

REVIEW ARTICLE

# Managing natural disaster risk with earthquake damage scenarios and shakeout exercises: Lessons from $M_w = 8$ Mandi multi-stakeholders scenario in India

Pawan Kumar Taneja<sup>1\*</sup>, Shallini Taneja<sup>2</sup>

<sup>1</sup>Department of Operations Research, Indian Institute of Public Administration, New Delhi, India

<sup>2</sup>Department of Economics and Business Policy, FORE School of Management, Qutub Institutional Area, New Delhi, India

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**ARTICLE INFO**

Received: November 18, 2019  
Accepted: January 10, 2020  
Published: January 16, 2020

**\*CORRESPONDING AUTHOR**

Dr. Pawan Kumar Taneja,  
Indian Institute of Public  
Administration, New Delhi,  
India.  
dr.p.k.taneja@gmail.com

**CITATION**

Taneja PK, Taneja S.  
(2020). Managing natural  
disaster risk with earthquake  
damage scenarios and  
shakeout exercises: Lessons  
from  $M_w = 8$  Mandi multi-  
stakeholders scenario in  
India. *International Journal of  
Population Studies*, 6(1):30-40.  
doi: [10.18063/ijps.v6i1.1078](https://doi.org/10.18063/ijps.v6i1.1078)

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**Abstract:** Scientifically simulated Earthquake Damage Scenario (EDS) and Shakeout exercises help the policymakers to set up emergency plans for the immediate consequences and medium-long-term mitigation and prevention for a seismic event. The purpose of this study is to draw important lessons and a deeper understanding of issues and challenges in planning and implementing such exercises in a highly populous developing country like India. The Government of India developed a first-ever multi-state and multi-stakeholders EDS naming  $M_w = 8$  Mandi and conducted a Mega Multicity Shakeout Exercise in the Western Himalayan Region during 2014. A cross-sectional research design consisting of a mainly qualitative research approach using a multi-stakeholders perspective approach was used to factor key lessons. The scenario development and shakeout exercise faced several challenges such as lack of awareness among concerned stakeholders, lack of technical know-how at the grass-root level, lack of poor coordination among various stakeholders, and unavailability of data on important issues. Due to the lack of understanding of the sensitivity of the issue, the success of implementation largely depends on the involvement of the top leadership of state governments. Scientific EDS exercises followed by mega shakeout exercises helped not only the community up to some extent but also mainly helped administration, government agencies in generating awareness of the earthquake and possible risk attached to it.

**Keywords:** Disaster risk management; Earthquake damage scenarios; Shakeout exercises; Mock drills; Earthquake management India; Multi-stakeholders simulation exercises

*This article belongs to the Special Issue: Environment and Population Dynamics in South Asia*

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## 1. Introduction

Disasters are large intractable problems that test the ability of communities and governments to effectively protect their people and infrastructure by reducing both human and property loss, and speedy recovery (Altay and Green, 2006). Earthquakes are one of the worst natural disasters that cause huge loss to lives, property, and the economy. Recent earthquakes (e.g., Turkey in 1999, Taiwan in 2001, Gujarat, India in 2001, the Indian Ocean in 2004, Kashmir, India in 2005 Sikkim, India in 2011, Tohoku, Japan in 2011, and Nepal in 2015) showed that seismic areas with concentrated population,

buildings and infrastructures are highly exposed to human and economic losses environments (Jaiswal and Wald, 2008). The earthquakes can neither be predicted nor prevented. However, preparation for such disasters in a diligent manner can save lives and livelihoods. The reduction of seismic risk of these areas, therefore, is of primary concern policymakers, for earthquake risk mitigation.

The past two or three decades have witnessed a growing interest of multidisciplinary researchers around the world to assess the seismic vulnerability of major cities and analyzing the associated risk (Dolce, Kappos, Masi, *et al.*, 2006; Altay and Green, 2006). For analyzing the risk associated with earthquake disasters, the researchers usually prepare an Earthquake Damage Scenario (EDS) which provides a complete picture of what will happen when such an earthquake occurs (Altay and Green, 2006). A typical EDS exercise involves analyzing risk by estimating the probability of damages and losses based on all the previous earthquakes, over given earthquake circumstances (i.e., tracing the possible complex series of social, economic, and technical events likely to be triggered by an earthquake), combined with GIS technology to check and visualize the effects of any risk mitigation strategy (Dolce, Kappos, Masi, *et al.*, 2006; Arya, 1992). The preparation of an EDS is a multidisciplinary and multi-stakeholders task. It involves the unification of knowledge workers from diverse fields such as seismology, soil mechanics, geotechnical engineering, structural engineering, transport engineering, urban planning, social studies, preventive medicine, economics, and emergency response. The outcome of such EDS exercises has helped the policymakers to (1) set up emergency plans for the immediate consequences of a seismic event by local and national authorities; (2) plan prevention policies for medium long-term mitigation in those areas; and (3) set up tools to forecast losses in a multidisciplinary as well as practical way.

Nations across the world started to use these EDSs, not just for preparing post-earthquake response plans and training (capacity building) of the concerned personnel in various roles, but also for getting local communities involved in the process of disaster mitigation (Arya, 1992; Dolce, Kappos, Masi, *et al.*, 2006; Porter, Jones, Cox, *et al.*, 2011). These scientific EDSs also help in identifying necessary earthquake risk management programs and to develop specific shake out exercises for public awareness. The shakeout exercises based on these scientific EDS has a positive impact on community participation (Dolce, Kappos, Masi, *et al.*, 2006; Bernknopf *et al.*, 2008; Muto and Krishnan, 2011; Porter, Jones, Cox, *et al.*, 2011; Wein and Rose, 2011; McBride, Becker, Johnston, *et al.*, 2019).

The National Disaster Management Authority (NDMA) is a federal government agency, responsible for framing policies, laying down guidelines, and best-practices for coordinating with the State Disaster Management Authorities (SDMAs). It developed a first-ever multi-state (involving more than one state [province] government) EDS naming  $M_w = 8$  Mandi for a hypothetical earthquake of moment magnitude 8.0 in India. The developed EDS was used for conducting a Mega Shakeout Exercise on in the four cities of northern India, i.e., tri-cities of Mohali (Punjab), Panchkula (Haryana) and Chandigarh (UT), and city of Shimla (Himachal Pradesh). The success of this scenario would depend largely upon the active participation of the SDMAs, District Disaster Management Authorities (DDMAs), various line departments and other stakeholders in coordination with the NDMA and other central ministries/agencies.

The main objective of this paper is to document and learn from the experiences for bringing about improvement in designing and implementing EDS and conduct similar mega mock exercises in other seismically prone regions. The next section of the paper briefly explains the background and details about developed EDS and Mega Shakeout exercise. The third section explains the Methodology used for the evaluation of this EDS and Mega Shakeout exercise. The fourth section discusses the findings of the evaluation and the fifth section puts forward the discussion in the form of the lesson learned and the last section concludes the paper.

## 2. The Intervention: $M_w = 8$ Mandi Earthquake Scenario in India

India lies at the north-western end of the Indo-Australian Plate, which encompasses India, Australia, a major portion of the Indian Ocean, and other smaller countries. This plate is colliding against the huge Eurasian Plate and going under the Eurasian Plate. Three chief tectonic sub-regions of India are the mighty Himalayas along the north, the plains of the Ganges and other rivers, and the peninsula. The Himalayas consist primarily of sediments accumulated over long geological time in the Tethys. The Indo-Gangetic basin with deep alluvium is a great depression caused by the load of the Himalayas on the continent. The peninsular part of the country consists of ancient rocks deformed in the past Himalayan-like collisions (Sinha, Goyal, Krishna, *et al.*, 2012). The seismic zoning map of India shows that about 58% of India's landmass is vulnerable to moderate or severe seismic hazards, i.e., prone to shaking of Medvedev-Sponheuer-Karnik intensity VII and above (India Meteorological Department, 2002). During the period 1990-2014, India has experienced 10 major earthquakes that have resulted in over 30,000 deaths and caused enormous damage to property and infrastructure (Meena, Shinde, Sapre, *et al.*, 2013). The vast extent of damage and the consequent losses of life associated with these events reflect the poor construction practice in India (Jaiswal and

Wald, 2008). Federal and State Governments have initiated several programs from time to time to manage disasters, as well as to mitigate their adverse impacts. However, assessment of the effectiveness of these programs to mitigate earthquake risk was never done due to the lack of scientifically valid EDS (Meena, Shinde, Sapre, *et al.*, 2013; Sinha, Goyal, Murty, *et al.*, 2014).

To understand the direct and indirect consequences of high magnitude earthquake and needed preparedness of administration for it, NDMA initiated a study to develop a multi-state earthquake disaster scenario for a hypothetical earthquake of moment magnitude 8.0. Indian Institute of Technology (IIT), Bombay, and Madras undertook this scientific exercise to develop earthquake scenarios for the Northwest Himalayan Region. The epicenter of the hypothetical earthquake was planned in a “seismic gap” in western Himalaya and several scientists expect this region to experience a large earthquake soon. The project was undertaken in the states of Punjab, Haryana, Himachal Pradesh, and Union Territory of Chandigarh, considering the high level of seismic vulnerability (seismic zone III to V) in the Himalayan belt (Sinha, Goyal, Murty, *et al.*, 2014).

The earthquake scenario developed under the project involved as many as 32 stakeholders ranging from various government agencies at federal, state and local levels, defense organizations, and academic institutions, including schools, colleges, and non-government organizations with well-defined responsibilities. The EDS development team was led by the NDMA, consisted of scientific experts in the field of earthquake engineering (from IIT Bombay and IIT Madras). Representatives from Himachal Pradesh, Haryana, Punjab, state governments, and Union Territory of Chandigarh were also involved in the project. Inputs were also sought from organizations involved in earthquake monitoring, hazard assessment, and managing major infrastructure or facilities in the affected region such as IMD, Geological Survey of India, Border Roads Organisation, Central Water Commission, and Bhakra Beas Management Board. A part of seismotectonic information for the Western Himalayan was provided by the Wadia Institute of Himalayan Geology. The project team also includes a Coordination Agency (namely, Geo-Hazards Society India) to facilitate the coordination between the various stakeholders, particularly at the state level. Software RISK.iitb v3.1 developed by IIT, Bombay, for integrated seismic hazard, vulnerability, and risk assessment was used for simulations in Mandi EDS (Sinha, Aditya, Gupta, *et al.*, 2008).

Table 1 shows the silent features of the developed EDS by considering the seism-tectonic profile of the region. It could be observed that the Main Boundary Thrust which runs along South-West districts has not been ruptured due to a great earthquake in the past 100 years. The Indian plate is moving toward the Asian Plate, but it is observed there are no many great earthquakes in this region which appears insufficient to compensate the 15-20 mm/year movement observed geodetically (Zhang, Santosh, Wang, *et al.*, 2012). For the selected moment magnitude and location of the earthquake,

**Table 1.** Multi-state earthquake scenario.

Parameters	Details
Earthquake	Multi-state earthquake scenario
Region	Mandi district
Mw	8
Depth	15 km
Epicenter	Sundernagar, Mandi District, Himachal Pradesh
	Latitude 31033'00" N
	Longitude 76052'48" E
Parameters	Details
Fault	Main boundary thrust (MBT)
GMPE	Bore and Atkinson (AB08, NGA)
Source	Line source
Rupture model	WC84-all
Rupture length	200 km
Maximum MSK intensity	IX-X
Grid size for analysis	0.5 × 0.5 km

Source: Sinha *et al.* (2012, 2014). MSK: Medvedev-Sponheuer-Karnik.

the severity of ground shaking was estimated by using following Bore and Atkinsons' (2008) Ground Motions Prediction Equations (GMPE) (Figure 1).

$$\ln Y = F_M (M) + F_D (R_{JB}, M) + F_S (V_{S30}, R_{JB}, M) \tag{1}$$

Here,  $F_M$ ,  $F_D$ , and  $F_S$  were the magnitude scaling, distance function, and site amplification.  $M$  was the moment magnitude,  $R_{JB}$  was the Joyner Boore source to site distance, and  $V_{S30}$  was the inverse of average shear wave slowness from the surface to a depth of 30 km. The ground motion parameters were amplified towards the southwest which is due to the Indo-Gangetic plain region. The maximum Peak Ground Acceleration (PGA) was estimated to be 1.17 g. The damage intensities were obtained from the equations following proposed by Wald, Quitoriano, Heaton, *et al.* (1999) based on observations noted from the California Earthquake,

$$\text{For } I < 5 \\ I_{mm} = 2.20 \log (PGA) + 1.00 \tag{2}$$

$$\text{For } I \geq 5 \\ I_{mm} = 3.66 \log (PGA) - 1.66 \tag{3}$$

Information regarding the population, housing types, etc., was obtained from the Indian census 2011 data for the regions under study. The exposure was estimated for a night scenario. The resulted in injuries and deaths due to scenario

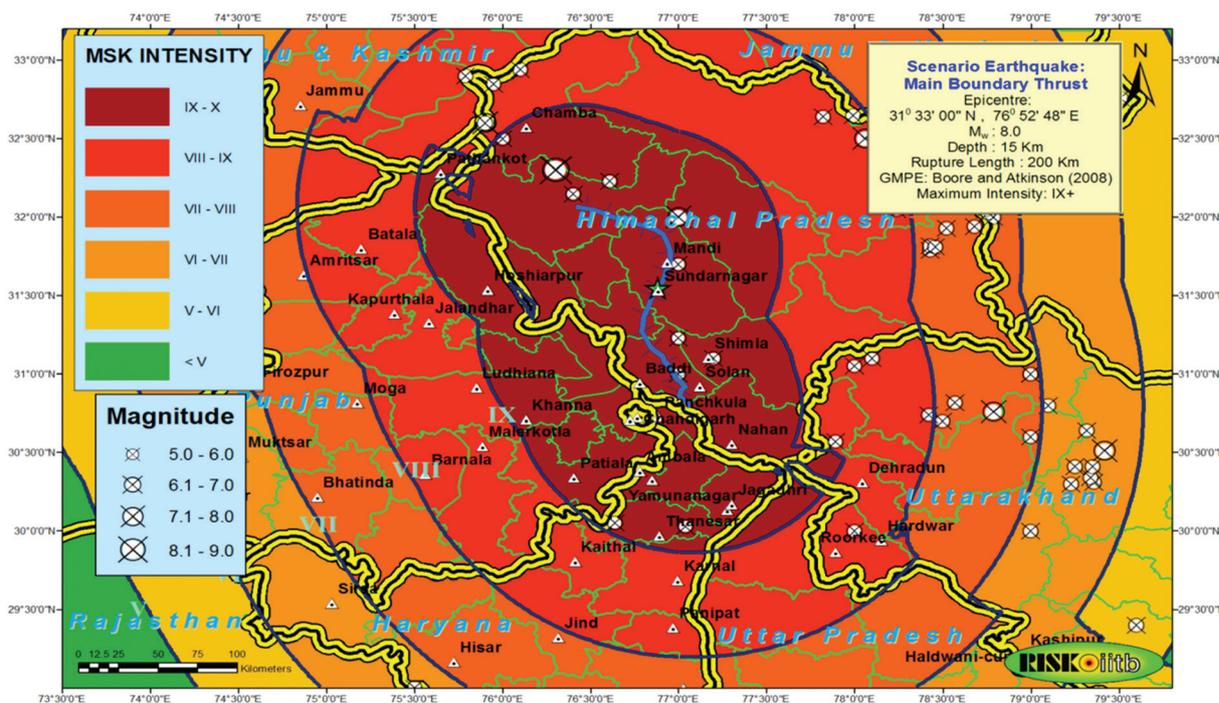


Figure 1. Population densities (persons per sq. km) over intensity contours (Source: Sinha 2014).

Table 2. Projected injuries and deaths in Mandi EDS.

State/UT	Injuries	Injuries (% population)	Deaths	Deaths (% population)
Himachal Pradesh	1,109,500	16.18	161,000	2.35
Haryana	1,596,100	7.66	345,800	1.36
Punjab	2,014,700	8.96	462,500	1.67
Chandigarh UT	102,400	12.00	24,200	2.33
Total	4,822,700		993,500	

Source: Sinha *et al.* (2012; 2014). EDS: Earthquake Damage Scenario.

earthquakes were estimated through the injury and death model RISK.iitb v3.0 (Sinha, Aditya, Gupta, *et al.*, 2008). Table 2 highlights the total estimated social loss in the scenario.

Based on developed  $M_w = 8$  Mandi EDS, rapid visual screening of water tanks, pipelines, and building training and capacity building program on Incident Response System (IRS) for various stakeholders were conducted. After necessary training and capacity building programs, a Mega Shakeout drill was planned and executed in all four states involved in the four main cities Shimla (Himachal Pradesh), Panchkula (Haryana), Mohali (Punjab), and Chandigarh (Union Territory). The Shakeout exercise was carried out in 15 locations in each city simultaneously with a sound of the siren as a symbolic occurrence of an earthquake. The shakeout exercise was followed by activation of response mechanism, including rescue and relief as per the directions from Emergency Operation Center (EOC) in district headquarters. The Shakeout exercises were coordinated by the DDMA team, National Disaster Response Force, local police administration, and the district administration in the presence of SDMA and NDMA members' experts.

### 3. Data and Methods

To evaluate the effectiveness of developed EDS and disseminate, the learning from these exercises (i.e., EDS team and Shakeout team) cross-sectional research design was used. Since this evaluation, as conducted after the intervention being carried out, therefore, a qualitative research approach was preferred as it gives deep insights into issues and challenges faced. The qualitative research approach also helped to trace and verify the effectiveness of various documents prepared during the EDS exercise. Both primary and secondary data sources were used in the study. The secondary data sources were used to analyze the facts and details about the developed EDS and Shakeout exercises. These resources include (a) detailed project report and its annexures submitted by IITs to NDMA on Multi-state Mega Mock Exercise under "Mw 8 Mandi Earthquake Scenario: Multi-state Exercise and Awareness Campaign," (b) developed district and state disaster management plan as the part of the exercise, and (c) unpublished documents/reports of the state governments and district administration related to disaster actions carried out by them.

The primary data were collected to get deep insights into the issues and challenges faced in the preparation and implementation of  $M_w = 8$  Mandi EDS. For this purpose, first, a multi-stakeholder expert group consisting of 12 members was formulated. Other than the authors of the paper, the other members of the expert group were eminent national and international experts from both academic and practitioner working in the field of disaster risk management or civil society organizations. Each member of the expert group had an experience of more than 15 years in their respective area of work. A day-long round table discussion was organized in which the expert group, the members of the IITs team involved in preparing scenarios and NDMA observers involved in conducting the mega mock exercise participants. The expert group members discussed and evaluated the various technical, economic, social, and administrative aspects of the EDS and the mega shakeout exercise in the round table discussion.

In addition to round table discussion with NDMA observers and IIT team, authors conducted 45 in-depth discussions with multiple stakeholders working at the state, district, and local levels who have participated in either formulation of EDS or conducting Shakeout exercises. These stakeholders include policymakers, top officials from the state government responsible for disaster management, and head of the various emergency services such as public administration, water sanitation services, fire, medical services, and transport. An in-depth interview guide was prepared to interview these stakeholders. Since it was an official assignment, therefore, each official responded to the interview in its official capacity, hence did not require any informed consent. However, each stakeholder was assured by the study team that their personal detailed will not be shared at any forum.

## 4. Results

### 4.1. Data Availability for EDS Development

The success of an effective EDS development depends on the availability of data not just of seismic hazards such as fault locations, but also it requires data on various demographic, social, and economic issues such as population density, vulnerable age groups, occupation and level and type of industry existence, literacy rate, building typology, and the income level of the population. During the in-depth discussion with IIT Bombay and IIT Madras, it was found that the Central Government/State Governments need to adopt data policy that should articulate the nature and resolution of data that would be collected and compiled by the government as most of the available data are not follow same standards. IIT Bombay team commented following about data availability:

*"....In the Mandi project, where only a macro-level scenario was planned, the absence of data did not pose a critical obstacle. However, when higher-resolution simulations are carried out, the availability of data would need to be*

*carefully factored into the program until such time that more detailed data becomes available..... we feel that the Central Government/State Governments may be encouraged to adopt data policy articulating the nature and resolution of data that would be collected and compiled by the government....”* (IIT Bombay Project Team, Round Table Discussion)

*“....the engineers of the State did not have formal details and data of all buildings and structures in their jurisdiction. Hence, the analysis of the built environment was a tedious task. Moreover, only “seemingly” representative structures were taken, and departures from these in other structures could not be addressed.....”* (IIT Madras Project Team, IDI).

## 4.2. Awareness of Key Stakeholders about the Earthquake Disaster Risk

The success of an effective EDS development and Shakeout exercise was largely dependent on the active participation and coordination of all stakeholders, i.e., SDMAs, DDMA, various line departments, NDMA, and other central ministries/agencies with the technical team from the IITs.

In the initial phase, the project had a slow start which was mainly due to lack of awareness, understanding, and importance of the project among state governments’ officials. With continuous and repeated efforts of NDMA, IITs team, coordination agency, and involvement of political leadership, the activities gathered momentum. The project activities were duly endorsed by the top leadership of states. IIT Bombay and Madras’ study team found it very tough to convince state and district administration, especially in Punjab and Haryana, about the chance of occurring such a high magnitude earthquake in their states as there is no recent history of such a high magnitude earthquake in these states. Similar issues were faced by the NDMA capacity building team.

*“In the 3 days capacity building programs ..... except for the nodal district, representatives from other districts were few or nominal in numbers..... the key functionaries at the cutting edge-level (district level), namely, Deputy Commissioners, Senior Superintendent of Police, and District Medical Officers mostly did not attend or were represented by junior level officers who could not apprehend the enormity of the disaster.....”* (Master Trainer, NDMA, New Delhi Round Table Discussion)

The Shakeout exercise designed based on scientific EDS was able to major contributors to convince district and state authorities to get sensitized about the problem. Shakeout exercises with the involvement of the technical team from IITs build not only the confidence of the state and district officials but also helped them to identify the gaps in their preparation for high magnitude earthquake disasters.

*“The Chandigarh Administration’s participation in the Mega Mock Exercise ‘Mw=8 Mandi, Earthquake Scenario’ conducted by NDMA indeed proved to be a milestone in the direction of disaster preparedness. The event helped the Administration to assess its disaster preparedness and response during an emergency, to mitigate threats and also help for the preparation of the Chandigarh Disaster Management Plan, SOPs of the line departments along with resource inventory. This exercise also gives an idea about the tools and equipment required during the rescue operation, areas of the capacity gap among staff and areas needing coordination with the line departments and improving the capability of rescue officials in enhancing their effectiveness and efficiency to respond in any disaster.”* (Chairman, District Disaster Management Authority, Chandigarh, IDI).

Due to the lack of understanding of the importance of issue, among district and local officers’ mass advertisements for Shakeout exercises were very late as a result of which community participation in these exercises was less than expected. State and district governments where these activities were implemented had not taken any commendable action after almost 1 year of completion of the exercise on the gaps identified during Shakeout exercises. The main reasons for such inaction reported by state and district officials are lack of technical capacity, trained manpower, and no allocation of budget on these activities as these were not the priority of state and local governments.

## 4.3. Rapid Visual Survey (RVS) Training and Capacity Building Programs

The selection of representatives from various line departments for RVS training or IRS capacity building programs was not rational, which impinges on the sustainability of the Incident Response Team. Most of the participants, who have undergone training for IRS, have already been either transferred to other departments or retired from services.

*“....we have not organized RVS training in the district, only one of our assistant town planner took part in such training before mega mock drill (13 Feb.). Our engineers are curious to take part in such types of training programs in the future to prepare a team but we don’t have the capacity for the same. Similar is the situation for the capacity of district officials..... We like to organize departmental training programs for them to make them understand their duties before, during and after any disaster.....”* (Deputy Commissioner of Mohali District, IDI).

Expert Group pointed out Scenario Manual developed, did not have an instructor manual containing key discussion points, a checklist for action required for ideal disaster management and Trainer of the Trainer Module for effective current and future capacity building program.

“.....Scenario building and conduct of shakeout exercises were two important parts of the project. There was no synergy between them.....while formulating the hypothetical scenario, the scenario building team of scientists from IITs Bombay and Madras, did not consult the mock exercise experts at the NDMA and the State/ UT, who was going to implement it. The scenario was also made with half-baked and incomplete data/information from the concerned Ministries/Departments/Organizations. This resulted in the credibility of the scenario becoming suspect, as several inputs, including the large fatalities and injuries to humans and animals could not be substantiated with scientific proof. It turned out to be a scientific/academic exercise with little practical inputs from States/ experts.....” (Master Trainer, NDMA, Round Table Discussion).

#### 4.4. Technical Issues Relating to Mw = 8.0 Mandi Earthquake Scenario

The Expert Group pointed many weaknesses in Mw=8.0 EDS. Major weaknesses include: (i) The scenario has considered only immediately nearby epicenter severely affected areas. It did not consider other potentially affected areas near the fault line densely populated areas of Delhi and Western Uttar Pradesh and hilly regions of Uttarakhand and Jammu and Kashmir by the Mega Earthquake. (ii) The EDS also ignored the effects of earthquake-triggered landslides, sub-soil characteristics, depth of soil, soil stratification, and the cascading effect of buildings/infrastructures in hilly areas. (iii) The EDS has not considered the infrastructure, and economic losses due to mega-earthquake, which have major implications for post-earthquake relief planning operations. (iv) The factors like demographic distribution such as gender, age, occupancy classification, and socioeconomic status of the population in the affected area play a key role at the time of disasters. However, EDS did not consider these important factors in their calculations. (v) Similarly, the timing of earthquakes such as working hours or nighttime is a significant factor to determine the total number of injured and deaths. This factor is also missed in EDS development. (vi) The EDS has also not factored in the micro-zonation information and the community preparedness, i.e. level of awareness among the community about disaster management due to the unavailability of data.

#### 5. Discussions

Based on the results mentioned above, we have developed a framework for effective planning and implementation of multi-stakeholder EDS and shakeout exercises (Figure 2). The main features of the framework are discussed in the following subsections.



Figure 2. Framework for effective multi-stakeholder earthquake damage scenarios planning and implementation.

## 5.1. Leadership

Strong effective leadership with a clear command system is a must during disaster events to improve both outcomes for casualties and the positive experience of the attenders (Filmer and Ranse, 2013). In EDS which involves multiple state governments, effective leadership by federal government agencies like NDMA becomes very important. The federal agencies need to not just ensure collaborative efforts of state government agencies (Waugh and Streib, 2006) but also bottom-up approach (Arai, 2006; Musacchio, Falsaperla, Bernhardsdóttir, *et al.*, 2016) in the form of participation by district-level officials and community in the planning of such exercises.

## 5.2. Mass and Social Media

The growing adaption of Information and Communication Technologies and social networking platforms such as WhatsApp, Twitter, and Facebook has created numerous opportunities (Imran, Castillo, Diaz, *et al.*, 2015) of information propagation that would not exist otherwise before, during, and after the disasters. However, harnessing credible information about disaster events from social media is a very challenging task (McBride, Llenos, Page, *et al.*, 2020). If the right information is sifted through social media, it can facilitate the authorities to make better decisions for emergency response (Yin, Karimi, Lampert, *et al.*, 2015). Therefore, effective preplanning and timely utilization of mass and social media are must for such mega Shakeout exercise to ensure community involvement. As a part of preparedness exercises, the mass sensitization and awareness must be generated in a manner that is impressionable and remains etched in the memories of the people at the time of disaster (McBride, Llenos, Page, *et al.*, 2020).

## 5.3. Vulnerability Assessment

Vulnerability assessment surveys and mock drills should be a part of ongoing activities of national, regional, and local bodies for building sound programs to effectively mitigate the negative effects of natural disasters (Duzgun, Yucemen, Kalaycioglu, *et al.*, 2011). These vulnerability assessments should also include a periodic survey on existing knowledge level, awareness and preventive practices of disaster management by the community (Dolce, Kappos, Masi, *et al.*, 2006; Goltz, Park, Nakano, *et al.*, 2020). These assessments would help to design future media strategy, development of EDS, and device action plans as done by Himachal Pradesh State Government in India.

## 5.4. Capacity Building

Regular Training of the Trainers at the state and district levels should be undertaken to ensure the outreach of such programs (Kaur, 2006). To develop the capacity of the state, district, and local bodies' officer focused executive development programs (EDPs) for 2-4 days should be organized (Goltz, Park, Nakano, *et al.*, 2020). EDPs on disaster management should be made compulsory for all licensed and registered private practicing civil engineers, architects, and town planners (Shaw, Gupta and Sarma, 2003). Three-day EDPs focusing on the application of earthquake safety-related codes and standards should be organized for professionals working in the local bodies.

## 5.5. Training Material

For success and future utilization of tabletop exercises, conduct experts, simulation exercise building experts, and trainers from both federal and state should work in synergy. A detailed trainer's manual consisting of what is the scenario, learning outcomes of tabletop exercise, how to conduct the tabletop exercise, etc., should also be developed which can be used by the trainers during capacity building programs (Hosseini and Izadkhah, 2010). Further, Tabletop exercises need to be further tailor-made as per the local needs (McBride, Llenos, Page, *et al.*, 2020). Similarly, training materials should be peer-reviewed and pretested before disseminating across the level.

## 5.6. Emergency Operating Centre

Competent agencies like Federal Government should help both technically and financially to build EOCs at each state and district (Engelmann and Fiedrich, 2007) as this is the bare minimum requirement for the functioning of the IRS.

## 5.7. Community Participation

Before organizing mega shakeout exercises, small scale shakeout exercises should be organized in decentralized locations to ensure effective community participation (Yin, Karimi, Lampert, *et al.*, 2015). Single toll-free numbers for all types

of emergencies covering fire, accident, ambulance, police, and the emergency operating center should be designated and widely publicized (McBride, Llenos, Page, *et al.*, 2020).

### **5.8. Practical EDS**

The simulation exercise for earthquake magnitude 6.0 and 7.0 for seismically prone locations should be designed as they have more probability of occurrence (Larsson, Bynander, Ohlsson, *et al.*, 2015). This will lead to better participation of stakeholders (Waugh and Streib, 2006). Parameters related to topography and all parameters mentioned above should be included for the future development of scenarios as lack of information on these parameters defeat the very purpose of scenario development (Brainard, Ladd, Tappen, *et al.*, 2019). Further, it should also include cost and timeline for rescue and rehabilitation.

### **5.9. Data Availability**

State government and related agencies (national and state level) should be directed by the federal government to make relevant data accessible to the teams engaged in developing such type hypothetical scenarios. This will help to integrate the outcome of the scenario by the inclusion of infrastructure and economic losses.

### **5.10. Financing**

Considering the lack of awareness and sensitization about earthquake disasters in the high-risk zone among community and administration, appropriate funds and time should be allocated (Wein and Rose, 2011). Appropriate funding should be given for such exercises so that technical aspects pointed by the Expert Group should be incorporated in future projects.

## **6. Conclusion**

The scientific EDS exercise followed by mega Shakeout exercises helped the administration, government agencies, and community in generating awareness of the earthquake and possible risks attached to the high magnitude earthquake. The exercises also helped the administration to know their level of preparedness and identified gaps that need immediate attention. The scenario developed exercise faced several challenges such as lack of awareness among concerned stakeholder, lack of technical know-how at the grass-root level, lack of poor coordination among various stakeholders, unavailability of data on important issues such as the effect of earthquake-triggered landslides, sub-soil characteristics, depth of soil, soil stratification and cascading effect of buildings/infrastructure, and socioeconomic status of people living affected areas. Indian experience has shown a threefold framework for effective EDS planning and implementation. This includes a strategic action map, i.e., pre-requisites for EDS and Shakeout exercise, action needs at the planning stage of EDS, and checklist for the implementation of EDS and Shakeout Exercises in other countries. These practical suggestions are a must for successful EDS and Shakeout exercises planned for other states.

### **Authors' Contributions**

Authors have collected the data from all relevant sources and stakeholders after due informed consent obtained and carried out detailed analysis using qualitative data analysis methodology with a systematic literature review.

### **Ethics Statement**

The ethical clearance was not required for this study, as this study mainly involved post-event study. The study involved in-depth discussions with the key stakeholders and officials involved in the process. The informed consent of the officers was taken in advance before inviting them for the workshop. All views expressed by the officials were in their official capacity.

### **Availability of Supporting Data**

All important relevant data related to the study can be found at the NDMA website and the IIT Bombay website.

### **Acknowledgment and Conflict of Interest**

This study is a part of the study titled “**Independent Evaluation of Mw 8 Mandi, Earthquake Scenario: Multi-State Exercise and Awareness Campaign,**” sponsored by NDMA, India, conducted by the first author. We are grateful to Joint Secretary, CBT division of NDMA and her team, Dr. Ravi Sinha, and Prof. C. V. R. Murthy teams, IIT, Mumbai and Madras, Prof. Vinod K. Sharma, IIPA and members of the Expert Group and Shri T. N Gupta who had helped us in that study. The authors have not had

any conflicts of interest concerning this study. The authors alone are responsible for the content and writing of the paper. We are very also very thankful to district and state government officials who have consented to share their views and experiences related to the project. Academic and infrastructural support given by FORE School of Management is also acknowledged here.

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