Journal of Engineering and Applied Sciences 13 (20): 8584-8590, 2018
ISSN: 1816-949X

Security System at Level-Crossing Using the Principles of Internet of Things

Ashish Kumar Aman and Amit Kumar
Department of Mechanical Engineering, National Institute of Technology Patna, Patna, India

Abstract: The railways being the lifeline of transportation and the most preferential mode of transportation, tends to move through the thickly inhabited areas more often than not. This, however, leads to a situation where railway tracks traverse the roadways which is yet, another important genre of transportation. The point of juncture of railway-track and the roadway is acknowledged as level-crossing. One important concern of transportation experts is to exercise robust safety at the level crossings. The researchers intend to make use of the developments in the communication system and the internet of things to devise an early warning system for unmanned crossings. Objective of current work is to deliver an audio-visual caution to commuters about an upcoming vehicle (train). The need for such systems and its design implementation along with feasibility is discussed herein.

Key words: Arduino IDE, automation control of vehicle, auto-transmission, HC-SR04, internet of things, NodeMCU

INTRODUCTION

Railway level-crossings are serious potential encounter junctures for collision between on road automobiles and the trains. Of late the problems concerning safety at level crossings have steered itself to a global concern and has drawn attention of the concerning authorities viz. transport, railway and the public administration towards it.

Safety at the level crossings is area of major concern and is likewise echoed in the relevant domain of research. Several researchers in general and Austin and Carson (2002), Hu *et al*. (2010), Zalinger *et al*. (1977) and Schlossberg *et al.* (2006) proposed models predicting and forecasting frequency of the level-crossing associated accidents and studied their underlying factors. Lewinski *et al*. (2009) presented a wireless warning system that shall caution road users near railway crossings before approaching train arrives. Stephens and Long (2003) estimated additional pavement patterns for refining safety at crossings. Welk (1997) utilised the data and information obtained from Global Positioning System (GPS) located on the locomotives or rail road crossings to develop a model to study accidents arising owed to level-crossings. Shirkey and Casella (1996) utilized the same technology to estimate speed of the approaching train along with its position to avoid collision. Later on a similar case was studied by Mostafa *et al*. (2011) but the model was a radio link based system. Xishi *et al*. (1992) informed that the devising of a fault resistant anti collision devise warrants the robustness of hardware and software components.

The application of magnetic sensor based warning system is being done in Korea, since, 2000 and seems to bode well in reducing the accidents at the level crossings. Another technology based on JESS and OGSi was devised by Jeong *et al*. (2008) for improving the safety concerns at the level crossings.

But all systems are not capable of computing arrival time and train speed related statistics for multiple trains simultaneously. Moreover, it is challenging to identify the characteristics of the trains leaving or entering the security and safety umbrella.

The level crossings form a complex agglomerate of the rail and road vehicles thereby making the safety related issues intricate. The dynamics responsible for collisions at crossings might be challenging to determine and usually consist of several parameters. According to a public report in Europe the road commuters are accountable for the 95% of the accidents that occur at the level crossings. The same report states that in the number of accidents in 2008 was 2000 and it resulted in about 600 fatalities. The harsh weather condition and the poor state of the road cause majority of accidents at level crossings in Australia. The other major reasons everywhere in the world causing the accidents may be enumerated as: unintended motor vehicle driver error, alcohol/drug use by motor vehicle driver, unnecessarily fast speed of road vehicle driver, fatigue of road vehicle driver and other risk taken by road vehicle driver. Hence, it might be resolved that the human error is largely responsible for the accidents at level crossings.

Corresponding Author: Ashish Kumar Aman, Department of Mechanical Engineering, National Institute of Technology Patna, Patna, India

A study on current scenario: Indian railways is the principal mover and delivers a prime role in transport sector of India. The track of Indian railways spans over 64000 km which is used for transportation of about $2.72*10^6$ ton of freight along with $22*10^6$ passengers daily. Being among the larger single management units in world Indian railways employ about 1400, 000 employees. As on 1st April 2014 Indian railways network has 30, 348 level crossings out of which 18, 725 (62%) are manned and remaining 11, 563 (38%) are unmanned. In the Indian scenario majority of accidents at the level crossings are because of the unmanned level crossings and it has finally resulted in 6, 000.

Currently the steps taken to minimize the fatalities at the unmanned crossings is taken via. building the rail over bridges and or changing them to manned type crossings. However, these measures prove to be effort, cost and time laden. For example, problem with R.O.B. is that it requires huge financial investment to build one and takes years to complete without any deadlocks. Also, execution level issues caused non-execution of about 60 crossings. The proposed prototype is a cheaper solution and much simpler to execute as compared to existing traditional methods (Fig. 1).

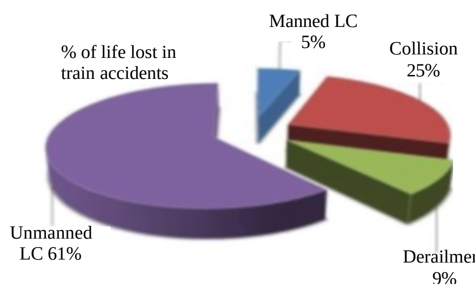

Fig. 1: Loss of lives in train mishaps (%)

Conceptual framework: Present work deliberates a methodology in which road vehicles will automatically stop according to their speed with help of auto gear changing mechanism just before level crossing when train would be at a distance of 1000 m from the level crossing. After passing of train driver will control their vehicles. The flowchart of the anticipated procedure is shown in Fig. 2. Initial step is detection of arrival of train. For detection of distance of the train from level crossing ultrasonic remote sensor (HC-SR04) module is used. When some object comes near this module it measures distance of object from itself. It has decent range of up to 400cm for the detection of object.

This sensor gives indication of arrival of train to NodeMCU development board. NodeMCU is basically a combo module of Microcontroller and WiFi. This module receives signal of the arrival of train from HC-SR04 and broadcast this message. The complete system (NodeMCU and HC-SR04) will be placed at a distance of 1000 m from the level crossing, so that, this system can broadcast the message of arrival of train to the road-vehicles.

Each road vehicles will have an Electronic Control Unit (ECU). In ECU of each road-vehicle there will be another NodeMCU. This NodeMCU will receive the massage broadcasted by NodeMCU which is placed at a distance of 1000 m from the level crossing. The set-up of ECU is portrayed in Fig. 3.

After the reception of message of arrival of train electronic control unit of road vehicle will check the instantaneous velocity of train and on basis of value of instantaneous velocity it will allow the process of auto transmission to retard the vehicle. After the deduction in

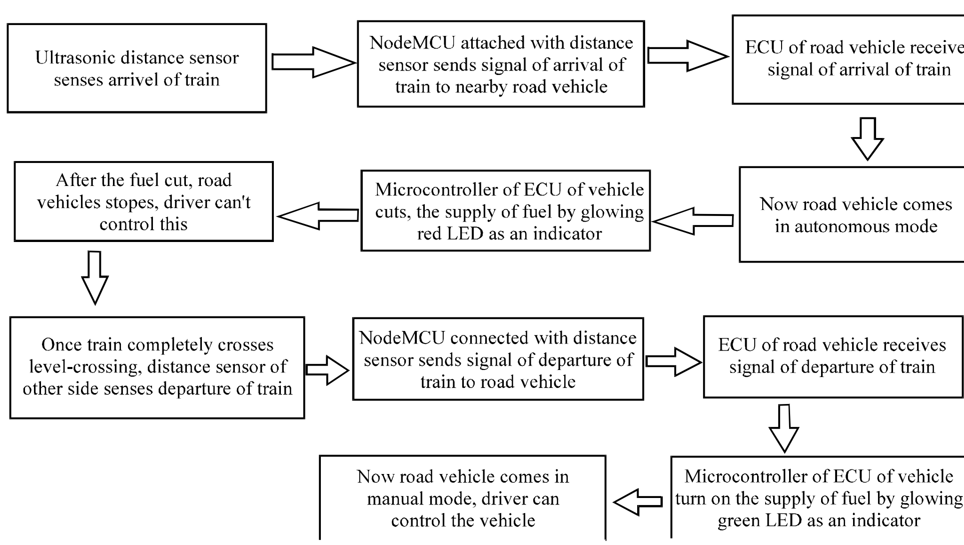

Fig. 2: Flowchart for the proposed methodology

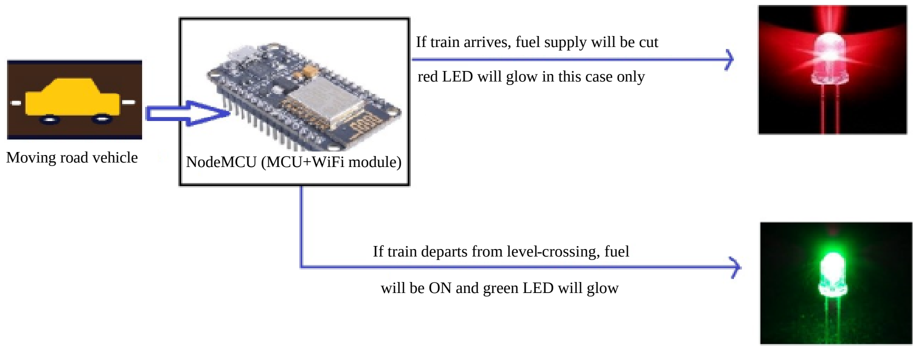

Fig. 3: Schematic representation of the working of ECU on road vehicle

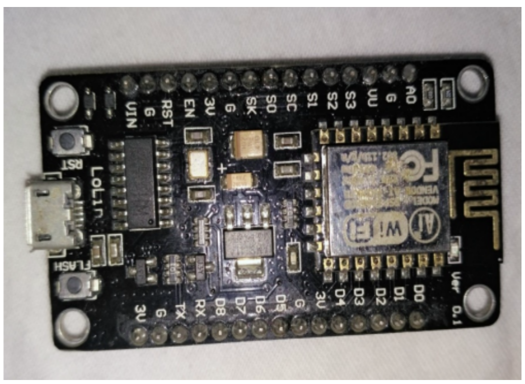

Fig. 4: NodeMCU

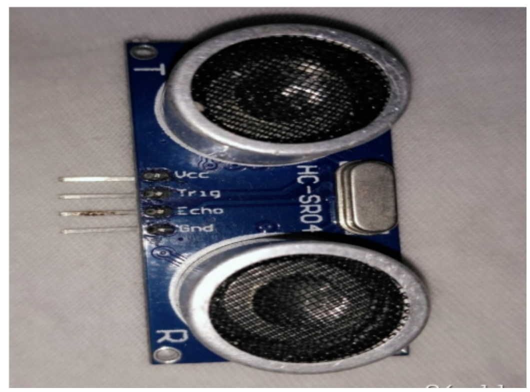

Fig. 5: Ultrasonic distance sensor

velocity of road-vehicle through auto transmission process automatic brake will be applied and hence vehicle will stop.

Now vehicle will wait till the incoming of signal of departure of train. Once a message from the combined module of NodeMCU and HC-SR04 installed at the 1000 m from the level-crossing at other will indicate the departure of train to electronic control unit of vehicle, ECU of vehicle shall permit driver to control over vehicle.

Hardware requirement

NodeMCU: NodeMCU is heart of this system (Fig. 4). This is a combo module of microcontroller and WiFi module. Such boards can be easily programmed using Arduino IDE (Integrated Development Environment). All the controlling action and WiFi based communication is done by this module. This module is also present is electronic control unit of road vehicle.

Hardware description of NodeMCU: A WiFi module based on the ESP12E is used. A micro USB is used for the power supply of %V and also debugging of the program. A header having dimensions of 2 by 2.54 mm^2 is used. This has contact to the power pins besides the ADC, SPI and UART, etc. The hardware also has a key used for flash and reset. The complete module has size of 49 mm by 24.5 mm by 13 mm.

HC-SR04 (Ultrasonic proximity and distance Sensor): The distance of the object is estimated via. HC-SR04 ultrasonic sensor using SONAR technology. They radiate sound pulses of very small wavelength and high-frequency at regular intervals. These waves promulgate in air at velocity of sound. In cases they impinge on an object they are echoed back in the form signals to sensor. The sensor then computes distance of target using the time elapsed between the radiations and receiving the pulses. The HC-SR04 adopted in said model is portrayed via. Fig. 5.

Specifications:

- Power supply: +5 V_{DC}
- Dormant current: <2 mA
- Working current: 15 mA
- Effective angle: <15°
- Stretching distance: 2- 400 cm/1”-13 ft
- Resolution: 0.3 cm
- Assessing angle: 30°
- Trigger input pulse width: 10 μsec
- Dimension: 45×20×15 mm

Fig. 6: Arduino board

Fig. 7: Arduino's USB cable

Arduino board: Arduino Uno is ATmega328P based micro controller board having 20 pins (14 digital I/P and O/P and 6 analog I/P). It further consists of quartz crystal (16 MHz) besides buttons for reset, jack for power supply and USB connection, power jack. It has all the elements to support the microcontroller and may be interfaced to computer system (Fig. 6).

Power USB: Power USB provides power to the Arduino board from the computer system or any other power source (Fig. 7).

L293D-motor driving IC: L293D is a motor driving IC which permits DC motor to drive in both directions. L293D is a 16-pin IC that is used to control two DC motors concurrently in whichever direction. The L293D can drive all capacity of motors (Fig. 8).

It works on the principal of H-bridge which permits voltage to be bidirectional. A L293D chip consists of two H-bridge circuits contained in the IC which shall revolve 2 DC motor autonomously. Because of its favourable dimensions they are extensively employed in robotic applications. Figure 8 represents pin diagram of L293D motor controller.

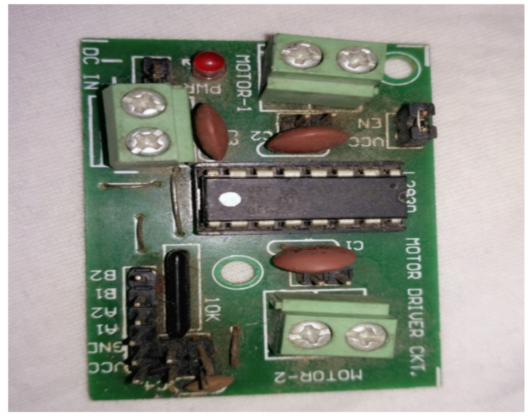

Fig. 8: Motor driver module

Fig. 9: DC motor

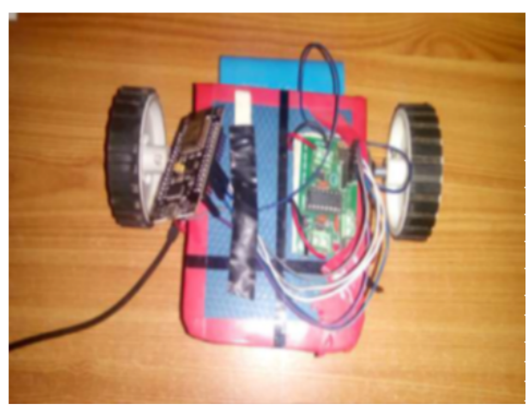

Fig. 10: 3-wheeler robotic car as a road-vehicle

The two enable pins namely pins 1 and 9 is set at high to drive motor. Pin one when high drives motor on left whereas pin 9 on a high drives motor on right.

DC motor: Motor is anelectrical appliance converting electrical energy to mechanical energy. All the movement activity of demo vehicle is organized by this motor.

Every time a current laden rod is placed in magnetic domain it experiences mechanical force whose direction can be acknowledged from fleming left hand rule and extent can be computed as:

$$F = \beta \mu L$$

Where:

β = Magnetic flux density
μ = Current
L = Length of conductor within magnetic field

Mechanical related mechanisms: Mechanical work includes design and integration of 4 wheeler robotic car with the help of four wheels, 4 motors and wooden chassis. Design and integration of robotic car is first step of work to facilitate the testing of prototype. Initially a 3-wheeler robotic car was fabricated to validate the concept (Fig. 9-10). After testing of prototype a 4 wheeled robotic car was fabricated as depicted. So, when the robotic car will get the information about arrival of train, the NodeMCU module mounted over it will turn off all motors and hence robotic car will stop.

MATEIRALS AND METHODS

In India most of railway tracks are two-way, so, two ultrasonic distance sensors (HC-SR04) has been placed, one of each side of railway track and the same configuration is repeated on either side of level-crossing. When a train, approaching towards level-crossing comes in front of the distance sensor it emits short and high-frequency sound pulses at steady intervals. These propagate in the air at velocity of sound. On striking an object the pulses are reflected and received by the sensor which further estimates the distance of the object on the basis of time elapsed between the emissions and receiving of pulses (Fig. 11). Thus, ultrasonic distance sensor senses arrival of train and NodeMCU connected with it will broadcast the information of arrival of train to all the nearby road-vehicle. NodeMCU is combo module of microcontroller and network processor (WiFi). This is heart of this project. Operating voltage of NodeMCU is 5 V_{DC}. All the controlling activates and WiFi based communication is carried out by it only.

The entire level-crossing is connected over the internet. So, the NodeMCU sends the signal of arrival of train to the Electronic Control Unit (ECU) of all the road vehicle. Actually the electronic control unit of road vehicle also contains a NodeMCU which will receive the signal transmitted by HC-SR04 over the WiFi. Once ECU of road vehicles receives signal of arrival of train it comes in autonomous mode. Driver can't control the vehicle.

Now the auto fuel pump shuts off system is being activated. According to this system when ECU of vehicle receives the signal of arrival of train it immediately stops the supply of fuel to engine of vehicle. For the demonstration purpose a red LED is connected to the GPIO (General Purpose Input/Output pin) of NodeMCU which glows when fuel pump shut-off system is activated. So, red LED is indicator for auto fuel pump shut-off system. It continues glowing till the ECU of vehicle does not receives the complete departure of train (Fig. 12).

After the activation of auto fuel pump shut-off system, train does not stop immediately due to its momentum. So, the auto gear changing mechanism first slows down the speed of vehicle, so that, brake can safely be applied on road vehicle. Wheels of the vehicle used for demonstration are directly coupled to dc motors. Motors installed in demo vehicle have 100 rpm. Motion of these motors are controlled by using L293D-motor driver IC. Operating voltage of this IC is 4.5-36 V_{DC}. Motors are

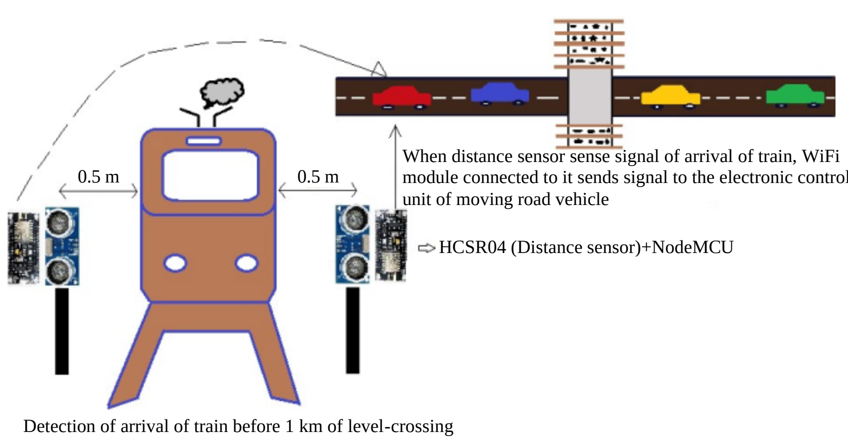

Fig. 11: Schematic representation of the working of module

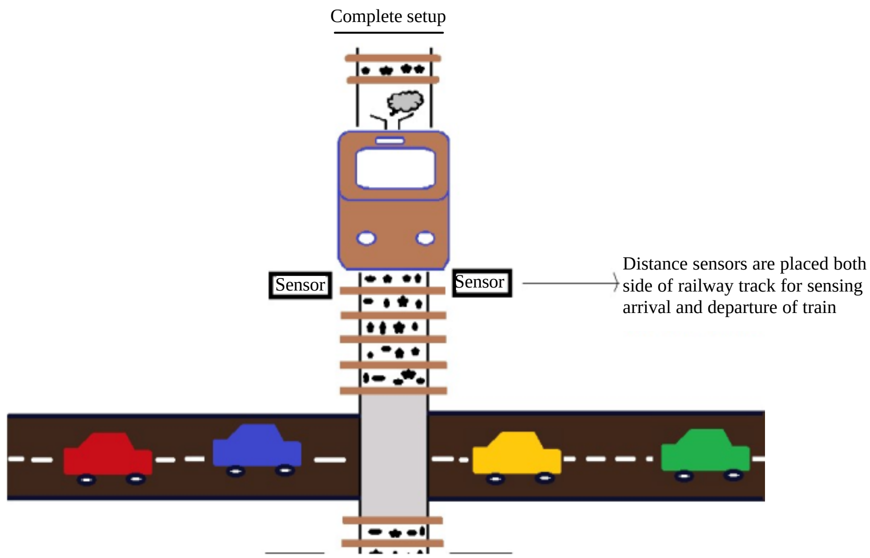

Fig. 12: Working of the sensors

connected to inputs of this IC and out of this IC is connected to GPIO of NodeMCU. So, after activation of auto fuel pump shut-off system All the GPIO of NodeMCU corresponding to the output of motor driver IC becomes LOW and thus vehicle completely stops.

Now the road vehicle stays on the road and wait till the electronic control unit of vehicle does not receives the complete departure of train from the level crossing. There is another set of ultrasonic distance sensors on other side of level-crossing. When train comes in front of the distance sensor after crossing level-crossing, again the NodeMCU connected to distance sensor sends signal of complete departure of train from the level-crossing over the WiFi to the ECU of road vehicles. This job is similar to the broadcasting of the information of arrival of train.

When ECU of road vehicle receives the information of departure of train from the level-crossing it deactivates the auto fuel pump shut-off system and starts supply of fuel to the engine of vehicle. Deactivation of auto fuel cut system is indicated by glowing the green LED connected to GPIO of NodeMCU. Now the GPIO of motors becomes high. Complete controlling mechanism of vehicle comes under the driver of the vehicle. Hence, the driver can control the vehicle manually.

RESULTS AND DISCUSSION

Article commenced with brief description of the current scenario of the level crossing security system. Seeing the critical nature of the security issues concering the level crossing an effort was made to develop a prototype to avoid the collision at level crossings. The developed prototype is capable of controlling the vehicles on course of plausible collision. The prototype developed herein is capable of slowing down and stoping the vehicle near the level crossing if the need arises using the auto gear changing mechanism. An interface of the ultrasonic distance sensor and NodeMCU was fabricated to devise an amalgamated module consisting of a WiFi and microcontroller unit. Every vehicle needs to contain a NodeMCU which will be interfaced with micro controller unit and provide the signal to the vehicle instructing it to stop or decrease the approach speed whenever warranted.

CONCLUSION

The initial results acquired on testing of such a system was found to be quite encouraging. A full scale model shall be developed in the next phase of study and the shall be tested outside the laboratory environment.

REFERENCES

Austin, R.D. and J.L. Carson, 2002. An alternative accident prediction model for highway-rail interfaces. Accid. Anal. Prev., 34: 31-42.

Hu, S.R., C.S. Li and C.K. Lee, 2010. Investigation of key factors for accident severity at railroad grade crossings by using a logit model. Saf. Sci., 48: 186-194.

Jeong, Y.S., C.S. Nam, H.J. Jeong and D.R. Shin, 2008. Train auto control system based on OSGi. Proceedings of the 10th International Conference on Advanced Communication Technology (ICACT) Vol. 1, February 17-20, 2008, IEEE, Gangwon-Do, South Korea, ISBN:978-89-5519-135-6, pp: 276-279.

Lewinski, A., A. Rogowski and L. Bester, 2009. The modeling of collision with train-car respect to integrated transport safety system. Adv. Transp. Syst. Telematics, 1: 179-184.

Mostafa, S.S., M. Hossian, K.J. Reza and G.M. Rashid, 2011. A radio based intelligent railway grade crossing system to avoid collision. Intl. J. Comput. Sci. Issues, 7: 1-5.

Schlossberg, M., J. Greene, P.P. Phillips, B. Johnson and B. Parker, 2006. School trips: Effects of urban form and distance on travel mode. J. Am. Plann. Association, 72: 337-346.

Shirkey, K.L. and B.A. Casella, 1996. Wireless train proximity alert system. US5554982A, United States Patent and Trademark Office, Washington, D.C. USA. https://patents.google.com/patent/US5554982A/en

Stephens, B. and G. Long, 2003. Supplemental pavement markings for improving safety at railroad-highway grade crossings. Transp. Res. Rec. J. Transp. Res. Board, 1844: 18-24.

Welk, J.E., 1997. Railway crossing collision avoidance system. US5699986A, United States Patent and Trademark Office, Washington, D.C., USA. https://patents.google.com/patent/US5699986A/en

Xishi, W., N. Bin and C. Yinhang, 1992. A new microprocessor based approach to an automatic control system for railway safety. Proceedings of the IEEE International Symposium on Industrial Electronics, May 25-29, 1992, IEEE, Xian, China, pp: 842-843.

Zalinger, D.A., B.A. Rogers and H.P. Johri, 1977. Calculation of hazard indices for highway-railway crossings in Canada. Accid. Anal. Prev., 9: 257-273.