

**Building Bhutanese Resilience Against Cataclysmic Events** 

# **Resilience Strategies and Perceptions of the Potential Impacts of Earthquakes in Bhutan**

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# **BRACE** partner organisations



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# **Executive Summary**

This report summarises the perceptions of a wide range of stakeholders to earthquakerelated risks and their current resilience strategies. The research arises from the interdisciplinary project Building Bhutanese Resilience Against Cataclysmic Events (BRACE) project which brings together a range of natural and social scientists from the Bhutan, UK and the USA, to address the challenges of developing Bhutan's resilience to earthquakes. This report presents the perceptions gathered from interviews in 2017 and 2018 with 52 people covering differing roles, with the aim of scoping out the issues that require further attention.

The greatest reported concerns relate to the collapse of building structures, with subsequent effect on human injury, and reduction in housing and shelter. An earthquake is expected to precipitate landslides, which may in turn block roads and may also bring about glacial lake outburst floods (GLOF), with consequent impacts downstream. Throughout interviews conducted as part of BRACE, it was widely assumed that the telecommunications network would be affected. Within hospitals efforts are being made to ensure buildings and their contents are safe ahead of an earthquake and prepare staff to treat injuries from earthquakes. It was felt that farming activities would be less affected than other industries in the event of an earthquake but that damage to roads would limit the movement of food, which could also affect the Food Corporation of Bhutan (FCB) depots and their stocks across the country. The responses to interviews indicated concerns about how water is delivered to households, and waste water removed after an earthquake. It is perceived that electricity supplies would be affected (and therefore communications by mobile telephone or internet), as well as fuel supplies for road or air transportation. Any damage to hydropower generation would impact on energy generation and potentially on revenue from energy sales abroad. Other businesses, particularly tourism could be adversely affected.

The report identifies a range of impacts which could be anticipated in the immediate, medium and longer term if a major earthquake occurred. Some of the consequences are already experienced such as road damage and seasonal flooding during the annual monsoon. Thus, resilience planning activities could take advantage of the existing structures and practices for preparation against all disasters, such as the National Disaster Management Authority and the Instant Command Structure. There are, however, some impacts which are specific to earthquakes which will require additional resources for resilience building.

# Introduction

This paper summarises the perceptions of a wide range of stakeholders to earthquakerelated risks and their current resilience strategies. The major Gorkha earthquake in Nepal (7.8 on the Richter scale) in 2015, as well as two smaller earthquakes in Bhutan in 2011 and 2009, served to highlight the potential impact of an earthquake should something of similar magnitude occur in Bhutan. These events have galvanised efforts to focus on earthquake preparedness, including the development of an Instant Command System, and planning across many levels of society. The focus has tended to be on the immediate consequences of such an event such as initial disaster response methods and search and rescue. However, the impacts of an earthquake can extend far beyond this initial period. Resilience to earthquakes requires not only disaster preparedness but also long-term plans for disaster avoidance. While an earthquake cannot be controlled, increasingly the focus on disaster management has related to anticipatory activities which seek to identify potential consequences, and make changes to build resilience. Such an approach requires a clear understanding of the potential impacts of earthquakes, so that mitigation and adaptation measures can be put into place.

This report arises from the Building Bhutanese Resilience Against Cataclysmic Events (BRACE) project funded by the UK's Global Challenges Research Fund. This interdisciplinary project, funded jointly by several UK research councils (ESRC, NERC, AHRC) and the UK Government's Department for International Development (DFID), brought together a range of natural and social scientists from the UK, Bhutan and the US, to focus their combined expertise on addressing the challenges of developing Bhutan's resilience to earthquakes. Thus the project involves research into seismic hazards and risk, historical records of earthquakes, physical, cultural and economic impacts of earthquakes in Bhutan. Further details can be found at www.bracebhutan.org. By merging new research in these fields with close consultation with in-country policymakers and engineers, the long-term aim is to develop a sustainable framework for improving Bhutanese resilience to earthquakes and their cascading effects on environment, infrastructure, and society.

A fundamental part of the project was a series of interviews with stakeholders from across Bhutan to discuss the potential impacts of earthquakes, how people assess hazards, where they source information, and how it is used to make decisions regarding building resilience, the development of plans to build resilience at national, regional and local levels. This report summarises the findings from the interviews concerning the cascading impacts of earthquakes on different stakeholders, and how these are interrelated. It presents the perceptions of these different interviewees and should be used as a basis for identifying further areas of resilience building. Within the BRACE project we define resilience as more than emergency rescue and operations and humanitarian assistance. Instead, we consider it as a return to a functioning economic and governance system through both disaster preparedness and, more importantly, disaster avoidance. DFID goes further to consider resilience as "building back better" – improving on what existed before disaster. Resilience can be enhanced through proactive preparedness measures. A key part of our interviews concerned what scenario earthquakes stakeholders were preparing for, and what measures were being put into place to mitigate the anticipated impacts.

A caveat to the findings which follow: There is much uncertainty as to the nature and impact of an earthquake, and therefore there is a large degree of uncertainty as to the extent of the impacts an earthquake might have. This will depend on the magnitude and depth of the earthquake, the consequent peak ground acceleration, the distance of the earthquake from areas of habitation, and the characteristics of the ground where buildings are located (hard rock, softer sediments etc.). Furthermore, the nature and extent of aftershocks could exacerbate the effects of an initial quake. Therefore, the severity of the consequences of earthquakes will depend on these issues.

# 1. Interview Strategy

As part of the research in 2017 and 2018, we interviewed stakeholders from across society to determine their perceptions of the likely impacts of earthquakes. Stakeholders included government ministers, regional government officials, local Gewog representatives, village leaders, farmers, and businesses. This exploratory study selected interviewees purposefully to ensure a cross-section of people working across sectors, from tourism, insurance and farming through to disaster management, transportation and hydropower sectors. In total, 52 people were interviewed, some alone and some in groups. A list indicating the range of interviews is below. In reporting the findings, we have avoided assigning quotes to individuals or individual positions to preserve anonymity.

The interviews were transcribed and analysed. A semi-structured interview approach was taken, based on core questions which were common to all interviews, and further enquiry to go into depth on particular issues according to interviewees' expertise and experience. Interviews were carried out with at least two members of the project team present, allowing us to draw out both social science and natural science implications of the discussion.

Interviewees
2 interviews with international organisations or projects operating in Bhutan
9 interviews with people from the Royal Government of Bhutan across 7 departments.
8 interviews at regional government level, focussing on Dzongkhags of Haa,
Wangdiphodrang (Phobjikha) and Paro.
4 interviews at local government level
1 interview at Thimphu Thromde
17 interviews with businesses, including tourism (6), Insurance (3), telecoms (2),
food/farmers (4) and other businesses (2)
3 interviews with people from the health sector
4 interviews with monastic body and faith leaders
1 representative of the Dessup

# 2. Findings

# 3.1 What sort of earthquake is anticipated?

There were considerable differences between interviewees concerning in the type of earthquake that was expected. The anticipated scale of a future earthquake depended on what the interviewees had personally experienced. A small number of those interviewed had been to Nepal, witnessed the impact of the Gorkha earthquake, and therefore used this as a frame of reference, fearing "the big one", that "Bhutan would be flattened" and commenting that "the aftermath [in Nepal] was chaos, and it acts as a warning to Bhutan to prepare." However, most interviewees who had only experienced the 2011 earthquake in Sikkim (magnitude 6.1, felt in Bhutan in the western region of Haa) and the 2009 Mongar earthquake (magnitude 6.9) were found to be expecting an earthquake of similar magnitude. While there were comments about aftershocks, there seemed to be less understanding about how variables such as distance from the earthquake, ground type, and depth of the earthquake would affect shaking/severity. Some recalled near death experiences during the 2009 and 2011 events, and one interviewee commented that they knew of one person who died, due to secondary effects of landslips, rather than the initial quake itself.

# 3.2 Impact on Buildings

The greatest concern regards the collapse of building structures, with subsequent effects on human injury, and reduction in housing and shelter. This report focusses initially on housing, and then on public buildings and buildings of cultural and heritage value. Bhutan has adopted the Indian building code, IS1893, and in particular adopts the standards for their Zone 5, the area with highest seismic activity. Seismic design was only made mandatory after 1997, therefore buildings which pre-date this time may not have been built to this standard.

Recently built houses made in modern styles are built using reinforced concrete construction (RCC) techniques, but older buildings using concrete are not necessarily built to the standards of the building code. The Department of Engineering Services within the Ministry of Works and Human Settlement overseas building standards, and engineers inspect new constructions, supervised by Thimphu Thromde in the capital, and regional officers in each Dzongkhag in the rural areas.



The variety of building types in Thimphu ©K. Wangmo

More than 66% of the buildings in Bhutan are built using traditional construction methods such as rammed earth or stone masonry<sup>1</sup>. Rammed earth construction is the basis for many of the traditional buildings in rural areas. Wide walls (more than 1m thick at the base) are created by compacting earth, and are believed to provide safety. Blocks of rammed earth are supported by timber framework. There are no nails or fixed points, which it is believed means that the building can withstand some tremors or movements without collapsing. Traditionally villagers would work together on construction, so people took turns to labour

<sup>&</sup>lt;sup>1</sup> Project for Evaluation and Mitigation of Seismic Risk for Composite Masonry Buildings in Bhutan, http://www.mohca.gov.bt/index.php/satreps-program/,

on each others' houses. More recently, such communal working systems have been replaced by paid labour, increasing the costs of construction, and it was reported also that people want to build houses more quickly. Interviewees reported that there has been a gradual decrease in the width of walls, which it is believed is related to costs. This narrowing of walls is also believed to reduce the resilience of buildings to earthquakes. Regional building inspectors are now encouraging people to build buildings with fewer storeys, thereby improving safety. Currently, the Bhutan building code does not provide specifications for these traditional structures.



A traditional rammed earth house showing cracks caused by small earthquakes ©K. Wangmo

Building inspection processes (approval of design, and later of construction) were reported to be more formalised in urban areas, and focussed on reinforced concrete structures. Interviewees reported less inspection of traditional construction methods in rural areas.

Public buildings are required to achieve a higher standard than houses, so that schools, hospitals, government buildings and public venues built since 1997 will be more robust than houses. Buildings of cultural value, such as Dzongs and temples, are overseen by the Department of Culture. Many of these are historical buildings constructed using traditional methods.

## 3.3 Roads and Transport

An earthquake is expected to precipitate landslides, and these landslides may in turn block roads. An earthquake may also bring about glacial lake outburst floods, with consequent impacts on downstream rivers and flood plains, as well as buildings, bridges and people living within the flooded area. The collapse of bridges marks particular cut off points to the road infrastructure, and pinch points such as the bridge at Wangdue – Phodrang could mark the effective limit of land-based travel between the east and west of Bhutan.

Road engineers interviewed perceived that the impact on roads and bridges will mean that road transportation networks will be cut off. With the primary national highway comprising 1822 km of road, and the secondary national highway a further 930 km, there is almost 2000 km of major roads to be maintained. Interviewees expected that there will be multiple blockages due to landslides, impacting on major roads (e.g. national highway) as well as minor roads. The main Paro – Phuentsholing road carries a lot of goods, so a blockage could limit a major land-based access route to Bhutan.



Roads and bridges are at risk from earthquakes, resulting in multiple blockages ©K. Wangmo

The nature of road building in Bhutan means that there are many points where road cuttings are hazardous. There are a range of measures to reduce landslides including supporting walls, restraining bolts and netting to prevent road collapse or debris landing on the road. However, the impact of a large earthquake was not known.

The Department of Roads has a range of equipment dispersed along the road network to enable road clearing. There is a strategy of clearing main roads first, and secondary roads afterwards. In interviews it was suggested that roads could be cleared hours after a minor earthquake, however due to the nature of roads in Bhutan, a major earthquake could severely disrupt main highways, requiring longer periods to repair. Bridges are also vulnerable. There are 361 motorable bridges, and a further 420 non-motorable bridges. A series of Bailey Bridges could be installed to repair roads, however they have a maximum span of 160 feet, beyond which a pier is needed.



Earthquakes are expected to affect non-motorable bridges as well as road bridges ©K. Wangmo

It is not clear how alternative transportation via airplane or helicopter will be affected: the two Royal Bhutan helicopters are normally stored in a hangar at the international airport in Paro, and could be damaged if the hangar collapses. The impact on the runway at Paro

airport will depend on the proximity of the earthquake and the effect on the soft sediment in this broad valley.

# **3.4 Communications**

Bhutan has 650,000 mobile numbers and 20,000 land lines. Throughout the interviews it was widely assumed that the telecommunications network would fail. An interview with a telecoms business indicated that a major disaster would likely disrupt the servers which underpin the mobile telephone network. There are two mobile phone providers, each located within a short distance of each other in Thimphu. Therefore an earthquake that affected Thimphu would likely impact on both equally. Land lines are located underground and believed by some interviewees to be more resilient than the mobile networks. There was some suggestion that internet servers were more resilient than the telephone system, so that a situation might arise where social media apps might work when phone calls would not, providing at least some methods of communication.



There are 650,000 mobile numbers; the two phone providers are based in Thimphu ©K. Wangmo

The process of sourcing parts for and reinstalling the mobile network was estimated to take 6-7 months. Dzongkhags have been provided with satellite telephones, yet recent experiences have highlighted that these take longer to activate than anticipated, and crucially, require a phone call to be made to Singapore during business hours. Further, it

was reported in the interviews that after the Nepal earthquake there was dust in the air which hampered the phones' connectivity.

Media organisations providing radio, TV, newspapers and online services have a particularly important role to play in transmitting information about the extent of an earthquake, consequent impacts, and response needs. Many media organisations are based in Thimphu, and only the Kuensel newspaper and the Bhutan Broadcasting Service (BBS) have regional reporters. However, without appropriate telecommunications, it may be difficult to report information. Communications will depend on electricity and generators are present in each Dzongkhag's telecoms office. The limitation will be the amount of fuel that has been stockpiled to keep these running.

# 3.5 Impact on health services

There are 3 large hospitals in Bhutan, and a further central referring hospital in the capital, Thimphu. These are supported by 185 Basic Health Units (BHUs) in more rural areas (25 grade 1, 160 grade 2). A grade 1 BHU is staffed by doctors and nurses and has an ambulance. A grade 2 BHU is staffed by primary health workers, including a minimum of 2 health assistants – people who have trained at the nursing faculty in Bhutan for 3 years.

Assessments of the risks of an earthquake to hospitals have been made and, through scenario and planning exercises, efforts are being made to ensure structural and non-structural safety. Non-structural safety refers to the potential for injury from falling or loose items such as shelving, equipment etc.

The health service is primed to treat injuries from earthquakes, which will include physical injury from collapsed buildings, but also injuries arising from the secondary effects of earthquakes – fire, electrocution, and falls. There is also recognition of the psychological trauma of earthquakes for those who survive, as well as those who are coping with injury, and those who are bereaved. However, the health services acknowledge they have limited capacity to administer counselling and psychological support.

An earthquake may also result in lives lost. The health service will focus on those needing care, and will look to support from monks and others to address the needs of the deceased.



The monastic body will play a key role in supporting communities following an earthquake ©K. Wangmo

# **3.6 Food Production and supply**

It was felt that farming activities will not be impacted heavily by an earthquake, though severe ground motion could disrupt terracing and affect irrigation. In urban areas there was a belief that farming communities were largely self-sufficient, producing rice, vegetables etc., and only need oil, salt and sugar. However in rural areas, it was clear that this is not always the case. In some areas, farmers have specialised in growing particular crops for market rather than staple subsistence crops. Although some rice is grown, the country still relies heavily on rice imports from India. Wealthier households can purchase stores of rice while poorer households were reported to be buying rice more frequently due to financial constraints.



While many farmers are self-sufficient, many are growing cash crops that require roads to access markets ©к. wangmo

Farmers also rely on road transportation networks to take their products to market, and to bring in inputs such as fertilisers. Road closures would limit this.

The Food Corporation of Bhutan (FCB) has a series of depots across the country, and a larger depot in Thimphu. Some see these as being a potential source of food in an emergency. However they have limited stocks. The FCB in Thimphu was perceived to have only 3-4 day's worth of food, and smaller FCB depots in rural areas do not keep large stocks of perishable foods.

The practice of keeping food reserves varied among households, with some households assuming that it would not be necessary as "the road will be opened but the government have reserve rations and a reserve for us." This was in stark contrast to responses from some regional government offices, which said they did not have any food reserves at all.



Access to a variety of foods may be affected with some traditional local foods being important ©K. Wangmo

#### 3.7 Water

Water and sanitation could play a significant role in ensuring that people remain healthy after an earthquake. However, from the responses to interviews it was not clear that there is a strategy concerning how water is delivered to households, and waste water removed after an earthquake. New towns, such as Wangdue, had 30,000 litre water reservoirs made of ferro-cement, which then feed houses through gravity flow on high density polythene pipes. It is believed that these would be more able to withstand ground movement than a more rigid pipe structure. However, towns which have grown more organically, such as Thimphu, have a less clear layout of water sources and pipelines. At Thimphu Thromde, concerns were raised about the lack of centralised information about the location of main water pipes and the distribution network. Such information is held by individuals who have helped develop water distribution systems as houses have been built, but is not in a format to be passed on when those holding the information retire. It is believed there are some main lines 30-60 cm below the ground. In other interviews, it was pointed out that each of the 4 major towns, Thimphu, Phuentsholing, Paro, and Gelephu are located on a river, and so there would be fresh flowing water whatever happened. It was also noted that following the 2011 earthquake some water sources dried up, and others emerged, due to ground movement. Thus existing sources on which people rely may change.

#### 3.8 Fuel and energy resources

Transportation, heating, cooking and communication (emails, phones) will require energy. Assuming that road blockages may leave some regions cut off, any existing distribution structure for fuel cannot be relied upon. In some remote areas, interviewees referred to fuel reserves, but it was also acknowledged that while ideally there was 1 week's supply of fuel, in practice it was likely to be less (estimates varied between 3 and 6 days), but that it might last 9 days if rationed carefully. A further issue identified was the structural stability of fuel depots, and whether they would withstand an earthquake.

The helicopter service had planned ahead, and have a series of fuel stores across the country, to enable to helicopters to refuel in different areas when out on operations. However, these stores would need replenishing.

Communications systems such as satellite phones, VHF radios (for local communication) and internet etc. all require electricity to charge the equipment. Interviewees reported that these are stored with charged batteries, but the lifetime of a battery, especially when under heavy use, is not long.

Energy from hydropower stations could be disrupted if an earthquake impacts on the station. Even if the infrastructure of the station withstands the earthquake, debris in the water, or exceedingly high water levels due to glacial lake outburst floods would result in temporary closure of the station to avoid damaging turbines. Energy distribution networks may fail if the network is damaged in the earthquake.

## 3.9 Impact on business and the economy

In addition to the economic impacts of a loss of hydropower income, interviewees noted that there is a risk of damage to other businesses. Tourism is a growing industry in Bhutan, providing roles for people across the country through accommodation, tour guides, transportation and visitor attraction venues. An earthquake was perceived to impact on tourism in several ways. Tourists may cancel visits, buildings such as hotels and homestays could be damaged, and closed for some time while awaiting repair, those reliant on income from roles in the tourism sector may find that there is no or reduced work for some time following an earthquake, so reducing their income. For those tourism-related businesses who have taken out loans, there may be further problems with repayment if the income stream is reduced or stopped altogether. Other businesses may be affected by reduced customer demand and difficulty getting supplies.

The insurance sector in Bhutan is relatively young and led by two main providers. In the past few years there has been an increasing awareness of insurance, especially after the 2011 Sikkim earthquake. In rural areas, subsidised insurance is compulsory, and payments are collected by the local government. This covers houses against fire but there is the opportunity to add wind (particularly against roof damage) and earthquake damage. Most claims are from the fire portfolio but there were many claims after the 2009 and 2011 earthquakes.

Interviews with both insurance companies have revealed that some sectors are insured, others not at all. Significantly, government structures, including public buildings such as schools and hospitals, are not insured. This means there will be significant costs to be borne when these have to be rebuilt.

# 3. A timeline of impacts

# 4.1 Immediate consequences of an earthquake

- Structural damage to buildings, including houses, public buildings, schools, hospitals and other lifeline infrastructure
- Communications will be impacted through the effect on telephone lines (landlines and mobiles), and roads and bridges. Airports may also be affected.
- Buildings for hospitals and BHUs may also be damaged, impacting on their usefulness.
- Water and sanitation may be affected through damage to water supplies and reservoirs, water pipelines, and sewage / drainage systems.

# 4.2 Cascading impacts

- An earthquake may trigger subsequent challenges such as glacial lake outburst floods (GLOFS), landslides, and fires.
- Shortages of energy sources (fuel, electricity) as stores and batteries are depleted.
- Shortages of water, though it has been noted that the major cities are all located on rivers.
- Access to food, safe drinking water and shelter will all be concerns if people are unable to remain in their houses.

# 4.3 Longer term impacts

- Education systems and governance structures are likely to be impacted as they cope with disruption to buildings, and diversion of staff to cope with disaster management.
- An earthquake is likely to impact on the day to day functioning of local businesses as they cope with damage to buildings and stock, delays in restocking due to damage to communication infrastructure.
- Insurance companies will have large amounts of claims.
- An earthquake may have a significant impact on the hydropower generation systems, which will impact on government revenue.
- Tourism will be impacted as hotels need to be repaired, roads cleared, and potentially the airports reopened.

# 4.4 Interlinkages between cascading impacts

The above impacts are not independent of each other. We recognise that structural building collapse in hospitals will have impacts on health provision. Likewise, disruption to water sources will impact on health. Building collapse may also impact on food availability and food stores. It has been noted that the Food Corporation of Bhutan depot in Thimphu is not

situated in an earthquake-resilient building. Road blockages due to landslides will impact on the possibility of bringing in relief materials and food supplies by road. Key transportation routes, such as the road from Phuentsholing to Thimphu and Paro, and the bridge at Wangdue, may be pinch points which limit road traffic. Likewise, the impact on Paro international airport and regional airports will be significant.

Communications by telephone are also likely to be impacted. The effect on landlines and mobile networks may differ, but there are many more people reliant on mobile networks than landlines.

# 5 Conclusions

This study focussed on the perceptions of those interviewed. It is important to understand these perceptions in order to develop sustainable strategies for buildings resilience. The interviews identify a range of anticipated impacts which might arise if a major earthquake occurred. The extent and severity of these impacts would depend on the extent, severity, and location of the earthquake. Some of the consequences are similar to those already planned for due to annual events such as monsoons which can cause landslips and road closure, and flooding. The health service is already planning for coping strategies based on high demand due to disease outbreaks. Thus disaster management or resilience planning activities can be put in place which will be of value for several scenarios. Others are specific to an earthquake scenario. Building resilience may take advantage of the commonalities required for preparation against all disasters, such as the National Disaster Management Authority and the Instant Command Structure which has recently be put in place, however there are some impacts which are specific to earthquakes which will require additional strategies and resources for resilience building.



# Building Bhutanese Resilience Against Cataclysmic Event

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