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Disasters and Mitigation in Civil Engineering Perspective (Case Study: Flooding Overflow Occurred and Hit Dili, Capital of Timor-Leste on 4th April, 2021)

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ABSTRACT

Civil engineering disasters refer to failures in infrastructure and construction that result in catastrophic consequences, often leading to loss of life, property damage, and economic setbacks. These disaster can be caused by natural hazards, design flaws, material failures, or human errors. Mitigation strategies in civil engineering focus on designing resilient structures, implementing strict building codes, and using advanced technologies to prevent or minimize disaster impact. This paper presents the concept of civil engineering disasters, their characteristics, classification, causes, and mitigationtechnologies. Civilengineering disasters are caused primarily by civil engineering defects, which are usuallyattributed toimproper selection of construction site, hazard assessment, design and construction, occupancy, and maintenance. Fromthis viewpoint, manynatural disasters such as earthquakes, strong winds, floods, landslides, and debris flowsare substantially due to civil engineering defects rather than the actual natural hazards. Civil engineering disasters occurfrequently and globally and are the most closely related to human beings among all disasters.

Keywords: disaster, hazard, infrastructures, failure, earthquake, advance, technology.

INTRODUCTION

Disasters have been a part of human experience from earliest times and have been significantly impacting human development and civilization. From a modern scientific viewpoint, a disaster is an abrupt (or unexpected/unpredicted) event thatleads to loss of human lives, properties, resources, or environmental wellbeing, exceeding the capacity of thehazard-bearing body, a term that is used herein to referred to any exposure of human society to a hazard. Thefollowing four characteristics are inherent to the above definition of disasters. Firstly, disasters are consequentto the presence of human beings and communities as hazard-bearing bodies. There would be no disasters if there were no humans; violent changes and movements have occurred since the beginning of the earth, but didnot constitute disasters until the appearance of man. Secondly, disasters are uniquely expressed in terms oflosses by human beings and communities. Such losses are not limited to life and property, but also include natural resources and the environment. Thirdly, there is a threshold of the extent of loss due to an event for itto be considered a disaster. In other words, not all loss causing events are considered disasters. The loss threshold/beginning for categorizing an event as a disaster primarily depends on the capacity of the hazard-bearing body to resist the disastrous event and accommodate the loss.

While a car accident may constitute a disaster for a family, it is far from a disaster to the city. Moreover, there are always fortunate individuals or families that remain intact (*whole*) during major earthquakes, which may otherwiseconstitute devastating (or *create shocking*) disasters to local communities. Hence, the aim of disaster mitigation is not necessarilyto eliminate loss entirely, but to decrease the loss below the disaster threshold, which is often a more practicalstrategy.

Finally, the above definition of disaster emphasizes the abruptness of the event. Disastrous eventsare typically abrupt, such as earthquakes, landslides, aviation accidents, and terrorist attacks. However, some disastrous events may occur gradually, such as global warming due to excessive and extended carbonemission, metropolitan smog due to air pollution, and the desertification of a forest or prairie. In contrast to such gradual events, which are to some extent expected and observed during their development, abrupt disasters take place suddenly without effective forecast or prediction. Their durations are short, but they cause significant and often lasting consequences. In addition, such unexpectedevents frequently impose severe mental pressure on the public, and this may exacerbate the disastrous consequences. Unexpected and gradual disasters differ in other ways, including in their occurrence mechanisms, consequences, and mitigating measures.

Common Types of Civil Engineering Disasters

1. Structural Failure – Example: Building or bridge collapses due to poor design, substandard materials, or overloading (e.g., the Tacoma Narrows Bridge collapse in 1940).
2. Dam Failures – Example: The Banqiao Dam failure (1975) in China, which led to massive flooding and loss of life.
3. Earthquake Damage – Example: Buildings and roads collapsing due to inadequate seismic design, such as in the 2010 Haiti earthquake.
4. Flooding and Levee Failures – Example: The levee/protection failures during Hurricane Katrina (2005) in New Orleans.
5. Fire-Induced Collapses – Example: Infrastructure failures caused by fires, such as the Grenfell Tower (2017) in London.
6. Landslides and Soil Failures – Example: Improper slope stabilizationleading to landslides, as seen in the 2014 Oso landslide in Washington.
7. Transportation Infrastructure Failures – Example: Bridge failures like the I-35W Mississippi River Bridge collapse in 2007.

Mitigation Strategies in Civil Engineering

1. Improved Building Codes and Regulations – Enforcing stricter construction codes to ensure buildings can withstand disasters like earthquakes, floods, and hurricanes.
2. Use of Advanced Materials – Utilizing high-strength concrete, reinforced steel, and composite materials for greater durability.
3. Structural Health Monitoring – Implementing sensors and real-time monitoring systems to detect stress or damage before failure occurs.
4. Seismic-Resistant Design – Designing earthquake-resistant structures with base isolators and flexible foundations.

5. Sustainable Urban Planning – Incorporating flood control systems, green infrastructures, and proper land-use planning to reduce disaster risks.
6. Disaster Preparedness & Emergency Response – Developing early warning systems and training professionals to respond effectively in crises.
7. Retrofitting Old Structures –Strengthening existing buildings and infrastructure to meet modern safety standards.

CIVIL ENGINEERING DISASTER

Definition

Disasters have been classified into two major categories based on the natures of the related hazards, namely, natural disasters and man-made disasters. Natural disasters are further classified as (1) geological disasters, which are caused by hazards in the lithosphere, such as earthquakes, landslides, debris flows, and volcanic eruptions; (2) meteorological disasters, which are caused by hazards in the atmosphere and hydrosphere, such as hurricanes, tornados, droughts, forest fi res, heavy rains, and floods; and (3) biological disasters, which are caused by hazards in the biosphere, such as plagues and pests. Man-made disasters can also be classified by hazards into the following three categories: (1) disasters caused by technical mistakes, such as nuclear accidents, explosion of dangerous substances; (2) disasters caused by human faults, such as fi res in buildings, traffic accidents, and gas explosions; and (3) disasters caused by unfriendly (hostile) actions, such as wars, riots, and terrorist attacks. Human beings play a special role in a disaster system. They are usually the hazard-bearing bodies, being the direct or indirect victims of disasters. However, people may also be the hazards that cause disasters. In some cases, people are simultaneously both the hazards and hazard-bearing bodies. Civil engineering works are major examples in which humans play this dual role. In the evolution of manydisasters, civil engineering works are attacked by external hazardous actions such as earthquakes and winds, and they may then go on to constitute deadly hazards to human life and property in the event of their failure or collapse due to insufficient resistance capacity. The failure of civil engineering works also usually disrupts/disturbs the delivery of emergency services. For example, the damage of transport, roads, bridges and water supply infrastructure may impede rescue operations, hamper the delivery of health services, and cause disease. It is thus clear that, in many natural and man-made disasters, civil engineering works are not only the hazard bearing bodies, but their failure also constitutes furtherhazards. Especially in flooding, landslide and earthquake disasters, building collapse is the most significant cause of casualties andfinancial loss. This mechanism is yet to receive adequate emphasis in the investigation of disasters. Indeed, losses that have been attributed to many so-called natural disasters, such as earthquakes or winds, were actually caused by civil engineering factors rather than the actual natural phenomena. This is the key to developing proper methods for disaster prevention and mitigation. To clarify the aforementioned/abovementioned mechanism, the concept of *civil engineering disaster* is here proposed. As already noted, civil engineering works includingbuildings and infrastructure are the carriers of human civilization. However, such developments may also harm civilization by inducing disasters. We define ***acivil engineering disaster*** **as a disaster caused by thefailure of a civil engineering work due to technicalissues.**

The concept of civil engineering disaster does not conflict with the recognition of natural phenomena and man-made events as hazards. Nevertheless, the latter are merely necessary but not sufficient conditions for the occurrence of disasters. Civil engineering works may fail because of their own defects and therefore evolve into hazards that cause disasters. This is the most important mechanism of a civil engineering disaster event. The concept of a civil engineering disaster has thefollowing two implications. First, all the losses are essentially due to the failure of civil engineering works. Second, civil engineering methods are the primary means of preventing and mitigating such disasters.

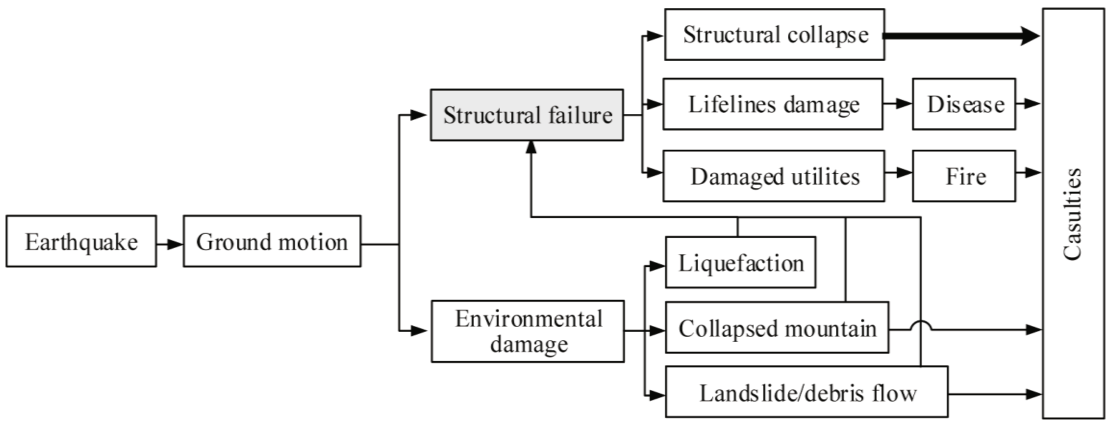


Figure 1: Evolution of Earthquake Disaster

The first implication has been discussed above. With regard to the second, it is important that the mitigation of civil engineering disasters connotes the enhancement of the capacity of civil engineering works with the purpose of reducing the likelihood of their transformation into hazards. Many factors could have contributed tothe significant difference between the consequences of these two disasters. disasters was the enhancement of the seismic capacity of civil engineeringworks. It is, however, noteworthy that some building related disasters are not necessarily civil engineeringdisasters.

Classification

Civil engineering disasters can be classified as natural hazard-related and man-made hazard-related based on the external causes of the failure of the civil engineering work. In addition to inducementby earthquakes, as discussed above, civil engineering disasters may be related to diverse other natural hazardssuch as strong winds, floods, landslides, and freezing weather. For example, electricity supplytowers may collapse under strong winds, resulting in financial losses through the disruption of power supplies. In 2021, Dili and territory of Timor Leste experienced unusually (or remarkably) which caused the collapse and damages of many buildings, roads, bridges, etc causing human and goods/properties losses. In contrast/difference, civil engineering disasters relatedto man-made hazards are usually caused by technical inadequacies and mistakes, general human faults, andhostile actions.

Causes of Structural Deficiency (or lack)

Civil engineering works are designed, constructed, occupied, and maintained by human beings. Consequently, the underlying cause of all civil engineering disasters, irrespective of whether they are related to natural or man-made hazards, is structural deficiency in the civil engineering work, and this can always be attributed to human factors such as lack of knowledge or mistakes. In this context, the reasons for structural deficiency in civil engineering works can be summarized as follows:

Improper (inappropriate) Site Selection:
Sites that are located on active faults, exposed to landslides or debris flows, or vulnerable to non-uniform settlement are a few examples of sites that are improper for civil engineering constructions. It is presently either technically impossible to achieve adequate disaster resistance in buildings and infrastructure on such sites, or the cost of doing so would be unreasonably high. A practical strategy is thus to avoid such improper sites. In the region affected by the aforementioned (above-mentioned) Timor Leste flooding in 04 April 2021, the city of Dili was located in an area that is highly vulnerable to landslide and debris flow—a typical example of an improper civilengineering construction site. This constituted approximately 25% of the total human loss to the disaster. The mountainous town of dili was completely destroyed also by the landslides, floods, and debris flows that followed. The suitability of a site for construction is changeable. Investigations showed that the landslide was from mountains of constructional debris that had been dumped (discarded/waste).

Improper (Inappropriate) Hazard/Risk Assessment:
Effective mitigation of civil engineering disasters can be achieved by designing the construction for an appropriate hazard level. None of the civil engineering works in the city, including the buildings and infrastructure, was seismically designed and constructed. Most of the buildings thus collapsed during the earthquake and the city was entirely destroyed. What these two disasters had in common was the failure of a large amount of non-seismically designed civil engineering works, which constituted the primary hazards for the disasters, although the earthquakes received greater attention. Even if hazards are taken into consideration in the design of civil engineering works, improper assessment of the hazard levels may lead to the construction of inadequate structures.

Figure 2: Town of Beichuan after debris flows in September 2009

Figure 3: Buildings in Shenzhen, China buried by landslide in December 2015 (Source: Baidu Baike).

Figure 4: Unprepared cities damaged by earthquakes: (a) Tangshan city China and (b) Port-au-Prince Haiti after earthquakes.

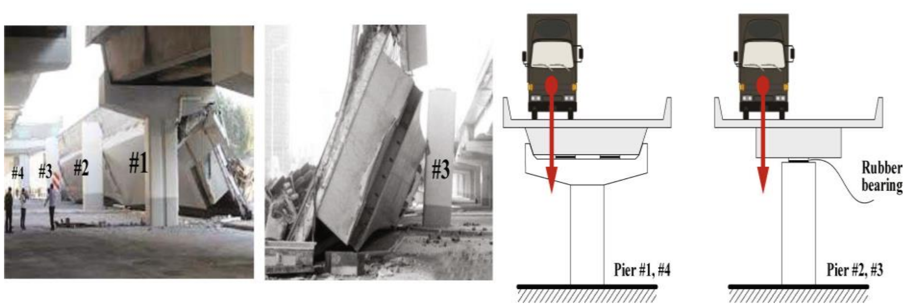


Figure 5: Design defects of fallen segment Bridge (Qu,2014).

Figure 6: School building in Hachinohe, Japan damaged during 1968 Tokachi-oki earthquake (Aoyama, 2010)

Figure 7: Collapsed high-rise apartment building—result of improper construction

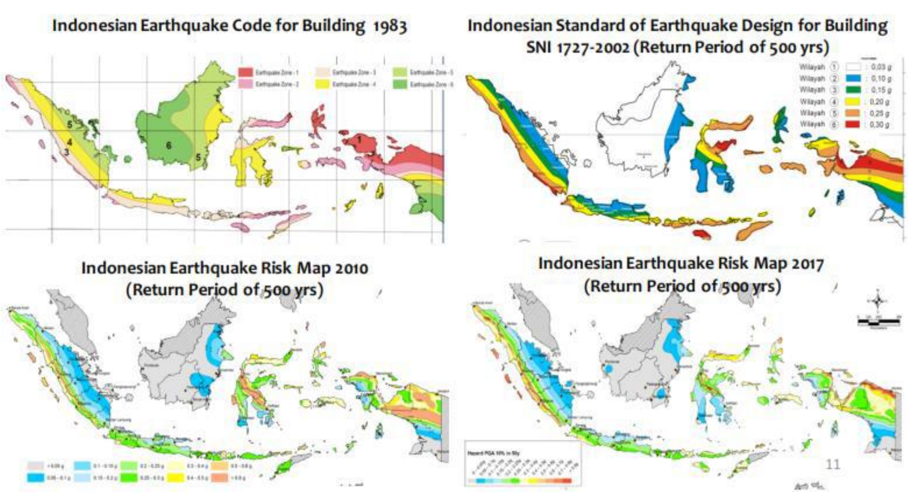


Figure 8: Peta Gempa Indonesia (Indonesia Earthquake Maps)

Figure 9: Flooding Overflows Hit Dili, Capital of Timor Leste on 04 April 2021

Figure 10: Another Side Natural Disaster Occurring in whole territory Timor Leste on 04 April 2021.

Decision-Makingimmediate (Or Executive Summary):

Threats and hazards present long-term risks to people and their property. Mitigation is risk management action taken to avoid, reduce, or transfer those risks. By reducing the impact of disasters, mitigation supports protection and prevention activities, eases response, and speeds recovery to create better prepared and more resilient communities. The National Mitigation Framework establishes a common platform and forum for coordinating and addressing how the Nation manages risk through mitigation capabilities. This Framework describes mitigation roles across the whole community. The Framework addresses how the Nation will lessen the impact of disaster by developing, employing, and coordinating core mitigation capabilities to reduce loss of life and property. Building on a wealth of evidence-based knowledge and community experience, the Framework seeks to increase risk awareness and promote resilience building by leveraging mitigation enhancing products, services, and assets across the whole community.

Mitigation exists at every level—from the family that creates a sheltering plan in case of a tornado, to corporate continuity of operations plans, to emergency plans for manufacturing facilitates to local codes and zoning that systemically address risks in a community's buildings. Developing and maintaining a culture of preparedness to build widespread resilience throughout communities is a priority for the Nation. Cultivating this culture across the whole community will reduce the human impact of disasters, enhance emergency response professionals' ability to perform critical tasks more effectively, and allow communities to recover more efficiently. Individuals, families, businesses, non-profit organizations, and local, state, tribal, territorial, and Federal governments share responsibility for preparedness. Drawing upon the support and guidance of the whole community, these entities can manage risk and vulnerability, and community residents can feel confident knowing they live in safer, more secure, and resilient communities.A culture of preparedness is built over time on a shared acknowledgment of the certainty of future catastrophes; the importance of initiative and accountability at all levels; the role of individuals and stakeholders in preparedness; and finally, the roles of the whole community in creating a prepared Nation. Additionally, the culture of preparedness is demonstrated by the four guiding principles, which include; Resilience and Sustainability, Leadership and Locally Focused Implementation, Engaged Partnerships and Inclusiveness, and Risk-conscious Culture. These principles lay the foundation for the Mitigation mission and the execution of its core capabilities.

Effective mitigation begins with a comprehensive understanding of risk based on vulnerabilities to threats and hazards. Aiming toward the ultimate goal of sustainability and resilience, mitigation requires a process of continuous learning, adapting to change, managing risk, and evaluating progress. Sound assessment requires risk information—based on credible science, technology, and intelligence—validated by experience. Understanding the risks makes it possible to develop strategies and plans to manage them. Managing risks from threats and hazards requires decision making to accept, avoid, reduce, or transfer those risks. Avoiding, reducing, and transferring risks are ways to reduce the long-term vulnerability of a community and build individual and community resilience. This Framework is driven by risk, rather than the occurrence of incidents. By fostering comprehensive risk considerations, the Framework encourages whole community behaviors and activities that will reduce the likelihood of exposure and vulnerability of communities.The Nation increases its resilience when it manages risks broadly, from local incidents to widespread, severe, and catastrophic disasters. Building and sustaining a culture of preparedness and a mitigation-mindset will make the Nation more socially, ecologically, and economically resilient before, during, and after an incident. Resilience in communities and the Nation depends on the whole community working together.

National Mitigation Framework

The National Mitigation Framework explores seven core capabilities required for entities involved in mitigation: threats and hazards identification, risk and disaster resilience assessment, planning, community resilience, public information and warning, long-term vulnerability reduction, and operational coordination.

Coordinating structures are composed of representatives from multiple departments or agencies, public and/or private sector organizations, or a combination of these. Coordinating structures are able to facilitate the preparedness and delivery of capabilities, and they provide guidance, support, and integration to aid in the preparedness of the whole community and building resilience locally, regionally, and nationally. They ensure ongoing communication and coordination among all parties involved in preparing and delivering capabilities.

The coordinating structures for mitigation focus on enabling efforts that embed risk management, adaptation, and mitigation in all planning, decision making, and development. Regardless of the level of the coordinating structure, consideration of risk management, adaptation, and mitigation will reduce the Nation's risk and associated consequences. Given the risk-based premise (rather than an incident-based focus), the majority of coordinating structures originate and are sustained at a regional and local scale.

At the National scale, the Mitigation Framework Leadership Group (MitFLG) coordinates mitigation efforts across the Government and assesses the effectiveness of mitigation capabilities developed and deployed across the Nation. The MitFLG includes relevant local, state, tribal, and Federal Government representatives. The MitFLG non-Government members help to ensure appropriate integration of Government efforts across the whole community.

In implementing the National Mitigation Framework, partners are encouraged to develop a shared understanding of broad-level strategic implications as they make critical decisions in building future capacity and capability. Effective implementation of this Framework hinges on the inclusion and understanding of the whole community in carrying out the Mitigation unifying (uniting) principles and doctrine.

Comprehensive mitigation strategies consider the systems that make up communities and the Nation. Mitigation activities are implemented through the core capabilities with consideration given to the economy, housing, health and social services, infrastructure, and natural and cultural resources (Shown in Fig. 8: Comprehensive Mitigation Includes Strategies for All Community Systems).

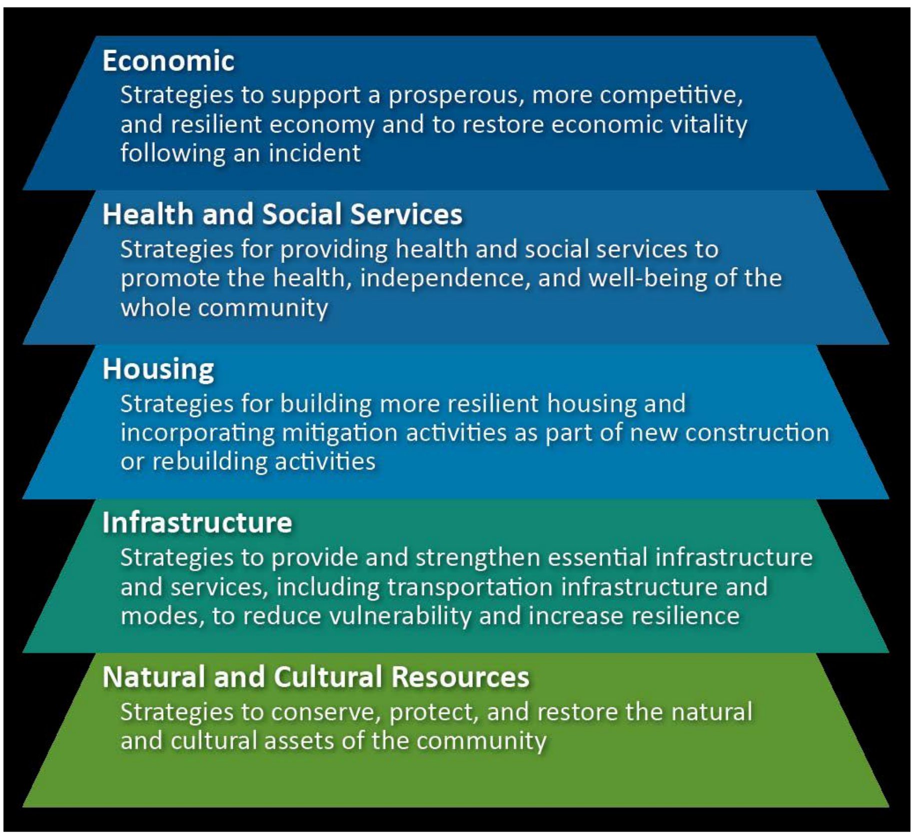
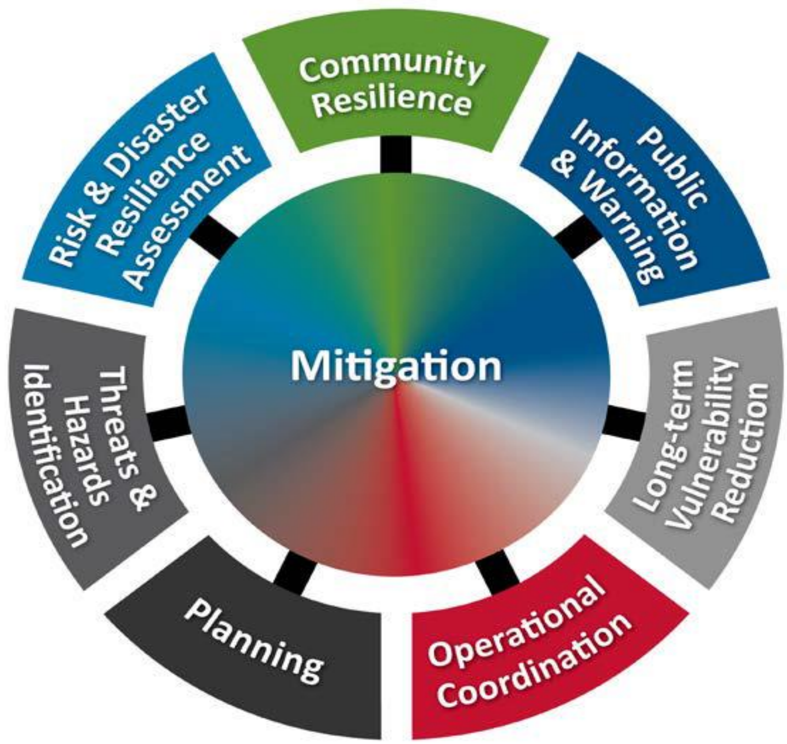


Figure 8: Comprehensive Mitigation Includes Strategies for All Community Systems

The community systems listed here intentionally parallel the components of the National Disaster Recovery Framework. These are the essential systems that constitute the backbone of effective communities.

the seven core capabilities. The Threats and Hazards Identification and Risk and Disaster Resilience Assessment capabilities enable risk-based decision making based on both general and localized information about threats, hazards, and vulnerabilities. The Planning capability enables a process that evaluates and prioritizes mitigation options for reducing risk, which are then implemented through the Long-term Vulnerability Reduction capability by taking actions to reduce risk and increase resilience. The whole community contributes to and benefits from the Operational Coordination capability, which promotes effective collaboration and avoids duplication of effort. The whole community also shares information about risks to increase awareness and ongoing or recommended mitigation activities through the Public Information and Warning capability. The Community Resilience capability enables all of the other capabilities by providing the leadership and collaboration necessary to identify, build support for, initiate, and sustain mitigation efforts that reflect the needs and priorities of all pertinent stakeholders.

There are three capabilities that cross all five mission areas: Planning, Public Information and Warning, and Operational Coordination. These capabilities are shared and provide direct linkages among the mission areas.



Problem Solutions

Science and Technology:

Science and technology (S&T) capabilities and investments are essential for enabling the delivery and continuous improvement of National Preparedness. The whole community should design, conduct, and improve operations based on the best, most rigorous scientific data, methods, and science-based understandings available. Commitments and investments that ensure global leadership in science and technology will yield leading-edge technology and scientific understanding to guide National Preparedness actions. In addition, coordination across the whole community, including scientific researchers, will ensure that scientific efforts are relevant to National Preparedness.

Effective mitigation relies upon the whole community's ability to establish science-based understanding of their threats and hazards and make well-informed decisions to reduce risks as a result. Mitigation requires technical analyses of vulnerabilities and the ability to invent, design, implement, and validate actions that reduce risk. Science and technology investments in the mitigation mission area include improving fundamental understanding of evolving hazards and threats; design and testing of hazard resilient buildings, materials, and infrastructure; development of improved building, land-use and engineering codes and standards; improved methods to assess vulnerabilities, and science-based approaches to communicating effectively about risk and the value of risk reduction.

Some natural hazards, such as hurricanes, heat waves, extreme precipitation events, and droughts (or lacks) are expected to increase in intensity due to climate change. Consider, for example, that uncertainty about these climate change effects on natural hazards complicates mitigation-action decision making. Scientific investments providing more reliable and localized information on climate change will enable more effective mitigation and adaptation, such as improved model engineering standards and codes for resilient design and construction, as well as improved communication and incentive structures to encourage communities and business mitigate risk.

Ensuring long-term S&T investments advance the ability to mitigate against hazards, and sustaining a healthy science and technology workforce, supports the mitigation mission area core capabilities for years into the future. Coordination between those with mitigation mission responsibilities and science and technology communities and institutions will be necessary to ensure that scientific efforts, education, and investments are relevant to mitigation.

CONCLUSIONS

Among the different types of disasters, civil engineering disasters are the most closely related to human beings and have constituted an important stimulus for civil engineering development. Many scientific and technological topics are relevant to the understanding and mitigation of civil engineering disasters, the concept of which emphasizes the transformation of civil engineering works from hazard-bearing bodies into hazards when they fail. Unlike disasters caused by natural hazards, which often cannot be predicted or controlled, civil engineering disasters can be effectively mitigated based on a thorough understanding of the associated failure mechanisms and by enhancement of the resistance capacity of engineering works.

Working together, risks can be recognized and addressed through a culture of preparedness and mitigation that is built and sustained over time. This begins with a comprehensive understanding of risk that is translated into plans and actions through partnerships. Aiming toward the ultimate goal of sustainability and resilience, mitigation requires a process of continuous learning, adapting to change, managing risk, measuring successes, and evaluating progress.

In implementing the National Mitigation Framework to build national preparedness, partners are encouraged to develop a shared understanding of broad-level, strategic implications as they make critical decisions in building future capacity and capability. The whole community should be engaged in examining and implementing the strategy unifying principles and doctrine contained in this Framework, considering both current and future requirements in the process. This means that this Framework is a living document, and it will be regularly reviewed to evaluate consistency with existing and new policies, evolving conditions, and the experience gained from its use. Reviews of this Framework will be conducted in order to evaluate the effectiveness of the Framework on a quadrennial basis.

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