GIS AND MODELLING INTERFACE FOR SUSTAINING ROAD SAFETY – POSITIVE EXTERNALITY PERSPECTIVE

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Abstract— The ungovernable increase in usage of motor vehicles on the road has created a major social problem – the loss of lives through road accidents. The atrocious human misery and significant economic loss caused by road accidents demand the attention of the society and call for solution of the problem. A multi-disciplinary approach is needed in understanding the problem and providing solutions. The Study area of NH-67 covering a length of 80kms from Nagapattanam to Tanjavur is chosen as a study area. The road layout plan has been exported from CAD to Arc GIS for georeferencing. In this study area, the geometric factors increasing accidents are collected by using Tools like Arc GIS, Google earth & Auto CAD. From the data collected, the factors which are incorrect those are responsible for increasing the accidents are sorted out by comparing the values with IRC Specifications. The sorted out values are converted into co-ordinates(x, y). Then all the factors are divided into three combinations with standard values and present values. The accident increasing rate is estimated by triangle model methodology in these following steps like Representing in Triangles , Finding the distance between the centroids, deriving Lagrange Interpolation Equation, Integrating the derived equation with respect to distance as the limit. After integrating we get a value and it is taken as accident rate.

Index Terms— Georeferencing, Triangle Model, Increasing Accident Rate, Centroid, Lagrange Interpolation Equation

I. INTRODUCTION

1.1 ACCIDENT SCENARIO IN INDIA:

The economic development of any country is closely associated with the development of transportation infrastructure. The socio economic status of the people bound to rise because of the increased frequency in travelling has been facilitated by rapid growth of automobile industry, on the negative side, the sheer increase in the number of automobiles has lead to steep rise in the number of accidents which results in the loss of life and property.

Road safety is a serious concern in developing countries like India. Heterogeneous mix road traffic, poor road geometrics, Road user factors and supportive infrastructure are some of the important causative factors to the high accident rates. In terms of road network, India is the second largest country in the world having stretch of 33,13,739 km. National highways having stretch of 65,569 km respectively. During 2015, a total of 5,01,423 road accidents were reported by all States/Union Territories. Of these 26.3 per cent (1,31,726) were fatal accidents. The number of persons killed in road accidents were 1,46,133 i. e an average of one fatality per 3.4 accidents. A comparison of States which accounted for 86.7 per cent of share in road accidents during the calendar year 2015). It reveals that Tamil Nadu stood on top in road accidents in the entire country with a percentage share of 13.8 per cent followed by Maharashtra 12.7 per cent and Madhya Pradesh 11.0 per cent.

1.2 FACTORS RESPONSIBLE FOR ACCIDENTS

Road accidents do not just happen but are caused" is a common cliche in the area of traffic safety. The accidents are caused by some factors, surely they can be identified and appropriate remedial measures could be developed and implemented for their prevention to the extent feasible for the reduction of ill effects and trauma of the accidents. The factors that contribute directly or indirectly are: Road users, Geometric factors, Vehicle condition, Road condition, Supportive infrastructure, Environmental factors**.**

1.3 OBJECTIVES OF THE STUDY:

1. To map the given AUTOCAD file of study area with locations in physical space using GIS
2. To identify the incorrect geometric factors of the study area.
3. To determine the accident rate of different combinations of the incorrect factors using Triangle model.

1.4. STUDY AREA:

The area chosen for the study is NH67 which has been proposed for re-aligning a new stretch of road covering a length of 80kms starting from Nagapattinam to Thanjavur in Tamilnadu. Due to a long-standing demand of the people of Thiruvarur and Nagapattinam , the vehicular are enduring a bumpy, slow ride on the damaged stretch, with accidents, particularly, at night causing another concern for people As the number of vehicles increase manifold every year, the road became too congested. The problems are mounting for road users due to traffic congestion too. As the traffic on the damaged stretch became a bitter experience to the road users. Journey time is also increasing as four railway crossings on the narrow route from Needamangalam to Thiruvarur clamp down on speed, as many vehicles have to wait at the gates However, G Antipathy, project director, National Highways Authority of India (NHAI), told that plans are afoot to convert the road into a two-lane one. Hence, a proposal for laying a two-lane road on the existing stretch has been prepared.

II. DATA COLLECTED

2.1 AUTOCAD-13 AND ARC.GIS-10.1:

Pre plotted drawing plan layouts of NH67 road alignment containing data like:

- Length of the road.
- Location of junctions
- Location of curves

1. CAD to GIS

Add the cad .dwg file to "Table of Contents" (TOC) in arc map. The data is exported using "Data Export" option by right clicking on the layer file added to TOC. The exported data will be saved as individual shape files in catalogue window. Coordinate system has to change for the shape files generated in the catalogue window to Projected Coordinate System -> UTM -> WGS1984 -> NORTHERN HEMI SPHERE -> ZONE 44' N through properties by right clicking on the shape file.

2. World Topographic Map

Add world topographic map from arc online through ESRI website. The added map can be viewed in TOC layers. Change the coordinate system of world topographic map added to Projected Coordinate System -> UTM -> WGS1984 -> NORTHERN HEMI SPHERE -> ZONE 44' N. Save the map as a layer file for further use. Now add the shape file exported from CAD to TOC. The shape files added automatically fits to the world map as the cad data is geo-referenced

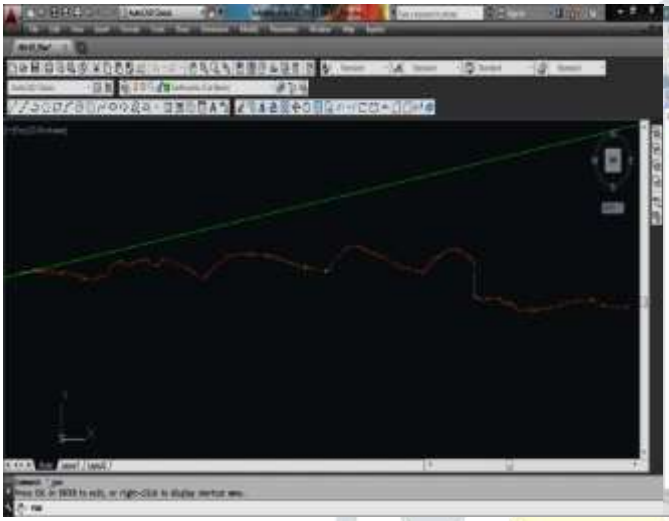


FIG:1-AUTOCAD FILE

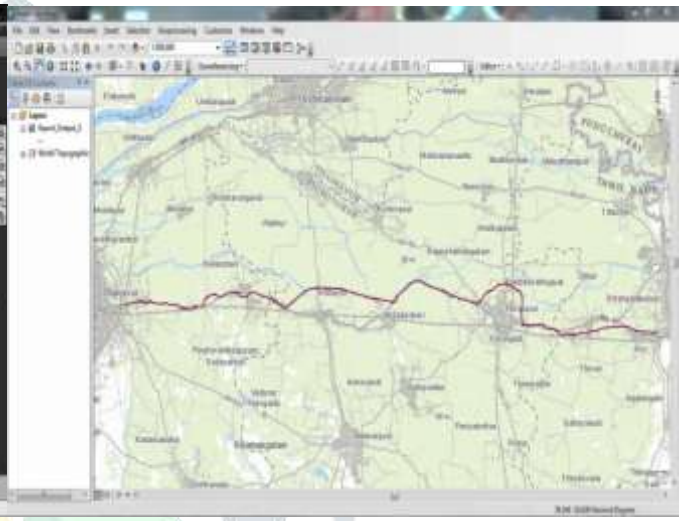


FIG:2- GEOREFERENCED FILE

2.2 EXAMINED DATA

A. Shoulder

The provided shoulder along the entire stretch of 80km is 1.5m. In open country with isolated built up area and having plain or rolling terrain and where average daily traffic is greater than 10,000 PCUs in plain terrain or 8,000 PCUs in rolling terrain, 1.5 m width adjacent to the carriageway shall be paved.

B.Median

Median is not provided for entire road length of 80kms. Absence of median reduces the speed of the vehicle, increases the accident rate mainly at night time.

C. Junctions

It is observed that there are more number of junctions along the entire length of 80km. There are about 56 junctions out of which 35 are 4 leg junctions. The table below shows the junction points.

D. Sight Triangle

Visibility to an intersection is another important requirement on becoming aware of approaching intersection. The driver must be able to observe and comprehended the speed and direction of approaching traffic from all other legs of the intersection. Special care to ensure visibility should be taken is intersection is located on high land in a cutting at or near a summit or near a bridge. The data collected is shown in Ttable:2.1.

E. Stopping sight distance:

At some curve points SSD is below the IRC specifications which leads to the occurance of accidents due to the invisibility of vehicle in opposite direction.

F. Curves:

Radius of curve at some points are not as per IRC speifications. The radius of curve is given in Table 2.2

Table:2.1 Sight Triangle

SL.NO	SIGHT TRIANGLE	DISTANCE	SL.NO	SIGHT TRIANGLE	DISTANCE
1	2+1	21.9	16	36+7	19.2
2	4+3	23.9	17	44+9	23.6
3	5+3	23.9	18	49+3	20.2
4	7+5	21.7	19	52+3	42.9

5	8+3	18.4	20	52+7	19.3
6	10+1	23.8	21	54+3	15.5
7	10+7	27.5	22	56+1	24.6
8	13+6	20.3	23	62+8	18.8
9	15+2	20.8	24	68+3	17.2
10	17+2	22.2	25	71+6	18.2
11	17+8	23.8	26	73+5	23.66
12	23+2	26.7	29	77+3	20.4
13	25+3	50.3	30	78+2	17.9
14	29+4	51.5	31	80+1	19.9
15	33+5	18.9	32	82+8	22.3

Table 2.2 Curve points along length of 80km

SL.NO	CURVE POINT-KM	CURVE RADIUS-m	SL.NO	CURVE POINT-KM	CURVE RADIUS-m	SL.NO	CURVE POINT-KM		CURVE RADIUS-m
1	4.50	2250	26	23.5	1500	37	29.3		-500L
2	5.60	-2250 L	27	23.9	10000	38	29.8		34
3	8.9	-2250 L	28	24.6	-500 L	39	29.9		-2000L
4	9.6	4000	29	24.8	-500 L	40	30.2		-500L
5	11.2	-5000 L	30	25.4	-1000 L	41	30.6		500
6	11.5	5000	31	26.3	-1000 L	42	31.6		-1800L
7	12.3	3000	32	27.2	1500	43	32.1		360
8	12.8	1500	33	27.9	-500 L	44	32.4		-400L
9	13.50	-1500 L	34	28.9	600	45	34.5		-1200L
10	14.7	360	35	29.2	-800 L	46	35.0		1200
48	35.5	-360L	70	58.7	1500	93	72.2	600	
49	35.8	420	71	59.0	-700 L	94	72.3	-2500 L	
50	36.8	1000	72	59.3	1200	95	72.6	-500 L	
51	36.9	-800L	73	5.6	-2250 L	96	73.3	-700 L	
52	37.1	1200	74	60.2	1850	97	73.8	3000	
53	38.0	-1200L	75	61.3	-2250 L	98	74.1	1200	
54	38.8	-1000L	76	62.1	-650 L	99	74.8	-420 L	
55	39.0	700	78	62.8	700	100	75.1	1000	
56	39.3	-360L	79	63.6	360	101	75.6	2250	
57	39.8	1900	80	64.5	2500	102	76.2	1250	
58	40.0	-2250L	81	64.7	-500 L	103	76.7	-360 L	
59	41.3	-400L	82	64.9	400	104	77.2	360	
60	41.8	400	83	65.3	-1100 L	105	77.7	-500 L	
61	45.3	5000	84	65.6	700	106	78.0	-2900 L	
62	47.8	-10000 L	85	65.9	-600 L	107	78.1	-3200 L	
63	49.3	-2500 L	86	66.1	600	108	78.8	15000	
64	52.3	-3500 L	87	66.6	400				
65	53.9	-2250 L	88	67.5	-600 L				
66	57.3	400	89	68.7	1000 L				
67	58.0	800	90	69.5	360				
68	58.2	-2250 L	91	70.4	-360 L				
69	58.3	-1200 L	92	70.9	800				

III. METHODOLOGY

3.1 After selecting the factors that are reduction in speed flow this model undergoes a step wise procedure which is the following:

Step 1: Firstly selected factors are represented as co-ordinates e.g.: (x, y) for each side of the triangle.

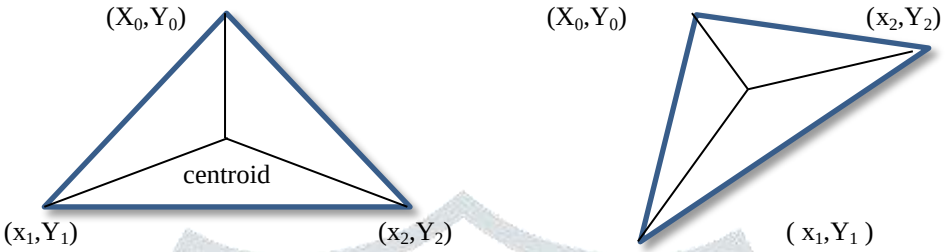
Step 2: For the same factors standard values are also taken and they are also represented as co-ordinates.

Step 3: Triangles are formed for the selected factors both with standard values and the present values which are taken as co-ordinates.

Step 4: We get two triangles of different shapes from which we can visually observe the difference.

Step 5: Centroids for two triangles are calculated based on the $\left(\frac{X0+X1+X2}{3}, \frac{Y0+Y1+Y2}{3}\right)$

Step 6: Triangles with centroids are represented



Step 7: Finding distance between two centroids

Step 8: Distance formulae: $\sqrt{(x1-x2)^2+(y1-y2)^2}$

Step 9: We get the distance between the standard triangle and present triangle. This distance value acts as the limit in further calculation by using the present values in the form of co-ordinates quadratic polynomial equation is derived.

Step 10: Equation is derived into a Formulae: $\mathbf{Y(x)= ax^2+bx+c}$

$$Y(x)=\frac{(x-x1)(x-x2)}{(x0-x1)(x0-x2)}\times y_{\circ}+\frac{(x-x0)(x-x2)}{(x1-x0)(x1-x2)}y^1+\frac{(x-x0)(x-x1)}{(x2-x0)(x2-x1)}\times y^2$$

Step 11: Integrating by using the distance as the limit $\int ydx = \int (ax2+bx+c)dx$

Step 12: After integrating we get a value which represents the accident rate.

IV. DATA ANALYSIS

6.1 From the data collected, accident rate for different factors are calculated. Factors which do not have the standard IRC values are selected.

FACTOR	STANDARD VALUE	PRESENT VALUE
Sight triangle	130m	80m
Median	2.5	Not provided
Junctions	40	56
shoulder	2.5m	1.5m
SSD	120m	80m
curves	360m	34m
glare	No precautions taken	Planation of trees in median

6.2 From the factors listed in table we select 3 different combinations. Select three different factors in each combination. The values of different factors are taken as co-ordinates (x,y).

1st combination	2nd combination	3rd combination
curves	Junction	SSD
SSD	Median	Junction
Sight triangle	shoulder	Shoulder

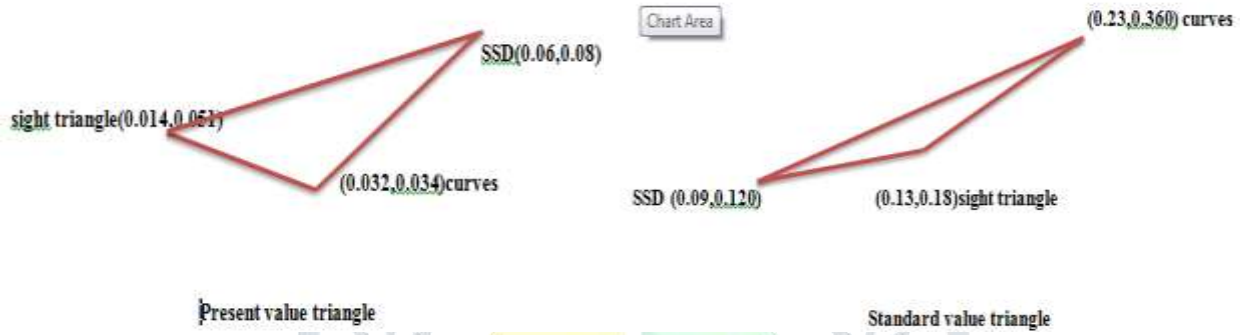
6.3 The values of different factors are taken as co-ordinates (x,y).

FACTORS	PRESENT VALUE	STANDARD VALUE
Sight triangle	(14,51)	(90,130)
Median	(0,0)	(2.5,2.5)
Junctions	(56,56)	(40,40)
shoulder	(1.5,1.5)	(2.5,2.5)
SSD	(60,80)	(90,120)
curves	(32,34)	(360,230)

6.4 Evaluation of case example (combination-1)

Combination of factors	Present values	Standard values
Curves	(0.032,0.034)	(0.230,0.360)
SSD	(0.060,0.080)	(0.090,0.120)
Sight triangle	(0.014,0.051)	(0.130,0.180)

Formation of triangle:



Centroid of triangles

For standard values	For present values
$(\frac{X0+X1+X2}{3}, \frac{Y0+Y1+Y2}{3})$	$(\frac{X0+X1+X2}{3}, \frac{Y0+Y1+Y2}{3})$
$(\frac{0.230+0.090+0.130}{3}, \frac{0.360+0.120+0.180}{3})$	$(\frac{0.032+0.060+0.014}{3}, \frac{0.034+0.080+0.051}{3})$
(0.15, 0.22)	**(0.035, 0.055)**

Distance between two points: The two points are (0.15, 0.22). (0.035, 0.055)

- $\sqrt{(x1-x2)^2+(y1-y2)^2}$
- $\sqrt{(0.15-0.035)^2+(0.22-0.055)^2}$
- $\sqrt{0.0132+0.027}$
- $\sqrt{0.0404}$
- **0.200**

Derivation of quadratic polynomial equation for present values:

$$Y(x) = \frac{(x-x1)(x-x2)}{(x0-x1)(x0-x2)} \times y1 + \frac{(x-x0)(x-x2)}{(x1-x0)(x1-x2)} \times y1 + \frac{(x-x0)(x-x1)}{(x2-x0)(x2-x1)} \times y2$$

$$Y(x) = \frac{(x-0.060)(x-0.014)}{(0.032-0.06)(0.032-0.014)} \times 0.034 + \frac{(x-0.032)(x-0.014)}{(0.060-0.032)(0.060-0.014)} \times 0.08 + \frac{(x-0.032)(x-0.060)}{(0.014-0.032)(0.014-0.060)} \times 0.051$$

$$Y(x) = [-(x^2-0.074x+0.00084) \times 67.44 + (x^2-0.046x+0.000448) \times 62.5 + (x^2-0.092x+0.00198) \times 61.59)$$

$Y(x) = 56.63x^2 - 3.551x + 0.0229$.

Integrating the equation:

- $\int ydx = \int 56.63x2 - 3.551x + 0.0229.dx$
- Limit = 0.200
- $\int ydx = 56.63\frac{x^3}{3} - 3.551\frac{x^2}{2} + 0.0229x$

- 0.151 - 0.07 + 0.00458
- 0.0855
- **85.5%**

VII. RESULTS & DISCUSSIONS:

. The analysis is done for different combination of factors. In each combination from the result obtained we can know the factors that are more effecting**.**

Accident rate of different combinations

Combination	Accident rate %
1st	85.5
2nd	20.1
3rd	83.43

RECOMMANDATIONS

1. Black spot sensitization is highly preferable.
2. Centroid and difference between actual and present values leads on non eccentricity of road safety.
3. Road geometrics, spatial dimensions, road user reaction time need to be consistent.
4. Limiting number of junctions based on the design. More number of junctions reduces the speed and increases the journey time.
5. Provision of median reduces accidents, especially at night times and increases the speed flow.
6. Sign boards should be provided for all curves according to specifications
7. Extra guidance should be given drivers before they arrive the curves with radius of 32m and 34m.
8. At improper SSD locations curve radius should be increased
9. Provision of median with plantation of trees reduces the glare effect upto some level.
10. Width of the shoulder should be increased to 2.5m
11. Right of way should be increased to 14 or 14.5m.

CONCLUSIONS

For interpretation of road accident rate, the identification of factors such as median, shoulder, curves, sight triangle, junctions, SSD, glare effect responsible for accidents has been accomplished in the study. Due to the absence of median glare effect will be more during night times which reduces the visibility and increases the accidents. Using the triangle model percentage of accident rate is calculated in three different combinations for entire road length of 80kms of study area. These combinations display the factors that are more effecting. A 2kms stretch of road length of 80km is taken and accident rate is calculated.

From the results obtained there is a difference observed in the percentage of accident rate of total length of 80kms and particular stretch of 2km from study area when compared, because the sensitivity or accident rate observed in the 2km stretch may not be seen in other stretches of road in the study area. So it is concluded that, the analysis of accident rate can be performed for total stretch of 80km and safety measures are provided as mentioned in recommendations for reduction of accidents. It is observed that, journey time will also be reduced because of all these factors. It is also concluded that analysis based on black spot sensitization would be appropriate so that measures implemented can provide more sustainable road safety.

FUTURE SCOPE

Analysis based on Black spot sensitization will be more helpful in reducing accident rate because the sentivity differs from place to place and the factors effecting also changes from poin to point . so considering particular stretch and performing analysis based on factors effecting helps in providing sustainable road safety.

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