EARTHQUAKE AWARENESS AND EFFECTIVE PLANNING THROUGH PARTICIPATORY RISK ASSESSMENT: AN EXPERIENCE FROM NEPAL

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ABSTRACT
Earthquake risk evaluation is the first step for realistic and effective planning and implementation of earthquake risk reduction as well as preparedness initiatives as it helps understanding the underlying problems and its magnitude. Either simple earthquake loss estimation based on secondary information on seismic hazards and vulnerabilities or detail quantitative analysis of individual buildings and infrastructures, the risk assessment has been a very strong awareness raising and planning tool for implementing earthquake risk management activities in Nepal. Earthquake risk assessment is done in small communities with population of a couple of thousands to mega cities with millions. The methodologies and tools are customized to represent local situations and are used based on objectives of the assessment and the resources available. Active participation of all concerned stakeholders including communities, city officials and lifelines in the process of assessment itself, is most for proper utilization of its outcomes.

KEYWORDS
Participatory Risk Assessment, Action Planning, Awareness

1. INTRODUCTION

Earthquake risk evaluation is the first step for realistic and effective planning and implementation of earthquake risk reduction as well as preparedness initiatives as it helps understanding the underlying problems and its magnitude. The first earthquake risk assessment at city level carried out in Nepal was in Kathmandu Valley under Kathmandu Valley Earthquake Risk Management Project (KVERMP) implemented jointly by National Society for Earthquake Technology–Nepal (NSET) and Geo-Hazards International (GHI) in 1997.

NSET continued different earthquake risk assessment studies in different cities/communities in Nepal where different approach and methodology were adapted in the period of 1997-2007. Starting from simple earthquake loss estimation based on secondary information on general building typology distribution in the city combined with intensity distribution of past earthquake [NSET, 1999a], to comprehensive one with detail analysis of individual buildings [Jimee, 2006] were carried out. Assessments were carried out in small communities with population of a couple of thousands to the mega cities with million. However, in any case, the active participation and effective involvement of communities, city level officials and concerned city and central level line agencies was insured.

This experience revealed that the risk assessment is a strong awareness raising and planning tool unless concerned stakeholders are involved in the process of assessment itself. The general evaluation has created the demand from the communities for detail evaluation. There are cases of the communities which started risk management initiatives after the assessment; there are cities which conducted systemic earthquake risk management action planning and there are cases of influence to higher level authorities that cause formulation of related policies.

This paper describes six different methodologies used in Nepal for earthquake risk assessment, highlights the positive outcomes of the assessment works, compares different methodologies of earthquake risk assessment implemented in cities and communities of Nepal; shares the lessons learned on effective earthquake risk assessment approaches and their potential replication to other cities and communities.

2. EARTHQUAKE RISK ASSESSMENTS METHODOLOGIES USED IN NEPAL

Six different methodologies are used in Nepal for evaluation of earthquake risk of cities and communities in

Nepal. They not only differ in accuracy but the approaches and process too. The brief description of each methodology is described in this section.

2.1. KVERMP Methodology

Kathmandu Valley Earthquake Risk Management Program used an approach of using existing information on earthquake hazard than investing resources on refining it with new tools and equipment. The program used the previous documented largest earthquake shaking to the study area as the worst case scenario in terms of hazard. Intensity distribution of 1934 Nepal-Bihar Earthquake in Kathmandu [Figure 1], which was published in 1936 by geological survey of India, was used as the basic potential earthquake hazard for loss estimation. In addition, liquefaction susceptibility map prepared by [NBC, 1994] was used for estimating potential loss of lifelines and critical infrastructures.

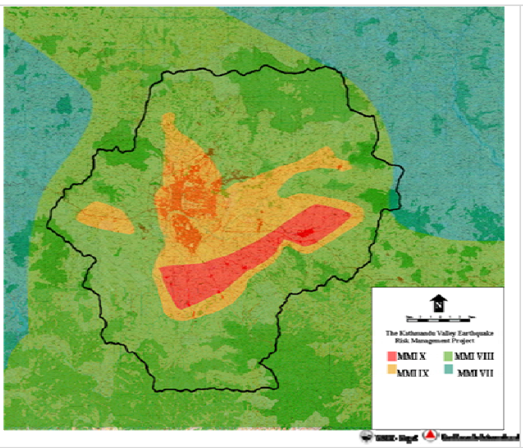

Figure 1: Intensity Distribution of 1934 Nepal-Bihar Earthquake in Kathmandu Valley compiled by KVERMP

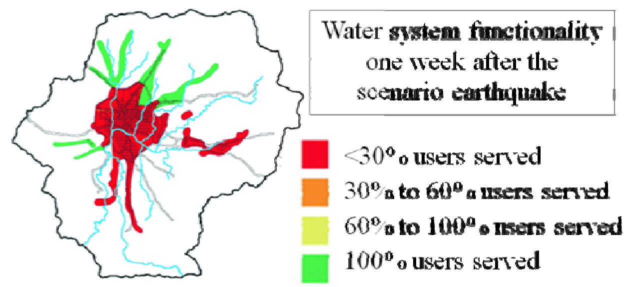

Figure 2: Water supply system damage map in Kathmandu Valley prepared by KVERMP

General information on building typology and their distribution based on census data limited survey data carried out for other project [building code development project] was used as the building and population information. Different lifelines networks like water supply network, road etc. and important critical facilities like hospitals were overlaid with the seismic hazard maps i.e. the intensity distribution and liquefaction susceptibility. Earthquake risk in terms of damage to buildings and infrastructures was calculated based on loss functions in [ATC-13, 1995] and [ATC-25, 1991]. In addition, possible death and injury figures were determined by looking at statistics from previous comparable earthquakes from around the world.

All sectors of community, technical community, decision makers/authorities, lifelines, schools, hospitals etc. were involved in the process of earthquake scenario preparation. Program conducted series of interactions with stakeholders including all lifelines facilities for their opinion on estimated damage and also their preparedness level and recovery capacities. 30 people representing different national and city level organizations participated in earthquake scenario workshop as participants and 22 more as observers. After the realistic assessment of capacities of all concerned stakeholders, the risk maps were interpreted in common people language. For example, the number of possible breaks to water supply pipelines combined with repair capacity of Water Supply Corporation interpreted to water system functionality map showing the availability of water in different part of the city after different time of scenario earthquake as shown in Figure 2.

The participation of all concerned stakeholders in the risk assessment process itself was educatory for them on possible consequence of potential earthquake to their daily life and helped to planning some risk management activities. A scenario document explaining the results of the earthquake loss estimation study in layman's terms was written and published in English and Nepali languages [NSET, 1999a]. This document includes a description of possible damages to various lifelines systems in Kathmandu and an explanation of the repercussions of this damage on in the society. The document also presents a story of a representative citizen, “Bhaicha”, for an entire year after the scenario earthquake, illustrating how his life is impacted.

After this process of scenario, the project worked with over 80 government and non-government institutions to develop an action plan [NSET, 1999b] to systematically reduce the risk over time. The main purpose of the plan is to assist the Government of Nepal, concerned agencies and the municipalities of the Kathmandu Valley to reduce the earthquake risk over time by coordinating and focusing risk management activities. The specific objectives that this plan will focus on in order to achieve that purpose are: improving emergency response planning and capability, improving awareness of issues relating to earthquake risk, integrating seismic resistance into new construction processes, improving safety in school buildings, improving the seismic performance of existing structures, improving the seismic performance of utility and transportation systems, increasing experts' knowledge of the earthquake phenomenon, vulnerability, consequences and mitigation techniques, and preparing for long-term community recovery following damaging earthquakes.
The action plan is then under implementation and some of the activities like school earthquake safety program, mason training, earthquake safety day etc. initiated as the activities of the plan are now successful programs in Nepal and the region.

2.2. RADIUS methodology

UN IDNDR (UNISDR) implemented during 1996-1999 the project called Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters (RADIUS). The project included development of earthquake damage scenarios and action plans for earthquake disaster mitigation for nine different cities (Bandung, Tashkent, Zigong, Addis Ababa, Izmir, Skopje, Antofagasta, Guayaquil, and Tijuana). RADIUS has produced a tool for earthquake damage estimation. The scenario methodology developed under KVERMP was adopted by the RADIUS project for implementation in the RADIUS cities around the world [RADIUS, 2000].
A computer program in excel for simplified Earthquake Damage Estimation was developed as a component of the RADIUS project. The program requires input of a simple data set and provides visual results with user-friendly prompts and help functions. Input data are population, building types, ground types, and lifeline facilities. Outputs are seismic intensity (MMI), building damage, lifeline damage and casualties, which are shown with tables and maps. The concerned city needs to be divided to specific grid and the input data has to be provided for all grids.
NSET implemented Municipal Earthquake Risk Management Project (MERMP) used the RADIUS tool for earthquake loss estimation in three selected cities, Banepa, Vyas and Dharan, under the project. As the RADIUS tool is easy-to-use and does not require detail technical knowledge on earthquake engineering, the municipality officials conducted the risk assessment themselves with small guidance from NSET. They run the tool for different possible earthquake scenarios. The difference of earthquake impact, if it is small or large; it occurs in day time and night time etc. was analyzed. The city officials also analyzed the impact of implementing earthquake risk management activities like building code implementation by developing different scenario after a certain period of time.

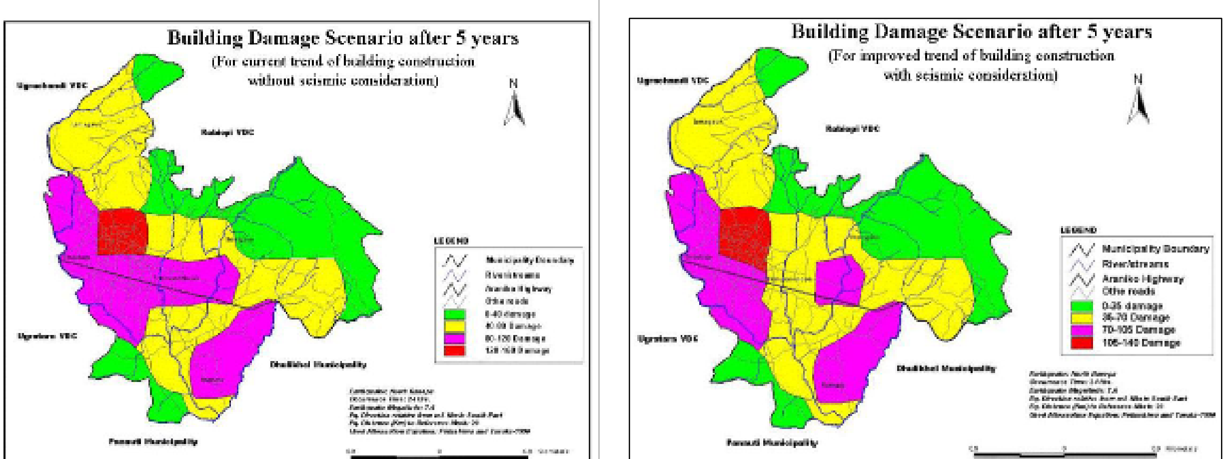

Figure 3: Comparison of damage scenario for building construction with and without seismic consideration
Figure 3 shows two building damage scenarios one after 5 years of implementing building code, i.e. improved trend of building construction and another with usual building construction trend. The result shows that if the

building code is implemented, the potential risk, after 5 years, can be reduced to half. Potential risk if the city if expanded to one direction or others were also analyzed.

Series of interactions and discussions with different stakeholders including lifelines and critical facilities to discuss on possibility of damage to different city system and facilities and its consequences after the earthquake were organized by city officials. The interaction process lead to the scenario and earthquake risk management action planning workshops where all the concerned stakeholders made commitment to include earthquake risk management in their routine work. The cities started implementing some immediate short term initiatives like folk lore competitions, earthquake safety rally etc. for awareness rising and also some long term initiatives of earthquake risk reduction like implementation of building code at city level.

So, this participatory risk assessment helped to understand the importance of implementing earthquake risk reduction activities in the city, the officials felt responsibility on it, and both the short term and long term initiatives were started implementation.

2.3 GIS in Grid

Ministry of Home Affairs (MOHA) the Government of Nepal with support from Japan International Cooperation Agency (JICA) implemented a project on “Earthquake Disaster Mitigation in Kathmandu Valley” in 2001 [JICA, 2002]. NSET worked with JICA study team for some components related to risk assessment. In this study, hazard and risk assessment was done in GIS environment. The whole Kathmandu valley was divided to 500mx500m grid and distribution of seismic hazards and vulnerability were calculated for each grid.

As the study area covered whole valley with the population of about 2 Millions, it was not possible to conduct vulnerability assessment of all individual buildings and infrastructures. So the whole valley was divided to six different categories based on the buildings typology distributions, population density and the development pattern. First, the valley was divided to urban, sub-urban and rural areas based on development pattern and all three areas were further divided to core and fringe based on population density. Distribution of different building typologies in these different areas was then counted in some of the selected areas and extrapolated the similar distribution in other similar areas.

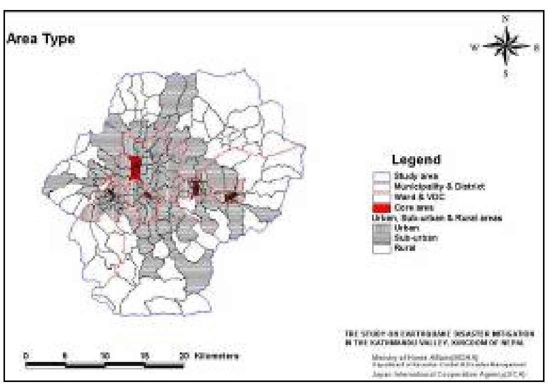

Figure 4: Three different area types in Kathmandu Valley

Table 1: Building sample areas and total number of building assessed

No.	Building Sample Areas	Settlement Type		No. Of areas sampled	Total Number of samples
		Main Type	Sub-type		
1	Institutional	Urban		(Schools, Hospitals, College, Cinema)	32
2	Commercial	Urban		6	150
3	Industrial (Light Industry)	Urban		4	40
4	Residential	Urban	Urban Core	19	281
			Urban Fringe	17	219
		Suburban	Suburban Core	2	46
			Suburban Fringe	7	151
		Rural	Rural Core	3	81
			Rural Fringe	7	183
5	Total				1183

Source: (NSET 2001)

About 1200 buildings were surveyed in detail to understand the vulnerabilities of different typology as well as use of the buildings. About 80 students from engineering institute were involved for the building inventory survey which gave them an exposure on earthquake risk assessment. Some of the students continued their professional carrier in the field of earthquake risk management later on. The fragility functions given in Nepal National Building Code [NBC, 1994] were modified based on building damage data of 1988 Udayapur earthquake in eastern Nepal. These modified fragility functions were then used for calculation of buildings damage. Figure 5 shows the fragility functions given in the Nepal National Building Code and the Figure 6 shows the modified fragility functions modified by the project.

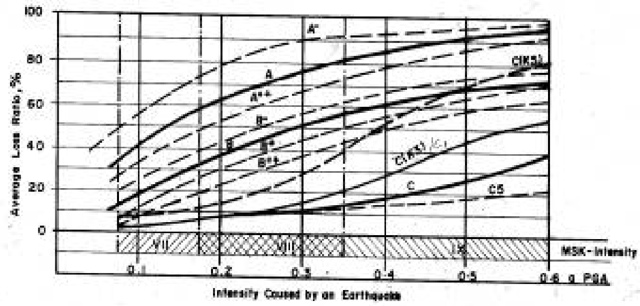

Figure 5: Building fragility functions given in Nepal National Building Code

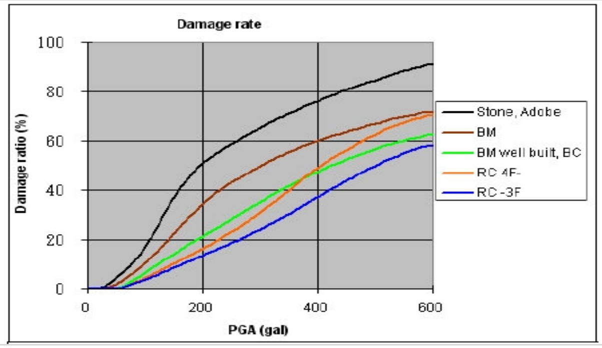

Figure 6: Building fragility functions modified by the project

2.4. SLARIM Methodology

In 2002 the International Institute for Geoinformation Science and Earth Observation (ITC) launched a research project with the acronym SLARIM, which stand for Strengthening Local Authorities in Risk Management. The main objective of this research project was to develop generic methodologies for GIS-based risk assessment and decision support that can be beneficial for local authorities in medium-sized cities in developing countries. The project was implemented in three cities Naga city, Philippines; Lalitpur Sub-Metropolitan City, Nepal and Dehradun, India. NSET involved in SLARIM project in Nepal.

Many students from ITC worked under SLARIM in Lalitpur Sub-Metropolitan City, a city with about 300,000 populations, for different aspects of earthquake risk assessment and management. In terms of methodology, project took two approaches for buildings damage and casualty estimation. In the first method, the city was divided to different homogeneous clusters [Guragain, 2004]. The clusters were made considering similar type of buildings by their number of stories, building use, building system and materials etc. In this study the same fragility functions developed during JICA project were used for damage calculation. HAZUS-MH methodology was used for casualty estimation [Islam, 2004]. The outcome of this risk assessment methodology is detail enough for city level planning for emergency response. It gives the detail information i.e. which roads are blocked by debris and which are open after an earthquake. Figure 7 gives the buildings distribution and Figure 8 the number of collapsed buildings in different clusters in Lalitpur sub-metropolitan city.

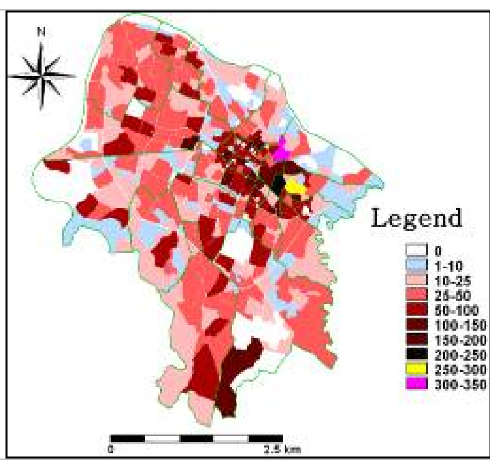

Figure 7: Buildings distribution in Lalitpur Sub-Metropolitan City area

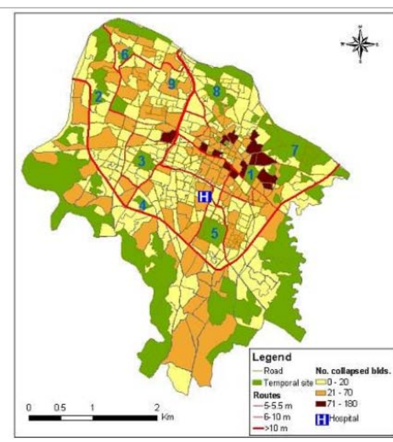

Figure 8: Buildings damage estimation in Lalitpur Sub-Metropolitan City area

In the second method, the information was collected in individual household level. Both the physical characteristics and socio-economic information of individual buildings were collected. Different building related vulnerability factors, socioeconomic conditions, public awareness, response capacity, risk perception and preparedness level of individual household were collected from the field survey [Jimee, 2006].

An intensity-damage matrix, considering existing Nepalese building types, prepared by Guragain et al. (2004) was used for building damage estimation.

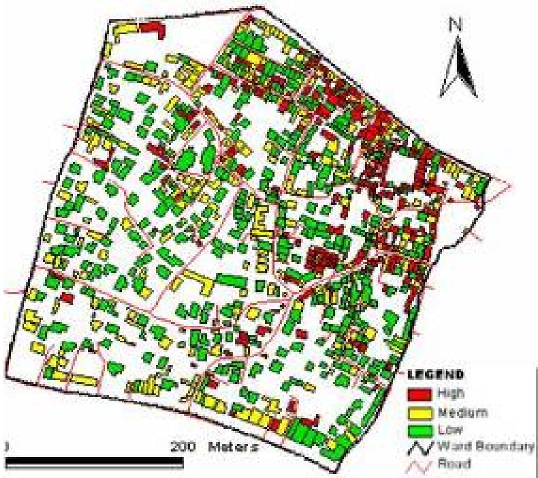

Figure 9: Buildings collapse probability at MMI IX level of shaking

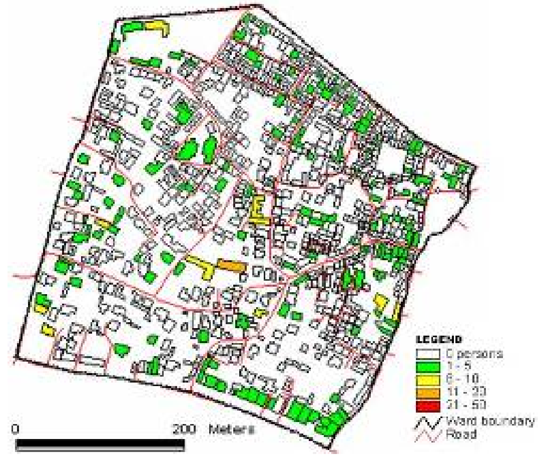

Figure 10: Possible casualty (death) at MMI IX level of shaking

Once the building damage was assessed, human casualties were estimated in relation of population distribution and building damage/collapse probability. Casualty ratios related to building damage were derived from HAZUS-MH. However, this detail study was done at ward level only. Figure 9 shows the buildings collapse probability at MMI IX level of shaking and Figure 10 shows the estimated casualty at the same level of shaking.

2.5 Community Watching

NSET is implementing Community Based Disaster Risk Management Program, which is exemplary to develop synergy of resources and understanding among the key players and stakeholders including central and local government, communities and civil society, in different parts of the country. Recently, the program was implemented in selected 5 wards of Lalitpur Sub-metropolitan City in Kathmandu Valley with the support from Oxfam GB Nepal and in 5 municipalities outside Kathmandu Valley with the support from United Nations Development Program (UNDP). The major components of the project were establishing disaster risk management organization at community Level; hazard, vulnerability and capacity assessment by community; preparation of disaster scenario and participatory action planning and implementation of pilot activities as demonstration.

Figure 11: Example of vulnerability and capacity map prepared by community

Figure 12: Leading community members finalizing the vulnerability and capacity assessment map prepared by community

The communities conduct vulnerability and capacity assessment of their community after a 3 days training on vulnerability and capacity assessment. Concerned community members visit together to all individual buildings and infrastructures in their community and identify them as highly vulnerable, medium or low vulnerable directly in the field. They discuss will all households about the problem and also collect suggestions from individuals in the community on how to reduce the vulnerability and also on how to prepare. The community also collects the resources that can be helpful during emergency. The resources includes both the human resources i.e. doctors, nurses, emergency rescuer etc. and community infrastructures like well, open spaces etc. Figure 11 shows an example of vulnerability and capacity assessment map prepared by one of the community in Lalitpur Sub-metropolitan City. After the vulnerability and capacity assessment work, the leading community members sit together and prepare a draft action plan. The draft plan then is discussed in a wider range of community members and finalized for implementation. Figure 12 shows leading community members analyzing the vulnerability and capacity assessment result for the formulation of action plan.

2.6 HAZUS Methodology

The most advance loss estimation software, which is publicly available, is the HAZUS software, interactive software released by the Federal Emergency Management Agency (FEMA) since 1997. Where the first version of HAZUS was only dealing with earthquake loss estimation, the recent HAZUS-MH is a multi-hazard loss estimation system, dealing with earthquakes (ground shaking, and earthquake induced hazards such as liquefaction, landslides, fires, floods, debris etc.) windstorms (hurricanes) and floods (coastal and riverine flooding). HAZUS-MH worked in GIS environment and full datasets on the level of census tract can be obtained for the entire United States [HAZUS, 2003].

The HAZUS software is used for Kathmandu Valley on a research basis to check if it is possible to use it with the available information or not. It is found that it is relatively complex in comparison to other methodologies described above and requires and a large quantity of the input data. It further needs adaptation for use at different levels of details, and different applications (e.g. nation-wide, or municipal scale). Some technical difficulties like changing acceleration based fragility functions to displacement based functions, limitations on building occupancy class etc. needs to resolve empirically to use it immediately. Further research is required to meet the local requirements better. However, it is found that the HAZUS can be used and can be a basis for a national level risk assessment system if the objective is to conduct detail assessment work by professionals.

3. COMPARISON OF RISK ASSESSMENT METHODOLOGIES

A comparison of earthquake risk assessment methodologies and tools used in different cities and communities in Nepal are compared for their characteristics in terms of different stakeholders involved, motivation to community for implementing earthquake risk management activities, accuracy of the assessment result, resources required for assessment works in terms of trained manpower and cost, simplicity for use and possibility to use in developing countries.

Table 2: Comparison of risk assessment methodologies

Methodologies	Stakeholders Involvement			Motivation to Community	Accuracy	Resource Required	Simplicity	Possibility of use in developing countries
	Professionals	Local Authorities	Community					
KVERMP	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM	LOW	SIMPLE	YES
RADIUS	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM	LOW	SIMPLE	YES
GIS GRID	HIGH	LOW	LOW	LOW	MEDIUM -HIGH	HIGH	COMPLEX	YES
SLARIM	HIGH	MEDIUM	LOW	LOW	HIGH	HIGH	COMPLEX	YES
COMMUNITY WATCHING	LOW	MEDIUM	HIGH	HIGH	LOW	LOW	SIMPLE	YES
HAZUS	HIGH	LOW	LOW	LOW	HIGH	HIGH	COMPLEX	YES

4. LESSONS LEARNED

By implementing different risk assessment methodologies in different communities and cities in Nepal, following lessons are drawn:

Risk assessment can be done in various scales with different accuracy: Risk assessment by community watching was done in small communities; GIS grid, KVERMP and HAZUS were used in all Kathmandu valley and SLARIM at municipal and ward level. The accuracy depends on the accuracy of input data but the possibility to go to individual buildings and infrastructures level is there in HAZUS and SLARIM methodology. Individual buildings are assessed in community watching also but it is done by non-technical community members and chance of higher accuracy is very less. So, the risk assessment can be done in different geographical scale and different accuracy level.

Simple methodologies have better impact to communities: Simple methodologies like KVERMP, RADIUS and community watching have better impact to communities and local authorities as they involve them during the assessment process. The methodologies like GIS Grid, SLARIM and HAZUS have better accuracy but due to their difficult to use by local government officials (Non-technical people) and also the communities.

Higher the resource used better the accuracy: Accurate output depends on accurate input as well as the detail options on analysis. Even if a methodology with several options is used there are chances that the output is not accurate. However, if analyzed the capacity of different tools for ability to produce detail output, HAZUS and SLARIM methodologies, which require more resources, found more accurate.

Participation is most for better utilization of outcome: Participation by concerned stakeholders who use the product is found important for proper utilization of the outcome. If the communities are suppose to start risk management activities at community level, the methodologies which involved them even in risk assessment process motivated them to start the communities activities.

5. CONCLUSIONS

Different earthquake risk assessment tools are used for evaluation of earthquake risk in cities and communities in Nepal. Some tools are easy-to-use and insure involvement of community and local authorities in the assessment process. Planning and implementation of earthquake risk management activities at local level depends more on the involvement of concerned stakeholders than the accuracy of the assessment result. Comprehensive and resource demanding detail tools can better serve to develop the system at national level than the local level.

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