TOWARDS THE IMPROVEMENT OF HIGHWAY-RAIL INTERSECTIONS WITH AN INTELLIGENT GRADE CROSSING SYSTEM

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Abstract

Safety at highway-rail intersections (HRIs) is currently dependent on installed active warning systems such as flashing lights and gates. The volume of trains, highway vehicles, and pedestrians traversing the HRIs has increased over the years. Despite the improvements and activation of warning devices, crashes at HRIs still occur. In this study, the author examined crashes that involved motorists, who violated activated warning devices and other causes combined at HRIs from 2000-2015 in New York State. The methodology involved gathering accident data for the 16-year period from the New York State Department of Transportation. Descriptive and inferential statistics were employed to analyze the data. Chi-square goodness-of-fit was used to test the hypothesis to determine the statistical significance difference between the total number of accidents that occurred as a result of violation of activated warning devices by motorists as well as all other accidents. While the minimum expected frequency for the respective classified accidents was approximately 234, the test indicated that the number of accidents involving motorists that violated activated warning devices and other causes was statistically significant and are unequal ($X^2(1) = 4.336$, $P=0.037$). Findings indicated that accidents, which occurred as a result of motorists' violation of activated warning devices, were more than other causes of accidents. The intelligent grade crossing system (IGCS), which consists of the integration of intelligent transportation systems used for roadways with intelligent railroad systems technology towards enhancing safety at HRIs, was described and recommended towards improving safety at HRIs. In addition, the New York State law should be reviewed so that cameras installed as a result of this solution could aid law enforcement and reduce motorists' violation of activated warning devices at HRIs.

Introduction

A highway-rail intersection (HRI) is a point at grade where rail and road systems meet. Measures have been taken to reduce crashes between vehicles and trains through provision of active warning devices at public HRIs, which are used interchangeably with public at-grade railroad crossings in this study. Despite improvements made at these HRIs, accidents still occur and continue to be a major problem at public railroad crossings, specifically in urban areas. Since trains have the right-of-way, motorists needing to cross the railroad track must stop and give way to approaching trains.

For adequate warning, public crossings have been equipped with gates and flashing lights, which are regarded as active warning devices, to reduce collisions between highway vehicles and trains. When flashing lights only, or flashing lights with gates, are absent at a given HRI, such a crossing is considered passive. The upgrading of a passive crossing with active warning devices improves safety at the crossing. There is higher potential for conflicts between the two systems of transportation due to of the volume of trains and vehicles passing over active crossings. About half of all HRI accidents between 1994 and 2003 occurred at railroad crossings that were equipped with active warning devices [1]. The only method for eliminating exposure between highway users and trains is to separate both systems from at-grade.

Since the cost of a grade separation or installation of a bridge for eliminating a high-risk candidate HRI is so expensive, it is necessary to find solutions to safety improvements at railroad grade crossings. The volume of motor vehicles traversing a crossing is increasing, while pedestrians, bicyclists, and motorists do foul the tracks. Similarly in urban centers, commuter train movements have increased over the years, based on population growth and demand for public transit. Therefore, in order to improve mobility and combat crashes at highway-rail intersections, the author investigated crashes involving motorists that violated active warning devices, and all accidents based on other causes at HRIs in New York State, so as to provide intelligent grade crossing systems to help reduce crashes.

Background

The highway-rail intersections in New York State (NYS) include both public and private crossings. Public crossings are highway-rail intersections that are open and used by the general public. The installations of warning devices at these crossings were funded by federal and state governments, while the maintenance of such devices remains in the hands of railroad organizations. In addition, the highway approaches are being maintained by the municipalities having jurisdiction over the public roads. Private crossings are HRIs that consists of roadway, which leads to private properties and are maintained by private owners. The installation and maintenance of warning devices are based on agreements made between the railroads and owners of the private crossings. As of 2016, in New York State, there were 2911 public railroad crossings and 2944 private railroad crossings. Figure 1 indicates the percentages of public and private HRIs in New York State.

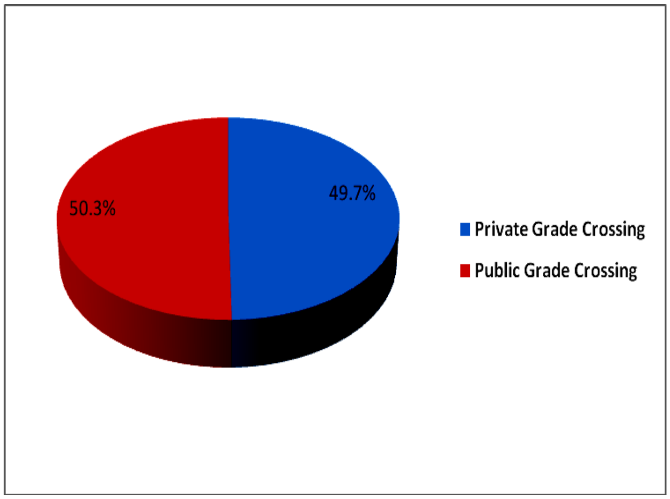

Figure 1. Public and Private HRIs in New York State

The improvements of public crossings have gulped millions of dollars annually through share-cost funding between the federal and state governments, and sometimes with local authorities, in order to mitigate risks encountered by the general public using the intersections. The public crossings attract a high volume of road traffic, while urban cities, specifically in downstate New York, attract a high volume of train and highway traffic. Despite the improvements made to warning devices at public HRIs, addressing the causes of accidents with advance awareness to users of the system as well as the ability of train operators/engineers to stop quickly during emergencies is quite necessary. The New York State Department of Transportation classified causes of accidents based on the following:

- Deliberate violation of activated gates by motorists
- Deliberate violation by pedestrians and/or bicycles
- Vehicle striking train
- Outside factors and conditions
- Crossing characteristics
- RR error/malfunction

In this study, the author investigated causes of accidents involving motorists, who deliberately violated activated warning devices, as well as other causes at public HRIs in NYS. These at-grade railroad crossings require government intervention and funding to reduce fatalities, thereby saving the lives of the traveling public that uses them.

Problem Statement

Highway-rail intersections have claimed many lives in the U.S., including NYS, and caused countless injuries. The federal government has appropriated funds for states to improve public crossings and install active devices, which includes flashing lights and gates to warn motorists. Despite this investment, lives are still being lost. However, while it is difficult to eliminate these crossings, it is also expensive to grade-separate all of the crossings. Motorists and other road users need to safely cross the tracks in the course of travel. Therefore, this study provided a solution by integrating intelligent transportation systems with a positive train control system at HRIs in order to alert highway users.

Methodology

In this study, the author examined the crashes at HRIs for a 16-year period in New York State in order to complement the improvements made to current warning systems at highway-rail intersection (HRI) locations, where crashes have occurred. The methodology involved gathering accident data at HRIs for the years 2000-2015 from the New York State Department of Transportation. The data was the population of all accidents occurring during the period of study. The data were categorized into accidents that occurred as a result of driver violation of activated gates, and all other causes during the 16-year period. Data retrieved were copied into Microsoft Excel. These data were sorted and checked for errors. The data were then imported into SPSS 20 for statistical inferences, using the entire data population. The descriptive and inferential statistics were employed to analyze the data. In other to test statistical significance, a non-parametric chi-square goodness-of-fit test was conducted to determine the significant difference between the total number of accidents by motorists who violated activated warning devices and the total of all other accidents caused by other factors. The alpha level was set at 0.05. Therefore, the following hypothesis was tested:

Hypotheses

$H_{0:}$ There is no statistically significant difference in the number of accidents that occurred as a result of violation of activated gates by motorists and all other accident causes at HRIs from 2000-2015 in New York State.

H_1: There is a statistically significant difference in the number of accidents that occurred as a result of violation of activated gates by motorists and all other accident at HRIs from 2000-2015 in New York State.

Findings

The accident data gathered during the study period were analyzed using Microsoft Excel as well as SPSS 20 for descriptive and inferential analyses. The total number of HRI accidents that occurred during the study period was 467. Figure 2 indicates the trend of the total accidents per year from years 2000 to 2015.

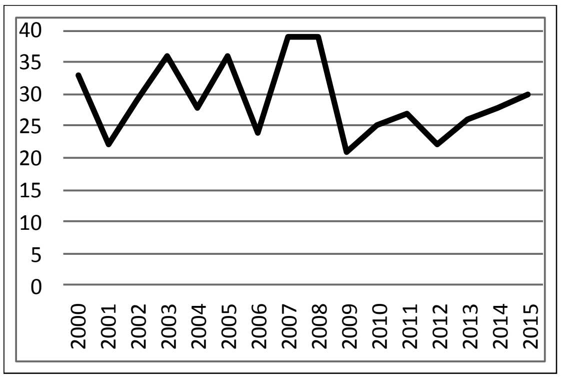

Figure 2. Trend of the Total Accidents per Year from 2000-2015

These accidents fluctuated based on the period. They were collections of all types of accidents. Despite the improvements made to HRIs annually, there was no indication of consistency or steady reduction in total annual accidents. The peak of the total annual accidents at HRIs occurred in years 2007 and 2008, while the fewest accidents occurred in 2009. Relative to the cumulative percentage of the number of accidents, Figure 3 indicates that over 50% of the total accidents occurred between 2007 and 2015.

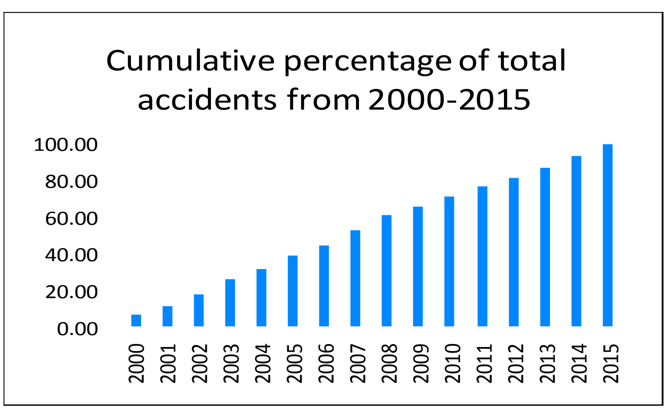

Figure 3. Cumulative Percentage of Accidents from 2000-2015

During this period, there were improvements at railroad crossings but not all candidate crossings were improved simultaneously, because funds appropriated by the federal government for annual improvement for these HRIs have remained the same—about six million dollars—while project costs have been increasing. In addition, traffic volume at these crossings is also increasing. The accident occurrence at railroad crossings in this study was classified as motorists violating the activated gates as well as accident occurrences as a result of other causes. Figure 4 indicates that 55% of the accidents occurred as a result of deliberate violations by motorists, while other causes were 45% throughout the study period.

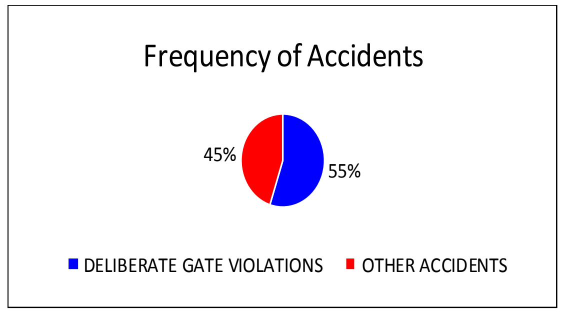

Figure 4. Accidents as a Result of Deliberate Gate Violations to Other Accidents at Railroad Crossings from 2000-2015 in New York State

Table 1 shows the number of accidents based on the classification. A total of 467 accidents occurred during the 16-year period.

Table 1. Accident Classification

	Observed N	Expected N	Residual
Motorists Gate Violation	256	233.5	22.5
Other Causes	211	233.5	-22.5
Total	467		

Out of the 467 accidents at HRIs, 256 of them involved motorist gate violations, while 211 involved all other causes including, deliberate violation by pedestrians and/or bicyclists, weather conditions, vehicle striking trains, malfunction of warning devices, and crossing characteristics. The minimum expected frequency indicated in Table 1 was approximately 234, which satisfies the assumption of a minimum of five in each category for the chi-square test. The chi-square goodness-of-fit test conducted determined whether the number of accidents caused by motorists that violated warning devices were equal to all other accidents caused by other factors at HRIs in New York State. Table 2 shows the test of significance.

Table 2. Chi-Square Test Statistics

	Accident Classification
Chi-Square	4,336 [a]
Df	1
Asymp. Sig	0.037

a. 0 cells (0.0%) had expected frequencies less than five. The minimum expected cell frequency was 233.5

The chi-square test of significance, indicated that accidents that occurred as a result of violation of activated warning devices and other accident causes was statistically significantly different (X^2 (1) = 4.336, p = 0.037). Over 45 more accidents occurred as a result of violation of active warning devices over other accident causes altogether. The expected cell frequency of 234 was not met.

Discussion

Based on the findings, most of the accidents occurred in years 2007 and 2008. Over half of the number of accidents occurred from 2007 to 2015. The activated devices meant to warn motorists were violated by drivers either driving around the gates or not heeding to the signals. This was termed as deliberate actions by the drivers, who could not wait for the approaching trains to pass the crossings. This action surpassed other accident causes altogether, which included violation by pedestrians and/or bicyclists, weather conditions, vehicle striking trains, malfunction of warning devices, and crossing characteristics. This justified the relative assertion that most accidents involving commuter rail lines occur when people ignore railroad crossing gates. When the safety signals at a railroad crossing are ignored, it is dangerous and illegal in New York State, in accordance with the vehicle and traffic law (section 1170), which imposes criminal penalties and fines against those disobeying active warning devices [2]. Since it is very expensive to grade-separate each of these high-risk crossings, an intelligent grade crossing system (IGCS) could complement the active warning devices that are currently installed at HRIs and help mitigate the accidents.

Intelligent Grade Crossing

An intelligent grade crossing system (IGS) utilizes technology that would help mitigate crashes and collisions at HRIs. It is a location where an intelligent transportation system (ITS) used for the roadway is integrated with an intelligent railroad system, most especially the positive train control (PTC) system [3]. It is the ultimate solution for railroad grade crossing safety. It utilizes many ITS applications used for roadways such as vehicle detection, Global positioning system (GPS) tracking, advance traveler information systems, etc., towards enhancing safety [4] as well as railroad transponders and wayside detection systems. The ITS technology was applied to roadway systems to improve safety by integrating communication and information technology [5]. The PTC system provides information on train speed as well as the location of the train in real-time. It uses communication-based technology to control trains for effective prevention of trains from accidents, especially when a train engineer or operator cannot take appropriate action to stop the train when required [6]. The technology involves computers on-board in trains, wayside interface devices with servers from the control center using wireless communication networks, positioning system such as global positioning system (GPS), and transponders to continuously control rail operation in real-time [7].

Based on the aforementioned application of ITS technology for roadways, it could also be applied to vast transportation infrastructure and vehicles. The field devices, which include cameras, detectors, and dynamic message signs, could be integrated with the railroad system and the existing warning devices at a grade crossing location. A dynamic message sign (DMS) is an electronic sign positioned along highways. It is used to display information on traffic conditions, travel time, incidents, and roadway construction [8]. It was formerly called a changeable message sign and sometimes called a variable message sign, which is needed as a link between transportation agencies and the public they serve for traffic conditions [9].

The DMS term was developed within the NTCIP (National Transportation Communication for ITS Protocol) in order to create a standard that would support changeable message sign and variable message sign with a common set of data [10]. In this study, the system's primary information was to help provide the position and speed of trains at HRIs to motorists approaching highway-rail intersections. The DMS should be placed in a visible position to attract roadway users. Messages indicated must be shown in a manner that can be understood by motorists.

The closed circuit television (CCTV) camera is a field device within the ITS. It is installed on highway corridors to capture images and sends information to centers at remote locations. Such centers consists of equipment including large-screen monitors, servers, computers, and cable networks that link and communicate with the devices from such centers to the field [11]. The sensors used to detect and collect traffic data along the highway were applicable to this study. The non-intrusive sensors were required for detecting vehicle and train presence as well as speed. These sensors and CCTV can detect stalled vehicles as well as any blockage at HRIs and send such information to the cabin of train engineers/operators and the control centers for immediate response [4].

Architecture

The architecture encompassed layers that include institution, transportation, and communication. The institution entails the organization that will provide the funding mechanism and policies as well as the effective implementation, operation, and maintenance of the system. The architecture is needed for planning and project development. From the transportation layer point of view, the user service applicable to this study is the HRI. Based on the user service, railroad crossing safety requires integration of both the highway and rail systems relative to logical and physical architecture. According to USDOT-RITA, the national architecture consists of logical and physical architecture, which also provides a framework for designing transportation systems that define ITS user services [12].

The key components of the architecture are vehicles and field, which are regarded as the environment, while roadway users and centers are remote areas. The HRI user service in the national architecture uses ITS technologies to improve train control and detect/alert highway traffic so as to avoid or mitigate the severity of crashes between trains and highway vehicles at HRIs. It was indicated that nine constituents make up the HRI national architecture and include track circuit, wayside signals, flashing lights and gates, traffic signals, dynamic message signs (DMS), and surveillance cameras [13]. Presently, the operational speed of most commuter traffic in New York State is 79 mph. The standard speed rail subservice used by light rail transit, commuter, and heavy trains with operational speeds up to 80 mph in the national architecture was adopted for this study. Their integration with each other required digital data link communication networks as well as dedicated short-range communication (DSRC) so that they could talk to each other on the same protocol in real-time. The architecture is a standard that will reduce time when tailored accordingly. The process specification applicable to the roadway system as well as market and equipment packages for standard rail crossings in the national architecture was adopted for implementation. The packages consist of the system elements, which entail the advanced traveler information system (ATIS), the advanced traveler management system (ATMS), and the advanced detection system (ADS).

The System Engineering Process

The system engineering process (SEP) follows various steps that guide accomplishment of the design for the IGS at a given HRI in order to avoid excessive cost of implementation. The concept of operation would be tuned in line with the overall goal of improving safety. The major feature is precise warning time, highway motorists' information, and the tendency for trains to stop during emergencies at HRIs. Field devices, such as CCTV and other detective devices, are integrated with a grade crossing controller, railroad wayside technology, and train cab-based technology towards information sharing between the railroad and the municipalities in charge of the roadway. The DMS is located on roadway approaches. For proper functioning, the installed devices at crossings send information to the railroad center, while the controller at the grade crossing communicate with the train operator when a stalled vehicle is detected prior to arrival at the HRI. The municipality or regional transportation center, railroad center, and emergency management center should be integrated with applicable packages so that they are interoperable. The design should accommodate all future protocols. The system functionality would conform to specifications, test, and verification. The system must continue to fulfill its objective and be failsafe, based on continuing operation and maintenance, as well as upgrade. Figure 5 shows an IGC design.

System Deployment

The system would use the existing grade crossing controller and track circuitry at the grade crossing approach. Devices such as CCTV and loop detectors are installed at the crossing. Real-time conditions, such as obstacles detected at a crossing, are processed through the grade crossing controller and conveyed directly to the approaching train cabin and the railroad center through wireless communication or transponders. In order to determine the position of the train, the GPS mounted on antennas on the train help determine the location of the train in real-time. Similarly, transponder systems that were mounted on track beds or rail ties could help determine train locations. This could be achieved through the reader antennas mounted on the trains to capture power from installed transponders located at intervals along the tracks. The transponders have the advantage of indicating track locations and loss of signals because they use radio frequency (RF) signals. The train can locate itself on the map through the identity of the transponder. The read data that are transmitted to the on-board computer for speed and position of the train are then relayed to the field devices such as DMS to alert motorists through its integration through the grade crossing controller to the railroad center.

Where there are multiple tracks, particularly at crossings near train stations, it also helps alert pedestrians of the approach of secondary trains. The main attribute of the train-based technology is that an on-board computer determines

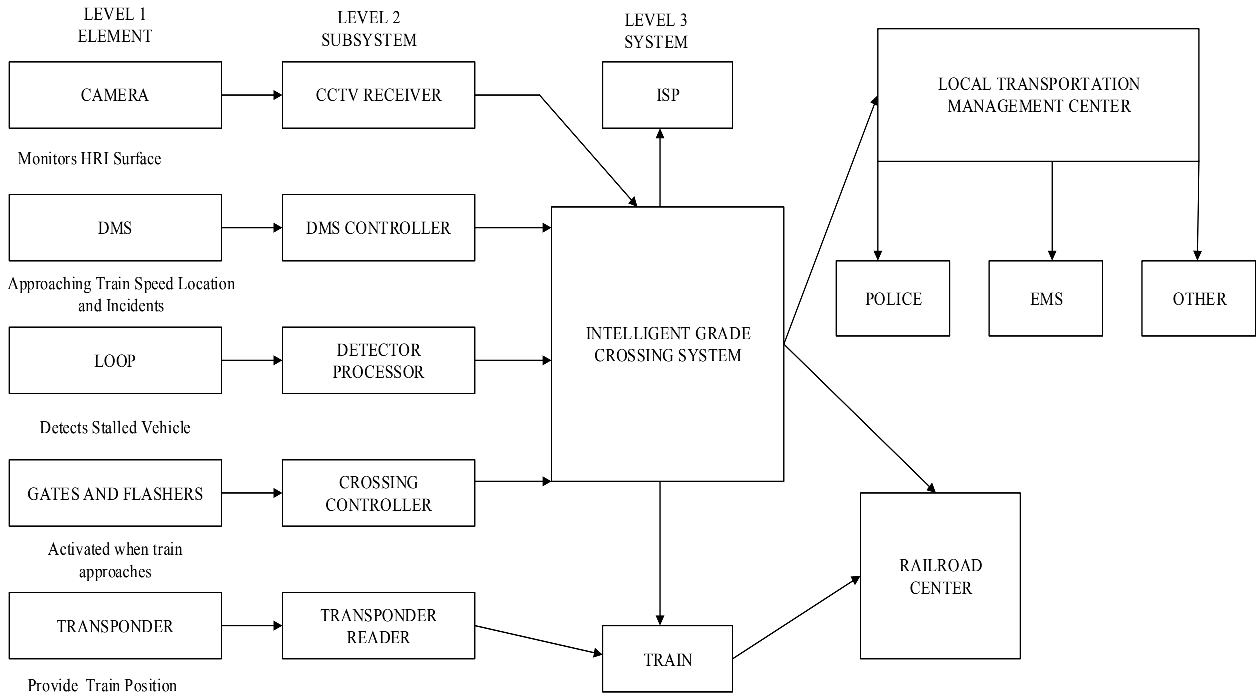

Figure 5. Intelligent Grade Crossing System

its location and transmits data to the system for processing and dissemination [2]. Figure 6 indicates the HRI layout with a deployed IGC.

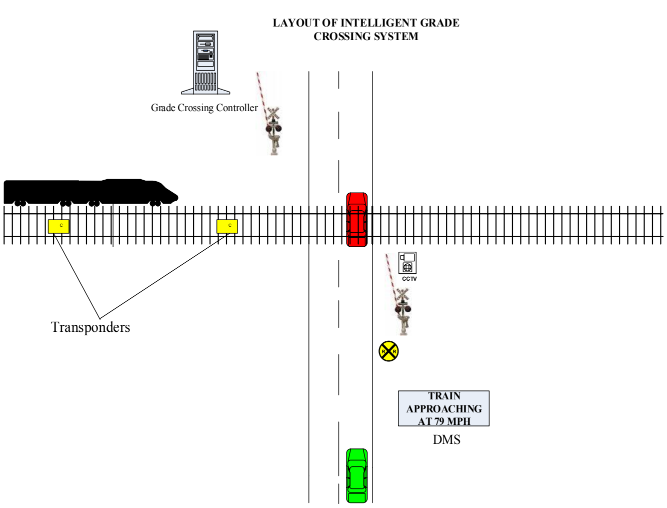

Figure 6. Intelligent System Deployment

The integration of the rail system with the ITS requires appropriate standards to ensure proper exchange of information between the traffic management center (TMC) and any other centers and field devices. The standards would ensure interoperability, reduce costs, and avoid proprietary rights, since products of multiple vendors can be chosen. This would allow the centers to talk to each other for effectiveness. Notable standards include the National Transportation Communication for ITS Protocols (NTCIP), which provides the communication rules and defined applicable data for controlling field devices from a given center. Traffic management data dictionary (TMDD) adds additional vocabulary not in NTCIP for center-to-center communication. Incident management (IM) consists of various standards developed by IEEE to address interfaces between the emergency management center and traffic management center as well as other centers, and provide data elements and messages. The integration of local TMCs with the railroad center allows them to have access to information relative to incidents at the local TMC to manage the corridor for traffic routing.

Conclusions

In order to eliminate crashes between trains and highway vehicles at crossings, a grade separation is needed. Because the cost of replacing an HRI with a bridge is extremely expensive, the high risk of crashes at existing crossings within a railroad corridor can be mitigated with intelligent grade crossing (IGC) technology, which integrates a detection system, DMS, and railroad wayside system. Based on the causes of accidents in New York State, deliberate/illegal driver actions dominate these factors. Drivers fail to heed to devices when activated, with the aim of beating the train before it arrives at the crossing. However, the trains are killing the drivers and their occupants. Other identified causes include vehicles getting stalled on the tracks, drivers abandoning their vehicles, suicide, etc. These accidents could be minimized by providing an IGC system. The IGC will provide drivers with the speed and location of trains through a dynamic message sign so that they can stop in a timely manner, even when visibility at the HRI is poor. Similarly, train engineers or operators would be informed ahead of any stalled vehicles at the crossings, so that the train could be stopped before arriving at the crossing. In the event of an emergency, rail transponders could help force the train to stop.

Presently, there are no cameras at HRIs; similarly, state law does not allow enforcement with CCTV. In order to prevent drivers from deliberately going around the gates at HRIs in New York State, statewide enforcement would be necessary through CCTVs connected to the IGC system, rather than relying only on a police presence before imposing penalties and fines. This would help reduce the number of accidents at HRIs. Therefore, as a starting point, the author recommends that this system be applied to a select group of high-risk, high-volume crossings to curb impatient motorists.

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Biography

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