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Prediction of Economic Consequences of Earthquake Based on Its Past Occurrence Data

Prince Poddar, Kanhaiya Lal Pandey, Amit Singh, Sauhardra Ojha*

Department of Civil Engineering, IET, Dr. Rammanohar Lohia Avadh University Ayodhya, U.P, India

ABSTRACT: Earthquake is very catastrophic disaster and cannot be predicted hence prior preparation is necessary. Based on the previous data related to loss occurred during earthquake will help in revising the policies and building standard for minimizing the economic loss due to seismic activity across the countries around the globe. In this study, Impact of earthquake on infrastructure sector (in terms of loss % in GDP) will be studied by reviewing previous four major earthquakes—Chamoli Earthquake (29 March 1999) Magnitude: 6.6, Kashmir Earthquake (8 Oct 2005) Magnitude: 7.6, Nepal Earthquake (25 April 2015) Magnitude: 7.8, and Gujarat Earthquake (26 Jan 2001) Magnitude: 6.9. From these four major earthquakes, the loss % in GDP due to effect of earthquake on infrastructure sector will be evaluated and the average % of this GDP loss will be obtained. By keeping the average % GDP loss constant and intensity of earthquake constant, the estimated loss in infrastructure sector will be obtained in present time.

KEYWORDS: Earthquake, GDP, Infrastructure Loss, Chamoli Earthquake, Kashmir Earthquake, Nepal Earthquake

I. INTRODUCTION

An Earthquake is shaking of ground results sudden release of energy and creates surface waves. It cause when two blocks suddenly slips on one another results to the formation of faults. The point below earth surface where earthquake starts is called hypocenter and just above the point on ground is called epicenter. An effect of earthquake depends on several factor such as distance from epicenter, amplitude, frequency etc. Earthquake results shaking of ground, liquefaction of soil, impact on human properties, landslides, Tsunamis etc. and these results cause lots of infrastructural and lives loss. Estimating the loss from the earthquake is important for revising policies and drawing up requirements for assistance both for within and outside India. Various types of losses that can be distinguished are: casualties, number of homeless, impairment of functionality of essential facilities, and loss of output. Most earthquake-caused deaths and injuries are result from damaged buildings. This is why the loss from an earthquake depends on the density of buildings in the affected zone as well as their structural and nonstructural problems. Given all the limitations of the data, firm estimates of losses from the recent quake will take time to compile. This paper is an attempt to estimate the economic impact of the earthquake. While it is recognized that the earthquake had an adverse impact on the cultural environment of the affected districts, state, and country in general, the focus is on the economic impact. The economic impact of an earthquake or any natural disaster can be classified as: (i) losses to immovable assets, (ii) losses to movable assets (iii) economic losses due to business interruption, (iv) public sector economic costs, and (v) household income losses due to death, injury, and job disruption. The first impact consists of the direct economic losses due to destroyed or severely damaged buildings and other structures (such as power substations). Losses to movable assets consist of economic losses due to damaged or destroyed contents of buildings and other private property. Public sector economic costs occur because of loss of revenues and increases in expenses for the public sector. According to Swathi and Venketramana, majority of damage occurred in stone or brick masonry in building in case study of Nepal earthquake occurred in 2015 and total infrastructural loss is 2-2.7 billion whereas overall loss is approx. 3 billion. Case study conducted by Bahram & Paradise on Kashmir earthquake 2005 had founded that about 600000 houses, 6000 to 7000 school and 700 hospitals were destroyed due to which 4 million people were homeless. The economic losses due to earthquake were; housing damage US\$1.03 billion; reconstruction US\$1.55 billion; agriculture livestock and irrigation US\$223 million; transport US\$340 million; education US\$335 million; health US\$120 million; water supply US\$20 million, governance and institution US\$50 million. A micro earthquake survey in the Sikkim Himalaya by Reena and Kayal, raised a question whether the north south segment of the Main Central Thrust (MCT) in the part of the Himalaya is seismically active. Fault - plane solution of a cluster of events occurred below this segment of the MCT shows right - lateral strike - slip motion. The seismic observations and the geological evidences suggest that a NNE -



SSW trending strike - slip fault, beneath this segment, caused right lateral movement on the MCT, and is seismically active. The entire area of Sikkim lies in Zone IV of the Seismic Zonation Map of India (Chakraborty et al., 2011). The seismic Zone IV is broadly associated with seismic intensity. The event that falls under the category of severe earthquake was also reported to be widely felt in Sikkim, Assam, Meghalaya, and northern parts of West Bengal, Bihar, parts of other eastern and northern regions of India. The epicenter lies in a seismically known and active belt called Alpine-Himalayan Seismic Belt.

II. MATERIALS & METHODS

In this study, impact of earthquake on GDP (in terms of loss % in GDP) will be studied by reviewing previous four major earthquakes namely Chamoli Earthquake (29 March 1999) Magnitude: 6.6; Kashmir Earthquake (8 Oct 2005) Magnitude: 7.6; Nepal Earthquake (25 April 2015) Magnitude: 7.8 and Gujarat Earthquake (26 Jan 2001) Magnitude: 6.9. From these four major earthquakes, the percentage loss in GDP due to effect of earthquake is evaluated and the average percentage change in GDP per decade is obtained. By keeping the average percentage GDP change constant and intensity of earthquake constant, the impact of earthquake in these regions are obtained for future 5 decades. Chen et al. (1997) found that estimated economic loss for a given area can be determined from the following relationship:

$$L = \sum P(I) \times F(I, GDP) \times GDP$$

Where L is the economic loss, P(I) is the probability of an earthquake of intensity I, and F(I,GDP) is a measure of the area’s vulnerability to earthquake damage for the given GDP value and the earthquake of intensity I. The GDP is used as a macroeconomic indicator to represent the total exposure of an area in the earthquake loss estimation. In this study, the P(I) is determined from the GSHAP data, the computed GDP of an area is determined from GDP and population density, and F(I,GDP) is determined from the relationship between reported losses from earthquakes to the computed GDP of the affected zone. Chen et al. (1997) found a strong correlation between GDP and population density for the States in the United States and the Provinces in China. The GDP of an individual unit can be determined according to the following relationship:

$$GDP \text{ per unit area} = (GDP \text{ of region}) \times \frac{(\text{population in unit area})}{(\text{regional population})}$$

Table- 1: Disaster Effects in Nepal Earthquake in NPR million(NPC Nepal; 2015)

	Disaster Effects (NPR million)
Social sector	408625
Housing and Human settlements	21242
Health	8695
Education	3349
Cultural Heritage	22118
Productive sector	178121
Agriculture	28366
Irrigation	383
Commerce	16953
Industry	19271
Tourism	81242
Finance	31905
Infrastructure sector	66783



Electricity	21242
Communications	8695
Community Infrastructre	3349
Transport	22118
Water and Sanitation	11379
Cross cutting issues	52933
Governance	18575
Disaster Risk Reduction	155
Environment and Forestry	32267
Total	706462
	7065 million USD

Table-2: Disaster Effects in Gujarat Earthquake in Crore Rs(Lahiri et al., 2001)

	LOSSES (IN CRORE RS.)
SOCIAL SECTOR	6,070
Housing	5,166
Health	220
Education	684
INFRASTRUCTURE SECTOR	1627
Municipal infrastructure	141
Public Buildings and Historical Monuments	340
Rural water supply and sanitation	253
Irrigation	286
Power	137
Transport	321
Ports	98
Telecommunications	51
PRODUCTIVE SECTORS	2047
Agriculture	545
Industry	340
Trade and Commerce	1162
ENVIRONMENT	256
TOTAL	10,000

III. RESULTS AND DISCUSSION

In table 3, we can see the annual average GDP growth per year for three countries Nepal, India and Pakistan because the 4 major earthquakes which are taken into this study is from these three countries only. These annual average GDP growth per year values are calculated with the help of previous 30 years GDP data (1991 – 2020) from World bank.



Table 3. Annual Average GDP growth per year

Country Name	Country Code	Annual Avg. GDP growth per year
Nepal	NPL	4.41%
India	IND	5.79%
Pakistan	PAK	4.03%

In table 4, percentage loss in GDP is obtained based on the GDP of country in which earthquake was occurred and the loss due to that earthquake in that country is taken into account. In this study, the obtained percentage loss in GDP is treated as constant and used in forecasting loss estimation due to same earthquake intensity in future 5 decades.

Table 4. Percentage loss in GDP in four earthquakes

Earthquakes	Country	Year	GDP (in crore USD) in that year	Loss in GDP (in crore USD)	Percentage loss in GDP
Chamoli	India	1999	45882.04	7	0.015256514
Nepal	Nepal	2015	2436.08	1000	41.04955502
Gujarat	India	2001	48554.1	132.85	0.27361232
Kashmir	Pakistan	2005	12005.53	312.14	2.599968515

In table 5, we can see the GDP in crore USD for three countries. These GDP values for future 5 decades are calculated with the help of Annual Average percentage GDP growth and GDP of that country in 2020 in crore USD.

In table 6, Forecasted loss (in crore USD) in all 4 regions is calculated by keeping percentage loss in GDP as constant and by taking the forecasted GDP values for future 5 decades in these regions. The percentage loss in GDP is maximum in Nepal Earthquake is maximum but the maximum estimated loss is in India due to Gujarat Earthquake because GDP of India is more than the GDP of Nepal.

Table 5. Forecast for 3 decades as per Annual Average percentage GDP growth

Country Name	AVG % GDP GROWTH PER YEAR	GDP IN 2020 (in crore USD)	GDP IN 2021 (in crore USD)	GDP IN 2031 (in crore USD)	GDP IN 2041 (in crore USD)	GDP IN 2051 (in crore USD)	GDP IN 2061 (in crore USD)
Nepal	4.408211	3365.72	3514.088054	5409.525856	8327.33	12818.9	19733.3
India	5.788275	226200	239293.0779	420054.3517	737362	1294363	2272121
Pakistan	4.02744	26368.66	27430.64189	40711.30933	60421.9	89675.4	133092

Table 6. Forecasted Loss (in Crore USD) in all 4 regions by keeping percentage loss in GDP as constant

Earthquake	Percentage loss in GDP	2021		2031		2041		2051		2061	
		GDP (In crore USD)	Loss (in crore USD)	GDP (In crore USD)	Loss (in crore USD)	GDP (In crore USD)	Loss (in crore USD)	GDP (In crore USD)	Loss (in crore USD)	GDP (In crore USD)	Loss (in crore USD)
Chamoli	0.02	239293.08	36.51	420054.35	64.09	737362.15	112.50	1294363.31	197.47	2272121.47	346.65
Nepal	41.05	3514.09	1442.52	5409.53	2220.59	8327.33	3418.33	12818.95	5262.12	19733.26	8100.42
Gujarat	0.27	239293.08	646.09	420054.35	1134.15	737362.15	1990.88	1294363.31	3494.78	2272121.47	6134.73
Kashmir	2.60	27430.64	713.19	40711.31	1058.48	60421.87	1570.95	89675.39	2331.53	133092.13	3460.35



In Figure 1, Forecasted GDP for these three countries in crore US dollars are shown. If we take a look on this figure, we can easily understand that the GDP curve is straight i.e. its slope is constant throughout. It implies that the GDP growth per year is taken as constant.

In Figure 2, loss in crore USD is shown by keeping the percentage GDP loss as constant in the four regions. If we take a look on this figure, we can easily understand that the loss in GDP curve is straight. It implies that the GDP growth per year is taken as constant.

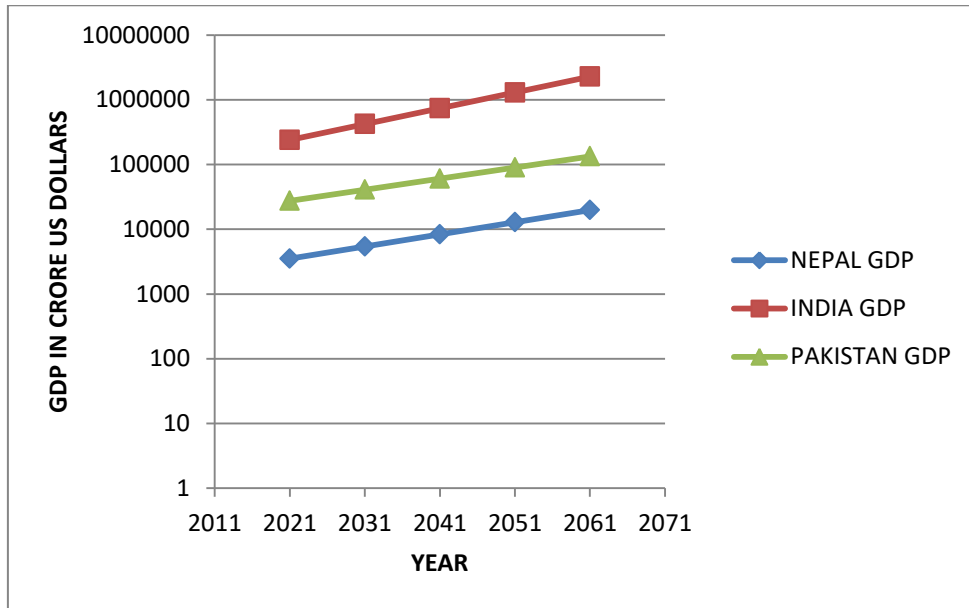


Figure 1. Forecasted GDP in crore US Dollars (Vertical axis is in log scale)

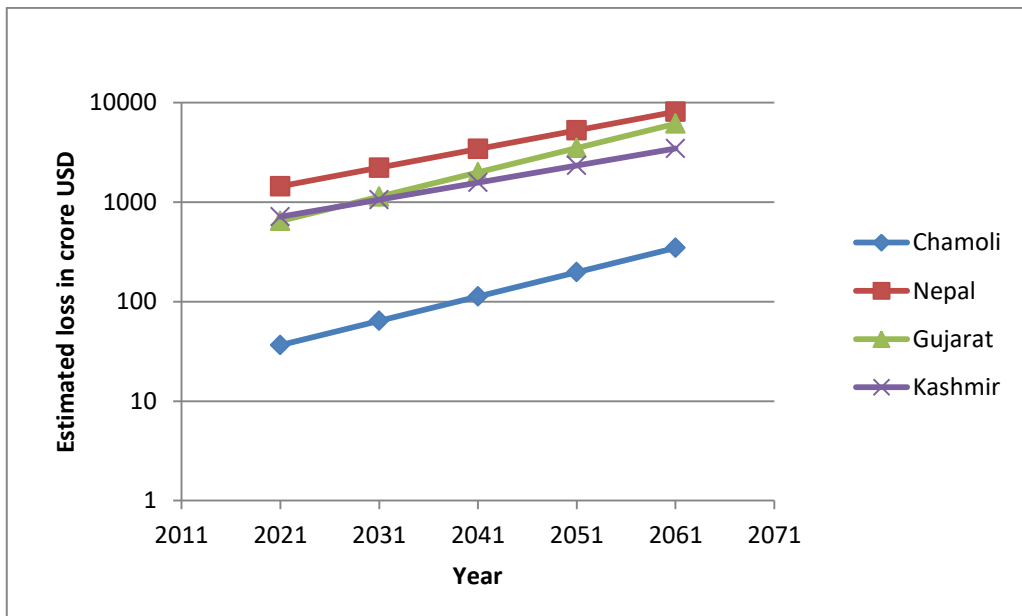


Figure 2. Estimated loss in crore US Dollars (Vertical axis is in log scale)

IV. CONCLUSION AND FUTURE SCOPE

In this study, the loss due to earthquake is calculated for future 5 decades from the data of past 4 major earthquakes. Due to gradual increase in GDP of country, the loss due to earthquake is also increasing by keeping the average annual GDP growth rate as constant and by assuming that if the same intensity of earthquake will occur in future 5 decades, it



will have same percentage GDP loss as compared to the past 4 major earthquakes. But there are vast differences in past and future decades due to various technological advancements. The finding from this study is that earthquake plays very crucial part in loss of GDP.

- The infrastructure sector should need many improvements as it is very crucial part of the economy of any country.
- Earthquake resistant buildings are the need of the hour in areas which are more prone to earthquake.
- Before construction of any infrastructure, Expected Earthquake impact should be evaluated and the infrastructure is constructed that can withstand the expected earthquake.
- The major recommendation is that in analysis of any structural construction should consider the expected seismic effect i.e. earthquake in design must be considered.

Future Scope:-

- The limitation of this study is that the percentage GDP loss due to earthquake is taken from the past data but as of now there are lots of improvements in construction sector. So in future studies, Researchers can take consideration of these improvements also to get some better results.
- The researchers, in future, can suggest some policy recommendations so as to reduce the future risk due to seismic effects.

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