Attachment 1 to Comments Submitted February 26, 2021

Comments Concerning: **NHTSA Framework for Automated Driving System Safety.**
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The NHTSA Framework has been written from a perspective of safety being derived solely from the capabilities of each individual automated vehicle's ADS, without consideration of the role that intelligent infrastructure should play – particularly in the most complex operating environments that are commonly found in dense urban settings. Roughly 50% of accidents occur at roadway intersections, with many involving pedestrians, bicyclists or other "vulnerable roadway users" (which will be referred hereafter as simply "non-vehicular modes"). The deployment of automated vehicle (AV) technology, when left to the sole capability of the ADS onboard vehicle sensing and AI perception is not expected to dramatically reduce the critical concentration of accidents at intersections. This prospect alone makes major intersections and other complex roadway junctions an element of the roadway network a place where dedicated safety-oriented technology application is needed.

The configuration of roadway junctions—particularly in dense urban settings – is typically such that the approach of vehicles and/or non-vehicular modes cannot be seen or sensed by the equipment on a single vehicle approaching from a crossflow direction. The ability to install fixed infrastructure that has been designed to sense and perceive all approaching vehicular and non-vehicular modes is therefore fundamentally important to ensuring safe operations through complex roadway junctions, while maintaining reasonable speed and throughput performance. Just as existing traffic signalization has been justified through traffic warrants, infrastructure-based vehicle control and deconfliction with respect to automated vehicles is a critical layer that must be added to these studies as a justification of the installation of intelligent infrastructure at specific locations in the roadway network. As an example, intersections that would be considered having "complex operations" would comprise a junction with two major arterial streets in areas where high levels of non-vehicular mode activity can occur.

The NHTSA Safety Framework identifies what SAE calls cooperative driving automation (CDA), but the NHSTSA approach does not give credence to the CDA between ADS Level 4 and 5 vehicles and intelligent roadway infrastructure. The concept of vehicle-to-vehicle (V2V) communications to achieve CDA is not flawed, but what V2V alone is expected to accomplish in terms of major advances in safety at major roadway junctions is (in the opinion of the authors) over-estimating its effectiveness.

Current intersection operations are extremely hazardous zones within the roadway network. Within these intersection zones, current operations with conventional human-operated vehicles require only one fault, such as an inattentive driver, to create a safety critical hazard. AVs, though more vigilant than human drivers, persist this limited safety layer at intersections that is subject to a single point of failure. Other automated systems, such as communication-based train control used on Automated Guideway Transit, require fail-safe design of guideway junctions which eliminates the possibility of a single fault creating a hazardous condition. Similarly, infrastructure-based sensing and control at intersections can greatly enhance safety when AVs are introduced into the traffic operations, while maintaining high-performance throughput and improving safety protection against single point of failure hazards.

Engineering Measures

Using the core elements of ADS safety provisions that the NHTSA Safety Framework describes as "Engineering Measures", the means of achieving safe operations of highly automated vehicles around each major roadway junction or intersection should also be applied to roadway infrastructure. The application of sensing, perception, planning and control to intelligent infrastructure within a "safety zone" can used to direct safe vehicular movements and to deconflict vehicle paths within the zone. This will be essential to bringing automated mobility solutions to urban settings, while also optimizing traffic operations with respect to energy use and emissions reductions as a secondary but important additional benefit.

Without the deployment of intelligent infrastructure dedicated to protecting specific major intersections and all the approaches to that specific location, the only solution for safe operations – when AVs are limited to the vehicle-based sensors and perception – is to slow down the AVs operating speed when approaching the critical safety zone around an intersection. This is a valid solution to safety of the individual AV that cannot perceive what is coming "around the corner". However, in the presence of other conventional human-operated vehicles this safety feature of slowing down the speed of AV vehicles has been found to create anxiety and more aggressive behavior for the human-operated vehicles sharing the traffic flow. To put it simply, at the very time when almost all AVs would be slowing down on approach to an intersection, human drivers are instinctively speeding up to get through the intersection before the signal phase changes. This situation creates a more hazardous operating condition, rather than the intended objective of the AV response of slowing down to improve safety.

The best solution to managing efficient operations where all vehicles (including AVs) can safety approach a major roadway junction while maintaining a reasonable operating speed is to apply intelligent infrastructure as part of the CDA engineering design. The safety functions previously limited to "alerts" in prior DSRC research would then be able to be enhanced to certain aspects of command and control. Vehicle ADS would need to cooperate by executing safe responses of each AV's approach to the intersection while being "directed" to perform specific actions by the intelligent infrastructure.

Such an approach is even more critical in the transition period in which AVs and conventional human-driven vehicles will share the same roadway. Failure to yield at intersection by conventional human-driven vehicles will continue to be one of the most prominent (if not the most prominent) safety hazard for AV or conventional human-driven vehicles. Even a 100% reliable and attentive AV vehicle will experience only a 50% decrease in crash probability due to the safety hazard presented by conventional human-driven vehicles. For example, a 90-degree high velocity impact at an intersection due to failure of a conventional human-driven vehicle to appropriately yield will still pose a significant safety hazard to AVs when operating with safety protection solely limited to the threatened vehicle's ADS. Unless the AV slows its operating speed through the intersection, while constantly monitoring side approaches for safety hazards presented by conventional human-driven vehicles, the AV will expose itself to possible crash hazards. If the goal of the USDOT is truly progress toward the goal of zero traffic fatalities, infrastructure-based sensing and control as part of a Cooperative Driving Automation design, the zero fatality future will be seriously compromised. A much safer operating environment will be accomplished if intelligent infrastructure is created which is capable of monitoring the approaches from all legs of the intersection conflict zone for all modes of roadway users, and communicating safety affirmative control signals to all approaching AVs.

With respect to vehicle-to-infrastructure (V2I) communications, the NHTSA Framework is silent. This is a critically important part of the vehicle and infrastructure CDA. The communication links must, as a minimum, be highly reliable, extremely low latency (milliseconds, not 1-2 seconds) and highly secure from cyber-attacks.

Process Measures

The safety assurance process by which hazards are analyzed and safety risks are mitigated, should include the preparation of a "safety case" by a suitable authority having jurisdiction for each major intersection's intelligent roadway infrastructure. This process would ensure that proper sensory equipment is designed and implemented to accomplish the location-focused AI perception that is necessary to be applied for the specific roadway configuration. Critically important will be the perception and protection of both the vehicular and non-vehicular mode movements through the intersection.

This approach of having dedicated intelligent infrastructure designed to protect specific roadway intersections will more successfully address the most difficult problems of either conventional vehicles or non-vehicular modes "breaking the rules," particularly when crossing vehicular travel lanes. The monitoring can then be focused on detecting (or even anticipating) these movements and initiating appropriate commands to be sent to specific automated vehicles in specific lanes that might be at risk of striking the errant vehicle or pedestrian/bicyclist. In addition, the intelligent infrastructure would also send alerts to connected L1, L2 or L3 human-operated vehicles, or even connected non-vehicular mode users, to initiate their proper response.

Research Needs

The lack of attention to roadway infrastructure sensing, perception, and control, and the missing research for this critical element of the CDA technology development, has raised the possibility that safer and more efficient roadway operations will NOT be realized as vehicle automation begins to enter the roadway network. It is proposed that research in the field of intelligent roadway infrastructure would be most effective if it is accomplished in dense urban environments where AV fleet operations will be concentrated in the coming decade. It is further noted that the missing contributor to this critical development area is the ITS industry, which understands the entire multimodal operating environment described herein.

NHTSA can enhance the Nation's preparedness for the future of automated mobility if this attention to R&D of intelligent roadway infrastructure was supported by the Framework's revision to include the missing CDA safety functionality being accomplished through infrastructure technology applications at complex roadway junctions.