WHITE PAPER

How to Make Railroad Level Crossings Safer and Smarter

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Executive Summary

High-traffic railroad level crossings remain a global safety concern despite the widespread use of active warning systems to clear the tracks for oncoming trains. Although most train-and-car collisions are highly preventable, both real-time and historical data about railway assets, wayside equipment, and warning devices are required to help car drivers and pedestrians, railway operators, and local authorities avoid future accidents and perform root cause analysis in the wake of a crash. Consequently, transportation and safety professionals are increasingly deploying advanced data acquisition and IP video surveillance technologies to provide more complete and accurate information to make existing level crossings smarter and safer.

Overview

Modern **level crossings** (or **railroad crossings** in American terminology) have come a long way from the early days of human railway employees waving red flags and shining lanterns to clear railroad tracks of vehicles and pedestrian traffic for oncoming trains. As is still the case today, nineteenth century railways were deeply concerned with preventing accidents and protecting assets. Responding to these concerns, railroads began to implement manual, and eventually electrical, boom gates (crossing barriers) to block road traffic from the rail tracks. Although clear, simple signage may be sufficient for level crossings in sparsely inhabited regions, high traffic intersections today often feature **active warning systems**, which include electrical boom gates, flashing lights, and warning bells that are triggered when an approaching train trips a nearby track circuit.

However, despite these modern safeguards, railroad crossings continue to pose a serious safety issue around the world. In fact, level crossing accidents claim the lives of roughly 300 Americans[1] and 400 Europeans[2] every year. Besides the tragic loss of human life, railroad crossing accidents cause expensive asset damage (e.g., train cars, rail tracks, level crossing equipment, etc.), time-consuming traffic jams, and inconvenient service suspensions. More so than other railway failures, such as those related to turnouts[3] (railroad switches), railroad crossing accidents **tend to be attributed to human error and violations of traffic regulations**.[4] For example, 98% of collisions between a train and a vehicle or pedestrian at level crossings in France can be attributed to carelessness.[5] Although human error may seem like an ineliminable obstacle, it is one cause of accidents that can be reduced by equipping people with the right information at the right time.

At first, removing level crossings through grade separation may appear to be an obvious and

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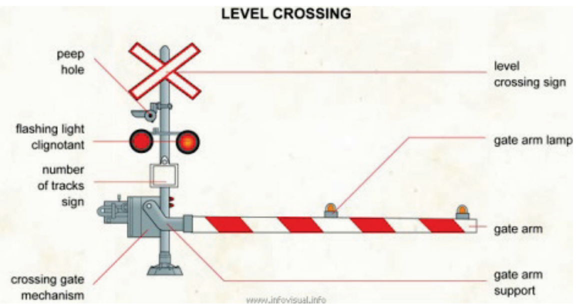
simple solution to this international safety concern, especially since transportation and safety professionals generally agree that grade separation would lead to freer flowing traffic and fewer accidents. However, grade-separated junctions—comprised of bridges or tunnels at different elevations—are not only space-intensive projects requiring significant engineering effort, but also very expensive and time-consuming to construct. If a particular level crossing is shown to be exceptionally dangerous, then a major infrastructure overhaul would, of course, be warranted. On the other hand, the economic and social costs of acquiring adjacent land, displacing local residents and businesses, and disrupting existing road and rail traffic of **removing a normally safe level crossing may actually outweigh the benefits.** As a result, many countries have been investigating "smarter" ways to improve existing railroad crossing warning systems by implementing advanced communication and control technologies to prevent accidents.

How to Build a Smarter Level Crossing

Similar to how physicians rely on medical histories and test results to diagnose a patient's ailments and prescribe treatment, transportation safety professionals need to have both historical and real-time information about the equipment and environmental conditions at a particular level crossing in order to determine the cause of past accidents and prevent future accidents from happening. In this light, removing a railroad crossing would be analogous to performing invasive surgery or amputation, risky procedures that should only be undertaken following a careful cost-benefit analysis. Likewise, transportation professionals need to have all relevant data to conduct thorough risk evaluations before proceeding with expensive and space-intensive grade separation projects. More specifically, an effective "smart" level crossing will need to be designed to provide **data accuracy for accident prevention** as well as **data completeness for accident analysis** in the event of a collision.

Typical Level Crossing Warning System

Active warning systems for level crossings generally include barrier gates, flashing lights, and warning bells.



Source: Wikimedia Commons

Smart Level Crossing

This smart level crossing in the United Kingdom features pole-mounted CCTV cameras.

Source: Wikimedia Commons

Data Accuracy for Accident Prevention

Active warning systems for level crossings have traditionally been train-oriented and geared more towards protecting railway assets than helping vehicles and pedestrians make better split-second decisions. Although protecting and monitoring the condition of railway assets remain crucial objectives in ensuring journey reliability and preventing derailments, smart level crossings go even further by providing more accurate, real-time information to pedestrians, vehicles, train drivers, and even a faraway OCC (operation control center). The following improvements are three important ways improved data accuracy can make level crossings smarter and prevent accidents.

Advanced Obstacle Detection

Exposed to the elements, the clearance zone of a level crossing is shared by trains, vehicles, pedestrians, and even wildlife and wind-blown debris. Although we always want to avoid collisions between a train and a stranded vehicle or pedestrian, it may not be necessary to stop a speeding locomotive each time an agile deer leaps across the tracks. As a result, smart level crossing systems are now adopting the latest in CCTV surveillance and image processing technology to visually inspect boom gate conditions, identify trapped objects, and monitor the movements of the object in real time. In particular, **industrial-grade network video recorders**—installed inside a wayside cabinet to process high quality images streamed from **rugged IP video cameras**—are used to help railway operators determine if a real obstacle exists by checking the detected object’s entry and dwell time in the clearance zone.

Real-Time Equipment Status

Smart railroad crossings also need to keep track of vital parameters and constantly changing conditions for many different kinds of assets. Increasingly sophisticated data acquisition systems—comprised of the latest **RTU (remote terminal unit) controllers**—are now used to provide around-the-clock monitoring for wayside equipment, operating statistics, and environmental conditions. Tucked inside a space-saving wayside cabinet, compact RTU controllers can connect all the myriad I/O, Ethernet, and serial interface sensors at a level crossing to an integrated wayside monitoring system. More specifically, by sending error messages about potentially malfunctioning barriers, motors, lights, and alarms from a far-flung railroad crossing to the OCC, advanced RTU controllers enable railway operators to instruct a speeding train to slow down or stop well before it reaches an intersection.

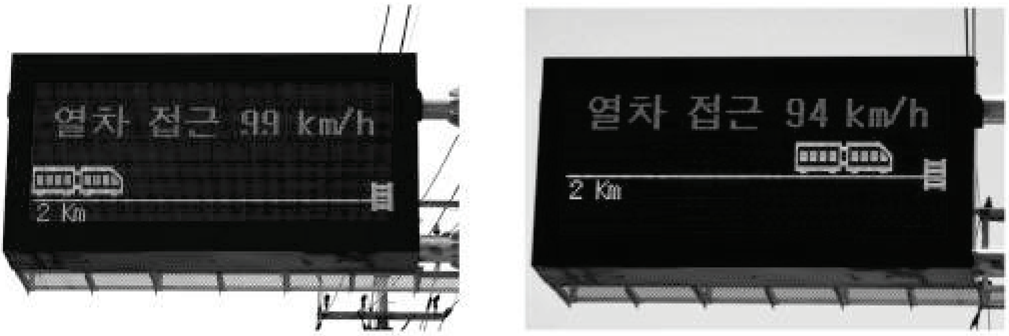
Variable Message Warning Signs

Besides providing real-time data to warn railway operators and train drivers about potential obstacles on the tracks and malfunctioning equipment, smart level crossings are also deploying LED variable message signs to display important information about approaching trains so vehicle drivers and pedestrians can make better decisions on the spot. For example, if an impatient driver knows that a speeding train will arrive at the intersection in less than 3 seconds, he or she may think twice before trying to “run” the crossing. As a result, “smart” warning signs should also provide real-time status updates about an approaching train to help drivers and pedestrians answer the following questions:

- How much time before the train reaches the level crossing?
- Which direction is the train coming from?
- What is the speed of the train?
- How far away is the train?

"Smart" Signs

LED variable message signs at a smart level crossing in South Korea provide real-time speed and distance information of approaching trains.



Source: B.K. Cho & J.I. Jung[4]

Data Completeness for Accident Analysis

In the unfortunate event of an accident, smart level crossings should also provide more **historical information** to railway operators, law enforcement agencies, and regional transportation authorities for accident analysis and future prevention. This means that vital data about the condition and operation of all the data acquisition and monitoring subsystems comprising the level crossing need to be **recorded and logged even before an accident takes place** so that investigators can go back and examine all the factors contributing to the crash.

Around-the-Clock Asset Monitoring

In order to determine whether an accident was caused by mechanical failure, smart level crossings deploy advanced data acquisition systems to continuously monitor the condition of vital assets and warning system components. In particular, investigators will need this information to answer the following questions and determine the cause of the accident.

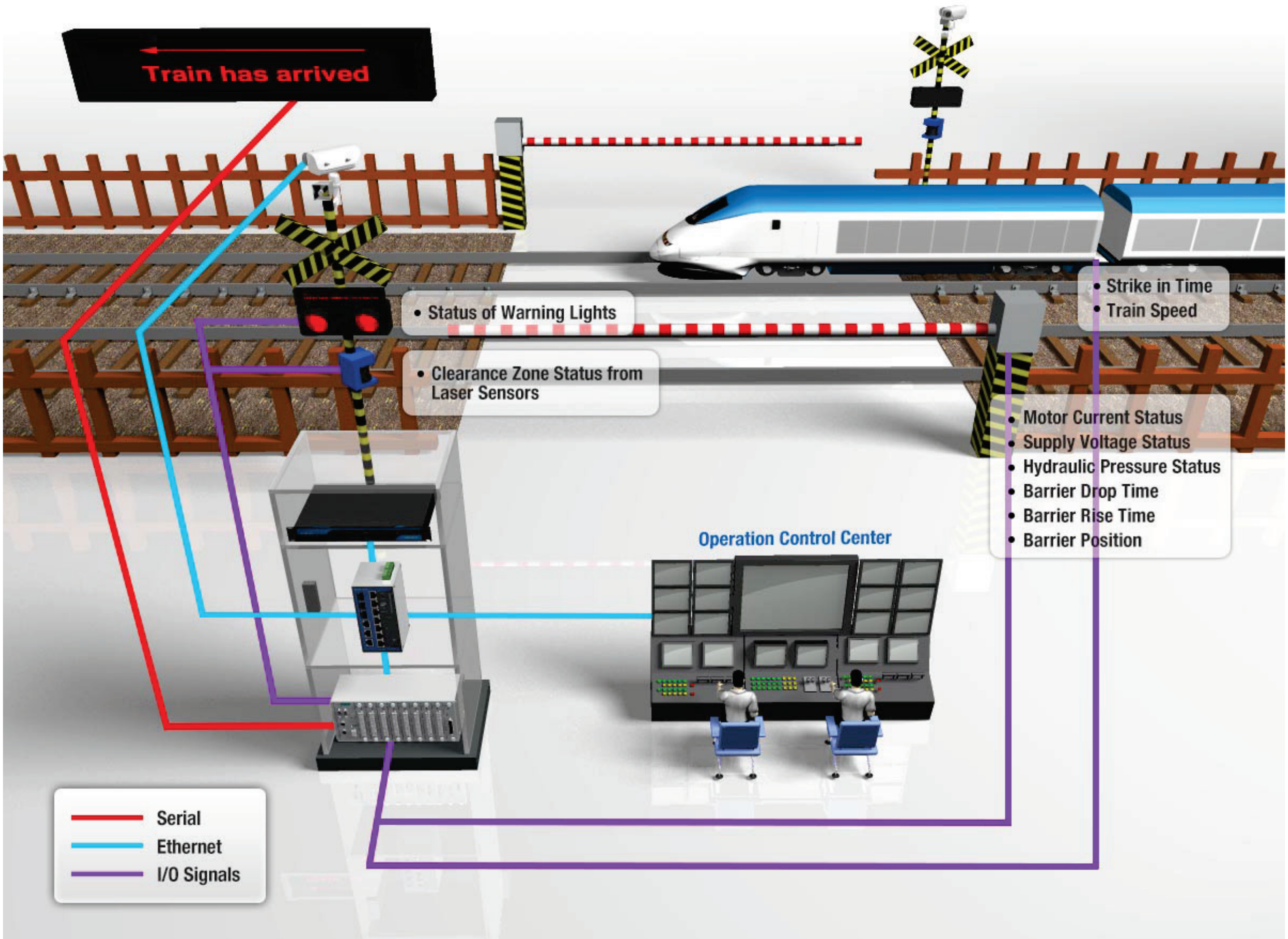
- How long did it take for the boom gate to drop after the strike-in time?
- Were the warning lights and alarms working properly?
- How fast was the train going?
- Did environmental conditions (e.g., operating temperature, wind speed, wind direction) play a role in the accident?

Non-Stop Network Video Recording

Besides high quality image processing for obstacle detection, advanced CCTV cameras designed for harsh, outdoor environments are used in smart level crossings to provide 24/7 video surveillance for the clearance zone. In addition, high quality state-of-the-art network video recorders are also installed in the wayside cabinet to store video streamed from the cameras so that accident investigators can replay the events leading up to a collision and identify its cause.

Anatomy of a Smart Level Crossing

Although many high traffic railroad crossings in developed countries are already equipped with active warning systems (such as electrical boom gates, flashing lights, and warning bells), smart level crossings bring together the latest communication and surveillance technologies for data acquisition and image processing to make these intersections even safer. This section will discuss specific ways remote terminal units, rugged IP video cameras, and industrial network video recorders can be used create a smarter and safer level crossing that provides both real-time and historical data for accident prevention and root cause analysis.



Smarter Data Acquisition

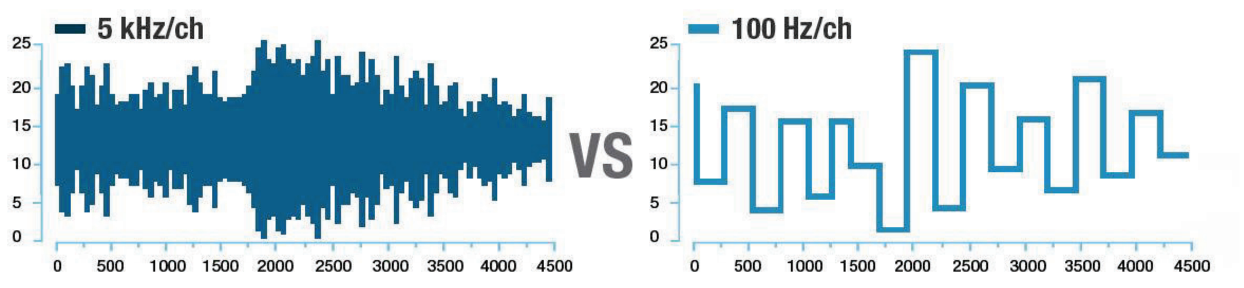
In the smart level crossing system above, Moxa's ioPAC 8500 modular RTU controller is used to monitor the status of all the active warning devices, including the warning lights and bells, electrical boom gates, laser sensors, and nearby track circuits. Besides its compact size (which is ideal for wayside cabinets with limited space), the ioPAC 8500 RTU controller's modular design supports a versatile collection of I/O modules—including digital inputs, digital outputs, analog inputs, resistance temperature detectors, thermocouples, HSPA, and serial modules—to connect all the different interface precision instruments and sensors used to monitor the active warning system. Tailor-made for railway applications, the following features illustrate some of the unique benefits the ioPAC 8500 RTU controller offers level crossings.

Millisecond-Level Timestamps for More Accurate Data Analysis

First, an approaching train usually trips the track circuit about 30 seconds before it reaches the level crossing. This initial I/O event, known as the **strike-in time**, immediately triggers the warning lights and bells at the crossing to start flashing and ringing. In addition, motion sensors may also be deployed at the track circuit to detect the speed of the moving train. Approximately 5–10 seconds following these initial I/O events, the boom gates come down to bar vehicles and pedestrians from the tracks. Since the ioPAC 8500 adds a millisecond-level timestamp to each I/O event that is triggered, you will still be able to clearly identify the sequence in which the events occurred, even if 10 separate I/O events are triggered and recorded by different interface modules within a 10-millisecond time interval.

kHz-Level Analog Input Sampling Rate for Precise Data Acquisition

Second, the ioPAC 8500 RTU uses an ARM9 dual CPU architecture that supports a high frequency sampling rate of 5 kHz per analog input channel, giving railway operators the precision they need to accurately monitor the status of various active warning devices. For instance, transmitting analog input from the crossing barrier's motor current and voltage supply at a much higher frequency provides more accurate and real-time information about the barrier's condition and operation.



Prerecording Analog Input Prevents Missing Data

Finally, the ioPAC 8500 RTU's prerecording function allows the RTU controller to continuously record analog input data before an event trigger point. For level crossings, waiting until after the track circuit has been triggered to begin motor current logging for the boom gate may lead to the loss of critical data due to the latency between the strike-in time and when the data logging actually begins.

Smarter Surveillance

Besides taking advantage of RTU controllers tailor-made for wayside applications, the smart level crossing above also uses Moxa's VPort 36-1MP rugged IP cameras to capture and encode real-time video of the clearance zone, which is then streamed to an MxNVR-IA8 industrial network video recorder inside the wayside cabinet. Although the principal image processing technology that makes the above solution so "smart" is Moxa's IVA software application, the CCTV cameras and network video recorders deployed also need to be ruggedly designed with industry certified reliability.

Rugged Design

Since the CCTV cameras and network video recorders are mounted outside, they must be tough enough to withstand extreme environments and harsh weather conditions. Both the VPort 36-1MP and MxNVR-IA8 have a wide operating temperature range of -40 to 75°C, without the need for a heater or a cooling fan. In addition, the VPort 36-1MP is also IP66-rated and possesses Level 3 high EMI/EMC protection for consistent performance in rainy, dusty, or high EMI environments.

Industry Certified Reliability

The VPort 36-1MP cameras also comply with the EN 50121, EN 55022, UL/cUL Class 1 Division 2, ATEX Zone 2, and NEMA TS2 certifications for electrical equipment used in railway applications, which ensure reliable performance when exposed to extreme shock/vibration, high levels of surge/EMI, and explosive environments.

Intelligent Video Analysis

Last but not least, the key feature of Moxa's CCTV surveillance solution is **IVA (intelligent video analysis)**, an emerging application trend of IP video systems, which can increase the efficiency and protection coverage of a surveillance system by using triggered alarms, such as the following:

- **Camera Tamper:** Triggered when the camera lens is blocked, redirected, defocused, or painted.
- **Virtual Fence:** A virtual "tripwire" in the camera frame will trigger an alarm whenever motion across the line is detected.
- **Alert Zone:** Any motion detected inside the detection zone will trigger an alarm.
- **Removed Object:** The camera detects whenever an object is removed from the frame, and will trigger an alarm after a certain user-defined time threshold.
- **Unattended Objects:** Tracks moving objects in the camera frame and detects abnormal loitering.

Although the following IVA screenshots are taken from a railway station monitoring application, the same triggers can also be used to automatically detect the following level crossing scenarios:

- People entering the level crossing at any time
- Any moving object other than trains identified on the track
- Objects abandoned at trackside
- Large metallic or organic objects on the tracks, such as logs, shopping carts, or a motorcycle
- People crossing the railroad tracks

Alert zone

Virtual fence

Unattended object.

Missing object

Indeed, the Moxa ioPAC 8500 RTU controller, VPort 36-1MP IP camera, and MxNVR-IA8 network video recorder are not the only solutions that can be used to make a traditional level crossing smarter and safer. In fact, there are even more robust technologies and applications that can be implemented at level crossings. For instance, adding a VPort 56-2MP IP camera would provide railway operators with the additional capability of zooming into an area on the screen for more detailed visual inspection. Moreover, both the VPort 36-1MP and the VPort 56-2MP can be transformed into an IP positioning system with PT (point-tilt) capability by adding the optional VP-PT1201 PT scanner accessory. Regardless of the specific solution deployed, the goal is still to make level crossing smarter and safer by deploying advanced data acquisition systems and new CCTV surveillance technologies.

Modular RTU Controller
ioPAC 8500 series

HD box type IP cameras
VPort 36-1MP Series

Full HD Zoom IP Camera
VPort 56-2MP Series

Conclusion

Although active warning systems featuring barrier gates, flashing lights, and warning bells are a fairly common site at high traffic level crossings around the world, these at-grade intersections continue to present real dangers to both rail and road traffic. At the same time, it may not always be practical or necessary to remove a railroad crossing through costly grade separation in order to improve safety for rail and road travelers. As illustrated in the smart level crossing example discussed above, the latest advancements in data acquisition and IP video surveillance can equip active warning systems with both real-time and historical information to make level crossings smarter and safer.

In other words, smarter data acquisition and IP video surveillance technologies are keys to building an effective intelligent level crossing. More specifically, advanced remote terminal units, such as the ioPAC 8500, can provide millisecond-level time stamps, kHz-level analog input sampling rates, and analog input prerecording to improve data accuracy and completeness, in addition to connecting all the active warning devices to an integrated wayside monitoring system. Furthermore, industrial-grade IP video cameras and network video recorders, such as the VPort 36-1MP and MxNVR-IA8, offer rugged design, industry certified reliability, and intelligent video analysis capabilities for smarter surveillance. By providing railway operators, automobile drivers, and pedestrians with the right information at the right time, needless train-and-car collisions can be avoided. Consequently, global efforts to reduce highly preventable accidents at railroad crossings are moving towards developing “smart” level crossings that provide both real-time and historical data about railway assets and wayside equipment for accident prevention and root cause analysis.

For more information about RTU controllers, visit:
http://www.moxa.com/Event/DAC/2013/Railway_Preventive_Maintenance_Solutions/index.htm.

For more information about rugged IP video surveillance solutions, visit:
http://www.moxa.com/Event/Net/2012/IP_camera/index.htm

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Credits/Sources

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