Implementing Connected Vehicle and Autonomous Vehicle Technologies at Highway-Rail Grade Crossings

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FRA High-Rail Intersection (HRI) accident records between 2008 and 2012 yielded 9775 incidents, 969 fatalities, and 4336 injuries*
- 80 percent of these incidents and 88 percent of all fatalities involved a train striking a motor vehicle.
- “Trains striking a motor vehicle” resulted in fatalities at twice the rate as a “motor vehicle striking train” scenario.

Study showed that annual combined grade crossing accident costs were between $20 million and $35 million dollars.

NHTSA study estimated the annual costs of HRI at $650 million and 18,000 functional years lost
- Includes economic losses associated with medical and legal costs, lost productivity, and travel delay

Accidents occurred even in the presence of grade-crossing technology designed to impede motorists at crossings

*Hellman and Lopez-Bernal (2015)
Enhancing Grade-Crossing Safety

♦ On a positive note, grade crossing accidents involving trains and motor vehicles over the past 20+ years have declined significantly

♦ Opportunities exist to reduce the accident rate further.

♦ Areas to focus on:
  ▪ Driver/crossing interactions and traffic patterns
  ▪ Standardized incident/accident data collection and analysis
  ▪ Regulations and enforcement
  ▪ Education and public awareness
  ▪ Institutional issues
  ▪ Technology modernization and development

♦ Existing technologies to prevent grade-crossing accidents have changed little over the past fifty years
A Changing Infrastructure

- Modern wireless technology facilitates automated forms of communication between transportation infrastructure and the vehicles
  - Wireless technology creates an opportunity to innovate the next generation grade-crossing warning systems
- ITS Joint Program Office at DOT’s Office of the Assistant Secretary for Research and Technology sponsors the Connected Vehicle (CV) Safety for Rail initiative
- Research focuses on integrating Dedicated Short Range Communication (DSRC) hardware with existing grade-crossing safety systems
  - Crossing status broadcast to approaching CVs to be interpreted by the vehicle OBC and, if necessary, a driver warning activated.
Grade Crossing and CV Technology

- UMTRI conducted the Safety Pilot Model Deployment (SPMD) study where they equipped a fleet of vehicles with V2V communications technology to demonstrate its viability.
- Goal was to evaluate DSRC technology for V2V safety applications, which operate at 5.9 GHz in a real-world, concentrated environment.
- During the study, a grade-crossing warning system was developed to warn drivers of the presence of a train approaching the crossing, either gated or ungated.
- System was a low-cost supplement that uses wireless communications at the crossing to deliver in-vehicle warning messages for equipped vehicles.
- Technology and system evaluation was ultimately not deployed due to a lack of cooperation by participating railroads.
Dedicated Short-Range Communications

As a result of the high demand for new Wi-Fi products and services, policymakers in the US began looking at areas of underutilized spectrum that could be opened up to help alleviate the spectrum shortage

- Finding more spectrum for Wi-Fi is considered strategic by US Government*

- FCC allocated 75 MHz of spectrum in the 5.9 GHz range (5825 – 5925 MHz) for Dedicated Short Range Communications (DSRC).

- Furthermore, the FCC issued NPRM 13-22 (13-49) regarding sharing of DSRC band with Wi-Fi / Unlicensed National Information Infrastructure (U-NII).

- To address spectrum sharing, two proposals are being considered:
  - “Detect and avoid” - If an unlicensed device detects any transmitted DSRC signal, it would avoid using the entire DSRC band to assure no interference occurs to DSRC communications
  - “Spectrum repacking” - the DSRC spectrum would be split into two contiguous blocks: one for safety-related communications and one for non-safety-related communications

*US Congress passed the Middle Class Tax Relief and Job Creation Act, which among other things directed the National Telecommunications and Information Administration (NTIA) to examine the potential for spectrum sharing in the 5.9GHz bands used by DSRC.
Communication Protocols in CV and Grade-Crossing Technology

♦ CV concept is well developed and in various stages of testing.
♦ In December 2016, NHTSA issued a NPRM regarding V2V communication technology for new passenger vehicles in the U.S.
  ▪ NPRM describes transmission protocols known as DSRC and message contents known as the basic safety message (BSM).
♦ NHTSA estimates that the number of crashes avoided are 400,000-600,000 with the potential to save 780-1080 lives with the implementation of V2V communications alone with full deployment.
♦ Estimates do not take into account the added benefit of rail-to-light vehicle communications.
Vehicle-to-infrastructure (V2I) technology offers the potential for bi-directional exchange of data between vehicles and roadway infrastructure. It aims to coordinate vehicle group behaviors based on collected information about traffic and road conditions. This includes:

- Velocities and accelerations of vehicles based on traffic congestion
- Information about the status of a grade crossing
- Controls infrastructure to improve road safety.
- Broadcasting messages via road displays or adjusting traffic signals
- Alerts motorists when it is unsafe to enter intersections and grade crossings
AV technology is advancing rapidly and shows great promise for improving the safety and efficiency of roadway operations.

Development of AVs in real-world operational test environments is limited to a subset of operational scenarios that occur in roadway operations, including grade-crossings.

Future development of AV platforms should consider all operational scenarios, particularly grade crossings.

Integrating existing CV technology at grade crossings into AVs builds upon the functional ability of AVs ensuring safe and efficient grade crossing interaction.
Levels of Automation

♦ AVs are equipped to sense the driving environment and can navigate with reduced or no driver input depending on the level of automation.

♦ The SAE J3016 standard (i.e. Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems) defines six levels of driving automation that span from no automation to full automation.

♦ A key distinction is between level 2, where the human driver performs part of the dynamic driving task, and level 3, where the automated driving system performs the entire dynamic driving task.
State of AV Technology

- AV development has been driven by consumer demand and development efforts by Tier 1 suppliers and OEMs

- Currently, light passenger vehicles have largely reached Level 2 automation (or partial automation)
  - Specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment
  - Expectation that human driver perform all remaining aspects of the dynamic driving task

- While this level of automation relieves a significant amount of burden from the driver, it requires continuous driver vigilance and system correction in some fringe cases

- Current development efforts are focusing on sensor fusion and onboard information processing as well as driver acceptance and levels of reliance on driver assistance technology

- Overreliance on such systems remains a human factors concern as system performance continues to improve and human attention during operations will decline
Future AV Research

- Engaging OEMs and Tier 1 suppliers will help to define the state of AV technology and the readiness of these systems as they relate to safe navigation of grade crossings.

- A variety of sensor technologies are necessary to detect and safely interpret the driving environment that increase in complexity as the level of automation increases:
  - Vision-based systems, currently in use for Level 2 and Level 3 automated driving, which can detect and safely interpret roadway signs and assess their viability to recognize grade crossings.
  - Stereo-based camera systems (two or more lenses) that simulate human binocular vision.
  - Deep learning models designed to rapidly perform moving object detection and classification tasks to assess their viability for recognition of approaching trains.

- These technologies have been successfully demonstrated in today’s passenger and commercial motor vehicle fleet and continue to evolve.

- However, the viability for implementation at grade-crossings is innovative and unexplored at this time.
Integrating CV and AV Technology at Grade-Crossings

- Implementation of CV technology could have prevented 14,800 crashes that occurred at or near a grade-crossing, saving approximately $230 million per year*
- CV technology investment can be protected by ensuring that the government’s R&D efforts are aligned with the development of related AV technology in the automotive industry.
- Without this partnership, the singular efforts of either the government or the automotive industry could result in:
  - CV technology that may never be realized in AVs
  - the development of AV technology that does not incorporate grade-crossing safety technology into ADASs
- Need to bring together stakeholders in both the railroad and automotive industries to lay groundwork for successful adoption of future grade-crossing technologies
- Need mutually agreed upon design requirements for next generation grade-crossing technology in AV and CV applications.

*Hellman and Lopez-Bernal (2015)
THANK YOU!

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