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RESEARCH RESULTS

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LINE-OF-SIGHT ANALYSIS USING DRONES AND PHOTOGRAMMETRY

SUMMARY

Between 2016 and 2020, 28 percent of fatalities at highway-rail grade crossings that lacked active warning devices. At these crossings, it is the driver's responsibility to look for trains and to stop safely when necessary. In some cases, visual obstructions can make it difficult to see approaching trains, making an already risky situation even worse.

The U. S. Department of Transportation's (U.S. DOT) John A. Volpe National Transportation Systems Center (Volpe), under the direction of the U.S. DOT Federal Railroad Administration (FRA) Office of Research, Development and Technology (RD&T), evaluated the effectiveness of using drones and photogrammetry software to conduct line-of-sight analyses of selected grade crossings. Researchers selected crossings with no active warning equipment nor stop signs for this study because they assumed drivers would stop upon seeing a train approach. This study aimed to determine if conditions allowed for sufficient time to stop, given the visual obstructions that exist.

A driver's vision might be obstructed by vegetation, parked cars, or a variety of other temporary conditions. Of primary interest in this study were immovable obstructions such as buildings or walls. Volpe reviewed numerous crossings in New England to identify candidates that had no active warning equipment *and* had permanent structures that might obscure a driver's vision.

Volpe identified two crossings in Milford, New Hampshire, that had these conditions. A team of Volpe researchers used a drone to capture a set of aerial photographs of these crossings. One of these images, taken at the South Street crossing, is shown in Figure 1. These images were later processed into orthomosaic images, and drivers' stopping distances and sightlines were analyzed.

Figure 1. South St. Crossing in Milford, NH

Results indicate that despite the low maximum speed of trains at these locations, the visual obstructions posed by permanent structures and the lack of warning equipment at these locations present hazardous conditions for drivers with poor reaction times, especially on wet or icy roadways.

BACKGROUND

Volpe has conducted prior rail safety research using drones for trespasser detection, the results of which were documented in a Technical Report [1]. Research is ongoing in using drones to analyze grade crossing profiles to determine ground clearance requirements, and to quickly capture data needed to perform accident reconstruction.

OBJECTIVES

The objective of this study was to determine the ease and effectiveness of using drones to capture data that can then be used to conduct line-of-sight analyses of grade crossings with visual obstructions for drivers.

METHODS

Volpe conducted a scan of local crossings using the FRA Highway-Rail Crossing Database, looking for worst-case scenarios. These were defined as crossings with no active warning equipment and located near structures that might obstruct a driver's line-of sight. It was noted that two of these candidates were located near one another, in the town of Milford, New Hampshire.

On September 15, 2021, a Volpe drone captured a complete set of aerial imagery at two crossings: one on Union Street (Crossing ID 844288R) and one on South Street (Crossing ID 844286C).

Volpe processed these imagery sets separately in Pix4D, a professional photogrammetry and drone mapping software program, to produce highly detailed orthomosaic images. To the untrained eye, these images may appear to be no different than one large aerial photograph. However, they are not subject to lens distortion or angular perspective differences characteristic of photographs. In other words, a measurement taken near the edge of an orthomosaic image is the same length as the same measurement taken in the center of the image. This makes orthomosaics valuable tools in conducting analyses involving distances and angles such as these.

Next, Volpe imported the orthomosaics from both crossings into a geographic information system (GIS) software package called QGIS. This free, open-source GIS product enabled Volpe to draw sight lines on the orthomosaics and to take accurate measurements because the orthomosaics were overlaid onto the Web Mercator coordinate reference system.

Volpe used the American Association of State Highway and Transportation Officials (AASHTO) Green Book [2] to determine the approximate stopping distance of a vehicle. For level pavement, the formula is:

$$d_B = \frac{V^2}{30\left[\left(\frac{a}{32.2}\right) \pm G\right]}$$

where:

d_B = braking distance on grade, ft

V = design speed, mph

a = deceleration, ft/s^2

G = grade, rise/run, ft/ft

A design speed of 30 mph on both roadways, and a reaction time of 2.5 seconds, results in a safe stopping distance of 197 feet. AASHTO notes that this is somewhat conservative even on wet pavement, and that 90 percent of drivers can stop in less distance. Nonetheless, Volpe chose this number to account for speeding, variations in stopping time, and inclement weather.

Using AASHTO's conservative 11.2 feet/second deceleration rate, and including the 2.5-second reaction time, a driver takes 6.4 seconds between seeing an approaching train and stopping. The timetable speed for trains on this segment of track is 10 mph.

RESULTS

Volpe used QGIS software to draw sight lines and measure distances on the orthomosaics. Lines were drawn from the vehicle's position at the point at which it passed the safe stopping distance through the corner of structures obscuring the driver's view of the approaching train, and measurements were taken between the train's position and the edge of the travel lane.

South Street Analysis

For the South Street example, a sight line analysis was conducted for drivers heading northbound as they reached the safe stopping distance before the tracks. For trains approaching from the east, there is only 51 feet of track between where a driver can first see the train and when it enters the travel lane (Figure 2). At 10 mph, the train travels this distance in only 3.5 seconds, far less than the 6.4 seconds that the bottom 10 percent of drivers take to safely stop. This results in a dangerous condition where some drivers will be unable to stop in time.

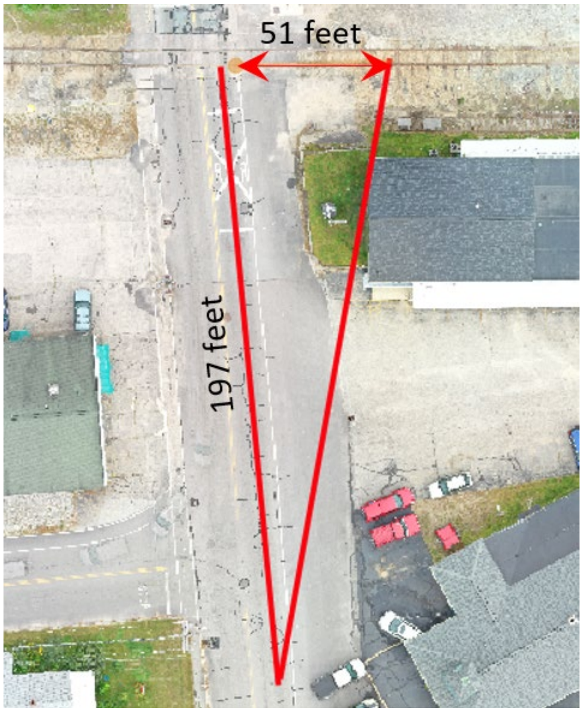

Figure 2. Orthomosaic of South Street crossing showing obstructions for northbound drivers

For trains approaching from the east, the situation is only slightly better. Northbound drivers passing the safe stopping location can see the train when it is 83 feet from entering their travel lane. At the maximum speed of 10 mph, it will take 5.7 seconds for the train to reach the northbound travel lane, which is still less than the 6.4 seconds needed for the driver to react and safely stop.

Union Street Analysis

The same process was used for the data collected at the Union Street crossing. Drone images were processed using Pix4d, and the orthomosaic imagery was imported into QGIS, where site lines were drawn and measurements taken.

At this location, visual obstructions exist for both northbound and southbound drivers for westbound trains. Since the speed limit is the same, the safe stopping distance is also 197 feet. From that point, northbound drivers can only see 25 feet of track east of their travel lane, and southbound drivers can only see 40 feet of track east of their travel lane (Figure 3). Both of these conditions are more dangerous than those on South Street.

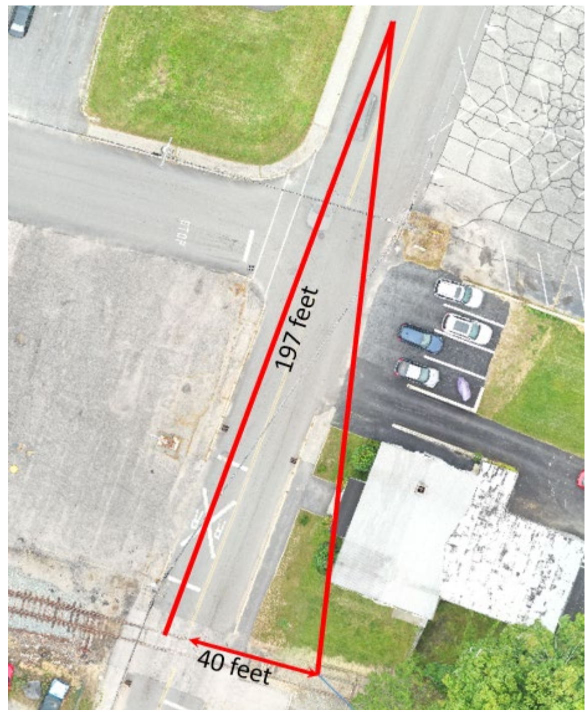

Figure 3. Orthomosaic of Union Street crossing showing line-of-sight for southbound drivers

CONCLUSIONS

Results of this study show that conducting line-of-site analyses using a drone, photogrammetry software, and GIS software is a rather simple and straightforward process. However, getting to this point requires some investment. In addition to the equipment and software, drone pilots must obtain a Remote Pilot Certificate and aircraft must be registered with FAA; photogrammetry and GIS software training is also necessary.

FUTURE ACTION

Municipalities can use this research to analyze grade crossings that lack active warning equipment for similar dangerous conditions. If hazardous conditions are found, mitigations can include installation of stop signs, yield signs, or notifying the railroad that active warning equipment is required.

REFERENCES

[1] Federal Railroad Administration (2020). Trespasser Detection on Railroad Property Using Unmanned Aerial Vehicles [RR 20-33]. Washington, DC: U.S. Department of Transportation.

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[4] Federal Highway Administration (2020). Improving Pedestrian Rail-Crossing Safety with Hinged Pedestrian Gate Skirts [FHWA-SA-19-037]. Washington, DC: U.S. Department of Transportation.

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