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Modelling to Track Negative Externalities Influencing on Speed Control with GIS

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Abstract — *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 digitizing. In this study area, the factors reducing the speed of the vehicles 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 decreasing the speed is 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 speed reduction rate is estimated by triangle model methodology in these following steps like Representing in Triangles , Finding the distance between the centroids, deriving Quadratic Polynomial Equation, Differentiating the derived equation with respect to distance as the limit. After differentiate we get a value and it is taken as speed reduction rate. The process is repeated for remaining combinations.*

Keywords*- Digitization, Triangle Model, Speed Reduction Rate, Centroid, Quadratic Polynomial Equation*

I. INTRODUCTION

In terms of Road network India is the second largest country in the world. As per the government statistics 40% of the road traffic runs on the 2% stretch of National Highway road network. Road network is the backbone of a nation and speaks about the degree of development of a Country. Hence, a lot of care has been taken by the Government and NHAI to develop the National Highways to International Standards.

Models are built with the a speed rate as a dependent variable and road geometrical parameters such as width of road way, pavement unevenness, shoulder width, camber, horizontal and vertical curve, median details independent variables. The model can be useful to determine expected speed reduction if improvement measures are carried out in future.

1.1. 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 factors of the study area.
3. To determine the speed rate of different combinations of the incorrect factors using Triangle model.

1.2. 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.

1.2. Data Collection

Pre plotted drawing plan layouts of NH67 road alignment containing data like: Length of the road, Location of junctions & Location of curves. For better understanding and observation AutoCAD file is Georeferenced. Arc GIS 10.1 software is taken as the major interface for the purpose of data collection, since the data collected from this particular source will be more accurate having closer readings of real time data of the location. Data like latitude longitude vales and elevation values are collected by digitizing the map of NH 67. The clear process of data collection is explained in step by step manner.

i. 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.

ii. 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.

II. 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.

Table 1. Sight Triangle data for study area

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

C. Bump Integrator Values

Kms	Pavement surface	Kms	Pavement surface	kms	Pavement surface	kms	Pavement surface
1.6-2.6	3.82	18.6-19.6	2.98	36.6-37.6	2.58	58.6-59.6	4.8
2.6-3.6	3.6	19.6-20.6	4.3	37.6-38.6	2.18	59.6-60.6	1.94
3.6-4.6	5.7	20.6-21.6	4.7	38.6-39.6	2.38	60.6-61.6	2.84
4.6-5.6	4.5	21.6-22.6	4.8	39.6-40.6	3.32	61.6-62.6	2.84
5.6-6.6	2.5	22.6-23.6	4.74	40.6-41.6	2.38	62.6-63.6	2.26
6.6-7.6	1.8	24.6-25.6	3.1	42.6-43.6	3.3	63.6-64.6	3.34
7.6-8.6	1.6	25.6-26.6	3.94	43.6-44.6	3.16	64.6-65.6	2.5
8.6-9.6	1.5	26.6-27.6	4.1	44.6-47.6	3.6	65.6-66.6	3.38
9.6-10.6	1.6	27.6-28.6	4.16	47.6-48.6	2.68	66.6-67.6	1.96
10.6-11.6	1.8	28.6-29.6	4.14	48.6-49.6	5.32	67.6-68.6	3.3
11.6-12.6	2.0	29.6-30.6	5.0	49.6-50.6	5.32	68.6-69.6	3.14
12.6-13.6	2.6	30.6-31.6	3.3	50.6-51.6	4.08	69.6-70.6	3.56
13.6-14.6	2.18	31.6-32.6	2.72	53.6-54.6	5.94	70.6-71.6	3.06
14.6-15.6	2.72	32.6-33.6	3.16	54.6-55.6	5.42	71.6-72.6	3.8
15.6-16.6	1.84	33.6-34.6	2.64	55.6-56.6	5.0	72.6-73.6	3.1
16.6-17.6	1.94	34.6-35.6	3.28	56.6-57.6	3.7	73.6-74.6	4.7
17.6-18.6	2.38	35.6-36.6	2.34	57.6-58.6	3.82	74.6-75.6	2.96

D. Stopping sight distance

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

III. METHODOLOGY

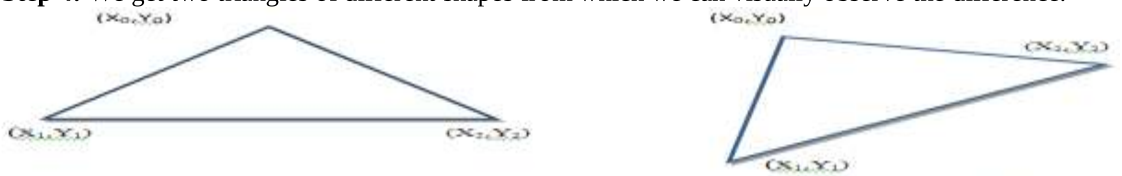
After selecting the factors that are reduction in speed flow this model undergoes a step wise procedure which is the following:

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.

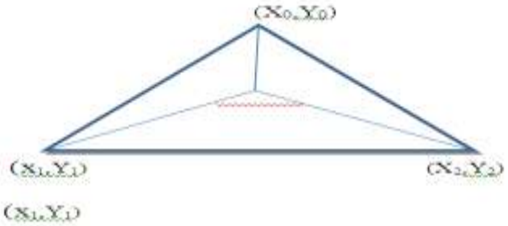
Step 4: We get two triangles of different shapes from which we can visually observe the difference.



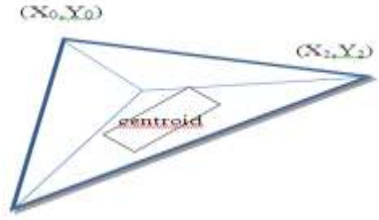
a. Standard value triangle   b. present value triangle

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

Step 6: Triangles with centroids are represented



a. Standard value triangle



b. present value triangle

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.

Formulae: **Y(x)**

Step 10: Equation is derived into a form**(x)= ax^2+bx+c**

$$=\frac{(x-x1)(x-x2)}{(x0-x1)(x0-x2)}\times y_0+\frac{(x-x0)(x-x2)}{(x1-x0)(x1-x2)}y^1+\frac{(x-x0)(x-x1)}{(x2-x0)(x2-x1)}\times y^2$$

Step 11: The differentiating by using the distance as the limit

$$x_1+\frac{dy}{dx}+x_2+\frac{dy}{dx}=y$$

Step 12: After differentiating we get a value which represents the speed reduction rate.

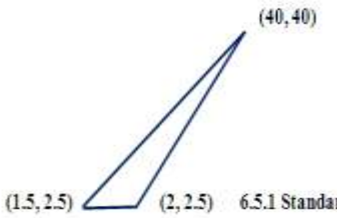
IV. DATA ANALYSIS

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

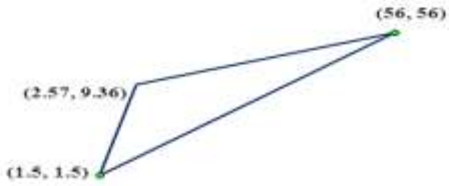
FACTORS	PRESENT VALUE	STANDARD VALUE
Sight triangle	130m	80m
Median	Not provided	2.5m
Junctions	56	40
Shoulder	1.5m	2.5m
SSD	120m	80m
Curves	360m	34m
Glare	No precautions taken	Plantation of trees in median
Bump integrator	2.57,9.36	1.5,2.5

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).

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)
Combination of factors	**Present values**	**Standard values**
Bump integrator	(2.57,9.36)	(1.5,2.5)
Junction	(56,56)	(40,40)
Shoulder	(1.5,1.5)	(2,2.5)



6.5.1 Standard value triangle



6.5.1.1 Present value triangle for 1st combination

A. *Evaluation Case Example-1 (1.6 To 3.6 Km):*

Combination of factors	Present values	Standard values
Bump integrator	(3.02,7.7)	(1.5,2.5)
shoulder	(1.5,1.5)	(2.5,2.5)
Slight triangle	(21.9,21.9)	(130,180)

Step 1: For standard values

$$\left(\frac{X0+X1+X2}{3}, \frac{Y0+Y1+Y2}{3}\right)$$

$$\left(\frac{1.5+2.5+130}{3}, \frac{2.5+2.5+180}{3}\right)$$

(44.6, 61.6)

Step 2: For present values

$$\left(\frac{X0+X1+X2}{3}, \frac{Y0+Y1+Y2}{3}\right)$$

$$\left(\frac{3.02+1.5+21.9}{3}, \frac{7.7+1.5+21.9}{3}\right)$$

(8.80, 10.37)

The two points are **(44.6,61.6) (8.80, 10.37)**

Step 3:

$$\sqrt{(x1-x2)^2+(y1-y2)^2}$$

$$\sqrt{(44.6-8.80)^2+(61.6-10.36)^2}$$

$$\sqrt{1281.64+2625.53}$$

$$\sqrt{3907.17}$$

62.50

Step 4: Quadratic polynomial equation is formed using present values:

Present values	
X_0= 0.032	Y_0= 0.034
X_1= 0.060	Y_1= 0.08
X_2= 0.014	Y_2= 0.051

Step 5:

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

$$\frac{dy}{dx}=2\times 0.053x-0.251$$

= 6.37 %

Same calculations are applicable for different combinations. The first combination is bump integrator, shoulder and junction. The second combination is curves, median and sight triangles and the third combination are curves, stopping sight distance and sight triangle.

V. RESULTS

The speed reduction rate of total stretch 80kms with different combinations

Combination	Speed reduction rate %
1st	5.68%
2nd	12.73%
3rd	85.5%

A case example of 2kms stretch (1.6 to 3.6 km) is taken from study area and analysis is done. The speed reduction rate obtained is 6.37 %.

VI. CONCLUSIONS

Identification of factors that are responsible for decrease in speed flow is accomplished. By taking different combination of factors decrease in speed flow for entire road length of 80km is identified. A case example of 2 km stretch from study area is taken and reduction in speed flow is determined. It is observed that there is a difference between the percentage when compared between the total stretch and a stretch of 2km of study area. So it is concluded that percentage of speed reduction should be done based on sensitivity of that particular area.

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