Disaster Preparedness and Resiliency-Indian Context

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Abstract

This article aims to develop an in-depth perspective on disaster management of natural and man-made disasters so as to minimize the loss accountability after occurrence of a disaster. Disaster management aims at managing the disaster in an efficacious way by performing a pre- and post-disaster analysis of the concerned area so that the disaster should cause least damage to the affected society. Disasters are now increasing day by day due to various anthropogenic causes such as ignorance of proposed structure for earthquake-resistant design in different areas for various types of building material leads to massive destruction during occurrence of earthquake in the concerned areas, floods have become quite frequent in middle and lower regions of the Himalayas due to road construction on the Himalayas for promoting tourism, overburdening of the Himalayan rivers with already installed and newly commissioned hydel projects leads to provoke landslides in uphill and foothill regions of northern India, where many more natural disasters are happening. Man-made disasters, like political disturbance leading to civil riots and insurgency-like situation in the country, rash and drunken driving leading to road accidents which kill 382 people in India every day out of which youths and children form the major part, whereby disasters are swallowing the manpower or economy of the country in a lethal way. This article depicts the level of preparedness, response, recovery and mitigation measures to be adopted for natural and man-made disasters.

Keywords: Disaster management, Anthropogenic, Hydel, Floods, Landslides, Insurgency, Preparedness, Response, Recovery, Mitigation.

Introduction

Disaster is an activity comprising mishappening or grave occurrence in an area that leads to loss of life, property, causes human injuries, economy loss as disaster is considered as a catastrophe that outreaches the coping capacity of the nation.

Disaster management aims to manage disasters in an efficacious way by minimizing the aftermath of the disaster. Disasters cannot be avoided but the effects of disasters can be commuted through incorporation of four steps of disaster management such as mitigation, preparedness, response and recovery. Disaster mitigation can be done by the adoption of various preventive measures to bear the brunt of disasters, thereby increasing the level of resiliency of the vulnerable community against the disaster. Disaster preparedness means the state of readiness to deal with any disaster, by providing training to the personnel of the communities and increasing the awareness with non-structural measures to deal with the disaster which fosters the level of preparedness of vulnerable community. An effective and prompt response is required, which should be put in place immediately after a disaster strikes so as to rescue the affected community to a safer place and last step required for management of disaster is recovery, which aims to rebuild the damaged infrastructure and rehabilitate the affected community in an abode far away from the disaster affected place.

Table 1.Types of Natural and Man-Made Disasters

S. No.	Natural	Man-Made
1.	Earthquake	Road accidents
2.	Floods	Civil riot
3	Cyclones	Biological and chemical disaster
4.	Liquefaction	Crowd mismanagement
5.	Drought	Terrorism
6.	Volcanic eruption	
7.	Tsunami	

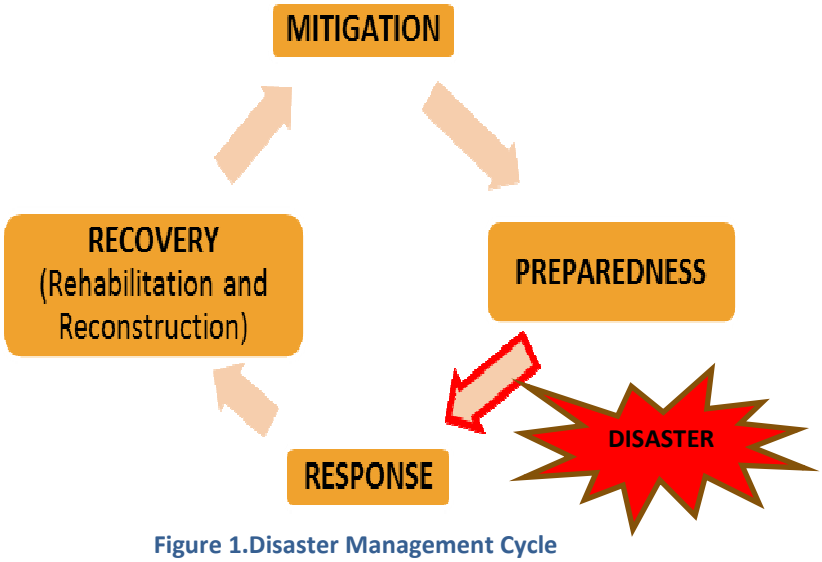

Figure 1.Disaster Management Cycle

Man-Made Disasters

Road Accidents

Road accidents in India is one of the major and most frequent disasters that is happening daily in the entire nation and is shaking roots of the country's economy in an adverse way by causing deaths majorly of the youths. Every year road accident percentage is increasing by approximately 2.2%. Total road accidents which happened in 2015 in India was 501,423, out of which 146,133 people lost their lives. This analysis of 2015 road accidents shows that about 1374 accidents happen daily out of which 400 people die; this can further be transformed in 57 accidents and loss of 17 lives every hour in India because of the road accidents. About 54.1% people killed in road accidents are in between the age of 15 and 34 years, which shows the rate at which India is continuously losing its manpower and economy in the form of youths lost.

Road accidents can be minimized through proper maintenance of roads and strict implementation of traffic rules within the local areas as according to the survey of transport research out of total road accidents caused, 28.4, 24.0 and 47.6% of road accidents took place on national highways, state highways and other roads respectively in the country in 2015. Traffic junctions are major cause of road accidents accounting for a total of 49% road accidents; so measures must be taken to make traffic junctions accident proof. Various causes that led to road accidents were defective vehicle (5% of total road accidents), pot holes (2.2% of total road accidents), speed breakers (2.2% of total road accidents), drunken driving (4.2% of total road accidents), overloaded vehicles (15.4% of total road accidents) and exceeding lawful speed (62.2% of total road accidents).

So an appropriate and immediate action is required from the government of India to keep upon its signatory of Brasilia Declaration to reduce road accidents by 50% before 2020. The maximum number of road accidents happened at T-junctions, which hold higher share than other road accidents. Few methods that can reduce road accidents are redesigning of roads, filling of potholes, installation of large hoardings or making of humps on roads to reduce accidents in transition zones (zone in which vehicle enters from non-crowded area to a crowded area suddenly), keen checking of drunken driving by traffic police in local areas apart from the national highways, development of an action group to provoke awareness of safe traffic speed in the community, modification of T-junction in various forms

out of which one is divided channelizer, which controls the traffic flow of incoming and outgoing vehicles and provides a safe waiting space in the middle for pedestrians thereby reducing the accidents of vehicles turning at high speed with pedestrians or raised platform for pedestrians at T-junction but nobody can prevent accidents only by adoption of technology as till an individual does not prepare oneself for safe driving by keeping it in his/her mind that he/she will not break the traffic rules, otherwise this deadly disaster will continue to happen, so an awareness program needs to be started on mass scale which should cover the entire 125 crore of population to train them about the traffic rules and their necessity.

Road accidents' response requires immediate response from local community to save and provide relief to the affected persons in the form of medical aid but above than that recovery matters as it raises the need for formulation of new and strict guidelines by concerned departments so as to avoid road accidents. Among fatality rate of road accidents, Uttar Pradesh possesses highest rate in Indian states and union territories, which shows the work of inefficacious administration to rectify the roads conditions and promotion of improperly trained drivers for tourism.

Terrorism

Terrorism is an activity done by misguided and ill-minded people to prove any worthless objective which leads to loss of life, property, human injuries, manpower, and mental harassment among the affected community. Terrorism does not have any religion and if terrorism consists of any religion then that religion is called as 'brutality'. According to various researchers, terrorism is most often provoked by different insensitive and non-patriotic leaders within the nation to usurp power or to earn huge money. As a person would not get arms, passport of different nation and various other measures to cause destruction of the place as instructed in an earlier way to those ill-minded people without support of various leaders. It can be concluded that enemy within the nation is multiple times dangerous than enemy outside the nation.

Terrorism in India is possible only with negligence of Indians, for example in Mumbai attacks of 26/11, none of the terrorists could have entered into India if there would not have been any fishing trawler close to the border area of India and Pakistan near Gujarat which was hijacked by terrorists in the Indian Ocean. Hence, a nation should keep a keen eye and provide all the basic amenities to the people who are living close to border areas or whose livelihood is dependent on the border areas. Also, people of border areas should be taught patriotic lessons elaborating the fact 'How terrorism can lead to massacre of the country's morale and people.'

Terrorism mitigation requires preparedness level at international level as whenever any dispute breaks out within a nation then the enemy state enjoys that particular chance by gaining support of the community which is unhappy with the policies of government and may further provoke any civil riot-like condition as it can be observed happening in Kashmir quite frequently. Terrorism can be mitigated greatly by collaborative efforts of the leaders of various countries and these steps have already been adopted in various MOUs signed by different nations. Terrorism mitigation requires an extensive study of the area or community responsible for spreading terrorism as many times a community is incited by misguidance created by a man capable of brainwashing the community on behalf of the religion or huge sum of money is provided to poor community to spread terrorism. So, terrorism can be mitigated greatly by keeping a keen eye on the affected community and within the legal boundaries, all the needs of the respective community should be fulfilled so as to persuade them that internationally all the governments are in their support for maintenance of peace throughout the world. 'If an ill-minded person can brainwash the community for spreading terrorism then why not a highly literate and civilized group teach the same community the lesson of humanity and love'. Root of terrorism arises from words which spread the misguidance that needs to be cut down or be replaced by good words. If the love, humanity, and legal boundaries fail to cut terrorism, then bloodshed of the root cause is required to make the tree of terrorism fall down as it is better to remove the damaged part of the body which possess the threat to entire body and may lead to death.

Civil Riots

As the term depicts, civil riots mean riots among civilians. Civil riots arise mostly due to the internal disturbances between two different communities in respect of religions and political views. In India, riots have become quite frequent due to the civil unrest in some areas created by political interference of a leader or by an act of a few distinguished personalities laying emphasis on rude and ill government rules, policies and act as mentioned by the personality in their respective acts.

Mitigation and preparedness to deal with civil riots require an effective implementation of laws and revision of policies to be made to avoid any rebel within

different communities of the nation leading to civil riot. Sometimes riots happen due to speeches of political leaders in favor of a community for earning votes in a large extent. It is easy to kill the enemy of state living outside the state rather than the enemy living within the state. So it can be said that the most cruel and insane ones are within the nation itself and thus by enlightening their minds against violence can mitigate the riots to a great extent. Currently, a dynamic and positive change can be observed in India in relation with defense, economic reforms, railways, energy sector, women empowerment, and infrastructure development. All the ongoing changes will be left in lurch if civilians do not try to understand the importance of these developments. Their worthful needs should be fulfilled and government should take a keen notice on the education system of the area which have higher percentage of rebellions as there are various areas in India where civilians have turned against the government due to some personal cause or due to needs of the community not fulfilled easily by the government as stated by them. These civilians bearing the hatred among government often turns into 'Naxals' and they can be found easily in areas of Dandkaranya Van in Chattisgarh, Andhra Pradesh, Karnataka, Bihar, and Jharkhand. So an efficacious management and development is especially required in the areas where Naxalism is spreading. Also, responsible civilians should take the initiative by themselves to tackle the rebellions by showing them the right path as government cannot reach personally to every rebellion. Most of the rebellions or people having rebel-like thinking do often encounter with responsible and patriotic-minded civilians then one should perform his duty towards the nation by trying to show the right path to rebellions.

When a civil unrest breaks out in India then it is fully enjoyed by the nation against the prosperity of India by sowing seeds of revenge in the minds of unrest-affected community and by supplying them with the materials required for taking revenge against the community or against the government. So, civil riots should be avoided and mitigated by proper and effective training, love and education by an administration bearing the ability to check the condition of civil unrest at micro level within a district by doing timely survey of the people in relation with their views regarding religion, political views and government policies and act.

Crowd Mismanagement

Crowd is when the number of people exceeds the livable capacity of a space or surroundings, leading to inadmissible flow of function and time. Crowd can occur at various places such as airports, commercial venues, stadiums and arenas, public transport terminals and political and religious events. Some major recent events like Sabarimala stampede in Kerala, 2011 had 102 casualties, another stampede at a railway station in Allahabad, Uttar Pradesh, 2013 (During Maha Kumbh Mela) with 36 casualties and the latest in Ratangarh, Datia, Madhya Pradesh, 2013 with 121 casualties, where a stampede took place due to broken section of the railing.

Crowd is intensified due to various reasons such as inefficient planning of structural systems, fire or electricity fault, underestimation of public, staffing and services, behavior of crowd, security, and lack of coordination between stakeholders. Crowd can be handled with considerations on safety, communication and event logistics. But no considerations are made in this line to rectify the issue. For example, at the time of Kumbh Mela that is held in various cities of India, the cities get overcrowded by people for performing their rituals. After enquiring from the sources, the devotees are many a time misguided from the directions to the main temples and Ghats like *Har ki Pauri* so as to prevent the area from becoming overpopulated which in turn leads to hatred among the pilgrims against administration responsible for guarding the congregation that may result in unmanageable crowd. Not only during Kumbh Mela but also during the month of Saavan, the crowd gets unmanageable. Devotees (*Kaavadiyas*) from all over India reach Haridwar and many more districts on foot to the banks of Ganga to take water of the sacred river to accomplish their rituals, which further creates hindrance in logistics movement in the holy city or in the routes which pass through holy cities as apart from the roads even national highways are also blocked many a times in daytime. Such an event results in a huge loss of goods and services and economic capacity of the industries.

Measures should be undertaken to mitigate the impact such as alternate routes must be made for diverting the devotees on to that route so as to reduce the loss during these events. Also an application software needs to be created in order to counter the number of visitors checked in and out of the region so as to make suitable arrangements for controlling the crowd. The application should be designed and distributed in such a way that the bus ticket issuing authority, railway reserved and unreserved ticket generating authorities, tolls, and air ticket issuing authority can check the inflow and outflow of passengers in the crowd-concentrated area. There should be a token system, which needs to be assigned for handling religious gathering of crowd. Installation of

cameras at junctions where crowd can accumulate will help in coping with difficult circumstances by sending the rescue teams if any stampede-like situation arises. Rescue teams should be in close proximity to public-concentrated areas. With the implementation of some mitigation and response techniques, crowd can be controlled and managed effectively.

Biological and Chemical Disasters

Although it cannot be quantified but risk of biological and chemical disaster is well understood. Table 2 shows details of these disasters in India since 1960. A biological disaster is a disease that spreads far beyond the reach of authorities to handle. Causes and consequences of these disasters may be different but generally a large part of population is affected. A chemical disaster is destruction of life and property due to hazardous chemicals. It could occur due to emission, fire or explosion. The main issue in this context is that chemical and biological agents are weaponized and could be used by terrorists.

Response in case of these disasters is highly specialized. Experts are required to plan response according to the nature of disaster and extent of damage. Special equipment and gears are required by response personnel. Also special training is required. In case of a biological disaster, disposal of bodies also poses a problem. NDRF in India is trained for these kinds of emergencies but other state forces must also be trained as exposure of these disasters are increasing day by day.

After chemical disasters, affected areas mostly become unusable for any productive activities. Biological disasters leave large number of affected people in their aftermath who need care and further medication. Caring and treating of patients is the main issue in recovery from biological disasters. India as a country needs to be prepared for these disasters. Also more number of personnel need to be trained for response. Awareness about biological threats need to be spread among general population. Also our country needs plans for safekeeping of chemical and biological agents so that in no natural disaster could exacerbate these disasters.

Table 2.List of Industrial Disasters in India from 1960 to 2015 (after Emdat)

Disaster Type	Disaster Subtype	Events Count	Total Deaths	Total Affected
Industrial accident	Explosion	43	2009	5223
Industrial accident	Poisoning	14	980	1743
Industrial accident	Chemical spill	2	2	100460
Industrial accident	Other	41	2143	6549
Industrial accident	Gas leak	4	2506	300964

Natural Disasters

Floods

Flood is defined as a body of water which rises to overflow land which is not normally submerged.

Flood mitigation is achieved by adopting structural and non-structural measures. Reservoirs are one of the direct methods to control flood by storing surface runoff, attenuating and storing flood water to be redistributed without exceeding downstream flood conditions. Reservoirs should be maintained at the lowest level to store flood water. Levees are earthen walls constructed parallel to river flow at some distance from the river between river and area to be protected in case of occurrence of flood in river. Channel improvements are done in different ways such as reduction of hydraulic resistance to flow by clearing the banks of vegetation and debris, increasing the cross-sectional area by increasing the depth or width of channels and increasing the river slope through a decrease in length. Floodways are dedicated pathways to divert flood water into a topographical depression near the river. Soil conservation is achieved by combining methods of management and land use to protect soil against depletion by natural or man-made factors to minimize run off and soil degradation. Check dams are temporary grade structures placed in drainage channels to limit the erosivity of water by reducing flow velocity. Non-structural measures aim to develop and build up the mitigation preparedness level of affected community to flood by making proper assessment of flood arising like situation and thereby issuing an effective and prompt early warning of the flood, also responsible for providing training to the community at risk against the flood to safeguard their lives.

Preparedness for flood includes enquiry about the areas that are in flood plain, vulnerable community's emergency plans, effective early warning signals of flood by CWC or IMD to which state authorities should immediately respond to evacuate and rescue the affected community, location of emergency shelters, evacuation routes should be determined, prepare the vulnerable community to learn and follow the flood

evacuation route, install sumps with backup power in the affected community to avoid drainage problem, inform local authorities about the handicapped and elderly persons of the community to prepare a plan for rescue of these people. Evacuation is a pre-disaster process to help people of the affected community in reaching up to a safer place by the concerned authority on the warning of flood.

Response including rescue is a move to protect life and property after occurrence of flood by the concerned authority such as NDRF battalions and Indian defense. Mostly due to lack of necessary amenities and information, standard of living during evacuation and rescue becomes painful against which NDMA is continuously taking efforts to improve their rescue operation.

Flood recovery involves usage of local land use policies and strategies to improve resiliency against flood. For post-disaster recovery after flood, an effective and immediate plan is considered and required to rehabilitate the affected community in an area protected from the flood-prone zone by a large extent so as to mitigate the mental trauma of the affected community. These plans include river corridors to conserve land and reduce development in vulnerable areas along riverbeds such as flood plains and wetlands, vulnerable settlements details, protect people and infrastructure to reduce future flooding risk, safe areas where plan for encouraging new development in the areas are least vulnerable to floods, an effective storm water management technique to slow, spread, and infiltrate floodwater.

Table 3.List of Measures to Mitigate the Aftermath of Flood

Structural Measures	Non-structural Measures
Reservoirs (Storage and detention reservoir)	Watershed management
Flood embankment and levees	Flood plain zoning based on flood hazard maps and regulations
Channel improvements	Flood forecasting
Flood ways	Creation of flood risk assessment and awareness raising
Soil conservation	
Check dams	

Cyclones

Cyclones are huge mass of air which rotates inward around the center of a low barometric pressure system in an anticlockwise direction in northern hemisphere and in clockwise direction in southern hemisphere. About 8% of the total area of India is prone to cyclones. An analysis on the occurrence of cyclones on the east and west coasts of India between 1891 and 1990 showed that nearly 292 cyclones occurred in a 50-km wide zone on the East Coast. Least severe cyclonic activities are noticed on the West Coast; a few major cyclones that hit India were cyclones that occurred on the 29th Oct. 1999 in Orissa, Cyclone Nargis in 2008, Cyclone Hudhud on October 12, 2014, and Cyclone Phailin.

The mitigation strategies that may be adopted are proper technology development for providing accurate and prompt cyclone warning, design and construction of robust infrastructure besides “cyclone proof” buildings, which have storage as well as sleeping areas at enough height above the ground and use water-resistant materials, hazard reduction by controlling the hazard in advance through usage of seawalls, coastal shelterbelts, diversion for drains protection and promotion of natural sea side vegetation (mangrove), etc., land use planning which “builds in” distance between the hazard and the community, contingency plans at all levels (community and government) and management of delta zones. Educational awareness campaigns that provide advice to the stakeholders on cyclone preparedness as well as mitigation measures should be launched in the areas prone to cyclones and develop healthy relation between communities at all levels to achieve sustainable mitigation strategies. Along the coastal areas, building codes should be strictly followed close to the coastal areas and all buildings, majorly government buildings within a radius of 50 km from the coast should have cyclone-resistant features.

Response towards cyclone should involve immediate evacuation of the affected community with their necessary belongings as was done excellently by NDRF and Indian defense in the case of Cyclone Hudhud in India after accurate and prompt warning of IMD following which 700,000 people, including 500,000 people in Andhra Pradesh, were evacuated and put up in relief camps. Cyclone Phailin led to evacuation of 128,915 people from Orissa and Andhra Pradesh but even then a great amount of material loss was caused to the government.

Recovery after cyclone should favor the construction of infrastructure and administration set up in a way to reflect high level of cyclone-resistant structures and

great amount of preparedness level of the stakeholders respectively.

Tsunami

A tsunami is series of body waves with a long wavelength and time period generated by large impulsive displacement of the sea bed level triggered by landslides into or under the water and can be generated due to volcanic activity and meteorite impacts. Earthquakes generate tsunamis by vertical movement of the sea floor. If the sea floor is moved horizontally then tsunami is not generated. Earthquakes of magnitude greater than 6.5 on Richter scale are critical for tsunami generation.

Tsunami mitigation is done by identifying the areas that face a high level of vulnerability to tsunami by remote sensing techniques and geographic information system which can be used to identify the tsunami hazard area which is empirically defined by deterministic approach. According to NDMA for tsunami mitigation, there are four zones in sea shore areas of urban and rural sector depending on their risk of damage due to Tsunami. A probabilistic approach is required for evaluating tsunami hazard due to seismogenic activity from distant sources because many uncertainties exist in a process of estimating tsunami heights along coastal areas from tsunamigenic models. For tsunami mitigation, Indian government has developed an Indian Tsunami Early Warning System (ITEWS), which comprises real-time network of seismic stations, tide gauges, 24×7 operating early warning issue center and bottom pressure recorders (BPR) to detect tsunamigenic earthquakes, thereby monitoring tsunami-like activity so as to provide timely advisories on the basis of standard operating procedure (SOP) to community that are vulnerable to the hazard. The ITEWS is capable of issuing bulletins in less than 10 minutes after any great earthquake in the Indian Ocean thereby leaving with a lead time of about 10 to 20 minutes near source regions in the Andaman & Nicobar and up to few hours in the case of mainland.

Tsunami response comprises immediate evacuation and warning to vulnerable community similar to that of cyclone but evacuation in case of tsunami must be multiple times faster that cyclone and recovery done after tsunami should focus mainly on rehabilitating the affected community.

Earthquake

According to Vulnerability Atlas of India, around 54% of land area is vulnerable to earthquakes. Most of this risk is concentrated around Himalayas since Indian plate is continuously sliding toward Asian plate at a rate of 47 mm/year. Population in several states like Uttarakhand, Jammu and Kashmir and all North Eastern states are at risk due to their geographical location near faults. Earthquake risk also increases due to developmental works which do not follow codes and regulations. Additionally, earthquakes can cause landslides, dam outburst floods and tsunami making it the most deadly disaster of all.

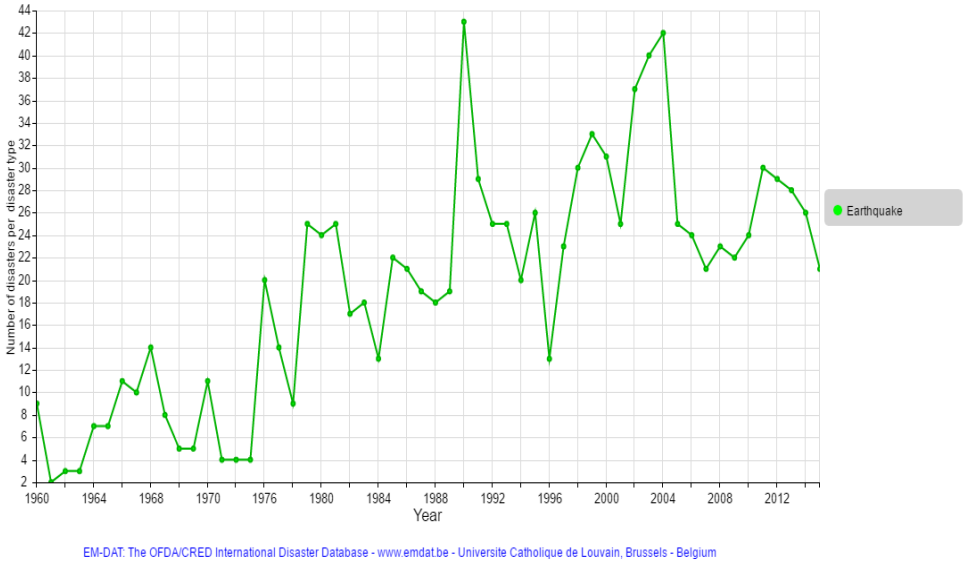

Figure 2.Total Number of Earthquake Events in the World from 1960 to 2015 (after Emdat)

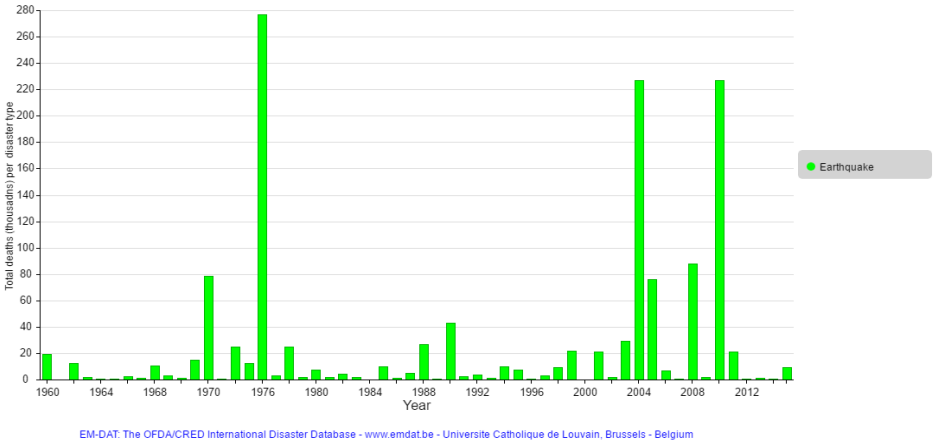

Figure 3.Total Number of Deaths due to Earthquakes in the World from 1960 to 2015 (after Emdat)

Earthquake disaster is always big and highly understood in present era but we do not possess the ability to predict it yet. So in case of an event, effective response during golden hours could save many lives. In India judging by current risk NDRF and SDRF are trained to handle response. In case of bigger events, army can also be called in which in past has proven to be highly efficacious. Response must be highly professionalized with trained teams equipped with all essential supplies. For instance, many lives were saved by Nepalese army and Indian NDRF after 2015 Nepal earthquake.

Recovery after an event is an investment not only to provide normality to lives of affected people but also to ensure less disruption by any other future events. Structures, restored and new, must follow all the codes and regulation like what India did in case after Bhuj earthquake of 2001.

Since earthquake cannot be predicted we can only prepare for it. Mitigation measures involve retrofitting of existing structures and following codes for building new structures using response spectrum and site studies. We can also make people aware of hazards and train them for immediate response. In India one early warning system is also installed that would provide 72 seconds early warning to Delhi in case of an event at fault in Garhwal and Kumaon region.

Volcanic Eruptions

A volcano is a cavity or hole in Earth's surface through which magma, ash, hot gases, and rock fragments escape from far down the planet. Volcanoes had a large part in the formation of Earth's atmosphere, continents and oceans. They are found on land as well as under the oceans. Different materials erupt from volcanoes having their own style of erupting. Variations in eruptions depend on the type of magma a volcano contains. Magma that has high gas and silica content is thick and gives rise to violent explosions whereas magma with low silica and gas content yields quickly spreading lava.

For any eruption to occur, the magma pushes the rocks apart resulting in fractures and earthquakes of small magnitude.

Barren Island volcano is one active volcano in India that lies between the Indian and the Burmese tectonic plates. The volcano has a height of 1161 feet above sea level. Major eruptions were in 1789, 1795, 1803 to 1804, 1852, 1991, and 1994 through 1995, 2005 to 2007, and 2010 to 2011.

Preparedness measures include the installation of monitoring systems, and the establishment of emergency response plans for warning and evacuation, search and rescue, and rehabilitation and reconstruction. Geophysical, geological and geochemical observations can be collectively used in forecasting volcanic eruptions.

Volcanic earthquakes are monitored with a network of seismometers surrounding the volcanic area. Seismometers can detect very small earthquakes even of 1 Richter magnitude. Many seismic waves are emitted from the site of the earthquake with every shock. As different waves travel at different speeds, their time of arrival can be used to calculate the distance between the seismometer and the center of the earthquake.

Liquefaction

Liquefaction occurs in the saturated soil due to excessive percolation of water by strong ground shaking which is mostly generated due to earthquake. During an earthquake, the layers of the ground are shaken which causes water to move through different layers of the soil that leads to saturation of loose cohesion-less soil,

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thus forming a semisolid material of the soil. Liquefaction increases when the groundwater level is less and decreases as it becomes more and it generally occurs when the ground water depth is about 10 to 15 meters. Liquefaction mostly occurs in loose or granular soil. The prominent effects of liquefaction are loss of bearing capacity, settlement of the ground surface, failure of flow and lateral spreading of the ground surface, sinking of buildings leading to human injuries, loss of property and life. Some of the most important examples of liquefaction are the Assam earthquake in 1897, the Niigata Earthquake, Japan in 1964 and the Bhuj earthquake in 2004.

The process of liquefaction can be controlled with implementation of various methods. Soil reinforcement, reduction in degree of saturation and drainage are some of its mitigation methods. Some common ground improvement techniques can be used to mitigate the liquefaction such as vibro compaction, deep soil cement mixing and compaction grouting. Biocementation, air injection and biogas are some of cost-effective and environmental-friendly liquefaction mitigation techniques.

Also emergency plans should be made with due consideration on water supply and sewage treatment as they are liable to be affected by liquefaction. Soil investigations including bearing capacity, quality and its composition must be checked before any construction. Hazard maps can be used to identify areas that are more prone to hazard. Infrastructure in the area should be strictly made according to the prescribed building codes of the respective area so as to avoid any hazard in the area.

Landslides

Landslides are simply flow of debris across a slope. Debris mostly consist of soil and rocks. Main causes of landslides are incessant rains, seismic activity, and volcanic activity. Most vulnerable areas in India are Himalayas and Western Ghats. Due to proactive steps by authorities, loss of lives in case landslides is less than loss of property. Some landslides do occur in remote areas and affect no population but others may occur on national highways and cause high economic damage. Sometimes landslides block streams and cause flood.

Response in case of landslides is mostly removal of debris and saving people under it. Specialized machinery is required to be transported to affected locations which sometimes create nightmare for logistics. In landslide response also, we need to provide relief within the golden hours which could save lives of people under debris.

Recovery work includes restoring roads, creating infrastructure and fixing other facilities after landslide. It also includes installing essential instruments on slopes to monitor its condition.

Authorities now focus on generating awareness about landslides so that people understand which slopes are vulnerable. It is seen that mostly rains cause landslides, so rains are monitored to give early warning for landslides. Many GIS-based systems are also in India which monitor and issue warning for landslides. Amrita University has developed a sensor-based early warning system which monitors differential movement and slope and issues warning accordingly. Also GSI is developing user-friendly hazard maps for end user to understand landslide.

References

1. Earthquake engineering research institute-Liquefaction. 2016. Retrieved 25 May 2016, from https://eeri.org/wp-content/uploads/store/Free%20PDF%20Downloads/LIQ1.pdf.
2. Gujarat's astonishing rise from rubble of 2001 quake. *BBC News* 30 Jan 2011.
3. Huang Y, Wen Z. Recent developments of soil improvement methods for seismic liquefaction. 2015.
4. Indian cities under threat of storms & earthquakes by 2050: World Bank & United Nations. *The Times of India* 2011-12-09.
5. Indian Meteorological Department - Cyclones. 2016. *Imdtvm.gov.in*. Retrieved 29 Jul 2016 from: http://imdtvm.gov.in/index.php?option=com_content&task=view&id=15&Itemid=30.
6. Indian Tsunami Early Warning System. 2016. *Tsunami.incois.gov.in*. Retrieved 20 Jul 2016, from http://www.tsunami.incois.gov.in/ITEWS/earlywarningsystemcomponents.jsp.
7. Liquefaction of Soil During Earthquakes | Maps, Video. 2016. *Geology.com*. Retrieved 19 Jun 2016 from: http://geology.com/usgs/liquefaction/.
8. National Disaster Management Guidelines, Management of Tsunamis, Aug 2010, National Disaster Management Authority, Government of India.
9. National Disaster Management Plan (NDMP), May 2016, National Disaster Management Authority, Ministry of Home Affairs, Government of India.
10. National workshop for developing strategy for cyclone mitigation in the coastal and island regions

of India. Administrative Training Institute, Kolkata 4-5 Feb 2003.
11. Office of Communications, W. 2016. About Liquefaction. *Geomaps.wr.usgs.gov*. Retrieved 17 May 2016 from: http://geomaps.wr.usgs.gov/sfgeo/liquefaction/aboutliq.html.
12. Paton D, Smith L, Daly M et al. Risk perception and volcanic hazard mitigation: Individual and social perspectives. *Journal of Volcanology and Geothermal Research* 2008; 172(3): 179-88.
13. (2016). Retrieved 14 July 2016, from Landslide early warning system 2016. Amrita.edu. Retrieved 14 Jul 2016, from: https://www.amrita.edu/news/early-warning-system-amrita-wna.
14. (2016). Retrieved 4 Jun 2016 from: National Disaster Management Authority-Landslide Awareness. 2016. Ndma.gov.in. Retrieved 20 May 2016 from: 2.http://www.ndma.gov.in/en/media-public-awareness/disaster/natural-disaster/landslides.html
15. (2016). Retrieved 21 Aug 2016 from: Geological Survey of India - Landslide prone areas of India. 2016. Retrieved 3 Jun 2016 from: http://www.portal.gsi.gov.in/portal/page?_pageid=127,671641&_dad=portal&_schema=PORTAL
16. (2016). Retrieved 21 Aug 2016 from: International Disaster Information Data-Images. 2016. Emdat.be. Retrieved 11 Apr 2016 from: http://www.emdat.be/country_profile/index.html.
17. (2016). Retrieved 21 Aug 2016, from Centre for Disease Control and Prevention-Bioterrorism. 2016. Retrieved 8 Jul 2016 from: http://emergency.cdc.gov/bioterrorism/
18. Road Accidents in India-2015. Government of India, Ministry of Road Transport and Highways, Transport Research Wing, New Delhi.
19. Sparks R. Forecasting volcanic eruptions. *Earth And Planetary Science Letters* 2003; 210(1-2): 1-15. http://dx.doi.org/10.1016/s0012-821x(03)00124-9.
20. The Disasater Management Act, 2005, N. 53 of 2005, 23rd December 2005, enacted by Parliament in the Fifty-sixth Year of the Republic of India.
21. Volcanoes facts, information, pictures. *Encyclo pedia.com articles about Volcanoes*. 2016. *Encyclo pedia.com*. Retrieved 15 Apr 2016, from: http://www.encyclopedia.com/topic/Volcanoes.aspx.