The Bhuj Earthquake
District of Kutch, State of Gujarat (India)
January 26, 2001

A Reconnaissance Report
Identification of Priority Issues

Prepared for
DRM-World Institute for Disaster Risk Management

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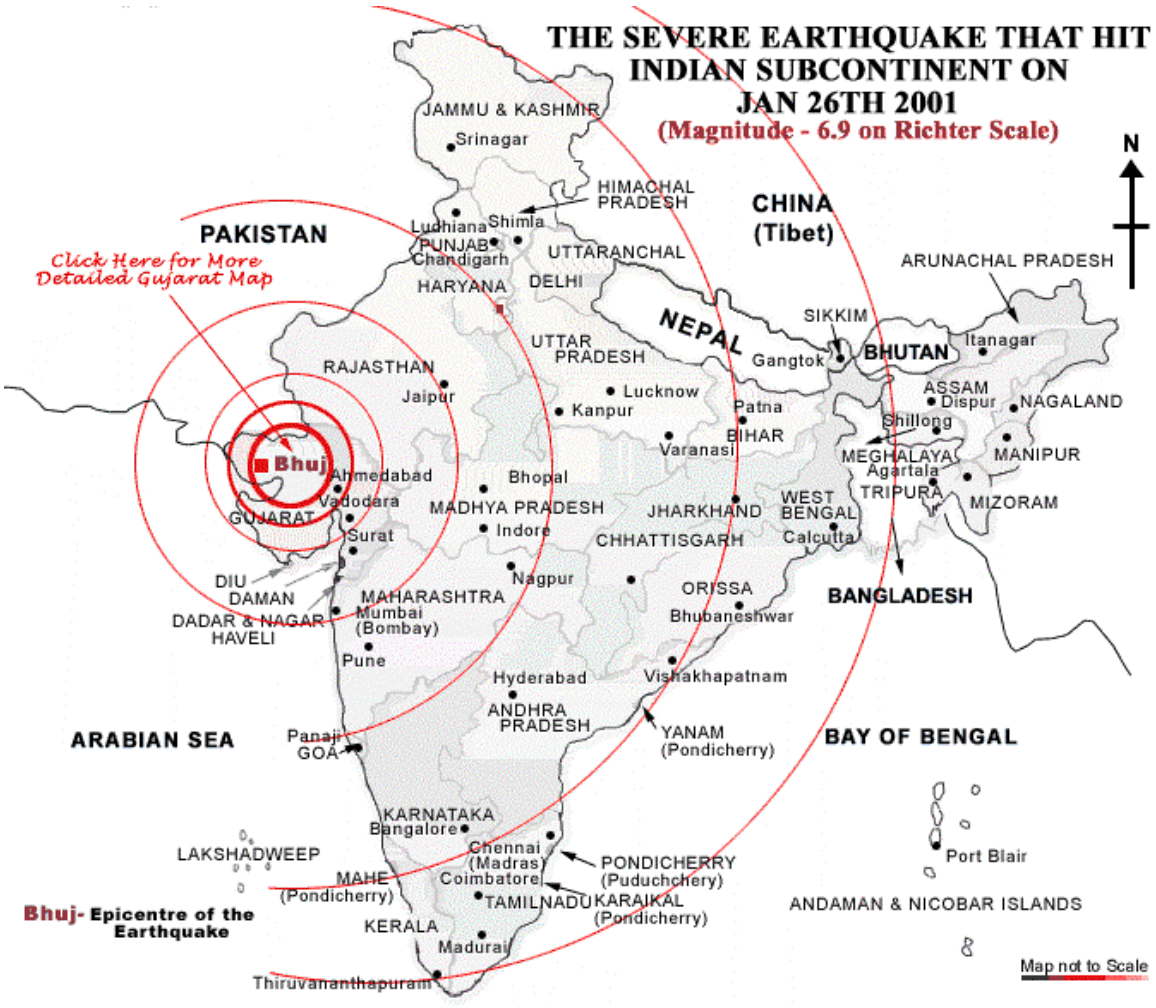
INDEX



Source: The Government of India's Official web site on the Gujarat earthquake http://gujarat-earthquake.gov.in/final/indiaeq.html

1 Introduction

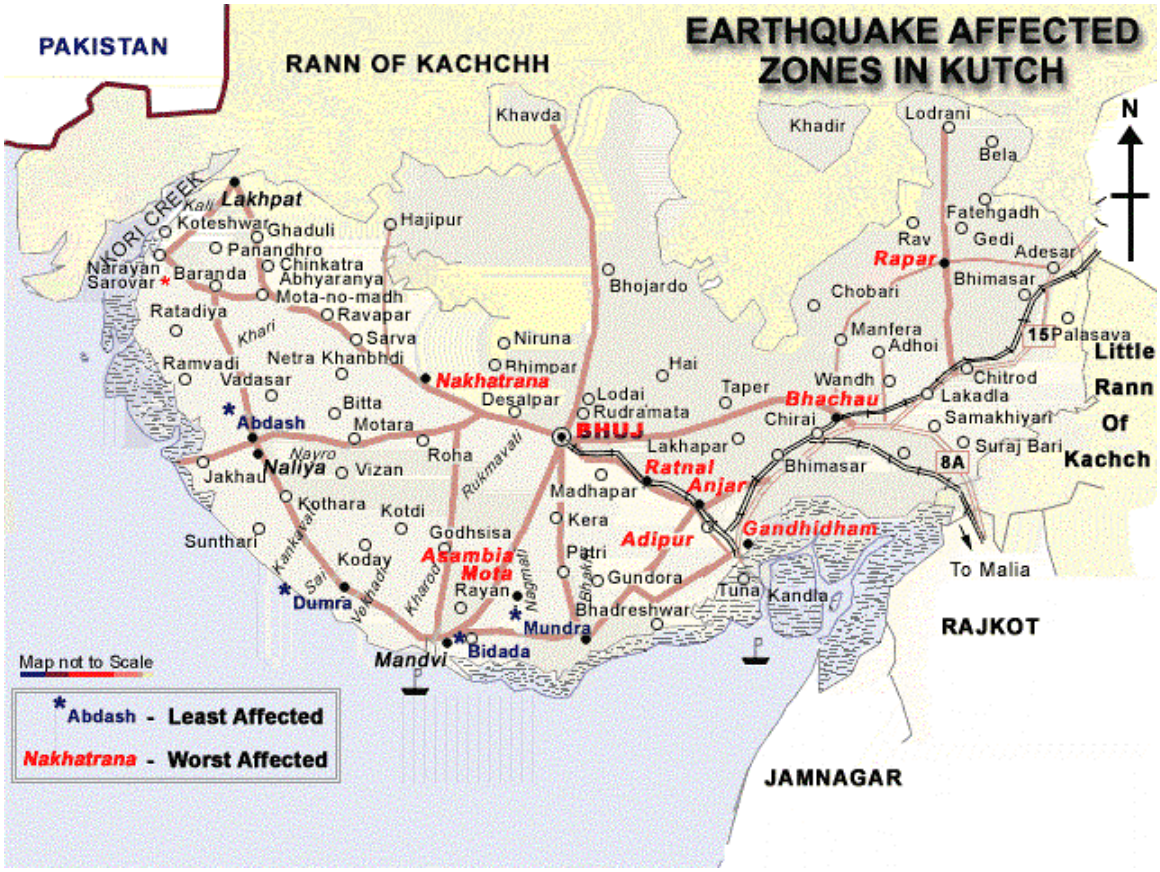
This is a reconnaissance report of the Bhuj earthquake that struck Kutch and other districts in the western state of Gujarat, India on January 26, 2001. On behalf of the World Institute for Disaster Risk Management (DRM), Krishna S. Vatsa joined a mission organized by the Earthquake Engineering Research Institute, Oakland, CA and visited Gujarat from February 4 to 12, 2001. The report provides a brief account of the physical details of the earthquake. It also discusses the human and economic impact of the earthquake. However, the main objective of the report is to identify those issues, which are crucial for long-term rehabilitation and mitigation. These issues are: (i) reconstruction and development (ii) disaster management planning, (iii) emergency communications,

(iv) seismic rezoning, (v) seismic engineering, (vi) building codes, (vii) microzonation, (viii) essential facilities, (ix) critical infrastructure protection, and (x) disaster risk insurance. The report provides the institutional and regulatory context for each of these issues. The report also makes recommendations for implementing appropriate action plans with respect to each of these issues. The Government of Gujarat has commenced a large-scale rehabilitation program with the financial assistance of the World Bank and the Asian Development Bank. It will be necessary to address these long-term issues in the course of the program implementation to reduce physical and social vulnerability in the region. A rehabilitation program encompassing these issues could be a great learning experience for the rest of India and other developing countries.

2 Overview of the Event

On January 26, 2001, an extremely severe earthquake struck the state of Gujarat in western India at 8.46 a.m. The earthquake devastated the district of Kutch in the northwestern part of the state, and many other districts of the state also suffered terrible human and property losses. The city of Ahmedabad, the commercial capital of Gujarat, which lies 300 kilometers from the epicenter of the earthquake, had a collapse of more than 70 high-rise residential buildings. It was the worst disaster to have struck India in the last 50 years.

The Kutch region forms a crucial geodynamic part of the western continental margin of the Indian sub-continent, and falls in the seismically active Zone-V outside the Himalayan seismic belt. It extends for approximately 250 km (E-W) and 150 km (N-S) and is flanked by Nagar Parkar Fault in the north and the Kathiawar Fault in the south. The area bounded between these two faults comprises several E-W trending major faults viz. Katrol Hill Fault, Kutch Mainland Fault, Banni Fault, Island Belt Fault and Allah Bund Fault (Malik, et al, 2000).



Source: Government of India's official web site on the Gujarat earthquake
http://gujarat-earthquake.gov.in/final/bhuj.html

Zone V, which includes Andaman & Nicobar Islands, all of North-Eastern India, parts of north-western Bihar, eastern sections of Uttaranchal, the Kangra Valley in Himachal Pradesh and the Rann of Kutchh in Gujarat, is the highest level of seismic hazard. Earthquakes with magnitudes in excess of 7.0 have occurred in these areas, and have had epicentral intensities higher than IX on modified Mercalli scale. The Rann of Kutch has experienced above normal levels of microseismicity throughout the past 200 years, and probably for many millennia. Altogether 56 earthquakes have struck the region with magnitude ranging between three and four, and about seven quakes of five and above (1819, 1845, 1846, 1856, 1869, 1956, and 2001), the two major ones being Allah Bund and Anjar in last two hundred years. A severe earthquake of magnitude 8.0 occurred in 1819 at Bhuj and this gave rise to an 80 km-long fault scarp, Allah Bund, a natural dam uplifted at its crest by 6.5 meters, on the northern edge of the Rann. The second biggest earthquake recorded was on July 21, 1956 in Anjar. Of a magnitude of 7.0, this earthquake killed about 700 people.

Magnitude, Epicenter and Depth

There are varying interpretations about the magnitude and epicenter of the earthquake. The India Meteorology Department (IMD), which has a seismograph at Bhuj claimed that the magnitude was 6.9 on the Richter scale; the Geological Survey of India (GSI) at its Jabalpur observatory recorded the magnitude of 7.6. The US Geological Survey (USGS), which has the largest network of seismographs and satellites for observation, claimed that it was 7.9, but later revised it to 7.7. The India Meteorology Department explained this difference by saying that the US and other foreign agencies calculated the magnitude with surface waves as the basic input, whereas the IMD figure was arrived at by using P waves, i.e. the calculation was done on Local Magnitude (ML) and the Body Wave Magnitude (MB). The updated USGS estimate M7.7 is the Energy or Moment magnitude, a more reliable measure, particularly for large earthquakes.

The earthquake was followed by a large number of aftershocks. The Indian Meterology Department (IMD) recorded more than 500 aftershocks of magnitude 3.0 and above, which continued through the month of March.

Initial reports from the Indian Meteorological Department (IMD) on January 26, suggested that the epicenter was 23.6 degrees North and 69.8 degrees East which is near village Lodai, located some 20 to 25 km north-northeast of Bhuj. But the Geological Survey of India (GSI) puts the epicenter at 23.21 degrees north and 70.41 degrees east, about 76 km east of Bhuj or 100 km NNE of Jamnagar. However, the US Geological Survey (USGS) claimed that the epicenter was located at 23.4 degrees North and 70.32 degrees east and 110 km NNE of Jamnagar.

The earthquake was a shallow-focus event. The USGS estimated the hypocenter at 23.6 km below the surface. The preliminary IMD estimate was of a 15 km. Depth. The University of Tokyo further revised this estimate to an even shallower depth of 10 km. However, the Incorporated Research Institutions for Seismology (IRIS) consortium and the National Geophysical Research Institute (NGRI), Hyderabad have confirmed the focal depth of the earthquake at 23.6 km.

3 Impact of the Earthquake

The state of Gujarat was the worst hit by the earthquake. Bhuj, Bachhau, Anjar, Rapar, and Gandhidham are the worst affected towns in the district of Kutch, with Ahmedabad, Rajkot, Jamnagar and Patan also severely affected. Though the impact of the earthquake was felt in most of the states of India, there were no reports of significant damages from other states.

According to the information available on the web site of the Government of Gujarat, the total number of people who died in the earthquake is 20,086. The figures of deaths, quoted as more than 50,000 have generally been exaggerated in the media. The total number of injured is reported to be 166,000 out of which around 20,000 persons are seriously injured. The number of people still missing is 233 in Kutch. More than 20,000 head of livestock have perished in the earthquake. Around 300,000 houses, engineered

and non-engineered, have collapsed. Approximately 1 million houses have suffered partial damage and destruction. A report on the government response to the earthquake is available on the web site: www.eeri.org.

The economic losses have been reported as follows:

Loss Categories	US$ Million
Personal Property	82
Household Property	2382
Public Utilities	27
Public Infrastructure & Amenities	230
Industrial Establishment	1060
Commercial Establishment	638
Total	4519

The figure of US$4.5 billion provided by the Government of Gujarat is an approximate estimate. The precise estimate of economic losses due to the earthquake is yet to be established.

3.1 Damages to Infrastructure

Among the first utilities to get knocked out by the quake was the communications network and power supply. There was an immediate loss of 3000 MW in the power grid. The tripping of a 220 KV line in Kutch resulted in total blackout of the whole district. Though the power supply in Ahmedabad was restored within a few minutes, it took as many as 15,000 Gujarat Electricity Board (GEB) personnel, 30 truck-loads of electricity poles, conductors, insulators and circuit breakers to restore power supply in Bhuj within two days.

The damage in the electricity sector has been primarily in distribution. Most generation plants, which had initially tripped following the earthquake, started generating within 24 hours and the transmission systems too were up and running. It was, in fact, the damage caused to the sub-stations that held up power distribution to cities and villages. For instance, although Bhuj was supplied with 12 MW within a day's time, there were no takers for the power.

Most of the water supply schemes failed because of the collapse of pump houses, and damage to the intake towers and pipelines. Water supply in the districts of Rajkot, Jamnagar and Surendranagar were also affected for similar reasons (The Economic Times, February 2, 2001).

The telecom building in Bhuj collapsed, with most of the telecom equipment destroyed. Fibre-optic cables that gave connectivity to the district of Kutch were also broken, resulting in isolation of the district from the rest of the state.

The earthquake most seriously affected the Kandla port, the busiest port in India, which caters to the hinterland of western, central and northern India. It handles crucial imports of petroleum products, crude oil and chemicals and exports of agricultural commodities. About five of 10 jetties may have been damaged, reducing the berthing facility at the port. There are serious damages to the customs house, the administrative house, and cargo handling equipment. Several warehouses have also suffered significant damages. The workers have migrated from Kandla due to fear of earthquake. This is the second time in the last two years that the port has suffered heavily due to natural disaster. In 1998, Kandla was dealt a severe blow by a cyclone in the Kutch district. The effect of these calamities is more severe as most of the ports in India do not have insurance cover. The losses suffered have to be offset through internal accruals and government assistance.

Roads are relatively less affected. Aside from Surajbari bridge which connects Gujarat to Kutch district, the national highways continued to be functional. The earthquake substantially damaged the Surajbari bridge, and for about 15 days only light commercial vehicles were allowed over the bridge. More than 6000 Heavy Motor Vehicles (HMVs) cross the Surajbari bridge everyday, which is the arterial connectivity to the Kandla port. The bridge has been repaired and is now fully functional. A new bridge connecting the Rann of Kutch to the national highway, parallel to the Surajbari bridge, is also being commissioned soon.

3.2 Loss of Livelihood

Large-scale petrochemicals and fertilizer plants in Gujarat emerged unscathed through the earthquake. However, small-scale industry in Saurashtra and Kutch has received a severe blow. More than 10,000 small and medium industrial units have stopped production due to damage to plants, factories and machinery. Diesel engine manufacturing and machine and tools industry in Rajkot, ceramic units in Morbi and Surendranagar, and art and small tools industry in Kutch may find it difficult to recover. Work at thousands of salt pans has also stopped after the earthquake. A large number of workers (it is difficult to get a precise figure)from all the quake-affected cities have left and returned to their own states.

There are about 50,000 craftspersons who live and work in Bhuj, Anjar, Rapar, Hodka, and surrounding villages, now completely devastated by the earthquake. Kutch is nationally recognized for its rich quality and variety of craftware. Many of the local craftspersons have died in the earthquake. Besides, most of them lost their houses, workshops, and tools, and are likely to face bleak days ahead. The loss of their income opportunities due to loss of productive human and physical assets in the Kutch and Saurashtra areas has been a major consequence of the earthquake. People with little access to income-earning opportunities are more vulnerable. Along with shelter, the restoration of livelihood will be a priority for the rehabilitation program.

4 Planning for Rehabilitation

The Government of Gujarat (GoG) has set up the Gujarat State Disaster Management Authority (GSDMA), which would implement the reconstruction and rehabilitation, with support from various other agencies in the quake-hit area. The GoG has announced four packages amounting to almost US $1 billion for reconstruction and economic rehabilitation for more than 300,000 families.

- The first package takes care of 229 villages where more than 70 per cent of the houses have collapsed. At the rate of nearly Rs. 30 million per village, it has earmarked Rs. 3 million for land acquisition, Rs. 7 million for infrastructure, and Rs. 18 million for constructing 200 engineered, quake and cyclone-resistant engineered houses, and Rs. 2 million for other emergency facilities in each village.

- The second package is for villages with less than 70 percent destruction and whose residents do not wish to be shifted to a new location. Here, the poor[1] whose houses have been destroyed would get Rs. 35,000. Others owning between 25 and 45 square meters of land, but whose houses have been totally destroyed, will receive between Rs. 50,000 to Rs. 90,000.

- The third package is for those villages, which are situated far away from the epicenter but where individual houses have been destroyed. Here, the aid ranges from Rs. 7,000 for totally destroyed huts to Rs. 40,000 for fully destroyed semi-pucca houses. Houses suffering 50 per cent destruction would get Rs. 20,000 and those having minor cracks Rs. 2,000 per house or hut.

- There is also a fourth package, meant to take care of the middle-class flats and houses wrecked by the earthquake in Ahmedabad, Rajkot, and Surat. The Government will announce the fifth package later for the residents of Bhuj, Anjar, Bhachau, Rapar, and Gandhidham after consulting residents.

The details of these rehabilitation packages are available on a web site: www.gujaratindia.com. The government has also announced US$2.5 million package to revive small, medium and cottage industries. Damage assessment is still going on, and the final shape of the rehabilitation program will soon be firmed up.

Resource Mobilization

The World Bank and the Asian Development Bank have announced loans worth $300 million and $500 million respectively. The Government of Gujarat (GoG) has put forward a soft loan proposal of $1.5 billion to these two multilateral agencies. A number of other bilateral agencies including the European Union (EU), the Department for

[1] In India, those who get less than Rs. 11,000 as annual income are considered to be below poverty line or the poor.

International Development (DFID), the United States Agency for International Development (USAID), and the Canadian International Development Agency (CIDA) have also agreed to provide financial assistance for the rehabilitation program. The Housing and Urban Development Corporation (HUDCO) and the National Housing Bank (NHB), two major public sector institutions in India's housing sector, have also offered to provide financial assistance of US$400 million. While there has been no major impact on industrial units owned by major corporate groups, the leading chambers--the Confederation of Indian Industries (CII) and the Federation of Indian Chambers of Commerce and Industries (FICCI)-- have offered to adopt clusters of quake-ravaged villages for relief and long-term rehabilitation. A number of business groups such as Reliance, VSNL, Larsen & Toubro, Tata Steel, Coca-Cola, Essar and Videocon have decided to contribute to the rehabilitation program. Public sector industries too have provided huge donations for rehabilitation.

A large number of NGOs, national and international, have participated in the relief operations. Many of these NGOs will gradually withdraw after the relief phase closes, as they do not have sufficient resources to participate in the reconstruction program, or do not have a long-term plan for local involvement. However, a number of larger NGOs will continue and contribute to the rehabilitation program. The government is actively seeking the NGOs to adopt villages for rehabilitation. It has announced a contribution of 50 per cent of the cost of rehabilitation, if a NGOs adopts the village for rehabilitation. Gujarat has a large number of prosperous expatriates settled abroad, and they will also contribute generously to the rehabilitation program.

The prompt assistance declared by the World Bank, the Asian Development Bank, a host of other donors and the Government of India has made it possible for the Government of Gujarat to mobilize adequate resources for the reconstruction program. The corporate sector and NGOs have also decided to contributed to the cost of reconstruction in a significant way. The cost of reconstruction would be funded through the following sources:

- From the Government of India and the Government of Gujarat
- Through grants and loans of bilateral agencies
- Through multilateral loan funding from the World Bank and the Asian Development Bank
- From the Prime Minister's and Chief Minister's Relief Funds
- From the corporate sector and NGOs
- From Insurance companies, banks and financial institutions

However, it will be a great challenge to utilize the resources effectively for rebuilding Gujarat. An earthquake rehabilitation program of this magnitude requires careful planning and efficient management structures. It will also be important to establish norms of accountability and transparency in the implementation of the program. A strong community orientation is also critical for the success of the program.

5 Long-term Issues for Reconstruction and Mitigation

A reconstruction program is always a great opportunity for civic improvement. It regenerates the local economy due to massive investment over a short period of time. It can improve the quality of housing, and social and community infrastructure. It can also be a context for introducing mitigation and preparedness practices. People also tend to accept regulations better in these circumstances. In Gujarat, and also in the whole of the country, reconstruction programs should aim to realize these opportunities. This report identifies a number of issues that may be considered for rehabilitation and mitigation planning at the state and national level:

5.1 Reconstruction and Development

Besides engineering issues involved in reconstruction, a number of planning and architectural issues are involved, which require a wide range of consultations:

5.1.1 *Relocation versus In-situ Reconstruction*: It is always a contentious issue, which makes it difficult to build a consensus within the community. It is important to be flexible, and seek extensive consultation with the community at the village and town level. The decision could be taken on the basis of choice of the community for every village or town, and so a policy pronouncement should not preempt making these choices. However, there are certain areas that require expert inputs.

First, it is important to have a geological and geotechnical investigation of the site on which the settlement is planned. If the existing site is exposed to elevated, it is preferable to shift the village to a new location.

Second, it is essential to assess if the present population of the settlement could be resettled on the existing site of the village or town. All these villages and towns have been settled a long time back for a much smaller population. In the intervening years, the population has grown, and it is likely that the existing area may prove to be inadequate. In such a case, it will be necessary to look for more land or an alternative site on which the extended settlement could be planned.

Third, are the poor and marginal sections of the society getting a fair deal in the rehabilitation? They generally live in the most unfavorable parts of the village, and rehabilitation should give them an opportunity to rebuild their lives in a more equitable way.

Fourth, there should be enough area available for social and community infrastructure, and all the segments of the population must be able to access these facilities. In fact, the rehabilitation could be a combination of relocation and in-situ construction. It therefore demands land use and rural resettlement planning for every village and town individually.

5.1.2 *Architecture and Building Materials*: These constitute the most critical issues for the success of a rehabilitation program, and need detailed inputs of experts. A number of designs and technical recommendations could be prescribed for substructure, superstructure, roofs, walls, and openings. Choices could be made among prefabricated, modular, and regular structures. Similarly, there could be a number of options for building materials—RCC, stone masonry, brick masonry, and adobe. Expert opinion helps the community in making an informed choice.

5.1.3 *Urban and Regional Planning*: In the rehabilitation program, five towns in the Kutch region need to be rehabilitated. These towns will require considerable land use and infrastructure planning. There is also a great opportunity to upgrade many of the facilities in these towns such as water supply, sewage, waste disposal, and parks and recreation. While these towns can be resettled, many of their traditional features and landscapes could be preserved through careful planning.

Since the rehabilitation will cover almost the entire Kutch region, a number of

initiatives can be taken for regional planning. For example, a new transportation system for the entire region can be planned. Similarly, a new education and health system, much different from the existing system and of very high standards, can be introduced. Industrial estates, technology parks, and craft enclaves can be built in different areas, creating a balance of sectoral activities in the entire region. A great deal can be achieved through the involvement of institutions and experts specializing in urban and regional planning and architecture.

5.1.4 *Revival of Crafts and Cottage Industries*: Kutch has an abundant diversity of crafts, and the district alone has perhaps more honored and recognized craftspersons than any other part of the country. For every material—wool, textile, wood, clay, stone, brass, zari, and mirror—there is a specialist craftsperson who can produce exquisite products. Kutch is also a unique resource center for all kinds of techniques—vegetable dyes, embroidery, block prints, resist dyes, turning and lacquering, etc. The rehabilitation program in Kutch will have to make a prioritized plan for the economic recovery of these crafts and craftpersons, restore their workshops, and ensure that they are able to continue their activities in their own rural environment. Microfinance services can be of great relevance in reviving these economic activities. The NGO network in Gujarat has used microfinance as an empowering instrument for the poor and women, and the rehabilitation program provides an appropriate context for its application.

5.2 Disaster Management Planning

Gujarat is a disaster-prone state. In the last few years, cyclones, floods, and droughts have repeatedly struck the state of Gujarat. The cyclone that struck Kandla in 1998 was particularly severe, causing deaths of more than 3,000 people. The frequency of disasters impressed upon the Government of Gujarat the importance of developing a comprehensive disaster management plan. However, the state could not mobilize resources for its implementation. After this earthquake, there is a consensus on capacity building in this area within the state and the country. The Government of Gujarat's renaming of the Earthquake Rehabilitation Authority as the Disaster Management Authority is symbolic of the importance it attaches to the disaster management system in the state. The state seems to have taken a broader approach to disaster management, by constituting this focal agency for dealing with all the hazards. Disaster management will be one of the most important components of the rehabilitation program supported by the World Bank and the Asian Development Bank.

At the national level too, there are major initiatives under consideration. The Prime Minister Atal Bihari Vajpayee constituted a committee under his own chairmanship to suggest the necessary institutional and legislative measures required for aneffective and long-term disaster management strategy. A number of senior ministers and opposition leaders are members of this committee. The Government of India has decided to set up a National Center for Calamity Management. A High Powered Committee is also

deliberating institutional changes in disaster management organization at the national level.

In Gujarat, a new disaster management system may address the following priorities:

5.2.1 *Emergency Response*: The weaknesses in emergency response during the recent earthquake and 1998 cyclone point to a number of steps required for strengthening emergency response and quick deployment of resources by the government agencies:

- Emergency Response Plan at the state and district level
- Equipment Inventories
- Control Room Network
- Communications Network
- Fire Services
- GIS-based Disaster Management Information System
- Cyclone Preparedness Program
- Earthquake Preparedness Program

5.2.2 *Institutional Development*: Institutional strengthening of the government agencies, backed by a statutory scheme, is necessary for the implementation of the disaster management system. The agenda for institutional strengthening may address the following issues:

- Disaster Management Legislation
- State Disaster Management Agency
- Disaster Management Set-up in Municipal Corporations
- State Training, Resource and Documentation Center

5.2.3 *Long-term Disaster Mitigation*: There is a strong case for implementing long-term mitigation programs, which promote access to and application of financial and technical resources, and applied research. These specific programs are:

- Risk and Vulnerability Analysis
- Mitigation Strategy
- Mitigation Fund
- Insurance and Microfinance
- Seismic Hazard Map, Microzonation and Seismic Building Code
- Multidisciplinary seismic research
- Drought Early Warning System
- Flood Forecasting and Storm Surge Modeling
- Cyclone Warning System

These initiatives require a great deal of planning, organization, and technical assistance. The disaster management system also requires a long-term financial commitment and resources for sustainability. It must therefore be implemented as a program separately from the reconstruction activities. India and the state of Gujarat can benefit from the experience of disaster management institutions and practices in the developed countries. It will also be useful to build collaboration with national and international research institutions and universities from abroad for the implementation of technical components of the disaster management plan. Applied research, technology transfer and training will be important components of a disaster management system.

5.3 Emergency Communications

Of all the disaster management components, the emergency communications network is most crucial to emergency response. It ensures the flow of information, tracks emergency needs and helps in deployment of the emergency personnel. In this earthquake, the communication link with Bhuj could be restored only two days after the earthquake, and even after 10 full days, communication with Bhuj was not back to normal. The cellular network in the state failed. A large part of the state remained completely disconnected. The lack of communications impeded information flow and seriously affected relief operations. The situation was similar to the Orissa cyclone or the Marmara (Turkey) earthquake in 1999, where the disaster-affected areas were completely cut off from the rest of the country due to communications breakdown, impeding the rescue and relief efforts.

These recent disasters clearly demonstrate that despite significant technological advances, the basic need for communications in extreme situation still remains—getting the right information at the right time. The tools now available to gather and deliver that information range from small, hand-held shortwave radio units to complex satellite systems, but, unfortunately, they are not always in the right place when disaster threatens or strikes and even, if they are, they do not provide the necessary information on vulnerable situations. It has created serious problems for those who rely on receiving the right information.

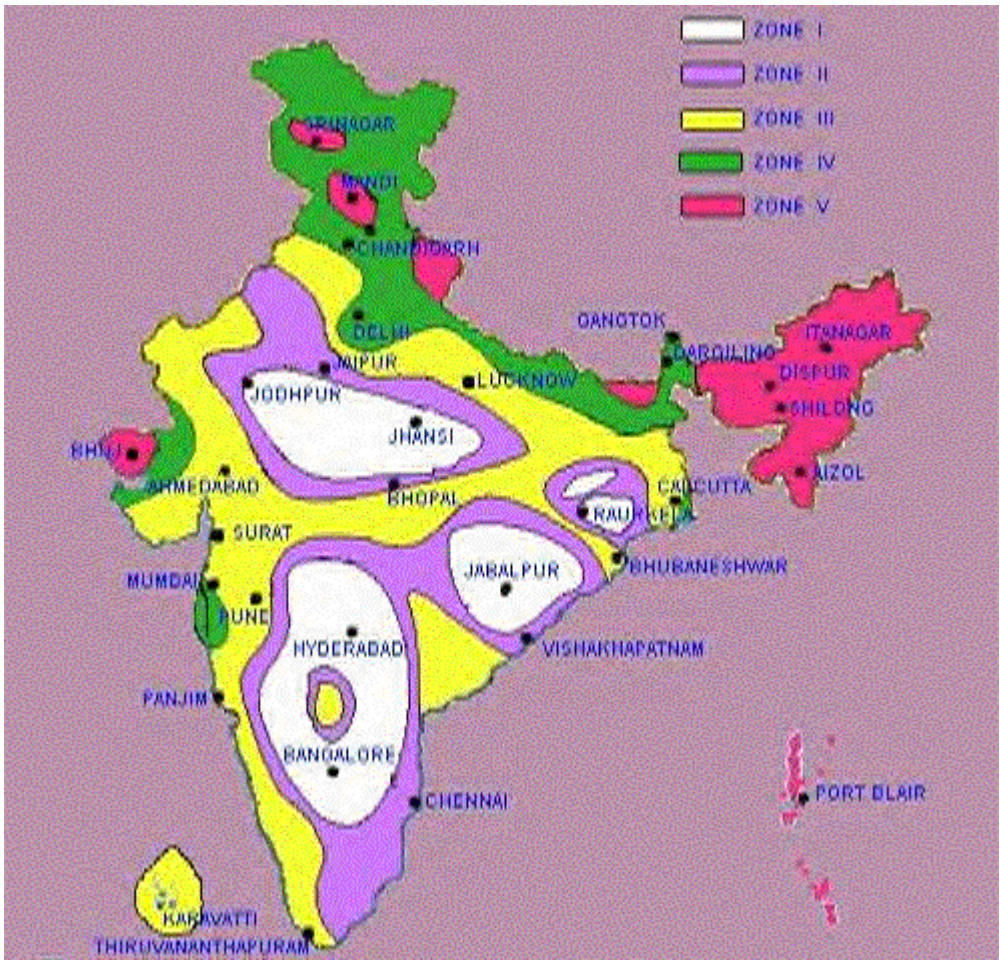
A disaster management plan must persuade for the creation of an efficient communications infrastructure. A new telecom network may be designed connecting the state capital to the lowest administrative units. The network must be robust and dependable, and in case of a breakdown, alternative arrangements must be activated. It could be a multi-tier network, between different levels of administration—state to district, district to Taluka, and further down to villages-- with combination of technologies. Given that the cellular operators were the first to bring back their services even in the most affected areas like Gandhidham and Bhuj, the first choice of technology should be wireless. VHF and HF communication, mobile radio trunking system, and wireless in local loop are some of the technological alternatives. A great deal of applied research is going on for the development of advanced versions of wireless technology, and the new applications must be harnessed for building the communications network. ().

A detailed feasibility study for setting up a communications network is the first step. All the relevant technologies should be assessed for the appropriateness in the context of Gujarat's physical terrain. The participation of private sector and technical groups will be very important for setting up the statewide communications network.

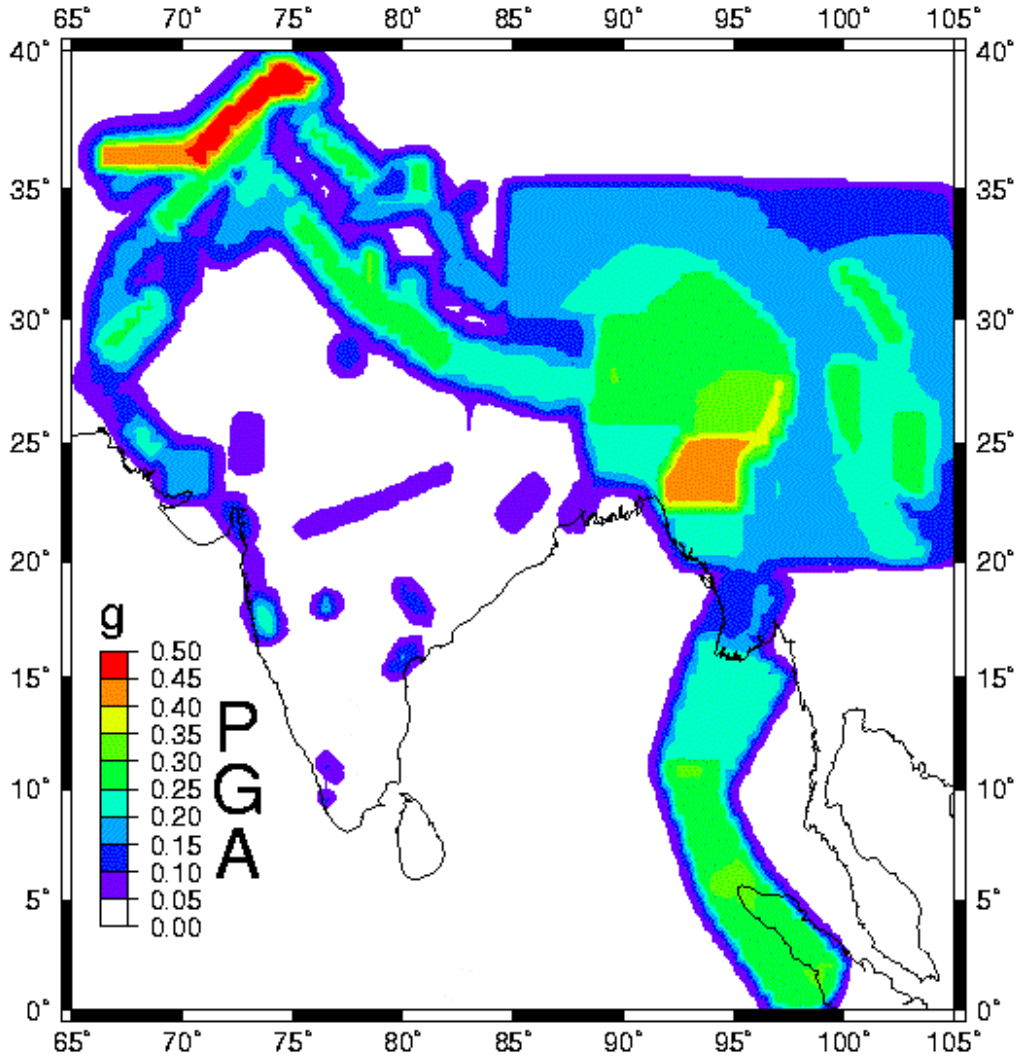
5.4 Seismic Zonation

The first national seismic hazard map of India was compiled by the Geological Survey of India (GSI) in 1935. A second national seismic hazard map was published in 1965, based primarily on earthquake epicentral and isoseismal maps published by the GSI.

The Bureau of Indian Standards (BIS), which is the official agency for publishing seismic hazard maps and codes in India, produced a six-zone map in 1962, a seven zone map in 1966, and a five zone map in 1970 / 1984 (Bhatia, et al., year not specified) The last of these maps is accepted by all the national agencies currently valid; this map was created based on the values of maximum Modified Mercalli intensities observed in various parts of the country, in historic times.



Source: The Government of India's official website on the Gujarat earthquake http://gujarat-earthquake.gov.in/final/seismic.html



Seismic hazard map of India and adjoining regions for 10% probability of exceedance in 50 years Source: GSHAP, available on http://seismo.ethz.ch/gshap/ict/fig3.gif**.**

The National Geophysical Research Institute, Hyderabad prepared this seismic hazard for the Indian region under the Global Seismic Hazard Assessment Program.

These successive seismic zonation maps of India more closely represented known seismotectonic features without sacrificing the information obtained from earthquakes and from theoretical ground motion attenuation relationships. Another significant change in the revised maps was the abolition of zone zero, in recognition of the fact that it was not scientifically sound to depict any region of India to have the probability of an earthquake equal to zero. This had the desired effect of including some level of seismic provisions in the design of important structures.

Khattri, et.al. (1984) prepared a probabilistic seismic hazard map of the Himalayas and adjoining areas that depicts contours of peak acceleration (in %g) with a 10% probability of exceedence in 50 years (Bhatia, et.al., year not specified). The present five-zone map, which is currently under revision, is as follows[2]:

Zone V (Very high risk quakes of magnitude 8 and greater): The entire North-east, including all the seven sister states, the Kutch district, parts of Himachal and Jammu & Kashmir, and the Andaman and Nicobar islands. These areas may experience Intensity IX and above on Modified Mercalli Intensity Scale.

Zone IV (High risk quakes up to magnitude 7.9): Parts of the Northern belt starting from Jammu and Kashmir to Himachal Pradesh. Also including Delhi and parts of Haryana. The Koyna region of Maharashtra is also in this zone. These areas may experience to MM VIII.

Zone III (Moderate earthquakes up to magnitude 6.9): A large part of the country stretching from the North including some parts of Rajasthan to the South through the Konkan coast, and also the Eastern parts of the country. A moderate risk zone associated with the intensity maximum of MM VII.

Zone II and Zone I (Seismic Disturbances up to magnitude 4.9): These two zones are contiguous, covering parts of Karnataka, Andhra Pradesh, Orissa, Madhya Pradesh, and Rajasthan, known as low risk earthquake zones. These areas may experience intensity MM VI .

The Deccan Peninsula, known as the Stable Continental Region (SCR), has experienced a number of seismic disturbances in the recent past. In the last decade, two major earthquakes (Jabalpur, 1998), and Latur (1993) have occurred in this region. Bhuj too lay in the northern fringe of the stable continental region of India. Besides, in recent times,

[2] More information on seismic zonation of India are available on the following websites:
http://seismo.ethz.ch/gshap/ict/india.html
http://www.geocities.com/stasertin/seisindia.htm
http://www.mapsindia.com/overview/seismiczone.htm
http://wwwdel.vsnl.net.in/bis.org/quake.htm
http://www.taru.org/quake/quake/event/

the country has experienced a series of earthquakes in other areas too: Bihar-Nepal (1988), Uttarkashi (1991), and Chamoli (1999). The frequency of earthquakes in India has necessitated a major re-assessment of its hazard potential on a national basis.

A reconsideration of seismic zones of India has also become necessary in view of the growth in population and built environment across the country. The death toll from the Bhuj earthquake is almost 20 times higher than that of the 1819 earthquake[3], though both the earthquakes had a comparable magnitude. The rise in death toll is largely due to greater risk exposure on account of population growth in the Kutch district. Today, Delhi and Mumbai have become extremely vulnerable to seismic hazard, largely due to unregulated construction in these cities.

The Koyna (1967) and Latur (1993) earthquakes followed by Jabalpur (1998) are the first few recorded earthquakes in the Stable Continental Region (SCR) in recent history. These represented a new phenomenon for the earthquake scientists, and underlined the need for reconsideration of the seismic zones of India. The BIS undertook a program to reconsider the seismic zone of India, but it is yet to be completed. In the meanwhile, an international seismic hazard map has been developed by Global Seismic Hazard Assessment Program (GSHAP). Seismic instrumentation in India has improved somewhat. The Indian Meteorological Department has upgraded 10 seismological observatories in peninsular India. A National Seismological Database Center and a Central Receiving Station have been established in New Delhi to receive, archive and analyze seismic data.

At the level of states too, specific programs have been undertaken to study seismic hazards. The state of Maharashtra has prepared a probabilistic seismic hazard map for the state. A similar exercise is underway in Uttar Pradesh and Uttaranchal. The Government of India has prepared a Vulnerability Atlas, which provides state-wise details of housing stock, exposed to seismic hazard.

These developments provide the opportunity for a major collaborative effort to review the seismic zones of India. Various state agencies and research institutions from India and abroad can collaborate on such a project project.The project can also identify and implement a seismic instrumentation program, which would improve seismic monitoring in the country. The project, based on seismological and geological investigations, can harness recent developments in seismic studies, sensor design, and telemetry to draw an updated and relevant seismic zone map for the country.

5.5 Seismic Engineering

In the earthquake, reinforced concrete (RC) buildings of ground floor plus four storys (G+4) and ground floor plus ten storeys and above (G+10) collapsed in Ahmedabad

[3] A detailed account of 1819 earthquake is available in Bilham (1999) on the website http://cires.colorado.edu/~bilham/Bilham(1998).html.

resulting in 746 causalities[4]. In the city, only minor damage was observed in single, or two story short-period structures. Most of the damage was limited to G+4 through G+10 storey buildings having "soft story" at the ground floor. These buildings were not designed for lateral loads as required by IS 1893 (Zone III) and had, of course, no concept of ductile detailing for G+10 buildings as recommended in IS 13920 (Goyal, et al, 2001)[5].

After the earthquake, the Ahmedabad Municipal Corporation (AMC) deployed several teams of structural engineers, architects and senior civil engineers for a technical survey of all the damaged buildings. Each team came up with at least four to five buildings on an average, which would have to undergo major repairs before the occupants can move back in. These teams found apparent violations of the Indian Standard Code for Zone III. Building code violation was most prevalent in low-rise structures. The quality of concrete used in columns and building frames deviated from norms stipulated in the building codes.

At Bhuj, all of more than 100 multi-storey buildings that were built over the last five years either collapsed, or, have been certified as unsafe for habitation. Over the last two years, buildings of up to eight floors had been approved in Bhuj without adequate technical review. The building plans ---- are supposed to be approved as per the IS building code for Zone V. However, there was little effort at compliance with building codes on the part of the municipal authorities. The builders cut cost, used more concrete and less steel. Staircases were not integrated into buildings, which caused their collapse.

In fact, the Government of Gujarat regularized illegal structures and violations in six major cities of the state by levying an 'impact fee'. Conceding that several buildings were constructed in contravention of regulations, the government pleaded that "administratively, removal or pulling down of a large number of buildings is neither feasible nor desirable" and that it was "fraught with the possibility of creating law and order problem and hardships to the people". Within the jurisdiction of Ahmedabad Municipal Council, about 200 of 450 multi-storey buildings do not have Building Use permission[6]. In the areas covered by the Ahmedabad Urban Development Authority (AUDA), hardly 25 of the 200-odd multi-storey buildings have bothered to take the building permission (Indian Express, Feb. 8, 2001).

The AMC has appointed the Centre for Environmental Planning and Technology (CEPT) as a nodal agency for providing technical services. However, the CEPT has not been able to find enough structural engineers. A great number of structural engineers will be

[4] Most of the buildings that collapsed in Ahmedabad were in two categories: ground plus four and ground plus ten and above.

[5] More detailed reports on building damages are available on the following websites:
http://www.civil.iitb.ernet.in/BhujEarthquake/Report1.htm
http://www.nicee.org/NICEE/Gujarat/gujaratslides/build_rc.htm

[6] Building Use permission is given after a thorough technical inspection of the completed building. A building can be occupied for use only after the permission is given by the regulatory authority.

required to deal with the reconstruction and retrofitting elsewhere in the state. In addition, damages to non-engineered buildings also need to be addressed on a large scale.

One of the most important priorities of the reconstruction program will, therefore, be a capacity building program in seismic engineering at the state level. The program may include several components:

- Development and enforcement of Indian Standard (IS) building codes for different seismic zones
- Training to civil and structural engineers in seismic resistant design
- A demonstration program in seismic technology at different places
- Technical assistance and training for retrofitting / reconstruction of non-engineered buildings
- Technical assistance for earthquake-resistant construction of schools and hospitals.
- Spread of seismic technology through academic and research institutions.
- Development of an information, education and communication program for popular spread of seismic technology.

Seismic engineering must be the cornerstone of the rehabilitation program. This is an area where significant work has been done in the US, Japan and many developed countries. There are new technologies available, base isolation being one of the most important among them. In the beginning of the rehabilitation program, the following steps may be taken:

- A pilot program can be implemented in different parts of the quake-affected region, demonstrating these new technologies and seismic resistant structures.
- The state engineering colleges could be involved in training of a large number of civil and structural engineers in seismic technology.
- It will be essential to organize a large-scale training program for local masons. It will also be important to train women masons. It helps in spreading awareness among the community.
- A mobile exhibition of seismic technology can be organized for spreading mass awareness.
- It will be very useful to organize an orientation program for non-technical officials and panchayat leaders.
- A technical guidebook for reconstruction, retrofitting, and strengthening can be prepared which guides engineers in seismic resistant construction.

Engineering experts from India and abroad can work with the government, municipal corporations, engineering colleges, and research institutions on seismic engineering issues. A continuous education and training program can also be supported through a collaborative effort of earthquake engineering experts from abroad and the national institutions.

5.6 Building Codes

The earthquake has dramatically demonstrated the need for compliance with building codes in the state. The Government is reviewing its existing building by-laws and regulations as per the provisions of the National Building Code, and till these regulations are finalized the state government has directed the municipal commissioners of all the six big cities not to approve building plans irrespective of their status.

Non-compliance with building codes has been a serious issue for the Government of India too. The Ministry of Urban Development is considering introducing a national engineering law for the enforcement of building codes and certification of structural engineers. However, much more needs to be done.

It is argued that though India has rigorous building codes, their enforcement is not mandatory. However, this is not entirely true. While there is no national law regarding the enforcement of building codes, these codes have been incorporated into the by-laws adopted by the municipal corporations. These by-laws require mandatory compliance with the building codes. However, the enforcement of these by-laws has been a serious problem due to the lack of trained engineers, poor monitoring of building practices, and corruption. It is also true that popular awareness about the importance of code compliance is very low. Unless these issues are appropriately addressed, the legal provisions will not be very effective in reducing risk.

In rural areas, most of houses are non-engineered. Though there are standards for non-engineered houses, enforcing these codes will require a regulatory authority and technical guidance for a very large area, which is difficult to provide. A village council (panchayat) cannot be expected to enforce building codes. It requires enormous investment in setting up and sustaining a regulatory mechanism for the entire country.

In fact, the enforcement of building codes is not possible without a national initiative. A national program comprising several measures and incentives should be instituted to promote compliance with building codes. National legislation for building codes, technical courses in seismic engineering, a certification system for qualified structural engineers, interaction with local governance structures, and public awareness about the codes are the essential constituents of a national earthquake mitigation program. It will be useful to commission a multi-disciplinary study as a first step that could discuss the state of compliance with building codes in India, and suggest relevant measures to improve them.

5.7 Microzonation

Local geological and soil conditions contributed significantly to structural failures. .
A preliminary analysis of the pattern of collapsed, partially collapsed and damaged buildings in Ahmedabad has led scientists to believe that there may be many more

factors, mainly geological and geotechnical that need to be considered while analyzing a collapse or constructing buildings afresh. The location of the building is of utmost importance. If it lies in a fault zone or on soft soil as most of Ahmedabad does, then the danger is even greater.

Seismic microzonation maps, , are essential tools for effective earthquake and related land use planning. Seismic microzonation maps are detailed maps that identify the relative potential for ground failure or amplification during an earthquake in different areas. They may include one or more seismic characteristics (liquefaction, amplification, land sliding, tsunamis, subsidence). They are compiled from geological and geotechnical data and they reflect local site conditions

It is necessary to produce seismic microzonation maps, which have all the above-mentioned details at the local level, following an earthquake, before deciding on future locations for rebuilding. There is always a possibility of geological hazards, at locations where the earlier buildings have collapsed. All decisions regarding the land use planning must be subject to the exercise of microzonation.

Macro zones are useful for broad specification and design of ordinary buildings. However, microzonation is particularly needed for big cities and the most vulnerable areas. The local ground vibration varies depending on the local soil conditions. Microzonation would incorporate these small-scale variations also. In microzonation one can incorporate conditions of existing buildings with seismic hazard to arrive at a seismic risk status of the built environment down to the block or street level. This is of great help in minimizing the damage through strengthening measures. An expert group formed after the earthquake has recommended microzonation of all the Zone V areas in the country.

It is important to undertake a detailed microzonation exercise for the settled areas of the Kutch region, which falls in Zone V. Besides, Ahmedabad and other major cities of Gujarat should also be included in this exercise. The microzonation program will help in deciding the location of new settlements, if it is undertaken along with the rehabilitation. In India, comprehensive microzonation has not been attempted in any part of the country, and so a beginning in Gujarat will be a very positive initiative in seismic mitigation.

5.8 Essential Facilities: schools, hospitals and public buildings

Essential facilities are those buildings that support functions related to post-disaster emergency response and disaster management. These include state secretariat, district headquarters, police and fire stations, hospitals, potential shelters (including school buildings), and buildings that house emergency services. The unimpeded availability and functionality of these buildings immediately after a disaster is a top priority in disaster preparedness.

It may be useful to develop a separate rehabilitation strategy for this group of buildings. In the case of these buildings, their public use and availability are far more important than the potential economic loss. A statewide retrofitting program for the buildings should be initiated. For example, in Ahmedabad, the office of the Municipal Corporation and the Collector must be retrofitted on a priority basis. Based on a rapid seismic appraisal of these buildings, a retrofitting solution can be developed. If it is not possible to include all the essential facilities, at least a few public buildings in every district of Gujarat may be selected on the criteria of functional criticality, predicted ground motions, and expected structural performance. New economical retrofit methods should be developed and standardized. Technology developed for the seismic retrofit of these essential facilities can be transferred later to commercial and industrial facilities.

Since a large number of deaths in the Bhuj earthquake took place due to collapse of schools and hospitals, it is most important to implement a specific program of seismic retrofitting and strengthening of all the schools and hospitals in quake-prone areas. It is necessary to prepare earthquake resistant designs for all the existing schools and hospitals, and implement it under expert guidance. It will require a large-scale engineering effort. The program may benefit greatly from the experiences of seismic strengthening and retrofitting of school buildings and hospitals in other countries.

A lot of new technology and building designs have evolved in Japan, New Zealand and the US for earthquake-resistant buildings, including extensive use of shear walls to take lateral loads. All of them should necessarily be incorporated in all our future designs to ensure better protections.

5.9 Critical Infrastructure Protection

The Gujarat State Electricity Board (GSEB), which has suffered damage of US$75 million is now considering quake-resistant designs of control rooms, sub-stations and other structures housing key equipment at different locations in the state. According to the GSEB, it will adopt designs suggested by the Power Grid Corporation Limited (PGCL) and the National Thermal Power Corporation (NTPC) for their key installations. The GSEB is also looking for possible sources to finance its quake resistant construction.

Kandla port has been hit repeatedly by natural disasters. Gujarat has some 40 ports including India's busiest at Kandla – which was affected by the earthquake. Kandla handles most of India's shipping with the Middle East and Africa. These ports face a serious hazard of cyclones too. None of these ports has insurance cover. According to officials, the premium charged by the insurance companies on ports is so high that it does not make economic sense to purchase insurance , especially since these disasters normally occur only once in about 50 years. After the earthquake, the experts from the Indian Institute of Technology, Madras have visited Kandla port for damage assessment. They will provide structural solutions for retrofitting and future loss reduction.

The Bhuj airport was seriously damaged and the air traffic control tower came down in the earthquake. The Indian Air Force made it operational the same day by setting up a

makeshift control tower facility. There were long cracks on major highways, and water supply schemes were rendered completely dysfunctional.

In recent times, Gujarat has taken significant initiatives in infrastructure building, in particular, roads, and water supply programs. The Infrastructure Leasing and Finance Limited (IFCL) has made a number of investments in Gujarat in the transport sector. The Gujarat government plans to set up a Rs 5000 million-infrastructure fund. It will be important to develop an action plan and provide resources for a critical infrastructure protection plan in view of serious natural and technological hazards in Gujarat. It will require new technology, higher safety standards, and better maintenance protocols. It is also very important to address the issue of interdependence of critical infrastructure system. For example, power breakdown results in interruption of water supply systems. The rehabilitation program provides an opportunity to suggest measures for reducing the vulnerability of critical infrastructure and building redundancies in the system.

5.10 Disaster Risk Insurance

5.10.1 *Predominance of Life Insurance*: The state of Gujarat has one of the country's highest concentrations of insured. Most of the insurance is for life. There are close to 7.2 million policyholders in Gujarat out of the total state population of 48.3 million. The total exposure amounted to about Rs 330,000 million and the average sum insured is about Rs. 46,000[7]. Various government, rural-based schemes, householder policies have supported life insurance in Gujarat.

In Gujarat, a large number of deaths took place in high-rise buildings where the proportion of people with insurance policies is quite high. The State-owned Life Insurance Corporation (LIC) expects about 13,000 death claims, with about 10,000 claims coming from Bhuj and other parts of Kutch district. Another 30,000 claims are expected on account of injury resulting in partial or full disablement. The LIC could end up paying close to Rs 2000 million towards settlement of insurance claims in the earthquake-hit areas of Gujarat.

5.10.2 *Insurance for the Poor*: Interestingly, however, it has been the government's initiative that has expanded insurance cover across the nation among the poor. Just before the earthquake, a large number of farmers and villages in the devastated parts of Gujarat had opted for the Janata Personal Accident Cover, whereby they were insured against death on account of personal accident by any means. These covers insurance for the poor in the rural sector to the extent of Rs 15,000 per person. The district authorities pay the premia, of Rs. 10 per year per person, for this cover. Though the quantum of claims is small, the number of those insured is very large in number. The National Insurance Company is looking into covers issued to more than 100,000 rural people under the Janata Personal Accident Cover. Other insurance firms too like the Oriental Insurance

[7] The per capita income of Gujarat is Rs. 7,586 annually at 1992-93 prices.

and New India Insurance have insured landless labor and marginal farmers under similar government-paid schemes.

The spread of credit card usage by issuing banks has also resulted in greater insurance coverage in the area of personal line, including accident and death due to earthquake. The credit card holders in India are covered for life where the compensation amount varies between Rs 100,000 to 200,000. In the case of those who had opted for the New India Assurance Good Health, Personal Accident or Mediclaim Policy, individual reimbursement of hospitalization expenses and loss of life vary between Rs 200,000 to 500,000.

5.10.3 *Commercial and Property Insurance*: It is in buildings and factories, where the massive destruction took place, however, there was virtually no insurance cover. The level of property insurance in India is very low. In addition, the cost of earthquake insurance in India has been quite high. Premiums collected by the four national insurers against the occurrence of earthquake that fall under fire insurance policies amount to just Rs 4,500 million (US$100 million). This is just 7.5 per cent of the aggregate Rs 60,000 million-premium income for the four companies.

Many households tend to take property insurance without paying additional premium for the earthquake cover. Only those who have taken loans against their property have taken a comprehensive cover as defined by housing finance companies, which insist on earthquake protection. Property mortgaged to any of the leading financial institutions, such as the Housing Development and Finance Corporation (HDFC), the General Insurance Company (GIC) and the Life Insurance Company (LIC) are necessarily fully insured, inclusive of earthquake cover.

The payment of additional premium for the earthquake cover is a worldwide phenomenon, and one that will be practiced by the new general insurance players once their products enter the market. The availability of earthquake coverage comes at a price relative to the risks. Obviously, the premium for earthquake coverage in Madhya Pradesh will be much less than in the Himalayan areas, where the level of seismicity is very high.

The big firms operating in Gujarat, like Reliance, Indian Petrochemicals Company Limited (IPCL), Indian Oil, or Essar, are covered under a mega policy, which includes earthquakes and even potential loss of profit due to disruption of business caused by earthquakes. These industries have not suffered much damage in the earthquake. While the total risk cover of these top firms is around Rs. 300,000 million in Gujarat, other smaller industries are insured for around Rs. 100,000 million. Of this, around a fourth is in the Bhuj-Ahmedabad area. Virtually, none of these smaller industries has the coverage for earthquake risk.

The infrastructure in India does not really have the insurance cover. According to one report, the Kandla port was in the midst of negotiating an insurance cover for the port. The Mundra port, a joint venture between the private sector and the Gujarat government, was, however, insured. The Mundra port was not affected much by the quake, and operations continued without any major disruptions.

The maximum total payment from insurance firms in settlement of insurance claims in earthquake affected areas of Gujarat is likely to be around Rs. 10,000 million (US$200 million).

5.10.4 *Liberalization of Insurance Sector*: Insurance sector in India has recently opened up to international participation. The Insurance Regulatory Development Authority (IRDA) has been set up, which provides license to insurance companies in the private sector to operate in the country. It has issued licenses to about 10 private international insurance companies for operating in the Indian market. With new operators getting into the Indian market, it is expected that the coverage of property insurance will increase, and the insurers will provide new tools for disaster risk management.

In India, for seismic risk, areas are graded on a scale of 1 to 5 for the likelihood of quakes, and this is reflected in the insurance rates offered to property -owners in those areas. In India, premiums vary from Re 1 per Rs. 1,000 sum assured in Zone V, the most risk-prone area, to as little as Rs. 0.1 per Rs. 1,000 sum assured in zone I, the least risk-prone area. In addition to states like Gujarat and Tamil Nadu, the coastal areas of Andhra Pradesh and some parts of Assam fall under the most sensitive category. Eastern Bihar, areas adjoining Nepal, Darjeeling in West Bengal, Delhi, Jaipur and western Uttar Pradesh have been classified as semi-sensitive, and quake cover rates stands at Rs. 0.6 per Rs.1,000 sum assured.

While the Tariff Advisory Committee has undertaken to outline tariffs based on seismically active zones, private insurers feel a lot more can be done if the tariff regime is done away with, in light of the opening up of the Indian insurance market. Should new players be given a free hand, it would facilitate them to price products better, even in the case of quake cover.

In developed countries, the criteria for pricing homeowners' risks are based on various aspects, including the soil it was constructed on, the foundation of the construction, the height of the building and the occupancy of the premises, among others. Earthquake insurance rates differ from one insurance company to another, depending on several rating factors. Older constructions generally cost more to insure than new homes. Wooden houses get better rates than brick ones because they tend to withstand quake stresses better.

The Indian scene is expected to change not so much in terms of products addressing earthquake cover, but in assuring a good basket of risk-based

premiums. New players intend to verify and inspect premises prior to granting insurance cover against earthquakes. New players are in the process of mapping out these risks, city-wise. However, given the limitations on account of the tariff regime, their hands are tied to a large extent.

5.10.5 *Setting up of a Catastrophic Reserve*: The Insurance Regulatory and Development Authority (IRDA) is planning to set up a catastrophe reserve where insurance companies could be asked to contribute 2 per cent of their premium income annually. According to the IRDA, the regulator is planning to approach the Central Board of Direct Taxes seeking a tax exemption for the contribution made by life and general insurance companies. It is still being contemplated whether it would be better to set up a catastrophe reserve or an equalization fund, but the first option seems more feasible. At last year's level of premium income, a 2 per cent contribution to the catastrophe reserve by the five state-owned insurance companies would result in an initial corpus of about US$160 million.

In the accounting guidelines issued by the IRDA, there is a provision for a catastrophe reserve. The guidelines said that the reserve is aimed towards meeting losses, which might arise due to an entirely unexpected set of events and not for any specific known purposes. The reserve is in the nature of an amount set aside for potential future liability against insurance policies in force. The IRDA will issue a set of guidelines for the creation of a catastrophic reserve.

A number of new initiatives must also be taken at the level of the government. In Turkey, after the Marmara earthquake, the Government has taken a decision to set up an insurance pool for covering seismic risk. India faces a regular series of natural disasters each year. Cyclones, floods, droughts and earthquakes are all part of the geographic profile of the sub-continent. They all impose a financial responsibility on the national and state governments. Surely it would be in the interest of the state to create a mechanism — a natural disaster insurance or hedge fund — to which mandated annual contributions be made out of the budget. The size of the contribution can be determined by a statistical analysis of the occurrence of disasters and their financial impact. The government support for personal insurance has been a welcome step. Many more products and services could be offered with the government support. The IRDA can take a major initiative in this area. One of the first steps could be to commission a detailed study of the feasibility of increasing insurance cover against natural disasters in the context of liberalization of insurance sector.

A rehabilitation program on the scale that is being planned in Gujarat provides a great opportunity for supporting all the initiatives mentioned above. These initiatives can be implemented at the national as well as state level. However, it will require resources, planning, and an implementation strategy. It also requires collaborative programs across agencies and institutions within the country and abroad. It will be necessary to support the Government of Gujarat in planning and implementing all the activities. A successful

implementation of the above-mentioned activities in Gujarat will demonstrate the importance of disaster management and mitigation planning for all the developing countries.

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