Risk Mapping as a Tool for Disaster Risk Reduction in Urban Areas of Sri Lanka

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ABSTRACT: Hazard, Vulnerability, Capacity and Risk are the key words in the sphere of disaster management. Identification of hazard, vulnerability and risk are, key considerations for creating safer human settlements, through a process of disaster risk reduction. Risk is associated with hazard, vulnerability and capacity. Therefore in the process of creating safer human settlements, understanding the vulnerability, hazard and capacities of the related settlements are very important. People, who are living in the area, are well aware about their hazard effects through their own experiences. Spatial distributions of these hazard locations are essential tool for disaster management planning. Hence, preparation of the Hazard map is very important interms of the risk mapping since the hazard map act as the base map for all other maps. For this purpose a two channeled data collection approach is used. Initially the hazard map is prepared by collecting data from the existing sources. The data were fine tuned by using a community based approach. Relevant communities, through a series of workshops, detailed out the hazard levels, frequencies and capacities of them to developed the hazard map, vulnerability map and capacity details.

In most cases these settlements are urban local authorities. In Sri Lanka these urban settlements are limited to the current Municipal Councils (MCs) and Urban Councils (UCs). Due to the limited extent in the urban areas the mapping scale is determined as 1:5000. This also requires greater details of mapping.

Risk mapping is a process of analyzing the hazard, vulnerability and capacity through a scientific methodology. The process of risk map preparation includes analysis of several variables and parameters which are sub-sets of base categories; hazard, vulnerability and capacity. Hence, preparation of multi hazard risk map is a combination of all risk elements on several hazards. This process is important in risk map preparation and obviously in disaster management field for appropriate implementation of disaster risk reduction activities. One of the key actions that can be associated with Disaster Risk Reduction (DRR) map will be re organising of urban spaces to strengthen urban morphology with appropriate spaces and several disaster management elements. The risk mapping technology will bridge the gap currently existing in urban settlement for hazard mapping. This mapping technology will allow the decision makers to carry out their work more rationally, by adopting a more scientific process than what is currently used; a mapping technology that is used for DRR in urban settlements.

This paper discuss, community based disaster risk mapping methodology for the risk reduction in Matara Municipal Council Area which was developed under the Project for Hydro metrological Disaster Risk Reduction in Urban Areas implemented by Asian Disaster Preparedness Center (ADPC) of Thailand with the funding from USAID.

Key words: Hazard, Vulnerability, Capacity, Risk, Disaster Risk Mapping, Disaster Management

1 INTRODUCTION

Disaster Risk Reduction (DRR) has become an important tool in Disaster Management (DM). Since DM is comparatively a young subject in Sri Lanka, the mainstream of DRR activities is not directly considered as a subject of DM. In Sri Lanka, DM as a mainstream was introduced in the year 2005 after the tsunami disaster in 2004. At that time, Government of Sri Lanka (GOSL) hurriedly identified the need of a main stream DM system in the country after the unprecedented damage to life and property. In 2004, the existing mechanism was not adequate to address the needs

of the situation. DM was not taken as a mainstream activity at that time, only the relief portion of the DM was addressed and the others were only done haphazardly by certain institutions.

By the act No 13 of 2005, the 'Disaster Management' was introduced as a mainstream subject in Sri Lanka and the government streamlined the DM activities through the newly appointed institution – Disaster Management Center (DMC). Main role of DMC was initially confined to coordination activitiesand coordinators appointed at district level were expected to work along with District Secretaries. This created a vacuum in the provincial council (PCs) and local government (LAs) setup. In Sri Lanka, most of the developmentwork will be implemented with a development permit issued by the LA system. This is an important system in the urban areas of the country. One of the key tools used for development guidance in LA system is the development plan that gives the policy framework for intended development. Development plan includes number of components; land use plan is one of the important components. Proposed land use plan is used to guide the development in an appropriate manner without creating conflicting land uses. This is planed according to the development policies of the LA.

On the other hand, various hazards are threatening to the sensitive land uses. Sometimes this threatening factor exceeds the capacities of the communities creating a vulnerable situation. Therefore, the decision makers were searching for a reliable tool that can be supportive. However, due to non availability of a risk map to working scales of a LA system deprived adequate consideration of the disaster vulnerability in land use planning.

The dilemma of non existence of a risk map and land use allocation process creates a situation where LAs, without considering the vulnerabilities, taking important decisions on lands use planning or land allocation leading to unplanned development interms of DM. Therefore, this paper attempts to discuss a methodology that was developed by NBRO under one of their research/consultancy project conducted recently.

2 APPROACH

In developing urban settlement risk mapping there are various approaches; physical risk mapping, social risk mapping, environmental risk mapping and sometimes even the economical risk mapping. Each of these mapping gives very specifically the aspect that is mapped. For example; physical risk map will show the physical risk of the intended hazard. This may be affecting people or settlements directly or may be not. Nevertheless, Human settlement risk map is a combination of all the above factors and therefore, it needs greater attention. The approach for the human settlement risk map is developed through the general equation of risk which is given below.

$$Risk = \frac{Hazard \times Vulnerability}{Capacity} \qquad (1)$$

It is always useful to go by the basic approaches especially in a multi-varying analysis of number of elements. In this approach the basis of risk reduction is elementarily indicated. Risk is a combination of hazard and vulnerability where;

Hazard – Any phenomenon, substance or situation, which has the potential to cause disruption or damage to infrastructure and services, people, their property and their environment.

Vulnerability – A concept which describes factors or constrains of an economic, social, or geographic nature, which reduces the ability of a community to prepare for and cope with the impact of hazards.

Capacity– The resources and skills people posses, can develop, mobilise and assess, which allow them to have more control over shaping their own future and coping with disaster risks.

Risk– The probability that negative consequences may arise when hazards interact with vulnerable areas, people, property and environment.

Identification of hazard, vulnerability and capacities of a particular settlement will lead to determine the risk level. Yet, above mentioned variables have number of parameters which are also interrelated. Hence, understanding the variables of hazard, vulnerability and capacities and their interrelationships will be an important task in the risk assessment process.

Disaster Management is one scheme under Environmental Planning in the concept of sustainable development. Several literature reviews were conducted in developing the methodology including the theoretical phenomenon in risk assessment of settlements.

Web based documents, which were under the domain of "prevention web" and "NOAA" (National Oceanic and Atmospheric Administration in USA) helps to understand the analytical process. Key steps in risk analysis as per information gathered from above search;

- Hazard analysis
- Societal analysis

- Economic analysis
- Environmental analysis
- Critical facility analysis
- Mitigation opportunity analysis
- Risk analysis
- Risk evaluation
- Action planning

Before caring out the above steps, primary and secondary data were gathered by conducting several stakeholder and community workshops. Mostly, these steps were conducted through a steering committee consisting scientists, professionals, donor agencies etc. With the direction of the steering committee a questionnaire format was developed for data collection for the next step.

2.1 *Hazard Analysis*

This is the first step in hazard map preparation. Types of hazards, affected geographical area, magnitude and frequency of hazard are identified for the hazard map preparation. At the end of this step, a hazard zonation map of the area for several hazards is developed. This map is technical, named as the multi hazard map.

Following data collection table shows the information required in preparation of the multi hazard map of a settlement. Normally this information is collected for a smaller administrative unit. In case of an urban local authority in Sri Lanka a ward boundary is considered.

Table 01Hazard Data Collection

Hazard	Occurred years	Months of occurring	Damage

In this information collection process, damage related information given by the community is not very reliable. Most people tend to have most over estimated the damage since their knowledge on damage assessment is very limited. Therefore, the steering committee directed to collect the information as; high, moderate and low damage.

2.2 *Societal Analysis*

Social characteristics of the area are considered in this analysis especially the vulnerable groups that are indentified by the community during their consultation workshops. The demographic profile of the study area plays a significant role in the risk map preparation and it also gives vital information on the background of the community as well.

Through the questionnaire following information of vulnerable communities were collected.

- Pregnant mothers
- Infants
- Children
- Elderly people
- Unmarried women/ divorced women
- Disable persons
- Dwellers living in temporary shelters
- Persons who lives closer to sea/ river/landslide area/

The analysis of the social characteristics of the community was done through a descriptive process considering the availability of the data which was mostly at 'GramaNiladari' (GN) level. Therefore this method can be used for regional level analysis.

2.3 *Economic Analysis*

The economic analysis was the third step of the main analysis. The purpose of economic analysis is to examine the economic status of the community/area. In Sri Lanka every local authority has to prepare a budget estimate annually and resource profile to the area. This information was used along with the data collected through the community workshops in doing the economic analysis. Further, concentration of economic activities is also identified through the analysis.

Cross checking of the economic analysis was done through the land use and town development pattern of the area.

2.4 *Environmental Analysis*

Environmental aspect to the disaster risk assessment is considered in this step. The main consideration was how environment phenomena/degradation impacts the disaster risk assessment. The simple answer was that, it disturbs the natural process. As an example, the wetlands are the excess water absorbance area where the natural process allows sustaining the biodiversity of the area. Hence human activities could affect the absorbing capacities of the wetland and thereby local floods can occur.

In this analysis, environmental features which can be affected from the disasters are identified and through giving weightings risk level can be determined.

2.5 *Critical facility analysis*

Critical facilities are also associated with physical aspect of the area. This analysis consisted infrastructure facilities available in the area that intern is identifies the elements at risk in the area.

Critical facilities were analysed quantitatively considering the critical locations, availability of alternatives, de-routing possibilities, capacities etc. Infrastructure facilities such as police, fire & rescue, communication, transportation etc were considered for this analysis.

2.6 *Analysis of Mitigation Opportunities*

This is a task consisting of a complex multiple sectoral analysis including the capacity and vulnerability assessment, hazard level and evacuation process etc. Following table was used to collect the information from communities.

Table 02Vulnerability Data Collection

Hazard	Impacts & vulnerability	Likelihood	Consequence Severity

Combination of factors such as societal, economic, environment and facility can be revalued through the above table. Considering the evacuation places and routes the severities of the hazard were assessed.

2.7 *Risk analysis*

Risk analysis is the most important step in the whole exercise. Finding, the risk areas from hazards are done in this step. Results of all analysis from hazard to risk profile will be used in deriving the risk levels. The process of analysis is graphically shown in the following table considering the hazard as Tsunami.

Table 03Hazard frequency, vulnerability and Risk

Frequency					*Risk*
Frequent					
Moderate					
Occasional					
Unlikely					
Highly unlikely					
Vary rare event				Tsunami	
	very low	low	high	very high	Vulnerability/ Impact

The disaster risk reduction measures or mitigation work helps to reduce the risk level for the community. The possible risk reduction measures that could adapt to the mitigation of hazards are also considered in the final analysis.

2.8 *Risk evaluation*

This will be a continuous process of the risk in the area in the future. Normally this has to be conducted several times in different time periods and it should also assess the stakeholder group participation in disaster risk reduction process. Following table was used to collect the data on stakeholder participation in DRR activities.

Table 04 Risk Evaluation

Hazard and risk	Stakeholders	Issues

By considering the above mentioned theoretical background, NBRO in their project with Asian Disaster Preparedness Centre (ADPC) for the preparation of the risk map for Matara Municipal (MMC) area was able to develop a risk mapping methodology for urban settlements. Considering data and resource availability the mapping technology was developed. In this process a previous hazard mapping experience of NBRO was also helpful.

2.9 *Mapping Methodology*

Through a brainstorming session the team identified several attributes that can be used in the risk analysis. Hazard, societal, economic, environmental, critical facilities, mitigation opportunities, risk analysis, risk evaluation, action planning were the listed ten attributes by the team. However, due to unavailability or non-updating of data, five attributes were not considered in the final risk map preparation. Also, some data were revised according to the scale of the availability. The following table illustrates the attributes that were considered and selected for final analysis.

Table 05Selected analysis for the study

Analysis	Reasons for Rejection	Considered or not for Analysis
Hazard Analysis		Yes
Societal analysis		Yes
Economic Analysis		Yes
Environmental Analysis	Due to lack of accuracy of the contour data, environmental barriers, this analysis was not considered.	No
Critical Facility Analysis		Yes
Mitigation Opportunity Analysis		Yes
Risk Analysis		Yes
Risk Evaluation	Time (?)	No
Risk Evacuation	Risk Evacuation process was not defined.	No
Action Planning	Action plans were identified but feedback analysis was not considered.	No

3 METHODOLOGY

The revised process also categorised in to basic steps of Hazard Assessment, Vulnerability Assessment and the Risk Assessment. The risk mapping process can be illustrated graphically as follows.

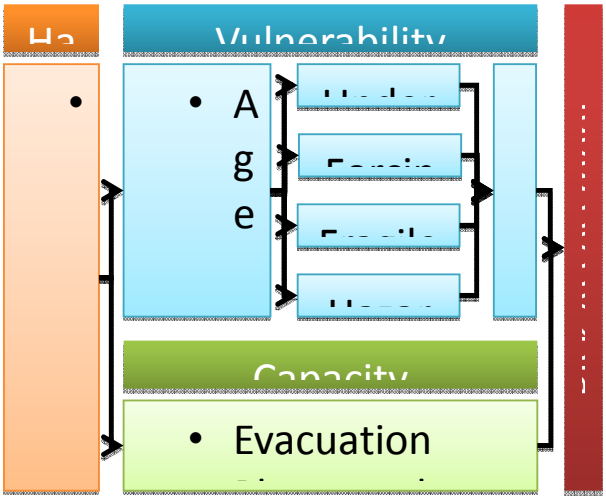

Fig 01Process

3.1 *Hazard Assessment*

Communities are the well aware of their local level hazards and disasters by their own experiences and their traditional knowledge. The aim of this step was to list down the hazard/ disasters, their frequency and magnitude in the area.

In the hazard assessment, the hazard locations were identified in the map by the community. These locations were finetuned by the relevant stakeholders in the ground level. For example historical tsunami inundated area was initially marked by the community and then verified by the local coast conservation department (CCD) and Disaster Management Centre (DMC). The community data collection was done through a series of ward level workshops. In these workshops, communities demarcated in large scale maps the location of hazard with severity and frequency. This was done for all the hazards that were identified by the communities.

The hazard locations were identified through the PGIS technique, which collected through several community workshops in Matara MC Area.

These workshops were conducted ward wise in Matara MC Area which had 15 wards. It was possible to identify the types of hazard, frequency of hazards, pair-vice ranking of hazards and capacities of the disaster management.

The data were then converted to a GIS data base using ArcGIS mapping software. Testing the accuracy of the hazard areas, especially tsunami, was coordinated with the DMC and CCD as mentioned earlier. The final multi hazard zonation map is given below. (Hazard assessment can be done using various methods, such as hazard modeling and developing, community hazard maps using community knowledge and, past/historical data. Each method has limitations and advantages. Scale and fund availability are the main criteria applicable to use in selecting the method)

Fig 02Multi Hazard Map - Matara MC

3.2 *Vulnerability Assessment*

Vulnerability is defined as "A concept which describes factors or constraints of an economic, social, physical or geographic nature, which reduce the ability of a community to prepare for and cope with the impact of hazards." Vulnerability has a close relationship with the human settlements and the hazards. Therefore, completion of the vulnerability analysis requires additional information like physical, social and economic indicators to understand the human settlement.

Hence during these workshops following information were collected for evaluation of the risk status for each GN division.

- Age structure
- Vulnerable groups/equipment
- Houses/dwellings
- Infrastructure
- Disaster history
- Evacuation places/routes
- Hazardous location

A questionnaire was developed for the collection of the demographic data such as age groups, housing characteristics, livelihood, water consumption, energy consumption, disaster records, vulnerability groups, evacuation centers, evacuation routes and resource persons. These variables were listed according 'Disaster Crunch Model' and then calculated using the above mentioned methodology. For this purpose Arc GIS and excel spreadsheets were used for calculations and map preparation.

The inter relationship between variables is an important element in this process. Disaster 'Crunch Model' is used to determine the relationship between each variable.

Table 06Relationship between variables

	Underline Causes	**Forcing Factors**	**Fragile Factors**	**Hazard**
Age structure			X	
Vulnerable groups/ equipments			X	
Houses			X	
Infrastructure			X	
Disaster History				X
Livelihood		X		
Evacuation places				X
Disaster Location				X

For the purpose of weighting each field was reclassified into segments as follows.

- Get the Z-score of the field values
- Used the quartile methodology for the classifying the z-value
- Weight the classes 1 to 5 in ascending order

The Z score was considered for the reduction of the variances between the highest value and the lowest value of each field and quartile used to group the values.

Through the equation, R=(H x V)/ C, the risk status was calculated by using above indicators.

H = [Disaster History] x [disaster locations]

V = [Age structure – (14-60 age group)] x [Vulnerable groups/ equipment] x [house – (permanent houses)] x [livelihood] x [un-skilled labour]

C = [evacuation places] x [14-60 age group] x [permanent houses] x [skilled labour]

Vulnerability is linked with the spatial location of the settlement. Therefore, in this step, by overlaying the above variables with the human settlement distribution pattern developed the vulnerability map and the capacity map in the settlements which help to understand the spatial distribution of vulnerability and Capacity. 40m X 40m was selected as a grid area (53.25 perch).

Hazard zonation map and the building density map were independently weighted in the preparation of the multi hazard vulnerability map.

Hazards were weighted by using following methodology.

- Weight: (Area of hazard affected)*100 % / (total area in affected GN)
- Building density was weighted by the percentage of urban areas of Sri Lanka.
- Final weight for the hazard area and settlement area was equal to settlement area and the environmental area.

Following indicators were used in the analysis of the capacity of the area

- No of population that can be accommodated in the evacuation center
- Availability of infrastructure and facilities (water, electricity and toilets) in the evacuation center
- Availability of goods, vehicles in evacuation centre

Where,
[infrastructure] = [(electricity) +(water)+(toilet)]
[goods& vehicles] = [(goods) + (Vehicles)]
Capacity = [Population size] {[Infrastructure] + [goods & vehicles]}

3.3 *Risk Assessment*

The risk is defined as "the probability that negative consequences may arise when hazards interact with vulnerable areas, people, property and environment". By overlaying above developed hazard assessment, Vulnerability assessment and capacity assessment could be developed for the final risk assessment of the area.

Fig 03Multi Hazard Risk Map of Matara MC

4 CONCLUSION

Comparative risk mapping is a possible activity which helps to identify disaster risk management strategies of the area. However, a lack of focus onthe hazard creates a magnification of disasters in the settlements.

MMC is a coastal urban settlement which has high risk due to several hazards which were experienced as evident from the past records. However, through a paper understanding of the risk status of the MMC area, it was possible to provide sustainable development in the area. Following table gives the final risk analysis of the MMC by each ward and basic evaluation criteria of hazard level, vulnerability and capacities. The final risk level is the outcome of using the formula of risk, hazard, vulnerability and capacities. According to the results, most of the areas have moderate risk status.

This study was trying to develop a methodology for the identification of risk levels by comparing risk levels in same premises. Therefore, comparative risk analysis was possible for the identification of different risk status as well as risk changes due to changes of elements in the settlement. These elements were helped to develop the disaster risk management strategies in settlements.

National level multi hazard risk assessment helps to develop the strong reactions for the establishment of regional and local level risk mapping for the establishment of suitable disaster risk management process in the country.

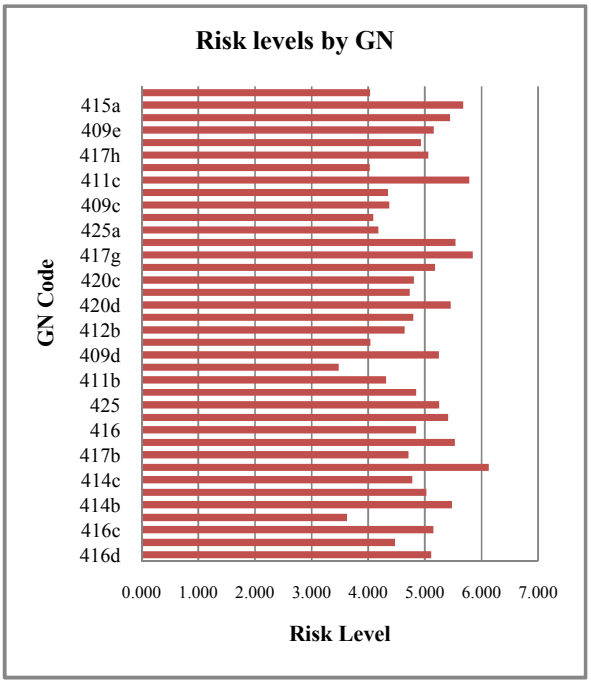

Fig 04Risk Levels by GN divisions

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