

How Pavement Marking Quality Impacts ADAS and Machine Vision: Insights from Connecticut's Groundbreaking Study



As Advanced Driver Assistance Systems (ADAS) and Connected and Automated Vehicles (CAVs) become more prevalent, the role of pavement markings is undergoing a fundamental shift. No longer serving only human drivers, these markings now provide critical visual cues for vehicle cameras and machine vision systems that enable lane keeping, departure warnings, and other life-saving ADAS functions.

Several authors and groups have analyzed the effects of pavement marking properties and the interaction with human drivers and ADAS. A recent 2024 study from the Connecticut Department of Transportation (CTDOT) added to this body of work, particularly focusing on the detection capabilities of ADAS. Conducted by the Connecticut Transportation Institute and the Connecticut Transportation Safety Research Center at the University of Connecticut, the study titled "Automated Vehicle and Pavement Marking Evaluation in Connecticut" (Report No. CT-2326-F-23-5) examined how real-world pavement marking characteristics affect the detectability of longitudinal lane markings by ADAS-equipped vehicles.

The research provides essential findings that DOTs across the nation can use to inform maintenance standards and material choices.

This article distills key insights from the study highlighting the performance benefits of highly retroreflective and consistent lane markings, and the case for using wet-retroreflective materials.

What the study evaluated

The study set out to explore how factors like retroreflectivity and color of pavement markings influence their detection by vehicle-mounted cameras across multiple makes and models of consumer vehicles equipped with ADAS features. Researchers collected data before and after restriping operations on selected Connecticut roadways using:

- A vehicle-mounted retroreflectometer
- Eight consumer vehicles with varying ADAS configurations
- Real-world driving conditions (daytime and nighttime)

Key Findings: High-Quality Markings Make a Difference

1. Detection Improved Substantially After Marking Enhancements

A primary takeaway from the before-and-after comparison is clear: vehicles detected pavement markings more reliably after restriping with higher-quality materials.

On multiple routes, the detection success rate of both centerlines and edgelines increased significantly after markings were refreshed or upgraded.

- Centerline and edgeline retroreflectivity, and visibility all improved after final paint applications.
- Vehicles' ADAS systems, across multiple makes, registered more frequent and consistent detection events.
- These findings suggest that marking upgrades yield measurable benefits in system performance.

2. Detection Results Were Consistent Across Multiple Runs

To test repeatability, researchers conducted multiple runs on the same route with the same vehicle. The detection outcomes were consistent, validating that high-performing markings lead to reliable ADAS system response over time, not just during isolated conditions. This reliability reinforces the value of investing in premium marking materials for corridors prioritized for safety or CAV readiness.

3. System Improvements Were Observed Across Multiple Vehicle Models

Importantly, vehicles from different manufacturers with distinct ADAS hardware and software configurations all demonstrated better lane marking detection post-improvement.

- This cross-platform improvement underscores a key message: when markings are clear, retroreflective, and consistent, all vision-based systems benefit, regardless of proprietary technology.
- It also validates that infrastructure-level improvements (like striping) can provide wide-reaching safety and performance enhancements, independent of vehicle make.

Commentary on Pavement Marking Quality Impact

The study highlights the importance of pavement marking quality in enhancing ADAS and machine vision capabilities. Wider pavement markings can be seen from further distances, improving response times for both human drivers and machine vision systems. This is why future studies should focus on measuring visibility over longer distances to capture the full impact of marking quality.

Recommendations on Pavement Marking Quality and ADAS Impact

Enhance Pavement Marking Visibility:

Invest in wider pavement markings to improve visibility over greater distances, supporting both human and machine vision systems. Increase contrast in pavement markings, as recommended by the MUTCD, to enhance detection robustness for ADAS and human drivers.

Improve Study Methodologies:

Future studies should measure visibility from greater distances, beyond the short range from the front bumper, to better assess the impact of pavement marking quality on response time for both human and machine vision. Consider the impact of pavement marking visibility on concrete, where contrast and width are critical for effective detection.

The Value of Wet-Retroreflective Pavement Markings

Although most of the Connecticut study's testing occurred under dry conditions, both the researchers and national literature point to a critical concern: wet weather and low-light conditions significantly reduce the visibility of pavement markings, which directly affects both human driving and ADAS functionality.

Wet-retroreflective markings, which are engineered with specialized optics or embedded glass bead technology, help maintain consistent retroreflectivity under rainy and nighttime conditions. This makes them crucial for roadway safety and automation readiness.



Why this matters

Weather and Visibility Challenges:

- Rain and low-light conditions frequently contribute to lane departure crashes, especially on highways and rural roads with limited visibility¹.
- Machine vision systems perform optimally when markings maintain visibility across all weather conditions, including wet-night scenarios^{2,3}.
- Infrastructure Investment:
 - DOTs investing in wet-retroreflective pavement markings enhance safety for human drivers and future-proof infrastructure for automated vehicles and broader ADAS adoption³.

Final Thoughts

This study affirms the long-standing advocacy by traffic engineers for well-maintained, high-visibility pavement markings as a cornerstone of roadway safety.

With the integration of vehicle-based vision systems, the importance of quality markings is even greater. Pavement markings are essential not only for human drivers but also for automated systems navigating modern roads.

For DOTs modernizing infrastructure in line with vehicle automation trends, the message is clear:

- Invest in quality markings:
- Focus on high retroreflectivity and wet-retroreflective capabilities.
- Standardize Dimensions and Contrast:
 - Support both human and machine vision with standardized marking practices.
- Update Maintenance Practices:
 - Reflect the dual role of markings in traditional and automated driving environments.

References

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Citations

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