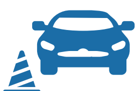
December 2025

Work Zone Management for Light Vehicles Using Cooperative Driving Automation (CDA)

Work zone fatalities have increased 61 percent since 2013.[1] CDA can help decrease these fatalities and support safer automated vehicle (AV) operations with infrastructure-communicating work zone configurations and with restrictions to AVs before they reach the work zone. These strategies increase the AVs' situational awareness and plan their motion. Due to the implementation of temporary traffic controls, work zones pose a challenge for automated driving systems to navigate, as some of these systems may be using previously created maps of roads for their driving environment. Work zones often change lane configurations, disrupt lane markings, and obscure other vehicles and pedestrians, which can challenge AV perception and navigation systems.

FACT SHEET

BENEFITS TO TRANSPORTATION



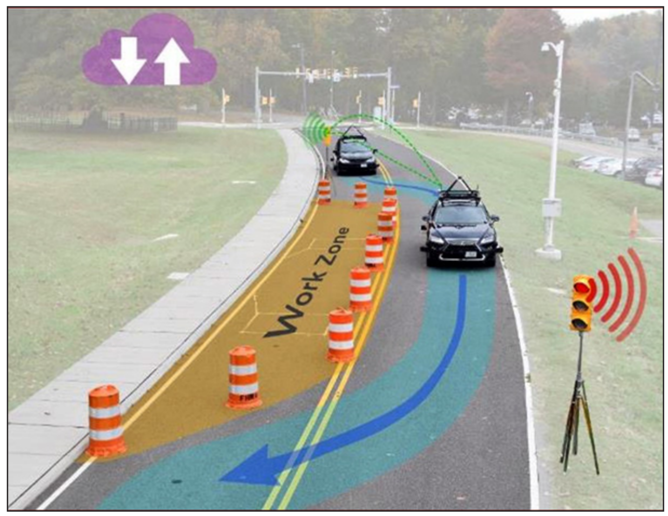
Improved Safety: CDA improves safety by facilitating communication between work zone infrastructure and vehicles; this enables vehicles to adapt their routes and speeds for safe navigation through the work zone, thereby reducing the probability of accidents. Safety was further improved by utilizing a traffic controller instead of a flagger to regulate bidirectional traffic in the open lane of a two-lane arterial road when a lane is closed due to road work. The traffic signal controller provides the signal phase and timing (SPaT) data to the vehicles for safe navigation.

All images source: FHWA.

Improved Mobility: CDA improves mobility by enabling autonomous vehicles to update their internal maps with real-time work zone configurations and react proactively to evolving driving conditions by adjusting their trajectories to optimize traffic flow. This technology mitigates congestion at work zone entrances and exits and potentially provides some energy usage benefits.

EVALUATION OF THE CONCEPT:

The light-vehicle work zone scenario was designed to test how CDA can improve work zone safety on a two-lane arterial road with one lane closed due to a work zone and with traffic alternating directions in the open lane. In this scenario (figure 1), a vehicle equipped with CARMA Platform℠[2] approaches the work zone. A fixed-timed traffic light controls traffic in the open lane, replacing a flagger.



Source: Federal Highway Administration (FHWA).

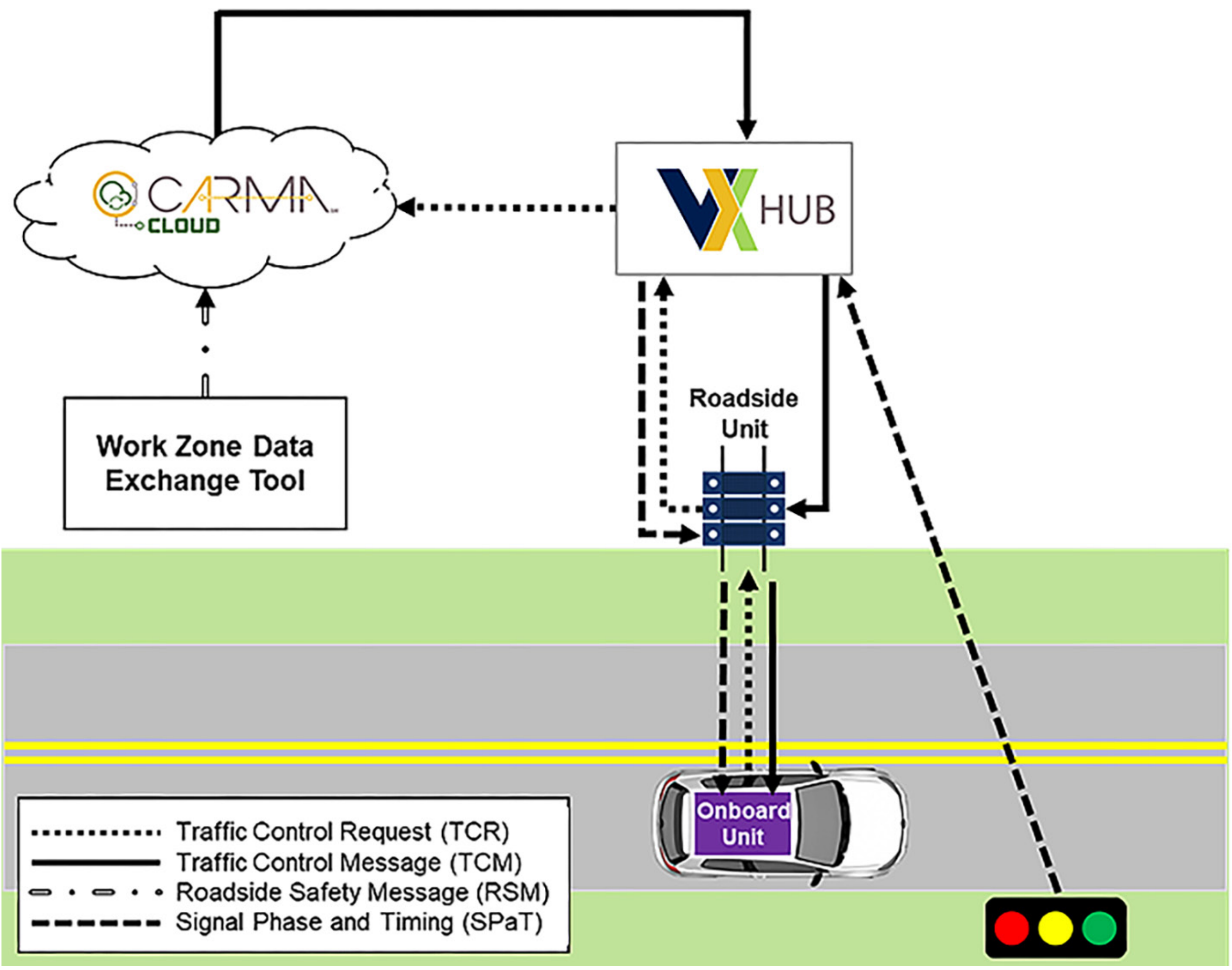
Figure 1. Image. Traffic control requests (TCRs) and traffic control messages (TCMs) communicated to and from vehicles and infrastructure.

The work zone configuration was communicated to the vehicle through custom-made TCMs, including signal group identifiers, so that the vehicle could identify SPaT[3] messages from the appropriate traffic signal positioned at the work zone. Using the received TCMs, the vehicle updated its internal map to match the work zone configuration, and the vehicle proceeded past the traffic signal properly by processing the received SPaT messages. This process allowed the vehicle to reroute through the work zone and respond appropriately to the traffic signals. This technology is important because it communicates updated traffic rules to the vehicle, allowing the vehicle to operate safely.

USE CASE ARCHITECTURE

This scenario uses the following parts of the CARMA℠ ecosystem: CARMA Cloud℠,[4] CARMA Platform,[2] and Vehicle-to-Everything (V2X) Hub.[5] The scenario also uses the work zone data exchange tool,[6] creates work zone configurations in the online work zone data exchange interface, marks lane closures, and marks the location of workers. These configurations can then be disseminated by the work zone data exchange to inform other entities (such as AVs) and systems (such as CARMA Cloud) about nearby upcoming work zones. In this case, CARMA Cloud regularly requests all work zone events from the work zone data exchange tool and generates the appropriate TCMs. Once in CARMA Cloud, these messages can be requested by AVs. The AVs can then use the information in those messages to adapt their routes based on the configuration of the work zones they encounter.

Figure 2 depicts a vehicle equipped with CARMA Platform[2] approaching a work zone. The vehicle then sends TCR messages to a roadside unit (RSU). Next, this unit forwards the request to CARMA Cloud[4] via the V2X Hub.[5] CARMA Cloud sends back the latest work zone information it received from the work zone data exchange[6] in the form of TCMs. These TCMs are then forwarded to the RSU by the V2X Hub. The RSU then sends these TCMs to the vehicle. Next, the vehicle uses these TCMs to adjust its route through the work zone. Additionally, a traffic signal sends its SPaT[3] messages to the V2X Hub, which forwards the messages to the RSU so that they can be broadcast to the vehicle. The vehicle processes these received SPaT messages and updates its trajectory to either stop at the associated stop bar or proceed past it.



Source: FHWA.

Figure 2. Image. Work zone information data flow.[2,4,5,6]

FACT SHEET

RESULTS AND LESSONS LEARNED

Independent evaluators from the U.S. Department of Transportation Volpe National Transportation Systems Center tested this system, in the planned scenario, to confirm that the following testing criteria were met:

- The vehicle could respond appropriately to SPaT[3] messages received from a traffic signal equipped with V2X Hub[5] and an RSU. Acceptable responses by the AV include continuing past the traffic signal in the event of a green light or slowing to a stop and waiting until the signal changes to green before proceeding.
- The vehicle could follow a path that matches the lane geometry described in the TCMs created in CARMA Cloud[4] and broadcasted by the V2X Hub, when traveling through the work zone.
- The vehicle could maintain a normal speed limit of 20 mph when not within the work zone, and a reduced speed limit of 15 mph when in the work zone, as described in the TCMs created in CARMA Cloud and broadcasted by the V2X Hub.

Across all test runs, the systems involved correctly communicated information to each other. More specifically, the V2X Hub-equipped RSU with a connection to CARMA Cloud successfully broadcasted both TCMs and SPaT messages, and the AV received and processed both message types. This outcome allowed the AV to respond appropriately to the traffic signals and navigate the work zone.

CONCLUSIONS

The test case demonstrated the practicality of CDA-enabled vehicles receiving notifications about alterations due to temporary traffic control in the presence of a work zone. These messages enable the vehicles to navigate through the work area safely and precisely. Future research could potentially focus on the following areas:

- Tests using cellular and cellular vehicle-to-everything.
- Collaboration with stakeholders to determine best practices and potential standard updates.
- Tests in simulation at scale to identify and evaluate benefits and impacts.

All images source: FHWA.

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Recommended citation: Federal Highway Administration, *Work Zone Management for Light Vehicles Using Cooperative Driving Automation (CDA)* (Washington, DC: 2025) https://doi.org/10.21949/ka80-3467

U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank Highway Research Center

FHWA-HRT-25-090
HRSO-40/12-25(200)E