Approach for National Scale Earthquake Risk Assessment: Case Study from Nepal

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SUMMARY:
The paper presents the approach for earthquake hazard, exposure, vulnerability and risk assessment for Nepal. The approach amalgamates various scientific streams, which are structured and integrated on GIS platform. The exposure, vulnerability and risk assessment are carried out for primary sectors including population, housing, education, hospital, industry, power and roadways. The risk assessment is carried out in two ways targeting emergency management agencies. One aspect of risk assessment represents expected number of sector units falling in specific grade of damage and the second aspect covers expected loss and impact on GDP due to large magnitude earthquake (i.e., Bihar-Nepal Earthquake 1934). The earthquake risk for the size of the 1934 event may mean losses exceeding 15 billion USD, can lead to large fiscal and economic impacts. Based on these findings the paper recommends DRR interventions at the national scale to tackle gaps in risk reduction, risk financing and risk governance.

Keywords: *hazard assessment, risk assessment, scenario modelling, Economic assessment*

1.0 BACKGROUND

Global to local leadership have recognized strong institutional system for effective disaster risk reduction (DRR) in line with Hyogo Framework of Action (HFA). The risk identification, assessment and monitoring are basic steps for short to long term DRR planning. Earthquake risk assessment encompasses all sectors, disciplines, expertise and stakeholders towards comprehensive understanding of causes and mitigation measures. The assessment provides decision making tools for policy formulation, allocation of resources and capacity building. Several global, regional, national and local initiatives are implemented for risk assessment and mitigation programmes across earthquake hazard prone regions. Due to its tectonic dynamics, Nepal has witnessed large magnitude earthquakes in past. Under Global Facility for Disaster Reduction and Recovery (GFDRR) programme, national scale hazard, vulnerability and risk assessment study was carried out by Asian Disaster Preparedness Center, Bangkok for Nepal. The approach for this multi-hazard risk assessment largely based on existing national and international risk assessment practices and inputs from national experts, research agencies and focal national departments. The paper presents the approach for earthquake hazard, exposure, vulnerability and risk assessment at the national scale. The paper analyzes earthquake hazard distribution across the country for 500 years return period (RP), its' impacts on various economic sectors including human life, housing, education, health, transportation, power, industries etc. The methodology is applied to major earthquake events (1833 and 1934) damage distribution and analyse the sectoral economic losses and impact on its' GDP with appropriate DRR recommendations.

2.0 METHODOLOGY FOR EARTHQUAKE RISK ASSESSMENT

The methodology is presented in Figure 1. The initial step of the risk assessment involves collection and review of data related to administrative boundaries, geology, geography, demography, disaster events, damage data, past scientific reports, research studies etc., The earthquake hazard assessment study is carried out based on PGA map developed by Department of Mines and Geology, Government of Nepal ((Pandey, 2002). The modified PGA maps are developed for 500, 250, 100 and 50 years RPs. The maps are further converted to MMI scale. The maps are developed based on Wald attenuation model (Wald, 1999) and compared with Trifunac (Trifunac, 1975) model. Wald's method is most suited to Nepal's geological condition, hence adopted for further hazard assessment. The developed maps will help potential stakeholders to understand severity of hazards and link to DRR planning. The hazard analysis further explains severity of earthquake in the country at district level. The earthquake hazard map is shown in Figure 2.

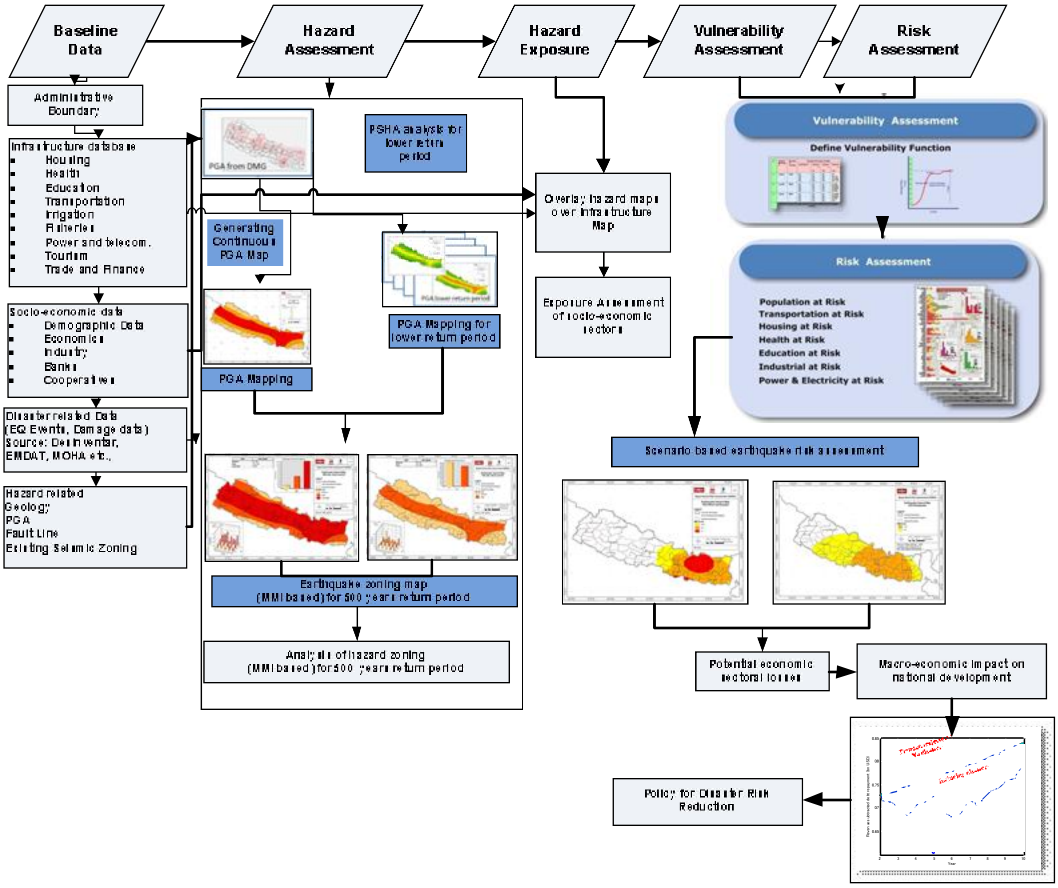

Figure 1: Methodology for national scale earthquake risk assessment

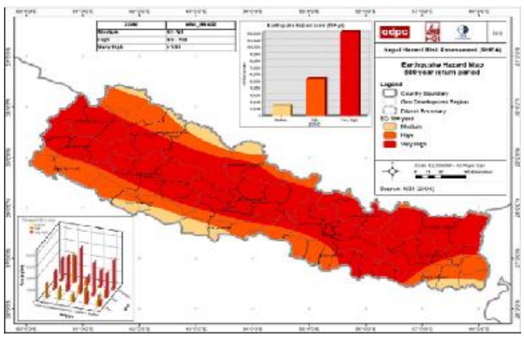

Figure 2: Earthquake hazard zoning for 500 RP

The GIS and remote sensing tools are applied to assess the exposure of earthquake to various economic and social sectors. After detailed exposure assessment, vulnerability assessment is carried out for important sectors like human lives, housing, education, health, industry, transportation and power & electricity. The vulnerability assessment provides strength and weakness of each sectors and present thorough understanding of future mitigation approach. For casualty estimation, Lethality Ratio (Coburn, 1992) is applied, which provides profile of various grades of injuries and death. Vulnerability assessment of housing at the national level is developed based on classification of buildings according to their materials and structure. In Nepal, housing has been categorized into four

classes (Kayastha, 2005), namely permanent, semi-permanent, temporary and other. This classification is also been used in the national census. However, issues arose when census data does not differentiate between buildings according to construction material and load paths. The building stock and building practices in Nepal are similar to those in South and South-East Asia. An effort is made to sync the housing classifications used in this study with already established classes and typologies. Arya characterized building response for the South Asian region. In addition, he developed potential building damage for the 1905 Kangra earthquake (Arya A.S., 2007) for the Indian region. The damage levels are categorized as (D1) slightly damaged, (D2) moderate damage, (D3) severe damage, and (D4) completely collapsed. Health infrastructures includes health posts and hospitals. Health posts in Nepal are classified as permanent and semi-permanent structures, while hospitals are permanent structure. Transport infrastructure in Nepal includes roads and bridges. The vulnerability damage matrix was derived from the ATC-13 (Rojahn, 1985). The fragility curve for transport infrastructure design is largely the same in all countries. Bridges are more vulnerable than roads due to the inherent nature of the structure itself. In Nepal industrial structures are classified as permanent buildings and are considered in the same manner as the permanent class of housing.
The risk assessment is next important step, which is presented in two ways. One approach quantifies number of infrastructure, susceptible to various earthquake damage grades, ranging from “minor”(D1) to “complete collapse (D4)”. Similarly, the approach quantifies level of casualties due to various severity of earthquake. The second approach assesses the economic losses due to earthquake and macro level impact on national development planning. The developed methodology has been further applied to past two major earthquakes in the region i.e., 1833 and 1934 earthquakes. The historic earthquake’s intensity distribution is overlaid on current physical infrastructure and sectoral damage and losses are calculated.
The macro and micro economic analysis in case of a major disaster was carried out using the Catastrophic Modeling (CATSIM) and Social Accounting Matrix (SAM). A national strategy for risk reduction is recommended based on the combined analysis of the CATSIM and SAM models. The process brings out probability of GDP losses to the country. The risk assessment process sets the basis for national level earthquake safety policy and recommendations. The study identifies gaps in various agencies approach for disaster risk reduction, institutional mechanism, capacity building and mainstreaming DRR in development planning. The details of data analysis and their graphical presentation can be referred in the project report (Nepal hazard risk assessment, 2010).

3.0 ANALYSIS OF EARTHQUAKE HAZARD AND RISK ASSESSMENT

3.1 Hazard Assessment

As the RP increases, the risk zone also increases accordingly. For 500 Years RP earthquake hazard mapping, 29 districts including Sankhuasabha, Bhojpur, Khotang, Okhaldhunga, Siraha, Dhanusha, Mahottari, Sindhuli, Ramechhap, Kabhrepalanchok, Lalitpur, Bhaktapur, Kathmandu, Nuwakot, Dhading, Lamjung, Kaski, Tanahu, Syangja, Parbat, Baglung, Myagdi, Gulmi, Rukum, Jajarkot, Dailekh, Kalikot, Accham, Baitadi are 100 % falling under very high earthquake risk. More than two third of the geographical area of 19 districts including Pyuthan,Sarlahi, Panchthar, Manang, Dadeldhura, Makawanpur, Rasuwa, Bajura, Solukhumbu, Jumla, Udayapur, Taplejung, Rolpa, Terhathum, Bajhang, Dolakha, Sindhupalchok, Doti and Darchula are under very high risk zone.

3.2 Exposure, Vulnerability and Risk Assessment (EVRA)

The exposure assessment quantified population, number of houses, their classes, and the number of schools, hospitals, health posts, industries, transportation and power infrastructures falling in the earthquake hazard zones irrespective of their strength and weakness. The details of the result and their analysis are summarized in following section.

a. Population at risk

The exposure of the population in earthquake hazard zones is estimated. The analysis for the population exposure is based on age distribution in each district. The analysis reveals that around 10 %

of the elderly population in 60 districts, 60 % of adults in 40 districts and around 40 % of the children living in 35 districts are prone to very high earthquake hazard zone. The analysis reveals that the night time scenario results in more casualties than the daytime scenario. The casualty distributions during mid-day and mid-night scenarios are calculated. Terai districts such as Siraha, Dhanusha and Mahottari show very high mortality rates. The Terai and hill regions have a comparatively high population density combined with regular seismic activity, the population living at the Nepal–India border at very high risk. The analysis further discloses that western and far-western Terai and mountain districts are comparatively safer than other regions. Casualties in Terai zones can reach up to 45,000 in the daytime scenario and more than 100,000 in night time scenario earthquake. The spatial distribution of Casualty is presented in Figure 3(a & b).

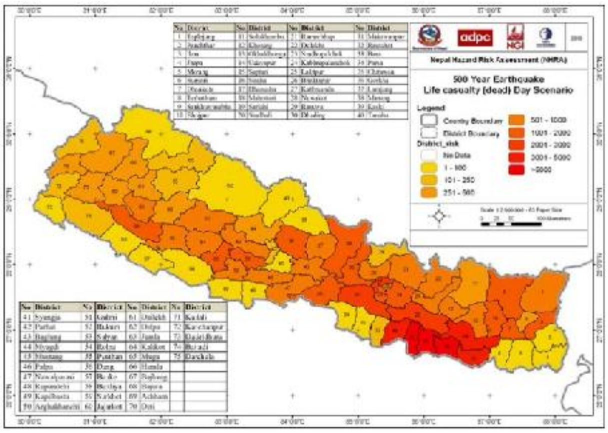

Figure 3 (a): Earthquake casualty (day time scenario)

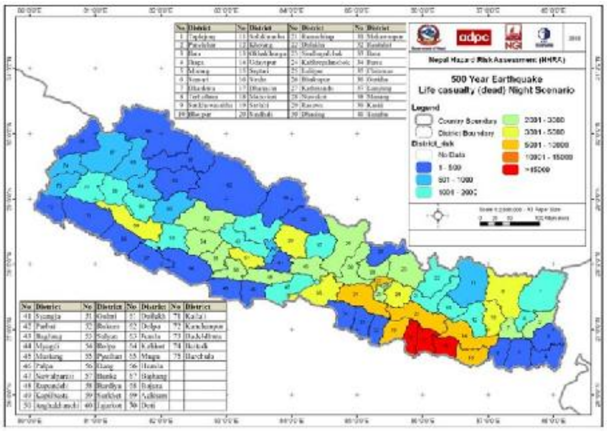

Figure 3(b) Earthquake casualty (Night-time scenario)

b. Housing sector

Kathmandu has the highest proportion of permanent houses exposed to a very high hazard zone. On average, 35 % of permanent houses in Nepalese districts are exposed to a very high hazard earthquake zone. Baitadi, Darchula, Kathmandu, Baglung, Doti are the 5 districts with the highest percentage of permanent houses exposed to a very high hazard zone. The damage to housing sector is presented in Figure 4. The vulnerability and risk assessment for the housing sector is carried out using the aforementioned methodology. To simplify, all four damage grades have been considered together and to determine the risk of damage to each particular district. Most of the houses will endure a D3 grade of damage. Several districts of western Terai zones such as Rupandehi, Kapilabastu and Banke sustain no damage. Kathmandu sustains the highest amount of damaged houses. The analysis results that 14 % of homes will sustain D4 grade, 35 % houses D3 grade and 30 % D2 grade. The housing damage assessment reveals that most houses in Nepal need seismic retrofitting to better sustain the impact of earthquakes.

c. Education sector

The 500 years RP analysis reveals that schools from 39 districts are located in a very high earthquake hazard zone. 84.8 % of schools in the districts of Nepal are exposed to very high hazard zone areas. The most exposed schools are in Bara, Parsa, Kanchanpur, Illam and Rautahat; located in the very high earthquake hazard zone. The distribution of damage grades to school buildings explains that D3 damage is distributed uniformly throughout the country. 3.6 % of school buildings will sustain a D4 grade of damage; roughly 35 % of schools sustain a D3 grade of damage while 30 % will sustain a D2 grade of damage. The expected damage distribution is illustrated in Figure 5.

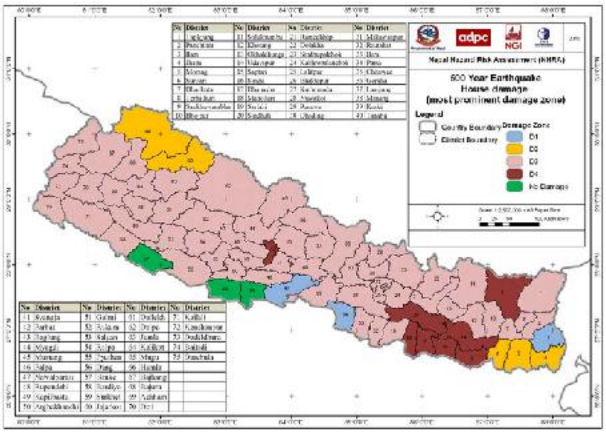

Figure 4 : Housing sector at risk

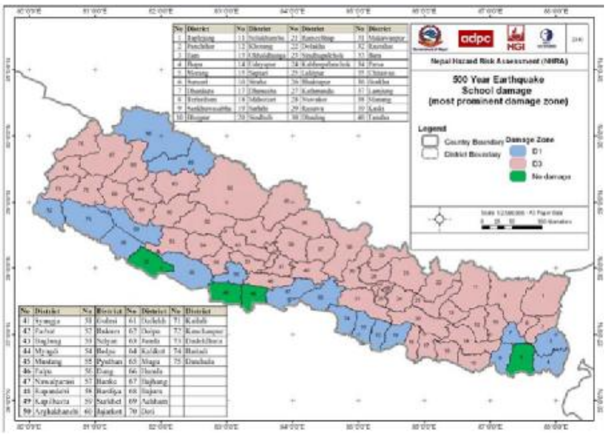

Figure 5 : School infrastructure at risk

d. Health sector

Health post infrastructure exposure exhibits that Dhanusha, Accham, Kaski, Sindhuplachok districts have the highest number of health posts exposed to a very high hazard zone. There are 41 districts that are exposed 100 % to a very high hazard zone. Illam, Rautahat, Parsa, Bara and Kanchanpur are the most exposed districts. The proportion of health posts found in a high hazard zone area is higher than in a moderate hazard zone area. The profile shows that in Kathmandu, Gorakha and Chitwan districts more than 4 hospitals are exposed to a very high earthquake hazard zone area. The assessment explains that most districts' health posts are at risk for a D3 grade of damage. Rupandehi, Kapilbastu and Banke have no risk of damage to school buildings. Over 40 districts will have 50 % of their health post suffer a D3 grade of damage. The D4 grade damage of health post structures will be less than 10 % of the total number of health posts in majority of districts. More than 45 districts will have severely damaged hospitals. As a central urban area, Kathmandu will have 3 severely damaged hospitals. All other hospitals in Kathmandu will suffer a lower level of damage.

e. Transportation sector

The risk assessment for the transport sector includes three types of roads i.e., national highways, district highways and other roads. The district roads in Kathmandu, Lalitpur, Bhaktapur and Nuwakot, which are densely populated, are located in a high hazard zone area. More than in 20 districts roads are located in a very high hazard zone area. The exposure assessment is carried out for bridges. In over 25 districts, the bridges are located in a very high hazard zone area. A comprehensive network of roads is an important factor in earthquake risk management, particularly in landlocked country like Nepal. District-wide transportation damage risk assessment will also assist the government and stakeholders in allocating their rehabilitation and maintenance budgets for transport infrastructure. The roads in the south, central and east districts have D2 Grade damage. The central district around Kathmandu is with a high population density and consequently a high density of roads and bridges. More than 40 districts are at D2 damage risk to their road networks. The analysis reveals that less than 10 % of roads are at D3 Grade damage risk. More than 25 districts' bridges in Nepal are prone to D3 Grade damage risk. Over 25 districts are at risk of 30% of their bridges D4 Grade damage. More analysis is necessary to identify bridges at risk of damage as the serve as vital infrastructure during disaster relief; bridges are especially crucial for delivering food and medical supplies after a disaster.

f. Power and electricity sector

The high electricity lines in more than 35 districts are located in a very high earthquake hazard zone area. The damage risk for high tension electric lines reveals that moderate damage (D2) risk is widespread throughout Nepal. D3 grade damages would be experienced in Kathmandu, Tanahu and Kaski.

g. Industrial sector

Kathmandu has by far the highest number of industries; 1460 of which are fully exposed to a very high hazard zone area. The study shows that industries in more than 25 districts are completely exposed to a very high hazard zone area. Earthquakes have longer impact on the industrial sector when critical infrastructure is damaged. The degree of damage to the industrial sector is an important factor when assessing the risk present in an area where industries are operational. The most D3 grade damage risk to industries occurs in the central and eastern districts. Lower damage zones are seen in most of Terai area with the exception of the Siraha, Dhanusha and Mahottari districts. Several districts in hill zone such as Kathmandu, Kaski, Bhaktapur and Dhadingare at risk of D4 industrial building structures. However, these structures only represent a small fraction of the industrial sector of those districts. Hilly zone districts are also at risk of experiencing a high number of D3 Grade. Overall, these districts are at greater risk of facing industrial non-functional.

3.3 Scenario Based Risk Assessment

For sectoral risk scenario development, MMI distribution zones (Bilham, 1995) for 1833 and 1934 earthquakes is used which is digitalized and presented in Figure 6(a & b). The 1934 earthquake was stronger than the 1833 earthquake. Nevertheless the 1833 earthquake impacted a larger area. The 1934 Bihar earthquake reached X on the MMI scale in the eastern mountain areas of Nepal and stretched up to VIII around central Nepal. The origin of the 1833 earthquake was at the Nepal-India border and spread to almost the whole of Nepal. Based on this MMI scale and proposed methodology, a damage and loss estimation analysis for these earthquakes is carried out. The cost of sectoral infrastructure is worked out based on current market rate and 2010 price index. The sectoral direct damage is summarized and presented in table 1 (a & b).

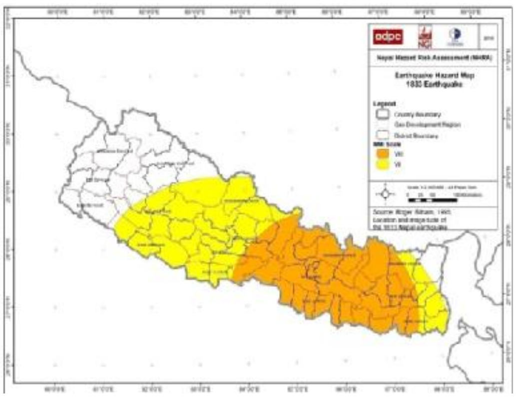

Figure 6 (a) MMI distribution for the Bihar-Nepal 1833 earthquake (Bilham, 1995)

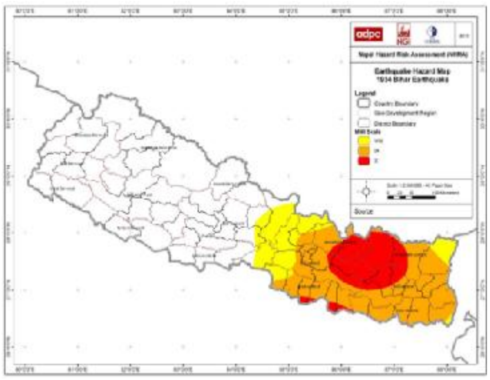

Figure 6 (b) MMI distribution for the Bihar 1934 earthquake (Bilham, 1995)

3.4 Economic Impact of Disaster Risk: *Mainstreaming Disaster Risk into Development Planning*

In order to assess the economic risks imposed by disasters in Nepal, mainstreaming is carried out for direct disaster risk in terms of losses into macroeconomic projections based on the IIASA CATSIM model (see Hochrainer, 2006; Mechler et al., 2006).

The IIASA CATSIM model uses a production functiona approach and I-O analysis in the form of a Social Accounting Matrix (SAM), is applied for the economic risk assessment. CATSIM approaches the modeling and decision problem in five steps: (1) estimate the risk of (direct) asset damages (2) analyze economic resilience of the public and private sectors (3) measure economic and fiscal vulnerability, (4) consequence analysis of macroeconomic outcome variables (5) propose strategy for risk reduction.

**Table 1.a : ** Damage estimates for the 1833 earthquake(Million Rs.)

Sector	Type		MMI VIII	MMI IX	MMI X	Total	Total / sector
			Million Rupee				
Housing	Permanent		5,833.81	41,807.34	98,148.39	145,789.54	513,942.77
	Semi Permanent		1,886.03	57,058.56	111,246.54	170,201.13	
	Temporary		5,894.33	148,875.54	41,238.82	196,008.69	
	Other		69.44	1,340.06	533.91	1,943.41	
Education building	Permanent		115.54	705.90	4,466.23	5,287.67	7,944.79
	Semi Permanent		46.56	810.59	1,799.97	2,657.12	
Health infrastructure	Health post	Permanent	13.78	56.95	757.48	828.21	1,325.60
		Semi Permanent	4.59	18.98	252.49	276.07	
	Hospital	Permanent	8.40	19.43	193.49	221.31	
Transportation Infrastructure	Road	Permanent	4,537.08	32,914.85	295.34	37,747.27	107,678.63
	Bridges	Permanent	10,358.36	48,960.00	10,603.00	69,931.36	
Industry	Factory		2,059.59	2,075.63	2,338.03	6,473.25	6,473.25
Power infrastructure	High electric line	Permanent	101,036.00	316,057.22	48,081.60	465,174.82	465,319.42
	Transformer	Permanent	37.21	75.88	31.51	144.60	
						Grand Total	1,102,684.46

Table 1.b: Damage estimates for the 1934 earthquake (Million Rs.)

Sector	Type		MMI VII	MMI VIII	Total	Total / sector
			Million Rupee			
Housing	Permanent		14,839.08	62,568.85	77,407.93	369,719.96
	Semi Permanent		7,662.53	80,391.77	88,054.30	
	Temporary		32,614.66	169,699.32	202,313.99	
	Other		325.84	1,617.90	1,943.74	
Education building	Permanent		459.23	1,127.59	1,586.81	3,075.39
	Semi Permanent		186.23	1,302.36	1,488.58	
Health infrastructure	Health post	Permanent	74.25	125.93	200.18	295.54
		Semi Permanent	24.75	0.00	24.75	
	Hospital	Permanent	21.00	49.61	70.61	
Transportation Infrastructure	Road	Permanent	1,402.49	6,800.76	8,203.25	100,437.87
	Bridges	Permanent	17,470.01	74,764.62	92,234.63	
Industry	Factory		3,521.81	3,899.81	7,421.63	7,421.63
Power infrastructure	High electric line	Permanent	203,100.51	333,606.40	536,706.91	535,877.00
	Transformer	Permanent	69.79	100.30	170.09	
					Grand Total	1,017,827.39

Asset risk estimation: In the first step, the risk of direct losses is assessed in terms of the probability of asset losses for Nepal in consistent with a function of hazard (frequency and intensity) and the elements exposed to those hazards and their physical sensitivity. CATSIM involves devising loss-frequency distributions, which relate probabilities to assets damages. The deterministic asset damage is estimated as explained in section 3.3. The total damage cost is estimated for 100 and 500 RPs which are based on 1833 and 1934 earthquakes. Table 2 shows estimated damage for 100 and 500 RPs. If disaster strikes, the government of Nepal will need to take responsibility for the reconstruction of public assets, roads, bridges, schools, hospitals etc., support to private household and business for relief and reconstruction and provision of relief to the poor. The government is liable (contingent liabilities) for approximately USD 37.5 billion. Table 3 shows the total estimated assets elements exposed to risk. The probabilistic asset damages for earthquakes are estimated as asset damage in %age GDP versus cumulative probability. The annual expected damage is the sum of all damages weighted by the probability of occurrence. Earthquake asset risk is much higher and probability is set for a first damage due to an earthquake to the 10 year RP, so that it is possible to estimate generalized extreme values (GEV) with reasonable estimates. The comparisons with the damages from the CAT models show an underestimation of damages for the 100 year event scenario and an overestimation for the 500 year scenario. Again, the process applies minimum estimate here as well to account for uncertainty. Table 4 presents potential damage (central estimate) due to earthquake risk with range of several RPs.

Table 2: RP and estimated damage

Return period	Probability	Damage (Million Rs.)	Damage (Million USD)
100	0.99	1017,827.4	14,540.4
500	0.998	1,102,685.0	15,752.6

Table 3: Estimated assets **exposed to risk**

Capital type	exposure (Billion USD)
Private Capital	52.8
Public capital	22.5
Total Capital	75.3
Govt. contingent liabilities	37.5

Table 4: Potential damage due to earthquake risk

Return period(RP)	Central estimate billion USD	Low estimate billion USD
20 year event damage	7.1	5.1
50 year event damage	9.3	6.6
100 year event damage	11.2	7.9
250 year event damage	14.2	10.1
500 year event damage	16.8	11.9

Assessment of economic and fiscal resilience: An understanding of the sources for financing a disaster in Nepal, including the costs and constraints, is crucial for planning a DRM strategy. Concerning ex-post sources, Nepal is constrained by its fiscal inflexibility and low revenue base. Diversion from the budget is considered highly constrained, and it is assumed that 10% of the budget can be diverted. In line with empirical estimates across a sample of events, international assistance is assumed to be up to 10% of the total damages. Also, Nepal has limited access to international capital market. It is assumed that Nepal can borrow only from multilateral sources at concessional rates and cannot issue any bond in international capital market after a disaster. The present value of external debt is over 240% of revenue in 2008. This means that the amount of debt which government can additionally borrow from abroad is quite limited. This is based on assuming debt value 250% of GD, as binding threshold for debt sustainability.

Measurement of financial vulnerability by the "fiscal gap": For the massive earthquake risk, the situation is very different and fiscal vulnerability is highly significant. Even for a 20 year event, the public authorities in Nepal would face difficulties raising sufficient funding, and the fiscal gap could amount to more than 2 billion USD. The analysis reveals that aid inflows could amount to as much as 850 million USD, and 50 million USD may be diverted from the budget, then another 24 million USD could actually only be borrowed even on highly concessional terms, such as offered by the World Bank through the International Development Bank (IDB). Keeping data limitations and restrictive assumptions in mind, this analysis shows that the government of Nepal has insufficient financing available even using international assistance as well as budget diversion. It is observed that the extent covered by external borrowing is relatively limited. While individual risks and vulnerabilities may be examined, it is most meaningful to assess the fiscal and economic consequences of exposure to both hazards jointly, as those are independent and thus may coincide. Over this time horizon, on average the present value of budgetary resources would now decrease by about 30% when factoring disaster risk in explicitly with a standard deviation of about 36%. The probability of a fiscal gap is close to 60%, which means that over the 10 years it seems quite likely that an event occurs that deteriorates public finances and causes longer term adverse macroeconomic impacts.

The process identifies aggregate impacts on GDP based on severe risk, very limited ability of the private sector and public authorities to respond to a large event. The GDP indicator show that given the fiscal resilience of the government and private sector's financial vulnerability, disaster events may put the economy on a lower trajectory. The occurrence of such trajectories is stochastic and depends on the probability distribution of the damages. About 10,000 trajectories are calculated (Figure 7 a,b). These trajectories do not have equal probability, the cases with economic growth proceeding as planned (the trajectories in the upper part) have a higher probability than the catastrophic cases at the bottom. Overall, such an assessment is meant to illustrate the worst outcomes compared to the planned business-as-usual case of economic development.

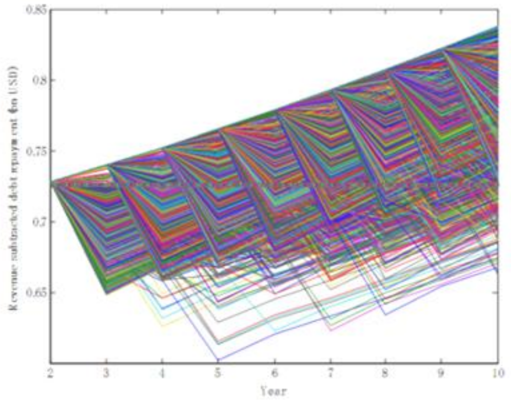

Figure 7.a: Potential fiscal impacts due to the joint risk of flood and earthquake.

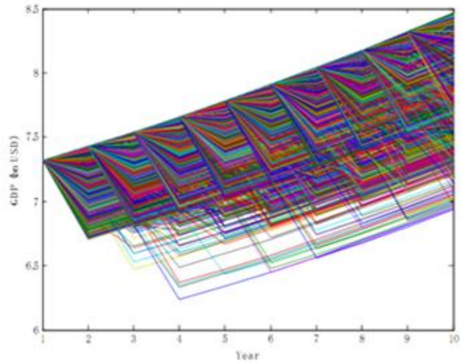

Figure 7.b: Potential GDP impacts due to joint risk of flood and earthquake

Inter-sectoral linkages: The next step is to assess the inter-sectoral distribution of losses using a social accounting matrix(SAM). The proposed SAM is calibrated based on (Acharya S., 2007) for Nepal. Based on the damage distributions estimated with CATSIM and the aggregate GDP estimates presented above, sector specific loss and income impacts are estimated, for household groups taking into account higher-order effects. The characteristics of the matrix approach includes four industrial sectors, the production factors (capital, low-skilled labour and high-skilled labour) and population groups (urban households, large rural households, small rural households, and landless rural households.

Due to computational problems, SAM approach cannot generally be reconciled with a risk analytical methodology, and a scenario earthquake event with a 100 year RP, roughly equal in intensity to the devastating event of 1934 is considered. In the case of such an event estimated above, lead to asset losses of about 14.5 billion USD. The primary affected sectors are housing, education, health, transportation, industry (manufacturing), and power infrastructure. Among them, the shutdown of the manufacturing sector would most seriously decrease its purchase of intermediate input. This study, therefore, focuses on the ripple effect due to shutdown of manufacturing sector. Table 5 summarizes the primary loss and calculated loss as well as income impact of households for this scenario earthquake as one example. It can be observed that the primary GDP loss (730 million USD) is doubled (1,420 million USD) by the multiplier effect through the involved economic interdependencies considered as linkages reduce demand for agricultural goods as well as commercial and public services. The total value of the higher order loss would amount to as much as approximately 19 % of today's GDP, which seems reasonable for such a catastrophic event destroying a fifth of the total assets. Figure 8 shows the primary and higher order losses for 1934 earthquake and Figure 9 presents income effects for 1934 earthquake.

Table 5: Primary and higher order losses of a scenario earthquake of 1934 scenario earthquake current (million USD)

Sector	Primary GDP loss	Higher order GDP loss	Income loss
Agriculture	-	383.3	-
Industry	731.5	731.5	-
Commercial service	-	228.6	-
Public service	-	80.7	-
Urban household	-	-	201.4
Large rural household	-	-	143.0
Small Rural household	-	-	181.9
Landless rural household	-	-	97.3
Total	731.5	1,424.1	624.5
% GDP	10 %	19 %	-

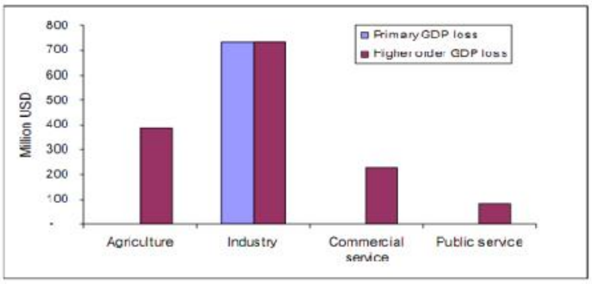

Figure 8 Primary and higher order losses for a 1934 scenario earthquake

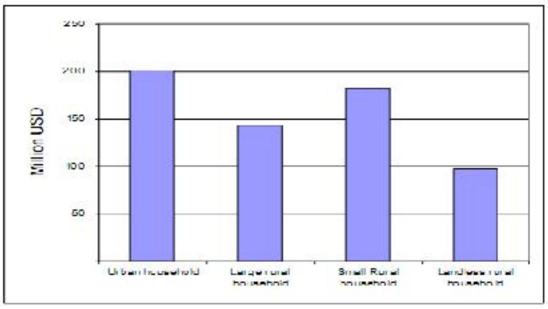

Figure 9 Income effects for an earthquake of the size of the 1934 event

4.0 RECOMMENDATIONS FOR EARTHQUAKE DISASTER RISK REDUCTION

The risk assessment is resulted in two ways which largely targets emergency management agencies. One aspect of risk assessment represents expected number of sector units falling in specific grade of damage. Another aspect of the risk assessment had the point that disasters in Nepal are considered a serious and regular threat to lives and property, and the disaster burden imposed is considered heavy, yet little is known in terms of economic impacts and losses. This is where the economic risk analysis based on the CATSIM model as undertaken becomes important. The study assessed the fiscal and economic effects of earthquakes and flood risk over Nepal, which was considered the key hazards leading to macroeconomic impacts. The analysis shows that the economic and fiscal risks posed by natural disasters are large for Nepal, and there is a clear case for considering these impacts in economic and fiscal planning. In particular, earthquake risk, for which an event of the size of the 1934 event may mean losses exceeding 15 billion USD, can lead to large fiscal and economic impacts. In terms of fiscal vulnerability, already a 20 year event may lead to a resource gap, e.g. the inability to provide key relief and reconstruction requirements post disaster. Also, explicitly incorporating disaster risk within a 10 year planning horizon, budgetary resources may be by about 30% lower compared to a case without consideration of disaster risk. As well, when using a social accounting matrix approach to derive intersectoral linkages, it is found that large events, such as that of the size of the 1934 earthquake, lead to substantial (20%) reductions in GDP due to linkages across primarily unaffected sectors such as agriculture.

Based on the results from this report a set of recommendations have been developed for setting up a national strategy for DRR. These recommendations have been categorized various heads e.g., policy, institutional mandates and institutional development, hazard, vulnerability and risk assessment, multi-hazard EWS, preparedness and response planning, integration of DRR into development planning, community-based disaster risk management (CBDRM) and public awareness, education and training. Within each component of the recommendations, geographical area of project, associated activities, expected outputs, focal or lead departments and cooperating agencies are provided. while the details of the recommendations are referred to in Nepal hazard risk assessment (2010), the economic risk assessment may inform contingency liability planning for public and private sector agents in disaster exposed and vulnerable countries. The analysis demonstrates that disasters like earthquakes and floods may ripple through an economy and indirectly affect sectors that were not hit directly by the disaster event. Thus, such cross-sector linkages should be considered in any strategy to approach disasters risk and their consequences on the affected economy as well.

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REFERENCE

Acharya S. (2007). Flow Structure in Nepal and the Benefit to the Poor. *Economic Bulletin, Vol.15, No.17* , 1-14.

ADPC Bangkok. (2010, December 15). *Nepal hazard risk assessment*. Retrieved February 05, 2012, from GFDRR: http://gfdrr.org/gfdrr/node/331

Arya A.S. (2007). Vulnerability Atlas of India Part -2. New Delhi: BMTPC.

Bilham, R. (1995). Location and magnitude of the 1833 Nepal earthquake and its relation to the rupture zones of contiguous great Himalayan earthquakes. Current Science 69(2), 101-128.

Coburn, A. a. (1992). Earthquake Protection. Chichester, West Sussex: John Wiley & Sons Ltd.

Hochrainer, S.(2006). Macroeconomic risk management against natural disasters. Wiesbaden: German University Press.

Kayastha, R. S. (2005). Housing and household characteristics and family, Chapter 5. . Kathmandu: Central Bureau Statistics (CBS).

Mechler, R., J. Linnerooth-Bayer, S. Hochrainer, G. Pflug (2006). Assessing Financial Vulnerability and Coping Capacity: The IIASA CATSIM Model. In J. Birkmann (eds.). Measuring Vulnerability and Coping Capacity to Hazards of Natural Origin. Concepts and Methods. (pp. 380-398).Tokyo: United Nations University Press.

Pandey, M. C. (2002). Seismic Hazard Map of Nepal. Kathmandu: Department of Mines and Geology.

Rojahn, C. a. (1985). ACT-13: Earthquake damage evaluation data for California. California, USA. : Applied Technology Council, .

SAARC. (2011). Seismic Microzonation: Methodology for vulnerable cities of south Asian countries. New Delhi, India: SAARC Disaster Management Centre.

Trifunac, M. B. (1975). A Study on the Duration of Strong Earthquake Ground Motion. Bulletin of Seismology Society America , 581-626. .

UNISDR. (n.d.). Hyogo Framework for Action. Retrieved July 11, 2011, from United Nations-International Strategy for Disaster Reduction: http://www.unisdr.org

Wald, D. Q. (1999). Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California. Earthquake spectra.