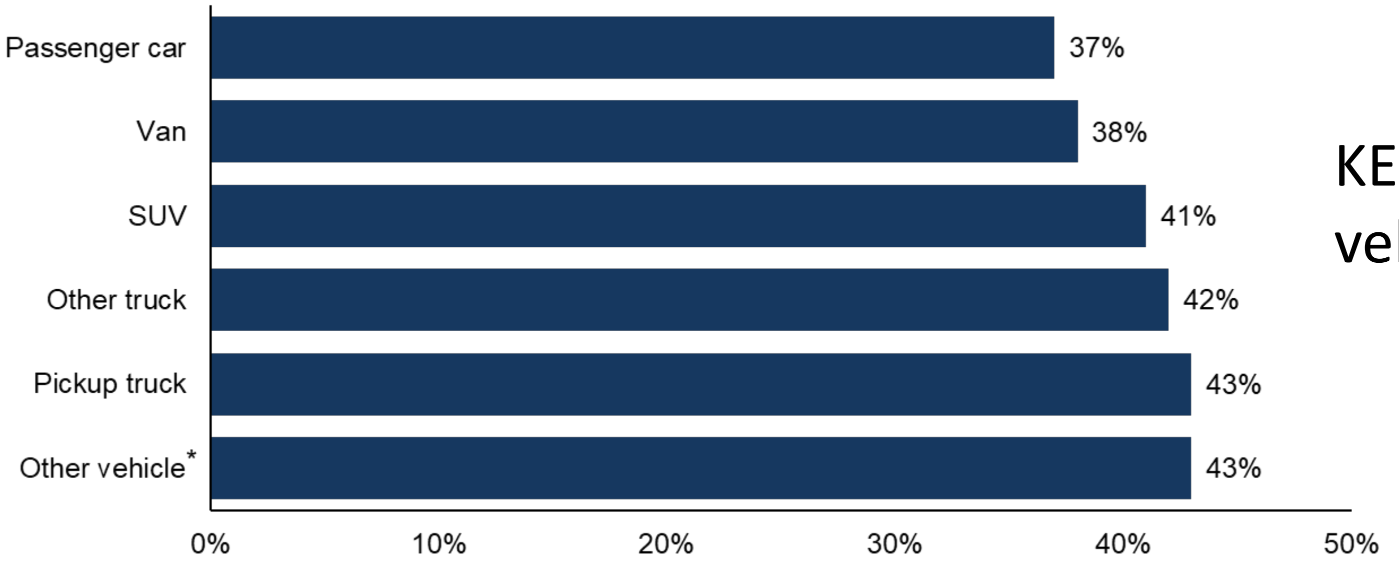


The human body cannot tolerate large energy forces

Safe Speeds

Safe Vehicles

Percent of pedestrians treated in NC emergency departments who are diagnosed with a serious injury, by striking vehicle type



*Other vehicle includes emergency vehicles, motorcycles, mopeds, taxicabs, buses, and other vehicles.
$p=.05$

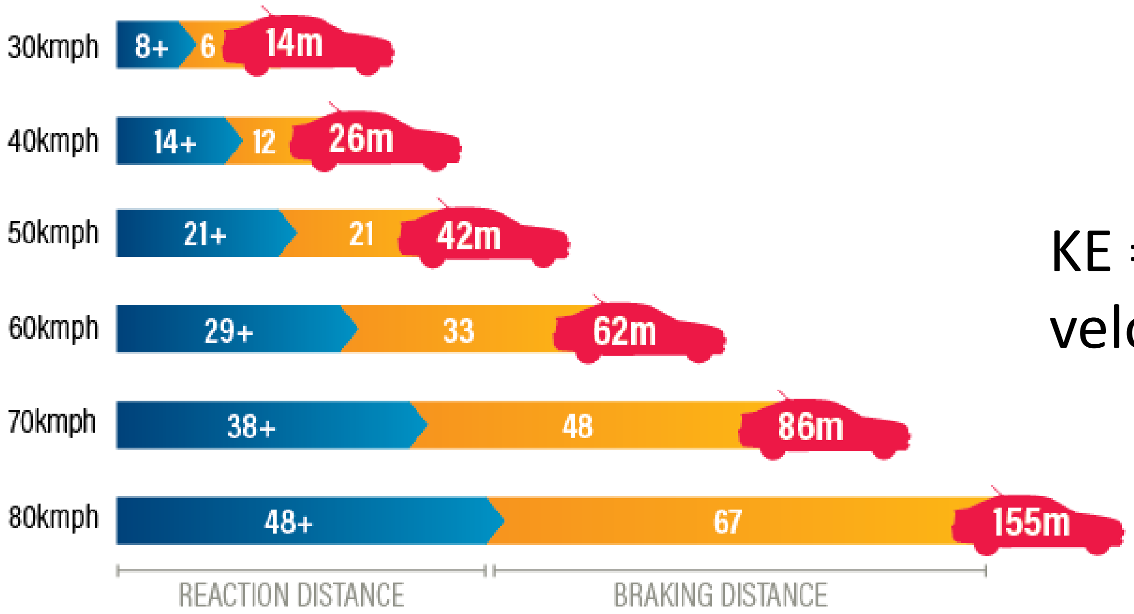
KE = ½ mass * velocity^2

Source: Harmon et al., 2021

Higher speeds and vehicle masses require more time to avoid a crash

Safe Speeds

Safe Vehicles



Note: Above distances are typical distances. The total stoppoing distance also depends on the thinking distance, road surface, weather conditions and age/condition of the vehicle.

Source: Cities Safer by Design (2015)
wri.org/publication/cities-safer-design

WORLD RESOURCES INSTITUTE

KE = ½ mass * velocity^2

Auto makers have *designed IN* opportunities for distraction and *designed OUT* time for risk response

Safe Speeds

Safe Vehicles

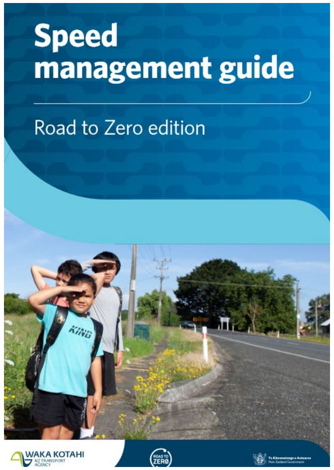
Source: Photos by Laura Sandt

The US *designs IN* high levels of kinetic energy in the system compared to Safe System adopting nations

Table 2 – One Network Framework urban street categories and safe speed limit ranges

Category	Description	Safe and appropriate speed limit*
Civic spaces	These streets have a higher place classification than other urban street categories, representing a higher level of on-street activity and higher-density adjacent land use generating that activity. These streets have a lower movement classification because they are mainly intended for localised on-street activity with little or no through movement.	10–20km/h (6-12mph)
Local streets	These streets provide quiet and safe residential access for people of all ages and abilities and foster community spirit and local pride. They are part of the fabric of Aotearoa New Zealand neighbourhoods, and they facilitate local community access.	30km/h (19mph)
Activity streets	These streets provide access to shops and services by all modes. They have a significant movement demand as well as place, so competing demands need to be managed within the available road space.	30–40km/h (19-25mph)
Main streets	These streets have an important place function and a relatively important movement function. They support businesses, on-street activity and public life and connect with the wider transport network.	30–40km/h (19-25mph)
City hubs	These are dense and vibrant places that have a high demand for people movement.	30–40km/h (19-25mph)
Urban connectors	These streets provide safe, reliable and efficient movement of people and goods between regions and strategic centres and mitigate the impact on adjacent communities.	40–60km/h (25-37mph)
Transit corridors	These streets provide for the fast and efficient long-distance movement of people and goods within the urban realm. They include motorways and urban expressways.	80–100km/h (50-62mph)

*The safe and appropriate speed limit will typically be at the lower end of the range unless design and infrastructure criteria are met to justify a higher speed limit. For details on the criteria for each ONF street category see tables 4 and 5.



Source: *New Zealand Speed Management Guide: Road to Zero Edition*, https://www.nzta.govt.nz/assets/resources/speed-management-guide-road-to-zero-edition/speed-management-guide-road-to-zero-edition.pdf

We often fail to integrate land use and transportation planning

School

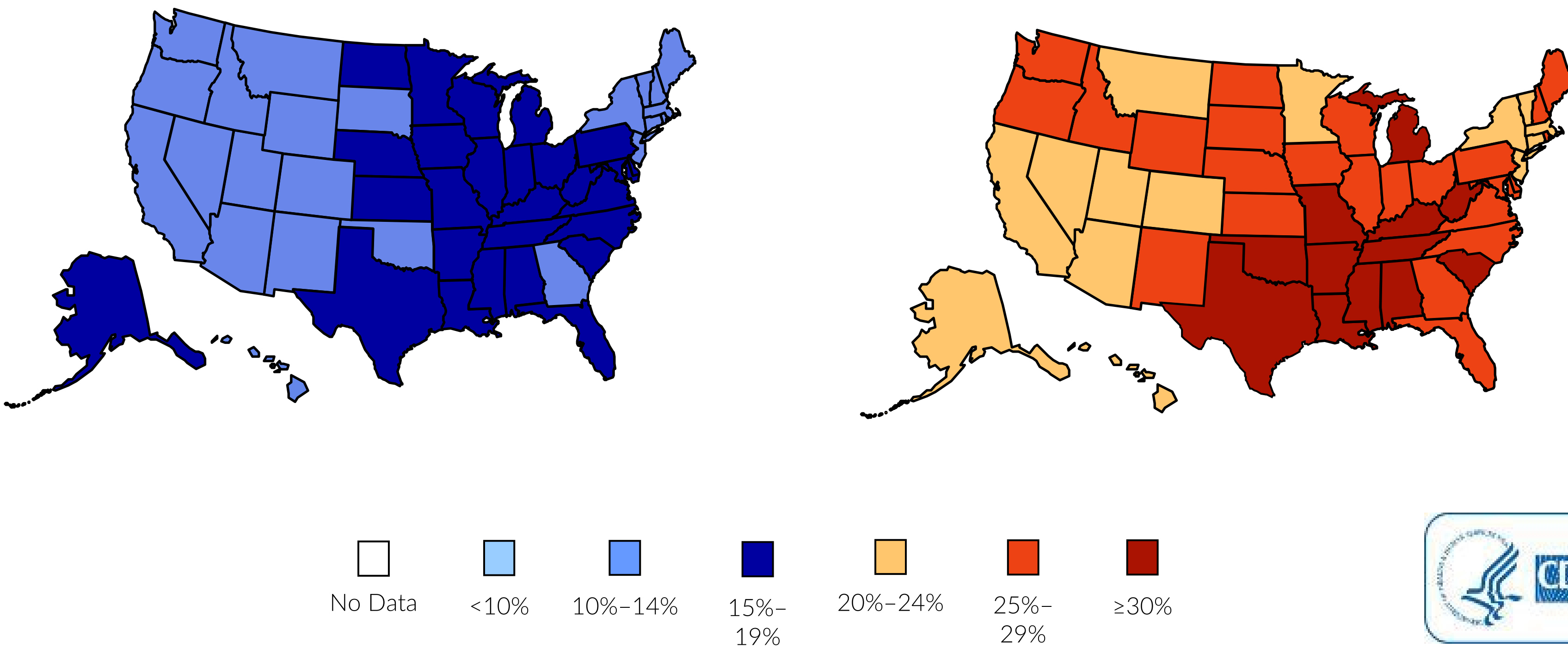
Transit stop

Pedestrian facility

Obesity Trends* Among U.S. Adults

BRFSS, 1995 and 2010

(*BMI ≥30, or ~ 30 lbs. overweight for 5’ 4” person)



Poor health makes us less able to survive an injury

- Aging makes us more sensitive to injury forces
- Other co-morbidities make us crash “intolerant” and more prone to falls:
  - Obesity and diabetes
  - Coronary artery, liver, renal disease
  - Dementia
  - Prescription and nonprescription opioid use, alcohol, and drug addition
  - Non-opioid prescriptions (e.g., warfarin, benzos, sleeping aids, antihypertensives, etc.)
  - Poly pharmaceutical use
  - Mental health conditions

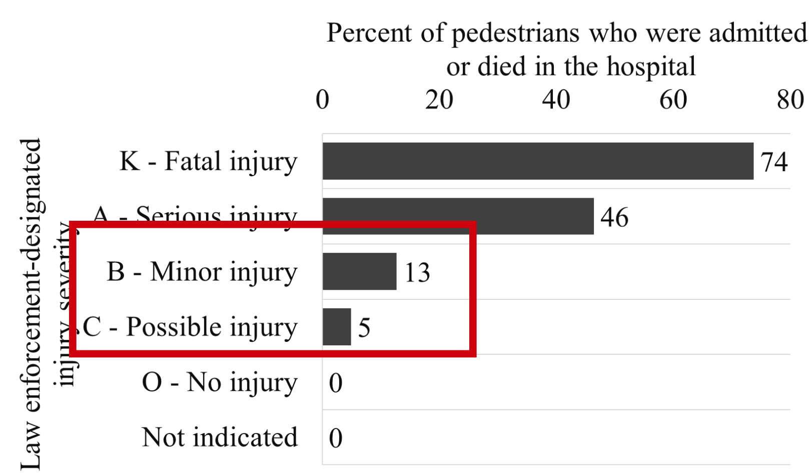
von Oelreich, 2020; Compton et al., 2016; Chihuri et al., 2017; Dassanayake et al., 2011; Hill et al, 2017; Rogeberg et al; 2019; Harmon et al., 2020; Ridella et al., 2012; Zegeer et al., 1993; Brown et al. 2016; Kirshenbom et al., 2017; Shankuan, 2006; Bhatti et al., 2015; Parreco et al., 2018; and others

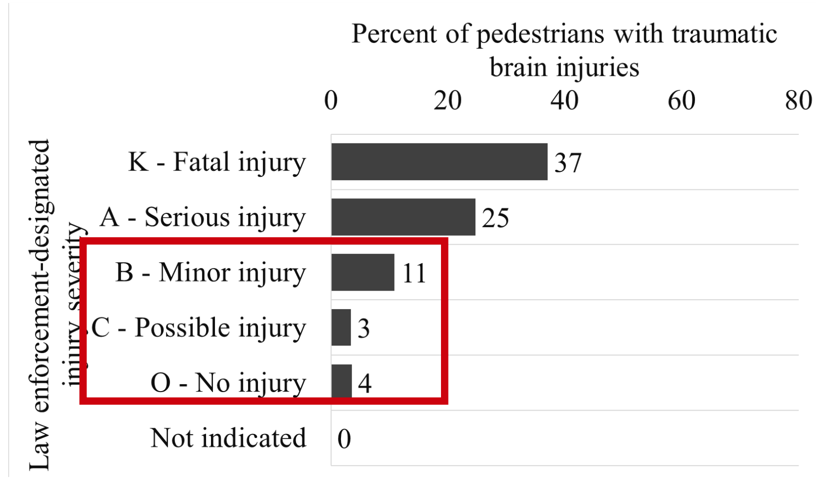
We significantly undercount pedestrian injuries and mismeasure injury severity

Post-Crash Care

Safe Roads

Serious Injury Indicators Found for Pedestrians with Minor Injury KABCO Designation

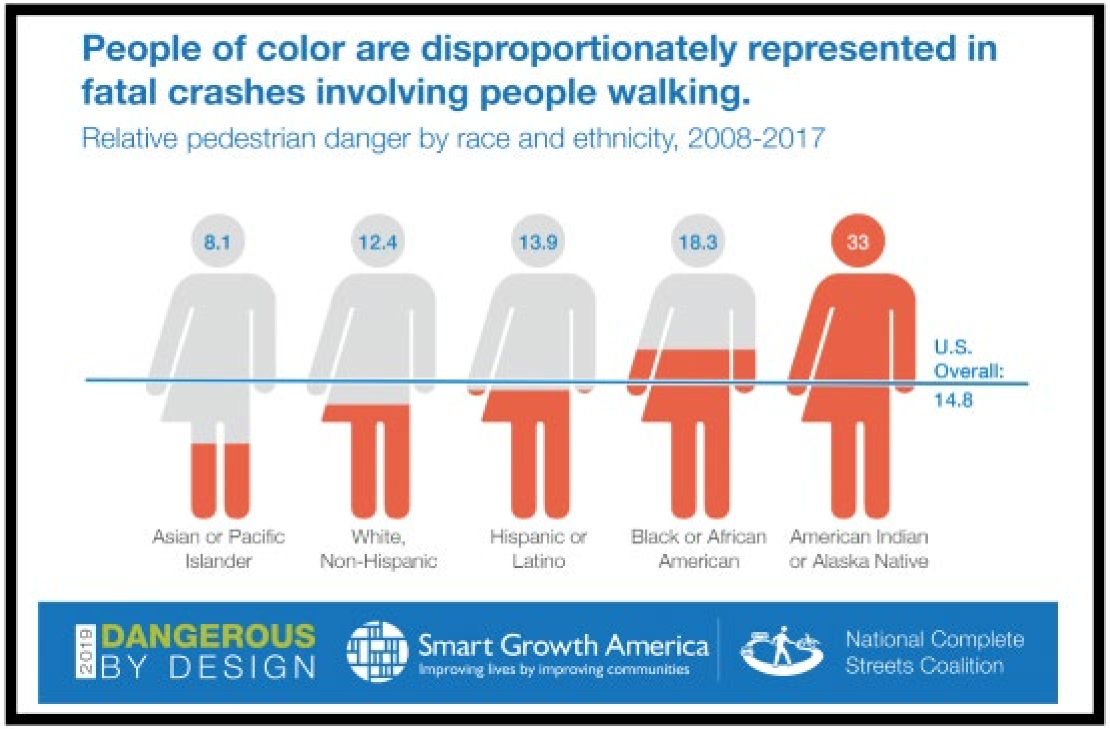




Peticolas, Harmon, Sandt, Waller, 2019.

As a result of system failures, we're facing widening disparities in transportation and health

- Access to opportunity
- Access to safe transportation facilities
- Access to and quality of post-crash care



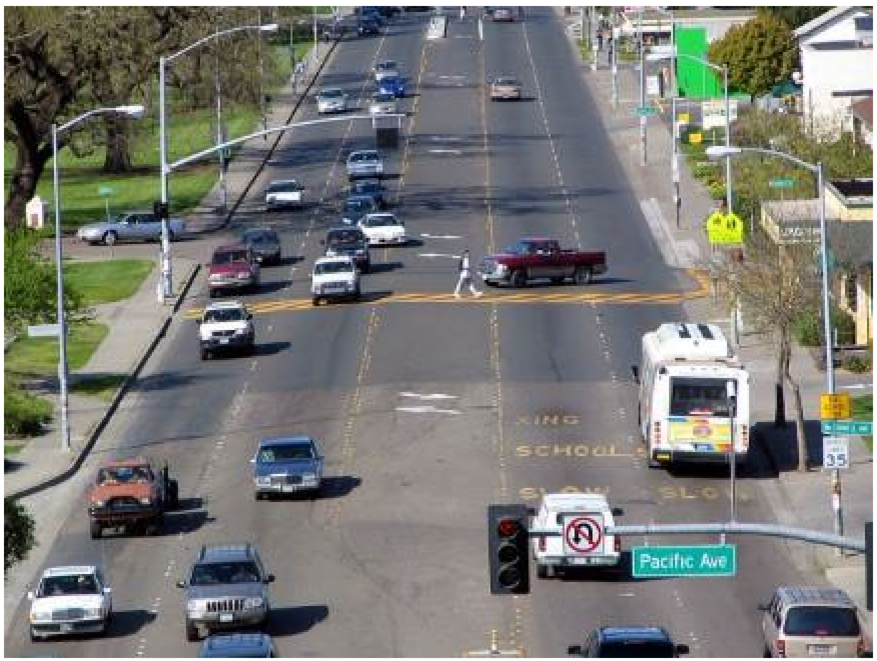
Can we acknowledge that responsibility and power for injury prevention is *not equally shared* and must be designed into the system?

Source: pedbikeimages.org / Dan Burden

Source: Laura Sandt

Can we limit exposure to kinetic energy while expanding options for affordable, equitable, and HEALTHY mobility?

Less of this…



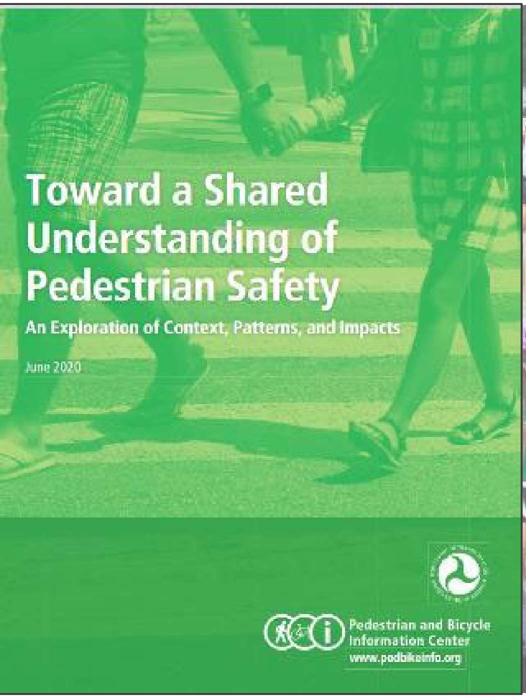
And more of this…

Predictability (of bike traffic)
Forgiveness (buffer)
Restrictiveness (turning movements)
Simplicity (color)
Separation (of modes)
Speed control

Source: www.pedbikeimages.org.

Thank you!

Laura Sandt, PhD
sandt@hsrc.unc.edu
@pedbikeinfo



THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

PEDESTRIAN CRASH FACTORS, TRENDS, & TREATMENTS: LESSONS FROM TEXAS & THE US

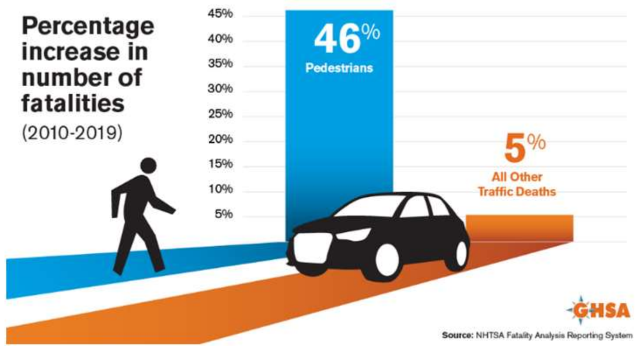
Drs. Kara Kockelman & Natalia Zuniga
+ Ken Perrine, Max Pleason, Max Bernhardt, Mai Vellimana et al.

Texas Department of Transportation

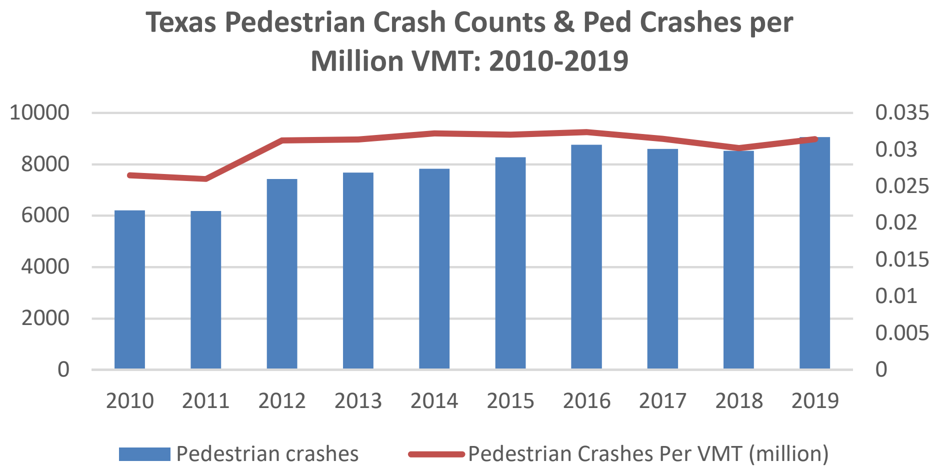
INNOVATE. EDUCATE.

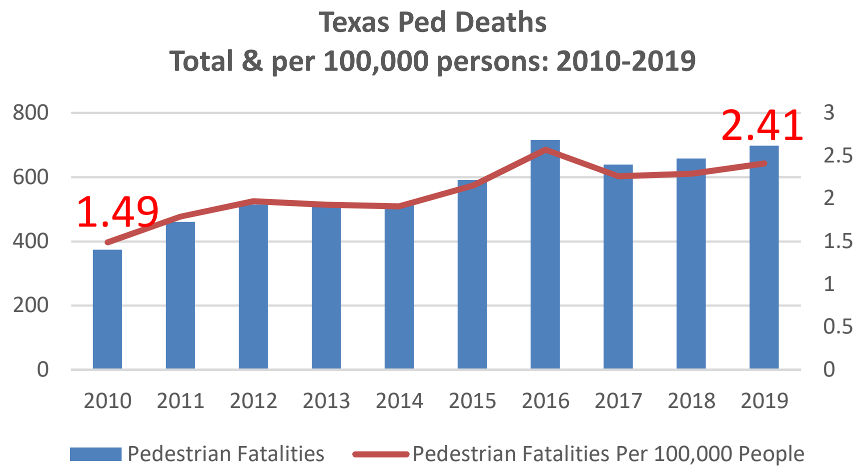
Pedestrian Crash Trends

Ped crashes per VMT appear **stable,**
but deaths rising: **+46% in USA**
& **+86% in Texas**, 2010 to 2019.



% Ped shares of crash deaths also rising:
12% → **17% US** & 12% → **19% Texas**



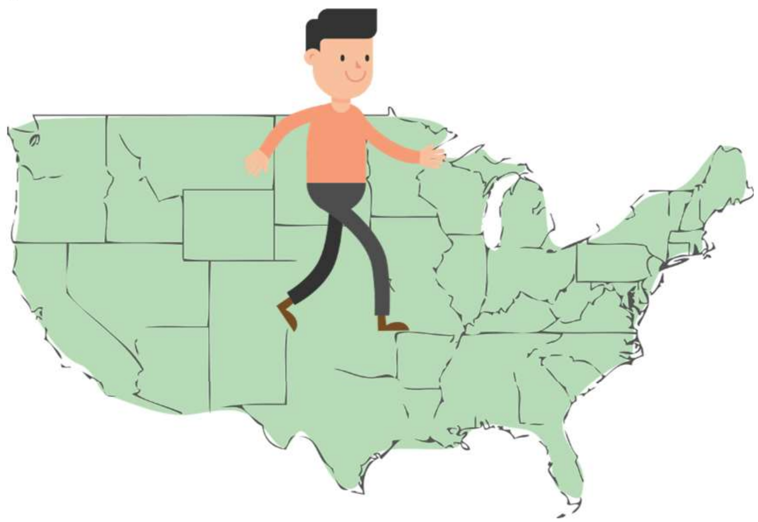


Ped Deaths: US vs EU

- Those in **UK, France, Germany, & Netherlands walk 136%, 118%, 90%, & 45% more than average American** (Buehler, 2022).
- **US ped death rates are 5-10 times higher per mile walked** (Buehler & Pucher, 2021).
- From 2010 to 2018, **US ped deaths per capita rose +19%** vs **+4%** in **UK** & **-16%, -11%, & -9%** in Denmark, Netherlands & Germany (Buehler & Pucher, 2021).
- **What are Americans doing wrong?** And what about **Vision Zero?**

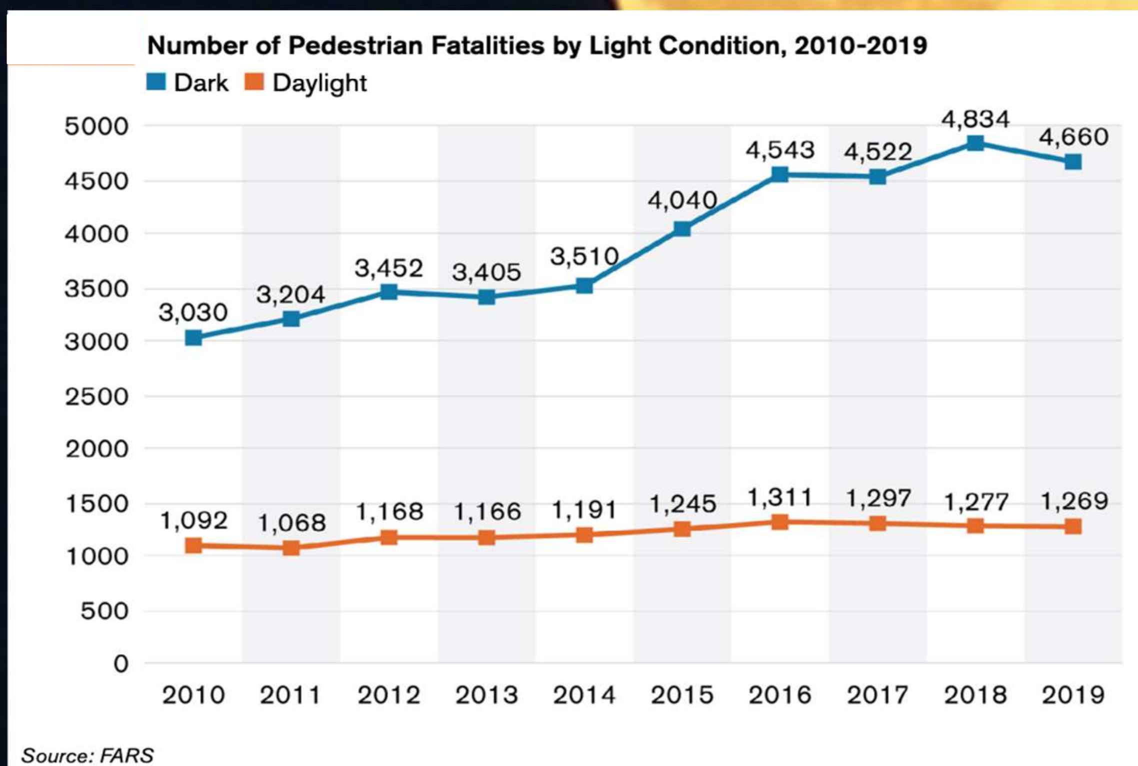
Walking in the US

- **Walking** = **10.5%** of **US mode split**, but **just 0.8%** of **person-miles traveled** (PMT) (NHTS, 2017).
- Pedestrians = **17%** **of all traffic deaths** (NHTSA, 2021).
- **Walk-trips** per household rose **6.5%** from 2001 to 2017, while **ped deaths** rose from **12% to 16%** of total deaths (NHTSA, 2019).



76% Deaths are in Darkness

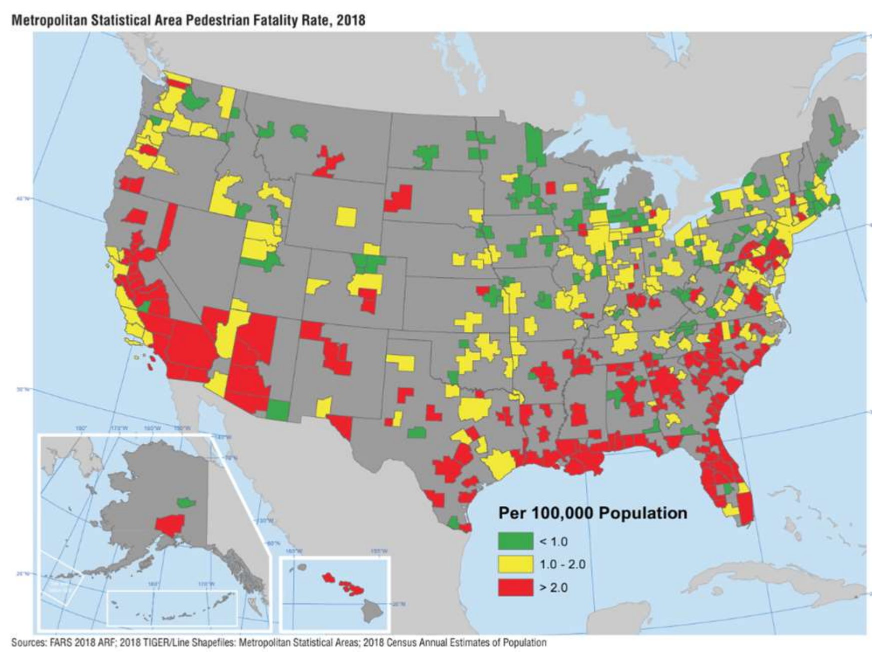
 # US ped deaths in darkness rose +54%, from 2010-19, while **daylight** deaths rose 16% (GHSA).



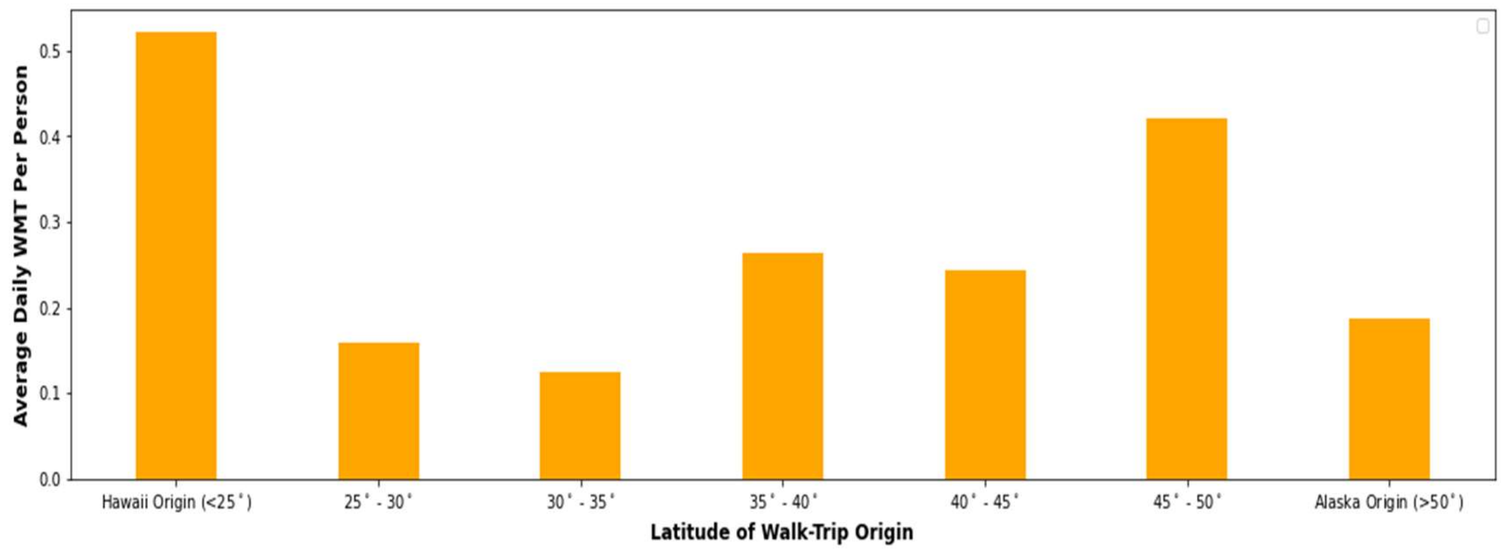
(GHSA, 2021)

US State by State

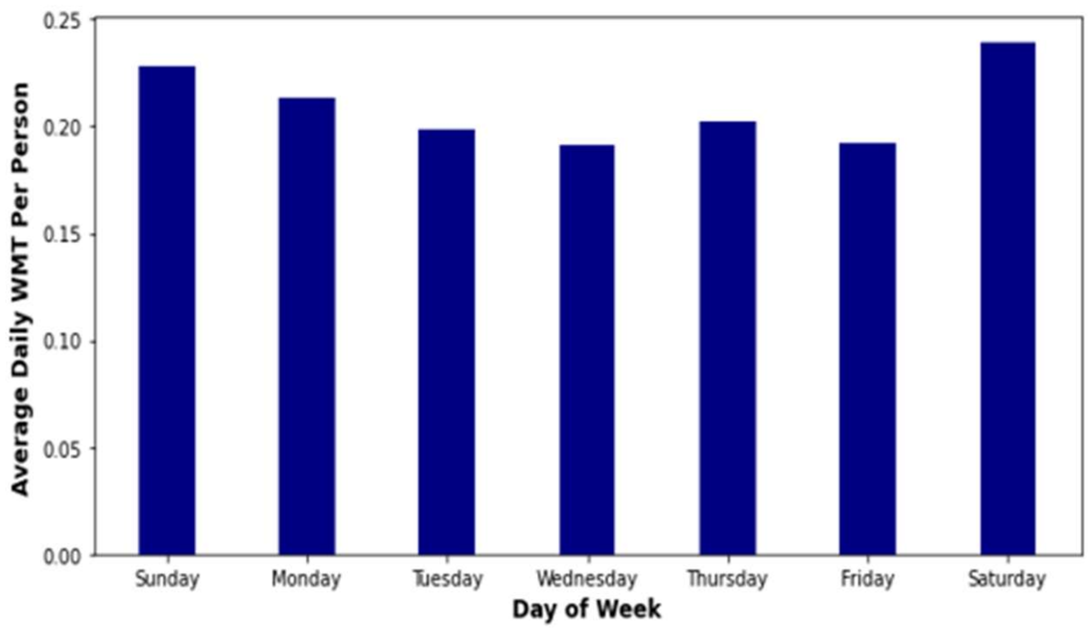
- **47% of deaths** = **Arizona, California, Florida, Georgia & Texas** = **southern latitudes**, vs. **33% U.S. population** (GHSA, 2020).
- **15 highest ped fatality rates** = **southern states**, & **New Mexico #1** - with 3.95 ped deaths/yr/100k persons (NHTSA 2019, 2022).
- Regardless of ped death **rate**: **southern US always leads.**



Sources: GHSA 2020 & NHTSA 2019

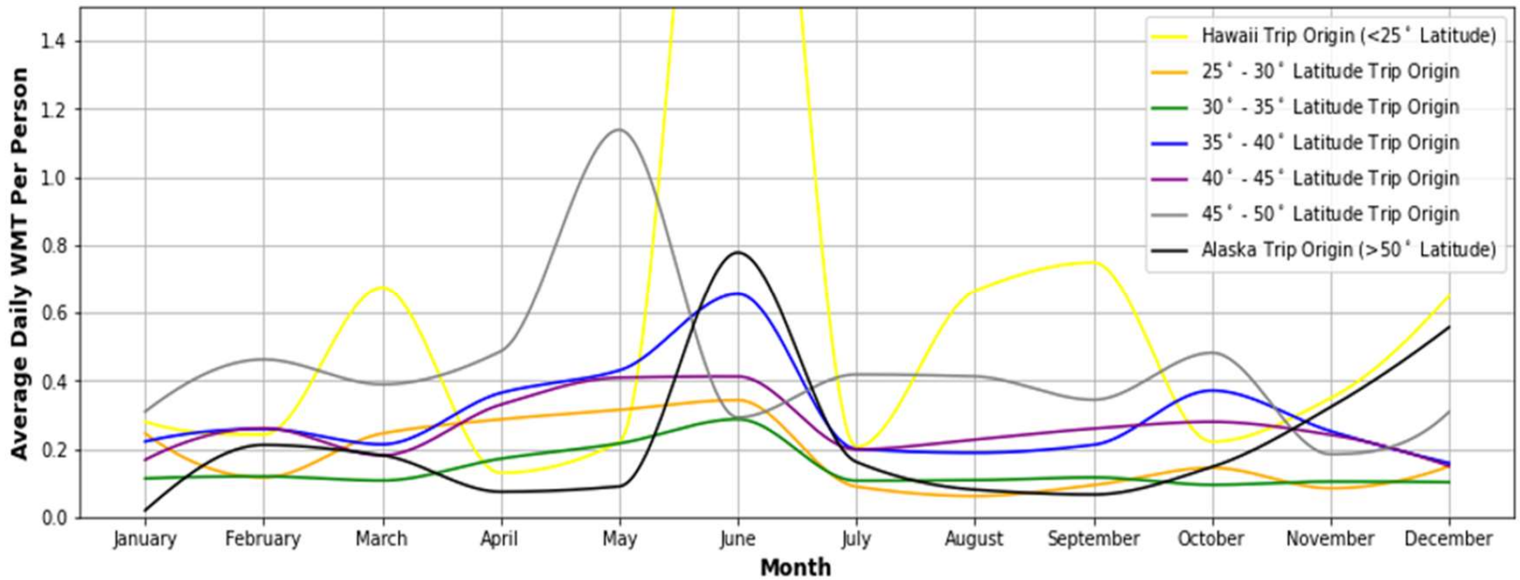


WHO WALKS MOST? WHEN & WHERE?

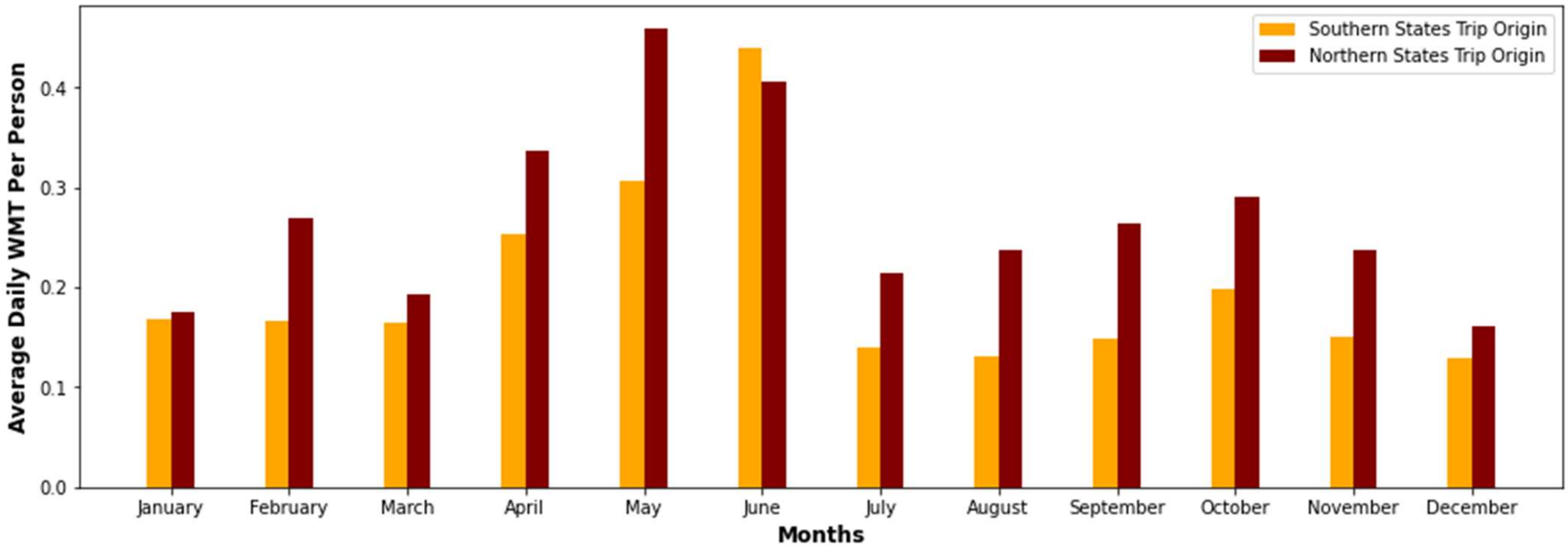


NHTS DATA

- **2016/2017 National Household Travel Survey** of 130k households (264k persons), making 924k person-trips over 375+ days (April through April).
- Provides **various demographic, location/position, time of day & day of year details** for **Americans' walk-miles traveled (WMT)**.
- **85%** of respondents did **not walk at all on the survey day**.
- **99.6%** did **not walk at night** on the survey day.



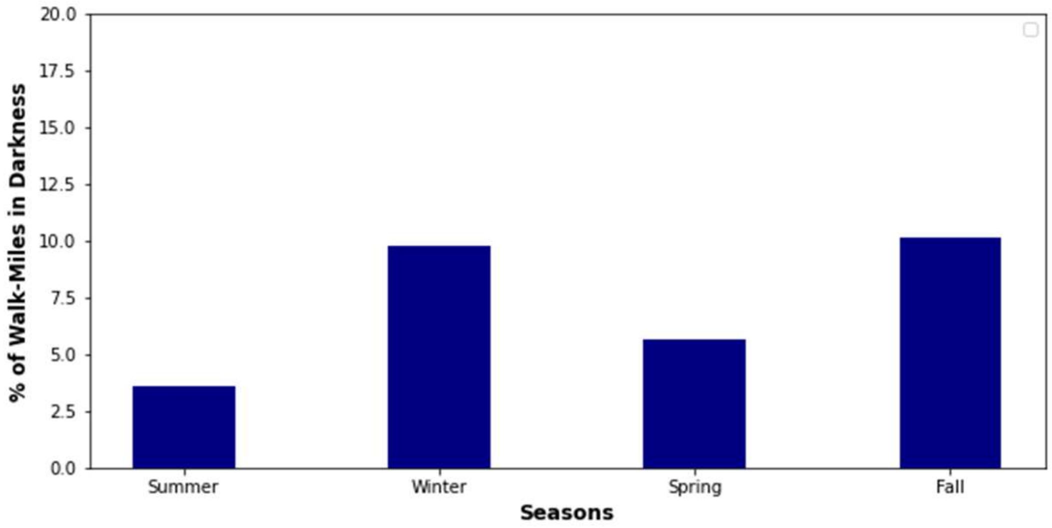
WMT/Person/Day by Month, for Northern vs Southern Trip Origins

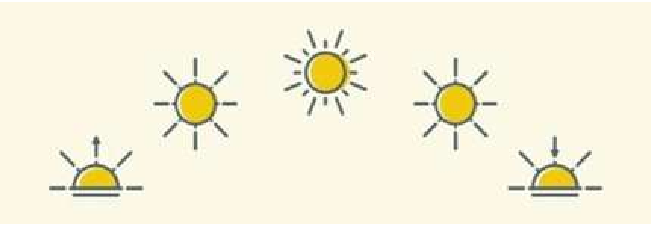


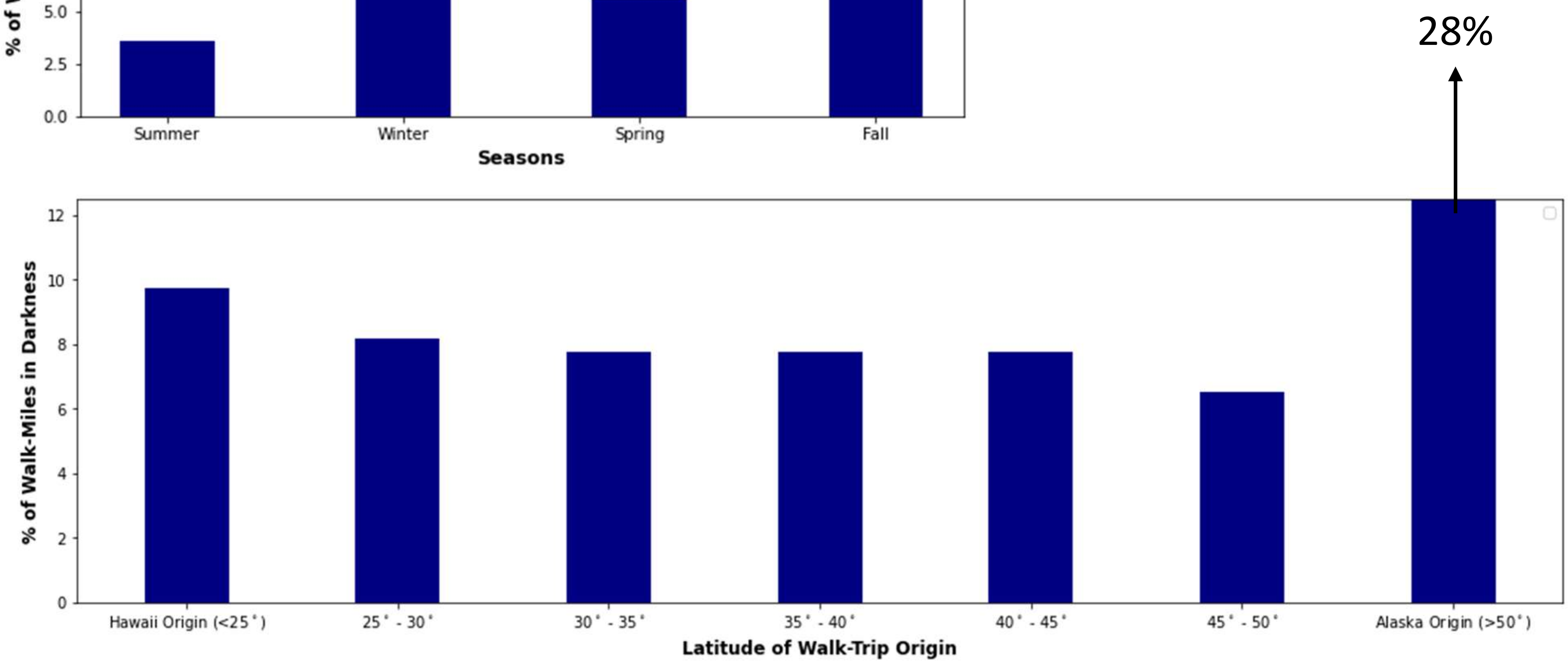
Northern = Above 40° latitude

%Walk-Miles in DARKNESS

by Season + Trip Origin Latitude







WMT Prediction: Logistic + Exponential

Hurdle regression models split WMT into (1) **probability of walking** on survey day + (2) **distance-walked** distribution.

Hurdle Selection (Logistic Model)		
	Coef.	*+1 SD Effect*
Constant	-0.834	
Age/10	-0.030	* next slide
Worker	-0.129	*
HH Income/10,000	-0.006	-4.9 %
African American	0.098	+3.9 %
Asian	0.141	+ 4.5%
Other Race	0.055	+ 2.2%
HS Graduate	-0.151	*
Some Degree	-0.063	*
Bachelor's Degree	0.221	*
Graduate Degree	0.370	*

- **Younger, non-whites of lower income** with **college** degrees are more likely to **take a walk** on survey day.
- **Non-working, more educated males** are walking **longer distances**, on average.
- **Season effects** on WMT **exceed Latitude** effects, which **exceed Demographic** impacts.

Base Case = White Traveler with high school degree, on Saturday, during Fall, in Alaska.
All variables = very statistically significant (p-value < 0.05). N = 254,295, Pseudo R2 = 0.019.
* Variables appear in both walk + distance equations, with Net effects showing on next slide.

Distance Model (Y = WMT/day if Walk trip taken)

Exponential Regression Model		
	Coef.	*+1 SD Effect*
Constant	-1.761	
Age/100	-0.035	-7.4%
Male	0.126	6.5%
Worker	-0.162	**-16.4%**
Length of Daylight	0.034	6.3%
High School Grad	0.285	2.2%
Some Degree	0.212	5.3%
Bachelor's Degree	0.335	**30.7%**
Graduate Degree	0.407	**+ 44 %**
Monday	0.119	4.4%
Wednesday	0.126	4.6%
Thursday	0.139	5.2%
Summer	0.964	**-88 %**
Winter	1.341	**-94 %**
Spring	0.771	**-80 %**
Hawaii Origin (< 25 Latitude)	0.870	-5.9%
25 - 30 deg Latitude Origin	0.925	**-33.9**
30 - 35 Latitude Trip Origin	1.157	**-66 %**
35 - 40 Latitude Trip Origin	1.069	**-64 %**
40 - 45 Latitude Trip Origin	0.933	**-65 %**
45 - 50 Latitude Trip Origin	1.100	**-31.4**

Exponential Regression Model (cont.)		
	Coef.	*+1 SD Effect*
Alabama Resident	-0.657	-3.2%
Arizona Resident	-0.223	-3.2%
Florida Resident	-0.167	-1.7%
Georgia Resident	-0.139	-3.4%
Idaho Resident	-0.350	-1.9%
Louisiana Resident	-0.376	-1.6%
Mississippi Resident	-0.662	-2.6%
New Mexico Resident	-0.576	-2.4%
North Carolina Resident	-0.115	-2.8%
South Carolina Resident	-0.329	**-7.1%**
Texas Resident	-0.202	**-7.7 %**
Virginia Resident	-0.305	-2.2%
West Virginia Resident	-0.356	-1.4%

Base Case: White Traveler w/ High School Degree, on Saturday, during Fall, in Alaska.
Season x Latitude interaction effects are negative, causing negative practical impacts for Summer, Winter & Spring overall.

WMT at Night Results

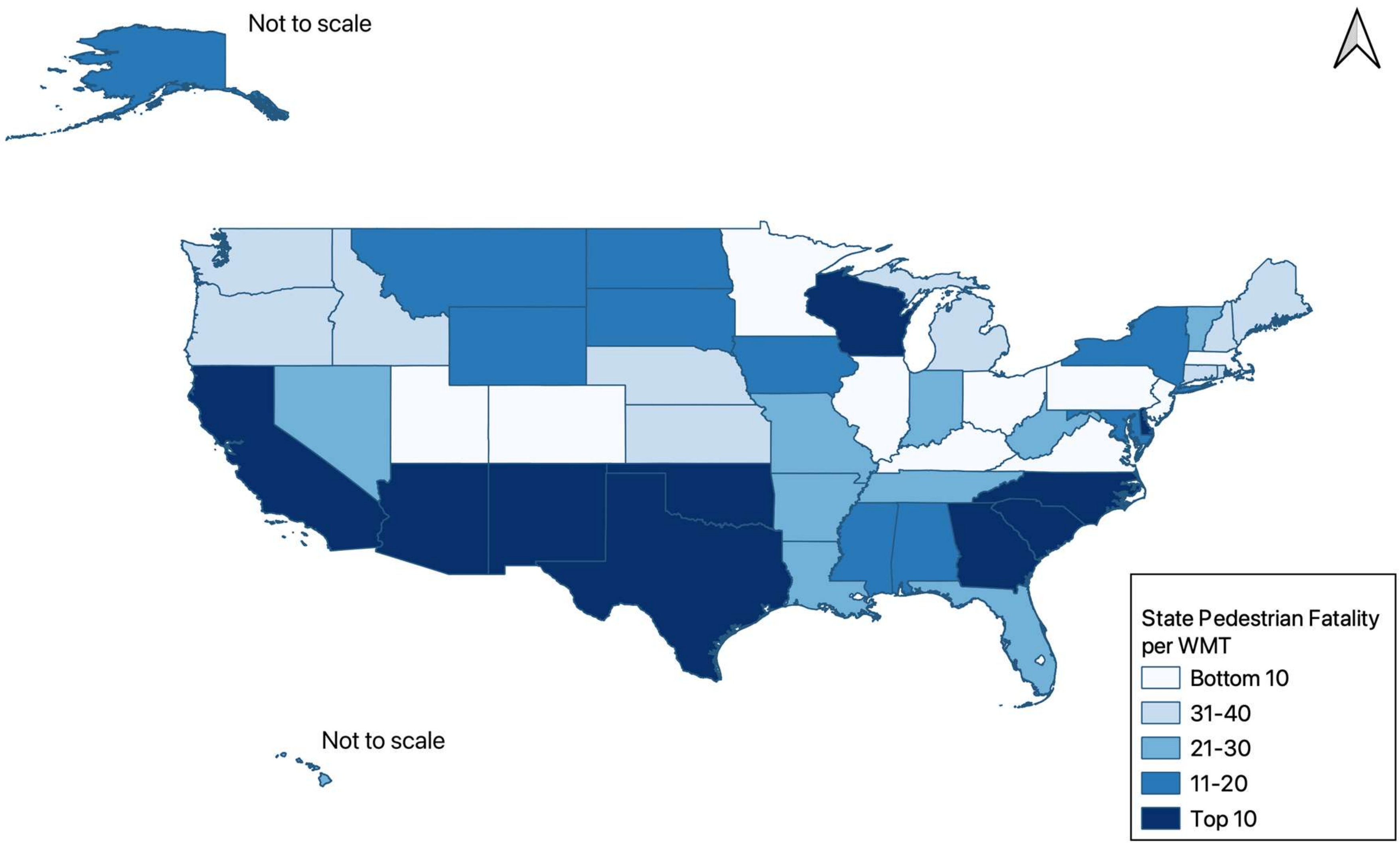
Night-time walking distances are **very hard to predict…**

Hurdle Selection (Logistic) Model			
	Coef.	*P-val*	*+1 SD*
Constant	0.134	0.000	
Male	0.076	0.013	*
Worker	0.112	0.001	+14.6 %
HH Income/10k	-0.011	0.000	-12.7 %
African American	0.091	0.079	5.6%
Bachelor Degree	0.177	0.000	+18.9 %
Graduate Degree	0.269	0.000	+24.6 %

Exponential Regression Model			
	Coef.	*P-val*	*+1 SD*
Constant	-0.987	0.000	
Age/10	0.094	0.000	+22.7 %
Male?	0.156	0.051	+15.4 %
Asian?	0.306	0.018	2.6%
E Coast Origin (Long > 80°)	-0.216	0.081	-9.5%
Connecticut Resident	0.785	0.010	3.4%
Washington DC Resident	0.463	0.041	2.0%
Illinois Resident	0.357	0.128	3.1%
Louisiana Resident	1.573	0.000	6.5%
Massachusetts Resident	0.450	0.017	2.6%
New Mexico Resident	1.337	0.000	5.6%
Ohio Resident	0.541	0.050	4.6%
Pennsylvania Resident	0.434	0.157	3.8%
South Dakota Resident	0.827	0.008	4.0%
Tennessee Resident	0.884	0.000	5.3%
Wisconsin Resident	0.246	0.042	6.9%

Base Case: White Traveller w/ High School Degree, on Saturday, during Fall, in Alaska. N = 254,295, pseudo R2 = 0.072

Ranking States by Ped Deaths per WMT

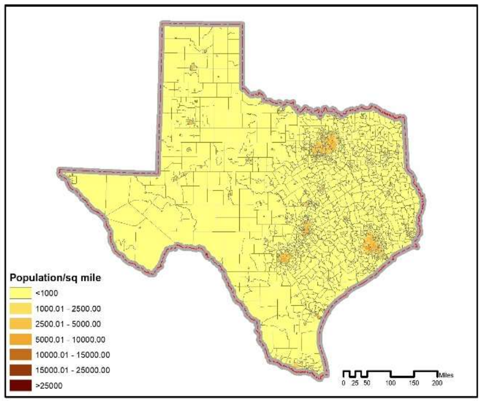


WMT Summary

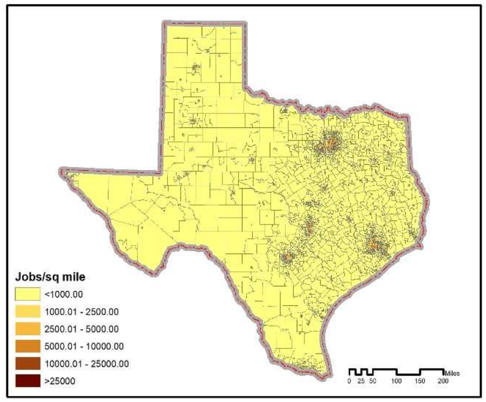
- **Season & latitudes** (locations) have **greatest impacts on walk-mode & distance choices**.
- **Day of the week, race, education, age, income, & worker status also important** for WMT.
- **Night-time walking** is very hard to predict.
- **Americans in southern latitudes walk less & face higher crash risk per mile walked,** despite **more sunshine & warmer weather.**
- **Are less enforcement, poor design, weaker licensing laws, drinking & driver culture** contributing to **higher ped fatality rates** in **southern settings?**

FINDING HOT SPOTS & SELECTING TREATMENTS

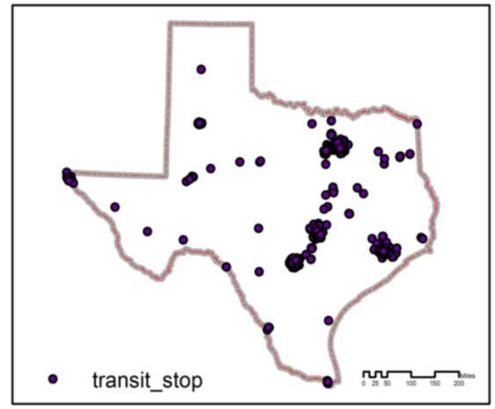
Population Density



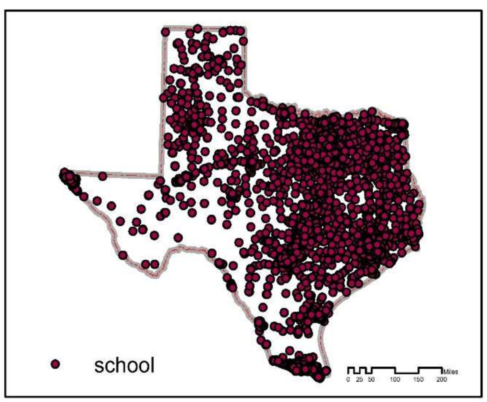
Job Density



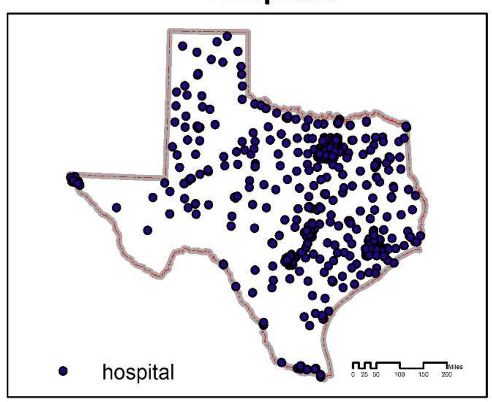
Transit Stops



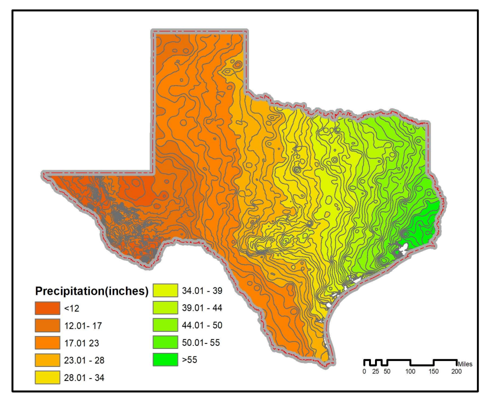
Schools



Hospitals



Average yearly precipitation(1981-2010)



Data Details

CRIS = TxDOT's **Crash Records Information System**

= police-**reported** + **recorded crashes only**.

Over **5.6M** police-recorded crashes 2010-2019:

- **78,497 ped crashes** & **5,674** pedestrian **deaths**.

Available Variables:

- **Crash** type, injury severity, location, time, lighting, …
- **Vehicle** & **Person** attributes.

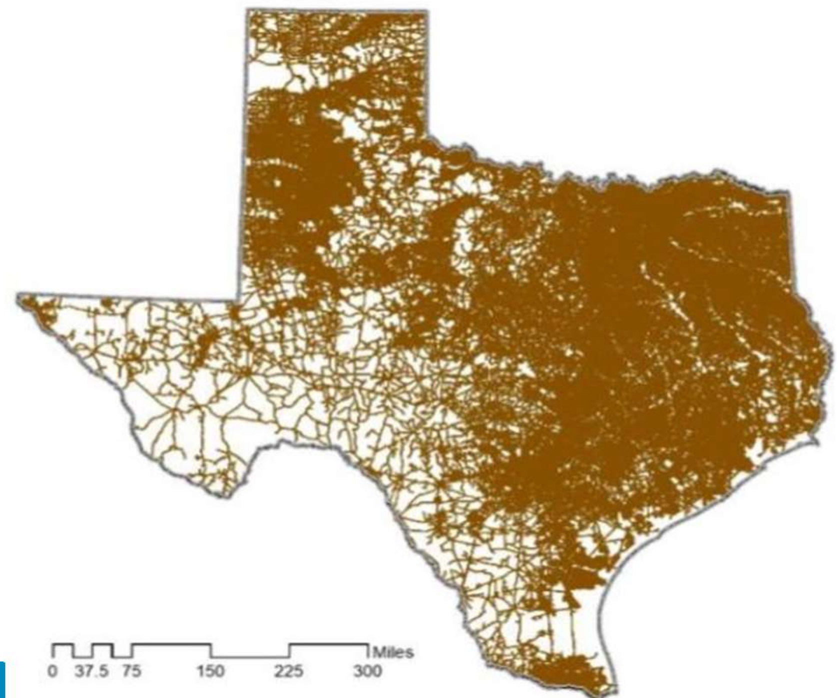
+ **Roadway details:** Link design attributes, AADT, VMT + geometry

+ **Land Use:** Population & jobs densities (from ACS & LEHD), matched to nearest Census tract centroid.

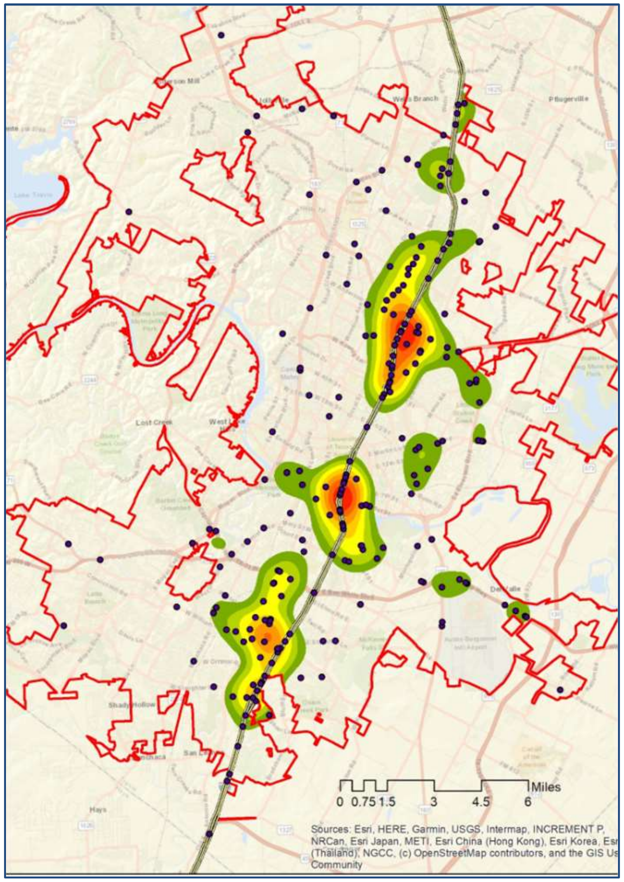
+ **Annual Rainfall**, distances to nearest School & Hospital, **#Transit Stops** along segment, inferred **Walk-miles traveled** nearby, ...

Texas' Roadway Inventory

- **Massive** shapefile of **all roadways.**
- **Over 800,000 segments** averaging 0.43 miles, representing >**330,000 centerline-miles** of geometry:
  - Street name & functional class
  - # Lanes & width
  - Curvature & grade
  - Median/shoulder type & width
  - Average daily flow (estimated)



Austin's Hotspots 2010-2019



28% of Austin's ped **deaths** on **IH-35**

- South of 290 & Between 290 & 183
- Between East Cesar Chavez & Riverside Dr
- Between Wlm Cannon & Slaughter Ln

Other Hotspots:

- North Lamar Blvd (183 to Braker Ln)
- US 183 (East of IH-35, to 290)
- US71 (between US 183 & SH 130)

>50% of dead may be **Homeless** **(!)**

Texas' Top 100 Most Crash Prone Corridors, Ranked

These are among **Top 100 corridors**
found in central Austin area using this methodology.

Identifying Hotspots Within Corridors: Austin IH-35 Example

Visual distribution of crashes for I-35 frontage roads north of river shows **clear problem spots at 6th & 7th Streets**.

Computing Benefit-Cost Ratios (BCRs)

B_{ijt} = **Benefits** = saved crash costs (using crash modification factors & crash history at site), due to improvements "*j*" in location "*i*" in year "*t*"

C_{ijt} = **Costs** = treatment cost + delayed motorists (if relevant)

$$BCR = \frac{\sum_i \sum_t B_{ijt}}{\sum_i \sum_t C_{ijt}}$$

$$B_{ijt} = CrashCost_{ijt}(1 - CMF_j)$$

$$C_{ijt} = Treatment_{ijt} + Delays_{ijt}$$

where CMF_j = crash modification factor of treatment j, &
$Delay_{ijt}$ = delay cost (if applicable) of adopting treatment j at location i in year t (assuming **$14.14/vehicle-hour** value of travel time).

Benefit-Cost Ratio Example

6th St. & SB I-35 Frontage Rd: Pedestrian Leading Interval (1 sec added delay for vehicles)

Cost of installation = $1,750 with **15% ped-crash reduction factor (CRF)**

Delay Costs = ADT on I-35 SB Frontage Road (30,614) + ADT on 6th St (11,695) x 365 days = 15,442,420 vehicles x 10 years = 154.4M seconds of delay over 10 years

= 42,896 vehicle-hours of delay over 10 years

x **$14 value of time** (per vehicle-hour) **= $606,544 delay costs**

Total Costs = $606,544 + $1,750 = **$608,294 cost estimate**

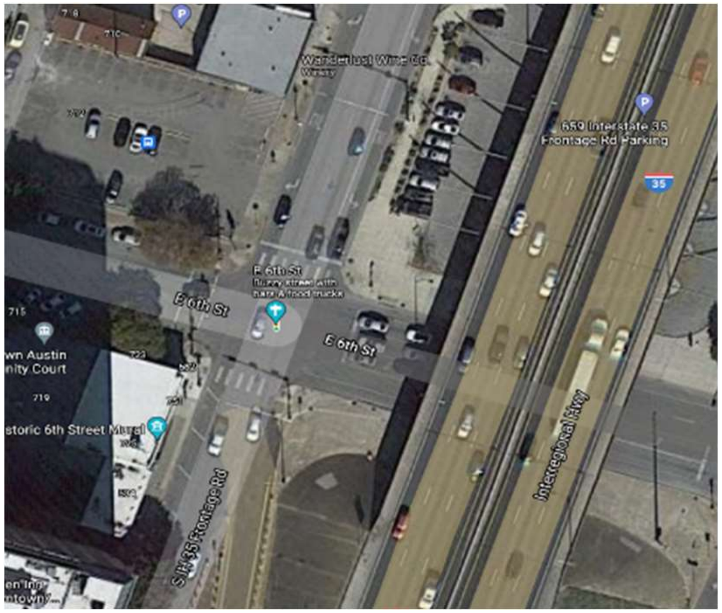
versus Benefits:

5 non-incapacitating + 2 incapacitating injuries 2010-2019

= ($500,000 x 5) + ($3.5 million x 2) = $9.5 million total

$9.5 M x **0.15 CRF** = **$1,425,000 benefits estimate**

→ BCR with delay costs = $1,425,000 / $608,294 = 2.34



Basic Roadway Treatments

Treatment	Cost (average)	Cost Unit	Avg CMF
Basic curb & gutter	$21	Linear Foot	0.89
"Daylighting" Left Turns & Crossing Locations	$300	Each	0.75
Gateway signage	$22,750	Sign + Structure	0.83
Narrowed curb radii	$32,500	Per corner	0.81
Pedestrian-hybrid Beacons	$57,560	Each	0.71
Prohibition of left turns	$800	Per sign	0.28
Prohibition of right turn on red	$800	Per sign	0.77
Crosswalk (Hi-vis)	$2,540	Each	0.63
Raised Crosswalk	$18,995	Each	0.64
Flashing Beacon	$10,010	Each	0.85
Rectangular Red Flashing Beacon (RRFB)	$22,250	Each	0.53
Raised Center Medians (Uncontrolled)	$7.26	Square Foot	0.93
Barriers Installed on Top of Concrete Median	$210,000	Per mile	0.63
Advanced Stop/Yield Sign	$520	Each	0.75
Install Crosswalk Sign	$570	Each	0.91
Narrow Roadway from 4 Lanes to 3 Lanes	$20,000	Per Mile	0.71

These treatments include **construction** of basic infrastructure & are focused on limiting &/or warning **drivers**.

Basic Roadway Treatments

Raised Crosswalks

Shorter Corner Radii

Crosswalk Signage

Traffic Calming Treatments

Treatment	Cost (average)	Cost Unit	Avg. CMF
Speed Humps	$2,640	Each	0.64
Speed Limit Reductions - 15% decrease	$135	Each (sign)	0.89
Speed Limit Reductions - 10% decrease	$135	Each (sign)	0.79
Speed Limit Reductions - 5% decrease	$135	Each (sign)	0.705
Chicanes	$9,960	Each	0.69
Diverters	$26,040	Each	0.69
Curb Extensions	$13,000	Each	0.75
Traffic circle	$85,370	Each	0.75
Road Diet	$40,000	per mile	0.71
Hardened left turns	$2,500	Each	0.65

- These treatments lower **speeds** &/or **narrow roadways**.
- Typically considered when **pedestrian traffic** volumes are **high.**

Curb Extension Example

At Austin's 6th Street & IH-35 SB's Frontage Road.

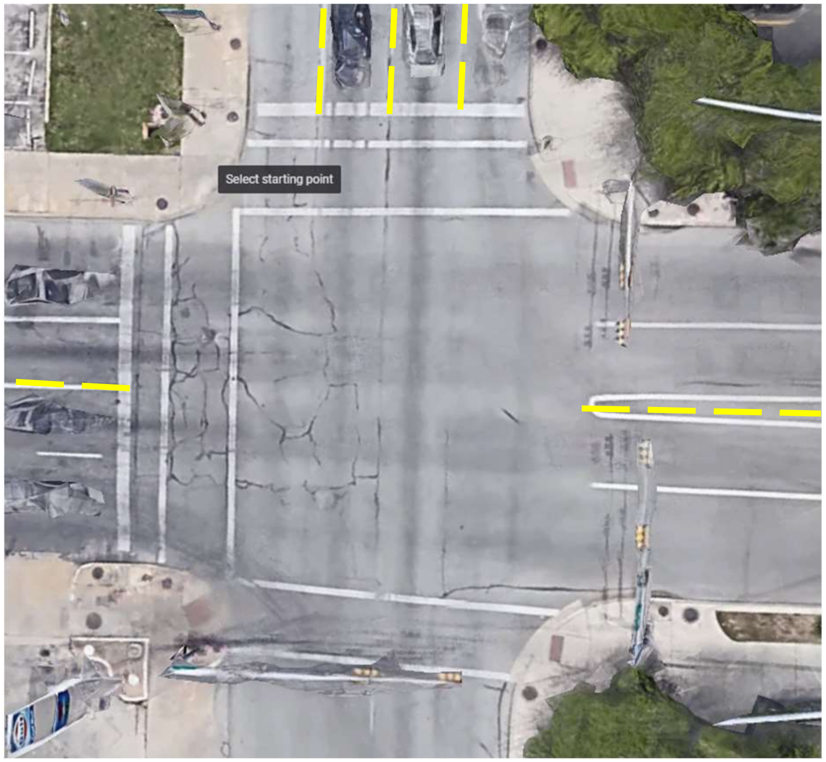
Curb extensions **lower vehicle speeds**, crash **counts, &** crash **severity**.

Pedestrian-specific Treatments

Treatment	Cost (average)	Cost Unit	Avg CMF
Streetlight	$4,880	Each	0.44
In-pavement lighting (flashing crosswalks)	$17,260	Per intersection	0.71
Pedestrian Leading Intervals	$1,750		0.85
Crosswalk Signage (for road users)	$30	Square foot	0.84
Bollards (at crossing points)	$730	Each	0.93
Curb Ramps (to crossings)	$810	Each	0.95
Pedestrian Refuge Islands	$10	Square foot	0.44
Fence (general purpose)	$130	Linear foot	0.63
Pedestrian **overpass** (wooden)	**$124,670**	Each	0.63
Pedestrian **overpass** (steel)	**$206,290**	Each	0.63
Pedestrian underpasses		Square foot	0.63
Sidewalk railings	$100	Linear foot	0.83
Access management improvements (esp. at commercial centers)	$4,000	Per Driveway removed	0.5
Ped Detection - Detector (actuate)	$390	Each	0.55
Ped Detection - Push Button	$350	Each	0.83
Audible Pedestrian Signal	$800	Each	0.72
Increase Crossing Time	negligible	Per re-timing	0.49
Countdown timers	$740	Each	0.48
Pedestrian signal (complete)	$3,260	Each	0.6
Traffic **signal** (new)	**$90,000**	Each	0.44
Dedicated pedestrian interval	$1,750	Per re-timing	0.41
Speed trailers	$9,510	Each	0.95

- Focused on **pedestrian needs**.
- Some **limit pedestrian contact with vehicles** & a couple carry very high cost.

Bollards Example



At Austin's 7th Street + IH35’s southbound frontage road.
Lane bollards **create a protective perimeter, guide traffic**, & mark boundaries (BCR = 1.21 at this site).

Street Furniture Treatments

Treatment	**Cost** (average)	Avg. **CMF**
Street trees	$430	0.82
Bench	$1,550	0.82
Bus shelter	$11,560	0.82
Trash/recycling receptacle	$1,420	0.82

- **Street furniture** provides a **visual cue to drivers** that peds may be present, **while slowing speeds** & providing others services (for rest, shade, aesthetics).

Sidewalk Treatments

Treatment	Cost (average)	Cost Unit	Avg. CMF
Widen paved shoulder	$5.56/sf	Square Foot	0.72
Asphalt Sidewalk	$35/lf	Linear Foot	0.26
Concrete sidewalk	$32	Linear Foot	0.26
Concrete sidewalk w/curb	$150	Linear Foot	0.26
Multi-use trail - paved	$481,140	Mile	0.14
Multi-use trail - unpaved	$121,390	Mile	0.14

- Sidewalks are one of **simplest treatments** for ped safety (& comfort, access, & exercise), especially if these don't exist.
- **Big crash reduction** values - vary by sidewalk type, width, & material.

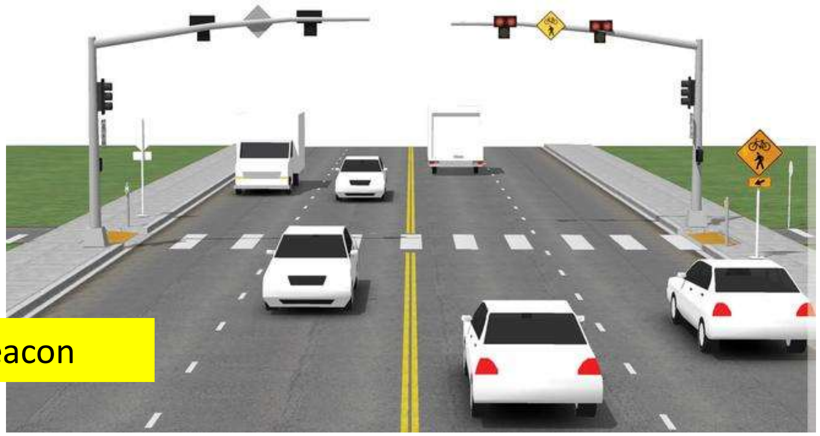
Other Treatments

Advanced Yield Sign

Barrier on Top of Median

Pedestrian Refuge Island

Signal Treatments



Pedestrian Hybrid Beacon

Prohibit Right-turn on Red

Pedestrian Leading Interval

Signal Modification BCRs

Treatment	Location	BCR
Prohibit Right-turn on Red	Congress Ave & Cesar Chavez St in Austin	5.38
	Congress Ave & 6th St in Austin	4.15
Pedestrian-Hybrid Beacons	Tomball Parkway in Houston (Fallbrook Drive to Bammel Road)	**11.6**
	Westheimer Road in Houston (Fondren Road to Chimney Rock Road)	3.16
Pedestrian Leading Interval	6th St & I-35 SB Frontage Road in Austin	2.34
	Congress Ave & 6th St in Austin	2.76
	East Riverside Drive & Wickersham Lane in Austin	2.97
	Zarzamora St & Culebra Road in San Antonio	**21.1**
	Fannin St & Walker St in Houston	8.79
	Fannin St & Congress St in Houston	5.38

Signal changes → Some travel delay costs

Speed Reduction BCRs

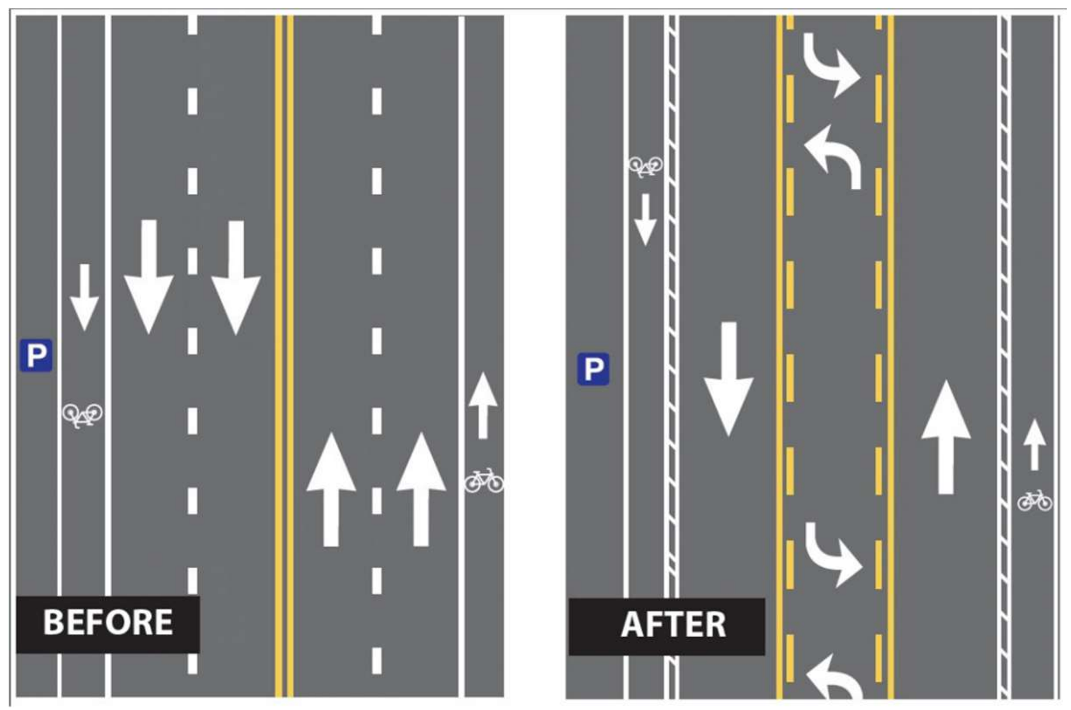
Treatment	Location	BCR
10% Lower Speed Limits	Tomball Parkway in Houston	1.67
	Westheimer Road in Houston	2.40
	Congress Avenue in Austin	3.92
	E Riverside Dr & Pleasant Valley Rd in Austin	2.40

Note: Speed limit reductions deliver **less-than-equivalent** changes in **average speed** (NCHRP 2006) + **large delay costs**, but lower crash counts & injuries endured.

Traffic Calming/Road Diet BCR

Treatment	Location	BCR
Road Diet	Milam St in Houston (from McGowan Steet to Alabama St)	3.03

- Most effective with **high pedestrian traffic** (+ regular vehicle traffic).
- **Saved right of way** can become **sidewalks or ped/bike paths**.

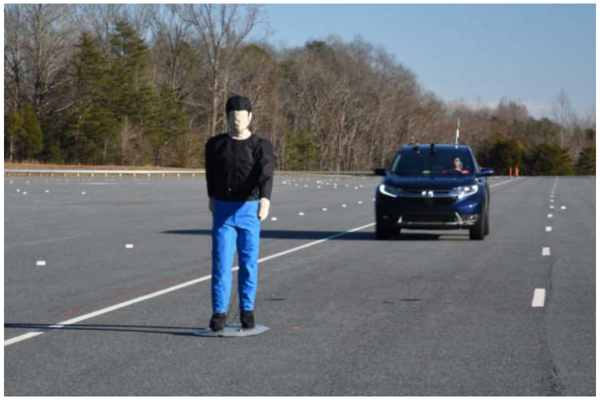


Other Treatments: Education

- Age-appropriate **education programs** in schools.
- More requirements for driver's license.
- Mass media campaigns.
- Educate not only the road users, **but also the system designers**.

One More: Vehicle Design

- **Our nation** (NHTSA & IIHS) **does not really consider pedestrian safety & injury likelihood** when rating vehicle safety.
- **IIHS** evaluates **autobraking** now, but still not a vehicle's ability to protect pedestrians in collision.
- **EU tests** how vehicle **bumpers & hoods** protect pedestrians' **lower legs** at **40 kph** (25 mph) for **both children & adults**.
- We recommend requiring much **higher standards & safety design measures** for US vehicle sales.



Summary

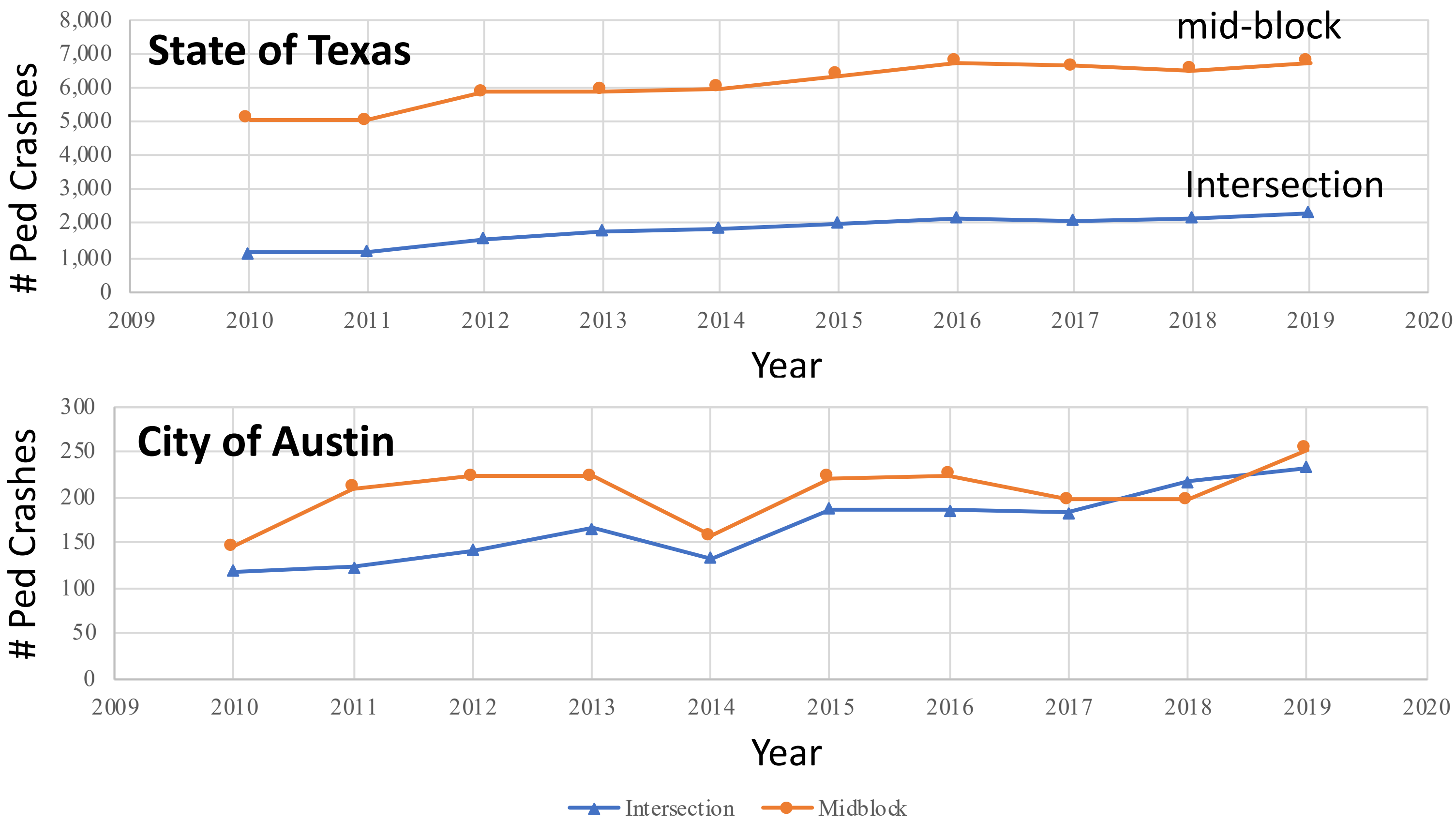
- **We don't know why we have rising ped deaths** across the US & Texas. Are drivers less careful? Traffic more chaotic?
- **Hot spots for deaths** are freeways & major arterials, big cities, mid-block, often near schools & transit stops, at night, unlighted, with alcohol &/or drug impairments.
- Use of **light-duty trucks** (including SUVs, pickup trucks, CUVs, & vans) significantly increases the risk of pedestrians being severely injured or killed (especially off street, in driveways).
- **Older pedestrians** are much more likely to die.
- **Benefit-cost ratios (BCRs)** lead to *many* valuable treatment options! But **we need policies** too (**automated enforcement**, **speed governors**, **public reporting** of bad behavior, …).
- **What do treatments do you feel have highest BCRs?**

Intersections vs. Mid-Block vs. Entire Roadway Segments

CRASH COUNT + SEVERITY PREDICTION

Intersection & Mid-block Crashes

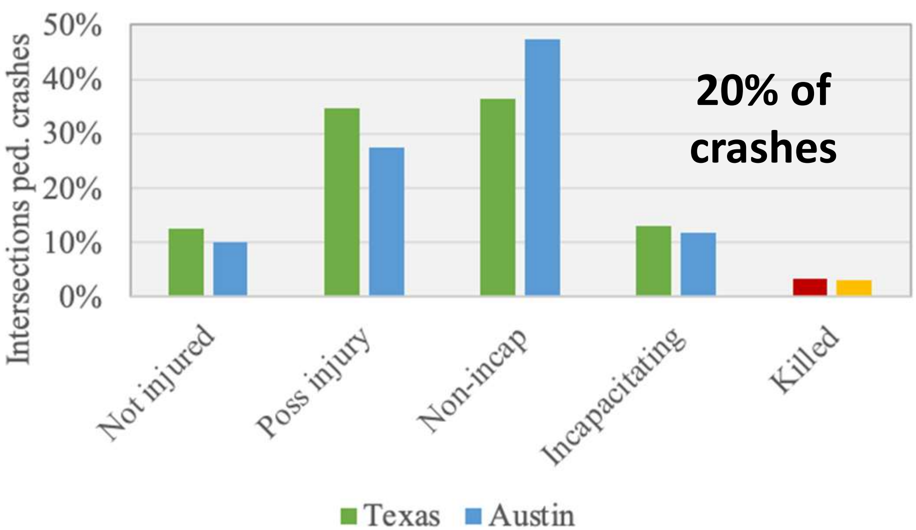
- **Texas intersection ped crashes <u>doubled</u>** between 2010 & 2019, while **mid-block ped crashes rose 30%**.
- **Austin = 5% of Texas'** pedestrian crashes.



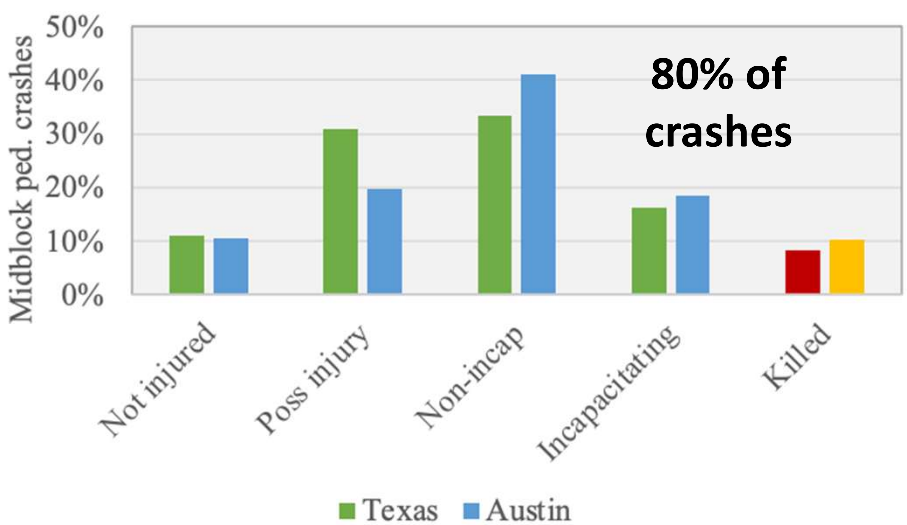
Intersection vs. Mid-block Data

- **Most crash studies** are **segment-based** & **don't distinguish intersections**, due to **challenge of separating thousands (or millions) of intersection points** (& identifying covariates for all sites).

- Ped crashes = **more severe & most common mid-block**.



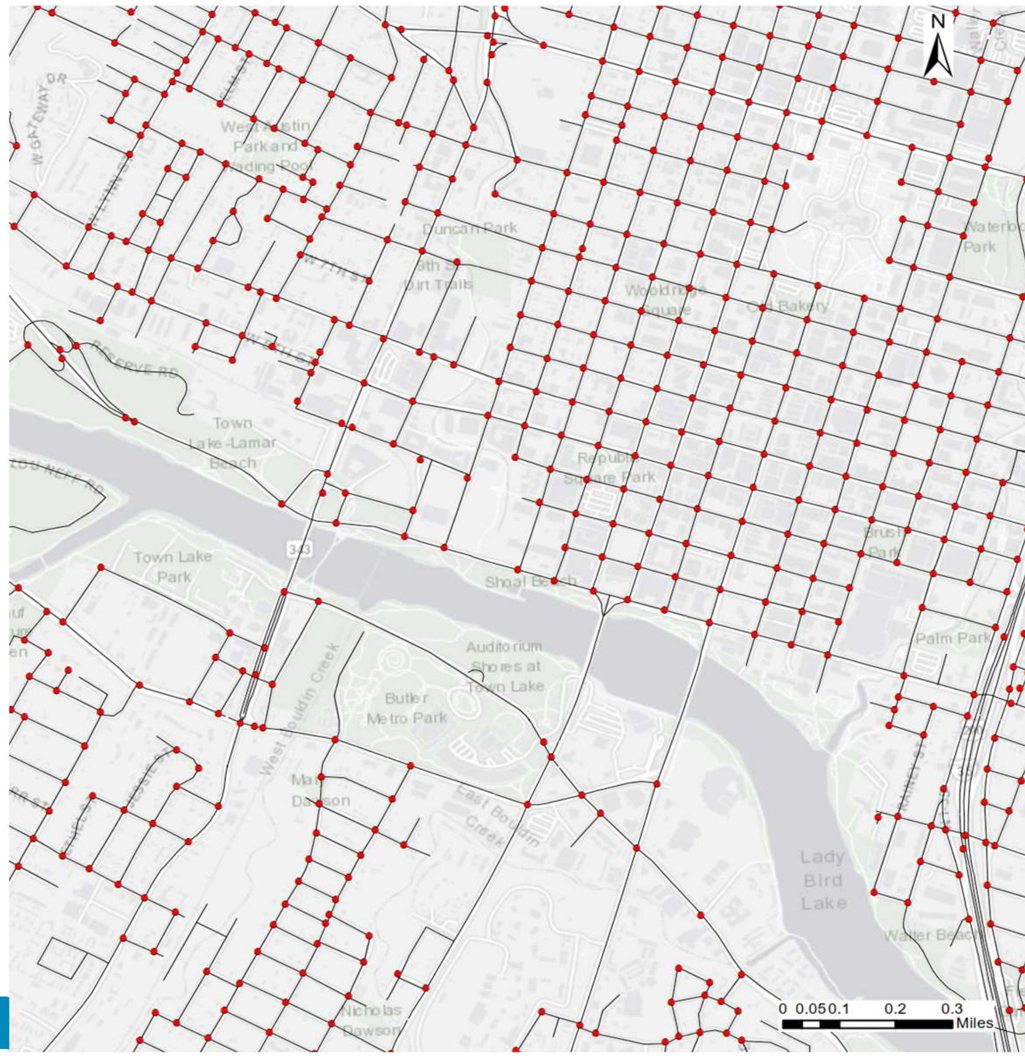
Intersection Severity



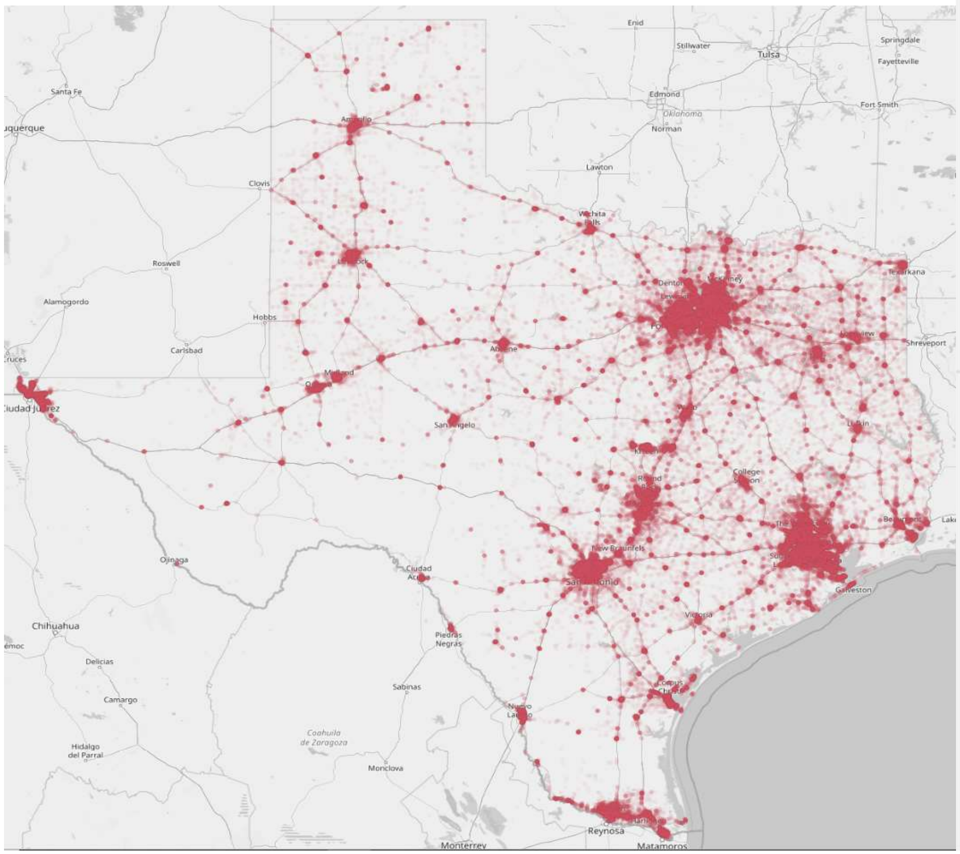
Mid-block Severity

Intersection + Mid-block Segments Example

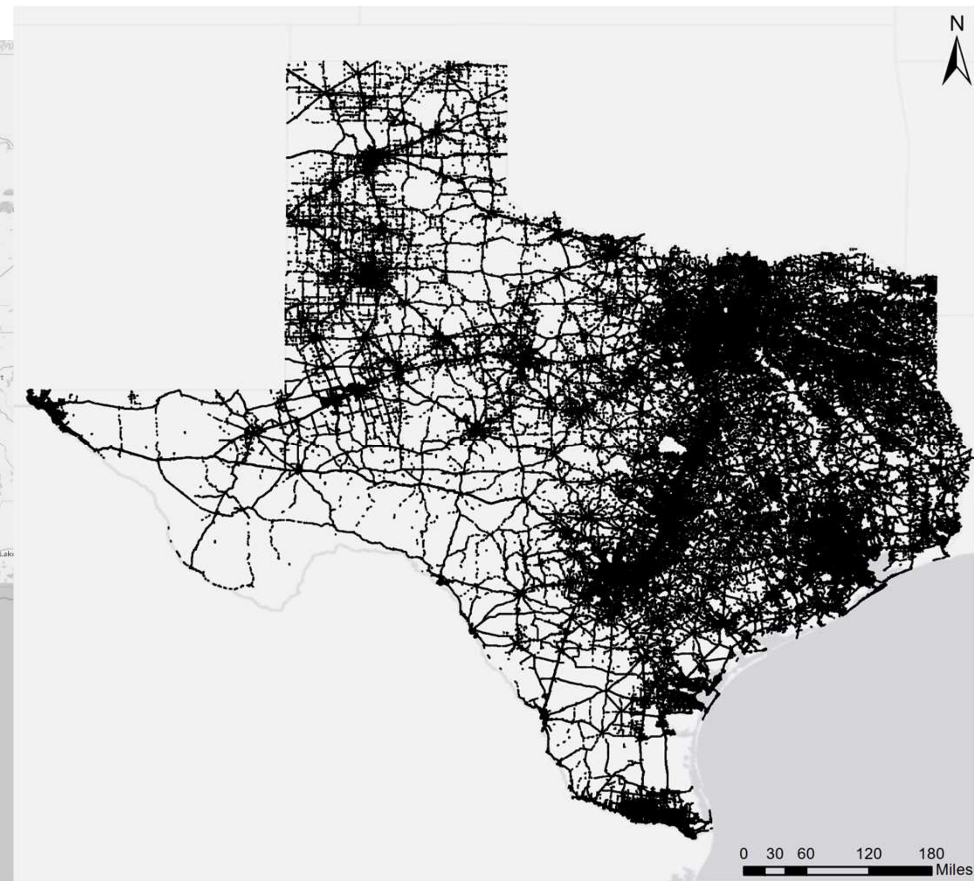
Central Austin



Intersections & Mid-block Segments across Texas



700k+ Intersections



575k+ Mid-block Segments (1-mile)

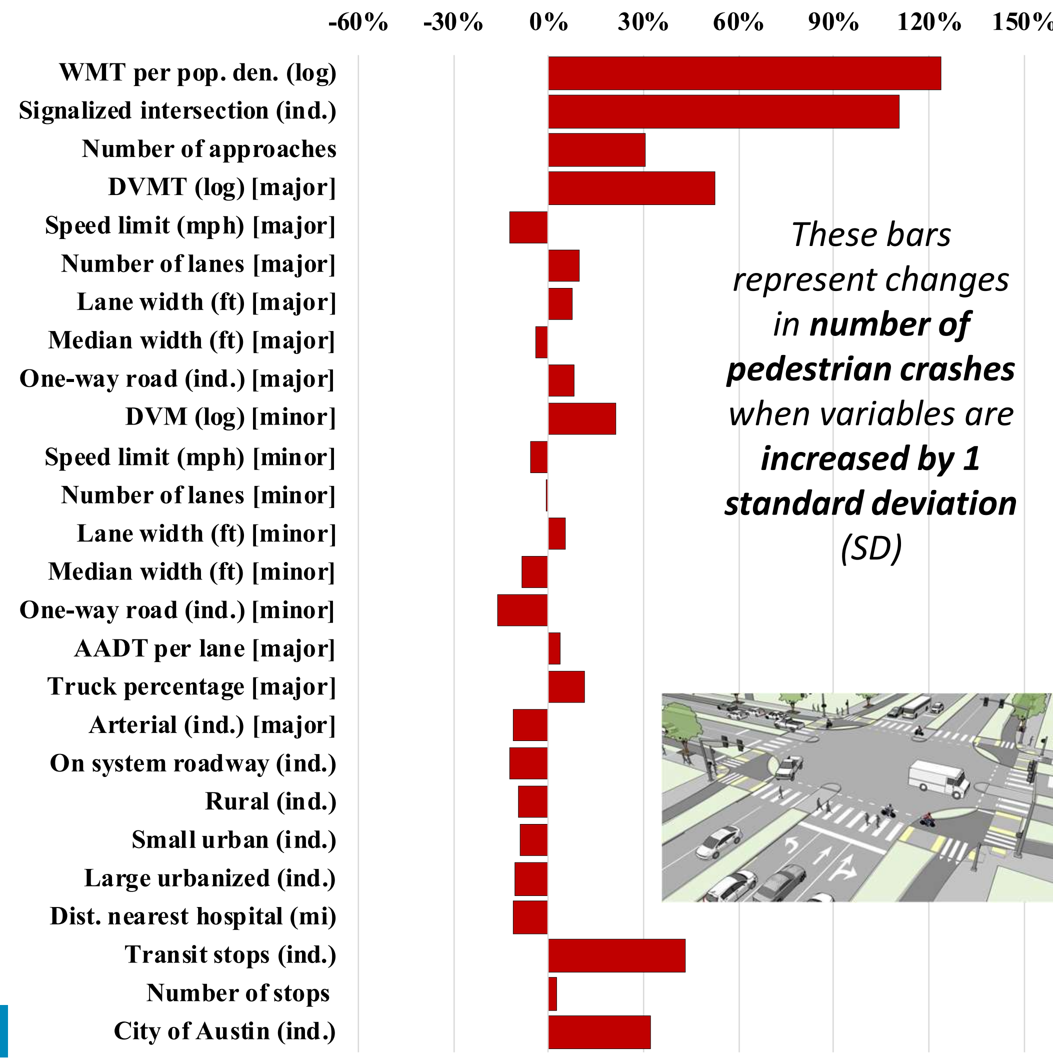
Crash **Count Prediction**

- **#Ped Crashes** over 10 years (2010-2019) at each segment or intersection follow **negative binomial (NB) distribution.**
- Analyses at **State & Austin City** levels. Big dataset means every variable is statistically significant.
- We identify the **most practically significant factors**.

EDUCATE.

Results: Texas Intersections

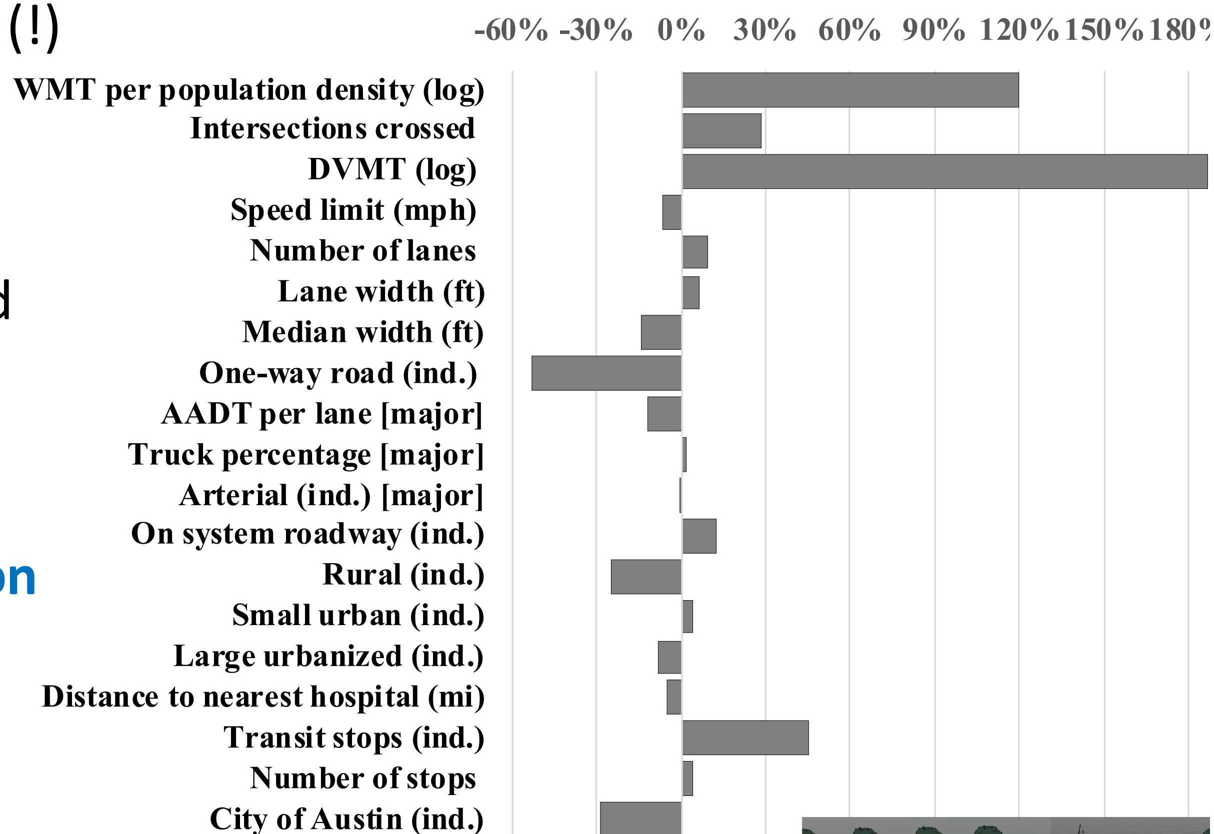
- #Ped **crash counts double with WMT & when intersection is Signalized** ! (ceteris paribus)
- **+52% ped crashes** when 1 SD flow (VMT) is added
- **Transit stops** → **+43%** ped crashes
- **#Approaches** → **+31%** (1 SD = +0.67)
- **+ 7 mph Speed limit** → **-12%** (as peds avoid that location)
- **#Ped crashes rises** with #lanes, lane width, AADT, truck %.
- **Ped crashes fall** with one-way, wider medians, longer distances to hospital.
- **City of Austin** indicator suggests **+40% (!)** vs. same kind of intersections in rest of the state. (Due to more homeless persons?)

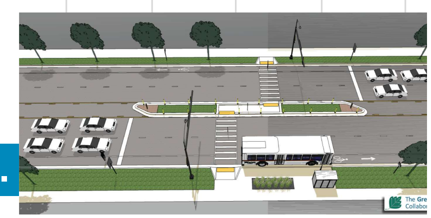


Results: Texas Mid-block

(1-mile segments)

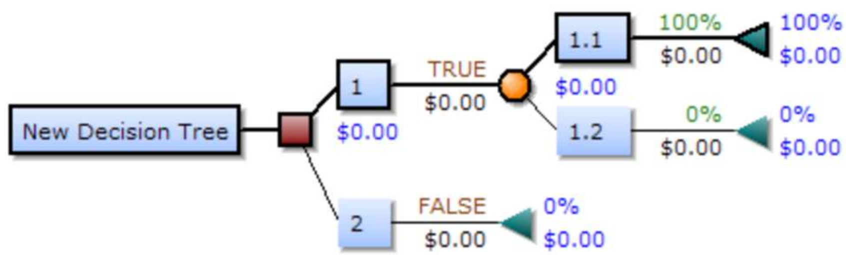
- +1 SD **Walk-miles Traveled (WMT)** → **+120%** crashes (!)
- +1 SD **VMT → +187% (!)**
- +1 SD **# Intersections crossed** (2.8) → **+29%** ped crashes.
- **#Transit stops**: **+45%**
- **One-way → 52% reduction**
- City of **Austin** → **-30% fewer crashes** than elsewhere.





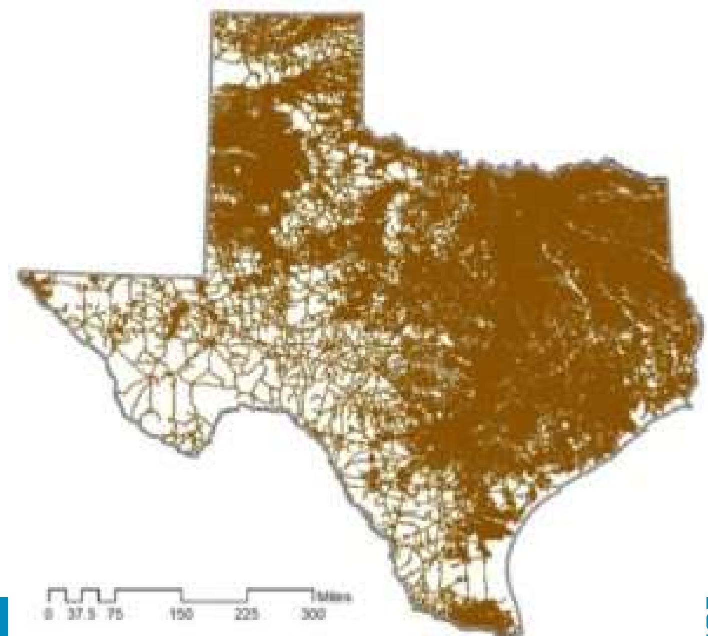
USE OF TREE-BASED MACHINE LEARNING **MODELS**

Crash Count Models + Crash Severity Models

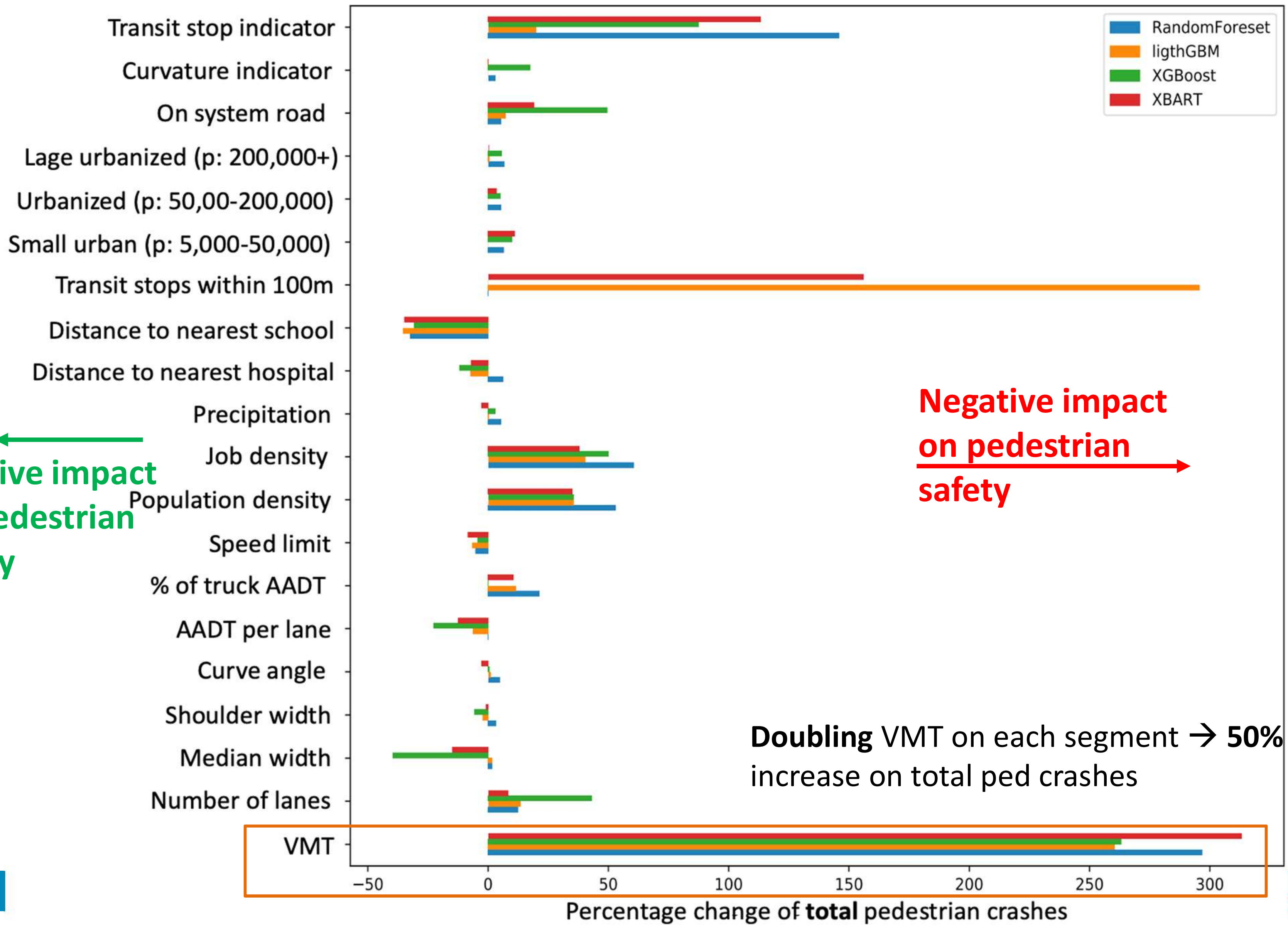


- **Random Forest**
- **XGBoost**
- **LightGBM**
- **XBART**

vs **Negative Binomial & Ordered Probit** specifications



Sensitivity **Results**



Positive impact on pedestrian safety

Negative impact on pedestrian safety

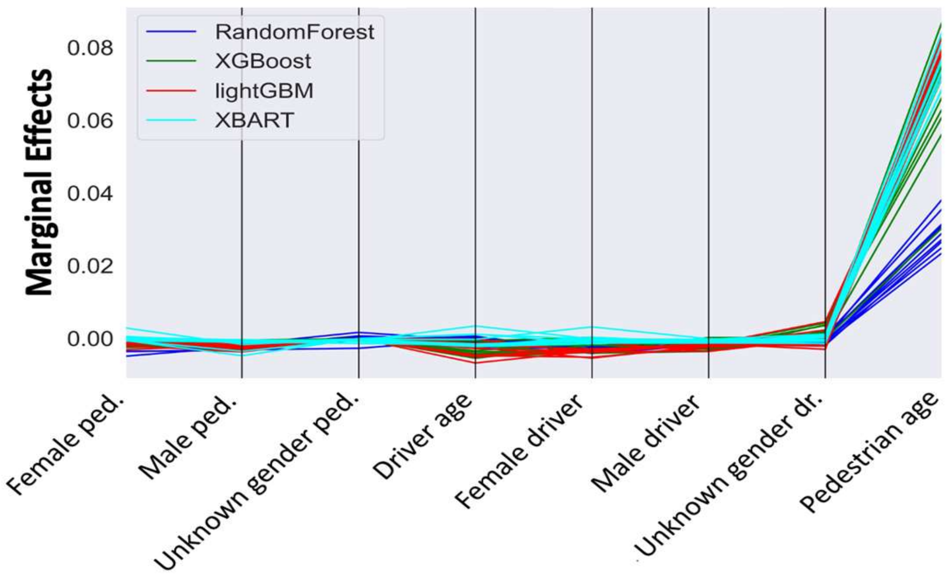
Doubling VMT on each segment → **50%** increase on total ped crashes

CATE.

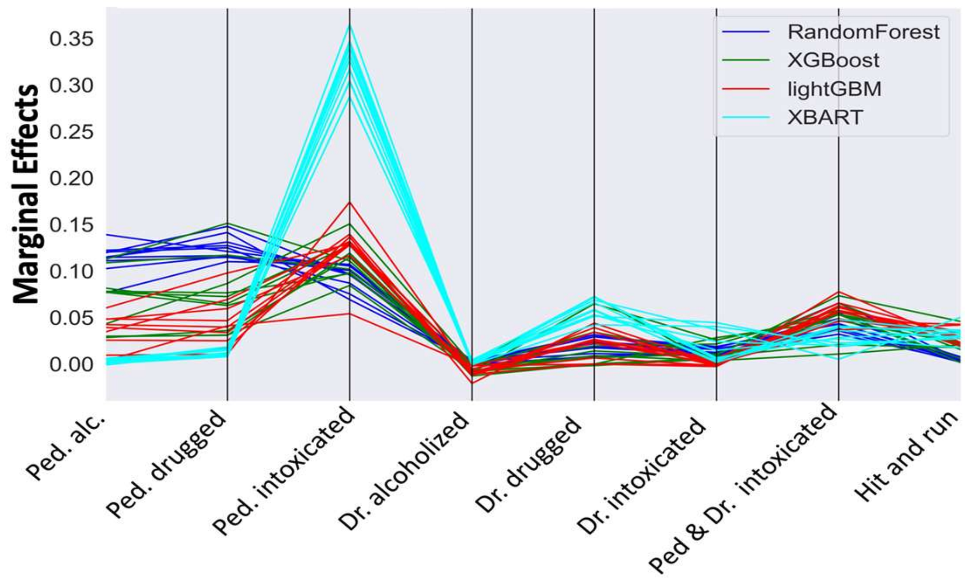
Pedestrian Crash
Severity Model Comparisons

Marginal Effects of X's

- **Older pedestrians** at greater risk, & **intoxicated pedestrians** at much greater risk of severe outcomes. Lower **speed limits & signalized** controls lower risk slightly.



Demographics



Impairments or Hit & Run

Other Factors?

- **More** **aggressive vehicle designs** (**high hoods & grills** on pickup trucks & SUVs, as well as vans & some CUVs).
- Rising use of **smartphones** (by drivers & peds).
- **Homeless** populations living & crossing on high-speed roads.
- Rising **drug use** **or what else?**

In Conclusion…

- **Southern states** have a longer way to go.
- **Mid-block segments** more vulnerable than intersections.
- **Data ambiguities exist:** in crash direction & exact location, WMT at each site, speeding & enforcement, design details (lines of sight, curb & sidewalk, etc.). For better results, **read crash narratives & add variables** to standard data sets.
- **Hot spots** are **freeways & major arterials**, **big cities, mid-block**, often near **schools & transit stops, at night**, unlighted, with **alcohol &/or drug** impairments.
- Use of **light-duty trucks** (including SUVs, pickup trucks, CUVs, & vans) significantly increases death & injury risks.
- **Intoxicated (& older) pedestrians** are at greatest risk.

THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

Papers available at
www.caee.utexas.edu prof/kockelman

THANK YOU!

Questions & Suggestions?

Kara Kockelman (kkockelm@mail.utexas.edu)
& **Natalia Zuniga-Garcia** (nzuniga@utexas.edu)

Today's presenters

Noah Heath
Noah.Heath@txdot.gov

Texas Department of Transportation

Kara Kockelman
kkockelm@mail.utexas.edu

TEXAS
The University of Texas at Austin

Laura Sandt
sandt@hsrc.unc.edu

THE UNIVERSITY OF NORTH CAROLINA
HIGHWAY SAFETY RESEARCH CENTER

Natalia Zuniga Garcia
nzuniga@utexas.edu

Argonne
NATIONAL LABORATORY

Upcoming events for you

July 9-13, 2023

TRB's 2023 Automated Road Transportation Symposium

July 19, 2023

TRB Webinar: Community-Based and Equitable Transportation Response in Disaster

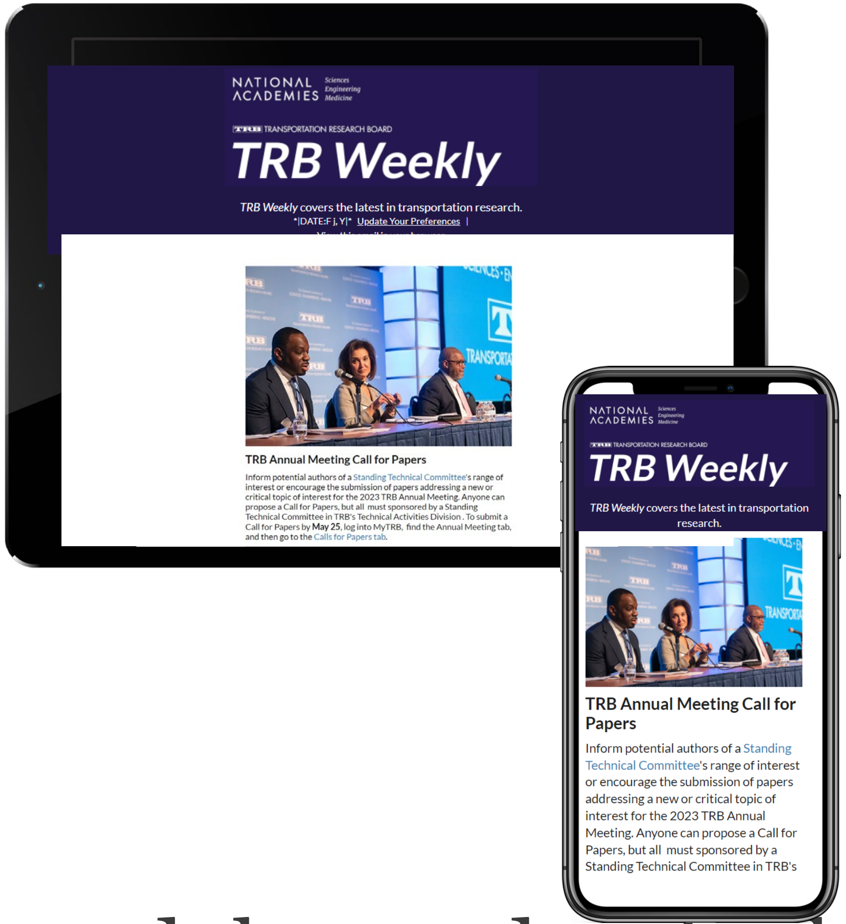
https://www.nationalacademies.org/trb/events

Subscribe to *TRB Weekly*

If your agency, university, or organization perform transportation research, you and your colleagues need the *TRB Weekly* newsletter in your inboxes!

Each Tuesday, we announce the latest:

- RFPs
- TRB's many industry-focused webinars and events
- 3-5 new TRB reports each week
- Top research across the industry



Spread the word and subscribe!

https://bit.ly/ResubscribeTRBWeekly

Discover new TRB Webinars weekly

Set your preferred topics to get the latest listed webinars and those coming up soon every Wednesday, curated especially for you!

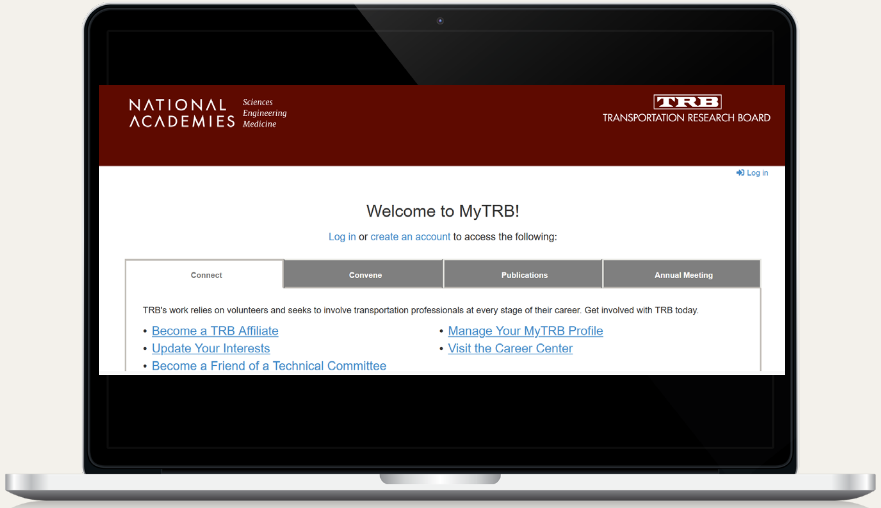
https://mailchi.mp/nas.edu/trbwebinars

And follow #TRBwebinar on social media

@NASEMTRB
@NASEMTRB
Transportation Research Board

Get involved

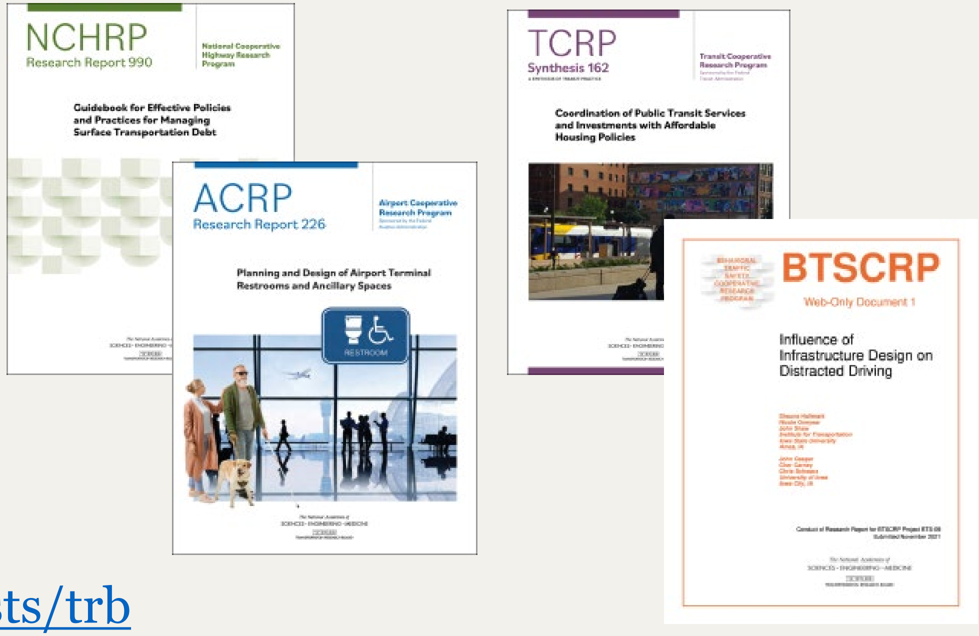
https://www.nationalacademies.org/trb/get-involved



- **Become a Friend of a Standing Technical Committee**

  Network and pursue a path to Standing Committee membership

- **Work with a CRP**



- **Listen to our podcast**

Apple Podcasts | Spotify | Google Podcasts | Overcast | Castbox | Pocket Casts | RSS feed

https://www.nationalacademies.org/podcasts/trb

We want to hear from you

- **Take our survey**
- **Tell us how you use TRB Webinars in your work at trbwebinar@nas.edu**

NATIONAL ACADEMIES *Sciences Engineering Medicine*