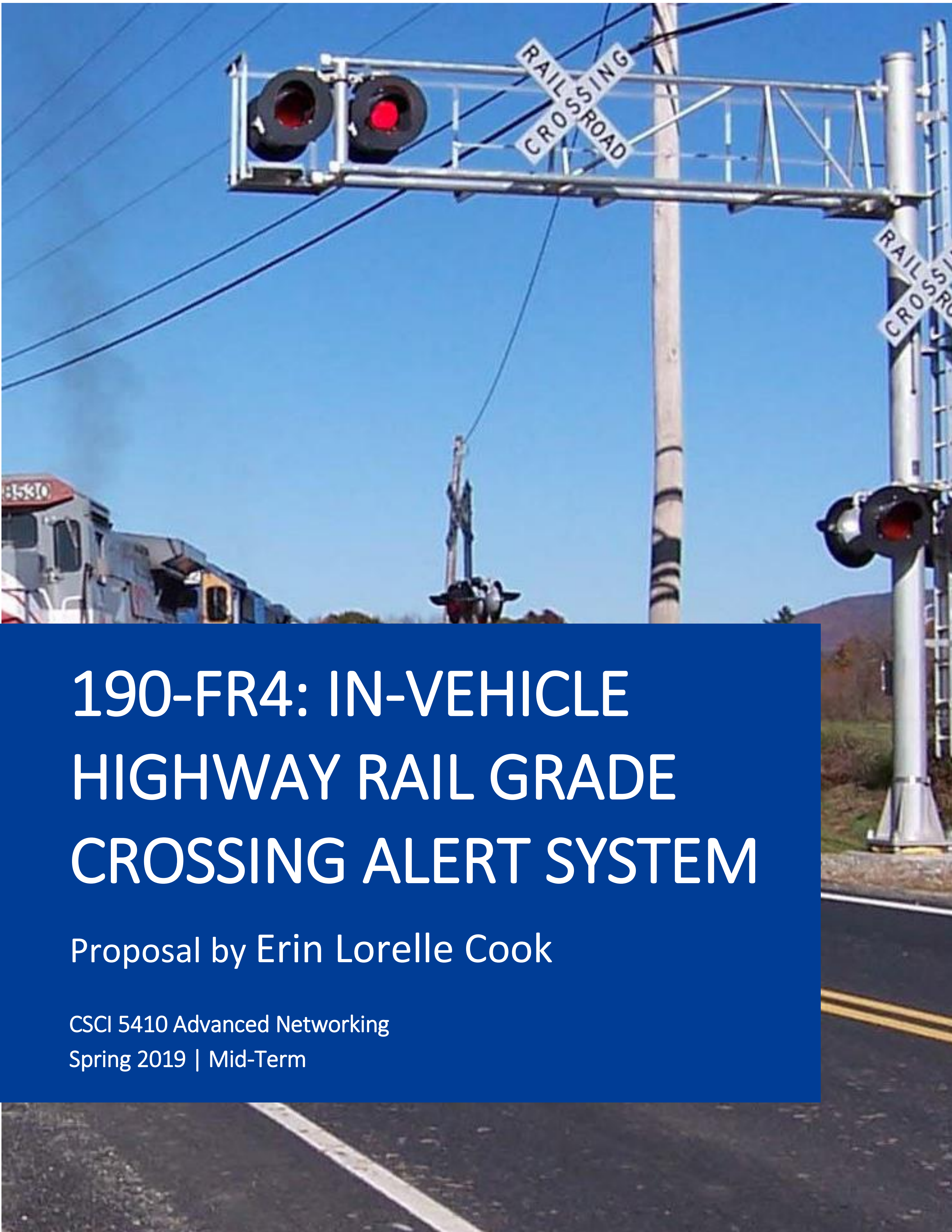

190-FR4: IN-VEHICLE HIGHWAY RAIL GRADE CROSSING ALERT SYSTEM

Proposal by Erin Lorelle Cook

CSCI 5410 Advanced Networking
Spring 2019 | Mid-Term

190-FR4: In-Vehicle Highway Rail Grade Crossing Alert System

Proposal by Erin Lorelle Cook

Introduction

With advances in technology and the availability of hand-held devices, distracted driving has become a concern in railroad grade crossing accidents. Some railroad grade crossings are statistically high-risk with a higher rate of accidents. In 2013, distracted driving has been linked to 3,154 fatalities, most which could have been prevented. According to the Federal Railroad Association, "A motorist is almost 20 times more likely to die in a crash involving a train than in a collision involving another motor vehicle [1]." An alert system installed within a vehicle would be able to alert the driver as the vehicle approaches a high-risk crossing.

The three types of distracted driving are: cognitive such as talking on the phone and listening to music, manual such as hands off the wheel, and visual which is taking your eyes off the road. Hands-free devices are shown to be no safer than normal devices. Studies have shown that the behavior of drivers using hand-held devices is equivalent to a driver with a blood alcohol level of 0.08 and four times more likely to be in an accident [2]. Where railroad fatalities have steadily decreased over the years, they've started increasing since 2015 and are still increasing [3].

In South Carolina, distracted driving makes up an average of fifty fatal crashes per year. In 2011, distracted driving accounted for three thousand deaths in the country. South Carolina's Target Zero Plan organization is trying to combat distracted driving by researching the problem, reducing the likelihood with road enhancements (i.e., raised markers, edge-line rumble strips), enhancing driver awareness with a statewide campaign, and researching distracted driving laws [2].

Although distracted driving is on the rise, some railroad deaths are caused by drivers driving around visible signs and barriers. Railroad deaths caused by drivers disregarding signs and barriers accounted for 41% of railroad accidents from 2008 to 2012 [4]. Collisions involving a train are twenty times deadlier than collisions involving another motor vehicle. Drivers frequently use GPS to navigate, sometimes following the directions on the device over following the road. Since railroad crossings don't appear on maps, users don't know they're there, increasing the risk of crossing rail grades [5]. Although Google and other technologies have stated that they'll include railroad crossings on their maps, railroad crossings currently aren't included. Instead, they're focusing their attention on preparing for their upcoming autopilot vehicles.

The Caltrans Railroad Grade Crossing Evaluation Report [6] evaluated eighteen high-risk grade crossings in California and scheduled upgrades to help improve safety. Planned improvements include moving and realigning railroad tracks so vehicles can avoid crossing grades altogether and installing guad gates that prevent vehicles from driving around barriers. Although these efforts are an improvement, they don't focus improving driver awareness of upcoming crossings. As drivers focus more heavily on smartphones to navigate, a high-risk grade crossing application installed on smartphones may alert drivers of dangerous crossings they may not otherwise be aware.

Literature Review

Efforts to increase railway grade awareness have focused primarily on the railroad themselves to better alert drivers. These efforts include signs, bells, gates, and flashing lights. Few measures have been made to provide an application available to drivers to aid in detecting high-risk railroad crossings.

Internet of Things: Freight railroads are elevating efforts to collect, analyze and merge information for many sources

V2V infrastructure will soon be emerging between self-driving vehicles. Freight railroads are upgrading their systems with IoT technology to assist with monitoring, such as tracking speed and fuel level. IoT allows past and current data to be gathered and analyzed to prevent future incidents and enhance safety. An onboard unit sends current data for analysis to alert the engineer of upcoming track or speed issues. The hardware and software are currently being installed, and as of January 2019, "the railroad had installed 67 percent of total track miles with hardware and software, partially installed equipment on about 81 percent of locomotives and installed 72 percent of necessary wayside antennas [7]."

A complication with the IoT upgrades is ensuring that each railroad system can communicate with each other, such as passenger and freight trains. The different trackside equipment must be able to communicate seamlessly to prevent risks that could cause safety issues, and these changes and upgrades are costly. So far, the upgrades have reduced hard braking by ninety percent, which reduces wear on the train which helps avoid safety issues. Some locomotives have an on-board GPS-enabled device that monitors the train speed and fuel through the Internet.

Monitoring and predicting events with IoT provides improved efficiency and safety, but the technology provides preventative measures on the side of locomotives and the engineers, rather than alerting drivers directly. Also, the upgrades can be costly and take a while to integrate with all train types and systems, considering hardware and software for all mobile and stationary units.

How to Make Railroad Crossings Safer and Smarter

Chen C, et.al. [8], discusses another approach to alerting drivers of railroad crossings involving building a smarter crossing. These smarter railroad crossings must be accurate and provide complete data to avoid collision. CCTV surveillance will be incorporated to monitor the crossing area such as debris or pedestrians. The camera can be monitored by train operators to detect animals versus a parked vehicle. The smart railroad crossings also monitor the condition of the equipment, sending alerts for malfunctioning alerts or barriers, allowing time for operators to adjust their speed or stop to avoid obstruction. If an accident does occur, the information is sent for analysis to help prevent future collisions.

Smart railroads also alert drivers to help them make better judgements before attempting to proceed through a crossing. LED signs display messages that answer questions such as: "how much time before the train reaches the crossings, which direction is the train coming from, what is the speed of the train, and how far away is the train [8]."

For the smart railroad crossings to perform these advanced activities, they'll need to be able to have around-the-clock asset monitoring to determine the exact speed of a train, the environmental conditions, the status of the components. This data can be used to answer questions should an accident occur. Non-stop network video recording will need to provide 24/7 video surveillance for the railroad grade which can withstand harsh whether conditions. The equipment will need to be custom for each railroad grade and must have a connection with low latency. To help prevent loss of data, the timestamps are recorded per millisecond and a 2.5 kHz-Analog input sampling rate for rapid transmission of data.

For the surveillance, an application called the Intelligent Video Analysis (IVA) is used as a monitoring system that sends alerts in the event of tampering of equipment, equipment left on the tracks, and movement on the tracks [8].

These efforts focus on alerting the drivers in addition to the train side of communication. These upgrades can be costly and not applied to all high-risk crossings. The LED signs may not be effective to distracted drivers who are not paying attention to the road, less a railroad sign.

Smartphone Usage Restriction During Crossing Roads and Railways

Smartphones distract pedestrians in addition to drivers. A study was done by Saeki T. et.al. [9] that proposed a system that restricted cell phone usage for pedestrians crossing roads and railroads who are otherwise distracted. Fatalities and accidents have increased as pedestrians are more likely to multitask and use their smartphones while walking, unaware of their surroundings. The proposed system limits the functionality of the smartphone, requiring the user to pay attention to her surroundings.

The architecture involves locating the exact location of the pedestrian "based on a Pedestrian Dead Reckoning (PDR) technology using 3-axes accelerometer, 3-axes magnetometer and GPS [9]." To estimate the walking position of the user, an artificial neural network (ANN)-based non-linear regression was able to predict based on previous steps. By predicting the steps, the application should be able to determine if the user intends to cross or not cross the street. If the application determines that the user does not intend to cross, nothing happens. If the user does intend to cross, the application restricts usage to the user. Device restriction is based on the status if the device. If the screen is off, the network is turned off, so the device cannot receive nor alert the user of incoming calls or text messages. If the device is in use, the user is presented with an alert message that warns the user of the danger of an upcoming crossing.

The experiment was done with one person for thirty-two set cases. The results show that the application triggered as intended when it judged that the user was about the cross a road or railroad. However, the application sometimes triggered when the user did not intend to cross the street. Safety is priority over convenience, but further work is needed to avoid the user from being unnecessarily inconvenienced. This application is currently unavailable for smartphone operating systems and the test was run from a PC environment. Also, this application was not designed to be run in vehicles where increased speeds and last-minute changes may be difficult to adapt by ANN to make quick decisions on the user's anticipated next position.

Automatic Alert Generation from Train to the People at Unmanned Level Crossings Using Principles of IoT

Abhinav, J. et.al. [10] proposed an idea of using current technology to send automatic alerts at unmanned level crossings without the high cost of upgrading railroad infrastructure. The application uses API from Telecom Service Providers and using IoT with GPS in the train unit. The train unit then communicates with smartphone users as it approaches grade crossings sending SMS alerts. The alert will be subscription based for privacy and legal concerns. The benefit of this proposal is the use of existing technology proving a low-cost solution. Also, most drivers own a smartphone and can have access to this application.

However, this application is a solution targeted at unmanned level crossings to compensate for the gates and bells normally present at regular crossings. Also, having a safety alert only available to subscribers can be challenging since railroad safety may not be a priority to push users to subscribe.

Research Problem

To successfully warn drivers of high-risk grade crossings within a given proximity. This proposed application should be able to address the below issues. Accuracy is a must and applies to all issues listed below.

- Definition of high-risk grade crossing. Defining the specific criteria.
- Location of high-risk grade crossings
- List of high-risk grade crossings must remain current

- Notify drivers without further distracting them

Solution Approach

Plan

The final product should be a free application that can be installed on an Android or iOS that alerts the driver of an upcoming high-risk railroad crossing. High-risk crossings should be paid extra attention by the driver to reduce risk while crossing. The application will run continuously in the background, so the driver can still use the phone's GPS. The application will notify by different alarm levels if the crossing is high-risk versus a "regular" risk grade. The purpose is for the driver to always be alert while crossing a railroad and never to assume a regular-risk grade crossing is safe. As a result, the application will present two types of alerts. At regular-risk, the application will sound warning bells and the screen will display only a yellow caution background and the estimated seconds to the crossing. At high-risk, the application will sound a blaring alarm following by a voice indicating a high-risk crossing ahead. The screen will display only bright orange background and the estimated seconds to the crossing. The alarm will continue to alert until the vehicle is across the intersection.

The application will be separate from Google maps for legal reasons and will be available on a smartphone. The application will utilize GPS for current locations and mapping. The application will have access to the US DOT railroad records, such as a dataset of all railroad collisions and their locations, which is publicly available. The database also includes latitude and longitude coordinates for each railroad crossing allowing the application access to the locations of each of the railroad crossings. The application itself assigns the risk rating of each crossing based on the criteria requested by the DOT. The DOT can determine what constitutes a high-risk railroad such as locations in the top percent, or locations with the highest number of collisions; a number chosen by the DOT that can be changed when as needed. The application will update weekly by syncing to the database keeping risk ratings for railroad grades current.

A possible feature to enhance the pervious infrastructure is for the application to also signal when a train is approaching, rather than simply when the grade is high-risk. This would involve a unit installed on each locomotive and a fixed unit at each crossing. As the train approaches the crossing, it sends a signal to the fixed crossing unit which sends a signal to all devices in the vicinity, pedestrian or vehicle. As the train approaches the crossing and the alert is triggered, all devices in the vicinity will receive a red alert (e.g., bright red screen) and a voice indicating a train is approaching. The bright red screen remains until the train has passed. The voice repeats for thirty seconds and then ceases to avoid frustrating a parked driver.

Specify Approach or Technologies

The application will use GPS to determine the location of the device. To sync with the database and perform weekly updates, the applicate will require 802.11n/ac or at minimum 4G LTE. Using the enhanced features that include IoT would require 5G to insure the train communicates promptly to the fixed crossing unit. The IoT infrastructure includes the train onboard units, the fixed crossing units, and the individual devices for the enhanced features.

As part of IoT, the fixed crossing unit will listen for an approaching train. Once the train approaches the range of the fixed crossing unit, the fixed crossing unit picks up the signal transmitted by the train, broadcasting an alert to nearby devices via IoT. The fixed crossing unit will not need to sync to the database for updates since it only needs to receive communication from the train to broadcast an alert to all devices within a radius of the crossing. The device in the vehicle will receive communication via IoT from the fixed crossing unit, triggering the warning alert. In the enhanced feature, the train-is-coming alert overrides the default yellow and orange alerts with the red alert indicating a train is approaching.

The devices receiving the signal from the fixed crossing unit will not transmit to additional devices keeping the alerts within a set proximity. This is to keep from broadcasting indefinitely via IoT to irrelevant devices that are four blocks away and to nearby neighborhoods.

Challenges

The US DOT railroad database needs to remain current for the application to be current. The application sync schedule can be adjusted to sync more or less frequently, but the application has no control over the accuracy of the database. Another issue is the cost of the locomotive onboard units and the fixed crossing units. The fixed crossing units can be limited to only high-risk grade crossings, but any new crossings added or deleted will need a crew at the crossing to either add or remove the fixed unit. An option is to simply add and never remove units.

Another complication is the device itself. The train units and fixed crossing units will be custom and include 5G, but personal smartphones will need to be equipped with 5G to provide low latency to receive train-is-coming alerts timely. If not using the enhanced train-notification feature, current technologies suffice for the application.

Also, the device must be powered on. Most smartphones are turned on hence why drivers are distracted, but the volume control must also be set. The application would not be as effective if the sound is muted.

It is unavoidable to alert a driver without adding further distraction. If the driver is already distracted, this warning alert may startle the driver potentially causing an incident. An alternative is an application that completely shuts off all vehicles that approach a high-risk grade crossing, but that would frustrate many drivers. Possibly shutting off only vehicles when a train is approaching may seem more desirable but may include further issues such as stalling stick-shift vehicles and causing car collisions if multiple cars are at the same grade location.

Some of the most high-risk grade crossings are already equipped with warning signs, bells and whistles, and gates, yet they're still considered high-risk grades due to drivers making poor judgements. This application, however, should help many drivers who simply glanced at their phone too long and didn't notice an upcoming high-risk grade crossing, and other drivers who think their phone knows more than they know.

Bibliography

[1] "Collisions by State," 10 March 2018. [Online]. Available: https://oli.org/about-us/news/statistics/collisions-by-state. [Accessed 8 March 2019].

[2] "Distracted Driving," 2019. [Online]. Available: http://www.sctargetzeroplan.org/target-zero-safety-plan/distracted-driving. [Accessed 08 March 2019].

[3] "Crossing Collisions & Casualties by Year," 10 March 2018. [Online]. Available: https://oli.org/about-us/news/collisions-casulties. [Accessed 5 March 2019].

[4] "INTERSECTIONS & OTHER HIGH RISK ROADWAY LOCATIONS," [Online]. Available: https://www.rtands.com/safety-training/fra-releases-list-of-the-15-most-dangerous-railroad-crossings-in-the-us/. [Accessed 5 March 2019].

[5] J. Kim, "Why aren't railroad crossings on your map app?," 06 February 2017. [Online]. Available: https://www.marketplace.org/2017/02/06/tech/why-doesnt-your-driving-app-show-railroad-crossings. [Accessed 8 March 2019].

[6] "High-Risk Railroad Crossings Graded," March 2017. [Online]. Available: http://www.dot.ca.gov/milemarker/docs/articles/2017/Q1/MM-2017-Q1-Railroad-Crossings.pdf. [Accessed 5 March 2019].

[7] J. Stagl, "Internet of Things: Freight railroads are elevating efforts to collect, analyze and merge information from many sources," March 2016. [Online]. Available: https://www.progressiverailroading.com/rail_industry_trends/article/Internet-of-Things-Freight-railroads-are-elevating-efforts-to-collect-analyze-and-merge-information-from-many-sources--47509. [Accessed 6 March 2019].

[8] C. Z. Chen and H. Hsiao, "How to Make Railroad Crossings Safer and Smarter," *Occupational Health & Safety*, 1 March 2017.

[9] T. Saeki and K. Fujinami, "Smartphone Usage Restriction During Crossing Roads and Railways," ACM, Florence, Italy, 2015.

[10] A. Jha, A. K. Agrawal and C. Bhaumik, "Automatic Alert Generation from Train to the People at Unmanned Level Crossings Using Principles of IoT," 2012. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-642-29667-3_14.

[11] "3 types of distracted driving," [Online]. Available: https://www.esurance.com/info/car/3-types-of-distracted-driving. [Accessed 8 March 2019].

[12] Preliminary 2017 Federal Railroad Administration Statistics, "Collisions by State," 10 March 2018. [Online]. Available: https://oli.org/about-us/news/statistics/collisions-by-state. [Accessed 8 March 2019].

[13] J. Nunez, "FRA releases list of the 15 most dangerous railroad crossings in the US," 25 April 2016. [Online]. Available: https://www.rtands.com/safety-training/fra-releases-list-of-the-15-most-dangerous-railroad-crossings-in-the-us/. [Accessed 5 March 2019].

[14] C. Smith, "Train crossing deaths are down, but problems with distracted driving and impatience persist," 26 December 2012. [Online]. Available: https://www.tulsaworld.com/archives/train-crossing-deaths-are-down-but-problems-with-distracted-driving/article_8802d2f6-1b01-5dfd-a029-171654947e43.html. [Accessed 5 March 2019].

[15] D. Wakabayashi, "Rail Crossing Warnings Are Sought for Mapping Apps," 19 December 2016. [Online]. Available: https://www.nytimes.com/2016/12/19/technology/google-digital-maps-railroad-crossings-ntsb.html. [Accessed 7 March 2019].