Journal of Engineering and Applied Sciences 14 (19): 7020-7027, 2019
ISSN: 1816-949X

Behavioural Study of Pedestrians at Railway Level Crossing with Special Reference to India

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Abstract: Railway level crossings are quite vulnerable for accidents and the road users are responsible for about 95% of such accidents. Railways have concentrated more attention on types of gate and technologies involved in gate operation. The behavioural study of road users comprising of vehicle drivers and pedestrians have remained neglected for long time while controlling and taking steps to improve safety at railway level crossings. Since, sometimes back, the safety engineers and planners have been attracted towards this neglected aspect. The mental process of human beings is very complex system to be understood and accordingly provide suitable holistic approach to safety at railway level crossings is a challenging problem. The mental process of human beings is very complex system to be understood and accordingly provide suitable holistic approach to safety at railway level crossings is a challenging problem. All the stakeholders, i.e., railway authority, road authority, road users including pedestrians, community and government should take holistic view, cooperate and interact to improve the safety at railway level crossings.

Key words: Automatic gate control, behavioural studies, level crossing, microcontroller, behavioural study, remained neglected

INTRODUCTION

Human beings are extremely sensitive to emotions generated by external as well as internal variations in the environment. This factor makes humans the weakest link in an embedded system. The human component of the system has considerably higher rate of failure in comparison to other components of the system. A considerable number of persons are involved in the operation of railway level crossing gates. This is the responsible for higher human errors and disastrous consequences (Kumar and Sinha, 2009).

Behavioural psychology of human beings explains all mental and physical activities in terms of response by glands and muscles to surrounding external factors (Anonymous, 2019) whereas behavioural science is defined as the branch of science which studies the actions and interactions of organisms, specially humans and animals.

It is usual to study human activities by observing and monitoring under natural and controlled conditions. Behavioural science studies two levels of behaviour i.e., rational and relation levels.

There are a total of 28,607 level crossings across India of which 19,267 are active and 9340 are passive.

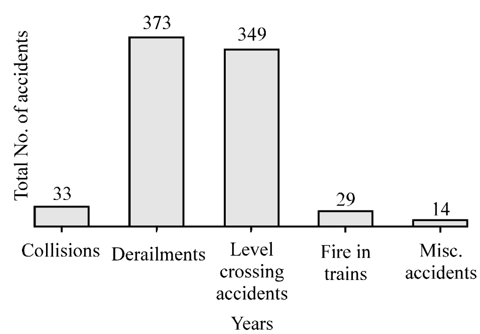

Fig. 1: Number and types of accidents in Indian Railways (2009-10 to 2014-15 www.faculty.inindian-railway accidnts-statistics)

Unmanned level crossings, i.e., passive level crossings spell danger across the world. Passive railway crossings continue to take a heavy toll of human lives. According to latest available figures, 31, 115 and 48 people were killed in accidents at passive railway crossings during 2010-11-13, respectively in India.

During the period 2009-10 and 2014-15, a total of 803 accidents took place in Indian Railways which resulted in 620 deaths and 1855 serious injuries. The number and percentage of accidents by type are illustrated in Fig. 1 and 2 (IRJ., 2015).

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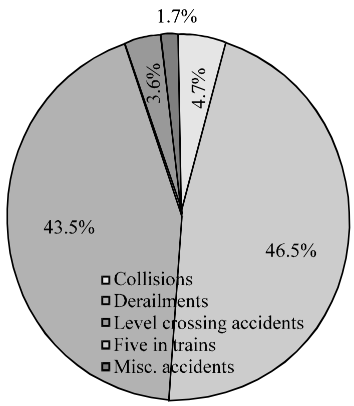

Fig. 2: Percentage of accidents by types (2009-10 to 2014 15 www.factly.in/indian-railway-accidents-statistics)

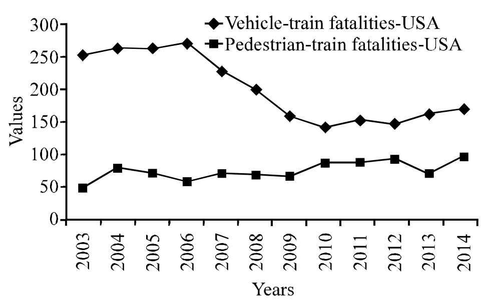

Fig. 3: Fatalities at railway level crossings in USA

Cause of accidents: Several causes are responsible for train accidents. They are human failures, equipment failures, sabotage, etc. In India, during the period 2009-10 to 2014-15, 86% failures of the total accidents occurred due to human failures. About 41% out of this is attributed to the failure of railway staff and rest due to failures of other people. Only 2.2% of the accidents are due to the equipment failure (Dubbudu, 2016).

It is reported that in United States, the number of pedestrians fatalities at railway level crossings has increased by 48% between 2003 and 2014, though accidents at railway level crossings has declined by 49% during the same period (Fig. 3) (Metaxatos and Sriraj, 2015).

Literature review

Level crossing gate control technologies: In the recent past, the railway level crossing gates have been made more efficient and effective by using various technologies for automatic operation of the gates. These take care of the following three aspects:

- There is reduction in gate closure duration for the same purpose
- The probability of the accidents is minimised and therefore, safety of the road users is improved
- Automatic gate operation eliminates the human errors, likely to be committed by the conventional gate operators

Some of the recent technologies developed to achieve the above goals are being presented as follows:

Automatic railway gate control system using microcontroller: The operation cycle consisting of sensing of arrival of train, gate closing and opening of the railway LC gate is controlled and monitored by a microcontroller. The sensing gadgets are fixed at certain distance from the LC gate on either sides of each track which senses the approaching train and sends signal to the microcontroller at the gate. The microcontroller monitors the gate operation as per requirement. Pwint *et al*. (2014) have suggested the use of microcontroller to operate the railway crossing gates. The components used are as follows:

Microcontroller: Main control unit consists of PIC 16F 887A microcontroller to monitor and operate the operation cycle of the railway LC gate.

Railway sensors: Railway sensors are placed at certain distance from the railway level crossing gate on both sides of gate in each track. They are employed to sense the arrival and departure of the train at certain distance from the gate.

Motor driver: The four transistors of the H-bridge in motor driver circuit control. The rotation in forward or reverse direction of DC motor for opening and closing the gate is controlled by the four transistors of the H-bridge in motor drive circuit control panel.

Display board: LCD display board indicates the status of the LC gate, i.e., open or close position and caution message for road users.

Light signal and bell: The road users are warned by light signal and ringing bell that the train is approaching the gate.

Power supply: A continuous DC current supply is essential to operate the system. The suggested flow chart of the system is as follows (Fig. 4).

Kumar and Sinha (2008) have developed a system for automated control of rail-road level crossing gates using axle counters and 8085 microprocessor. Use of track circuits has been also employed for automatic operation control of railway level crossing gates.

Ronics Labz located at Ernakulum, North (India) has conducted a project namely “Automated Railway Gate Level Crossing Scrutinize and Control System” for operation of railway level crossing gates when the train is about to approach a level crossing gate. RF signals are continuously transmitted by a transmitter attached on the train. The receiver of the RF signals is placed near the level crossing gate which receives the signal as the train reaches at certain distance from the level crossing gate. This distance can be adjusted through alteration in programming as per location of the site. Suitably designed and programmed microcontroller controls the driving mechanism to close the gate and provide alert signals to the road users. The block diagrams for working of transmitter and receivers are shown (Fig. 5 and 6).

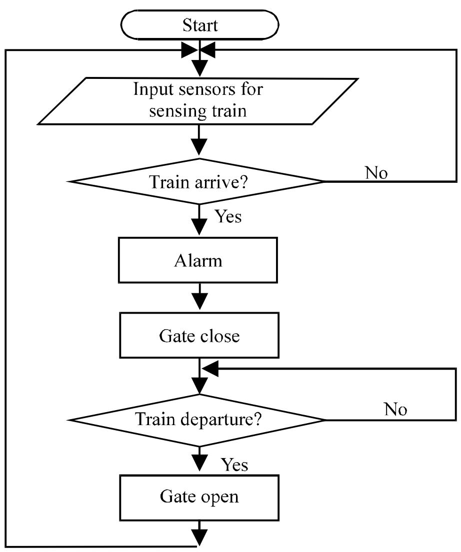

Fig. 4: Flow chart of the system

Automatic railway level crossing gate control alert via. SMS: Various technologies such as GSM, Bluetooth and Android can be used for automatic gate control. Two methods involving Android and GSM are discussed as follows (Bharathi and Vijetha, 2016):

Remote railway gate operation by an android device: An Android device can be used by a station master to control the gate operation at the railway level crossings. Such a system is conveniently operated by a smart phone or tablet with an android-OS with graphical user interface, based on touch screen operation. The system uses a microcontroller for regulating the operations and is programmed in such a way that any control signal from the Android phone controls the motor for operating the gate (Bharathi and Vijetha, 2016).

Remote operation of the microcontroller is done by interfacing Bluetooth devices with the system. The Bluetooth device sends signals from the station master or the engine driver to the Bluetooth device fixed in the control circuit which transmits the signals to the microcontroller. The microcontroller performs the rest of the operations.

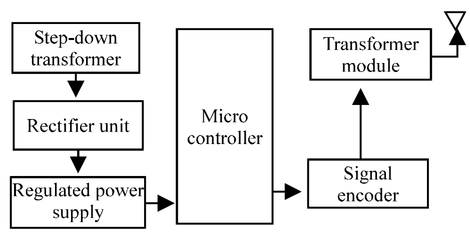

Fig. 5: Block diagram for transmitter (Ronics Labz)

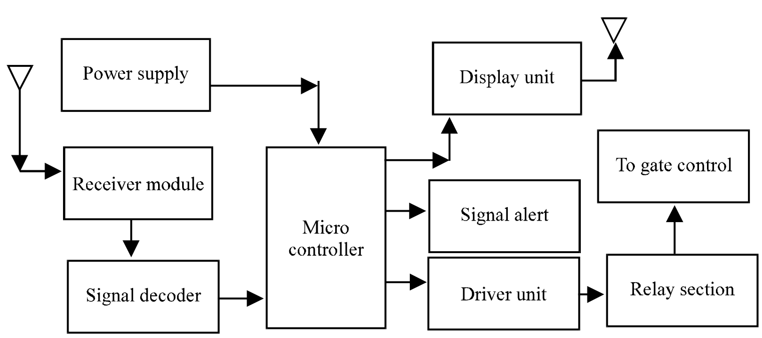

Fig. 6: Block diagram for receiver (Ronics Labz)

MATERIALS AND METHODS

Level-crossing gate control by using GSM: The control systemof the gate is interfaced with a GSM modem. The GSM modem receives the message to open or close the gate from the station master or the train driver and transmits the SMS to the microcontroller. The microcontroller, accordingly sends the command signals to the motor driver IC which controls the direction of the motor for opening or closing the level crossing gate.Simultaneously, the status of the gate is also displayed on the LCD display board.

Human behavioural study: An individual's observable response in a particular situation with respect to a fixed target is known as behaviour. Human behaviour is the responses of individuals or groups of humans to internal and external stimuli. It indicates the array of every physical action and observable emotion associated with human beings. Ajzen (1985) states that "behaviour is a function of a compatible intentions and perceptions of behavioural control". The perceived behavioural control is expected to moderate the effect of intention on behaviour, such that a favourable intention produces the behaviour only when perceived behavioural control is strong.

Behavioural study is a systematic attempt to understand human behavioural actions. Primary assumption is that all behaviours are either reflexes produced by a response to certain stimuli in the environment or a consequence of that individual's history including especially reinforcement and punishment, together with the individual's current motivational state and controlling stimuli. Therefore, the behavioural studies concentrate mainly on two aspects, i.e., inheritance of the person under observation and the surrounding environment.

Factors influencing human behaviour: In the modern times, physical surrounding and working environment are completely transformed from the natural way of living habits of human beings. The following human characteristics have been found to influence the interaction with the surroundings and the working environment.

Perception: For safe interaction with the surroundings, one must perceive it properly and the danger it may result. The surrounding and its reaction within-self challenge human perception system and the information received are liable for misinterpretation.

Attention: In modern times, human attention is quite overburdened with large number of information as compared to that of in the natural world. The large number of information available reduces demands on one's attention. But it is not always true and sometimes can create other problems.

Memory: Memory space for human beings is limited and hence, undue pressure is exerted on an individual while accessing too many information at an instant of time.

Logical reasoning: Illogical reasoning and delayed decision making, result in severe implications for complex systems such as railway level crossings, chemical plants and for tasks like maintenance and planning.

Environment: It may be defined as the sum total effects of all surroundings of a living organism including humans which provide conditions for development and growth as well as of danger and destruction. Environment influences the thinking, working and decision-making domain of an individual.

Health: Good health is necessary for normal behaviour of human beings. An individual having poor vision or suffering from hearing impairment or having high fever cannot think or act in normal way. The health consists of many factors such as diseases, eye sight, hearing ability, age, mental condition, decision making ability, etc.

Stress: High level of stress is undesirable and dangerous to most people. It adversely affects health, mood and productivity and decision-making ability of human beings. Hence, conclusion may be drawn that the performance of human is being strongly influenced by the factors mentioned above as well as their educational and social backgrounds. It may be concluded that the performance of human is being strongly influenced by the factors mentioned above as well as their educational and social backgrounds.

Pedestrians behaviour: In view of considerable number of accidents at the level crossing gates all over the world, it has become necessary to carry out detailed study of pedestrian's psychology and their effects on decision making capability of pedestrians at the level crossings. The psychology and decision making ability depends on large many factors as discussed earlier. As pedestrians are more prone to severe or fatal injury in rail accidents than the vehicle drivers at level crossing gates, it becomes imperative to conduct study the behavioural aspects of pedestrians. This is bound to provide better understanding of the factors responsible for such incidents and in deciding suitable counter measures for safety. According to Siques (2001), the safety of a pedestrian who is crossing railway tracks depends on the following factors:

- Awareness of the pedestrians about the railway crossing
- The pedestrian's path followed across the track way
- The pedestrians' ability to observe an approaching train and estimate the distance and speed of the train
- Health considerations of pedestrians such as hearing impediments, defective vision, age factor, mental health, etc.

Sometimes, putting up sign posts and providing suitable paving strips near the crossings improves the awareness and alertness of the pedestrians. The pedestrian's action at a level crossing is mainly dependent on level of education, health and socio-economic background, as well as signage displayed atthe crossing. There is often a large number of hoardings and signage at a crossing which confuses the pedestrians and restricts them to pick out the most important and appropriate information. Preferably symbols on display board should be used. It can be conceived more conveniently by the pedestrians (RSSB., 2009).

Pedestrian's awareness of an approaching train is primarily governed by vision and hearing capabilities besides their educational level and social backgrounds. The 'passive' crossings require adequate sight distance at railway crossings to see the approaching trains from a safe distance.

Observations from North American research disclose a number of age and gender differences with regards to risky behaviour at railway level crossings. The studies reveal that generally, women are more safety conscious than men. Further it indicates that among pedestrians, young men are trespassers in larger proportion to cross against activated warning signals in larger proportion to cross against activated warning signals. Pedestrians attempt to cross the railway track under the following conditions:

- When they realise that there is enough time
- When they observe others crossing the track
- When they are in a haste
- When they get impatient in waiting at the closed level crossing gate
- When they fail to see an approaching train

Pedestrian non-compliance at LC gates: A good number of pedestrians do not respect and comply with warning signals. They enter the track area even after seeing the stop signal and closed gate. Such defiance of the activated warning signals are dependent on factors like gender, age, personality, attitude, education, social factors, situational factors, weather, distraction and temperament. Male, young and over smart people dare frequently to disobey the warning signals (Edquist *et al*., 2011).

Passive railway level crossings: Passive level crossings have only static warning sign posts which can be seen on approach road. This signage is fixed without any mechanical aspect or light signals. They only provide assistance by notifying the presence of a level crossing ahead to the road users. The road users have to asses through their wisdom and judgement the probability of an approaching train. At passive level crossings, the road users have sole responsibility to explore the safety parameters before going through the rail-road crossing. The clear visibility of the railway track and the approaching train with clear concept of distance and speed are the factors need to be mobilised for taking appropriate judgement. The following are collision risk at passive level crossings:

- Collision risk depends on the train speed, visibility and audibility
- Frequency of use
- Behaviour of the users
- Adventurous behaviour of users, especially youth

McPherson and Daff (2005) studied pedestrian behaviour at a passive level crossing in Melbourne's outer suburbs where most of the pedestrians were well acquainted with the crossing. The behaviour of pedestrians was studied through video recordings for several months. It was found that only 52% of pedestrians in the age group of 12-17 and 60% in the age group of 18-30 looked both ways before crossing. Remaining percentage of youth crossed the passive level crossing looking straight forward without expecting any approaching train. Many other cases of risky behaviour were also noticed such as pedestrians walking along the tracks to reach the station platform or houses further along the tracks and some pedestrians who stopped walking midway through the crossing to look for a friend coming behind, handbag or pick up rubbish, etc.

No significant information is available on road user's behaviour at closed level crossings. A number of research findings are available on road user's behaviour at the level crossings where there are long intervals between the warning alert and arrival of the train. In such situations,

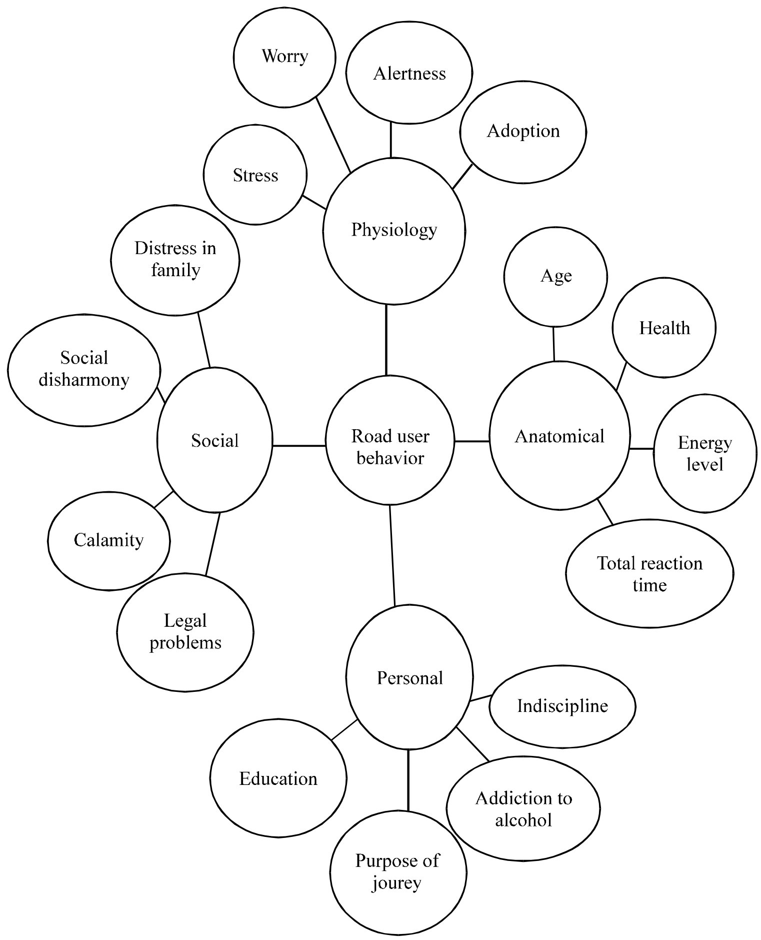

Fig. 7: Components of railway level crossing safety

aggressive drivers or pedestrians take daring decisions. A few studies also recognise the perceptions of waiting time and risk-taking tendencies for various demographic segments and probabilities to improve them positively. Further it has been found that vehicle drivers in the age group of 25-35 years have greater tendencies for driving violations at the level crossings. Kumar (2012) has summarised the various components and characteristics of behavioural safety at railway LC gates and is shown in Fig. 7.

RESULTS AND DISCUSSION

Present study: The present study was undertaken to explore few parameters of pedestrian's behaviour at railway level crossings which may contribute, sometimes to serious accidents. Four No. of active and three No. of passive level crossings on main line and branch line on E.C Railway were selected for the study. The level crossing gate closure time and actual train crossing durations were recorded. At passive crossings some of the pedestrians were interviewed and their movements were observed. The idea behind this was to know their state of mind while moving through the level crossings. The questionnaire included gender, age, educational qualification, marital status, number of children, other liabilities origin, destination and purpose of journey. About 100 and 80 pedestrians were interviewed at active and passive level crossings, respectively. The results are presented in Table 1 and 2 as follows.

Observations at active level crossings: The pedestrians are not aware that how long a gate would remain closed? This causes frustration and erratic behaviour of the pedestrians. It has been observed that the barrier closure time varies between 2.5 and 15 min whereas the train clears the crossing in 20 sec to 1.5 min.

No pedestrian or cyclist was observed to stop at the gate. All of them moved close to the track. If they judged the train was at reasonable distance away, they crossed

Table 1: Observations on pedestrians at active railway level crossings total number of pedestrians interviewed: 100

			Educational status			Vision (out of persons interviewed)	
Age range (year)	No. of persons interviewed	Average reaction time (sec)	More than class X	Literate	Illiterate	Normal	Defective
15-25	20	0.204	7	8	5	12	8
25-40	30	0.180	12	9	9	17	13
40-50	20	0.760	8	6	6	9	11
50-60	18	1.050	7	5	6	8	10
>60	07	1.600	2	2	3	2	5
Old and infirm	05	4.250	1	2	2	00	5
Total			37	32	31	48	50

Table 2: Observations on pedestrians at passive railway level crossings total number of pedestrians interviewed: 80

			Educational status			Vision (out of persons interviewed)	
Age range (year)	No. of persons interviewed	Average reaction time (sec)	More than class X	Literate	Illiterate	Normal	Defective
15-25	20	0.220	4	7	9	10	10
25-40	20	0.200	5	7	8	7	13
40-50	15	0.880	2	7	6	6	09
50-60	10	1.360	1	5	4	3	7
>60	10	2.820	1	3	6	2	8
Old and infirm	05	4.540	00	1	4	00	5
Total			13	30	37	28	52

the track, otherwise, they would stand about 1.5 m away from the track waiting the train to pass. About 70 % of the bikers crossed the closed barrier from beneath and waited close to the track along with the pedestrians.

About 52% of pedestrians were found to have defective vision. This may not enable them to see the train properly and correctly estimate the distance of the train from the gate and its speed. About 31% of pedestrians were educated, 32% literate and rest 37% were illiterate. Education provides strong reasoning which helps in taking decisions.

Female pedestrians were found more confused while crossing the track while the barriers are closed. They are more attentive towards their children and other fellow pedestrians which distract to observe the situation at the crossing. They catch hands of their family members which results in retarded and slow movement at the crossing. The reaction time goes on increasing appreciably after 50 years of age. The youth in the age group of 25-40 years have much lower reaction time but their adventurous attitude makes them more vulnerable to the accident.

Observations at passive level crossings: Passive level crossings are provided where frequency of rail/road traffic is quite less and provision and maintenance of the level crossing gate becomes highly uneconomical. Most of such crossings are located the rural area. About 65% of pedestrians were found to have defective vision. This may not enable them to see the train properly and correctly estimate the distance of the train from the gate and its speed.

About 16.25% of pedestrians were educated, 37.5% literate and rest 46.25% were illiterate. Education provides strong reasoning which helps in taking decisions. No difference in the behaviour of pedestrians and the two-wheelers at passive level crossings and their behaviour at the active level crossings was observed. They were altogether similar.

The travel pattern, animal's reaction to the surrounding and time needed to clear the level crossing cannot be correctly assessed by the animal cart drivers. This increases the probability of misjudgment which may culminate into serious accident. In India, majority of the passive LCs are not equipped with light/sound warning system for the road users. This makes the situation control free at passive level crossings.

Observations and discussions: The barriers have varying closure times due to many reasons. The road users are not able to ascertain the closure time. Early closure of the barriers at LCs results in impatient and erratic behaviour of the road users, especially, pedestrians. The ignorance, sight defects and poor educational background of pedestrians are factors responsible for their unawareness about the safety considerations while moving across a level crossing.

Unauthorised ribbon development along the railway track or the road creates obstructions for road user's visibility of the approaching trains. Sometimes, poorly planned LCs are also not able to provide the minimum clear sight distance. In India, passive railway crossings are in much neglected state. Neither there are light signals nor sound alarms provided at passive crossings. Only sign posts are provided which is mostly in shabby condition without any care.

Pedestrians have rustic and arrogant attitude towards observing safety norms. Most of the pedestrians have higher "Reaction Time? which makes them more vulnerable to the accidents. Animal (s) driven carts moving on the roads is a common sight in India. These carts also have to cross the LCs at times. The unpredictable behaviour of the animals is an additional factor endangering the safety. The cart drivers need to take special care on this count.

CONCLUSION

In absolute block system of railway operation, longer closure time of the gates at railway level crossings is a common feature, as the barriers are closed immediately after the departure of the train from the neighbouring station. Due to this reason, the pedestrians, cyclists and some bikers have developed the concept that barriers are only meant for vehicles and not for them. It has been observed during the present study that about 15-20% pedestrians have higher reaction time (i.e., >2 sec). This indicates as one of the reasons for delayed decisions and actions which increase the probability of accidents at the crossings.

SUGGESTION

There is need to conduct behavioural characteristics study of pedestrians and other road users at the railway L.Cs. All the stakeholders need to interact and coordinate for planning, designing and executing the safety measures. There is need to develop methodology for the integration of human behavioural results in the planning, design and execution.

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