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

- 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.

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](https://gfycat.com/gifs/tag/highway+safety)
Scenarios

**Figure Source:** Insurance Institute for Highway Safety:
Pedestrian autonomous emergency

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

**Prepender adult:**
**Scenario 3:** (CPNA_25)
Adult walks across road
Tests run at 20 km/h (12 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 2:**
Child runs into road;
Parked vehicles obstruct view;
Tests at 40 km/h (25 mph)

**Scenario 4:**
Adult walks across road
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)

Source: Internet [https://gfycat.com/gifs/tag/highway+safety](https://gfycat.com/gifs/tag/highway+safety)
[https://imgur.com/gallery/JcIBBeo](https://imgur.com/gallery/JcIBBeo)
Study Framework

Assess PCP System Performance

IIHS data
3,025 tests of 91 vehicles from 2018 to 2021

Random-effect Heckman Sample Selection Model with Panel Data

Data preprocessing
- Collecting vehicle attributes from other sources
- Data Integration
- Data Cleaning
- Data Manipulation

Descriptive statistics analysis

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.

Percent of Successful Collision Avoidance

Vehicle model year / Test year  Percent of Successful Collision Avoidance

- 2018 ➔ 50%
- 2019 ➔ 61%
- 2020 ➔ 77%
- 2021 ➔ 81%
Given a crash, PCP systems, on average, **mitigated impact speeds** by more than **50%**
**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

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*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 midsize cars by IIHS

<table>
<thead>
<tr>
<th>Vehicle Brand</th>
<th>Test Speed (km/h)</th>
<th>Success Rate of PCP system</th>
<th>Average speed at impact (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tesla Model3 (2019)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>67%</td>
<td></td>
<td>15.340</td>
</tr>
<tr>
<td>40</td>
<td>60%</td>
<td></td>
<td>24.910</td>
</tr>
<tr>
<td>60</td>
<td>60%</td>
<td></td>
<td>31.910</td>
</tr>
<tr>
<td>All tests</td>
<td>63%</td>
<td></td>
<td>21.975</td>
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<tr>
<td><strong>Ford Fusion (2019)</strong></td>
<td></td>
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<tr>
<td>20</td>
<td>0%</td>
<td></td>
<td>18.690</td>
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<tr>
<td>40</td>
<td>33%</td>
<td></td>
<td>36.846</td>
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<tr>
<td>60</td>
<td>0%</td>
<td></td>
<td>43.440</td>
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<tr>
<td>All tests</td>
<td>17%</td>
<td></td>
<td>29.100</td>
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<tr>
<td><strong>Audi A4 (2019)</strong></td>
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<tr>
<td>20</td>
<td>100%</td>
<td></td>
<td>0</td>
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<tr>
<td>40</td>
<td>100%</td>
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<td>0</td>
</tr>
<tr>
<td>60</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All tests</td>
<td>83%</td>
<td></td>
<td></td>
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<tr>
<td><strong>Volvo S60 (2019)</strong></td>
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<tr>
<td>20</td>
<td>100%</td>
<td></td>
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<td>40</td>
<td>87%</td>
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<td>24.221</td>
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<td>60</td>
<td>40%</td>
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<td>27.201</td>
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<td>All tests</td>
<td>83%</td>
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<td>26.009</td>
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<td><strong>Lexus ES350 (2019)</strong></td>
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<tr>
<td>20</td>
<td>90%</td>
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<td>33.515</td>
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<tr>
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<td>0%</td>
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<tr>
<td>All tests</td>
<td>83%</td>
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<td>29.568</td>
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<tr>
<td><strong>Honda Civic (2019)</strong></td>
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<tr>
<td>20</td>
<td>100%</td>
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<td>40</td>
<td>80%</td>
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<td>60</td>
<td>20%</td>
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<td><strong>Toyota Prius (2021)</strong></td>
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<tr>
<td>20</td>
<td>100%</td>
<td></td>
<td>0</td>
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<tr>
<td>40</td>
<td>100%</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>0%</td>
<td></td>
<td>19.601</td>
</tr>
<tr>
<td>All tests</td>
<td>83%</td>
<td></td>
<td>19.601</td>
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<tr>
<td><strong>Acura TLX (2021)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>20</td>
<td>93%</td>
<td></td>
<td>18.516</td>
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<tr>
<td>40</td>
<td>100%</td>
<td></td>
<td>0</td>
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<tr>
<td>60</td>
<td>20%</td>
<td></td>
<td>11.433</td>
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<tr>
<td>All tests</td>
<td>83%</td>
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<td>12.850</td>
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</tbody>
</table>

• 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 midsize cars by IIHS
Modeling Results

- Increase in the **maximum deceleration rate** of PCP system (9 to 11 m/s²)
- Lower weight of vehicles

Decrease in the speeds at impact with pedestrians
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

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—**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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