begirale
CONTROLLING RISK
a Dominion company

Comparative study of technologies for the detection of obstacles in level crossings

Introduction

This document contains the main conclusions of a study of two of the main technologies used to detect obstacles in level crossings. One of them is the most widespread technology at the international level and is being used for decades while the other is a very recent alternative based on state-of-the-art digital technologies.

Background

A level crossing is a crossing or intersection at the same level between a railway track and a road. In them trains always have priority because they have a lot of inertia and need a long time to stop. Level crossings are usually properly signaled and they can use mechanisms such as barriers or traffic lights to warn those who intend to cross them of the arrival of a train.

These are points that present a certain danger, which is usually measured according to the number of trains that circulate through them and the number of vehicles and pedestrians that cross them. Another factor that affects the intrinsic danger of level crossings is the visibility, both of the users of the road and of the trains.

Safety in level crossings

From the point of view of safety, level crossings can be basically divided into two types:

Protected: Those that have barriers, semi-barriers, light and acoustic signaling, manual or automatic action, which cut the way to the road vehicles when approaching a train. Within this group, several types could be distinguished:

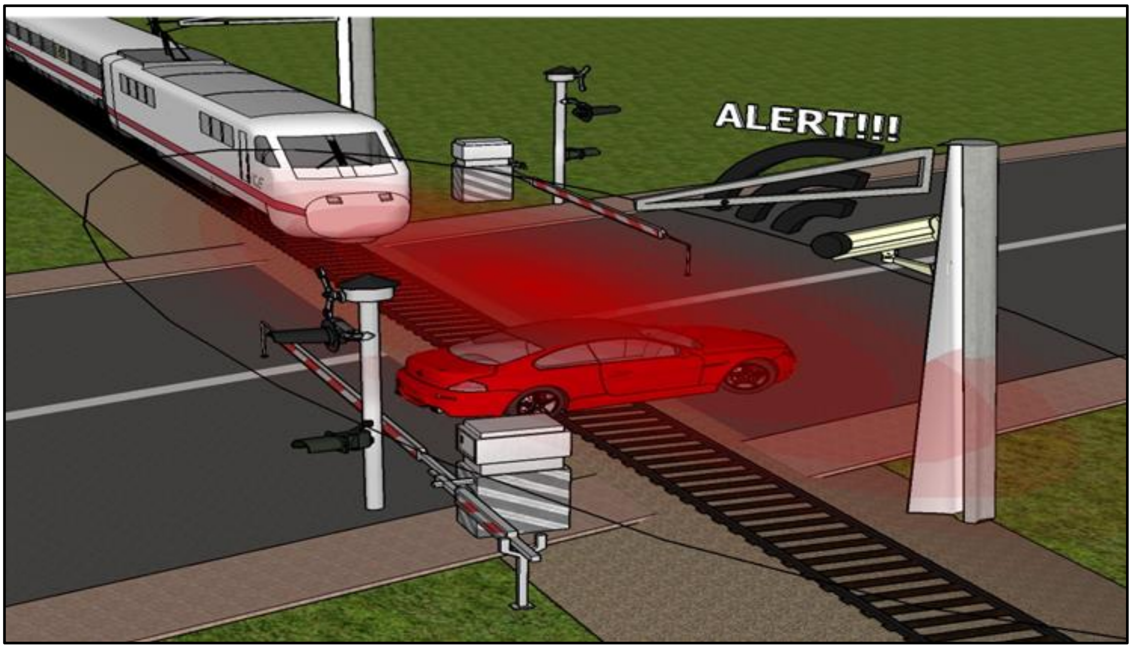
> Manual protected: The one that has a presence of personnel in charge of the activation of the protection systems.
> Semi-barrier Automatic: The one that has barriers or semi-barriers and light and acoustic signals that are automatically activated when a train approaches.
> Luminous and Acoustic Signaling: With no barriers but has light and acoustic signaling that are automatically activated when a train approaches.
> Semi-Barrier Interlocked: One whose protection (barriers and acoustic and light signals) is interlocked with the signaling of a station.

Without protection: Whose safety depends only on the road user driver. Normally signposted, does not have barriers that block the passage to road vehicles or light and acoustic signals that warn of the proximity of a train.

Obstacle detectors

Normally, level crossings that present a higher risk usually incorporate protection systems. The higher the risk, the greater the number of security elements. However, in spite of the installed protection facilities (fixed signals, light signals, sound warnings and barriers mainly), there are situations that are not covered and that can cause serious incidents.

The main one is when there is an invasion of the railway track in the level crossing derived from a problem with a vehicle that was crossing it and that is immobilized in the "risk zone".



Vehicle stopped at a level crossing

That is why level-crossing protection facilities are often complemented by other control systems that detect and inform of the presence of obstacles (mainly road vehicles) in the risk area of the level crossing; they are the obstacle detectors.

Technologies used for the detection of obstacles

The system that is mostly installed in the world is the so-called induction loop. This is the first technology that allowed in a reasonably reliable and effective way to perform this type of detections and began to be used decades ago.

In recent years, as a result of the strong technological development in the fields of software and hardware, three technological applications have emerged that propose alternative detection models to the induction loops: Radar, Lidar and Computer Vision.

Of these three technologies, BEGIRALE opted for Computer Vision since it is the most likely future alternative: it is the most versatile of the three, the most economically competitive, it provides additional information about the situation of the level crossing that can be interpreted by any person and its potential for evolution is very high. In addition, the incorporation of Artificial Intelligence to these systems allows them to learn from experience what results in a constant improvement in their reliability.

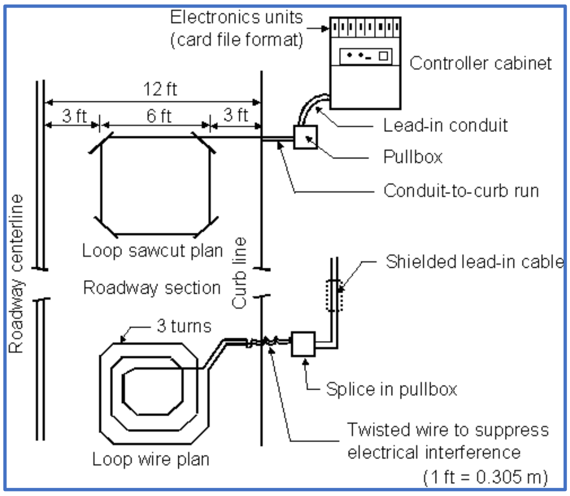
Next, a description is made of the two technologies that were compared in order to carry out the study.

Induction loop

An induction or inductive loop is an electromagnetic communication or detection system which uses a moving magnet or an alternating current to induce an electric current in a nearby wire. Induction loops are used for transmission and reception of communication signals, or for detection of metal objects in metal detectors or vehicle presence indicators.

Vehicle detection loops, called inductive-loop traffic detectors, can detect vehicles passing or arriving at a certain point, for instance approaching a traffic light or a Level Crossing. An insulated, electrically conducting loop is installed in the pavement. The electronics unit applies alternating current electrical energy onto the wire loops. The inductive-loop system behaves as a tuned electrical circuit in which the loop wire and lead-in cable are the inductive elements. When a vehicle passes over the loop or is stopped within the loop, some of the vehicle's ferrous body material increases the loop's inductance, in the same principle as including a metal core within a solenoid coil. However, the peripheral metal of the vehicle has an opposite effect on the inductance due to eddy currents that are produced.

The decrease in inductance from the eddy currents more than offsets the increase from the ferrous mass of the engine, and the net effect is an overall reduction in the inductance of the wire loop. The decrease in inductance tends to decrease the electrical impedance of the wire to alternating current. The decrease in impedance actuates the electronics unit output relay or solid-state optically isolated output, which sends a pulse to the traffic signal controller signifying the passage or presence of a vehicle.



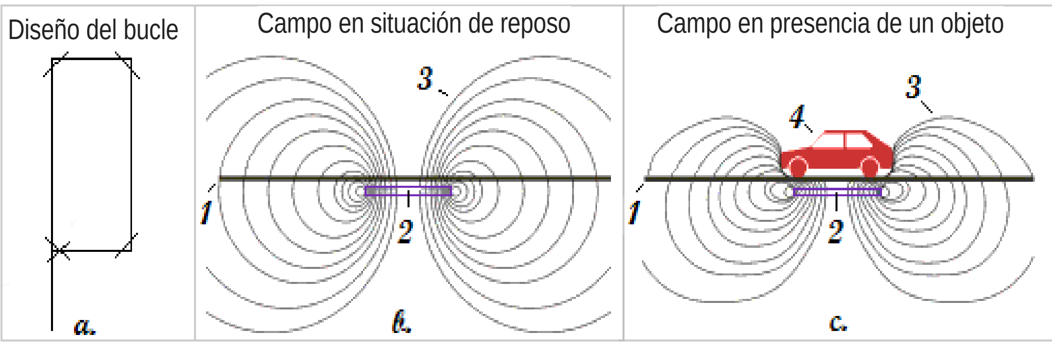
Induction loop Scheme

The relatively crude nature of the loop's structure means that only metal masses above a certain size are capable of triggering the relay. This is good in that the loop does not thus produce very many "false positive" triggers (say, for example, by a pedestrian crossing the loop with a pocket full of loose metal change) but it sometimes also means that bicycles, scooters, and motorcycles stopped at such intersections may never be detected by them (and therefore risk being ignored by the switch/signal).

An Induction Loop Detector is a term used to describe an electromagnetic detection system, from the fact that a moving magnet induces an electric current in a cable near the same, or that a ferromagnetic material alters the magnetic field of a coil when it is near it, and therefore can be detected. Its functionality is to detect the presence of vehicles in the zone of the level crossing and to inform the train of the situation by means of the specific railway signalling.

Depending on the size of the "risk zone" of the level crossing one or more integrated loops are installed in the rolling area and connected to an electronic module that detects the frequency variations.

Its detection is usually limited by the physical characteristics of the elements to be detected: for example, to vehicles of more than 2 wheels with metallic base of more than 2 m2, parallel to the ground plane at a height not exceeding 50 cm.



Induction loop operation

Computer vision obstacle detector

It is a system that uses intelligent video content analysis Technologies (VCA or video content analysis) to facilitate early detection of incidents in level crossings, caused by obstruction of the Risk Zone or because a malfunction of one of the security elements of the level crossing protection system.

The VCA system processes the signal from a camera that is focused on the "risk zone" of the level crossing. The "Risk zone" is defined as the space of the level crossing that should be free of obstacles when the train is going to pass. In case of level crossings with very large areas that cannot be covered by a single camera various detectors can be combined.

The risk zone is configured for each level crossing adjusting the image to the physical characteristics of the area. This is done by means of an application that allows to define graphically the zone to be observed.

Area identified as "risk zone"

This technology allows to discriminate the different elements that can be found in the risk zone, distinguishing between free zone, pedestrians and small objects, vehicles and large objects and trains.

The system is permanently processing the video streaming so it can determine the existence of abnormal or dangerous situations even when the train is not coming.

In addition to its main function (obstacle detection), the system is prepared to detect anomalies in the operation of the level crossing, produced by failures of any of the other protection elements.

If the system is equipped with communications, it can provide real-time viewing of cameras and reception of live alarms in a control center and an easy recovery of recordings for forensic analysis.

Comparative Analysis

To carry out the performance comparison of both technologies, two level crossings were maintained with the two obstacle detection systems running in parallel. The test was carried out at the end of 2018 and lasted for six months.

Two systems begiCROSSING Obstacle Detector (BC-OD) based on Artificial Vision were installed in two level crossings that were equipped with induction loops. One of the level crossings is protected with four automatic semi-barriers (in addition to luminous and acoustic warnings) and the other with two.

Level crossing with 4 automatic semibarriers

During the 6 months that the study lasted, the signals provided by the induction loops and the begiCROSSING Obstacle Detector (BC-OD) systems were captured, recorded and compared.

In addition to analyzing the collected data, the video recordings made by the BC-OD cameras were also used in both level crossings to clarify the possible differences in the behavior of both obstacle detection systems.

From the point of view of rail traffic, both level crossings have a similar railway frequency of about 25 trains per day. However, from the point of view of the vehicles, there are important differences, since one is located in an urban environment, while the other is in a rural environment.

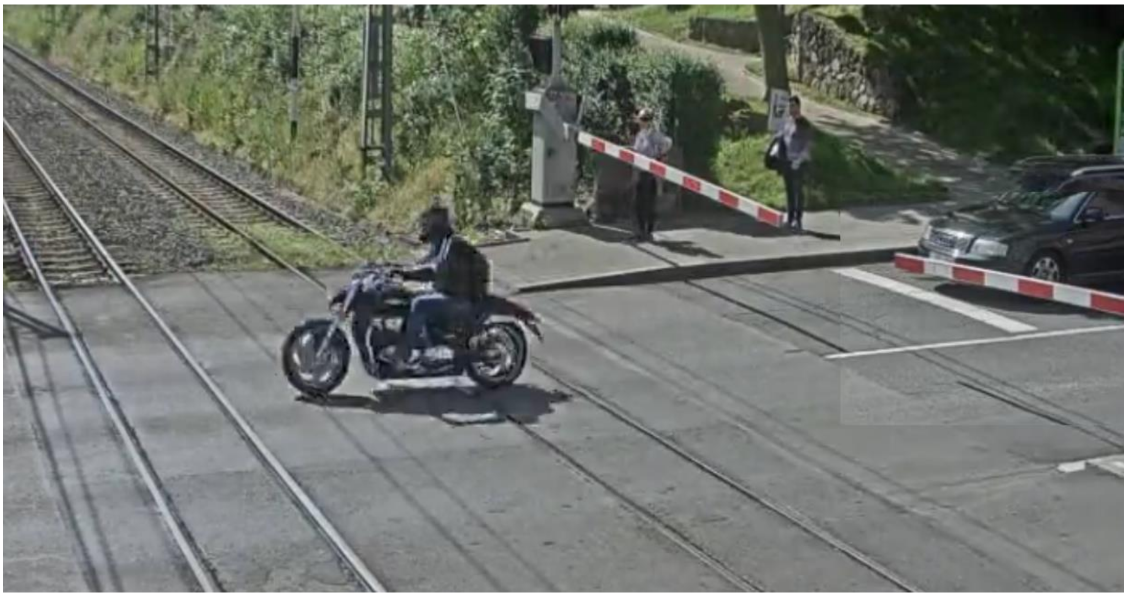
The obstacle detection systems based on induction loops installed in both level crossings had a different configuration. One was always in active mode detecting the passage of all vehicles crossing the intersection zone of the level crossing. The other is activated only at the beginning the procedure of closing the level crossing. As the BC-OD systems were in active mode permanently, in one of the level crossings the comparison between the two obstacle detection systems has been carried out continuously 7x24 during the 6 months. In the other level crossing the comparison was made only when the induction loop system was active.

During the 24 weeks that has lasted the study, has been recorded and analyzed the passage of more than 42,000 vehicles in one of the level crossings, while in the other there have been analyzed about 4,500 vehicles that have circulated by the level crossing after the closing procedure had begun.

In the case of the level crossing located in the rural zone, a total of 3 incidents were detected in which three vehicles were stopped inside the level crossing once the protection semi-barriers were lowered. In these three cases, both obstacle detection systems correctly signaled the presence of the obstruction, giving timely notice to the railway signalling system.

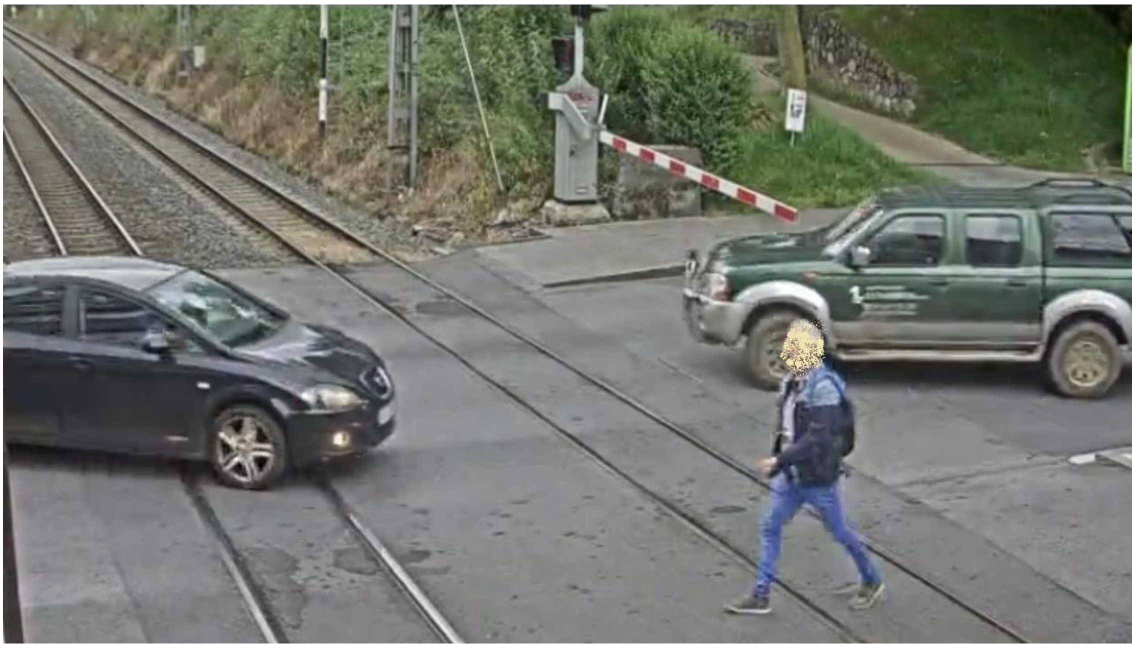
Vehicle "trapped" in a level crossing with 2 semi-barriers

In the case of the level crossing situated in the urban location there were not situations with a vehicle stopped in the risk zone once the semi-barriers were closed, but there were several situations, detected by the BC-OD, in which a motorcycle crossed the level crossing once the semi-barriers were closed.



Motorcycle detected as an obstacle by the BC-OD system

In addition, it was be observed that the induction loop system was disabled after verifying the closing of the “entry” semi-barriers even if the “exit” semi-barriers were still open. This means that there were vehicles in the risk zone during the closure process that were not detected. The BC-OD system was able to detect this type of behavior in several occasions; nevertheless, none of the vehicles involved were locked inside the level crossing once the 4 semi-barriers had been lowered.



Vehicles crossing the level crossing in the middle of the process of closing semi-barriers

Results

The analysis was carried out based on the following indicators: "availability", Number of "No detections" and number of "Overdetections".

"Availability" is the time that systems have been operating during the testing period. It is calculated by dividing the time that the systems have been operative between the total time of the study and expressed in percentage mode.

"No detections" correspond to situations where there is an obstacle in the risk zone that the system has not been able to detect. These are the most dangerous situations as they can result in the collision of the train with the obstacle. It has been measured as a percentage from the division of the wrong cases (undetected obstacles) between the total obstacles detected.

"Overdetections" are situations in which there is no obstacle in the risk zone (not considering obstacles to pedestrians or cyclists) but the obstacle detector indicated that there is an obstacle. These are situations that do not create danger but can affect rail traffic, making trains to stop for no reason. It has been measured as a percentage from the division between the total time in a “false obstacle” situation divided between the total time that the system has been in a correct “free state”.

The results that the study has thrown over the entire period of the test (6 months) are as follows:

	BC-OD	**Induction loops**
Availability	100%	100%
No Detections	0	1.17%
Overdetections*	0.02%	0.06%
	0.01%	0.07%

(*) Two values are presented for Overdetections: The first row corresponds to the complete period of the study and the second to the results excluding the first 4 weeks, in which there were problems that affected the BC-OD system due to lack of night lighting.

The "No Detections" of the induction loop systems were mainly due to two causes: the physical disposition of the induction loops did not cover certain areas by which vehicles could cross the level crossing, and the physical characteristics of certain vehicles (height, size of wheels, materials,...) combined with their speed didn’t generate enough induction to activate the signal of the loops. In most cases were vehicles higher than normal and circulating at reduced speed.

Obstacle not detected by the induction loop system

Some discrepancies were also identified between both systems in the detection of two-wheeled vehicles. The review of recorded videos showed that sometimes the induction loop system did not detect some of the motorcycles that crossed the level crossing, while it did identify as obstacles the passage of some bikes.

Bicycle detected as an obstacle by the induction loop system

Regarding the "overdetections", in the case of the induction loop systems, most of them occurred when bicycles were classified as obstacles, or when the system had a failure when releasing the obstacle signal after the passage of a vehicle.

In the case of the BC-OD system based on VCA, part of the "overdetections" was due to the presence of shadows or reflections on the road that were interpreted by the system as obstacles. A significant number of the "false positives" that occurred during the first few weeks were motivated due to the lack of night lighting.

Level crossing with low night lighting

Level crossing with infrared lighting

This issue was solved by applying infrared lighting. Once the forced night lighting system was installed, the number of "overdetections" that were identified was reduced by 50%, passing from 0.02% to 0.01%.

Conclusions

The main conclusions that can be extracted from the study are the following:

- The two technologies show extremely high levels of availability. Both are designed to operate continuously for long periods of time without problems.
- The Artificial Vision product, BC-OD, has been much more effective than the induction loops systems, in terms of the ability to detect obstacles (it has detected 100% of situations), as well as the level of false alarms produced (with one-sixth of those generated by the induction loop systems).
- Although we could consider that the levels of reliability of both technologies have been quite high, the values of "No detections" obtained with the induction loop technology can be considered too high for a critical use such as the Obstacle Detection in the railway tracks.

In addition to the conclusions of the study, some other facts that position the technology of Artificial Vision, BC-OD, as a better option are the following:

- Intrusiveness: The installation of induction loops requires carrying out works that affect the road that crosses the passage, affecting both the traffic of vehicles and the railway traffic. The artificial vision system is installed on the side of the level crossing, not interfering with the railway route nor with the road.
- Maintenance: Maintenance work is much more complex in the case of the induction loop system. If a loop is damaged its substitution requires almost the same effort as a new installation.
- Flexibility: The configuration of the Artificial vision system, both in terms of the definition of the risk zone and the sensitivity of the system or the type of alarms, is done in a simple way through software. The configuration of the induction loop systems implies a physical design of the installation, and its modification is complex and usually expensive.
- Management information: BC-OD stores the video recording of all the alarms; these videos provide information that can be important to clarify conflict situations. If it's connected to a communications system, BC-OD provides access to the video signal of the camera in real time.
- Continuous improvement: The Artificial Intelligence techniques incorporated in the VCA technology used, provide BC-OD with the ability to learn, and therefore to improve its effectiveness and reliability in a recurrent way.