Title

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Intelligent Intersections Reduce Crashes and Will Support the Safe Introduction of Autonomous Vehicles

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Issue

Intersections are dangerous. In the U.S., approximately 40% of all crashes, 50% of serious collisions, and 20% of fatalities occur in intersections. Intersections are challenging due to complex interactions among pedestrians, bicycles and vehicles; absence of lane markings; difficulty in determining who has the right of way; blind spots; and illegal movements (e.g., vehicles running red lights). Many cities have developed Vision Zero plans seeking to eliminate traffic injuries and deaths through modifications to road infrastructure, such as adding bike lanes and pedestrian refuge islands. These modifications can be expensive (e.g., the cost of a protected intersection can range between $250,000 to more than a $1 million) and have mixed safety results.

It is claimed autonomous vehicles (AVs) will prevent 94% of all crashes involving human error. However, the safety performance of AVs is far below that of human-driven cars. In California, the number of accidents and disengagements per AV mile traveled is 13 to 100 times worse than human-driven cars. The AV fatality rate is equally as bad. AVs find intersections especially challenging; 58 of 66 (88%) AV crashes reported to the California Department of Motor Vehicles (DMV) occurred in intersections.

Crashes in intersections occur because vehicles, pedestrians, and bicyclists are missing critical information. Intelligent intersections can provide this information at a relatively low cost of $25,000 to $100,000 per intersection. Intelligent intersections are able to report the traffic signal from all approaches, predict when the signal phase will change, relay information on blind spots, predict red light violations before they occur, and more. This information is broadcast via radio to every traveler in the intersection equipped with a smartphone or Bluetooth device.

Research Findings

With over 300,000 signalized intersections in the U.S., it is helpful to identify intersections where instrumentation is critical or, at least, is desired to ensure safe and efficient AV operation. The following four indicators were developed to provide guidance on classifying and prioritizing intersections for instrumentation.

1. **Number of approaches leading into the intersection.** As the number of approaches increase, the number of associated guideways and conflict zones will also increase.
2. **Presence of dedicated left-turn channelization.** The presence of dedicated left-turn channelization can act as a proxy for both significant left-turn traffic, as well as potential increase in operational complexity of the intersection.
3. **Presence of bicycle lanes.** Presence of a dedicated bicycle lanes implies that both conventional and autonomous vehicles have to be cognizant of cyclists at the intersection, especially when making turns.
4. **Maximum difference in number of lanes across approaches.** While number of lanes can be correlated with the vehicular throughput of the intersection, differences across approaches with regards to the number of lanes may represent some asymmetry across approaches, such as a motorway intersecting with a residential street. In such instances, the complexity of navigating the intersection, especially when approaching from a minor approach to make maneuvers, such as right-turns-on-red, may present challenges.

Findings (continued)

Additional work from UC Berkeley on intelligent intersections includes developing and improving the suite of hardware and software necessary for implementation (see call-out box on intelligent intersection algorithms). To date, UC Berkeley has implemented algorithms for analysis of intersection geometry, including conflict and blind zone identification and classification. These algorithms are available in the open source Python package called Intelligent Intersection Toolbox.

Conclusion

Results and products developed from research described in this brief as well as from UC Berkeley's ongoing efforts related to intelligent intersections provide a multitude of benefits, including:

- Improved tools cities can use to evaluate performance of signalized intersections and compare potential improvements resulting from Vision Zero plans with those provided by intelligent intersections.
- Guidance Caltrans and DMV can use when developing specifications for sensing capabilities on vehicles. Both Caltrans and DMV are unavoidably getting more engaged in AV regulation (i.e. design, testing and modifying the rules of deployment). In most intersections safe operation of AVs will require augmentation of the intersection's capabilities with infrastructure-based sensing, which must be provided by Caltrans and local transportation authorities.
- Real-time information about presence of agents (e.g., vehicles, pedestrians, bicyclists) in intersections, which AV companies can use to understand hidden dangers in intersections and how to address potential blind zones.

Intelligent Intersection Algorithms

Intelligent intersections rely on a suite of algorithms that are able to:

- Analyze intersection geometry to identify possible maneuvers, conflicts and blind zones;
- Compute likelihood of blind zones based on traffic pattern and signal timing;
- Classify conflicts and blind zones by level of importance;
- Compute optimal and minimal sensor placements in the intersection to ensure desired coverage of blind zones;
- Interpret sensor readings to determine traffic presence and dynamics in the blind zones;
- Prioritize signal phase to ensure safe and efficient passage of different modes (e.g., trucks, vehicles); and
- Predict signal phase duration.

Further Reading

This policy brief is drawn from the research report "Introducing an Intelligent Intersection" prepared by Offer Grembek, Alex A. Kurzhanskiy, Aditya Medury, Pravin Varaiya, and Mengqiao Yu with Partners for Advanced Transportation Technologies (PATH) at the University of California, Berkeley. The full report can be found here: https://escholarship.org/uc/item/2qm9h8jb. Suggested readings for those that want to learn more about this topic are included below:

- O. Grembek, A. Kurzhanskiy, A. Medury, P. Varaiya, M. Yu. Augmenting AV Awareness with I2V Information
- O. Grembek, A. Kurzhanskiy, A. Medury, P. Varaiya, M. Yu. Intelligent Intersection

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