Signal and Highway Factors Attachment – Field Evaluation of Smart Sensor Vehicle Detectors

Clarendon Hills, IL

HWY22MH009

(8 pages)

CIVIL ENGINEERING STUDIES
Illinois Center for Transportation Series No. 15-002
UILU-ENG-2015-2002
ISSN: 0197-9191

FIELD EVALUATION OF SMART SENSOR VEHICLE DETECTORS AT RAILROAD GRADE CROSSINGS—VOLUME 4: PERFORMANCE IN ADVERSE WEATHER CONDITIONS

Prepared By
Juan C. Medina
Rahim F. Benekohal
University of Illinois at Urbana-Champaign

Research Report FHWA-ICT-15-002

A report of the findings of
ICT-R27-95
Field Evaluation of Smart Sensor Vehicle Detectors at Intersections and Railroad Crossings

Illinois Center for Transportation

January 2015

EXECUTIVE SUMMARY

The performance of a microwave radar system for vehicle detection at a railroad grade crossing with four-quadrant gates was evaluated in four adverse weather conditions: rain (light and torrential), snow (light and heavy), dense fog, and wind. The system consisted of two radar units aimed at the crossing from two opposing quadrants; each radar unit covered a detection area similar to that provided by standard inductive loops located between the tracks and between the gates and the outer tracks. The outputs from the two radar units could be used independently or together to provide redundancy in vehicle detection and to achieve potential improvement in system performance.

The first chapters of this report compares the results of the modified system setup in good weather, presented in Volume 3 of this study, with the results observed in adverse weather conditions. Then, in Chapter 6, the results of a re-modification of the system by the vendor are presented as a response to increased detection errors in adverse weather. System performance with the modified and the re-modified setups is summarized as follows:

Performance with the Modified Setup

Analysis of the adverse weather data shows that system performance was affected by certain weather events, and the effect of such events varied significantly. Snow-covered roadways with significant snow accumulation and freezing rain/ice (part of the heavy snow data) resulted in the most significant performance changes in terms of missed calls. For all heavy snow datasets combined, missed calls by single radar were estimated at 13.51%, while missed calls by the two radar outputs combined (i.e., systemwide missed calls) were 11.66%. In addition, one of the datasets showed stuck-on calls (2.6%) with durations ranging between 10 and 270 seconds. It should be noted that missed calls were not observed in all datasets with heavy snow but were generated primarily in periods of freezing rain/ice.

During rainy conditions, missed, stuck-on, and dropped calls did not increase. However, the system generated an increasing number of false calls, specifically when the rain was torrential. A precipitation of 0.10 inch or higher within 10 minutes, as reported by a nearby weather station, with heavy rain confirmed at the crossing using video images, was classified as torrential. During torrential rain, and when traffic was using the crossing (e.g., May 28 and June 1), the false calls increased to 24.82%–27.08%. However, when there was torrential rain but only one vehicle (e.g., May 31) or no traffic flow (e.g., June 10), the radar units generated 15 false calls on each of these 2 days. All false calls during torrential rain were generated when there were no objects in the crossing and the gates were in the upright position. These results contrast with results from good weather conditions, for which this type of false calls had a low frequency (0.15%), and some false calls occurred when the gates were moving or down.

For the evaluation of fog conditions, only dense fog datasets with visibility of 0.8 mile or lower were selected. It must be noted that weather stations report a visibility of 10 miles in clear conditions. In dense fog conditions, false calls increased to 11.58%, and all false calls occurred when gates were moving or in the down position. Thus, the false calls generated during fog were attributed to different causes than the false calls generated during rain. Other types of error did not increase in fog conditions.

The evaluation of windy conditions was based on datasets with sustained winds of more than 20 mph and less than 36 mph and gusts of more than 28 mph and less than 57 mph. The video images did not show any swaying or oscillation of the radar units or the mounting poles. The frequency of errors did not increase in wind datasets, indicating no performance concerns when the sensors were mounted on the poles holding the gates.

In summary, the performance of the microwave radar vehicle detection system was affected by different types of weather events. The frequency of errors was affected by the intensity and characteristics of

weather conditions. Performance degradation in short periods of heavy (torrential) rain was significant and greater in magnitude compared with light rain, and the effects of freezing rain/ice with snow accumulation on the road were more significant than those during light snowfall. Dense fog increased false calls caused by gates that were moving or in the down position. Finally, the overall system performance during periods of high wind was similar to that observed in good weather conditions.

Performance with the Re-Modified Setup

The re-modified system was the result of further configuration changes made to the modified setup by the vendor. The need for a re-modified system emerged after the results from adverse weather conditions in the modified setup, particularly the false and missed calls during heavy (or torrential) rain and snow.

Results of the performance evaluation showed that the re-modified setup reduced the frequency of errors in heavy rain and heavy snow conditions, while maintaining a similar performance in good weather, light rain, and light snow. In heavy rain, false calls were reduced to 2.6% with the re-modified setup compared to 30.5% in the previous setup. This reduction was the result of a significant decrease in the false calls generated without objects in the crossing.

In heavy snow the most critical error frequency in the modified setup was the systemwide missed calls (11.7%). The re-modified setup eliminated systemwide missed calls. False calls were also reduced from 3.9% to 0.3% by preventing activations without objects in the crossing and because of the gates being lowered or raised.

More favorable conditions (good weather, light rain, and light snow) had less than 1% false calls and practically no missed, stuck-on, or dropped calls.

Results from this evaluation show that the performance of detection system improved after re-modification.

The redundancy obtained by having two units sensing the same areas in the crossing reduced the frequency of systemwide missed calls, as expected. This redundancy is strongly recommended because missing a single vehicle at a grade crossing has the potential to result in inadequate gate operation, increasing risks of accidents.

Installations using this detection system are recommended to be tested at crossings with a greater number of tracks, as well as locations with multiple lanes in a given direction of traffic.

Further monitoring is also recommended to build confidence on system performance at other locations and different weather conditions.

CHAPTER 1 INTRODUCTION

This report presents an analysis of the performance of a system with two microwave radar units for vehicle detection at a railroad grade crossing, specifically during adverse weather conditions. Datasets for this evaluation were carefully selected to evaluate the detection system under a variety of adverse weather scenarios that included rain (light and torrential), snow (light and heavy), dense fog, and wind.

This system was first evaluated in good weather, and the findings were presented in Volume 3 of this report series (report number FHWA-ICT-13-028, available on the ICT website: https://apps.ict.illinois.edu/projects/getfile.asp?id=3105).

Previous parts of this study also included two microwave radar vehicle detection systems were evaluated at stop bar and advance detection zones of a signalized intersection. One system was manufactured by Wavetronix, and the second system was manufactured by MS SEDCO. The findings of the evaluation at the signalized intersection were reported in Volumes 1 and 2 of this report series (report numbers FHWA-ICT-12-016 and FHWA-ICT-13-014, respectively, available on the ICT website: https://apps.ict.illinois.edu/projects/getfile.asp?id=3065 and https://apps.ict.illinois.edu/projects/getfile.asp?id=3084).

The vehicle detection system at the railroad crossing evaluated in this report was manufactured by Wavetronix LLC and installed and configured by ByStep LLC. The main components of the system were two identical microwave radar units aimed at the crossing from opposing quadrants. The radar units were modified versions of the Wavetronix Matrix radar, typically used for vehicle detection at stop bar zones of a signalized intersection. The units were installed at a height of about 19.5 feet, on extension poles attached to the poles that held the gates.

Additional radar features for the railroad application included bidirectional detection of vehicles, AREMA-compliant power supply, and operation based on combining outputs from multiple radar units.

An aerial view of the test site is shown in Figure 1, and the locations of the radar units and detection zones are shown in Figure 2.

Figure 1. Top view of selected grade crossing on Monroe Street, near Hinsdale Avenue.

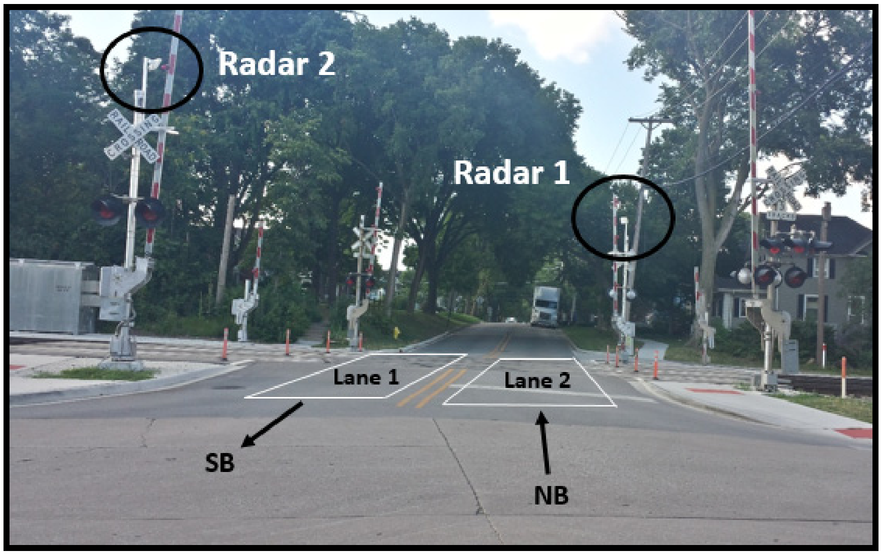

Figure 2. Location and numbering of radar units and detection zones.

CHAPTER 7 CONCLUSIONS

This report presents an evaluation of a microwave radar system for vehicle detection at a railroad grade crossing with four-quadrant gates in the following adverse weather conditions: rain (light and torrential), snow (light and heavy), dense fog, and wind.

7.1 MODIFIED SETUP AND INTERMEDIATE CONCLUSIONS

The evaluation of the modified setup was based on data from 2012 and 2013 and after the system was "modified" by the vendor following feedback on the performance from the initial setup. The results of the system with the modified setup showed that system performance was sensitive to some weather events, and the effects of such events varied significantly. In torrential rain, the false calls increased significantly. When traffic was using the crossing in torrential rain (such as on May 28 and June 1), false calls increased to 24.82%–27.08%. However, when there was only one vehicle (on May 31) or no traffic flow (on June 10) in torrential rain, the radar units generated 15 false calls on each of those two days. All false calls registered in torrential rain were generated when there were no objects in the crossing and the gates were in the upright position. Missed, stuck-on, or dropped calls were not affected by light or heavy rain.

Snow datasets were divided into light and heavy snow, based on the extent of snow accumulation on the roadway and the type of precipitation. The system was not severely affected by light snow, but errors increased significantly in heavy snow. For all heavy snow datasets combined, false calls increased to 3.9%, missed calls by a single radar unit were 13.51%, and missed calls by the two radar devices working as a combined unit were 11.66%. The most severe effects were found during freezing rain/ice, with significant snow accumulation, and when the roadway was partially covered with snow. The missed calls were not observed in all datasets with heavy snow but were generated mainly in periods of freezing rain/ice. In addition, one of the datasets showed 2.6% stuck-on calls, with durations that ranged between 10 seconds and 270 seconds.

In dense fog, the false calls increased to 11.58%, and all false calls were generated when the gates were moving or in the down position.

Wind did not affect system performance in any of the four types of errors evaluated in this study. Thus, the frequency of false, missed, stuck-on, and dropped calls was similar to the frequency observed in good weather.

In summary, the performance of the system with the modified setup was affected by different types of weather events, and the intensity and characteristics of the weather condition affected the frequency of errors. Performance degradation in short periods of heavy (torrential) rain was greater in magnitude than in periods of light rain, and the effects of freezing rain/ice with snow accumulation were more significant than the effects during light snowfall. Lastly, dense fog increased false calls when the gates were moving or in the down position.

7.2 RE-MODIFIED SETUP AND FINAL CONCLUSIONS

The re-modified system was the result of further configuration changes made to the modified setup by the vendor. The need for a re-modified system emerged after the results from adverse weather were made known to the vendor, particularly the false and missed calls during heavy (or torrential) rain and snow.

Results of the performance evaluation showed that the re-modified setup reduced the frequency of errors in heavy rain and heavy snow conditions, while maintaining good performance in good weather, light rain, and light snow conditions.

In heavy rain, the false calls with the re-modified setup were reduced to 2.6% compared with 30.5% in the modified setup conditions. This reduction was the result of a significant decrease in false calls without objects in the crossing.

In heavy snow, the most critical error frequency in the modified setup was the systemwide missed calls (11.7%). The re-modified setup eliminated those missed calls. False calls were also reduced from 3.9% to 0.3% by preventing activations without objects in the crossing and from the gates being lowered or raised.

More favorable conditions (good weather, light rain, and light snow) had less than 1% false calls and practically no missed, stuck-on, or dropped calls.

Results from this evaluation show that the performance of the detection system improved after re-modification.

The redundancy obtained by having two units sensing the same areas in the crossing reduced the frequency of systemwide missed calls, as expected. This redundancy is strongly recommended to avoid missing vehicles.

Installations using this detection system are recommended to be tested at crossings with a greater number of tracks or where longer detection zones are needed, as well as locations with multiple lanes in a given direction of traffic.

Further monitoring is also recommended to build confidence in system performance at other locations and under different weather conditions.