Development of Smart Safety Net at Level Crossings for Indian Railways

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Abstract: Each Level Crossing (LC) has unique and typical characteristics. These high-risk intersection spots of transport system in general and railways in particular are matter of concern all over the world. The operation of trains is under the control of railways and at the same time road transport may be under the control of various other transport agencies. There may be uniform road design standards and traffic operation bye-laws in a country but the movement of traffic and pedestrians are seldom planned, monitored and regulated. This freedom and uncontrolled movement of road users make these intersections more vulnerable to accidents.

Each year a large number of accidents take place at LCs throughout the world. The majority of these accidents occur due to the negligence, and incompetence of road users, who generally operate their vehicles in the environment where ignorance of safety rules and safety measures are in practice.

Human factors have been ignored till sometimes back while considering safety at railway crossings. Consequently, most of the protection systems and alarming systems employed at railway LC relied upon technology and traditions only.

A smart, dynamic integrated system of safety net, particularly suitable for Indian Railways has been developed to take care of various safety aspects at rail-road level crossing. The system is based on modern technology and behavioral psychology of the road users. The system consists of digital sensors, microcontroller (AT mega 328P), buzzer, signal lights, flippers, comparator and position encoder. It is an automatic and supposedly, fool proof system for safe operations at level crossings.

Keywords: Level crossing, Sensor, Microcontroller, Flipper, Safety.

1. Introduction

Road and railway transportation are the most convenient and economical modes of transporting men and materials. Railways and road transport intersect each other at several places. At, these intersecting places they put obstruction and restriction of movement on each other.

Each year a large number of accidents take place at Level Crossings (LCs) throughout the world. Numerous road users and train passengers meet fatal accidents or injury every now and then all over the world.

In India, there were 1,788 level crossing accidents in 2019, up from 1048 in 2018, according to latest NCRB data. Last year, level crossing accidents killed 1, 762 people, while the year before they claimed 1, 507 lives, the report says. Level crossing accidents saw a 20% jump in 2019 even as the number of accidental deaths in railway premises remained largely constant compared to the previous year.

A level crossing, whether manned or un-manned, may prove to be fatal spots for road users. The Indian Railways (IR) have concluded after study that majority (nearly 89 %) of accidents at LCs occur between 6 a.m. and 6 p.m. and not at night as widely perceived. This is mainly because people are in a hurry during day time to reach their destinations and thus, end up paying least or no attention to the risk involved.

1.1 Overview of Engineering Measures

Most of the safety and alarming devices employed at active LCs are based and designed on engineering concept and traditions only. The human behavioral factors are comparatively new area of attention and research in transport safety system. This has necessitated research on human behavioral factors and its consideration in the design of safety protection at LCs.

According to Stephen (2002) safety and alarming devices at railway LCs are generally less intense and effective than those employed at road intersections. Cairney (2003) states that most of the railways are not able to upgrade the safety and alarming system to match the international standards, due to financial constraints.

Cairney (2003) studied safety aspects at the level crossings. He states that the type of traffic control system being used at a railway LC has considerable effect on the decision making of the vehicle drivers and pedestrians and thus, the overall safety at the LCs. At some of the upgraded LCs with modern engineering solutions and automated devices, it has shown remarkable improvement in the safety performance at the rail-road intersections.

A number of influencing engineering factors such as sight distances, level crossing surface, speed limit at approach roads, vehicle dimensions, signage and markings, information handling zones, conspicuity of trains, alarming systems, etc., may be enlisted for consideration to minimize accident probability at LCs. Risk assessment at LCs. Risk assessment at a level crossing is evaluated by considering each influencing factor by risk-based scoring systems.

In spite of suitable alarming devices used to warn road users to be alert while negotiating a LC, the behavioral consideration of the vehicle drivers plays vital and significant role in avoiding mishaps at LCs (Carroll et al. 1995). Errors are committed by a good number of motorists which may be the main reason for accidents at the rail-road intersections, in spite of proper safety measures and precautions in force at the crossing. Some of such situations may be listed as follows:

- Failure to spot the train, correctly estimate the speed and distance of the train from the crossing.
- Incompetence of the motorists and pedestrians to understand and evaluate the intrinsic hazard of the coming train; and
- Incorrect assessment of arrival time of the train at the rail-road intersection.

1.2 Overview of Human Factors causing accidents at LCs

According to Dekker (2002), there are two views on human perspectives responsible for causing accidents at LCs, i.e., (i) the old perspective, and (ii) the new perspective.

(i) The old perspective according to American Medical Association (1998) explains that the old perspective realizes human error as a reason of failure. This was further clarified by Dekker (2002) in the following manner:

- Most accidents are caused due to human error;
- A considerable number of people work in engineered systems. To avoid accidents, the system must incorporate intrinsic safety in the system. People working in any system are the weakest link of the system and their unpredictable behavior makes it more complex. The major concern to safety originates from the inherent unpredictable behavior of the people concerned; and
- Safety may be improved by protecting the system from inconsistent human behaviors. This can be achieved through proper selection of the workers, laying out clear working procedure, automation training, maintaining discipline and introducing automation in the system.

American Medical Association (1998), Hoffman and woods (2000), Reason (2000) and Woods et al. (1994) have somewhat different opinion. Their views are known as the new perspective which does not consider human error as a cause of failure. Instead, the human errors are considered as symptom of failure and subscribe the following opinions:

- Human error reflects a symptom of trouble within the working system;
- Complete safety cannot be ensured in any system. People are generally asked to pursue multiple goals simultaneously which puts the system itself in contradiction. Thus, people should be fully aware of the environment and self- conscious towards the necessary safety measures. People are supposed to create safety, wherever they are.
- Human error is related in a systematic way to features like people, tasks, tools, and working environment. Safety improves at a working place by understanding and influencing these related parameters.
- Human error is representative of a considerable movement within the fields of human elements and safety of the organization. It promotes the investigation and analysis of these elements that may be ignored under the cover of ‘human error’.

1.3 Cost of accident

An accident at level crossing, results in large human fatalities/injuries and huge financial loss, which is ultimately born by the society. The actual cost of accident is impossible to evaluate as the human life is priceless.

Therefore, it becomes imperative to provide a safe, efficient and effective system of gate operation and warning devices at the LC gates to protect against any mishap and consequent loss of human lives and damage to properties

1.4 Sight Distances

A road user may not be able to view an approaching train on various counts. Ward and Wilde (1995) state that while viewing an approaching train the problem of drivers of vehicular traffic is increased by the presence of

restricted sight distance at the LC and creates problem in estimating the speed of approach correctly.

According to Caird et al. (2002) the objects such as display boards except the crossing awareness signs, buildings, vegetation, peculiar human activities, etc. present visual distractions to the drivers which may prove to be hazardous in observing an approaching train.

Berg et al. (1982) state, that lapse in spotting a train by a vehicle driver or pedestrian is mainly due to availability of insufficient sight distance at LC in general and at passive crossings in particular. A number of drivers may be well conversant with the restricted sight distance at an LC but even then, they may be tempted to compensate it anyhow. Ward and Wilde (1996) conclude that the behavior of vehicle drivers and pedestrians is altered and it is expected to sustain the perceived risk situation. On the other hand, some drivers fail to recognize that sight limitations are disastrous for driving at LCs.

Most of the experts consider sight distances as one of the significant engineering parameters for the safety of LCs. But Ward and Wilde (1996) have different views and state that there is no conclusive evidence that restricted lateral sight distance is hazardous and makes LCs more vulnerable to accidents. They are of the opinion that the relationship between restricted lateral visibility and higher number of accidents is only intuitive; and lacks the conclusive evidence. Some other researchers such as Russel et al. (1974) have arrived at the conclusion that there is no correlation between sight distances and mishaps at the rail-road intersections.

The above opinions seem to be quite illogical. The sight distance is considered as one of the most significant variable parameters. In case, a vehicle driver or even a pedestrian is not able to see the LC and the track for adequate lateral distance, the driver or pedestrian is handicapped to take a correct safety measure required at the LC.

According to Dewar (2002), speed of the train and speed of the road vehicle are the governing factors for the sufficient sight distance needed for the safety. Because motorist requires certain minimum time to perceive the situation and take suitable decision. During this required minimum time, the distance travelled by the train and the road vehicle are dependent on their respective speeds. Mortimer (1988) has advocated that at a level crossing which is located at an angle other than a right angle to the road, the visibility of the train is reduced for the vehicle driver. A good number of such level crossings are present in U.S having LCs at angles between 60o and 90o. 4% of the LCs is located at very acute angles of less than 30 degrees.

1.5 Factors governing probability of accident occurrence at LCs

- Rail traffic density: It is the optimum number of vehicular traffic of all types crossing the LC per day;
- Visibility of the track, warning signage meant for vehicular traffic and pedestrians being impaired due to the presence of physical obstructions;
- Restricted barrier protection at LCs;
- Non-provisions of flashing lights and audible warning devices at LCs;
- Uneven surface of the pavement at LCs;
- Improper alignment of road stretch crossing the rail track.
- Inclement weather;
- Mechanical or equipment failure
- Human error

2. Objectives of the present study

The following are the objectives of the present study:

- The main objective of the present study is to develop a dynamic smart safety net at railway crossings for Indian Railways.
- To develop a system for automatic control and operation of level crossing gates including various elements involved in it, such as railway operation, vehicle drivers' characteristics, pedestrian's variable reaction times, signaling system, interlocking, environmental aspects, etc.

- To develop a smart system to provide an advance gradually increasing audio alarm with flashing lights besides automatic closure of the level crossing gates. Therefore, an integrated system has been developed which may be called as smart safety net. For the automatic and continuous operation of the system, software in ARDUINO INTEGRATED DEVELOPMENT ENVIRONMENT has been developed and indicated in a flow chart which depicts the conditions of gates (open or close), Flippers (off or on), traffic signal light color (red or yellow or green) and buzzer or alarm (off or on) with respect to the six sensors depending on the sensor which the train is crossing. The sensor's output act as input to the microcontroller which is AT mega 328P and gives necessary instructions for the different components of the system which act accordingly and produce the desired results. The speed of the motor which operates the gate and flippers is controlled by a position encoder. This eliminates the use of servo motors which are heavy devices.

2.1 Elements of Safety Consideration

The following aspects of safety has been considered in the present study:

1. Automation of level crossing gates: The automation of operations of level crossing gates is bound to reduce the cost on man power and errors caused by human errors. Automation may be achieved by using Track Circuit or Axle Counter technology. Better control of LC gate opening and closing through automation should reduce the probability of accidents to a great extent.
2. Provision of a suitable Light Warning system for the road users.
3. Provision of Audio Warning bell with increasing intensity for the benefit of the road users.
4. Provision of Flipper gates on road before LC gates on both sides of the track.

An integrated and dynamic program has been developed considering all the above parameters. This program controls the different components viz. LC gates, Flippers, Light Signals and buzzer (alarm) in such a way that it gives warning and creates a fear environment for the road users near the level crossing as and when the train is approaching a level crossing. The system developed uses modern technology and psychology together to control the rash behavior of the road users.

3.0 Development of the proposed system

An integrated and dynamic program has been developed considering all the above parameters. This program controls the different components viz. LC gates, Flippers, Light Signals and alarm in such a way that it gives warning; and creates a fear environment for the road users near the level crossing as and when the train is approaching a level crossing. The system developed uses modern technology and psychology together to control the rash behavior of the road users.

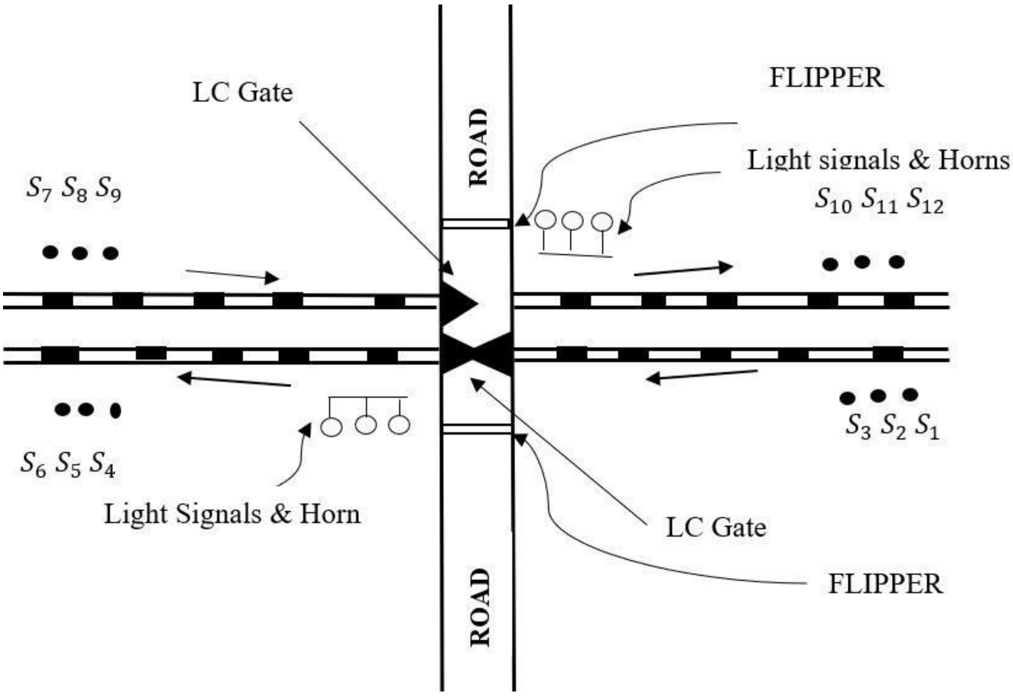

Figure. 1. Arrangement of System Developed (Top View)

The system utilizes six powerful laser emitters and six receivers for each track; three pair of transmitters and receivers (S1, S2, S3) are fixed up side the track at a level higher than a person in exact alignment and in the same way the other three sensors (S4, S5, S6) are fixed downside of the train direction. Each sensor has three emitters and three receivers (for example sensor 1 has sub parts namely 1.a, 1.b, and 1.c and similar for the other five), so that if any animal or bird crosses through them, triggering of the system can be stopped.

So even, if one of three sensors is blocked by a bird or some other obstacle, the other two will help to check wrong message of train's arrival. So, when all three sensors find obstacle in front of it for some specified time (in this case 1 sec) then only the next steps are executed.

Sensors are fixed at a suitable distance (say,1km) from each LC. These are the sensors which decide when the gate will close and when it will open. Other components like alarm, traffic lights and flippers are also controlled by the sensor outputs.

The first three sensors i.e., S1, S2 and S3 are used to detect approaching train and are used to start alarm, set traffic signal to yellow and then to red, to close the gates and to make the flippers on. The other three sensors i.e., S4, S5 and S6 are used to detect the departure of the train and set the whole system to its initial condition i.e., to open the gates, to set traffic light to yellow and then to green and buzzer off and flippers off again.

3.1 Gate Control Unit

There is a set of three sensors which is fixed at some distance away from the railway level crossing. These sensors will detect the upcoming train and subsequently, it controls the opening or closing of gate as per requirement at that time.

As train approaches and crosses first sensor of the three sensors and a message is sent to the Microcontroller housed near the LC gate. As soon as the message is received, the traffic light is set to yellow and alarm is made on as a warning signal to the vehicles on the track. This allows the vehicles to move out of railway track and also checks any further entry of the vehicles.

When the train crosses the second sensor, alarm is still on and flippers are taken out of the ground and set to start (but not actually started) and the signal turns red. When the train crosses the third sensor, the gate is still closed, the alarm is on, signal is red and flippers start moving up and down. The UP and DOWN motion of flippers stop human and even innocent animals to enter into railway track. The speed of the moving flippers increases with approaching train and starts decreasing with its increasing distance.

As train crosses the LC and then crosses the fourth sensor the gate remains closed, alarm is still on, signal is red and flippers are still on. When train crosses the fifth sensor the flippers are made off, gates are still closed and signal is turned yellow. When the train crosses the sixth sensor the whole system comes to its default position

3.2 Flipper Control

Flippers are kept inside the ground and comes out from the ground when train crosses the second sensor, but not actually started. But after the train crosses the third sensor, the flippers start moving UP and DOWN. It has been seen that people often cross the railway crossings after gates being closed which sometimes turn into serious accidents. Such incidents are only because of people's ignorance attitude. Placing a flipper will not allow people to cross the gates once they are closed and thus can save many lives.

It not only protects ignorant people but also saves innocent animals from getting inside the gate, as it poses a fear in everybody's mind which force them not to cross the gates in any urgent situation. The flow chart for the entire operation is given as follows:

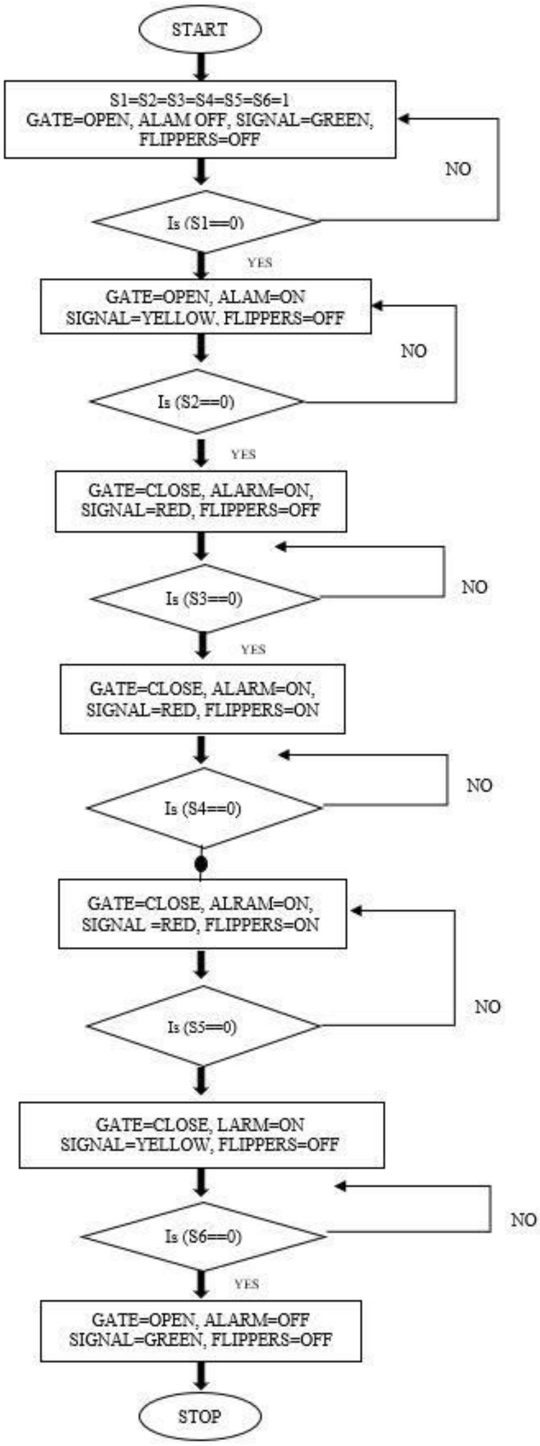

Figure. 2. Functional Diagram of the developed system

3.3 Software Development

For the automatic and continuous operation of the proposed integrated system, software in ARDUINO INTEGRATED DEVELOPMENT ENVIRONMENT (ARDUINO IDE) has been developed. The flow chart presented earlier depicts the conditions of gates (whether CLOSE or OPEN), flippers (whether OFF or ON), traffic signal light color (whether RED or YELLOW or GREEN) and alarm (whether OFF or ON) with respect to the sensors depending on the sensor with train crossing. Fig. 3 shows connection of Sensors to AT mega 328P.

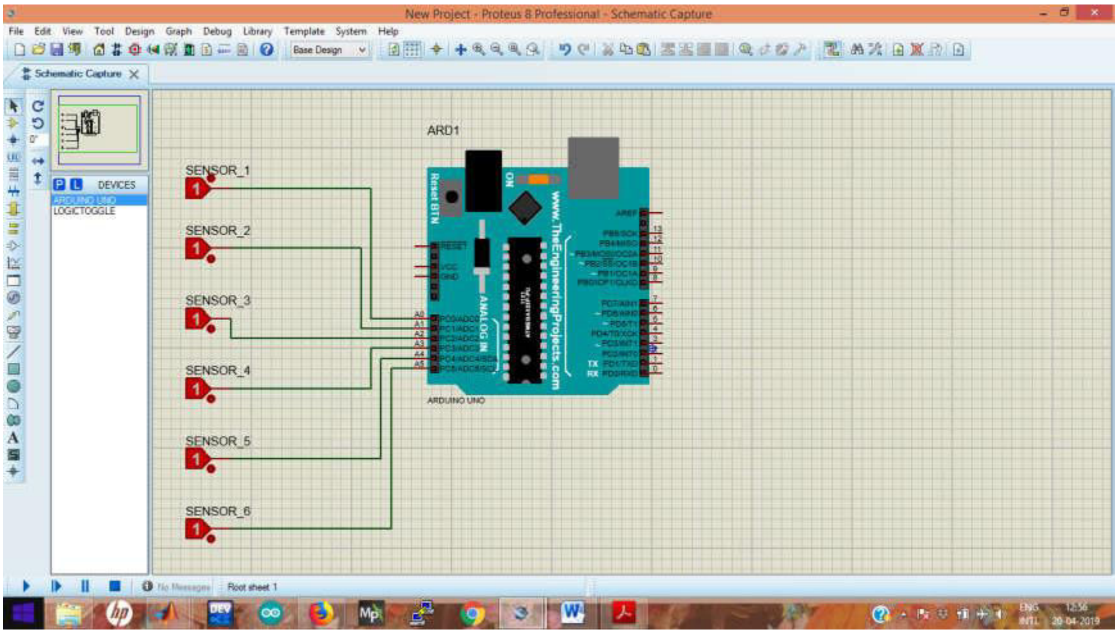

Figure. 3. Connection of Sensors to AT mega 328P

4.0 Results

Several components of safety have been integrated into the system operated automatically to create an environment of high alertness. The software developed has been run successfully. Thus, this systems approach may be considered as unique as well as effective, especially in a developing country like India, where total reaction time of individuals vary in large range.

5.0 Conclusions

1. An integrated smart system of safety net, particularly suitable for Indian Railways has been developed to take care of various safety aspects at railway level crossing. The system incorporates modern technologies and human behavioral psychology of the road users. The system consists of digital sensors, microcontroller (AT mega 328P), alarm, signal lights, flippers, comparator and position encoder. It is an automatic and supposedly, a fool proof system for safe operations at level crossings.

2. The system developed is dynamic and various parameters can be readjusted.

3. The sensors are fixed before and after a level crossing at a suitable distance (say,1km) on the railway track. This distance depends on the maximum expected speed of the train on a particular route. At each of the above two locations three powerful laser emitters and three receivers are fixed on the track to pass on the information of the train nearing or distancing from the level crossing. The microcontroller placed near the level crossing receives the information and initiates the necessary actions.

4. The presence of flippers makes this system safer from all other existing system. The speed of the motor which controls the movements of the flippers and gates is controlled by the position encoder consisting of an encoder disc, position encoder sensor, encoder mount and motor mount.

The digital sensor is equipped with a comparator (LM 324 N) which gives an output corresponding to the value of current from photodiode and comparing with the current value from photodiode and the current value from potentiometer, both of these components being constituents of digital sensor.

5. The system is suitable to draw the attention of road users, even for people having higher reaction time by creating overall environment more serious and alarming, when the train is nearing or passing over the LC.

References

Stephen, N 2002, Some legal consideration, Paper presented at the 7th International Level Crossings Symposium, Melbourne, Australia.

Cairney, P 2003, Prospects of improving the conspicuity of trains at passive railway crossings (no. CR 217), Canberra; Australian Transport Safety Bureau.

Carroll, A, Multer, J, & Markos, S 1995, Safety of highway-railroad grade crossings: Use of auxiliary external alerting devices to improve locomotive conspicuity, Cambridge: U.S Department of Transportation.

Dekker, S 2002, Reconstructing human contributions to accidents: The new view on error and performance, Journal of Safety Research, 33, 371-385.

American Medical Association, 1998. A tale of two stories: Contrasting views of patient safety. Report from aworkshop on assembling the scientific basis for progress on patient safety. Chicago; National Patient SafetyFoundation at the AMA.

Hoffman, RR, & Woods, DD, 2000, Studying cognitive systems in context. Human Factors, 42 (1), 1 - 7.

Reason, JT 2000, Grace under fire: Compensating for adverse events in cardiothoracic surgery. Paper presented at the 5th Conference on Naturalistic Decision Making, Tammsvik, Sweden.

Woods, DD, Johannesen, LJ, Cook, RI, &Sarter, NB 1994, Behind human error: Cognitive systems, computers and hindsight. Dayton: CSERIAC.

Ward, NJ, & Wilde, GJS 1995, A comparison of vehicular approach speed and braking between day and night time periods at an automated railway crossing. Safety Science, 19, 31- 44.

Caird, JK, Creaser, JI, Edwards, CJ, & Dewar, RE 2002, A human factors analysis highway-railway grade crossing accidents in Canada, Calgary: Transportation Development Centre, Canada.

Berg, WD, Knoblauch, K, &Hucke, W 1982, Casual factors in railroad-highway grade crossing accidents. Transportation Research Record, 847, 47-54.

Ward, NJ, & Wilde, GJS 1996, Driver approach behavior at an unprotected railway crossing before and after enhancement of lateral sight distances: An experimental investigation of risk perception and behavioral compensation hypothesis. Safety Science, 22(1-3), 63-75.

Russell, ER 1974b, Analysis of driver reaction to warning devices at a high accident rural grade crossing. (No.#74-16): Purdue University/ Indiana State Highway Commission.

Dewar, RE 2002, Railroad grade crossing accidents. In Dewar, RE, & Olson, PL (Ed), Human factors in traffic safety {pp. 507-523). Tucson, Arizona: Lawyers & Judges Publishing Company Inc.

Mortimer, R 1988, Human factors in highway-railroad grade crossing accidents. In G. E peters & BJ peters (Eds.), Automotive engineering and litigation (Vol. 2, pp. 35-69). New York: Garland Law Publishing.