

# Road Safety Audit of Kochi Metro During its Construction Stage

Rejivas.V. A  
PG Student

Department of Civil Engineering  
Rajiv Gandhi Institute of Technology,  
Kottayam, India

Bindhu. B. K  
Assistant Professor

Department of Civil Engineering  
Rajiv Gandhi Institute of Technology,  
Kottayam, India

Bino I. Koshy  
Professor

Department of Civil Engineering  
Rajiv Gandhi Institute of Technology,  
Kottayam, India

**Abstract—** India is a developing country and safety of road is still in a premature stage. Accident severity is increasing in huge order due to increasing in vehicle population. Road Safety Audit (RSA) is a formal procedure for identifying the accident potential and to suggest the safety performance of new and existing roads. RSA appears to be as basic and accurate data on accidents which is an ideal tool for improving road safety in India. Kochi metro is a well known construction work which is under taken by Delhi Metro Rail Ltd (DMRL). It is an ongoing project taking place at Ernakulam city between Aluva and Petta. Study area is chosen as 25 km of construction stretch. The location in a roadway where the traffic accident often occurs is called a black spot. The accident data were analysed based on annual variation of accidents, hourly variation of accidents, and vehicles involved in accidents etc. The road safety audit was done at selected black spots in the study stretch i.e., Kaloor, Palarivattom and Edapally. Several safety deficiencies were detected in each black spot by the road safety audit. The severity of all safety issues were suggested as high, medium and low. The deficiencies along with the counter measures for further improvement have been presented in this paper. Based on the switching criteria of severity of the safety issue, the exact reasons of accidents were identified and also the counter measures for reducing the accidents are presented.

**Key words:** Road safety audit, blackspot, F.I.R, Accident analysis

## INTRODUCTION

Kochi is the main city in Kerala having area about 94.88 km<sup>2</sup>. A city is known as a good city when the transportation of the city is developed in an efficient manner. The main problem in Kochi city is the inefficient transportation system. Kochi needs to grow more and more to accommodate the changes in the transportation system. In this context the importance of Kochi metro arises. The Kochi metro is a better solution for the accommodation of the present and future transportation needs. As the Kochi metro constructions work is going on, several safety issues are also being generated. Since the work is undergoing, there is an urgent need to reduce the accidents.

Road Safety Audit is an important tool for Road Safety Engineering, which has the potential to make a significant contribution to highway safety. The formal audit process involves looking at schemes throughout the various stages of design, and trying to identify road safety problems and to recommend solutions to the problems that have been

identified. The Road safety audit can be performed in different conditions such as preconstruction, during construction and post construction. In this paper the road safety audit during the construction stage is presented. Several safety problems were identified by the accident analysis and road safety audit. The remedies for the accident reduction were also suggested based on that.

The construction cost of Kochi metro is about 5146 Crores which is a one of the highest investment made in the field of infrastructure in Kerala. The Kochi metro work is under taken by DMRC (Delhi Metro Rail Corporation) which known as Kochi Metro Rail Ltd (KMRL). The work is extended over a 25 km stretch starting from Aluva to Petta. It comprises of 5 packages namely, KC 1, KC2, KC3, KC4 and KC 5.

Traffic engineers in U.K. developed the idea of Road Safety Audit as a safety check for new and improved road projects and schemes in the early 1980s. The Road Safety Audit (RSA) process in the U.K. started to gather pace when safety engineers realised that they were carrying out accident remedial schemes on relatively new roads. Road Safety Audit is an important tool of Road Safety Engineering, which has the potential to make a significant contribution to highway safety. The formal audit process involves looking at schemes throughout the various stages of design, and trying to identify road safety problems and to recommend solutions to problems that have been identified.

The road safety audit of Kochi metro was done during the construction stage. The main objective of this work is to identify the safety issues developed during the construction stages of metro. The metro work is undertaken between Aluva and Petta. It covers the major towns in Ernakulam district. The accident data between Aluva and Petta for the past three years were collected from traffic police stations in Ernakulam. The accident analyses were done to determine the pattern of accident occurred over the years. the analysis were done based on the annual variation, hourly variation, and vehicle involved in accidents etc. different black spots were identified by he accident analysis. The road safety audit was performed in these black spots.

DATA COLLECTION AND ANALYSIS

Aluva (10.1167N, 76.3500E) to Petta (9.5659N, 76.1954E) is the study section of the road stretch where the metro construction work is in progress. It is a 25.623 km stretch which passes through the major junctions in Ernakulam town. The Google map picture of study area is given in Figure 1. The road stretch between Aluva and Petta which is NH 49 is passing through the heart of Kochi city. This road stretch carries all types of vehicles ranging from light goods to heavy goods and passenger vehicles. Moreover the study area contains a large number of educational institutions like Engineering Colleges, high school, Arts & Science College, government & private schools, industries, Cochin University which provide employment for thousands of people.

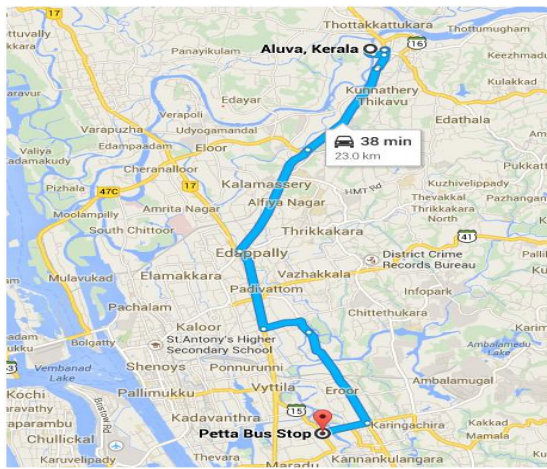


Fig 1. Study Stretch

ACCIDENT DATA COLLECTION

The accident data of 2011, 2012, and 2013 were collected from various police stations between Aluva and Petta. The accident analyses were done based on annual variation, hourly variation and vehicles involved in accidents. The numbers of accidents occurred in each black spots over the three years were identified. From that, three black spots were selected for road safety audit. They are Kaloor, Palarivattom and Edappally.

ANNUAL VARIATION OF ACCIDENTS

The accidents before July and after July in each year were compared since metro construction started in July 2013. The accidents occurred between Aluva and Petta for the year 2011, 2012 and 2013 were compared based on the severity such as fatal injuries, major injuries, and minor injuries.

TABLE 1: COMPARISON OF ACCIDENTS BEFORE AND AFTER JULY IN EACH YEAR

	2011		2012		2013	
	Before July	After July	Before July	After July	Before July	After July
No. of Accidents	107	196 (64.69 %)	116	235 (66.95 %)	101	275 (73.14 %)
Total accidents	303		351		376	

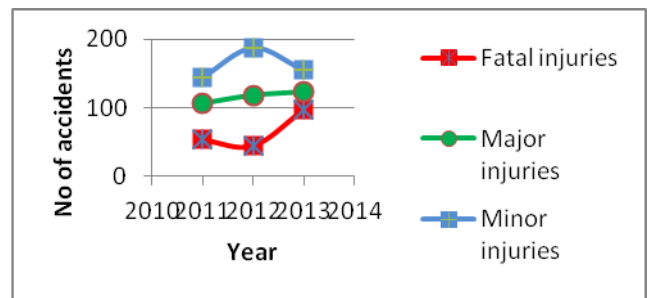


Figure 2: No of accidents Vs Year

After the metro construction started (July 2013) the accident occurrence increased significantly. From Table 1 it is clear that after the metro construction has started the accident rate increased to about 73.14% of total accidents in 2013. In the previous years it was found to be 64.69% and 66.95% for the years 2011 and 2012 respectively. It was found that there is an increase 7% of accident after the metro construction started. The Figure 2 shows the fatality, major injuries and minor injuries changes over the years. It can be seen from the graph that the fatality and major injuries increased after the metro construction. From these result, it can be attributed that the safety provided on the black spots are not satisfactory.

HOURLY VARIATION OF ACCIDENTS

The Table 2 shows the number of accidents occurred in the peak hour and in the night over the years. The peak hour accidents are measured as the sum of accidents occurred between 8-10 AM and 4-6 PM. The night time accidents were calculated as the sum of the all accidents occurred between evening 6 to morning 6.

TABLE 2: NO. OF ACCIDENTS AT PEAK HOUR AND AT NIGHT

Years	Accidents at peak hour	Accidents at night
2011	60	49
2012	77	61
2013	99	82

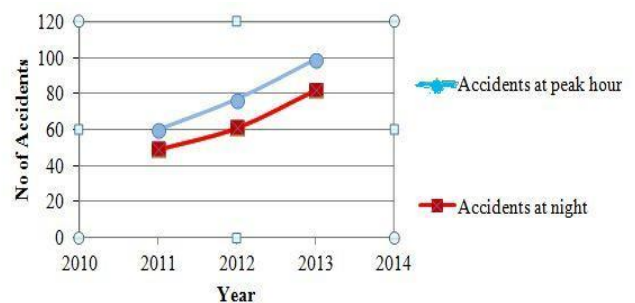


Figure 3: No of accidents Vs year based on peak hour and night condition

The Figure 3 shows that the accidents occurred in peak hour after the metro construction showed an increasing trend. The percentage of accidents occurred in the peak hour during the year 2013 was found to be 37% of total accidents. In other years it is only 32.77% and 30.61% for the years 2011 and 2012 respectively. From that, it is attributed that the safety

measures during peak hour is not efficient. The accidents occurred at night after metro construction started increased to 30.8% of total accidents. In other years it was only 25.95% and 25% for the years 2012 and 2011 respectively. So it can be found that the issue of night visibility is dominating as the cause for accidents. The street lights and visibility at night should be taken care of to reduce the accident rate.

#### VEHICLES INVOLVED IN ACCIDENTS

It is found that after the metro construction started the percentage of contribution in accidents by the motor cycles increased to 38.3% whereas during the previous years it were 36.31% (2012) and 35.89 % (2011) respectively. The pedestrians involvement in accidents is also increased to 17.89% than previous years (15.94% (2012) and 15.92 % (2011)). The reason is attributed that the lack of pedestrians facility such as shoulder deficiency, deficiency in pavement marking at junctions etc.

#### BLACK SPOTS

By the accident analysis the number of accidents occurred at each black spots were identified. The Table 3 shows the number of accidents occurred at each black spots in the work zone after the metro construction started.

TABLE 3: NO OF ACCIDENTS IN DIFFERENT BLACK SPOTS

Black spots	Accidents after metro construction (July 2013 onwards)
Aluva	8
Pulinchoodu	11
Companypady	9
Ambattukavu	11
Muttom	14
Kalamasseri	18
Edapally junction	40
Palarivattom	44
Kaloor	55
Lissy jun	11
Townhall	10
Padma jun	11
GCDA	6
Kadavantra	10
Elamkulam	9
Vytilla	8
Total	275

#### ROAD SAFETY AUDIT

IRC SP 88:2010 specifies different checklist which should be followed in RSA at different stages of construction. The road safety audit on these black spot is executed with the help of this these check list of IRC SP 88:2010.

#### SEVERITY PREDICTION

There are lots of safety issues detected in each black spot while conducting the road safety audit. The severity prediction for the each safety issue was a difficult task. For predicting the severity, there are 15 questions prepared related to the road conditions. The severity of a safety issue is measured by answering the checklists. These questions are answered in such a way that the positive response is expressed as 'A' and the negative response as 'B'. If the negative responses (B) are more than 10 out of 15, it is termed as severity HIGH. If B lies between 5 to 9 out of 15, it is termed as severity MEDIUM. If B is less than 5, it is termed as severity LOW. Table 4 shows the 15 checklists which are used for predicting the severity and Table 5 shows the severity response prediction.

TABLE 4: CHECKLISTS FOR SEVERITY

Sl No	Questions	Severity Response	
		Yes-A	No-B
1	Is there sufficient road width?	Yes-A	No-B
2	Is there sufficient shoulder width?	Yes-A	No-B
3	Are the pot holes in the road surface normal	Yes-A	No-B
4	Is there any parking problem?	Yes-B	No-A
5	Are the vehicles travelling with in the speed limit of 30 km per hr?	Yes-A	No-B
6	Is there any speed reduction hump near the spot?	Yes-A	No-B
7	Is there any object near the road which affects the smooth flow?	Yes-B	No-A
8	Is there a sufficient warning sign ahead of the spot to inform the hazard situation?	Yes-A	No-B
9	Is there any visibility problem?	Yes-B	No-A
10	Is there any access road close to the spot?	Yes-B	No-A
11	Is there any problem in night for visibility?	Yes-B	No-A
12	Is there any sudden turning movement possible near the spot?	Yes-B	No-A
13	Is there any pedestrians crossing near the spot?	Yes-B	No-A
14	Is there any attracting feature near the road which attracts driver's mind?	Yes-B	No-A
15	Is there any bus stop, school, hospital or junction near the spot?	Yes-B	No-A

TABLE 5: SEVERITY RESPONSE PREDICTION

Severity response	Severity
If the negative responses (B) are greater than 10 out of 15	HIGH
If the negative response (B) are between 5 to 9	MEDIUM
If the negative response (B) are less than 5	LOW

#### RSA IN KALOOR, PALARIVATTOM AND EDAPALLY

Kaloor is a major intersection in this region of the city, intersecting the two major arteries of downtown Kochi namely, the Banergy road and the K K road. The stretch which is selected for road safety audit is 1.3 km starting from Lissie junction to Deshabhimani junction. The stretch which is selected for road safety audit in Palarivattom is of 2.7 km starting from Palarivattom to Nehru stadium. The 2.3 km stretch of road section is selected for the audit in Edapally. The major findings of safety issues which got from the road safety audit of three black spots and the remedies for that were listed below.

#### MAJOR FINDINGS FROM RSA

The road safety audit in the three black spots (Kaloor, Edapally and Palarivattom) was done with the help of IRC.SP 88:2010. The major safety findings observed are improper placement of shoulder slabs, deteriorated pavements surface, the existence of electric post near the road, visibility obstruction by objects such as trees and buildings etc, insufficient warning signs, improper street lights, presence of severe pot holes, unexpected turning movement between the barricades, insufficient pedestrians crossings at the junctions, unexpected side road entry, presence of bus stops near the congested area and over speeding etc.

#### SAFETY PROPOSAL

The major safety measures to be adopted on the site are to provide enough road width in the work zone, the shoulder width should be maintained well, the pavement surface should be urgently tarred for avoiding the severe pot holes, the electric posts near the road sides should be replaced or paste the reflective tape over that for detecting at night, remove the branches of tree for proper visibility, provide enough warning signs to inform the hazardous condition, the street light should be repaired and avoid the unexpected turning movement through the barricades. The side road entry should be properly warned to the main road users and also place speed humps at the major junctions and important places such as hospitals, schools etc. Several safety issues were identified in the road safety audit in the black spots. The severity of each safety issue is expressed with severity response as explained earlier.

#### INTERPRETATION FROM THE ROAD SAFETY AUDIT IN BLACK SPOTS

Several interpretations were generated from the result of road safety audit of three black spots. The main interpretations are based on.

1. Switching of severity response criteria
2. Correlation of switching response with accidents

#### SWITCHING OF SEVERITY RESPONSE CRITERIA

The analysis was done based on the switching of the response to questions of checklists from one segment to another. The severity response of each question of the checklists changes in an uneven manner. The nature of the severity was analysed by this criteria.

In a straight road the driver will be more comfortable due to the uniformity in the road condition. It can be clearly explained if we take the width into consideration. If the road width of a stretch is uniform, then the accident will be considerably less. A road where switching happened in a small stretch there will be variation of width. Due to these switching criteria, the driver behaviour will be fluctuating and leads to accidents. The switching leads to many fatal and non fatal impacts. In that case the switching is one of the most important factors which are to be considered in road safety audit.

#### CORRELATION OF SWITCHING OF SEVERITY WITH ACCIDENTS

The accidents in the black spot are increased due to the switching of condition of the road. The usually occurring accidents are Vehicle-Vehicle, Vehicle- Pedestrians, and Vehicle-Objects collision. These type of accidents usually generated is correlated with switching criteria. The exact reason for the accidents occurred in each black spot can be easily identified by this correlation. The checklist question with highest number of switching value will be the major reason for the accidents. Vehicles to Vehicles, Vehicles to Pedestrians and Vehicles to Objects are the types of accidents usually generated. The exact reason of accidents and remedies in each black spot were suggested by this correlation.

#### INTERPRETATION FROM RSA IN KALOOR, EDAPALLY AND PALARIVATTM

##### Findings

It is found that, there is lot of switching of severity response for the checklist question. So the natures of safety issue in the black spots are listed. They are

1. The shoulder width of the black spot is not uniform. In some places the road width is very less compared to other area.
2. There are lots of stationary objects such as electric post, shoulder extension, concrete projection which affects the smooth flow of traffic in the black spots.
3. The road width varies in uneven manner. In some places the road width is very less. It is due to the presence of stationary objects on the road.
4. The night visibility is not uniform in the black spot. In RSA it is found that in some places the street light is not working.

5. There are lots of attracting features like advertisement boards, illuminating boards etc in the black spots. They attract the motorists attention while driving.
6. There is only limited number of speed humps in the black spots for reducing the speed.
7. In some places there are no warning signs over the stretch.
8. The road segments include several pedestrian crossings.

#### CORRELATION WITH ACCIDENTS

It is found that the accidents occurred by vehicle to vehicle, vehicle to pedestrians and vehicle to objects in the black spots are 52, 11 and 2 respectively.

#### VEHICLE TO VEHICLE COLLISIONS

- The main reason for vehicle to vehicle collisions is the poor visibility at night. The number of switching of severity response for this is 17 which is the highest.
- The other important reason for the accidents is the insufficient road width (The number of severity response is 16).
- The presence of attracting features such as advertisement boards, illuminating boards etc are also the reasons for accidents (severity response is 15).
- The insufficient warning signs, lack of speed humps, stationary objects on the roads etc are also affect the safety.

#### REMEDIES FOR AVOIDING VEHICLE TO VEHICLE ACCIDENTS

- The street light should be maintained properly. The street lights should be placed at 15 m interval over the road stretch in black spot.
- The road widening should be done in the stretch.
- Remove the attracting features on the road which attracts human attention on driving.
- Provide enough warning signs in the road section.
- The speed humps should be provided at the junctions, near schools, hospital etc.
- Remove the stationary objects such as concrete projections, shoulder extension etc.

#### VEHICLE TO PEDESTRIANS COLLISIONS

- The main reason for vehicle to pedestrians collision is the poor visibility.
- Other important reason for accidents is the insufficient road width and shoulder width. (The number of severity response for shoulder width is 15).
- Other reasons are insufficient warning signs, lack of speed bumps and frequent and uncontrolled crossing of pedestrians etc.

#### REMEDIES FOR AVOIDING VEHICLE TO PEDESTRIANS

##### ACCIDENTS

- The street light should be maintained properly. The street lights should be placed at 15 m interval over the road stretch in black spot.
- The road and shoulder widening should be done. The shoulder should be properly maintained.
- The speed humps should be provided at the junctions, near schools and hospital etc.

- Provide enough warning signs in the road section.
- Provide pedestrian crossing at the junctions and provide speed hump near to that.

#### VEHICLE TO OBJECTS COLLISIONS

- The main reason for the vehicle to object collision is the poor visibility.
- The other important reason for the accidents is the insufficient road width.
- The presence of objects near the road sides.

#### REMEDIES FOR AVOIDING VEHICLE TO OBJECTS COLLISIONS

- The street light should be maintained properly. The street lights should be placed at 15 m interval over the road stretch in black spot.
- The road widening should be done.
- Remove the stationary objects such as concrete projections, shoulder extension etc. the reflective tape should be pasted over the objects for the visibility at night.

#### CONCLUSIONS

The metro construction work is taking place between the road stretch Aluva and Petta. The fatalities and major injuries seemed to be increased to a large extend after the metro construction started. From this, it is attributed that safety provided during metro construction is not efficient. The accidents occurred at peak hour and at night increased to remarkable extend after the metro construction started. Kaloor, Edapally and Palarivattom are the black spots in the work zone in where most of the accidents occurred after the metro construction started.

The major safety issues identified in RSA on black spots are inefficient street light and speed reducing measures, presence of severe pot holes, insufficient warning signs, visibility problem, concrete projections in to the road surface, presence of electric posts on the road side, red rope in workability over the barricades, parking of vehicle in the non parking area, presence of unwanted sand deposits on the road, shoulder deficiency, unexpected side road entry and improper pavement markings. The speed of vehicles is insisted to follow 30 km/hr in the work zone by the KMRL. But it is observed that none of the vehicles are following that speed limit. So the proper enforcement and the installation of speed bump at the junctions are the solution for reducing the accidents. The lane marking, installation of high mast street lighting, pedestrian markings at junctions etc are the urgent safety measures to be provided in the black spots for enhancing the safety. The presences of several pot holes in the road surfaces were identified. The proper maintenance of road is the only solution for this. The other remedies should be provided on the black spots for reducing the accidents are to make the visibility of road by cutting the branches of trees, cutting of the concrete projections, removing of unwanted sand deposits near the road and provide enough shoulder width.

The major deficiencies in the black spots were identified with the help checklist questions and the remedies for that are also suggested. The natures of safety issue in the black spots were identified by the switching criteria. This switching of road condition was correlated with the type of accidents for identifying the exact reason causing accidents. Based on that the counter measures to black spots were suggested.

#### REFERENCES

- [1] Bagi, A.S., and Kumar, D.N. (2012). "Road safety Audit". *IOSR J of Mechanical and Civil engineering*, Vol.1(6), 01-08.
- [2] Bhuyan (2003) Accident Analysis on Two-Lane Road, M-Tech Thesis Indian Institute of Technology Roorkee .
- [3] Devang, G.P., Umrigar, F.S.,Mishra, C.B., and Vankar, A.A. (2013). "Road Safety Audit of Selected Stretch from Umreth Junction to Vasad Junction." *Int.J. of Science and Modern Engineering*, 2319-6386.
- [4] Dehuri, A.N.(2011)."Impacts of roadway condition, traffic and manmade features on road safety".M Tech thesis, National Institute of Technology, Rourkela.
- [5] Dehury, A.N., Patnaik, A.K.,Das, A.K.,Chattraj,U.B., Bhuyan,P., and Panda, A(2012). "Accident Analysis and Modeling on NH-55(India)".*Int. J Engineering Inventions.*, Vol.2,80-85.
- [6] 'Detailed project report'(2011),Kochi-metro project, Aluva-Petta corridor, Delhi Metro Rail Cooperation Ltd.
- [7] FHWA, Road safety audit-case studies(2010),U.S Department of Transportations, Federal Highway Administration.
- [8] "Geometric Design Standards for Rural (Non Urban) Highways", *IRC 73 – 1980*.
- [9] IRC, Manual on road safety (2010), IRC SP 88, New Delhi.
- [10] Pillai, B. B. and Joseph, K.(2011), "Causes and Consequences of Road Accidents in Kerala", *Int J of Research in IT & Management*, Vol. 1,83-95.
- [11] Raju, G.S.S.V., Balaji, K.V.G.D, Durga, R.K, and Kumar, S.V.(2012). "Identification of black spots and junction improvements in Visakhapatnam city". *Indian J. Innovations Dev.*, Vol. 6(1), 2277 – 5390.
- [12] Rao, B.S., Madhu, E., Jalihal, S, and Reddy,T.S.(2005). "Accident study on national highway - 5 between Anakapalli to Visakhapatnam." *Eastern Asia Society for Transportation Studies*, Vol. 5, pp. 1973-1988.
- [13] Report on Road Safety Audit of National Highway – 5 near Bhubaneshwar and Visakhapatnam, CRRI, New Delhi, 2004.
- [14] Singh, P.K., Dr.Jain, S.S., and Dr.Parida, M.(2011). "Road safety audit for four lane national highways." 3<sup>rd</sup> *Int.J. of Road Safety and Simulation*, Indianapolis, USA.
- [15] Singh,S.K., Mishra, A. and Dr.Singh S.K, (2006). "Road accident analysis: a case study of Patna city". *Urban transport J* 2(2),60-75.
- [16] Srinivasan, N. S., Iyer, V. S., Chand, M., and Srinath, K,(1987). "Scientific identification and improvement of accident prone locations on national highways in Kerala, *J of the Indian Road Congress*, Vol.48 (3), 1-10.