Disaster mitigation and management for West Bengal, India – An appraisal

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We examine the predominant natural hazards in West Bengal, along with an analysis of the prevalent disaster mitigation and management perspectives. Pre-hazard activities towards its mitigation are emphasized and explicated. In cognizance with the existence of multiple hazards in the region, a composite vulnerability map is prepared through integration of earthquake, flood, wind and cyclone, landslide, and subsidence hazard distributions along with vulnerability components represented by district-wise population density, and industrial output distribution to project a combined first-hand qualitative hazard and vulnerability description of the region. A combined management strategy through collaborations and coordination has been thought of to be more pragmatic than segregated efforts.

Keywords: Disaster, management, mitigation, natural hazards.

SYSTEMATIC mitigational approaches towards the impact of physical phenomena that pose a threat to human lives and property with particular reference to West Bengal have been evaluated in this article. Quantifiable threat to human lives and property due to a natural or man-made phenomenon is referred to as a hazard that in conjunction with vulnerability represents the possible risk. Thus, hazard is mainly controlled by the environmental setting and the risk is primarily influenced by socio-economic and demographic variables[1]. Since the supporting institutional and administrative machinery is always guided by socio-cultural ethos, as well as economic and political principles, region-specific review towards its mitigation and management is important.

West Bengal has been no exception as far as sufferings inflicted by natural and man-made hazards are concerned. The state has been frequented by cyclones, floods, droughts, landslides, subsidence and occasional earthquakes. Progressive trends of any region are controlled to a large extent by the requirements of the inhabitants, agriculture, industries, transportation, communication, education and culture, which generally form the vulnerability attributes. Because of the high population density and concentration of industrial and agricultural activities across West Bengal, risk or vulnerability to natural or man-made disasters is particularly high. With increasing developmental activities in high-hazard zones, e.g. the coastal regions, the vulnerability scenario appears to be worsening with time.

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The regional perspectives

The prevailing hazards are seen interlinked to each other in many cases. Nevertheless, individualistic hazard scenario is reviewed in the regional context to understand the needs and priority distribution.

Floods

Approximately 55.8% of the region is susceptible to floods[2]. Furthermore, complicacy is implicated by the origination of major flood-producing rivers beyond the state jurisdictional limits[3]. Table 1 provides historical records of large floods in the state[4].

An outline of flood management

A monograph on flood management prepared on the basis of hands-on experience of the State Government officials[5] recommends a standard operating procedure (Figure 1). Three phases of actions are specified: pre-flood, during flood and post-flood.

The pre-flood phase activities consist of preparatory measures, which involve vulnerability assessment, personnel and organizational database development, viable emergency action plan such as deployment of early warning system, training of personnel for rescue and evacuation, verification and updating of existing search, rescue and evacuation plans, and inventories of essential commodities and relief materials.

A district disaster management committee is expected to be coordinated before the onset of the monsoon season

Table 1. Records of large floods in West Bengal derived from the Dartmouth flood observatory global archive of large flood events[4]

Period	Description
18–20/10/1985	Caused by tropical cyclones
22/09/1986–10/10/1986	Flooding due to heavy rains in some areas of Kolkata, Hooghly, Howrah, Parganas and Midnapore
23/08/1988–09/15/1988	Monsoonal rains caused flooding in areas of Balurghat and Dinajpur lying under the purview of the Ganges and Churani rivers
03–24/07/1990	Flooding due to monsoonal rain
14–15/09/1991	Flash floods caused damage 35,000 houses
08/07/1993–13/08/1993	Flooding observed in Jalpaiguri district
26/09/1995–02/10/1995	Flooding triggered by heavy rains caused erosion, severe agricultural damage and outbreak of diseases
10–24/07/1996	Flooding due to monsoonal rains
01/08/1997–01/08/1997	Flooding due to monsoonal rains
05/07/1998–02/09/1998	Monsoon rains caused flooding of the Ganges river
11/07/1999–03/08/1999	Flooding due to monsoonal rains
24/10/1999–12/11/1999	Tropical cyclones caused destruction of an estimated number of 1500 villages. Floods due to brief torrential rains affected areas of Kolkata, Burdwan and Birbhum
02/08/2000–01/10/2000	Besides flash floods triggered by incessant torrential storms, disaster is also accredited to the opening of sluice gates of dams. The fatalities counted to the tune of 1262, besides affecting millions of people
31/07/2001–01/09/2001	Monsoonal rains caused flooding in Kolkata
21/06/2002–28/08/2002	Flooding in Jalpaiguri, Cooch Behar and Jalpaiguri in north Bengal due to monsoonal rains. Flash floods swamped ten villages, causing four deaths and 11,000 displacements
11/06/2003–10/10/2003	Monsoonal rains caused floods affecting the regions of Darjeeling, Jalpaiguri, Malda and Murshidabad
20/06/2004–07/10/2004	Heavy monsoonal rains affected several districts
21–28/10/2005	Heavy rains caused floods in many areas. About 3000 coastal villages were inundated and 60,000 huts and many roads washed away
07–27/07/2005	Heavy monsoon rains triggered flash floods and landslides
24/06/2006–03/08/2006	The regions of Birbhum, Burdwan and Murshidabad were affected mainly from continuous monsoonal downpour
18/09/2006–05/10/2006	Monsoonal rains and tropical cyclone-driven storms in the Bay of Bengal hit India and Bangladesh. West Bengal recorded 50 deaths, 300 were injured and 30,000 mud houses destroyed. Heavy rains left large parts of Kolkata city under water; subsequently 2000 people were evacuated from the city
03/07/2007–22/09/2007	The hazard affected Kolkata and several other districts. Eighty-three deaths were reported, and millions of people were marooned in 3000 villages in coastal areas of the state
22/09/2007–08/10/2007	Heavy rain from tropical depression in the Bay of Bengal caused flooding leading to 51 deaths, and affecting 3.2 million people

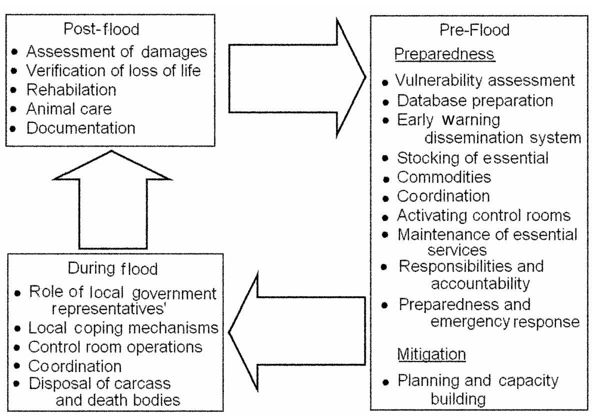

Figure 1. Standard operating procedure for managing flood hazard depicted in a nutshell.

to ensure adequate preparedness[6]. Participation of various government and non-governmental organizations is anticipated in knowledge and expertise sharing. Strategic planning focuses on hazard elements and formulates actions such as construction, restoration or improvement of drainage channels, and removal of human encroachment along the riverbanks. On the very onset of the hazard, the highest priority is on 'search, rescue and evacuation', in addition to 'organization of relief facilities'. Quick and correct damage assessment would enable speedy restoration and rehabilitation in terms of physical, economic and social aspects. The disaster related information should be well documented to enable future management plans.

The overall impetus at the national and global level is on preparedness and mitigation[7,8]. Several recent commissions have been formed at the national level, such as National Water Policy, 1987; National Commission for Integrated Water Resource Development Plan, 1996 and Regional Task Forces, 1996, and the ensuing recommendations adopted. However, effectiveness of recommendations seems to be lacking in several cases[9]. The National Commission for Integrated Water Resources Develop-

Table 2. Damaging cyclones in the West Bengal region[10,11]

Period	Description
17/10/1737–12/10/1737	An earthquake possibly coincided with this storm[12]
02–21/03/1833	The event occurred at Sagar Island/24 Paraganas with 3 m high surge and caused 50,000 deaths and about 100,000 cattle perished
03/10/1854	The surge went up to 12 m and water level increased at Kolkata and its vicinity. About 50,000 deaths reported
02–05/10/1864	Caused flooding up to 13 km on either side of the Hooghly River with 80,000 deaths reported
05–01/11/1867	Reported to have damaged Port Canning, and caused 13 m high surge at Hatia and Bhola Islands
13–16/10/1874	About 3049 deaths reported
21–26/09/1887	No estimation of associated deaths
18–29/09/1916	Extensive damage reported; however, no estimation of deaths
14–16/10/1942	About 5 m high surge reported at Midnapur (64 km upstream in Hooghly River). Overall 15,000 deaths reported
29/05/1956–01/06/1956	Caused flooding in Midnapur District, and also damage to agriculture due to saline water intrusion
13–20/08/1974	Cyclonic storm over land with maximum wind speed of 139 kmph caused floods in several districts. Seven deaths reported
12–11/09/1976	About 2.5 m high surge along with 1.4 m tide caused 40 deaths
27/09/1971–01/10/1971	Sixty people died and thousands of houses collapsed
24–28/09/1981	Caused loss of five launches in the Bay and damage to many houses in Midnapur District
09–14/10/1984	Caused damage in Midnapur district
23–27/05/1989	Sixty-one persons died and thousands of cattle perished
12/11/2002	Caused 78 deaths along with the destruction of agricultural crops and property

ment, 1999, recommended management approach rather than control, emphasizing failure to render complete protection. The strategies include flood-plain zoning, flood proofing, forecasting, disaster preparedness, response planning and insurance, etc. In respect of flood-plain zoning, the National Commission on Floods–1980 proposed a legislation to classify flood-prone zones according to occurrence and intensity. However, in West Bengal, the problem is rather vexing due to high population density and large flood-prone areas. While it is imperative to prevent encroachment of river beds, it is not feasible to relocate structures and developmental activities from all the hazard-prone areas. In recent times, flood forecasting is advancing with utilization of satellite and remote-sensing techniques. If the approaching flood can be predicted/observed, evacuation through monitoring and warning is possible.

Cyclones and storm surges

West Bengal has been one of the most cyclone-affected territories of the country (Table 2)[10–12].

Perspectives on cyclone management

The Cyclone Distress Mitigation Committee was launched nationwide during 1969 for the coastal states, with a major objective to formulate a communication system for quick dissemination of meteorological warnings and prevention measures thereof[7]. The World Meteorological Organization established in 1972, introduced a Tropical Cyclone Project to assist member countries in increasing their capabilities to forecast tropical cyclones, and in developing strategies for disaster prevention and preparedness.

At the state level, the Relief Department has developed a disaster-management system, outlining sustainable development with disaster mitigation at state and district levels[13]. This involved delineation of planning areas for departmental activities, including those at the village level within two frameworks – prevention and crisis management. The approach embodies integrated coastal environmental planning combined with cyclone mitigation strategies to reduce susceptibility. The strategies include development of accurate and prompt cyclone-warning systems, design and construction of robust structures (‘cyclone proofing’ through incorporation of storage and sleeping areas high-off the ground and use of water-resistant materials), implementation of hazard-reduction methods such as construction and strengthening of sea embankment, drains, shelterbelts, conservation and promotion of natural windbreakers (mangrove), reliable communication system, mass awareness on preparedness and mitigation, and community preparedness at all levels to meet the exigencies. Further, landuse planning is suggested to reduce the risk. Timely relay of information is of utmost importance. In this respect, a cyclone dissemination system has been set up by India Meteorological Department at Kolkata. Special addresses are given to cyclone forecast and warning services, rapid dissemination of warnings to the government agencies, ports, fisheries, shipping, the general public, and organizations to construct cyclone shelters in cyclone-prone areas and ready machinery for evacuation of people, and involvement of the local community.

The Meteorological Department has been equipped with cyclone surveillance radars, and satellite picture-receiving equipment. Further, Indian geo-stationary satellite INSAT-1B (operative since 1983) has enhanced tracking and forecasting through continuous monitoring. The operations are carried out through Area Cyclone Warning Centres and Cyclone Warning Centres. The present scientific knowledge and tools enable predictions with an average error of about 200 km for a 24 h forecast[14].

Formulation of contingency plans must be done at all levels – community, government and civil society[15]. Forecasting and early warning systems involve coordination by a steering committee for continual appraisal and improvement in the analyses of different forecasting methods, facilitating resources sharing and collaborations, training of personnel, and capacity enhancement. The working plan for an integrated coastal zone and flood control developed for the state addresses natural windbreak development and preservation, assessment of impacts and risks, community participation, education and awareness, and village-level planning. Technical aspects include a multidisciplinary approach towards environmental and social concerns, water-flow management, relocation/resettlement if needed, and designing break waves and sea walls. Preparedness implies mitigation and prevention rather than just response. Therefore, the need to link disaster management with development plans.

Landslides

The landslide hazard in West Bengal has been observed mostly in the hilly terrains of Darjeeling District. However, incidents of landslide have also been reported to have occurred on the banks of Hooghly River. In 1968, floods in the Darjeeling area destroyed vast areas of West Bengal and neighbouring state of Sikkim by unleashing about 20,000 landslides and killing thousands of people[16]. These landslides occurred over a three-day period, with precipitation ranging from 500 to 1000 mm in an event of a 100-yr return period. The 60 km hilly highway from Siliguri to Darjeeling was cut off at 92 locations by landslides, resulting in total disruption of the road transportation system.

Urbanization, especially in the hilly terrains, involving construction activities often causes perturbations in the hill slopes triggering landslides. Prior identification of the hazard potential is therefore necessary. Major tools employed for hazard delineation include remote sensing and GIS techniques. Various thematic layers describing the geological characteristics, water conditions, material properties, topographical inclinations, seismic activities, prediction of soil behaviour under load, etc. are considered for the thematic integration to achieve hazard zonation.

Drought

The districts of Bankura, Purulia and Birbhum have been affected by drought at regular intervals, mainly due to deficient rainfall and adverse soil conditions. While droughts due to shortage of rainfall are common, agricultural droughts due to lack of sufficient soil moisture have also been noted[13].

Towards hazard management, an advisory committee has been coordinated by Meteorological Department to regulate mitigational actions such as advance planning of arrangements, supply of irrigation water, fertilizers, etc. A review of the schemes and relief work (in the advent of a drought) is performed by the Relief Department with the help of other departments.

Drought management and planning involves water-supply augmentation and conservation (e.g. rainwater harvesting techniques), expansion of irrigation facilities, effective dealing with drought, and public awareness and education[17,18]. Transport and communication links are a must to ensure supply of food and other commodities during and just after a drought. Successful drought management requires community awareness on the mitigational strategies, insurance schemes for farmers, crop contingency plans, etc.

Earthquakes

West Bengal experiences earthquakes at a relatively lower frequency of the seismic hazard zonation map. The Bureau of Indian Standards places the region in the seismic zones II–IV, corresponding to peak ground acceleration (PGA) of 0.1, 0.2 and 0.25 (1 g = 980 Gal) respectively[2,19]. The lowest perceived hazard, zone II, is in the southwestern part of West Bengal (Purulia), while zone IV covers the north and southeast of Kolkata. Zone V is delineated on the eastern parts of Jalpaiguri and Coochbehar. The districts of Kolkata, Murshidabad, Birbhum, Bardhaman, Hooghly, Howrah, Nadia, Bankura and East and West Midnapur come under zone III. Darjeeling, North and South Dinajpur, the remaining parts of Jalpaiguri and Coochbehar, North and South 24-Parganas and Malda fall under zone IV. Similarly, the Global Seismic Hazard Assessment Programme classifies the seismic hazard variation in terms of PGA from low ($0.2\ m/s^2$) in the southwest to high ($6.0\ m/s^2$ and above) in the north, with 10% probability of non-exceedance in 50 years[20]. The earthquakes mostly occur either in the Himalayan ranges in the north or in Northeast India, and a few also occur in the Bengal Basin/Fan areas. The Great Assam earthquake of 1897 is reported to have caused widespread damage in Kolkata[21]. The largest instrument-recorded earthquake occurred on 15 April 1964, West of Sagar Island (m_b 5.2), which caused damages in West Bengal and Orissa[13].

The region has considerable area close to river basins and deltas that are characterized by Holocene alluvium deposits, which are likely to soften and hence are susceptible to liquefaction during an earthquake. Considerable spatial variation is associated with seismic hazards owing to the variation of geological-dependent site response[22]. This necessitates local specific analysis, especially in urban areas where the implications are far higher. The utility of seismic microzonation is emphasized in such cases. Seismic microzonation combines geological, geotechnical, seismological and earthquake engineering approaches towards spatial hazard classification. The zonation enables decision-making process towards planning and organization of landuse, response and mitigation. The site-specific design parameters obtained through microzonation would enable cost-effective structural designs.

Tsunamis

Although hazards due to trans-oceanic tsunamis have not been quantified for the coastal areas of West Bengal, because of the presence of mangroves and shallow continental shelf (unlithified fan deposits at the mouth of the Meghna–Ganges estuary) extending to several hundred kilometres, tsunamis are unlikely to pose a significant hazard. As such, there is no report of damage in the territory due to the catastrophic tsunami earthquake of 26 December 2004. However, any future offshore developments off the coast may be affected by tsunamis.

Subsidence

Subsidence hazard has been exhibited in underground coal mining areas of the state, such as Raniganj and Asansol. A fundamental preventive approach towards avoidance of adverse impacts of the hazard is reliable prediction[23] and the ensuing geotechnical considerations. The techniques involve tomography–sub-surface mapping[24,25], subsidence profiles and behaviour model, e.g. visco-elatsic model.

Composite vulnerability macro zoning

Composite vulnerability as depicted in Figure 2 has been prepared following an integration of various hazard and vulnerability themes. The earthquake, flood, and wind and cyclone hazard classifications for the region are adopted from the *Vulnerability Atlas of India*[2]. The earthquake hazard zones II–IV are assigned ratings of 2, 4 and 6 respectively. Flood-prone zone is assigned a rating of 4 and the other areas a rating of 2. For the wind and cyclone hazard, zones with velocities of 39, 47 and 50 m/s were assigned ratings of 2, 4 and 6 respectively. Landslide hazard[16] categorized as 'unlikely', 'moderate to low', 'high' and 'severe to very high' was assigned ratings of 2, 4, 6 and 8 respectively. Subsidence-prone zone (western areas of Burdwan District) was assigned a rating of 4 and the other areas a rating of 2. Population density designated as 'very low', 'low', 'medium', 'high' and 'very high', categorized according to whether the population density in persons per square kilometres is less than 550, 750, 1200, 5000 and more than 5000 respectively, was assigned vulnerability ratings of 2, 4, 6, 8 and 10 respectively. These are based on the Government of India 2001 census data. Similarly, industrial output indicated for the zones 'very low', 'low', 'medium', 'high' and 'very high' respectively, were assigned vulnerability ratings of 2, 4, 6, 8 and 10 respectively.

The exercise outlined above is essentially a first-order attempt based on a rather simplistic approach and macro-zoning information obtained from various sources cited above. Consequently, resolution of the composite vulnerability map is rather coarse. In a more elaborate and rational approach, the hazard ratings require normalization on the basis of quantified damages to areas with similar population and industrial density.

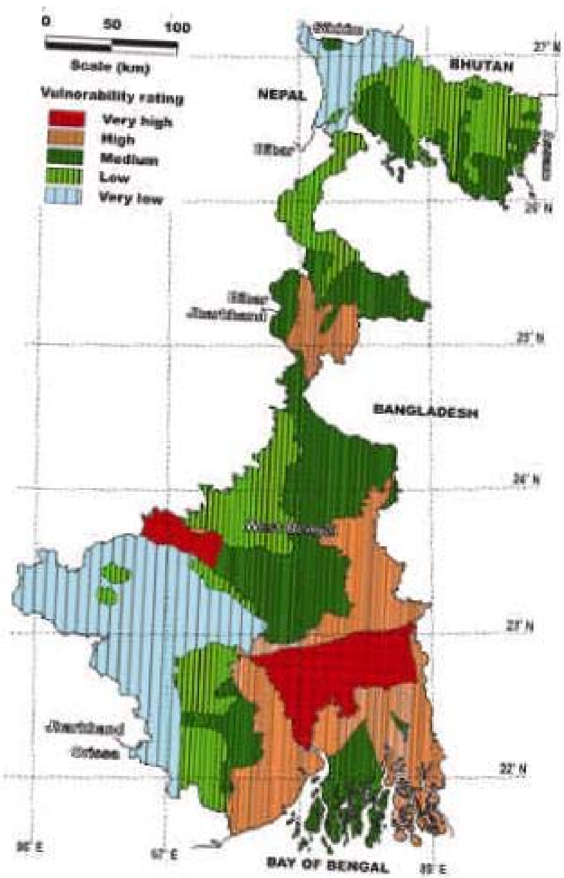

Figure 2. A composite vulnerability macro-zone map of West Bengal computed from integration of hazard distributions – earthquake, flood, wind and cyclone, landslide, and subsidence along with vulnerability components represented by district-wise population density, and industrial output distribution.

Nevertheless, the zones of Figure 2 appear to reflect the relative vulnerability across West Bengal in qualitative terms. Broadly, the southeastern parts of the region are observed to be of higher risk. The simple approach illustrated in this exercise can be readily adapted to accommodate microzonation data pertaining to hazard and vulnerability, as and when they become available. At that stage a more rigorous attempt can be made to estimate the risk in terms of rupees at a Block or Panchayat level, covering the entire state.

Natural hazards mitigation aspects

Statistical probability of the occurrence of an event with a certain destructive capability in an area within a specific duration can often be estimated. In some cases, likelihood of occurrence can be established for several hours or days in advance. If a hazard is unlikely to cause any damage to the environment or lead to any loss of life, intervention to minimize the hazard is not required. Because of uneven distribution of industrial centres, lifeline facilities and population densities, estimated risk is not expected to have a perfect correlation with the corresponding hazard estimate across the region. It may not be appropriate to directly adopt the risk estimates, considered admissible in developed countries, in the Indian context by policy makers because of the differences in psychological perceptions of the stakeholders, and also because the cost involved in directly adopting the risk perceptions of a more affluent society may be prohibitively expensive.

More often, rare and low probability events with long return times do not warrant investment on prevention or moderation mainly from social and economic standpoint[1]. High-density population and expansive infrastructure in cities and large towns implicate high risk. On the other hand, in small towns and villages, alternative mitigation measures such as organizing the local community to cope with hazards may be more suitable because of the unorganized nature of the construction industry. Implementation of these measures would require participation of all stakeholders, particularly the local population and government as well as non-governmental organizations.

Specific short-term action plan towards risk management with regards to major natural hazards includes quantification of hazard associated with a natural event, estimation of the potential impacts, and thereafter implementation of measures to reduce vulnerability. Measures such as building bylaws, zoning ordinances, insurance and tax incentives are also used to manage the risk associated with several types of natural hazards in developed countries.

Road map

The hazard mitigation endeavours start with pre-event measure actions of prevention, mitigation and preparedness. Immediate response is anticipated as and when a natural disaster strikes. On the other hand, the post-disaster steps account for rehabilitation, reconstruction and gathering of information.

Strategic approach necessitates identification and quantification of hazard and subsequent risk assessment. The hazard assessment involves gathering of information, precise to an acceptable extent, on the probable site, the associated severity and likelihood of occurrence within a specific time-period. The analysis incorporates geological and geomorphological scientific data as well as statistical records of past occurrences. The local specific hazard information developed through synthesis of the available and processed data can be produced in the form of a hazard map/atlas. In holistic approach, a vulnerability map reflecting a multi-hazard scenario can be developed and integrated on priority and weightage basis towards risk assessment.

Risk assessment involves quantification of anticipated loss or damage from the projected hazard. The analysis of risk is achieved through integration of results from hazard analysis and vulnerability assessment. Vulnerability is mostly accounted for by landuse accompanied by various combinations of factors like, rapid urbanization, improper construction practices, inadequately enforced building bylaws, socio-economic attributes, lack of awareness, environmental degradation and lack of preparedness. An approximate first-order attempt towards estimating composite vulnerability in a multi-hazard scenario for West Bengal is illustrated in Figure 2. Based on delivered risk assessment, further mitigational activities can be formulated covering every administrative level, from rural to urban set-ups. Capacity-building programmes may be enforced following recognization of the needs and the hazard priority.

Challenges

The difficulties associated with hazard and risk management are mostly due to inherent unpredictability of the hazard and the dearth or outright absence of damage statistics in many jurisdictions across India. This is further augmented by the lack of proper management and coordination amongst participating stakeholders. Resources management is an important aspect that can deal with shortage of resources. Disaster risk management and development process must go hand in hand. Policies should incorporate socio-cultural aspects through involvement of grassroots workers. The challenges of disaster management dominantly lie in the rampant utilization and manipulation of natural resources, lack of proper guidelines, economic conditions, inadequate capacity and non-obligatory regulations. Various governmental, non-governmental and private organizations form the core of the management process that should address the following: (1) pre-

Figure 3. Schematic flow diagram illustrating an overall picture of disaster management processes forming the disaster management life cycle.

disaster actions, (2) hazard mitigation for development projects, (3) requirement of common information, (4) long-term mitigation, (5) vulnerability of lifeline infrastructure, (6) information for hazard management practitioners, (7) participation of local communities, (8) incorporation of updated knowledge in post-disaster reconstruction activities and (9) awareness.

Conclusion

The predominant natural hazards in the West Bengal territory are investigated through historical accounts and prevailing mitigation aspects. A preliminary integrated perspective on the prevailing hazards has been qualitatively estimated as a first-order composite vulnerability distribution across the state. Consequently, a holistic outlook of disaster management as envisaged in Figure 3 is emphasized to incorporate (a) collaborations of different organizations, (b) local participation, (c) inputs from scientific and research institutions, (d) awareness and promotion, and (e) delivering appropriate regulations and policies. Addressing multiple hazards, such as usage of multi-hazard maps, synergized methodologies, etc. is recommended to be more pragmatic.

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