# Estimation of probable financial loss occur due to future earthquakes in the Shillong Plateau

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ABSTRACT: Northeast India is a seismically active region. The region is interwoven with numerous faults which gave rise to two great earthquakes (EQs) ($M_W$≥8.0). The tectonic movements along these faults were also responsible for the formation of the Shillong Plateau (SP) in the region. The faults surrounding the SP have been the sources of several of the major EQs (MW≥7.0) and one great EQ. During these EQs, the state of Meghalaya which comprises of the SP had suffered casualties as well as moderate to severe damage to infrastructure. At several locations, intensities from VI to IX on the Rossi Forel scale were reported during the 1930 Dhubri EQ. During the 1897 Assam EQ, intensity up to X on the Rossi-Forel scale was reported close to the epicenter. Compared to the population density and the Gross State Domestic Product (GSDP) at the time of occurrence of the last major EQ, the present population as well as the GSDP of Meghalaya has increased manifolds. Thus, the occurrence of a major to great EQ in Meghalaya in present times would result in huge financial losses compared to the past. The objective of this study is to draw an estimate of the financial losses that Meghalaya may suffer, in case of occurrence of a major to great EQ in the near future.

**Keywords:** *MMI; GSDP; Shillong Plateau; financial loss estimate*

## 1. Introduction

Natural hazards have been a primary cause for loss of life and damage to property across the world. Natural hazards such as earthquakes (EQs), tsunamis, cyclones and floods have particularly left trails of destruction throughout history. According to Kellenberg and Mobarak (2011), 9800 natural disasters have occurred across the world since the year 1970. These disasters have claimed the lives of 3.7 million people and affected more than 5.8 billion people across the globe (Kellenberg and Mobarak 2011).Although these hazards are equally likely to occur in all parts of the world, developing countries like India are affected more by the occurrence of such disasters. Due to relatively low preparedness and investment towards disaster mitigation, developing nations like India are at higher risk (GAR 2015).Factors such as faster population growth, rapid industrialization and poor construction practices contribute further to vulnerability in India cities during natural disasters. According to the Centre for Research on the Epidemiology of Disasters (CRED 2004), India is one of the ten worst disaster prone countries of the world. Disasters occurring due to natural hazards have a direct impact on the economy of a nation. As per the Global Assessment Report on Disaster Risk Reduction (GAR, 2015) throughout the world economic losses from natural disasters have reached an average of US$250 billion to US$300 billion each year. India has suffered a loss of around 2%of its GDP and 12% of the state and central government revenue to natural hazards during 1996-2000 (Parida 2016). EQs are one of the prominent natural hazards that have occurred throughout the history of India claiming several lives and causing damage to properties. The unpredictable nature and terrain independent characteristic of EQs make them particularly difficult to be prepared for. Further due to the unique geological setting of India, the country has always been vulnerable to EQs. As per Jain (1998) more than 50% of the country's area is reportedly susceptible to EQs. The country is particularly vulnerable along the entire Himalayan mountain belt in the north. This is due to the ongoing subsidence movement of the Indian plate below the Eurasia plate. One of the great EQs ($M_W$≥8.0) of India, the 1934 Bihar-Nepal EQ ($M_L$8.4) is a result of this tectonic movement. Other noteworthy EQs that have occurred in the Himalayan region are 1833 Nepal EQ (7.0>M>7.5), 1905 Kangra EQ (Ms 7.8), 1988 Bihar EQ (Ms 6.6), 2005 Kashmir EQ ($M_W$7.6) and the recent 2011 Sikkim EQ ($M_W$ 6.9). The Himalayan region extends from west in Kashmir to northeast in Arunachal Pradesh. In northeast the Himalayas collide with the Burmese mountain ranges. The zone of contact is known as the Assam syntaxis zone. The Assam syntaxis zone was the source zone of the1950 Assam EQ ($M_W$ 8.7). As per the Centre for Natural Disaster Management (CNDM) the 1950 Assam EQ killed approximately 1500 people. This EQ had occurred during the monsoon season which resulted in massive floods in the region and were the primary cause of casualties and damages (CNDM). Apart from the Assamsyntaxis zone, the subsidence of the Indian plate under the Eurasian plate in the north and the collision with the Burmese plate to the east also occurs within the north-eastern region of India. This tectonic movement of plates further contributes to the seismicity of the north-eastern region. This has led to the occurrence of another great EQ in the region, the1897 Assam EQ ($M_W$=8.1). According to the National Geophysical Data Centre a total of 1542 people lost their lives during the 1897 Assam EQ. Along with these two great EQs several major EQs ($M_W$≥7.0) have occurred in northeast India. All of these EQs had led to loss of life and damage to properties. Although these EQs caused wide spread damages, however the loss of life was not alarming due to relatively less population in the nearby regions during each of these events. However with India becoming the second most populated nation in the world and the haphazard growth of buildings across the country, an EQ similar to 1897, 1934 or 1950 could lead to enormous financial losses and casualties.

## 2. Study area

As mentioned earlier the northeastern region of India has witnessed several EQs in the past. A number of faults exist within the region and the tectonic movement along these faults led to occurrence of EQs. The movement along these faults has also resulted in the formation of the Shillong Plateau (SP) around60myatowards the south western part of the region. The SP comprises of the northeastern state of Meghalaya with Shillong as its capital city. Some of the noteworthy faults surrounding the SP are the Dauki fault, Dhubri fault, Oldham (or Brahmaputra) fault and Kopili fault. The Dauki fault lays to the south of the SP, towards west lies the N-S trending Dhubri fault, towards the north of the SPlaysthe Oldham fault and to the northeast is the Kopili fault. All of these faults have generated EQs in the past. The Dauki fault generated the 1923 Meghalaya EQ (Ms7.1). During this EQ, heavy damages were reported in Mymensingh in Bangladesh, Cherrapunji and Guwahati in India (Baro and Kumar 2015 a, b). The Dhubri fault caused the 1930 Dhubri EQ (Ms 7.1). The1930 Dhubri EQ shook the town of Dhubri in Assam with an intensity of IX on the Rossi Forel scale which resulted in cracked walls of several government buildings(Baro and Kumar 2015 a, b). Gee (1934) reported that during this EQ the town of Tura in Meghalaya was shaken with an intensity of VIII on the Rossi Forel scale. Most of the government buildings in Tura at that time were made of *ikra* or split bamboo, the wooden post of the framework were embedded into the ground. The shaking from the EQ caused shearing of the wooden posts and distortion of the walls of the houses (Gee 1934). Goalpara and Guwahati in Assam were shaken with an intensity of VII and Cherrapunji and Shillong in Meghalayawere shaken with an intensity of VI on the Rossi Forel scale during the same 1930 Dhubri EQ (Baro and Kumar 2015 a). As per Bilham and England (2001), the Oldham fault lying to the north of the SP was the source fault of the 1897 Assam EQ ($M_W$ 8.1). This EQ caused severe damages to the bazaar (market), governmental houses, local church, the Telegraph Office, tombs and the gate pillars of the cemetery in Shillong (Bilham2008). Most of the residential buildings in Shillong at that time were built of rubble masonry filled in with mud. This type of construction did not withstand the intense shaking of the EQ whereas houses made of wood performed better (Ambraseys and Bilham 2003). In Tura most of the houses were built on stilts or piles which were severely damaged. Taking into account the severe damages and casualties reported across Meghalaya during the 1897 Assam EQ, Ambraseys and Bilham (2003) attributed an intensity of X on the Rossi-Forel scale. The Kopili fault towards northeast of the SP was the causative fault for the 1869 Cachar EQ ($M_W$ 7.5), 1943 Assam EQ ($M_S$ 7.2) and 2009 Assam EQ (Mw 5.1). The 1869 Cachar EQ caused moderate to severe damages to public and governmental buildings in Shillong. During the 1869 Cachar EQ a MMI of VI was reported across Shillong (Kumar and Baro 2016) Very limited information is available about the damages caused during the 1943 Assam EQ and 2009 Assam EQ. In addition to the EQs generated by faults surrounding the SP, the 1918 Srimanagal EQ ($m_b$ 7.6) also shook up Cherrapunji with an intensity of VI on the MMI scale. The 1918 Srimanagal EQ had occurred in the Sylhet fault further south of the Dauki fault in Bangladesh. Thus it can be observed that the shaking from several past EQs which had occurred in the vicinity of the SP have been felt across Meghalaya. Also these shakings have led to severe damage to properties in the past across Meghalaya. Pertaining to the inherent nature of EQs to recur, similar damage to properties across Meghalaya could be expected in the future. It has to be kept in mind that 74 years have passed since the occurrence of the last major EQ in the SP. During this time the population of Meghalaya has increased to 2.96 million (Govt. of Meghalaya). Along with the increase in population the growth in the number of infrastructure has also occurred. The present day construction practices of reinforced concrete structures have replaced the traditional split bamboo walled houses. Although byelaws for construction of buildings are provided most of the houses across India do not follow these practices. Similar trend can be observed in Meghalaya also with the rapid and haphazard growth of buildings on the hill slopes of the state. This increases the risk of loss of life and property. Thus if an EQ similar to 1897 were to occur in Meghalaya with a present population of 2.96 million there would be a massive loss of lives. Further due to the rapid growth in poorly constructed residential buildings the financial losses incurred by the state during the past would also multiply by several times if a similar EQ occurs in the near future. Thus the objective of this study is to draw an estimate of the financial loss that the state of Meghalaya could suffer in case of a major or a great EQ in the near future.

## 3. Methodology

The conventional method of financial loss estimation is to take into account the seismic vulnerability of the infrastructure in the region. This method provides a very detailed picture of the losses that a region could undergo due a probable EQ scenario. For this method, information about the infrastructure existing within a region has to be taken into account. Next, the expected intensity of shaking in the region needs to be estimated which will be related to the expected damages. These damages will have to be categorised for different types of infrastructure which would be finally related to the financial losses. However, this is an expensive and time consuming method since it requires a detailed record of the entire infrastructure existing within a region. Further in developing countries like India such information is not readily available. To overcome this hurdle, a new method was developed by Chan et al (1998) where the EQ loss was estimated by taking into account the Gross Domestic Product (GDP) of a country rather than a detailed record of the infrastructure. As per the International Monetary Fund (IMF), GDP of a country is the measure of the monetary value of final goods and services produced in a country in a given period of time. In simple words the GDP of a country is a measure of the state of economy of the country. As the economic loss due to an EQ is closely related to the economy of a country, Chan et al (1998) suggested that the GDP could be used to estimate the financial losses. Along with the GDP the method proposed by Chan et al (1998) also uses seismic hazard, population data, EQ loss data and the relation between GDP and known seismic loss. Chen et al (1998) proposed the following relation for seismic loss estimation of an area;

$$L = \sum P(I) \times F(I, GDP) \times GDP \qquad (1)$$

where *L* is the economic loss, *P(I)* is the probability of an EQ of intensity *I*, and *F(I,*GDP) is a measure of the area's vulnerability to EQ damage for the given GDP value and the EQ of intensity *I*. Dunbar et al (2003) applied this methodology for Indian scenario. Dunbar et al (2003) determined the P(*I*) using Global Seismic Hazard Assessment Program (GSHAP) data. To determine the GDP of an areaDunbar et al (2003) used the GDP of India for the year 2000 from the World Bank and the population density from 30-arc-second Landscan 2000 population data. *F(I,*GDP) was determined from the relationship between reported losses from earthquakes to the computed GDP of the affected zone. The EQ loss data was in turn collected from the National Geophysical Data Center's (NGDC) Significant Earthquake Database.Dunbar et al (2003) then developed two correlations between the GDP and the seismic loss for Indian scenario. To develop these correlations Dunbar et al (2003) plotted the NGDC Significant Earthquake Database against the computed GDP for events with Modified Mercalli Intensities (MMI) ≥ VI. The two correlations are shown below

$$L = -0.638 + 1.002G \qquad (2)$$

for intensities VI-VIII

$$L = 1.452 + 0.829G \qquad (3)$$

for intensities IX-X

where L is log of Loss and G is log of GDP. In this study these two correlations are used to estimate the future seismic loss for Meghalaya.

## 4. Analysis

As mentioned earlier, during the past EQs Meghalaya has experienced different intensities of shaking. A wide range of intensities have been reported, from VI during the 1930 Dhubri EQ to X during the 1897 Assam EQ.Hence in this study, both Eq. (2) and Eq. (3) are used to estimate losses that Meghalaya could suffer in case of different levels of shaking. It has to be mentioned here that in Eq. (2) and Eq. (3) the intensities are in MMI scale. However, the reported intensities during past EQs in Meghalaya are mostly in the Rossi-Forel scale. The Rossi-Forel scale intensity values are converted to MMI using the conversion table given by Richter (1958). Further, Dunbar et al (2002) developed the correlations for the entire country. Since this study is for one state and not the entire country the GDP is replaced by Gross State Domestic Product (GSDP) in the equations. According to Data.govin Gross State Domestic Product (GSDP) is defined as a measure, in monetary terms, of the volume of all goods and services produced within the boundaries of the State during a given period of time, accounted without duplication.As per Economic and Statistical organization Government of Punjab (ESOPB) the GSDP for Meghalaya for the year 2016-17 is 295.67 billion rupees. Although the GDP of India is the seventh-largest in the world measured by nominal GDP and the third-largest by purchasing power parity (PPP) the GSPD of Meghalaya is very low. The GSDP of Meghalaya is comparable to the GDP of one of the poorest countries of the world. Applying the GSDP of Meghalaya i.e. 295.67 billion rupees to Eq. (2), the economic loss for Meghalaya in case of an EQ with MMI of VI-VIII is estimated as 71.7 billion rupees. Similarly using Eq. (3) for intensities IX-X on the MMI scale, the financial loss is estimated as 91.3 billion rupees. The losses are summarised in table 1 shown below. Thus, in case of occurrence of an EQ with an intensity of VI-VIII on the MMI scale, Meghalaya could lose one fourth of its GSDP. Similarly, in case of occurrence of an EQ of magnitude close to the 1897 Assam EQ Meghalaya at present day could lose approximately one third of its GSDP in one single day.

Table-1 Financial losses in case of different MMI values

| **GSDP (Rupees)** | **MMI** | **Loss (Rupees)** |
|---|---|---|
| 295.67 billion | VI-VIII | 71.7 billion |
| | IX-X | 91.3 billion |

However, it has to be highlighted here that the correlations given by Dunbar et al (2003) are developed for two groups of intensities. This does not allow estimating the economic losses in case of every single MMI value. Hence, within a state if a location has experienced an intensity of IX as well as VIII, correlations given by Dunbar et al (2003) would give an estimate of two very different economic losses. Further attempt could be made in future study to address this discrepancy.

## 5. Conclusions

The SP has experienced several EQs throughout the history of its existence. All of these EQs have claimed several lives and caused damages. Compared to present day the population and urbanization at that time within the plateau was relatively less. Hence the affect on the economy of the state was also less. However in present day Meghalaya a major or a great EQ could have a far higher affect. It has been estimated in this study that in case of occurrence of an EQ with intensity of VI-VIII Meghalaya could suffer an economic loss of 71.7 billion rupees. This amounts to one fourth of the GSDP of the state. Further in case of an EQ with intensity of IX-X the loss could be 91.3 billion rupees which is one third of the GSDP of Meghalaya.

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