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Safe vehicles: How effective are pedestrian crash prevention systems in improving pedestrian safety?

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How effective are pedestrian crash prevention systems in improving pedestrian safety? Harnessing large-scale experimental data

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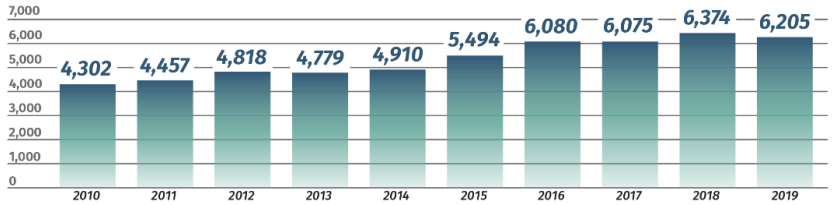
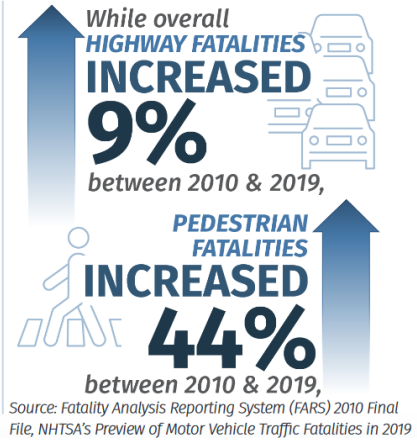
Introduction



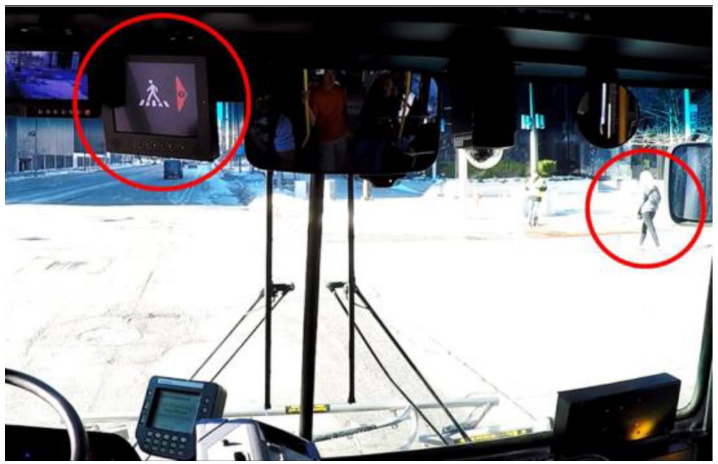
Source: FARS 2010 to 2018 Final File, NHTSA's Preview of Motor Vehicle Traffic Fatalities in 2019

- Increasing **fatalities/ severe injuries** of **vulnerable road users**
- **44% increase** in pedestrian fatalities-2010 and 2019 (6,516 in 2020): USDOT Ped Safety Action Plan
- **Safe mobility of pedestrians** is critical in our transportation system
- **Technology can help** reduce vehicle-pedestrian crashes, fatalities, and injuries.

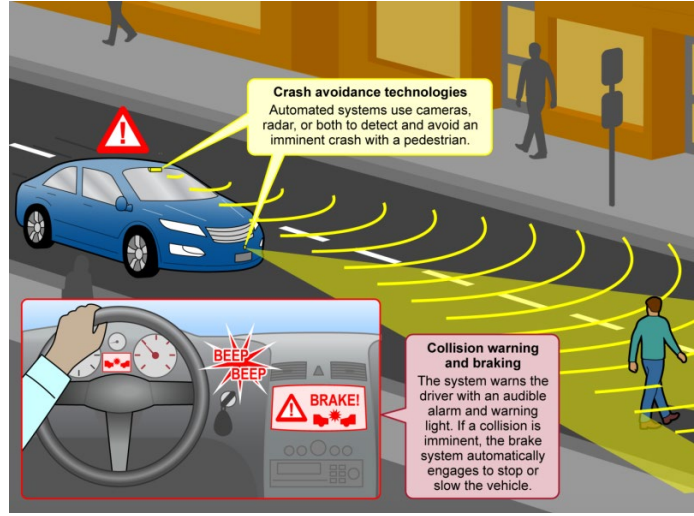


Source: Fatality Analysis Reporting System (FARS) 2010 Final File, NHTSA's Preview of Motor Vehicle Traffic Fatalities in 2019

How emerging technologies can improve the safety of vulnerable road users?



Pedestrian Crash Prevention Systems



Also known as:

- "Pedestrian Automatic Emergency Braking System"
- "Pedestrian Collision Avoidance System"
- "Frontal Pedestrian Impact Mitigation Braking"

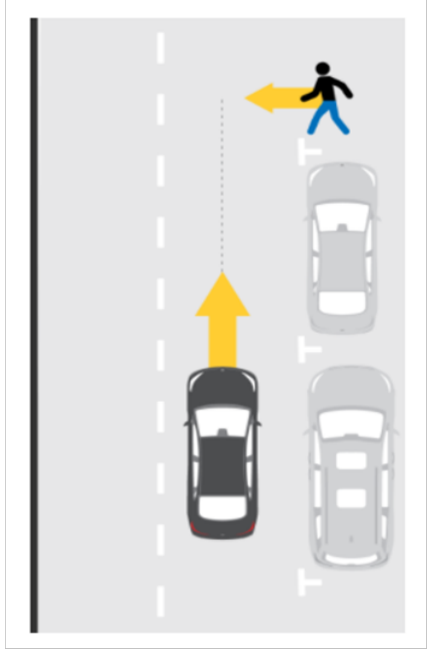
An emerging safety technology in vehicles with a **low level of automation**

Automatic braking when facing pedestrians & driver has taken insufficient action to avoid an imminent crash

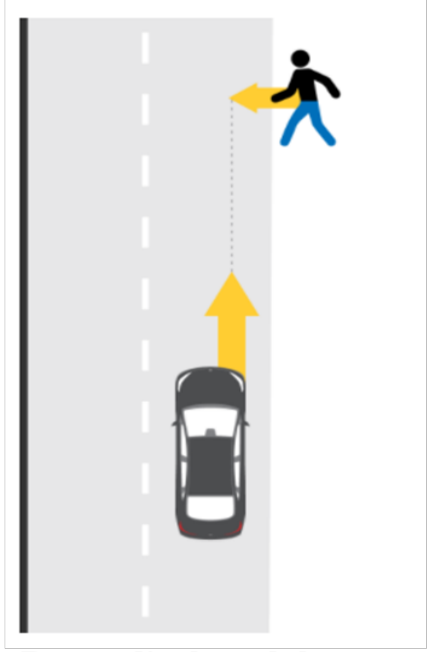
- **Insurance Institute for highway safety** (IIHS) dataset from 2018 to 2021
- PCP systems for several on-road vehicles **evaluated in terms of safety**
- **3,095 tests of 91 vehicles**

Source: Internet https://gfycat.com/gifs/tag/highway+safety

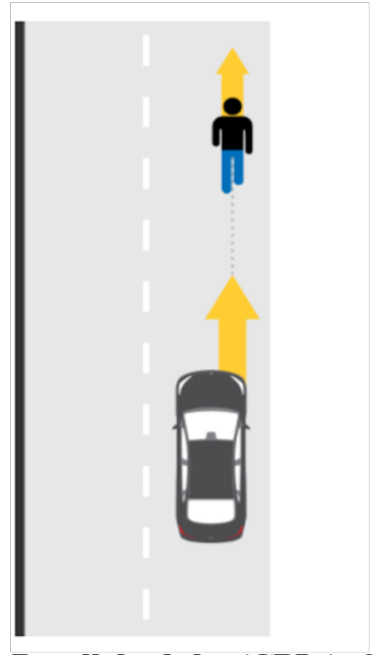
Scenarios



Prependicular child:
Scenario 1: (CPNC_50)
Child runs into road;
Parked vehicles obstruct view;
Tests run at 20 km/h (12 mph)
Scenario 2:
Child runs into road;
Parked vehicles obstruct view;
Tests run at 40 km/h (25 mph)



Prependicular adult: (CPNA_25)
Scenario 3:
Adult walks across road
Tests run at 20 km/h (12 mph)
Scenario 4:
Adult walks across road
Tests run at 40 km/h (25 mph)



Parallel adult: (CPLA_25)
Scenario 5:
Adult in right lane near edge of road, facing away from traffic;
Tests run at 40 km/h (25 mph)
Scenario 6:
Adult in right lane near edge of road, facing away from traffic;
Tests run at 60 km/h (37 mph)

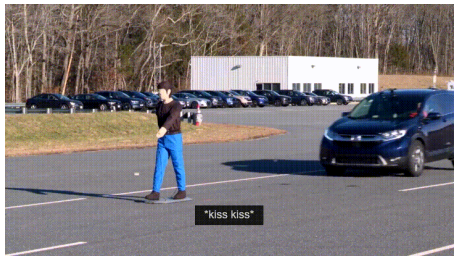
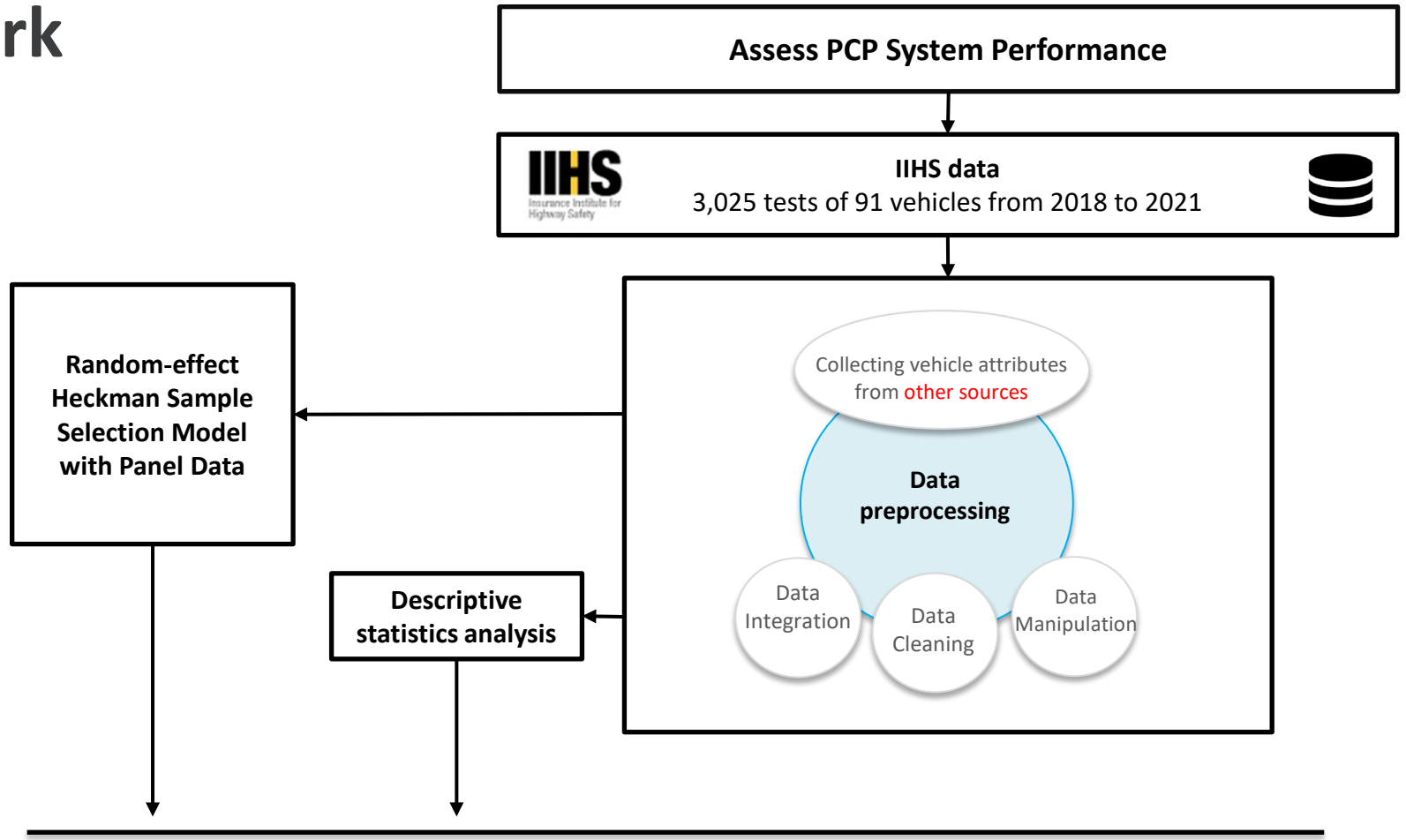


Figure Source: Insurance Institute for Highway Safety: Pedestrian autonomous emergency braking test protocol (version 1). Virginia, 2018.

Study Framework

$$y_{it} = x_{it}\beta + v_{1i} + \epsilon_{1it}$$

$$s_{it} = 1(z_{it}\alpha + v_{2i} + \epsilon_{2it} > 0)$$

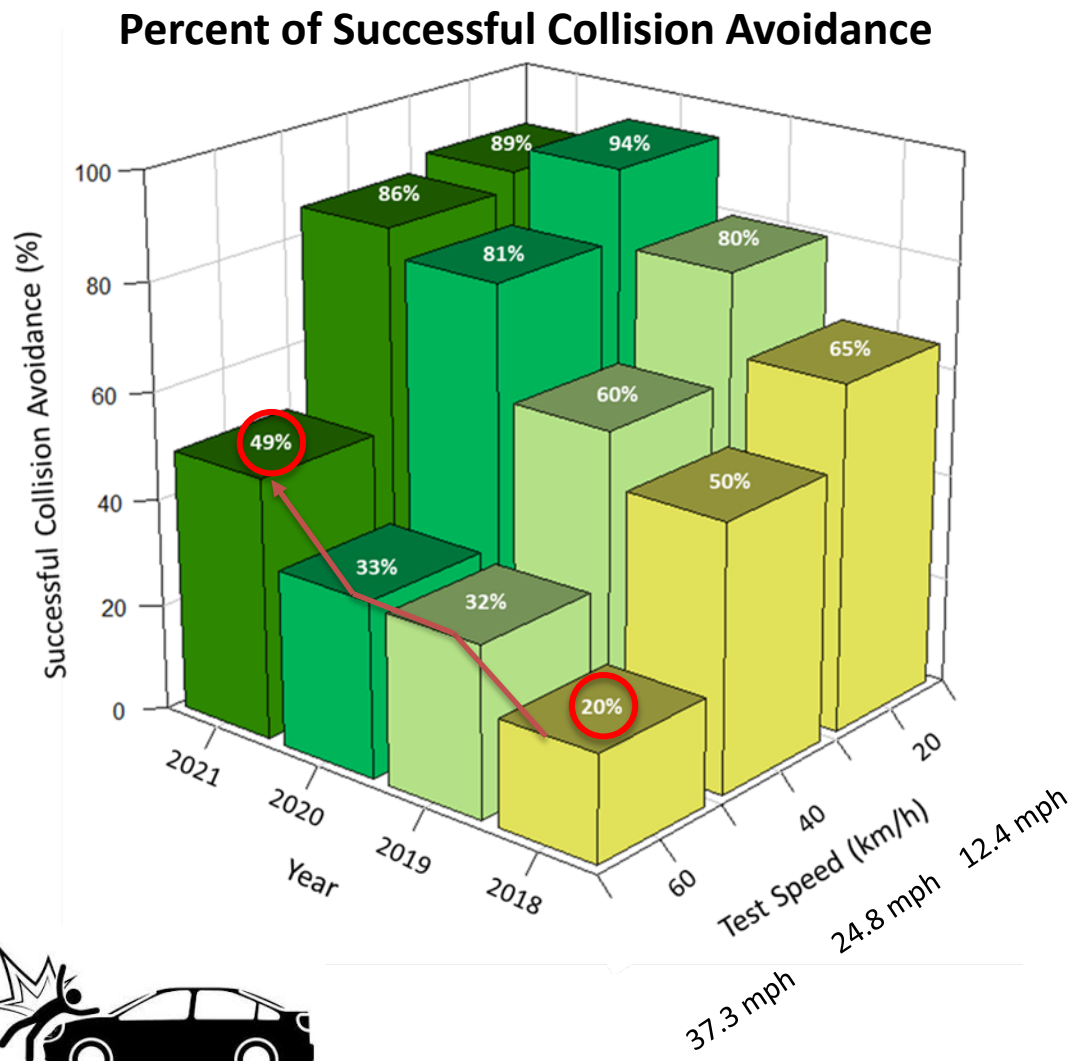


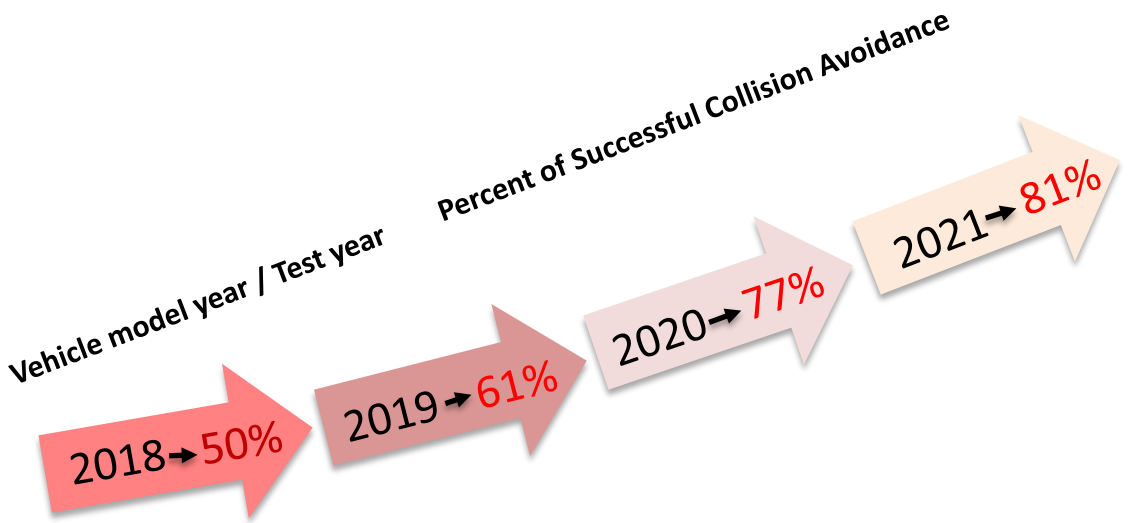
Outcomes

- PCP system performance in improving pedestrian safety
  - Correlates of PCP system performance
  - Hazardous pedestrian crossing scenarios

Crash Avoidance Results:

- Collisions with pedestrians occurred in 30% (=933/3095) cases, but in 70%, PCP systems avoided pedestrian crashes
- Test speed is a major factor
- Successful collision avoidance rate increased over time



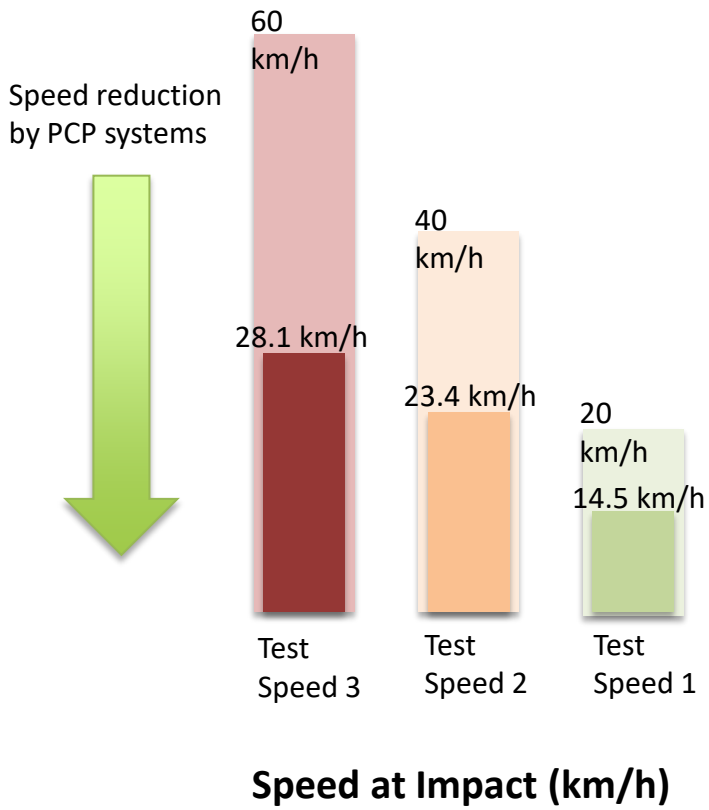


Speed Reduction Results:

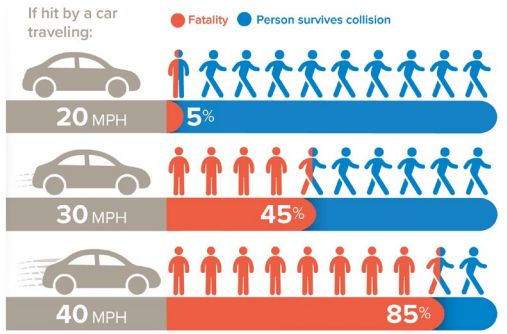
Given a crash, PCP systems, on average, **mitigated impact speeds** by more than **50%**

Descriptive Statistics of Variables.

Variable (N = 91 Vehicles and 3095 Tests)		Min	Max	Mean	SD
Speed at Impact with Pedestrians (km/h)	All Years and Test Speeds	0	60.78	7.15	13.34
Conditional Speed at Impact with Pedestrians (Given that Collisions Occurred, N = 933 Tests)	All Test Speeds	0.03	60.78	23.70	14.07
	20 km/h	0.50	20.71	14.53	5.53
	40 km/h	0.03	40.89	23.41	11.49
	60 km/h	2.70	60.78	28.06	17.40
Conditional Speed Reduction by PCP System (Given that Collisions Occurred, N = 933 Tests)	All Test Speeds	0	56.77	20.38	16.39
	20 km/h	0	19.54	5.33	5.37
	40 km/h	0	39.88	16.34	11.47
	60 km/h	0	56.77	31.94	17.37



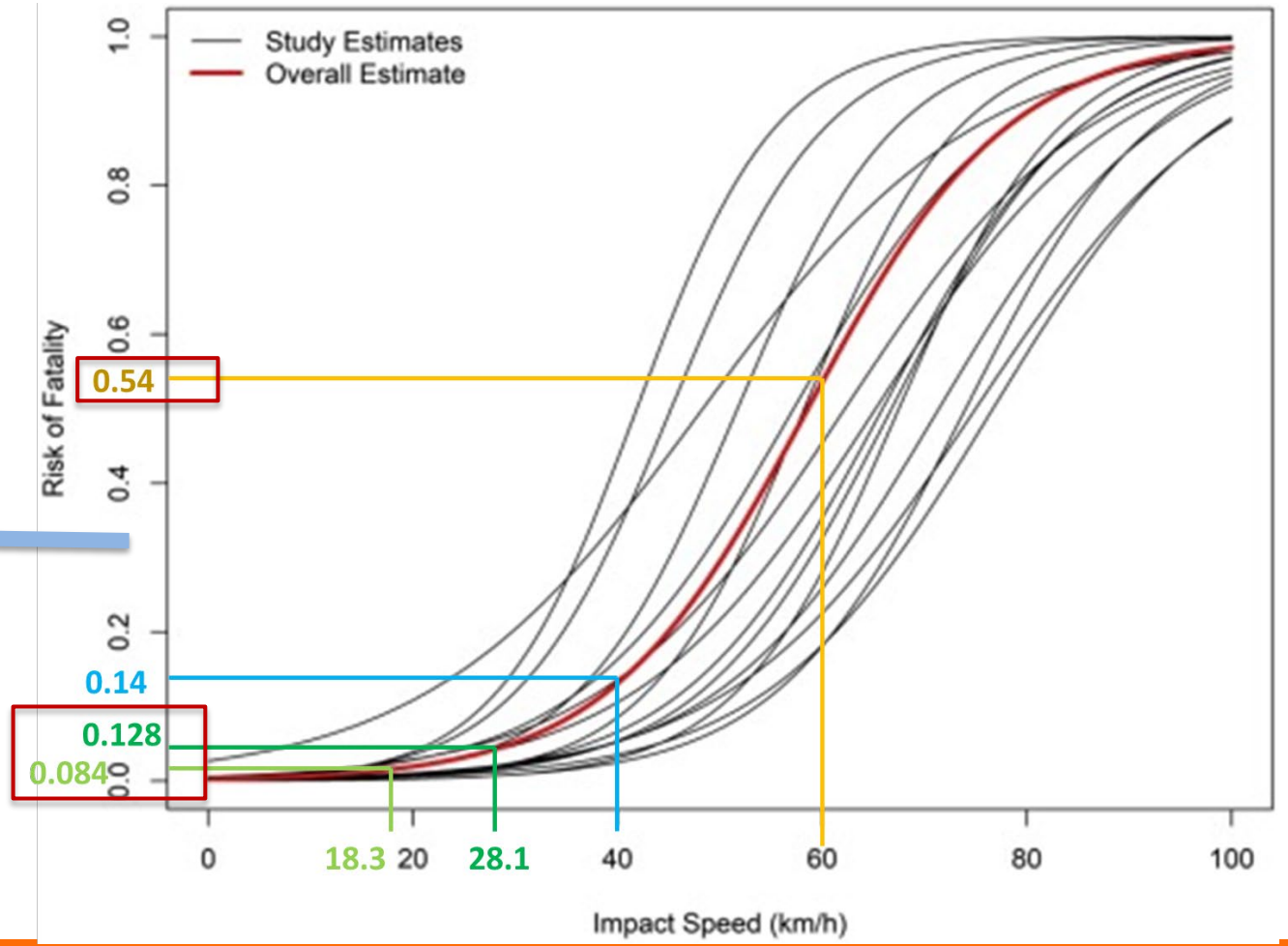
Speed vs. fatality risk



If drivers do not brake* → PCP systems can **substantially mitigate risk of fatality for pedestrians**

- 70% crash avoidance-for 30% in crashes…
- Impact speed of 60 km/h → 54% risk of fatality
- PCP reduces speed to 28.1 → 12.8% risk of fatality

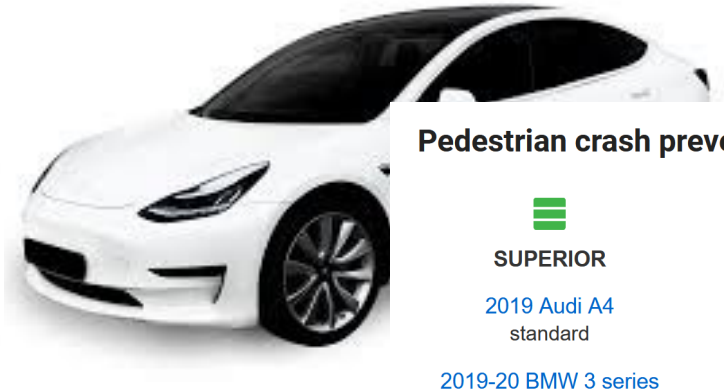
No PCP system		PCP system (only tests with crashes)	
Impact speed	Risk of fatality	Average impact speed	Average risk of fatality
20 km/h	2%	14.5 km/h	2.2%
40 km/h	14%	23.4 km/h	5.4%
60 km/h	54%	28.1 km/h	12.8%



*72% drivers did not recognize hazard in SV crashes-AAP Paper 160 (2021) 106304

Vehicle performance & speeds

- At higher speeds (60 km/h), **Tesla Model 3** performs relatively **well** – collision avoidance 60%
- However, at lower speeds (20 and 40 km/h), Tesla performs relatively worse
- Ratings for midsized cars by IIHS



Pedestrian crash prevention ratings for midsize cars

SUPERIOR	ADVANCED
2019 Audi A4 standard	2019-20 BMW 3 series optional
2019-20 BMW 3 series standard	2019-20 Honda Accord standard
2020 Subaru Outback standard	2019-20 Lexus ES 350 standard
2019-20 Mercedes-Benz C-Class optional	2019 Mazda 6 standard
2019-20 Nissan Maxima optional for 2019/standard for 2020	2019-20 Nissan Altima optional
2019 Volvo S60 standard	2019-20 Tesla Model 3 standard

Vehicle Brand	Test Speed (km/h)	Success Rate of PCP system	Average speed at impact (km/h)
Tesla Model3 (2019)	20	67%	15.340
	40	60%	24.910
	60	60%	31.910
	All tests	63%	21.975
Ford Fusion (2019)	20	0%	18.690
	40	33%	36.846
	60	0%	34.430
	All tests	17%	29.100
Audi A4 (2019)	20	100%	0
	40	100%	0
	60	0%	9.871
	All tests	83%	9.871
Volvo S60 (2019)	20	100%	0
	40	87%	24.221
	60	40%	27.201
	All tests	83%	26.009
Lexus ES350 (2019)	20	90%	9.831
	40	100%	0
	60	0%	33.515
	All tests	80%	29.568
Honda Civic (2019)	20	100%	0
	40	80%	19.577
	60	20%	11.344
	All tests	77%	14.872
Toyota Prius (2021)	20	100%	0
	40	100%	0
	60	0%	19.601
	All tests	83%	19.601
Acura TLX (2021)	20	93%	18.516
	40	100%	0
	60	20%	11.433
	All tests	83%	12.850

Modeling Results

- Increase in the **maximum deceleration rate** of PCP system (9 to 11 m/s^2)
- **Lower weight of vehicles**

Decrease in the speeds at impact with pedestrians

Random-effects Heckman Sample Selection Regression with Panel Data.

Speed at Impact (km/h) (N = 3095) Variables		β	Z-statistic	P-value
Constant		21.416	8.730	0.000
Maximum Deceleration (m/s2)		−2.999	−20.570	0.000
Scenario	1-Perpendicular Child 20 km/h (base)			
	2-Perpendicular Child 40 km/h	19.270	10.950	0.000
	3-Perpendicular Adult 20 km/h	−3.760	−1.680	0.093
	4-Perpendicular Adult 40 km/h	9.543	5.050	0.000
	5-Parallel Adult 40 km/h	6.304	2.800	0.005
	6-Parallel Adult 60 km/h	23.345	13.140	0.000
Vehicle Model Year	2018	3.621	1.440	0.151
	2019	4.428	2.710	0.007
	2020	−1.109	−0.650	0.516
	2021 (base)			
Vehicle Manufacturer's Reported Weight (base model)	≤3,000 lbs. (base)			
	3,001 – 3,500 lbs.	1.310	0.890	0.376
	3,501 – 4,000 lbs.	2.050	1.350	0.176
	4,001 – 4,500 lbs.	4.489	2.440	0.015
	> 4,500 lbs.	4.370	2.220	0.026

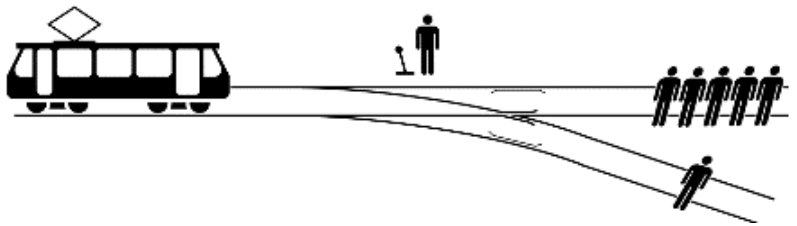
Night-time vs. daytime (or well-lit roads)

- Ped crashes 27% lower for equipped veh vs. unequipped
- Injury crash rates 30% lower
- Night/unlit roads-no difference
- 75% fatal ped crashes at night
- Single/dual camera, camera + radar, radar only (infrared?)
- Low-beam/high beam

Source: IIHS-https://www.iihs.org/news/detail/pedestrian-crash-avoidance-systems-cut-crashes--but-not-in-the-dark

Conclusion

- **PCP Technology** reduces vehicle-pedestrian crashes, fatalities, and injuries
- **Performance improving** substantially in recent years
- **Did not detect**/stop in **30%** of the tests-in **70%** of tests **avoided pedestrian crashes**
- For crashes, PCP systems **mitigated impact speeds by about 50%**
- PCP can/do mitigate the risk of fatality for pedestrians
- **Higher market penetration → reduction in** ped crashes, injuries/fatalities
- Future research-**Other modes; darkness**



Thank You!
Questions?

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