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Evaluation and treatment of accident black spots using Geographic Information System

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Abstract: The location in a road where highest number of traffic accidents occurs is called a Black Spot. The recent study conducted by the Kerala Road Safety Authority (KRSA) found that, the maximum numbers of accident-prone stretches or the black spots are in Alappuzha district. In traditional identification of black spots, methodologies developed based on the total number of accidents occurred in that particular location. These criteria do not provide consideration to the road improvements and result in misidentification of locations that are not truly hazardous from the road safety perspective. The present study attempts to identify the most vulnerable accident black spots in Alappuzha district using Geographic Information System. The study includes collection of secondary accident data and prioritizing the accident prone locations by using Weighted Severity Index (WSI) method. WSI method follows a system of assigning scores based on the number and severity of accidents in that particular location in the last three years. The evaluation of six identified black spots in Alappuzha district was done using ARCGIS 10.1 software package by incorporating field survey data.

Key words: Accident black spots, GIS Applications, Weighted Severity Index (WSI), Passenger Car Units (PCU), Average Daily Traffic (ADT)

I. INTRODUCTION

Traffic accidents are the major cause of death and injuries worldwide. The location in a road where the traffic accidents often occur is called a black spot. In these black spots, accidents are not a random event, but common due to varying factors. Expansion of road network, motorization and urbanization in the country has been accompanied by a rise in road accidents leading to road traffic injuries and fatalities as a major public health concern. Today road traffic injuries are one of the leading causes of deaths, disabilities and hospitalizations with severe socioeconomic costs across the world. In Kerala around 11 persons died and 158 persons hospitalized everyday due road accidents. These statistics indicate that accidents prove to be a socio-economic burden on the society. To tackle this situation effectively, it is essential to concentrate on measures which improve the road safety and hence reduce the number of accidents and accident severity in particular. The identification, analysis and treatment of road accident black spots are widely regarded as one of the most effective approaches to road accident prevention.

GIS integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information. The capability of GIS to link attributes data with spatial data facilitates prioritization of accident occurrence on roads and the results can be displayed graphically which can be used for planning and decision making. Accident –prone locations can be identified using GIS by analysing spatial characteristics about identified locations, and also able to figure out the underlying factors causing accidents. Then reasonable actions can be taken to improve safety in the accident-prone locations. In many developed countries, GIS has been widely used for analysing the accident prone locations or the accident black spots. Many academicians and even government agencies are working on building new tools and improving the existing scenarios for road safety analysis. In this study, GIS analysis is performed using ArcGIS 10.1 software.

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A brief review of the various studies on black spot identification is given as follows.

Srinivasan et al. (1987) ^[1] developed a scientific method for the identification and improvement of accident prone locations on national highways (NHs) in Kerala. Three methods were used in their study to identify the black spots, i.e. i) Quantum of accident method; ii) Accident prone index (API) method and iii) WSI method. The study concluded that the method based on WSI was found to be most suitable in identifying black spots.

Reshma and Sheikh (2012) ^[2] in their study prioritized some of the major accident spots generally referred to as black spots in South Bangalore by using ArcGIS software by assigning possible weights for various accident components.

Nagarajan and Cefil (2012) ^[3], used remote sensing (RS) & GIS for identification of black spots and accident analysis for a particular stretch of NH -45 starting from Tambaram to Chengalpet. Eleven accident locations were identified in the study using high resolution satellite map (IKONS) based on the non-spatial data collected from police department and the field survey conducted in terms of traffic volume and vehicle spot speed, and plotting of the study stretch using Arc GIS software.

Many highway agencies have been using Geographic Information System (GIS) for analyzing accident data. Identification of problematic locations is one of the most important aspects in accident studies. The GIS based application combines the information collection capabilities with the visualization. The GIS and Road Accident View System are a set of applications developed for managing accident database entries. Lim Yu LIANG et al (2005) ^[4], in their study use this developed system designed based on the University Putra Malaysia (UPM) community area and may be adapted very easily to any other places. The system was developed using Microsoft Visual Basic 6.0 in Windows XP platform. The database was designed in terms of textual format. They also record the location of accident on a map.

Iljoon Chang and Seong W. Kim (2011) ^[5], in their study use Bayesian Approach with a Poisson Mixture Model for Identifying Accident-Prone Spots. During their study they consider a mixture of the zero-inflated Poisson and the Poisson regression models to analyse zero-inflated data sets drawn from traffic accident studies. They also perform simulation study and real data analyses are performed to demonstrate model fitting performances of the proposed model.

Binu B Pillai and Dr. Kurian Joseph (2011) ^[6], make a study on Causes and Consequences of Road Accidents in Kerala. During their study they find out the main causes of accidents occurring in Kerala and suggest some remedial measures. According to their study, the main causes of road accidents in Kerala are Over speeding and unhealthy competition of vehicles, Poor surface conditions, road cutting, lack of pedestrian crossing facilities, Uncontrolled access streets and unmanned junctions, Bad driving habits and lack of discipline by road users, Haphazard parking on road side, Absence of proper bus bay and shelter, Visual acuity of drivers, Encroachments/dumping of materials on road, and Protruded lamp post, unscientific check barriers, speed breakers etc.

Srinivas Rao. B et al (2005) ^[7], conducted an accident study on NH - 5 Between Anapallli to Visakhapatnam during the year 2003 and it runs through urban, semi urban and rural areas. The accident data for the last five years were collected from the concerned police station and analysed thereafter. Various traffic studies such as Details of road Inventory, Signage inventory, Traffic volume, Pedestrian volume count, Spot speed, Speed and Delay, Accident Study were also conducted for suggesting the improvement measures

II. SCOPE AND OBJECTIVES

The objectives of the study can be given specifically as the following.

1. To collect accident data regarding Alappuzha district for three years 2009, 2010 and 2011 from the concerned police department.
2. Comparison of real time data with records available in the police station.
3. To find out different methods to prioritize hazardous locations.
4. To identify various traffic and road related factors causing accidents.
5. To carry out analysis of black spots using GIS.
6. Detailed analysis of the top ranked spots and suggestion of possible improvements.
7. Identification of the best suited improvement for each black spot.

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III. STUDY AREA

Alappuzha is one of the 14 districts in Kerala state gifted with bountiful natural beauty. The district lies between north latitude 90° 05' and 90° 52' east longitude 76° 17' and 76° 48' and is bounded on the north-east by Ernakulam and Kottayam districts, on the east by Pathanamthitta, on the south-east by Kollam district and on the west by the Arabian Sea. The district is a widely known tourist destination, and is well known for its coir factories.

The climate is moist and hot in the coast, and it is slightly cooler and drier in the interior of the district. The average monthly temperature of this district is approximately 18° C. As in the case of other parts of the State, this district also gets the benefit of two outstanding monsoons.

Alappuzha is connected to other places by railways, roadways and waterways. There are two railway lines that pass through Alappuzha which is the Ernakulam-Kollam railway line via Kottayam and Alappuzha. The road network plays a vital role in the transportation system among the district. The length of the PWD roads in Alappuzha is estimated to be around 967 kms as indicated in 1990. Alappuzha is connected to other places by State Highways, National Highways and district roads. The State Highways starting from Alappuzha are, SH 11, SH 40, and SH 66. The National Highway through Alappuzha is NH 47. A small section of NH 220 and State Highways SH 1, SH 5, SH 6, SH 10 and SH 12 are also passes through a small part of Alappuzha district.

The Alappuzha district is blessed with many things, but the accident rate increases dangerously throughout the district. Because the Alappuzha district is a tourist destination and the tourists coming from other states are unaware about the Kerala roads and entrapped in accident. The figure 4.1 below shows the accident rate of Alappuzha district for 2009, 2010 and 2011.

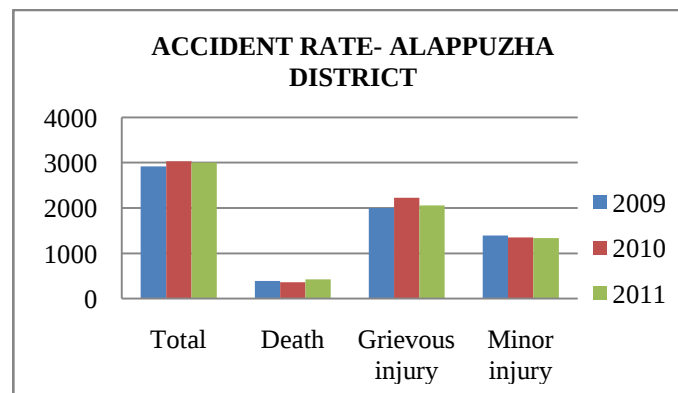


Fig 1: Accident rate of Alappuzha district

IV. METHODOLOGY

The following detailed methodology has been adopted for obtaining the various aspects of the present study. The steps involved in the study are explained in the following sections.

A. Data Collection

Primary and secondary data were collected for the study. Secondary data collection includes the collection of required accident data for the past three years from the concerned police department. Primary data collection includes road inventory data collection, traffic volume count, speed and delay study and spot speed survey from the identified accident prone stretches.

B. Analysis of secondary data using WSI method

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Three years accident data (secondary data) for the Alappuzha district was collected from State Crime Records Bureau (SCRB), Trivandrum. The top ranked six accident black spots (Table I) were identified using Weighted Severity Index Method (WSI) by assigning scores based on the number and severity of accidents in that particular location in the last 3 years.

Weighted Severity Index, **(WSI) = (41 x K) + (4 x GI) + (1 x MI)** (1)

Where, **K** is the number of persons killed; **GI** is the number of grievous injuries; and **MI** is the number of minor injuries.

TABLE I: TOP RANKED ACCIDENT SPOTS

Place	WSI Value	Place	WSI Value
Eramalloor Jn	1695	Kalavoor	1105
Karuvatta	944	Aroor	938
Chandiroor	923	Purakkadu	890

C. Analysis of the Primary data

Road inventory study, traffic volume count, speed and delay study etc. (primary data collection) were conducted at the above identified accident black spots.

1) *Road Inventory Survey*: A detailed road inventory survey was carried out on the entire identified spots to measure the roadway geometric parameters like the roadway width, footpath width, median, shoulders, surface type, surface condition, edge obstruction, road markings, road signs, drainage facilities and adjoining land use.

All the study stretches of Alappuzha district are National Highways. From the road inventory survey it is observed that, the carriage way width of all stretches varies from 8 m to 10 m. It is not sufficient for accommodating huge traffic and the width is not satisfying the standards of national highways. In Kalavoor, Karuvatta and Purakkadu there is no median for differentiating the direction of traffic. It may cause head on collision and night time road accidents due to glare problem. Bituminous surfacing is provided in all the spots and it is in fair condition. Presence of a number of T- Junctions is the primary causes of road accidents in these six stretches. The alignment of the road is straight in all places and it encourages drivers to take over speed while travelling through these spots. Drainage facilities are given in most places and it is not good condition. Uncovered drainages compel pedestrians to use roads for walking and lead pedestrian accidents. Presence of advertising hoardings and illegal boards divert the attention of drivers while driving. The road signs and markings provided are visible and capable for necessary enforcement of traffic. Adequate shoulder width is provided in all stretches and helps drivers especially for two wheeler riders to keep the left side of the road. Regular maintenance is required for removing all the above ill effects of national highways and for providing safety for all road users.

2) *Traffic Volume Count*: The traffic volume count gives the measure of how many vehicles pass through a particular location during a period of time. According to the traffic volume, the time can be classified to peak hour and off peak hour. For any traffic infrastructure design and accident study peak hour traffic volume is necessary. So, in the present study, four hour traffic volume count was taken for all the spots and peak hour traffic in terms of Passenger Car Units (PCU) was found.

From the survey it was observed that the road stretch under consideration carries highly mixed traffic of both fast moving vehicles and slow moving vehicles. The fast moving two wheelers and passenger cars are predominant in all the six stretches. The peak hour traffic volume ranges from 1000 PCU to 3600 PCU. The highest peak hour traffic observed at Eramalloor Jn and lowest peak hour traffic observed at Purakkadu. Fast moving light commercial vehicles (LCV) are predominant in all the six study spots. Traffic volumes for the identified spots are given in table below.

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TABLE II: TRAFFIC VOLUME IN TERMS OF PASSENGER CAR UNITS (PCU)

Accident Black Spot	Peak Hour Traffic Volume (PCU)	Average Daily Traffic (PCU)
Eramalloor Jn	3,549	41753
Kalavoor	2,058	24212
Karuvatta	1,342	15788
Aroor	2,785	32765
Chandiroor	2,408	28329
Purakkadu	1,335	15706

3) *Speed and Delay Study*: The speed and delay study was carried out by using moving observer method on entire identified black spots in Alappuzha district to find out the average journey speed and delay of the traffic stream.

The average journey speed on the entire study stretch varied from a minimum of 34.48 km/hr to a maximum of 47.44 km/hr without delay. The minimum journey speed observed at Kalavoor and the maximum journey speed observed at Aroor, both are national highway stretches. The maximum stopped delay of 50 sec observed at Aroor and it is due to electronic signal and pedestrian crossing. The main reasons for delay at selected stretches are parked vehicles, slow vehicles, vehicle crossings, bridge cutting, bus stops, traffic signals, and pedestrian crossing. The Table III gives the average journey speed of vehicles on the selected stretches.

TABLE III: AVERAGE JOURNEY SPEED

Place	Average journey speed (km/hr)	
	Without Delay	With Delay
Purakkadu	38.65	38.48
Kalavoor	34.86	34.48
Eramalloor Jn	35.68	34.89
Chandiroor	37.91	36.82
Karuvatta	36.86	36.07
Aroor	52.09	47.44

D. Analysis of identified black spots using GIS

The map required for the desired road network for the study has to be digitized in a suitable form and certain specified road attributes to carry out prioritization are to be input to GIS. Then the identified black spots further prioritized using GIS.

1) *Prioritization*: The following prioritization scheme was used for the GIS analysis and which involves assigning suitable weights to different factors which tend to influence the occurrence of accidents on identified study stretches in the district in such a manner that the factors which tend to increase the probability of the accidents have lower weights (Table IV). The final weight (Eq. 2), assigned to each road link was obtained by adding all the individual weights and normalizing the value using maximum weight. The maximum weight assigned in this case is 110.

$$\text{Total weight} = (\sum \text{Individual Weights}) \times 100 / 110 \quad \dots (2)$$

The classification of roads for occurrence of accidents is based on the final weights obtained by using Eq. 2. The road links with low final weight were considered as highly accident prone stretch (Table V).

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TABLE IV: FACTORS USED IN PRIORITIZATION WITH POSSIBLE WEIGHTS

Sl. No.	Factors	Possible Variation	Weights assigned	Sl. No.	Factors	Possible Variation	Weights assigned
1	No. of Lanes in each direction	1	2	6	Drainage facility	Good	10
		2	6			Satisfactory	6
		4	10			Poor	2
2	Width of the road					No drainage	1
		< 6 m	1	7	Vehicle type	Heavy Vehicles	10
		6 – 8 m	3			Bus/Truck	8
		8 – 10 m	5			Car	4
		10 – 12 m	7			Two wheelers	1
		> 12 m	10	8	No. of Vehicles per day	<10000	10
3	Type of Road	NH	1			1000 - 30000	7
		SH	4			30000 - 50000	4
		PWD	8			> 50000	1
		Other Roads	10	9	Shoulders	Paved	10
4	Surface type	Bituminous	4			Unpaved	6
		Concrete	10	10	Edge obstruction	No	1
5	Surface condition	Good	10			Yes	4
		Fair	6	11	Median	No	10
		Poor	1			Yes	10
						No	4

TABLE V: PRIORITIZATION SCHEME

Final Weight	Accident Prone Level
>60	Very Low
50 – 60	Low
40 – 50	Medium
0 – 40	High

V. RESULTS AND DISCUSSION

The values of the various factors contributing to accidents were collected from the top ranked accident black spots and the GIS analysis was carried out. The most vulnerable accident stretches in Alappuzha district are shown in Figure 2.

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TABLE VI: ACCIDENT PRONE LEVEL

Place	Final Weight	Accident Prone Level
Kalavoor	33	High
Karuvatta	44	Medium
Aroor	45	Medium
Eramalloor	46	Medium
Purakkade	52	Low
Chandiroor	53	Low

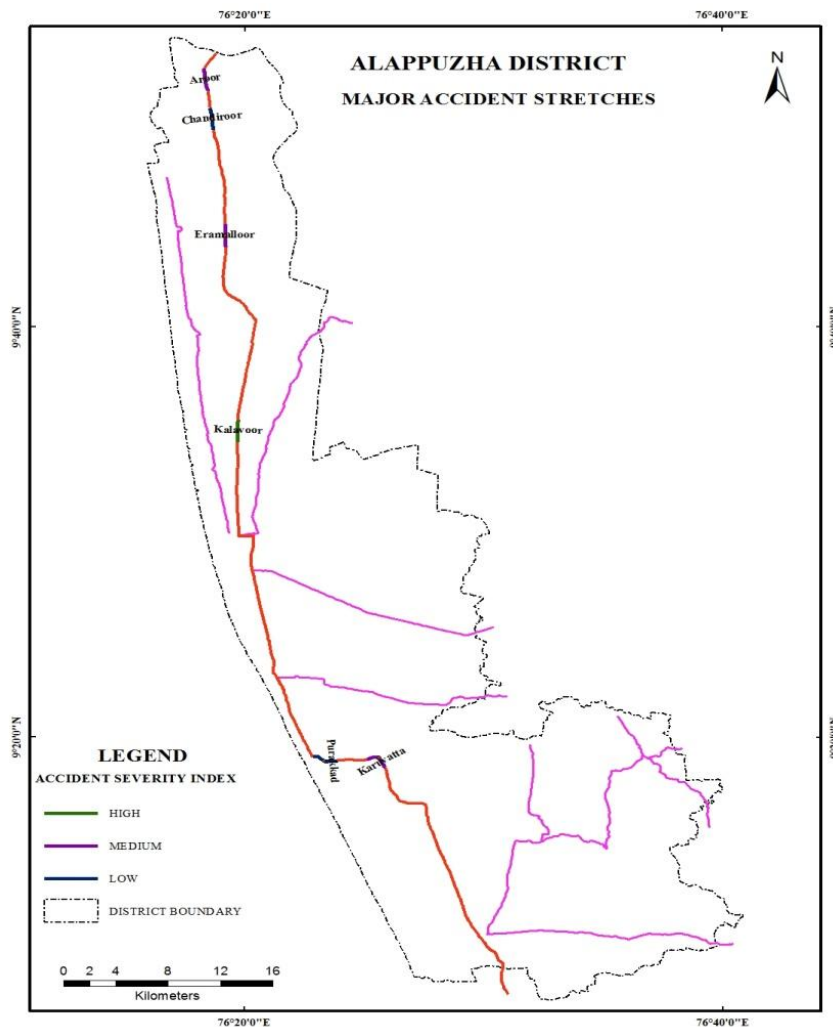


Fig 2: Most vulnerable accident stretches in Alappuzha district

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Kalavoor is identified as the most vulnerable accident stretch of Alappuzha district. It is a village located at 10 km towards north of Alappuzha. Kalavoor is well connected by road and rail. The accident stretch identified in Kalavoor is a stretch of National Highway 47. Kalavoor is also one among the prominent villages in Alappuzha, having a numerous private as well as public institutions.



Fig 3: Kalavoor accident location

The identified accident stretch is a straight stretch having necessary lane width and shoulders. So, the drivers have a tendency to increase the speed while travelling through this straight stretch. The spot speed of different vehicles passing through the study stretch is given in table VII. Absence of median is the main cause of road accidents in this stretch. Because, overtaking of vehicles cause head on collision with vehicles coming from the opposite direction. Due to the absence of foot paths, pedestrians use the shoulder for walking and this increases the number of pedestrian accidents especially during night time. The heavy vehicles parked on either side of the road make congestion during the peak hour. It also encourages pedestrians to use the carriage way for walking and cause serious pedestrian accidents. Presence of potholes increases two wheeler accidents especially during rainy season. It is essential to develop certain improvement measures to mitigate the above circumstances leading to the accidents.

TABLE VII: SPOT SPEED OF VEHICLES IN KALAVOOR

Type of Vehicle	85 th Percentile Speed
Car	70
Two Wheeler	76
Auto Rickshaw	51
Heavy Vehicles	52

The suggestions for improvement of Kalavoor zone is given below:

1. Increase the number of lanes from two lanes to four lanes. As per IRC: 106 – 1990 the maximum volume of traffic for two lane road with paved shoulder is 17250 PCU/Day and for four lane road with paved shoulder is 40000PCU/Day. In this stretch the traffic volume is 24212 PCU/Day. So, it is recommended to increase the number of lanes from two lanes to four lanes.
2. Provide median of 3m width. As per IRC 73 – 1980, the minimum recommended width of median is 3m.
3. Provide footpath on both the sides of the road for the safety of pedestrians.
4. Provide adequate drainages.
5. Provide separate bus bays for avoiding delay of other vehicles at the bus stops.
6. Take suitable enforcement measures to reduce the speed of vehicles.

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7. Remove or repair potholes for the safety of road users.

VI. CONCLUSIONS

The spot on road where traffic accidents are frequently occurred is termed as black spots. The current study was an attempt to find out the most vulnerable accident locations or the black spots in Alappuzha district using Geographic Information System (GIS). The Weighted Severity Index (WSI) method was used to rank the accident locations. The top ranked six spots were selected as per the WSI value for the data collection and analysis in GIS platform. Based on the analysis, Kalavoor was identified as most vulnerable accident location in Alappuzha district, and suggested some possible alternative measures to improve the transportation system in Kalavoor. The overall methodology was found to be effective for the identification, evaluation and treatment of accident black spots if sufficient data is available.

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