UTC Project Information	
Project Title	Connected Vehicle Safety Applications using V2X Under Consideration of Bicycles, Pedestrians and Persons with Special Needs
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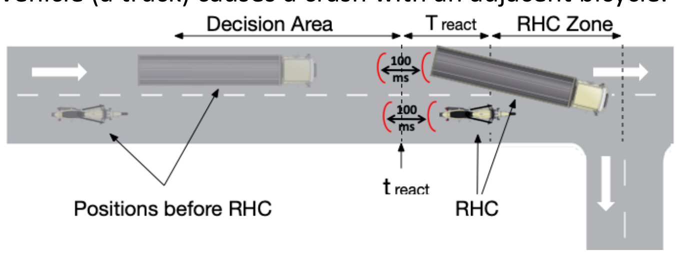
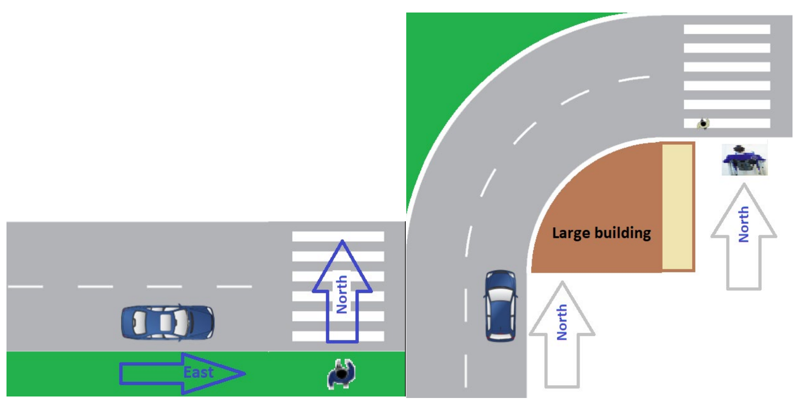
Brief Description of Research Project	This research first investigates bicycle safety applications that use the same basic communication capabilities as vehicles, thus allowing vehicle-to-bicycle communication. We simply assume that bicycles have comparable communication capabilities as motor-vehicles and are therefore capable of V2V and V2I communication. Second, Safety Applications for slow moving traffic participants are considered, specifically wheelchair users or visually impaired people who intend to cross a street. Both have one property in common in that they may change their heading over very short distances, e.g., a person may turn on the spot. This is very different from motorized vehicles, which have a much larger turning radius.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	The research resulted in several solutions. For bicycles, a Basic Safety Application (BSA) was derived and implemented, to address the so-called right-hook-conflict, a common collision scenario where a right-turning vehicle (a truck) causes a crash with an adjacent bicycle.  The accuracy of the communication was tested in open spaces and in a more challenging scenarios, as shown below.

The truck (in our case substituted by a car) and a bicycle were equipped with OBUs, identified by red circles.

For slow moving participants the scenarios considered a visually impaired person crossing a street,



and a wheelchair operator attempting a crossing, while out of sight of an approaching vehicle. Safety applications for both were derived and implemented to address multiple challenges related to changes in heading over small distances.

Impacts/Benefits of Implementation (actual, or anticipated)	As a first contribution, a bicycle safety application was introduced that uses Basic Safety Messages emitted by every VANET node. The bicycle safety application extracts information from BSMs such as speed and geographic locations to alert vehicle driver of possible right hook collision scenarios. The bicycle safety application has different algorithms for vehicles and bicycles, yet, both issue alerts when the minimum stopping sight distance of the bicycle is greater than or equal to the distance between them. This calculated distance uses coordinates provided periodically by BSMs, but it can be affected by GPS inaccuracies. During extensive field experiments we could observe that in the absence of large buildings the safety application could issue a reliable right hook alert. Whereas in a constricted area, e.g., between two large buildings, the safety application will be affected by the GPS inaccuracy, and as a result the effectiveness of the safety application was reduced. As a second contribution, an algorithm for a bicycle safety application was introduced to address the right hook conflicts that can overcome the impact of BSM omissions as the result of natural phenomena or malicious attack. The algorithm uses dead reckoning during the time spanned by the omissions. The solutions were tested using commercial OBUs in experiments conducted in open space. The results showed that sub-meter GPS accuracy could be achieved, even during jamming attacks. This suggests that the algorithm can mitigate the impact of jamming attacks and avoid possible crash scenarios. As a third and final contribution, safety applications for VANET participants that have different mobility models were investigated. Specifically, micro-mobility models such as applicable for visually impaired persons and wheelchair users were considered. First, the ability of OBUs to calculate accurate distances for vehicles at larger separation was investigated. The findings showed that distances were accurately computed with only small GPS errors, mostly ranging from sub-meter accuracy to a maximum of 2.5 meters. Second, the OBUs capability of recognizing trajectory changes over very short distances, such as turning on the spot, was investigated. In the absence of gyros, bearing had to be calculated from OBU data, which required an examination of how much travel an OBU required to provide reliable bearing information. Field tests showed that the OBUs needed at least 3 feet to be able to produce an accurate heading.
Web Links • Reports • Project Website	The results of the research were so far included in: https://www.lib.uidaho.edu/digital/etd/items/baqer_idaho_0089e_11809.html