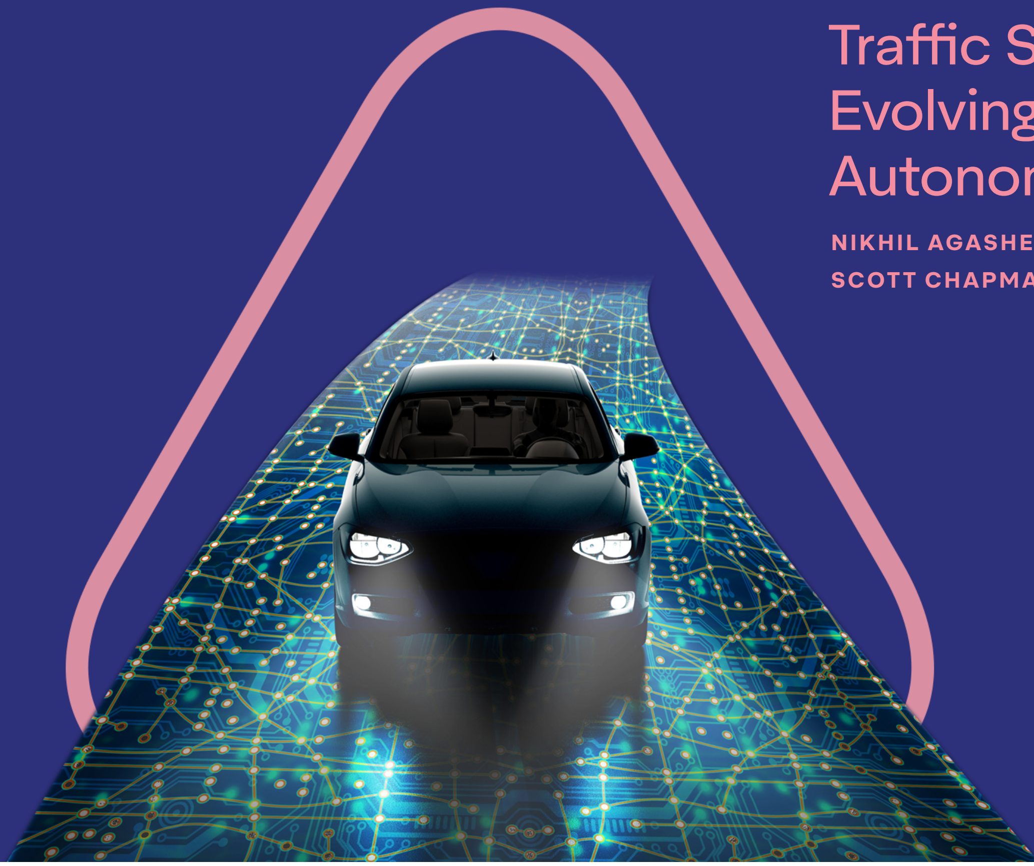

Traffic Signs in the Evolving World of Autonomous Vehicles

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As a manufacturer of retroreflective sheeting used on highway signs that improve roadway safety around the world, our safety commitment keeps us focused on issues that contribute to making traffic signs more effective both today and tomorrow.

"Will signs be used in the future, and will they really need embedded bar codes or *smart technology*...?"

The automotive industry is moving into a transportation future where connected and autonomous vehicles will outnumber those driven by humans. With rapid advances in Advanced Driver Assistance Systems (ADAS), highway professionals charged with designing, building, and maintaining our roadways are keenly interested in understanding what changes in today's safety infrastructure will be required in the future. While we can't predict the future, we can address today's concerns around the relationship between traffic signs and self-driving vehicles. Will signs be used in the future, and will they really need embedded bar codes or *smart technology* to communicate in non-visual modes with vehicles (V2V), infrastructure (V2I), and pedestrians (V2P)? Will camera vision systems improve on existing Traffic Sign Recognition (TSR) technology to process today's sign symbols and legends? Will real time changes in road conditions such as speed limit reductions in work zones or temporary lane closures cause insurmountable issues to the online autonomous controller systems?

Certainly the pace of technology may well change the answers to these questions in the future. But let’s start with what we know now in order to help those making design decisions today; these decisions impact traffic signs that will still be operational for many years in the future. After all, traffic sign production, installation, and ongoing maintenance is a significant investment for every public transportation agency around the world. Avoiding obsolescence of these assets is of supreme importance.

Detection Systems

Multiple features are available on vehicles today that detect lane markings, other vehicles in the front, rear, and driver blind spot, as well as pedestrians or other objects in the vehicle’s path. These features are enabled by a variety of sensors, including radar, sonar, lidar, and camera systems. If automotive history teaches us anything, it is that the technology platform that ultimately prevails will need to demonstrate reliability, consistency, and be suitable for low-cost mass production across multiple vehicle types and models.

Perhaps the most important system may be in-vehicle high pixel resolution cameras used to gather data. These systems continuously monitor vehicles moving in the same direction, oncoming traffic, vehicles stopped on the roadside either parked, merging, or waiting to merge. Some camera systems are also coupled with radar systems. The on-board radar or lidar systems ping the surroundings with a preset frequency radio wave looking for the echo when these waves bounce off surrounding objects. In this mode the camera system functions as the first or second line of warning for the vehicle’s computer systems. The primary responsibility for this system is to detect and avoid a physical interaction between the vehicle and object.

“Perhaps the most important system may be in-vehicle high pixel resolution cameras”

Avery Dennison, 2019

Vehicle mounted high resolution camera sensors allow traffic signals and signage to be detected.

Camera systems rely on daylight bouncing off the surroundings which is then captured using a Charged Couple Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) sensor. These sensors can be designed to be extremely sensitive to the amount of light available so that these camera systems can be used in low light situations such as dawn, dusk, cloudy and inclement weather. In some cases these sensors can be complemented by a thermal imaging (TIR) camera or a forward looking infrared (FLIR) camera to detect the heat radiated from an object to help in detecting and positioning the object.

Camera-based TSR technology has seen steady improvement over the past decade, and will continue to become more relevant as ADAS technology improves, enabling driving to become more reliably automated. The most significant work with TSR to date has taken place in Europe, with speed limit signs the initial target of this technology. A number of tech companies have developed sign detection and classification software and deployed it in limited geographies on a number of models offered by BMW, Mercedes, Mazda, Honda, and others.

Mobileye, an industry leader of ADAS enabling cameras and software, has asserted that a single-lensed camera (mono-camera) will prevail as the primary sensor to support ADAS and eventually fully autonomous vehicles. Mono-cameras can identify shapes, including vehicles and pedestrians, as well as identify textures such as lane markings and traffic sign text. Cameras will collect and transmit data on sign location and legend to mapping aggregation systems in the cloud that are available to technology equipped vehicles. This redundancy of highly detailed and accurate maps are critical for ensuring safety. Cameras act as real-time sensors for driving path geometry and sign verification with the cloud based map.

However, camera systems used today have not advanced to the level of a human driver who can read and interpret the complete variety of messages contained in regulatory, warning, and informational signs. Nor can cameras identify and interpret traffic signs on par with their human counterparts in the relative blink of an eye. Light conditions, signs placed at severe angles of approach, signs hit and knocked askew, signs covered by dirt or dew, or signs obscured by large vehicles in the camera's field of vision—these all pose challenges for visual-dependent systems and mapping verification.

Mobileye, Intel, 2017

Mobileye uses computer vision algorithms to detect free road space, traffic signals, signage, vehicles, and pedestrians.

Sign Design Challenges

Although TSR has developed significantly in the past several years, the extreme variation in traffic signs around the world means that the problem of consistent, accurate detection and recognition is far from being solved. To date, much of the successful work in this area has been conducted in Europe, using signs which conform to the Vienna Convention on Road Signs and Signals. Australia, Japan, and to a lesser extent China, also design their signs similar to Europe. The differences between European and US signs matter significantly in the context of detection, actually placing European sign standards in a more favorable position. Figure 1 illustrates this issue on only a small sampling signs.

Figure 1

Sign Examples from the Vienna Convention

Keep Right Mandatory | Left Turn Danger | 60 km/h Speed Limit Prohibitory

Corresponding US Signs from the Manual on Uniform Traffic Control Devices

Keep Right Regulatory | Left Turn Warning | 60 mph Speed Limit Regulatory

Each European sign class employs greater use of shape, border widths, and colors that not only are very distinct from each class, but from most things seen in a roadway environment.

The US employs sign elements not as distinctive and visually strong as their European counterparts. Warning signs may use yellow, orange, fluorescent-yellow or fluorescent yellow-green.

Only the US STOP sign and railroad crossing sign have meanings specific to their shape.

The vast majority of US signs are just white rectangles with different aspect ratios, conveying their message by text alone, posing challenges to detectors looking for color cues, whereas European signs feature pictograms and other icons which aid recognition.

Avery Dennison, 2018

Detailed logos for communities add visual flair to traffic signage, but can come at a cost of increasing the difficulty for cameras to read and recognize.

Improved Optical Character Recognition (OCR) technology is expected to take simple shape and legend recognition to the next level in the future. However, even with enhanced technology, systems will still need to contend with non-uniformity of size, font style, and text location prevalent on today's traffic signs. Design features popular with many jurisdictions, including community identification logos and other special characters, will add to the complexity that camera systems will need to overcome to distinguish between essential and nonessential messaging. Each of these factors can introduce processing delays, and depending upon vehicle speed, are critical determinants of a safety system that must include the capability to avoid negative events.

Today, the camera vision industry acknowledges that traffic sign recognition can be improved by initiating these actions:

1. Increase sign size to assure signs exceed minimum pixel size filtering, and are detected at a greater distance to allow longer processing and reaction time by the TSR system.
2. Use the symbol sign equivalent of the text version of warning signs.
3. Standardize font type, size, message, and sign placement.
4. Adopt sign maintenance practices to keep signs clean and unobstructed by vegetation or other roadway infrastructure—offering a clean line of sight for cameras.

Each of these improvements benefit TSR systems that will enable the continued improvement of connected and autonomous technology. Importantly, they also improve visibility and legibility for all human vision—including non-motorized roadway users. If each of these improvements sound familiar, you are not alone.

1 Increase sign size

2 Use symbols

3 Standardize

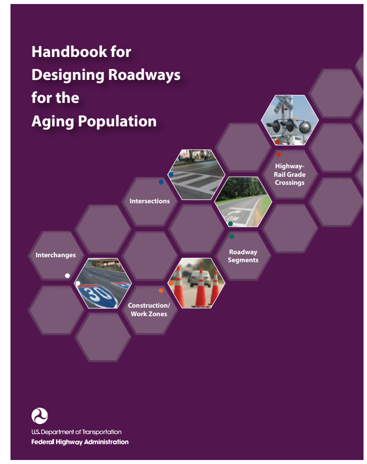
4 Maintain

Traffic Signs—Back to the Future?

Since the late ‘80’s, the traffic engineering community has increased efforts to improve safety for our increasing population of aging drivers and pedestrians. This group of roadway users typically experience declining vision, slowed decision-making and reaction times, exaggerated difficulty when dividing attention between traffic demands and other important sources of information, and reductions in strength, flexibility, and general fitness. In June 2014, the Federal Highway Administration published the *Handbook for Designing Roadways for the Aging Population*[1]. The handbook is a valuable resource containing multiple research-backed safety treatments to improve safety, making it easier for older drivers—and all roadway users—to maintain their mobility. Among the many safety treatments suggested, these stand out with respect to traffic signing:

- The use of the largest practical sign sizes specified in the Manual on Uniform Traffic Control Devices (MUTCD) for a variety of signs including WRONG WAY, DO NOT ENTER, KEEP RIGHT, ONE WAY.
- To accommodate the reduction in visual acuity associated with increasing age, use a minimum letter height of 6" uppercase, 4.5" lowercase on ground mounted street name signs on roads with a posted speed limit at or below 25 mph. Use a minimum letter height of 8" uppercase and 6" lowercase on ground mounted street name signs on roads with a posted speed limit greater than 25 mph.
- Use advance street name plaques or advance street name signs using minimum 6" uppercase and 4.5" lowercase letters.

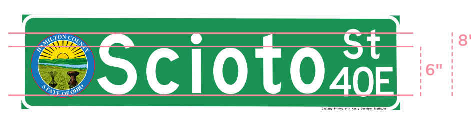
Similar recommendations for improving traffic sign recognition for older drivers are being made in many countries around the world. But in addition, many transportation agencies are improving sign legibility by placing increased emphasis on proper sign placement and implementing sign inspections to verify sign retroreflectivity. It’s important to note that all of these improvements in sign and letter size—and sign maintenance to aid older drivers—are consistent with industry recommendations to aid TSR systems.



FHWA, 2014

“The handbook is a valuable resource containing multiple research-backed safety treatments to improve safety, making it easier for older drivers, and all roadway users, to maintain their mobility.”

Ground-mounted signs on roads with speed limits at or below 25 mph should use minimum type sizes of 6" uppercase and 4.5" lowercase letters.



Ground-mounted signs on roads with speed limits above 25 mph should use minimum type sizes of 8" uppercase and 6" lowercase letters.

[1] Handbook for Designing Roadways for the Aging Population, FHWA-SA-14-015, June 2014

Today's Actions

Our industry has a responsibility to provide for the needs of all road users, including motorized vehicles, bicycles, and pedestrians. It will be many years, perhaps decades, before our transportation system experiences a complete fleet change to self-driving technology. This means that humans will still form the vast majority of drivers for the foreseeable future. In the meantime, traffic signs need to accommodate the needs of all road users—including those without the technology. This responsibility will continue through all stages of autonomous vehicle deployment.

Transportation agencies have a clear path on signing improvements to prepare for tomorrow's technology. Start today by reviewing your sign standards to ensure they are consistent in required fonts and letter height. Make greater use of symbol signs, and increase sign size where possible. Larger and brighter signs can be detected and read at longer distances by both human and camera vision, improving safety by permitting increased comprehension and reaction time. Review your agency's standards for retroreflective sheeting type. Are you taking advantage of OmniCube™—a high efficiency prismatic sheeting—to maximize light return to roadway users? And finally, adopt effective maintenance practices to review signs in the field, ensuring they are properly placed and allow unobstructed viewing.

"You can rely on Avery Dennison... to remain at the forefront of developing reflective traffic sign technology—all while sharing those learnings with our global audience."

These incremental signing improvements can be implemented immediately by our highway safety industry. They incorporate existing materials, processes, and proven safety measures that will benefit generations of roadway users as we move forward into the future. It may require realigning budget priorities, but positive results can be achieved without an exponential investment in infrastructure. You can rely on Avery Dennison to continue remaining engaged in industry developments related to traffic sign performance, and to remain at the forefront of developing reflective traffic sign technology—all while sharing those learnings with our global audience.

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