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# Protection system for level crossings by geospatial analysis in real time

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## Abstract

In this work a system has been developed to improve the safety of level crossings. These facilities are located on railways without supervision, in most cases, and they are a source of accidents and deaths every year. The safety system works in two ways in real time.

On the one hand, the position of a vehicle on the level crossing is identified, taking into account the vehicle location and the level crossing. If a user declares that the vehicle is immobilized, by pressing a button in the app on board, this sends the location and incident event to the central server, and an alert message, through different channels, is sent to the infrastructure manager.

Furthermore, it can alert vehicles approaching a level crossing indicating the distance that is, through text, icons and audio. The vehicle location is computed with a frequency depending on its speed.

The system exploits the Comobity system, developed for the Traffic Department (Dirección General de Tráfico, DGT). It consists of an app for Android and iOS devices, which communicates in real time with the central platform

The result is a system that improves the protection of intercepting vehicles left the road in the level crossing for breakdowns, plus improved information to vehicles approaching such facilities. The system can reduce material costs as much in human lives due to such accidents
*Keywords: railway, GIS, level crossing, algorithm, spatial data infrastructure.*

## 1 Introduction

Level crossings are a point of risk in road safety, and a source of serious accidents involving both vehicles and railway circulations. At present, we can find a lot of

 
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them, many without automatic systems that allow an effective warning to drivers. Depending on the location, they have different protection systems. In Spain they are regulated under Article 8 of the Orden del Ministerio de Fomento 2 August 2001 about suppression and protection of level crossings (Table 1).

Table 1: Types of LC protection.

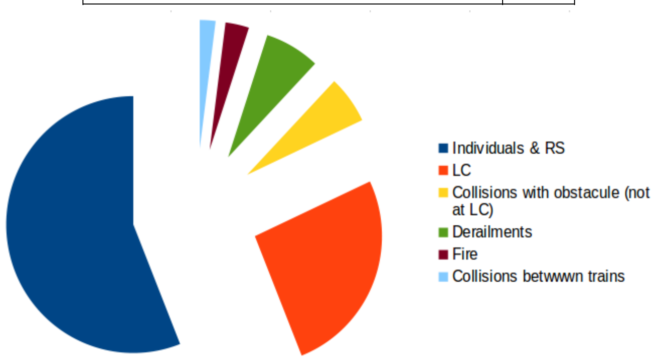
| | |
|---|---|
| CLASS A | Protected level crossings exclusively with fixed signals. |
| CLASS B | Protected level crossings with light and acoustic signals. (S.L.A). |
| CLASS C | Protected level crossings with half-barriers, double half-barriers or barriers, automatic or nailed (S.B.E., S.B.A. or S.B.E./S.B.A.). |
| CLASS D | Protected level crossings in luggage regime (chains or barriers or manual half-barriers). |
| CLASS E | Protected level crossings daycare walk Paso. |
| CLASS F | Step by exclusive level or pedestrian and livestock. |

Although a study conducted by Perlasia Giol [1] shows that the number of LC has been reduced from 10,755 in 1975 to 2779 in 2009, there are still many points of risk that exist along the road network.

In various studies such as those carried out by [2–4], show that 26% of accidents occur in LC, reaching 479 in 2014. A comprehensive study collecting data since 1920 can be checked in the Federal Way High Administration, 2007. In these works, the main cause of this kind of accidents are caused by invasion of the way, with 25% responsibility of pedestrians, and 75% of vehicles (see Table 2).

Table 2: Distribution of the number of accidents UIC Safety Report 2014.

| | |
|---|---|
| Pedestrians and RS | 56 |
| LC | 26 |
| Collisions with obstacles (not at LC) | 6 |
| Derailments | 7 |
| Fire | 3 |



The main consequence of these accidents is not only the extensive material damage that occurs in railway facilities, but also the destruction of vehicles. So that, the worst consequence is the death of people. Heavy vehicles and light are responsible for these statistics (see Table 3).

Table 3: Distribution of accidents in LC by years.

| | Accidents at LC | Number of fatalities | | | % of all accidents | % of all fatalities | LC accidents per million train-km | LC fatalities per million train-km |
|---|---|---|---|---|---|---|---|---|
| | | Passengers | Staff | Third parties | | | | |
| 2013 | 479 | | 1 | 280 | 26 | 26 | 0.12 | 0.07 |
| 2012 | 510 | | 1 | 325 | 26 | 32 | 0.12 | 0.08 |
| 2011 | 447 | 6 | 1 | 277 | 22 | 26 | 0.11 | 0.07 |
| 2010 | 495 | 1 | 3 | 315 | 23 | 28 | 0.12 | 0.08 |
| 2009 | 493 | 2 | 1 | 374 | 22 | 28 | 0.12 | 0.09 |
| 2008 | 539 | | 3 | 325 | 25 | 27 | 0.13 | 0.08 |

The most effective way to avoid this risk is to replace it by overpass, but it is not possible to carry out these infrastructures in all cases. Many of the LC are in roads with low vehicle traffic, so the replacement is very expensive [5]. Therefore, it is necessary to implement a new protection system.

Up to now, the protection of facilities of a level crossing installation has focused on the warning to drivers primarily:

- Signaling its location on the road by traffic signals in a passive way.
- closing by detecting the proximity of a train by an active way.

This signaling is performed by visual, light and sound systems. Depending on the country, as well as traffic signals, are provided chains, barriers or half-barriers that are closed when a train is detected. They prevent access to the road of vehicles, but they can create dangerous situations when vehicles stay within the safety zone of the crossing. In LC with chains exists also a danger resulting from not having warnings when the train is approaching.

In cases where there is no physical impediment to access the railway, the security resides only on driver's care. In the work carried out by Salmon *et al.* [6], this aspect is shown in detail. It concludes that hard work is needed in order to improve road safety education. In addition, it is necessary a better accurate and specific warning to the drivers, to improve the safety of these facilities.

In this work it has been designed and implemented a protection system in order to alert drivers, railway operators and infrastructure managers.

## 2 Problem definition and objectives

The goal is to solve the problem of warning to drivers in advance to take precautions when they are approaching a level crossing. This notice cannot be sent too close or too far from the facility. On the other hand, other aim is also to avoid accidents due to the occupancy level crossing for vehicles that have been stopped on the railroad. To achieve this, an alert is sent to the infrastructure managers.

Furthermore, it is known that drivers can cross the railroad at any point, and interceptions occur at places that are not authorized to do it, in full route, what is an added risk. A methodology to detect stopped vehicles at any location, that are not included as level crossing, is also proposed.

Therefore, objectives are:

a) Notify drivers of a nearby level crossing.
b) Notify to infrastructure managers about the interception of a level crossing by a vehicle when the driver indicates incidents.
c) Notify to infrastructure managers about the interception of the track, at any point, by a vehicle when the driver indicates incidents.

## 3 System design

This paper describes a system for all level crossings, regardless of type, to improve the safety of these facilities. The system is not intended to replace existing systems, but it can be a complement. It is based on geolocation in real time of all parts of the system, and notifications to drivers and infrastructure managers. As parts of the level crossing facility are identified as follows:

- Level crossing facilities.
- Vehicles.
- Trains.
- Infrastructure managers.

It is a distributed system, part of it is located in the car, and the logic that involves spatial analysis resides in a centralized server cloud. The system identifies the vehicle by using an embedded application. This is an app developed for Android and iOS, in a first phase, although the last goal is to embed it within those already installed in the cars.

### 3.1 Initial system

Connected car concept begins to take shape in all countries. It collects real-time information from different variables related to vehicles, sends them to central systems, and returns information to these vehicles with different events.

Spain has launched DGT 3.0. An initiative in which the "Dirección General de Tráfico" has as an aim to reduce accidents and fatalities to zero. Within this, the connected car it is included as a fundamental tool. The first application created to do this is COMOBITY [7].

The application sends to the central system (Singularity) vehicle locations as well as alphanumeric attributes. This information includes the type of vehicle and its status, not only if it is in motion (speed), but also (and more important) if the vehicle has any problem and it is stopped. A detailed description of these attributes is shown in the API Road Safety [8]. At present, the application works on any Android and iOS devices [9].

The information is sent to the central system and, depending on its contents, the risk level of the vehicle is determined. In addition, to do this, we take into account the position of other vehicles and their types, weather conditions, road conditions, relevant information provided by the Dirección General de Tráfico, geographical area and season. Having evaluated the proximity of a specifically calculated risk, an individualized notification is returned to the vehicle in a synchronous way.

These notifications are displayed to the user with text and audio messages (Fig. 1). This ensures that the user does not touch the mobile device and he receives notifications automatically and unattended. An example of notification is shown in the figure in which the system detects the proximity of a group of cyclists or a stopped vehicle.


Figure 1: Notification of group of cyclists and incidents (original view). Left, “You are near a cyclist. Keep a distance of 1.5 m from them”. Right “Stopped vehicle at KP 432 of road N-332”.

### 3.2 Application to level crossings

Within this scheme it has been implemented a system that has localized LC with an accuracy of 5 meters, so now it is possible to alert a driver with enough time.

To solve the problem a) described in the previous section, notifications are sent based on the vehicle speed, specifying the name of the road and where KP is located. These notifications are sent when it is detected that the LC is less than 1000 meters from the vehicle. The position of the vehicle is checked at least every 5 seconds.

To achieve this objective, we have been implemented an algorithm that calculates the Manhattan distance between objects, and evaluates the degree of risk between them. The alerts are displayed by graphical and audio messages.

On the other hand, to solve the problem b) the position of vehicles is computed in real time, and if its driver declares an incident, the system is able to identify if he is located within the Level Crossing facilities. In this case, an alert is sent to the Infrastructure Manager Incident Center.


Figure 2: Detection and notification areas.

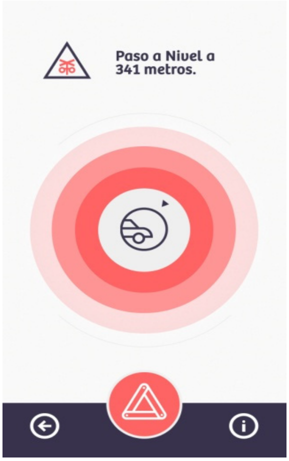



Figure 3: Notification sent to vehicle when a level crossing is detected (original view). "Level crossing at 341 meters".

According to Article 7 paragraph 5 of O.M. Of 08.02.2001, mandatory stop point on highway or a road is defined up to 5 meters before the nearest rail of the track. In other countries this distance is extended to 9 meters [10]. To determine if a vehicle is within the LC, the centroid is taken from its geometry, in the center of the track, if only route, and between the two tracks in case of double track. From this point it has been considered a radius of 20 meters to delimit a security area. It has taken into account the value of the distance to the mandatory stop point and the measurement error in the GPS.

Therefore, a risk situation is determined when the driver declares an incident within 20 meters away from the centroid of the LC by his application. This distance is calculated in a straight line from the vehicle position to the centroid.

In the case of a vehicle stopped in the middle of the railway, problem c), the distance is calculated from its location at the center of the track. It is a risk when the distance is less than 20 meters.

Due to the inaccuracy resulting from errors in the GPS reception and LC location, notifications to the Infrastructure Manager have an informative and preventive sense. So the Administrator can take steps to inform the trains arriving to that location and take prevent measures.

At the moment, the system is in production for the three reported cases a), b) and c), and sends notifications to drivers within the Comobity application context. The detection of incidents within the LC needs an interface with the Infrastructure Manager, but the detection is already operational. We are trying to carry out a pilot project for implementation.

As a final result, the LC and vehicles become a virtual beacon within the system that allows them to be visible to other parties.

## 4 Data used

For this work we have been using open data sources in all cases. In addition to the positions sent from each device it has been used mapping provided by the Instituto Geográfico Nacional through download services from Centro Nacional de Información Geográfica.

INSPIRE European Directive [11], and especially in Annex I, the Technical Guideline 3.2 corresponding to Transport Networks, have been used to define data models and services available to access these data.

We used the following products:

- BTN100 and BTN25.
- Orthophotos PNOA.
- Cartociudad.

911 level crossings in BTN100 have been identified, within the BTN100_0617P_PASO_NIVEL layer, distributed by all railway lines. In Figure 4 a distribution of level crossing (red points) is shown over the Spatial Data Infrastructure of Spain Transport Network layer.

We performed a study about the accuracy of the locations of the LC collected in BTN100 and we corrected their positions using the methodology described in [9]. This is necessary in order to have the location of the LC with accuracy less than 5 meters. We proceeded to download tiles 1000 m x 1000 m, centered on the position marked for each LC, using a program developed ad-hoc. Orthophotos come from the layer “Plan Nacional de Ortofotografía Aérea”. Subsequently, we obtained the real position of each LC.

After correcting positions, this database has been used as a reference for the positions for the centroids of LC. In other countries the information about Level Crossing is published with open data licensees, but not in Spain, which allow a better understanding of these facilities. For example, in Australia [12] Britain [13] and France [14].

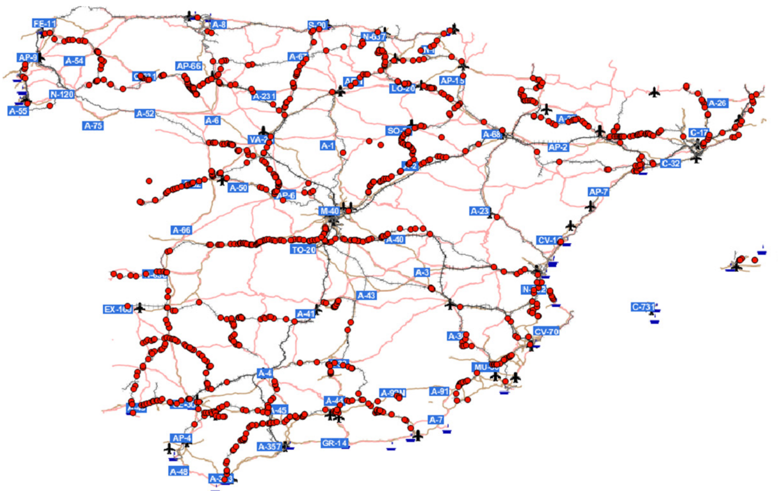



Figure 4: Level crossings (red dots) over roads (blue labels) distribution graph.


Figure 5: Correcting the position of a level crossing.

## 5 Tools used

In system development tools open licenses have been used:

- Linux operating system installed over the Amazon AWS cloud.
- PostGIS database.
- Python and Java.
- Desktop tools QGIS [15] and gvSIG [16].

## 6 Accuracy of GPS positions

The position of the vehicle is obtained directly from the onboard device. This Comobity version is developed for Android and iOS platforms. There are plenty of works that have been addressed to study the accuracy provided by the various types of GPS receivers [17–19].

These studies show that the accuracy depends on vehicle speed, urban or suburban environment, forest, etc. The details vary from tens of meters to less than 1 meter. When speed is 0, as is needed to detect incidents on LC, the accuracy is within 2 meters.

Figure 6: Position accuracy.

In Fig. 6, vehicle positions are shown in red when they drive on a highway with different speeds. In the service road (top), accumulation of measures can be detected and improved accuracy is observed due to the slower speed.

When we compare the positions sent from devices with the axis of the road geometry, errors are less than 10 meters when they are in motion. In our case, we are interested in the position when they are in detention; in this case the accuracy is better than 2 meters. Actually, level crossings only appear as points of interest (POI)

# 7 Future situation

Looking ahead to the near future, we consider a complete integration with information systems belong to the Infrastructure Administrators to send real time warning notifications about vehicle incidents on LC.

Furthermore, the possibility that the system receives location information of the trains and the possible proximity to notify drivers. This is an additional and special interest to LC without barriers or any other saving measure.

There is no open data information about the location of trains by Infrastructure Managers or railway undertakings in Spain, but in other countries such as France [17], Great Britain [18] and recently Germany [19] there are different initiatives. Therefore, it has devised a solution that gets this location provided directly by rail users. Traveler trains activate their transport travel mode, and the system determines which trains are in the vicinity of a vehicle approaching a LC. So far, it is only possible to receive information from passenger trains, but the possibility to receive it from the railway undertakes or Infrastructure Managers directly are open.

Last but not least, it is very important that Infrastructure Managers provide more accurately locations of LC to those organizations responsible for the publication of national cartography.

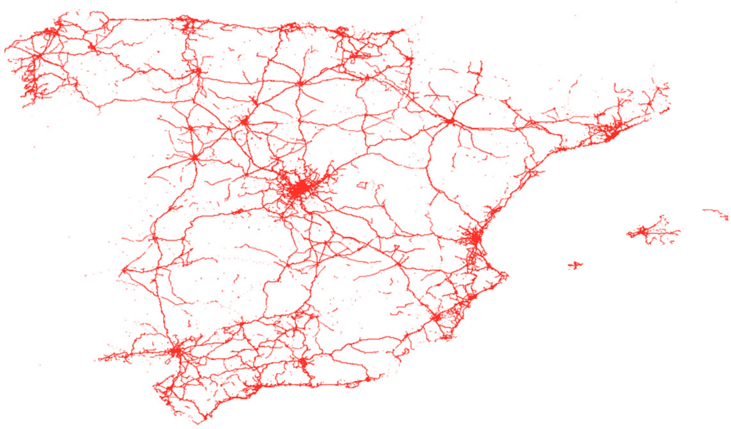


Figure 7: User distribution of Comobity and Singularity system.

## 8 Conclusion

It has been shown that level crossing railway facilities are a high risk for trains and vehicles, and the need to protect them until the moment they can be replaced.

There are different technologies for the protection of these facilities based on roadside signage, barriers, half-barriers and alerts when trains nearby to LC are detected.

This paper has implemented a protection system that integrates connected car technology and geolocation of vehicles and trains to alert all stakeholders. As a final result, the LC and vehicles become a virtual beacon within the system that allows them to be visible to other parties.

Drivers of heavy vehicles and agricultural ones especially are benefiting from this technology that allows them to be integrated into a system of global road safety. This kind of technology is also beneficial in those countries with large amount of LC.

Currently, INSPIDE and the Dirección General de Tráfico implement the system in the Comobity software. There are over 16,000 devices and 20.000 users using the API of Singularity platform, which is opened to any connected car device.

Being a system based on an INSPIRE directive, it can be applied to any part of the European Union and also it is totally exportable to any other railway infrastructure.

## Acknowledgements

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