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Evaluation of radar vehicle detection at four quadrant gate rail crossings

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ABSTRACT

As train frequencies and traffic volumes increase, the need for safer at grade highway/rail crossings is paramount. Closing or grade separating crossings ultimately cannot work for all situations; therefore four quadrant gates may be used to provide a higher level of safety than conventional crossing treatments. At crossings between two adjacent signalized intersections, signal preemption may prevent vehicles from queuing within the crossing island, but some risk of vehicles becoming trapped by the timed exit gate descents still remains. Sensors can be installed to detect vehicles and would extend exit gate closure until the crossing island is clear or conversely allow for either simultaneous or near simultaneous entry and exit gate descents, if no vehicles are present. Radar detection was installed at three sites on North Carolina Railroad Company's H-Line in January 2014. Each crossing activation was broken down into 8 stages based on operating conditions of the gate system. The average duration of the time period when all gates are fully deployed increased considerably during the after period (when radar modified the exit gate behavior) by 10–17 s, providing a longer duration of a sealed crossing before the train arrived.

1. Introduction

As train frequencies and traffic volumes increase the exposure at grade crossings also increases. The safest solution is either crossing closure or grade separation, but in many cases site constraints or cost will not allow these solutions. Instead four quadrant gates can be used as an alternative to deter motorists from driving around active entrance gates, effectively sealing a crossing while it is active.

However, there is a risk of vehicles becoming trapped within the four quadrant gates especially in crossings between two adjacent intersections where queuing is likely due to short throat storage conditions. To mitigate this risk, sensors can be installed to detect vehicles within the crossing to delay an exit gate descent. This delay allows potentially trapped vehicles an opportunity to exit the crossing island prior to train arrival. The sensors also help to reduce the window of opportunity where gate running behavior is possible by lowering the exit gates as soon as the crossing island is clear instead of waiting on a

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preset time. With sensors, the exit gates can operate independently so that only the exit gate in the direction of travel of a detected vehicle would need be extended. Currently, inductive loops are installed within the roadbed by some agencies, but non-intrusive technologies like radar detection could offer a wider detection area along with lower installation and maintenance cost and longer expected life cycles.

Fig. 1 shows grade crossing collisions in the State of North Carolina between January 2003 and June 2013. The locations of the current radar detection systems are shown, and these are the first vehicle detection systems of any kind to be installed at crossings in the State. All of the sites are in urban environments with closely spaced intersections on both sides and along the North Carolina Railroad, where a majority of the State's Amtrak trains operate.

This research focused on verifying the performance characteristics of the radar device, the interaction of the radar system with the warning devices, the influence of site characteristics on crossing conditions, and the observed driver behavior. A framework for analyzing grade crossing activations was developed via a timeline of the sequence of events. Data were collected in two evaluation phases, a passive phase where the radar was installed and sensing vehicles but did not modify the exit gate's behavior, and an active phase where the radar sensed vehicles and controlled the exit gate behavior. During the passive phase, the system was calibrated as necessary to address sensitivity and site constraint issues.

The following terms will be used throughout this report:

Exit Gate Operating Mode (EGOM): Functionality of exit gate
- Dynamic EGOM: Use vehicle detection to determine if island is clear, then close exit gates.
- Timed EGOM: Use calculated time to close exit gates after entrance gate closure.

Intrusive Sensor: Installed within the roadbed to detect vehicles, primarily inductive loops.
Non-intrusive Sensor: Installed overhead to detect vehicles, includes infrared, acoustic, radar or video.
Activation: An event where a train is detected by the approach circuit, which triggers the warning devices.
Detection: An event where the radar senses a vehicle within a crossing island zone.

2. Literature review

Although the number of incidents of at-grade highway-railroad crossings in North Carolina has decreased steadily throughout the last decade, the 45 incidents that did occur in 2012 resulted in 39 injuries and 2 fatalities (NCOLS, 2013). As the state continues to invest in the Southeast Corridor, train speeds and frequency will continue to increase along with the potential conflict with stopped or trapped vehicles within grade crossings. Since 1995 North Carolina's "Sealed Corridor" program has focused on consolidating, closing, and grade separating hundreds of crossings throughout the state (Carroll, 2001). Due to site or budget constraints, not all crossings can be grade separated, and in these cases the next safest alternative is four-quadrant gated crossings.

Four-quadrant gates are an active warning system that block all automobile lanes in either direction to prevent drivers from weaving around the entry gates. The American Railway Engineering and Maintenance-of-Way Association's (AREMA) Communications and Signals Manual describes the operating characteristics of four-quadrant gates, specifically the exit gate operating modes (EGOM) (Hilleary and Omar, 2012).

A timed EGOM delays the closing of the exit gates from the entry gates to allow vehicles to clear the crossing and is the most common EGOM (Hilleary and Omar, 2012). Guidelines for gate delay suggest three or more seconds, but crossings with multiple tracks, significant distance between tracks, rough pavement, or the presence of heavy vehicles could impede the vehicles (Coleman and Moon, 1995). Dilemma zone research by Coleman and Moon establishes an algebraic approach to determining exit gate delay considering crossing geometry and vehicle speed (Coleman and Moon, 1995). Engineered exit

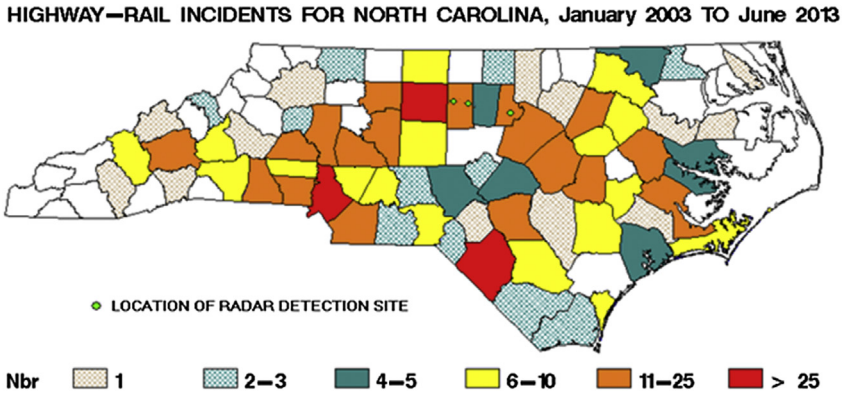

Fig. 1. Grade crossing collisions by county and locations of radar detection sites (adapted from FRA).

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