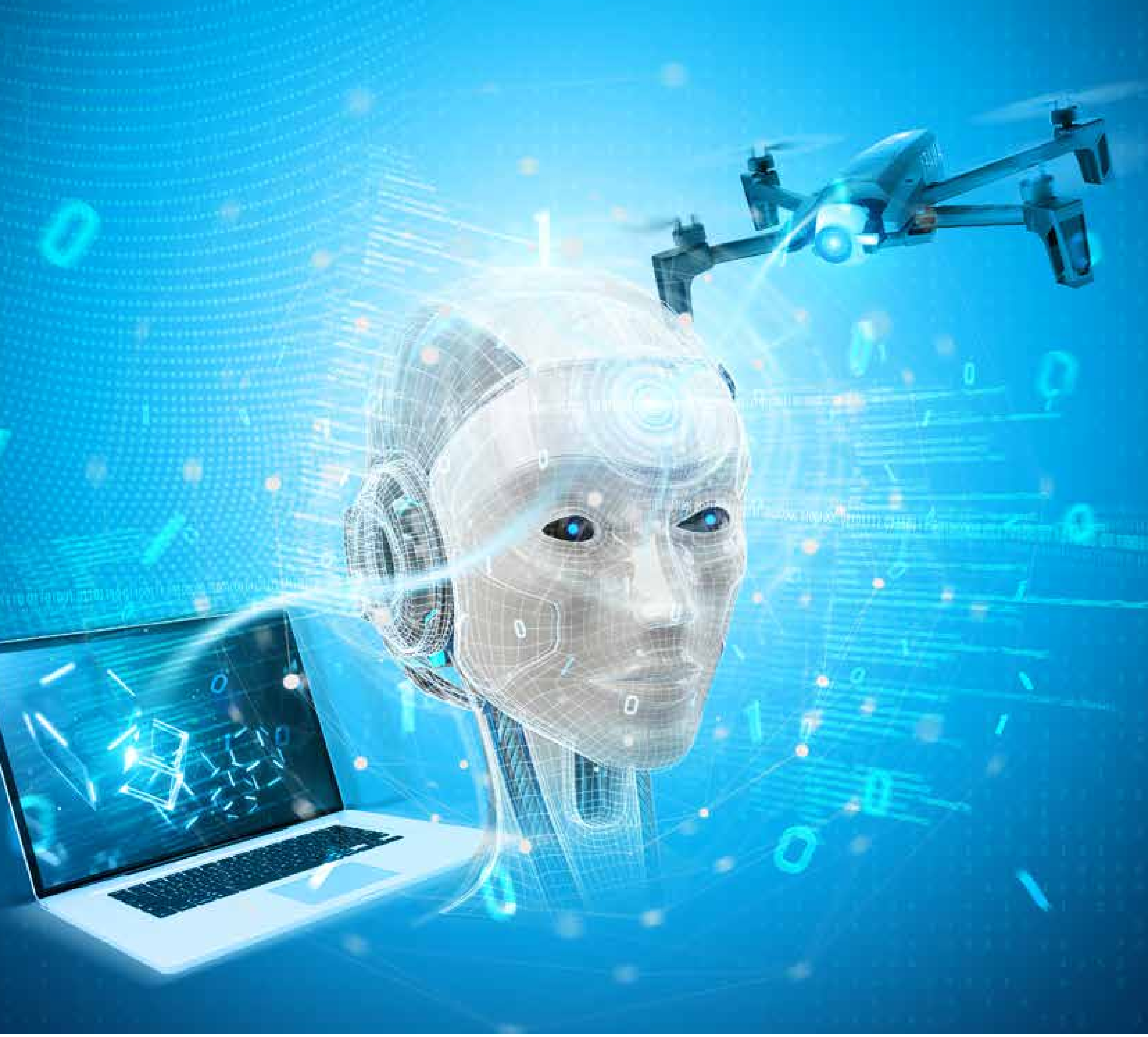
PROMOTING DISASTER RISK RESLIENCE TECHNOLOGIES AND INNOVATIONS IN INDIA

Guide for **Innovators**



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Contents

List of Figures

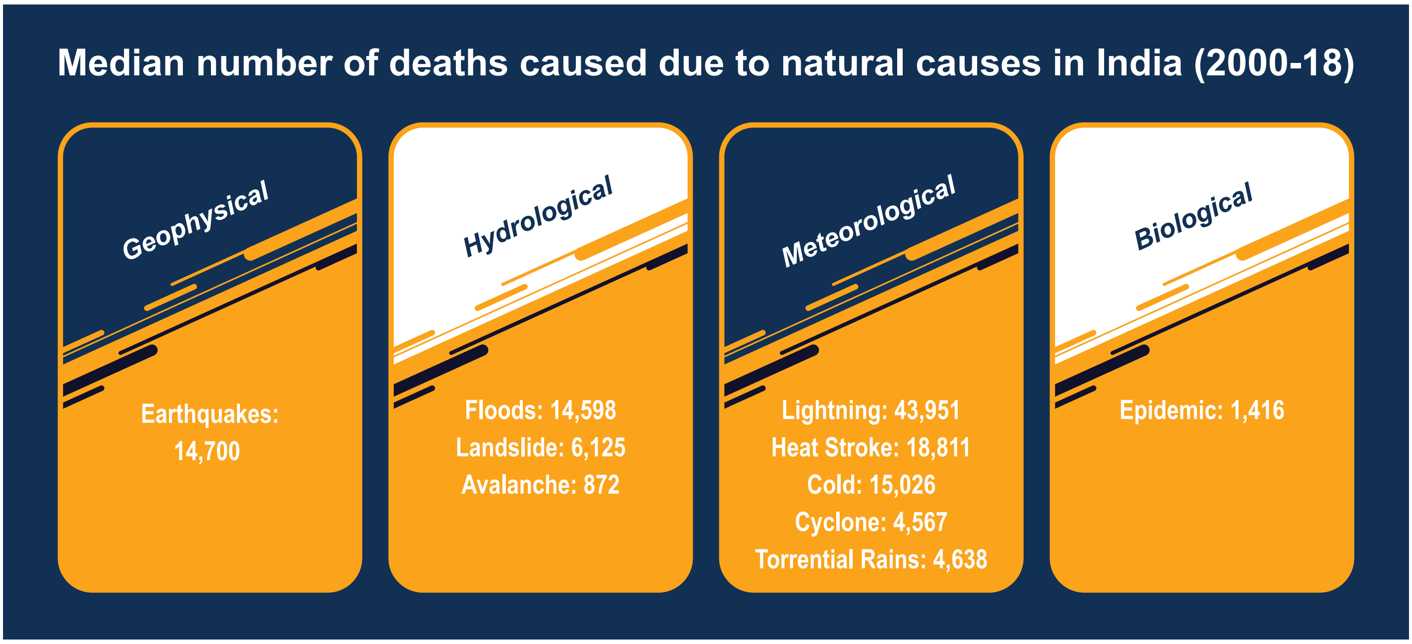
List of Tables

01.
Introduction

India has a unique geophysical and topographical structure, which makes it vulnerable to many disasters: more than 58.6 percent of the landmass is prone to earthquakes of moderate to very high intensity; around 5,700 km of the coastline, which is 3/4th of the total area, is at-risk from cyclones and tsunamis; over 40 million hectares (12 percent) of land is prone to river erosion and floods; and 68 percent of the cultivable area is vulnerable to droughts.[1] Hilly areas are also at risk from landslides and avalanches. Moreover, India is also vulnerable to chemical, biological, radiological, and nuclear (CBRN) emergencies and other man-made disasters.

The increased frequency and intensity of disaster risks in recent years has led to huge social and economic losses, both in India and around the world.[2] India, being a climate sensitive nation, with a large vulnerable population, unplanned physical infrastructure development, and poor institutional capacity is worse affected by disaster related impacts. The estimated economic losses sustained by India from 1998-2017 due to disasters amounted to USD 79.5 billion.[3] Between 2000 to 2018, natural disasters also resulted in approximately 3.67 lakh deaths in India.[4] The rising likelihood of extreme weather events due to climate change increases the vulnerability of

Figure 1



1 https://ndma.gov.in/en/vulnerability-profile.html
2 Economic Losses, Poverty and Disasters (1998-2017); United Nations Office for Disaster Risk Reduction; October 2018
3 Ibid
4 http://ncrb.gov.in/StatPublications/ADSI/adsimainpage.htm

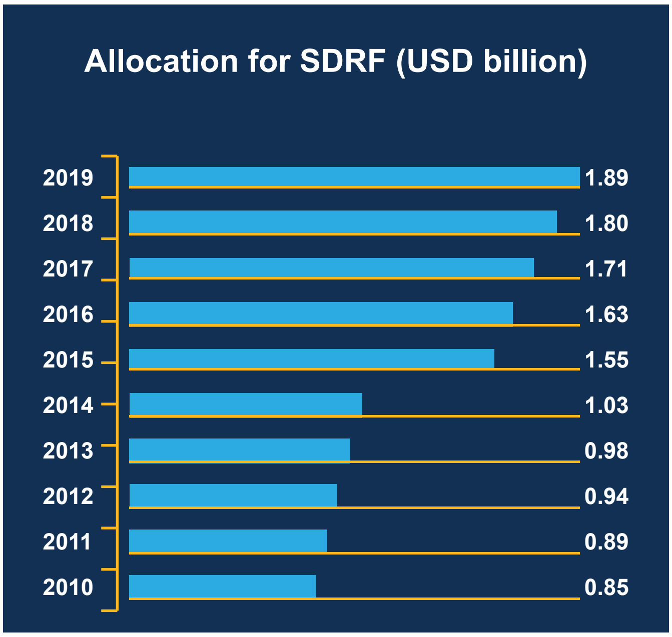
the communities to disaster risk. In certain regions drought spells will increase and become more widely distributed, while in other areas heavier precipitation will increase the frequency and severity of floods.[5] Rising temperatures and consequent ecosystem changes will negatively impact food and water availability, which will increase vulnerability amongst certain populations. This is further compounded by increasing vulnerabilities related to changing demographics and socio-economic conditions, unplanned urbanization, infrastructure development within high-risk zones, environmental degradation, geological hazards, epidemics, and pandemics. The most prevalent disasters due to natural causes in terms of median number of deaths over these 19 years are lightning (2,387), heat stroke (932), exposure to cold (762) and floods (726). India has suffered human losses largely due to hydrological, meteorological, biological and geo-physical disasters[6] as shown in figure 1. Other natural causes have accounted for 2.43 lakh deaths.

To promote a holistic approach towards designing strategies for disaster risk resilience (DRR) and building community resilience, India has adopted the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030, Sustainable Development Goals (SDGs) 2015-2030 and Paris Agreement on Climate Change (CoP 21),[6] in its National Disaster Management Plan 2019. Science and technology contributions, along with policy and planning mainstreaming, have been considered after several science policy negotiations and multilateral dialogues that were initiated in 2015. It is expected that science and technology will help achieve more effective risk reduction. The Sendai Framework prioritized the development and dissemination of science-based risk knowledge, methodologies and tools on DRR. It also strengthened the interface between science and policy. This includes understanding risk across all dimensions of exposure, hazards and vulnerabilities; ensuring incorporation of disaster risks into planning and development at all decentralized levels; designing strategies for disaster preparedness, rehabilitation, recovery and reconstruction; and prioritizing investments through cost-benefit analysis for DRR aimed at long-term resilience. Innovation and technology for DRR drives economic development and promotes environment sustainability, thus contributing to improved community resilience.

The government sources funds for disaster preparedness and response from the national disaster relief fund (NDRF) and state disaster relief fund (SDRF). The total funds allocated under SDRF from 2010-11 to 2019-20 amounted to USD 13.27 billion. SDRF provides the main source of financial assistance for disaster affected areas with a 75:25 central and state share for all states, apart from the Hilly States and North-East Region. In these regions the distribution is 90:10 between the Centre and State.

Between 2019-20, the government spent USD 3.31 billion[7] on disaster relief and response. In 2019-20, the total funds released from the SRDF and NDRF were USD 1.33 billion (utilisation of 71 percent) and USD 1.98 billion, respectively. Goa was the only state that did not expend any resources in 2019-20. The state wise allocation and release of funds between 2019-20 is given in Annexure A. The increased severity of disasters reflects a huge fiscal burden on the state, due to lack of mitigation. The recent *Standing Committee Report on Disaster Management and Relief*[8] recommends incorporation of a Disaster Mitigation Fund, to invest in prevention and mitigation of disaster risks in the most disaster-prone states. This will reduce expenditure on disaster relief and response to a great extent.

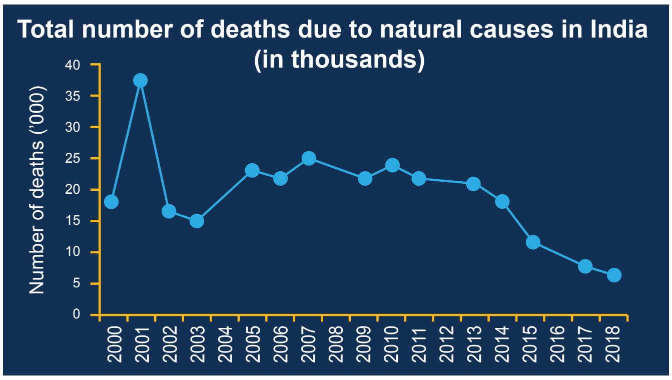
Figure 2



In this context, it is extremely important to promote the application of innovations and technology for DRR aimed at improving adaptive capacity of communities and reducing losses due to disaster related impacts. Considerable efforts are being taken towards enhancing the role of technology in reducing vulnerabilities of communities and ecosystems-at-risk, preventing risks, and building resilience of critical infrastructure. In recent times, with the increased frequency of disasters, Governments (both at the central and state level) have shifted their priorities from post-disaster reconstruction towards

5 IPCC Fourth Assessment Report of the Working Group II "Impacts, Adaptation and Vulnerability"
6 National Disaster Management Plan 2019; National Disaster Management Authority; November 2019
7 Annexure A (https://www.ndmindia.nic.in/response-fund)
8 https://prsindia.org/report-summaries/central-assistance-disaster-management-and-relief

Figure 3



building resilience of infrastructure and communities. There has been a significant decrease in the number of deaths due to natural causes since 2000 (see figure 3). This could be partially attributed to a more effective disaster risk preparedness and disaster risk response mechanism. The Government, along with private sector, has been using technologies such as Geographic Information System (GIS), weather forecasting and predictive analytics, early warning systems and remote sensing to identify risks and improve response to disasters. It is evident that an increased implementation of technology for DRR will create new and improved methods which might enable evidence-based policies. The Government of India (GoI) recognizes that investment in DRR requires evidence-based risk management methods and effective application during emergency.

This study aims to; (a) map the landscape of technologies that can be used in the DRR space, (b) define the current ecosystem, (c) examine the challenges, and (d) provide suggestions for promoting DRR technologies and innovations in India.

02. Disaster Risk Resilience Technologies and Innovations

Disasters have a significant impact on the economic and social resources of a country. The yearly average global impact in the period 2007 to 2017 was 354 disasters; this affected 210 million people, of whom 68,000 lost their lives. The damages of these disasters amounted to USD 163 billion.[9] However, technological innovations and advancements are creating opportunities for improving resilience to disasters and supporting risk reduction.

Globally, developments in disruptive technologies[10] such as internet of things (IoT), artificial intelligence (AI), drone technology, predictive analytics, risk modelling, remote sensing etc. are transforming the field of disaster risk reduction and management. The application of these technologies has improved with advancement in digital infrastructure such as wireless broadband networks, cloud computing, smart phones, and mesh networks. However, the spread and availability of these new technologies varies amongst developed and developing nations, which is further disaggregated between low- and high-income regions. This influences the availability and applicability of technology for varied disaster management scenarios (pre, during and post). There is an increased application of new and updated technology in the DRR space in the developed nations. However, the application of new innovations for DRR in developing nations remains limited due to certain key challenges pertaining to information asymmetry (specifically applicability and usage of technology for DRR), poor funding, and low technical capacity.

The DRR technology and innovation market in terms of availability and applicability of disaster specific innovation/ technology is still at a nascent stage in India, in comparison to applications globally. There is an increased application of AI, drones, and IoT, which are being indigenously designed; although this is largely for agriculture and water sectors. These technologies are being used for DRR, on a demand driven basis and applied either during or post-disaster. Most of the technology application in India (drones, satellite imagery) has been constrained to disaster risk response and supporting relief and rehabilitation measures. It is important to support targeted innovation to enable application of existing technology for disaster preparedness to reduce the economic and social losses. There is a need to create a market driven ecosystem for DRR technologies and innovations to enable more research and development and create resilient communities. These

9 *Disruptive technologies and their use in disaster risk reduction and management; ITUGET 2019 (https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Documents/2019/GET_2019/Disruptive-Technologies.pdf)*

10 *30 innovations for disaster risk reduction; IRIDeS, Keio University, the University of Tokyo, UNU-IAS, CWS Japan; March 2019*

customised solutions will be most effective if they are easy to use, scalable, accessible and affordable.

The sections below showcase examples of the key disruptive and traditional technologies that are being deployed globally for DRR. Specific case studies from India are shared wherever applicable.

2.1. Disruptive Technologies

Disruptive technologies are enabling countries[12] to effectively address disasters across all scenarios (pre, during and post). They help in understanding disaster triggers, enhancing predictive analytics and forecasting to enable early warning systems, assessing pre- and post-disaster physical damages, ensuring accuracy and timeliness of response strategies and information dissemination, and increasing knowledge of economic impact and social behaviours post-disaster. In this stead, these DRR targeted innovations and technologies are supporting strategic interventions across all three phases: pre-disaster, during disaster and post-disaster response.

Drones enable remote sensing at the time of pre and post disaster; they monitor geophysical structures to mitigate the impact of disasters and support relief measures by showcasing live pictures/footage from sites affected by disasters. There has been an increased application of **AI driven computational** models and cloud-based data integration results for predicting and detecting extreme events and establishing early warnings for disasters. **IoT** for disaster management is driven by monitoring sensors which are embedded to provide real-time information and send alerts in case of catastrophic events. Earth movements can be detected by ground sensors and flood management can be enabled by river level monitoring. An IoT based early warning system[11] has been successfully implemented in a village in Colombia for controlling river flooding in 2017, which included solar powered sensors to monitor air temperature and water levels with cloud storage for data and mesh networks for information dissemination. **Cryptocurrencies** are also being used by some relief agencies for accepting donations. For example, Oxfam[12] provided '*Dai'*[13] *(stable coin)* for distributing aid to 200 people and 30 vendors in islands of Vanuatu that were prone to natural disasters in 2019. Information dissemination enabled through **mesh networks** ensure connectivity post-disaster and help in the exchange of information during a crisis. There is continuous research and development being undertaken by international institutes and agencies on new technologies and innovations that can support DRR. This includes **blockchains** and **robotics**.[14] The scientific community validated that a blockchain distributed ledger system can verify information and records. This will allow for a faster disaster response. This technology is being piloted by *United States of America Centers for Disease Control and Prevention*[15] to enable reliable and rapid data collection during a disease outbreak. This could be relevant for disaster management at the time of relief and rehabilitation, as it requires timely sharing of trusted information and data to enable collaborative efforts by different agencies. In the case of robotics, the *Human–Robot Informatics Laboratory of Tohoku University*[16] in Japan is designing different types of robots for disaster response, which are embedded with cameras, wireless communication, infrared sensors, and GPS.' These technologies can help detect human presence in damaged areas.

Disruptive Technology for DRR

- Drones support disaster preparedness and response through remote sensing
- Artificial intelligence (AI) for predictive analytics, early warning systems, hazard mapping etc.
- Mesh networks for information dissemination in disaster affected areas in case of network breakdown
- Internet of things (IoT) for monitoring parameters and detecting hazards
- Cryptocurrencies provide aid during disasters or post-disasters
- Blockchain technology enables decision support systems
- Robotics assist relief and rehabilitation measures by removing obstacles and detecting people

2.1.1. Drones

Technology Application

In the DRR space, drones can be used for pre-disaster surveys to enable disaster risk planning. They can also help in providing an aerial view of disaster impacted areas. Drones can effectively enable disaster risk preparedness and response, and improve a community's resilience. Drones can provide granular information over large areas while reducing labour and time cost. They have been utilised affectively by various organisations for conducting surveys in agriculture,

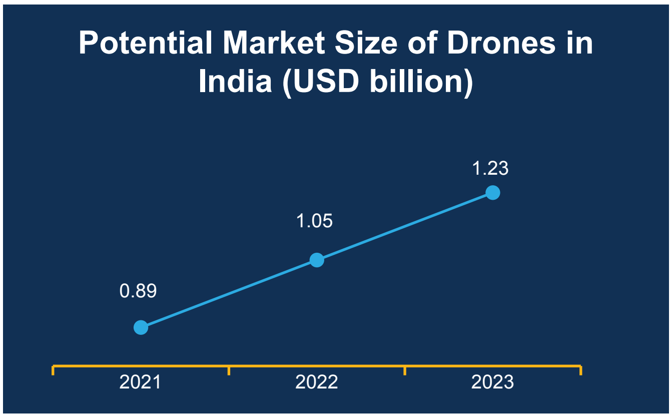
11 Disruptive technologies and their use in disaster risk reduction and management; ITUGET 2019
12 https://economictimes.indiatimes.com/markets/stocks/news/a-crypto-backed-crypto-everything-you-need-to-know-about-dai/new-breed/slideshow/72110376.cms
13 Note: Dai is a stable coin pegged to the dollar and backed by ethereum cryptocurrency locked in publicly viewable contracts that are stored on the blockchain.
14 Ibid
15 Disruptive technologies and their use in disaster risk reduction and management; ITUGET 2019
16 Ibid

specifically for crop monitoring and verification. Drones can also support remote object measurement which can help in planning and rehabilitation works. For example, in Nepal, after the 2015 earthquake, drones were used to create 3D maps of affected areas using image processing software. This helped in assessing the extent of damage, and identifying relief and rehabilitation measures. In recent times, drones have been successfully used during fires, enabling targeted response and securing lives of firefighters as well. Drones were equipped with thermal sensors[17] to identify 'hotspots' and accelerate response. These sensors can also detect body heat signatures and aid rescue operations post disasters. Drones can also be used to drop relief packages with important supplies such as food, water, and medicines in isolated locations.

Market Size and Potential

The global drone market, valued at USD 19.3 billion in 2018, is expected to grow to USD 45.8 billion by 2025, at a compounded annual growth rate (CAGR) of 15.5 percent.[18] This market is dominated by drones for military applications. In recent years, with the easing out of government regulations on the use of drones, there has been a significant increase in applications for commercial and business operations. In terms of investment, since 2012, there is a visible, increasing global trend with more than USD 3 billion invested in drone companies. This peaked in 2018, with investments worth USD 702 million. However, between 2014 and 2018, investments in India[19] only contributed to 2.26 percent of total funding (USD 732 million). The drone start-ups in India raised only USD 16.56 million for business to business (B2B) solutions during this period. These were deployed mostly for industries such as construction, defence, agriculture, security and surveillance, and last mile delivery services.

Figure 4



The total value of the drone industry and market in India is estimated to be around USD 885.7 million, i.e. 4.13 percent of the global market size by 2021.[20] From 2017 to 2023, the market is projected to grow at a CAGR of 18 percent, bringing the size to USD 1.23 billion. The share of commercial drones estimated at 14 percent[21] is projected to be USD 173 million by 2023. The recent policy framework[22] adopted by the Government of India (GoI) eases out regulations and provides a platform for drone companies to scale up business opportunities in the commercial sector. Currently, commercial drones are being used for construction, security, media and entertainment, land use surveys and planning (water, agriculture, forestry).

In terms of emergency management, drone application in the commercial market is estimated to exhibit a 25 percent growth rate. This is due to an increased adoption of drones for disaster management.[23] In recent years, with an increased frequency and severity of disasters, commercial drones have been used for rescue and relief operations. The demand for drones in DRR is expected to increase to improve effectiveness of response measures. Recently, the National Disaster Management Authority (NDMA), held a national session on the

Case Study: Disaster Risk Planning and Reduction by Application of Solutions Through Drones

Indrone Aero Systems[24] is a drone-based application agency for project mapping, planning, management, and monitoring. They can provide solutions at all three stages of disaster response: i.e. pre-disaster, during disaster, and post-disaster, through innovative application of their drone-based systems. In the pre-disaster stage, climate simulation data can be collated by images captured from drones to identify disaster risk zones. This can help governments in designing targeted disaster management plans based on the severity of risk in an area. At the time of a disaster, thermal sensing by drones can help identify people stuck in disaster affected locations, and enable immediate disaster rescue and relief efforts. Post-disaster, the volume of destruction can be mapped by drones, along with planning the route for reaching inaccessible areas through aerial mapping. The application of drones can be extremely successful in enhancing DRR action plans. Indrone Aero Systems has previously supported the Disaster Management Department of Karnataka Government during the Madikeri floods of 2018 and North Karnataka floods of 2019, for disaster rescue and relief.

17 https://www.precisionhawk.com/blog/how-drones-aid-in-disaster-response
18 https://www.marketsandmarkets.com/Market-Reports/unmanned-aerial-vehicles-uav-market-662.html
19 https://inc42.com/datalab/flying-on-low-15-drone-startups-in-india-that-are-soaring-despite-lack-of-investments/
20 https://www.investindia.gov.in/team-india-blogs/growing-market-drone-technologies-in-dia
21 https://defproac.com/?p=2041
22 https://www.geospatialworld.net/news/indian-government-announces-drone-policy-2-0/
23 https://www.gminsights.com/industry-analysis/unmanned-aerial-vehicles-UAV-commercial-drone-market
24 http://www.indroneaerosys.com/

"*Application of Unmanned Aerial Vehicles (UAVs) in Disaster Management*"[25] to build capacity of stakeholders (members of state disaster management authorities, educational institutes, research organisations) on its use for disaster preparedness and response. This expresses the NDMA's willingness to adopt technology for reducing disaster risks. This showcases the potential market opportunity for innovators to re-purpose or design application of drones for DRR in India.

2.1.2. Artificial intelligence (AI)

Technology Application

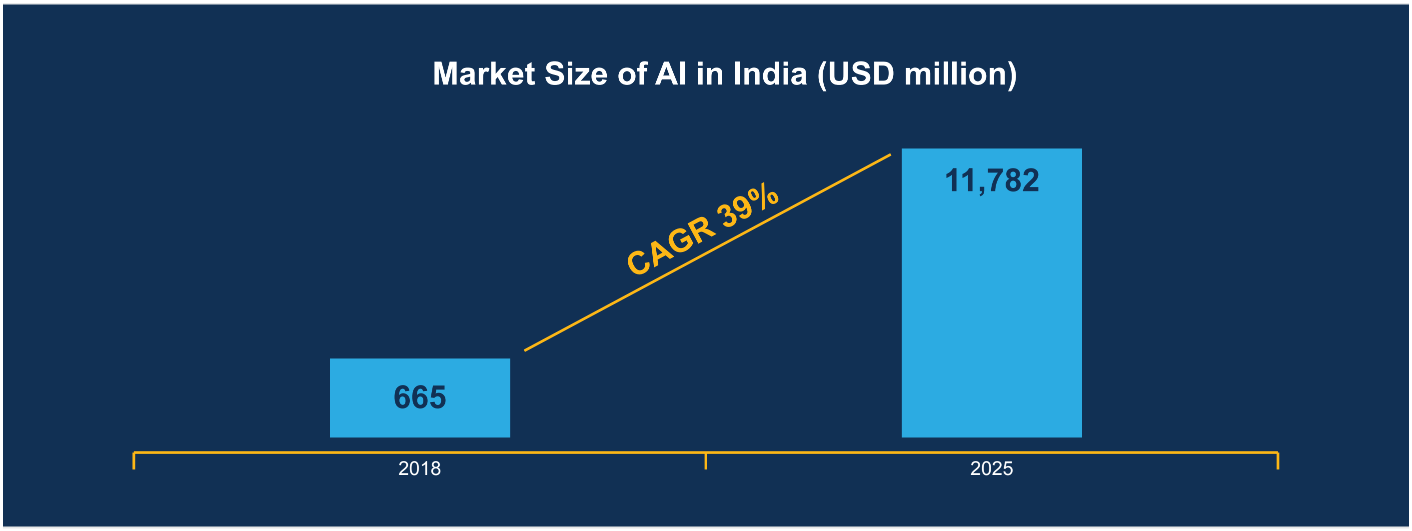
Artificial intelligence (AI) i.e. software algorithms and computation models are generating insights about disaster phenomena. AI, and satellite imagery, is being used for identifying damaged infrastructures, flooded areas and road obstructions. Machine learning is being widely used for hazard and vulnerability mapping. AI enables combining multiple data points and overlaying with thematic maps (natural resources, heat, topographical) to identify disaster impact areas. For example, relief groups used crowdsourced data analysis, pre- and post-disaster images and machine learning to identify disaster affected areas after the Nepal earthquake in 2015. AI also enables predictive machine learning. It can be used to analyse data of seismometers to design detection models for earthquakes. This can help in timely disaster recovery and response in case of disasters. Scientists are constantly innovating to find effective uses of AI for disaster management. An example of innovation includes waveform analysis processing for earthquake detection, which improves the accuracy of detection.

Big data analytics is being used to conduct analysis of large historical data sets and predict the likelihood of extreme events, as well as disaster impact. In India, machine learning in conjunction with geospatial analysis is being widely used for predictive weather analytics and provision of alerts in case of extreme events. This data can be integrated to create online real-time dashboards that enable quick disaster response by authorities. For example, In Kerala, after the floods of 2018, the State IT Mission developed a public crisis management system,[26] using crowdsourcing within 12 hours of the first day of floods. The requests generated were analysed by AI driven algorithms. This prioritized actions based on keywords such as 'urgent,' 'elderly,' and 'pregnant'. This allowed the text posts to be geo-tagged, and enabled quicker response. A geospatial analysis was used to generate heat maps and cluster maps for rescue operations. Further, a mobile application was designed for field surveys to document damages caused by floods and ensure provision of aid in a timely manner. In recent years, improved accuracy of warning systems and lead time has helped in saving lives and reducing economic losses by supporting targeted evacuation measures.

Market Size and Potential

Global investments in AI are expected to be valued at USD 190.61 billion by 2025 from USD 21.46 billion in 2018, at a CAGR of 36.62 percent.[27] This growth can be attributed to increased adoption of big-data analytics, cloud-based application systems and machine learning across business functions largely, such as accounting, finance, information technology, and administration.

Figure 5



25 https://economictimes.indiatimes.com/news/defence/uavs-can-be-effectively-used-in-disaster-management-ndma/articleshow/61549333.cms
26 https://www.expresscomputer.in/egov-watch/how-technology-can-help-india-cope-with-natural-disasters/43603/
27 https://www.marketsandmarkets.com/Market-Reports/artificial-intelligence-market-74851580.html?gclid=EAIaIQobChMInLay5f2M6AIV2worCh2gFAH4EAAYASAAEgIDAPD_BwE

In India, investments in AI increased by 109.6 percent during 2018 alone to reach total investment size of USD 665 million.[28] AI start-ups raised less than USD 100 million from venture capitalists between 2014 to 2017, which peaked at USD 87 million in 2017.[29] It is expected that the market will be valued at USD 11,782 million in 2025, growing at a CAGR of 39 percent between 2019 and 2025. The recent efforts by the Government of India (GoI) towards establishing a national strategy and policy for artificial intelligence and investments of USD 493 million to Digital India[30] for research on new technological innovations (AI, IoT, robotics) are the main drivers of growth. As of 2019, India had approximately USD 50.3 billion investment in research and development of AI technology, and 546 researchers in the domain. It is estimated that AI could boost India's growth rate by 1.3 percentage point by 2035, potentially creating a USD 1 trillion economy.[31]

With an increased frequency of disasters in India, there is a prevailing demand from state disaster management authorities to develop early warning systems and public crisis management systems for better disaster preparedness and response. There has been an upsurge in efforts by research and development institutes to design AI based solutions in this sphere. For example, IIT Bombay[32] has developed an AI based algorithm that can help track natural disasters on the ground, monitor cities from the skies, and help security forces identify insurgents in the dark. This algorithm captures and analyses data/information from radar-based satellites and can be used to create maps of disaster affected areas by identifying all settlements, and effectively generating an evacuation plan that can be fed into Google maps to help locals. Additionally, the Government of India (GoI) is launching initiatives for digital growth that could prioritise AI for disaster management services, healthcare and agriculture supply. In 2018, Invest India[33] and the UAE (United Arab Emirates) Minister for Artificial Intelligence (AI) signed a Memorandum of Understanding (MoU) to spur development across areas like Blockchain, AI and analytics. It is expected that this will generate economic benefits of USD 20 billion over two decades for both the countries.

Case Study: Multiagent Simulations for Interoperability During Disaster Management

Fields of View[34] is a non-for-profit group that designs tools for policymakers to enable better decision making by conducting research at the intersection of social sciences, technology and art. They have a policy lab to undertake research on designing new tools and methods in areas of simulation and games to make policy more participatory and actionable. They also conduct training on these new approaches for government institutions and civil society organisations including disaster management practitioners.

In the sector of disaster management, they have been implementing projects in planning for disaster management and post disaster response. To ensure sustainability, they use participatory methods to design tools and integrate those within the government system. This brings a sense of ownership and ensures continuity of application. Some of their key initiatives in the disaster management sector are vulnerability and hazard mapping based on spatial and ground-level data, designing infographics for awareness generation campaigns, conducting disaster modelling and preparing simulation games.

One such unique initiative was developing a gaming and simulation framework to design, test and validate the Standard Operating Procedures (SOPs) for disaster management, which correspond to local institutional mechanisms. These are semantically and process interoperable. This tool has been designed based on a participatory paper-based gaming simulation (PIEMAC) method in conjunction with computerised simulation tool. This provides a platform for experiential learning and ground-level validation of SOPs. A simulation test helps to test the efficacy of the shared vocabularies used by different agencies across different disaster scenarios. The results of the simulation were analysed to provide recommendations on the communication strategy for participants in terms of means and nodes of message construction and applicability. This can support policymakers as they explore multiple scenarios that will enable the creation of relevant and responsive policy making. This project was supported by the Department of Science and Technology (DST), Government of India.

Fields of View implements grant-aid based projects funded by government or philanthropic institutions. It engages with these institutions proactively by sharing ideas and concepts aligned to the focus areas, as well as applying for research assignments through tenders.

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28 https://www.globenewswire.com/news-release/2020/01/09/1968230/0/en/India-Artificial-Intelligence-AI-Market-Size-2016-2025-and-Spending-Across-18-Sectors-140-Application-Segments-AI-Domains-and-Technology-Applications-Services-Hardware.html

29 https://niti.gov.in/writereaddata/files/document_publication/NationalStrategy-for-AI-Discussion-Paper.pdf

30 https://www.investindia.gov.in/team-india-blogs/national-artificial-intelligence-mission

31 https://www.investindia.gov.in/team-india-blogs/national-artificial-intelligence-mission

32 https://theprint.in/science/using-new-ai-algorithm-iit-bombay-to-reduce-damage-caused-by-natural-disasters-in-india/96056/

33 https://pib.gov.in/Pressreleaseshare.aspx?PRID=1540480

34 http://fieldsofview.in/projects/interoperability/; http://fieldsofview.in/brochures/DST.pdf

Case Study: Analysis of Hyper Local Weather Data Using AI for Identifying Extreme Events

IBM Weather Company[35] uses the IBM Global High-Resolution Atmospheric Forecasting System (IBM GRAF), a high-precision global weather model to relay weather activity globally. It is updated on an hourly basis. This enables prediction of extreme events and emergencies up to two days in advance. They provide accurate data by using AI-driven analytics and IoT based applications. This weather information is disseminated through a mobile based application for the public as well as displayed by websites such as Google and Facebook.

IBM Weather Company provides hyperlocal weather data i.e. 500m by 500m on forecast, current and historical data across both spatial and temporal resolutions. They collate the raw data on weather from opens source Automatic Weather Stations (AWS), wholly installed 250,000 AWS globally and crowd sourcing data from mobiles which have pre-installed thermometers, barometers, humidifiers etc. The AI-driven analytics provides information on extreme weather events with respect to the probability of its occurrence, intensity and patterns of movement. This is based on predictive analysis of historical data, and helps in proactive planning for disaster risk mitigation and response.

They also provide sectoral analytics to government agencies and private sector at a localised level. For example, in the agriculture sector, they predicted the risk of damage to banana crop due to increased wind speed based on weather forecasting. This advance warning to the farmers enabled them to implement the requisite measures and reduce losses. In India, they are providing the Ministry of Agriculture with daily forecasts and disseminating this information to 3.5-4.5 lakh farmers by SMS. This narrative is shared in regional languages and provides information on rainfall, temperature, wind and extreme events. Crop based advisory services are also provided to farmers. This data was used by Kerala Government at the time of floods. They also undertook predictive analytics of thunderstorms for the Rajasthan Government. This supported disaster preparedness by helping the government agencies to prepare utility services in case of disaster impact. They have also used weather forecasting to enable route optimization for organisations in supply chain management and logistics. A similar application can support relief and rehabilitation measures in a post-disaster scenario.

The IBM applications and systems are embedded with mesh network systems to enable communication in case of a disaster-related network breakdown.

Case Study: Radar-Based Remote Sensing Analysis for Creating Risk Profiles

Earth Analytics India[36] is a start-up incubated by IIT Kanpur that uses geospatial intelligence to develop insights for better decision making on agricultural food security and urban resilience. They specialise in radar-based remote sensing applications i.e. synthetic-aperture radar (SAR) that overcome cloud coverage to provide accurate data analytics and are supported by the Swiss SAR specialist organisation, Sarmap SA. They are using machine learning to analyse the observed risks with spatial data collated through radar-based sensors. The radar-based remote sensing data is openly sourced from the European Space Agency.

They are currently working in the agriculture sector, both on the risk prevention and adaption side. They are supporting implementation of the national crop insurance programme i.e. *Pradhan Mantra Fasal Bima Yojana* (PMFBY) by determining the risk profile of the crops based on interpretation of SAR data. This data is more accurate than GIS data, specifically during the kharif season as radar-based sensors overcome the dense cloud coverage. This technology identifies the cropping schedule of an area, as well as the extent of damage caused by natural calamities. SAR based analytics is also being analysed for insurance companies to understand the exposure of the beneficiary to risk. They have successfully established engagements in the states of Maharashtra, Uttar Pradesh, Odisha and Karnataka across India. Similarly, machine learning based SAR analytics can be used to observe changes and examine risk profiles in the forestry and water sector. This will help in design and implementation of risk mitigation measures. As a part of the World Bank funded '*Project on Climate Resilient Agriculture'* (POCRA) in Maharashtra, Earth Analytics, is observing changes in villages ponds across the intervention areas using SAR.

35 https://www.ibm.com/weather
36 https://www.earthanalytics.in/

As a pilot for urban resilience, Earth Analytics used SAR technology to observe instabilities in metro and airport infrastructure in Mumbai. The radar-based sensor measures the distance between satellite and ground every 12 days. This displays any shift that is a result of uplifting or subsiding of the structure. Risk mitigation measures can be developed based on a shift's rate of change during a specific time period. This can be effectively deployed to identify instability in existing infrastructure, or new infrastructure development in disaster prone areas by overlaying the hazard maps. In case of identified structural instability based on SAR data, the infrastructural design can be strengthened by reinforcements to withstand the impact of disasters. This can also support in improving community resilience by identifying sites where evacuation shelters can be developed in case of a disaster. This can enable design for disaster risk resilience infrastructure, and decrease loss of infrastructure and human resources due to impact of disasters. In the case of disaster management, they have deployed technology to detect areas most prone to landslides in Sikkim. This helps government agencies to engage in risk mitigation measures in a timely manner.

Earth Analytics provides the technical decision-making tool for analysing SAR data. Implementing these strategies requires validation by ground engineers and concerted efforts by government agencies.

Case Study: Predictive Weather Analytics and Hazard Mapping for Disaster Planning

Skymet Weather operates across 27 states of India providing real-time data on weather conditions and predictions and alerts for extreme weather events up to three days in advance. Historical, current and forecasted data on weather is available through its website and phone application (available in regional languages). The detailed analytics of weather are provided on a subscription basis to corporate clients and government institutions through email, call or mobile application. In the case of extreme events, information on weather forecasts is also disseminated to government institutions without any cost implications. Some of their prominent clients are renewable energy companies, state disaster management cells, infrastructure and mining companies, and organisations in supply chain management and logistics.

The organisation provides data and analytics based on geospatial intelligence (satellite imagery, remote sensing, radar sets) and by monitoring around 7500 ground observation points (automatic weather stations, lightning sensors, air quality indices). To support disaster preparedness, they have been collating and analysing data on lightning for disaster management departments of states like Bihar, Odisha, Jharkhand and Chhattisgarh, amongst other. S*kymet Weather* has deployed lightning sensors developed by Earth Network: a US based organisation. These sensors measure the electromagnetic waves in clouds, and triangulate cloud voltage based on the charge and pulse of lightning. The algorithm-based model calculates the intensity and frequency of each lightning flash as per the data detected by the sensor to predict the formation of a storm. The severity of the storm is assessed by collating data on cloud movement identified by the frequency and intensity of lightning flashes with the wind speed generated from the AWS. For example, during the Odisha cyclone, the sensors observed multiple lightning flashes. These were analysed to map the pathway of the storm, and send alerts to the areas that would fall in the line of storm for disaster preparedness. Email is used to disseminate information for extreme events. The information is relayed to stakeholders through videos of extreme events which showcase the pathway and impact area of the phenomena. This is compatible with mesh network systems, ensuring functionality in case of disruption in communication network during disasters.

Skymet Weather has also created dedicated web pages on disaster related information, such as the page that tracks floods in Mumbai. This system collates rain gauge data with contour maps and creates short-term weather forecast to predict areas of flooding. There most recent initiative is to enable street level mapping of pollution levels specifically for Delhi and NCR region, where air pollution is hazardous.

They have deployed air quality sensors be expending their own financial resources across 54 cities in India, with the densest network in the NCR region. The air quality index measured by the sensor is being correlated with satellite imagery to develop pathways with highest and lowest intensity of pollution at street level. This will enable people to avoid routes with the most hazardous air quality.

2.1.3. Internet of things (IoT)

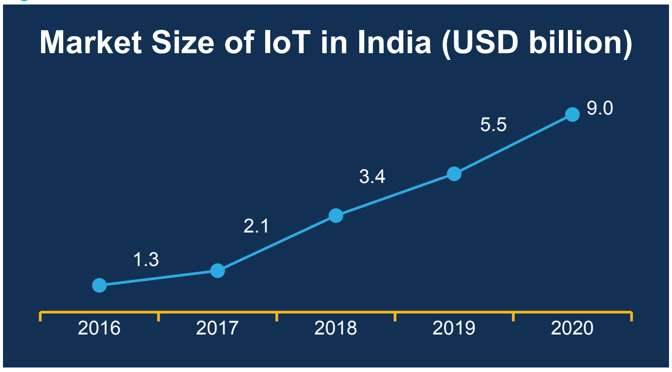
Technology Application

Internet of things (IoT) can be used effectively for disaster preparedness as sensors can provide alerts for potential hazardous events. These are integrated real-time systems enabled by development of digital infrastructure and technology software such as computational modelling, wireless network systems, sensors and machine learning approach for data analytics. IoT systems can be designed to improve disaster risk resilience as they can be applied across all disaster scenarios (before, during, and after). For planning and preparedness, IoT can help in detecting hazards through sensors, enable early warning monitoring systems, support hazard mitigation, assist in the protection of critical infrastructure, help predictive resource deployment and asset tracking/tracing. In terms of response and recovery, it can support GIS integration for tracking, use sensors to monitor personnel in rescue operations, support AI and big data analytics for situational awareness and incident management, enable relief disbursement through smart cards/ RFIDs, create virtual networks for logistics and use sensor technology for identification of beneficiaries. For example, the earth's movements can be detected by ground sensors, and flooding can be predicted by monitoring water levels through sensors. IoT provides a dynamic approach for improving research, generating knowledge and creating awareness at the community level. IoT enabled devices are battery powered and can transmit data wirelessly. This can enable communication services in case of failure of network systems and promote disaster resilience. Similarly, an IoT solution can enable processing of large data across rivers, that can be monitored and analysed to forecast flood situations. A dashboard application can relay the information to the authorities and automatically provide alerts to the authorities and citizens on probable occurrence of floods. This will help in minimizing risk to lives and structural damages. In India, currently, IoT systems are being popularly used in the agriculture sector for irrigation management.

Market Size and Potential

The global market revenue from IoT is predicted to reach USD 1.1 trillion by 2025. From 2017 to 2025, the global IoT connections will increase at a CAGR of 17 percent, from 7 billion to 25 billion.[37] This increase in the IoT market revenue share will be distributed across different industry sectors like utilities, manufacturing, transport and logistics, automotive, and healthcare.

Figure 6

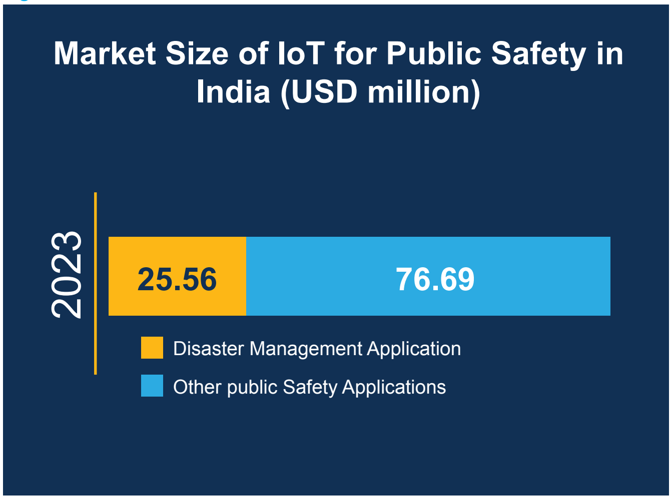


In India, the IoT market size is expected to be valued at USD nine billion by 2020 at a CAGR of 62 percent from USD 1.3 billion in 2016.[38] The number of IoT connections are expected to grow at a CAGR of 137 percent, increasing from USD 60 million in 2016 to US 1.9 billion in 2020. Furthermore, the Draft IoT policy by Ministry of Electronics and Information Technology aims to create an IoT industry in India of USD 15 billion by 2020.[39] As per 2019 data, India has 1500 IoT start-ups which are working across the sectors of agriculture, smart cities, supply and logistics, water management etc.[40]

Specially, in terms of IoT for public safety, the global market size was valued at USD 851.3 million in 2017, and projected to reach USD 2,045 million by 2023, with a CAGR of 15.9 percent. This market includes application of IoT for emergency communication and incident management, critical infrastructure security, surveillance and security, disaster management.

India has a share of 5 percent of global IoT market. Its market for public safety by an IoT application will be valued at USD 102.25 million by 2023.

Figure 7



37 http://ficci.in/spdocument/23092/Future-of-IoT.pdf
38 Ibid
39 https://meity.gov.in/writereaddata/files/Revised-Draft-IoT-Policy_0.pdf)
40 https://yourstory.com/2019/12/iot-india-industry-startups

Considering the focus on disaster preparedness by governments at scale, we can estimate a market size of USD 25.6 million by 2023. This exemplifies the great opportunity for IoT start-ups to innovate for disaster management. Recently, students from IIT Mandi[41] developed an IoT system for predicting and monitoring landslides that costs approximately USD 280.[42] This system is enabled by sensors to monitor weather and soil movement in landslide prone areas. In case the IoT system detects a significant soil shift, it will send a warning by enabling blinkers alongside roads to alert vehicles. These sensors can also send bulk SMS to enable prompt evacuation in affected areas. This system has been deployed in ten locations in a town in Himachal Pradesh, with support from local administration. This functions as an early warning system for impending landslides.

Case Study: Off Grid Remote Monitoring and an Analytics IoT based solution

Yuktix[43] develops and applies sensor network technologies for agriculture and environment sensing enabled by an IoT system. Machine learning and satellite imagery enable forecasting and prediction models.

This IoT is a wireless, solar powered system that provides an effective monitoring and management tool for disease, pest and irrigation of crops. This device has humidity, temperature, leaf wetness, soil moisture, and rain sensors. The soil moisture sensor supports irrigation management for flood or drought prone areas. The data recorded by the sensors and satellite imagery can be accessed on a central dashboard with cloud storage. Ground level data from sensors and satellite imagery are used to run AI driven prediction models for the crop across varied parameters. In Odisha, this IoT system is being implemented by the *Gram Vikas Trust* for irrigation scheduling and management. Predictive analytics enabled by the system on rain forecasts and water levels are helping farmers adopt sustainable agriculture practices and address climate change. This system provides regular alerts through messages and emails on weather forecast and crop diseases.

This wholly integrated IoT system is extremely dynamic and can be easily customized for DRR application. The application can run prediction models to provide alerts for disasters based on sensors that identify disaster risk such as vibration sensors to detect ground movement or smoke sensors to identify forest fires. This would help transmit early warnings, and enable communities and government agencies to undertake preventive measures. Since this is integrated with a wireless communication system, it can relay information and alerts in disaster impact areas with network breakdown and support quicker disaster response measures. The solar powered battery backup IoT device can ensure connectivity in disaster impact areas.

Case Study: Agro-climate Advisory for Farmers Enabled on the IoT application

BharatAgri[44] is a farming technology platform that deploys critical information for enhancing crop production and yield based on scientific techniques.

This platform has developed an IoT system that supports the farmer in seed selection, nutrient management, and irrigation scheduling. It provides weather prediction and methods of crop protection. It also analyses the parameters such as water availability, rain forecast, soil moisture, crop type, and land topology for an individual farmers' field to design a predictive crop calendar across all seasons. This is enabled through a mobile application that also allows schedule tracking of the farm. This IoT system has been demonstrated in 80 model villages in drought prone areas under the World Bank funded '*Project on Climate Resilient Agriculture'* in Maharashtra. This application is enhancing crop productivity and minimising weather risk for the farmer. The agro-climate advisory services are provided through the mobile application, as well as messages in regional languages. The application enables advance prediction up to three days to enable the farmer to take preventive action. This IoT system that enables predictive analytics and information dissemination such as weather alerts can be customised for application in the DRR space.

41 *https://theprint.in/science/using-new-ai-algorithm-iit-bombay-to-reduce-damage-caused-by-natural-disasters-in-india/96056/*
42 *Taking average exchange rate of 1 INR = 0.014 USD*
43 *https://www.yuktix.com/about/*
44 *https://bharatagri.com/about*

2.1.4. Blockchain

Technology Application

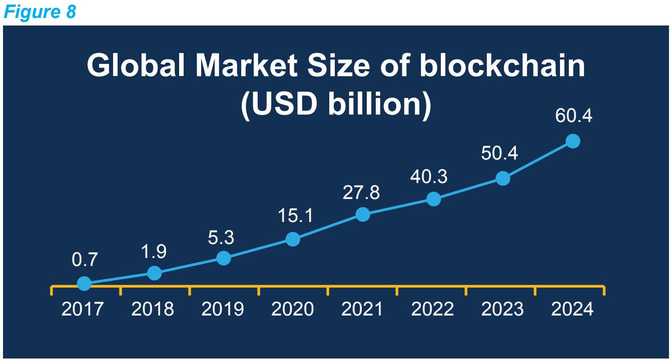
Blockchain is a technology that is based on distributed ledger system and can transform the disaster management sector by providing multiple solutions. It provides solutions for validating information obtained from multiple sources, and integrates information systems to give consistent and reliable information in a transparent manner. It also delivers relief and aid during emergency situations. This technology can also support in monitoring of drones[45] that are registered on a blockchain network during natural disasters and enable quicker response. In India, a recent innovation, *Project Purva Suchak*,[46] integrates blockchain technology for flood prediction. It continuously checks water levels across water bodies, reservoirs and dams, and collates the data with weather forecast information. It generates data on flood prediction that can be stored on a blockchain and accessed by relevant stakeholder groups. This solution that aims to prevent pervasive flooding across India won USD 5,000 at the IBM Call for Code 2019, Asia Pacific.[47] One of the proven cases of integration of blockchain technology for humanitarian purposes has been provision for relief of approximately USD nine million to refugees by the World Food Programme[48] (WFP). In a disaster relief scenario, multiple parties are often contributing resources to aid an affected area. If all parties involved in this scenario adopt a blockchain-based shared system of record, they can coordinate more efficient disaster responses, ensuring resources were allocated to the areas where they are needed most.

Market Size and Potential

The global blockchain market size is expected to be valued at USD 60.4 billion by 2024 from USD 706 million in 2017.[49]

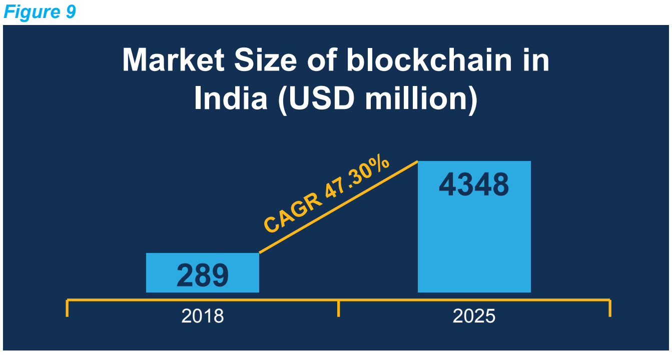
Blockchain is currently being used extensively across five major segments[50] that includes financial services (banking, financing and accounting), cybercurrency, supply chain, and healthcare. In terms of segment distribution, financial services have the largest market share of 56 percent which is expected to increase to 65 percent between 2017 to 2024. The lowest market share of 1 percent, accrued to the IoT segment, is expected to increase significantly to 10 percent during this period. There is sharp decline expected in cybercurrency from 36 percent to 16 percent between 2017 to 2024. This could be due to the changing norms and policies by regulators. The increase in share of IoT for blockchain could be promising for innovations in the DRR space.

Figure 8



In India, investments in blockchain increased by 103.4 percent to USD 154.8 million in 2018.[51] It is expected that the market will be valued at USD 4,348 million in 2025 from USD 289 million in 2019 growing at CAGR of 47.3 percent during the period. Investments by venture capitalists for blockchain amounted to only USD 5.3 million as on June 2019 in India, i.e. a meagre 0.27 percent of the money raised globally.[52]

Figure 9



In terms of market segment, there are around 40 blockchain initiatives being implemented for the public sector, with only 8 percent at the pilot stage.[53] Some of the applications that are being explored across India are for land records, immunization supply chain, chit funds, insurance, electric vehicle battery swapping, organic farming, and energy trading.[54] There is definitely scope for blockchain technology in DRR space, with recent developments in integration of blockchain to support relief measures by using cryptocurrencies and creating databases for disaster related information.

2.1.5. Wireless Mesh Networks (WMN)

Technology Application

To support disaster risk response, wireless mesh network (WMN) systems are being used to enable communication and information dissemination. This technology offers

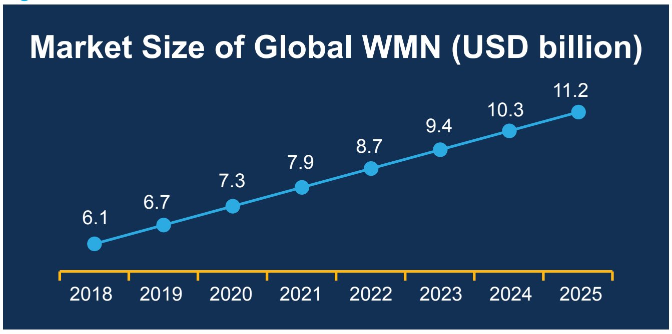
45 https://www.nasdaq.com/articles/blockchain-powered-drones-and-natural-disaster-management-2018-10-24
46 https://inc42.com/buzz/blockchain-this-week-blockchain-development-centre-india-juno-funding-and-more/
47 https://timesofindia.indiatimes.com/india/indian-team-wins-5000-ibm-award-to-prevent-flooding-in-country/articleshow/71578314.cms
48 http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8986483&fileOId=8986495
49 https://www.ibm.com/downloads/cas/PPRR983X
50 Ibid
51 https://www.globenewswire.com/news-release/2019/09/17/1916428/0/en/India-s-Spend-on-Blockchain-is-Expected-to-Record-a-CAGR-of-47-3-Increasing-from-289-Million-in-2019-to-4-34-Billion-by-2025.html
52 https://economictimes.indiatimes.com/small-biz/startups/newsbuzz/move-to-ban-cryptocurrency-has-indian-blockchain-firms-worried/articleshow/69749629.cms?from=mdr
53 https://www.livemint.com/industry/infotech/blockchain-to-gain-momentum-in-india-in-2020-driven-by-startups-11577101749234.html
54 Blockchain: The India Strategy, Niti Aayog, Jan 2020

multiple communication paths across each node throughout the networks. Each node relays data for the network. This enables automatic routing of messages across alternative pathways in case of link failures. WMN systems are designed as self-correcting and self-configurating networks. In India, there has been recent research conducted on designing a *UAV-aided post-disaster emergency network*[55] which enables a Wi-Fi chain network over a disaster region to support relief and rehabilitation measures. One of the applications that uses mesh network systems, *Fire Chat*[56], was widely used in India during the Chennai Floods in 2015, to relay information for disaster relief.

Market Size and Potential

The market size for global wireless mesh network, valued at USD 6.11 billion in 2018, is estimated to increase by 9.1 percent CAGR from 2019 to 2025.[57] The main drivers of the market are an increased used of IoT and AI applications at scale.

Figure 10



Disaster management and public safety segment are expected to dominate the market; this will be supported by increasing investments from governments, and technological innovations on a global scale. In this respect, the ad-hoc mesh network would have a larger market share, as it provides wireless connectivity at high-speed for effective use in fluid situations like natural disasters. This network does not need any prior design or planning, and is created as per the requirement. With the increasing proportion of disasters induced by high climate risks in the Asia Pacific regions, WMNs can aid faster relief and rescue operations by enhancing communication.

2.2. Traditional Technologies

In India, relatively older technologies such as seismometers and satellite imagery are still the most prevalent approaches for detecting, monitoring and assessing disasters, with text messaging being most common for communicating with the public since it has the widest reach. Smart phones can capture the user's geographic location and help in locating people most affected by disasters. Satellite technologies are critical for preparedness and response. **Geospatial technology** is being used to collect aerial imagery to assist in disaster planning and response, and for remote sensing to measure parameters related to water, seismic and cloud activity. **Online networking** has also assisted in disaster response by enabling identification of vulnerable areas and population, management of available resources and deployment of requisite relief measures. Increased monitoring and **social media** use by organisations for relief and rehabilitation measures has been noted in recent disasters in 2019, such as Cyclone Fani and the Kerala Floods in India. Social media also alerted people about crowdfunding websites, which provided donations to affected areas in India. In 2010, following the Haiti earthquake disaster, a contribution of more than USD 40 million was received through text messaging.[58]

2.2.1. Geospatial Intelligence

Geographic Information System (GIS) is the mostly widely used tool for mapping disasters and creating a database

Case Study: Communication Enabled Through Mesh Networks for Alerts

The *Skymet Weather* information systems are compatible with mesh network systems, and ensure functionality in the case of disruption in communication network during disasters. This is a peer to peer-based network system which connects the system to the nearest available communication network (mobile phone, telephone tower etc.). This enables automatic routing of messages across alternative pathways in case one of the link failures within a 10 km radius. This is currently being used to pilot IoT applications for irrigation in remote rural areas. The open source software *LoRa* i.e. low power wide area technology is being used to enable mesh network systems. This system can be deployed in case of disasters. Similarly, the *IBM Weather Company*, has embedded mesh network systems in its application and system to enable communication in case of network breakdown due to impact of disasters

55 *https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8778653*
56 *https://economictimes.indiatimes.com/tech/internet/firechat-alerts-to-help-people-communicate-without-mobile-networks/articleshow/52346969.cms?from=mdr*
57 *https://www.grandviewresearch.com/industry-analysis/wireless-mesh-network-wmn-market*
58 *Disruptive technologies and their use in disaster risk reduction and management; ITUGET 2019*

at the national and local level. Remote sensing images can be used for pre and post-disaster measures, as they enable identification of critical resources along with risks. GIS and remote sensing have enhanced the spatial interpretation of resources and risks, resulting in effective disaster preparedness and response. The more advanced methods of geospatial analytics by using synthetic-aperture radar (SAR) sensors is being explored in India specifically in the agriculture sector.

Traditional Technology for DRR

- Digital infrastructure such as smart phones and wireless broadband network for location tracking, capturing images and information dissemination
- Geospatial technology i.e. geographic information system (GIS), satellite aperture radar (SAR), remote sensing for predictive analytics, planning, aerial imagery, mapping etc.

Satellite imagery and corresponding mathematical modelling and computing is also being used by companies to create indices for disaster risk insurance (DRI). DRI reduces the burden of arranging rehabilitation capital in the disaster impacted areas. It is increasingly recognized as a tool that deals with loss of capital amidst increasing disaster losses. This tool covers the cost incurred in case of natural disaster or extreme weather conditions, against a premium. The insurance payment is assessed based on predictive analytics of weathers and hazard mapping. Such weather and climate index-based insurance can help vulnerable communities deal with natural calamities. They enhance their adaptive capacity to deal with disasters. At the community level, micro-insurance products can provide support to most vulnerable populations such as small farmers and fishermen to deal with impacts of natural disasters.

Case Study: Disaster Risk Planning and Modelling Based on Remote Sensing

Weather Risk Management Services (WRMS)[59] is a smart farming company. It leverages data, technology and financial services to provide holistic solutions to enhance agricultural productivity. Overall, it helps in securing farmers' income in an environmentally sustainable manner.

The organization provides technical support to the Government in improving resilience be identifying areas to create resilient infrastructure based on remote sensing and weather data. They have remote sensing data on a pixel level of 10m by 10m to 250m by 250m. This data along with weather analytics can help identify risks in an area. This database along with ground-level information (such as livelihoods, agriculture, population etc.) is used to design a frequency and severity matrix at a grid level. WRMS calculates the loss and damage ratio of an asset based on this information and examines the exposure to design preventive infrastructure. For example, in case of high loss damage ratio and frequency of a cyclone in coastal areas, the government can design cyclone shelters at identified areas. This solution can be customized based on the needs of the client. They also have the expertise to undertake pixel level flood loss assessment using DEM, Optical and SAR data for doing profiling at 10m to 30m resolutions. They have previously used weather and remote sensing data to undertake flood modelling for Chennai in the urban microfinance sector. This included calculating the damage ratios and hazard mapping of the area, which was used to offer an index insurance solution with fast pay-out options.

WRMS has developed a NatCat insurance product using remote sensing and 3-D hydraulic modelling catering to risks related to floods, earthquakes and cyclones. They have developed a multi-parameter index for covering all major risks pertaining to natural calamities at the grid level. This solution uses remote sensing and automatic sensor devices for evaluation of the index and calculation of insurance claims. A frequency and severity matrix is prepared at the community/individual level for analysing data from weather forecasts, and developing remote sensing images and ground-level information. WRMS subsequently estimates the possible loss and damage ratio to identify the value of pay out in case of a natural calamity. They are going to begin the pilot stage of this solution with the Microfinance Institutions Network (MFIN). This solution provides a platform for quick deposit of money into the borrower's account in case of any disaster and enables a waiver for low-income borrowers of the microfinance institution (MFI). Overall, it aims to enable better risk management for the borrowers.

59 *https://www.weather-risk.com/*

Case Study: Post Disaster Response by GIS Mapping and Analysis

GeoSpoc,[60] is an organisation that undertakes geospatial analytics to seek solutions for businesses and governments. They supported rescue efforts in response to the floods that affected Kerala in 2018, by conducting an analysis of the extent of damage through geospatial analysis. They collaborated with *SatSure,* to develop Digital Elevation Models (DEMs) of the flooded area using Sentinel data, and subsequently prepared an interactive webpage for the Government of Kerala (GoK). They also undertook spatial analysis incorporating GIS, and weather and administrative data to identify varied flood risk zones (high, medium, low) in Kerala. This enabled the GoK to target relief and rehabilitation efforts in the most vulnerable zones. Moreover, this database was used by an insurance company to identify insured properties which might get affected by floods. It also assisted the insurance company in planning for a prospective insurance claim and directing their field officers in a timely manner to the identified customers.

2.2.2. Online Networking

In recent times, social network services/systems (SNS) such as Twitter, Facebook, Instagram have been used extensively for disseminating information to support relief and rehabilitation measures in case of disasters. The development of smart phones and tablets has propagated the use of SNS. This has become an important DRR tool that is helping in resilience building. It offers opportunities for knowledge building on hazards, allows collection of data on disasters, and provides logistical information in case of crises. In most disasters, the public is the first respondent: they support mobilisation of skills, resources, and network systems through SNS for immediate action. The use of SNS has also been noted for crowdfunding resources for relief measures. Data obtained by SNS can be collated and analysed by researchers for decision making purposes. It can be further validated by AI to make predictive analysis by classifying information appropriately. An open source software, '*Artificial Intelligence for Disaster Response*'[61] was created to process tweets based on hashtags and keywords generated during a crisis. This uses machine learning to automatically process data and information in real time and supporting disaster risk response. SNS is an online system which is dependent on telecommunication network, which may fail in post-disaster scenarios.

They are various complementary technologies and innovations that are being applied in India. These can be packaged for identifying disaster specific measures. This will enable government agencies to respond more effectively across all disaster scenarios/phases. The above-mentioned case studies showcase some examples of application of these technologies varies based on disaster scenarios. Predictive analytics based on GIS, and remote sensing and advanced SAR based analytics, can enable disaster preparedness as it supports application of early warning systems. Similarly, IoT applications can monitor ground-level hydrological conditions and be utilised for disaster preparedness. The use of drones involves both: response by displaying damage through aerial view as well as recovery by informing relief workers about possible prioritization of assistance. Social media platforms like Twitter are used for information dissemination, and enable coordination amongst relief teams during disaster response scenarios.

Case Study: Social Media Assisting in Relief and Rehabilitation Measures

In 2015, during the Chennai floods, Twitter was used by different groups to establish communication and disseminate information. Government agencies, non-governmental organisations (NGOs), media and the community used this real-time public platform to exchange information. This assisted in collaboration for disaster response and supported quick deployment of relief and rescue measures. To enable communities to help rescue teams, Twitter publicised three hashtags (#ChennaiRainsHelp, #ChennaiRescue and #ChennaiVolunteer)[62] for deployment during floods. A wide variety of information was generated, including weather forecasts, relief efforts, public transport schedules, helpline numbers and safety tips. The critical messages were magnified which enabled quicker response for relief efforts resulting in a decrease in losses and damages due to disaster impact. This enhanced community resilience building as it provided real-time information and data to the communities trapped in the severe floods.

60 https://geospoc.com/how-gis-helped-kerala-flood-response-and-disaster-management/
61 http://aidr.qcri.org/
62 Disruptive technologies and their use in disaster risk reduction and management; ITUGET 2019

03. Existing Ecosystems for Enabling Disaster Risk Resilience Innovation

The policy and regulatory framework should facilitate an environment to enhance mission-oriented and long-term planning by technology and innovation actors. There is a need for coherence between policies pertaining to technology and innovation and sectoral areas such as disaster risk reduction and climate change. An enabling ecosystem whereby the public authorities engage with the private sector for designing and implementing innovations is a pre-requisite for building a resilient community. This ecosystem should address resource requirements in terms of access to finance for innovators and skilled human capital for enabling research and development targeted at DRR. Furthermore, social norms should promote inclusive participation of the most vulnerable communities to build disaster risk resilience amongst communities and achieve sustainable development. The sub-sections below provide brief information on the current ecosystem in India. They include details about institutional and policy framework, development support partners, and science and technology landscape that influences DRR.

3.1. Institutional and Policy Framework for DRR in India

3.1.1. Policy Mechanism

In India, there are policies for disaster risk management that facilitate community-centred decisions and policy systems. The regulatory and institutional framework for DRR[63] is governed by the Disaster Management Act (DMA) 2005, National Policy on Disaster Management (NPDM) 2009, Compendium of Laws on Disaster Management 2015, and the National Disaster Management Plan (NDMP) 2019. The DMA lays down the overarching policy framework for preparing and responding to natural disasters. It states the financial, institutional, legal and coordination mechanism across all governance levels: national, state, district and local. The DMA 2005 advocates for design and implementation of disaster management plans across all governance levels based on scientific and evidence-based principles of disaster risk preparedness and response. The critical areas addressed by NPDM 2009 are establishing the institutional and techno-legal frameworks for disaster preparedness and response, providing approaches for mainstreaming disaster management into developmental planning, and designing innovative systems with information technology support amongst other approaches for DRR. The Compendium of Laws 2015 collates all laws and legislations that govern any act or object that can be affected by disasters. In 2019, the National Disaster Management Authority (NDMA) prepared the NDMP that provides a strategic action plan for the implementation of disaster management with short, medium, and long-term goals from 2022 to 2030. This plan focuses on how to leverage technology to improve the efficiency of DRR. There is a need to increase investment in technology and innovation to enhance early warning systems,

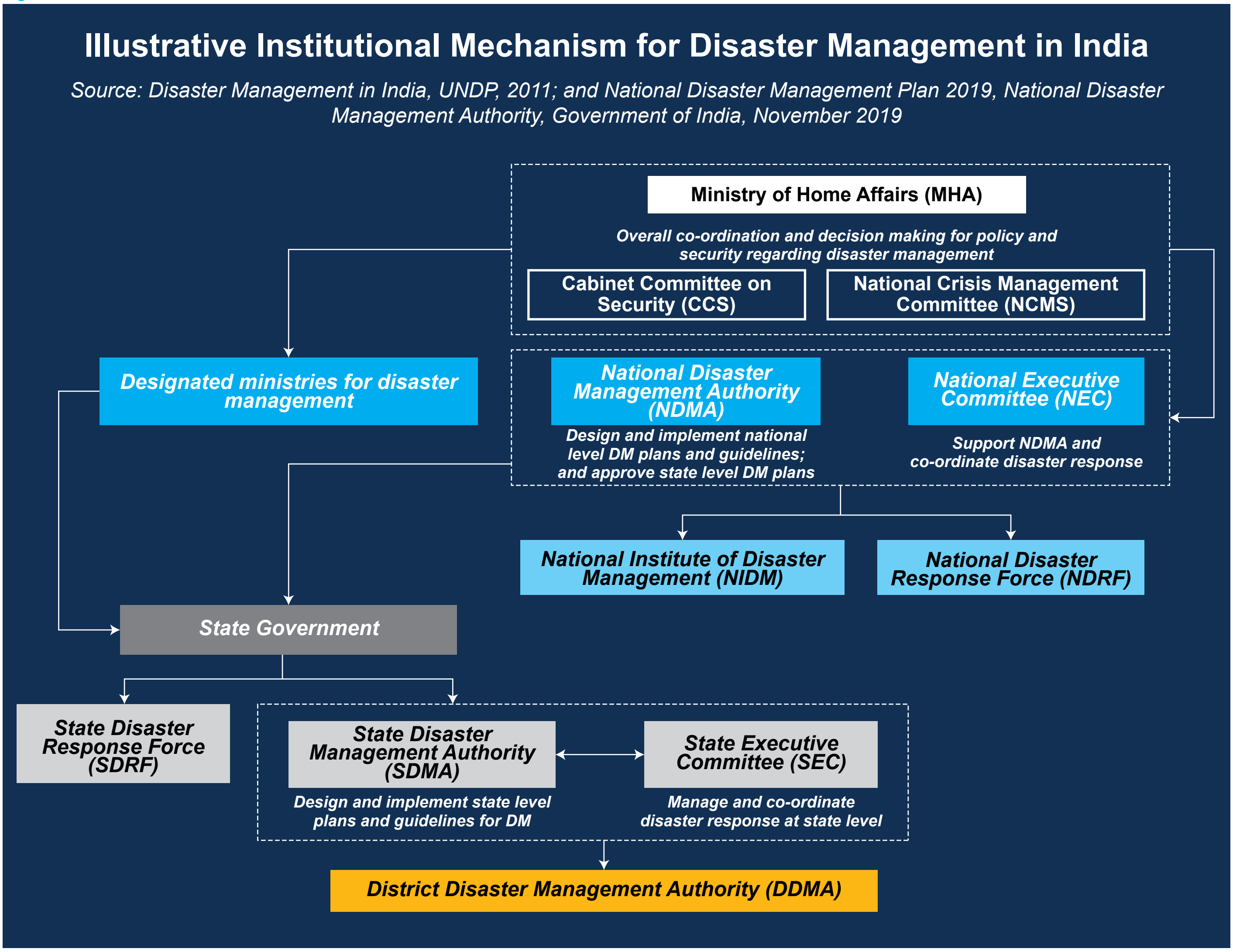
63 https://ndma.gov.in/en/#

preparedness, recovery, response and relief in case of disasters. NDMP suggests establishing an e-platform to enable an exchange of knowledge, resources and technology for DRR amongst individuals and organisations. It also exemplifies the role of social media and mobile technologies in transforming disaster response. This plan lays down all the interventions that need to be implemented to enhance disaster management and the corresponding role of institutions.

3.1.2. Governance Structure

The overarching management and coordination vests with the Ministry of Home Affairs (MHA) at the National Level. The National Disaster Management Authority (NDMA) is the apex body that lays down the guidelines, policies and plans for disaster management. The MHA is supported in decision making for policy and security regarding disaster management by high level committees i.e. Cabinet Committee on Security (CCS) and the National Crisis Management Committee (NCMC). The CCS mainly address aspects of disaster preparedness, mitigation and response, with security implications. The NCMC oversees the disaster response and provides directions during crisis situations. NDMA approves the plans prepared by the various ministries and departments for addressing disaster management. The enforcement and implementation of the NDMP 2019 is the responsibility of the NDMA. It is supported by the National Executive Committee (NEC), which comprises of the Secretaries of the various Ministries and Departments of Government of India. The NEC assists the NDMA in the preparation, implementation, coordination and monitoring of national plans and policies. It is responsible for coordinating disaster response, ensuring compliance to Standard Operating Procedures (SOPs), and managing the deployment of forces for rescue and relief efforts. The National Institute of Disaster Management (NIDM) is the

Figure 11



research and development arm of NDMA, which is wholly responsible for all training, awareness generation and research initiatives regarding disaster management. It also provides technical support to state governments through the Disaster Management Centres (DMCs). The National Disaster Response Force (NDRF) deploys resources for relief and rehabilitation in case of a disaster or natural hazard.

At the State level, coordination and management lies with the State Disaster Management Authority (SDMA), which further governs the District Disaster Management Authority (DDMA). The State Executive Committee (SEC) assists the SDMA in executing its functions as well as coordinating and monitoring the implementation of the policies/plans at the national and state level. The SDMA and DDMA are responsible for the planning, coordination and execution of their respective State and District Disaster Management plans (SDMP and DDMP), provisioning funds for the policies/plans, monitoring implementation, and ensuring department compliance at the state and district level respectively. The institutional mechanism[64] adapted from the disaster management plans[65] and policies is given in figure 11.

This governance structure is supported by civil society organisations (CSOs), research and development institutes/organisations and academia, non-governmental organisations (NGOs), and think tanks across all phases of disaster management. This structure ensures effective risk response to reduce economic and social losses. CSOs and NGOs actively support the government institutions in implementing plans and policies by engaging with communities. The goal is to improve their resilience to disasters.

3.1.3. Government Initiative to Mainstream DRR technology at the National Level

Disaster and climate risk are being mainstreamed in the development planning process. With disasters increasing in frequency and intensity in the last few years, states have realised that it is beyond their fiscal capacity to effectively respond to disasters. Based on this cost-benefit analysis, the Government is willing to undertake higher upfront capital cost by investing in solutions that can help in DRR, rather than expend more money post disaster. This has created political will in the direction of pre-planning and pre-deployment for DRR. There is an evident shift in the government's attitude from conventional traditional approaches of disaster risk management to more technology driven solutions. Some of these initiatives are highlighted below:

At the national level, the Government has developed a GIS-based *National Database for Emergency Management* (NDEM) in collaboration with various Government Ministries/agencies. This is a web based geo-spatial national data repository to assist with decision making at various levels of disaster management. It is also coupled with a set of decision support tools for managing emergency situations. This database includes national level core geo-spatial data at 1:50,000 scale,[66] hazard specific data for multi-hazard prone districts at 1:50,000 scale, database for multi-hazard prone cities/ towns at 1:10,000 scale, database for major cities (~5nos) at 1:2,000 scale. This is generally used by Government officials for the development of commands/instructions to address emergencies in case of calamities. This can be effectively used for science-based policy planning for DRR.

It also has BHUVAN, a GIS portal providing free data and services across India to enable effective developmental planning based on spatial analytics. This allows 3D visualization, 2D visualization, and street map overlays. It also helps in web map services for land use and land cover, flood inundation (events wise rapid assessment and annual inundation), geohazards, forest fire (daily), free RS data download, free 30m DEM from Cartosat-1 data, among others. This is widely used by research and development institutes for designing tools for planning and development including disaster management. This has supported resilience-building by providing spatial datasets for identification of resilient infrastructural designs and plans.

The NDMA[67] supports seven dedicated hazard forecasting and early warning systems/networks that target the most severe natural disasters in India such as floods, cyclone, earthquakes, droughts and tsunamis. These systems are based on innovations such as radars and satellite imagery which assess movement of cyclones, and algorithm-based analytics of hydrological data for flood forecasting. It also allows for wave detection in terms of size and continuity for warnings, for example in the case of a tsunami.

The government has also been enabling partnerships with countries at a regional level and private sector enterprises to spearhead research and development on new and innovative approaches to DRR. To take forward the agenda of technology in DRR, the Government has launched the coalition for disaster resilient infrastructure (CDRI) with members from 12 other countries. This aims to provide a common platform for

64 Note: This is merely an illustration that represents the main pathways for coordination, decision-making and communication for enabling disaster management in India. This does not imply any specific chain of command.
65 Disaster Management in India, UNDP, 2011; and National Disaster Management Plan 2019, National Disaster Management Authority, Government of India, November 2019
66 Note: 1:50,000 scale = 1 centimetre on the map equals 50,000 centimetres (or 500 metres) on the ground
67 https://ndma.gov.in/en/#

enhancing knowledge sharing, and expanding the development of resilient infrastructure, which will lead to a significant reduction in losses. The members will work collaboratively in the areas of policy making, emerging technology, risk estimation, resilience standards and certification. In 2019, Federation of Indian Chambers of Commerce and Industry (FICCI)[68] signed a Memorandum of Understanding (MoU) with Asian Disaster Preparedness Centre (ADPC) to promote disaster risk management in the private sector specifically DRR. It encourages corporates to undertake actions for improving resilience, conducting sectoral trainings, creating awareness on disaster management and knowledge sharing of relevant projects. India was one of the first countries to partner with social networking website Facebook to enable a quicker disaster response in 2017. *"Aapda Samachar Karyakarta - Disaster Information Volunteer (DIV) Programme"*[69] was piloted in the state of Assam and Uttarakhand. Here, a network of trained volunteers used Facebook Workplace to provide information on disasters in their local communities and supported relief efforts by the government. This was supported by a non-for-profit organisation (NPO), Sustainable Environment and Ecological Development Society (SEEDS) for field level implementation. Facebook also offered disaster maps[70] data that would provide information on concentration of users and their movement in a specific area pre and post natural disaster.

3.2. Development Support Programmes on Innovations in the DRR space

Multi-lateral and bi-lateral agencies provide technical and financial assistance support to the government for implementing disaster risk management projects. Some of the most prevalent projects[71] that target innovation and technology for the DRR space have been briefly described below:

In India, the World Bank has a portfolio of over two billion dollars that helps support projects on disaster recovery reconstruction, disaster preparedness, and risk mitigation. The World Bank has been supporting projects on emerging technologies such as internet of things (IoT), artificial intelligence (AI) and drones to provide states with better risk information, understand impacts of potential disaster, and assess real-time impacts of damage. In one of the projects, it has supported application of drones enabled with machine learning models that can automatically detect the point of infrastructural damage and compute the quantum of damages in a post-disaster scenario. The Bank is also supporting the Government to understand exposure of assets based on current and future climate change scenarios.

Another aspect of resilience building is implementation of the Hyogo Framework of Action (HFA) and SFDRR to build adaptive capacities of communities. This is being enabled by the United Nations International Children's Emergency Fund (UNICEF)[72] by providing disaster planning and management support to state governments. In 2018, amongst its various initiatives on DRR, UNICEF developed DRR roadmaps, prepared disaster risk management plans and scaled-up its school safety programme. These identified innovative tools and approaches build community resilience to reduce loss and damages in case of any disasters.

Oxfam[73] is implementing a program called *Volunteer Network Management Systems* that strengthens community based early warning systems by enabling coordination amongst local actors in the last mile. As one of its outcomes, this included developing localised technological systems for information dissemination. They created a volunteer base network system that interprets data relayed by the Government on weather forecasts and disaster warnings and disseminates information in vernacular languages through SMS and displays. Its decision support system can instantly send real-time messages in vernacular languages to its large volunteer database across the country. The messages prevented disaster impact at a great scale due to a system that would provide warnings with specific actionable areas within communities.

The Department for International Development[74] (DfID) has implemented two programmes with the Ministry of Environment, Forestry and Climate Change (MoEFCC) namely, 'Infrastructure for Climate Resilient Growth (ICRG)' and 'Climate Proofing for Growth and Development (CPGD), which includes components of community resilience building. The ICRG programme has supported the MoEFCC in designing '*Climate Resilient Infrastructure Design Document*' using satellite imagery and remote sensing, which includes approaches for making natural resource management works more resilient to climate change. This could enable mitigation against floods for the communities. Under the CPGD programme, the state governments of Assam, Odisha and Bihar have been supported in the development and implementation of flood risk management plans and early warning systems for natural disaster such as floods and cyclones.

68 *http://ficci.in/pressrelease-page.asp?nid=3413*
69 *https://economictimes.indiatimes.com/news/politics-and-nation/india-first-to-partner-with-facebook-on-disaster-response-kiren-rijiju/articleshow/61580125.cms?from=mdr*
70 *https://www.thehindu.com/news/national/facebook-brings-in-disaster-response-tools-to-india/article20009679.ece*
71 *Note: This brief description only lists the key activities pertaining to technology and innovation that can support disaster management across each of these projects. This does not describe all the initiatives being supported by these agencies under the purview of these projects with respect to disaster management or climate change.*
72 *http://unicef.in/Publications/MorePublications/8*
73 *https://www.oxfamindia.org/blog/3-innovations-disaster-risk-reduction-india-you-should-know-about*
74 *https://devtracker.dfid.gov.uk/projects/GB-1-204794; https://devtracker.dfid.gov.uk/projects/GB-1-203180*

3.3. Science and Technology Ecosystem Supporting Solutions for Disaster Risk Management

India's policy landscape acts as a catalyst for promoting innovation through national level programs such as Start-Up India and Atal Innovation Mission. To provide support to entrepreneurs for ideation, technical assistance, and access to resources, national and state governments had established more than 140 incubators[75] by 2014. In the disaster management sector, innovations on methods and approaches in science and technology are largely undertaken by nationally acclaimed academic institutes and research and development organisations such as Indian Institute of Technology (IIT), Indian Institute of Science Bangalore (IISc) and Indian Space Research Organization (ISRO). ISRO has a Disaster Management Support (DMS) Programme[76], which enables efficient disaster management by providing timely support of imaging and communication from aero-space systems. This includes data acquisition through satellite imagery and remote sensing, development of decision support systems and tools, establishment of satellite communication network and research on early warning systems. ISRO has created a digital database for supporting the above activities, including hazard mapping and damage assessment. Furthermore, leading academic institutes (IITs, IISc, IIMs) provide technical support in designing and implementing technologies for disaster preparedness such as early warning systems, impact forecasting models, zonation maps, and risk assessment models. Some of these institutes have developed incubator programmes to promote entrepreneurship in disaster risk management. Students from these institutes participate in accelerator programmes[77] and develop indigenous technologies targeted at disaster relief rehabilitation, such as drones for enabling quick response in case of disaster risk, IoT based solution that detects disaster and implements precautionary measures for reducing impact, and applications based on augmented reality navigation functionality to support disaster response.

In recent years, private sector organisations in the technology sector such as Microsoft, Facebook and National Association of Software and Services Companies (NASSCOM), have also begun accelerator programmes to derive innovation for seeking solutions to social and environment problems. In India, engagement between government agencies, private sector players, and academic institutions has been successful in fostering an atmosphere of innovation. It has helped address the two critical barriers of technical and financial assistance. Some of the recent initiatives in the DRR space are mentioned in the box below. As concerns around disaster management and climate change rise, there could be a more focused shift to innovate technology for this sector.

Recent Incubator and Accelerator Programs for DRR in India

- IIT Mandi Tech Incubator 'Catalyst' designed the Himalayan Innovation Challenge 2019; which invited participants undertaking innovation in disaster management as well. This included total prize money of Rs. 1 lakh for best ideas and incubation support that will include Rs. 16 lakh worth of grant and investment from IIT Mandi Catalyst.
- 'AXLE' an academia accelerator program by Microsoft in 2019, targeted technology innovations by students to predict or manage natural disasters better. It was awarded to team from IIT Mandi who designed an end-to-end autonomous system, to provide precise information about where exactly the people are stuck in case of a disaster with the use of unmanned aerial vehicles (UAVs) that are powered with AI and computer vision. In 2019, Microsoft also implemented the 'Codefundo++ National Challenge' which was won by students from IIT Madras who designed UAVs for DM.
- In 2019, IBM implemented a 'Call for Odisha' hackathon for developing solution for disaster preparedness. This saw participation form 300 software developers. The grand prize of the hackathon was USD 200,000.
- Kerala Start up Mission (KSUM) in collaboration with IBM and NASCCOM designed a hackathon, ''Call for Code Kerala Challenge' for innovation in natural disasters in 2018.
- Chhattisgarh Start up Mission implemented a SKYHack in 2018; which had a theme on disaster management.
- Under the Atal Innovation Mission, the MoH, organised a 'Innovation Challenge for Disaster Reduction' in 2017. The selected 12 innovators demonstrated their technology at the National Platform for Disaster Risk Reduction.

75 *Enhancing Science and Technology based Entrepreneurship – The Role of Incubators and Public Policy; DST Centre For Policy Research, Indian Institute of Technology Delhi; January 2018*
76 *Disaster Management in India, UNDP, 2011*
77 *https://timesofindia.indiatimes.com/city/chennai/iit-madras-students-develop-an-eye-in-the-sky-for-disaster-relief-and-humanitarian-aid/articleshow/71501825.cms; https://timesofindia.indiatimes.com/city/bengaluru/ai-iot-power-student-projects-to-manage-disasters/articleshow/67858079.cms*

04. Challenges constraining development of innovative solutions for the DRR space

Development aimed at resilience-building includes integration of disaster risk reduction into development planning by focusing on science and technology-based policy making. While there has been significant effort by the Government, there are gaps in transferring knowledge into evidence and policy making for disaster risk management. Based on stakeholder consultations, some of the key challenges for developing and implementing technology and innovations for DRR are given below:

- **Limited awareness amongst the entrepreneurs on the opportunities for innovation available in the DRR space:** In recent years, there has been a significant increase in application of new technologies for addressing social, economic and environment issues, such as AI, drones and IoT. However, the application of these indigenously designed technologies is largely dedicated to the natural resource management sector. During consultations, it was observed that there are various entrepreneurs implementing IoT systems for irrigation management based on data drawn from sensors. These systems can easily be customized to enable disaster preparedness by installing sensors such as temperature and carbon dioxide which could help predict forest fires. However, a lack of awareness amongst entrepreneurs about the DRR space limits customizing solutions or developing new technology specifically for DRR. These new and innovative technologies are adopted for DRR space on an ad-hoc basis based on the demand from agencies working on disaster risk management. For example, during the Kerala floods of 2019, there was an immediate need to assess the extent of damage and enable quick relief. Considering the exigency of the matter, *GeoSpoc*[78], assisted the Government of Kerala in rescue efforts during floods by analysing damage caused by floods through geospatial intelligence. They used a pre-existing analytical framework for delineating flood zones and creating an interactive map for the government. Additionally, most of the existing DRR innovations are being deployed either during or post-disaster. For instance, drones are mostly used for aerial imagery of disaster affected areas, while they can also assist in disaster preparedness to identify risk zones. There exist gaps in developing and implementing solutions for disaster preparedness.

- **No linkages between the entrepreneurs and agencies working on disaster risk management:** This challenge

78 *Organisation that undertakes geospatial analytics to seek solutions for businesses and governments*

pertains to both demand and supply side actors. There is a disconnect between entrepreneurs and agencies working in the DRR space, in terms of technology applicability and the scale of operations required for disaster risk management. Entrepreneurs have limited information on the priorities and requirements of government agencies, in terms of DRR technology usage. This restricts innovation. Furthermore, due to cumbersome administrative processes, entrepreneurs find it difficult to reach out and proactively liaise with the government agencies. This is constrained due to limited willingness and a lack of awareness amongst the government agencies on applicability of technology solutions for DRR. For example, *Skymet Weather Services*[79], provides analytical predictive data for lightning as a subscription service to state governments like Bihar, which are severely affected by lightning. However, due to internal administrative bottlenecks and a limited understanding of technology, the procurement from the Bihar disaster management authorities has been delayed by three years. This has disrupted mitigation efforts for lightning in the state. Additionally, there is no continuity in engagement with the agencies in the DRR space, which restricts development of technology solutions focused at DRR. During consultations, most agencies stated that the government gets in touch with them only at the time of the disaster or post-disaster to support relief and rescue efforts. Furthermore, the absence of a common platform for knowledge building and information dissemination on DRR technology limits engagement. There is no large platform to demonstrate existing technologies and innovations related to disaster management. This lack of evidence on feasibility of DRR technologies limits uptake of DRR technology and innovation by government agencies and development support partners. The stakeholders stated that most conferences and workshops on disaster management in India focus on theoretical discussions which focus on disaster management approaches, rather than practical solutions. The representative from the organisation *Earth Analytics* expressed the need for having showcase events that demonstrate applicability of technology. According to him, this will garner government interest and help agencies working in the DRR space.

- **Insufficient financing options to scale up DRR technologies and innovations:** The upfront capital investment required for such technology innovations is high, and pricing the investment is a challenge considering the lack of methodology on risk pricing. There are a few incubators and accelerator programmes providing initial capital for research and development, which is only enough for a demonstration or pilot. The cost for implementing and scaling up technology is mostly borne by entrepreneurs. For example, *Skymet Weather Services* submitted a concept note to the Mumbai Municipal Corporation to create a real-time dashboard for predicting the areas of flooding based on their weather analytics and flood mapping. They requested support from the corporation to provide contour maps of the flooded areas, river monitoring sensors, and the flood height. However, this proposal has not yet been approved due to lack of resources. It is a known fact that government agencies have the requisite financing options, but they are not targeted for DRR innovations. This is a major bottleneck in developing solutions for disaster risk resilience. There is a need to support strategic research and development through pooled financing.

- **Institutional bottlenecks within the government lower engagement by entrepreneurs:** Some of the key barriers that restricts entrepreneurs for undertaking innovations for a targeted segment such as DRR, where the government is the main stakeholder, are the delay in payments and cumbersome procedures. The government tendering procedure can be lengthy and have stringent terms and conditions such as turnover and scale of implementation. This may keep away new innovators from applying. Most entrepreneurs who have worked with the government in the DRR space have mentioned that non-conducive payments terms with respect to timeliness and distribution stages have resulted in lower engagement with the government.

In addition, to the challenges above, there are various others that could influence demand and supply side actors in the DRR space. Based on stakeholder consultations and literature review, it was observed that the most critical challenges are related to developing a favourable ecosystem that looks at aspects of market creation, partnership development, and financing initiatives. The next chapter provides some specific suggestions that can be implemented to address these challenges and its prospective modalities.

79 Skymet Weather operates across 27 states of India providing real-time data on weather conditions and predictions and alerts for extreme weather events up to 3 days in advance

05.

Key Suggestions for Promoting Disaster Risk Resilient Technologies and Innovations

Enabling an ecosystem for promotion of DRR technologies and innovations needs multiple interventions. These need to be directed to solve the challenges of market creation, customization, enabling partnerships and financing. Some of the suggestions to enable such an ecosystem are stated below:

- **Create an annual consultative platform to enable dialogue between entrepreneurs and key stakeholders of the disaster management community:** To ensure the formulation of an efficient market for technology solutions in the DRR space, it is necessary to create a platform to enable dialogue between the government, entrepreneurs, disaster community and academia. This will help entrepreneurs to understand the needs of the government to derive new/customized solutions. In turn, government agencies can provide information about the solutions in the market available for immediate application. The disaster community could provide the requisite contextual understanding based on ground insights that could derive relevant innovations for DRR. Similarly, considerable relevant research is being undertaken by the academic community on innovative solutions which can be scaled up by the entrepreneurs. This will help create a market for DRR solutions in India. The World Bank can enable this through direct outreach programmes with specific government players based on their interest, and organize showcase events to demonstrate solutions developed by entrepreneurs. A regular consultative process at the national level that strengthens ties between these key players will ensure the development of DRR principles that embody science and technology. Additionally, entrepreneurs should be given an opportunity to demonstrate existing technologies through an annual showcase event to gather the confidence of government agencies. This will help remove the barrier of information asymmetry in the DRR market. This showcase event can be adapted from the '*Innovation Challenge for Disaster Risk Reduction'* that was conducted by the Assam State Disaster Management Authority[80] in 2017. This brought together varied stakeholder groups (policymakers, administrators, departmental functionaries, NGOs) to identify opportunities for disaster risk management and practices to improve community resilience. They also set up an exhibition event to give exposure to selected entrepreneurs to demonstrate their application of DRR innovations, such as microwave remote sensing, flood resilient shelters, drones, and mobile

80 *Compendium on innovative tools for DRR-IDRR way forward, Assam State Disaster Management Authority, 2017*

application based early warning systems. This provided the requisite exposure on DRR innovations to varied stakeholder groups and enabled creation of a market for DRR solutions. Additionally, it is necessary to pilot the existing DRR technologies to demonstrate the reliability and sustainability of solutions before scaling up across similar scenarios in varied geographies. Currently, interventions in DRR technology are being implemented in an ad hoc manner. There is a need to scale these interventions to enhance impact and decrease deployment costs. This would help in fostering confidence amongst government agencies on the effectiveness of the technology. It will also enable greater replication at the national and state level across types of disasters in varied scenarios.

- **Provide financial assistance at the national level to motivate development and implementation of technologies and innovation in DRR by entrepreneurs:** Currently, entrepreneurs are deploying their innovation in other lucrative sectors apart from DRR, due to uncertainties regarding applicability, market and financing. During stakeholder consultations, it was noted that entrepreneurs require financial assistance at two stages: (1) research, development and demonstration of innovations and (2) customization and scaling up of existing technologies and innovations in the DRR space. Developing two financing mechanisms at the national level could support entrepreneurs for uptake of these two initiatives:

    - *Implement a challenge fund for promotion of innovations in DRR* - There is a need to design and implement a challenge fund at the national level to motivate entrepreneurs to undertake research and development specifically for the DRR space. In India, there are hackathons for disaster management such as Himalayan Innovation Challenge by IIT Mandi, and SKYHackathon 2018 by Chhattisgarh Start-up India. A similar challenge fund could be established at the national level. This can be designed for multiple parameters such as specific technology (e.g.: drones, IoT), type of disaster (e.g.: flood, earthquakes, landslides, lightning) or disaster scenario (preparedness, during or disaster response) based government requirements. This would help in easing out finance specifically at the stage of development and demonstration of innovations for DRR.

    - *Establish a national level fund for scaling-up of DRR technologies and innovations* – There is a need to support higher value financing for DRR innovations at the customization and scale-up stage. A dedicated national level fund could be formulated through contributions from the unutilized national/state level budgets designated for DRR, existing funding from development support partners and incubators at technical universities. This fund could be used for financing grant-in-aid projects to scale-up innovations and technologies by entrepreneurs that have been successfully demonstrated across various disaster scenarios.

  These financing mechanisms will accrue dual benefits: it would create opportunities for new entrepreneurs to develop solutions for disaster risk resilience, and enable scale-up of existing technologies and innovations. These funds could be managed by the National Disaster Management Authority.

- **Enable partnerships to develop and customize new technological solutions for all disaster scenarios:** There is a need to create a coherent supply chain that focuses on addressing challenges related to disaster preparedness and disaster response. This includes enabling partnerships across varied stakeholder groups such as (a) disaster management practitioners and entrepreneurs, (b) academia and entrepreneurs, and (c) between entrepreneurs supporting innovation across different disaster scenarios. This will support the development of localised and customized solutions. Moreover, entrepreneurs need to repurpose existing technological innovations to enable application for DRR, and design new customised solutions through a co-creation process partnering with national and global partners. These partnerships can support innovations that can be implemented across all disaster scenarios. These solutions need to be customized in the given context, both in terms of identifying the right market price and ensuring sustainability of solutions. For example, a provider who develops drones could partner with an entrepreneur adept at AI computational models and IoT system design and implementation. The drones could relay satellite imagery and collate data from sensors on climate and weather scenarios. This can be analysed based on AI computational models and fed into the IoT system to provide alerts in case of extreme events or information disseminations.

- **Develop a digital platform for enhancing knowledge on DRR technology:** A national repository with information on the application of technology for disaster risk management will improve knowledge across varied stakeholders. This platform can also compile existing data of disaster-prone sectors, and a compendium of global and national best practices in DRR technology and innovation. These learnings will help entrepreneurs in identifying what innovations have worked, how they have been implemented, and their relevance to national circumstances and types of disasters. In 2019, a similar initiative was suggested in the National Disaster Management Plan, which reiterates the importance of establishing an e-platform to enable exchange of knowledge, resources and technology for DRR amongst individuals and organisations. This could be developed and managed by the National Disaster Management Authority, and could be the central database for all government data. It could assist in disaster risk planning and response such as climate and weather analytics, granular remote sensing data, hazard and vulnerability maps, health and population data, and land use planning maps. This will assist entrepreneurs in developing technology solutions for DRR.

These suggestions will enable entrepreneurs to develop innovative approaches and technology for DRR by providing the requisite technical and financial support. The findings of the study suggest the need to create partnerships and networks for enabling interaction between varied stakeholder groups in the DRR space. This is critical to address the two most prevalent challenges: knowledge creation and market development that focusses on technology and innovations for disaster risk resilience. The study has tried to provide suggestions that can be prioritised for immediate implementation in the medium-term to build an ecosystem for DRR technology in India.

Annexure A.

Data tables

Table 1: Allocation and release of funds for disaster relief and response (USD million)

States	Allocation of SDRF			Releases from SDRF		Releases from NDRF
	Centre Share	State Share	Total	Instalment 1	Instalment 2	
Andhra Pradesh	56.07	18.69	74.76	28.04		79.93
Arunachal Pradesh	7.94	0.88	8.82	3.97	3.97	
Assam	70.43	7.83	78.26	35.22	35.22	
Bihar	59.85	19.95	79.80	58.43	29.93	56.00
Chhattisgarh	30.66	10.22	40.88	9.49		
Goa	0.42	0.14	0.56			
Gujarat	89.88	29.96	119.84	79.21	44.94	
Haryana	39.27	13.09	52.36	12.16	19.64	
Himachal Pradesh	36.2	4.0	40.2	9.5	18.1	72.5
Jammu & Kashmir	39.1	4.3	43.4	56.7		
Jharkhand	46.4	15.5	61.9	23.2	17.6	447.6
Karnataka	35.3	11.8	47.0	10.9		
Kerala	23.6	7.9	31.5	7.3		
Madhya Pradesh	111.9	37.3	149.2	34.6	56.0	239.7
Maharashtra	189.3	63.1	252.4	94.7	94.7	480.4
Manipur	2.9	0.3	3.2	1.4		
Meghalaya	3.7	0.4	4.1	3.6		
Mizoram	2.5	0.3	2.8	1.3		
Nagaland	1.5	0.2	1.7	0.8	0.8	
Odisha	95.4	31.8	127.3	47.7	29.6	436.0
Punjab	49.8	16.6	66.4	43.8		
Rajasthan	140.7	46.9	187.6	70.4		163.1
Sikkim	4.8	0.5	5.3	2.4	2.4	
Tamil Nadu	86.6	28.9	115.5	43.3		
Telangana	35.0	11.7	46.6	50.8	17.5	
Tripura	4.8	0.5	5.3	2.4	2.4	
Uttar Pradesh	86.1	28.7	114.8	75.9	43.1	
Uttarakhand	32.1	3.6	35.7	16.1		
West Bengal	65.9	22.0	87.9	58.1	33.0	
Grand Total (USD million)	**1448.1**	**437.0**	**1885.1**	**881.2**	**448.6**	**1975.2**
Grand Total (USD billion)	**1.45**	**0.44**	**1.89**	**0.88**	**0.45**	**1.98**

Annexure B.

Details of stakeholders consulted

Stakeholder Name and Organisation	Brief Description of the organisation and DRR solution
Dhruva Rajan and Nisha Devar; GeoSpoc	Undertakes geospatial analytics to seek solutions for businesses and governments. In 2018, Kerala floods, analysed areas affected by damages and prepared a flood map showcasing risk zones using GIS and remote sensing.
Sujay Ojha and Anuj Kumbhat; Weather Risk Management Services (WRMS)	Leverages data, technology and financial services to provide holistic solutions to enhance agricultural productivity. For disaster management, undertake weather analytics, remote sensing for resilient infrastructure and disaster mapping, and design a NatCat insurance product for disaster risk financing.
Michael Anthony; Earth Analytics	Uses geospatial intelligence to develop insights for better decision making on agricultural food security and urban resilience. Specialise in radar-based remote sensing applications i.e. synthetic-aperture radar (SAR) and machine learning for analysing observed risks with spatial data.
Yogesh Patil; Skymet Weather Services	Provides real-time data on weather conditions and predictions and alerts for extreme weather events up to 3 days in advance. Use remote sensing and GIS to analyse data and predict extreme events such as lightning and floods and send alerts, and hazard mapping.
Anurag Joshi, Indrone Aero Systems	Undertake project mapping, planning, management, and monitoring through drones. In 2018 and 2019, supported Karnataka government in rescue and rehabilitation during and post floods.
Bharat Palavalli, Fields of View	Designd tools for policymakers to enable better decision making by conducting research at the intersection of social sciences, technology and art. In the field of disaster management, conduct training and capacity building of disaster management practitioners, vulnerability and hazard mapping based on spatial and ground-level data, design infographics for awareness generation campaigns, and undertake disaster modelling and preparing simulation games.
Manish Modani, IBM Weather Company	Uses the IBM Global High-Resolution Atmospheric Forecasting System (IBM GRAF), a high-precision global weather model to relay weather activity globally, updated on an hourly basis. To enable disaster preparedness, undertakes AI-driven analytics for prediction of extreme events and emergencies up to two days in advance.
Shailendra Singh, Yuktix	Develops and applies sensor network technologies for agriculture and environment sensing enabled by an IoT system. Machine learning and satellite imagery enable forecasting and prediction models. This solution can customize for DRR, by installing sensors to identify the natural hazard and running prediction models.
Aman Verma, Bharat Agri	Deploys critical information for enhancing crop production and yield based on scientific techniques through an IoT system. Can be customized for DRR as it enables predictive analytics and information dissemination such as weather alerts.

Annexure C.

List of other key players in the DRR space

Key Players	Role in the DRR space
Technology Service Providers	
RMSI (*https://www.rmsi.com/*)	Design geospatial and engineering solutions. Some of their solutions for DRR are flood and earthquake risk model, multi-hazard risk assessment, GIS and remote sensing-based analytics, early warning systems, structural interventions post disaster needs assessment, risk financing etc.
GeoHazards Society India (*http://www.geohaz.in/about-us/*)	Implement projects on disaster mitigation and preparedness with the aim of reducing vulnerability of the community. Includes hazard mapping, disaster resilient infrastructure, disaster safety etc.
ideaForge (*https://www.ideaforge.co.in/*)	Design & develop Quadcopters, Fixed Wing UAVs and Drones for Defence & Industrial application. Drones have assisted organizations in numerous disaster management operations by disseminating real-time information of the on-ground situation, assessing damage to infrastructure to plan rescue routes, locating people in disaster affected in areas.
Asteria Aerospace Pvt Ltd (*https://www.asteria.co.in/*)	Develops drone-based solutions to provide actionable intelligence from aerial data including solutions for disaster management.
Global Parametrics (*www.globalparametrics.com*)	Redefine the market for disaster preparedness and response by decision support systems for risk mitigation and financial resilience. Produce financial disaster risk solutions by linking open source data sets on weather and climate with indicators of exposure for a client/company to create an index on impact of disaster risk.
Blue Sky Analytics (*https://blueskyhq.in/*)	Use Big Data and AI to build Geospatial Data Platforms for Environmental Data. Create spatial and temporal contiguous data sets for air quality and undertake water body mapping.
Cesta Enterprise (*https://cesta-enterprise.business.site/*)	Create solutions for unmanned system applications based on aerial robotics including drones for disaster risk management.
Satsure (*https://satsure.co/*)	Leverage advances in satellite remote sensing, machine learning and big data analytics to support decision making across multiple domains including disaster management.
Rural Volunteers Centre (RVC) (*http://rvcassam.blogspot.com/*)	Develop community based early warning system for floods in Assam and innovations for disaster affected areas such as high raised hand pump for flood affected areas
Jhai Foundation	Support initiatives on community-based disaster risk resilience which includes designing flood resilient shelters, promoting off-grid electricity etc.
Fork IT (*https://itsforkit.github.io/*)	Design an android app (Surakshit) for situational information messaging, crisis mapping, GPS-enabled search & rescue. Develop a communication mesh box (XOB x.1), 36hr+ battery backup, seamless networking (coverage NLOS 600-800 m), data processing barring internet.
Cortex Construction Solutions Pvt. Ltd. (*http://www.cortexsolutions.in/*)	Design a GPS-based free mobile application for Rapid Visual Survey of buildings for potential earthquake damages called QuakeSavo. It is based on globally accepted earthquake standards.
Technical Institutions	
National Remote Sensing Centre	Development of techniques for remote sensing applications for disaster management support and information dissemination.
Indian Institute of Technology	Research and development on new innovative solutions in science and technology including disaster risk mitigation and response.
Indian Institute of Science Bangalore	Research on risk assessment and planning for natural disasters based on AI-driven modelling and geospatial analysis.
North Eastern Space Application Centre	Research and development using geospatial intelligence. For example, they have designed a solution for microwave remote sensing for near real-time inundation mapping and identification of embankment breaches in Assam.

Annexure D.

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