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SUGGESTING SAFE ROUTES FOR EVACUATION DURING FLOOD SITUATION – A CASE STUDY OF SAVARKUNDLA TOWN

Mayank D Sanghani[1], Prof. V. R. Gor[2]

[1]*P.G. Student, Civil Engineering Department, Government Engineering College, Modasa*
[2]*Assistant Professor, Civil Engineering Department, Government Engineering College, Modasa*

Abstract — *Flood frequently occurs in every 2-3 years in Savarkundla region leading to many regional traffic problems. Evacuation of region on the riverbank is a crucial problem emphasized in past studies. To check the route availability for evaluation of flood affected area needs to be carried out.*
In present study the solution for this disastrous flood situation in terms of safe routes for evacuation has to be suggested based on observed volume and recommended capacity for existing road network. The methodology includes calculation of probable submerged area from contour map and identification of safe routes from existing road network by using the observations of volume – capacity ratio of vehicles and pedestrians.

Keywords- *Flood situation, evacuation, disasters, safe routes, evacuation analysis*

I. INTRODUCTION

Disasters have always been a major concern for societies due to their impact on human life and activities. Floods may cause extended damages to infrastructures, loss of lives and disruption of human activities. The impact of disasters on society and the economy has increased in the recent years. Transportation networks are identified as critical lifelines in cases of disasters for a number of reasons: first, the transportation system will support evacuation, emergency response, and relief and recovery operations. Second, the transportation network will remain the sole means for ensuring physical access to the affected communities. Third, transportation infrastructures are highly prone to disasters and therefore their capacity and serviceability will be reduced following event. Evacuation is the rapid movement of people away from the immediate threat or impact of a disaster to a safer place of shelter.

II. OBJECTIVE OF THE STUDY

The traffic routing for problems of evacuation operation seeks to efficiently relocate the threatened/affected population to safe places using the available transportation network, thereby avoiding or mitigating potential loss of life due to disasters. Most current approaches to address evacuation operations focus on the traffic management aspects of the problem, where traffic-related network performance is of major concern.
Followings are the prime objectives of the present study:

1. To find most critical zones for evacuation.
2. To identify flood affected route.
3. To suggest safe route for evacuation.

III. METHODOLOGY

The present study is an attempt to determine safe route for evacuation based on observed volume and recommended capacity of existing road network by using Indo HCM 2017. Following important characteristics should be considered while selecting evacuation routes for safe passage of people.

- Shortest route to the designated destination areas
- Capacity of proposed routes to accommodate the mode of transportation to be used
- Availability of infrastructure to disseminate real time conditions

Following are steps to be performed for determining safe routes.

1. To collect the data of submergence during flood situation using contour map & past HFL.
2. To identify flood affected zone in city.
3. To study about existing network in the flood affected zone
4. To ensure availability of sufficient of existing road network in the flood affected zone.
5. To suggest appropriate safe route for evacuation.

IV. STUDY AREA AND DATA COLLECTION

4.1. Study Area

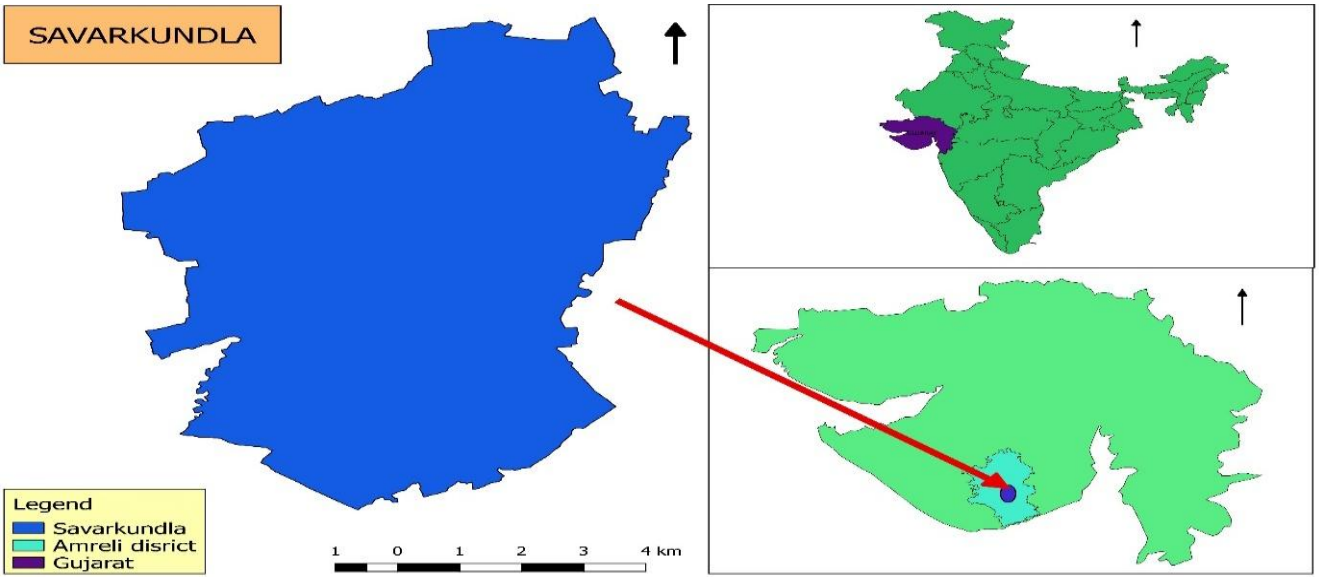

Figure 1. Index Map of Savarkundla Town

Savarkundla is situated on the southern Saurashtra plateau. Savarkundla lies at 21.337° N 71.310° E in western India. Total density of the city geographical area of Savarkundla municipality is 8 km^2. Population is 9794 persons per km^2. According to the 2011 census, Savarkundla had a population of 78,354.

4.2. Data Collection

Road Inventory data, exiting traffic volume and pedestrian volume is collected manually. Traffic volume is converted into PCU/hr by using IRC-106[5]. Digitization of maps and preparation of contours is done using QGIS software, also record of past HFL is determined from HFL points marked at various location on field. Area under submergence for the selected study area is determined using past HFL data and contour maps. Figure 2. shows road and river map of Savarkundla.

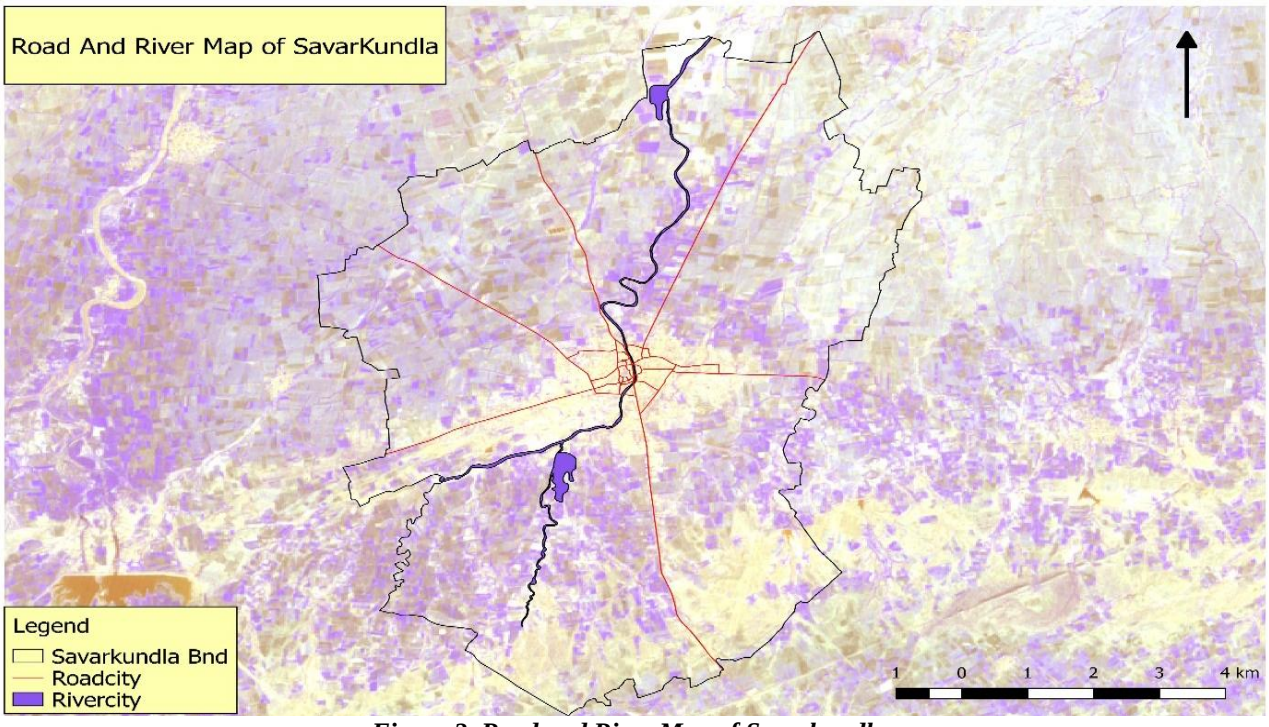

Figure 2. Road and River Map of Savarkundla

Sr No.	Origin	Destination	Width (m)	Elevation (m)	Length (m)	No. Of Lanes
1	Khatarwadi	Pick up stand	14.8	125	330	4
2	Khatarwadi	Marutinagar	5.2	125	280	2
3	Khatarwadi	Upavan wadi	5.2	130	170	2
4	Khatarwadi	Bhuvaroad Bridge	8	124	52	2
5	Pick up stand	Nadi Bazar	11.3	127	150	3
6	Nadi Bazar	Shak market Bridge	6.6	126	19.6	2
7	Shak market Bridge	Kansara Bazar	4.5	130	170	1
8	Nadi Bazar	Main Bazar	5.5	129	170	2
9	Nadi Bazar	Ridhi Sidhi	11.3	132	450	3
10	Ridhi Sidhi	Juna Bus stand Bridge	9.6	133	26.5	2
11	Ridhi Sidhi	Mahuva Road Bridge	10	139	45.7	2
12	Ridhi Sidhi	Post office Road	9.2	137	160	2
13	Ridhi Sidhi	Akheda	11.3	140	290	3
14	Akheda	Gayatri Mandir Bridge	6.6	140	65.2	2
15	Gayatri Mandir Bridge	Nesadi Road	7.6	150	500	2
16	Gayatri Mandir Bridge	Modi School	7.6	142	100	2
17	Juna Bus stand	Jesar Road	14.8	140	650	4

Table 1. Road Inventory Data

Table 1. shows various origin and destination for selected study area. Also details of road width, road length and type of road (i.e. No. of lanes) and Elevation is shown. QGIS software is used for finding elevation points of various road.

V. DATA ANALYSIS

5.1. Calculation of Submerged area and time of concentration

Contour map is converted into nodes and are interpolated using Inverse Distance Weighting (IDW) method in QGIS. Raster calculator tool is used for generating submerged area. The detail of submerged area is shown in figure 3.

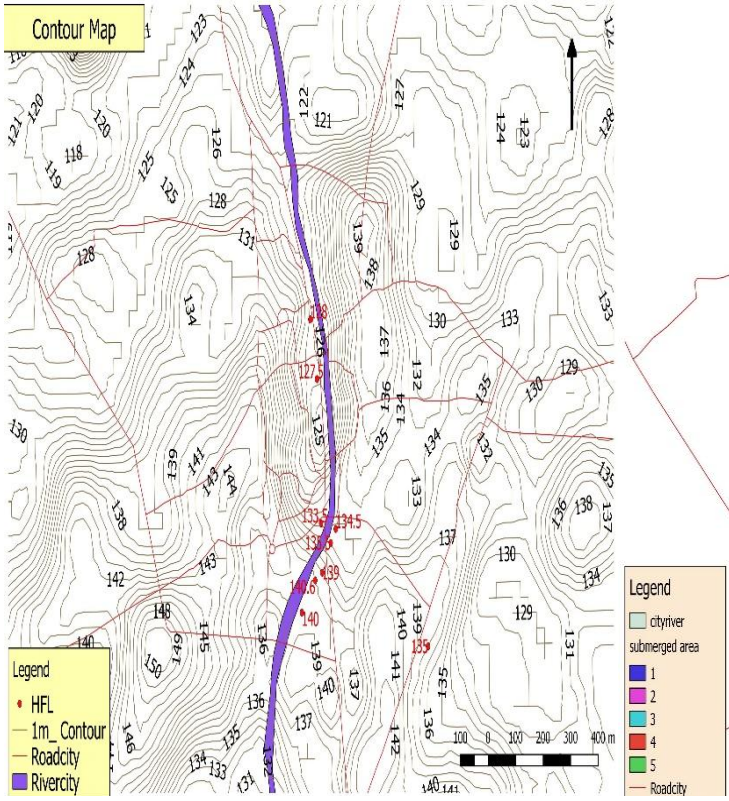

Figure 3. Contour Map with past HFL location

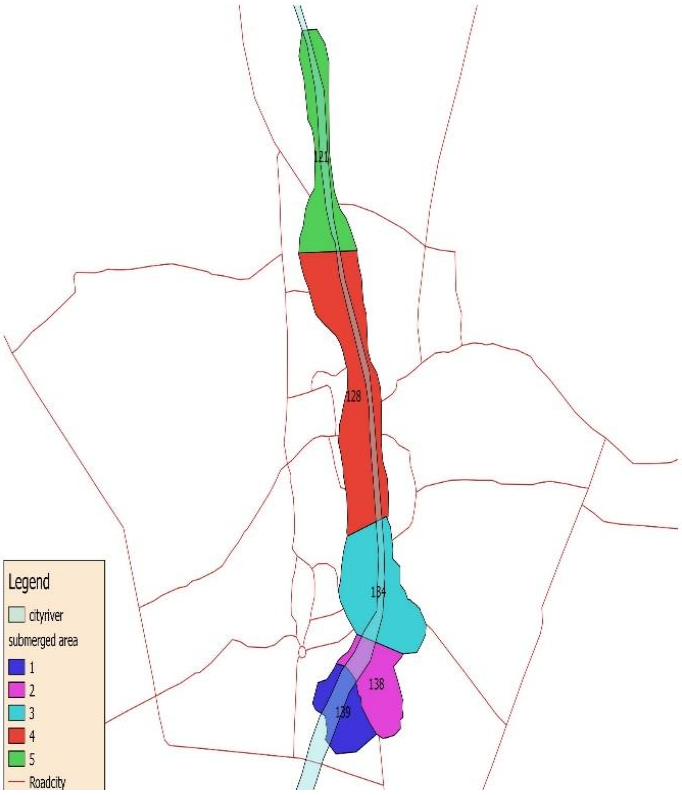

Figure 4. Submerged area Map of Savarkundla

Time of concentration (Tc) is the time required for runoff to travel from the hydraulically most distant point in the watershed to the outlet. The hydraulically most distant point is the point with the longest travel time to the watershed outlet, and not necessarily the point with the longest flow distance to the outlet. In present study NRCS Lag Method [1] has been used.

Table 2. Submerged Area and Time of concentration

Zone No.	Type of zone	Population	Area under Submergence (hectares)	HFL observed from past data (meter)	Time of Concentration (minutes)
1	Educational and commercial	667	1.79	139	142
2	Commercial	452	2.14	137	141
3	Commercial	523	3.97	134	131
4	Commercial and Residential	1145	6.19	128	123
5	Commercial	374	3.2	< 128	131
Total		3161	17.29		

5.2. Route Availability

In figure 4 blue line shows available routes on existing road network and points with red marks shows safe location for evacuee of corresponding available routes.

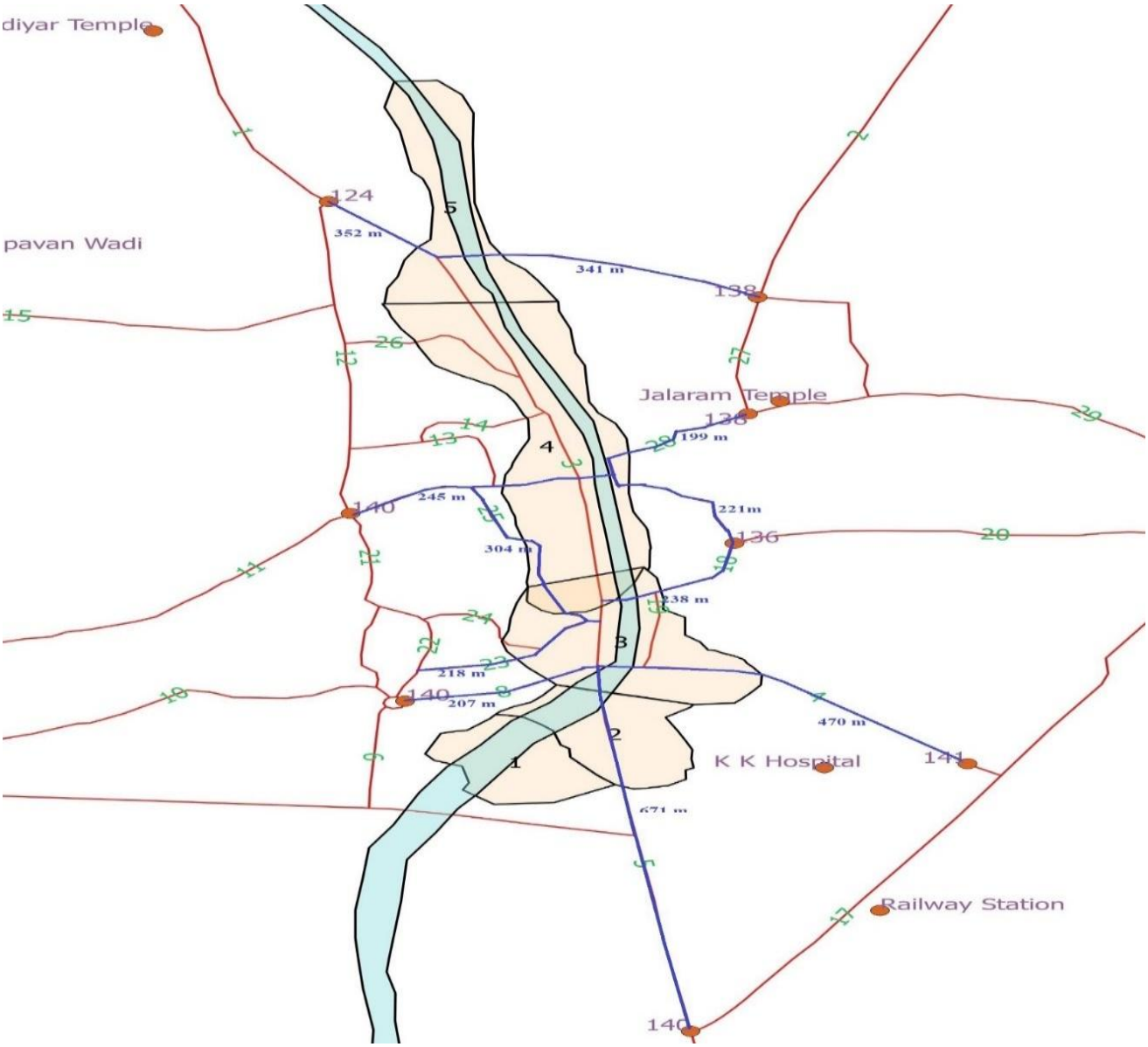

Figure 5. Safe location for evacuees

Table 3. Route Availability

Zone (1)	Route no. (2)	Available Length from zone to safe place (m) (3)	Road width available (m) (4)	Suggested road width for motorized vehicle (m) (5)	Suggested Width of footpath (m) (6)	Distance to approach route from zone (m) (7)	Total Travel Distance for reaching to safe place (m) (8)
1	5	671	11.3	9.5	1.8	210	881
2	5	671	11.3	9.5	1.8	116	787
	4	470	9.6	7.5	2	133	603
	8	207	9.2	7.5	2	133	340
3	5	671	11.3	9.5	1.8	161	832
	4	470	9.6	7.5	2	161	631
	8	207	9.2	7.5	2	161	368
	25	304	3.2	0	3.2	90	394
	23	218	3.2	0	3.2	90	308
4	5	671	11.3	9.5	1.8	164	835
	4	470	9.6	7.5	2	164	634
	8	207	9.2	7.5	2	164	371
	18	238	3.2	0	3.2	177	415
	25	304	3.2	0	3.2	105	409
	23	218	3.2	0	3.2	105	323
	28	199	3.2	0	3.2	250	449
	11	245	4.5	3.5	1	250	495
	2	341	8	7.5	0.5	90	431
5	2	341	8	7.5	0.5	56	397
	1	352	14.8	12.8	2	56	408

Zone	Route no.	Recommended Capacity for suggested road width (PCU/hr) [Indo HCM] (9)	Recommended Capacity for suggested width of Footpath (PCU/hr) [IRC 103] (10)	Observed Peak hour volume (11)		Volume/ Capacity for suggested road width (12)	
		Vehicle	Pedestrian	Vehicle (PCU)	Pedestrian	Vehicle (PCU)	Pedestrian
1	5	2680	1500	2685	1446	1.0	1.0
2	5	2680	1500	2685	1446	1.0	1.0
	4	2110	2400	1850	1090	0.9	0.5
	8	2110	2400	1884	1441	0.9	0.6
3	5	2680	1500	2685	1446	1.0	1.0
	4	2110	2400	1850	1090	0.9	0.5
	8	2110	2400	1884	1441	0.9	0.6
	25	900	4800	185	372	0.2	0.1
	23	900	4800	77	201	0.1	0.0
4	5	3180	1500	2685	1446	0.8	1.0
	4	2110	2400	1850	1090	0.9	0.5
	8	2110	2400	1884	1441	0.9	0.6
	18	900	4800	137	120	0.2	0.0
	25	900	4800	185	372	0.2	0.1
	23	900	4800	77	201	0.1	0.0
	28	900	800	402	496	0.4	0.6
	11	1266	1200	374	472	0.3	0.4
	2	2110	1200	653	21	0.3	0.0
5	2	2110	1200	653	21	0.3	0.0
	1	5420	2400	794	13	0.1	0.0

Route availability data is prepared based on road network map, submerged area detail and observed volume on existing road network showing in Table3. Recommended capacity for suggested road width is taken as per Indo HCM [3]. Recommended capacity for suggested width of footpath is taken as per IRC-103[4]. Volume/Capacity ratio for suggested road width is determined by using observed peak hour volume on existing road network.

VI. SUMMARY AND CONCLUSION

It is concluded from table 2 that population of various zones varies from 372 to 1142, which may be Educational, commercial or residential. The zone wise area of submergence varies between 1.79 hectares to 6.19 hectares. Also it is observed that HFL lies between the range of 128 and 139 meters. Time of concentration is referred as minimum time available for evacuation within range of 123 to 142 minutes. The safe routes selected are taken based on the study of observed volume and existing capacity and also available distance to reach safe place.

From table 3 it is clear that for evacuation both vehicles and pedestrian volume are considered. V/C for both vehicles and pedestrian are determined for selection of safe routes for various zones. It is found that route no. 5, 4 and 8 have V/C nearer to 1, which are very congested for traffic operation, so for increasing the capacity, such routes are provided with extra lane for safely evacuating the people during flood situation.

Other route having v/c less than 1 and width of road less than 4m can be used for safe passing of pedestrians

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