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Recommendation

Science, Technology, and Innovation to Strengthen Disaster Resilience in Megacities Facing Catastrophic Disaster Risks

10 April 2026

Science Council of Japan

This Recommendation is largely the outcome of the deliberations of the Subcommittee on IRDR of the Committee on Civil Engineering and Architecture, Science Council of Japan, and is issued under the auspices of the Science Council of Japan.

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Executive Summary

Science, Technology, and Innovation to Strengthen Disaster Resilience in Megacities Facing Catastrophic Disaster Risks

1. Background

We live in a vulnerable society. Recognizing this reality, we seek to transform society into one that is sustainable, safe, secure, peaceful, healthy, and prosperous for present and future generations. From this perspective, this Recommendation presents our observations and proposes appropriate measures, particularly with respect to catastrophic disasters. Earthquakes, volcanic eruptions, and tsunamis triggered by crustal movements, as well as extreme weather events associated with climate change, cause multiple forms of loss and damage. These hazards may occur simultaneously or in rapid succession.

Meanwhile, society is also undergoing significant transformation. Urbanization is a global trend, and the world's urban population is projected to double by 2050. As of 2023, there were 44 urban areas worldwide with populations exceeding 10 million ("megacities"), as well as an additional 56 cities with populations exceeding 5 million that are expected to become megacities in the near future. Many large cities have developed in an unplanned manner, making them highly vulnerable to disasters and susceptible to catastrophic damage. Once socioeconomically significant megacities suffer devastating disasters, the impacts can spread rapidly both domestically and internationally, and recovery and reconstruction may require extremely long periods.

The Sendai Framework for Disaster Risk Reduction 2015-2030, the Sustainable Development Goals (SDGs), the Paris Agreement, and the New Urban Agenda (Quito Declaration), all adopted in 2015 and 2016, recognize disasters and their impacts as critical global challenges to human survival and well-being. Despite the various countermeasures over the past decade, many issues remain unresolved.

This Recommendation is primarily intended for all stakeholders involved in megacities, as disasters affecting such cities can escalate into national crises, drawing surrounding municipalities into their impacts and causing consequences to spread rapidly across broad areas. The primary actors include disaster management authorities and other decision-makers, including the heads of municipalities that comprise megacities. Equally important are the many organizations, groups, and individual residents who are committed to addressing these challenges through collaboration and cooperation with decision-makers. In urban disasters, public assistance must function effectively in coordination with self-help, mutual help, and community-based assistance.

Notably, the Subcommittee on IRDR (Integrated Research on Disaster Risk) of the Committee on Civil Engineering and Architecture published the Recommendation "Transforming Society to Become Resilient and Sustainable beyond Catastrophic Disasters" in August 2023. The present recommendation builds on that earlier recommendation by identifying challenges specific to megacities and is intended for application to megacities worldwide.

2. Current Situation and Challenges

The 1995 Great Hanshin-Awaji Earthquake and the 2011 Great East Japan Earthquake fundamentally reshaped perceptions of disasters and approaches to disaster risk reduction (DRR) in Japan. Nevertheless, according to the damage estimates for the anticipated Nankai Trough Earthquake, which would have an even wider impact than these disasters, revised in March 2025, a maximum-scale earthquake and tsunami could result in approximately 298,000 deaths nationwide: 215,000 due to tsunamis, 73,000 from building collapses, and 9,000 from earthquake-induced fires. In addition, indirect disaster-related deaths are estimated at 52,000. The projected economic loss is estimated at 270.3 trillion yen, which is more than twice Japan's annual national budget. Tokyo (the Tokyo Metropolitan Area), ranked first among the world's megacities with a population of 37.79 million; Osaka (the Keihanshin Metropolitan Area), ranked 26th with a population of 14.92 million; and Nagoya (the Chukyo Metropolitan Area), ranked 48th with a population of 9.44 million, are all located along extensive coastal zones, where large populations and enormous concentrations of assets are situated on low-lying land.

Globally, the vulnerability of megacities is closely linked to socioeconomic factors. Socially vulnerable populations are often concentrated in precarious housing and seismically vulnerable buildings, placing them at notably greater risk of severe impacts during disasters. Urban-specific issues, such as traffic congestion and inadequate evacuation routes, can significantly hinder effective evacuation and emergency response operations. In addition, the deterioration of urban infrastructure, including roads, bridges, and water systems, as well as unstable energy supplies can further exacerbate confusion caused by disasters. Moreover, the rapid proliferation of smartphones, social media platforms, and AI-driven information systems is fundamentally transforming how disaster-related information is disseminated.

Although national and local governments, as well as residents in countries with megacities, are aware of these challenges, it remains unclear which specific preventive measures should be implemented and when they should be introduced. Investment is typically made only after disasters occur, resulting in reactive responses and excessive costs. Even when the importance of prevention is recognized, DRR investments are often postponed due to the uncertainty surrounding disaster occurrence. In many countries, the lack of reliable data and statistics to assess the benefits of prevention-oriented investment remains a significant barrier.

3. Recommendations

This Recommendation aims to strengthen disaster resilience in megacities worldwide where catastrophic disasters are anticipated and could have global consequences. In addition to conventional infrastructure-based countermeasures, it proposes, as measures that have become increasingly important in recent years, comprehensive approaches that include risk-informed urban planning and development; medical, welfare, and public health measures during disasters; quantitative assessment of disaster risks and the effectiveness of DRR investments; effective use of disaster information; strengthened international cooperation; and the application of science and technology.

With a focus on integrating DRR into the sustainable development of megacities, this Recommendation identifies specific actions that researchers should undertake immediately, national and local governments should implement as part of their public assistance, and residents, the private sector, and other stakeholders should pursue through self-help, mutual help, and community-based cooperation. These actions may help reduce urban vulnerability and respond effectively to catastrophic disasters. This Recommendation is intended not only for Japan's megacities but also for megacities around the world and seeks to promote international outreach and collaboration.

The chapter-specific recommendations are as follows:

(1) DRR Measures for Disaster-Resilient Cities (Chapter 3)
Recommendation 1: Implement land-use management based on disaster risk.
Recommendation 2: Account for uncertainties associated with future changes and disaster risks.

(2) Public Health in Megacities during Disasters (Chapter 4)
Recommendation 3: Minimize health impacts.
Recommendation 4: Prevent indirect disaster-related deaths.
Recommendation 5: Maintain health, medical, and welfare systems.

(3) Loss and Damage Assessment (Chapter 5)
Recommendation 6: Promote the standardization of disaster risk assessment.
Recommendation 7: Encourage DRR investment.

(4) Dissemination and Distribution of Disaster Information (Chapter 6)
Recommendation 8: Utilize the latest technologies and knowledge in disaster information
Recommendation 9: Lead the development of AI technologies that are effective for DRR.
Recommendation 10: Promote the international dissemination, communication, and sharing of disaster information.

(5) Capacity Building for Urban Disaster Reduction (Chapter 7)
Recommendation 11: Promote interdisciplinary education to foster a comprehensive understanding of disasters.
Recommendation 12: Build societal systems that incentivize disaster education.

(6) Science, Technology, and Innovation (STI) for DRR in Megacities (Chapter 8).

Recommendation 13: Establish an STI platform for DRR.
Recommendation 14: Provide strategic recommendations that address DRR challenges based on societal needs.

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1. Background and Purpose of This Recommendation

Human survival and livelihoods are influenced by tectonic activity, climate change, and social change. Among these, tectonic activity—particularly along the Pacific Ring of Fire and the Alpine–Himalayan orogenic belt—gives rise to earthquakes and volcanic eruptions, often triggering tsunamis and causing widespread devastation. Since the Industrial Revolution, human activities have increased greenhouse gas emissions, contributing to global warming. This has led to increasingly extreme weather events—such as powerful cyclones (typhoons), torrential rainfall, heavy snowfall, heat waves, and desertification—which trigger large-scale meteorological and hydrological disasters while also affecting agriculture and fisheries. At the same time, social changes, including population growth and uncontrolled urban concentration, have created megacities that are highly vulnerable to disasters. Human-induced risks, such as conflict, poverty, environmental pollution, and ecosystem destruction, are also consequences of these social changes.

Against this backdrop, in 2015, the Sendai Framework for Disaster Risk Reduction (SFDRR [1,2]), the Sustainable Development Goals (SDGs [3]), and the Paris Agreement on climate change [4,5,6] were all adopted internationally, with 2030 established as the target year for their implementation. In 2016, at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) held in Quito, Ecuador, it was recognized that the global urban population was projected to nearly double by 2050 and that urbanization would become one of the most transformative trends of the 21st century. Based on this recognition, the conference adopted the Quito Declaration on "Sustainable Cities and Human Settlements for All," focusing on SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable). This declaration, known as the "New Urban Agenda," sets forth a shared vision for cities and human settlements. One of its key objectives is "to adopt and implement disaster risk reduction and management, reduce vulnerability, build resilience and response capacity to natural and human-induced hazards, and enhance climate change mitigation and adaptation" [7].

Meanwhile, the International Science Council (ISC) and the United Nations Office for Disaster Risk Reduction (UNDRR) launched Integrated Research on Disaster Risk (IRDR) in 2008 as an international collaborative research project based on the Hyogo Framework for Action (adopted in 2005), which preceded the Sendai Framework for Disaster Risk Reduction. In response to this initiative, the Science Council of Japan established the Subcommittee on IRDR under the Committee on Civil Engineering and Architecture, which serves as Japan's National Committee for IRDR. The first phase of IRDR has been completed, and the second phase (2022–2031) is currently underway. Accordingly, the framework for international collaborative research has been discussed [8], and in October 2024, the Research Priorities for the subsequent three years were established [9]. The eighth of the nine priority themes for the second phase of IRDR is "Measurement to Help Drive Progress." Regular measurement of progress toward achieving the goals of these international agreements and frameworks is therefore essential.

During the previous term (the 25th term) of the Science Council of Japan, the Subcommittee on IRDR issued the Recommendation “Transforming Society to Become Resilient and Sustainable beyond Catastrophic Disasters” (August 2023) [10]. In this Recommendation, the Subcommittee integrated insights from a wide range of academic disciplines and identified future actions aligned with the four priorities of the Sendai Framework for Disaster Risk Reduction 2015–2030. During the preceding 24th term, the Committee on International Cooperation for Promoting Science-Based Disaster Risk Reduction issued the Recommendation “Building a Sustainable Global Society by Strengthening Disaster Resilience: Developing an 'Online Synthesis System (OSS)' and Fostering 'Facilitators' to Realize Consilience” (September 2020) [11], which emphasized the role of the SDGs. In addition, the Subcommittee on Earth and Human Sphere of the Earth and Planetary Sciences Committee and the Subcommittee on IRDR jointly issued the Recommendation “How to Prevent the Vulnerability of Local Communities in an Era of Intensifying Disasters” (May 2020) [12]. Furthermore, during the 24th term, the Low-Frequency Mega-Disasters Subcommittee of the Committee on Civil Engineering and Architecture was established and published the Report “Record of Discussions by the Low-Frequency Mega-Disasters Subcommittee: To Prevent a National Crisis” (August 2020) [13]. During the current 26th term, the Academic Collaboration Committee on Disaster Prevention and Mitigation published the Advisory Opinion “Preparing for Large-Scale Regional Disasters Based on Lessons from the Noto Peninsula Earthquake and Heavy Rain Disasters” (November 2025) [14]. These publications address disaster risk reduction (DRR) from different perspectives and should be consulted alongside this Recommendation as complementary materials.

With a focus on the sustainable development of megacities and an integrated approach to DRR, this Recommendation aims to address urban vulnerabilities and strengthen responses to catastrophic disasters such as the anticipated Nankai Trough Earthquake and a major Tokyo metropolitan earthquake. To this end, it identifies the following key issues and, for each of them, proposes actions that researchers should undertake immediately, actions that national and local governments should implement through public policy, and actions that residents, private companies, and other stakeholders should pursue through self-help, mutual help, and community-based cooperation.

・DRR in Megacities (Chapter 2)
・DRR Measures for Disaster-Resilient Cities (Chapter 3)
・Public Health in Megacities during Disasters (Chapter 4)
・Loss and Damage Assessment (Chapter 5)
・Dissemination and Distribution of Disaster Information (Chapter 6)
・Capacity Building for Urban Disaster Reduction (Chapter 7)
・Science, Technology, and Innovation (STI) for DRR in Megacities (Chapter 8)

We live in a vulnerable society, which we seek to transform into one that is sustainable, safe, secure, peaceful, healthy, and prosperous for present and future generations.

From this perspective, this Recommendation presents considerations, particularly from the standpoint of science, technology, and innovation (STI), on how society should respond to catastrophic disasters.

This Recommendation is primarily intended for all stakeholders involved in megacities, as disasters affecting megacities can escalate into national crises, drawing surrounding municipalities into their impacts and causing consequences to spread rapidly across broad areas. The primary actors include disaster management authorities and other decision-makers, including the heads of municipalities that comprise megacities. Equally important are the many organizations, groups, and individual residents who are committed to addressing these challenges through collaboration and cooperation with these decision-makers. During urban disasters, public assistance must function effectively in coordination with self-help, mutual help, and community-based assistance.

2. DRR in Megacities

(1) Current Status of Megacities Worldwide

Since the latter half of the twentieth century, Asia has experienced remarkable economic growth and population increases. Consequently, metropolitan areas with populations exceeding 30 million have emerged, including Tokyo, Jakarta, Delhi, Guangzhou, and Mumbai. Urban areas with populations exceeding 10 million are defined as "megacities." As of 2025, there are 42 megacities worldwide, and another 62 cities with populations exceeding 5 million are considered potential future megacities [15].

Rapid economic development and population concentration have created highly complex urban infrastructure and social systems. However, because urban development has often proceeded without adequate DRR measures, many cities remain highly vulnerable to catastrophic disasters. Unplanned or poorly regulated urban development had led to the emergence of densely populated residential areas and “informal settlements” in many cities. In regions frequently affected by hazards such as earthquakes, tsunamis, cyclones (typhoons), storm surges, and floods, urban expansion has outpaced the integration of DRR into planning and infrastructure development, resulting in increased exposure and the potential for catastrophic impacts.

Disaster risk (DR) can be understood as the interaction of three elements: hazards (H), external forces such as earthquakes or typhoons; exposure (E), the presence of people and assets that may be affected; and vulnerability (V), the susceptibility of society to harm. The increasing intensity of disasters (increases in H) is amplifying their socioeconomic impacts on megacities. For example, climate change has increased the frequency of extreme weather events, including heavy rainfall and droughts, resulting in increasingly severe impacts on urban infrastructure. Furthermore, in many emerging megacities, unplanned development and expansion have led to rapidly growing populations settling in high-risk areas, such as steep slopes and low-lying floodplains, thereby increasing both V and E and escalating disaster risks.

The vulnerability of megacities is also closely linked to socioeconomic conditions. Socially vulnerable populations often reside in precarious environments and in housing with poor seismic performance, making them highly vulnerable to severe disaster impacts. Additionally, urban-specific challenges, including traffic congestion, inadequate evacuation routes, deteriorating urban infrastructure such as roads, bridges, and water systems, and unstable energy supplies, can significantly impede evacuation and emergency response operations.

The world's urban population is increasing by approximately 60 million people per year, and by 2050, it is projected that seven out of every ten people worldwide will live in urban areas. Much of this growth is occurring in low- and middle-income countries. In rapidly expanding cities, urban growth often proceeds in a disorderly manner, outpacing the capacity of infrastructure and services needed to support health and welfare. As a result, urban residents face significant health risks even under normal conditions. High-income countries also face major challenges. The consolidation and closure of hospitals due to aging facilities and shortages of healthcare professionals, together with population aging and decline in surrounding communities, are reducing access to healthcare services. Consequently, there is an increasing need to address diverse health, medical, and welfare needs.

(2) Approaches to DRR in Megacities

Given these circumstances, reducing disaster risk by integrating DRR with sustainable urban development has become an urgent priority. This requires reducing vulnerability (V), minimizing exposure (E), and fundamentally strengthening capacities (C), including preventive measures, to address anticipated hazards (H). In other words, more effective DRR measures are required. Enhancing disaster resilience in megacities requires a multifaceted approach, including the introduction of risk-informed urban planning, strengthened land-use regulations and urban redevelopment, reinforcement of critical infrastructure, development of early warning systems, and improved support for socially vulnerable populations, including older persons and persons with disabilities. Furthermore, strengthening the resilience of megacities cannot be achieved through isolated efforts; it requires comprehensive strategies supported by international cooperation and the sharing of knowledge and expertise.

In particular, collaboration with the Association of Southeast Asian Nations (ASEAN) and the South Asian Association for Regional Cooperation (SAARC) should be further strengthened, as these regions share several geophysical and socioenvironmental characteristics with Japan, including their location along the Pacific Ring of Fire and Alpine-Himalayan orogenic belt, humid climatic conditions, high population density, and exposure to a wide range of natural hazards. By drawing on local organizations, human resources, knowledge, and available resources while appropriately adapting Japan's experience and technologies, disaster resilience can be enhanced throughout the region.

Given the significant disaster risks faced by ASEAN and SAARC countries—including earthquakes, tsunamis, cyclones (typhoons), floods, and storm surges—Japan is expected to contribute to strengthening urban infrastructure and lifeline systems by supporting urban disaster management planning, seismic-resistant technologies, urban flood risk reduction measures, and early warning and disaster response systems.

In doing so, emerging concepts such as “Digital Transformation (DX) for DRR” and “Smart Infrastructure for DRR” may be introduced while adopting co-creative approaches that take into account the future development of local communities.

The following sections outline the fundamental principles of DRR in megacities.

(a) Approaches to DRR in Building Disaster-Resilient Megacities

In cities originally established in geophysically safer locations, central urban areas generally face fewer disaster management challenges. However, residential development and the construction of social welfare facilities for people requiring special assistance in peripheral areas—such as steep slopes and flood-prone river zones—significantly increase urban vulnerability. In addition, densely developed commercial districts and residential neighborhoods, as well as so-called informal settlements that have developed in an unplanned manner or outside formal planning, may become places where fires and crime are more likely to occur and may be inaccessible to emergency vehicles such as ambulances and fire trucks. As a result, public health and safety are threatened, and these areas are particularly susceptible to damage during disasters. It is therefore necessary to conduct appropriate hazard risk assessments, establish regular measures for disaster preparedness, crime prevention, and fire control, and promote land redevelopment or the relocation of residents to safer locations. In doing so, future uncertainties associated with climate change and demographic transformations must be considered. Advancing “risk-informed development,” as advocated by IRDR, and implementing land-use management based on disaster risk assessments will contribute to creating cities that are more resilient and capable of quick recovery and reconstruction.

(b) Public Health in Megacities during Disasters

Following the onset of a disaster and the transition to life in evacuation shelters, a wide range of health risks emerges. Sanitary conditions often deteriorate rapidly, posing significant threats to the health of both affected populations and support personnel. To mitigate these risks, residents should, as a form of self-help, adopt hygiene practices such as handwashing and mask use, stockpile safe water, food, and essential medications, and prepare personal health records, while governments should, as a form of public support, strengthen public health preparedness and awareness before disasters. During disasters, comprehensive policies should be implemented at the prefectural level to ensure the coordinated operation of emergency medical services and public health systems. Since the Great Hanshin-Awaji Earthquake in 1995, growing attention has been paid to indirect disaster-related deaths (indirect disaster mortality) resulting from physical and mental deterioration. Many of these deaths can be prevented or minimized through appropriate measures that reduce disuse syndrome, prevent infectious disease outbreaks, and manage non-communicable diseases appropriately. Because disasters generate surging demand for public health, medical care, and social welfare services while disrupting the systems that provide them, coordinated support systems should be established and maintained across metropolitan regions (clusters of several cities) during normal times. Incorporating business continuity (BC) planning in advance and considering wider areas can help prevent disruptions and functional breakdowns in essential services.

(c) Loss and Damage Assessment in Urban Disasters

Loss and damage assessment provides an essential foundation for determining appropriate levels of investment in regional development. It is therefore desirable to promote the development of international standards, including International Organization for Standardization (ISO) standards, through collaboration among industry, academia, and government, with national governments and international organizations, while leveraging Japan's scientific and technological expertise. Such efforts will help encourage investment by governments and industry and support the continuity and further development of advanced technologies. Objective and accurate risk assessment requires the sharing of data with assured quality, including accuracy and update frequency, based on common standards across countries. Accordingly, risk assessment methodologies should be improved, and data should be standardized to facilitate database interoperability. Improving and standardizing disaster risk assessment should also include identifying the population size and residential distribution of socially vulnerable groups, older persons, people requiring assistance, and foreign residents, and quantifying the disaster risks they face. It is necessary to demonstrate that pre-disaster investments in DRR can generate substantial benefits. Standardized methodologies for assessing damages and losses, together with cross-country comparability, are essential for harmonizing DRR measures and promoting DRR investments. These efforts enable the visualization of investment outcomes and provide clear evidence of their effectiveness in reducing disaster risk to the general public, particularly taxpayers. This is expected to further promote risk-informed development in countries and regions, including Japan.

(d) Dissemination and Distribution of Disaster Information

The use of smartphones, social media, and virtual reality (VR) technologies for disaster education and risk communication during normal times can strengthen societal resilience. Preparing for catastrophic disasters in megacities requires advance simulation of information dissemination, including message content, communication methods, and anticipated population responses involving hundreds of thousands of people. Mechanisms should also be established to rapidly restore communications and maintain multiple communication channels for individuals and organizations during disruptions. Although artificial intelligence (AI) offers significant benefits, it also presents technical challenges, including bias, the "black box" problem, and the generation of misinformation, as well as social challenges related to responsibility and accountability. Therefore, the application of AI to DRR remains in its early stages. Given its extensive disaster experience, Japan should collect multi-source, heterogeneous data and play a leading role in advancing AI technologies for DRR and promoting their international dissemination. Applying AI to disaster response operations and support for affected populations offers the potential to make disaster response more effective and efficient.

(e) Nurturing Leaders in Urban DRR

There is a need to cultivate leaders who understand the overall nature of disasters. As the risk of unprecedented disasters continues to increase, disaster education should extend beyond existing approaches to develop the ability to view issues from local, national, and global perspectives; anticipate future challenges based on historical experience; and cultivate resilience, leadership, and collaborative skills. Such education is essential for nurturing individuals capable of leading both nations and local communities. Education for future leaders in urban resilience should foster the ability to develop scenarios of how society may evolve over the next 10 to 30 years, anticipate the challenges that disasters may pose under those future conditions, and develop appropriate responses using a backcasting approach. Accordingly, disaster education should encourage both short- and long-term perspectives while promoting a comprehensive understanding of DRR. When a social system is established in which learning serves as an incentive for individuals while also benefiting society, it can cultivate competent DRR leaders and strengthen overall disaster preparedness and resilience. Furthermore, large numbers of foreign nationals live and work in megacities around the world. There is also a need to cultivate DRR leaders within communities of foreign nationals as well as within local communities.

(f) STI for DRR in Megacities

The complex and multifaceted DRR challenges facing megacities require inclusive dialogue among a broad range of stakeholders, grounded in scientific and technological perspectives while recognizing the institutional and cultural dimensions of society. The insights, innovations, and technologies generated through such dialogue should be incorporated into DRR policies and planning. To this end, platforms for sustained collaboration among experts, policymakers, and beneficiaries should be institutionalized and established within each megacity. At present, these collaborative processes depend solely on small-scale local governments. In Japan, this situation stems from the Basic Act on Disaster Management, which assigns primary responsibility for disaster response to municipalities. This institutional framework needs to be improved. The central government should therefore fully recognize that megacities, as large metropolitan areas, are highly vulnerable to disasters and that their resilience must be strengthened. By establishing scientific and strategic approaches and institutional frameworks for addressing DRR challenges in light of the characteristics of megacities, governments can play a central role in strengthening DRR policymaking and decision-making both domestically and across megacities worldwide and contribute to global safety and security.

3. DRR Policies for Resilient Cities (Recommendations 1 and 2)

Recommendation 1: Implement Land-Use Management Based on Disaster Risk

In megacity policies, it is necessary to restrict the use of low-lying and sloping areas with high disaster risk and promote urban development in safer areas. In addition, policymakers must also assess land-related disaster risks and, through appropriate zoning, implement land-use guidance measures to curb further population concentration and develop incentives to encourage relocation to safer areas. Where residents already live in high-risk areas, measures are needed to prevent further population growth. In addition to legal regulations and administrative guidance, each region must formulate a long-term vision and establish indicators to measure progress toward achieving it. Sharing successful practices among regions is also beneficial. Particularly in low- and middle-income countries, more effective land-use management requires the dissemination and advancement of high-precision disaster risk assessment technologies, as well as the development and accumulation of the data necessary to support such assessments.

Recommendation 2: Account for Uncertainties Associated with Future Changes and Disaster Risks

Policies are needed to mitigate socioeconomic losses caused by disasters and prevent catastrophic damage in the future. It is necessary to implement multilayered protective measures that account for uncertainties in disaster risk assessment methods and data, as well as uncertainties associated with future population trends and climate change. In this context, priority should also be given to the development of strategic infrastructure with enhanced disaster resilience. Policies should promote the concept "risk-informed development" advocated by the IRDR, implement disaster-risk-based land-use management, and develop disaster-resilient cities capable of rapid recovery and reconstruction.

(1) Characteristics and Impacts of Urban Disasters

Disaster risks in urban areas arise from both natural factors (hazards) and human-related factors (vulnerability, exposure, and their interaction with technological factors). Japan's three major metropolitan areas—Tokyo (the Tokyo Metropolitan Area), ranked first globally with a population of 37.79 million; Osaka (the Keihanshin Area), ranked 26th globally with a population of 14.92 million; and Nagoya (the Chukyo Area), ranked 48th globally with a population of 9.44 million—extend across low-lying areas, including zones below sea level, and face various disaster risks such as earthquakes, tsunamis, floods, and storm surges. Seismic shaking is often amplified across these alluvial plains because of local ground conditions, and they are also highly susceptible to tsunami damage. Many megacities outside Japan face similar disaster risks, with populations concentrated in low-lying areas and on steep slopes, often accompanied by the development of informal settlements. In addition, the effects of climate change and the increasing frequency of wind- and flood-related disasters have raised concerns about a wider range of disasters, including compound disasters combining earthquakes and tsunamis with wind- and flood-related disasters, as well as Natech (natural hazard-triggered technological) disasters.

In urban areas, primary damage, such as damage to buildings, often triggers secondary and tertiary damage, creating cascading disaster effects and diverse social impacts. Earthquake disasters in urban areas are characterized not only by primary damage, such as building collapse and fires in densely built-up areas, but also by secondary damage resulting from large numbers of stranded commuters and evacuees exceeding local response capacity, disruptions to lifeline infrastructure (roads, electricity, gas, and water supply), and damage to industrial complexes and manufacturing clusters. These, in turn, can lead to tertiary impacts, such as health problems, the loss of educational and employment opportunities, and the emergence of social problems such as poverty and inequality. Many of these secondary and tertiary impacts are also common to earthquakes and flood disasters. Furthermore, in cities, local communities have become fragmented, making mutual help more difficult to sustain during disasters. In apartment buildings—which are common in urban areas—communication among neighboring residents is often limited, even under normal conditions. Consequently, vulnerable persons requiring special assistance, such as older adults who may have difficulty accessing disaster information, are at risk of being left behind during evacuation and emergency support activities.

In urban flood disasters, alongside primary damage caused by hazards such as river and pluvial flooding and debris flows, secondary damage, such as building collapse and inundation, may also occur. In recent years, improvements in the accuracy of forecasting technologies in meteorology, hydraulics, and hydrology have made flood disasters predictable in many cases. When pre-disaster evacuation and planned suspensions of railway services are possible, the risk of commuters and others being stranded can be reduced. In widespread and prolonged flood disasters, delays in recovery operations lead to sanitation issues such as sewage contamination, mold, foul odors, and dust, thereby increasing the risk of adverse health impacts.

(2) Scenarios for Urban Disasters

In developing countermeasures for urban disasters, their potential impacts must be anticipated. In Japan, various disasters are anticipated, including earthquakes and tsunamis, river flooding, pluvial flooding, storm surges, landslides, and volcanic eruptions, and hazard maps have been prepared and distributed accordingly. Attention must also be paid to disasters, particularly inundation and fires, that occur in the large, complex underground spaces characteristic of megacities, such as underground shopping areas, utility tunnels, and subway networks. The following section focuses specifically on disaster scenarios related to floods and earthquakes.

(a) Flood Scenarios

The accuracy of short-term flood forecasting has improved steadily in recent years, and efforts have begun to establish action plans (timelines) that specify when actions should be taken, who should take them, and what actions should be taken based on such forecasts. However, in densely populated megacities located in low-lying areas, evacuation sites within urban areas are limited, and the difficulty of conducting large-scale, wide-area evacuations requires advance preparations through regional coordination, as well as related training and exercises. Confidence in long-term climate change forecasts has also increased steadily in recent years. To reduce the rising risk of inundation in low-lying areas, infrastructure development should incorporate climate change projections in addition to planning based on historical data. However, both short- and long-term projections involve uncertainties, and preparations are also needed to respond to hazards that exceed existing assumptions.

(b) Earthquake Scenarios

Earthquakes are difficult to predict immediately before they occur, and tsunami forecasts are typically available only within time frames that allow for urgent evacuation. Unlike floods, earthquakes do not allow several days for advance preparation. However, through seafloor observation networks such as the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net) and the Nankai Trough Seafloor Observation Network for Earthquakes and Tsunamis (N-net), which are part of MOWLAS (Monitoring of Waves on Land and Seafloor), it has become possible to predict seismic motion approximately 20 seconds earlier and tsunami arrival approximately 20 minutes earlier immediately after an earthquake occurs than is possible using systems that rely solely on land-based observations [16, 17]. These are referred to as “real-time predictions,” and an Earthquake Early Warning system is currently in operation in Japan. Nevertheless, because it remains impossible to predict exactly when an earthquake will occur, it is necessary to continuously improve the seismic and fire resistance of buildings to prevent collapse and fires caused by seismic motion, and to develop infrastructure to minimize disruptions to lifeline systems. In addition, preparations are required to respond to stranded commuters and evacuees following a disaster, including the provision of evacuation shelters and stockpiles of essential supplies.

(3) Proposals for the Development of Urban and Social Infrastructure Based on Disaster Risk

(a) Land-Use Management Based on Disaster Risk

In megacities where future population growth is anticipated, the use of low-lying, sloping areas at high disaster risk must be restricted; rather, urban development in safer areas with lower disaster risk must be promoted. Disaster risks associated with land should be assessed, and appropriate zoning measures should be implemented to guide land use and restrain further population growth in high-risk areas. Where residential development is permitted, it is important to promote housing equipped with appropriate seismic, flood, and fire resistance measures. Furthermore, where residents already live in high-disaster-risk areas, incentives should be designed to encourage relocation to safer areas, and measures should be taken to prevent further population inflows driven by lower land prices.

Conversely, in megacities such as those in Japan, where future population decline is anticipated, population movement should be guided from high-risk to lower-risk areas, thereby reducing the number of people exposed to disaster risks.

Structural measures alone are insufficient to address hazards and ongoing societal change. Therefore, there is a strong need to implement disaster-risk-based land-use management as described above. In addition to establishing legal and regulatory frameworks, public awareness must be enhanced and effective land-use management practices must be established.

i. High-Precision Disaster Risk Assessment

High-precision disaster risk assessments, including projections of future risks, are essential for zoning, regulatory measures, and land-use planning. Achieving this goal, particularly in low- and middle-income countries, will require continued advances in disaster risk assessment technologies. It is equally important to develop the foundational data required for high-precision risk assessment, compile comprehensive records of past disasters, and strengthen the scientific and technical knowledge base for assessing disaster impacts in accordance with regional characteristics.

ii. Promoting Understanding and Building Consensus on the Use of Disaster Risk Information

Criteria for determining how urban development should be undertaken in areas with different levels of disaster risk vary across countries and regions. It is therefore necessary to communicate disaster risk information in a manner that is readily understandable to diverse groups, including socially vulnerable populations living in high-risk areas. Such communication should aim to promote discussion of local-level measures, such as zoning designations and ordinances, and to build consensus on standards and approaches for risk-informed urban development. Consideration should also be given to consensus-building processes, such as workshops and participatory community planning, that enable the participation of diverse groups, including socially vulnerable populations.

(b) Uncertainties Associated with Future Changes and Disaster Risks

Disaster risk assessments should consider not only the uncertainties inherent in disaster risk projections arising from the methodologies and data on which they are based, but also the uncertainties associated with future population trends and climate change. In megacities, it is necessary to both reduce the socioeconomic impacts of disasters and implement multiple layers of measures that account for such uncertainties to prevent catastrophic consequences. In this context, approaches that prioritize the development of strategic infrastructure with enhanced disaster resilience must be adopted. Likewise, zoning, regulatory measures, and land-use guidance policies should account for uncertainties in future scenarios.

The following example from Japan illustrates how uncertainty can be addressed. In Japan, flood control plans have been revised based on climate change projections. To facilitate their implementation, nine laws, including the Act on Countermeasures against

Flood Damage of Specified Rivers Running Across Cities, were amended simultaneously. This promoted River Basin Disaster Resilience and Sustainability by All, under which all stakeholders within a river basin collaborate to address flood-related risks [18]. For example, in the Arakawa River basin, which flows through the Tokyo metropolitan area, climate change adaptation measures include river improvement projects aimed at enhancing water retention and flood storage functions through the use of extensive river floodplains. In parallel, plans for elevated urban development are being advanced in busy station-front areas, where clusters of buildings equipped with evacuation spaces are connected by elevated walkways and related structures to ensure life safety and maintain acceptable living conditions during evacuation. Furthermore, in the five Koto wards along the Arakawa River, the Koto 5 Wards Wide-Area Evacuation Promotion Council has been established to formulate hazard maps and wide-area evacuation plans, aiming to achieve zero casualties from large-scale flooding.

4. Public Health during Disasters in Megacities (Recommendations 3, 4, and 5)

Recommendation 3: Minimize Health Impacts

Evacuation living conditions lead to a variety of health issues, and policies are needed to prevent the rapid and severe deterioration of sanitary conditions from exacerbating health impacts among disaster survivors and responders. Drawing on experiences from the COVID-19 pandemic, public health preparedness and awareness before disasters should be strengthened, including handwashing, mask use, stockpiling water and food for general needs and for people with allergies, maintaining reserve supplies of regularly prescribed medications, and ensuring access to information necessary for individual health management. Through the implementation of comprehensive measures centered on health and medical coordination, the headquarters established in each prefecture, emergency medical care, and public health services should function as complementary pillars of disaster response.

Recommendation 4: Preventing Indirect Disaster-Related Deaths

Indirect disaster-related deaths (indirect disaster mortality) are regarded as “preventable disaster deaths,” and policies and practical measures are urgently needed to prevent them. Individual evacuation plans—in which evacuation methods and destinations are determined in advance according to individual circumstances and shared with local authorities—and disaster case management—which identifies disaster-related and post-disaster living challenges faced by individuals and supports problem-solving, self-reliance, and livelihood recovery in collaboration with relevant stakeholders—should be promoted through DX. In cases where individuals require specialized support, multiple stakeholders should collaborate to prepare individual evacuation plans and promote disaster case management, including ongoing monitoring and appropriate interventions tailored to individual needs.

Recommendation 5: Maintain Health, Medical, and Welfare Systems

During disasters, demand for health, medical, and welfare services increases, while related facilities and delivery systems may be disrupted or lose functionality. Business continuity plans (BCPs) are essential for preventing such disruptions and maintaining critical functions. In addition, business continuity management (BCM), which includes the use of checklists, training, and exercises, verification of BCP effectiveness, and continuous improvement, is essential. In megacities, health, medical, and welfare services can be sustained even during large-scale disasters through the advance establishment of BCPs and systems for providing and receiving support.

(1) Health and Public Health

Public health, with its primary focus on disease prevention, is becoming increasingly important as a field of science that seeks to prevent health impacts during disasters and provide evidence-based guidance on standard practices for communities and individuals [19]. The concept of health is broad and encompasses a wide range of perspectives. Public health judgments and interventions do not always command social consensus. At the same time, disaster-induced deterioration in the overall health of communities can have particularly far-reaching impacts in megacities. Social consensus should therefore be established in advance on the shared objectives of disaster response activities among relevant organizations and on how to protect “the dignity of individual citizens (who are diverse individuals whose choices should be respected)” during life-saving activities. According to the World Health Organization (WHO) definition [20], health is not merely the absence of disease or infirmity but a state of physical, mental, and social well-being, and is one of the fundamental human rights.

Because public health under normal conditions is directly linked to vulnerability and health impacts during disasters, adequate investment in infrastructure and social services before disasters occur is necessary to ensure well-being as urban populations grow and age.

(2) Minimizing Health Impacts

In megacities, crush syndrome, urban fires, burns, poisoning, drowning caused by the failure of ventilation and drainage systems, and economy class syndrome (deep vein thrombosis) may occur on a scale far exceeding response capacities. In addition to direct injuries and illnesses caused by hazards, evacuation living conditions may also give rise to a wide range of health impacts. Nutritional disorders resulting from food shortages and diets that rely excessively on carbohydrates, as well as mental health problems and alcohol dependence arising from anxiety and sleep disturbance, are also likely to increase. In megacities, disruptions to lifeline services and transportation networks, water and food contamination, and the accumulation of waste, human waste, rodents, and insect pests can rapidly and severely degrade sanitary conditions, thereby exacerbating health impacts among disaster survivors and responders. The extent of these health impacts is determined by the balance between population size and available resources in megacities. Beginning around the first week after a disaster, shortages of regularly prescribed medications, delays in the reopening of medical facilities, shortages of foods suitable for people with allergies, fatigue, sleep disturbance, and constipation are likely to become increasingly serious. The risk of health impacts associated with prolonged disruption extends to all disaster survivors and responders. In cities where chronic malnutrition is already widespread under normal conditions, food shortages during disasters can become particularly severe, and socially vulnerable populations tend to experience disproportionately greater impacts.

To address health impacts in urban disaster management, behavioral changes aimed at preventing direct deaths caused by hazards should be promoted, including seismic retrofitting of houses, securing furniture to prevent overturning, installing earthquake-sensitive circuit breakers, and undertaking rapid voluntary evacuation. Improvements in sanitary conditions, including handwashing and mask use, should also be promoted to prevent indirect health impacts. Water and food, including provisions for people with allergies, should be stockpiled, reserve supplies of regularly prescribed medications maintained, and information necessary for individual health management prepared. To increase awareness of these measures, health systems and administrative authorities should implement pre- and post-disaster awareness programs and evaluate their effectiveness.

During disasters, health and medical coordination headquarters should be established at the prefectural level, and emergency medical care and public health services should function as complementary pillars of disaster response. The short- and long-term well-being of disaster survivors provides an essential foundation for recovery and reconstruction. Action plans with specific numerical targets, such as “Health Japan 21,” Japan’s national health promotion initiative, should be extended to the DRR sector, and integrated measures involving not only academia but also government agencies, political sectors, the mass media, and private enterprises should be implemented.

(3) Prevention of Indirect Disaster-Related Deaths

In Japan, deaths that occur after disasters are legally recognized as “indirect disaster-related deaths” for the purpose of determining eligibility for disaster condolence payments. In this context, the concept encompasses both “direct deaths” caused by hazards and “indirect deaths” resulting from physical and psychological deterioration following a disaster. Examples of deaths certified as indirect disaster-related include the worsening of pre-existing medical conditions due to interruptions in medications, physical disorders caused by stress, deterioration in health resulting from unsanitary conditions, death from debilitation caused by malnutrition or loss of appetite, economy class syndrome (deep vein thrombosis) resulting from prolonged stays in vehicles, suicide resulting from despair following disaster impacts, liver cirrhosis caused by excessive alcohol consumption stemming from loneliness in temporary housing, and death from overwork during disaster recovery operations.

In the aftermath of the 1995 Great Hanshin-Awaji Earthquake [21], a major urban disaster, 921 of the 6,434 deaths were certified as indirect disaster-related by a review committee established under local ordinances. Following the 2011 Great East Japan Earthquake, 3,808 of the 22,228 deaths and missing persons were certified as indirect disaster-related deaths [22]. In the 2016 Kumamoto Earthquake, 218 of the 273 deaths

[23] were certified as indirect disaster-related, while in the 2024 Noto Peninsula Earthquake, 356 of the 584 deaths received the same certification [24]. Some of these indirect disaster-related deaths are considered “Preventable Disaster Deaths” [25], as they represent losses that could have been avoided through appropriate preventive measures.

Individual evacuation plans involve determining evacuation methods and destinations in advance based on individual circumstances and sharing this information with the relevant authorities before disasters occur. Disaster case management refers to assessing the disaster impacts and post-disaster living conditions of affected individuals and, in collaboration with relevant stakeholders, supporting problem-solving, self-reliance, and livelihood recovery. These measures play an important role in reducing indirect disaster-related deaths. Disaster case management, including individualized monitoring and appropriate interventions, should be promoted through collaboration among multiple stakeholders.

Japan is at the forefront of collecting statistics on indirect disaster-related deaths (indirect disaster mortality). Although the U.S. Centers for Disease Control and Prevention (CDC) provides guidelines for recording disaster-related deaths on death certificates, the United States does not have a nationwide statistical system for tracking such deaths. In contrast, the current number of indirect disaster-related deaths in Japan is based on cases certified by review committees following applications submitted by bereaved families seeking disaster condolence payments. As a result, a gap remains between the officially certified number of indirect disaster-related deaths and the actual number of people who die from indirect health impacts attributable to disasters.

Preventing indirect disaster-related deaths requires not only improving the recording of disaster-related factors on death certificates but also establishing medically and epidemiologically grounded definitions, statistical frameworks, and analytical methods for indirect disaster-related deaths, while building public consensus on their use and application. Indirect disaster-related deaths represent only a small proportion of possible indirect health impacts. It is therefore an urgent priority to implement DX, including the use of the My Number (personal ID) system, to comprehensively collect and analyze health impact data in disaster-affected areas and create an environment that facilitates matching support needs with available assistance.

(4) Continuity of Health, Medical, and Welfare Systems

During disasters, demand for health, medical, and welfare services increases; however, damage to facilities and the effects of the disaster on personnel may disrupt these services or render them nonfunctional. To prevent such disruptions and maintain critical functions, BCPs for health, medical, and welfare facilities are essential. BCPs should identify and address facility-specific risks, establish command and control systems, specify critical operations and target recovery times, develop damage control and contingency measures, prepare for acute-phase response, establish arrangements for receiving external assistance, and define response strategies for subsequent phases of the disaster to restore normal operations as quickly as possible. In Japan, all designated disaster base hospitals have established BCPs. Even after their establishment, BCM remains important. BCM includes the use of checklists, training, and exercises; verification of BCP validity; and their continuous improvement. Strengthening the seismic and flood resistance of hospitals and welfare facilities themselves is equally necessary. Furthermore, experience from large-scale disasters, including those requiring hospital evacuation, has shown that individual facilities cannot respond effectively on their own. Therefore, mechanisms for wide-area cooperation, together with BCPs covering regions and inter-organizational networks, should be established [14].

In Japan, various teams work to prevent disruptions to health, medical, and welfare services following disasters, reduce indirect disaster-related deaths, and support the maintenance of health during recovery and reconstruction. These include the Disaster Medical Assistance Team (DMAT), which provides rapid medical assistance; the Japan Medical Association Team (JMAT), which provides medium-term medical support in disaster-affected areas, the Disaster Psychiatric Assistance Team (DPAT), which provides mental health support; the Disaster Welfare Assistance Team (DWAT), which provides welfare support; the Disaster Health Emergency Assistance Team (DHEAT), which provides health management support through public health nurses, the Japan Rehabilitation Assistance Team (JRAT), which works to prevent physical decline, and the Japan Dietetic Association–Disaster Assistance Team (JDA-DAT), which provides nutritional and dietary support. Industry organizations, professional associations, NPOs, and NGOs also play important roles.

These organizations coordinate their activities through the Health, Medical, and Welfare Coordination Headquarters established within local governments. To ensure the sustainability of support systems during the medium- to long-term recovery and reconstruction phases after external support has ended, local health, medical, and welfare systems must be rebuilt, and support for affected residents must continue. Previous major disasters have shown increases in suicide mortality, a form of indirect disaster-related death, several years after disasters, suggesting that mental health problems may become even more pronounced during this period. Continuity of mental health support from the acute phase through recovery and reconstruction is therefore essential [26]. Accordingly, health, medical, and welfare systems in megacities should be strengthened during normal times, and BCPs and arrangements for receiving domestic and international assistance should be established in advance to supplement these systems after disasters. It is also important to establish mechanisms to support the physical and mental well-being of responders, as those providing assistance in disaster-affected areas are often disaster survivors themselves.

Although disaster medical systems vary according to national circumstances, the WHO is promoting the standardization of both national and international Emergency Medical Teams (EMTs). EMTs deployed as part of JICA's Japan Disaster Relief (JDR) Team have also been certified by the WHO. In addition, the Surveillance in Post Extreme Emergencies and Disasters (SPEED) disaster medical information reporting system, jointly developed by the Philippine Department of Health and the WHO, is widely used in international disaster medical assistance operations and serves as the standard Minimum Data Set (MDS) for reporting health information during disasters. Furthermore, under a bilateral agreement between Japan and Thailand, the ASEAN Regional Collaboration on Health System Strengthening for Responding to Disasters (ARCH Project) is promoting the standardization of disaster medical response across ASEAN member states. This initiative supports capacity building within individual countries, strengthens frameworks for disaster medical cooperation, and promotes academic exchange between ASEAN member states and Japan.

5. Loss and Damage Assessment (Recommendations 6 and 7)

Recommendation 6: Promote the Standardization of Disaster Risk Assessment

To advance "risk-informed sustainable development," disaster impact assessment and the monitoring of DRR measures should be standardized. Such standardized information provides an important basis for determining the appropriateness and prioritization of public and private investment in areas exposed to disaster risk. International standardization of disaster risk assessment, including ISO standards and other relevant frameworks, should be promoted through cooperation with national governments and international organizations, collaboration among industry, government, and academia, and by leveraging Japan's scientific and technological expertise.

In megacities, disaster risk assessment must consider impacts on core urban functions. By sharing and standardizing quality-assured data on hazards, exposure, and vulnerability, risk assessment can be more effectively linked to DRR investment.

Recommendation 7: Encourage DRR Investment

Raising awareness of the need for proactive investment in DRR is an important policy issue for strengthening disaster resilience and achieving sustainable development in megacities worldwide. International efforts to mainstream DRR, an area in which Japan has played a leading role, should continue. To assess and communicate the status of domestic DRR investment and international cooperation for DRR across countries, a framework is needed to quantitatively analyze the outcomes of domestic DRR activities and evaluate technical and financial DRR assistance provided by other countries. Such a framework would make the outcomes of DRR investment more visible and clearly demonstrate its contribution to reducing disaster risk.

(1) Challenges in Urban Disaster Loss and Damage Assessment

As discussed in Chapter 2, a common framework for quantifying disaster impacts examines three elements: hazard (H), exposure (E), which refers to populations, assets, and other elements that may be affected by disasters, and vulnerability (V). More recently, a fourth element, capacity (C), has also been incorporated. Together, these elements are used to analyze human and physical damage, as well as cascading impacts.

In cities, particularly megacities, populations and economic activities are highly concentrated, resulting in greater exposure of people and assets. Consequently, even where hazard intensity, hazard distribution, and vulnerability are comparable, cities with larger populations and economies tend to experience greater overall loss and damage. Furthermore, as cities grow, the services they provide become increasingly diverse and hierarchically organized, a characteristic known in geography and urban economics as the “urban hierarchy.” When disasters affect cities with concentrated populations and economic activities, the functions they perform may be disrupted, allowing impacts to spread widely to surrounding cities and other regions. In particular, the loss of political and economic core functions (hereinafter referred to as “core functions”) is expected to have far-reaching consequences. Mechanisms should therefore be established to provide substitutes for these core functions during emergencies, such as by securing backup facilities.

(2) The Situation in Japan

With regard to assessing loss and damage from urban disasters, the Japanese government estimates that if the “Southern Tokyo Metropolitan Area Earthquake” (assumed magnitude: M7.3), one of the anticipated earthquakes directly beneath the Tokyo metropolitan area, were to occur, total losses would amount to approximately 82.6 trillion yen, including approximately 45.1 trillion yen in asset damage within the affected area and approximately 37.5 trillion yen in nationwide economic losses [27]. The damage assessment published in 2025 estimates asset damage separately for the private sector, quasi-public sectors (such as electricity, gas, water supply, and railways), and the public sector (such as water and sewage systems and public civil engineering facilities). It also provides quantitative estimates of reductions in economic activity resulting from disrupted production and services. Separately, an independent assessment estimates the impacts of disruption to wide-area transportation networks, including approximately 8.2 trillion yen in losses resulting from a six-month disruption of road functions. For wind- and flood-related disasters, damage assessments for large-scale flooding caused by breaches of the Tone River [28] and Arakawa River [29] embankments, as well as storm surges in Tokyo Bay [30], were published between 2008 and 2009. These assessments estimated direct impacts, including fatalities, isolated populations, and damage to lifeline infrastructure. These assessments were made possible by Japan's extensive development and accumulation of data on hazards, exposure, and vulnerability. However, no scientific assessment has yet evaluated the impacts resulting from the loss of urban core functions, particularly those of megacities. Following the 2011 Great East Japan Earthquake, which was accompanied by a maximum-class tsunami, disaster scenarios have increasingly been based on the largest plausible hazard levels while considering all possible contingencies. As a result, increasing emphasis has been placed on worst-case scenarios.

(3) Global Context and International Initiatives

In many megacities across Asia, the geospatial data needed for disaster risk assessment have not been fully developed or maintained, making quantitative analysis difficult and limiting the quality of disaster loss and damage assessments. Although hazard data have been accumulated through infrastructure planning and design, data on exposure and vulnerability remain inadequate. Building on previous initiatives, including exposure data surveys conducted by the European Commission Joint Research Centre (JRC) and vulnerability data compiled by the Intergovernmental Panel on Climate Change (IPCC) and the Global Earthquake Model (GEM), further data collection on exposure and vulnerability, including in informal settlements, is required. Country-level risk assessments such as the INFORM Disaster Risk Index [31] and the World Risk Report [32] provide standardized, comparable measures. However, no standardized and internationally comparable disaster risk assessment currently exists for megacities.

Since the adoption of the Sendai Framework for Disaster Risk Reduction, the emphasis has shifted from disaster impacts to disaster risk. The IRDR has likewise promoted “Risk-informed Sustainable Development and Planetary Health” [33]. Consistent with this direction, robust disaster risk assessment is essential to ensure that urban development—whether led by public authorities or the private sector—is implemented efficiently while giving due consideration to disaster risks. In megacities, such assessments must also consider impacts on core urban functions. To incorporate assessment results into development and urban planning, quantitative risk assessments are required at both regional and district levels. The development and standardization of geospatial information, including Geographic Information System (GIS) datasets that support these assessments, are likewise essential.

Another key challenge is that many risk assessments, including those used in Japan to estimate disaster loss and damage, are primarily intended to support disaster response and crisis management. Consequently, they tend to emphasize worst-case scenarios and do not necessarily reflect the probability distribution of disaster losses. For development planning, the required information is not necessarily the worst-case scenario but rather estimates of value at risk—that is, the human activities and accumulated assets exposed to disaster risk—and the (conditional) expected value of losses.

An international initiative is needed to develop risk assessments that address these challenges using standardized and internationally comparable methods and to link those assessments to advance “Risk-Informed Sustainable Development,” as outlined in the IRDR framework [33].

(4) Standardization of DRR Countermeasures

Assessments of disaster loss and damage, together with the status of countermeasures, have become important factors in determining the suitability of investments in disaster-prone areas in a globalized society. In 2017, the Task Force on Climate-related Financial Disclosures (TCFD) recommended the appropriate assessment and disclosure of risks, including those related to climate change. In response, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) published “A Guide to Flood Risk Assessments for Enhanced TCFD Disclosures” in 2023 [34], which provides methodologies for assessing flood risk in the private sector.

Japan hosted the UN World Conference on Disaster Reduction in 1994, 2005, and 2015, and has played a leading role in establishing standard approaches to DRR (so-called “forum standards”) through its active involvement in developing the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction. Since 2020, Japan has also established a working group on DRR within the International Organization for Standardization (ISO) (TC268/SC1/WG6) and has led the development of a series of ISO standards (so-called “de jure standards”). These include the Guidance for Implementing Seismometer Systems (ISO 37174 [35]), published in February 2024, and the Basic Framework for DRR Implementation (ISO 37179 [36]), published in November 2024. In the field of water-related DRR, discussions began in 2025 through the ISO International Workshop Agreement process (IWA50: Hydrological Risks) [37].

The international standardization of disaster loss and damage assessments should be promoted through cooperation with other countries and international organizations including IRDR and UNDRR, collaboration among industry, government, and academia, and the effective use of Japan’s scientific and technological expertise. These efforts should build not only on Japan’s domestic experience but also on the extensive knowledge gained through DRR projects implemented by the Japanese government in many countries. In particular, for risks specific to disasters in megacities, loss and damage assessments comparable to those available for the Tokyo Metropolitan Area have not been conducted or publicly disclosed in many parts of the world. As a result, Japan’s megacities may be perceived as carrying relatively higher risk simply because more comprehensive assessments are available. Alongside domestic disaster loss and damage assessments, the international community should advance discussions on assessment methodologies to ensure consistency between domestic and international approaches. As discussed above, disaster assessments for megacities should also evaluate the impacts of disruptions to core urban functions. Accordingly, assessment methodologies that enable meaningful comparisons among megacities should be developed, standardized, and adopted internationally.

Risk assessment requires the sharing of quality-assured data. The establishment of a “consilience knowledge base,” as recommended in the Science Council of Japan’s Recommendation “Building a Sustainable Global Society by Strengthening Disaster Resilience: Developing an 'Online Synthesis System (OSS)' and Fostering 'Facilitators' to Realize Consilience” [11], particularly the OSS, would also support risk assessment. For example, Japan’s Data Integration and Analysis System (DIAS) provides global datasets and serves as a foundation for flood risk assessment in countries around the world. When developing risk assessment methodologies, discussions should also address the underlying data platforms and data standards required to achieve interoperability.

(5) Promotion of DRR Investment

UNDRR has consistently emphasized the importance of investing in DRR, noting that every US$ 1 invested in risk reduction and prevention can save up to US$ 15 in post-disaster recovery and US$ 4 in avoided losses and disruptions [38]. The World Bank has likewise reported investing in resilient infrastructure in low- and middle-income countries would generate an overall net benefit of US$ 4.2 trillion over the lifetime of new infrastructure, equivalent to approximately US$4 in benefits for every US$ 1 invested in resilience [39]. Consequently, the view that proactive investment in DRR “pays off” has become widely accepted within the international community. This reflects the fact that Japan has also been deeply involved in shaping international consensus on this issue. However, the share of DRR investment within overall disaster-related expenditure has not increased, and raising awareness of the need for DRR investment continues to be regarded as an important issue at international forums, including those organized by UNDRR.

As part of its National Resilience and DRR efforts, Japan has implemented initiatives including the “Three-Year Plan for Disaster Risk Reduction and Resilience” (2018–2020; approximately 7 trillion yen) [40] and the “Five-Year Acceleration Plan for Disaster Prevention, Disaster Mitigation, and Building National Resilience” (2021–2025; approximately 15 trillion yen) [41]. The “First Medium-Term Plan for the Implementation of National Resilience” [42], approved by the Cabinet in 2025, sets a target project scale of more than 20 trillion yen over the next five years. Building on these achievements, Japan should continue to strengthen the mainstreaming of DRR, an approach it has championed through the Sendai Framework for Disaster Risk Reduction 2015–2030 and promoted internationally.

To communicate the status and outcomes of DRR investment and cooperation both domestically and internationally, a framework should be established to quantitatively analyze the effects of DRR and evaluate not only domestic initiatives but also DRR efforts in other countries supported through technical cooperation and financial assistance.

Furthermore, as a leading donor in international DRR cooperation [43], Japan would benefit from a framework modeled on the Joint Crediting Mechanism (JCM) used in climate policy to quantitatively evaluate the effectiveness and cost-effectiveness of DRR efforts supported through technical cooperation and financial assistance. Through such a framework, public and private investment leveraging international DRR and climate finance can be further promoted.

6. Dissemination and Distribution of Disaster Information (Recommendations 8, 9, and 10)

Recommendation 8: Utilize the Latest Technologies and Knowledge in Disaster Information

Recognizing that the actors involved in disaster information dissemination have expanded beyond government agencies to include private-sector organizations, and that communication channels have evolved from one-way communication to more distributed and networked forms of information sharing, policies should promote the development of DRR technologies and the establishment of information dissemination systems that suppress the spread of misinformation and malicious content while encouraging prompt protective action.

The latest communication tools, including smartphones and social media platforms, as well as advanced technologies such as digital twins that replicate real-world conditions and environments in virtual spaces, should be fully utilized. Through continuous disaster education and risk communication during normal times, societal disaster resilience should be strengthened. At the same time, advance planning and simulation should be conducted regarding both the content of information to be communicated and the communication methods to be used during catastrophic disasters.

Mechanisms should also be established to ensure the availability of information and communication systems during widespread and prolonged communication disruptions. To promote efficient evacuation, early warnings should be issued in a timely, location-specific manner. By advancing “Digital Transformation (DX) for DRR” through the utilization of Japan’s technologies and expertise, Japan can also contribute to the development and dissemination of early warning systems worldwide.

Recommendation 9: Lead the Development of AI Technologies That Are Effective for DRR

Although AI offers significant benefits, it also presents technical challenges, including bias, the “black box” problem, and the generation of misinformation, as well as social challenges related to responsibility and accountability. Despite these concerns, expectations remain high for the application and advancement of AI in DRR. Policies should therefore support the collection of diverse, multifaceted data and promote collaboration among industry, government, and academia, enabling Japan to play a leading role in the development of AI for DRR.

In situations where support for disaster-affected people becomes difficult due to personnel shortages within government agencies, the development of AI technologies capable of rapidly and accurately analyzing large volumes of data and supporting decision-making could facilitate personnel deployment and case allocation, the management and delivery of relief supplies, procurement of needed supplies, and issuance of disaster victim certificates. AI-enabled robots can also support life-saving and rescue operations, further improving the efficiency of disaster response.

Recommendation 10: Promote the International Dissemination, Communication, and Sharing of Disaster Information

During catastrophic disasters, disseminating information to the international community is critically important for preventing disruptions to national governance and core systems, including the economy, financial markets, and national security, and for facilitating a rapid return to stability. It is also essential for maintaining international trust.

Measures should urgently be developed to ensure the physical availability of international communication channels; establish systems to ensure communication and information sharing with domestic and international political leaders, disaster management officials, and the media; strengthen the capacity to generate and disseminate accurate multilingual disaster information; diversify communication channels for domestic and international audiences; and establish systems for sharing critical crisis information and enabling rapid response.

For disaster information disseminated internationally, systems should ensure the timely collection, analysis, and disclosure of current conditions and forecasts that are of particular concern to the international community following a disaster. Such information includes the overall disaster situation, impacts on transportation and critical infrastructure, nuclear-related facilities, industrial and financial systems, and future outlooks. Measures should also be implemented to confirm the safety of and provide protection for foreign residents and international visitors.

(1) Recent Developments in Information and Communication Tools

Regardless of the type or scale of disasters, it is essential that necessary and sufficient disaster information be disseminated effectively so that individuals can prepare for disasters in advance, no one is left behind, lives and property are protected, and health and livelihoods can be restored as quickly as possible. The dissemination of disaster information, a core component of Japan's DRR measures, has continued to evolve before, during, and after disasters through advances in underlying technologies, refinement of information content, and a better understanding of how information influences the actions of recipients.

Over the past decade, the rapid changes in methods of information collection and dissemination, driven by the widespread adoption of smartphones, social media platforms, and AI, have fundamentally reshaped the way disaster information is disseminated and distributed. In Japan, smartphone ownership increased from approximately 4% in 2010 to approximately 97% in 2024 [44]. Although AI is expected to bring significant advances in the collection, analysis, and dissemination of disaster information, concerns remain regarding potential negative impacts, including the spread of disinformation and misinformation. Social media platforms such as X, Instagram, and YouTube have become important communication tools for people of all ages [45]. Traditionally, the public sector has been responsible for collecting, processing, and disseminating accurate information. However, because individuals are now also capable of performing such functions, the respective roles of the various sectors involved in the collection, processing, dissemination, and use of information should be reexamined. At the same time, there is an increasing need to strengthen risk communication through inclusive, cross-sectoral, and active discussions, both domestically and internationally [10].

Furthermore, particularly during catastrophic disasters that attract intense international attention, accurate information should be disseminated through a wide range of trusted sources in addition to official channels. The importance of strengthening information coordination and sharing (crisis communication) is also emphasized in the Recommendation "Transforming Society to Become Resilient and Sustainable beyond Catastrophic Disasters" [10], where it is discussed in the context of transnational resilience.

(2) Challenges and Directions for Disaster Information Dissemination During

Catastrophic Disasters

(a) Disaster Preparedness

In preparation for catastrophic disasters, where the circumstances people may face cannot be fully anticipated, disaster resilience across society should be strengthened through active risk communication during normal times. This should be supported by disaster education, which has proven effective in many disasters, and by advanced technologies such as digital twins that reproduce real-world conditions and situations in virtual spaces [46], enabling people to recognize disasters, understand their implications, and take appropriate action when necessary. This involves strengthening disaster resilience through the promotion of “Digital Transformation for Disaster Risk Reduction (DX for DRR)” and “Smart DRR.” Risk communication should make effective use of the influence of information disseminated through smartphones and social media platforms. Furthermore, information and messages shared during disasters by content creators and other communicators who routinely provide news and information to large audiences through video-sharing platforms and other media can significantly influence public behavior. Therefore, maintaining regular engagement with these communicators and providing them with accurate and necessary information before disasters occur should be regarded as essential. In addition, strengthening information literacy during normal times and establishing and promoting reliable official channels are also effective measures for countering disinformation and misinformation.

(b) Disaster Response

i. The Need to Reexamine and Strengthen Information Dissemination Methods

In recent disasters, public broadcasters and other media outlets have issued emergency messages strongly urging people to take protective actions, and continuous improvements have been made to both the content of those messages and the methods used to communicate them. Disaster information contributes to DRR only when people interpret the information appropriately and act on it. The dissemination of disaster information that encourages all citizens to take emergency protective actions remains both a longstanding and emerging challenge. For catastrophic disasters in particular, the content of disaster information and the methods used to disseminate it should be examined and simulated in advance, taking into account the likely responses of hundreds of thousands of recipients. Preparations should also address cyberattacks following disasters, as well as rumors and false information spread by malicious actors. The rapid dissemination of accurate primary information, as well as the detection of misinformation through automated monitoring and fact-checking, are therefore essential.

Information dissemination through social media platforms and related channels is also becoming increasingly important as a means of encouraging public action. In preparation for catastrophic disasters, the role of the public sector in relation to emerging methods of information dissemination—including institutional frameworks, guidelines and standards, information systems, and organizational arrangements—should be comprehensively reexamined.

Although disaster information systems are now widely established and continue to advance, their resilience during catastrophic disasters—including physical robustness, redundancy, and the reliability of communication networks—requires renewed verification and strengthening. Because uncertainty is unavoidable in catastrophic disasters, both organizational arrangements and information systems should be strengthened across a range of disaster scenarios to ensure that the minimum essential functions for collecting, analyzing, and disseminating disaster information can be maintained.

Catastrophic disasters are expected to cause widespread communication disruptions and the shutdown of administrative systems, critical infrastructure, financial systems, and production activities across various industries. Under these conditions, the rapid restoration of two-way communication is critical, particularly for life-saving operations.

When the public sector is unable to disseminate information effectively, individuals and private companies should be able to rely on their own information and communication tools. Mechanisms should also be developed to support routine information exchange enable the public sector to recognize and utilize such communication tools.

II. Effectiveness and Challenges of Early Warning Systems for Catastrophic Disasters

Early warning systems are an effective means of saving lives during disasters. In 2003, the United Nations convened the Second International Conference on Early Warning (EWC II) [47] in Bonn, Germany, where it introduced the concept of "people-centered early warning systems." This concept has since been advanced through the Early Warnings for All initiative, launched by UNDRR and the World Meteorological Organization (WMO), with the goal of achieving universal coverage between 2023 and 2027 [48].

For example, during the 1896 Meiji Sanriku Tsunami, when no early warning system existed, the mortality rate within inundated areas was approximately 40%. However, following the introduction of such systems, the mortality rate declined dramatically to approximately 3% during the 2011 Great East Japan Earthquake [49]. Although this reduction also reflects improvements in disaster awareness and structural countermeasures implemented after World War II, the effectiveness of tsunami warning systems is evident in the large numbers of residents who successfully evacuated in response to major tsunami warnings issued immediately after the earthquake. However, early warning systems can function effectively only when safe evacuation locations are available. Securing such locations and providing support for individuals requiring assistance are therefore also essential. In addition, improving the accuracy of early warning systems alone cannot substantially reduce economic losses.

To reduce disaster damage, the Recommendation "Transforming Society to Become Resilient and Sustainable beyond Catastrophic Disasters" [10] advocates reducing the concentration of human activities and accumulated assets in disaster-prone areas. Achieving this objective requires the implementation of a wide range of measures, including policy incentives that encourage residence in lower-risk areas, mechanisms that facilitate seismic resistance and seismic isolation technologies, and initiatives to support expanded infrastructure development.

Furthermore, the Advisory Opinion “Lessons Learned from the Noto Peninsula Earthquake and Torrential Rain Disaster—Preparing for Regional Disasters” (November 2025) [14] advocates the concept of “buildings and communities where evacuation is unnecessary.”

In catastrophic disasters, evacuation orders in megacities may affect millions of people. However, moving such large populations to safe locations within a limited period is extremely difficult. To promote efficient evacuation, early warnings should be issued with greater temporal and spatial precision.

For example, when special warnings are issued in advance of approaching typhoons, local governments often issue evacuation orders covering extensive areas. During Typhoon Hagibis in 2019, approximately 620,000 residents of Sendai City, accounting for approximately 60% of the city’s total population, were urged to evacuate. This far exceeded the capacity of available evacuation shelters, and subsequent reports identified challenges and proposed countermeasures related to ensuring the effectiveness of large-scale, wide-area evacuation [50].

Evacuation orders should be targeted to those who genuinely need to evacuate. Private weather forecasting companies, such as Weathernews, are working to bridge this gap by providing highly detailed weather forecasts and related services for local governments and private operators. National and local governments must therefore continue to play a leading role in promoting early warning systems by leveraging the technologies and expertise that Japan has developed over many years.

(c) Information Management During Recovery and Reconstruction

Recovery and reconstruction following catastrophic disasters are long-term, gradual, and difficult processes that the country and society as a whole must steadily pursue, overcoming various obstacles. To reduce future disaster risks, it is important not only to improve the provision and sharing of disaster information by drawing on lessons learned from past disasters but also to share encouragement, good practices, and positive messages through disaster information systems and other communication channels to support recovery and reconstruction.

At the same time, information should continue to be shared both domestically and internationally throughout the recovery process to help prevent the formation of informal settlements while remaining vigilant against those who may exploit confusion and disorder to engage in illegal activities. If the same information-sharing platforms are used in both normal times and disasters, seamless information sharing can be expected throughout the process, from disaster preparedness and emergency response to the restoration and recovery of normal social conditions.

(3) Utilization of AI

With the emergence of generative AI technologies such as ChatGPT, AI has rapidly become part of everyday life, and expectations for its application to DRR continue to grow. Practical applications are expanding to include fire detection using live camera feeds, assessment of disaster impacts through the automated classification of information posted by citizens, and flood forecasting based on real-time data.

However, because AI systems generate outputs based on diverse training data, their accuracy may decline when available data are insufficient or contain noise and misinformation. Disaster-related data are particularly scarce compared with data available during normal conditions, and challenges remain regarding both AI accuracy and data reliability. Therefore, at this stage, AI should be used as a supplementary tool in DRR measures. In addition, AI technologies face technical challenges, including bias and black-box processing, as well as social challenges related to responsibility and accountability. Consequently, the application of AI technologies to DRR measures remains at a developmental stage, and excessive reliance on AI carries risks. This underscores the importance of industry, academia, and government taking a leading role in developing AI technologies that are effective for DRR.

As a country that experiences frequent disasters, Japan is uniquely positioned to collect multifaceted data from disasters occurring each year and utilize such data for AI training. Through these practical efforts, the accuracy of AI can be improved, and more effective AI systems for DRR can be developed. As a result, AI technologies cultivated in Japan are expected to gain trust both domestically and internationally and to play a leading role in enhancing disaster resilience worldwide.

(4) Solidarity with the International Community and Domestic Multilingual and Multicultural Communities

Japan maintains close and friendly relations with many countries around the world. However, during catastrophic disasters, delays in information dissemination, incomplete information, or inaccurate information originating from Japan could potentially undermine international confidence. In recent years, the number of international visitors to Japan has continued to increase, reaching a record high of approximately 43 million in 2025. Under these circumstances, providing appropriate support during disasters for foreign nationals in Japan, including members of multilingual and multicultural communities, has become increasingly important. Depending on the manner in which information is disseminated and communicated, Japan's industries, economy, financial markets, political institutions, and international standing may be significantly affected. Dissemination of information to the international community is therefore critical for facilitating the rapid and stable restoration of national systems.

First, the content of information provided to overseas audiences and to foreign nationals within Japan during past disasters, including the Great East Japan Earthquake, should be reviewed. Based on this review, the current framework for external communication—including systems and arrangements for rapid information dissemination, message coordination, multilingual communication, and responses to information circulated by individuals and unofficial sources—should be reassessed. Such a review should also examine response speed and require each organization involved in information dissemination to redefine its role.

Furthermore, the potential use of emerging technologies such as AI should be examined, together with simulations addressing secondary impacts that may arise during disasters, including misinformation, disinformation, and cyberattacks. The physical resilience of international communication channels during catastrophic disasters and mechanisms for maintaining communication with disaster management officials in the international community and overseas media should also be evaluated. These issues should be addressed comprehensively, encompassing information dissemination methods, information-sharing frameworks, and rapid response systems.

7. Capacity Building for Urban Disaster Reduction (Recommendations 11 and 12)

Recommendation 11: Promote Interdisciplinary Education to Foster a Comprehensive Understanding of Disasters

Policies should promote the development of human resources capable of understanding the overall nature of disasters. As the risk of unprecedented disasters continues to increase, disaster education should extend beyond existing approaches to develop the ability to view issues from local, national, and global perspectives; anticipate future challenges based on historical experience; and cultivate resilience, leadership, and collaborative skills. Such education is essential for nurturing individuals capable of leading both nations and local communities. Learners should also develop the ability to envision future societal change, anticipate the challenges that may arise when disasters occur, and formulate countermeasures by assuming the achievement of desired outcomes and working backward from them. Educational programs that enable learners to understand the overall picture of disasters from both short- and long-term perspectives are necessary to nurture key actors in urban DRR together with local communities.

Recommendation 12: Build Societal Systems that Incentivize Disaster Education

Policies should be developed to establish a social system in which learning serves as an incentive for individuals while also benefiting society as a whole. Government and industry should establish phase-free mechanisms through which disaster education provides incentives in everyday life while also proving useful during disasters. Through multisectoral collaboration, the capabilities and functions of disaster prevention specialists, disaster volunteers, and support NPOs should be evaluated, and effective, sustainable networks and cooperative frameworks should be established with government agencies and local DRR organizations, including volunteer fire corps and community-based DRR organizations. Mechanisms should also enable the timely proposal and implementation of policies to update, strengthen, and reform existing DRR plans and organizational systems. By fostering such key actors, the disaster resilience of society as a whole can also be enhanced.

(1) Objectives of Fostering Key Actors

Advancing DRR across society requires people to recognize DRR as a personal responsibility and to take an active role in it. Achieving this goal depends on increasing the number of people with sufficient disaster literacy who regard DRR as their own responsibility. As more people recognize the value of investing in DRR, broader social consensus for promoting such investment can be built, leading to concrete DRR actions.

Furthermore, in light of disaster risks that can cause catastrophic damage, leaders capable of providing strong leadership grounded in DRR and informed by a national perspective should also be cultivated. As stated in the 2020 Science Council of Japan Recommendation, “Building a Sustainable Global Society by Strengthening Disaster Resilience: Developing an 'Online Synthesis System (OSS)' and Fostering 'Facilitators' to Realize Consilience [11],” it is essential to foster facilitators who serve as “catalysts on-site with capabilities of facilitating meetings, streamlining problem-solving processes, and offering expertise.” In addition, contributions from the scientific community are required to accelerate the development of specialized personnel who can serve as diverse actors within national and local governments, NPOs, private companies, and other organizations. Efforts to cultivate future leaders should also target diverse communities, including immigrants, in response to the ongoing internationalization of Japanese society.

(2) Challenges in Developing Key Actors

One challenge in developing key actors for DRR is that, because disasters occur unpredictably, the effectiveness of education and training is difficult to evaluate, making it challenging to motivate learners. Although disasters are primarily characterized by physical phenomena during the first few days after their onset, they subsequently evolve into social phenomena and, when sufficiently large, may develop into political and diplomatic issues. Disaster education tends to focus heavily on hazard-related topics, such as the mechanisms of earthquakes, while giving insufficient attention to integrating knowledge from the natural sciences, social sciences, and health sciences. Such integration should include risk-informed decision-making during emergencies, responses adapted to social conditions during disasters, and welfare-oriented perspectives aimed at protecting affected populations.

Because people cannot adequately prepare for situations they have never experienced and find difficult to imagine, it is important to cultivate individuals who are capable of realistically analyzing and envisioning potential disaster impacts even without prior experience. Disaster response also requires consideration of broader social conditions, making it necessary to provide education that enables a comprehensive understanding of the overall nature of disasters.

(3) Recommendations for Developing Key Actors

(a) Interdisciplinary Education for Understanding the Overall Nature of Disasters

Individuals capable of understanding the overall nature of disasters should be cultivated through the integration of the natural sciences, social sciences, and health sciences. Furthermore, in a future society facing the risk of unprecedented disasters, education is required not only to build on the elements of existing disaster education but also to prepare individuals to lead both nations and local communities. Such education should develop the ability to interpret future developments from historical perspectives, adopt a broad outlook spanning local, national, and global contexts, and strengthen resilience, leadership, and collaborative capacity.

Education for key actors in urban DRR has tended to emphasize short-term perspectives, such as actions that can be taken in one's immediate surroundings. Educational frameworks should therefore enable learners to understand the overall nature of disasters from both short- and long-term perspectives while anticipating societal changes over the coming decades.

i. Systematic Disaster Education Beginning with Compulsory Education

The education described above should be provided systematically and progressively rather than as isolated, fragmented learning. Fundamental content should be introduced during compulsory education, with curricula extending through higher education and continuing into adult education.

ii. Disaster Education Through Diverse Learning Methods

In cultivating individuals capable of understanding the overall picture of disasters, a wide range of educational approaches may be utilized in addition to classroom-based learning. These include learning at disaster memorial sites and preserved earthquake ruins, emotionally engaging education through exhibitions and storytelling by disaster survivors and narrators, and immersive learning using visualization technologies such as virtual reality (VR). Educational methods should be selected and developed according to specific learning objectives and content.

iii. Disseminating Information on the Development of Key Actors Domestically and Internationally

Information on the development of key actors and effective educational approaches should be disseminated widely, both domestically and internationally.

(a) Building a Social System that Provides Incentives for Disaster Education

Developing key actors requires a social system in which the educational outcomes serve as an incentive for learners while also benefiting the society. For example, local governments could establish systems through which both employees and local governments receive benefits when employees complete disaster education and training programs.

In this context, phase-free mechanisms are required so that learning about DRR also provides incentives in everyday life. These efforts should support the development of specialists with long-term expertise within national government agencies and local governments, including prefectural and municipal authorities.

i. Fostering a Multisectoral Workforce Through Updating Existing DRR Qualifications and Organizations

Cultivating diverse DRR actors with knowledge and experience across multiple sectors is an urgent priority, while simultaneously strengthening the decision-making capacity and initiative of the public as key actors in urban DRR. Beyond formal education, the scientific community should evaluate the roles of disaster volunteers and support NPOs, identify ways to utilize and enhance the efficiency of their activities, and establish networks linking certified professionals, such as disaster prevention specialists, to strengthen post-disaster support.

It is also necessary to work with the public to examine the strength and sustainability of local DRR organizations—such as volunteer fire corps and community-based DRR organizations—that are capable of providing rapid support during disasters. Mechanisms should also support the timely proposal of policies to review, update, strengthen, and reform existing DRR plans and organizational systems at both the national and local levels.

These multisectoral actors should include not only Japanese citizens but also immigrants and their communities living in Japan. Individuals should therefore be equipped to work inclusively with diverse communities.

ii. Standardization of Educational Content

When educational content varies across regions or organizations, challenges may arise in effectively utilizing the trained personnel. Standardizing of educational content is therefore necessary. The objectives of disaster education should be clearly defined, and learning content should be systematically organized and progressively deepened according to learners' age and level of development. Furthermore, based on such standardization, education that reflects local characteristics should become firmly rooted within local communities.

8. Science, Technology, and Innovation for DRR in Megacities (Recommendations 13 and 14)

Recommendation 13: Establish an STI Platform for DRR

To address the complex and wide-ranging DRR challenges faced by megacities, a transdisciplinary approach is needed in which diverse stakeholders engage in discussions from scientific and technological perspectives, integrate their knowledge into DRR policies and plans, and co-create and apply interdisciplinary research outcomes in collaboration with society. Establishing and institutionalizing platforms that enable continuous collaboration among stakeholders—including policymakers, experts, and beneficiaries—will promote the effective social implementation of science, technology, and innovation (STI). Recognizing both the vulnerability of megacities as extensive urban agglomerations and the potentially severe consequences of major disasters, the government should prioritize the establishment of such platforms within Japan's three major metropolitan areas.

Recommendation 14: Provide Strategic Recommendations That Address DRR Challenges Based on Societal Needs

The academic community should continuously provide strategic recommendations on DRR challenges grounded in scientific evidence and informed by societal needs, thereby supporting DRR policies and decision-making. Taking regional characteristics and practical challenges into account, the joint development of DRR technologies should be promoted to achieve an appropriate balance between conventional and innovative technologies while pursuing international standardization where necessary.

Interdisciplinary, practice-oriented, and international training and exchange programs for DRR should also be organized regularly, while promoting multidisciplinary and cross-sectoral collaboration among diverse domestic and international stakeholders. These efforts should support sustainable capacity development and nurture the next generation of practitioners, researchers, and community-based DRR actors in partnership with local communities. To achieve these objectives, policy support from both national and local governments is essential.

The following section highlights the importance and effectiveness of the transdisciplinary approach (TDA), through which STI can contribute to DRR policies and decision-making based on scientific evidence, together with the development of STI platforms as the foundation for its implementation. These approaches support the implementation of the recommendations presented in this report, including those related to addressing the complex DRR challenges faced by megacities, developing social infrastructure, strengthening public health, enhancing the assessment of disaster impacts and losses, utilizing disaster information, developing human resources, improving the accuracy of early warning systems, and promoting investment in DRR.

(1) TDA

DRR actions in megacities are influenced not only by hazards but also by exposure, including the concentration of populations and assets, and by vulnerability, such as high population density and development in flood-prone low-lying areas. Addressing these complex challenges requires transdisciplinary collaboration involving not only researchers and educators but also community stakeholders, including government agencies and private-sector entities. This challenge reflects the central question posed in “A Science Plan for Integrated Research on Disaster Risk” [51], which laid the foundation for IRDR activities: “Why do disaster losses continue to increase despite advances in our understanding of natural and social scientific aspects of hazards and disasters?”

The core principles of TDA—Co-Design, Co-Produce, Co-Deliver, and Co-Implement—are also reflected in the Sendai Framework for Disaster Risk Reduction, which states that: “There is a need for the public and private sectors and civil society organizations, as well as academia and scientific and research institutions, to work more closely together and to create opportunities for collaboration, and for businesses to integrate disaster risk into their management practices.”

In Japan, the “Strategic Innovation Promotion Program (SIP): Strengthening National Resilience (Disaster Prevention and Mitigation),” launched in 2018, promoted technology development based on TDA with the goal of ensuring effective social implementation. Relevant organizations expected to become implementation partners participated from the earliest stages of research and development, and efforts were made to implement an integrated evacuation and emergency response support system designed to support government decision-making and facilitate appropriate public evacuation. The resulting technologies have since been effectively implemented in practice [52]. Furthermore, the Asian Civil Engineering Coordinating Council (ACECC) established the Committee on "Transdisciplinary Approach (TDA) for Building Societal Resilience to Disasters" as its 21st Technical Committee in 2016. Through exchanges among policymakers, surveys, analyses, and seminars, the committee has promoted the dissemination of TDA for DRR throughout Asia [53].

(2) Toward the Establishment of an STI Platform for DRR

Implementing TDA requires the establishment of systems and mechanisms that maximize the utilization of STI. In particular, addressing the complex and wide-ranging DRR challenges faced by megacities requires discussions among diverse stakeholders on scientific and technological perspectives, resulting in the knowledge being incorporated into DRR policies and plans. This, in turn, requires continuous collaboration among experts, policymakers, and beneficiaries and the establishment and institutionalization of platforms through which STI stakeholders can work toward the realization of TDA.

Such platforms are expected not only to strengthen the interface that links scientific and technological knowledge with DRR policies and plans but also to facilitate cross-disciplinary and multi-sector collaboration. Furthermore, they can also strengthen regional and international cooperation and coordination while promoting investment in DRR. To achieve these objectives and realize a sustainable society through the strengthening of disaster resilience, STI platforms should perform the following functions:

(a) Providing Strategic Recommendations on DRR Challenges Based on Societal Needs

Continuously provide strategic recommendations on DRR challenges grounded in scientific evidence and informed by societal needs, thereby supporting DRR policies and decision-making processes that are responsive to societal needs.

(b) Developing, Innovating, and Standardizing DRR Technologies

Accelerate the joint development of DRR technologies that effectively balance conventional and innovative approaches while taking regional characteristics and on-field challenges into account, and pursue international standardization where necessary. Examples include improving the efficiency of disaster information management and sharing and advancing its effective use.

(c) Fostering Training and Exchange among DRR Personnel

Regularly organize interdisciplinary and practice-oriented training and exchange programs targeting DRR professionals, particularly early-career practitioners, researchers, and local champions who play active roles in their communities, while promoting multidisciplinary and cross-sectoral exchange and supporting sustainable capacity development programs.

(d) Building DRR Networks

Establish mechanisms that enable diverse stakeholders—including research institutions, government agencies, international organizations, private-sector organizations, companies, and local communities—to collaborate closely, thereby promoting the social implementation of science and technology while also diversifying DRR financing.

Japan has already incorporated the participation of science and technology stakeholders into disaster governance through policy frameworks such as the Central Disaster Management Council under the Cabinet Office, thereby achieving a significant degree of TDA. Going forward, closer collaboration with the Science Council of Japan is expected to facilitate smoother interaction between research and policymaking and further promote the social implementation of STI in DRR. Similar frameworks in other countries and regions can also serve as a useful reference for integrating scientific knowledge into policymaking and promoting collaboration among stakeholders, thereby supporting further advancement in the implementation of TDA-based approaches. For example, in the United States, the Federal Emergency Management Agency (FEMA) incorporates STI into disaster management under frameworks such as the National Emergencies Act and the Homeland Security Act. Within the European Union, scientific knowledge is increasingly being incorporated into policymaking under climate-related policy frameworks. Furthermore, at the city level, New York City Emergency Management (NYCEM) promotes participation and input from cross-sectoral STI stakeholders in disaster risk management and urban disaster prevention planning.

The concept of STI platforms is also gaining momentum across the Asia-Pacific region, one of the world's most disaster-prone regions. For example, the Philippine government has established the ASEAN Science, Technology and Innovation (STI) Platform for Disaster and Climate Resilience through the ASEAN Committee on Science, Technology and Innovation (ASEAN COSTI), with the aim of strengthening DRR management and climate change adaptation across the region while promoting cooperation among different sectors through the utilization of STI [54]. Japan and ASEAN member states are all located along the Pacific Ring of Fire, where diverse natural disaster risks converge, and share similar warm and humid climates and densely populated societies. In addition to facing many common disaster risks, they also maintain close socioeconomic ties, and this initiative is therefore also important for Japan.

9. Conclusion

Japan is home to three megacities—Tokyo (the Tokyo Metropolitan Area), Osaka (the

Keihanshin Metropolitan Area), and Nagoya (the Chukyo Metropolitan Area)—all of which have experienced catastrophic disasters causing enormous loss of life. The national government has identified a wide range of hazards, including earthquakes and tsunamis, volcanic eruptions, floods, and storm surges, together with their potential impacts; local governments are expected to prepare appropriate responses. However, comprehensive disaster risk reduction (DRR) measures for megacities as integrated urban regions have yet to be fully established. Although each megacity comprises multiple municipal administrative entities, no overarching mechanism exists to coordinate them comprehensively. If individual administrative entities continue to respond independently under the current Basic Act on Disaster Management, not only will pre-DRR measures remain insufficient, but emergency response, recovery, and reconstruction are also likely to be fragmented and uncoordinated. It is therefore essential for megacities to consider in advance how to respond in the event of a catastrophic disaster.

During the Noto Peninsula Earthquake in January 2024, insufficient situational awareness on the ground hindered the timely transmission of information and requests for assistance from municipalities to prefectural governments and from prefectural governments to the national government. In response, amendments to the Basic Act on Disaster Management, enacted in May 2025, enabled the national government to provide support in a top-down manner without formal requests from affected local governments. This amendment allows the national government to coordinate disaster response comprehensively even when a megacity spanning multiple prefectures is affected and can therefore represent an important step toward strengthening DRR in megacities. Nevertheless, before relying on national-level support, megacities themselves must recognize their vulnerabilities, address their weaknesses, and strengthen their resilience.

From this perspective, the following two recommendations are intended to encourage the diverse stakeholders comprising megacities to communicate on a regular basis, disseminate relevant information and recommendations, and prepare megacities as a whole in advance for emergencies:

Recommendation 13: Establish an STI platform for DRR

Recommendation 14: Provide strategic recommendations that address DRR challenges based on societal needs

It is important to identify the vulnerabilities and disaster risks of megacities and to propose measures for risk reduction and avoidance in advance. From this perspective, we proposed the following recommendations:

Recommendation 1: Implement land-use management based on disaster risk

Recommendation 2: Account for uncertainties associated with future changes and disaster risks

In addition, DRR planning and investment must be carried out rationally based on scientific analysis. This is essential both for comparing the disaster risks of Japan's megacities with those of megacities in other countries and for accurately evaluating costs and benefits. From this perspective, the following recommendations are important:

Recommendation 6: Promote the standardization of disaster risk assessment
Recommendation 7: Encourage DRR investment

Healthcare, medical services, and welfare play vital roles in providing relief and rescue to disaster victims and injured persons when disasters occur. At the same time, attention must also be paid to the large number of indirect disaster-related deaths observed following major disasters, including the 1995 Great Hanshin-Awaji Earthquake, the Great East Japan Earthquake, the Kumamoto Earthquake, and the 2024 Noto Peninsula Earthquake.
Recommendation 3: Minimize health impacts
Recommendation 4: Prevent indirect disaster-related deaths
Recommendation 5: Maintain health, medical, and welfare systems
These recommendations were formulated from a public health perspective, taking into consideration the need to address the health impacts on disaster-affected populations.

The collection, sharing, dissemination, and management of various types of information—both before and after disasters occur—are critical. In carrying out these functions, technological innovation must actively be pursued while also ensuring information security. This is key to maintaining and strengthening relationships of trust with partner countries.
In this regard, AI is increasingly recognized as one of the emerging technologies that can support these efforts.
Recommendation 8: Utilize the latest technologies and knowledge in disaster information
Recommendation 9: Lead the development of AI technologies that are effective for DRR
Recommendation 10: Promote the international dissemination, communication, and sharing of disaster information

To enhance regional disaster resilience and build a resilient society for future generations, it is essential to cultivate the next generation of human resources and leaders in urban DRR.
Recommendation 11: Promote interdisciplinary education to foster a comprehensive understanding of disasters
Recommendation 12: Build societal systems that incentivize disaster education
These recommendations focus on developing human resources. Concrete measures should be developed to enable individuals to assume leadership roles with a broad perspective across all phases of disaster management, including pre-disaster preparedness, emergency response, and post-disaster recovery and reconstruction.

Currently, the Basic Act on Disaster Management and the Disaster Relief Act serve as the principal legal frameworks for disaster management in Japan. Both fall under the jurisdiction of the Director General for Disaster Management within the Cabinet Office, and a Minister of State for Disaster Management is appointed. The “Disaster

Management Agency” is scheduled to be established in the autumn of 2026. At a Cabinet meeting held on December 26, 2025, the basic policy for establishing the agency was approved, positioning it as an organization “directly under the Cabinet,” similar to the Digital Agency and the Reconstruction Agency.

The agency’s principal functions are defined as follows:
(1) Formulating basic disaster management policies and national strategies
(2) Thoroughly implementing pre-disaster risk reduction measures
(3) Serving as the central coordinating body from disaster onset through recovery and reconstruction

It was also decided that four divisions—“Comprehensive Policy,” “Disaster Response,” “Disaster Management Planning,” and “Regional Disaster Management”—would be established under the minister in charge.

The basic policy states that the agency will be established through an expanded reorganization of the Cabinet Office’s existing disaster management functions and that the minister in charge will be granted the authority to submit recommendations directly to the Prime Minister. It also emphasizes the need to “eliminate bureaucratic sectionalism among ministries and agencies and exercise strong leadership.”

This may be regarded as a major turning point in Japan’s disaster management policy, and related legislation is expected to be further strengthened. In this context, we also recommend establishing a higher-level “Basic Act on Disaster Risk Reduction” that would comprehensively encompass the current Basic Act on Disaster Management and Disaster Relief Act.

<Abbreviations>

AI = Artificial Intelligence
ASEAN = Association of Southeast Asian Nations
ARCH = ASEAN Regional Capacity on Disaster Health Management
BCP = Business Continuity Plan
BCM = Business Continuity Management
CDC = Centers for Disease Control and Prevention
COP = Conference of the Parties, United Nations Framework Convention on Climate Change
COSTI = Committee on Science, Technology, and Innovation
DHEAT = Disaster Health Emergency Assistance Team
DIAS = Data Integration and Analysis System
DMAT = Disaster Medical Assistance Team
DPAT = Disaster Psychiatric Assistance Team
DWAT = Disaster Welfare Assistance Team
EMT = Emergency Medical Team
FEMA = Federal Emergency Management Agency
GEM = Global Earthquake Model
GIS = Geographic Information System
IPCC = Intergovernmental Panel on Climate Change
IRDR = Integrated Research on Disaster Risk
ISC = International Science Council
ISO = International Organization for Standardization
JCM = Joint Crediting Mechanism
JDA-DAT = Japan Dietetic Association-Disaster Assistance Team
JDR = Japan Disaster Relief Team
JICA = Japan International Cooperation Agency
JMAT = Japan Medical Association Team
JRAT = Japan Disaster Rehabilitation Assistance Team
MOWLAS = Monitoring of Waves on Land and Seafloor
NYCEM = New York City Emergency Management
OSS = Online Synthesis System
SAARC = South Asian Association for Regional Cooperation
SDGs = Sustainable Development Goals
SFDRR = Sendai Framework for Disaster Risk Reduction
SIP = Cross-ministerial Strategic Innovation Promotion Program
SNS = Social Networking Service
SPEED = Surveillance in Post-Extreme Emergencies and Disasters
STI = Science, Technology, and Innovation
TCFD = Task Force on Climate-related Financial Disclosures
TDA = Trans-disciplinary Approach
UNDRR = United Nations Office for Disaster Risk Reduction

VR = Virtual Reality
WHO = World Health Organization

<Glossary>

Inclusive

The term “inclusive” was introduced in the Sustainable Development Goals (SDGs), adopted internationally in 2015, and since has come to be widely used in a variety of contexts. In this report, the term refers to approaches that include various people and organizations.

Well-being

Well-being refers to the state of individuals and societies. Like health, it is a resource for everyday life and is shaped by social, economic, and environmental conditions. Well-being encompasses quality of life and the ability of individuals and societies to contribute to the world with meaning and purpose. Focusing on well-being makes it possible to consider the equitable distribution of resources, overall prosperity, and the degree to which sustainability is achieved. A society’s well-being can be assessed by the extent to which it is resilient, capable of taking action, and prepared to overcome challenges.

(Source) WHO: Glossary of Terms, 2021.

Crush Syndrome

This is a life-threatening condition caused by severe compression or crush injuries (the crushing of internal tissues or organs due to strong impact or compression) to the body’s skeletal muscles. It refers to localized crush injuries accompanied by systemic symptoms, in which the arms, legs, or other parts of the body are compressed, causing muscle swelling and neurological impairment in the affected areas. This condition commonly affects people trapped beneath collapsed buildings during major disasters such as earthquakes. Even if the victim appears relatively stable until rescue, their condition can deteriorate rapidly. The severity of the condition is sometimes overlooked, and the mortality rate is relatively high. In Japan, it became widely recognized following the 1995 Great Hanshin-Awaji Earthquake.

Digital Twin

A method or system that enables the anticipation and prediction of various phenomena by considering both the state of the physical world and its representation in cyberspace (virtual reality)—essentially, two counterparts or pairs (twins). In the digital space, the real world is modeled numerically, and various phenomena are predicted through computer simulations. These predictions are then verified using real-world data to improve the model's accuracy. Based on these predictive results, various measures can be considered and implemented to drive improvements.

Paradigm Shift

A fundamental change in the conceptual framework that shapes people’s perspectives and ways of thinking. In the example cited in the text, the public sector has traditionally regarded its mission as gathering, processing, and disseminating accurate information. However, as platforms such as YouTube and social media—which were not previously used for this purpose—have come to be utilized, the report suggests that the methods and mindset underlying such communication should be adapted accordingly.

Facilitator

In the narrowest sense, this refers to "efforts to conduct meetings effectively," meaning a person who facilitates meetings and oversees the smooth progress of discussions. In the broadest sense, it refers to a person who creates a variety of knowledge-creation spaces and promotes an organization's creativity, transformation, problem-solving, consensus-building, and learning.

(Source) NPO Japan Facilitation Association, https://www.faj.or.jp/facilitation/application/

A catalyst who is present on-site and combines the functions of moderation, problem-solving, and expert advice.

(Source) Science Council of Japan, Committee on the International Development of Science and Technology-based Disaster Prevention and Mitigation Policies, Recommendation: "Building a Sustainable Global Society by Strengthening Disaster Resilience: Developing an 'Online Synthesis System (OSS)' and Fostering 'Facilitators' to Realize Consilience," September 18, 2020.

Phase-Free

This term refers to concepts or products that are effective or applicable in both normal and emergency situations (phases). If an item used in everyday life is also useful during a disaster, it is considered a phase-free product. In recent years, this concept has attracted increasing attention as a means of ensuring an appropriate quality of life across all phases.

Resilience

Simply put, resilience refers to the ability of individuals, societies, and organizations to overcome adversity. The term "disaster resilience," defined in the 2009 glossary of the United Nations Office for Disaster Risk Reduction (UNDRR, then known as UNISDR), was redefined by the United Nations General Assembly in 2017 as "resilience," as follows:

"The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management."

Source) UNDRR, "Resilience": https://www.undrr.org/terminology/resilience

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