Towards the improvement of Highway-Rail Intersections with Intelligent Grade Crossing System

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Abstract

Safety at Highway-Rail Intersections (HRIs) is currently dependent on installed active warning system 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. This study examined crashes which involved motorists who violated activated warning devices and other causes combined at HRIs from years 2000-2015 in New York State. The methodology involved gathering of accident data for the 16-year period from the New York State Department of Transportation. The descriptive and inferential statistics were employed to analyze the data. The outcome was depicted by tables and graphs. Chi-Square goodness-of-fit was used to test the hypothesis to determine statistical significance difference in the total number of accidents that occurred as a result of violation of activated warning devices by motorist 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 enforcements and reduce motorists' violation of activated warning devices at HRIs.

Introduction

Highway-Rail Intersection (HRI) is a location where rail and the 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. Despite the improvements at these HRIs, accidents still occur and continue to be a major problem at public railroad crossings, specifically in urban areas. Since the railroad has the right-of-way, motorists who need to cross the track supposed to stop and give way to approaching trains.

For adequate warning, public crossings have been equipped with gates and flashing lights, which were regarded as active warning devices, to reduce collisions between highway vehicles and trains. When flashing lights only or flashing lights with gates are absent, such crossing is passive. The upgrading of a passive crossing with active warning devices improves safety at a crossing. Because volume of vehicles and trains is higher at active crossings, there is greater potential for conflicts between the two systems of transportation. Almost half of HRI accidents between 1994 and 2003 occurred at crossings that were equipped with active warning devices [1]. The only approach to eliminate exposure between highway users and trains is the separation of both systems.

Since the cost of a grade separation or installation of a bridge is so expensive to eliminate any candidate HRI, it is necessary to find solution to safety improvements at railroad grade crossings. The volume of motor vehicles traversing the crossing is increasing, while pedestrian/bicyclist and motorists fowl the tracks. Similarly in urban centers, commuter train movements have increased over the years based on population growth and demand for the public transit. Therefore, in order to improve mobility and combat crashes at highway-rail intersection, this paper 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 system 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 the Federal and State governments while the maintenance of such devices was done by the railroad organizations. In addition, the highway approaches are being maintained by the municipalities having jurisdiction over the public roads. Private crossings are HRI's 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 private crossings. As of 2016, in New York State, there were 2,911 public railroad crossings and 2,944 private railroad crossings. Figure 1 below indicates the percentages of public and private HRIs in New York State:

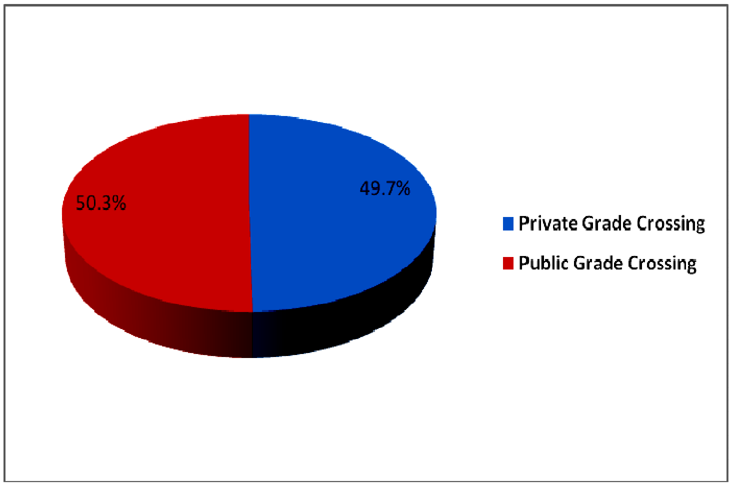

Fig 1: Public and Private HRIs in New York State

The improvements of public crossings have gulped millions of dollars annually through share costs funding between the Federal and State Governments, and sometimes with local authorities in order to mitigate risks encountered by the general public who use the intersections. The public crossings attract high volume of road traffic while urban cities specifically in the downstate of New York attract 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 Pedestrian/Bicycle
- Vehicle Striking Train
- Outside Factors and Conditions
- Crossing Characteristics
- RR Error/Malfunction

This paper investigated causes of accident which involved motorists which 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 towards reducing fatalities and safety of lives of the traveling public that use them.

Problem Statement

Highway-rail Intersections have claimed many lives in the United States including NYS, as well as injuries. Federal Government has provided funds to States to improve public crossings to 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 the crossings. Motorists and other road users need to safely cross the tracks in the course of travel. Therefore, this study provided solution by integrating Intelligent Transportation Systems with Positive Train Control System at HRI in order to alert highway users.

Methodology

This study examined the crashes at HRI 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 of accident data at HRIs for years 2000-2015 from the New York State Department of Transportation. The data was the population of all accident data during the period of study. The data is categorized into accidents that occurred as a result of drivers' violation of activated gates and all other causes during the 16 year period. The data retrieved were copied into Microsoft Excel. These data were sorted and checked for errors. The data were then imported into SPSS 20 statistical software for statistical inferences, using the entire data population. The descriptive and inferential statistics were employed to analyze the data. Analyzed data were depicted in Tables, Charts, and Graphs. In other to test statistical significance, a non-parametric chi-square goodness-of-fit test was conducted to determine the significant difference between 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:

Hypothesis

H_0: There is no statistical significance difference in the number of accidents that occurred as a result of violation of activated gates by motorists and all other accident causes at HRI from 2000 - 2016 in New York State.

H_1: There is statistical significance difference in the number of accidents that occurred as a result of violation of activated gates by motorists and all other accident at HRI from 2000-2016 in New York State.

Findings

The accident data gathered during the study period were analyzed using Microsoft Excel as well as SPSS version 20 for descriptive and inferential analyses. The total number of HRI accidents which occurred during the study period was 467. Figure 4 below indicated the trend of the total accidents per year from years 2000 and 2015. These accidents fluctuated and were collections of all types of accident. 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 HRI occurred in years 2007 and 2008 while the least accidents occurred in 2009.

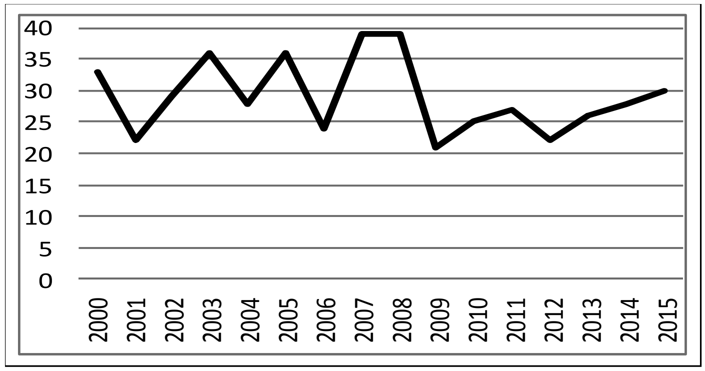

Figure 4: Trend of the total accidents occurrence per year from 2000-2015

Relative to the cumulative percentage of the number of accidents, Figure 5 below indicated that, over 50% of the total accidents occurred between 2007 and 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 for about six million dollars while project costs have been increasing. In addition, traffic volume at these crossings is also increasing.

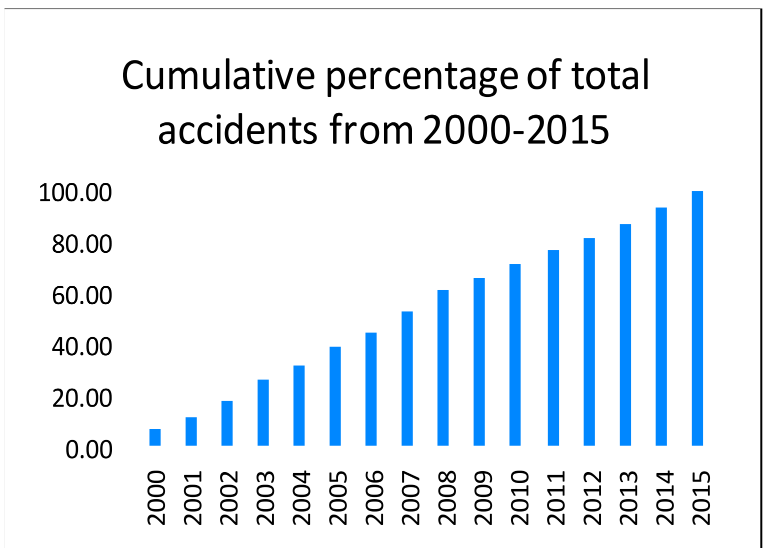

Figure 5: Cumulative percentage of accident occurrence from 2000-2015

The accident occurrence at railroad crossing in this study was classified as motorists violating the activated gates as well as accident occurrences as a result of other causes. Figure 6 below indicated that 55% of the accidents occurred as a result of deliberate violations by motorists, while other causes were 45 % throughout the study period.

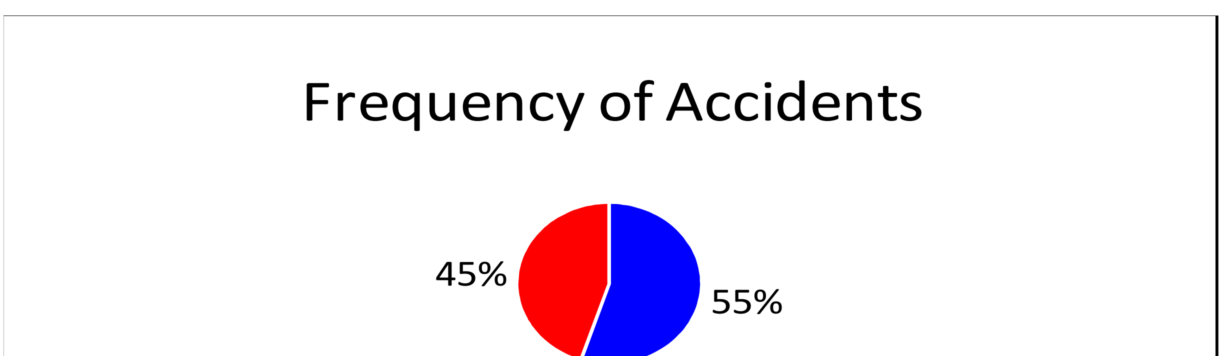

Figure 6: Show accidents as a result of deliberate gate violations to other accidents at railroad crossing from 2000-2015 in New York State

Table 2 below indicated that 467 accidents occurred during the 16 year period. Out of the 467 accidents at HRI, 256 of them involved motorists gate violation while 211 involve all other causes which include, deliberate violation by pedestrians/bicyclist, weather conditions, vehicle striking trains, malfunction of warning devices and crossing characteristics.
Figure 3 above showed the percentages of accidents as a result of Motorists' Violation as well as Other Causes.

Table 2: Show Accident Classification**.**

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

The minimum expected frequency indicated in Table 2 above was approximately 234 which satisfy the assumption of minimum of five in each category for the chi-square test. A chi-square goodness-of-fit test was conducted to determine whether the number of accidents caused by motorists that violated warning devices were equal to all other accidents caused by other factors at HRI in New York State. The minimum expected occurrence was 234. The chi-square test depicted that the accident 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 all together.

Table 3: The Chi-Square Test Statistics

	Accident Classification
Chi-Square	4.336[a]
Df	1
Asymp. Sig	0.037

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 233.5.

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 all together, which include violation by pedestrians/bicyclist, weather conditions, vehicle striking trains, malfunction of warning devices and crossing characteristics.

This justified relative assertion that most accidents involving commuter rail lines occur when people ignore railroad crossing gates. When the safety signals at a railroad crossing is ignored it is dangerous and illegal in New York State in accordance with Vehicle and Traffic law (Section 1170) which imposes criminal penalties and fines against those who disobeyed active warning devices [2]. Since it is very expensive to grade-separate each of these high risk crossings, Intelligent Grade Crossing System (IGCS) could complement the active warning devices that are currently installed at HRIs and help mitigate the accidents. IGCS is described as follows:

Intelligent Grade Crossing

Intelligent Grade Crossing System (IGS) utilizes technology that would help mitigate crashes and collisions at HRIs. It is a location where Intelligent Transportation System (ITS) used for roadway is integrated with Intelligent Railroad System, most especially the Positive Train Control (PTC) system [3]. It is the ultimate solution for railroad grade crossing safety. It utilized many ITS applications used for roadway such as vehicle detection, Global Positioning System (GPS) tracking, advance traveler information systems, etc., towards enhancing safety [4] as well as railroad transponders and way side detection system.

The ITS technology was applied to roadway system 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 towards effective prevention of trains from accidents especially when a train engineer or operator could not take appropriate action to stop the train when required [6]. The technology involved computers on-board of 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 aforementioned of the application of ITS technology for roadway, 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 the grade crossing location.

Dynamic Message Sign (DMS) is 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 changeable message sign and sometimes called variable message sign, which is needed as a link by transportation agencies with 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 primary information was to help provide the position and speed of trains at HRI to motorists approaching highway-rail intersections. The DMS should be placed in a visible position to attract road. Messages indicated must be indicated in a manner that they must be understood by motorists.

The Closed Circle Television (CCTV) camera is a field device within the ITS which is installed on highway corridors to capture images that sends information to centers at remote locations. Such center consists of equipment which include large screen monitors, servers, computers, and cable network that links the devices from the Center to the Field [11]. The sensors used to detect and collect traffic data along the highway are applicable to this study. The non-intrusive sensors are required for detecting vehicle and train presence as well as speed. These sensors and CCTV can detect stalled vehicle as well as any blockage at HRI 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 the institution, transportation and communication. The institution entails the organization that will provide the funding mechanism, policies as well as the effective implementation, operation and maintenance of the system. The architecture is needed for planning and the project development. From the transportation layer point of view, the User service applicable to this study is HRI. Based on the user service, the railroad crossing safety requires integration of both the highway and rail system 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 defined ITS User Services [12]

The key components of the Architecture are vehicles and field, which are regarded as environment, while roadway users and centers are remote areas. The HRI user service in the National Architecture use ITS technologies to improve train control and detect/alert highway traffic so as to avoid or mitigate severity of crashes between trains and highway vehicles at HRIs. It was indicated that nine constituents made up HRI National Architecture and includes track circuit, wayside signals, flashing lights and gates, traffic signals, dynamic message sign (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 operated upon 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 requires digital data link communication networks as well as Dedicated Short Range Communication (DSRC) so that they could talk to each other based on same protocol in real time. The architecture is a standard that will reduce time when being tailored accordingly. The process specification applicable to the roadway system as well as market and equipment packages for Standard Rail crossing in the National Architecture was adopted for implementation. The packages consist of the system elements which entail the Advance Traveler Information System (ATIS), the Advanced Traveler Management System (ATMS) and Advance Detection System (ADS).

The System Engineering Process

The System Engineering Process (SEP) is a process that follows various steps that guides 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 emergency at HRIs. The field devices such as CCTV, detective devices are integrated with grade crossing controller, railroad wayside technology and train cab based technology towards information sharing between the railroad and municipalities' in charge of the roadway. The DMS is located on roadway approach. For proper functioning, the installed devices at crossings send information to the railroad center, while the controller at grade crossing communicate with train operator when a stalled vehicle was detected prior to arrival at the HRI. Municipality or Regional Transportation Center Railroad Center and Emergency 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 2 below indicate an IGC design.

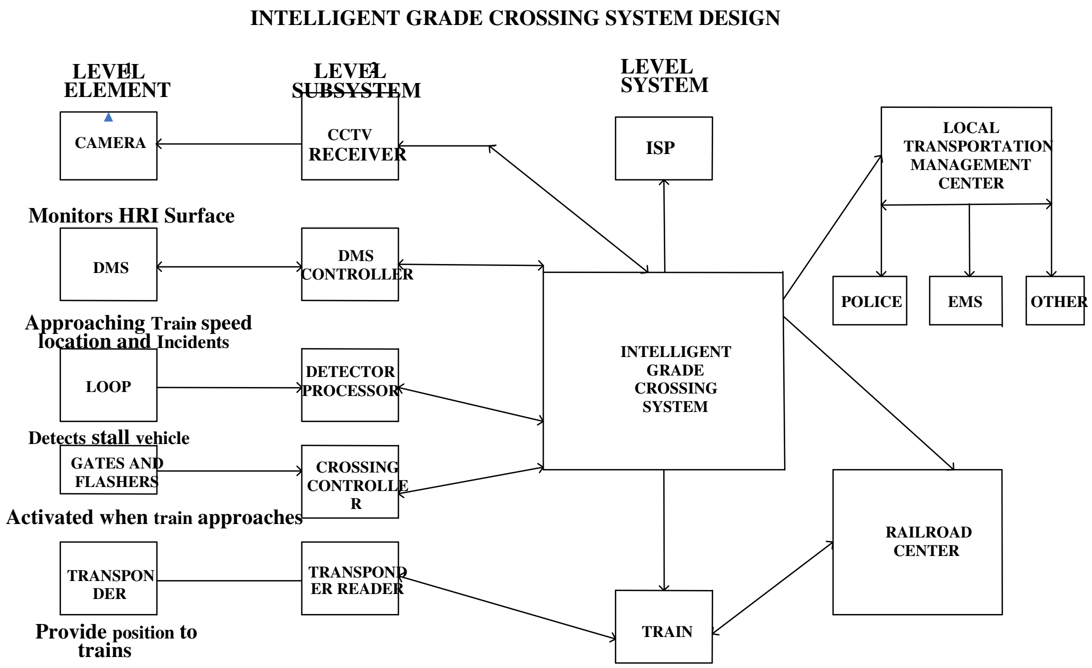

Figure 2: Intelligent Grade Crossing System

The system Deployment

The system would use the existing grade crossing controller and track circuitry at the grade crossing approach. Devices such as CCTV, 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 Global Positioning Technology (GPS) based on antennae mounted on the train help determine the location of the train in real-time. Similarly, transponders system that were mounted on track beds or rail ties could help determine train locations. This could be achieved through the reader antennas mounted on trains to capture power from installed transponders which are located at intervals. The transponders have an advantage of indicating track locations and loss of signals because it uses Radio Frequency (RF). The train can locate itself on the map through the identity of the transponder. The read data that is transmitted to the on-board computer whereby speed and position of the train are then relayed to the field device such as DMS to alert motorists through its integration through the grade crossing controller that was integrated with railroad center. Where there are multiple tracks, particularly at crossings near train stations, it also helps alert pedestrians of the approach of second trains. The main attribute of the train based technology is that on-board computer determines its location and transmits data to the system that needs such information [2]. Figure 3 below show the HRI layout with a deployed IGC.

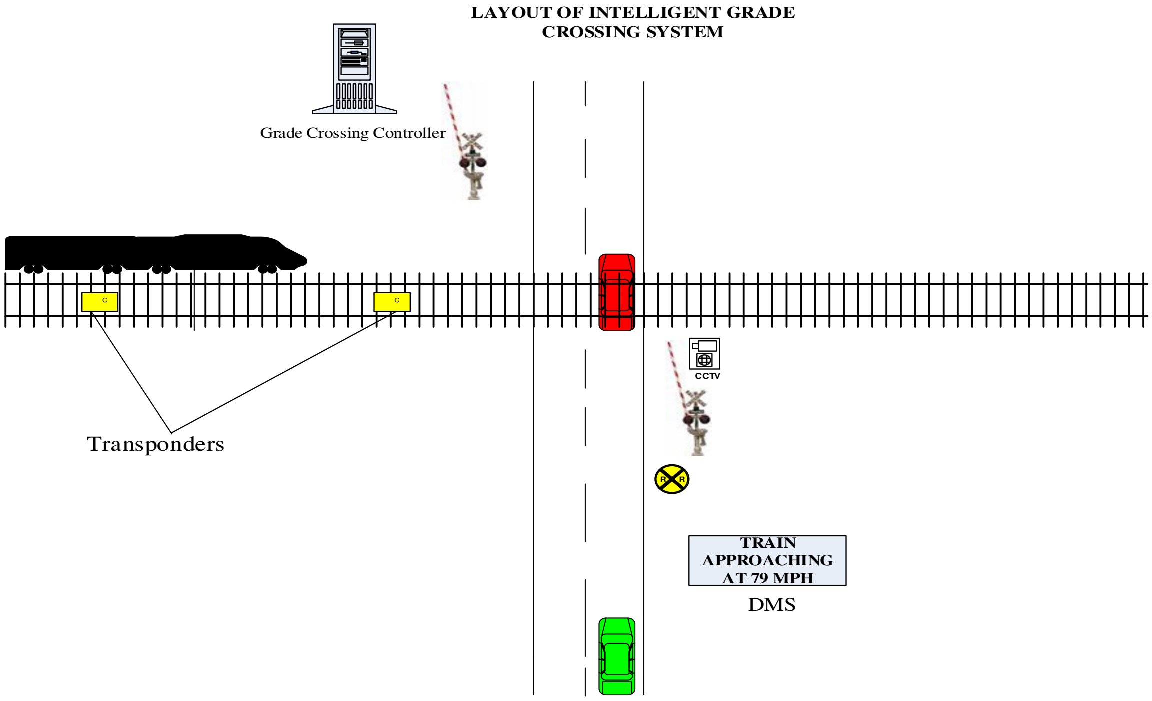

Figure 3: Intelligent System Deployment

The integration of the rail system with the ITS require appropriate standard to insure proper exchange of information between the Traffic Management Center and any other Centers and field devices. The standards would ensure interoperability, reduce cost and avoid proprietary rights since products of multiple vendors can be chosen. This will 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 to control 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 Emergency Management Center and Traffic Management Center as well as other Centers and provide data elements and messages. The integration of local Transportation Management Center (TMC) with the railroad center can allow it to have access to information relative to incidents at , the local (TMC) can manage the corridor for traffic routing.

Conclusion

In order to eliminate crashes between trains and highway vehicles at crossings, a grade separation needed to be provided. Because the cost of replacing an HRI with a bridge is highly expensive the high risk of crashes at the existing crossings should be mitigated with the Intelligent Grade Crossing technology which integrates detection system, DMS and railroad way side system to address high risk candidate crossings within a railroad corridor.

Based on the causes of accidents in New York State, deliberate/illegal driver action dominated these factors. Drivers failed to heed to devices when activated with the aim of beating the train before arriving at the crossing. However, they got killed by the trains. Other causes identified include vehicles getting stalled; drivers abandonment of vehicles, suicide, etc. These accidents would be minimized by providing the IGC system.

The IGC will enable drivers to know the speed and location of trains through the Dynamic Message Sign so that they can stop even when the sight distance at HRI is poor. Similarly, the train engineers or operators would be informed ahead of any stalled vehicles at the crossings so that the train could stop before arriving the crossing. In the event of any 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 the drivers who deliberately go around the gates at HRI in New York State, enforcements would be necessary statewide through installed CCTV applicable to the IGS rather than relying on just police presence before imposing penalties and fines. This will help reduce the overall accidents at HRI. Therefore, to start with, I recommend that this system be applied to high risk candidate crossings particularly where there are high volumes of train and highway traffic because of potential accidents particularly to curb impatient motorists.

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Biographies

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