Road Driver Behaviour Evaluation at Unmanned Railway Level Crossings

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Abstract

The study aims to analyze whether the developed vehicle collision threat detection and avoidance system can reduce the road driver problems created by parameters viz. sunlight glare on tracks, reaction distance, road driver visibility, age, style, literacy, distraction, impairment and frequency/purpose/compulsion of trip, false warning alarm and queuing delay on approach towards the unmanned railway level crossings. The scope of study is the road driver behaviour on approach towards unmanned railway level crossings and therefore, the prevention of life losses at unmanned railway level crossings. To fulfill these aims, a questionnaire was prepared and road driver survey was conducted on 458 road drivers moving across nineteen road vehicle–train collision prone unmanned railway level crossings on Shahdra-Shamli-Tapri railway route in the Northern region of India. Thereafter, the responses of the road drivers were analyzed. The results suggest that, the developed vehicle collision threat detection and avoidance system helps in masking the negative effect of all road drivers' problems that affect the road drivers approaching the unmanned railway level crossings.

Keywords: Information and Communication Technology, Unmanned railway level crossing, Road driver, Collision, Behaviour, VCTAS

1. Introduction

Indian Railway network constitutes of the railway level crossings, which incorporates an inflow of both rail and road traffic. Further, the crossings have been categorized into two types of railway level crossings viz. Manned and unmanned (with no barriers, gates and gateman).

Indian Railway network (Kumar and Garg, 2014) had approximately18,725 (62%) manned and 11,563 (38%) unmanned railway level crossings. Presently, according to (ABP News (2016)), till July 2016, only 6388 unmanned railway level crossings are left in India and their elimination requires 7500 Crores (approx.) of rupees.

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Therefore, the valid implementation of the vehicle collision avoidance systems will help in avoiding the rail-road collisions in a cost effective and reliable manner at Indian railway level crossings.

2. Past studies on road driver behaviour

Aberg et al. (1988) studied the road driver behaviour by interviewing 2000 road drivers approaching at the railway level crossings The flashing lights were implemented on the level crossings, a large number of road drivers raised their head to view the trains on crossings. Tenkink E. and Horst D.V.R (1990) described the car driver’s behaviour at Dutch railroad grade crossings with automatic flashing warning lights. Out of 900 road drivers, 73% of drivers crossed the red lights and 27% of road drivers passed the white flashing signal. Pickett and Grayson (1996) further analyzed the road driver behaviour at railway level crossings. A questionnaire was used to survey the road drivers approaching the railway level crossings. The result indicated that, a huge number of road drivers crossed the red light in Sunnydale. Only, 56% of drivers had a passing frequency of 200 times over the railway level crossings. Very less share of road drivers i.e. 20% (approx.) remembered the signs. More than 50% of the road drivers understood about the meaning of emitted amber light. Abraham et al. (1998) observed the road driver behaviour at 37 rail-highway crossings of Michigan, U.S.A.,. It resulted in the hypothesis that, the accident data helps in developing the safety measures at rail-highway crossing sites. Moon and Coleman (1999) described the road driver behaviour by measuring the speed on two railway level crossings. The results indicated that, the road drivers decreased their speed when approaching towards the unmanned railway level crossings. Liu and Salvucci (2001) studied and modeled the road driver's behaviour using the Hidden Markov Models (HMM) in the real-time. The study was successful in providing the different scenarios of the road driving conditions based on the driver’s activities viz. steering and acceleration activity done by the road driver. Wigglesworth (2001) studied the road driver behaviour with large number of accidents between road vehicles and trains at railway level crossings in Australia. The flashing lights were not effective for very big cities crossings due to large traffic activities faced by road drivers. The motorcycles accident reduction was observed to be 68% in 20 years. Caird et al. (2002) studied the human behaviour at Canadian railway level crossings. The study was a part of project called “Direction 2006”, which aimed to reduce the highway-railway grade crossing accidents to 50%. Benekohal and Aycin (2004) studied the road driver behaviour by preparing a questionnaire of possible questions about the railroad characteristics and their problems. The survey was conducted on 752 road drivers; who provided their data about the experiences and the problems faced by them. The results indicated that, 47% of drivers felt a higher rate of accidents at level crossing. The railroad crossings were best implemented with the warning system, as felt by 74% drivers approaching the railway level crossing. Approximately, twenty two percent of the road felt the need of the more warning devices. Jeng (2005) studied the road drivers and pedestrians’ behaviour at different types of railway level crossings. The study was conducted to study effectively the different driver perception, driving behaviours and traffic control systems at 1600 railroad crossings of New Jersey, U.S.A. Savage (2006) described about whether the public education may avoid collisions at rail-road collisions. The study discussed about the “Operation Lifesaver (OL) (1970)” by educating the road vehicle users for saving the life at railroad crossings in U.S.A. The OL indicated that –there was a decrement of 15% in road vehicle-train collisions count. Thereafter, the study observed the elasticity to be-0.81, when the active warning devices were implemented. Therefore, it decremented the collisions count, and reduced the fatalities with an elasticity of -1.18. Fuller (2007) studied the road driver behaviour based on the theory of risk homeostasis by Wilde (1981) and the zero risk model by Näätänen and Summala (1974). Therefore, based on the theory and models of road driver behaviour, it was proposed to be a threat-avoidance model. The model also motivated the road drivers for observing the rules and avoid danger of collisions. Savage (2007) described the road user’s behaviour at railroad crossings in U.S.A. The results indicated that, casualties lead to injuries/casualties, which came in the range of age group between 20-30 years. Out of the total road user’s, 90% were adults in the age group of 20-49 years, which were prone to collisions, while 80% of the adults were males. The study also conducted by road user’s behaviour at railroad crossings in U.S.A, Pelletier (1997) found that only 10% of victims were transients, 80% of deaths occurred within the victim's county of residence and 9%-10% of trespassers were homeless. High percentages (80%) of the trespassers were prone to alcoholic/drugs, out of which approximately 57% were loaded with alcohol/drugs and 37% were not found to be druggist/alcoholic. Davey et al. (2008) studied the road behaviour by knowing the experiences of heavy vehicles drivers for judging the problems that may lead to accidents. George (2008) further studied the road driver behaviour for the reduction of the railway level crossing collisions and fatalities. Rilett and Appiah (2008) discussed the countermeasures for the railroad safety at railway level crossings using Variable Message Signs (VMS). The results indicated that, VMS was very much effective in preventing the railroad collisions. Silla and Luoma (2008) studied the road vehicle users crossing the Finnish railway level crossings on the selected sites. The road vehicle users were a given a series of questionnaire to capture the different answers. The road and train driver’s interview results indicated that, fencing of tracks or underpass construction was found to be the most effective countermeasure for the prevention of the collisions at railway level crossings. Wallace (2008) studied the motorist behaviour at railway level crossings in Australia and measured the effectiveness by educating the road drivers. Khattak (2009) studied the distinctions between the drivers’ behaviour at Highway Railway Grade Crossings (HRGCs) in Waverly and Fremont cities of Nebraska. The observation of the study resulted in hazardous behaviour i.e. moving around the gateposts or turning back, till the approaching train clearly passed the railway level crossing. Rys et al. (2009) studied the drivers’ behaviour on the passive STOP warning signs at nine Kansas railway level crossings. The study indicated that, 79% road drivers didn’t stop, 13% completely halted and 8% stopped at STOP signs near the railway level crossings. Therefore, the study recommended to avoid STOP sign that is without proper sight distance evaluation. Beard and Little (2010) developed a tool for risk assessment at Portuguese railway level crossings. It displayed the risk characteristics analyzed on railways elsewhere including the Great Britain, Ireland and Austria. The data analysis by the tool resulted in risk factors having nonlinear relationship of the traffic moment risk. Ghaemi et al. (2010) modeled the road driver behaviour using the hierarchical fuzzy system. The input factors for framing the fuzzy rule base for modeling the driver behaviour used in the study were - climate, road, car conditions, precision, age and driving individuality. Three fuzzy models were created for checking the driver behaviour and decision making. This study says that, these models efficiently may be used to test the effect of influence of parameters, and predict the road driver behaviour of the system. The results were compared for different road drivers based on these models. Green (2010) studied the road driver behaviour at the Cressy railway level crossing, Victoria, Australia situated at Hamilton Highway LX1516. The study was conducted in two situations viz. before and after installation of Advance Warning Signs (AAWS). The data was collected over four week period in both situations. The study resulted in no change in speeds after the installation of AAWS. The result again concluded that, there was no change observed in road vehicle traffic approaching the level crossings and their traffic violations after the installation of AAWS. Lenné et al. (2011a) studied the road driver behaviour at unprotected railway level crossings in Australia implemented with stop signs. The driver study resulted, in the decrease of road vehicle speed when the level crossing were best implemented with flashing lights in comparison to the traffic signals and stop signs. Lenné et al. (2011b) again studied the road driver behaviour at railway level crossings. The methodology of the sudy was the data collection of 23 driver experiences in between the age group of 19-25 years. The output resulted in the better understanding of the road driver behaviour and to identify the factors which may affect the road driver behaviour at railway level crossings. Lindly (2012) studied and altered the road driver behaviour to make Alabama, U.S.A. highway/rail crossings safer from railroad collisions. The study was a part of a project named Federal Aid Project HPPF-AL49 (900). The study analyzed the driver behaviour depending upon the digital images for Quixote (in the country of Spain). Silla and Kalberg (2012) studied the Finnish railway level crossings accidents from year 1959 to 2008. The study shows that, from year 1970 there was a trend in decrease of collisions to 80%. Chantruthai et al. (2013) did the similar analysis of the factors like trip & travel time, fare, user income, education etc. using the multinomial and binary logistic regression model respectively for the commuting high speed train users. Lin et al. (2013) conducted a study by doing a road driver questionnaire conducted on the railway level crossings. The results concluded that, continuous updation of the safety information was to be done. Settasuwacha et al. (2013) described the driver behaviour in Songkhla province of Thailand at 25 highway rail grade crossings having 6 barriers, 2 flashing lights, 4 stop signs and 13 illegal crossings. The study emphasized on the use of warning system to inform the road drivers users about the highway rail grade crossing location, design, social education awareness, cost of accidents and their measures of accident reduction. Horst & Bakker (2014) also described the road users' behaviour at Netherlands railway level crossings.

3. Vehicle Collision Threat Detection and Avoidance System (VCTAS)

The VCTAS flow diagram as shown in Figure 1 is a road vehicle-train collision avoidance system, which alerts the road vehicle by visual awakening about the approaching train. It also gives the audio alert message to the road vehicle in order to provide them safe and easy passage at unmanned railway level crossings. The VCTAS flow diagram as shown in Figure 1 gives the following workflow-

1. GPS location data of client wireless communication sender (Tx) (IP: 192.168.1.254), installed near the track at 0.5 km to 1 km distance from unmanned railway level crossing, receiver wireless communication (Rx) (which also acts as an access point) is placed at unmanned railway level crossing with

(IP: 192.168.1.252). The Rx warning detection point location for road vehicle user is also collected.

2. If approaching train is in clear view of Charged Coupled Devices (CCD) image sensor, placed near track at 0.5 km to 1 km of distance from the unmanned railway level crossing with (IP: 192.168.1.254) then

a. Tx transfers CCD video/image signal to Rx with a propagation delay of 1 second.

b. Rx creates a Wi-Fi zone around the unmanned railway level crossing at a circular radial distance of 107.26-149.62 m from unmanned railway level crossing location.

c. Rx transfers the video/image wireless signal inside Wi-Fi zone.

   a. When the road vehicle approaches the Wi-Fi-Zone created by the Rx-

      i. The video/image wireless signal is received by the approaching road vehicle (car/jeep/van/truck/bus) HMI (laptop with Wi-Fi capability).

      ii. The high frequency wireless signal is also received by the laptop with Wi-Fi capability installed at unmanned railway level crossing (placed for pedestrians/animal drawn/2-wheeler/3-wheeler/cycle/cycle rickshaw truck/auto rickshaw/tractor/tractor-trailer/Jugad).The wireless connection is established (on both HMIs) and thereafter, the Java based web client software is installed automatically.

d. The Java based web client (IP: 192.168.1.18) installed on the road vehicle HMI is logged on by the road vehicle user. Again, another HMI setup at unmanned railway level crossing pre-installed with Java web client software is kept already logged on.

e. Afterwards, the visual awakening of approaching train is seen in web client software page on both HMIs.

f. An audio alert is given by web client software "Kripya dhyan de manav rahit crossing pe train ka aagman hone wala hai, Kripye dur rahe" and is heard continuously.

   Else

   Keep an eye view on the railway track for approaching train near unmanned railway level crossings.

3. End

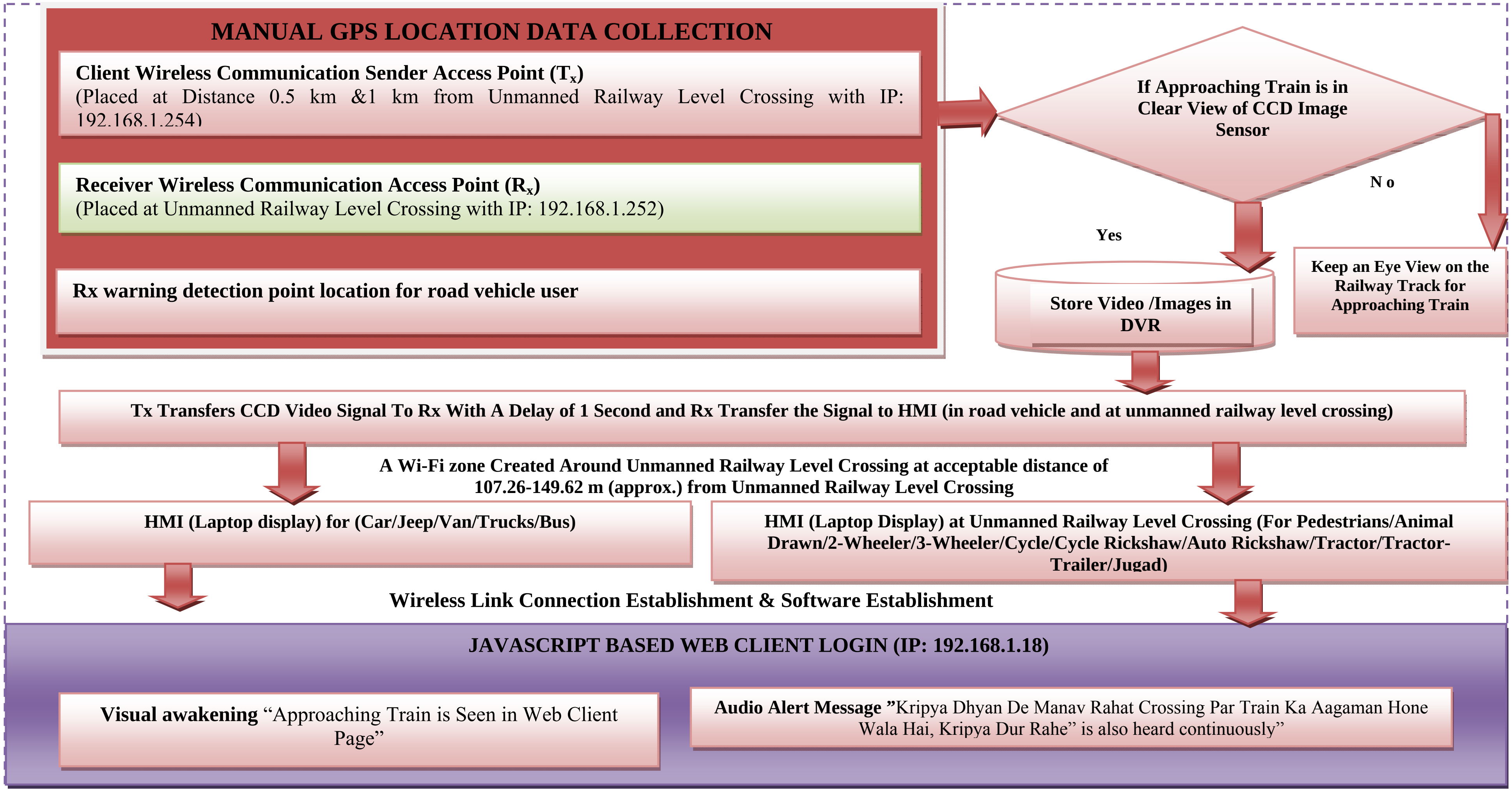

Figure 1: VCTAS Diagram

4. Data collection

The study has been conducted on 19 road vehicle-train collision prone unmanned railway level crossings situated on Shahdra-Shamli-Tapri (DSA-SMQL-TPZ) railway line. The railway connects Shahdra (near Delhi, a metro city in India) through Shamli (a city in State of Uttar Pradesh, India) to Tapri (a town in state of Uttar Pradesh, India). The railway line is about 165 km in length and it has 145 railway level crossings and 71 of them are unmanned railway level crossings. The unmanned railway level crossings on this railway route are situated mostly near rural areas i.e. (approximately 95%). The railway route operation and maintenance is done by Northern Railways (NR), a division of Indian Railways. According to Safety Information Management System (SIMS), the maximum design and booked speed on the DSA-SMQL-TPZ section is 75 km/hr and in foggy conditions the maximum permissible speed of the train is 48 km/hr. (Singhal and Jain, 2015). The study area is shown in Figure 2, which shows blue line as the railway track and yellow pins as the unmanned railway level crossings. Further, the details of the selected road vehicle-train collision prone unmanned railway level crossings are given in Table 1.

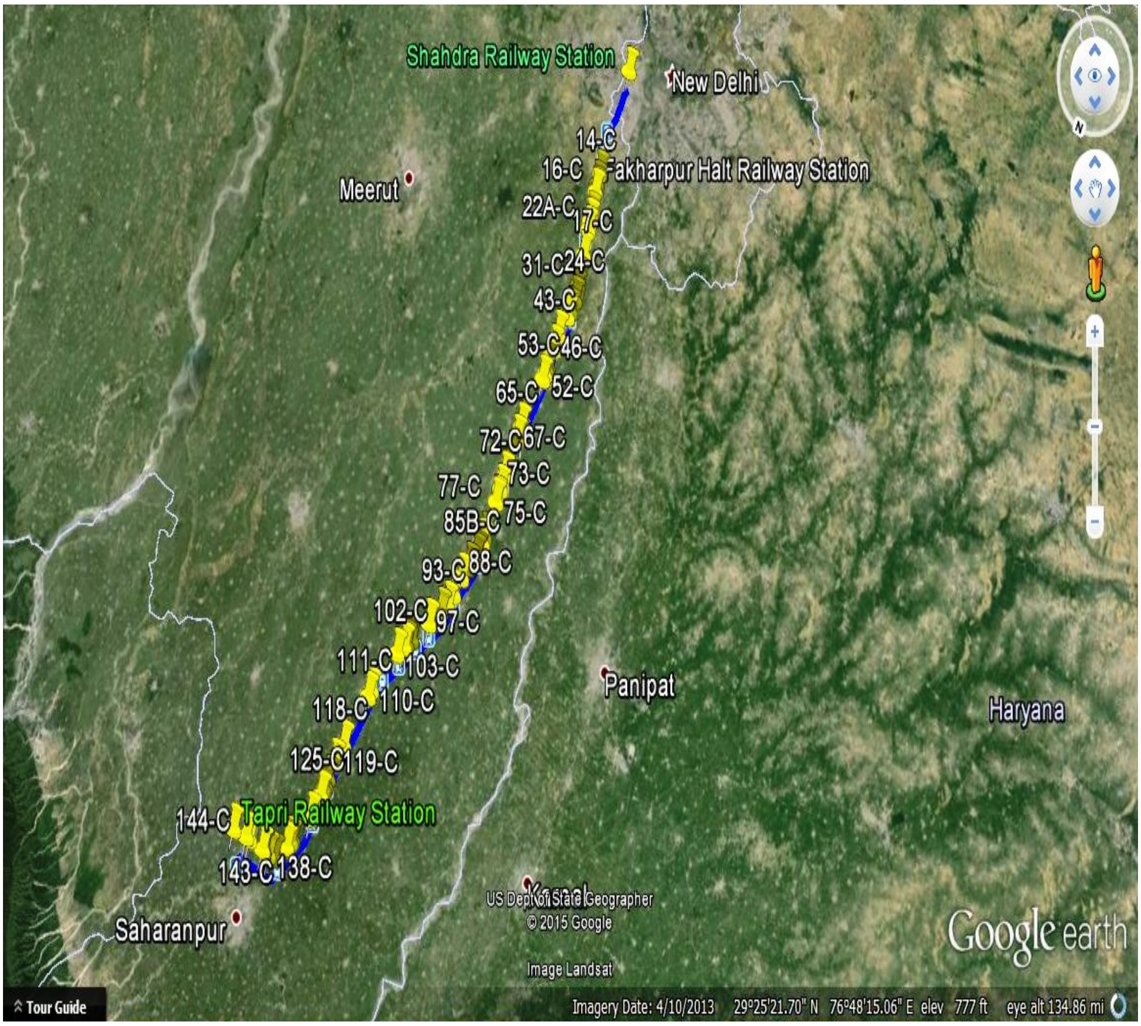

Figure 2: Study Area

Table 1: Details of selected unmanned railway level crossings

S. No.	*Unmanned Railway Level Crossing*	*Road Crossing the Unmanned Railway Level Crossing*			
		Block Section	*Direction1*	*Direction 2*	*Road Length Crossing the Unmanned Railway Level Crossing (in km)*
1	C-14	Noli Delhi-Khekra (NO-KEX)	Gotra/Mandula to Fakharpur	Fakharpur to Gotra/Mandula	3.633
2.	C-16	Noli Delhi-Khekra (NO-KEX)	Khekra to Fakharpur	Fakharpur to Khekra	1.823
3.	C-17	Noli Delhi-Khekra (NO-KEX)	Khekra to Fakharpur	Basi/Khekra to Sunhera	1.823
4.	C-21	Khekra-Baghpat (KEX-BPM)	Sunhera to Basi/Khekra	Basi/Khekra to Sunhera	3.541
5.	C-34	Baraut- Baghpat (BTU-BPM)	Saroorpur Kalan to Gaadhi	Gaadhi to Saroorpur Kalan	4.293
6.	C-35	Baraut- Baghpat (BTU-BPM)	Saroorpur Kalan to Sujra	Sujra to Saroorpur Kalan	3.222
7.	C-43	Baraut- Baghpat (BTU-BPM)	Irdispur to Badka	Irdispur to Badka	1.669
8.	C-50	Baraut-Quasimpur Kheri (BTU-KPKI)	Baoli to Latifpur to Sabha Kheri	Sabha Kheri to Baoli to Latifpur	1.432
9.	C-67	Baraut-Quasimpur Kheri (BTU-KPKI)	Ramala to Budhpur	Budhpur to Ramala	5.356
10.	C-72	Quasimpur Kheri-Kandhla (KPKI-KQL)	SH-57 to Ailum	Ailum to SH-57	0.557
11.	C-82	Kandhla-Shamli (KQL-SMQL)	PanjaKhara to Jasala	Jasala to PanjaKhara	1.135
12.	C-87	Kandhla-Shamli (KQL-SMQL)	Lilion to Balwa	Balwa to Lilion	1.710
13	C-93	Shamli-Heend (SMQL-HID)	Gohrani to Karodi	Karodi to Gohrani	2.7772
14.	C-103	Heend-ThanaBhawan (HID-THBN)	Raseedgarh to Hararfatehpur	Hararfatehpur to Raseedgarh	2.956
15.	C-110	Thanabhwan-Nanauta (THBN-NNX)	Ambeta YakubPur to Jalabad	Jalabad to Ambeta YakubPur	3.448
16.	C-122	Rampur Maniharan-Nanuta (RPMN-NNX)	Tipra to Sambhalkheri	Sambhalkheri to Tipra	2.624
17.	C-133	Rampur maniharan-Manani (RPMN-MNZ)	Jhandera to Nalhera	Nalhera to Jhandera	3.676
18.	C-136	Manani-Tapri (MNZ-TPZ)	Chunneti to NainKhera	NainKhera to Chunneti	2.085
19.	C-140	Manani-Tapri (MNZ-TPZ)	Fatehpur to Mavikhurd	Mavikhurd to Fatehpur	1.023

Further, the road vehicle-train collisions count per 5 years (2009-2013) on the selected road vehicle-train collision prone unmanned railway level crossings is shown in Figure 3.

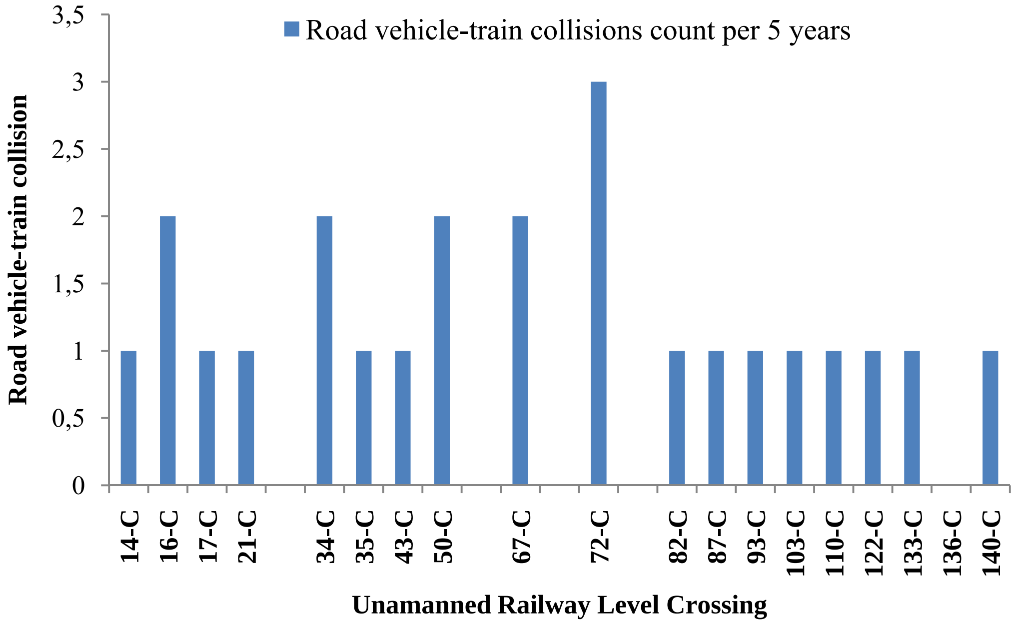

Figure 3: Road vehicle-train collision at unmanned railway level crossing

5. Results and discussions

The results of the road vehicles driver behaviour with or without VCTAS (Appendix-I) are discussed as-

5.1 Effect of sunlight glare on approaching road driver vehicle's behaviour

The effect of sunlight glare on approaching road vehicle's behaviour as shown in Figure 4 is that, 83% (approx.) of lesser road vehicles had a unbearable effect of sunlight glare on the railway tracks, when VCTAS was implemented in comparison to VCTAS non-implemented unmanned railway level crossings. Again, 84% (approx.) of lesser road vehicles were disturbed of sunlight glare imposed on the railway tracks with VCTAS implemented unmanned railway level crossings compared to VCTAS unimplemented unmanned railway level crossings. There is an 8% (approx.) decrement of the road drivers with "just acceptable" sunlight glare to drivers. With VCTAS implemented crossings, 72% (approx.) of total road drivers on VCTAS implemented unmanned railway level crossings were satisfied in comparison to only 3% (approx.) of road drivers only without VCTAS implementation on unmanned railway level crossings. About 67% (approx.) of fewer drivers noticed the sun glare on VCTAS undeployed unmanned railway level crossing in comparison to VCTAS implemented crossings. Table 2 shows that, sunlight glare effect levels on approaching road drivers at unmanned railway level crossings.

Table 2: Sunlight glare effect levels on approaching road drivers

S. No.	*Sunlight Glare Effect Levels On Approaching Road Drivers At Unmanned Railway Level Crossings*	*Levels Numbers*
1	Unbearable	1
2	Disturbing	3
3	Just acceptable	5
4	Satisfactory	7
5	Just noticeable	9

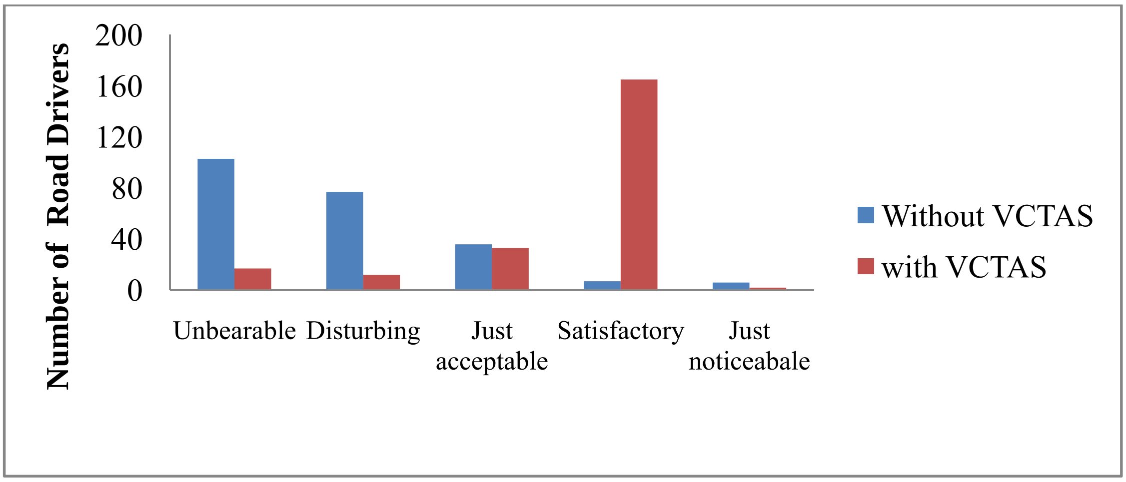

Figure 4: Effect of sunlight angle on approaching road vehicle's behaviour with or without VCTAS

5.2 Effect of reaction distance on approaching road driver vehicle's behaviour

The Figure 5 shows that, reaction distance deviation of road drivers approaching the unmanned railway level crossings to the approaching train with unimplemented and implemented VCTAS unmanned railway level crossings. The reaction of the road drivers with VCTAS implemented unmanned railway level crossings on average occurred at -10.21 (approx.) in comparison to the 45.4 meters (approx.) of unimplemented VCTAS farther to the critical reaction distance (i.e. 128.4 m). As shown in Table 3, the p-value is less than 0.05 and therefore the difference between both conditions is proved to be significant. The negative value indicates, the farther distance (away from unmanned railway level crossing) from the critical reaction distance and positive value indicates the, farther distance (towards unmanned railway level crossing) from the critical reaction distance.

Table 3: t-values and p-values

t-value	*p-value (95% (approx.)confidence interval)*
-16.4319	2.51E-43(<0.05)

The number of road drivers which did not react to the approaching train at unmanned railway level crossings at correct distance is 24 in number without VCTAS and 3 only in number with VCTAS as shown in Figure 6. The difference between them is very high as Chi-Square (χ^2 (1)) = 16.33 and p-value= 0.00005 less than at 95% (approx.) confidence interval where p-value< 0.05. Therefore, it proves that VCTAS implemented unmanned railway level crossing improves the road driver reaction time.

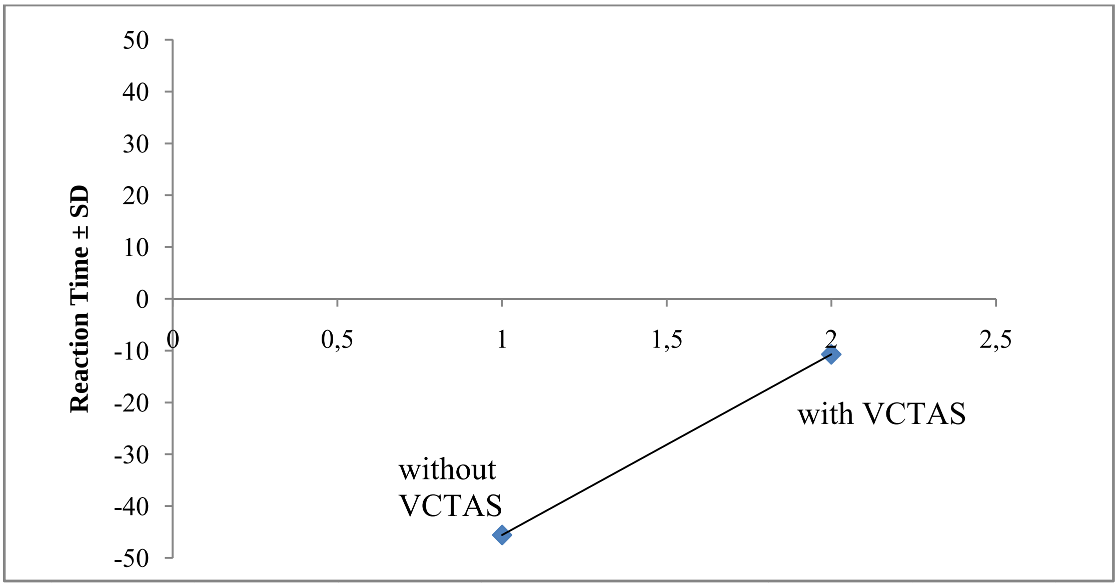

Figure 5: Reaction distance deviation of drivers with approaching train at unmanned railway level crossings (implemented and unimplemented)

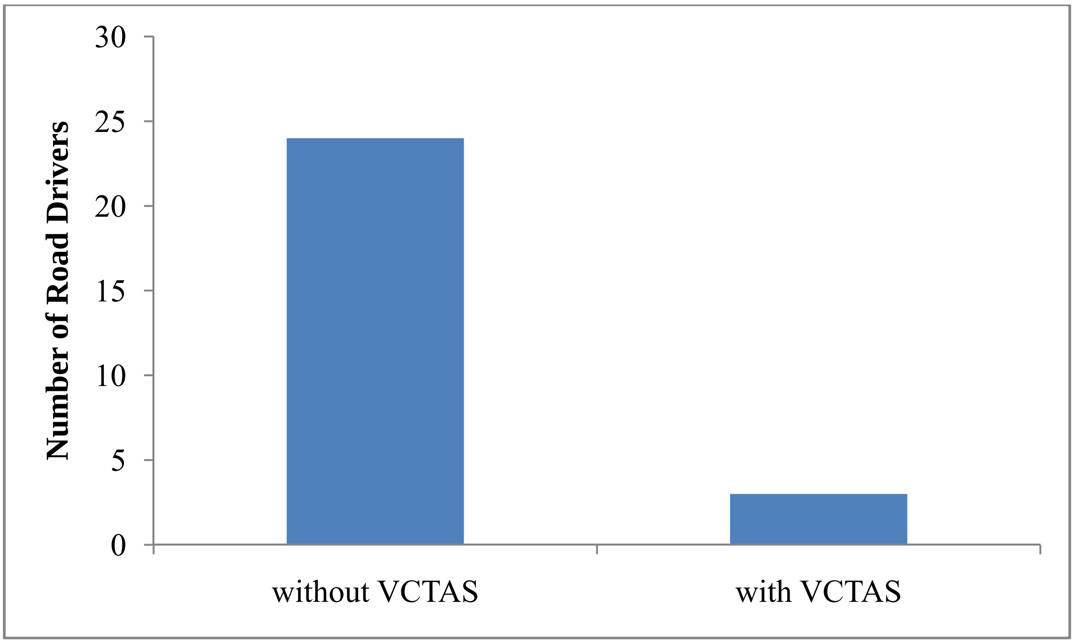

Figure 6: Number of drivers which did not react to approaching train at unmanned railway level crossings (implemented and unimplemented vctas)

5.3 Effect of visibility on approaching road driver vehicle's behaviour

1. Crossing angle based visibility effect on driver behaviour with vs. without VCTAS

The crossing angle effect on driver behaviour is directly dependent on the road driver visibility. Therefore, as the crossing type migrates towards skewing i.e. crossing angle decreases/increases from 90, the road driver visibility for the approaching train also goes down i.e. obstruction increases. Therefore, in this study, the driver view has been classified into three levels and is given in Table 4.

Table 4: Level of road driver view obstruction

S. No.	*Levels of Road Driver View Obstruction*	*Meaning*
1.	Low	Highly obstructive view for the driver to see the train approaching train on unmanned railway level crossings.
2.	Medium	Marginally clear view for the driver to see the train approaching train on unmanned railway level crossings
3.	High	Very clear driver view to see the train approaching train on unmanned railway level crossings.

The study shows that, 97% (approx.) of the additional drivers had a very clear view, when VCTAS is being already implemented on the 19 unmanned railway level crossings in comparison to unimplemented one. The marginal clear view of the approaching train on track increased to 33% (approx.) with VCATS implemented unmanned railway level crossings compared to non-VCTAS unmanned railway level crossings. There is a decrease of 80% (approx.) in the drivers view obstruction on the implementation of VCTAS on unmanned railway level crossings. Therefore, the study signifies that as the road driver could see the approaching train easily in HMI, in most of the cases even if the crossing angle is skewed i.e. acute/obtuse angled.

2. Weather and external Illumination based visibility effect on driver behaviour with vs. without VCTAS

The visibility level as given in Table 5 is done on weather based visibility effect on the road drivers approaching the unmanned railway level crossings. Further, the effect of heavy rainfall and dust on the road drivers has also been studied with VCTAS implemented rail/road crossings. The road visibility is not a concern as the VCTAS gives the audio alert; therefore the driver does not requires to be much concern about the approaching train to be visible. The detection accuracy as shown in Table 5 rises with increase in road visibility from low to high.

Table 5: Weather and external illumination based visibility effect on road driver behaviour with vs. without VCTAS

S. No.	*Number of Drivers With Approaching Train Detection Accuracy (with VCTAS)*	*Heavy Rain*	*Dust*
1.	Low	10%	5%
2.	Medium	17%	12%
3.	High	32%	24%
	Total	59%	41%
S. No.	*Number of Drivers With Approaching Train Detection Accuracy Visible (Without VCTAS)*	*Heavy Rain*	*Dust*
1.	Low	3%	2%
2.	Medium	0%	0%
3.	High	1%	1%
	Total	5%	4%

All the crossings are not illuminated with external lights and therefore, at night the road visibility goes to lowest position. Therefore, only 1% of drivers could only detect the approaching train beforehand. When VCTAS was implemented, audio alert of VCTAS helped in providing 92% of road drivers with accurate approaching train detection at unmanned railway level crossings.

5.4 Effect of age with reaction time on approaching road driver vehicle's behaviour

The road driver age affects the reaction time of the driver directly. To show the effect of the road driver age on the reaction time of driver at unmanned railway level crossing, the reaction time is divided in 3 ranges (0.8-2, 2.3-2 and >3.2) seconds. There is an increase in number of road drivers to 92 % (approx.)in 0.8 sec to 2 sec reaction time range, while there is a decrease in number of road drivers is about 64% (approx.)and 25% (approx.)in 2.3 seconds to 3.2 seconds and greater than 3.2 seconds reaction time range of road drivers respectively. It has also been observed that, VCTAS has been implemented on unmanned railway level crossings, there is vast increase in number of road drivers of age 18-25 and 26-33 years with quick reaction i.e. lied in reaction time range of 0.8 seconds to 2 seconds reaction time range as shown in Figure 7.

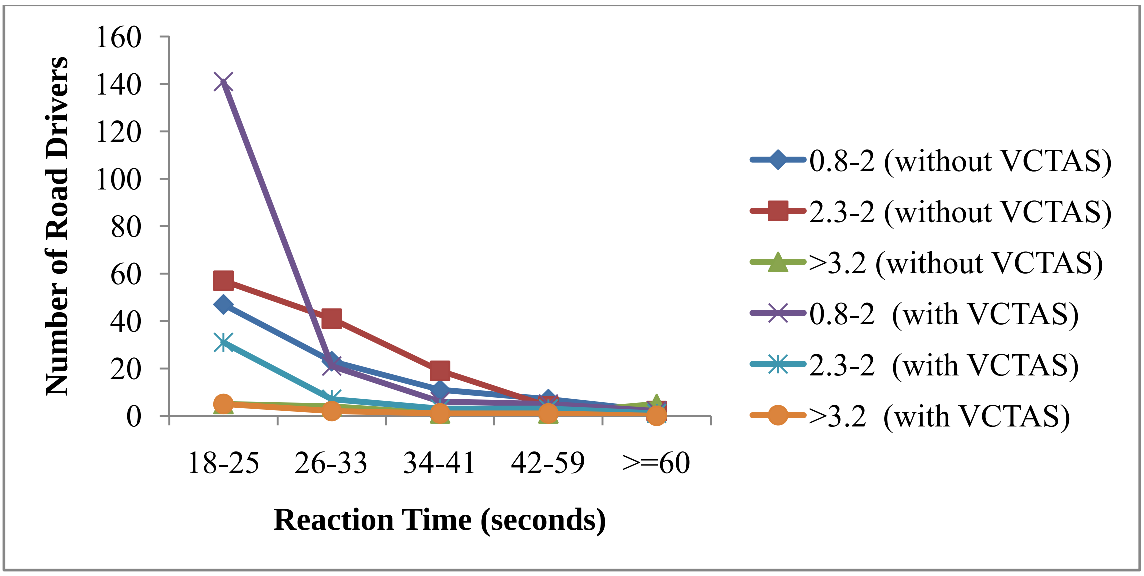

Figure 7: Number of road drivers based on reaction time and age of driver with vs. without VCTAS

5.5 Effect of driving style on approaching road driver vehicle's behaviour

The effect can be shown by defining the styles classification as given in Table 6.

Table 6: Road driving style classification

Driving Style	*Meaning*
Calm driving	When driver easily understands the approaching train easily, surrounding vehicles, stops signs and warning boards, no higher acceleration and fuel efficient
Normal driving	Controlled acceleration and less efficient
Aggressive Driving	Very urgent braking and least fuel efficient
No speed	Vehicle is stationary

The Figure 8 shows the results when VCTAS is being implemented on unmanned railway level crossings and shows that, road driver with calm driving behaviour increased by 74 in number, while the normal road driving behaviour also increased by 41%. The aggressive driving in turn decreased to 70% , therefore, safety increases with ease of driving as the alert is given by the VCTAS earlier to avoid collision with approaching train at unmanned railway level crossings.

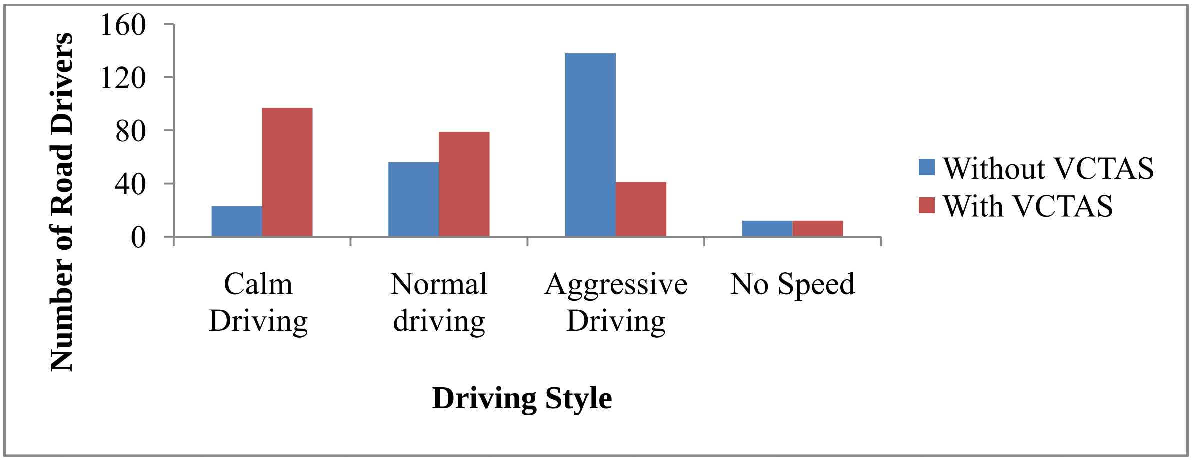

Figure 8: Road driving style with respect to number of road drivers

5.6 Effect of literacy on approaching road driver vehicle's behaviour

1. The road driver compositions observed on 19 unmanned railway level crossings have been observed to be 79% illiterate and only 21% are being observed to be the literate.
2. The effect of literacy on the road driver behaviour is that even out of 21% literate drivers, only 11% literate drivers are able to read and understand the instructions and warning sign boards about train danger at unmanned level crossing without the presence of VCTAS. The implementation of VCTAS has a positive effect to literacy point of view, in the sense that road drivers which are not able to read or view the warnings and warning sign boards, the VCTAS helped the illiterate people by giving the audio alert message to inform about the approaching train danger at unmanned railway level crossings.
3. Therefore, after the implementation of VCTAS, both 87% of the combined total literate and illiterate people could hear the warning easily.

5.7 Effect of level of driving experience on approaching road driver vehicle's behaviour

The composition of number of drivers with different driving experience levels of number of drivers are shown in Figure 9-

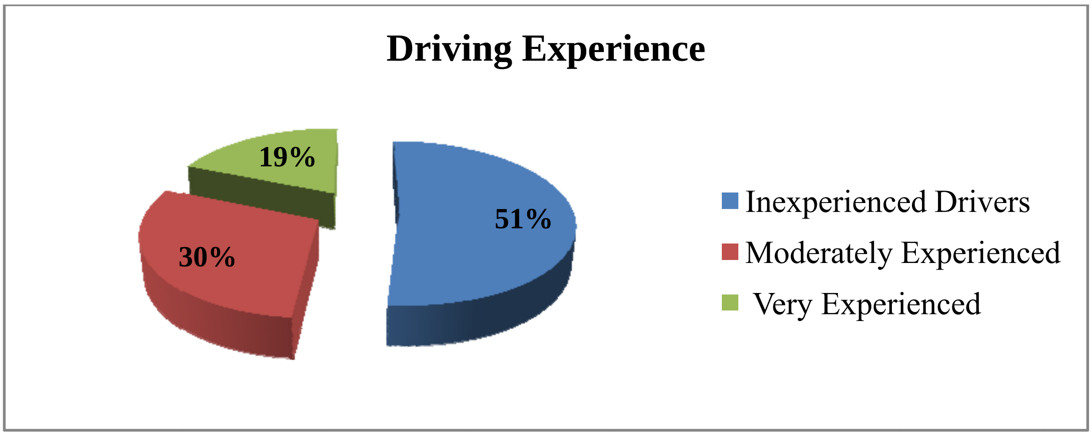

Figure 9: Level of driving experience

The effects on the driving behaviour of the road driver experience at the VCTAS implemented unmanned railway level crossings are as follows-

1. Out of all inexperienced drivers, approximately only 5.93% inexperienced drivers have been able to detect the approaching train audio alert in comparison to the 83% of road drivers with VCTAS implemented unmanned railway level crossings.

2. 82% of road drivers from moderately experienced drivers are able to know about the approaching train audio alert with VCTAS enabled crossings, and when it is compared with the unmanned railway level crossings without VCTAS only 33.82% of the road drivers were able to judge the train.

3. With VCTAS implementation on unmanned railway level crossings a small difference arises in the case of very experienced drivers with a marginal rise of 8% (approx.) of more road drivers are able to detect the approaching train compared to non-VCTAS implemented unmanned railway level crossings.

5.8 Effect of distraction on approaching road driver vehicle's behaviour

The effect of driver distraction on driver behaviour with vs. without VCTAS is given below:

1. 72.1% of the road drivers are being distracted without VCTAS and 6.6% of road drivers are being distracted with VCTAS implemented on 19 unmanned railway level crossings on Shahdra-Shamli-Tapri railway route.
2. On average, 73% (approx.) of the road vehicle-train collision prone unmanned railway level crossings have the highest rate of driver distraction without VCTAS implementation. Approximately, 5.2% of the crossings are observed to have the higher rate of driver distraction even on the implementation of VCTAS. As a result, a decrease of 93% of the road vehicle distraction is achieved.

5.9 Effect of impairment on approaching road driver vehicle's behaviour

The effect of impairment (alcoholic/fatigue/drugs) of drivers crossing the unmanned railway level crossings on road driver behaviour with and without VCTAS as shown in Figure 10-

1. The effect of VCTAS on alcoholic drivers on road driver behaviour is that 28.57% of more alcoholic drivers are able to detect the train when VCTAS is implemented.
2. The effect of VCTAS on road drivers with fatigueless is that 50% of more fatigue prone drivers are able to detect the train when VCTAS is implemented.
3. The VCTAS effect on normal road drivers is 56.88 % of more normal drivers are able to detect the train when VCTAS is implemented.

As there were no druggist road drivers observed on the 91 unmanned railway level crossings, therefore no change in driver behaviour is being observed.

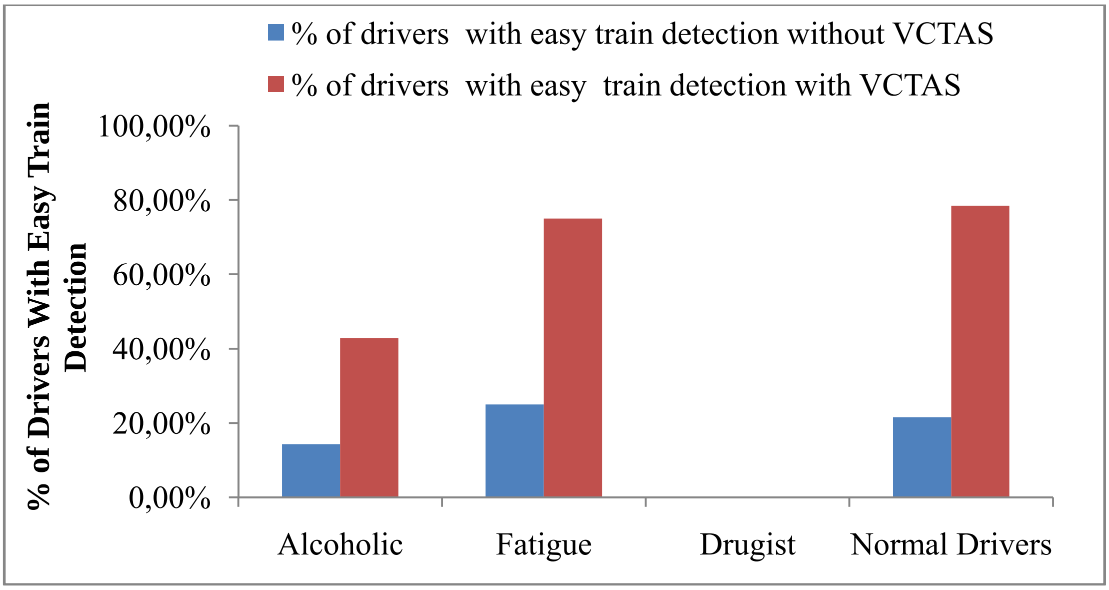

Figure 10: Effect of impairment on road driver behaviour with vs. without VCTAS

5.10 Effect of frequency, purpose and compulsion of trip on approaching road driver vehicle's behaviour

The frequency of trip on road driver behaviour on all selected unmanned railway level crossings is divided on four types and shown in Table 7 are given below-

Table 7: Classification of frequency of trip

S. No.	*Frequency of trip*
1.	First time
2.	< 5 times/day
3.	> 5times/day
4.	Monthly
5.	Weekly

The effect of the trip frequency on the driver behaviour, with or without VCTAS is shown in Figure 11. There is no change in first time, monthly and weekly frequency of trip on road driver behaviour, but there is significant increase of 55% of drivers which traverse the unmanned railway level crossings greater than 5 times/day. Therefore, a significant decrease i.e. 42% of lesser road drivers visiting and trying to cross the unmanned railway level crossings less than 5 times/day have been observed, when VCTAS is being implemented on the unmanned railway level crossings.

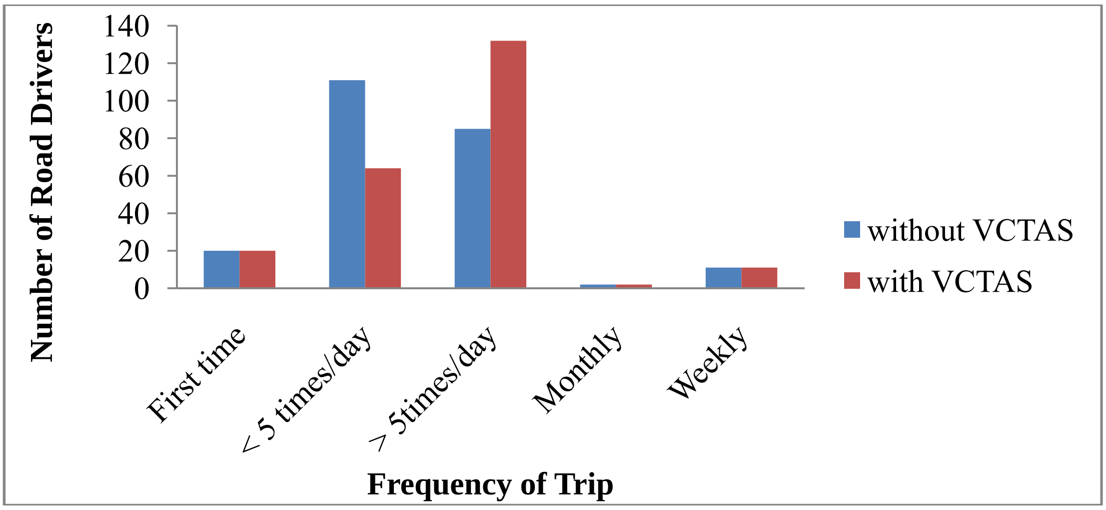

Figure 11: Frequency of trip with respect to number of road drivers

The composition of number of road drivers with work, leisure and other purpose of trip is shown in Figure 12. The highest trip observed for road drivers go for work from one village to other, for this reason they had to cross the unmanned railway level crossing daily. There has been no change observed in the purpose and compulsion of the trip in both situations i.e. with or without VCTAS implementation on unmanned railway level crossings.

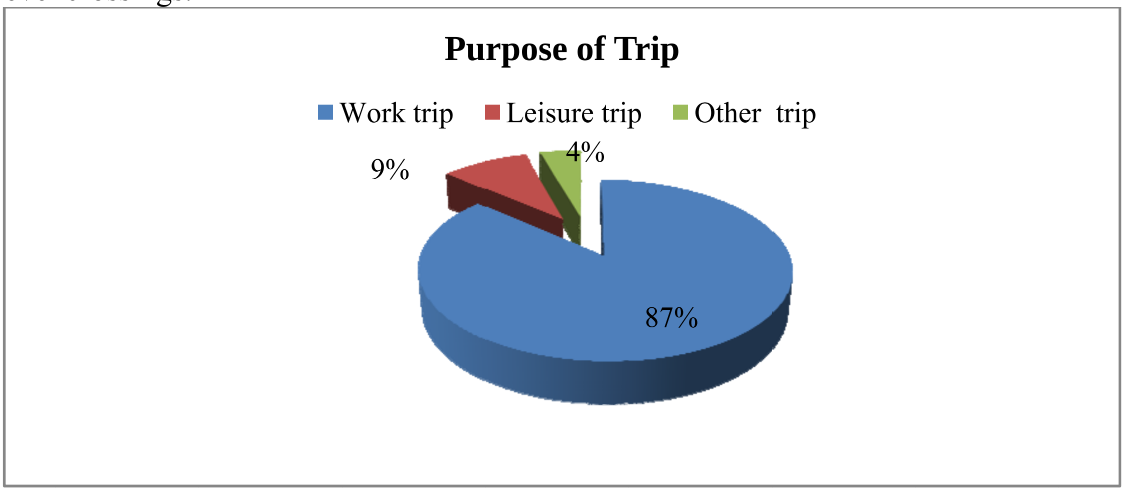

Figure 12: Composition of number of road drivers with work, leisure and other purpose of trip

5.11 Effect of false warning alarm on approaching road driver vehicle's behaviour

The number of road drivers facing the false warning of the approaching train decreased by 63% on implementation of the VCTAS on unmanned railway level crossings in comparison to the non-VCTAS unmanned railway level crossings as shown in Figure 13.

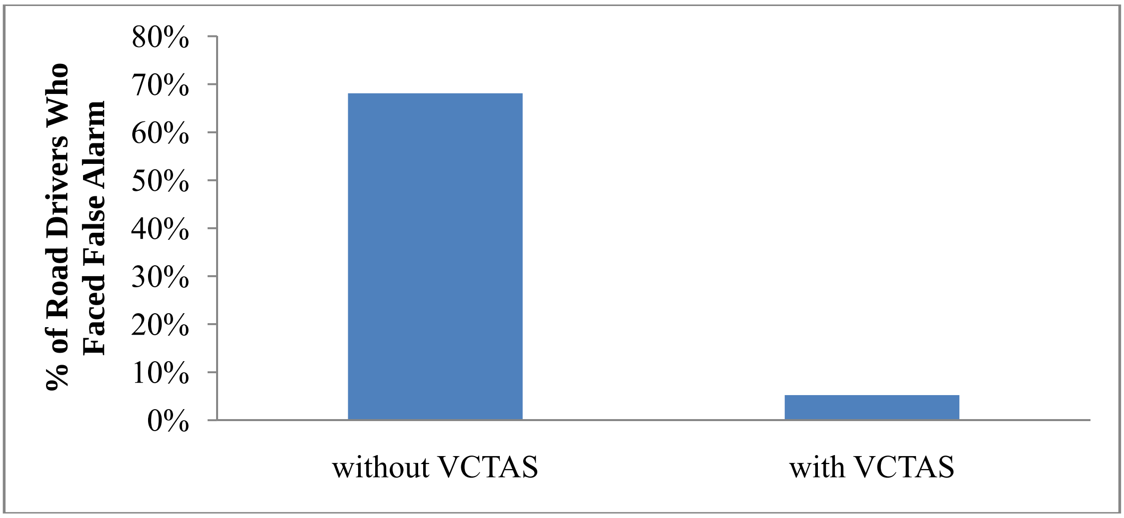

Figure 13: False warning alarm with respect to road drivers facing false alarm

5.12 Effect of queuing delay on approaching road vehicle's behaviour

The queuing delay to the road driver has a consequence effect on the trips observed on the route crossing unmanned railway level crossings. The number of road vehicles standing in a queue and facing the delay decreased to 98% with VCTAS implementation on the unmanned railway level crossings is shown in Figure 14.

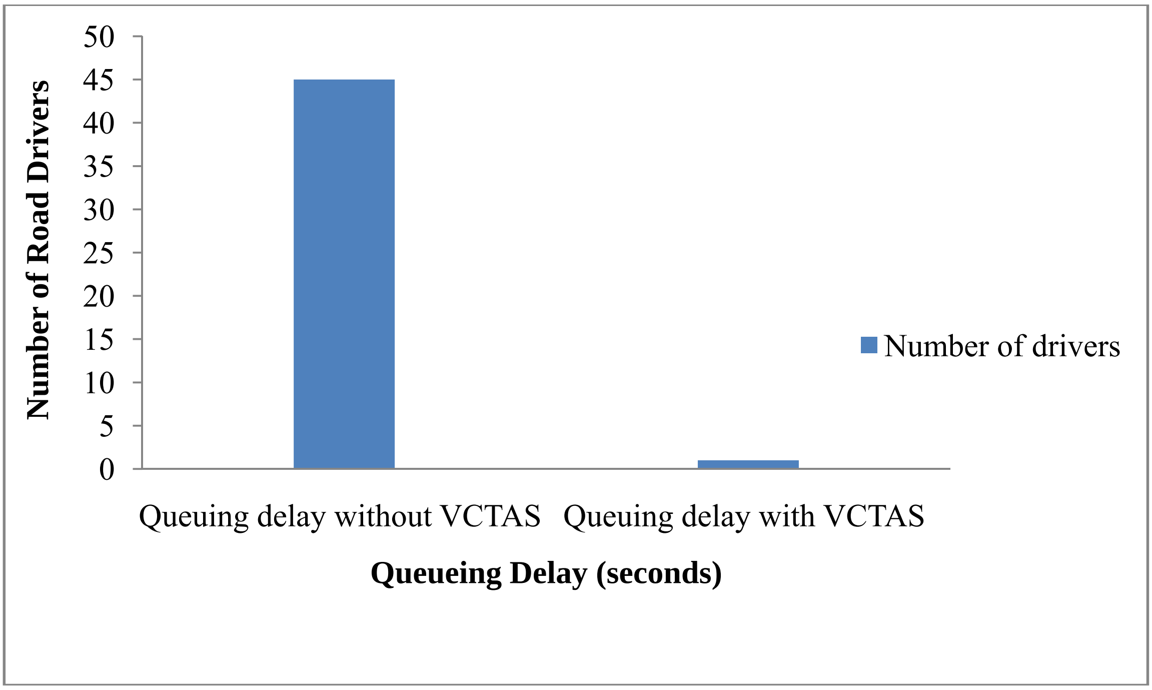

Figure 14: Queuing of drivers vs. number of drivers

6. Conclusions

A vehicle collision threat detection and avoidance system viz. VCTAS has been developed for avoiding road vehicle-train collision at unmanned railway level crossings. The study has been conducted on 458 road drivers approaching the unmanned railway level crossings on Shahdra-Shamli-Tapri railway route. The driver behavior is being observed in terms of road user personal, driving style, unmanned railway level crossing, characteristics, VCTAS warning system, environmental characteristics.

The road driver behaviour analysis on implementation of VCTAS at unmanned railway level crossings resulted in improvement of sunlight glare effect, reaction distance, visibility, age, driving style, literacy, level of driving experience, distraction, impairment, purpose of trip, frequency of trip, compulsion of trip, false warning alarm effect and queuing delay .

Therefore, the road driver behavior improvement with VCTAS may help in avoiding the life losses due to vehicle-train collisions at unmanned railway level crossings.

For further work, it is suggested to study the driver behaviour for different types of vehicles with VCTAS at unmanned railway level crossings.

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Appendix-I

Road Driver Behavior at Unmanned Railway Level Crossing (n=229-without VCTAS and n=229- with VCTAS)

My Reaction Time on Approach Towards the Unmanned Railway Level Crossings					
	18-25 (years) percent	26-33 (years) percent	34-41 (years) percent	42-51 (years) percent	greater than 60 years (%)
road drivers without VCTAS					
0.8-2 (seconds)	52%	26%	12%	8%	2%
2 - 2.3(seconds)	46%	33%	15%	3%	2%
over 3.2 (seconds)	25%	9%	65%	0%	31%
road drivers with VCTAS					
0.8-2 (seconds)	81%	12%	3%	3%	1%
2-2.3(seconds)	69%	16%	7%	7%	2%
>3.2(seconds)	56%	22%	11%	11%	0%

My Reaction Distance on Approach Towards the Unmanned Railway Level Crossings	
road drivers without VCTAS	road drivers with VCTAS
10%	1%

My Driving Style at Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
calm	10%	42%
normal	25%	35%
aggressive	60%	18%
no speed	5%	5%

My Driving Experience at Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
inexperienced	5.93%	83%
moderately experienced	33.82%	82%
very experienced	88.37%	95%

My Distraction at Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
distraction	47%	5%

My Impairment at Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
alcoholic	14.29%	42.86 %
fatigue	25%	75 %
Druggist	0%	0 %
normal	21.56%	78.5%
My Frequency of Trips at Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
first time	9%	9%
< 5 times/day	48%	28%
> 5times/day	37%	57%
Monthly	1%	1%
Weekly	5%	5%
My Purpose of Trips at Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
work trip	87%	61%
leisure trip	9%	9%
other trip	4%	30%
My Literacy and Whether I get the Warning on Approach Towards the Unmanned Railway Level Crossings		
	road drivers read or view warning sign boards	road drivers got warning after VCTAS
illiterate	0%	91%
literate	89%	72%
Whether I am Delayed Due to Wait in Queue on Approach Towards the Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS

delay	2%	98%
Did I Got False Alarm on Approach Towards the Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
false alarm	10%	5%
My Visibility on Approach Towards Skewed Crossing Angled Unmanned Railway Level Crossings		
	road drivers without VCTAS	road drivers with VCTAS
low	53%	10%
medium	5%	7%
high	42%	83%
My Train Detection Ease Based on Weather and External Illumination Visibility		
	road drivers without VCTAS	road drivers with VCTAS
train detection ease	1%	92%
Do I Feel Sunlight Glare on the Tracks When Crossing the Unmanned Railway Level Crossing		
	road drivers without VCTAS	road drivers with VCTAS
unbearable	45%	8%
disturbing	34%	5%
just acceptable	16%	14%
satisfactory	3%	72%
just noticeable	2%	1%