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Calculating Disaster Risk Index (DRI) for Greater Mumbai by Hazard Risk and Vulnerability Analysis (HRVA)using GIS

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ABSTRACT*-Since a long time, disaster researchers have emphasized the role of Geographic Information Systems (GIS) for effective management of disasters. Disasters as we know are severe, sudden and on a large-scale. During such times response may be quick but recovery takes time. Thus it is vital to focus more on Mitigation itself, as during this phase of disaster management, the magnitude as well as loss occurring due to a disaster can be minimized to a great extent, even though it is not possible to avoid it completely. The mitigation phase of disaster management essentially deals with hazard identification and vulnerability analysis. The present paper aims at focusing on mitigation of disasters in Greater Mumbai using GIS. Types of hazards in the city are identified and mapped. Further using GIS framework, vulnerability analysis is carried out which further categorizes each ward of Greater Mumbai into high or low vulnerability groups. Finally, Disaster Risk Index (DRI) is calculated for each ward in Greater Mumbai and spatial patterns are observed, discussed and analyzed. Analysis is carried out at micro-level taking into consideration all the twenty-four administrative wards of Greater Mumbai.*

Keywords-Disaster Risk Index, GIS, Hazard, Mitigation, Vulnerability

INTRODUCTION

Greater Mumbai city limit is divided into two districts, namely; Mumbai City district and Mumbai Suburb district. These districts are further divided into 24 administrative wards and 88 census sections. The Latitudinal and Longitudinal Extent of Greater Mumbai extends between 18º and 19.20º northern latitude and between 72º and 73.00º eastern longitude. Greater Mumbai covers an area of 603 sq. km. Total population for Greater Mumbai is 12,442,343 as per 2011 Census.

Due to being the economic capital of the country and having a coastal location the city is highly vulnerable to both, natural as well as man-made disasters.

The term disaster is derived from the ancient word ‘disastro’ which means an ill-starred event in Italian, thus disaster is precisely an event.

A disaster is defined as “an occurrence of widespread severe damage, injury, or loss of life or property with which a community cannot cope and during which the society undergoes severe disruption.”

Thus hazard and vulnerability in itself are not consequential, however, when a hazard strikes a community, which is vulnerable, and unable to cope up i.e. at risk, a disaster takes place.

Keeping into consideration these differences between hazard, vulnerability and disasters, Disaster Risk Index (DRI) was calculated for Greater Mumbai by first identifying the hazards in wards of Greater Mumbai, calculating vulnerability and then finally calculating DRI.

The present paper focuses on calculating these indices for each ward of Greater Mumbai, mapping them and analyzing the results. Thereby, making suggestions for better mitigation of disasters through maps.

METHODOLOGY

The methodology that was used for the study is Vulnerability index and Disaster Risk Index (DRI). This was done by, obtaining data regarding ward-wise exposure, hazard and capacity for Greater Mumbai. Some of the

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exposure and capacity data was obtained from socio economic parameters for Greater Mumbai (Abhyankar et. al, 2012). Ward-wise hazard data for Greater Mumbai was obtained from various sources such as BrihanMumbaiMuncipal Corporation (BMC) offices, Fire Brigade office, Traffic Police Office, Disaster Management cell of Greater Mumbai, Health Epidemic cell of Greater Mumbai etc.

ANALYSIS

Vulnerability Index for Greater Mumbai

A vulnerability index is a measure of the exposure of a population to some hazard. Typically, the index is a composite of multiple quantitative indicators that via some formula, delivers a single numerical result.

It is derived by obtaining the sum of aggregate scores for various parameters divided by the number of individual parameters:

$$\frac{\text{Parameter 1+ Parameter 2 +….Parameter n}}{\text{Total Number of Parameters}}$$

In the present study the parameters were categorized as follows:

- Human Capital= Population Density
- Social Economic Capital= Slum Population
- Environmental Capital = Flood Hazard + Fire Hazard + Landslide Hazard + Health Epidemic Hazard + Road Accidents Hazard

Thus the vulnerability formula was derived as:

$$\frac{\text{Human Capital + Socio Economic Capital + Environmental Capital}}{\text{Total Number of Parameters}}$$

The above formula gave us the **Vulnerability Index** for wards of Greater Mumbai.

After calculating Vulnerability Indices for all the 24 wards in Greater Mumbai, a map was obtained. Fig.1.

Disaster Risk Index (DRI) for Greater Mumbai

Natural disaster risk was measured in the World Risk Index, calculated by the United Nations University for Environment and Human Security (UNU-EHS) and featured in the 2013 World Risk Report (WRR 2013) published by the Alliance Development Works/BündnisEntwicklungHilft (BEH). The report systematically considers a country's vulnerability, and its exposure to natural hazards to determine a ranking of countries around the world based on their disaster risk.

The WRI developed by UNU-EHS and BEH the main feature of the WRR, determines the risk of becoming a victim of a disaster as a result of vulnerability and natural hazards such as earthquakes, storms, floods, droughts and sea level rise for 173 countries worldwide. The WRI is based on 28 indicators and research data, which are globally freely available, and results in a global risk ranking and maps, which allow for comparison between countries. Risk is at its highest where a high level of exposure to natural hazards coincides with very vulnerable societies. The countries and their corresponding Natural Disaster Risk were categorized and ranked as follows:

Key: Very Low - 0.10-3.61, Low - 3.62-5.68, Moderate - 5.69-7.43, High - 7.44-10.37, Very High - 10.38-36.43

India falls into the category of Natural Disaster Risk with 7.17 % and 100th Rank worldwide.

Thus, it would be apt to conclude that Mumbai falls under high-risk zone for Natural Disasters. The reasons contributing to the city's high vulnerability within India also include its coastal location, huge population and economic activities. Subsequently, these factors make the cities more prone to disasters both natural as well as man-made.

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Hence, in order to understand the distribution of disaster risk within the city limits of Greater Mumbai, Disaster Risk Index was calculated for each ward in Greater Mumbai using the following formula:

$$\text{Disaster Risk Index (DRI)} = \frac{\text{Hazard} * \text{Vulnerability}}{\text{Capacity}}$$

In the above given formula,

- **Hazard** is taken collectively both as Natural and Man-made Hazards in Greater Mumbai. The values are calculated as Rank Scores. The Five Hazards which are quantified and calculated are:- Floods, Landslides, Health Epidemic, Fire and Road Accidents.
- **Vulnerability-** The term Vulnerability refers to the susceptibility of the area to disasters. For the present study, vulnerability was measured based on exposure parameters for each ward. The exposure parameters were obtained by available data (Abyankar et. al, 2012), which considers socio economic factors for quantification and calculation of vulnerability in Greater Mumbai. The exposure parameters for wards of Greater Mumbai were:

1) Total Number of Households
2) Slum Population
3) Population Density

Along with the above parameters for the present study we also considered physical and socio-environmental parameters in the form of Hazards namely;

(i) Floods
(ii) Landslide
(iii) Health Epidemic
(iv) Road Accidents
(v) Fire

All the parameters were taken as rank score values and ranking method was used to enable comparative analysis. After all the calculations and ranking Vulnerability was obtained for each Ward (24)(Fig. 2). However, it must be noted that Vulnerability calculation for DRI and Vulnerability Index calculation are different as already stated and elaborated in both the formulae.

- **Capacity** - Capacity refers to policies and institutional systems at the national, provincial, local and household levels to reduce hazard-damaging potentials and reduce vulnerability.

For the present study capacity was calculated by using parameters that are incorporated by institutional bodies such as BMC(Brihanmumbai Municipal Corporation), Ward Offices and Govt Offices to reduce vulnerability in Greater Mumbai.

The relief parameters calculated and quantified for ward-wise vulnerability analysis for Greater Mumbai city limit were as follows:

1) Total Number of Schools in each Ward
2) Refuse Genearted in MT/Day
3) Total no. of available open spaces
4) Total Health Units

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RESULTS

Disaster Risk Index (DRI) – Greater Mumbai

Disaster Risk Index was calculated for each ward in Greater Mumbai using the above-discussed formula and mapped. For vulnerability mapping and analysis wards, which are highly susceptible to Disasters were identified and depicted in map.

Ranges

- 9.80 – 15.63 - Very Low
- 15.63 – 21.62 - Low
- 21.62 – 25.70 - Moderate
- 25.70 – 28.31 - High
- 28.31 – 36.69 - Very High

Fig.1.WARD-WISE VULNERABILITY INDEX FOR GREATER MUMBAI

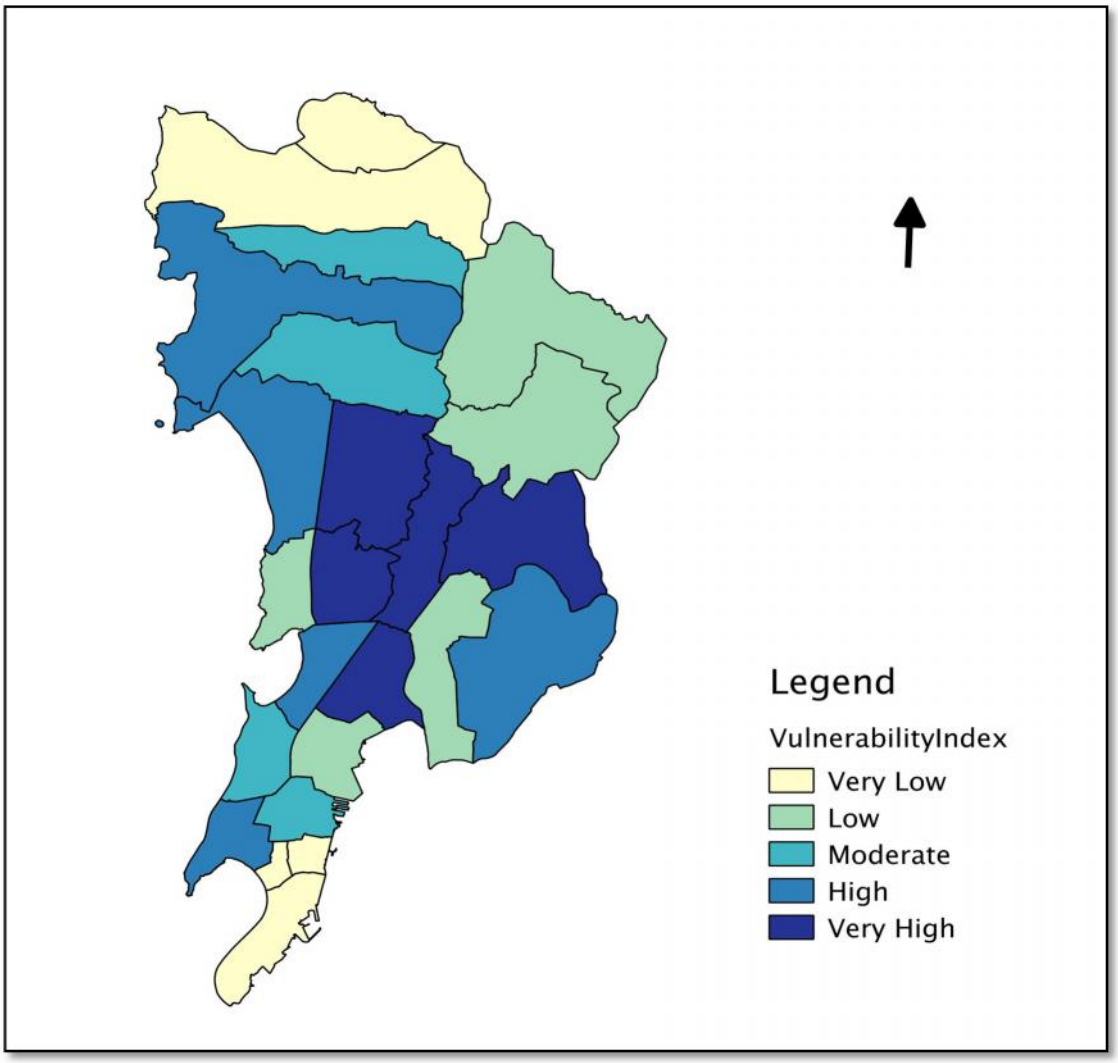

Fig.2.WARD-WISE DISASTER RISK INDEX (DRI) FOR GREATER MUMBAI

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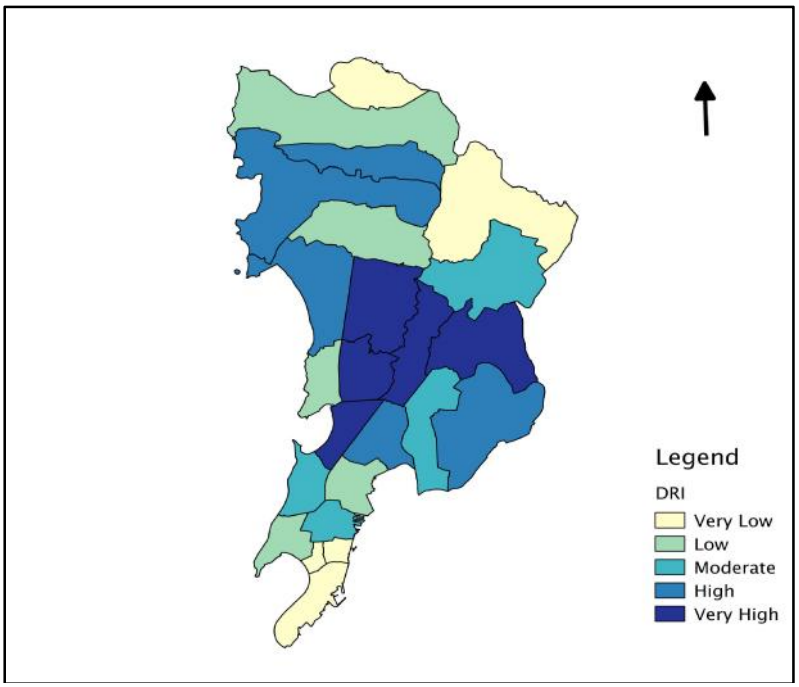

Table 1.WARD-WISE HAZARD, VULNERABILITY, CAPACITY & DISASTER RISK INDEX (DRI) FOR GREATER MUMBAI

Sr. No	Ward Name	Hazard	Vulnerability	Capacity	DRI
1	A	53.5	12	65.5	9.80
2	B	38	25	63	15.08
3	C	26.5	27	53.5	13.37
4	D	81.5	29	110.5	21.39
5	E	66.5	33	99.5	22.06
6	F/N	75	44	119	27.73
7	F/S	51.5	26	77.5	17.28
8	G/N	63.5	54	117.5	29.18
9	G/S	72	35	107	23.55
10	H/E	85.5	53	138.5	32.72
11	H/W	47.5	26	73.5	16.80
12	K/E	87	54	141	33.32
13	K/W	66	44	110	26.40
14	L	86	64	150	36.69
15	M/E	64	47	111	27.10
16	M/W	60.5	37	97.5	22.96
17	N	92	47	139	31.11
18	P/N	51	57	108	26.92
19	P/S	76	30	106	21.51
20	R/C	48	24	72	16.00
21	R/N	27	27	54	13.50
22	R/S	62	45	107	26.07
23	S	50	47	97	24.23
24	T	69.5	13	82.5	10.95

DISCUSSION

From the maps and the above table it can be observed that in some wards, though there is high vulnerability and hazard, capacity relief is lower comparatively. Both the Vulnerability Index and the Disaster Risk Index maps indicate an un-equitable distribution of risk and capacity to cope. It can be also observed that areas with high vulnerability and disaster risk are more in number.

It is also important to note that Vulnerability map shows high vulnerability mostly in the central low lying areas of Greater Mumbai, however, when disaster risk index map is presented it can be observed with a deeper analysis that capacity to cope or relief parameters in these particular wards should be higher than all other wards and thus DRI map also shows a similar picture. Not only capacity to cope should be enhanced but alsoeffective planning should be carried out by:

- Risk reduction activities
- Helping communities and families know where to take refuge and how to care for basic medical issues and;
- Efforts to reduce loss of life and property by lessening the impact of disasters should be taken

CONCLUSION

From the above analysis, it can be concluded that though Greater Mumbai is well equipped in terms of capacity to cope up with vulnerability, however when different types of Hazards are taken into consideration some areas such as Andheri, Bandra, Mahim, Kurla, Santacruz, Chembur, Dadar, Mahim, Ghatkoparetc are at high risk due to various reasons such as **Andheri, Bandra and Dadar**have high urban density, **Mahim**comprising of low lying areas, water logging, old building structures and house crashes, electric accidents in **Dharavi** slums, **Chembur** being prone to health hazards due to petro-chemical industries in the area,**Ghatkopar**prone to landslides, **Kurla** prone to water logging and road accidents etc. and **Santacruz**as the chronic water logging spot with vulnerable slum areas such as Shastri Nagar, Vakola, Ashok Nagar and areas along the **Mithi**River. Also one of the reasons for these areas having high disaster risk index value is that these areas comprise of some of the low-lying areas in Greater Mumbai. Thus it is necessary to increase the mitigation measures in these particular areas by not only enhancing the capacity to cope but also by improving the management of disasters. For example, not just open spaces, but rescue area or paths can be identified. Using local level data to build information systems and cope up with disasters in future by incorporating modern technology such as Geographic Information System (GIS). In brief, the aim should be to adopt equitable distribution of mitigation measures by minimizing the disparities as shown in the map (Fig.2) and improve each ward accordingly. Similar measures should be taken to reduce vulnerability in each ward.

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