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Road Traffic Induced Noise Pollution Modelling and Fuel Emission Analysis at Rail-Road Crossings

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Abstract— The railway crossings force both road traffic and trains to reduce their speed, increasing travel time, congestion and decreasing overall efficiency of the rail network. The main problems affected by such intersections are delay, poisonous gas emissions and the noise pollution from road traffic. The aim of this study is to find the delay and environmental impact of the major level crossings of Thrissur city. During the passage of train along the level crossings, the gates will be closed. This may lead to long time delay to the road traffic. Almost all the vehicles do not turn off their engines for the entire block time which will cause increased emissions of pollutants. Also, the poisonous gas emission will be very high due to slower speed and stop & go situation of vehicles. Emissions not only affect the passengers and riders, but also have severe effect on people living close to level crossing junctions. Along with air pollution there is a large amount of noise produced both from train and the road traffic. Also there will be a large amount of fuel consumption which will further cause extra fuel cost.The sound pollution were measured using Sound level meter. These air and noise pollution will be a great concern in terms of environmental pollution. So it is important to model for road traffic induced noise pollution at rail-road crossings. Also the delay analysis at these level crossings need to be done. According to results obtained, suitable solutions have been proposed to reduce delay and pollution at the level crossings.

Index Terms— Block Time, Delay, Emission, Gate closing, Noise Pollution, Railway Crossing, Road Traffic.

1 Introduction

The road traffic population is increasing over the years making travel very difficult in terms of driving comfort, travel time, tiredness and pollution. When a road and railway line meets a rail-road intersection or commonly called Level Crossing appears. At these intersections long delay may occur to the road traffic. The main reason for the traffic delay is due to the closing of gates at the level crossing for the passage of train. The delay occur not only due to train occurrences but also it varies based on the road condition, track condition, width of road, presence of shoulders and land use pattern. The road vehicles will experience a great loss of time and fuel due to congestion, delay and accidents. It will also cause loss of money due to fuel loss. Level crossings are responsible for economic losses, emission of harmful gases, and increase in accident risks for roadway traffic. Delay time is such that the cost incurred on travel time loss is greater as it includes travel time cost. The delay presents direct cost of fuel consumption and indirect cost of time lost to motorists.

Noise pollution is also a great problem of these intersections. The noise may be due to both the road traffic and train traffic. But the main noise generate from the road traffic after the gate opening. The vehicles will raise their engines to its maximum to indicate their urgency to pass the intersection. The major factors influencing the generation of noise due to railways are Frequency of Trains, Speed of Trains, Nature of Railway Track, Intensity of Horn and many more Noise pollution has become major concern for communities living near the rail-road crossings. Considering the sudden increase in the number of trains and road traffic there is rapid growth and illness effect due to noise pollution. So it is important to model for noise pollution at rail-road crossing for the road traffic.

The economic loss is mainly concerned about the extra fuel cost. When vehicles are waiting for a 'GO' signal, the drivers normally keep the engines of their vehicles "ON" and these result in extra fuel consumption. Though the amount of consumption by one vehicle is not mentionable as less fuel is required at lower speed but, aggregation of fuel consumption by all the waited vehicle cause the quantity become very high. The fuel consumption of vehicle is increasing day by day as a result of enhanced trip lengths, personal mode of transport and congested traffic condition. The extra fuel cost is derived from delay. When delay time increases, fuel consumption and fuel cost also increases.

The traffic waiting at the rail-road crossings during the gate closure cause emission of high amount of harmful gases which results in air pollution. These air pollution have many negative effects on environment as well as human beings. In this paper the emission rate of different gases from different vehicles were found out by collecting the traffic volume at rail-road crossing during the time of gate closure and it is multiplied with the emission factors.

2 Objectives

- To model for noise pollution created by road traffic at rail-road crossings
- Find the poisonous gas emission from the road traffic due to the idling at rail-road crossings
- To find the fuel consumption and extra fuel cost from the road traffic due to idling condition
- Suggest mitigation measures

3 Literature Review

According to Swarna Bintay Kadir and et.al "Vehicle operating cost and environmrental cost for delay at major railroad intersections of Dhaka city" the delay due to level crossings cause extra fuel cost and the fuel consumption amount will be very high when fuel consumption by all the waited vehicles is taken. The cost of fuel consumed in congestion time may depend on fuel consumption of each type of vehicle, volume of vehicles idling at intersection, idling time and unit price of fuel. The poisonous gas emission from road traffic can be found out using classified volume count and emission factor used for different types of vehicles.

In "Vehicle emissions and traffic measures:exploratory analysis of field observations at signalized arterials" by Nagui M. Rouphail explains that The emission of vehicle pollutants into the atmosphere is an increasingly important health issue that affects nearly everyone. Vehicle emissions account for approximately one-half of total Hydro Carbon emissions, one-half of total Nitric Oxide emissions, and two-thirds of total Carbon Monoxide emissions. Thus, a direct link can be seen between vehicle emissions and societal health.

"Impacts of rail-road crossings: international synthesis and research gaps" by Chris De Gruyter tells that Air quality impacts of rail-road crossings are generally expressed in terms of pollutant emissions from vehicles which can substantially increase during times of idling while a train is passing. Pollutants include carbon monoxide, carbon dioxide, hydrocarbons, volatile organic compounds (VOCs) and nitrogen oxide. Pollutant emissions were estimated by applying default conversion rates to vehicle traffic data available for the rail-road crossings. Rail-road crossings can result in noise associated with general traffic (e.g. stop-start conditions, crossing roughness) and the sounding of train horns. Noise levels associated with rail-road crossings can be quantitatively assessed through the use of nomographs, which can be used to predict highway traffic noise under different conditions. An assumption is that the worst noise impact is likely to be associated with a rail overpass (where noise from trains is likely to be spread over a wide area) while the greatest potential for noise reduction is with a rail underpass.

Anurag V. Tiwari and et.al studied "Noise pollution due to railway and vehicular traffic at level crossing and its remedial measures" and explained, noise is one of the environmental problem that un-comforts in daily life. Noise pollution has become major concern for communities living within the city. The noise of train as well as the road traffic is increasing due to increase in the number of vehicles in road and also due the increase in train frequency. The noise pollution can be controlled at the source of generation itself by reducing the noise levels from domestic sectors, Maintenance of automobiles, Control over vibrations, Low voice speaking, Prohibition on usage of loud speakers and optimum selection of machinery, tools or equipment reduces excess noise levels.

4 Project Description

The study locations where situated in the Thrissur district of Kerala State. In Thrissur district itself there are 40 rail-road crossings. Many of the crossings are closed recently due to the construction of over bridge near it. Most of the rail-road crossings are having heavy traffic. A total of 20 rail-road crossings were selected for selected from Thrissur district. 7 crossings are from Thrissur - Chalakudy direction, 9 crossings are from Thrissur - Shornur direction and 4 crossings are in Thrissur - Guruvayur direction.

Traffic volume survey and sound level survey were conducted. And also train frequency, closing and opening time of gate were noted. The survey was conducted during morning and evening peak hours.

5 Data Collection

For noise pollution modelling the data collected include sound level data. The data was collected by using a sound level meter which gives the minimum, average and maximum noise recorded by that meter. It also provide a graph of the sound for every 30second time. The gate closing time, gate opening time, time when the train passes, block time, queue clearing time, road condition and land-use pattern were noted. From this data the noise at the time of train passing and noise at the time of traffic passing after gate opening can be obtained. A large noise will be produced after the gate opening due to the rush of drivers to go as fast as possible. Central Pollution Control Board has noise limits for different places. So by using that we can find whether that rail-road crossing is producing noise pollution or not. And a model can be developed. The above mentioned variables can be considered for noise pollution modelling due to road vehicle at rail-road crossings.

To find air pollution due to the emission of poisonous gases from different types of vehicles data such as classified traffic volume count and emission factors for different gases for different types of vehicles were collected. The classified volume count were collected during the time of gate closure. On morning and evening peak hours the volume count of traffic waiting on both sides of the railway gate were counted manually. Almost all the vehicles are not turning off their vehicles while waiting at the crossings. So the emission rate will be very large. Also at the time of gate opening all the vehicles will raise their vehicles to pass the crossing as early as possible to compensate their time loss. At that time also a large amount of harmful gases get emitted from the road vehicles which in turn causes serious air pollution problems. Multiplying the number of vehicles with emission factor of each gases for different vehicles gives the emission rate. By comparing that emission rate with the standard values of emission given by Central Pollution Control Board (CPCB) we can know whether the air pollution level at that rail-road crossing is within the limits. Since most of the rail-road crossings are situated in residential area and also near schools the air quality index of that region will have great importance in terms of air pollution.

Due to delay the whole vehicle will wait at the intersection

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and most of the road traffic drivers will not turn of their engines. This will cause a great loss of fuel and cause extra fuel cost. So the rail-road crossings also contribute to economic losses.

The data required for delay analysis were collected from all the selected level crossings. A field survey was conducted to find out the basic details such as road condition, track condition, road width, shoulder width, number of tracks, track angle and land use pattern. Classified traffic volume count, gate closing time, gate opening time, queue clearing time and the delay were found out by noting the time taken by vehicles to pass a particular point during normal flow and during gate closing time were noted.

6 Methodology

In noise pollution modelling, the collected data were analyzed and the variables having high correlation with noise level is taken. The noise level is standardized by finding the equivalent noise level from the time of gate opening till the queue clearing time. The equivalent noise level is found out using the equation 1.

$$L_{equ} = 10 \log10 (10 \wedge (Li/10)*t1)) \quad (1)$$

Where,
L equ = Equivalent noise level
Li = Sound level for a particular time duration
t1 = Time duration for Li dB of sound

For noise pollution modelling the data collected were analysed and the variables having high correlation with equivalent noise level at level crossings were found out by doing correlation in SPSS software. The noise pollution model was developed using the two-third data collected. Model was based on the correlated variables and the developed model was validated using the remaining one-third data.

In air pollution analysis, the emission from road traffic at each level crossing were calculated. For this classified volume count of road traffic were noted. The emission factor required for calculating emission were taken from the study done by Central Pollution Control Board (CPCB) along with Automotive Research Association of India (ARAI) as a part of Indian Clean Air Programme (ICAP). The emission factor taken for different vehicles is shown in Table 1.

TABLE 1
Emission Factors

Vehicle type	CO (g/km)	HC (g/km)	NOx (g/km)	CO_2 (g/km)	PM (g/km)	Total (g/km)
Two Wheeler	0.72	0.52	0.15	45.6	0.013	47.003
Three Wheeler	2.29	0.77	0.53	73.8	0.015	77.405
Car	0.84	0.12	0.09	172.95	0.002	174.002
Light Motor Vehicle	3.66	1.35	2.12	401.25	0.475	408.855
Heavy Duty Vehicle	6	0.37	9.3	762.39	1.24	779.3
Bus	3.92	3.75	6.21	806.5	0.044	820.424

The fuel consumed by a single vehicle will be negligible while the fuel consumed by the whole vehicle waiting at an intersection will be very large. The idling fuel consumption for different types of vehicles from Central Road Research Institute (CRRI) is given in Table 2.

TABLE 2
Fuel Consumption Of Different Types Of Vehicles

Vehicle type	Fuel Consumption (ml/hr)	Type of fuel
Two wheeler	197	Petrol
Three wheeler	677	Diesel
Car	706	Petrol
Car	649	Diesel
Light commercial vehicle	690	Diesel
Heavy duty vehicle	920	Diesel
Bus	930	Diesel

The total fuel consumption is obtained by multiplying the idling time with fuel consumption and number of vehicles. From the survey it was found that all the two wheelers are petrol driven while the cars are almost half-half. And all the remaining types of vehicles are diesel driven.

7 Noise Pollution Modelling At Rail-Road Crossings

The two main sources of noise pollution at level crossings are train and road traffic. Train sound already produce noise pollution, apart from it the noise from road traffic during the opening of gate after the train passing is a great concern. A large amount of noise is produced by road traffic from their raising sound due their urgency in going from the blockage and compensating the lost time. The noise from train and road traffic is recorded by using sound level meter. The noise level is noted especially at the time of train passing and during traffic passing from the time of gate opening till the road traffic become normal. A graph is drawn between train noise and road traffic noise for 20 level crossings. From graph it is clear that road traffic noise is more than train noise. The graph between train noise and traffic noise is shown in figure 1. There are many factors that affect the noise pollution level. The factors include duration of gate closure, road condition, traffic volume, land-use pattern etc.

7.1 Pollution Modelling

The noise pollution modelling was done using SPSS software (Statistical Package for Social Science). The correlation between the variables were found out from the correlation matrix and significant variables were selected for modelling. According to the correlation matrix the significant variables are queue clearing time and land-use pattern. Linear regression model is preferred for pollution modelling in which equivalent noise level is taken as dependent variable and the significant variables were taken as independent variables. The best fit model was selected based on the R2 value, t-test values and significance values. The obtained model is shown in equation 2.

$$Lequ = 54.21 + 2.36*(t_{qc})^{(4/5)} + 0.303*(ld)^2 \quad (2)$$

Where,
Lequ = Equivalent noise level of road traffic after gate opening
t_{qc} = gate opening time to time of normal flow
ld = land-use pattern

7.2 Model Validation

From a total of 271 data collected, the analysis is performed by taking 181 samples and remaining 90 samples were taken for validation. The data is valid based on the RMS value.

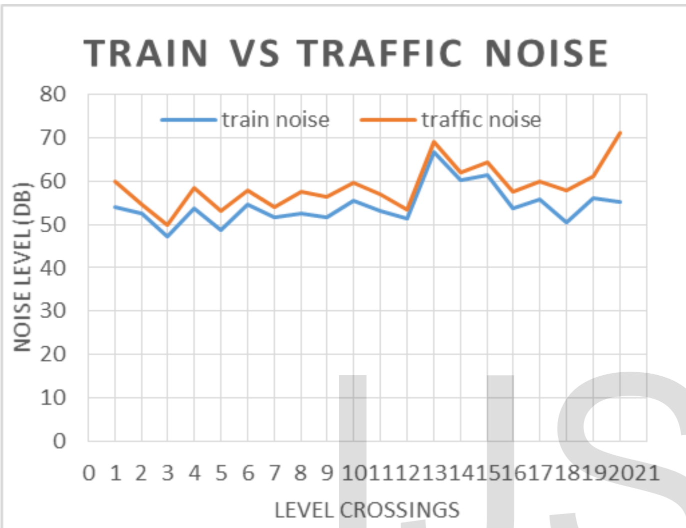

FIG. 1 TRAIN SOUND VS. TRAFFIC SOUND VARIATION

8 Emission Analysis At Level Crossings

The emission of vehicle pollutants into the atmosphere is an increasingly important health issue that affects nearly everyone. Vehicle emissions account for approximately one-half of total Hydro Carbon emissions, one-half of total Nitric Oxide emissions, and two-thirds of total Carbon Monoxide emissions. Large amount of harmful gases are emitted from the vehicles waiting in the queue during the closing period of level crossing gates. The gate closing at level crossings for the passage of train causes the road traffic to wait for a long time. This idling of vehicles at level crossing result in the emission of a large amount of poisonous gases into the atmosphere. The emitted gases were very dangerous to both the environment and human beings. The quantity of gas emission from each vehicle may not be mentionable but the emission from all the vehicles idling at level crossing will be very high. Emissions not only effect on passengers and riders but also it effect severely on the people living close to the level crossing junctions. There are emission factors published by CPCB which include the amount of different types of gases emitted from different types of vehicles, expressed in gram/kilometre. The emission factor of each gas is added up to find the total emission factor. Then the factor is multiplied with the classified volume count and the total emission at each level crossing were calculated. The classified volume count during gate closure of 20 intersection were shown in Table 3.

The emission factor for each vehicle was already given in Table 1. So by multiplying the total emission factor and the volume the total emission at each level crossing can be found out. The total emission in g/km at each level crossing is given in Table 4.

From the table it was clear that a large amount of poisonous gases were emitted from each type of vehicle. So the total emission at each level crossing will be very large which will result in the change of ambient air quality at that region and also high environmental pollution.

TABLE 3
CLASSIFIED VOLUME COUNT

Level Cross-ings	Volume Count (Number of Vehicles)					
	Two Wheeler	Three Wheeler	Car	Light Commer-cial Vehicle	Heavy Duty Vehicle	Bus
1	814	203	201	70	29	19
2	782	311	101	71	8	7
3	467	126	172	55	16	18
4	254	80	74	59	0	15
5	175	45	45	35	13	2
6	136	39	34	36	0	14
7	910	298	222	34	8	0
8	436	114	79	14	0	0
9	342	93	54	33	10	7
10	640	228	163	116	8	14
11	354	152	69	59	8	0
12	404	139	169	50	5	23
13	65	10	5	7	0	0
14	87	17	16	19	2	2
15	115	23	19	19	3	2
16	345	72	84	76	43	6
17	555	163	103	84	5	4
18	289	115	76	55	5	0
19	224	32	42	42	1	3
20	332	62	146	71	9	14

TABLE 4
TOTAL EMISSION AT EACH LEVEL CROSSING

No.	Two Wheeler	Three Wheeler	Car	Light Com-mercial Vehicle	Heavy Duty Vehicle	Bus
1	38260.44	15713.22	34974.4	28619.85	22599.7	15588.06
2	36756.35	24072.96	17574.2	29028.71	6234.4	5742.968
3	21950.4	9753.03	29928.34	22487.03	12468.8	14767.63
4	11938.76	6192.4	12876.15	24122.45	0	12306.36
5	8225.525	3483.225	7830.09	14309.93	10130.9	1640.848
6	6392.	3018.	5916.	14718.78	0	11485.

	408	795	068			94
7	42772.73	23066.69	38628.44	13901.07	6234.4	0
8	20493.31	8824.17	13746.16	5723.97	0	0
9	16075.03	7198.665	9396.108	13492.22	7793	5742.968
10	30081.92	17648.34	28362.33	47427.18	6234.4	11485.94
11	16639.06	11765.56	12006.14	24122.45	6234.4	0
12	18989.21	10759.3	29406.34	20442.75	3896.5	18869.75
13	3055.195	774.05	870.01	2861.985	0	0
14	4089.261	1315.885	2784.032	7768.245	1558.6	1640.848
15	5405.345	1780.315	3306.038	7768.245	2337.9	1640.848
16	16216.04	5573.16	14616.17	31072.98	33509.9	4922.544
17	26086.67	12617.02	17922.21	34343.82	3896.5	3281.696
18	13583.87	8901.575	13224.15	22487.03	3896.5	0
19	10528.67	2476.96	7308.084	17171.91	779.3	2461.272
20	15605	4799.11	25404.29	29028.71	7013.7	11485.94

8.1 Measures to Reduce Emission

- Give awareness to people about the negative impacts when the vehicles are turned 'ON' during idling time
- Don't raise the engine of vehicle after the opening of gate since it may cause emission of more amount of poisonous gases
- Turn of the vehicle suddenly without any delay when an intersection is reached

9 Fuel Consumption Of Road Vehicles At Level Crossings

The economic loss mainly include extra fuel cost due to the idling of road traffic at the time of gate closure. The cost of fuel wasted in congestion depends upon the fuel consumption, rate of various types of vehicles and unit price of fuel. The fuel consumption occurs at two stages, one at the time of gate closing time till the gate opening and other at the time of queue dissipation. At the time of gate closing, only 50% of the vehicles are turning off their engine. But at the time of queue dissipation a large amount of fuel is consumed from all the vehicles at that intersection. The classified vehicle volume count and the fuel consumption of different types of vehicles is already given in Table 3 and Table 2 respectively. The gate closing time (block time) and the queue dissipation time in hour is given in Table 5.

The total fuel consumed by the idling vehicles and fuel cost at each rail-road crossing is given in Table 6.

Then the fuel cost at each intersection is found out using the equation 2.

Fuel Cost = (Total petrol consumption * unit cost of petrol) + (Total diesel consumption * unit cost of diesel) (2)

Current unit cost of petrol is approximately 76 rupees and that of diesel is 70 rupees.

TABLE 5
Queue Dissipation Time And Gate Closing Time

Queue Dissipation Time(hr)	Gate Closing Time(hr)
0.22	0.34
0.26	0.40
0.28	0.34
0.20	0.24
0.24	0.27
0.27	0.34
0.37	0.46
0.45	0.56
0.36	0.43
0.25	0.36
0.25	0.34
0.26	0.47
0.24	0.33
0.28	0.39
0.19	0.24
0.21	0.30
0.26	0.36
0.29	0.39
0.27	0.34
0.21	0.29

TABLE 5
Total Fuel Consumption At Each Level Crossing (In Liters)

No.	Fuel consumption due to gate closing (L)	Fuel consumption due to queue dissipation(L)	Total fuel consumption(L)	Total fuel cost (Rupees)
1	89.20	116.51	205.71	15016.8
2	98.14	128.10	226.25	16516.19
3	62.05	99.89	161.94	11821.98
4	24.69	41.62	66.31	4840.757
5	18.06	31.52	49.58	3619.297
6	19.35	30.23	49.58	3619.458
7	129.55	206.39	335.94	24523.55
8	63.63	102.38	166.01	12118.93
9	44.29	74.54	118.83	8674.769
10	87.92	121.59	209.51	15294.53
11	45.64	66.86	112.50	8212.511

12	81.58	90.32	171.89	12548.03
13	4.63	6.57	11.20	817.4585
14	10.85	15.83	26.68	1947.852
15	8.25	12.91	21.15	1543.981
16	40.17	56.50	96.67	7056.993
17	63.66	92.05	155.71	11367.13
18	45.15	65.50	110.65	8077.295
19	21.34	34.01	55.35	4040.537
20	39.31	56.35	95.67	6983.548

From the table it is clear that the fuel cost at each crossing is very large and a lot of fuel is wasted during the idling at the level crossings

10 Conclusions

From the preliminary analysis itself it is found that the noise produced by the road traffic is more than that produced by the train traffic. So the noise produced by the road vehicles at the rail-road crossings is a great threat to the people living in the surrounding area and also to the people waiting at the intersection during each gate closing. So it is important to model for noise pollution at intersections. A model is developed for noise pollution at intersections by taking queue clearing time and land-use pattern as significant variables. This model will further help to find the noise pollution at other rail-road crossings.

A large amount of poisonous gas is emitted from the idling vehicles at rail-road crossings. Different types of vehicles emit different amount of poisonous gases. It will badly affect the environment. It also change the ambient air quality of that region. From the study it was found that, a large amount of poisonous gas is emitted from each type of vehicle and the total amount of emission at each intersection is above the emission limits given by the Central Pollution Control Board (CPCB). So it is very important to reduce the gas emission at these intersection by taking appropriate measures.

Also the delay at rail-road crossings will cause a great loss of fuel from the road traffic. The idling of vehicles at rail-road crossings during gate closing time and queue dissipation time resulted in a large amount of fuel consumption and extra fuel cost. From each level crossings a large amount of fuel is consumed. This also should be reduced to make that intersection more efficient.

11 Mitigation Measures

- Give awareness to people about the negative impacts when the vehicles are turned 'ON' during idling time
- Don't raise the engine of vehicle after the opening of gate since it may cause emission of more amount of poisonous gases
- Turn of the vehicle suddenly without any delay when an intersection is reached
- Give awareness to people about the adverse effects of large amount of noise produced
- Turing off the engine will help to reduce emission and also to save the fuel and fuel cost
- Convert the rail-road crossing to grade-separated crossing if the traffic volume at that crossing is too high.

References

[1] Chad, C., and Hoel, L. A., (2004) "Effects of light rail transit on traffic congestion". Center for Transportation Studies, University of Virginia.

[2] Chris, D.G, and Currie G. (2016) "Impacts of rail-road crossings, International synthesis and research gaps".

[3] Gajera, D. K., Juremalani, J., Chauhan, K. A (2017) "Key factors for defining traffic volume and delay over rail crossing under mixed traffic condition: A case study of kim town". International Journal of Advances in Mechanical and Civil Engineering, 4.

[4] Ghogare, K. K (2014) "Study of traffic noise pollution at intersection of major roads for Akola city". International Journal for Research in Applied Science & Engineering Technology, 2, 462-468

[5] Gitelman, V, Hakkert, A. S, Doveh, E and Cohen, A (2006) "Screening tools for considering grade separation at rail-highway crossing". Journal of Transportation Engineering, 52-59

[6] Hasnat, M. M, Hoque M. S, and Islam M. R (2016) "Evaluation of economic, environmental and safety impact of at-grade railway crossings on urban city of developing country". Global Journal of Research in Engineering.

[7] Hobeika, A.G, and Bang, L (2002) "Promoting safety at railroad crossings by reducing traffic delays". Computers in Railways.

[8] Jusayan, J. (2015) "Delay due to level crossing, traffic and transport data".

[9] Li-Sian T, Kim I, and Ferreira L (2012) "Evaluating safety at railway level crossings with microsimulation modelling". Transportation Research Record: Journal of the Transportation Research Board, 70-77.

[10] Mali D.M, Umrigar N.F, Patel N.A (2017) "Study of congestion of the road traffic at railway crossings". International Advanced Research Journal in Science, Engineering and Technology, 4.

[11] Michael, H, Schrader and Hoffpauer, J.R (2011) "Methodology for evaluating highway–railway grade separations". Transportation Research Record, 1-3015

[12] Sekhara, C.R., Rajb, P, Paridac, P and Gangopadhyayd S. (2013) "Estimation of delay and fuel loss during idling of vehicles at signalised intersection in Ahmedabad". 2nd Conference of Transportation Research Group of India, 1178-1187

[13] Tiwari, A.V, Kadu, P.A and Mishra, A.R (2013) "Study of noise pollution due to railway and vehicular traffic at level crossing and its remedial measures". American Journal of Engineering Research, 2, 16-1 .

[14] Xiangyang L, and Cheng L (2011) "Traffic congestion research of road and railway intersections". In ICCTP 2011: Towards Sustainable Transportation Systems, 1262-1269.

[15] https://www.cpcb.nic.in