MINISTRY OF URBAN DEVELOPMENT (MoUD)
MINISTRY OF HOME AFFAIRS (MoHA)
MINISTRY OF FEDERAL AFFAIRS AND LOCAL DEVELOPMENT (MoFALD)
DEPARTMENT OF MINES AND GEOLOGY (DMG)
FEDERAL DEMOCRATIC REPUBLIC OF NEPAL

THE PROJECT FOR ASSESSMENT OF EARTHQUAKE DISASTER RISK FOR THE KATHMANDU VALLEY IN NEPAL

FINAL REPORT

VOLUME 1: SUMMARY

APRIL 2018

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
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COMPOSITION OF THE FINAL REPORT

Volume 1: Summary

Volume 2: Main Report

Volume 3: Map Book

Volume 4: Appendix (Materials supplement to main report, on DVD)

Volume 5: Attachment (Outcomes of pilot activities including BBB RR plan, LDCRP, SOP and CBDRRM, reports of subcontract, technical notes and risk assessment manual, etc., on DVD)

Volume 6: GIS Data (Seismic Hazard and Risk Assessment, on DVD)

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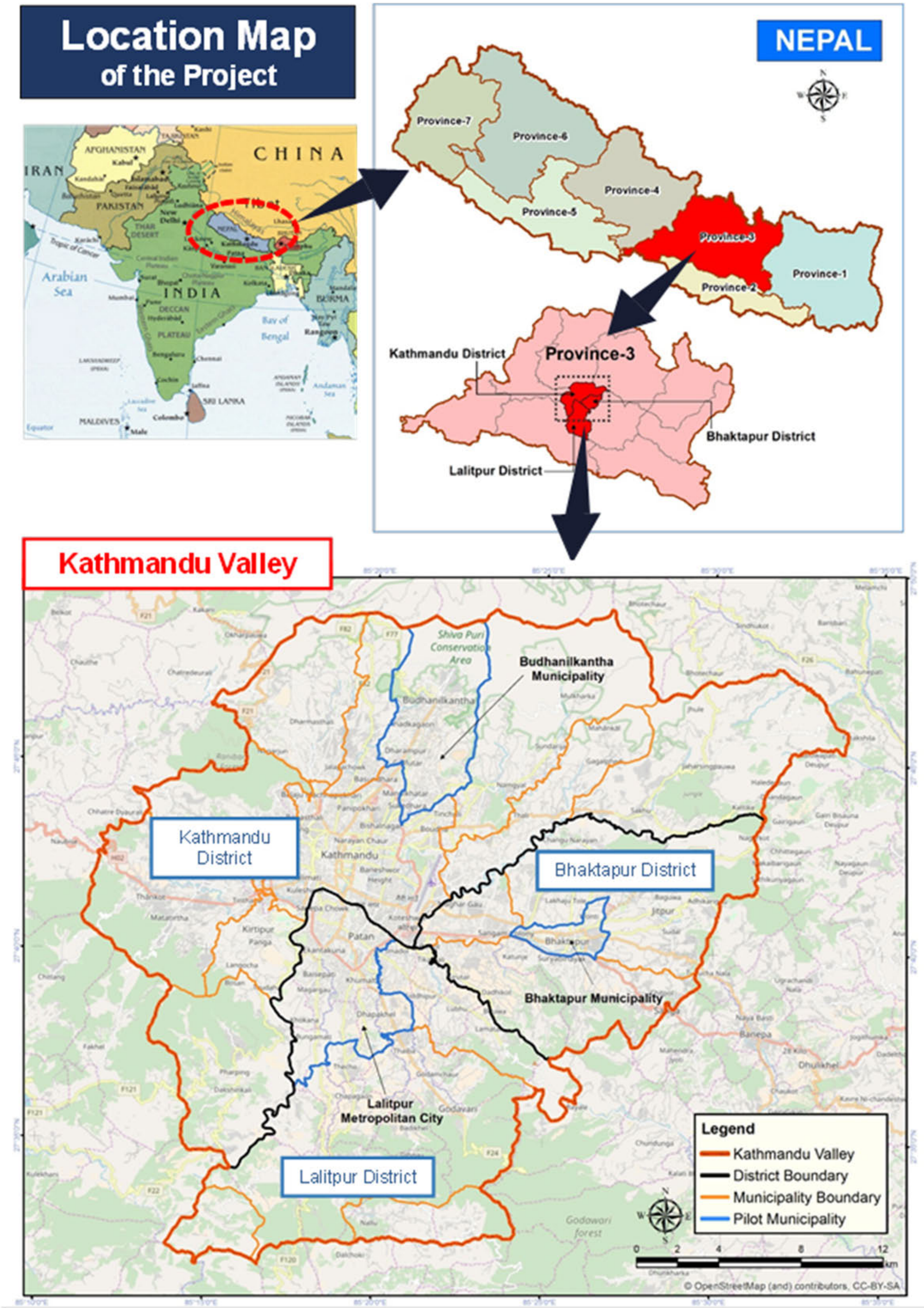
Location Map
of the Project
CHINA
INDIA
NEPAL
Province-7
Province-6
Province-5
Province-4
Province-3
Province-2
Province-1
Province-3
Kathmandu District
Bhaktapur District
Lalitpur District
Kathmandu Valley
Budhanilkantha Municipality
Kathmandu District
Bhaktapur District
Bhaktapur Municipality
Lalitpur Metropolitan City
Lalitpur District
Legend
Kathmandu Valley
District Boundary
Municipality Boundary
Pilot Municipality
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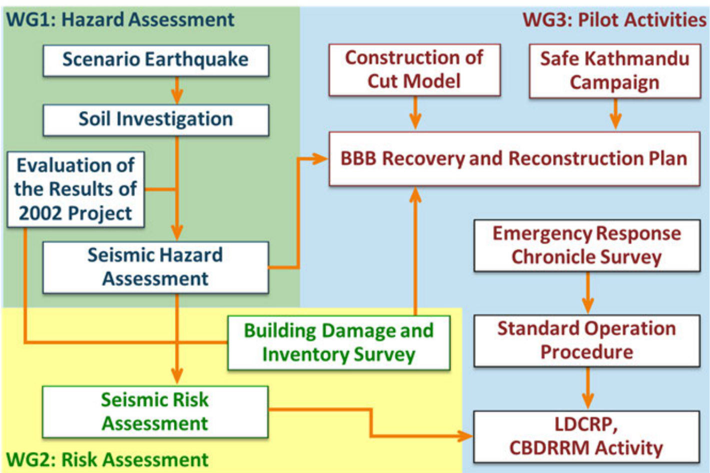
Executive Summary

1 Outline of the Project

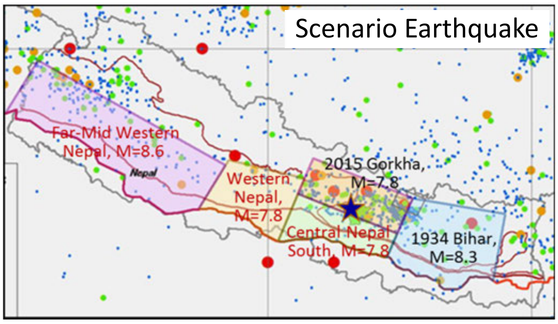
Nepal, located in the area where the Indian and Eurasian Plates hit, is one of the most frequent earthquake occurrence areas in the world. Kathmandu Valley (KV), which includes the capital city of Nepal, has experienced several disastrous earthquakes. Comparing the high risk of a future earthquake in Kathmandu Valley, countermeasures such as the retrofitting of buildings for seismic resistance, land use control and observance of the National Building Code have not been promoted enough. It becomes a necessary and urgent issue to update the risk assessment for the future development plans and policies concerned with disaster risk management. In this circumstance, the project was created with the main components of seismic hazard assessment, seismic risk assessment and formulation of local disaster and climate resilience plans.

However, the Gorkha Earthquake occurred on April 25, 2015, just before the commencement of the project. It is recognized by both JICA and GoN that a quick recovery and reconstruction is an urgent issue and, in the meantime, it is necessary to promote the DRR for future earthquakes. On the other hand, the simple recovery, which means constructing the same structures as that of before the quake, must be avoided in order not to have the same venerability as before. For this purpose, both the Project Team and the counterpart considered a recovery and reconstruction plan with the concept of Build Back Better (BBB) was necessary to be added to the project among the other modifications including the construction of demonstration models of safe buildings, implementation of a disaster risk reduction awareness campaign, damage data collection, a detailed soil survey, emergency response chronicle survey and the formulation of Standard Operation Procedure (SOP), as shown in the figure on the right. The seismic hazard and risk assessment were carried out for the whole KV and pilot activities targeted on three pilot municipalities: Lalitpur metropolitan city, Bhaktapur municipality and Budhanilkantha municipality.



Main Activities of the Project

2 Seismic Hazard Assessment

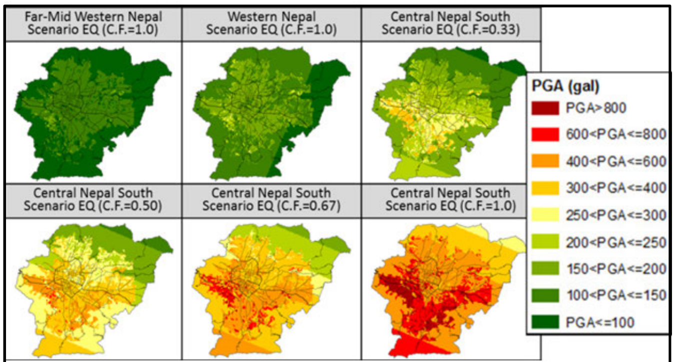


Scenario Earthquake

The main content of seismic hazard assessment in this project is the estimation of the seismic ground motion as the target at the time of planning. For this purpose, three scenario earthquakes were set based on the historical and current seismic activity, which are Far-Mid Western Scenario Earthquake, Western Nepal Scenario Earthquake and Central Nepal South Scenario Earthquake.

The surface ground was modelled for assessing the amplification of the earthquake motion. The detailed geomorphological map was prepared based on the aerial photographs and site survey. More than 400 drilling logs were collected, and the geological cross-section has been newly prepared (EW- 11, NS- 14 of a total 25 sections) with maximum depth of about 500m. The bedrock distribution has been estimated based on the gravity survey results and drilling data. To investigate the physical properties of the soil layers, microtremor measurement was selected, Five tripartite microtremor measurements were conducted to determine the S-wave velocity structure of deep grounds up to several 100 meters. An L-shape array Microtremor was conducted at 74 points to determine the S-wave velocity structure of shallow ground up to 50 meters. Based on the above, for each 250m × 250m grid (total 11,934), setting of the ground model of up to a maximum depth of about 500m has been done.

The earthquake motion at the bedrock was evaluated using the up to date ground motion prediction equation. The amplification of surface soil was evaluated by one dimensional response analysis. The largest issue was the fact that the observed earthquake motion (PGA) of the 2015 Gorkha Earthquake was extremely smaller than the calculated PGA. The reason of this discrepancy is not scientifically identified so far. To move ahead with the hazard/risk assessment and disaster risk reduction and management planning, the correction factor (C.F.) for the earthquake motion estimation was introduced. The value of C.F. was set by comparing the observed and calculated earthquake motion for 2015 Gorkha Earthquake and 1934 Bihar-Nepal Earthquake. Because of the current situation of methodology and limitation of data, several C.F. were introduced for the Central Nepal South Scenario Earthquake. Finally, six PGA distributions and five PGV distributions for three scenario earthquakes were prepared.



Distribution of Peak Ground Acceleration (PGA)

The liquefaction and slope failure possibility were assessed for scenario earthquakes. As the accurate data regarding ground materials for liquefaction and slope failure evaluation in Kathmandu Valley are very few, the evaluation had to be implemented referencing the past history, assuming several logistical points, estimating the parameters of soil layers, and in consideration of the following disaster management activities.

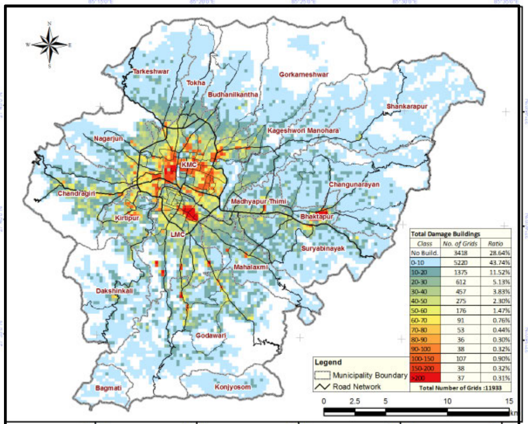
3 Seismic Risk Assessment

Seismic risk assessment was carried out for the purpose of providing basic information for the formulation of disaster risk reduction and management plans of pilot municipalities, as the update of the risk assessment results of 2002 JICA project of The Study on Earthquake Disaster Mitigation in the Kathmandu Valley. It was performed based on the latest situation of buildings, population, etc. and taking into account the new research results on risk assessment method as well as the characteristics of ground motion, building damage and human casualties caused by the Gorkha Earthquake.

The contents of risk assessment cover the structural damage of general buildings, schools, hospitals and government buildings, roads, bridges, water supply pipelines, sewage pipelines, power poles and mobile communication base transceiver stations as well as human casualties and economic loss. For the purpose of investigation the effect of building seismic strengthening, the damage of general buildings was estimated for both now (2016) and 2030, the end of the time horizon of local disaster risk reduction and management plans, for plural presumptive cases. Human casualties, including deaths, injured and evacuees were estimated for three scenes of earthquake occurrence: 2:00 in the middle of the night, 12:00 noon on a weekday and 18:00 afternoon on the weekend.

It should be pointed out that the basic information on buildings, infrastructure and lifeline inventories, essential for risk assessment, is insufficient. In this project, all buildings in four municipalities were surveyed, while the building inventory, including building number and structure type, of the other municipalities has to be estimated. Since it is important to have such kinds of basic data for not only risk assessment but also promotion on seismic retrofitting, the development of a GIS database is an urgent issue.

Major results of risk assessment are given in the following table. The building damage distribution, as an example, is shown in the right figure. Building damage and human



Total Damage Buildings		
Class	No. of Grids	Ratio
No Build.	3418	28.64%
0-10	5220	43.74%
10-20	1375	11.52%
20-30	612	5.13%
30-40	457	3.83%
40-50	275	2.30%
50-60	176	1.47%
60-70	91	0.76%
70-80	53	0.44%
80-90	36	0.30%
90-100	38	0.32%
100-150	107	0.90%
150-200	38	0.32%
>200	37	0.31%
Total Number of Grids :11933		

Distribution of Heavy Building Damage

casualties are mainly concentrated in the old urban area within ring road, where there are more buildings and higher population density. All of the figures showing the risk assessment results are compiled in a separate map book.

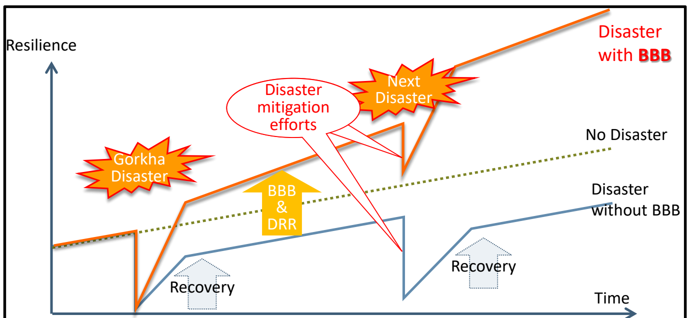
Main Results of Seismic Risk Assessment

Category	Status	Structural Damage and Human Casualty				Economic Loss (mil. NPR)			
		Scenario Earthquake Ground Motion				Scenario Earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3	WN	CNS-1	CNS-2	CNS-3
General building	Heavy damage (No.)	24,961	65,314	136,060	199,643	132,999	371,003	761,531	1,098,353
Death	Night (2:00)	3034	9133	22179	35726				
	Weekday (12:00)	2784	8282	19959	31956				
	Weekend (18:00)	2123	6393	15526	25008				
School building	Heavy damage (No.)	237	737	1,654	2,486	20,462	51,231	98,171	134,932
Health facility building	Heavy damage (No.)	20	64	153	235	27,534	68,588	165,683	232,782
Government building	Heavy damage (No.)	20	59	126	186	2,444	8,669	16,514	22,708
Road	Possible damage (km)	0	82.7	373.4	845.9	0	471	1,620	2,878
Bridge	Heavy damage (No.)	0	1	12	32	377	898	1,359	1,914
Water supply (Existing)	Damage points	982	1,921	3,496	5,161	36	71	129	191
Water supply (Planned)	Damage points	124	255	460	676	5	9	17	25
Sewage	Damage Length (km)	4.81	8.15	11.94	18.21	76	135	200	290
Power pole	Pole broken (No.)	1,327	3,991	9,156	13,992	19	56	129	197
Mobile BTS tower	Tower damage (No.)	43	143	372	601	82	272	707	1,142

4 Pilot Activities

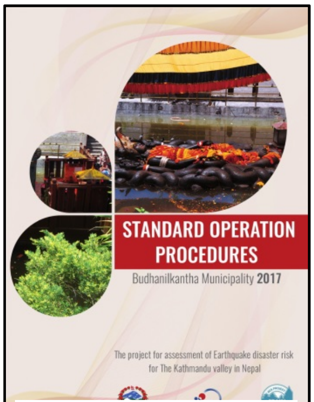
Pilot activities were carried out mainly based on the results of hazard and risk assessment in the three pilot municipalities: Lalitpur Metropolitan City, Bhaktapur Municipality and Budhanilkantha Municipality, which were selected from different districts with the regional characteristics and damage conditions of the Gorkha Earthquake, etc. The purposes of pilot activities are not only implementation of activities themselves such as formulation of plans and capacity building of the pilot municipalities, but also to develop the model of systematic local disaster risk reduction and management framework based on disaster risk assessment. In this sense, it was also aiming to consider the measures for nationwide dissemination to all the local governments in Nepal by summarizing and examining the outputs and issues collected through the activities.

In the first phase, activities for emergency response and recovery/reconstruction, which were added to the project considering the changes of the situation due to the Gorkha earthquake, were implemented. The BBB Recovery and Reconstruction Plans for pilot



Concept of BBB

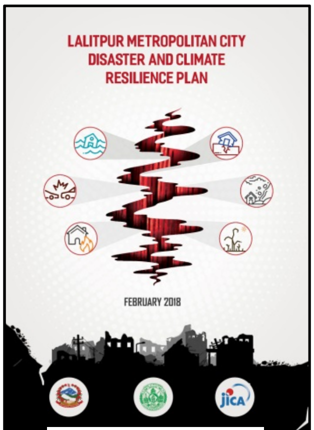
municipalities were formulated. They consist of the damage situation and direction of reconstruction along with basic policies and action plans based on the concept of Build Back Better. An Emergency Response Chronicle Survey of the Gorkha earthquake was prepared to clarify the status of actual emergency response and issues by interviews to the related organizations. DRR Awareness Activities were implemented for the community and residents in the pilot municipalities. The main purpose of the activity is to disseminate the basic knowledge for a safe building for reducing the damage by future earthquakes. Development and dissemination of earthquake awareness brochures, earthquake awareness workshops, broadcasting of radio awareness programs were implemented.



SOP (Budhanilkantha)

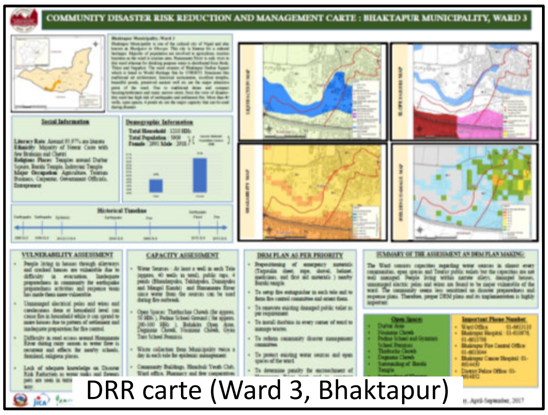
Standard Operation Procedure (SOP) was developed as one guideline which enables to understand specific emergency response activities in case of real disaster in order to make disaster response process effective, organized and result-oriented. It consists of four chapters and four appendixes including establishment of Emergency Response Head Quarters (ERHQ) and activity flowchart of each section.

The Technical Guideline for Formulation of Local Disaster and Climate Resilience Plans (TG LDCRP) for all local levels of Nepal was developed. TG LDCRP helps to formulate the practical and effective Local Disaster and Climate Resilience Plan (LDCRP) effectively at the local level and is a supporting manual aiming to give guidance. It is to be utilized as a reference document so that the local level entities such as a municipality can understand its detail contents, formulation procedures, examples of description and notes to be considered.



LDCRP (Lalitpur)

The Local Disaster and Climate Resilience Plans (LDCRP) were formulated for pilot municipalities. LDCRPs were developed by utilizing the result of the earthquake risk assessment to consider the target for disaster risk reduction according to Sendai Framework and consider the necessary activities to achieve its targets in accordance with TG LDCRP. Three times workshops were held to make the plan practical based on the local conditions and ensure direct and inclusive participation of all stakeholders in each municipality for planning. On the basis of the results of these workshops, LDCRPs were drafted and finalized. TG LDCRP can be utilized for nationwide dissemination for formulation of LDCRP including the disaster risk reduction strategy by local level entities of Nepal. Therefore it contributes to the global target (e) of the Sendai Framework for disaster risk reduction 2015-2030 which is substantially increasing the number of countries with national and local disaster risk reduction strategy by 2020. Furthermore, LDCRP formulated in this project also can be utilized for nationwide dissemination as a model plan in order to set the numerical disaster risk reduction target to be achieved for the resilience. It thus helps to promote the plan formulation processes in accordance with the understanding of the disaster risks by hazard and risk assessment.

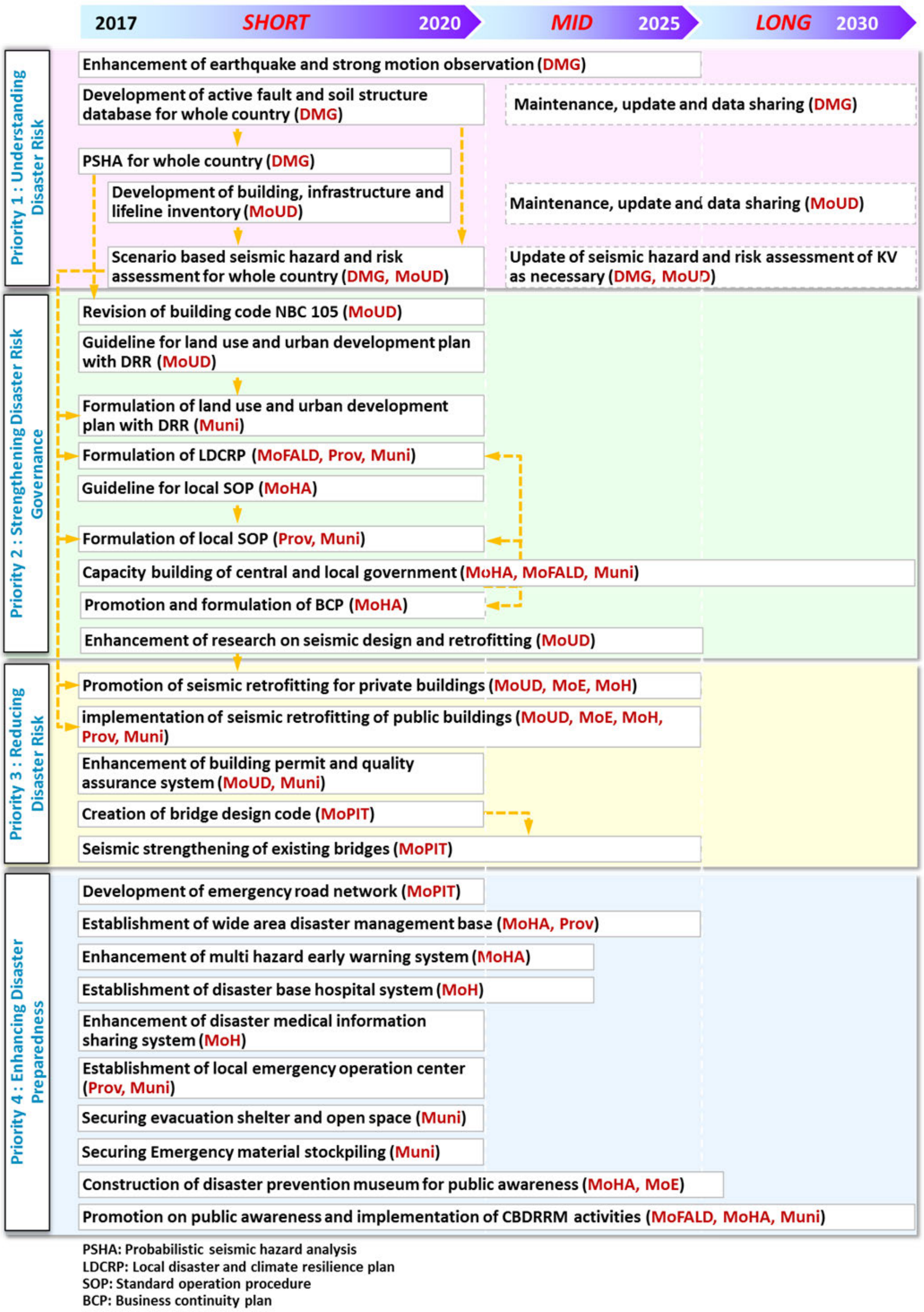


DRR carte (Ward 3, Bhaktapur)

Community Based Disaster Risk Reduction and Management (CBDRRM) activities were conducted in a selected pilot ward in each of the three pilot municipalities as one of the proposed activities in the BBB Recovery and Reconstruction Plan. For ensuring the sustainable CBDRRM activities, a 3-day training program was provided for the municipality officers to understand the contents of the CBDRRM activities. Then, the activities in the community were conducted mainly by holding the workshops with interactive lectures, field survey and participatory discussions. Based on these activities, the DRM plan and DRR carte in each ward were finalized, and one of the selected priority activities, the stockpiling of emergency management tools and equipment, was implemented in each pilot ward.

5 Recommendations for Mainstreaming Seismic Disaster Risk Reduction

There is a possibility of strong earthquake around KV in the future, which, according to the estimation of this project, may cause more damage than Gorkha earthquake. Both structural and non-structural measures are necessary and urgent to reduce the potential disaster risk. On the other hand, the Sendai Framework, with its four Priorities for Action and seven Global Targets, provides a guideline for development of DRR policy and activities. Considering the current situation of DRR policy and implementation of Nepal as well as the issues and challenges recognized through the implementation of the project, a roadmap, summarizing the recommendations for mainstreaming seismic disaster risk reduction, is proposed in line with the Priorities for Action of the Sendai Framework. In order to lead the recommendations to concrete implementation, a strong institutional system is necessary to manage the implementation in a cross-sectoral manner. The leadership of MoHA under the new DRRM Act is expected for the steady and continuous implementation of DRR policy and activities.



Roadmap for Enhancing Seismic Disaster Risk Reduction

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Abbreviations

Abbreviation	Official Name
BBB	Build Back Better
BCP	Business Continuity Plan
BSPS	Promotion on Building Seismic Performance Strengthening
BTS	Base Transceiver Station
CBDRRM	Community Based Disaster Risk Reduction and Management
CBS	Central Bureau of Statistics
CDMC	Community Disaster Management Committee
C.F.	Correction Factor
CNS-1	Central Nepal South Scenario Earthquake Ground Motion, C.F. = 1/3
CNS-2	Central Nepal South Scenario Earthquake Ground Motion, C.F. = 1/2
CNS-3	Central Nepal South Scenario Earthquake Ground Motion, C.F. = 2/3
C/P	Counterpart
DCC	District Coordination Committee
DDC	District Development Committee
DM	Disaster Management
DMG	Department of Mines and Geology
DoS	Department of Survey
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DRRM	Disaster Risk Reduction and Management
DoE	Department of Education
DOH	Department of Health
DoLIDAR	Department of Local Development and Agricultural Roads
DoR	Department of Road
DUDBC	Department of Urban Development and Building Construction
ERAKV	The Project for Assessment of Earthquake Disaster Risk for the Kathmandu Valley (This project)
ERHQ	Emergency Response Head Quarters
ESS	Earthquake Safety Solutions
ETRN	Emergency Transportation Road Network
GDP	Gross Domestic Product
GIS	Geographic Information System
GMPE	Ground Motion Prediction Equation
GoN	Government of Nepal
HFA	Hyogo Framework for Action
IDNDR	International Decade for Natural Disaster Reduction
JCC	Joint Coordinating Committee
JICA	Japan International Cooperation Agency
JWG	Joint Working Group
KUKL	Kathmandu Upatyaka Khanepani Limited
KV	Kathmandu Valley

KVDA	Kathmandu Valley Development Authority
KVRP	Kathmandu Valley Resilient Plan
LDCRP	Local Disaster and Climate Resilience Plan
MFT	Main Frontal Thrust
MHT	Main Himalayan Thrust
M/M	Minutes of Meeting
MMI	Modified Mercalli intensity scale
MoE	Ministry of Education
MoFALD	Ministry of Federal Affairs and Local Development
MoHA	Ministry of Home Affairs
MoHP	Ministry of Health and Population
MoPIT	Ministry of Physical Infrastructure and Transport
MoUD	Ministry of Urban Development
Mw	Moment Magnitude
NBC	Nepal National Building Code
NEA	Nepal Electricity Authority
NGA	New Generation Attenuation
NGO	Non-governmental Organization
NPR	Nepalese Rupee
NRRC	Nepal Risk Reduction Consortium
NS	Nepal Scout
NTA	Nepal Telecommunication Authority
NTC	Nepal Telecom
PDNA	Post Disaster Needs Assessment
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
PID	Project Implementation Directorate
PSHA	Probabilistic Seismic hazard Analysis
RC	Reinforced-Concrete
RRNE	The Project on Rehabilitation and Recovery from Nepal Earthquake
SATREPS	Science and Technology Research Partnership
Sendai Framework	Sendai Framework for Disaster Risk Reduction
SI	Spectrum Intensity
SOP	Standard Operation Procedure
TG LDCRP	Technical Guideline for Formulation of LDCRP
UNDP	United Nation Development Program
USGS	United States Geological Survey
VCA	Vulnerability Capacity Assessment
VDC	Village Development Committees
WG	Working Group
WN	Western Nepal Scenario Earthquake Ground Motion, C.F. = 1
WS	Workshop

Chapter 1 Outline of the Project

1.1 Background

Nepal, located in the area where the Indian and Eurasian Plates hit, is one of the most frequent earthquake occurrence areas in the world. Kathmandu Valley, which includes the capital city of Nepal, has experienced several disastrous earthquakes.

Comparing with the high risk of a future earthquake in Kathmandu Valley, countermeasures such as retrofitting of buildings for seismic resistance, land use control and observance of the National Building Code have not been promoted enough. It becomes a necessary and urgent issue to update the risk assessment for the future development plans and policies concerned with disaster risk management. In this circumstance, the Government of Nepal (hereinafter referred to as GoN) requested assistance from the Government of Japan on the implementation of earthquake disaster risk assessment in Kathmandu Valley.

Through the Gorkha Earthquake which occurred on April 25, 2015, it is recognized by both JICA and GoN that the quick recovery and reconstruction is an urgent issue and, in the meantime, it is necessary to promote the DRR for future earthquakes. On the other hand, simple recovery, which means constructing the same structures as that of before the quake, must be avoided in order not to have the same venerability as before. For this purpose, both the Project Team and the counterpart considered a recovery and reconstruction plan with the concept of Build Back Better (BBB) was necessary to be added to the project among the other modifications including the construction of a demonstration model for safe buildings, implementation of disaster risk reduction awareness campaigns, damage data collection, detail soil survey, emergency response chronicle survey and formulation of Standard Operation Procedures (SOP).

As the consequence of the discussion between the Project Team and the counterpart, the First Joint Coordinating Committee (JCC) meeting was held on 18th June 2015 and agreed upon the modification on the project components and schedule proposed by the Project Team.

1.2 Summary of the Project

1.2.1 Name of the Project

The Project for Assessment of Earthquake Disaster Risk for the Kathmandu Valley

1.2.2 Target Areas

Target areas include:

Risk Assessment: Kathmandu Valley (two Metropolitan Cities, sixteen Municipalities, a part of two Rural Municipalities in the Kathmandu District, Lalitpur District and Bhaktapur District)

Pilot Activities: Lalitpur Metropolitan City, Bhaktapur Municipality, Budhanilkantha Municipality

1.2.3 Overall Aim

To reduce earthquake disaster risk through effective and sustainable measures to be taken based on the disaster risk assessment.

1.2.4 Project Goal

To implement the earthquake risk assessment for future scenario earthquakes considering the earthquake environment after the Gorkha Earthquake, and to develop a DRRM plan for concrete and effective promotion on disaster risk management for future earthquakes.

1.2.5 Project Output

- Output 1: To conduct seismic hazard analysis based on scenario earthquakes utilizing the latest knowledge and create a detailed ground model for Kathmandu Valley.
- Output 2: To conduct seismic risk assessment based on the results of seismic hazard analysis (Output 1), and summarize as damage estimation by considering several occurrence scenes (time, date)
- Output 3: To enhance skills for updating risk assessment results in accordance with the social environment change in the future.
- Output 4: To formulate a BBB recovery and reconstruction plan utilizing the results of hazard analysis, and a disaster risk reduction and management (DRRM) plan based on the results of the seismic risk assessment for the pilot municipalities.

1.2.6 Counterparts

- Main Counterpart: MoUD
- Related Organizations: MoHA, MoFALD, DMG, Local Governments in Kathmandu Valley, and Working Group Members

1.2.7 Beneficiaries

- Direct: Central government and local governments in Kathmandu Valley
- Indirect: Residents in Kathmandu valley (Approx. 2.5 million people)

1.3 Project Objective

1) To estimate the damages of Kathmandu Valley caused by new scenario earthquakes in the future after the Gorkha Earthquake through seismic hazard analysis with detailed soil model and seismic risk assessment.

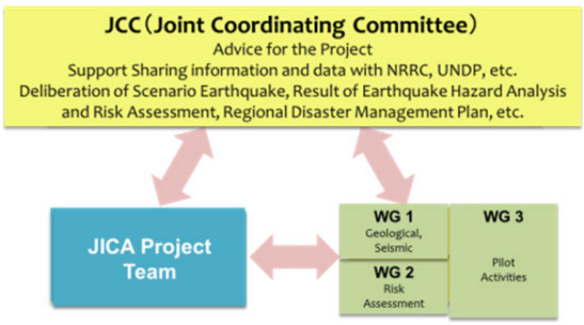
2) To formulate a Build Back Better recovery and reconstruction plan and disaster risk reduction and management plan, aiming for a resilient urban structure, based on the results of seismic hazard analysis and risk assessment.

3) To contribute to the seismic disaster risk mitigation of Kathmandu Valley by supporting promotion on the implementation of concrete disaster prevention and disaster risk reduction measures through the activities mentioned above.

1.4 Implementation Organization

1.4.1 Structure of the Implementation Organization

The JCC and three Working Groups (WGs) were established in the project based on the M/M. The structure of the organizations and collaboration system are summarized in Figure 1.4.1. Joint Working Group (JWG) meetings are held as necessary for collaboration among WGs.

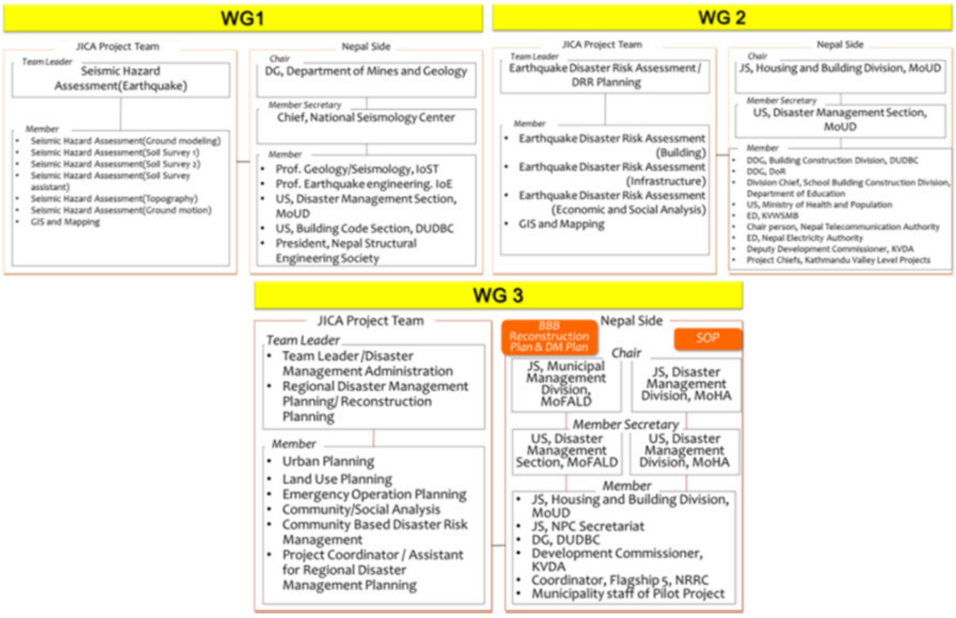


Source: JICA Project Team

Figure 1.4.1 Structure of the Implementation Organizations

1.4.2 Structure of Working Groups

The JICA Project Team examines the project in collaboration with the WGs. The structure of each WG is summarized in Figure 1.4.2.



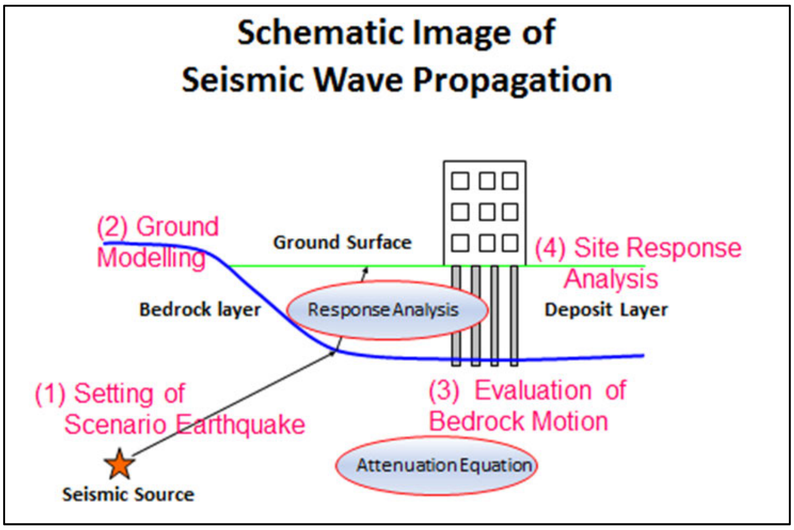
Source: JICA Project Team

Figure 1.4.2 Structure of each WG

Chapter 2 Seismic Hazard Assessment

In this chapter, seismic hazard assessment conducted prior to the seismic risk assessment and preparation for Disaster Risk Reduction and Management Plan is described. The main content of the seismic hazard assessment in this project is the estimation of the seismic ground motion as the target at the time of planning.

Seismic hazard assessment was implemented basically based on the propagation of seismic ground motion, (1) setting scenario earthquake, (2) modelling the ground, (3) estimation of ground motion at bedrock, and (4) evaluation of the response of the subsurface ground and estimation of seismic ground motion at ground surface. The assessment of liquefaction and earthquake induced slope failure are also included.



Source: JICA Project Team

Figure 2.1 Flow of seismic hazard assessment

Seismic ground motion radiated from a seismic source propagates through the deep rock layers, and reaches the basement of the target, such as base of the Kathmandu Valley. Then, it propagates to the subsurface and reaches the ground surface. In this project, first the verification and scenario earthquakes were set and then ground motion at rock surface was estimated using an attenuation equation. On the other hand, subsurface soil layers were modelled as ground models from rock surface to ground surface. In parallel with setting the scenario earthquakes and attenuation equations, based on the collection and compilation of ground information including a variety of ground surveys, ground modelling and response analysis were carried out.

2.1 Set-up of Scenario Earthquake

Target earthquakes of this assessment are three scenario earthquakes and two verification earthquakes. The three scenario earthquakes were set with DMG after consulting with the researchers of SATREPS (Science and Technology Research Partnership for Sustainable Development) project and the Scientific Community (the group of national and international scientists and experts; DMG as secretariat). They are Far-Mid Western Scenario Earthquake, Western Nepal Scenario Earthquake and Central Nepal South Scenario Earthquake. The two earthquakes for verification are the 1934 Bihar-Nepal Earthquake and the 2015 Gorkha Earthquake including the largest aftershock. The fault models of the scenario earthquakes are shown in Figure 2.1.1. The basis of scenario earthquakes and the relation with historical earthquakes are shown below.

2.1.1 Far-Mid Western Nepal Scenario Earthquake

Large earthquake motion was felt from the Far West Nepal to Midwest Nepal in 1505. Nepal, Tibet and India were severely damaged. The reoccurrence of this earthquake was adopted as the scenario to consider the effects in Kathmandu, even though no destruction was reported in Kathmandu at that time. The source area was determined following the outcome of SATREPS and the south border of the source fault was clipped at MFT (Main Frontal Thrust) following the comment of the Scientific Community.

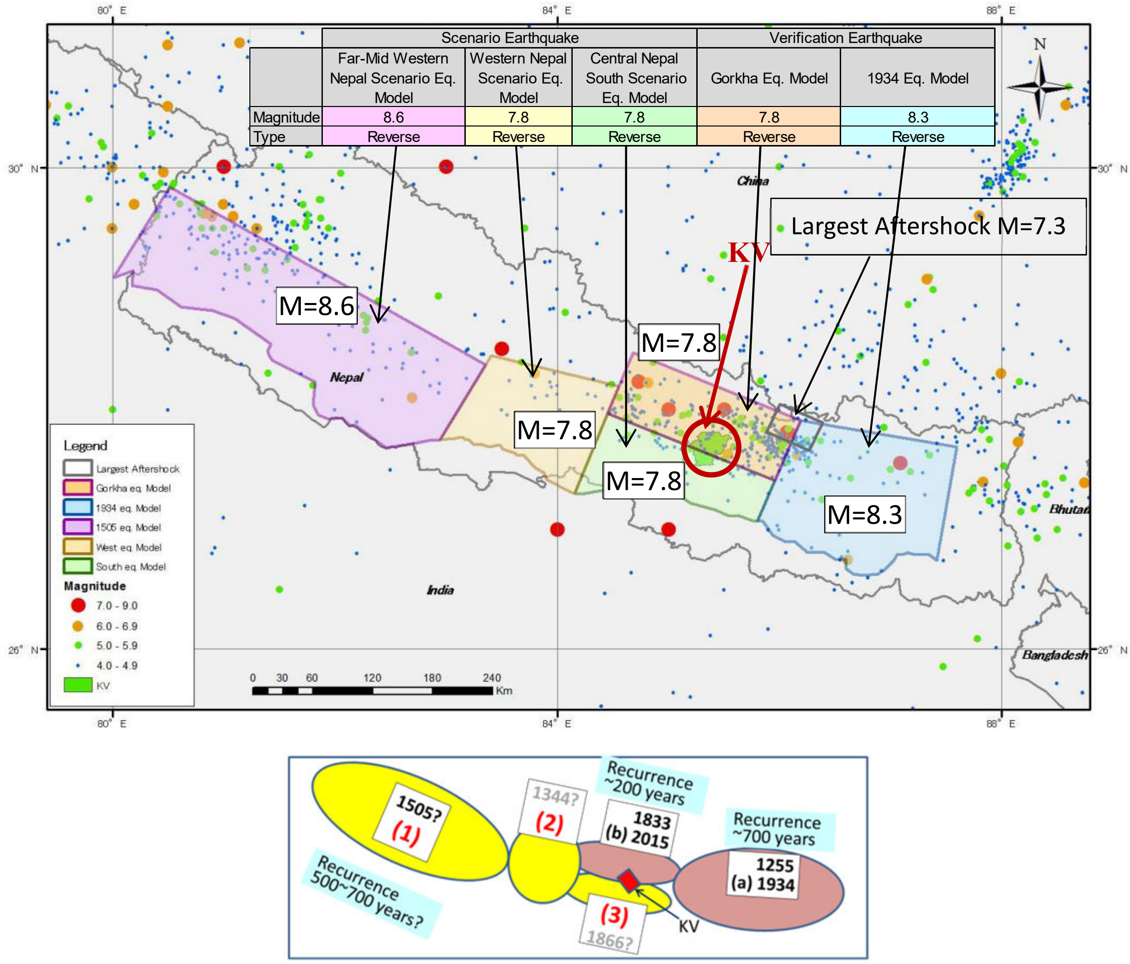
2.1.2 Western Nepal Scenario Earthquake

Since the 1344 and the 1408 earthquakes, no large earthquake has occurred in West Nepal which is over 600 years. A large earthquake occurred in 1255 in Central to East Nepal and Kathmandu suffered heavy damage. 679 years after that earthquake, in 1934, again another large earthquake occurred in East Nepal and at that time Kathmandu was severely damaged. If the reoccurrence process in West Nepal is common to that of East Nepal, the next large earthquake in West Nepal is just around the corner. The presumed next large earthquake in West Nepal is adopted as the scenario. The source area was determined following the outcome of SATREPS and the south border of the source fault was clipped at MFT following the comment of the Scientific Community.

2.1.3 Central Nepal South Scenario Earthquake

In Central Nepal, a magnitude 7 class earthquake occurred in 1833 and caused damage to Kathmandu and its surroundings. The epicentre of this earthquake is estimated to have been north of Kathmandu Valley. In 1866, an earthquake occurred in Kathmandu again, after an interval of 33 years. The magnitude of this earthquake may be almost the same as the 1833 event and the supposed epicentre was south of Kathmandu Valley.

The epicentre of the 2015 event was located in the Gorkha District, but the earthquake fault extends eastward to north of Kathmandu Valley. The northern part of Central Nepal was activated but no movement was found along MFT in south Central Nepal area. The northern part of MHT (Main Himalayan Thrust) section in Central Nepal may have moved but the southern part was calm during the Gorkha Earthquake (Elliot et al. (2016)). Regarding the analogy of the 1833 and 1866 events, an earthquake of almost the same magnitude as the Gorkha Earthquake may occur in the near future and the epicentre may be south of Kathmandu Valley. The supposed next large earthquake of the southern area of Central Nepal is adopted as the scenario. The earthquake fault of the Gorkha Earthquake was set based on the distribution of aftershocks by Adhikari et al. (2016). The southern adjacent area was bounded by the Gorkha Earthquake fault area and MFT was modelled.



Three Scenario Earthquakes

(1) Far- Mid Western Nepal Eq., Magnitude = 8.6
(2) Western Nepal Eq., Magnitude = 7.8
(3) Central Nepal South Eq., Magnitude = 7.8

Two Verification Earthquakes

(a) Recurrence of the 1934 Bihar-Nepal earthquake, Magnitude = 8.3
(b) Recurrence of the 2015 Gorkha earthquake, Magnitude = 7.8, 7.3

Determined after taking into account of comments from Scientific Community

Source: JICA Project Team compiled from JICA (2002)

Figure 2.1.1 Scenario Earthquake Fault Model

2.2 Modelling of the Ground

2.2.1 Preparation of Detailed Geomorphological Map

For ground modelling, the geomorphological map which reflects the detailed depositional environment plays an important role. Since existing geomorphological maps in the Valley do not have sufficient resolution, a new one was to be developed in this project. Therefore, aerial photographs with scales of 1: 15,000, and partly 1: 50,000 were purchased from DoS (Department of Survey). Geomorphological interpretation and site reconnaissance surveys were implemented, and a new detailed geomorphological map was prepared with DMG participation. Still the site survey has not yet been perfected, which will be supplemented by DMG, and then, DMG will be publicized after some further analysis.

(1) Method

The detailed geomorphological classification was carried out by stereo-view of large-scale aerial photographs taken in December 1998 (scale about 1:15,000). The aerial photographs are continuously taken in the E-W direction. Nine lines, eighteen photographs per line, are available for the Kathmandu Valley. Most areas of the Kathmandu Valley are covered by these aerial photographs taken in 1998, while large-scale photographs are not available in the western to southwestern margin of the Kathmandu Valley. Therefore, we used complementary small-scale aerial photographs taken in 1992 (scale about 1: 50,000). Adjoining photographs overlap within 60% of each other, and the overlapping images were stereo-viewed by a stereo-scope or naked eye. 3D images were useful to observe detailed geomorphologies.

(2) Detailed geomorphological classification

The detailed geomorphological classifications in the Kathmandu Valley are shown in Table 2.2.1. The geomorphology in the Kathmandu Valley was divided into fluvial surfaces (modern flood plain), deltaic-lacustrine terraces, and other surfaces. The detailed geomorphological map is shown in Figure 2.2.1.

Table 2.2.1 Detailed geomorphological classification in the Kathmandu Valley

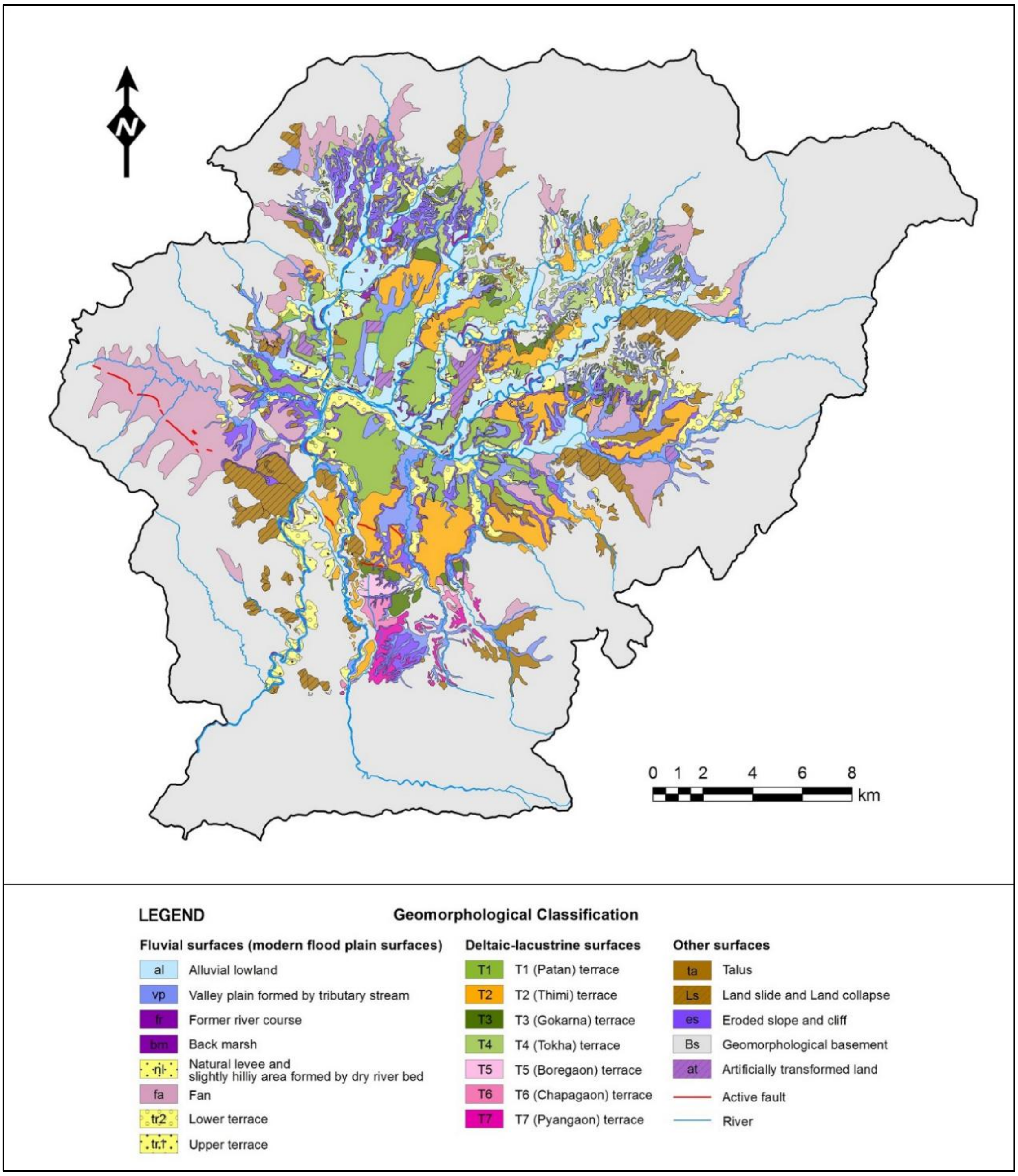
Classification	Detailed classification	abbr	Characteristics
Fluvial surfaces (modern flood plain)	Alluvial lowland	al	Lowland along modern rivers
	Valley plain	vp	Lowland in the narrow valleys
	Former river course	fr	Long and narrow depression
	Back marsh	bm	Marshes between natural levees
	Natural levee	nl	Long-narrow and slightly hilly area
	Alluvial fan	fa	Gentle slope with concentric contours at the exit of valley
	Lower terrace	tr2	Slightly hilly area
	Higher terrace	tr1	Fluvial terraces on the hillside
Deltaic-lacustrine terraces	T1 (Patan) terrace	T1	Terrace formed under the environment of the Paleo-Kathmandu Lake. The terraces are sub-divided into T1 to T7 depending on the altitudes (see Table 2.2.2).
	T2 (Thimi) terrace	T2	
	T3 (Gokarna) terrace	T3	
	T4 (Tokha) terrace	T4	
	T5 (Boregaon) terrace	T5	
	T6 (Chapagaon) terrace	T6	
	T7 (Pyangaon) terrace	T7	
Other surfaces	Talus	ta	Relatively steep slope formed by collapse of cliff
	Landslide and slope failure	Ls	Relatively gentle slope formed by sliding of mountainous slope
	Eroded slope and cliff	es	Cliff at the side of terraces
	Geomorphological basement	Bs	Hill and mountainous slope where hard rocks and the Kathmandu basin Group expose
	Artificially transformed land	at	Developed land by bank on the lowland Flat surface by cutting of terraces

Source: JICA Project Team compiled from several sources of literature

Table 2.2.2 ^{14}C age and altitude of the deltaic-lacustrine terraces

Terrace	Age of terraces (cal ka years BP)	Altitude of teraces (m above sea level)	
		Northern region	Southern region
T1 (Patan)	17-10	1,300-1,330	1,310-1,330
T2 (Thimi)	35-28	1,330-1,350	1,330-1,360
T3 (Gokarna)	>50-38	1,350-1,390	1,380-1,410
T4 (Tokha)	23-17	1,360-1,390	-
T5 (Boregaon)	>50	-	1,420-1,440
T6 (Chapagaon)	>50	-	1,440-1,460
T7 (Pyangaon)	>50	-	1,470-1,510

Source: Gautam et al. (2009), Sakai et al. (2006), Sakai et al. (2008), Sakai et al. (2012)



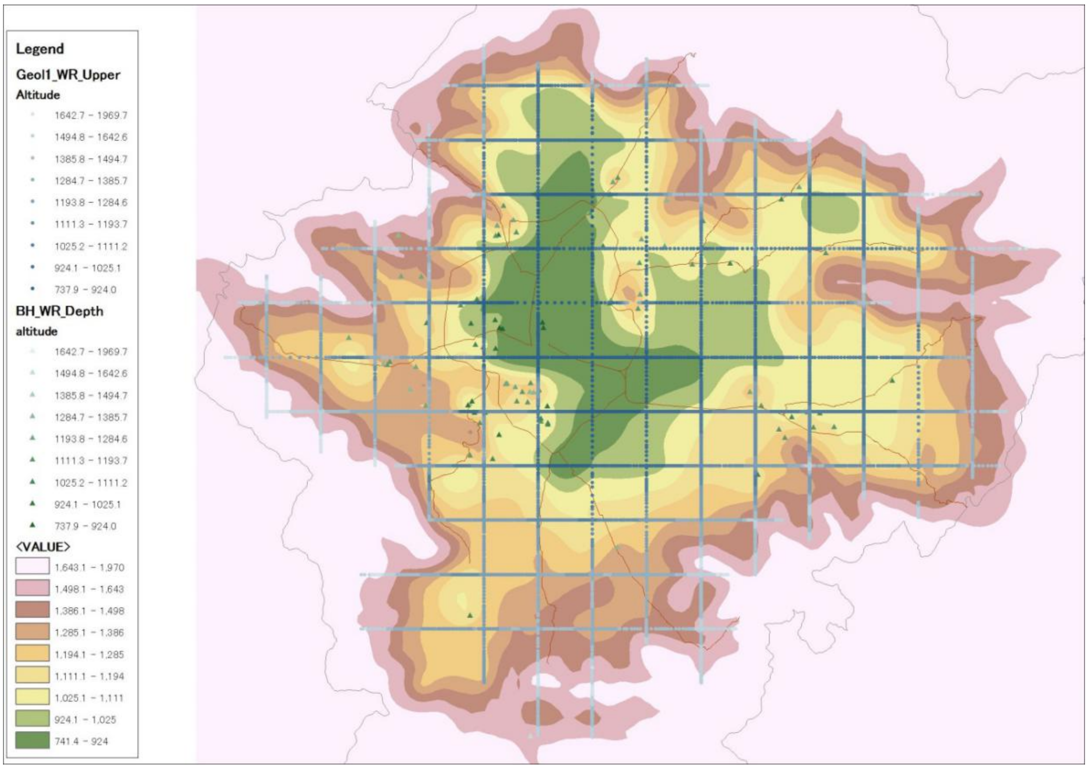
Source: JICA Project Team with DMG

Figure 2.2.1 Geomorphological map of the Kathmandu Valley

2.2.2 Depth of Rock Layer

Since the drilling information as point data that reaches the rock layer is limited to 56 bore holes, in order to clarify the distribution or contour of the rock depth, the gravity anomaly exploration results (Moribayashi and Maruo, 1980) were utilized. In other words, the relation between the gravity anomaly distribution and rock depth by drilling data was found. Then, together with rock depth by drilling, geomorphological map, geological map etc., the rock depth distribution was developed.

The results are shown in Figure 2.2.2. According to the figures, it is easily identified that the internal soil structure variation of the valley is not simple. The evidence indicates that during the process of the formation of the valley, the past mountain areas with ridges and valleys subsided, next the old lake was produced, and soils were blown in and deposited in the lake from surrounding slopes, and as a result the terrace layer was formed by changes of water level of the old lake. Overall, the topography is quite complex. Though the maximum depth of rock is more than 500m at the central region, there are situations where a face of the rock is exposed at the ground surface and can be observed.

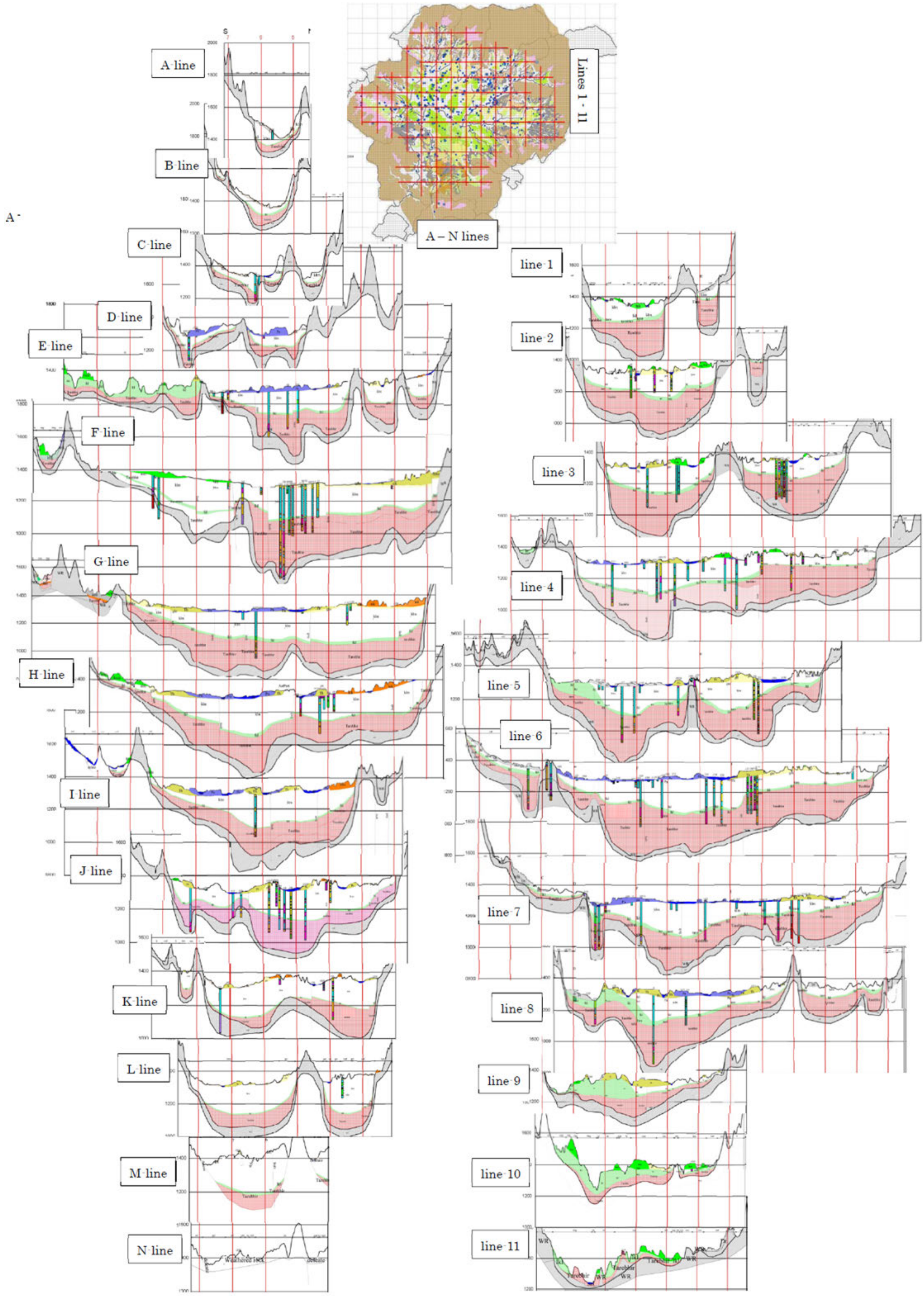


Source: JICA Project Team

Figure 2.2.2 Estimated rock depth distribution based on gravity anomaly and drilling data

2.2.3 Geological Cross-sections

As no usable geological cross-sections existed for the Kathmandu Valley, a new one has been developed for this project. There are a total of 25 sections (fourteen north-south and eleven east-west) at 2km intervals (Figure 2.2.3). The following are the main configurations of the cross-sections; under the top soil layers, the somewhat thick Kalimati layer mainly composed of relatively soft lacustrine clay was found, under Kalimati the somewhat rigid, thin Lukundol layer (mainly lacustrine clay) and thick Tarebhir layer (lacustrine) were found.

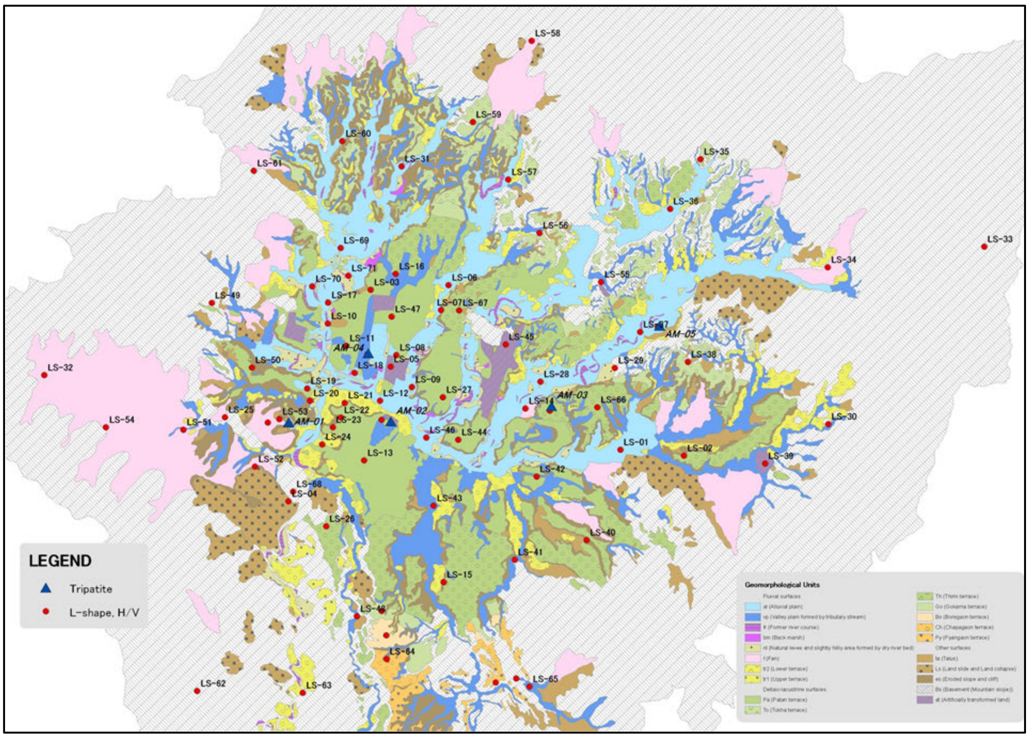


Source: JICA Project Team

Figure 2.2.3 Newly developed Geological cross-sections

2.2.4 Microtremor Measurement

The physical properties of the soil layer are necessary information to assess the amplification by response analysis. Microtremor measurement was selected as the method of ground survey. Three types of microtremor measurement were conducted for separate purposes. Tripartite Microtremor Measurement was conducted to know the S-wave velocity structure of deep ground up to several 100 meters. The purpose of the L-shape Array Microtremor was to determine the S-wave velocity structure of shallow ground up to 50 meters. Single Microtremor Measurement was conducted to determine the predominant period of the point and was used for the confirmation of the ground model. Figure 2.2.4 shows the distribution of Tripartite and L-shape array microtremor measurement points.

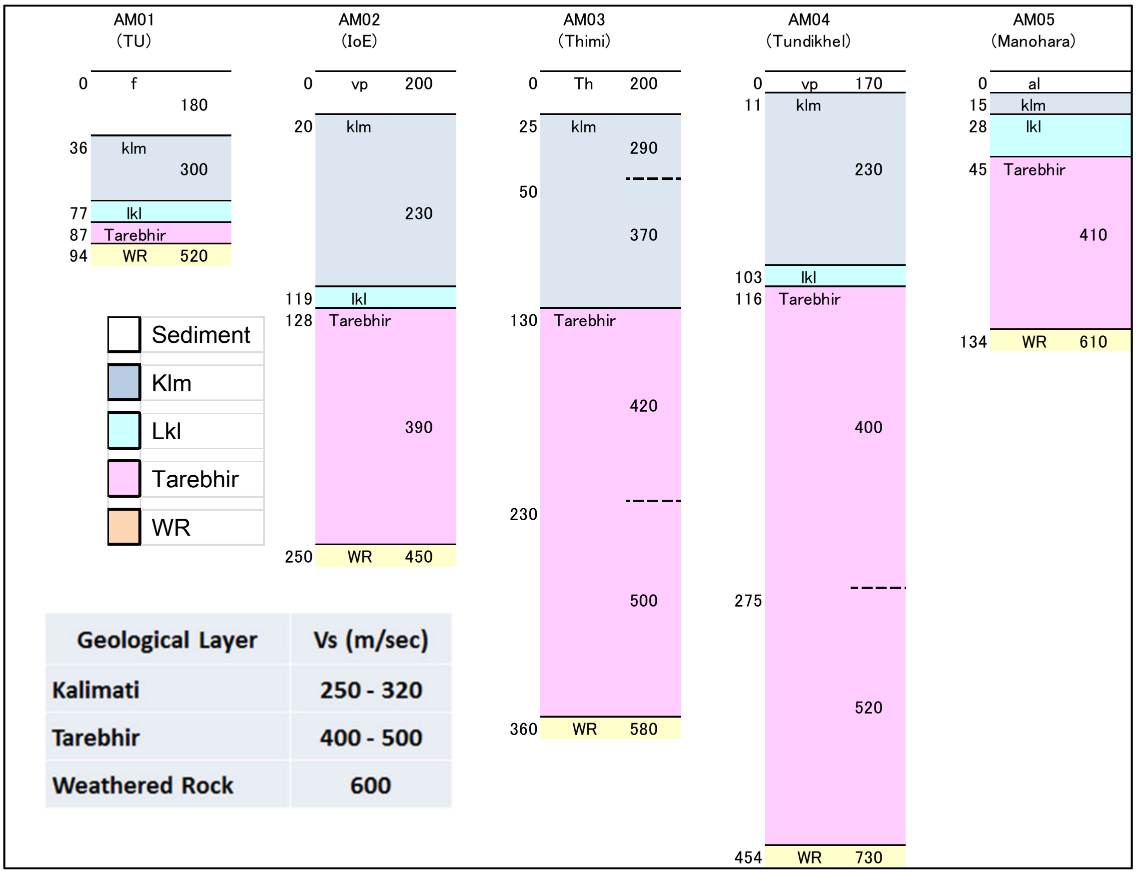


Source: JICA Project Team

Figure 2.2.4 Measurement Points of Microtremor Measurement

(1) Tripartite Array Microtremor Measurement

To determine the S-wave velocity structure of the soil layer over rock to the ground surface, tripartite array microtremor measurement was conducted. Five points were selected for measurement considering the distribution of strong motion observatories by DMG, USGS and Hokkaido Univ. The length of tripartite was set for 50m, 100m, 250m and 500m. In this study, the surveyed depth was 500m in maximum and the S-wave velocity was 600 to 800m/sec with some uncertainty. Figure 2.2.5 shows the analysed velocity structure model to fit the geological layer. The S-wave velocity of weathered rock, which is the deepest layer in this analysis is 600m/sec, the Tarebhir layer shows 400 to 500m/sec and rather soft clayey Kalimati (Klm) layer shows 250 to 320m/sec.



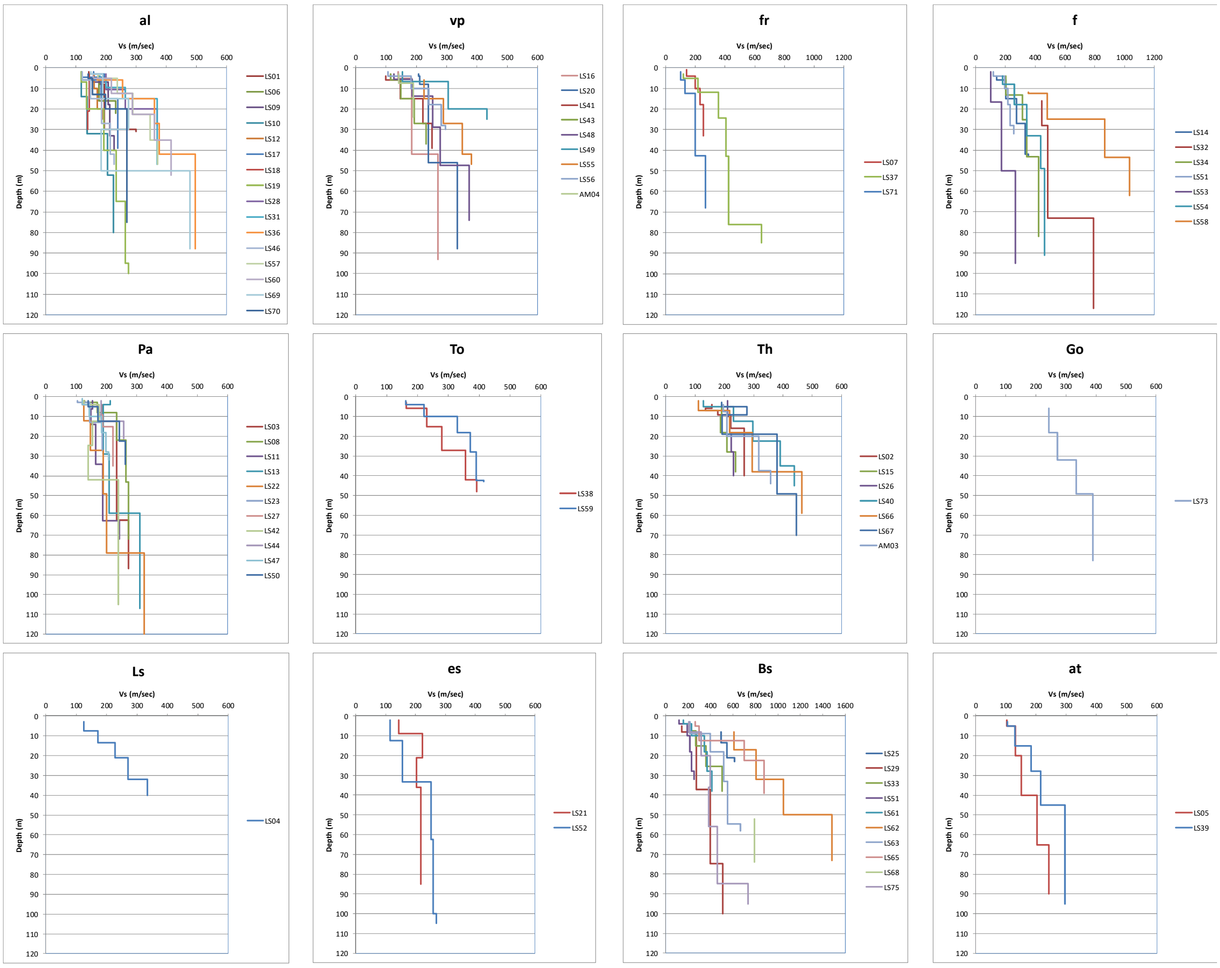
Source: JICA Project Team

Figure 2.2.5 S-wave Velocity Structure of Deep Ground by Tripartite Array Microtremor Measurement and Soil Layer

(2) L-shape Array Microtremor Measurement with Three Point Array

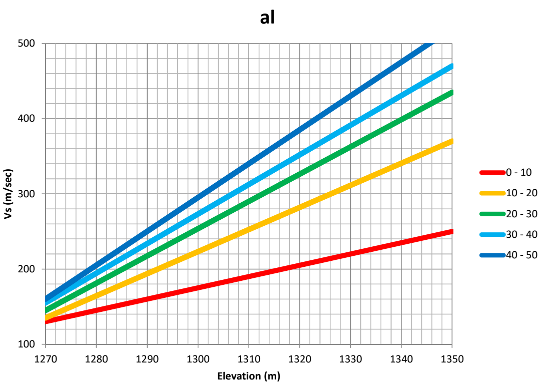
This survey was conducted to determine the S-wave velocity structure of the soft surface layer up to 30-50 meters. The 74 measurement points were arranged to cover all the geomorphological classes considering the complexity of the structure of the subsurface ground. The three point array microtremor measurements were also conducted simultaneously at 39 points among them to increase the survey depth to 50 meters.

Figure 2.2.6 shows the S-wave velocity profile along the depth by geomorphological units. Several units show almost the same profile, while several other units show dispersed profiles referring to the difference of elevation. For example, alluvial lowland (al) shows that low velocity continues to deep depths if the elevation is low and that the low velocity layer becomes thin and the high velocity layer appears from shallower depth if the elevation is high. Figure 2.2.7 shows the S-wave velocity structure model for alluvial lowland made from the relation with elevation. The relation of S-wave velocity of 10m depth intervals and elevation is modelled in this figure. In ground modelling, the S-wave velocity of the shallow layer was decided by this model.



Source: JICA Project Team

Figure 2.2.6 Observed S-wave Velocity Profile by Geomorphological Unit



Source: JICA Project Team

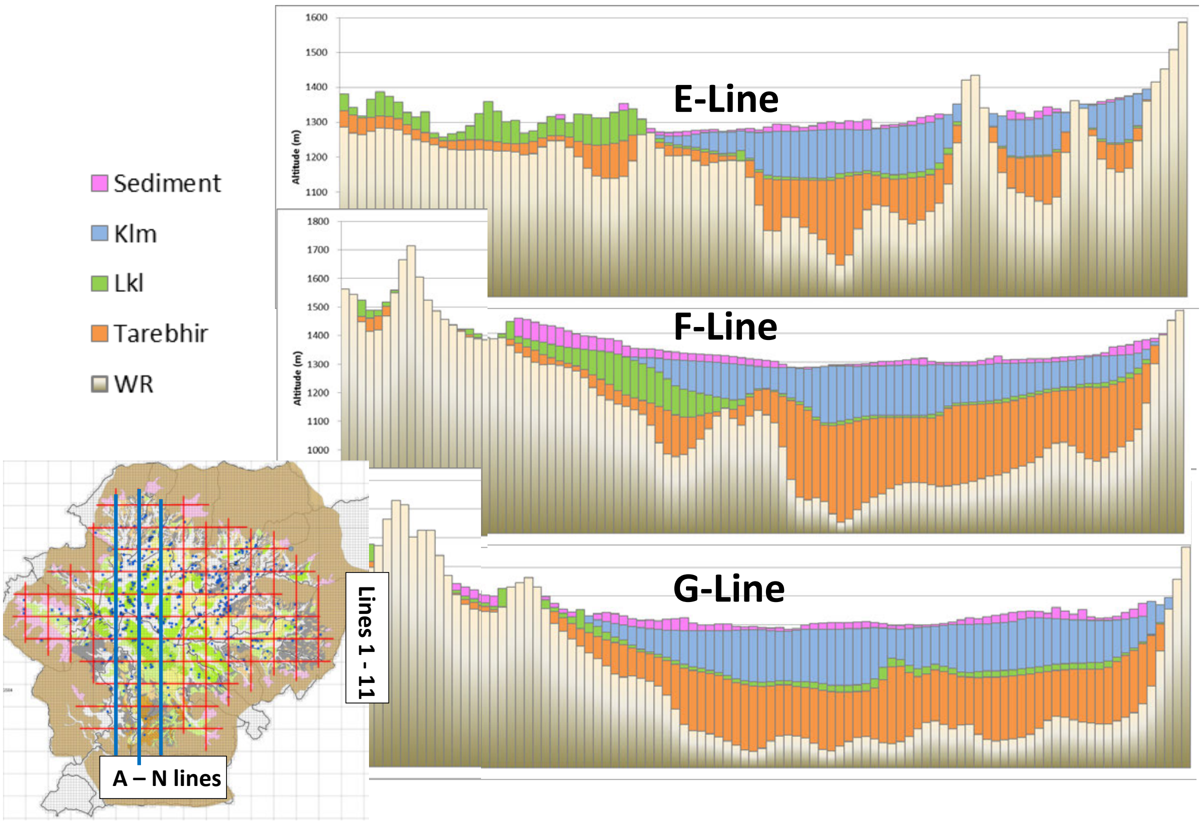
Figure 2.2.7 Relation of S-wave Velocity Structure Model in 10m Depth Intervals with Elevation for Alluvial Lowland (al)

2.2.5 Modelling of the Ground

The 3D distribution of Rock surface, surface of Tarebhir layer, Lukundor layer (Lkl) and Kalimati layer (Klm) was estimated based on the estimated rock surface distribution (Figure 2.2.2) and geological cross section (Figure 2.2.3). The rock outcrop area, which is shown in geomorphology map (Figure 2.2.1) was also considered. The S-wave velocity of Rock, Tarebhir, Lkl and Klm layer was estimated from tripartite microtremor measurement (Figure 2.2.5).

The surface layers between Klm to ground surface was modelled based on the geomorphological map (Figure 2.2.1) and L-shape array microtremor measurement (Figure 2.2.6). At first, one geomorphological unit which has the maximum area in the grid was assigned to each 250m grid. Next, the 10m depth interval S-wave velocity structure was made for the grid, except for the rock outcrop grid, based on Figure 2.2.6. The relation of S-wave velocity and elevation (ex. Figure 2.2.7) was also considered to create the grid model which was assigned to the geomorphological units al, bm, ta, nl, vp and fa.

A ground model was made for each 250m grid. Examples of cross sections of the ground model are shown in Figure 2.2.8.



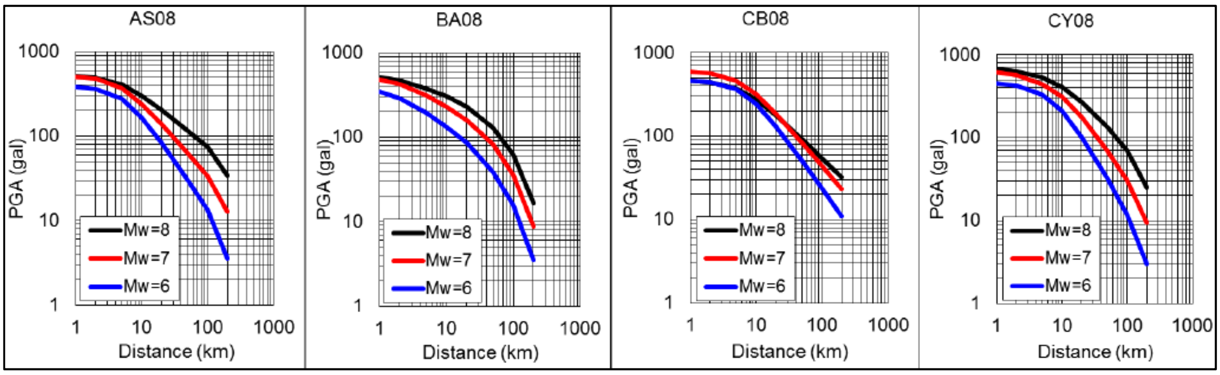
Source: JICA Project Team

Figure 2.2.8 Examples of North-South Cross Sections of the Ground Grid Model

2.3 Calculation of Earthquake Motion at Bedrock

The earthquake motion at the bedrock was evaluated using the Ground Motion Prediction Equation (GMPE) following the conditions below.

- Bedrock for the analysis in this project is defined as weathered rock (Vs=600m/sec), which corresponds to the deepest layer of the ground model.
- Earthquake motion at the bedrock is calculated using existing GMPE.
  GMPE derived from the observed strong motion records in Nepal is not proposed so far because of the shortage of data. The up to date New Generation Attenuation (NGA) equations were used. NGA was studied based on the strong motion records from around the world and it introduces the effects of fault type, ground condition, etc.
- Used GMPE are (AS08) Abrahamson N. and W. Silva (2008), (BA08) Boore D. M. and G. M. Atkinson (2008), (CB08) Campbell K. W. and Y. Bozorgnia (2008) and (CY08) Chiou B. S.-J. and R. R. Youngs (2008) (see Figure 2.3.1). The average of the above four equations was used considering the uncertainty.



Source: JICA Project Team

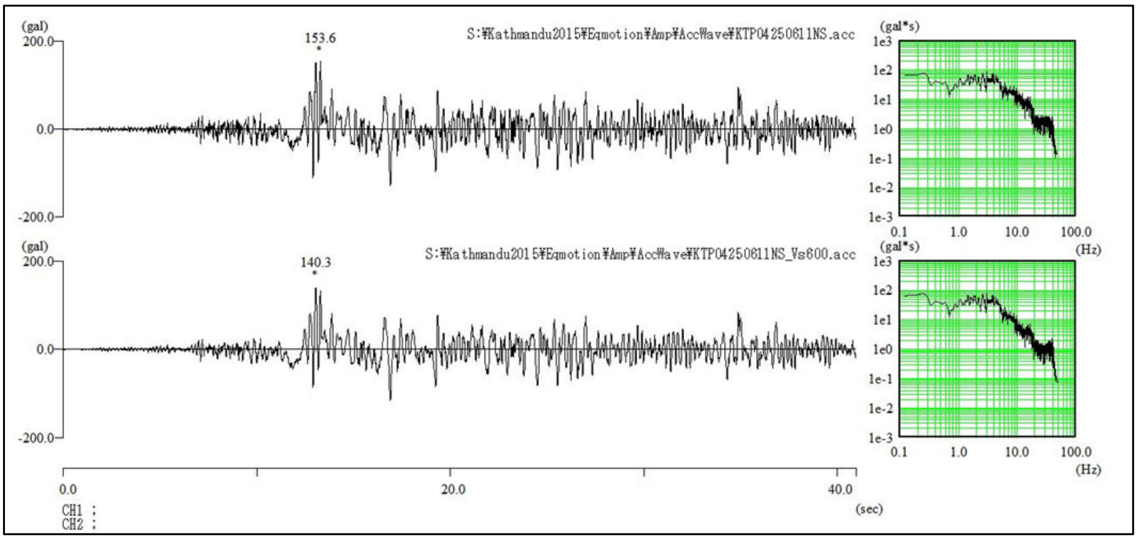
Figure 2.3.1 NGA Attenuation Function for PGA

2.4 Calculation of Earthquake Motion at Ground Surface

The earthquake motion (PGA) of the scenario earthquake at the ground surface was calculated. The amplification of surface soil was evaluated by one dimensional response analysis (SHAKE).

2.4.1 Input Waveform

The observed record at Kirtipur (KTP) (Takai et al. (2016)) during the 2015 Gorkha Earthquake was used as the input waveform for response analysis as the KTP record is the only waveform of the main shock observed at a semi-rock ground condition. The record observed at the rock site in or near the study area is usually used as the input waveform for the response analysis in an earthquake engineering project. As thin sediment covers the rock at the Kirtipur site, the observed record was converted to Vs=600m/sec rock condition by inverse response analysis (Figure 2.4.1). The amplitude of the converted waveform was adjusted to the calculated PGA by GMPE at the base rock in each grid and used as the input waveform for the response analysis of each ground model. The acceleration waveform at ground surface in each grid is the output of the response analysis.



Source: JICA Project Team

Figure 2.4.1 Input Waveform for response Analysis (lower), and original (upper), converted to Vs=600m/sec rock condition

2.4.2 Ground Model for Response Analysis

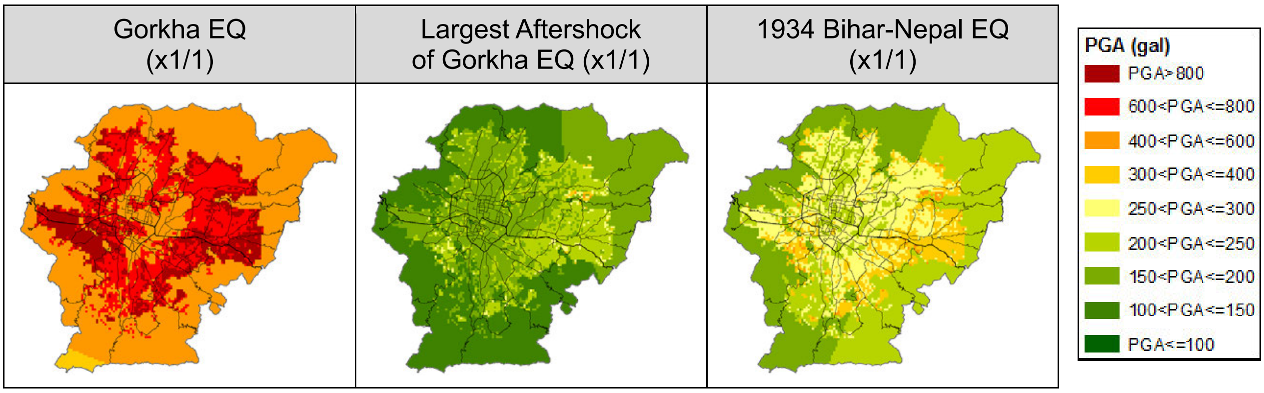
Ground model for response analysis was constructed using drilling logs, geomorphology maps, microtremor survey, etc. in this project. The grid size is 250m x 250m, total number of grids is 11,933 and maximum depth of the ground model is about 500m.

2.4.3 Calculation for Verification Earthquake

The earthquake motion of two verification earthquakes and largest aftershock of the Gorkha Earthquake was calculated and shown in Figure 2.4.2. The calculated PGA at ground surface for the Gorkha Earthquake was 400 ~ 800 gal and 150 ~ 200 gal for the largest aftershock, however the observed PGA was 150 ~ 200 gal and 60 ~ 110 gal respectively. The calculated PGA was extremely larger than the observed one. The estimated damage from the calculated PGA for the 1934 Bihar-Nepal earthquake was compared with actual damage because strong motion data is not available for the 1934 event and they don’t show a major discrepancy.

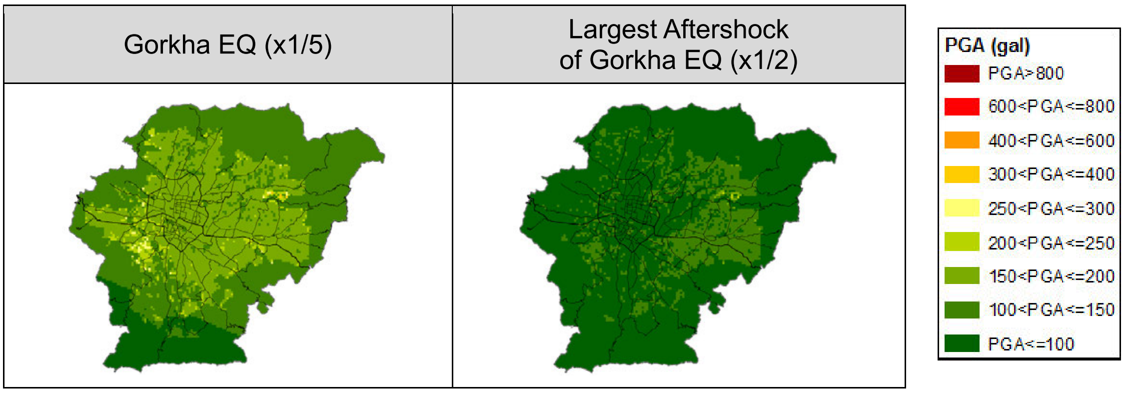
It is obvious that the Gorkha Earthquake deviates significantly from the average in terms of the attenuation characteristics of PGA as shown by Takai et al. (2016), Dhakal et al. (2015) and this study, however, the reason is not scientifically identified so far. Based on the above phenomena and below verification analysis, and the fact that the seismic source and propagation characteristics have not yet been solidified in seismology, it became necessary to consider the correction factor (C.F.) for the earthquake motion estimation in Kathmandu.

At first, the proper value of C.F. to reproduce the observed PGA of the Gorkha Earthquake was searched for by a trial-and-error method. C.F. = 1/5 could reproduce the actual value on average. The same study was applied to the largest aftershock and the proper value was 1/2 (Figure 2.4.3).



Source: JICA Project Team

Figure 2.4.2 PGA of Verification Earthquake (C.F. = 1/1)



Source: JICA Project Team

Figure 2.4.3 PGA of Gorkha Earthquake (C.F. is set to reproduce the observed PGA)

2.4.4 Study of Correction Factor

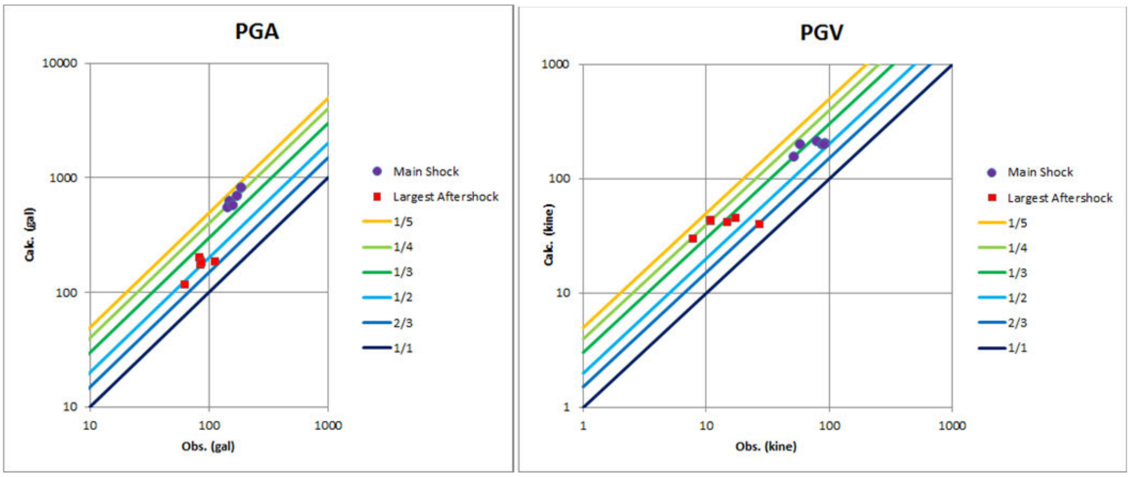
To study the correction factor (C.F.) for a scenario earthquake, the calculated PGA and PGV for the main shock of the Gorkha Earthquake by GMPE and response analysis with observed values at six strong motion stations in Kathmandu Valley, namely KANTP (USGS), DMG, Kirtipur, Tribhuvan University, IoE, Sano Thimi (Hokkaido Univ.) were referred to. The calculated PGA is around four times larger than observed and PGV is three times larger (Figure 2.4.4). The same study was conducted for the largest aftershock. The observed PGA is two times larger than the observed value. The calculated PGV is larger than observed but the ratio varies (Figure 2.4.4).

The summary of the study is shown below.

- Main shock: Observed PGA is 1/5 to 1/3 of calculated
  Observed PGV is 1/4 to 1/2 of calculated
- Largest aftershock: Observed PGA is 1/3 to 2/3 of calculated
  Observed PGV is 1/4 to 2/3 of calculated

As shown above, the characteristics of an earthquake differ site by site. The variation of the earthquake source or path effect may be reasons for the difference. The variation of the magnitude may be another reason of differences in the same region. There is very little information to study for the source and path effects for the two western scenario earthquakes, namely Far-Mid Western Nepal Scenario Earthquake and Western Nepal Scenario Earthquakes, therefore it is difficult to decide C.F. for these scenario earthquakes. For the Central Nepal South Scenario Earthquake, so far, not much data of middle to large earthquakes is available. However, because the source fault of this scenario earthquake is adjacent to the fault of the Gorkha Earthquake, it resembles the condition of source or path effect to Kathmandu valley and C.F. can be supposed based on the Gorkha Earthquake case study.

Because of the current situation of methodology, data and limitation of time, to show the possible range of C.F. may be the best solution of the hazard assessment in this project. The adopted C.F. is shown in Table 2.4.1.



Source: JICA Project Team

Figure 2.4.4 Comparison of Observed PGA/PGV and Calculated PGA/PGV; (left) PGA, (right) PGV

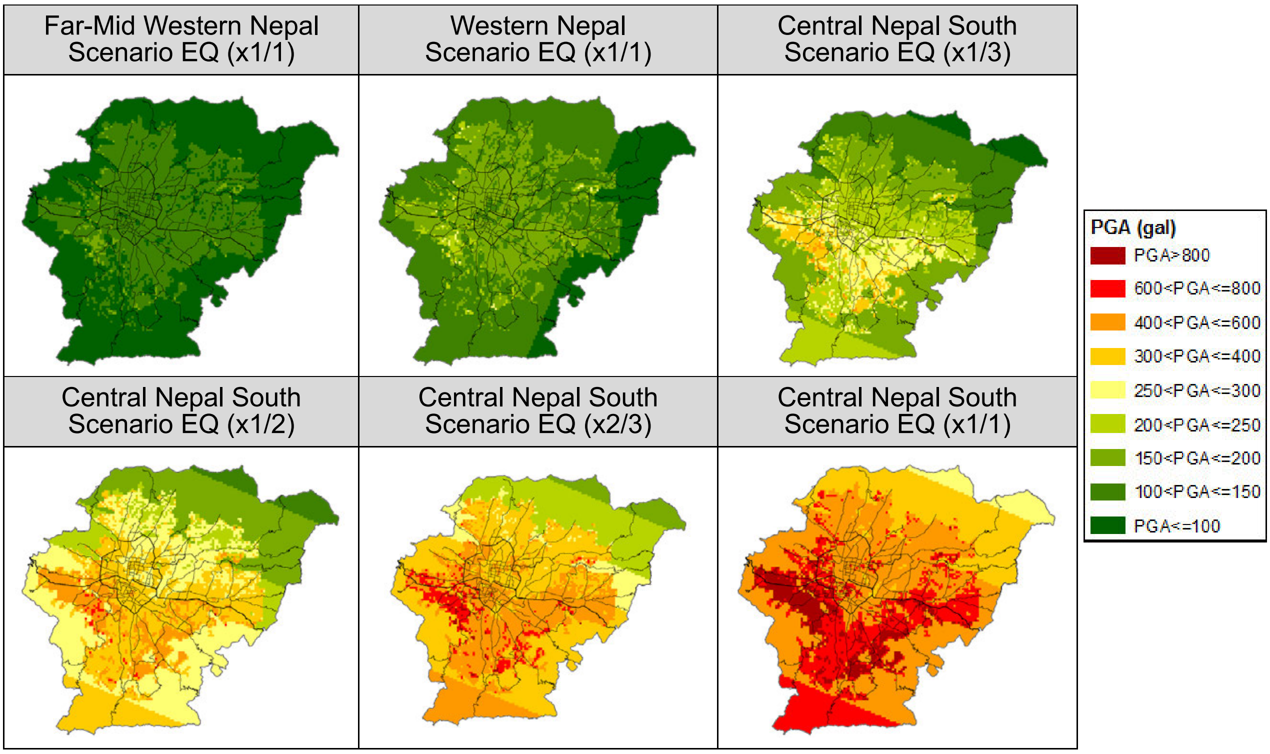
Table 2.4.1 Adopted Correction Factor

Scenario Earthquake	Correction Factor (PGA)	Correction Factor (PGV)
Far-Mid Western Nepal Scenario Earthquake	x1/1 (Normal)	x1/1 (Normal)
Western Nepal Scenario Earthquake	x1/1 (Normal)	x1/1 (Normal)
Central Nepal South Scenario Earthquake	x1/1 (Normal) x2/3 (cover max. aftershocks) x1/2 (average of aftershock) x1/3 (cover max. main shock)	x1/1 (Normal) x2/3 (cover max. aftershocks) x1/2 (cover max. main shock)
Verification Earthquake	**Correction Factor (PGA)**	**Correction Factor (PGV)**
2015 Gorkha EQ.	x1/5 (observed average)	x1/3 (observed average)
Largest Aftershock of 2015 Gorkha EQ.	x1/2 (observed average)	x1/3 (observed average)
1934 Bihar-Nepal EQ.	x1/1 (Normal / damage level)	x1/1 (Normal / damage level)

Source: JICA Project Team

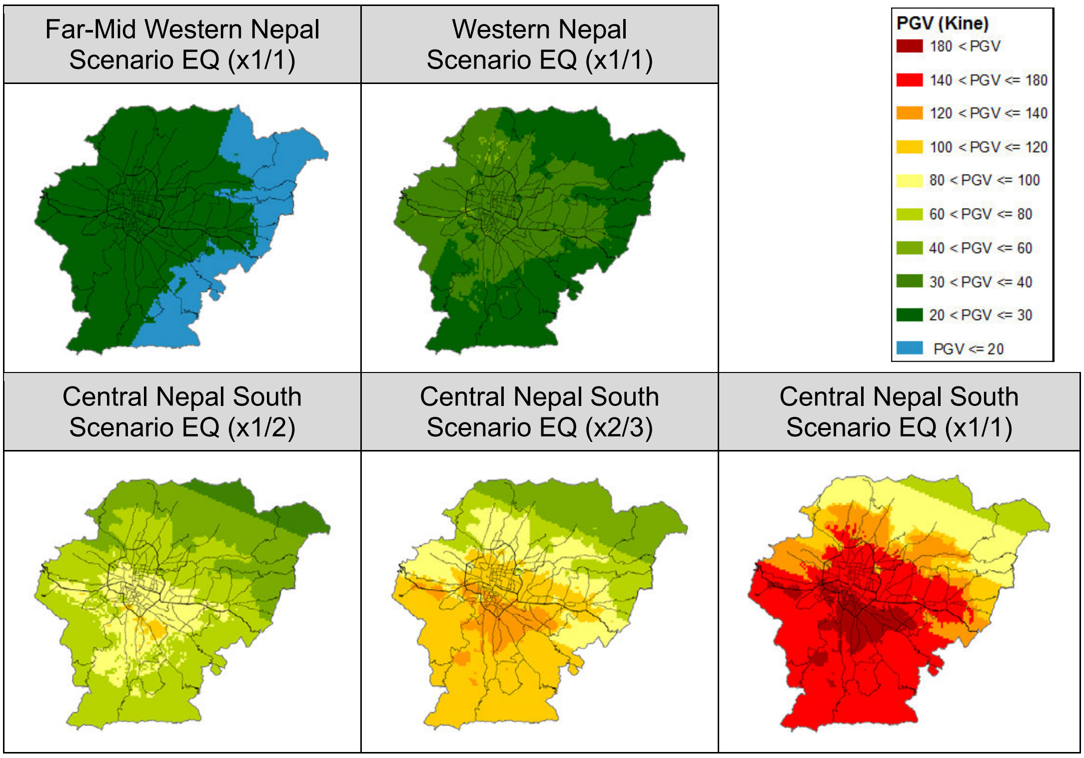
2.4.5 Calculation of Earthquake Motion at Ground Surface for Scenario Earthquake

Since little information about the observed earthquake motion or damage experience is available in the scenario fault area, the study of C.F. for the scenario earthquake was difficult. The calculation by C.F. = 1/1 is the first choice. For Central Nepal South Scenario Earthquake, based on the similarity of the source area to the Gorkha earthquake, C.F. = 1/3, 1/2 and 2/3 were also used for PGA calculation, however, which C.F. is most probable is a very difficult question. For PGV, 1/2, 2/3 and 1/1 were used. The calculated PGA and PGV of scenario earthquakes are shown in Figure 2.4.5 and Figure 2.4.6 respectively.



Source: JICA Project Team

Figure 2.4.5 PGA of Scenario Earthquakes



Source: JICA Project Team

Figure 2.4.6 PGV of Scenario Earthquakes

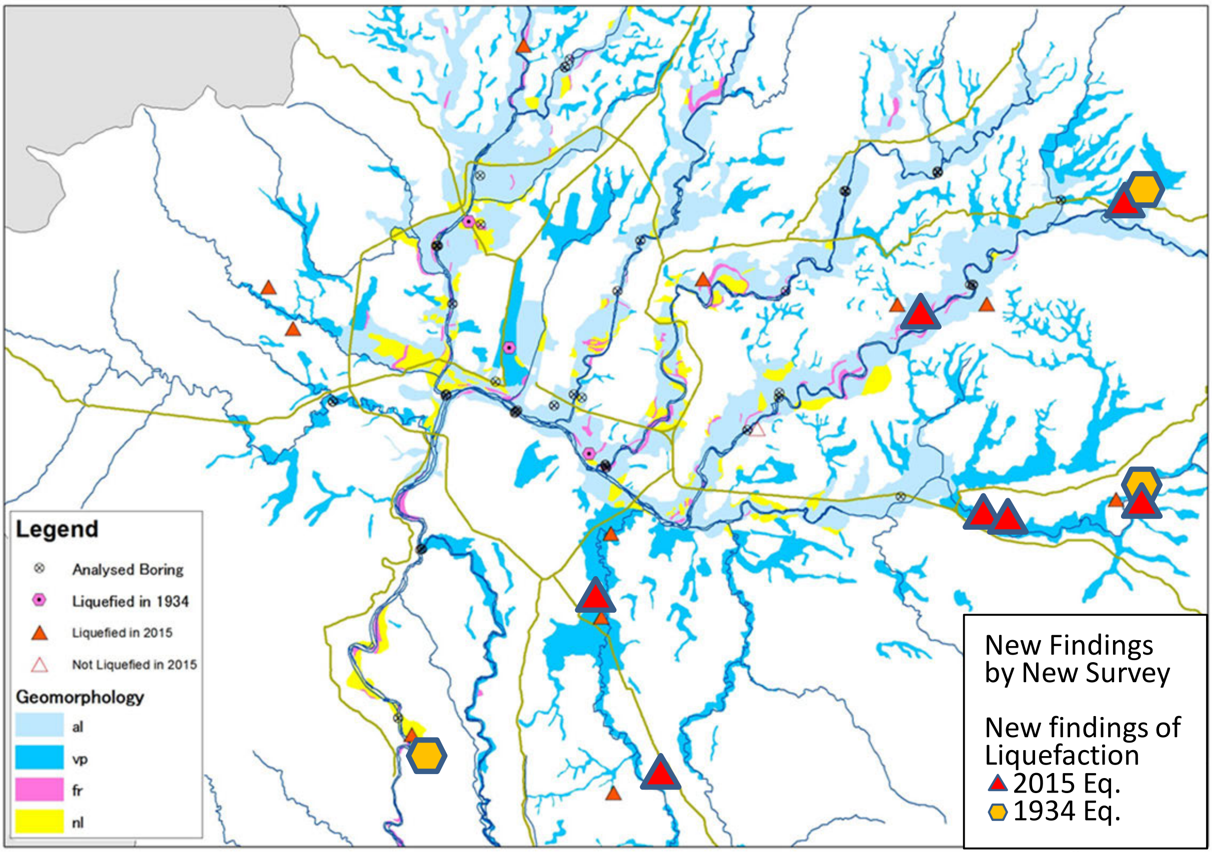
2.5 Assessment of Liquefaction

As there are very few accurate ground materials for liquefaction evaluation in Kathmandu Valley, the evaluation had to be implemented referencing the past history, assuming several logistical points and in consideration of the following disaster management activities.

2.5.1 Liquefaction history in Kathmandu Valley

According to Rana (1935), in the 1934 Bihar-Nepal Earthquake, liquefaction phenomena such as sand and/or water boiling or depression, seems to have occurred at various places in Kathmandu Valley. For the 2015 Gorkha Earthquake, liquefaction was confirmed to five sites in this project (Main Report, Attachment-11) and Okamura et al. (2016) have confirmed eleven liquefied locations (including the above five sites) in J-RAPID.

Also, an interview survey to the residents was conducted to learn about the liquefaction situation of the 1934 Bihar-Nepal Earthquake and the 2015 Gorkha Earthquake in this study. Five liquefaction points during 2015 Gorkha Earthquake were newly found. Three liquefaction points during 1934 Bihar-Nepal Earthquake were newly found and they were also liquefied during the 2015 Gorkha Earthquake (Figure 2.5.1). This may be evidence of repeated liquefaction occurrence at the same place.



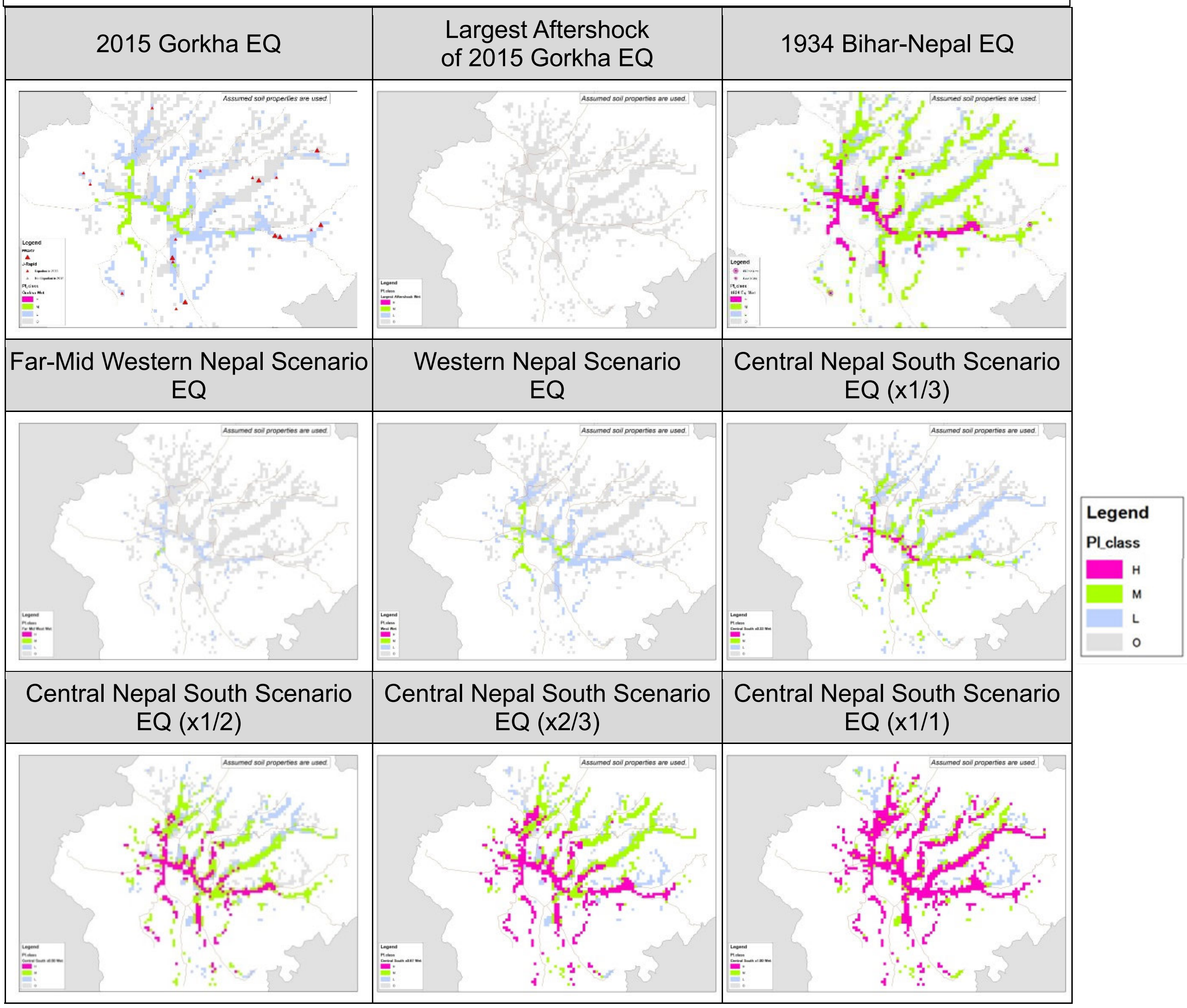
Source: JICA Project Team

Figure 2.5.1 Liquefaction history in Kathmandu Valley

2.5.2 Assessment of liquefaction for scenario earthquakes

The method of the Architectural Institute of Japan was adopted as an assessment method for this project. First, the geomorphological units of “al”, “vp”, “nl”, and “fr” are selected as the targets. They are mostly distributed along the river (Figure 2.5.1). Next, they were subdivided into six considering the sediment environment of the old Kathmandu lake. The typical relationship between the N value and depth for each subdivision was set based on the 60 existing boreholes. The density, fine fraction content and ground water level for the subdivisions were set based on the 2002 JICA study and field survey. The force of generating liquefaction and the force to resist at each depth of N value were calculated based on the parameters above and finally the liquefaction possibility at each 250m grid for scenario earthquakes was assessed both for the rainy season (Figure 2.5.2) and dry season (Figure 2.5.3).

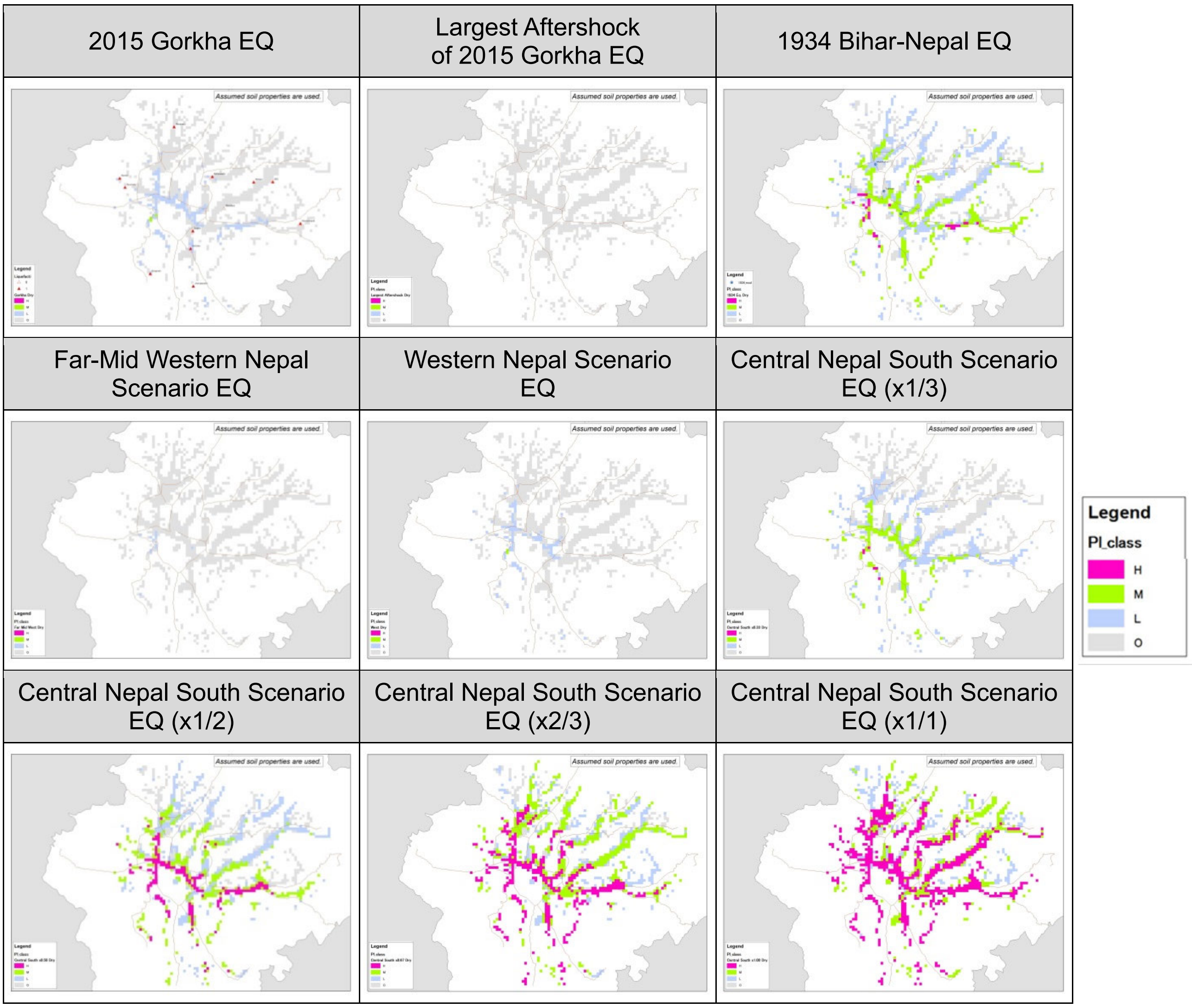
Judgement of liquefaction possibility	
$P_L=0$	(O) No possibility
$0<P_L<=5$	(L) Low possibility
$5<P_L<=15$	(M) Moderate possibility
$15<P_L$	(H) High possibility



Note: assumed soil properties are used according to their shortage

Source: JICA Project Team

Figure 2.5.2 Assumed result of liquefaction (rainy season)



Note: assumed soil properties are used according to their shortage
Source: JICA Project Team

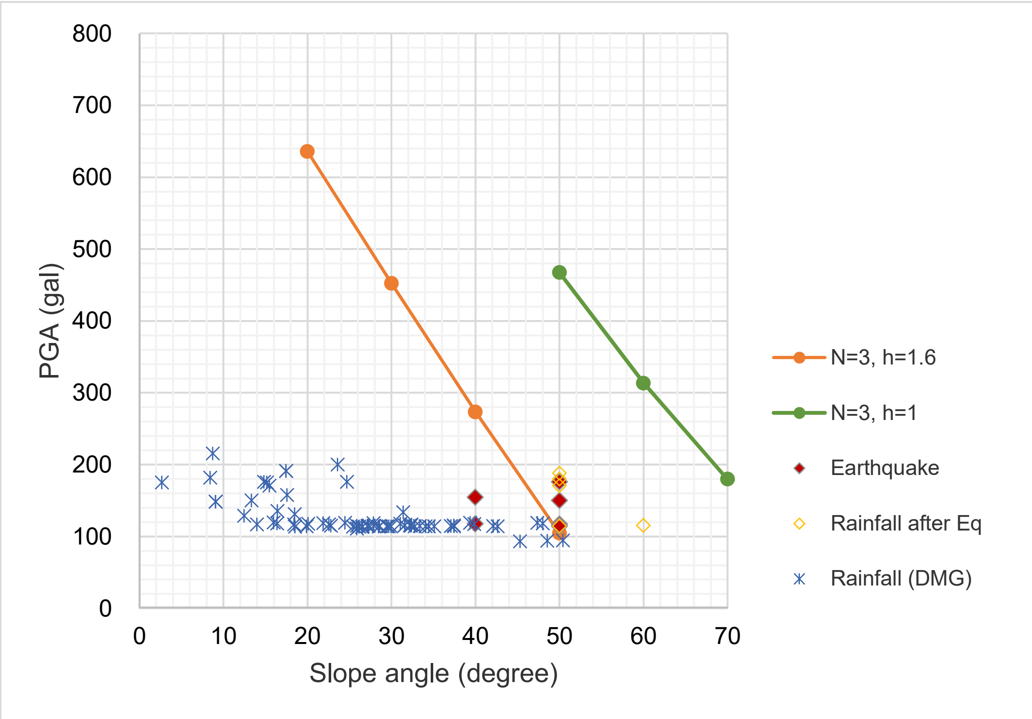
Figure 2.5.3 Assumed result of liquefaction (dry season)

2.6 Assessment of Earthquake Induced Slope Failure

The hazard map for slope failure potential was prepared considering PGA as an external force on the slope referring to Wilson et al. (1979), Tanaka (1982) and so on. These methods require soil parameters of C (cohesion), φ (internal friction angle) and density, as well as slope angles. Although the above parameters for slope sites in Kathmandu Valley are not sufficiently available, a suitable method that can show the trend of damage to slopes due to earthquake is adopted with assumed soil properties.

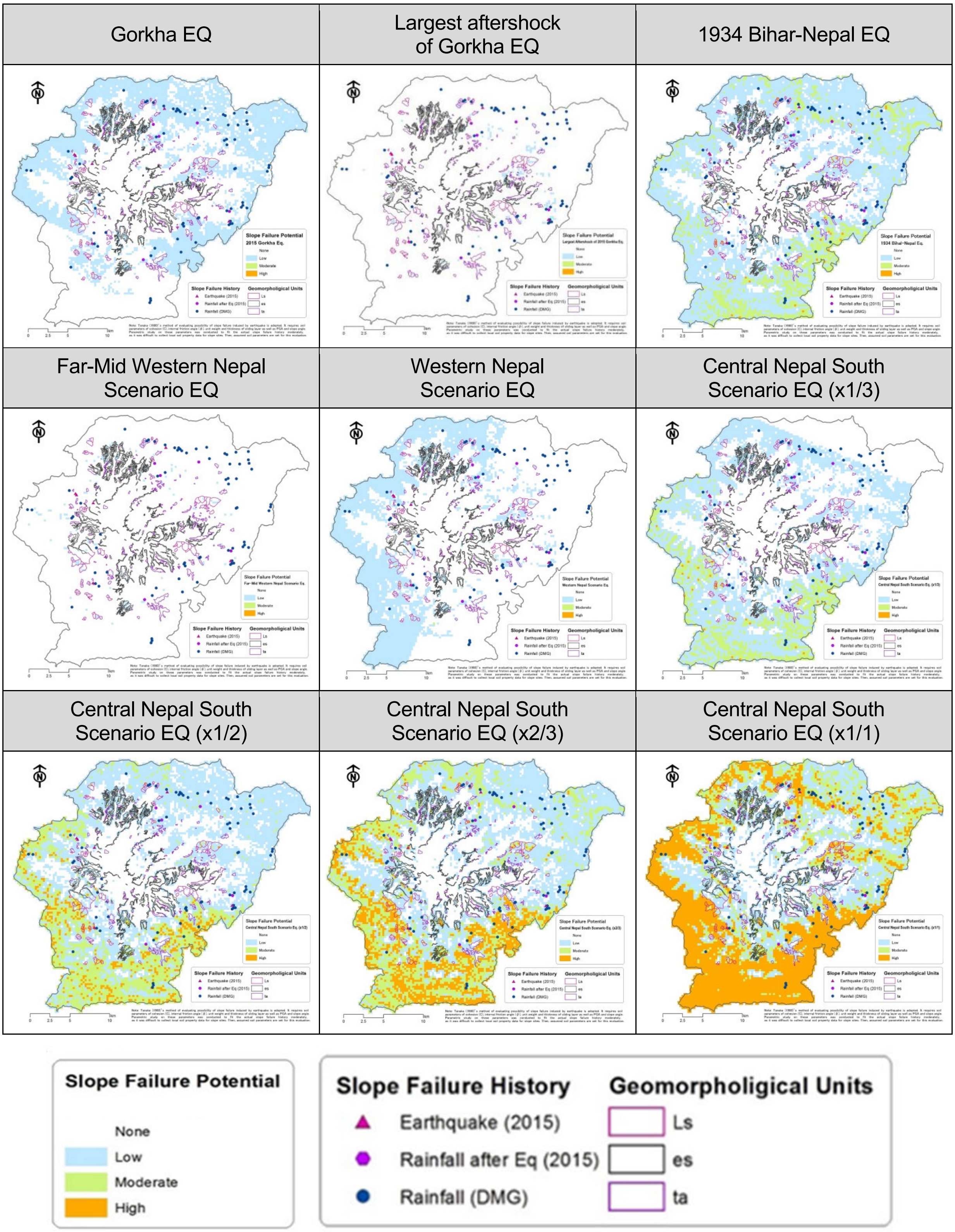
The equation of Wilson et al. (1979) or Tanaka (1982) for safety factor F = 1.0 can introduce relations between slope angle and PGA if values of C and φ are given. If the condition data (slope angle or PGA) is smaller than the line of F = 1.0, the slope is stable. The historical slope failures caused by rainfall, where no slope failure occurred by 2015 Gorkha Earthquake, are plotted in Figure 2.6.1 by blue crosses. The orange coloured line is modified from Tanaka's line by changing *N* value and *h* (thickness) in a trial and error method to separate the no slope failure due to the 2015 Gorkha Earthquake. Additionally, the following facts are considered in the analysis; there is no slope failure in the history where PGA is less than 100 gal, and there is little slope failure and surface slide is dominant if slope angle is less than 20 degrees.

The calculation was done at each 10m grid point and slope failure potential was judged by the ratio of unstable 10m grid points in the 250m grid. Figure 2.6.2 summarizes the results of earthquake induced slope failure evaluation for scenario earthquakes. In these maps, the slope failure relating geomorphological units, namely, Ls, ta and es are overlaid.



Source: JICA Project Team

Figure 2.6.1 Proposed Surface Failure Evaluation Criteria



Note: assumed soil properties are used according to their shortage

Source: JICA Project Team

Figure 2.6.2 Assumed results of earthquake induced slope failure due to scenario earthquakes

Chapter 3 Seismic Risk Assessment

Seismic risk assessment was carried out as the update of the risk assessment of 2002 JICA project of "The Study on Earthquake Disaster Mitigation in the Kathmandu Valley" for the purpose of providing basic information for the formulation of disaster risk reduction and management plans for pilot municipalities. The assessment was performed based on the latest available data and taking into account the new research results on risk assessment as well as the characteristics of ground motion, building damage and human casualties caused by the Gorkha Earthquake, which occurred on 25 April 2015, right before the commencement of the project. The main features of risk assessment of this project are summarized as below.

- No building inventory, which is important for risk assessment, exists in KV. In order to establish a building inventory, a building survey for all buildings was made by the project for former Lalitpur Sub-metropolitan City and Bhaktapur municipality. In addition, building information for all buildings in Budhanilkantha and former Karyabinayak municipalities was collected. Building inventories for the other municipalities were created by estimation based on satellite image and sample structure type survey.
- Damage function of buildings was developed based on the experience of Japan, building damage data of the Gorkha Earthquake as well as the seismic resistant capacity analysis of typical structures of Nepal.
- Ductility factor, the nonlinear flexural deformation of RC piers subject to seismic excitation was estimated by a statistical method, and was used to classify the damage degree of bridges.
- Human casualties were estimated based on the death rate and injured rate of the Gorkha Earthquake for different damage levels and different structure types. Three earthquake occurrence scenes: night, weekday noon and weekend afternoon, were targeted for human casualty estimation.
- Building damage and human casualties were also estimated for 2030 for the purpose of determination of disaster risk reduction targets, assuming different cases of structure type distribution.

The contents of seismic risk assessment cover structural damage of buildings, roads, bridges, water supply pipelines, sewage pipelines, power poles and mobile base transceiver stations (BTS) as well as human casualties, direct economic loss and impact on the tourism industry. The summary of risk assessment results is shown in Table 3.1

Seismic risk assessment results (Figure of damage distribution) from scenario ground motion CNS-2 are only shown in the report as an example due to limitation of space. A map book, which includes all of the risk assessment results together with the basic information for seismic hazard and risk assessment as well as seismic hazard results, was compiled for easy reference. The contents of the map book are given in Table 3.2

REMARKS: The scenario earthquake is not the prediction of a future earthquake. Risk assessment was carried out based on scientific research and investigation results but with inevitable assumptions. Its results might have uncertainties and are not the guarantee of the future damage of a scenario earthquake. The purpose of risk assessment is to provide basic information for the development of disaster risk reduction and management plans of pilot municipalities in KV.

Table 3.1 Summary of risk assessment results

Category		Physical Damage: Scenario Earthquake Ground Motion WN	CNS-1	CNS-2	CNS-3	Economic Loss (mil. NPR)*1: Scenario Earthquake Ground Motion WN	CNS-1	CNS-2	CNS-3
Building (2016) (Total building 444,554)	Heavy damage (EMS DL4&5)	**24,961**	**65,314**	**136,060**	**199,643**	**132,999**	**371,003**	**761,531**	**1,098,353**
		5.6%	14.7%	30.6%	44.9%				
	Moderate damage (EMS DL3)	**21,967**	**42,940**	**62,691**	**67,418**				
		4.9%	9.7%	14.1%	15.2%				
	Slight damage (EMS DL2)	**43,564**	**67,770**	**77,713**	**70,462**				
		9.8%	15.2%	17.5%	15.9%				
Building (2030) (Heavy damage, Total building 606,506)*2	Case-0	**33,763**	**88,681**	**185,796**	**273,269**				
		5.6%	14.6%	30.6%	45.1%				
	Case-1	**28,377**	**79,075**	**171,977**	**258,044**				
		4.7%	13.0%	28.4%	42.5%				
	Case-2	**13,627**	**56,452**	**146,361**	**234,477**				
		2.2%	9.3%	24.1%	38.7%				
	Case-3	**12,162**	**49,970**	**131,095**	**213,481**				
		2.0%	8.2%	21.6%	35.2%				
	Case-4	**16,147**	**52,413**	**129,904**	**210,181**				
		2.7%	8.6%	21.4%	34.7%				
	Case-5	**11,138**	**41,230**	**111,854**	**189,357**				
		1.8%	6.8%	18.4%	31.2%				
School (Total building 5,731)	Heavy damage	**237**	**737**	**1,654**	**2,486**	**20,462**	**51,231**	**98,171**	**134,932**
		4.1%	12.9%	28.9%	43.4%				
	Moderate damage	**253**	**539**	**810**	**875**				
		4.4%	9.4%	14.1%	15.3%				
	Slight damage	**568**	**916**	**1,057**	**960**				
		9.9%	16.0%	18.4%	16.8%				
Health facility (Total building 584)	Heavy damage	**20**	**64**	**153**	**235**	**27,534**	**68,588**	**165,683**	**232,782**
		3.4%	11.0%	26.2%	40.2%				
	Moderate damage	**24**	**55**	**83**	**94**				
		4.1%	9.4%	14.2%	16.1%				
	Slight damage	**51**	**85**	**105**	**97**				
		8.7%	14.6%	18.0%	16.6%				
Government building (Total building 478)	Heavy damage	**20**	**59**	**126**	**186**	**2,444**	**8,669**	**16,514**	**22,708**
		4.2%	12.3%	26.4%	38.9%				
	Moderate damage	**20**	**44**	**66**	**73**				
		4.2%	9.2%	13.8%	15.3%				
	Slight damage	**44**	**71**	**85**	**80**				
		9.2%	14.9%	17.8%	16.7%				
Road*3 (Total length 5,811 km)	Length in landslide area (km)	**0**	**6.6**	**98.5**	**390.6**	**0**	**471**	**1,620**	**2,878**
		0.0%	0.1%	1.7%	6.7%				
	Length in liquefaction area (km)	**0**	**76.1**	**274.9**	**455.3**				
		0.0%	1.3%	4.7%	7.8%				
Bridge (45 bridges assessed)*4	Heavy damage	**0**	**1**	**12**	**32**	**377**	**898**	**1,359**	**1,914**
		0.0%	2.2%	26.7%	71.1%				
	Moderate damage	**2**	**21**	**27**	**11**				
		4.4%	46.7%	60.0%	24.4%				
	Slight damage	**18**	**17**	**6**	**2**				
		40.0%	37.8%	13.3%	4.4%				
Water supply (Existing) (Total length 1,167 km)	Damage points	**982**	**1,921**	**3,496**	**5,161**	**36**	**71**	**129**	**191**
		0.84	1.65	3.00	4.42				
Water supply (Planned) (Total length 699 km)	Damage points	**124**	**255**	**460**	**676**	**5**	**9**	**17**	**25**
		0.18	0.36	0.66	0.97				
Sewage (Total length 1,192 km)	Damage Length (km)	**4.81**	**8.15**	**11.94**	**18.21**	**76**	**135**	**200**	**290**
		0.4%	0.7%	1.0%	1.5%				
Power distribution (Total pole 190,851)	Pole broken	**1,327**	**3,991**	**9,156**	**13,992**	**19**	**56**	**129**	**197**
		0.7%	2.1%	4.8%	7.3%				
Mobile BTS tower (Total tower 1,043)	Tower damage	**43**	**143**	**372**	**601**	**82**	**272**	**707**	**1,142**
		4.1%	13.7%	35.7%	57.6%				

Category	Human Casualty (Population: 2016: 2,786,929; 2030: 3,805,926)		Scenario Earthquake Ground Motion WN	CNS-1	CNS-2	CNS-3
Building (2016)	Night (Weekday and weekend)	Death	**3,034**	**9,133**	**22,179**	**35,726**
			0.11%	0.33%	0.80%	1.28%
		Injured	**11,880**	**35,766**	**86,861**	**139,914**
			0.43%	1.28%	3.12%	5.02%
		Evacuee	**279,031**	**642,743**	**1,196,080**	**1,613,314**
			10.01%	23.06%	42.92%	57.89%
	Weekday (noon, 12:00)	Death	**2,784**	**8,282**	**19,959**	**31,956**
			0.10%	0.30%	0.72%	1.15%
		Injured	**10,905**	**32,435**	**78,168**	**125,152**
			0.39%	1.16%	2.80%	4.49%
		Evacuee	**285,850**	**652,798**	**1,206,530**	**1,619,792**
			10.26%	23.42%	43.29%	58.12%
	Weekend (afternoon, 18:00)	Death	**2,123**	**6,393**	**15,526**	**25,008**
			0.08%	0.23%	0.56%	0.90%
		Injured	**8,316**	**25,036**	**60,803**	**97,940**
			0.30%	0.90%	2.18%	3.51%
		Evacuee	**279,942**	**645,483**	**1,202,734**	**1,624,032**
			10.04%	23.16%	43.16%	58.27%
Building (2030)	Case-0	Death	**4,121**	**12,508**	**30,583**	**49,381**
			0.11%	0.33%	0.80%	1.30%
	Case-1	Death	**3,434**	**11,017**	**27,930**	**46,017**
			16.7%	11.9%	8.7%	6.8%
	Case-2	Death	**1,721**	**8,135**	**24,356**	**42,526**
			58.2%	35.0%	20.4%	13.9%
	Case-3	Death	**1,438**	**6,733**	**20,526**	**36,715**
			65.1%	46.2%	32.9%	25.6%
	Case-4	Death	**2,052**	**7,887**	**23,086**	**41,146**
			50.2%	36.9%	24.5%	16.7%
	Case-5	Death	**1,476**	**6,524**	**20,842**	**38,733**
			64.2%	47.8%	31.9%	21.6%
School		Death	**444**	**1,545**	**4,002**	**6,555**
			0.05%	0.18%	0.47%	0.77%
		Injured	**1,739**	**6,051**	**15,673**	**25,671**
			0.20%	0.71%	1.84%	3.02%

Source: JICA Project Team

Table 3.2 Contents of Map Book

No.	Caption	No.	Caption
A.	**Basic Conditions**	**C.**	**Earthquake Risk Assessment**
A-1	Study Area and Pilot Municipality	C-1	Distribution of Heavily Damaged Buildings & Ratio in 2016 (WN)
A-2	Distribution of Population in 2016 at Night	C-2	Distribution of Heavily Damaged Buildings & Ratio in 2016 (CNS-1)
A-3	Distribution of Estimated Population in 2030 at Night	C-3	Distribution of Heavily Damaged Buildings & Ratio in 2016 (CNS-2)
A-4	Building Distribution in 2016	C-4	Distribution of Heavily Damaged Buildings & Ratio in 2016 (CNS-3)
A-5	Estimated Building Distribution in 2030 (without BSPS)	C-5	Distribution of Moderately Damaged Buildings & Ratio in 2016 (WN)
A-6	Estimated Building Distribution in 2030 (with BSPS Case-1)	C-6	Distribution of Moderately Damaged Buildings & Ratio in 2016 (CNS-1)
A-7	Estimated Building Distribution in 2030 (with BSPS Case-2)	C-7	Distribution of Moderately Damaged Buildings & Ratio in 2016 (CNS-2)
A-8	Estimated Building Distribution in 2030 (with BSPS Case-3)	C-8	Distribution of Moderately Damaged Buildings & Ratio in 2016 (CNS-3)
A-9	Estimated Building Distribution in 2030 (with BSPS Case-4)	C-9	Distribution of Heavily Damaged Buildings for 2030 without BSPS
A-10	Estimated Building Distribution in 2030 (with BSPS Case-5)	C-10	Distribution of Heavily Damaged Buildings for 2030 with BSPS Case-1
A-11	Distribution of School Buildings	C-11	Distribution of Heavily Damaged Buildings for 2030 with BSPS Case-2
A-12	Distribution of Health Facility Buildings	C-12	Distribution of Heavily Damaged Buildings for 2030 with BSPS Case-3
A-13	Distribution of Government Buildings	C-13	Distribution of Heavily Damaged Buildings for 2030 with BSPS Case-4
A-14	Road Network	C-14	Distribution of Heavily Damaged Buildings for 2030 with BSPS Case-5
A-15	Emergency Transportation Road Network (ETRN) Proposed by JICA RRNE	C-15	School Building Damage
A-16	Distribution of Bridges	C-16	Health Facility Building Damage
A-17	Distribution of Water Supply Networks (Existing)	C-17	Government Building Damage
A-18	Distribution of Water Supply Networks (Planned)	C-18	Possible Damage of Road by Liquefaction
A-19	Distribution of Sewage Networks	C-19	Possible Damage of Road by Slope Failure
A-20	Estimated Power Pole Distribution	C-20	Possible Link Blockage of Road by Building Damage
A-21	Distribution of Mobile BTS Towers	C-21	Possible Link Blockage of ETRN by Building Damage
		C-22	Damage of Bridges
B.	**Earthquake Hazard Assessment**	C-23	Priority Rank of Bridges for Seismic Strengthening
B-1	Geomorphological Map	C-24	Distribution of Water Supply Network Damage (Existing)
B-2	Altitude Distribution Map	C-25	Distribution of Water Supply Network Damage (Planned)
B-3	Distribution of Collected Borehole Data	C-26	Distribution of Sewage Network Damage
B-4	Rock Depth Distribution and Location of Borehole	C-27	Distribution of Power Pole Damage
B-5	Location of Microtremor Measurement	C-28	Distribution of Mobile BTS Tower Damage
B-6	Geological Cross-Section EW	C-29	Distribution of Deaths in 2016 at Night
B-7	Geological Cross-Section NS	C-30	Distribution of Deaths in 2016 at Weekday Noon
B-8	Estimated AVS30 from Ground Model	C-31	Distribution of Deaths in 2016 at Weekend Afternoon
B-9	Predominant Period of Ground	C-32	Distribution of Death Ratio in 2016 at Night
B-10	Fault Model of Scenario Earthquake	C-33	Distribution of Death Ratio in 2016 at Weekday Noon
B-11	Peak Ground Acceleration Distribution	C-34	Distribution of Death Ratio in 2016 at Weekend Afternoon
B-12	Peak Ground Velocity Distribution	C-35	Comparative vulnerability of municipalities in KV
B-13	Seismic Intensity (MMI) Distribution		
B-14	Distribution of Liquefaction in Rainy Season		
B-15	Distribution of Liquefaction in Dry Season		
B-16	Distribution of Slope Failure		
B-17	AVS30 Map base on Geomorphological Unit		
B-18	Liquefaction Susceptibility Map		
B-19	Earthquake Induced Slope Failure Susceptibility Map		

Source: JICA Project Team

3.1 Necessity and objectives of Seismic Risk Assessment

Natural disasters result in not only life and economic loss, but are also big obstacles to the sustainable development of an economy. In order to reduce disaster risk globally, the UN had initiated the International Decade for Natural Disaster Reduction (IDNDR) for the 1990s in 1987 at its 42nd General Assembly. After IDNDR, the Hyogo Framework for Action (HFA) was adopted in the 2nd World Conference on Disaster Risk Reduction in 2005. Based on HFA, the world has promoted disaster risk reduction activities and produced steady results with development of legal framework, establishment of DRR organizations, strengthening of collaboration among organizations, capacity development, and structural and non-structural measures to reduce vulnerability. On the other hand, the activities which lead to direct reduction of risk are comparatively limited due to the lack of budget and knowledge. In this circumstance, Sendai Framework for Disaster Risk Reduction (Sendai Framework) was adopted in the 3rd World Conference on Disaster Risk Reduction in 2015, where sustainable development with mainstreaming DRRM is emphasized through advocating for four priorities for action and assigning seven global targets. Risk assessment is closely related to the Priority for Action 1: Understanding Disaster Risk and Priority for Action 2: Strengthening Disaster Risk Governance to Manage Disaster Risk. Risk assessment is essential to provide basic information for the development of disaster risk reduction policy and plan to achieve the disaster risk reduction goal for human casualties, economy loss and critical infrastructure damage.

Seismic risk assessment of this project is planned to be utilized for the determination of risk reduction goals, creation of disaster risk reduction and management plan and support for CBDRRM activities of pilot municipalities. It has been used for the development of the Kathmandu Valley Resilient Plan (KVRP) under the JICA RRNE project and can be expected to be used for preparation of the disaster risk reduction and management plans of the municipalities in KV other than the three pilot municipalities. It also provides useful information for the formulation of Business Continuity Plans (BCP) for local government as well as utility companies.

A common issue for seismic risk assessment in many countries including Nepal is the lack of basic information such as earthquake damage data and structural inventory. Insufficient earthquake damage data makes it difficult to prepare a specific fragility curve. Lack of inventory will directly affect the precision of risk assessment. This project faced the same issues and some assumptions and presumptions had to be made to compliment the insufficiency. During the process of risk assessment, the damage data and findings from Gorkha earthquake have been used whenever possible. The update of risk assessment may be required in the future in case new findings from the Gorkha Earthquake are obtained and/or the building, infrastructure and lifeline inventories are completed.

3.2 Scenario Earthquake and Occurrence Scene

Three scenario earthquakes were adopted in seismic hazard assessment. In order to consider the ground motion attenuation characteristics of the Gorkha Earthquake, four possible ground motion levels were applied for Central Nepal South Scenario Earthquake, which is located adjacent to the Gorkha Earthquake. Considering the purpose of the project, among the six ground motion levels of seismic hazard results, four of them are chosen as the target ground motion for risk assessment. Besides, different scenario earthquake occurrence scenes were considered because the occurrence time of future earthquakes is unknown.

3.2.1 Ground Motion Used for Risk Assessment

Three scenario earthquakes, i.e. Far-Mid Western Nepal Scenario Earthquake (M = 8.6), Western Nepal Scenario Earthquake (M = 7.8) and Central Nepal South Scenario Earthquake (M = 7.8) were considered in the hazard assessment. Ground motion for Far-Mid Western Nepal Scenario Earthquake and Western Nepal Scenario Earthquake was estimated directly from the attenuation formula, while that for Central Nepal South Scenario Earthquake was estimated from attenuation formula with four correction factors of 1/3, 1/2, 2/3 and 1/1 to consider smaller accelerations recorded in KV from the Gorkha Earthquake. Considering the possibility of ground motion and reality of disaster risk reduction measures, the ground motion to be used for risk assessment was discussed in WG1 and 4th JCC meeting, which lead to the conclusion that ground motions from Western Nepal Scenario Earthquake (without correction) and Central Nepal South Scenario Earthquake with correction factor of 1/3, 1/2 and 2/3 would be used for risk assessment as shown in Table 3.2.1. To identify different ground motions from one scenario earthquake, the ground motion used for risk assessment are called scenario ground motion hereinafter.

Table 3.2.1 Scenario ground motion for risk assessment

Scenario Earthquake	Correction Factor for PGA	Notation
Western Nepal Scenario Earthquake	1/1	WN
Central Nepal South Scenario Earthquake	1/3	CNS-1
	1/2	CNS-2
	2/3	CNS-3

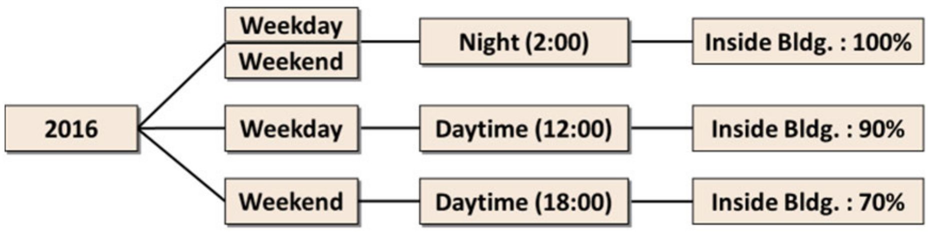
Source: JICA Project Team

3.2.2 Earthquake Occurrence Scenes

Different occurrence time of earthquakes will not cause a difference in structural damage of buildings, infrastructure and lifeline facilities, but does affect human casualties due to the different populations inside buildings at the time of earthquake occurrence. In this regard, earthquake occurrence scene (occurrence time) for 2016 was considered for night, weekday noon and weekend afternoon based on the survey results of inside building ratio in different days (weekday and weekend) and time. In this project, for the purpose of the determination of risk reduction targets, risk assessment was also conducted for 2030, where two scenes were considered: (1) extrapolation of building structure type of 2016, meaning without any strengthening measures to upgrade building seismic performance and (2) assuming building seismic capacity is somehow improved with five supposed cases to consider possible structure type distribution in the future.

(1) Earthquake Occurrence Scenes for 2016

Different population distribution, of weekday, weekend, daytime and night were considered mainly for the determination of earthquake occurrence scenes of 2016. As a result, three scenes at night (2:00 am), weekday noon (12:00 pm) and weekend afternoon (18:00 pm) were decided as shown in Figure 3.2.1. The main features of different occurrence scenes are summarized in Table 3.2.2. Population inside buildings for each occurrence scene was assigned based on the questionnaire survey. Population distribution for night comes from census and that for weekday daytime was derived from the origin-destination (OD) survey data, which accounts for the movement of workers and students from their home to office or school.



Source: JICA Project Team

Figure 3.2.1 Earthquake occurrence scenes for 2016

Table 3.2.2 Features of different earthquake occurrence scenes

Scene	Feature
Night (2:00 am) (Ratio of inside building 100%)	◆ More human casualties may occur as compared to daytime ◆ May cause delay on search and rescue due to the difficulty of personnel mobilization ◆ Difficulty in speedy evacuation, especially in winter or rainy season, which may increase human casualties
Weekday Noon (12:00 pm) (Ratio of inside building 90%)	◆ More human casualties may happen in office and commercial facilities, rather than in home ◆ There are a large number of people who have to stay in office and commercial facilities due to transportation problems caused by road and bridge damage
Weekend Afternoon (18:00 pm) (Ratio of inside building 70%)	◆ Less human casualties than the other scenes ◆ May cause delay on search and rescue due to the difficulty of personnel mobilization

Source: JICA Project Team

(2) Earthquake Occurrence Scenes for 2030

Two scenes for 2030, with and without strengthening of building seismic capacity, shown in Figure 3.2.2, were considered to provide information for determination of risk reduction targets in disaster risk reduction and management plans. The scene of without strengthening of the building seismic performance (Extrapolation) means the structure type distribution of 2030 is the same as that of 2016, while the scene with strengthening building seismic performance (Seismic Strengthening) changes the structure type distribution of 2016, having five cases with different assumptions. The effect of building seismic performance strengthening could be obtained by comparing the results from the two scenes of with and without.

Source: JICA Project Team

Figure 3.2.2 Earthquake occurrence scenes for 2030

3.3 Inventory Data

For the purpose of risk assessment, a GIS-based inventory for buildings, transportation infrastructure and lifelines was developed based on the primary data, surveyed by the project, and second hand data, collected from the Nepalese government and related organizations, like UNDP. The categories of inventory and data source are summarized in Table 3.3.1. Damage estimation was carried out by spread sheet, which was created based on calculation forms prepared by the project, with ground motion of scenario earthquakes and the inventory as input. In addition, GIS was used for creating and editing the inventory and mapping the results of risk assessment.

In this project, the mesh-grid of 250 m × 250 m (hereinafter referred to as "evaluation grid") was set as a minimum evaluation unit of analysis and estimation. The size of an evaluation grid was determined by considering the precision of seismic hazard analysis, the scale of the original map and the positional accuracy of each object in the inventory data. The total number of units of the evaluation grid is 11,933, which covers the whole study area in the Kathmandu Valley. The ground motion calculated from a scenario earthquake such as peak ground acceleration (PGA) and peak ground velocity (PGV) have different values for each evaluation grid.

The damage of buildings and damage ratio of road networks, pipelines of water supply and sewage, and electricity distribution networks were calculated for each evaluation grid. Also the damage probabilities for each building such as school, health and government facilities and BTS were calculated based on the PGA value of the evaluation grid, where the individual building is located. As for the estimation of human causalities and direct economic losses, the administrative boundary-based analysis were adapted, since the population data and various statistical data are organized by the administrative area such as municipality and ward.

Table 3.3.1 Category of inventory and data source

Kinds of Inventory Data	Types of Data	Sources of Data
Population (The results of Census 2001 and 2011)	Ward-wise data (Polygon Data)	CBS 2001・2011
Estimated Population data for Daytime and Night time ・Estimated number in 2016: 2,786,929 persons ・Estimated number in 2030: 3,805,926 persons	Ward-wise data (Polygon Data)	JICA ERAKV, 2017
General Buildings (The result of Census 2011)	Ward-wise data (Polygon Data)	CBS, 2011
Estimated General Building Distribution ・Estimated number in 2016: 444,554 buildings ・Estimated number in 2030: 606,506 buildings (For the general building distribution in 2030, six different cases of building structure component ratios were set in consideration of the different progress of building seismic performance strengthening in 2030.)	250m × 250m Grid-wise data (Polygon Data)	JICA ERAKV, 2017 UNDP/CDRMP, 2013
Schools ・2,115 schools, 5,731 buildings	Individual Building Data (Point Data)	DoE, 2015 Flagship 1 of NRRC, 2014, JICA ERAKV, 2017
Health Facilities ・363 facilities, 584 buildings	Individual Building Data (Point Data)	DoH, 2015 Flagship 1 of NRRC, 2014, JICA ERAKV, 2017
Governmental Buildings ・478 buildings	Individual Building Data (Point Data)	DUDBC, 2015 JICA ERAKV, 2017
Road Network Including the national highways, feeder roads strategic urban roads, districts and village roads ・Total length of roads: 5,811 ㎞	Network Data (Line Data)	DoR, 2015 DoLIDAR, 2015 JICA ERAKV, 2017 UNDP/CDRMP, 2013
Bridges ・145 bridges	Individual Bridge Data (Point Data)	DoR, 2015 JICA ERAKV, 2017
Water Supply Network (Existing) ・Total length of pipelines: 1,167 ㎞	Network Data (Line Data)	KUKL, 2005
Water Supply Network (Planned) ・Total length of pipelines: 699 ㎞	Network Data (Line Data)	KUKL, 2016
Sewage Network (Existing) ・Total length of pipelines: 1,192 ㎞	Network Data (Line Data)	KUKL, 2015
Estimated Power Pole Distribution ・190,851 poles	250m × 250m Grid-wise data (Polygon Data)	NEA, 2016 JICA ERAKV, 2017
Base Transceiver Stations (BTS) ・1,043 stations	Individual BTS Data (Point Data)	NTA, NTC, Ncell, 2015 JICA ERAKV, 2017

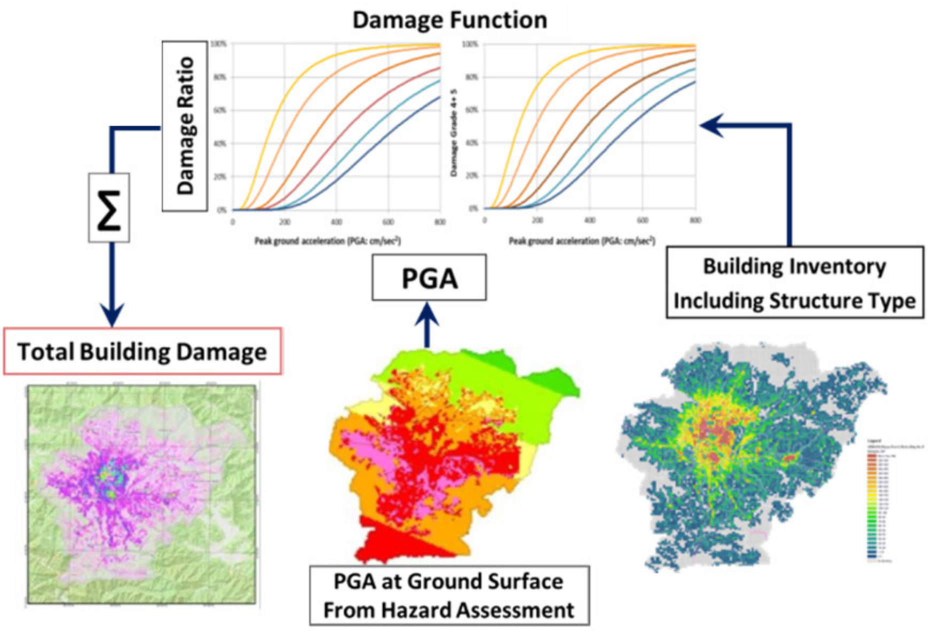
3.4 Approach and Results of Seismic Risk Assessment

Structural damage of general buildings, schools, hospitals, government buildings, roads, bridges, water supply pipeline networks, sewage pipeline networks, power poles and mobile base transceiver stations (BTS), human casualties and economic loss for each scenario ground motion was carried out. This approach of risk assessment is basically that which is commonly used in Japan and modified as necessary and depending on the availability of damage data from the Nepal side. The approach was discussed in WG meetings as well as individually with counterparts and related organizations, so as to reach common consensus.

3.4.1 Damage to Buildings

(1) Flow of building damage assessment

Flow of building damage assessment is shown in Figure 3.4.1. Building inventory data, result of hazard assessment and proposed damage function were used for the damage assessment for each 250 m x 250 m grid.

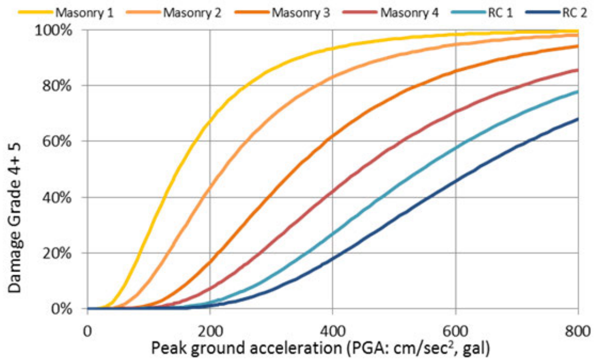


Source: JICA Project Team

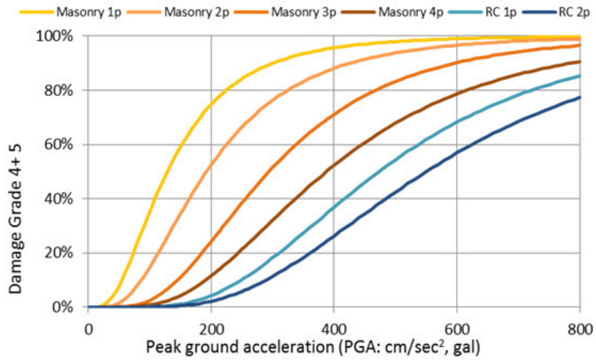
Figure 3.4.1 Flow of building damage assessment

(2) Proposed damage function

Proposed damage function for general buildings is shown in Figure 3.4.2. Damage functions for the typical (centre) area and the perimeter area were used per the predominant period of the ground. This allocation was done based on the response analysis at each grid for average building period of 0.3 to 0.7 sec. Category of the damage function and structural type is shown in Table 3.4.1.



a) General (centre) area of the Valley
(Tg > 1.5 sec & Tg ≤0.3 sec)



b) Perimeter area of the Valley, suffix p
(0.3 sec< Tg ≤ 1.5 sec)

Source: JICA Project Team

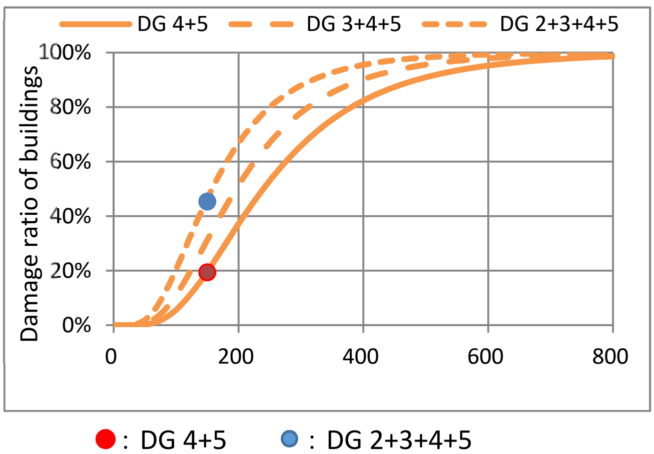
Figure 3.4.2 Damage function of EMS DL4+5 for general buildings

Table 3.4.1 Category of damage function and corresponding structural type

Category of damage function P denotes " perimeter area"		Structural type (Numbering indicates the number of building inventory survey)	
1	Masonry 1, Masonry 1P	1.Adobe	
2	Masonry 2, Masonry 2P	4.Brick masonry with mud mortar, flex roof & 20 years and more	2. Stone with mud mortar
3	Masonry 3, Masonry 3P	4.Brick masonry with mud mortar, rigid roof, & flex roof within 1~20 years	
4	Masonry 4, Masonry 4P	5.Brick masonry with cement mortar	3. Stone with cement mortar, 8. Others
5	RC 1, RC 1p	6.RC non-engineered	
6	RC 2, RC 2p	7. RC engineered with low to mid-rise	

Centre (general) area of the Valley: Tg > 1.5 sec & Tg ≤0.3 sec; Perimeter area of the Valley, suffix p: 0.3 sec< Tg ≤ 1.5 sec
Source: JICA Project Team

Damage function for historical buildings (monuments), which will be used for damage assessment for historical buildings and monuments in the Protected Monument Zone (PMZ) at three Durbar Squares in KV, are proposed as shown in Figure 3.4.3.



Source: JICA Project Team

Figure 3.4.3 Damage function for historical buildings (monuments)

(3) Assessment Results

Building damages estimated for each scenario ground motion are summarized in Table 3.4.2, followed by an explanation.

Table 3.4.2 Estimated building damage (Upper: damage number; Lower: damage ratio)

Category	Damage Level	Scenario earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Buildings (2016) (Total buildings 444,554)	Heavy damage (EMS DL4&5)	24,961	65,314	136,060	199,643
		5.6%	14.7%	30.6%	44.9%
	Moderate damage (EMS DL3)	21,967	42,940	62,691	67,418
		4.9%	9.7%	14.1%	15.2%
	Slight damage (EMS DL2)	43,564	67,770	77,713	70,462
		9.8%	15.2%	17.5%	15.9%
Buildings (2030, EMS DL4&5) (Total buildings 606,506)	Case-0	33,763	88,681	185,796	273,269
		5.6%	14.6%	30.6%	45.1%
	Case-1	28,377	79,075	171,977	258,044
		4.7%	13.0%	28.4%	42.5%
	Case-2	13,627	56,452	146,361	234,477
		2.2%	9.3%	24.1%	38.7%
	Case-3	12,162	49,970	131,095	213,481
		2.0%	8.2%	21.6%	35.2%
	Case-4	16,147	52,413	129,904	210,181
		2.7%	8.6%	21.4%	34.7%
	Case-5	11,138	41,230	111,854	189,357
		1.8%	6.8%	18.4%	31.2%
Schools (Total buildings 5,731)	Heavy damage	237	737	1,654	2,486
		4.1%	12.9%	28.9%	43.4%
	Moderate damage	253	539	810	875
		4.4%	9.4%	14.1%	15.3%
	Slight damage	568	916	1,057	960
		9.9%	16.0%	18.4%	16.8%
Health facilities (Total buildings 584)	Heavy damage	20	64	153	235
		3.4%	11.0%	26.2%	40.2%
	Moderate damage	24	55	83	94
		4.1%	9.4%	14.2%	16.1%
	Slight damage	51	85	105	97
		8.7%	14.6%	18.0%	16.6%
Government buildings (Total buildings 478)	Heavy damage	20	59	126	186
		4.2%	12.3%	26.4%	38.9%
	Moderate damage	20	44	66	73
		4.2%	9.2%	13.8%	15.3%
	Slight damage	44	71	85	80
		9.2%	14.9%	17.8%	16.7%

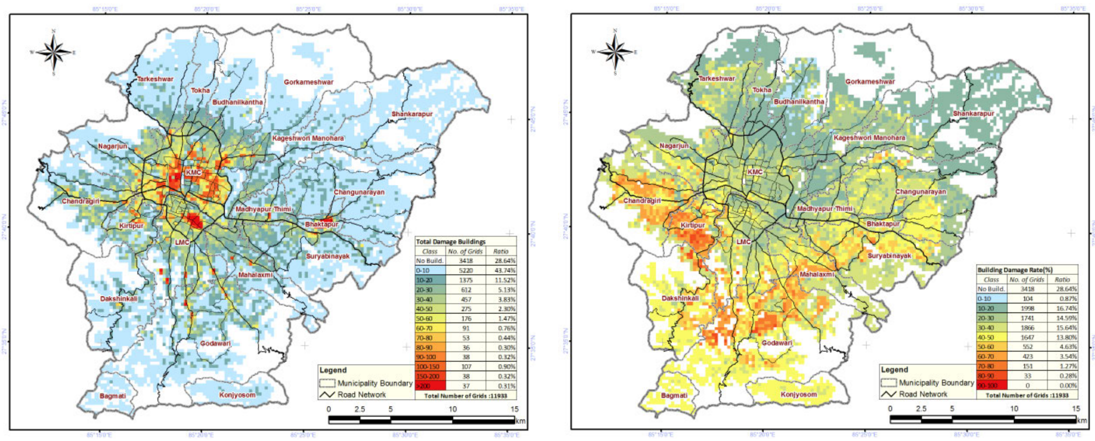
Source: JICA Project Team

a) Damage to general buildings

Damage at year 2016

The total number of buildings was estimated as 444,554 at year 2016. Ratio of structural type is 47% for "RC non-engineered", 28% for "Brick and stone masonry with cement mortar joint", 14% for "Brick and stone masonry with mud mortar joint", and 2% for "Others (RC engineered, and others)". The distribution of general building damage in 2016 is shown in

Figure 3.4.4 for CNS-2. In this case, buildings with heavy damage (EMS damage grade 4 and 5) were estimated as 136,060, which is 30.6% of the total number of buildings.



Source: JICA Project Team

Figure 3.4.4 Distribution of general building damage at year 2016
(CNS-2, Left：Damage number, Right：Damage ratio)

<u>Damage at year 2030</u>

The total number of buildings was estimated as 606,506 at year 2030. The results of the estimated building damage are shown in Table 3.4.5, with one case (Case0) for without Building Seismic Performance Strengthening (BSPS) and five cases (Case1-5) for supposed BSPS. Buildings damaged in the case of without BSPS at 2030 for CNS-2 was estimated as 185,796, which is 30.6% of the total number of buildings, meaning the damage will be increased along with the increase in the number of buildings if no measures are taken on building seismic performance strengthening.

Building damage and corresponding economic losses are shown in Table 3.4.3 for the cases of with and without BSPS for CNS-1. Varying according to the cases, the number of heavily damaged buildings is reduced from 11% to 53% and the amount of loss is reduced from about 8% to 30%. The cost for the case of with BSPS, comparing with those of without BSPS, is shown in Table 3.4.4. For Case 1, which means the masonry building with cement mortar are constructed instead of mud mortar for new buildings from 2016 to 2030, the building cost will increase about 9%. In the case of Case 2, where all new and existing mud mortar masonry buildings are replaced by cement mortar buildings, the cost increases about 14%. On the other hand, in the Case 4 and Case 5, which change the majority of masonry buildings from both mud mortar and cement mortar to engineered RC buildings, leads to a considerable increase of building cost due to the increase of building numbers and higher unit construction cost.

Table 3.4.3 Building Damage and Loss Amount

Case	Buildings with heavy damage	Reduction in number of damaged buildings	Loss amount (mil. NPR)	Reduction in loss amount (mil. NPR)	Reduction in loss amount (%)
Case0	88,681		269,789		
Case1	79,075	10.8%	247,974	21,815	8.1%
Case2	56,452	36.3%	227,573	42,216	15.6%
Case3	49,970	43.7%	187,832	81,956	30.4%
Case4	52,413	40.9%	221,349	48,440	18.0%
Case5	41,230	53.5%	207,520	62,269	23.1%

Source: JICA Project Team

Table 3.4.4 Cost Increase of Cases with BSPS to the Case without BSPS

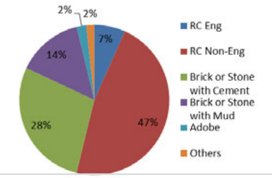
Case	Buildings to be rebuilt or newly constructed	Construction Cost (mil. NPR)	Cost increase to Case 0 (mil. NPR)	Ratio of increase cost (%)	Cost increase per year
Case1	161,953	881,718	79,718	9%	5,694
Case2	243,047	1,072,452	148,391	14%	10,599
Case3	452,543	2,690,179	299,228	11%	21,373
Case4	293,099	2,263,313	894,945	40%	63,925
Case5	389,795	3,009,995	1,233,103	41%	88,079

Note: Building increase from 2016 to 2030 is 161,952; construction cost is 802,000 mil. NPR
Cost increase per year is calculated for 14 years, from 2017 to 2030.

Source: JICA Project Team

Table 3.4.5 Results of building damage assessment for 2016 and 2030

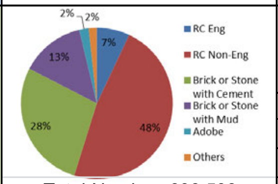
2016



Total Number: 444,554

Scinario Eq.	Building Damage			
	Heavily (DG4+5)		Partly (DG3)	
WN	24,961	5.6%	21,967	4.9%
CNS-1	65,314	14.7%	42,940	9.7%
CNS-2	136,060	30.6%	62,691	14.1%
CNS-3	199,643	44.9%	67,418	15.2%

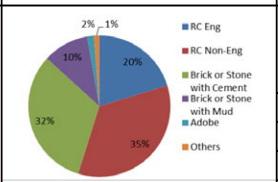
2030 without BSPS (※1)



Total Number: 606,506

Scinario Eq.	Building Damage			
	Heavily (DG4+5)		Partly (DG3)	
WN	33,763	5.6%	29,831	4.9%
CNS-1	88,681	14.6%	58,470	9.6%
CNS-2	185,796	30.6%	85,520	14.1%
CNS-3	273,269	45.1%	91,892	15.2%

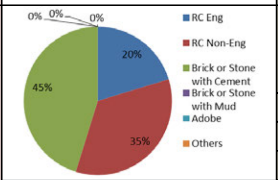
2030 with BSPS Case01



Total Number: 606,506

Scinario Eq.	Building Damage				Rate of Mitigating Damage by BSPS (※2)	
	Heavily (DG4+5)		Partly (DG3)		Heavily	Partly
WN	28,377	4.7%	26,558	4.4%	16.0%	11.0%
CNS-1	79,075	13.0%	55,103	9.1%	10.8%	5.8%
CNS-2	171,977	28.4%	83,859	13.8%	7.4%	1.9%
CNS-3	258,044	42.5%	92,321	15.2%	5.6%	-0.5%

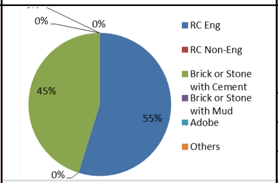
2030 with BSPS Case02



Total Number: 606,506

Scinario Eq.	Building Damage				Rate of Mitigating Damage by BSPS (※2)	
	Heavily (DG4+5)		Partly (DG3)		Heavily	Partly
WN	13,627	2.2%	18,881	3.1%	59.6%	36.7%
CNS-1	56,452	9.3%	50,010	8.2%	36.3%	14.5%
CNS-2	146,361	24.1%	83,717	13.8%	21.2%	2.1%
CNS-3	234,477	38.7%	95,133	15.7%	14.2%	-3.5%

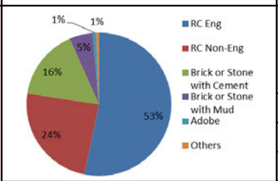
2030 with BSPS Case03



Total Number: 606,506

Scinario Eq.	Building Damage				Rate of Mitigating Damage by BSPS (※2)	
	Heavily (DG4+5)		Partly (DG3)		Heavily	Partly
WN	12,162	2.0%	16,590	2.7%	64.0%	44.4%
CNS-1	49,970	8.2%	45,067	7.4%	43.7%	22.9%
CNS-2	131,095	21.6%	78,997	13.0%	29.4%	7.6%
CNS-3	213,481	35.2%	93,462	15.4%	21.9%	-1.7%

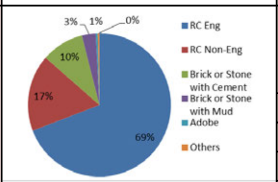
2030 with BSPS Case04



Total Number: 606,506

Scinario Eq.	Building Damage				Rate of Mitigating Damage by BSPS (※2)	
	Heavily (DG4+5)		Partly (DG3)		Heavily	Partly
WN	16,147	2.7%	17,900	3.0%	52.2%	40.0%
CNS-1	52,413	8.6%	45,293	7.5%	40.9%	22.5%
CNS-2	129,904	21.4%	79,695	13.1%	30.1%	6.8%
CNS-3	210,181	34.7%	95,190	15.7%	23.1%	-3.6%

2030 with BSPS Case05



Total Number: 606,506

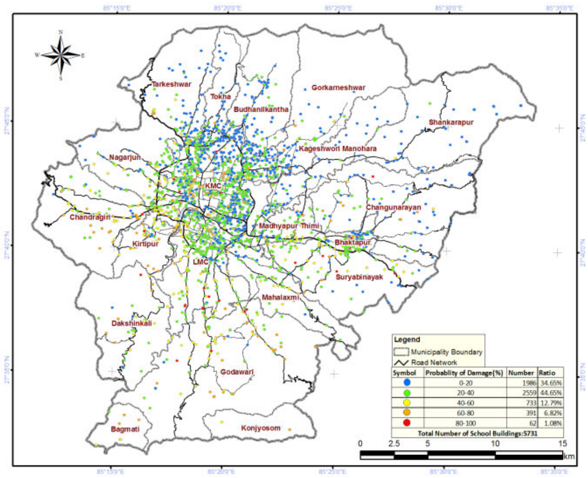
Scinario Eq.	Building Damage				Rate of Mitigating Damage by BSPS (※2)	
	Heavily (DG4+5)		Partly (DG3)		Heavily	Partly
WN	11,138	1.8%	14,252	2.3%	67.0%	52.2%
CNS-1	41,230	6.8%	40,974	6.8%	53.5%	29.9%
CNS-2	111,854	18.4%	77,650	12.8%	39.8%	9.2%
CNS-3	189,357	31.2%	96,203	15.9%	30.7%	-4.7%

※1: BSPS: Promotion on Building Seismic Performance Strengthening
※2: Rate of Mitigating Damage by BSPS Compared to 2030 Without BSPS

Source: JICA Project Team

b) Damage to school buildings

The total number of school buildings is 5,731. Building damage distribution for CNS-2 is shown in Figure 3.4.5 and the results for the four scenario ground motions are summarized in Table 3.4.6.



Source: JICA Project Team

Figure 3.4.5 Damage distribution of school buildings

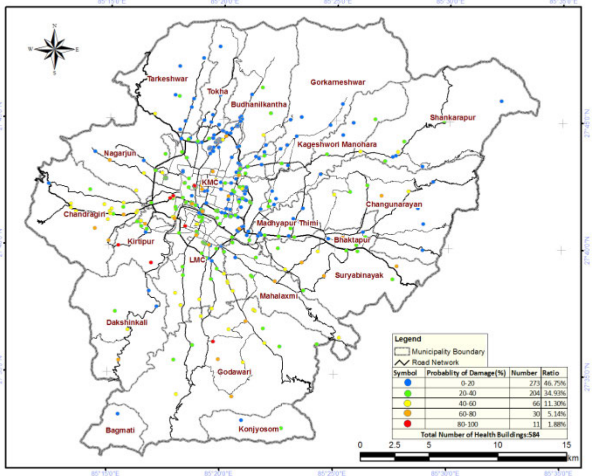
Table 3.4.6 Result of school building damage assessment

Scenario Earthquaake	Damage Level			Total (5,731)	
	DL2	DL3	DL 4 & 5		
WN	568	253	237	1,058	18.5%
CNS-1	916	539	737	2,192	38.2%
CNS-2	1,057	810	1,654	3,521	61.4%
CNS-3	960	875	2,486	4,321	75.4%

Source: JICA Project Team

c) Damage of health facility buildings

Total number of health facility buildings is 584. Building damage distribution for CNS-2 is shown in Figure 3.4.6 and the results for the four scenario ground motions are summarized in Table 3.4.7.



Source: JICA Project Team

Figure 3.4.6 Damage distribution of health facility buildings

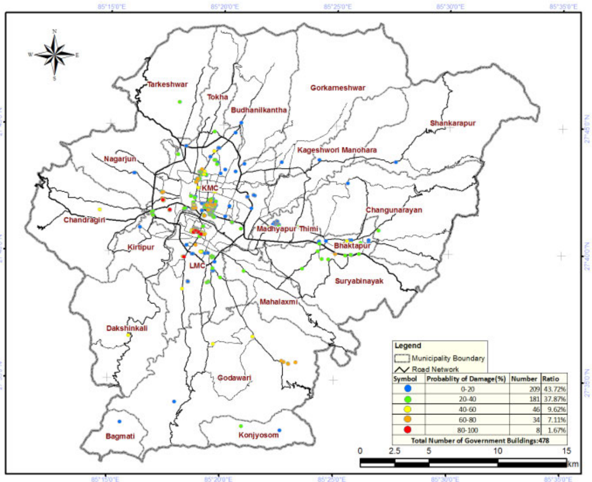
Table 3.4.7 Results of health facility building damage assessment

Scenario Earthquaake	Damage Level			Total (584)	
	DL2	DL3	DL 4 & 5		
WN	51	24	20	95	16.3%
CNS-1	85	55	64	204	34.9%
CNS-2	105	83	153	341	58.4%
CNS-3	97	94	235	426	72.9%

Source: JICA Project Team

d) Damage to governmental buildings

Total number of governmental buildings is 478. Building damage distribution for CNS-2 is shown in Figure 3.4.7 and the results for the four scenario ground motions are summarized in Table 3.4.8.



Source: JICA Project Team

Figure 3.4.7 Damage distribution of governmental buildings

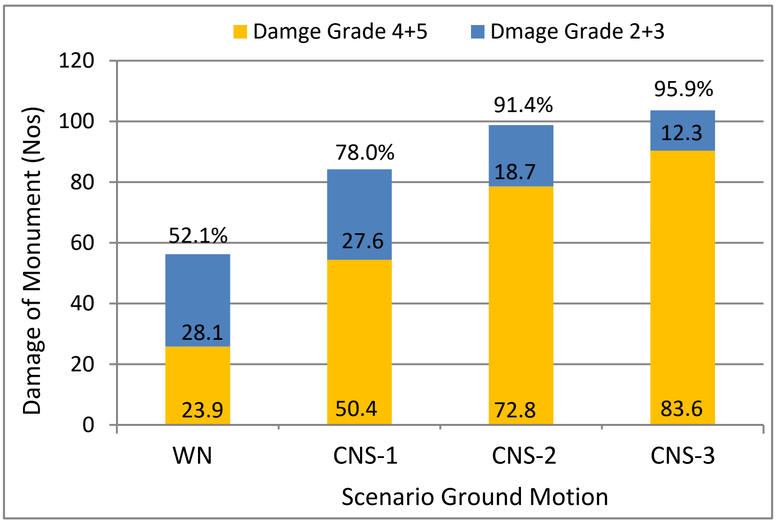
Table 3.4.8 Result of governmental building damage assessment

Scenario Earthquaake	Damage Level			Total (478)	
	DL2	DL3	DL 4 & 5		
WN	44	20	20	84	17.6%
CNS-1	71	44	59	174	36.4%
CNS-2	85	66	126	277	57.9%
CNS-3	80	73	186	339	70.9%

Source: JICA Project Team

e) Damage of historical buildings (monuments)

Damage assessment for historical buildings (monuments) is targeted for the Protected Monument Zone (PMZ) of 3 Durbar Squares in KV (Hanumandhoka, Patan, and Bhaktapur World Heritage Site). The total number of monuments is 108. The estimated monument damage and damage ratio is shown in Figure 3.4.8.



Source: JICA Project Team

Figure 3.4.8 Damage to historical monuments at 3 Durbar Squares

3.4.2 Damage to Transportation Infrastructure

(1) Damage to roads

The purpose of risk assessment on roads is to identify the degree of traffic disturbance induced by an earthquake. Landslide, liquefaction and blockage caused by collapsed building debris were the major reasons of road damage.

a) Damage by slope failure

Roads along the mountainside tend to be blocked or broken down by landslides caused by an earthquake. In this project, the road at high risk of traffic disturbance was identified by overlapping the high slope failure potential areas with road networks in a grid-wise pattern and the length of roads in such overlapped areas is calculated.

b) Damage by liquefaction

Roads located in the liquefaction area may be subject to subsidence or flood and then in turn cause traffic disturbance. In this project, the road length at high risk of traffic disturbance due to liquefaction was evaluated by superposing the high liquefaction potential area with the road network in grid-wise and counting the road length.

Table 3.4.9 shows the road length located in the high potential areas of slope failure and liquefaction. Please note that the roads in high potential slope failure and liquefaction areas have the possibility of damage but this does not necessarily mean all of them will be damaged during an earthquake.

Table 3.4.9 Possible road damage by slope failure and liquefaction

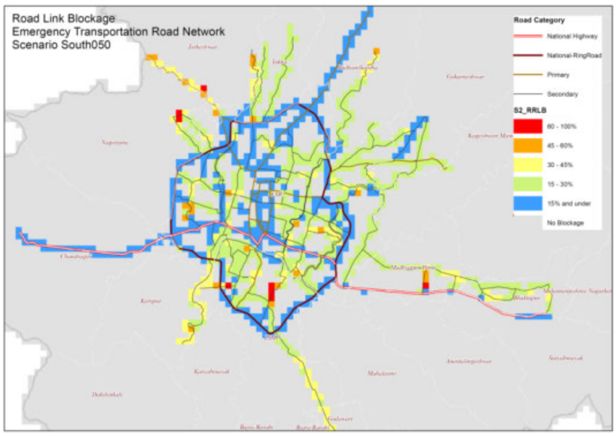
(Upper: Length of damaged road, Lower: Damage ratio)

Category	Damage	Scenario earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Road (Total length 5,811 km)	Length by landslide (km)	0	6.6	98.5	390.6
		0.0%	0.1%	1.7%	6.7%
	Length by liquefaction (km)	0	76.1	274.9	455.3
		0.0%	1.3%	4.7%	7.8%

Source: JICA Project Team

c) Road blockage of narrow streets

There is a risk of road blockage due to the debris of collapsed buildings in relatively narrow streets. Road link blockage rate is calculated as the indicator of the possibility of road blockage. As an example, Figure 3.4.9 shows the result of evaluated road link blockage for the emergency transportation road network (ETRN) proposed by the JICA RRNE project.



Source: JICA Project Team

Figure 3.4.9 Road link blockage rates of the ETRN (CNS-2)

(2) Bridges

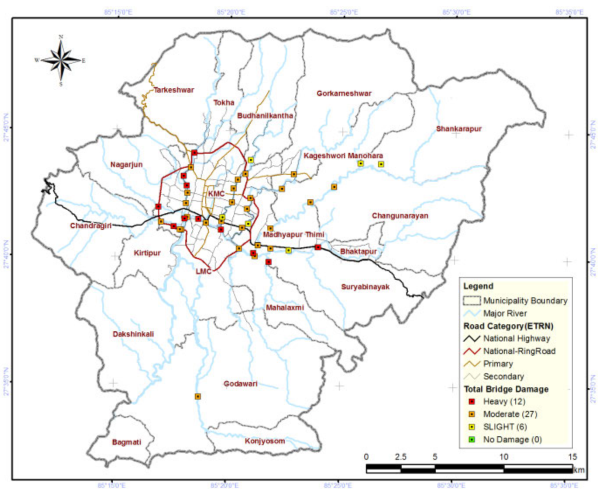
Collapse of piers is the most noticeable failure mode for multiple span bridges. In this project, the possibility of collapse of bridge substructure was evaluated with the ductility factor, which is used as the index for quantitative evaluation of bridge damage. The method, proposed in the Seismic Assessment Tool for Urgent Response and Notification (the technical note of the National Institute for Land and Infrastructure Management No.71), was referred to in order to calculate the factor. According to the value of the ductility factor, the damage of bridges is classified into heavy, moderate or slight damage.

There are a total of 145 bridges and the 45 multi span RC bridges among them are the target of assessment. Since the method requires the data of external shape and detail dimensions of piers, general drawings of targeted bridges were created by on-site survey. The estimated results of the bridge damage estimation are shown Table 3.4.10. The distribution of bridges and their damage degrees are shown in Figure 3.4.10 for CNS-2. Since bridges are critical points in the transportation network, it is expected to have detail diagnosis for each bridge and conduct seismic strengthening as needed.

Table 3.4.10 Bridge damage estimation
(Upper: Number of damaged bridges, Lower: Damage ratio)

Category	Damage	Scenario Earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Bridges (45 bridges assessed)	Heavy	0	1	12	32
		0.0%	2.2%	26.7%	71.1%
	Moderate	2	21	27	11
		4.4%	46.7%	60.0%	24.4%
	Slight	18	17	6	2
		40.0%	37.8%	13.3%	4.4%

Source: JICA Project Team



Source: JICA Project Team

Figure 3.4.10 Distribution of each bridge and its damage degree

3.4.3 Damage to Lifeline Facilities

(1) Damage to water supply pipeline networks

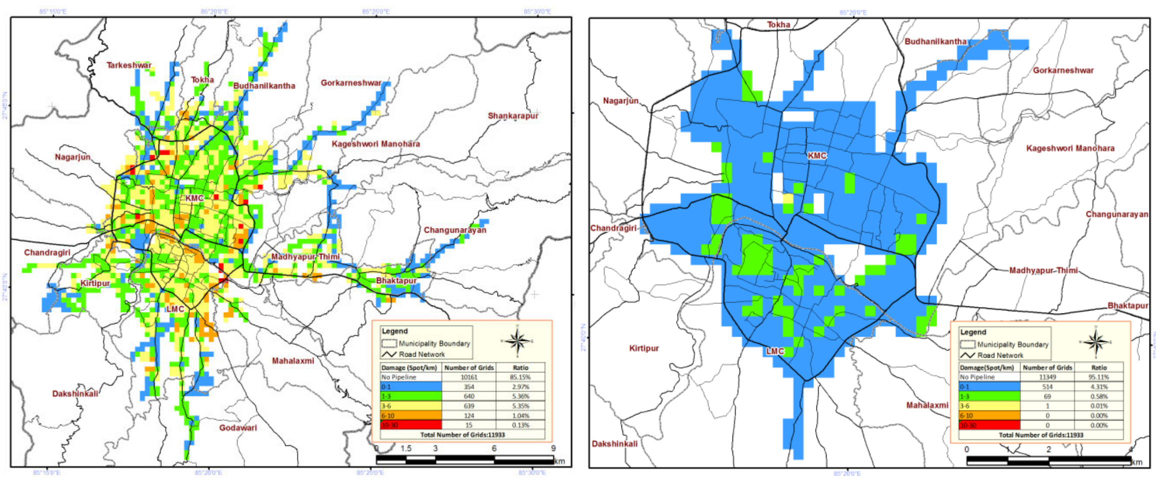
For the damage estimation of water supply pipelines, the standard damage rate is usually used and it is given as the function of the PGV based on the recent findings of earthquake damage of pipelines. Damage to underground pipelines due to an earthquake can be explained in terms of the effect of the deformation of the surface ground, rather than the vibration of the pipe itself. The damage rate of pipeline means the number of damage points per pipeline length and is the function of PGV, ground condition, pipe type, joint type and pipe diameter.

Pipeline damage was estimated for each 250m × 250m grid based on GIS data. Each grid can have pipes of different types. The number of damage points in a grid was firstly calculated by multiplying the damage rate by pipe length for each pipe type and, then, the total number of damage points was obtained by summing up those calculated numbers of all different pipe types. The results are shown in Table 3.4.11. Figure 3.4.11 shows the damage distribution for the current water supply network and the planned network (under construction) due to CNS-2. It is obvious that the planned network is less damaged than that of the existing one under the same ground motion level.

Table 3.4.11 Damage to water supply pipeline
(Upper: Number of damage points, Lower: Damage ratio)

Category	Damage	Scenario earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Water supply (Existing) (Total length 1,167 km)	Damage points	982	1,921	3,496	5,161
	Damage ratio (point/km)	0.84	1.65	3.00	4.42
Water supply (Planned) (Total length 699 km)	Damage points	124	255	460	676
	Damage ratio (point/km)	0.18	0.36	0.66	0.97

Source: JICA Project Team



Source: JICA Project Team

Figure 3.4.11 Damage distribution of water supply pipeline
(CNS-2, left: existing pipeline, right: pipeline under construction)

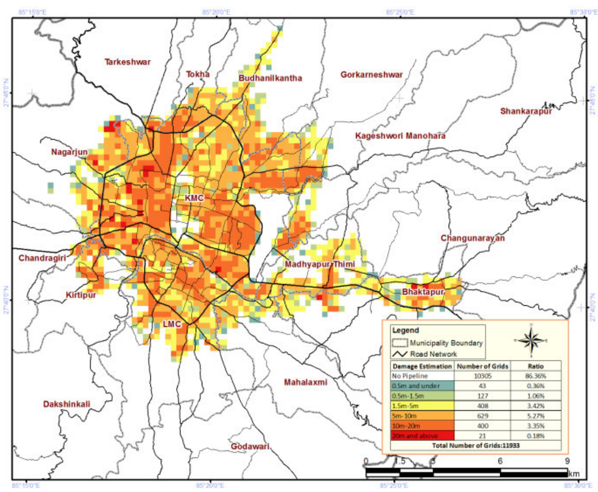
(2) Damage to sewage pipeline networks

It is known that sewage pipelines tend to lift up when surrounding ground liquefies, as the pipeline is almost empty if not in the case of full flow. Since liquefaction is not precisely assessed due to insufficient soil information, the effect of liquefaction to the damage of sewage pipelines is not included. There is no inside pressure in sewers as sewage is gravity flow. Although the appearance of sewage pipelines and water supply pipelines is similar, their damage tendency is completely different. Hence, the damage function for sewage systems is developed from a different concept than that of water supply pipelines. Damage to sewage pipelines is expressed by damage length, rather than damage points like a water supply pipeline. The damage to sewage pipelines is shown in Table 3.4.12. Figure 3.4.12 shows the distribution of damage length of pipelines due to CNS-2.

Table 3.4.12 Damage to sewage pipelines
(Upper: Damage length, Lower: Damage ratio)

Category	Damage	Scenario earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Sewage (Total length 1,192 km)	Damage Length (km)	4.81	8.15	11.94	18.21
		0.4%	0.7%	1.0%	1.5%

Source: JICA Project Team



Source: JICA Project Team

Figure 3.4.12 Damage distribution of sewage pipelines due to CNS-2

(3) Damage to power poles

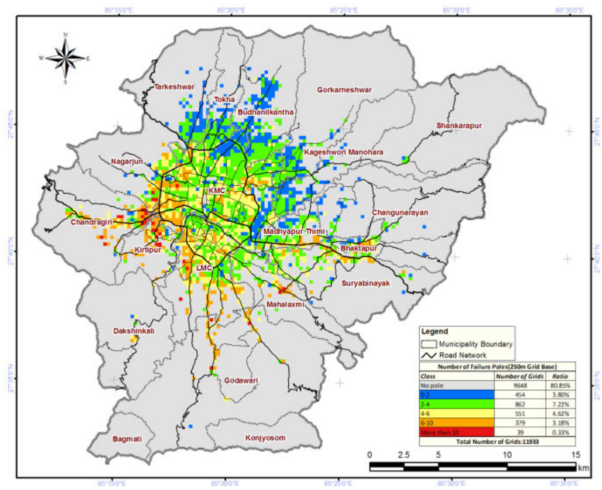
Risk assessment for the whole power system is very complicated since it covers power stations, transmission, substations and distribution. For the purpose of disaster risk management by local government bodies, it is generally limited to the assessment of the distribution system, especially for power poles because it directly leads to the power outage after an earthquake.

The main reason for power pole damage (broken) can be attributed to either ground motion or collapse of buildings in proximity. The broken due to ground motion is usually evaluated by the relationship between the broken rate and intensity of ground motion. It is preferable to have the relationship which reflects the actual situation of Nepal. However, it is difficult to develop the relationship due to the lack of damage data. Therefore, the relationship used in Japan will be applied to the power pole damage estimation in this project. Table 3.4.13 shows the results of power pole broken estimation and Figure 3.4.13 gives the distribution of power poles broken due to CNS-2. It should be pointed out that there is no power pole data existing and the damage assessment is conducted based on the estimated power pole inventory, which is derived from the road network and sample surveys.

Table 3.4.13 Damage to power poles
(Upper: Number of utility poles broken, Lower: Damage ratio)

Category	Damage	Scenario Earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Power distribution (Total pole 190,851)	Pole broken	1,327	3,991	9,156	13,992
		0.7%	2.1%	4.8%	7.3%

Source: JICA Project Team



Source: JICA Project Team

Figure 3.4.13 Distribution of power pole damage (CNS-2)

(4) Damage to mobile telecommunication BTS

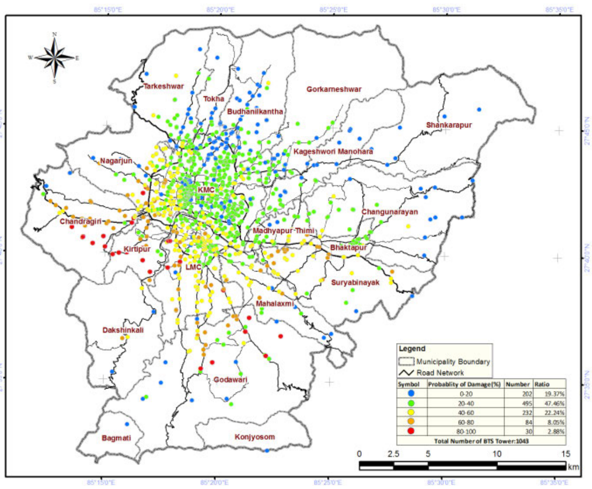
Currently, about 94% of telephone subscriber lines in Nepal are mobile phone contracts. Therefore, the concerning risk of communication interference would be the network damage of mobile phones, which can be represented by the damage of base transceiver stations (BTS). There are 1043 BTS in KV and the majority of them are roof-top installed. A vulnerability function for roof-top BTS was developed assuming that the function of BTS is retained only when neither building nor BTS itself is subject to damage. The estimated BTS damage is shown in Table 3.4.14 and Figure 3.4.14 shows the distribution of damage due to

CNS-2. Among all of roof-top BTS, approximately 77% of them are installed on non-engineered RC buildings, which becomes the dominant factor of damage for roof-top mounted BTS.

Table 3.4.14 Damage to mobile telecommunication BTS
(Upper: Number of BTS damaged, Lower: Damage ratio)

Category	Damage	Scenario Earthquake Ground Motion			
		WN	CNS-1	CNS-2	CNS-3
Mobile BTS tower (Total tower 1,043)	Tower damage	43	143	372	601
		4.1%	13.7%	35.7%	57.6%

Source: JICA Project Team



Source: JICA Project Team

Figure 3.4.14 Damage distribution of BTS (CNS-2)

3.4.4 Human Casualties

Human casualties are recognized to be mostly attributed to building damage from the past earthquake experience. The approach for death estimation used by the 2002 JICA project was a statistical relationship between the number of deaths and number of damaged buildings. In this project, considering the requirement for different earthquake occurrence scenes and data availability, the deaths are estimated from building damage, population inside the buildings when earthquake occurs and the death rate. The formula is shown below.

Number of deaths = Death rate * (Number of buildings damaged
* Population per damaged building
* Ratio of persons inside buildings)

The number of injured people was estimated from the relationship between the number of deaths and the number of injured. It is the same as that used by the JICA 2002 project.

Number of injured = Injured rate * Number of deaths

The number of evacuees, who need temporary housing after an earthquake, was considered to be the people whose residence suffered major damage of EMS damage level 3, 4 or 5 but not including fatalities. Buildings with damage level 3, 4 and 5 are considered not safe for immediate occupation after an earthquake and it will take some time to repair them.

Number of evacuees = Population in buildings with damage level 3, 4 or 5
- Number of deaths

Building damage and the number of dead and injured caused by the Gorkha Earthquake were used for the estimation of the death rate and the injured rate. It was observed from the Gorkha Earthquake that human casualties may have different features for different structure types (masonry or RC) and damage levels (damage level 4 or 5). In this regard, the death rate was estimated for masonry, RC structures and their damage level is 4 and 5, respectively. As the result, the death rate for masonry buildings with damage level 4 is 0.0101, damage level 5 is 0.0160 and that for RC buildings with damage level 4 is 0.0180 and damage level 5 is 0.0284. The difference in the death rate between damage level 4 and 5 could be considered that level 5 represents more severe damage and including collapse. During the Gorkha earthquake, it was found that some non-engineered RC buildings crashed like a pancake at the ground floor, which leaves little possibility of survival for the people trapped there. This could be one reason that the death rate of RC buildings is higher than that of masonry buildings. The estimated death rate is about average comparing with those observed on the other earthquakes that have occurred around the world.

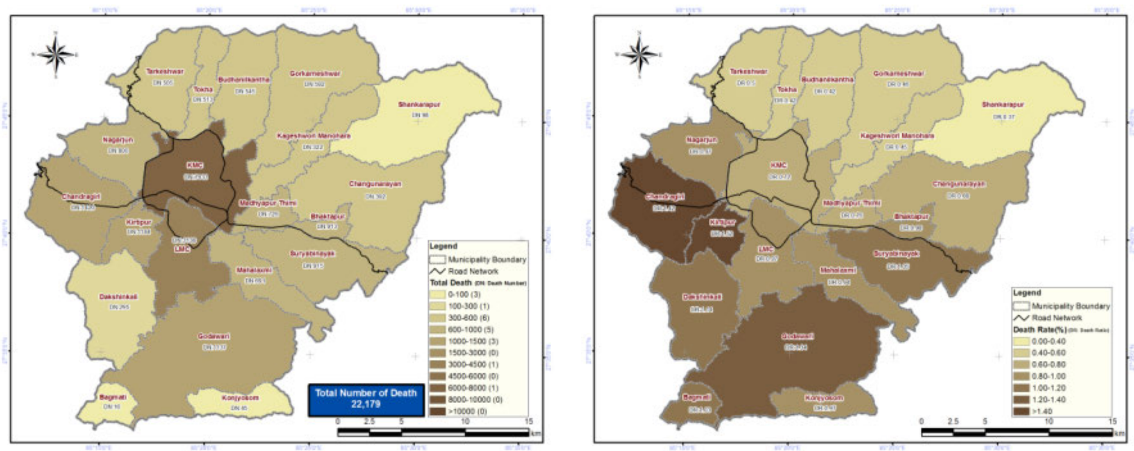
1) Human casualties due to general building damage

Human casualties caused by general building damage were estimated for four scenario ground motions and three occurrence scenes. The results are summarized in Table 3.4.15. The distribution of the number of deaths and ratio of deaths (number of death / population) for CNS-2 and the scene of night are shown in Figure 3.4.15. It is observed that the deaths mostly happened in the central area, within or around the ring road, because of its high building and population density. The southern part of KV shows a relative high death ratio since it is close to the earthquake fault, having stronger ground motion and higher building damage ratio.

Table 3.4.15 Results of human casualty estimation

Human Casualties	Scenario Ground Motion	Earthquake Occurrence Scene					
		Weekend (18:00)		Weekday (12:00)		Night	
		Number	Ratio	Number	Ratio	Number	Ratio
Deaths	WN	2,123	0.1%	2,784	0.1%	3,034	0.1%
	CNS-1	6,393	0.2%	8,282	0.3%	9,133	0.3%
	CNS-2	15,526	0.6%	19,959	0.7%	22,179	0.8%
	CNS-3	25,008	0.9%	31,956	1.1%	35,726	1.3%
Injured	WN	8,316	0.3%	10,905	0.4%	11,880	0.4%
	CNS-1	25,036	0.9%	32,435	1.2%	35,766	1.3%
	CNS-2	60,803	2.2%	78,168	2.8%	86,861	3.1%
	CNS-3	97,940	3.5%	125,152	4.5%	139,914	5.0%
Evacuees	WN	279,942	10.0%	285,850	10.3%	279,031	10.0%
	CNS-1	645,483	23.2%	652,798	23.4%	642,743	23.1%
	CNS-2	1,202,734	43.2%	1,206,530	43.3%	1,196,080	42.9%
	CNS-3	1,624,032	58.3%	1,619,792	58.1%	1,613,314	57.9%

Note: Total population: 2,786,929, Source: JICA Project Team



Source: JICA Project Team

Figure 3.4.15 Distribution of number (left) and ratio (right) of deaths

2) Deaths due to school building damage

There are a total of 2,115 schools in KV, including public and private schools, with an estimated 851,121 students. The deaths of students due to school building damage were estimated under the assumption, for the worst case, that all of the students were inside the buildings when the earthquake happens. The results are 444 deaths for the scenario ground motion of WN, 1,545 for CNS-1, 4,002 for CNS-2 and 6,555 for CNS-3.

3) Human casualties estimated for 2030

Human casualties were estimated for 2030 based on the six cases of building damage. The results are given in Table 3.4.16. The population of 2030 is estimated as 3,805,926, about 1.37 times of that of 2016 (2,786,929). In the case of Case-0, which has the exact same structure type distribution as 2016, the deaths of 2030 will increase around 1.37 times, almost corresponding to the same rate of population increase. For the other cases, the human casualty rate varies with different structure type distribution. Since human casualties depend highly on building damage, the strengthening of the seismic performance of not only new buildings but also existing buildings is a critical issue to reduce human casualties in the future.

Table 3.4.16 Human casualties estimated for 2030

Scenario Ground Motion	2016	Building Structure Type Distribution of 2030					
		Case-0	Case-1	Case-2	Case-3	Case-4	Case-5
WN	3,034	4,121	3,434	1,712	1,438	2,052	1,476
CNS-1	9,133	12,508	11,017	8,135	6,733	7,887	6,524
CNS-2	22,179	30,583	27,930	24,356	20,526	23,086	20,842
CNS-3	35,726	49,381	46,017	42,526	36,715	41,146	38,733

Source: JICA Project Team

3.4.5 Economic Impact Assessment

Economic loss due to earthquakes is composed of direct loss, accounting for physical damage to property and indirect loss, i.e. reduction of GDP brought about by retarded production activities due to an earthquake. The target for calculating direct loss is the damage to buildings and infrastructure and lifeline facilities. Restoration cost of building, infrastructure and lifelines is assumed to be the amount of direct loss. Quantitative evaluation of indirect loss is difficult because the causal correlation between damage and loss cannot be evaluated definitely. Thus, estimation of indirect loss was principally conducted by qualitative evaluation. However, as the tourism sector is an important source of foreign exchange earnings in Nepal, the decrease of revenue in the tourism sector due to the retarded production activities from earthquake damage was evaluated quantitatively in this project.

Direct loss due to building damage is estimated by multiplying the number of damaged buildings of each structure type by their respective restoration cost. The loss was calculated for each municipality and each scenario ground motion, shown in Table 3.4.17. Table 3.4.18 shows the estimated loss amounts of schools, health facilities, government buildings and historical architecture. Table 3.4.19 shows the losses due to road, bridge, water supply, sewage, power distribution and mobile BTS damage.

Table 3.4.17 Direct loss due to building damage

(Unit: Million NPR)

District	Municipality and VDC	CNS-1	CNS-2	CNS-3	WN
BHAKTAPUR	Bhaktapur	11,570	22,392	31,529	4,536
	Changunarayan	11,128	24,543	37,062	3,726
	Madhyapur Thimi	11,378	23,877	34,396	3,426
	Suryabinayak	15,769	32,751	47,208	4,260
	Total (BHAKTAPUR)	49,845	103,563	150,195	15,947
KATHMANDU	Budhanilkantha	7,490	21,198	36,607	4,279
	Chandragiri	25,664	48,190	64,429	8,275
	Dakshinkali	6,016	11,976	16,947	1,583
	Gokarneshwar	7,981	20,586	34,319	4,117
	Kageshwori Manohara	6,045	15,452	25,248	2,622
	Kathmandu	118,000	244,421	352,694	49,390
	Kirtipur	18,771	33,123	42,936	5,833
	Nagarjuna	14,650	31,653	46,616	5,959
	Shankharapur	1,441	3,931	7,090	939
	Tarkeshwar	6,875	17,998	30,095	4,521
	Tokha	5,911	15,983	27,094	3,396
	Total（KATHMANDU）	218,844	464,511	684,075	90,914
LALITPUR	Bagmati Rural Municipality	272	574	860	67
	Godawari	27,257	51,396	69,725	6,227
	Lalitpur Metropolitan	57,355	107,349	145,934	15,861
	Mahalaxmi	16,670	32,493	45,053	3,837
	Konjyosom Rural Municipality	761	1,649	2,511	147
	Total （LALITPUR）	102,314	193,460	264,083	26,138
	Grand Total	371,003	761,534	1,098,353	132,999

Source: JICA Project Team

Table 3.4.18 Direct loss of school, health and government buildings and historical architecture

(Unit：Million NPR)

Scenario ground motion	Schools	Health Facilities	Government Buildings	Historical Architecture
WN	20,462	22,534	2,444	1,321
CNS-1	51,231	68,588	8,669	1,925
CNS-2	98,171	165,683	16,514	2,267
CNS-3	134,932	232,782	22,708	2,377

Source: JICA Project Team

Table 3.4.19 Director loss of infrastructure and lifelines

(Unit：Million NPR)

Scenario ground motion	Roads	Bridges	Water supply	Sewage	Power distribution	Mobile BTS	Total
WN	0	377	36	76	19	82	590
	0.0%	63.9%	6.1%	12.9%	3.2%	13.9%	100.0%
CNS-1	471	898	71	135	56	272	1,903
	24.8%	47.2%	3.7%	7.1%	2.9%	14.3%	100.0%
CNS-2	1,620	1,359	129	200	129	707	4,144
	39.1%	32.8%	3.1%	4.8%	3.1%	17.1%	100.0%
CNS-3	2,878	1,914	191	290	197	1,142	6,612
	43.5%	28.9%	2.9%	4.4%	3.0%	17.3%	100.0%

Source: JICA Project Team

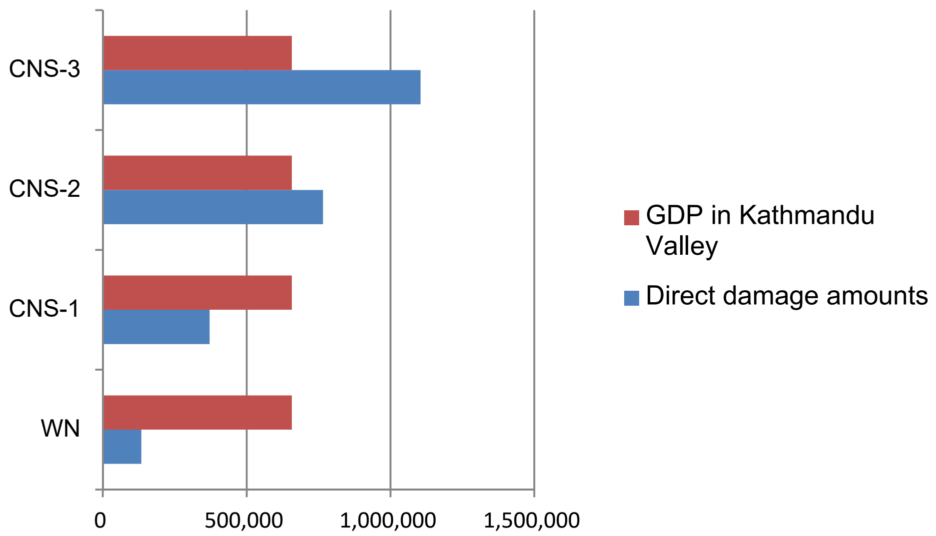
Table 3.4.20 summarizes the direct loss of each scenario ground motion and Figure 3.4.16 shows the comparison of direct loss with GDP of Kathmandu Valley. Current GDP in Nepal is approximately 2,120 billion NPR and GDP in Kathmandu Valley is 657,200 million NPR, accounting for 31% of national GDP. In case of CNS-2 and CNS-3, direct loss exceeds the current GDP of Kathmandu Valley.

Table 3.4.20 Total direct loss of each scenario ground motion

(Unit：Million NPR)

Scenario ground motion	Buildings	Infrastructure	Total
WN	132,999	590	133,589
	99.4%	0.6%	100.0%
CNS-1	371,003	1,903	371,275
	99.5%	0.5%	100.0%
CNS-2	761,531	4,144	765,675
	99.5%	0.5%	100.0%
CNS-3	1,098,353	6,612	1,104,965
	99.6%	0.4%	100.0%

Source: JICA Project Team



Source: JICA Project Team made this based on the data of Nepal Rastra Bank

Figure 3.4.16 Comparison of direct loss and GDP of Kathmandu Valley

Damage to historical architecture due to an earthquake and the effect of psychological factors after an earthquake will cause the decline of tourists and then lead to indirect loss. A decline of tourists will cause both the decrease of tourism income and loss of job opportunities in the tourism industry. A decrease of tourists from abroad will result in the decrease of foreign exchange earnings. As a consequence of the Gorkha Earthquake, 790,000 tourists of the previous year (2014) was decreased to 550,000, an approximately 30% decrease. The impact on the tourism sector of the future scenario earthquake is estimated based on this fact. In the case of the WN scenario, which is the smallest one, the number of tourists was estimated to decrease 27% within one year from the occurrence of an earthquake. In the case of scenario CNS-3, the strongest, the number of tourists was estimated to decrease 40%.

According to the data of the Ministry of Culture & Civil Aviation, the number of employees currently in the tourism sector is 138,148 and the current number of tourists is about 800,000 people a year, which means that one employee is responsible for about six tourists. Employees of the tourism sector have been estimated based on the decline in tourists for each scenario given in Table 3.4.21.

Table 3.4.21 Employees in tourism sector before and after earthquake

Scenario ground motion	Number of employee		Number of jobs lost	Rate of job loss (%)
	Before earthquake	After earthquake		
WN	138,148	96,718	41,430	30.0%
CNS-1	138,148	92,573	45,575	33.0%
CNS-2	138,148	89,810	48,338	35.0%
CNS-3	138,148	82,902	55,246	40.0%

Source：JICA Project Team estimated based on the stats of Ministry of Culture & Civil Aviation

The current ratio of foreign exchange earnings by the tourism sector is 470 million USD, around 4.7% of the total amount of foreign exchange earnings. After an earth quake, foreign exchange earnings are estimated to decrease, as shown in Table 3.4.22, due to the decrease of tourists and the decrease of the expenditure of tourists. The ratio of decrease is estimated at about 43% to 51%, showing a significant impact from an earthquake.

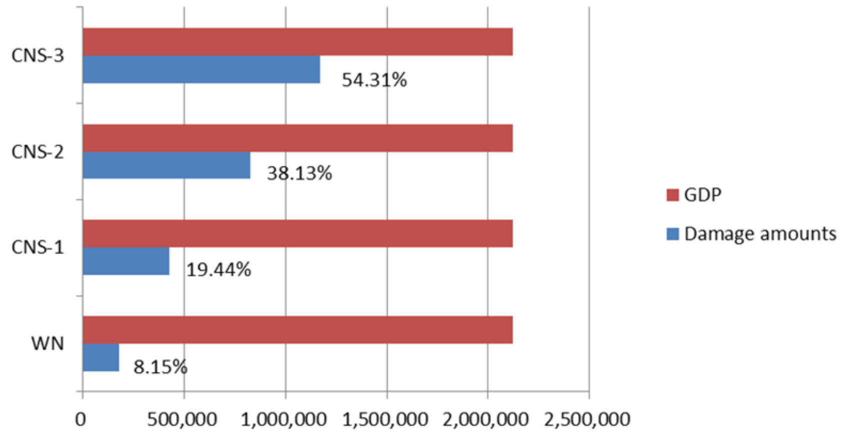
Table 3.4.22 Foreign exchange earnings before and after earthquake

(Unit：Million $)

Scenario ground motion	Before earthquake	After earthquake	Decreased amounts	Rate of decrease
WN	470	267.9	202.1	43.0%
CNS-1	470	258.5	211.5	45.0%
CNS-2	470	249.1	220.9	47.0%
CNS-3	470	230.3	239.7	51.0%

Source：JICA Project Team estimated based on the stats of Ministry of Culture & Civil Aviation

Figure 3.4.17 shows the total impact due to direct loss and indirect loss (tourism sector only). In the case of CNS-3, aggregated amounts of direct loss and indirect loss count for over 50% of the GDP of Nepal. Please note that the impact could be even more if the indirect losses of other sectors are considered.



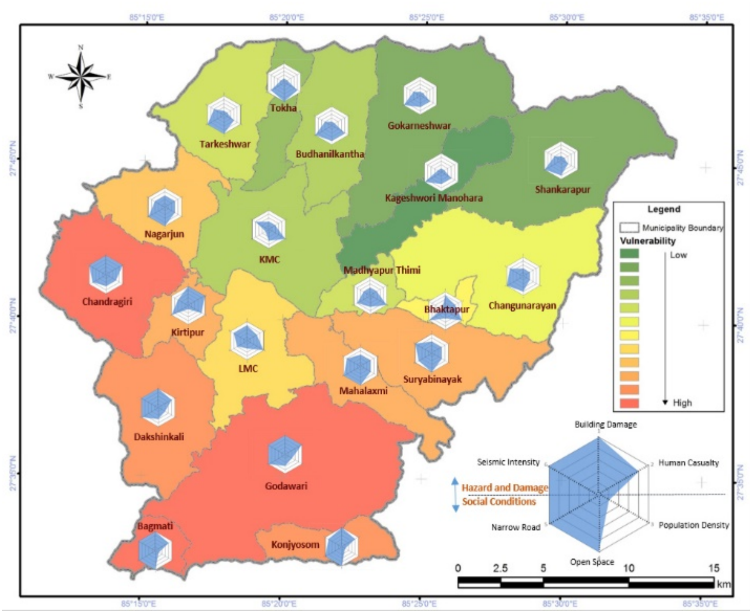
Source: JICA Project Team

Figure 3.4.17 Comparison of earthquake impact with GDP

3.5 Comparative Vulnerability Analysis of KV

Comparative vulnerability analyses among municipalities inside KV is performed based on the seismic hazard and risk assessment results as well as social conditions, which provides the information to understand the relative status of each municipality in terms of seismic hazard and its social condition. The indicators used for seismic hazard and risk are seismic intensity (MMI), building damage ratio and human casualty ratio, while the indicators for social conditions are population density, open space per person and narrow road ratio.

Comparative vulnerability analyses were carried out by ranking the indicators with a score from one to five. The score is given for each indicator according to their value range and is assigned by equally dividing the value range in normal or log scale, depending on the property of the indicator. The analysis is applied to the twenty municipalities inside KV based on the seismic hazard and risk assessment results of scenario ground motion of CNS-1. The score of each municipality and vulnerability distribution of KV is shown in Figure 3.5.1. From the figure, it can be observed that Bagmati, Godawari and Chandragiri are comparably more vulnerable. A possible reason for the higher vulnerability may be their proximity to the source area of a scenario earthquake. It should be pointed out that the vulnerability analysis is based on the Central Nepal South Scenario Earthquake, so that it is scenario earthquake specific and it may change for the scenario earthquake located in another area.



Source: JICA Project Team

Figure 3.5.1 Distribution of vulnerability of KV

3.6 Recommendations for Future Update of Risk Assessment

Seismic risk assessment was carried out based on the limited data of Nepal. Site survey and estimation were made to supplement the insufficiency. Collected data together with that obtained through surveys conducted by this project were compiled into a GIS database and shared with the Nepalese counterpart. The results of risk assessment reflected the seismicity and ground motion characteristics of KV after the Gorkha Earthquake, but could not incorporate the latest findings because the project started shortly after the quake. On the other hand, urbanization is progressing and the amount of buildings, infrastructure and lifeline facilities are increasing. The update of risk assessment may be needed after the building and infrastructure inventories are developed and/or the social situation is significantly changed. For the purpose of future update of risk assessment, some recommendations are given below.

(1) Overall Recommendations on Risk Assessment

- Seismic risk results depend considerably on the seismic hazard results. It is observed that the recorded ground motion of the Gorkha Earthquake in KV was much smaller than that estimated from attenuation. It is important to investigate and reveal the reason in order to have the hazard analysis more reliable.
- Building inventory was limited to only four municipalities out of the total of 22 municipalities (as at the time of the risk assessment). The building inventory used for risk assessment for the other municipalities is not a real one, but estimated. Since the results of the building damage estimation is directly affected by data precision, the

creation of a complete building inventory is essential.

- Likewise, the information regarding infrastructure and lifelines, necessary for risk assessment, is either not complete or does not exist. In order to supplement the insufficient information, site surveys were conducted for bridges and rooftop mobile Base Transceiver Stations (BTS). Additionally, the number and distribution of power poles was estimated. It is necessary to continuously develop, maintain and update the infrastructure and lifeline data for the future risk assessment.
- The creation and update of building, infrastructure and lifeline inventories is not only necessary for future updates of risk assessment, but also important for maintenance and retrofitting.
- The project of Science and Technology Research Partnership for Sustainable Development (SATREPS) is under implementation, aiming at updating the seismic hazard of KV with more detailed information of seismicity and ground condition. It is expected the risk assessment could be updated when the seismic hazard is updated.
- Risk assessment of this project is limited to the KV area only. The risk assessment for other cities and areas, where there is a high seismic risk, is considered necessary and urgent.

(2) Recommendations for Risk Assessment of Individual Items

a) Buildings

The lack of building inventories, especially public building inventories including structural type and GIS data, should be improved. NBC 105 was enforced in 2003, where the importance factor of 1.5 is stipulated for essential public buildings. If this factor had been applied to the engineered RC public buildings, the damage would be reduced by approximately 70%. In the future reparation of building inventories, the inclusion of such kinds of information is requested.

Building damage function is prepared incorporating damage data of the 2015 Gorkha Earthquake. Two damage functions for the centre area and perimeter area of the valley are provided. Accelerations observed at four locations are utilized for the purpose, but strong motion at the perimeter is not available. It is desirable that strong motion observation at the perimeter area should be strengthened. The damage function should be updated when more information on building damage and ground shaking intensity are available.

b) Roads

Seismic risk to roads is a comprehensive result of road collapse, liquefaction, collapse of bridges, and blockade of narrow streets by surrounding buildings. It is necessary for the road administrator to collectively manage the data to examine the possibility of occurrence of each individual phenomenon with integral management. It is important to make a ledger inventory at first and then decide the priority for action. The ledger should be maintained in a unified format.

c) Bridges

Detail as built drawings are necessary for accurately evaluating the seismic resistance capacity of bridges. Unfortunately, only a few bridges in KV have such kinds of drawings. The results of bridge damage assessment should be considered as preliminary because the information on reinforcing bar layout and foundation, which are indispensable for evaluation, are not available. Another critical issue for the evaluation is the applied design standard and it also is not clear. The DoR bridge database lacks the important information which is necessary for risk assessment. The creation of a complete bridge ledger is necessary and urgent.

d) Water Supply

The regression equation applied in the risk assessment of this project was derived from the result of a careful water leakage survey in Japan. It is desirable to implement verification by thorough investigation of water leakage caused by future earthquakes. The technology for post-earthquake water leakage surveys is needed.

e) Sewage System

The sewage systems in Kathmandu Valley do not cover the entire area currently. The sewage systems were built and managed by different entities. An integrated data set does not exist and the improvement of the situation is considered to be needed. There was no sewage damage reported from the Gorkha Earthquake. It is supposed some parts of the sewage pipeline might be damaged. The detail damage survey after an earthquake is important for the purpose of future damage assessment.

f) Electricity

Power poles in KV are quite different from Japanese cylindrical cross section RC poles. The pole is commonly a pre-stressed RC pole with rectangular cross section. In this case, the strength of the long axis (the strength against the horizontal force in the direction in which the electric wire is hung in tension) is quite weak compared to another direction. Due to the weak direction, there can be more damage than the damages observed in Japan from the RC cylindrical pole. For the purpose of future update of risk assessment, it is desirable to carry out research and investigation on the seismic strength of the unique poles of KV.

g) Telecommunication

Most of the mobile BTS (towers) are installed on the top of buildings in KV. Therefore, it is mandatory that the buildings should be strong enough to support BTS to make it functional during or after an earthquake. Unfortunately, it is estimated that many buildings would suffer damage from the scenario earthquake. It is recommended to make a seismic diagnosis for these buildings and retrofitting as necessary.

h) Human Casualties

The basic information regarding buildings and population is important for human casualty estimation. There are a large number of people who live in KV but their registration is not in KV. Since these types of people are not included in the census survey data, it is recognized there is a big discrepancy between the statistical population and real residence population. In this regard, the development of a real residence population database is important for the human casualty estimation.

i) Economic Impact

Loss due to physical damage of property (direct loss) was only assessed due to the lack of proper data for indirect loss estimation in this risk assessment. In the case of infrastructure damage, for example, indirect loss might be much larger than direct loss. It should be acknowledged that the result of economic loss assessed here may be smaller than the actual loss. It is recommended to arrange the socioeconomic data, in particular, Input-Output tables to make indirect loss estimations in the future.

Chapter 4 Pilot Activities

Pilot activities were carried out in the three pilot municipalities: Lalitpur Metropolitan City, Bhaktapur Municipality and Budhanilkantha Municipality which were selected from different districts with the regional characteristics and damage conditions due to the Gorkha Earthquake, etc., mainly based on the results of the hazard and risk assessment. The purposes of pilot activities are not only the implementation of the activities themselves such as the formulation of plans and capacity building of the pilot municipalities, but also to develop the model of systematic local disaster risk reduction and management framework with activities based on the disaster risk assessment in Nepal. In this sense, it was also aiming to consider the measures for nationwide dissemination to all the local governments in Nepal by summarizing and examining the outputs and issues collected through the activities. In the selected pilot municipalities, in the first phase, the activities for emergency response and recovery/reconstruction, which were added to the project considering changes of the situation due to the Gorkha Earthquake, were implemented such as BBB Recovery and Reconstruction Plan (4,1), Emergency Response Chronicle Survey of the Gorkha Earthquake in 2015 and DRR Awareness Activities. Then in the second phase, toward disaster risk reduction and effective emergency response in the future, activities included: formulation of Standard Operation Procedure (SOP) (4.2), formulation of Local Disaster and Climate Resilience Plan (LDCRP) (4.4), Community Disaster Risk Reduction and Management (CBDRRM) Activities (4.5) were implemented. For LDCRP, the Technical Guidelines for Formulation of LDCRP (4.3) were developed for all local levels of Nepal. Finally, through these pilot activities, Recommendations for Future Disaster Risk Reduction and Management Activities in the Municipal Level and Nationwide Dissemination of Pilot Activities (4.6) were considered.

Pilot Municipalities

For the implementation of the pilot activities, three pilot municipalities were selected for the project. The confirmed pilot municipalities were Lalitpur Sub-metropolitan City, Bhaktapur Municipality, and Budhanilkantha Municipality. The criteria to choose the pilot municipalities were differences of regional character and the damage situations, and they were selected from three different districts in Kathmandu Valley. The three pilot municipalities were agreed upon during the 1st JCC.

At the beginning of project, Kathmandu Valley consisted of 21 municipalities in three districts. However, while implementing the project activities, a new constitution was enacted and to fulfil the requirements of the constitution, all old municipalities and VDCs were restructured in 2017. Similarly, Kathmandu Valley was also restructured and it now consists of three districts with twenty municipalities including a part of two rural municipalities as shown in Figure 4.1. Especially for the pilot municipalities which were confirmed in the 1st JCC, Lalitpur Sub-Metropolitan City was promoted to be a Metropolitan City by incorporation with parts of former Karyabinayak Municipality as well as reorganized ward boundaries. The boundary of Bhaktapur Municipality and Budhanilkantha Municipality is same as before, however, the ward boundaries were restructured. Accordingly, the pilot activities were implemented for pilot municipalities as follows.

<u>Pilot Activities added after the Gorkha Earthquake:</u>

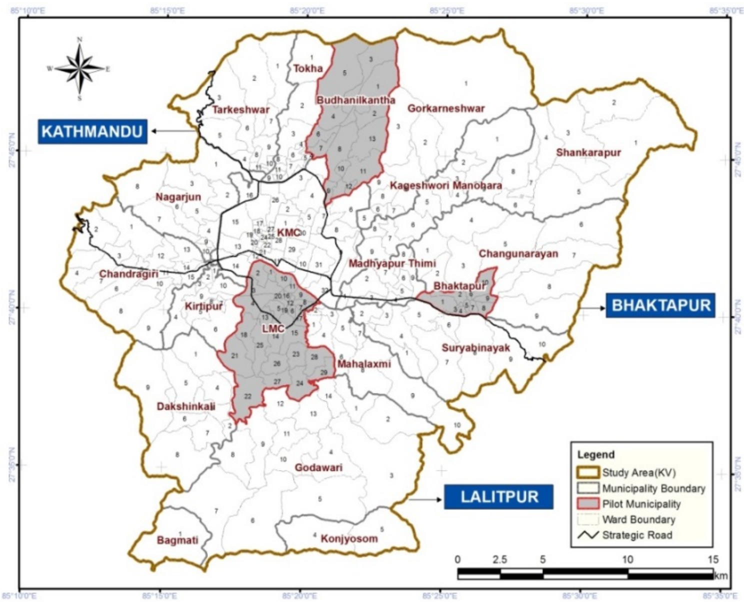
Old pilot municipalities (Lalitpur Sub-Metropolitan City, Bhaktapur Municipality, Budhanilkantha Municipality) with old ward boundary

- 4.1 BBB Recovery and Reconstruction Plan
- Emergency Response Chronicle Survey of the Gorkha Earthquake in 2015 and DRR Awareness Activities (for details refer to the Volume 4.)

<u>Pilot Activities of original component:</u>

New pilot municipalities (Lalitpur Metropolitan City, Bhaktapur Municipality, Budhanilkantha Municipality) with new ward boundaries

- 4.2 Standard Operation Procedure (SOP)
- 4.4 Local Disaster and Climate Resilience Plan (Including 4.3 Technical Guideline for Formulation of Local Disaster and Climate Resilience Plan)
- 4.5 CBDRRM Activities



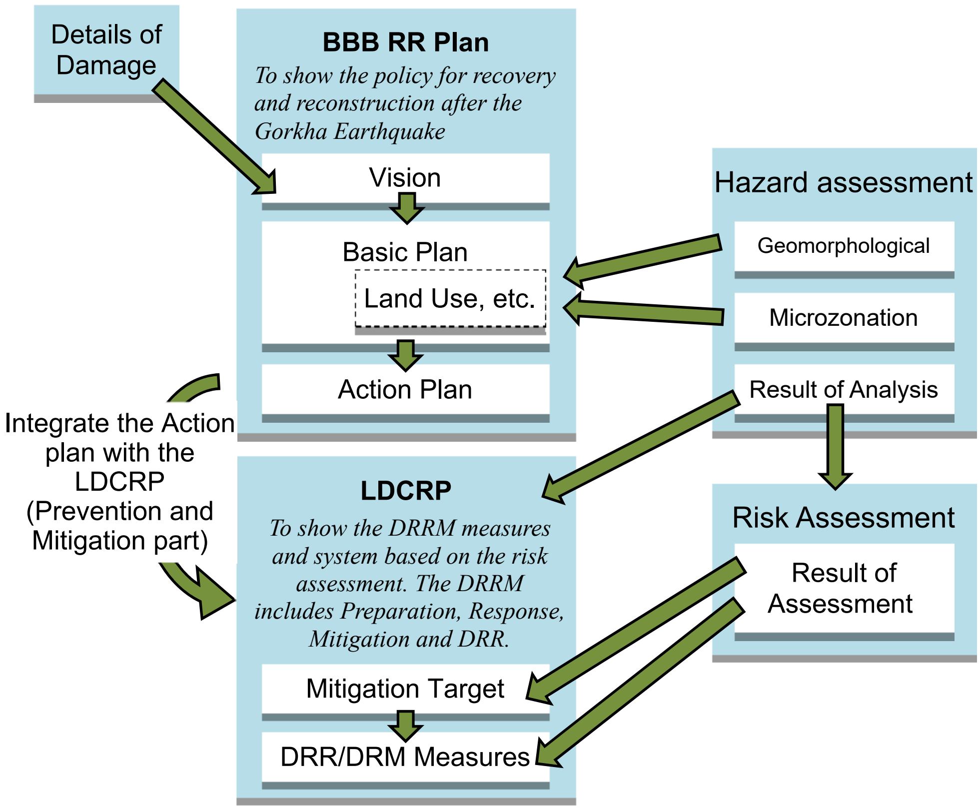
Source: JICA Project Team

Figure 4.1 Administrative boundary of municipalities in Kathmandu Valley at present and Locations of the pilot municipalities

4.1 BBB Recovery and Reconstruction Plan for Pilot Municipalities

4.1.1 Outline of BBB Recovery and Reconstruction Plan for Pilot Municipalities

The JICA Project Team formulated the BBB Recovery and Reconstruction (RR) Plan for quick revitalization after the Gorkha Earthquake in the three pilot municipalities. The plans helped to clarify the reconstruction policies and to act as the base for the reconstruction projects. Accordingly, it was required to be developed preferentially in the Project. In the formulation of the plan, based on the concept of Build Back Better which was proposed in the Sendai Framework for Disaster Risk Reduction, to take advantage of the recovery and reconstruction experience of Japan taking into account the actual situation of Nepal, the vision of recovery and reconstruction, the basic policy and action plan were included. In addition, the plan was configured to be integrated with the LDCRP which has been formulated by the project based on the result of the risk assessment.



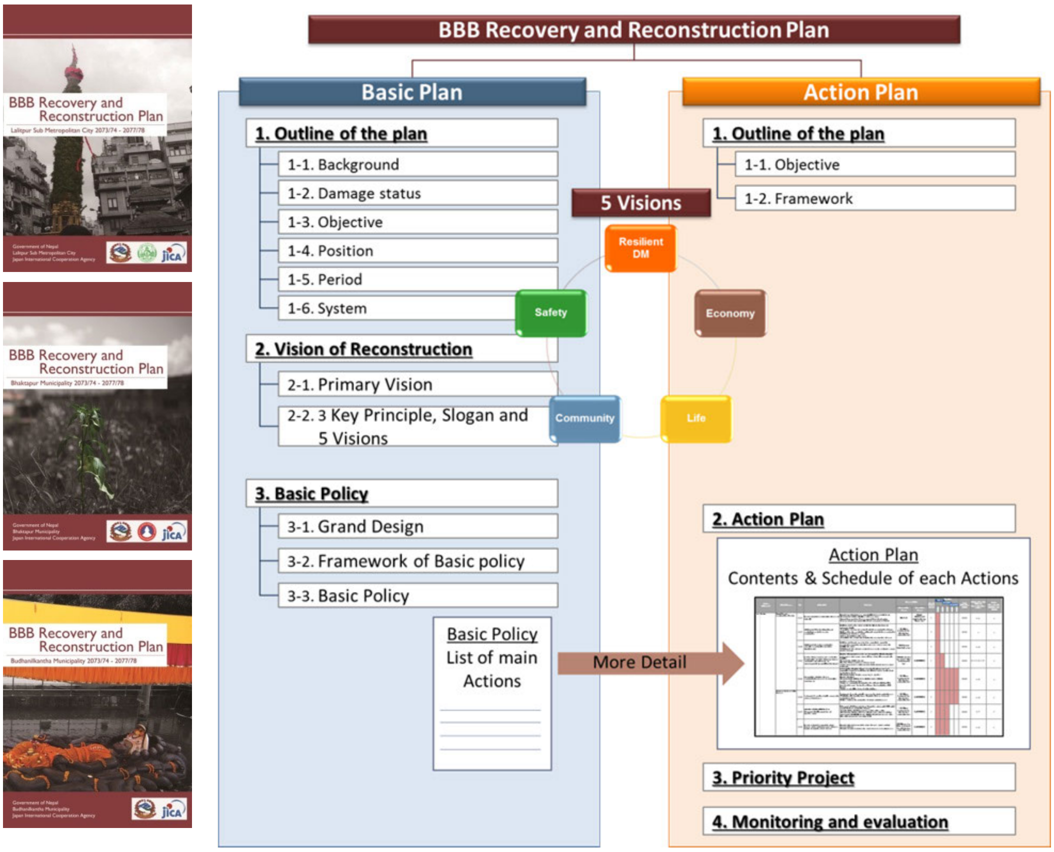
Source: JICA Project Team

Figure 4.1.1 Relationship among BBB RR Plan, LDCRP, and Hazard and Risk Assessment

4.1.2 Consideration of Structure of the BBB RR Plan

(1) Structure of the BBB RR Plan

The BBB RR Plan was planned to consist of two plans, one is the basic plan in which is indicated the basic policies, and another one is the action plan for the implementation in detail. The basic plan shows the entire image of the reconstruction such as vision and grand design based on the damage status and direction for the future. The action plan includes the responsible organizations in the municipality in consideration given to the coordination with national or district organizations in order to achieve the policies. In addition, in the action plan, by considering budget, importance, urgency and time needed, several actions were selected out of all the actions as the priority project. The structure of the plan is shown as follows.



Source: JICA Project Team

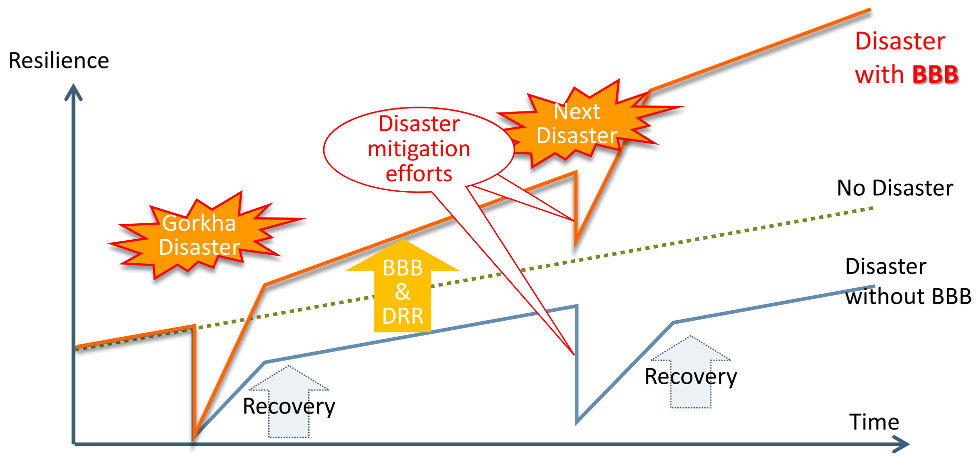
Figure 4.1.2 Structure of the BBB RR Plan

(2) Consideration of the Vision for the BBB RR Plan

1) Primary Vision of Build Back Better

The primary vision, which is commonly applied to the all municipalities, is Build Back Better. Disaster management can be formulated as a cycle of "Prevention and Mitigation", "Preparedness", "Emergency Responses", and "Recovery and Reconstruction". In the stage of "Recovery and Reconstruction", it is necessary to consider help to reduce the damage due to the disasters that may occur in the future. This means that the recovery and reconstruction aims at not only the restoration but also helps create a disaster-resistant condition. With lessons learned from the disaster experiences, this concept "BBB" has become one of the four priorities for action in the "Sendai Framework for Disaster Risk Reduction", adopted in Sendai, Japan 2015. Since the Gorkha Earthquake is the first large-scale disaster that occurred after the adoption of the Sendai Framework for Disaster

Risk Reduction, BBB was set as a primary vision to be formulated in the recovery and reconstruction plan in order to embody the concept of build back better reconstruction.



Source: JICA Project Team

Figure 4.1.3 Concept of BBB

2) Consideration of key principles

Key Principles for the recovery and reconstruction plan were set based on the primary vision “BBB”. The principles are to be applied to all BBB plans, not specific to the selected pilot municipalities. As shown in Table 4.1.1, the key principles adopted were "Life", "Safety" and "Economy", which have been the common principles according to the case study in Japan.

Table 4.1.1 Key principles

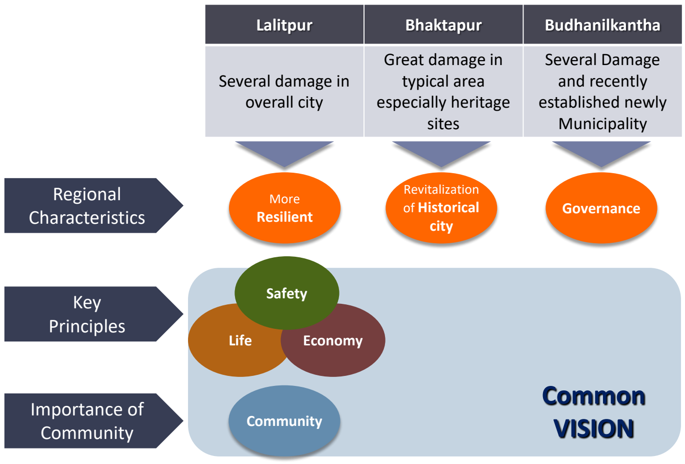
Life	The most important subject is to help the victims get back their ordinary lives. Furthermore, from the BBB point of view, the recovery and reconstruction plan should be a guide towards a better life with a stable livelihood for the future.
Safety	It is necessary to improve safety and create a resilient city against all possible disasters. Each and every measure of the recovery and reconstruction plan has to emphasize the safety and security of the people’s lives.
Economy	Economic activities which have been hampered by an earthquake have to be recovered at an early stage and they would be vital issues for the city. In addition, recovery of the basic infrastructures such as road networks is also necessary to support economic activities. Thus, the recovery and reconstruction plan should aim at the vital regional economy and further development.

Source: JICA Project Team

3) Consideration of the Vision for each pilot municipality

For each municipality, five visions were set; for four of the five visions, they were set to be common visions as basically essential for all municipalities. Specially, three of the visions were decided to be set from key principles "Life," "Safety" and "Economy". In addition, for the one vision other than the above, “community based disaster risk management” was decided to be set because the importance of community cooperation is very important, which has been confirmed in the past experiences in Japan and the Gorkha Earthquake as well.

For the last vision of the five visions, it was decided to set a specific one for each pilot municipality, considering the damage situation, and direction of reconstruction and regional characteristics as follows.



Source: JICA Project Team

Figure 4.1.4 Each Vision of the pilot municipalities

4.1.3 Formulation of BBB RR Basic Plan

Based on the considerations above, the basic plan for recovery and reconstruction of the pilot municipalities were formulated showing mainly the basic policies. The outline of the basic plan is shown as follows.

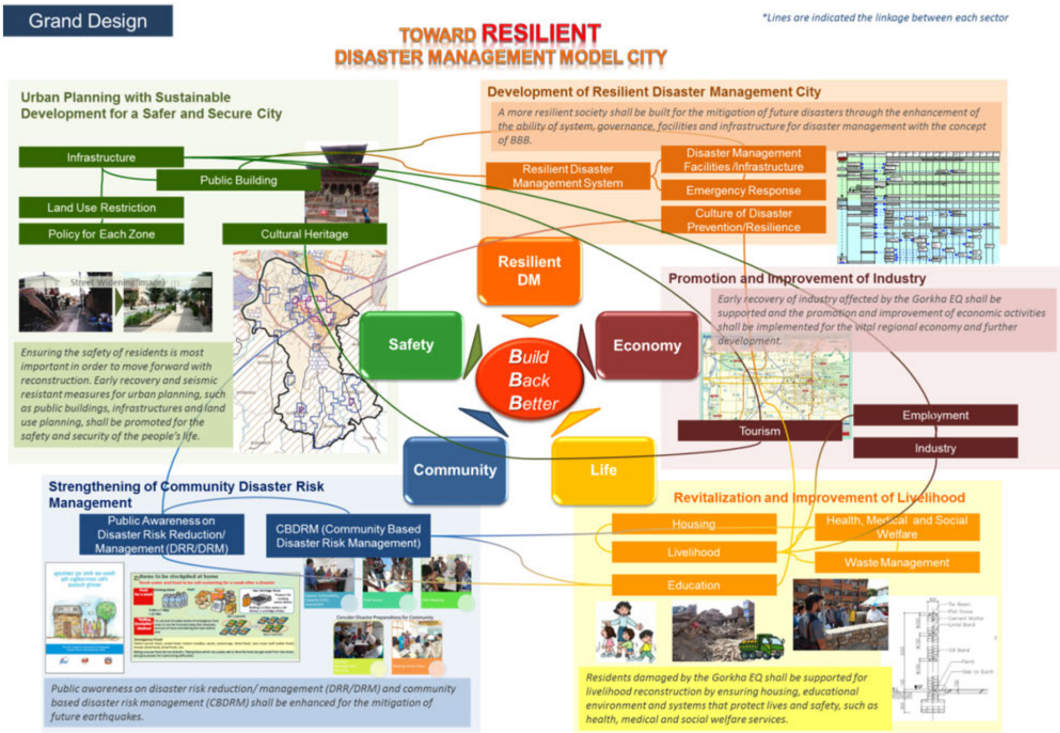
Table 4.1.2 Outline of the BBB RR Basic Plan

Table of Contents	Outline
CHAPTER 1. OUTLINE OF PLAN	
1-1. Background	Overview of the Gorkha Earthquake, damage status and necessity of the plan
1-2. Damage Status	Summary of the damage status on municipal level, the result of PDNA and detail building damage survey
1-3. Objective	Objective of the plan ・Setting and sharing of goals and direction ・Synchronized coordination of reconstruction projects ・Effective implementation of reconstruction actions
1-4. Position	Position of the plan (master plan for recovery and reconstruction)
1-5. Period	Period of the plan (five years and will be integrated into the regional disaster risk management plan)
1-6. System	Structure of the plan and reconstruction system
CHAPTER 2. VISION OF RECONSTRUCTION	
2-1. Primary Vision	Concept of Build Back Better (BBB)
2-2. Three Key Principles, Slogan and Five Visions	Three Key Principles（Life, Safety, Economy）, Slogan and Five Visions
CHAPTER 3. BASIC POLICY	
3-1. Grand Design	Image of the overall concept and the cooperation of the basic policy
3-2. Framework of Basic policy	Framework of Basic policy which shows the overall configuration of the basic policy
3-3. Basic Policy	Basic Policy which shows the basic policy included in the main action list and figures and tables.

Source: JICA Project Team

(1) Consideration of the grand design for the recovery and reconstruction

The grand design for recovery and reconstruction shows the image of the overall concept and the cooperation of the basic policy. It shows the basic policy of each vision and connection of each sector. An example of the grand design which was created is shown in Figure 4.1.5.



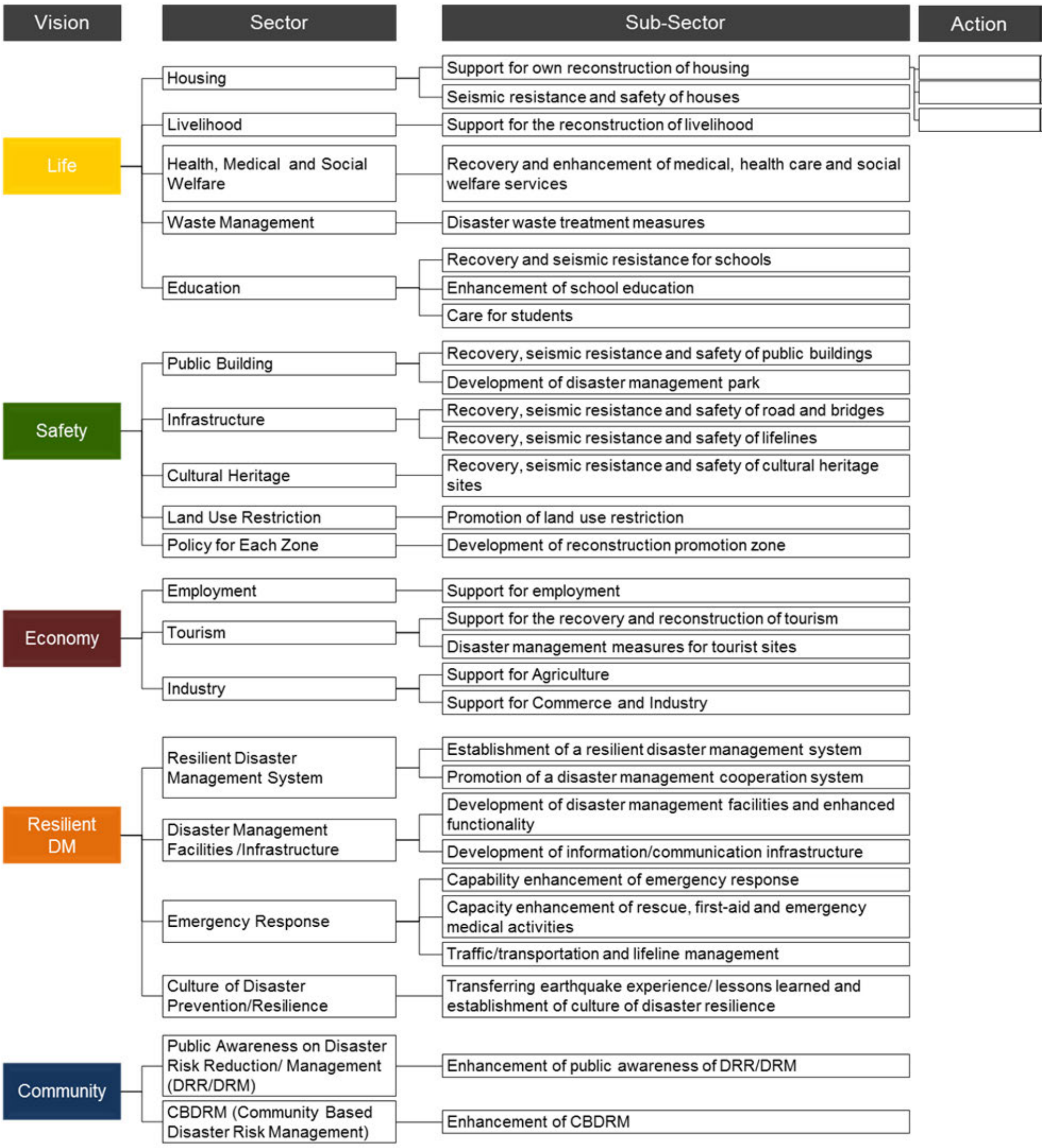
Source: JICA Project Team

Figure 4.1.5 Grand Design of the BBB RR Plan (e.g. Lalitpur)

(2) Consideration of the Basic Policy

The overall configuration and framework of the basic policy, was examined in consideration of the basic policy in the recovery and reconstruction plan. The visions were classified into several sectors, and in order to further embody the sector, the sectors were classified into several sub-sectors. The reconstruction actions were considered in each sub-sector. Classifications of sectors and sub-sectors were determined with examination of the PDNA and case study of past reconstruction plans in Japan. An example of the framework of the basic policy is shown in Figure 4.1.6.

The JICA Project Team discussed the basic policy and action list with the counterparts of each pilot municipality based on the draft of action list. Since the list is common for all municipalities, the list was modified according to the characteristics, damage status and priority, and finalized. The list was pre-configured so that it can be used until the formulation of the detail action plan. After the list was finalized, the JICA Project Team formulated the basic policy part including the figures and tables for ease of understanding visually.



Source: JICA Project Team

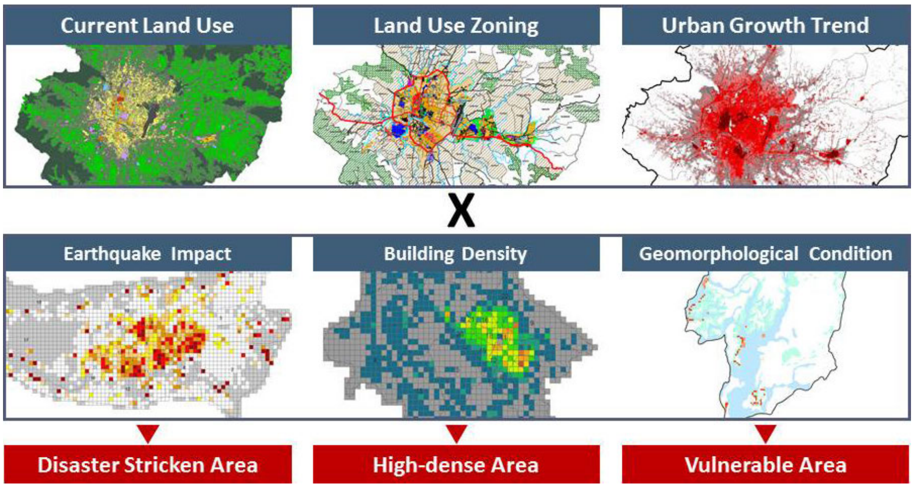
Figure 4.1.6 Framework of the basic policy (e.g. Lalitpur)

(3) Formulation of BBB RR Basic Plan

Based on the result of consideration and discussion with counterparts of each pilot municipality, the BBB RR basic plans were finally formulated.

4.1.4 Land Use Assessment

In order to set sectoral policies for urban planning and land use, "High-density Areas" and "Disaster Stricken Areas" are specified from the detailed building damage survey and "Vulnerable Areas" are specified from the hazard assessment. These specified areas are examined through GIS by overlaying on the current land use, zoning plan, and urban growth patterns in the whole Kathmandu Valley and the three pilot municipalities. Policies for land use are indicated in accordance with the characteristics of the pilot municipalities and compiled as a priority project in the BBB RR Plan.



Source: JICA Project Team

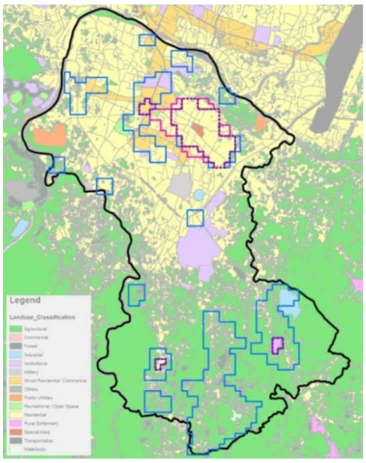
Figure 4.1.7 Overall Procedure for Land Use Assessment

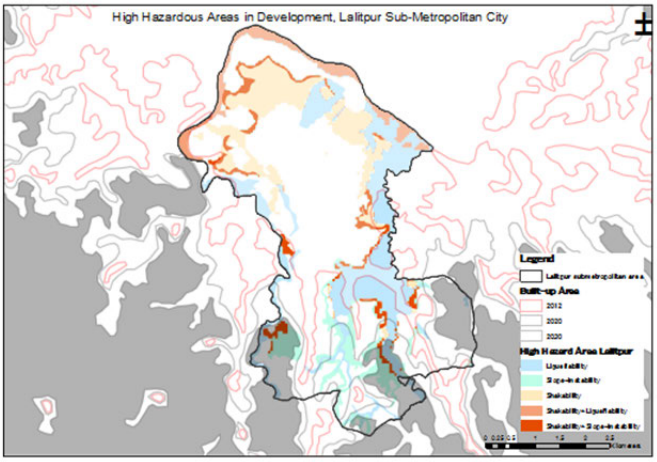
(1) Assessment by Building Density and Earthquake Impact (Actual Building Damage)

Basically, the assessment is for the urbanized areas and targets recovery from the earthquake damage and prevention from spreading more damage. Areas where the building density is high are generally vulnerable to disasters and need special attention for reconstruction, and, areas which have severe earthquake damage need comprehensive reconstruction measures and actions. In order to examine those areas, the results of the detailed building damage survey in Lalitpur Sub-metropolitan City and Bhaktapur Municipality were used. In the case of Budhanilkantha Municipality, the survey result had not been finalized yet, therefore the building density was examined from the building footprint estimated by satellite imagery.

(2) Assessing highly vulnerable areas: assessment by highly hazardous areas and built-up areas

Highly hazardous areas (HHA) were analysed based on the geomorphological conditions of the Kathmandu Valley. The reason for analysing HHA was to have the result serve as a basis for deciding land use, and where to promote and where to limit development. Three indicators: 1) shakability, 2) liquefiability, and 3) slope-instability are used for this HHA analysis (note: shakability and liquefiability are terms that do not exist in proper English, however, they were originated in this study to properly share the message and concepts of hazards). Data used in HHA assessment are, in a large part, originally developed by the Project Team; sub-surface geology zonation are used for shakability, liquefaction susceptibility is utilized for liquefiability, and a combination of slope failure susceptibility and areas with slopes steeper than 30 degrees are used for slope-instability. HHA are evaluated by overlaying these three types of information, all of which are classified into five levels. Areas targeted for evaluation include Kathmandu Valley and three targeted municipalities.





Source: JICA Project Team

Figure 4.1.8 Disaster Stricken Area (blue) and High-density Area (pink) on Land Use [Left] and Highly Vulnerable areas [Right] (Lalitpur)

(3) Indications for land use policy by municipalities

Priority measures listed below are developed based on the results of land use assessment, which included: "high-density area", "disaster stricken area", and "vulnerable area". Measures listed are divided into two types of urban areas, "high-density area and disaster stricken area", as well as "vulnerable area", and two types of development areas, "developed area" and "future development area".

Table 4.1.3 Land use policies of each municipality

Municipality	Priority Area	Priority Area	
		Develop Area	Future Development Area
Lalitpur	High-density Area Disaster Stricken Area	Historical city centre and rural town with high building density > Comprehensive reconstruction measures and appropriate rezoning	N/A
	Vulnerable Area	1) Measures against liquefaction > Improve soil and land 2) Measures against shakability > Improve seismic resistance	1) Measures against liquefaction > Minimize development 2) Measures against slope-instability > Avoid development
Bhaktapur	High-density Area Disaster Stricken Area	Historical area with high building density > Comprehensive reconstruction measures	N/A
	Vulnerable Area	1) Measures against liquefaction > Improve soil and land 2) Measures against shakability > Improve seismic resistance	1) Measures against liquefaction > Minimize development 2) Measures against shakability > Improve seismic resistance
Budhanilkantha	High-density Area Disaster Stricken Area	> Update zoning plan reflecting urbanization and hazard types	N/A
	Vulnerable Area	1) Measures against liquefaction > Improve soil and land	1) Measures against liquefaction > Minimize development 2) Measures against slope-instability > Avoid development

Source: JICA Project Team

4.1.5 Formulation of BBB RR Action Plan

The BBB RR Action Plan for pilot municipalities was formulated based on the basic plan as shown in Table 4.1.4. The outline of the action plan is shown as follows.

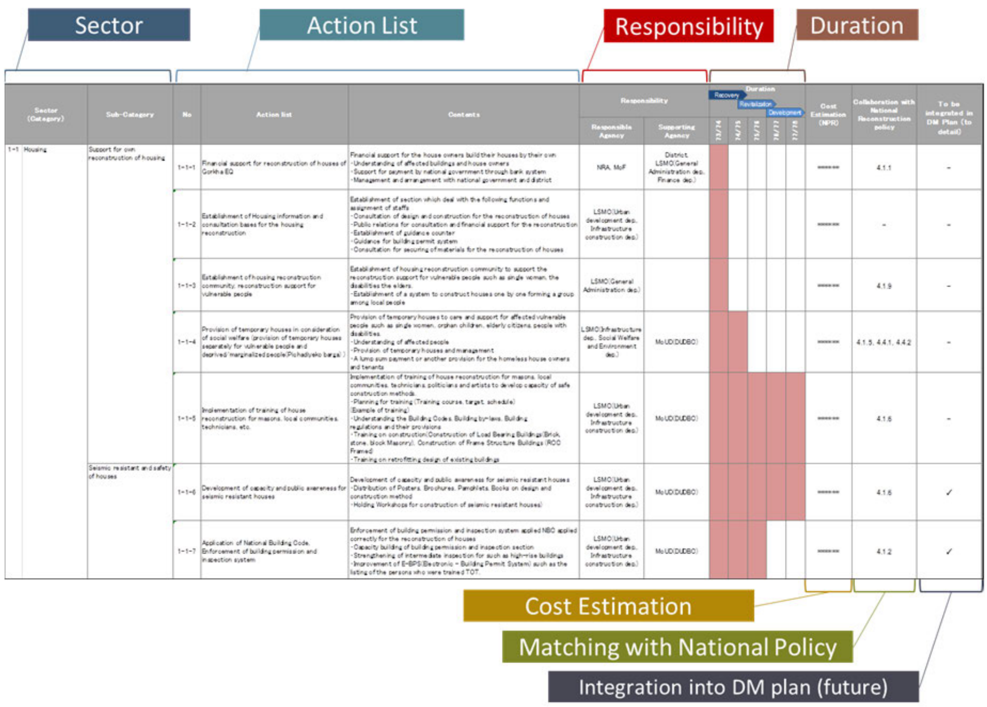
Table 4.1.4 Outline of the BBB RR Action Plan

Table of Contents	Outline
CHAPTER 1. OUTLINE OF PLAN	
1-1. Objective	Objective of the action plan (For the implementation)
1-2. Framework	Framework of the action plan (structure)
CHAPTER 2. ACTION PLAN	Action plan for each vision • Sector • Title of action, detail contents • Responsibility • Duration • Estimated cost • Matching with National Policy • Integration into disaster risk management plan
CHAPTER 3. PRIORITY PROJECT	Detail contents of the priority project selected from the action plan
CHAPTER 4. MONITORING AND EVALUATION	Method of monitoring and evaluation for the implementation of actions

Source: JICA Project Team

(1) Formulation of BBB RR Action Plan

The JICA Project Team formulated the action plan for specifically attaining the objectives which are shown in the basic plan of BBB RR Plan. The action plan included the responsible organizations in the municipality and relevant stakeholders in consideration of the coordination with the national and district organizations. By considering budget, importance, urgency and time needed, each action plan was sorted into three phases by priority.



Source: JICA Project Team

Figure 4.1.9 Framework of the action plan

(2) Selection of the priority projects

The priority projects were selected as per the priority, necessity and importance of the projects in the action plan. The priority projects were prepared as a project sheet for each project, and further details of the contents were described in order to start the implementation smoothly. Concretely, mason training, etc., were selected as the priority projects with the prospect of budgeting and high priority for seismic resistance of buildings. In addition, in this project, the formulation of local disaster and climate resilience plans and community disaster risk and reduction activities were implemented as the projects with high priority.

4.1.6 Finalization of the BBB RR Plan

(1) WSs for dissemination and public comment of recovery and reconstruction plans in pilot municipalities

Workshops (WS) were held in each pilot municipality for the introduction and dissemination of information and getting public comments. Municipal council members, municipal officials, each ward secretary and leaders of community disaster management committees, etc. were invited and the workshops were held in May and June in 2016 for three pilot municipalities.

(2) Official approval of the recovery and reconstruction plan from municipal council

As described above, the contents of the recovery and reconstruction were finalized. The JICA Project Team supported the official approval of the plan from the municipal council towards the comprehensive implementation of the plan. For the Lalitpur Sub-metropolitan City and the Budhanilkantha Municipality, the plans were finally approval by the municipal council (Lalitpur: August 2016, Budhanilkantha: September 2016). Then, in the pilot municipalities, several programs related to the BBB RR Plan which were developed in this project have also been budgeted. Table 4.1.5 shows the relevance between the actions of the BBB RR Plan and the approved programs which have been budgeted in the case of Lalitpur. Although they are not completely connected to the plan, several programs for recovery as well as targeted towards future disaster risk reduction have been budgeted under the concept of BBB.

Table 4.1.5 Budgeting of BBB RR Plan (e.g. Lalitpur)

BBB Recovery and Reconstruction Plan		2073/74		2074/75	
No	Action list	Approved programs (Sept. 16, 2016)	Budget (NPR)	Approved programs	Budget (NPR)
1. Revitalization and Improvement of Livelihood					
1-1-1	Financial support for the reconstruction of houses damaged by the Gorkha EQ			Exemption on municipal drawing permit (building construction permit) charges for new construction and reconstruction for both residential and commercial buildings	
				Tax exemption for completely damaged houses	
1-1-5	Implementation of training of house reconstruction for masons, local communities, technicians, etc.			Mason training	500,000
				Provide trainings for contractors as well as site visits for seismic design and construction	150,000
1-1-6	Development of capacity and public awareness for seismic resistant houses			Awareness program for earthquake resistant building construction (booklet, brochures, TV programs, radio, display, etc.)	150,000
1-2-1	Financial support for the livelihood reconstruction of victims			Charges exemption for recommendations based on the ID of earthquake victims	
1-2-2	Establishment of a livelihood help desk				
1-5-4	Training for teachers			Training for school teachers (form School DM committee) in 5 schools	300,000
2. Urban Planning with Sustainable Development for a Safer and Secure City					
2-1-10	Development of open spaces as evacuation sites and disaster management bases	Construction of park and management	1,600,000	Conservation of public land/open spaces and management and establishment of new parks	Several
				Select a open space and develop it as a model park for DM	500,000
2-2-2	Improvement of earthquake resistant roads for smooth transportation and evacuation, especially for designated emergency transportation roads and evacuation routes	Road construction, maintenance and expansion works	Several	Road expansion	Several
				Road maintenance	Several
				Mapping of emergency routes within municipality building and community building and manage for emergency exit	300,000
2-2-8	Development of sustainable stockpiling of water and fuel for emergency use stored in earthquake resistant and safe			Conservation of ponds	Several
				Conservation of water sources	Several
2-2-9	Improvement of the sanitation management system	Construction and maintenance of sewer lines	Several	Construction/maintenance of public toilets (including those near open spaces)	Several
2-2-10	Continuous development of the expansion of the supplying area and upgrading of existing facilities to be aseismic resistance and with a stable water, sewage, and electricity supply system				
2-3-2	Prioritizing recovery through the judgement of urgency from seismic diagnosis and historical importance	Prepare inventory of heritages	150,000		
2-3-3	Recovery of the prioritized cultural heritage sites in consideration of seismic resistance and their original value	Recovery and reconstruction of various heritages	8,182,000	Reconstruction and maintenance of various heritages	
3. Promotion and Improvement of Industry					
3-1-1	Support for the employment of victims who have lost work (financial support)			Skill development training for women who were victim of earthquake	200,000
3-1-2	Support for employment, employment training in consideration of vulnerable people and deprived/marginalized people (Pichadiyeko barga)				
3-3-3	Recovery support for stores, shops and cottage industries			The business run in completely damaged houses shall get 50% exemption in business tax	
4. Development of Resilient Disaster Management City				Disaster management	6,000,000
				Enhancement of DM fund	500,000
4-1-1	Formulation of disaster management plan			With the view of making policy for DM, gather the earthquake victims and share their experience, and prepare reports so to make it easier to prepare plans for them	250,000
4-2-2	Development of stockpile warehouses, and ensuring disaster stockpiles			Select three ward with earthquake resistant building and manage for emergency stockpile	500,000
				Manage emergency stockpile in Ward 9	500,000
4-2-3	Construction and management of disaster management training centre			Establish exhibition room for management of various photographs, preparedness materials, safe materials for contractors, etc.	100,000
4-3-4	Implementation of disaster management exercises for emergency response			Trainings and Management for fire control	300,000
4-3-5	Designation of disaster base hospitals, medical centres			Inspect the emergency management plans of some important hospitals in the municipality and prepare report including activities that have to be implemented	250,000
4-4-2	Implementation of events for promoting the establishment of culture of disaster prevention/ resilience			Conduct various programs on EQ safety day	200,000
5. Strengthening of Community Disaster Risk Management					
5-1-2	Implementation of awareness-raising programmes on DRR/DRM			Awareness programs	Several
5-2-4	Implementation of DRR/ DRM capacity development programmes for community leaders			DM related programs and trainings in each ward (compulsory fire control related training)	1,500,000

Source: Lalitpur Metropolitan City, edited by JICA Project Team

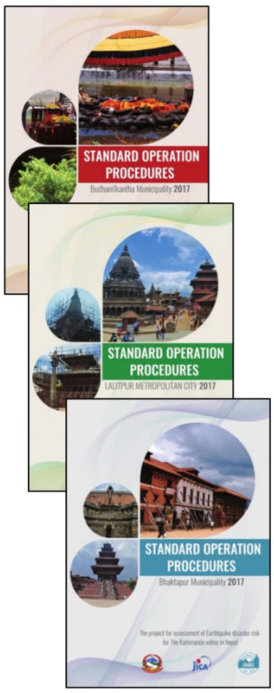
4.2 Standard Operation Procedure (SOP)

A Standard Operation Procedure (SOP) is the manual indicated step by step procedures of emergency response for municipal officials to understand the specific emergency response activity in the case of disaster. It is important for officials to confirm each role and responsibility by using SOP for swift emergency response and recovery in case of disaster. This activity aimed to develop an SOP for the three target municipalities based on the experience of the Gorkha Earthquake which hit in Nepal 2015.

SOP activity was started in December 2016. First, "Research and Development" was conducted for researching existent Guidelines and Manuals in Nepal and Japan. Second, several "Workshops and Meetings" were conducted for collecting opinions and suggestions from MoHA and participants in the workshops of each municipality. Third, SOP was finalized based on the result of the "Workshops and Meetings".

1. Preface
   - 1-1. Introduction
   - 1-2. Objectives
   - 1-3. Preparedness of Officials
   - 1-4. Duration of this SOP and Basic Flow
2. Mobilization of officials
   - 2-1. Flow of Mobilization (On and Off-duty)
   - 2-2. Preparation for Mobilization
3. Establishment of Emergency Response Head Quarter (ERHQ)
   - 3-1. Establishment of ERHQ
   - 3-2. Structure of ERHQ
   - 3-3. Function of ERHQ
   - 3-4. Relationship of ERHQ with other Organizations
   - 3-5. Role of Ward Office
4. Preparedness and Response Activities against Earthquake
   - 4-1. Preparedness Activities
   - 4-2. Response Activities

[APPENDICES]
Appendix A: Activity Flowchart
Appendix B: Disaster Information Format
Appendix C: List of Evacuee at Evacuation Shelter
Appendix D: Personal Data of Officials



Source: JICA Project Team

Figure 4.2.1 Table of Contents of the finalized SOP

Figure 4.2.1 is the table of contents. In Chapter 1 the "Introduction" and "Objectives" of this SOP are shown. And "Preparedness of Officials" is mentioned which is the responsibility of all officials to consider an appropriate response against disaster before a disaster occurs. Also "Duration of this SOP and Basic Flow" is described. In Chapter 2 where "Flow of Mobilization" and "Preparation for Mobilization" are described. This SOP is supposed to be for On-duty and Off-duty activities. In Chapter 3, the Project Team suggested a new idea, named "Emergency Response Head Quarters (ERHQ)". First, responsibility to establish

ERHQ is mentioned. This is regarding a high priority person who can make a decision for establishment of ERHQ. Next shown is “Structure of ERHQ”. This structure was adjusted based on present government structure in each municipality. And “Function of ERHQ” is also described. Members of ERHQ and Contents of discussion points are shown in the table. Last is “Relationships of ERHQ with other Organizations and Divisions”. In case of an earthquake, coordination of municipalities with other related agencies and committees in Nepal is very important, so a simple explanation is included. In Chapter 4, Preparedness and Response Activities against Earthquake are shown. It is mentioned that the collecting of information regarding official facilities must be done in the preparedness phase.

Appendix A is “Activity Flowchart”. This figure shows specific activities to be followed in case of disaster and developed for each present division. Officers can understand what, when and how the activities should be performed. Appendix B is “Disaster Information Format”. Before starting this SOP activity, no unified disaster information format was prepared yet in the three municipalities. So the Project Team suggested a new disaster information format in this SOP. Appendix C is “List of Evacuees at Evacuation Shelters”. This figure was referring to Japanese Guidelines and Manuals. In case of disaster, it is supposed that many affected people will be evacuated to an evacuation shelter. Appendix D is “Personal Data of Officials”. In case of disaster, it is necessary to have contact with all officials. So the Project Team suggested this form to collect information from officials. This format is expected to be compiled before a disaster. These forms were agreed at the workshops of each pilot municipality. In the future, Since Appendices A, B, and C are intended to be utilized in emergency situations, it is important to accumulate experience to utilize these forms through trainings and actual disasters. On the other hand, since information related to Appendix D can be collected and managed in normal times, it is expected that municipal officials who are familiar with this form through the workshops will use this form on a daily basis.

This SOP should be utilized for the next disaster and modified based on latest government situation. We expect local officials to: i) Update the SOP as per the latest government structure regularly, ii) Confirm the roles and responsibilities of each division/section for preparedness, and iii) Collect & share updated basic statistical information such as number of hospitals, students and teachers in each school, staff information, etc.

4.3 Technical Guideline for Formulation of Local Disaster and Climate Resilience Plans (TG LDCRP)

4.3.1 Outline of the TG LDCRP

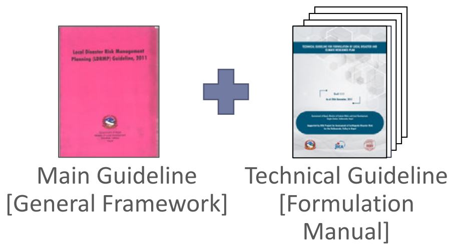
The JICA Project Team developed a Technical Guideline for Formulation of Local Disaster and Climate Resilience Plans (TG LDCRP) for the local level of Nepal in this project. TG LDCRP helps the local level, such as a municipality, to easily formulate the practical and effective Local Disaster and Climate Resilience Plan (LDCRP) and is a supporting manual aiming to give guidance; and is to be utilized as a reference document so that local levels, such as a municipality, can understand its detailed contents, formulation procedures, examples of descriptions and notes to be considered. TG LDCRP was developed both in English and Nepali.

Before the formulation of the Technical Guideline, the JICA Project Team reviewed the existing guideline "Local Disaster Risk Management Planning (LDRMP) Guideline, 2011" (2011 guideline) by MoFALD, and examined its issues. While the JICA Project Team and MoFALD were having discussions, it was perceived that the 2011 guideline was scheduled to be revised by MoFALD and the members of NRRC Flagship 4, and the context of the revised guideline (LDCRP guideline) was reviewed. On the basis of this situation, the JICA Project Team discussed with MoFALD regarding the positioning and structure of the TG LDCRP. As a result of discussions, TG LDCRP was drafted and finalized.

4.3.2 Consideration of Structure of Technical Guideline for Formulation of LDCRP

(1) Scope and position of Technical Guideline for Formulation of LDCRP

Setting of TG LDCRP was discussed and agreed with MoFALD as described here. Figure 4.3.1 shows the arrangement of TG LDCRP in relation to the LDCRP Guideline developed by MoFALD.

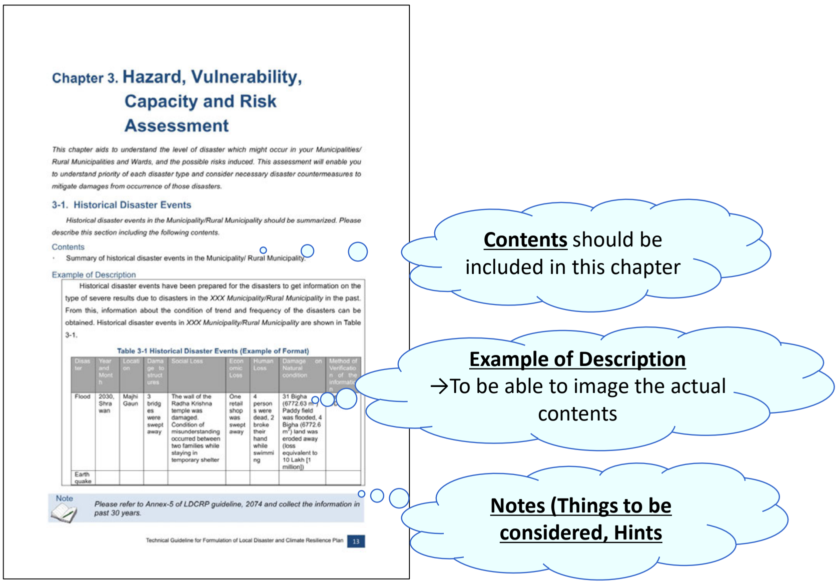


Source: JICA Project Team

Figure 4.3.1 Position of TG LDCRP

(2) Structure of Technical Guideline for Formulation of LDCRP

TG LDCRP was developed completely in accordance with the LDCRP guideline and was formulated as a revision of LDRMP Guideline, 2011. The concept of TG LDCRP is that the local level can easily understand the contents and grasp the overall picture of the LDCRP, and can formulate a practical LDCRP. The structure of TG LDCRP is shown in Figure 4.3.2.



Source: JICA Project Team

Figure 4.3.2 Structure of TG LDCRP

TG LDCRP includes concrete examples and images of descriptions for local levels to be able to understand what kind of contents to include and how to describe them easily when they formulate the LDCRP. The TG LDCRP is not just a template but a manual which includes the necessary information such as methodology for collection of data and information, the way to decide priority among activities, and other supporting information for formulating LDCRP. The table of contents for TG LDCRP has been developed referring to the ones stipulated by the LDCRP Guideline, such that the same can be followed for actual LDCRP formulation by local levels. The table of contents for TG LDCRP is shown in Table 4.3.1.

Table 4.3.1 Table of contents for TG LDCRP

Table of Contents	
Chapter 1 Introduction	
	1.1 Background
	1.2 Objective of Plan
	1.3 Rationale and Significance of Plan
	1.4 Limitations of Plan
	1.5 Methodology
	1.6 Plan Implementation Strategy
Chapter 2 General Description	
	2.1 Physical Condition
	2.2 Social Condition
Chapter 3 Hazard, Vulnerability, Capacity and Risk Assessment	
	3.1 Historical Disaster Events
	3.2 Hazard Identification and Ranking
	3.3 Hazard Analysis
	3.4 Vulnerability Analysis
	3.5 Capacity Analysis
	3.6 Risk Identification and Assessment
Chapter 4 Local Disaster and Climate Resilience Policy	
	4.1 Vision and Mission
	4.2 Disaster and Climate Resilience Strategy
	4.3 Institutional Structure of Disaster and Climate Resilience

Table of Contents	
Chapter 5 Local Disaster and Climate Resilience Activities	
	5.1 Understanding disaster risk
	5.2 Strengthening disaster risk governance to manage disaster risk
	5.3 Investing in disaster risk reduction for resilience
	5.4 Enhancing disaster preparedness for effective response, and to «Build Back Better» in recovery, rehabilitation and reconstruction
Chapter 6 Monitoring, Evaluation and Update of LDCRP	
	6.1 Monitoring and Evaluation
	6.1 Review and Update of LDCRP

Source: JICA Project Team

Chapter 1 is the "Introduction" which is the fundamental part of LDCRP that indicates the background and objectives of the plan. Chapter 2 is the "General Description" which indicates regional characteristics of the local level. This part is the basic information for understanding the specific region type to help identify the target disasters and issues in the municipalities. The data sources for collecting the necessary information have been included in the TG LDCRP. Chapter 3 is the "Hazard, Vulnerability, Capacity and Risk Assessment" which aids understanding the level of disaster which might occur in the municipalities, and the possible risks induced. Primarily, examples of formats and maps have been described in this chapter. Chapter 4 is the "Local Disaster and Climate Resilience Policy" which aids in formulation of the Disaster and Climate Resilience Policy with Vision, Mission and Strategies. It indicates the considerations for setting the vision and mission and how to set the strategies and targets for disaster risk reduction in consideration of the Sendai Framework. In addition, it indicates the confirmation of national and provincial action plans related to DCR in order to understand the residual risks to formulate it as a practical plan. Chapter 5 is "Local Disaster and Climate Resilience Activities" which is the main and the most significant part of LDCRP comprised of necessary activities related to disaster and climate resilience that need to be considered for implementation for all phases. It outlines how to consider the activities based on the previous chapters and according to the strategies set in Chapter 4. Chapter 6 is "Monitoring, Evaluation and Update of LDCRP" which details the principles of monitoring, evaluation, and update of the plan. In this part, the general concept of monitoring, evaluation, and update of the plan, and example format for monitoring and evaluation has been described. Additionally, example of activities and summary of risk assessment for earthquake disaster implemented by this project have been included in Appendixes.

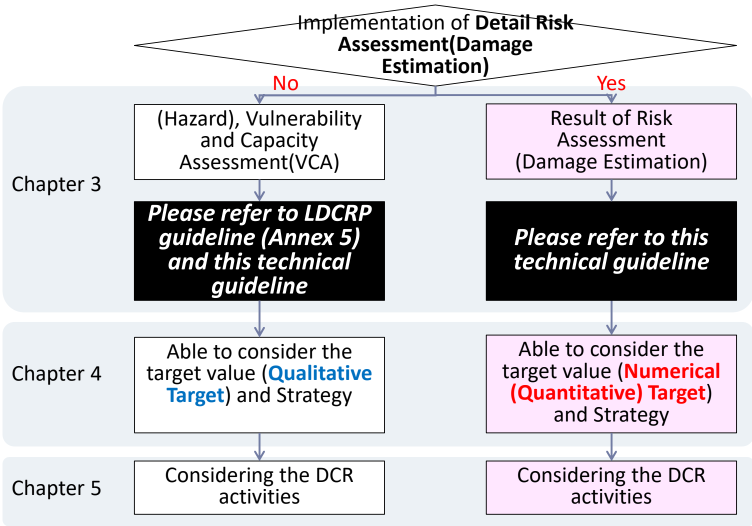
4.3.3 Formulation of Technical Guideline for Formulation of LDCRP

On the basis of consideration of structure as shown in 4.3.2, TG LDCRP was formulated. In this section, distinctive points of TG LDCRP are shown as follows.

1) Vulnerability and Capacity Assessment (VCA) and Risk Assessment

For the hazard and risk identification part, the 2011 guideline had only one VCA tool.

However, by integrating the utilization of risk assessment, the LDCRP guideline now comprises two ways of using the VCA tool and risk assessment. According to the LDCRP guideline, the detail of contents and differences between VCA and risk assessment (damage estimation), are also included in TG LDCRP.



Source: JICA Project Team

Figure 4.3.3 Formulation procedures from VCA and Risk Assessment (Damage Estimation) [Figure in TG LDCRP]

Benefits of risk assessment for LDCRP are as follows.

- It can be utilized to set the numerical DRR target based on the engineering results.
- On the basis of the target, the countermeasures to achieve DRR targets can be considered.
- It can be used for the prioritizing of countermeasures for critical infrastructures such as schools, health facilities, governmental buildings and bridges.
- Activities can be implemented with effective monitoring based on the DRR ratio (what level of DRR target to achieve)

2) Structure in accordance with Sendai Framework

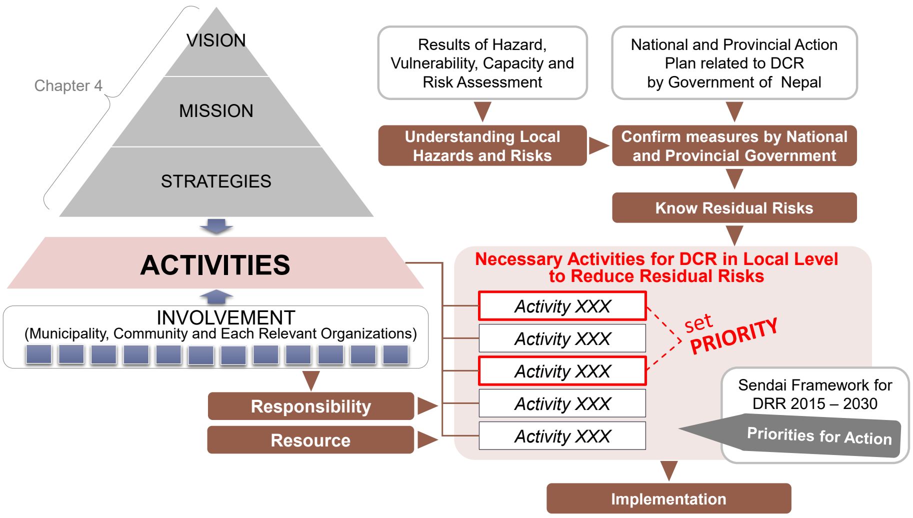
Several contents in the TG LDCRP are based on the Sendai Framework. For consideration of disaster and climate resilience strategies in Chapter 4 of the LDCRP, since the global targets of the Sendai Framework can be referred to, the example format for disaster and climate resilience strategies in TG LDCRP is based on the Sendai Framework. And four priorities for action of Sendai Framework are directly connected to the disaster management cycle: prevention and mitigation, preparedness, emergency response, and recovery and reconstruction. Thus, the Chapter 5, Local Disaster and Climate Resilience Activities, in the TG LDCRP, is divided into four sub-chapters according to the priorities for action of the Sendai Framework.

3) Consistency with legal framework

The legal framework related to disaster risk reduction and management in Nepal mainly consists of the Constitution, the Disaster Risk Reduction and Management Act 2017, and the Local Government Operation Act 2017, which was recently revised. These changes have been appropriately reflected in the TG LDCRP according to the current legal framework.

4) Consideration of disaster and climate resilience activities

Consideration of activities is the most important component for the planning. Therefore, TG LDCRP outlines how to consider the disaster and climate resilience activities in detail. Figure 4.3.4 indicates the structure for considering the disaster and climate resilience activities.



Source: JICA Project Team

Figure 4.3.4 How to consider the DCR activities [Figure in TG LDCRP]

DCR activities should be considered based on the results of the hazard, vulnerability, capacity and risk assessment, vision and mission, and prioritize them based on the strategies which were set in chapters 3 and 4 of LDCRP. In addition, to formulate it as a practical plan, national and provincial action plans related to DCR should be confirmed in order to know residual risks and to consider necessary activities at the local level to reduce its residual risks.

5) Development of an example of disaster and climate resilience activities

The JICA Project Team developed the example of disaster and climate resilience activities as an appendix of TG LDCRP so that local level entities can refer to it for considering their activities. The example of the activities shows not only the title of the activity but also its detail contents. Hence, the local level can understand each component of the activities, can consider their additional requirements, and easily formulate and implement the activities.

4.4 Local Disaster and Climate Resilience Plan for Pilot Municipalities

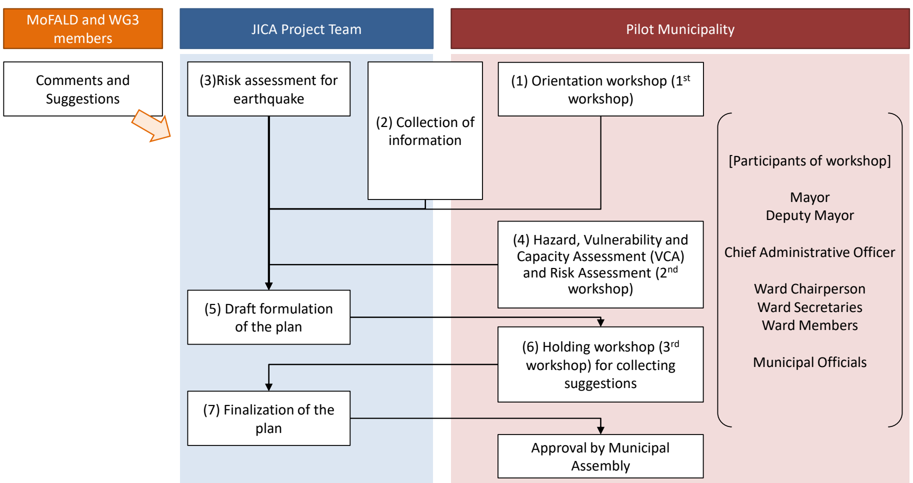
4.4.1 Outline of Local Disaster and Climate Resilience Plan for Pilot Municipalities

The JICA Project Team formulated the Local Disaster and Climate Resilience Plan (LDCRP) for pilot municipalities. The purpose of the earthquake hazard and risk assessment which this Project implemented as described in chapters 2 and 3 is not assessment but to connect the results to the real disaster management countermeasures and disaster risk reduction. So LDCRPs for pilot municipalities were developed by utilizing the result of the earthquake risk assessment to consider the target for disaster risk reduction according to Sendai Framework and consider the necessary activities to achieve its targets. LDCRPs for pilot municipalities were developed and the structure and basic contents of LDCRP follow the contents of TG LDCRP as well as LDCRP guideline by MoFALD.

Before the formulation of LDCRP for pilot municipalities the JICA Project Team reviewed the existing local disaster management plan based on the 2011 guideline. Necessary information for planning of each municipality was collected. In accordance with this information, JICA Project Team held workshops three times to make the plan practical and based on the local conditions and ensure direct and inclusive participation of all stakeholders in each municipality for planning. On the basis of the results of the workshops, LDCRP was drafted and finalized. Details are shown as follows.

4.4.2 Formulation of Local Disaster and Climate Resilience Plan

The JICA Project Team formulated the Local Disaster and Climate Resilience Plan (LDCRP) for pilot municipalities based on not only the collected information but also holding workshops as participatory planning. Figure 4.4.1 shows the planning framework and processes of LDCRP.



Source: JICA Project Team

Figure 4.4.1 Planning framework and processes of LDCRP

The table of contents of LDCRP for pilot municipalities is the same as proposed under TG LDCRP which was developed in this project as shown in 4.3. All of the contents of LDCRP are based on the LDCRP guideline, TG LDCRP, collected information, results of hazard and risk assessment of this project, and the results of workshops which were organized in each municipality as shown in Table 4.4.1.

Table 4.4.1 Contents and Basis of contents for LDCRP

Contents			Basis of contents
Chapter 1. Introduction			
1-1	Background	- Summary of history, population and location	- Collected from each municipality - Refer to LDCRP guideline and TG LDCRP
1-2	Objective of Plan	- Objectives of Plan	
1-3	Rationale and Significance of Plan	- Rationale and Significance of Plan	
1-4	Limitation of Plan	- Limitation of Plan	
1-5	Methodology	- Methodology	- Description of methodology adhered to this project
1-6	Plan Implementation Strategy	- Plan Implementation Strategy	- Refer to LDCRP guideline and TG LDCRP
Chapter 2. General Description			
2-1	Physical Condition	1) Topographic & geological conditions (Data & GIS)	- Collected from DMG and outputs of this project
		2) Land use (Data and GIS Map)	- Collected from Risk Sensitive Land Use Plan,UNDP Project
		3) Climate conditions (Data)	- Collected from Department of Hydrology and Meteorology
2-2	Social Condition	1) Population (Data & GIS Map)	- Collected from Census 2011 by CBS
		2) Building (Data and GIS Map)	- Collected from Census 2011 by CBS
Chapter 3. Hazard, Vulnerability, Capacity and Risk Assessment			
3-1	Historical Disaster Events	- Historical Disaster Events (Table)	- Based on the second workshop
3-2	Hazard Identification and Ranking	- Hazard Ranking in Municipality	
3-3	Hazard Analysis	- Earthquake	- Based on the risk assessment of this project
		- Results of VCA for Other disasters	- Based on the second workshop
3-4	Vulnerability Analysis	- Results of VCA for Other disasters	
3-5	Capacity Analysis	- Results of VCA for Other disasters	
3-6	Risk Identification and Assessment	- Earthquake	- Based on the risk assessment of this project
		- Other disasters	- Based on the second workshop
Chapter 4. Local Disaster and Climate Resilience Policy			
4-1	Vision and Mission	- Vision and Mission for disaster and climate resilience	- Based on the first workshop
4-2	Disaster and Climate Resilience Strategy	- Target and strategy for disaster and climate resilience	- Drafted based on the risk assessment of this project and discussed/finalized based on the second workshop
4-3	Institutional Structure of Disaster and Climate Resilience	1) Framework of related organizations	- Refer to LDCRP guideline and TG LDCRP
		2) Organization chart of municipality	- Collected from each municipality
Chapter 5. Local Disaster and Climate Resilience Activities			
5-1	Understanding disaster risk	- Necessary Activities for understanding disaster risk	- Drafted based on the TG LDCRP, Risk assessment of this project and second workshop, and discussed/finalized based on the third workshop
5-2	Strengthening disaster risk governance to manage disaster risk	- Necessary Activities for strengthening disaster risk governance to manage disaster risk	
5-3	Investing in disaster risk reduction for resilience	- Necessary Activities for investing in disaster risk reduction for resilience	
5-4	Enhancing disaster preparedness for effective response, and	- Necessary Activities for enhancing disaster preparedness for effective response, and to «Build Back	

Source: JICA Project Team

In this section, distinctive points of TG LDCRP are shown as follows.

(1) Organizing workshops

Three times workshops were held in each municipality as follows. The first workshop was held for discussion of the basic principles of LDCRP such as vision and mission. The second workshop was held for discussion of hazard, vulnerability, capacity and risk assessment since the risk assessment, which this project conducted, is only for earthquakes and LDCRP is for all target disasters. The third workshop was held for discussion of disaster and climate resilience activities with priority and provision of necessary suggestions, and LDCRP was finalized based on the result of the third workshop. Members of the municipal assembly, who would be members of local disaster and climate resilience committees, as indicated in the LDCRP guideline, participated in the workshops.

Source: JICA Project Team

Figure 4.4.2 Photo of workshops for LDCRP and SOP in pilot municipalities

(2) Hazard, Vulnerability, Capacity and Risk assessment

The hazard and risk assessment of this project was targeted only for earthquake as the most prioritized disaster. However earthquakes are not the only target disaster in the pilot municipalities considering past disasters and possible disasters which might occur in the future. LDCRP is a comprehensive plan to reduce risks for target disasters in each municipality, not only earthquake, but also other possible disasters. Therefore, disaster risks were identified and assessed based on the VCA results of the 2nd workshop.

1) Hazard identification and ranking

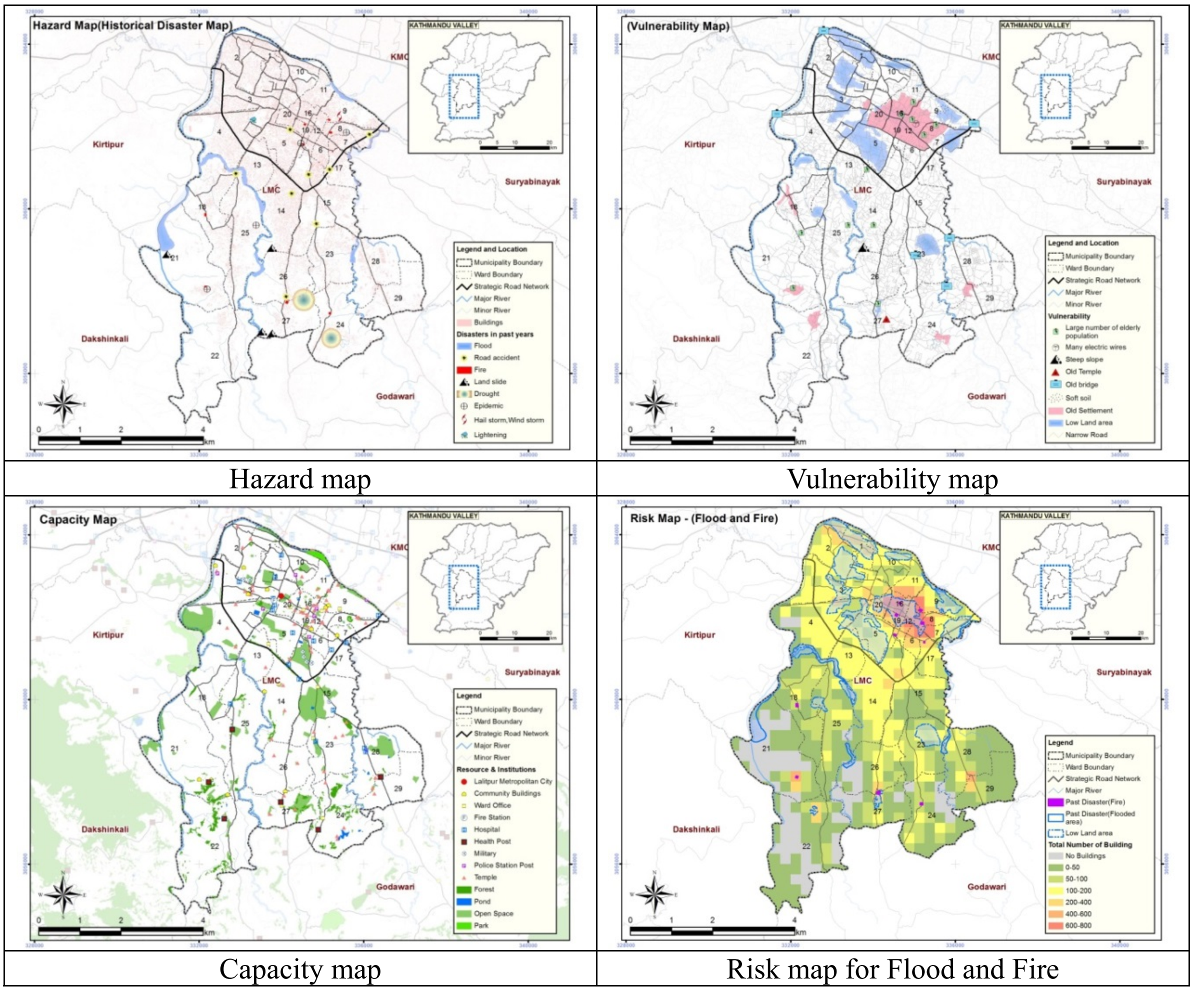
Based on the discussions in the 2nd workshop for formulation of LDCRP, disaster identification and ranking was summarized for the pilot municipalities.

Table 4.4.2 Target disasters with priority for pilot municipalities

Priority	Lalitpur Metropolitan City	Bhaktapur Municipality	Budhanilkantha Municipality
First	Earthquake	Earthquake	Earthquake
Second	Flood	Flood	Flood
Third	Road Accidents	Fire	Landslide
Fourth	Fire	Windstorm	Wild Fire
Fifth	Landslide	Road Accidents	Wildlife Attack
Sixth	Drought	-	-

Note: Information is based on the workshop for formulation of LDCRP, Source: JICA Project Team

2) Hazard, Vulnerability, Capacity and Risk assessment



Hazard map | Vulnerability map
Capacity map | Risk map for Flood and Fire

Note: Information is based on the workshop for formulation of LDCRP in Lalitpur Metropolitan City, and JICA RRNE Project for capacity map, Source: JICA Project Team

Figure 4.4.3 Hazard, Vulnerability, Capacity and Risk Map (Example of LDCRP for Lalitpur Metropolitan City)

The hazards of disasters other than earthquakes were summarized from the results of the 2nd workshop for formulation of LDCRP in each municipality based on the historical disasters.

The risks of disasters other than earthquakes were identified from the hazard, vulnerability, and capacity assessment and land use conditions such as built-up area by considering exposure to damages in each municipality.

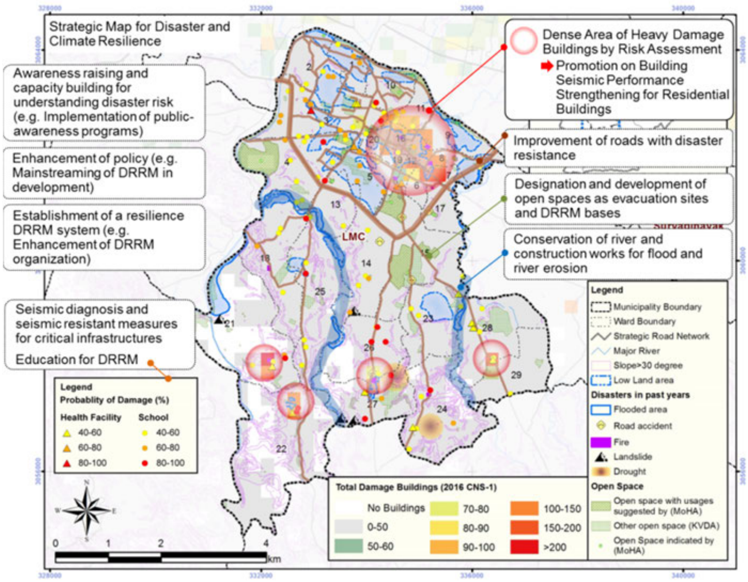
(3) Disaster and climate resilience strategies

As described in Chapter 3, the JICA Project Team conducted seismic risk assessments for 2016 and for 2030. Considering the future situations of the increase in the number of buildings and promotion for providing seismic performance strengthening for 2030, five cases and a case of extrapolation of building damages were assessed with the reduction ratio from 2016. In the 2nd workshop, Participants decided the disaster risk reduction target for reduction in the number of heavily damaged buildings in each municipality. On the basis of these target numbers, the JICA Project Team drafted the target value for the disaster and climate resilience strategy in accordance with the Sendai Framework as shown in Table 4.4.3.

Table 4.4.3 Disaster and climate resilience strategies in pilot municipalities

DRR target for 2030	Lalitpur Metropolitan City	Bhaktapur Municipality	Budhanilkantha Municipality
Heavily damaged buildings	35% (12,362 ⇒ 8,035)	40% (3,730 ⇒ 2,238)	40% (1,380 ⇒ 828)
Target of Sendai Framework			
(a)Mortality	Approx. 35% Reduction (1,761 ⇒ 1,150)	Approx. 40% Reduction (546 ⇒ 330)	Approx. 40% Reduction (235 ⇒ 140)
(b)Number of affected people	Approx. 35% Reduction (Evacuees) (118,485⇒77,000)	Approx. 40% Reduction (Evacuees) (37,843 ⇒ 22,700)	Approx. 40% Reduction (Evacuees) (20,803 ⇒ 12,000)
(c) Economic Loss related to heavy damage to buildings	Approx. 15% Reduction (43,377⇒37,000 (mil. NPR))	Approx. 20% Reduction (8,433⇒7,000 (mil. NPR))	Approx. 20% Reduction (4,373⇒3,500 (mil. NPR))
(d)Critical infrastructure	Reduction	Reduction	Reduction

Source: JICA Project Team



Source: JICA Project Team

Figure 4.4.4 Map for Priority Activities (Lalitpur Metropolitan City)

Based on the results of the risk assessment and workshops at each municipality, necessary disaster and climate resilience activities were examined. Figure 4.4.4 shows examples of priority activities. In order to achieve the above disaster risk reduction targets, it is essential to strengthen the buildings first of all. It is important to newly build buildings with high seismic resistance as well as the seismic retrofitting of existing buildings. There are more than 400,000 buildings in the whole of Kathmandu Valley and this will contribute greatly to achieve the target. Therefore, based on the risk assessment results, the JICA Project Team estimated the cost of seismic retrofitting for Lalitpur Metropolitan City as an example. The economic loss due to damage to the buildings that were included in the risk assessment which was implemented in this project is the total of the restoration cost in each damage grade. If it is assumed that the seismic retrofitting of buildings can be made at 20% of this restoration cost, the cost of seismic retrofitting of existing buildings in Lalitpur Metropolitan City is estimated as shown in Table 4.4.4 and the cost is about 11 billion NPR. The annual budget of Lalitpur Metropolitan City (2016 - 2017) is about 1.08 billion NPR and seismic retrofitting cost is more than 10 times that. Therefore, in order to promote the strengthening of the buildings and to achieve the disaster risk reduction targets, not only financial support is necessary by the provincial and national government for seismic retrofitting, but also technical support is important so that the citizens understand the importance of the strengthening of buildings and promote seismic retrofitting on their own.

Table 4.4.4 Estimated cost of seismic retrofitting for buildings (Lalitpur Metropolitan City)

		Building Damage	Economic Loss (million NPR)	Estimated cost of seismic retrofitting (million NPR)
Total number of buildings (52,821)	Heavy	9,603 (18.2%)	57,335	11,471
	Moderate	6,277 (11.9%)		
	Slight	9,322 (17.6%)		

Source: JICA Project Team

(4) Finalization of the plan

LDCRP of pilot municipalities were finalized by including the suggestions from the municipality, and participants of the workshops.

Source: JICA Project Team

Figure 4.4.5 Cover page of LDCRP (Lalitpur Metropolitan City)

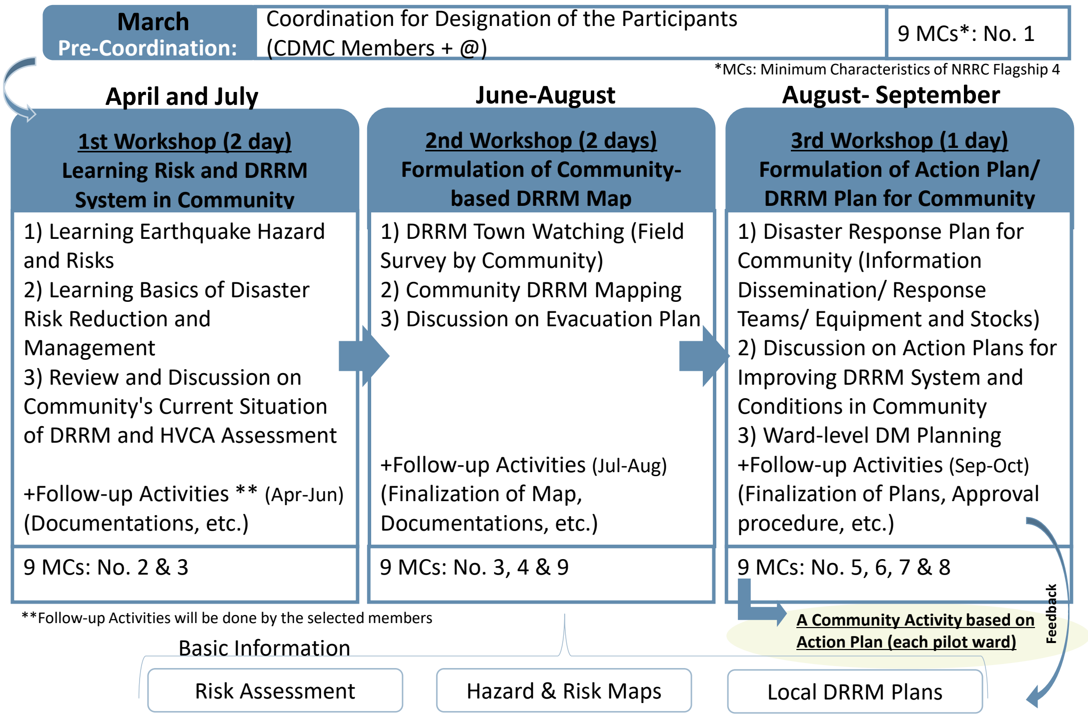
4.5 CBDRRM Activities

4.5.1 Outline of the Pilot CBDRRM Activities

Considering the importance of the promotion of the community DRRM activities for achieving the targets of the Sendai Framework, and as one of the proposed activities in the BBB Reconstruction Plans in the pilot municipalities, community DRRM activities were conducted in a selected pilot ward in each of the three pilot municipalities.

The flow of the activities was designed in consideration of the "Nine Minimum Characteristics of a disaster resilient community in Nepal", proposed by the Flagship 4 of the Nepal Risk Reduction Consortium (NRRC) which has been led by MoFALD to promote the CBDRRM activities, and is based on the result of the community baseline survey conducted by the Project. Further, for ensuring the sustainable CBDRRM activities, enhancement of the capacities of the municipality officers on implementation of the CBDRRM activities was considered in the process of the implementation of the activities.

Before the community activities in the pilot wards, a 3-day training program was provided for the municipality officers so that they could understand the contents of the CBDRRM activities. Then, with the active involvement of the municipality officers, the activities in the community were conducted as described in the Figure 4.5.1.



Source: JICA Project Team

Figure 4.5.1 Basic Contents and Flow of the Pilot Activities

4.5.2 Results of the Pilot CBDRRM Activities

In the 1st workshops, the participants of the pilot wards learned their own disaster risks and DRRM system in the community through interactive lectures and participatory discussions, including hazard, vulnerability, and capacity assessment activities (HVCA). The experience of the Gorkha Earthquake made the participants more active in the discussions and led to better understanding and identification of their own disaster risks.

In the 2nd workshops, the participants specifically identified their issues and problems in DRR through field surveys and DRR mapping, as well as utilizing the result of the HVCA discussions. Also, they drafted the DRM plan of the community referring to the "Local Disaster Risk Management Planning (LDRMP) Guideline, 2011."

Through the discussions in the 3rd workshops, the participants reviewed the draft DRM plans and DRR carte compiled based on the result of the 1st and 2nd workshops. Further, they discussed the priority activities in the DRM plans and chose one of the activities to be implemented with the budgetary support by the Project. The DRM plan and DRR carte in each ward were finalized by some follow-up meetings after the workshops.

Implementation of the selected priority activities was realized in December 2017 in each pilot ward. All of the pilot wards chose the stockpiling of emergency management tools and equipment in the community as the activity. A program for the handover of the final outcomes of the Project activities, and the DRM tools and equipment with the orientation was conducted and all the community activities in the Project were completed.

HVCA Discussion in the 1st Workshop

Field Survey in the 2nd Workshop

DRR Mapping in the 2nd Workshop

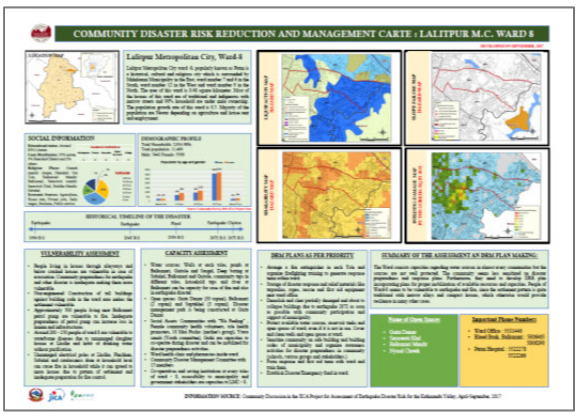
HVCA Discussion in the 1st Workshop

Orientation of DRM Tools in the final Workshop

Handover of the Project Outcomes and DRM Tools

Source: JICA Project Team

Figure 4.5.2 Pictures of the Workshops



Source: JICA Project Team

Figure 4.5.3 DRR Carte (front page) and DRR Map of Ward 8 of the Lalitpur MC

4.5.3 Lessons Learned from the Pilot CBDRRM Activities

From the experience of the pilot activities, the following points were identified to be necessary and important for the effective and successful implementation of the activities.

- Update and promote the guideline for the CBDRRM activities, such as “Minimum Characteristics of a Disaster Resilient Community in Nepal” proposed by the NRRC Flagship 4
- Sound understanding and active involvement of the representatives of the wards about the CBDRRM activities
- Consideration of the promotion of the collaboration between the existing community groups and the CDMC
- Securing budget for the involvement of the NGOs or other organizations for the support of the implementation of the CBDRRM activities
- Further consideration of the timing and venue for the involvement of the wider sectors in the community in the CBDRRM activities
- Attention to the management situation for better coordination of the utilization of parks as “Open Spaces” for evacuation and response activities for disasters.

4.6 Recommendations for Future Disaster Risk Reduction and Management Activities in the Municipal Level and Nationwide Dissemination of Pilot Activities

(1) Recommendations for Future Disaster Risk Reduction and Management Activities in the Municipal Level

Through the implementation of the pilot activities in the target municipalities and wards, the issues and challenges for conducting the DRRM activities were identified. Based on those issues and challenges, the following are the recommendations for future disaster risk reduction and management activities in the municipalities

- The number of the municipality officers in charge of DRRM is limited and it is difficult for them to be involved in each and every step of the DRRM activities. By enactment of the Constitution in 2015, and Disaster Risk Reduction and Management Act and Local Government Operation Act in 2017, many DRRM activities now fall under the municipalities’ responsibilities. Thus, it is necessary to increase the number of staff in charge of DRRM activities. Before then, it is crucial to establish a section or department related to DRRM in the municipalities.

  As a role of a section or department related to DRRM, it is necessary to promote the matters stipulated in the Disaster Risk Reduction and Management Act, and its work includes many things. Therefore, it is important to increase the number of staff in charge of DRRM, and for reference, Table 4.6.1 shows the number of staff in charge of DRRM by population scale in municipalities in Japan. Considering the population of the pilot municipalities of 50,000 to 300,000 scales, in Japan, 5 to 10 staff are engaged in DRRM. However, in the pilot municipalities, currently only a few staffs are engaged. In addition, in Japan, as an example, Kuroshio Town in Kochi Prefecture, all staffs are responsible for parts of DRRM with several different duties, and with reference to this information regarding Japan, it is important to promote strengthening of the DRRM system at the municipal level.

Table 4.6.1 Current situation of staffs in charge of DRRM of municipalities in Japan

Population scale of municipality	Number of staff in charge of DRRM/municipality (Average)	Total Number of staff of general administration work (including DRRM)/municipality (Average)	Ratio of staff in charge of DRRM to total number of staff of general administration work (Average)
Less than 50,000	1.66	131.87	1.26%
50,000 – 100,000	5.15	387.27	1.33%
100,000 – 150,000	7.08	602.11	1.18%
150,000 – 200,000	8.98	841.34	1.07%
200,000 – 300,000	11.29	1,207.44	0.93%
300,000 – 500,000	14.14	1,791.90	0.79%
500,000 – 1,000,000	22.33	3,098.75	0.72%
More than 1,000,000	41.27	8,273.36	0.50%
Total Average	(Ratio of Number of staff of general administration work in Population):0.53%)		1.00%

Source: Ministry of Internal Affairs and Communications, Japan, edited by JICA Project Team

- The capability of the municipalities to implement the DRRM measures is low, shortage of budget being one of the contributing factors. Thus, allocation of the regular budget for the DRRM activities in the municipality should now be reconsidered. On the other hand, the Government of Nepal is now preparing the National Strategic Action Plan for Disaster Risk Reduction 2017-2030, which clearly mentions "Ensure annual budgetary allocation for risk reduction to be at least 5% of all development sectors". It is strongly expected that this plan will be approved as stipulated above and that the budget will be appropriately allocated to the municipal level.
- At present, DRRM related organizations, at each government level, are undergoing many changes such as the establishment of the National Disaster Risk Reduction and Management Authority, establishment of provincial governments, replacement of DDC by the District Coordination Committee (DCC). In this manner, it is imperative for the municipalities to confirm the latest situation of institutional structure on the national and provincial level sequentially, and to coordinate and collaborate with each of those levels of government along with the confirmation of DRRM measures planned by national and provincial governments in consideration of the residual risks.

- To ensure the budget and to prioritize DRRM in the policy of municipalities toward resilience, it is essential to mainstream and prioritize the LDCRP to periodic and annual development processes. This has been clearly mentioned in the budget formulation and allocation processes in the Local Government Operation Act enacted in 2017. For synchronization of the LDCRP and periodic, annual plans, the timing of formulation of LDCRP should be properly considered.
- The regular monitoring and evaluation can reflect the progress of the implementation as well as issues observed during the process. The LDCRP guideline requires the establishment of the monitoring and evaluation sub-committee in a municipality. Furthermore, the plans which were developed in this project, LDCRP, SOP, Community DRM Plan, need to be reviewed and updated periodically as the social conditions, organizational structure and necessity of activities, etc. change with time.
- There are no regular opportunities for the training of municipality officers to learn CBDRRM activities as well as the DRRM aspects. Therefore, the activities are left entirely up to the NGOs and other organizations who implement such kind of activities. More training programs, preferably regular training opportunities should be considered for enhancing their awareness on the importance of the CBDRRM and strengthening their capacities to understand and manage the CBDRRM activities.
- Restructuring of the local administration and the change of the boundaries of the wards can greatly affect the sustainability of the activities. Hence, stability of the local governance is also one of the important facts for the sustainable CBDRRM activities.

(2) Nationwide Dissemination of Pilot Activities

The outcomes of this project can be utilized for nationwide dissemination of pilot activities to all other municipalities in Nepal. The measures of utilization of nationwide dissemination of pilot activities including formulation of LDCRP are summarized as follows.

1) Nationwide dissemination of pilot activities

All outcomes developed through the pilot activities can be utilized for other municipalities as follows. Mainly the outcomes can be utilized as a model and sample for the other municipalities.

Table 4.6.2 Measures for utilization of outcomes of pilot activities to other municipalities

Outcomes	Target level	Measures for utilization to other municipalities
BBB Recovery and Reconstruction Plan	Municipality	Utilize as a model and sample plan, and contents, overall structure and action list can be referred toward BBB through integrating disaster risk reduction measures.
SOP	Municipality	Utilize as a model and prototype since SOP has not been developed at the municipal level in Nepal
TG LDCRP	Municipality	Described in 2)

Outcomes		Target level	Measures for utilization to other municipalities
LDCRP		Municipality	Described in 2)
Outcomes of CBDRRM Activities			
	Community DRM Plan	Ward	Utilize as a model and sample plan
	DRR map and DRR carte	Ward	Contents can be utilized as a sample

Source: JICA Project Team

2) Nationwide dissemination for formulation of LDCRP

For LDCRP, this project developed the TG LDCRP for all the local governments in Nepal and LDCRP for the pilot municipalities. LDCRP developed in this project includes the local disaster risk reduction strategy. One of the global targets of the Sendai Framework is "Substantially increase the number of countries with national and local disaster risk reduction strategy by 2020" (global target (e)). Therefore the outcomes for LDCRP in this project contribute in achieving targets of the Sendai Framework, and the JICA Project Team recommends nationwide dissemination of the system and the framework in order to promote understanding of the LDCRP and its methodology. As per that concept, the measures of nationwide dissemination for formulation of LDCRP have been summarized in the following section. It is divided into two types, utilization of TG LDCRP and utilization of LDCRP as a model plan.

- Utilization of TG LDCRP

  The LDCRP has a broad scope as a comprehensive master plan for disaster risk reduction and management with the consideration of climate resilience, and it might be difficult for the municipal officials to formulate it on their own. Therefore, TG LDCRP was developed in this project so that it could be circulated to all local levels of Nepal. TG LDCRP helps to formulate a practical and effective LDCRP easily at the local level such as municipality. It is a supporting manual aiming to give guidance, and is to be utilized as a reference document so that the local level can understand its detail contents, formulation procedures, examples of descriptions and notes to be considered.

- Utilization of LDCRP as a model plan

  The three pilot municipalities were selected based on their regional characteristics and the target disasters in each municipality are different. If other municipalities have similar characteristics to one of the pilot municipalities, it is possible for them to refer to the plan formulated by this project as a model plan and formulate their own plan. In addition, LDCRPs of pilot municipalities are based on the hazard and risk assessment in this project. Since disaster risk management plans that exist so far have not been formulated by considering the results of hazard and risk assessment, LDCRP formulated in this project with TG LDCRP act as a model plan in order to set the numerical disaster risk reduction target to be achieved for the resilience. It thus helps to promote the plan formulation processes in accordance with the understanding of disaster risks by hazard and risk assessment.

- Required system and cost estimation for nationwide dissemination

  Utilizing the outcomes formulated in this project, the required system and cost estimation to disseminate this information to all local levels in Nepal for formulation of LDCRP. First of all, involvement of MoFALD is indispensable for nationwide dissemination. MoFALD is currently revising the Local Disaster Risk Management Planning (LDRMP) Guideline as the LDCRP Guideline, and in this project, TG LDCRP were formulated in accordance with the contents of the revised guideline. That is, MoFALD has a responsibility to promote the formulation of LDCRP to local level entities by utilizing the guidelines. In addition, the TG LDCRP was formulated while discussing with MoFALD. Thus, officials of MoFALD are familiar with the contents, and as the main counterpart of this project, they understand the importance of formulating an LDCRP based on the hazard and risk assessment implemented in this project. For this reason, it is required that MoFALD (or another Organization with the function of MoFALD after restructuring of the Ministries) continues to disseminate the LDCRP guideline with TG LDCRP widely such as by holding seminars and other events for municipalities.

  Also, each municipality has responsibility for actual formulation of the plan. Required duration and cost for formulation of the plan are estimated as shown in Table 4.6.3. Approximately 3 million NPR per municipality are estimated for total costs such as expenses of staff personnel, holding workshops, printing, etc. If the budget can be secured, the utilization of resources such as NGOs or consulting companies is realistically conceivable. Since it is very difficult to promote the formulation in all municipalities in parallel, in order to promote the plan formulation more effectively in consideration of the effects of disaster risk reduction for the whole of Nepal, it is desired that the plan is formulated for large cities preferentially.

Table 4.6.3 Estimated cost and duration for nationwide dissemination of formulation of LDCRP

	Unit cost and duration /municipality	Total cost and duration for 753 municipalities	Remarks
Duration	1 year	5 years	Assumption: 150 municipalities / year
Cost	3,000,000 NPR	2,250,000,000 NPR	

Source: JICA Project Team

Chapter 5 Contribution to Sendai Framework for Disaster Risk Reduction and Recommendations for achieving Disaster Risk Reduction

This project, aiming at earthquake disaster risk reduction, which was started immediately after the Gorkha earthquake, has achieved all of its goals for seismic hazard assessment, seismic risk assessment and formulation of BBB plans, LDCRP and SOP for three pilot municipalities, and implementation of CBDRRM activities, which contributed considerably to the commitment of Nepal on the enhancement of DRR and the response to the priority for action and global target of the Sendai Framework for Disaster Risk Reduction (Sendai Framework). It must be understood that the seismic hazard and risk assessment are carried out based on limited data and recognize that there is a long way to go to implement the LDCRP developed by the project. The further actions for mainstreaming seismic disaster risk reduction must be implemented in a planned manner.

As a conclusion of the project, this chapter covers contribution of the project to the Sendai Framework and recommendations to achieve disaster risk reduction and increase resilience in Kathmandu Valley. And last, a roadmap is proposed for the purpose of concrete disaster risk reduction. It is highly expected that all of the project outcomes could be widely utilized by a variety of stakeholders and contribute to disaster risk reduction in Nepal.

5.1 Contribution for Achievement of the target of the Sendai Framework

Disaster risk management has been greatly promoted and enhanced globally after the adoption of the Hyogo Framework for Action (HFA) in the Second World Conference on Disaster Risk Reduction in 2005. Steady progress was achieved by a variety of activities including development of laws, establishment of DRR organizations, strengthening of collaboration among organizations and regions, capacity development of DRRM related organizations, and non-structural activities for reducing vulnerability. On the other hand, the common issues are the activities which directly reduce the risk are comparatively limited due to the lack of budget and knowledge.

The Sendai Framework for Disaster Risk Reduction was adopted in the Third World Conference on Disaster Risk Reduction in 2015, where the development of a sustainable society with the mainstreaming of DRRM was emphasized. In order to concretely reduce natural disaster risk, the Sendai Framework advocates four priorities for action and sets seven global targets.

The Gorkha Earthquake is the first devastating disaster after adoption of the Sendai Framework. The achievement of BBB reconstruction, one of the priorities for action of the Sendai Framework, attracts global attention. This project, through its diverse activities, contributed to the achievement of the priorities for action and global targets of the Sendai Framework.

Disaster awareness in Nepal has been raised through the experience of the Gorkha Earthquake and a series of activities after the quake for recovery and reconstruction. However, the level of awareness will lower over time. Now, the time when many people have just experienced a real disaster, is the chance to further enhance mainstreaming DRRM into development. It is expected for Nepal to utilize this chance and implement the DRRM activities for reducing future risks.

The experience of risk assessment and development of DRRM plan in this project needs to be utilized for concrete DRRM activities. From the view of disaster prevention, the investment for reducing disaster risk should be implemented step by step together with economic development.

5.2 Recommendations on Utilization of Risk Assessment Results

From the risk assessment, the following risks and vulnerabilities of KV are observed.

- ✧ Future earthquakes may cause greater structural damage for buildings, infrastructure and lifeline facilities, and human casualties as well as economic loss than the Gorkha Earthquake.
- ✧ After the Gorkha Earthquake, the reconstruction of damaged buildings is required to follow Nepal Building Code to avoid reproducing the same vulnerability. In the meantime, many of the existing structures are seismically vulnerable, including the critical facilities like schools, hospitals, government buildings and infrastructure and lifeline facilities, which need to be seismically strengthened.
- ✧ Urbanization of KV will go on and population and the number of buildings will increase in the future. In the case of inadequate countermeasures for land use regulation, urban planning and seismic strengthening for buildings, the damage will be enlarged along with the increase of vulnerable buildings and population.
- ✧ To reduce the vulnerability of buildings, it is important not only to require the new buildings to follow the building code, but also to promote the retrofitting and reconstruction of existing vulnerable buildings. Besides, it is also important to update the building code and enhance research on building materials and construction technology.

Risk assessment results give a warning on the possible future damage. In order to reduce future earthquake disaster, it is important for both central and local governments to make their necessary policies and establish a concrete implementation mechanism. A long term continuous effort is indispensable. Disaster risk reduction targets should be determined based on the seismic assessment results taking into account the available resources and budget. To reach the target, it is necessary to make central and local disaster risk management plans including feasible measures and detail activities. It is urgently needed to launch the seismic strengthening program for buildings, infrastructure and lifeline facilities with priority on the critical facilities, such as schools, hospitals, and government buildings as well as bridges. The recommendations for utilizing the risk assessment results for disaster risk reduction are as below.

- Design ground motion is not clearly specified in Nepal building code and it is estimated around 160 gal. The scenario ground motion (PGA) of CNS-1 is about 150 – 200 gal for the central part of KV, which is close to the design ground motion and could be considered appropriate as the baseline for disaster risk management of local governments. For important buildings, like schools, hospitals, etc. an importance factor of 1.5 is specified in the building code. Since scenario ground motion of CNS-2 is about 1.5 times that of CNS-1, it can be the risk management target for important structures.
- For scenario ground motion of CNS-1, it was estimated more than 65,000 buildings (about 15% of total buildings) will suffer heavy damage in KV. In order to reduce the risk, countermeasures for both new and existing buildings are necessary. It is important to raise public awareness on risk reduction and promote retrofitting through legal arrangement, technology development and securing budget.
- Risk assessment of this project is based on a statistical approach, which is effective for knowing total damage and providing information for relative risks among areas, but not the detail information for individual buildings. For the purpose of retrofitting or reconstruction of an individual critical structure, detail investigation on its seismic performance is necessary.
- It is important to make use of the risk assessment results of critical buildings for promotion of seismic strengthening. Taking school buildings as an example, see following table, 62 buildings have an 80% probability of heavy damage, which accounts for about 1% of all school buildings and those with 50% probability of heavy damage totals 750 buildings, accounting for about 13%. The buildings with high damage probability are mostly adobe or masonry. They should be given the priority for reconstruction, rather than retrofitting, especially for adobe and masonry with mud mortar and those that are more than 20 years old. The cost for reconstruction is

estimated and shown in the table. It is assumed that all the reconstructions are engineered RC with the area of 1,000 square meters or more. It is necessary for MoUD and MoE to develop a retrofitting and reconstruction program for public schools and promotion on seismic strengthening of private school buildings.

Structure type	Heavy damage and reconstruction cost			
	(Probability > 50%)		(Probability > 80%)	
	Number	Cost (mil. NPR)	Number	Cost (mil. NPR)
Adobe	9	318	8	282
BM with mud mortar, > 20 years	288	10,166	48	1,694
BM with mud mortar, < 20 years	103	3,636	5	177
BM with cement mortar	301	10,625	1	35
Non-engineered RC	46	1,624	0	0
Engineered RC	3	106	0	0
Total	750	26,475	62	2,189

- A number of schools, hospitals and government buildings were estimated to suffer heavy damage for the scenario earthquakes. The safety of this kind of building, which is important not only for securing emergency response but also for saving lives of children and patients, should have high priority in seismic strengthening policy. The development of retrofitting technology with local available building materials and technology is important.

- Risk assessment results were used for the development of disaster risk reduction and management plans and community risk reduction activities of the pilot municipalities. Since the risk assessment covers the whole KV, it can also be used, as horizontal expansion of the pilot activities, for the municipalities other than the pilot municipalities in KV for the same purpose. The commitment of MoFALD is required and an early implementation is expected.

- The results of risk assessment for 2016 and several cases for 2030 provide useful information for setup of numerical targets of disaster risk reduction based on the time span and budget, etc. The risk assessment results are expected for the effective utilization for the development of policy with feasible numerical targets.

- From the risk assessment results, relative risk level among areas, facilities and individual structures can be identified, which could be used for determination of the priority for risk reduction and management among many necessities but limited resources, which is one of the purposes of risk assessment.

- Historical buildings (monuments) are essential resources of the tourism industry. Their damage due to earthquake should be minimized. To reduce the damage, Structural Health Monitoring (SHM) on a regular basis is recommended for the maintenance of the historical buildings (monuments). Since natural materials are used in the historical buildings, the influence of the deterioration of timber and joint mortar due to rainwater is significant. It is important to repair and replace timber and roof tiles if the deterioration is observed by a visual inspection. It is also necessary to make an integrated maintenance and management plan and secure its implementation.

- Bridges in KV did not suffer serious damage during the 2015 Gorkha Earthquake, but more devastating damage, such as bridge collapse, might occur when subjected to large ground motion, as estimated in this project. The damage to bridges will cause difficulty for emergency vehicles, which could affect the emergency response activities and lead to damage increase. In order to avoid such kind of situation, it is very important to implement earthquake-resistant reinforcement or replacement for bridges on emergency transportation roads.
- It is difficult to completely prevent damage from an earthquake. The early resumption of urban functions would be critical for the recovery and reconstruction activities. It is recommended for both public and private entities to make a business continuity plan (BCP) based on the risk assessment results for the rapid resumption of social and industrial activities after a disaster.

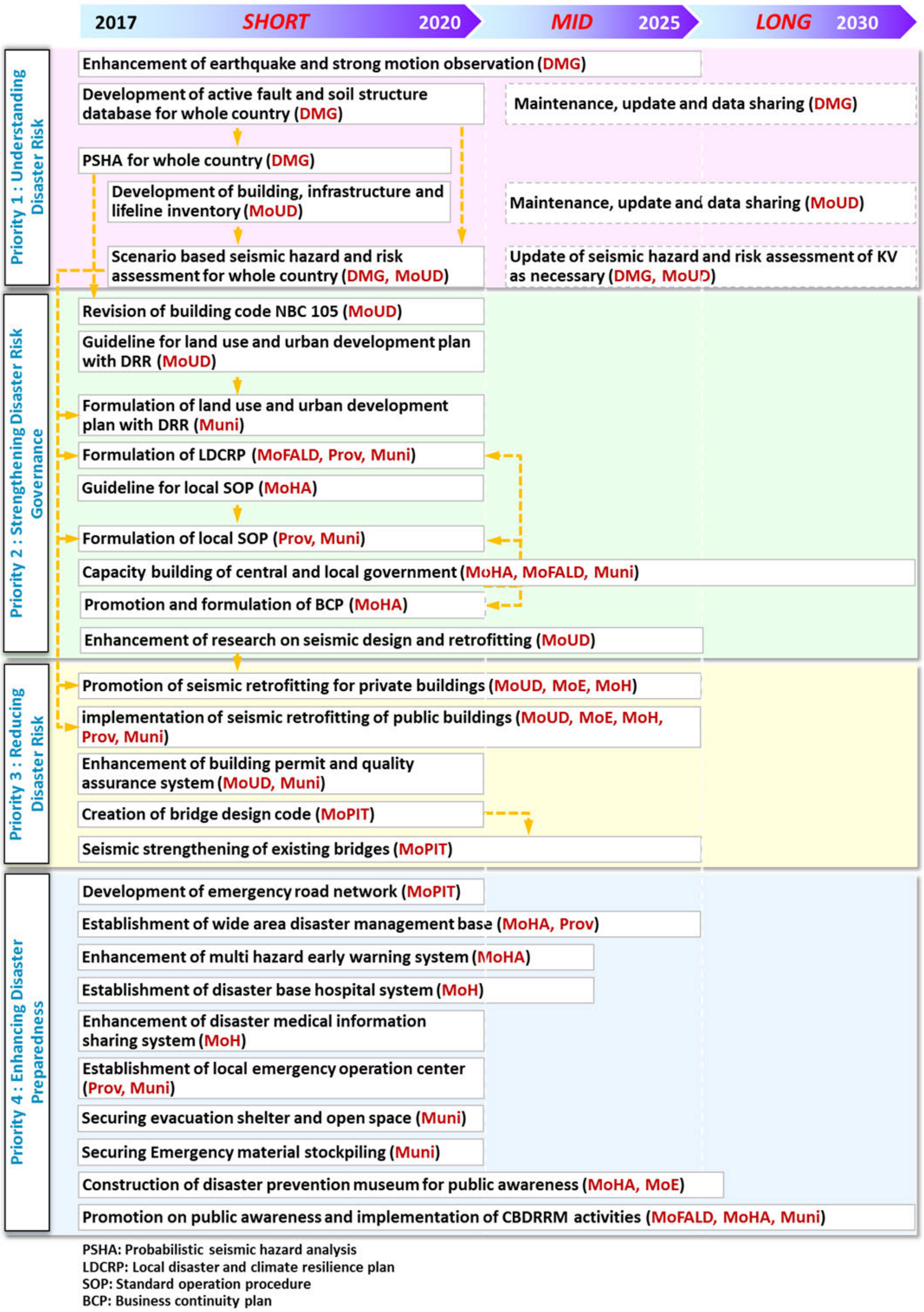
- The purpose of seismic hazard and risk assessment of this project is to provide basic information for the formulation of LDCRP and CBDRRM activities for Kathmandu valley. Seismic hazard assessment was carried out by scenario oriented method rather than stochastic method, which is commonly used to decide seismic load for seismic design. Hence the seismic hazard assessment results of this project could not be directly used for the revision of seismic design code: NBC 105. However, the output of the project, such as seismicity analysis during the determination of scenario earthquake, soil structure and amplification characteristics of KV as well as the seismic performance capacity analysis of buildings, may be referred for the revision of NBC 105.

5.3 Recommendations for Mainstreaming Seismic Disaster Risk Reduction

Nepal is an earthquake prone country, and has suffered several earthquake disasters in the past century, such as the 1934 Bihar Earthquake and the 2015 Gorkha Earthquake. This project focuses on seismic disaster risk reduction from seismic hazard and risk assessment for the formulation of disaster risk management plans and standard operation procedures for emergency response as well as community based disaster risk reduction and management activities. Nepal has recently enacted the Bill for Revision and Unifying Law Related to Disaster Risk Reduction and Management, called the Disaster Risk Reduction and Management Act, 2017, formulated the National Strategic Action Plan for Disaster Risk Reduction: 2017 – 2030 and published Seismic Retrofitting Guidelines for Buildings in Nepal: Adobe, Masonry and RCC for enhancing disaster risk reduction. On the other hand, risk reduction needs a broad range policy for structural and non-structural measures and the implementation is a pressing issue. The effective implementation of disaster risk reduction policy requires the cross sectoral cooperation and collaboration at all levels of central, and local government and private enterprise as well as individual citizens. It is also necessary to have an integrated scheme for effective and efficient implementation according to the priority and limited budget and manpower.

Referring to the priorities for action and the global targets of the Sendai Framework, the current situation of Nepal and the issues and challenges recognized through the implementation of this project, a road map for further enhancement of seismic risk reduction has been created and is shown in Figure 5.3.1

It is important to secure an organizational system for the concrete implementation of the recommendations. A leader agency to manage cross sectoral measures is necessary and the leadership of MoHA is highly expected based on the new Disaster Risk Reduction and Management Act. There is great variability of necessary cost among the recommendations depending mainly on whether it is a structural or non-structural measure. The development of guidelines and plans, requiring a relatively small amount of budget from several to several tens of million Nepal Rupee, should be created promptly, which is important for effectively promoting disaster risk reduction. While structural measures could directly reduce seismic risk, a large budget is needed. It is necessary to apply structural measures with priority to the structures of special importance, such as schools, hospitals, government buildings, bridges on emergency road networks and airports, etc. Seismic risk assessment results could be utilized for the determination of priority. The effect of disaster risk reduction measures doesn’t clearly appear if no earthquake occurs, but the severe consequences of an earthquake, if one occurs, could cause great negative impacts on the sustainable development. The money used for disaster risk reduction should be considered as an investment, rather than simply expenditure. The results of this project could play an important role to encourage disaster risk reduction investment.



Source: JICA Project Team

Figure 5.3.1 Roadmap for seismic disaster risk reduction