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Sustainable Development Plan for Tsunami: A Conceptual Vulnerability Analysis of Coastal Areas

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Abstract: ***The study mainly focuses on the drawbacks in the present Tsunami Mitigation Plans(TMP), since It has been identified from the assessment of the 2004 Tsunami, the major cause for the destruction of coastal lives is due to ineffective mitigation plan for Tsunami. The study proceeds in finding out the human vulnerability by means of questionnaire survey made with the community, responsible officials and administration of the considered region for scrutinizing the existing Tsunami Mitigation Plan using some specific vulnerability factors. The relevant research information is gathered and interpreted using logistic regression analysis and a model is determined to improve mitigation activities. The obtained model is used to identify the weakness parameters in existing system. Hence, in this study, the identified issues are resolved and from that certain recommendations and suggestions are given for the community which could serve as a fine strategy and better effective community based Tsunami mitigation strategies accordingly.***

Key words: Tsunami, mitigation, Community, Vulnerability

I. INTRODUCTION

Tsunamis may cause huge loss of life, destruction of coastal infrastructure and disruption of economic activity [1]. In India the 2004 Tsunami caused a major damage along the coast of Tamilnadu, Andhra Pradesh, and Kerala. In particular, most of the damages and death toll were recorded in Tamilnadu state, Nagapattinam where the water transgressed up to 1 km into the mainland of this area [2] [3]. This negligence was due to lack of public concern and also Tsunami hazard management was given a low priority by local governments without being strongly pressed in local plans before the 2004 Tsunami [4]. This event led to take broad international efforts to design and implement the Tsunami early warning system in the Indian Ocean on one hand, and on the other, to urgently strengthen community based disaster management strategies (e.g. awareness raising, preparedness strategies) so called “last mile” [5].

Wisner, stated a people-centered definition of vulnerability as “the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard” [6].

Villagran de Leon pointed out that Vulnerability assessment constitutes its systematization and evaluation in the contexts of a household, group of people, community, a province, a country, a sector or a system with respect to the different types of hazards [7]. Polsky proposed an eight-step method for vulnerability assessment. The steps are Define the study area, become aware of the study area and its contexts, hypothesize who (or what) is vulnerable to what, develop a causal model of vulnerability, find indicators for the components of vulnerability, weight and combine the indicators, project future vulnerability, communicate vulnerability creatively [8]. The main objective of this study is to analyze the community vulnerability using logistic regression model and to identify the pitfalls in existing Tsunami mitigation plan and to enhance a better community based plan for Tsunami. Since the needs and expectation of the community were not fulfilled by the existing measures, certain strategies are to be determined and implemented.

II. DESCRIPTION OF STUDY AREA

In 2004 Tsunami, severe destructions are recorded along the coast of Nagapattinam because of its geographic setting, prone to much inundation [9]. It is observed that the maximum run up level of sea water is 3.9 m and inundation in land is 750 m in this area (MoES, 2005 & Collectorate, Nagapatinam). Hence, the coast alone recorded 6065 confirmed deaths; which is equivalent to 76% of the state’s total toll. The area selected for the study consists of three hamlets namely Keechankuppam, Akkaraipettai and Kallar whose major occupation is fishing. Nearly 50% of the people who lost their lives in Nagapattinam district belong to Akkaraipettai, Keechankuppam and Kallar fishing hamlets (Collectorate Nagapatinam and NCRC), because of which these villages are almost like an island. The risk factor is high in this place because perpendicular evacuation is not possible during Tsunami. Hence this area is selected for study.

Fig. 1 Satellite Map of Study Area

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Table 1 Population Details of Study Area

S.No	Population category	Males	Females	Total
1	Children (0-6 yrs)	680	668	1,348
2	Scheduled Castes (SC)	523	491	1,014
3	Scheduled Tribes (ST)	0	0	0
4	Literates	4,398	3,658	8,056
5	Illiterate	1,020	1,750	2,770
6	Total Worker	2,988	813	3,801
7	Non Worker	2,430	4,595	7,025
8	Total	5,418	5,408	10,826

Table 1 shows the details of population category in three hamlets. The occupation details of the community details are furnished in Table 2.

Table 2 Occupational Pattern of the Study Area

Population	Main Worker		Marginal Worker		Total Main Worker	Total Marginal Worker
	Males	Females	Males	Females		
Fisheries	1753	295	152	147	2048	299
Cultivator	206	25	14	9	231	23
Agricultural Labour	202	85	165	118	287	283
Household Industries	17	15	3	7	32	10
Others	438	75	38	37	513	75

The community occupying corresponding to various types of housing such as Pucca, semi-Pucca and kutcha houses were 40%, 35% and 25% respectively.

III. METHODOLOGY

The study involves in drawing an enormous attention on literature surveys outlining that the community vulnerability is closely related to Tsunami mitigation plan. On the basis of the identified weakness a questionnaire is prepared. Even though the issue is common to community and officials, the questionnaire set to the officials reflect the view of community. The following The following steps are Involved in the Assessment of Community Vulnerability.

- Recognizing Factors influencing the vulnerability condition.
- Preparation of data collection format and questionnaire
- Collection of data using questionnaire from the respondents.
- Compilation of data obtained from the respondents using random survey method.
- Data Analysis using‘t’ test, ANOVA, Chi Square test.
- Identification of the vulnerability parameters using Logistic Regression model.
- Suggestions to improve the community resilience.

With the help of a thorough literature survey and expert’s opinion the factors greatly influencing the community vulnerability are identified and presented in Table 3.

Table 3. Factors Influencing Tsunami Mitigation

S.No	Group S.No.	Issues in Tsunami Mitigation Plan	Related Factor
1	1	Evacuation Programme	Awareness
2	2	Mock Drill	
3	3	New Developments	
4	4	Safe Places	
5	1	Evacuation Instructions	Service
6	2	Govt. Organization Services	
7	3	Government Vehicle Provision	
8	4	Shelter Maintenance	
9	1	Perpendicular Evacuation Route	Facility
10	2	Enough Higher Ground	
11	3	Short Route to Safe Place	

12	4	Place for Movable Assets	
13	5	Shelter Provision	
14	6	Easy Access Shelter	
15	7	Facilities During Emergency	
16	1	Belief in Next Tsunami	Belief
17	2	Tsunami Mitigation Plan Save Lives	
18	3	Managing Night Time Emergencies	
19	1	Warning Alert Through Announcement/Siren	Expectation
20	2	Warning Alert Via TV/Radio	
21	3	Warning Alert Through Mobile	
22	1	Night Time Emergency Experience	Experience
23	2	False Warning Experience	
24	1	View on Current Tsunami Mitigation Plan	Appraisal of TMP

A questionnaire is a preferable and a simple technique for data collection. The questionnaire should be in a sharp, apparent and well-designed manner so that it would provide reliable and relevant data from the respondents. Sample sizes of 159 respondents are selected from the three hamlets (71 members from Keechankuppam, 67 from Akkaraipettai and 21 from Kallar). Similarly, the questionnaire is distributed to 50 officials involved in Tsunami mitigation activities. A total of 209 responses were received on the site concerning Tsunami mitigation activity.

The collected data is analyzed using SPSS software. The profile of the respondents like gender, education, occupation, name of hamlets, building vulnerability is prepared using

descriptive statistics. The received responses are grouped under 'yes' or 'no' category. Further the group is subdivided into 'fair' and 'should improve' groups with respect to community appraisal of TMP. On comparing the proportions of 'fair' and 'should improve' groups the vulnerable factors are obtained. The same procedure is repeated for official group also. The respondents group are tested whether they are statistically significant using chi square, ANOVA and t-test.

The obtained data are converted into yes or no format (dichotomous). The logistic regression analysis is the suitable method for analysing the data. Regression methods are widely used for analysing the relationship between a dependent variable and one or more independent variables. Logistic regression in statistics is aimed at finding the best fitting and most economical and yet sensible model to assess the relationship between a response variables and at least one independent variables [10].

IV. STATISTICAL MODEL FOR COMMUNITY VULNERABILITY

In this study a statistical model namely logistic regression is employed to determine the community vulnerability factors. The appraisal of existing TMP is considered as the dependant variable and the other vulnerability factors are considered as the independent variables.

Like a linear regression, Logistic regression model, studies the effect of one or more independent variables on the dependent variable except the dependent variable which is not a continuous variable, but a dichotomous variable. Logistic regression coefficients can be used to estimate odds ratios for each of the independent variables in the model. It is often chosen if the predictor variables are a mix of continuous and categorical variables, or if they are not nicely distributed.

The data of all the 159 respondents are considered for the analysis. The base rates of the two decision options are given that is, 49.7% of total respondents (79/159) need the current Tsunami mitigation plan to be improved and 50.3% of total respondents (80/159) reported the existing Tsunami mitigation plan is fair.

At each step, with the inclusion of each variable, -2 log likelihood ratio and Pseudo R^2 are calculated. In linear regression, the R^2 statistics measures the proportion of the variation in response which is explained by the model. Since this value cannot be exactly calculated in Logistic regression model, the approximations are calculated instead. Larger pseudo R^2 statistics indicate more of the variation of the dependent variable. Table 4. shows that the Cox and Snell R^2 is low at 61% and the Nagelkerke R^2 which adjusts the Cox and Snell R^2 is 81%.

Table 4. Model Summary

Step	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
1	89.02	0.56	0.75
2	75.68	0.59	0.79
3	68.91	0.61	0.81

Table 5. helps to assess the performance of the model at each step by cross tabulating the observed value to the predicted value and predicts that 89% of the community sense on TMP remains idle in step 1 and 2 while the performance has been raised to 91% in step 3.

The accurate prediction of percentage for the option "Should Improve" is 94% in the first step and it decreased to 92% in the final step; whereas the corresponding proportion for the option 'fair" is only 84% in the first step and it increased to 90% in the final step.

Table 5. Classification Table

Classification			Predicted		
			community sense about Tsunami Mitigation Plan		Percentage Correct
			Should Improve	Fair	
Step 1	Community sense about TMP	Should Improve	75	4	95
		Fair	13	67	84
	Overall Percentage				89
Step 2	Community sense about TMP	Should Improve	74	5	94
		Fair	12	68	85
	Overall Percentage				89
Step 3	Community sense about TMP	Should Improve	73	6	92
		Fair	8	72	90
	Overall Percentage				91

The roles of the different parameters are summarized in Table 6. The ratio of 'β' (the estimated coefficient) to its Standard error is squared to get the Wald statistic. If the Wald statistic has a significant value lesser than 0.05, then the variable is useful to the model. Exp (β) is the predicted change in the odds for a unit change in the predictor. If Exp (β) is lesser than 1, then increasing the value of the predictor variable corresponds to decreasing odds of the event's occurrence and if Exp (β) is greater than 1, then a unit change in the predictor variable increases the odds of the event occurrence.

Table 6. Variables in the Equation

Step	Variables	β	S.E.	Wald	df	Sig.	Exp(β)
1	Belief	3.48	0.56	38.02	1	0	32.75
	Constant	-15.35	2.41	40.43	1	0	0
2	Facility	0.76	0.23	10.21	1	0	2.14
	Belief	3.35	0.6	31.25	1	0	28.64
	Constant	-22.76	3.97	32.74	1	0	0
3	Facility	0.8	0.25	10.35	1	0	2.24
	Belief	3.44	0.63	29.26	1	0	31.21
	Expectation	1.41	0.59	5.71	1	0.01	4.13
	Constant	-30.24	5.83	26.85	1	0	0

a. Variable entered on step 1: Belief.
b. Variable entered on step 2: Facility
c. Variable entered on step 3: Expectation.

From this table, the most significant vulnerability factors which fits the complete data set model is identified using Exp (β) values and the obtained factors are ranked in the order of Belief, Expectation and Facility. An equation to the model is interpreted using the 'β' values (final step) as shown below in Equation 2.

$$CVI = 3.44BF + 1.41EF + 0.8\,FF - 30.24 \qquad (1)$$

Where, CVI= = Community Vulnerability Index
BF = Belief Factor
EF = Expectation Factor
FF = Facility Factor

V. ANALYSIS OF IDENTIFIED FACTORS

From Equation 1, the factor belief (3.44), expectation (1.41) and facility (0.8) are identified as the most significant vulnerability factors using Logistic Regression method. The factor belief and expectation has three TMP issues and facility factor has seven issues. Hence, a separate logistic regression analysis is necessary to identify the contribution level of these issues. The issues are rated on a two-point scale as 'Yes' and 'No' and considered to be independent variable whereas TMP appraisal is considered to be the dependant variable.

From this separate logistic regression analysis, the influence of belief factor issues is identified and ranked in the order of (i) managing night time emergencies (ii) belief in next Tsunami (iii) Tsunami Mitigation Plan saves lives.

The influence of Expectation Factor issues is ranked in the order of (i) warning alert through mobile (ii) warning alert via TV/Radio. The announcement or siren warning issue is insignificant.

The influence of Facility factor issues is ranked in the order of (i) perpendicular evacuation route (ii) enough higher ground (iii) shelter provision (iv) easy access shelter. The other three issues are insignificant. By resolving the issues in the identified parameters an effective Tsunami Mitigation Plan is determined.

6.1 Overall Ranking of Each Category

To this point, the analysis was made on the full data set and here with the model splits up with respondents categorization like hamlet, occupation character, education nature and administration officials. The analysis further proceeds with the same tests which have been already performed in the full data set model. The split up model is important in predicting the factor which influences the model of each character. The ranking factors of various respondents are predicted and presented in Table 7.

Table 7. Overall Ranking of Each Category

Classification of Respondents	Factors Related to Community Vulnerability					
	Awareness	Service	Facility	Belief	Expectation	Experience
Keechankuppam		II	IV	I		III
Akkaraipettai			III	II	I	
Kallar				I		
Fisheries			III	I	II	
Cultivator				I		
Agriculture labour		II		I		
Non worker				I		
Male		III	II	I		
Female			II	I		
Literate			II	I		
Illiterate		III		II		I
Official	III			I		II
Full Data			III	I	II	

The Overall Ranking of Each Category illustrates that the contribution of 'belief' factor is high in all categories except Akkaraipettai and illiterate. The 'expectation' factor is the most influencing factor in Akkaraipettai. The 'experience' factor is the most influencing factor for the illiterate respondent group but shows a negative impact towards the model. Since the assumption made with the experience of community towards emergency is fair, the assumption goes wrong because community expect the TMP be improved and hence the factor has a negative influence.

VI. RESULTS AND DISCUSSIONS

The vulnerability parameters based on Tsunami Mitigation Plan issues are identified using logistic regression analysis. The present TMP appraisal of both community and officials are taken into account and hence considered to be the dependant variable and the other factors like Awareness, Service, Facility, Belief, Expectation and Experience are considered to be the independent variables in the first case. Using the 'β' coefficients, the community vulnerability index (CVI) equation has been interpreted; Where equation (1) suggests that belief, expectation and facility are the most influencing vulnerability factors. A logistic regression analysis has been carried out for the three factors individually to identify the contribution level of these issues. In this regard, firstly, it has been explored that belief factor is connected with three issues namely (1) managing night time emergencies (2) belief in next Tsunami (3) TMP save lives.To fulfil these issues, the following recommendations are suggested;

- Majority of community and official respondents believe that managing night time emergencies is highly a risk therefore a specific TMP should be recommended in particular for night time emergency to protect the coastal community.
- Majority of community believes that there is no chance for an immediate Tsunami but it is not true because Tsunami may occur anytime and it should be conveyed to them.
- More awareness regarding TMP should be given to the community because of the majority of community believes that a specific TMP alone do not save lives.

Secondly, it has been determined that the expectation factor is connected with two issues namely (1) warning alert through mobile (2) warning alert through TV/radio. To fulfil these issues, the following recommendations are suggested;

- Majority of community expects that the issue of warning alert will be effective only through mobile phones rather than sirens and alarms because it is a two-way communication and user friendly. Therefore, the study suggests that the warning alert can be given through mobile phones as a computerized voice call which should be clear and in a local language for easy understanding to the community.

- The illiterate and female expects warning alert through TV/Radio.

Thirdly, it has been identified that the facility factor is connected with four issues namely (1) perpendicular evacuation route (2) enough higher ground (3) shelter provision (4) easy access shelter. To fulfil these issues, the following recommendations are suggested;

- The foremost issue in facility factor is perpendicular evacuation route. Majority of community needs perpendicular evacuation route to manage during emergencies. Fig.2 shows the expected perpendicular evacuation route of community. Total length of the perpendicular route is 2.87 kilometres in East to West from the study area to Nagapattinam-Velankanni Bypass. In this route the first 0.83 kilometres in the East and last 0.42 kilometres in the West have already existing as a village road. A bridge is to be constructed for the remaining 1.62 kilometres to link the study area to bypass which will be a long term evacuation strategy.

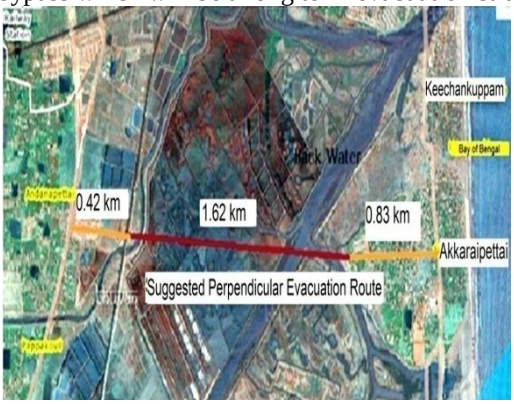

Fig.2 Expected Perpendicular Evacuation Route Map

- Even though the bridge is constructed the utility is only during emergencies like Tsunami. Therefore, as an alternative the existing village roadways in the hamlets can be widened and set right as a short term evacuation strategy.
- The other issues such as enough higher ground, shelter provision, easy access to shelter can be managed by constructing a new evacuation shelter in crowded areas like IZ-II.

Using Overall Ranking of Each Category analysis a clear view of respondents have been studied and analysed. From this it has been observed that the belief factor leads all other factors in all categories except Akkaraipettai and illiterate respondents. The expectation factor is the most influencing factor in Akkaraipettai and the experience factor is the most influencing factor for the illiterate respondents.

VII. CONCLUSION

In this study the community vulnerability to Tsunami are analysed and the factors influencing vulnerability are also studied. The main aim of the present study is to identify the community vulnerability factors to Tsunami. From the study of community vulnerability it is identified that a specific TMP should be recommended in particular for night time emergency to protect the coastal community. The warning alert will be more effective only through mobile phones because it is a duplex communication and a user friendly. The study suggests that the most appropriate choice to reduce the community vulnerability is constructing a perpendicular evacuation route for the people to evacuate on emergency situations which can also be a long term strategy. Local administration should take necessary steps for evacuation shelter provision and maintenance. The result from the study can be adopted by local government for developing TMP activities. This lays an emphasis on the development of community based TMP and also in helping the community to withstand emergency situations. The research work has ramifications in other types of disasters and in particularly other disasters like cyclone and flood risks. The result from the study can be adopted by local government for developing TMP activities. This lays an emphasis on the development of community based TMP and also in helping the community to withstand emergency situations. The research work has ramifications in other types of disasters and in particularly other disasters like cyclone and flood risks.

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