

# Quantitative Evaluation of Safe Driving Behaviors and Their Limitations for Autonomous Driving Vehicles in Car-to-Bicycle Crossing Scenarios

- (First Report) Near-Miss-Based Risk Assessment -

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This study proposes a data-driven framework for quantitatively evaluating the safe driving behavior and inherent limitations of autonomous driving vehicles (AD vehicles) in car-to-bicycle crossing scenarios at unsignalized intersections with occlusions. Using 483 near-miss cases extracted from the large-scale near-miss database of the Smart Mobility Research Center at Tokyo University of Agriculture and Technology, this research reconstructs each near-miss into a hypothetical "worst-timing collision scenario" to assess whether an AD vehicle could avoid a crash if the timing of arrival at the conflict point were unfavorable.

A key characteristic of the dataset is the diversity of occlusion geometries. As shown in Fig. 1, the positions of occluding wall corners vary widely, indicating that the distance at which the vehicle can begin to perceive the bicycle varies greatly from case to case, leading to inconsistent recognition opportunities for AD vehicles across different situations. Bicycle approach behavior is also highly variable. Fig. 2 demonstrates that bicycle speed and distance from the occluding wall show no clear correlation, confirming that no obvious trend exists, such as bicycles traveling slower when closer to the wall or faster when farther away. Understanding these real-world conditions is essential for objectively assessing the safety of AD vehicles.

To evaluate safety performance, each near-miss case was transformed into a collision-timing-aligned scenario by adjusting the time axis so that the AD vehicle's front corner and the bicycle's front end would coincide at the conflict point ( $t = 0$ ). The AD vehicle model used recognition and braking parameters derived from ASV Phase 6 and UN R157 standards. For each case, the minimum speed at which the AD vehicle could avoid collision was computed.

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sudden emergence of bicycles. Furthermore, the study evaluates the effect of proactive deceleration. Fig. 3 and Table 1 summarize the reduction in unavoidable cases as the AD vehicle reduces its speed in 5 km/h increments. The results show that: (i) at the posted speed, 43% of cases are unavoidable; (ii) with a -10 km/h pre-deceleration, 16% are unavoidable; and (iii) with a -20 km/h pre-deceleration, unavoidable cases fell to only 2%. However, such a substantial decrease in speed is unrealistic in actual traffic environments.

Overall, this first report establishes a robust methodology for converting real-world near-miss data into standardized collision-risk scenarios, demonstrating the necessity of considering both AD vehicle behavior and environmental constraints when evaluating safety.

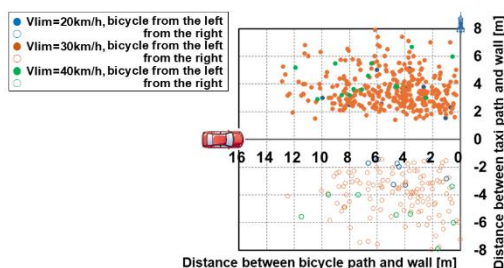


Fig. 1 Distribution of occluding wall corners

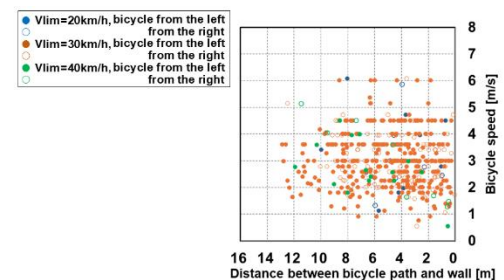


Fig. 2 Relationship between bicycle speed and bicycle-wall distance

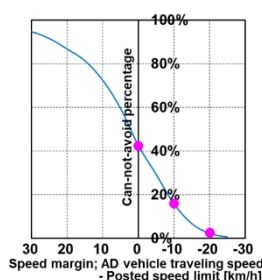


Fig. 3 Effect of pre-deceleration

Table 1 Effect of pre-deceleration

|                  | Cumulative case counts by speed limit |        |        |       | Percentage |
|------------------|---------------------------------------|--------|--------|-------|------------|
|                  | 20km/h                                | 30km/h | 40km/h | Total |            |
| More than 40km/h | 19                                    | 441    | 23     | 483   | 100%       |
| +35              | 19                                    | 424    | 18     | 461   | 95%        |
| +30              | 19                                    | 420    | 18     | 457   | 95%        |
| +25              | 18                                    | 406    | 18     | 442   | 92%        |
| +20              | 16                                    | 385    | 18     | 419   | 87%        |
| +15              | 15                                    | 362    | 16     | 393   | 81%        |
| +10              | 13                                    | 322    | 15     | 350   | 72%        |
| +5               | 9                                     | 267    | 12     | 288   | 60%        |
| 0                | 4                                     | 193    | 9      | 206   | 43%        |
| -5               | 4                                     | 134    | 4      | 142   | 29%        |
| -10              | 2                                     | 73     | 2      | 77    | 16%        |
| -15              | 0                                     | 32     | 1      | 33    | 7%         |
| -20              | 0                                     | 11     | 0      | 11    | 2%         |
| -25              | 0                                     | 3      | 0      | 3     | 1%         |