Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

CHAPTER FOURTEEN

Disaster risk management during COVID-19 pandemic

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1. Introduction

COVID-19, originated in Wuhan, China,[1,2] has caused a serious threat by claiming millions of human lives across the globe and posed serious social, economic, political, and environmental challenges on a long-term basis.[3] The disease is spreading daily[4] and this pandemic has been existing for the last 2 years or more across the world where some countries are battling with its 2nd wave (India and other south Asian countries) and some other countries have faced 3rd wave (European countries), and some are amid its 4th wave (Japan).[5] Recent pandemic caused by novel severe acute respiratory syndromes (SARS-CoV-2) shows similarity to these earlier CoVs such as SARS-CoV and MERS-CoV by causing mass mortality.[6] Due to the longer period of the pandemic, it is expected that multiple disasters and calamities will simultaneously hit areas already affected by COVID-19.[7] The urban population in various regions of Central and South America, South Asia, and Africa are more likely to be affected by flooding, and these flood-affected areas will, in turn, convert to an epicenter of the pandemic explosion, making the overall situation and disaster management far more challenging.[8] The COVID-19 situation of cities in Ottawa and Manitoba in Canada got worsened due to floods.[9,10] During the first wave of COVID-19, flood-affected East Africa observed increased vulnerability among people in terms of the death toll and rapid spread of the disease as social distancing and hygiene-related COVID-19 protocols could not be followed.[8,11] Concurrent hits of disasters during pandemic constrain and limit the effectiveness and application of prescribed mitigation strategies of disaster management.[12,13] There have been several other instances of multiple disasters during the current pandemic viz. COVID-19 coupled with cyclone in coastal areas of Cox's Bazar, Bangladesh[14]; COVID-19 coupled with cyclone (Yash) in coastal areas of West Bengal and Orissa, India;

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COVID-19 coupled with a heat wave in Florida and other parts of the United States. Multiple disasters have reportedly caused a higher rate of fatality and comorbidity.[15] When Japan was hit by typhoon Hagibis during the phase of COVID-19, the disaster management, rehabilitation and recovery operation was jeopardized due to the lack of volunteers required to carry out these operations.[16–19] Though unprecedented or as extremely rare phenomena, governments and society at large across the world are facing natural disasters (viz. flood, drought, and cyclone) alongside combatting the pandemic COVID-19.[20] Collaboration among various public departments (viz. disaster management group, department of health, meteorology, irrigation, agriculture, and finance) and preparedness among government, civil society, and private sector are the keys to an integrated approach of mitigating the risk of disaster during COVID-19.[20,21]

The role of top government officials in the administration is pivotal in undertaking appropriate policies in disaster risk management during this pandemic. However, at the same time, successful implementation of those policies and strategies at an operational level requires strengthening the local bodies, local administration, and local communities by decentralization of power, particularly because of restrictions of travel during a pandemic. Okura et al.[22] describe how flood-prone rural areas of Nepal combatted multidisaster environment during COVID-19 by effective dissemination of information done through communication devices (mobile phone) and CDMC (community disaster management committee) regarding resilience, preparation for coordination, and practical action against hazards.

When COVID-19 is discussed concerning disaster management and lessons learned from the current pandemic, the traditional disaster risk management practice should be integrated via a bridge with a more resilient and modern 21st century disaster risk management approach having the ability to tackle risk unknown in nature or not fully understood.[23] According to Mishra,[23] this modern holistic disaster risk management approach considers unknown and rare events (pandemic created by an unknown virus) and the elements of risk inherent in our global system.

Disaster risk management in general, with greater priority during a pandemic, should not only stick to risk mitigation and action during the shock of the disaster but also consists of an effort of rehabilitation, reconstruction, and implementing of other relief measures enabling the affected people and locality to bounce back to its original shape. With due support of civil society and government, many localities and disaster-affected people have been able to build a resilient and robust future for themselves. A comprehensive

disaster management plan must ensure timely help from the state and devise a method to compensate affected people for their economic losses due to disaster causing damage in the means of their livelihood. Similarly, in the context of health disasters like the current pandemic, lessons learned during COVID-19 guide us to include strategy and scientific recourse for the smooth recovery of affected people from COVID-19. The successful implementation of a strategy for recovery and rehabilitation of affected people will lessen the economic burden and promote a healthy social balance sheet on a long-term basis.

Disaster risk management as a discipline of interest both in the domain of academia and the practicing world is constantly evolving. From relatively less rigor it has grown tremendously, drawing heavily from STEM field, AI, and deep learning for more accurate technology-based scientific forecasting, viz. the end-to-end early warning system based on technology-based forecasting method launched in the Indian Ocean after the tsunami it suffered. It also requires knowledge and application of social and behavioral science for comprehensive management considering the human aspect.

The current chapter aims to develop a framework for integrating health or biological disaster management into the overall disaster risk management protocols and principles. It also suggests a shift from the traditional approach of reactive response after the outbreak/occurrence of the health disaster to a more proactive approach of health risk mitigation by building capabilities across the nation through the development of healthcare services and infrastructure to combat health disasters. Sustainable Development Goal-13 mentions the need for urgent actions to be taken and sets targets to combat the impact of climate change causing natural disasters. It is also discussed how to minimize risk and losses during COVID-19 and the required preventive measures to be taken during the pandemic in the light disaster risk reduction (DRR) framework.

2. The Sendai framework on the convention of disaster risk reduction

The Sendai framework for disaster risk reduction (SFDRR) and sustainable development goals (SDG) are two landmark achievements and steps the United Nations took in 2015. The Sendai framework recommends actionable steps to scale up risk mitigation strategies which in turn must build resilience against disasters across the world.[24,25]

The Sendai Framework on the convention of disaster risk reduction classifies different disaster events into two different categories of risk. (i) A hazardous event or disaster occurring with high frequency, low severity, and relatively less devastating was classified in an **extensive risk** category, e.g., landslides, localized draughts, and floods. (ii) A hazardous event or disaster occurring with low frequency, high severity, and relatively more devastating in nature, causing severe damage to lives and properties, was classified in an **intensive risk** category, e.g., tsunami, earthquake, and nuclear disasters. The convention opined that both these categories of events require comprehensive planning for management. There was an agreement regarding the possibility of efficient management and reduction of risk for these events as the risk is identifiable, quantifiable, and measurable, and an appropriate probabilistic risk evaluation may be carried out. According to the general disaster risk reduction principles, the impact of a disaster can be minimized and effectively managed by a multilevel, multidimensional, multidisciplinary coordinating approach.

However, the convention lacked broad-level discussion and fixing an effective protocol for combatting a black swan event.[26] A black swan event may be defined as a very rare event and has an impact on a large scale with widespread severe consequences.[27] The impact is extremely difficult to model as multiple disasters occur simultaneously in an almost unpredictable manner. The world has already witnessed black swan events having a catastrophic impact across the globe or inside a significantly large geographic region on most occasions. The Indian tsunami and earthquake in 2004, claiming nearly 230,000 lives and affecting countries like India, Maldives, Indonesia, Sri Lanka, Malaysia, and Thailand, is one of the well-known black swan events. The subprime crisis in the United States in 2008 led to a global economic crisis worldwide and impacted most of the countries in the world. Japan in 2011 faced a triple disaster one led to another, causing nearly 18,000 deaths. In an almost unpredictable and unprecedented manner, an earthquake led to a tsunami which in turn caused a nuclear disaster at the nuclear power plant at Fukushima.

Similarly, the COVID-19, which started during the latter half of 2019 in a small corner of the world, gradually spread worldwide and turned into a pandemic. Many countries have concurrently faced disasters like earthquakes, cyclones, chemical disasters, wildfire, drought, and floods during the COVID-19 pandemic. In Australia, the event of bushfires increased mortality and comorbidity during COVID-19.[28] In the United States, the firefighting to prevent wildfire was disrupted[29] and in Zimbabwe,

social initiatives to combat the situation of lack of food grains caused by severe drought got hindered during the pandemic.[30] Although the probability of the individual disaster and the impact thereon can be computed, the risk analysis of the concurrent occurrence of the disasters, and therefore evaluating the larger impact of this event, is computationally very complex.

3. Principle lessons for combatting biological disasters like COVID-19 pandemic

The COVID-19 pandemic disaster did not discriminate between rich and poor or among people from different social strata and statuses. Effective management against this disaster requires a collective effort from everybody. In big nations like India and the United States, information sharing between the central government and state governments, among different state governments, between public authorities and civil society, is crucial for the exercise. While the hallmark of success in managing the pandemic disaster lies in the crucial role played by doctors, nurses, and other public and private health workers, it is equally important to engage community workers, civil society, and every citizen by specifying their roles and responsibilities in containing the pandemic. Researchers have established the necessity of building a resilient public health system to successfully implement the public health disaster risk reduction (DRR) program.[31,32] The principles of DRM (disaster risk management) must be integrated into the public health management system on a long-term basis.[33,34] Few underlying basic principles that need to be followed for this disaster management are as follows:

i. Acknowledging the role of government as a central body passing regulations and laws to manage and control the pandemic
ii. Acknowledging the role of society and every citizen and ensuring their strategic participation
iii. Reorganizing and repurposing critical resources, including human resources, capacities (hospital beds, medicine, medical equipment and aids, etc.)
iv. Repurposing and enhancing diagnostic and clinical management capacities
v. Appropriate use of technology within the constraints and focus on evidence-based research and dissemination of knowledge for information sharing

3.1 Risk assessment and evaluation by advanced mathematical modeling

One of the most important exercises of disaster prevention and mitigation is risk assessment. For this purpose, advanced probability-based dynamic epidemiological models (agent-based models or compartmentalized Markov chain-based models) may be used, drawing heavily from other related STEM fields (deep learning, artificial intelligence, advanced probability and stochastic process).[35] As evident, since the source of risk, nature of the virus, and many other things are unknown, it is extremely difficult to capture the entire risk through these models. Therefore the untapped risk may be reduced by reducing the vulnerability or enhancing people's resilience and the region's environment under risk. The risk assessment should consider the hazard, exposure, vulnerability, emergency response, and recovery capability for a catastrophic event like COVID-19. The tools used in risk assessment use input variables such as rate of spread of the disease, infection doubling rate, positivity rate, prevalence rate, demographic variables such as gender distribution, and distribution of different age groups among the affected population. The impact and consequence of the event may be analyzed by noting the mortality rate, rate of recovery, classification of severity of the disease, availability of health infrastructure, etc. Higher casualty and a less effective postdisaster recovery effort after Hurricane Katrina and Haiyan in New Orleans in the United States and the Philippines may be attributed to the fragile health infrastructure, lack of health insurance, and access of healthcare services to the public.[24,36,37] It is also important to enhance the capacity of providing healthcare services and optimally allocate scarce resources and thereby minimize the fatality.

The purpose of risk analysis and evaluation of impact in the context of disaster management is integrated planning and decision-making. Some major hindrances in the planning and decision-making process during the management of COVID-19 were observed.

a. Determination of a proper unit of analysis of a geographical area. It may be too small or too large. A large unit of analysis loses its characteristics of granularity. For example, a complete restriction or shutdown imposed in an entire subdivision might be useless since the actual source of infection might lie in a small corner of that region. Similarly, a chosen unit that is too small might lack several sufficient data points required for an appropriate decision.

b. Local factors or drivers of risk were dominant in determining the nature of spread and other variables on COVID-19. A management information system which does not consider the variety of controlling and risk factors specific to a particular zone or locality will lead to erroneous decision-making.

c. Since the disease and the nature of the virus are very dynamic, real-time updates of information need to occur within very small time intervals—failing which appropriate and timely decision-making for disaster management becomes impossible.

3.2 Importance of local administration and community involvement

All countries have issued guidelines on COVID-19 (symptoms, testing, prevention, quarantine and isolation, caregivers, treatments, etc.) and enacted laws and implemented them through administrative surveillance to contain the spread of this pandemic. The surveillance to contain the disease is largely done by using digital technologies. Tracking needs usage of tools like data dashboard, machine learning, and migration maps; contact tracing requires usage of global positioning systems and quarantine; and isolation makes use of artificial intelligence, global positioning systems, real-time monitoring of mobile devices, etc. Screening is done by using artificial intelligence, mobile phone applications, and digital thermometers. However, the role of community-based surveillance is far more important to contain the infection and manage this disaster. Areas where the community played the roles of ears to the government have managed the spread of COVID-19 efficiently. Risk reduction programs organized by community groups have been greatly beneficial for building awareness, scientific knowledge, and behavioral patterns as per COVID-19 protocol. Wearing masks, usage of sanitizers, and disinfecting the residence of infected people also helped to bring down the rate of infection to a great extent. Hence, community leadership has been instrumental in efficient disaster management by providing the authority with appropriate feedback from the ground level regarding any hindrances and negative consequences of implemented actions.

3.3 Managing risk versus managing uncertainty in managing the disaster of COVID-19

The current pandemic is known for a faster rate of spread of the disease, a differential rate of mortality and recovery rate, and a higher rate of mortality among older people and people with a weaker immune system.[38] As

discussed, computation and capturing entire risk for managing the pandemic is extremely difficult since the scientific community is still pursuing scientific investigations to reveal facts on source of the virus, the emergence and characteristics of strains, etc. There exist uncertainty of effectiveness of various treatment protocols on people of different age groups, uncertainty concerning the opinion expressed by experts on acquired herd immunity, the effectiveness of different vaccines on generating sufficient antibody, and the timeline a vaccine can protect from the disease. Due to a lack of information on the virus and its different variants, most of the risk cannot be captured and remains unquantifiable for every pandemic. Risk analysis on any disaster is performed on past incidents and experience of that disaster, taking into account its impact, nature of devastation, frequency etc., future strategies for managing the disaster are prepared. Health hazards or biological disasters caused by pandemics require management of uncertainty. Hence, the management of health disasters warrants the advancement of risk analysis toward managing uncertainty and bridging the existing gaps.

3.4 Managing untapped global risk through reducing vulnerability or building local resilience

Today's open economy, the concept of the global village, and the interconnectedness within the world through fast connecting modes of transport have significantly contributed toward the fast spread of COVID-19 and ultimately turned into a pandemic. The impact and mortality rate in different parts of the world vary depending on the robustness of the public health system. Vulnerability in this context is defined as socioeconomic, physical, environmental, and other factors contributing positively to the population's susceptibility to hazards. During the monsoon, people in slum areas in India faced the dual hazards of flood and COVID-19 and were considered highly vulnerable under this pandemic.[39] Building resilience means reducing the vulnerability and thereby reducing the risk of a community from exposure to disaster. The vulnerable population, staff, and frontline warriors of COVID-19 may be considered groups at high risk,[17,40,41] and these groups must be given additional attention to get protection against the disease.

Considering the scale of impact of COVID-19, a good starting point of building resilience will be cooperation at a global level by sharing of information of outputs of research carried out worldwide and based on them deciding good practices to be followed. Those good practices might guide behavior and hygiene practices to be followed both at the individual and at the societal level, treatment protocols, diagnostic norms, repurposing, and

optimal usage of resources. It is also further emphasized that resilience to health disaster decreases because of lack of access to good housing facilities, proper education, basic sanitation, clean water, social support, etc.[42,43] Role of communities and society, as well as individual factors like awareness, integration, diversity, self-regulation, and adaptability, plays a crucial role in building resilience.[44]

The branch of study called disaster risk management has come a long way. In the initial phase, postdisaster recovery and rehabilitation were of primary interest. From postdisaster recovery and crisis management, the branch evolved to disaster risk reduction and risk mitigation. The latest focus lies in building resilience. Building resilience requires building redundancy in social, economic resources, health system and infrastructure, and other capacities. The shock-absorbing capability or degree of resilience also depends greatly on systemic redundancy and modular approach—converting each locality to a self-reliant modular entity.

4. Planning, risk mitigation, resilience building: Methods of protection against a rare event like COVID-19

A pandemic in COVID-19 has disrupted planet earth which experienced the last pandemic almost a century back in the form of Spanish flu. Since a biological disaster and pandemic like COVID-19 is rare and highly improbable and uncertain, it may be termed a black swan event. From the perspective of disaster management, it is important to note certain characteristics of such disasters.

i. The highly unpredictable, unlikely, and high-profile event blows out of proportion very fast and shows the catastrophic impact
ii. Profiling the risk of such events is difficult as it exhibits a very small probability
iii. Exploration of causality and other facts are revealed after the disaster

The principle behind protection against this uncertain black swan event is learning from experience: investigating the source and main cause of the disaster. Extensive research and investigation must take place to find out how it spread and caused outsized impact at a global level, how it created disproportionate pressure on the existing medical resources and capacities, etc. The spread of the Ebola virus in Liberia, Guinea, and Sierra Leone weakened the existing public health system and resulted in the death of a large number of health workers.[45–48] Learning from the experience is not

sufficient, but a forward-looking progressive philosophy to best prepare ourselves for the future is the key to prevent the disaster and limit its catastrophic impact. The latest philosophy lies in creating an antifragile system that works beyond building resilience. Resilience provides shock-absorbing capacity while the antifragile system promotes the evolution of the existing system as a better system. The objective is to absorb the shock of the disaster and minimize the damage and seek opportunities for the evolution of a new era of cultural changes; ideas; behavioral practices; social, economic, and political systems; and scientific and technological advancement. Because of the interconnected systems worldwide, penetration causing disaster to a particular system leads to failure of other connected systems located in other geographies very fast. (e.g., terrorized cyberattack). A country that wants to be better prepared for disasters like COVID-19 has to promote local resilience and build antifragile independent, modular, decentralized systems that can work as a self-sufficient unit.

4.1 Reinforcing risk management by implementing nationwide IT infrastructure, digitalization with local support

Digitalization nationwide is extremely important for managing risk arising out of a pandemic like COVID-19. It is essential to digitally capture data on various patient- and treatment-related information (demographics, symptoms, treatment protocols, test reports, finding responses to treatment, etc.) while treating patients of COVID-19 by creating and preserving relevant databases. The information may be used as inputs to appropriate models on predictive analytics to build a decision support system (DSS) necessary for strategic prioritization of resources and formulation of health policies. To gather data on each individual, the government must build IT infrastructure across the nation. People should have access to a device (smart phone or other handheld devices) connected to the internet. Penetration of internet and IT infrastructure is the necessary precondition for implementing tracking, tracing, and isolation—key steps to manage and contain the disease. This is more challenging because the asymptomatic people are spreading the disease without even knowing that they are transmitting it.[49] Community workers, organizations, and health workers at the local level may be deployed to successfully implement the digitalization process and establish a DSS. The local authority for disaster management and other related organizations and health institutions should be empowered for immediate response and recovery operations during postdisaster rehabilitation.

4.2 Resilience in supply chain through building robust infrastructure and redundancy

Keeping the supply chain disruption minimal is one of the important goals of disaster risk management during COVID-19. The Supply of essentials such as food items, groceries, medical equipment, and medicines was critical in combatting the disaster caused by COVID-19. During the phase of Ebola, some African countries experienced disruption in the supply and delivery of healthcare-related products and services due to weak supply chain and information systems.[50–52] During the outbreak of Yellow fever in countries like Angola, Uganda, and Congo, political unrest and warlike situations in different parts of Africa resulted in a larger death toll due to failure of supply chain infrastructure.[53–57] While restrictions in movement and lockdown created hindrances in supply, resilient businesses and firms made suitable adjustments in their operations including inbound and outbound logistics, inventory policies, and coordination strategies to provide uninterrupted supplies of essential items. The supply chain's resilience is also possible through redundancy in the mode of transportation and availability of strong infrastructural facilities to establish interconnectedness among various parts of a large nation through alternative modes of transportation (roads, railways, air, etc.). To ensure last mile delivery of food, vaccine at a doorstep government needs to scale up the capacity of the public distribution system by engaging human resources and efficient use of technology.

4.3 Economic, financial, and environmental resilience

During the phase of COVID-19, countries have faced natural disasters like floods, cyclones, and earthquakes. It is important to build and maintain disaster-resilient infrastructure for protecting life and properties from natural disasters. Building an economic resilience of a nation or the financial resilience of an individual is important for disaster management. It is more relevant in disaster management during COVID-19 because it has negatively affected the economy worldwide with rising unemployment and economic slowdown. Disaster management during COVID-19 requires financial resources to support the enhancement of capacities of healthcare services, undertake cutting-edge research, vaccinate people, provide food and economic support to marginalized, poor people. Instead of looking for financial resources after the disaster, a country should provide economic resources meant for disaster response as a part of long-term developmental planning. Countries that do not include the allocation of financial resources for disaster

Table 1 Different disasters, nunmber of affected people, number of deaths and economic losses from 1998 to 2017.

Type of disaster	Affected people (million)	Number of deaths	Economic losses (billion $)
Flood	2000	142,088	656
Draught	1500	21,563	124
Storm	726	232,680	1330
Earthquake	125	747,234	661
Extreme temperature	97	166,346	61
Landslide	4.8	18,414	8
Wild fire, volcanic activity	6.2	2398	68

Source: UNISDR (2017): Economic Losses. Poverty and disaster 1998–2017.

risk mitigation and management as a part of the national policy suffer from a financial crunch at the time of disaster. As disasters have become more frequent and are inevitable, countries should consider the financial allocation for disaster mitigation as the investment required to support long-term sustainable growth.[58] Literature is found on the impact of disasters on public health and clinical management-related matters.

Governments, NGOs, and civil society have come forward[59] and taken welfare measures for marginalized people, the weaker segment of the society, and people struggling for survival and livelihoods; arrangements for food, basic hygiene materials, healthcare facilities, and vaccination need to be done to extend support to people facing financial constraints due to restrictions imposed during COVID-19. One of the important measures of building economic resilience and providing social security is cash assistance and direct benefit transfer. This initiative also helps to boost up the demand side to provide resilience against economic slowdown. After due consultations with the central bank, the government may provide subsidies or loans at a cheaper rate to keep the businesses and affected industries running during the crisis period of COVID-19. Instead of looking for financial resources after the disaster, a country should provide for economic resources meant for disaster response as a part of long-term developmental planning (Table 1).

4.4 Sustainability practices, green initiatives, and conservation of scarce natural resources

It is well established that sustainability aspects are well connected in the prevention and mitigation of disasters.[60] Researchers may further explore the

linkages of the current COVID-19 pandemic with violation of sustainability practices, deviation from green initiatives, and excessive consumption of scarce natural resources. However, urban areas exposed to pollution and coastal areas prone to natural disasters need to integrate sustainability initiatives on ecosystem restoration, plantation, hazard, risk mapping, vulnerability reduction, eco-friendly policies for disaster risk management. Rampant urbanization, indiscriminate use of natural resources, rapid industrialization, and deforestation have led to the loss of natural balance by destabilizing the proportional existence of natural gifts like rivers, mountains, springs, forests, and biodiversities. Sustainability efforts to reduce pollution, carbon footprints, and limit human activities causing the emission of greenhouse gases are welcome initiatives to reduce the risk of disaster. These kinds of sustainable and green practices in consumption and production naturally immune us from various risk factors.

5. Intersection of health and disaster risk management

There has been a lot of emphasis on research works, theory building, and policy implementation-related works in the interdisciplinary area of health and disaster risk management. In the context of disaster risk management, public health becomes a critical factor. The world health assembly, through its resolution, has also urged for strengthening of the disaster risk management system by integrating it into a national health policy.[61] A weaker public health creates a hindrance in attaining national, regional, and global developmental targets and goals.[62–64] Literature is found on the impact of the disaster on public health and clinical management-related issues, the commonalities and coordination between public health and crisis management, the impact of strengthening public health on disaster risk reduction, and the description of disaster management cycles applicable in case of an epidemic affecting public health. The Sendai framework for disaster risk reduction (SFDRR) has also given due consideration to health-related issues under disaster management.[65]

Health is considered one of the important outcomes of disaster risk management initiatives. In the context of the current pandemic COVID-19, health has emerged as a matter of concern and one of the critical goals to be achieved. In the African context, it has been strongly advised to use a strong public health system to mitigate the risk of health vulnerabilities and inequalities arising from the disaster.[66–68] Any natural disaster damages the physical, mental, and psychological well-being of individuals. It also

causes significant morbidity and comorbidity among people affected by disasters. Therefore "Health-Emergency disaster risk management (Health-EDRM)," after adopting the health-related objectives from Sendai Framework, augments it further with its action and research agenda to decrease the risk of health hazards as a result of the disaster. It primarily encompasses focuses on the following:

a. A holistic approach to health-related interventions is required during all phases of disaster.
b. Cater to specific health needs of vulnerable sections of the population (people more likely to have health hazards), viz. children, elderly, differently-abled, and people having comorbidity, during a disaster.
c. Necessary steps to build health resilience among communities considering the entire spectrum of health hazards.
d. Internationally acknowledged standard of case-based reporting for measuring different health parameters during all phases of disaster (predisaster, during disaster, and postdisaster)
e. Agreed-upon guidelines regarding usage of terminologies and procedures for preparedness and building health resilience among communities should be prepared.

6. COVID-19: An economic disaster

COVID-19 pandemic has caused mortality and morbidity that keeps people out of work for a long period and slowed down the economy across the world. The pandemic also disrupted the global supply chain due to the lack of availability of inputs from major supplier countries caused by an interruption in production. Limited and restricted transportation among countries disrupted the global supply chain and logistics network, causing a further decline in economic activities. There has been supply and demand shock for various products and services, and regular consumption and production patterns were shattered due to the economic meltdown, lack of confidence among consumers, and other related reasons. As a consequence of the pandemic, there is an estimated loss of employment of 3%. Capital and labor being inputs of production, loss of confidence among investors, and lack of availability of labor have resulted in a supply shock.

An initial estimate predicted an average of 7% shrinkage for advanced economies, 2.5% contraction for developing countries and emerging economies, and an overall 4% contraction in the entire global economy. The actual contraction/growth of the first 10 countries (concerning nominal

Table 2 First 10 countries in terms of nominal GDP and their growth/contraction in GDP in 2020.

Country	Rank (nominal GDP)	GDP growth/contraction (in %)
United States	1	−3.505
China	2	2.27
Japan	3	−4.83
Germany	4	−4.903
United Kingdom	5	−9.92
India	6	−7.965
France	7	−8.232
Italy	8	−8.871
Canada	9	−5.403
Korea	10	−0.958

Source: https://statisticstimes.com/economy/world-gdp-ranking.php.

GDP) in the world during 2020 has been presented in Table 2. The contraction in economic activities in many countries worldwide has led to a huge number of losses in jobs and livelihood, a decrease in per capita income. The vulnerability was more impactful among low-wage earners.

In order to effectively manage the negative impact of COVID-19 on the economy and trade, each country should administer certain steps on a short- and long-term basis. Figs. 1 and 2 show global deflated and normalized losses due to natural disasters. While the disaster in the form of a pandemic may continue its devastating impact for a longer period than expected, the government, treasuries, and central banks are expected to implement policies to continue their normal functioning. An initial response to combat this financial crisis may be cutting the bank rates by the government and policymakers. It is also equally important to determine appropriate monetary policy, health policy, and fiscal policy to regulate and control planned and unplanned expenditures to manage the financial distress caused by COVID-19. As long-term measures, the government has imposed restrictions on mass gatherings in public and workplaces, mobility of the public, and thereby limiting economic activities. Although these restrictions reflect efforts from the government to contain the spread of the virus, it has impacted all sectors of the economy. There has been an increase in the cost of imports and exports. Demand for travel and tourism dropped heavily. Demands for many services requiring close physical proximity also saw a decline.

The current pandemic has also demonstrated the need for an increase in healthcare expenditures. Previous researches have shown that a health

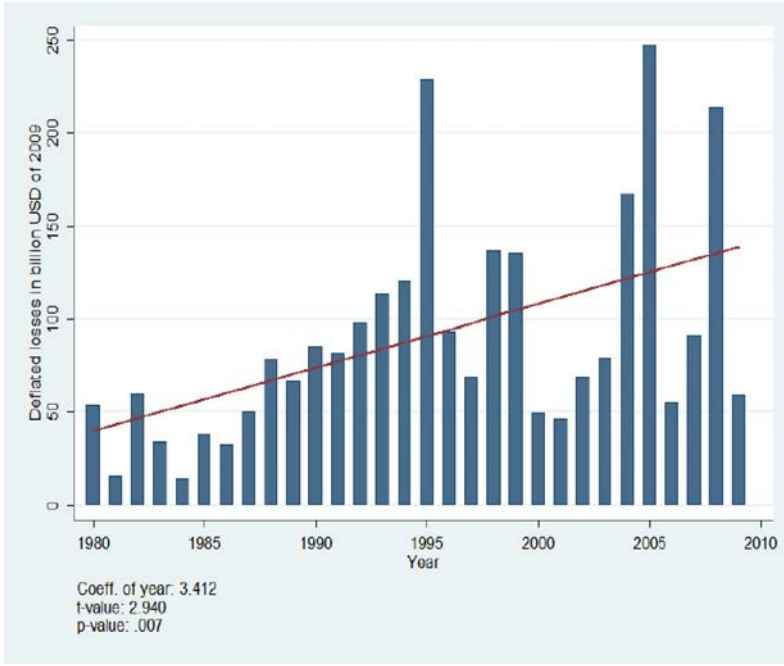

Fig. 1 Global deflated losses based on natural disasters. Note: based on 20,375 disasters. *(Source: Adopted from Neumayer E, Barthel F. Normalizing economic loss from natural disasters: a global analysis.* Global Environ Change *2011;**21**:13–24.)*

improvement improves GDP and vice versa.[69–71] Governments and policymakers must consider investment and increase aggregate expenditure in healthcare as a long-term strategy to manage a disaster like COVID-19. A nation consisting of a healthy population can cut down health expenses and experiences an increase in the productivity and earning potential of individuals.[72,73] Therefore the benefit of investment in healthcare can be observed both at an individual (micro) and country (macro) level. Another significant benefit of higher expenditure on healthcare is an increase in people's life expectancy, leading to an urge or motivation for future savings and investment in business activities resulting in economic progress. Many researchers have been conducted to explore the relationship between health and economic growth.[74–79] Various researchers have found a positive correlation between healthcare expenditures and personal income, per capita GDP, labor productivity, etc. Among the various predictors of per capita GDP, hospital expenditures and expenditures on personal healthcare are the two most important predictor variables of per capita GDP. However, there is

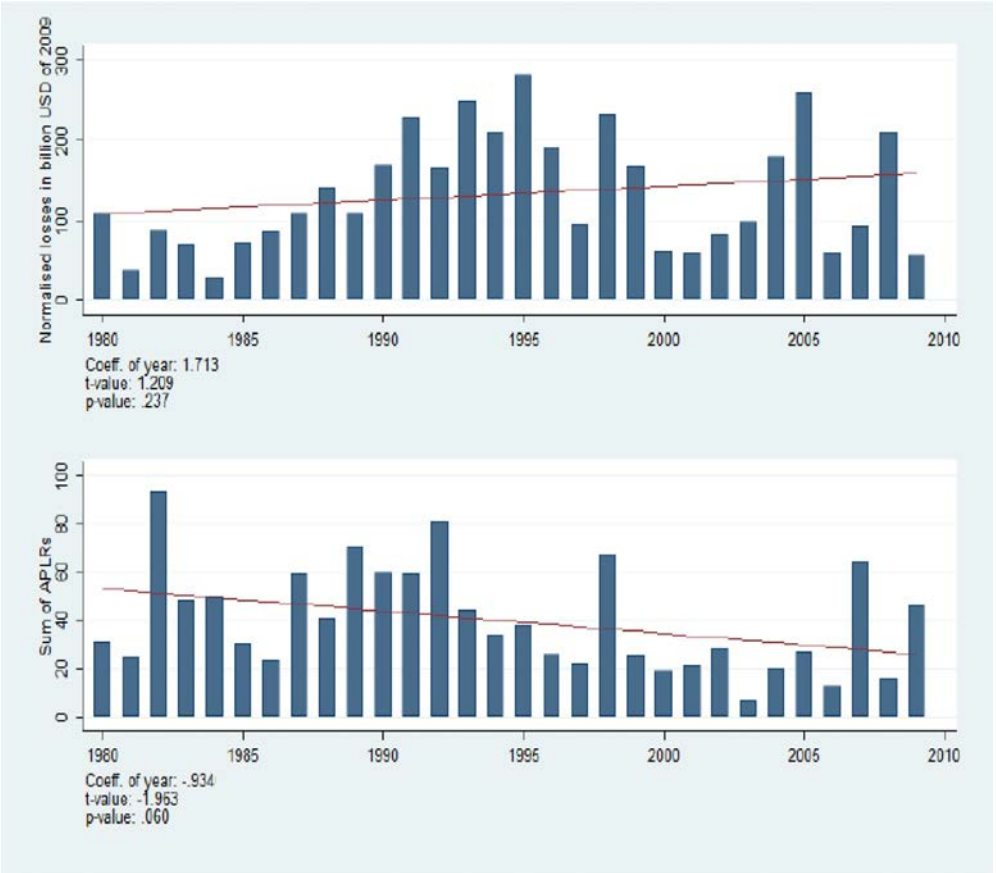

Fig. 2 Global losses from all natural disasters normalized with the conventional approach (top) and alternative approach (bottom). Note: based on 19,115 disasters. *(Source: Adopted from Neumayer E, Barthel F. Normalizing economic loss from natural disasters: a global analysis.* Global Environ Change *2011;**21**:13–24.)*

Table 3 Data of top 10 countries in terms of healthcare expenditures as % of GDP.

Countries	Rank (healthcare expenditure as % of GDP)	Healthcare expenditure as % of GDP (%)	Growth/ contraction in GDP (%) in 2020	Death/ million population	Deaths (absolute)
USA	1	16.9	−3.505	1838.57	603,491
Switzerland	2	12.2	−2.983	1270.7	10,896
Germany	3	11.2	−4.903	1096.41	91,148
France	4	11.2	−8.232	1628.25	109,190
Sweden	5	11	−2.818	1423.27	14,639
Japan	6	10.9	−4.83	117.59	14,848
Canada	7	10.7	−5.403	701.16	26,536
Denmark	8	10.5	−3.287	436.02	2537
Belgium	9	10.4	−6.424	2194	25,196
Austria	10	10.3	−6.59	1207.49	10,719

Source: https://www.statista.com/statistics/268826/health-expenditure-as-gdp-percentage-in-oecd-countries/.

debate regarding the optimal amount of healthcare-related spending required to boost economic growth.[80–82] Careful investment in various healthcare domains can boost productivity, income, and GDP of a country. It also promotes the general well-being of the population. Researchers need to further explore theories of welfare economics to decide how the scarce economic resources may be optimally allocated[83,84] after due consideration of data on GDP, per capita GDP, healthcare expenditures of different countries, etc., as provided in Table 3.

7. Conclusion

7.1 Disaster risk management: Challenges ahead

The current disaster of COVID-19 has taught us various lessons, and it is evident that disaster with its increased frequency and devastating capacity still poses a lot of challenges at the local, regional, and global levels. Especially, the current pandemic has shown how important it is to rethink the current approaches and mechanisms to combat and manage the risk of disaster. Researchers, administrators, and practitioners need to work together to find an efficient way of reducing the detrimental impact of disasters like COVID-19 on socioeconomic progress, poverty, and parameters of the human developmental index, security of life, livelihood, and property. The enormous pressure on healthcare facilities, and financial resources

due to COVID-19 necessitates scientific research to invent models for intelligent usage of existing tools and methodologies to better forecast such events, compute risks, and prescribe measures to control risk and minimize losses.

Modern disaster management encompasses all phases of disaster but places relatively larger importance on disaster response and postdisaster rehabilitation and reconstruction. A public health disaster like COVID-19 demands more emphasis on planning and risk mitigation. There has been discussion on disaster management approach when there is a flood situation during COVID-19.[85,86] It is equally important to compute and control risk for concurrent multidisasters viz. COVID-19 is coupled with a flood, cyclone, drought, and chemical disaster.

The entire world can learn from the experience of the current pandemic and apply those learnings to build a better, comprehensive disaster management system[12,87] Gathering from the experience of managing the risk of a pandemic like COVID-19, researchers and experts have appreciated the importance of building modular, stand-alone, self-reliant, independent systems so that restrictions may be imposed when required in a particular region without affecting the normal functioning of other regions or systems. It restricts the propagation of risk from one system to another and contains the disease at a smaller region by allowing the independent functioning of individual systems.

8. Future risk management

The spread of COVID-19 has resulted in a heavy increase in mass mortality. While antiviral drugs and immune-based treatment have been able to provide positive results to some extent,[88] the key to successfully mitigating the future risk lies in the design and implementing vaccination among all. COVID-19 is a new disease and designing a vaccine and making it available after completion of clinical trial consumes a good amount of time. Therefore successful risk mitigation and management of health disasters like COVID-19 requires the usage of AI, deep learning, and other methods of predictive analytics to forecast its advent, characteristics, and capacity of causing damage. It is also required to successfully build probabilistic, AI, machine learning, or hybrid models to find the optimal strategies to prior track, trace, isolate, and treat people affected by pandemics to minimize the risk.

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