Cyclist target and test setup for the evaluation of Cyclist-AEB systems

Olaf Op den Camp*, Sjef van Montfort, Jeroen Uittenbogaard, Joke Welten, TNO Integrated Vehicle Safety
Overview

- Introduction
- Method for development of test matrix
- Test matrix development
- Testing system specification and realisation
- Verification
- Conclusion
Cycling is increasingly popular

• In the Netherlands, 26% of all journeys occur by bicycle (CROW, ECF)

• Electric power-assisted bicycle:
  annual sales (in units) increased with factor of 10 in last 8 years in EU

• Social benefits of cycling
  – Scope for development (working, learning, recreating) in case no car / driving license
  – Elderly keep mobile avoiding social isolation
  – Environmental benefit (true zero emission)
  – Flow problem for car traffic
  – Parking problem in town centres and at workplace
  – Health of cycling
  – Traffic safety: more cyclists, less risks
Accident trends for cyclists (Europe, Netherlands)

- Trends of total road fatalities and cyclist fatalities for France, Germany, Italy, the Netherlands, Sweden plus the UK over the period of 2001 to 2012 according to CARE community road accident database as collected by the EU Member States.

- Trends for fatalities and seriously injured (total and bicyclists) for the Netherlands (NL) from 1996 to 2015.

30% of fatalities are bicyclists - 10% are pedestrians (2015)
Solutions to protect cyclists*

• **Injury mitigation:**
  - Pop-up bonnet
  - Windshield airbag
  - Personal protection equipment

* In car-to-cyclist accidents
Solutions to protect cyclists*

- **Collision avoidance / mitigation:**
  - Forward collision warning
  - Autonomous Emergency Braking

www.consumerreports.org

*In car-to-cyclist accidents*
Possible introduction of grid method
Update AEB VRU protocol

AEB in crossing, junction and head-on scenarios

**AEB Car2Car Rear stationary (CCRs):**
- 10 – 50 km/h
- 30 – 80 km/h
- 0 km/h

**AEB Car2Car Rear moving (CCRm):**
- 30 – 80 km/h
- 20 km/h

**AEB Car2Car Rear braking (CCRb):**
- 50 km/h
- 2 and 6 m/s²

**Possible introduction of grid method**
**Update AEB VRU protocol**
Objective

• Prepare the introduction of a protocol for consumer tests of Cyclist-AEB systems on board passenger cars
• Propose a test setup (incl. hardware) and test protocol for Cyclist-AEB systems based on technical/scientific considerations
• Base the tests on analysis of most relevant cyclist accident scenarios in EU countries

Timing: 2014 Q1 – 2016 Q2
Process to final test matrix

- Accidentology
- Observation study
- Simulation

NCAP pedestrian protocol (typical # tests, target) → First draft test matrix (July 2015)

Simulation studies → Initial tests with Volvo XC90 (2015)

Robustness tests TNO lab car → Updated draft test matrix (January 2016)

Verification tests (partners) → Final CATS test matrix (June 2016)

Final CATS test matrix (June 2016) → Euro NCAP AEB Working Group

Legend:
- : studies as input for CATS matrix
- : CATS matrix with relevant scenarios and parameter ranges
- : simulations and tests
- : input for AEB working groups
Development of a Cyclist-AEB testing system (CATS)

Approach

- Study databases for 6 European countries;
- Select severe car-to-cyclists accidents --> fatalities, seriously injured;
- Provide overview of distinguished accident scenarios;
- Determine the distribution of scenarios in the different countries;
- Prioritize scenarios & indicate coverage of fatalities and seriously injured.

<table>
<thead>
<tr>
<th>#</th>
<th>Country</th>
<th>Source</th>
<th>Killed (K) definition</th>
<th>Killed (K) n</th>
<th>Seriously Injured (SI) definition</th>
<th>Seriously Injured (SI) n</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>France</td>
<td>LAB</td>
<td>Fatal</td>
<td>72</td>
<td>severely injured</td>
<td>620</td>
<td>2011</td>
</tr>
<tr>
<td>2</td>
<td>Germany</td>
<td>GIDAS based PCM</td>
<td>Fatal</td>
<td>11</td>
<td>AIS2+</td>
<td>360</td>
<td>1999-2012</td>
</tr>
<tr>
<td>3</td>
<td>Germany</td>
<td>GIDAS</td>
<td>Fatal</td>
<td>12</td>
<td>AIS2+</td>
<td>514</td>
<td>2006-2013</td>
</tr>
<tr>
<td>4</td>
<td>Germany</td>
<td>National accident statistics</td>
<td>Fatal</td>
<td>345</td>
<td>AIS2+</td>
<td>11964</td>
<td>2008-2012</td>
</tr>
<tr>
<td>5</td>
<td>Italy</td>
<td>FIAT internal database</td>
<td>Fatal</td>
<td>23</td>
<td>AIS2+</td>
<td>17</td>
<td>2003-2014</td>
</tr>
<tr>
<td>6</td>
<td>Netherlands</td>
<td>BRON</td>
<td>Fatal</td>
<td>902</td>
<td>seriously injured</td>
<td>10854</td>
<td>2000-2013</td>
</tr>
<tr>
<td>8</td>
<td>UK</td>
<td>STATS19</td>
<td>Fatal</td>
<td>116</td>
<td>seriously injured</td>
<td>2699</td>
<td>2008-2010</td>
</tr>
</tbody>
</table>
Most common car-to-cyclist accident scenarios

- Weighted for 5* European countries upon # cyclist fatalities / million inhabitants

### Chart

- **C1**: 25%, 29%
- **C2**: 24%, 28%
- **L**: 7%, 6%
- **On**: 8%, 5%
- **T3**: 2%

### Table

<table>
<thead>
<tr>
<th>Country</th>
<th># road fatalities per million</th>
<th># cyclist fatalities per million</th>
<th>Weighting [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>62</td>
<td>2,8</td>
<td>11%</td>
</tr>
<tr>
<td>Germany</td>
<td>45</td>
<td>6,0</td>
<td>26%</td>
</tr>
<tr>
<td>Italy</td>
<td>68</td>
<td>5,4</td>
<td>-</td>
</tr>
<tr>
<td>Netherlands</td>
<td>32</td>
<td>9,2</td>
<td>38%</td>
</tr>
<tr>
<td>Sweden</td>
<td>28</td>
<td>3,6</td>
<td>15%</td>
</tr>
<tr>
<td>UK</td>
<td>30</td>
<td>2,3</td>
<td>10%</td>
</tr>
</tbody>
</table>

*Italy is dropped as the cases from the Italian database were too limited to be statistically relevant.
Typical parameter ranges for the scenarios

- Based on in-depth accident studies
Development of a Cyclist-AEB testing system (CATS)

Observation study into view-blocking obstructions

- Influence on speed profile of bicycle and car upon approach
- Posture and behaviour of bicyclist (e.g. pedaling or not)
**Observation study into view-blocking obstructions**

- Bicycles reduce speed with 6 km/h in case of a view-blocking obstruction
- More than 80% of all cyclists stopped pedaling

<table>
<thead>
<tr>
<th>Bicycle manouevre</th>
<th>Stopped pedaling</th>
<th>Full stop</th>
<th>Continued pedaling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continued riding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td>total</td>
<td>68</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>no cars present</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>car from left</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>car from right</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>cars from both sides</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Turning left</td>
<td>total</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>no cars present</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>car from left</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>car from right</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>cars from both sides</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Turning right</td>
<td>total</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>no cars present</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>car from left</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>car from right</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>cars from both sides</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total # bicycles</td>
<td></td>
<td>93</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
</tbody>
</table>
Development of a Cyclist-AEB testing system (CATS)

Cyclist target: soft bicyclist dummy on soft bike dummy

- Version 4activeBS v5

- Changeable handle bar for Dutch and European bike
- White reflector in the front mounted on the frame
- Polymer frame with metal layer for radar properties
- Plastic mud guard
- Real rubber tire with reflecting ring
- Rim with reflecting material
- Materials and properties of bicyclist same as Euro NCAP Pedestrian Target
- Adjustable torso-angle
- Rotational joint of hip connected to bike frame
- Rear red reflector mounted on the luggage rack
- Rotational joint at the knee point
- Rotating wheels due to contact to the ground
## Final CATS matrix – version June 2016

<table>
<thead>
<tr>
<th></th>
<th>CVNBU</th>
<th>CVNBO</th>
<th>CVFB</th>
<th>CVLB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle speed</td>
<td>20 – 60 km/h</td>
<td>10 – 40 km/h</td>
<td>20 – 60 km/h</td>
<td>30 – 60 km/h</td>
</tr>
<tr>
<td>Cyclist speed</td>
<td>15 km/h</td>
<td>10 km/h</td>
<td>20 km/h</td>
<td>15 km/h</td>
</tr>
<tr>
<td>Obstruction</td>
<td>Without</td>
<td>With D1=3.55m, D2=4.80m</td>
<td>Without</td>
<td>Without</td>
</tr>
<tr>
<td>Collision point</td>
<td>50 %</td>
<td>50 %</td>
<td>25 %</td>
<td>50%</td>
</tr>
<tr>
<td>AEB / FCW</td>
<td>AEB</td>
<td>AEB</td>
<td>AEB</td>
<td>AEB</td>
</tr>
<tr>
<td># tests [36]</td>
<td>9</td>
<td>7</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Layout sketch</td>
<td><img src="image" alt="Layout sketch CVNBU" /></td>
<td><img src="image" alt="Layout sketch CVNBO" /></td>
<td><img src="image" alt="Layout sketch CVFB" /></td>
<td><img src="image" alt="Layout sketch CVLB" /></td>
</tr>
<tr>
<td>Expected feasibility 2018</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>
| Important notes: | • Main challenge in CVNBU is system robustness (AEB response after collision is unavoidable: cyclist cannot break or steer away to avoid collision) | • Main challenge in CVNBO is the limited time for system response. | • CVFB is not expected to be feasible for production vehicles in 2018, especially due to challenges in Field-of-View requirements, response time and real-world robustness. | • Recommended to verify that the vehicle shows AEB performance with a 25% collision point with one VUT speed in the 30-60 km/h speed range to ensure AEB performance at a collision point below 50%.
• Field-of-View is a general issue for the 3 crossing scenarios at low vehicle speeds.
• System robustness is a general issue for the 3 crossing scenarios at high vehicle speeds. | • Evaluation of FCW considers collision avoidance by steering and not braking. |
Test track
Verification of the Cyclist-AEB testing system (CATS)

Simulation

- Decrease in performance to avoid false positive responses

The figures show the speed reduction of the AEB system at the end of a test for the different initial VUT speeds, where the markers indicate the results for one test. The upper row shows the results for a sensor field of view of 2 x 24° for the 3 different scenarios, the lower row shows the results for an FoV of 2 x 45°. The line for collision avoidance is the 45° grey dashed line in each figure:

- : full collision avoidance, VUT comes to full stop
- : full collision avoidance by reduction of speed
- : collision, no speed reduction or speed reduction insufficient
Euro NCAP proposes to postpone the introduction of CVNBO and CVFB until 2020.
Conclusion

- Successful process to develop the Cyclist-AEB testing system
- CATS protocol including test matrix proposed to Euro NCAP AEB VRU working group
- Euro NCAP proposal for 2018 and 2020 in line with CATS findings

Outlook

- Active communication and dissemination of CATS results
- Technical briefing October 6th, 2016, Helmond (NL)
- Euro NCAP Round Robin test of Cyclist-AEB protocol (spring 2017)
- Considerations towards 2020:
  - Specification of view-blocking barrier
  - Dealing with parameter ranges in protocol
- Development of cyclist intent prediction models to support Cyclist-AEB control law
- Market introduction of Cyclist-AEB systems on more production vehicles
Thank you very much for your attention