
**Resilience of buildings and civil
engineering works**

**iTeh STANDARD PREVIEW
(standards.iteh.ai)**

[ISO/TR 22845:2020](https://standards.iteh.ai/catalog/standards/sist/b19a4304-b1f4-4a40-ad51-1c00756a74f0/iso-tr-22845-2020)

<https://standards.iteh.ai/catalog/standards/sist/b19a4304-b1f4-4a40-ad51-1c00756a74f0/iso-tr-22845-2020>



iTeh STANDARD PREVIEW (standards.iteh.ai)

[ISO/TR 22845:2020](https://standards.iteh.ai/catalog/standards/sist/b19a4304-b1f4-4a40-ad51-1c00756a74f0/iso-tr-22845-2020)

<https://standards.iteh.ai/catalog/standards/sist/b19a4304-b1f4-4a40-ad51-1c00756a74f0/iso-tr-22845-2020>



COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

| | Page |
|--|-----------|
| Foreword | v |
| Introduction | vi |
| 1 Scope | 1 |
| 2 Normative references | 1 |
| 3 Terms and definitions | 1 |
| 4 Concept | 1 |
| 4.1 Perspectives in different contexts..... | 1 |
| 4.2 Definitions in ISO documents..... | 2 |
| 5 Disaster risk | 3 |
| 5.1 General..... | 3 |
| 5.2 Climate-induced..... | 4 |
| 5.3 Earthquake-induced..... | 5 |
| 5.4 Human-induced..... | 6 |
| 6 Countermeasure | 6 |
| 6.1 Strategy..... | 6 |
| 6.2 Measurement..... | 8 |
| 7 Compilation of existing information | 9 |
| 7.1 Concept..... | 9 |
| 7.1.1 Terminology: Resilience ^[10] | 9 |
| 7.1.2 Built-in resilience through disaster risk reduction: operational issues ^[36] | 9 |
| 7.1.3 Four concepts for resilience and the implications for the future of resilience engineering ^[37] | 9 |
| 7.1.4 Sendai Framework for Disaster Risk Reduction 2015-2030 ^[38] | 9 |
| 7.2 Climate-induced..... | 10 |
| 7.2.1 Global Assessment Report on Disaster Risk Reduction ^[39] | 10 |
| 7.2.2 Emergency Events Database (EM-DAT) ^[40] | 10 |
| 7.2.3 Global Warming of 1,5 °C ^[32] | 10 |
| 7.2.4 Climate Change 2014: Synthesis Report ^[41] | 10 |
| 7.2.5 Climate Change 2013: The Physical Science Basis ^[30] | 10 |
| 7.2.6 Global Climate Risk Index ^[42] | 11 |
| 7.2.7 Climate Change Knowledge Portal (CCKP) ^[43] | 11 |
| 7.2.8 CREAT Climate Scenarios Projection Map ^[44] | 11 |
| 7.2.9 Climate Projections ^[45] | 11 |
| 7.2.10 UK Climate Projections (UKCP) ^[46] | 11 |
| 7.2.11 Climate Atlas of Canada ^[47] | 11 |
| 7.2.12 CEDIM Risk Explorer Germany ^[48] | 12 |
| 7.2.13 Sea Level Rise Viewer ^[49] | 12 |
| 7.2.14 Will half a degree make a difference? Robust projections of indices of mean and extreme climate in Europe under 1,5 °C, 2 °C, and 3 °C global warming ^[50] | 12 |
| 7.2.15 North China Plain threatened by deadly heatwaves due to climate change and irrigation ^[51] | 12 |
| 7.2.16 Climate Change 2014: Impacts, Adaptation, and Vulnerability ^[52] | 13 |
| 7.2.17 National Climate Assessment ^[53] | 13 |
| 7.2.18 Myanmar National Framework for Community Disaster Resilience ^[54] | 13 |
| 7.3 Earthquake-induced..... | 13 |
| 7.3.1 Global Seismic Risk Map ^[55] | 13 |
| 7.3.2 Global Earthquake Fatalities and Population ^[56] | 13 |
| 7.3.3 Earthquakes ^[57] | 14 |
| 7.3.4 China Earthquake Networks ^[58] | 14 |
| 7.3.5 Japan Meteorological Agency ^[59] | 14 |
| 7.3.6 2011 Christchurch earthquake ^[60] | 14 |

| | | |
|--------|--|-----------|
| 7.4 | Human-induced — Global Terrorism Index 2018: Measuring the impact of terrorism ^[35] | 14 |
| 7.5 | Strategy | 15 |
| 7.5.1 | Community resilience planning guide for buildings and infrastructure systems - Volume I ^[61] | 15 |
| 7.5.2 | Climate-Resilient Buildings and Core Public Infrastructure Initiative (CRBCPI) ^[62] | 15 |
| 7.5.3 | RELi ^[63] | 15 |
| 7.5.4 | LEED IPpc98/IPpc99/IPpc100 ^{[64],[65],[66]} | 15 |
| 7.5.5 | DGNB criteria "Local environment" ^[67] | 16 |
| 7.5.6 | BREEAM Adaption to Climate Change ^[68] | 16 |
| 7.5.7 | Durability and Climate Change: Changing climatic loads as may affect the durability of building materials, components and assemblies ^[69] | 16 |
| 7.5.8 | Ocean at the door ^[70] | 16 |
| 7.5.9 | Inundation Mapping ^[71] | 16 |
| 7.5.10 | Climate Resiliency Design Guidelines – Version 3.0 ^[72] | 16 |
| 7.5.11 | Coastal Flood Resilience Design Guidelines ^[73] | 17 |
| 7.5.12 | Flood Resilient Homes Program ^[74] | 17 |
| 7.5.13 | Designing flood resilience into new buildings ^[75] | 17 |
| 7.5.14 | Resilient Design Institute ^[8] | 17 |
| 7.5.15 | Boston’s Spaulding Rehabilitation Center designed with rising sea levels in mind ^[76] | 17 |
| 7.5.16 | Cognitive infrastructure – a modern concept for resilient performance under extreme events ^[77] | 17 |
| 7.5.17 | A framework to quantitatively assess and enhance the seismic resilience of communities ^[78] | 18 |
| 7.5.18 | Earthquake Disaster Simulation of Civil Infrastructures: From Tall Buildings to Urban Areas ^[79] | 18 |
| 7.5.19 | Resilience of a hospital Emergency Department under seismic event ^[80] | 18 |
| 7.5.20 | Strict building codes helped Anchorage withstand quake ^[81] | 18 |
| 7.5.21 | 2019 Ridgecrest earthquakes ^[82] | 19 |
| 7.5.22 | Integrating counter-terrorist resilience into sustainability ^[83] | 19 |
| 7.5.23 | Resilient Design Tool: For Counter Terrorism ^[84] | 19 |
| 7.5.24 | Climate change resilience strategies for the building sector: examining existing domains of resilience utilized by design professionals ^[85] | 19 |
| 7.6 | Measurement | 20 |
| 7.6.1 | USRC Building Rating System ^[86] | 20 |
| 7.6.2 | B-READY ^[87] | 20 |
| 7.6.3 | FORTIFIED Commercial™ ^[88] | 20 |
| 7.6.4 | Attributes and metrics for comparative quantification of disaster resilience across diverse performance mandates and standards of building ^[89] | 20 |
| 7.6.5 | The Resilient City ^[90] | 21 |
| 7.6.6 | Seismic Performance Assessment of Buildings ^[91] | 21 |
| 7.6.7 | Standard for Seismic Resilience Assessment of Building ^[92] | 21 |
| 7.6.8 | REDi™ Rating System ^[93] | 21 |
| 7.6.9 | Framework for analytical quantification of disaster resilience ^[94] | 21 |
| | Bibliography | 22 |

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 59, *Buildings and civil engineering works*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Resilience is not a new concept. It is widely used in many fields such as human psychology, ecology, disaster risk management and product specification.

With an increasing impact, resilience is contributing to sustainable development on humanitarian issues at a global level, focusing on providing the general public, including vulnerable groups, with an environment that can better adapt to future disaster risks.

In view of the increasing demand for resilience of buildings and civil engineering works, this document attempts to collect and summarize typical relevant existing information to provide reference for research and standard preparation. Information is aggregated mainly on concept, disaster risk and countermeasure:

- 1) For concept, this document sorts out some perspectives of resilience in different contexts and definitions of resilience that have appeared in ISO documents.
- 2) For disaster risk, this document describes three categories of disaster risk closely related to buildings and civil engineering works, i.e. climate-induced, earthquake-induced and human-induced, and indexes some typical related reports and data.
- 3) For countermeasure, this document summarizes typical relevant information from the two dimensions of strategy and measurement. Some of this information is relatively mature, already in the form of standards, guidelines, etc., some are implemented in cases, and some are at the research stage.

iTeh STANDARD PREVIEW

Resilience of buildings and civil engineering works involves interested parties and participants which can include specialists in the field of buildings and civil engineering works (such as material manufacturers, engineers, architects, constructors and estimators, etc.), scientists, standard setters, investors and financial institutions, regulatory agencies, communities, residents and occupiers, government administrative departments, etc.

<http://www.iso.org/standards/catalog/standards/sist/b19a4304-b1f4-4a40-ad51-1c00756a74f0/iso-tr-22845-2020>

Resilience of buildings and civil engineering works

1 Scope

This document provides an index of typical existing information on concept, disaster risk and countermeasure for resilience of buildings and civil engineering works.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

4 Concept

4.1 Perspectives in different contexts

Resilience is derived from the Latin word "resilio" for bounce^[2] and in most cases its use retains this concept either literally or figuratively. The Oxford Dictionary of English gives two explanations of resilience, "the ability of a substance or object to spring back into shape" and "the capacity to recover quickly from difficulties"^[3], which could be understood as mechanical and functional resilience respectively. Some domains also have understandings of resilience from different perspectives. [Table 1](#) is a summary of some typical descriptions of resilience in different contexts, extracted from the literature found.

Table 1 — Resilience in different contexts

| Context | Perspective | Citation |
|-----------------|---|---|
| Ecology | A measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables. | Holling, C.S. 1973 ^[4] |
| Risk management | Resilience is the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back. | Wildavsky, A. 1988 ^[5] |
| | The ability to recoil effectively from adversity and enhancing the likelihood of exposure to adversity leading to growth. | Paton, D. and Johnston, D. 2001 ^[6] |
| Building | A resilient built environment should be designed, located, built, operated and maintained in a way that maximises the ability of built assets, associated support systems (physical and institutional) and the people that reside or work within the built assets, to withstand, recover from, and mitigate for the impacts of extreme natural and human-induced hazards. | Bosher, L. 2008 ^[7] |
| | Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. | Resilient Design Institute ^[8] |

Table 1 (continued)

| Context | Perspective | Citation |
|---------|---|---------------------------------------|
| Urban | The capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience. | Rockefeller Foundation ^[9] |
| | 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. | UNDRR ^[10] |

4.2 Definitions in ISO documents

There are 26 hits when searching for definitions of “resilience” on the ISO Online Browsing Platform (ISO OBP). In material and product standards, different forms of mechanical resilience are defined. Standards dealing with systems, on the other hand, focus on forms of functional resilience appropriate to the systems. [Table 2](#) shows examples of these two types of definitions in ISO documents.

Table 2 — Definitions in ISO documents

| Type | Term | Definition | Source |
|-----------------------|---|--|------------------------|
| Mechanical resilience | resilience | ability of ceramic fibres to spring back after compression to 50 % of thickness | ISO 836:2001, 113 |
| | resilience | ability of a textile floor covering to regain thickness after a static or dynamic compression | ISO 2424:2007, 9.1.2.1 |
| | rebound resilience | ratio between the returned and the applied energy of a moving mass which impacts a test piece | ISO 4662:2017, 3.1 |
| | elasticity, noun springiness, noun resilience, noun | mechanical textural attribute relating to: the rapidity of recovery from a deforming force; and the degree to which a deformed material returns to its original condition after the deforming force is removed | ISO 5492:2008, 3.50 |

Table 2 (continued)

| Type | Term | Definition | Source |
|---------------------------------|--|---|--|
| Functional resilience of system | resilience | ability of an organization to resist being affected by disruptions | ISO/IEC 27031:2011, 3.14 |
| | resilience | ability to absorb and adapt in a changing environment | ISO 22300:2018, 3.192 |
| | resilience fault tolerance | tolerance of a system to malfunctions or capacity to recover functionality after stress | ISO 18457:2016, 3.9 |
| | organizational resilience | ability of an organization to absorb and adapt in a changing environment | ISO 22316:2017, 3.4 |
| | resilience | ability to recover from security compromises or attacks | ISO/IEC 29180:2012, 3.2.10 |
| | resilience | adaptive capacity of an organization in a complex and changing environment | ISO Guide 73:2009, 3.8.1.7 ISO 28002:2011, 3.44 ISO 18788:2015, 3.47 ISO 37101:2016, 3.33 ISO 37100:2016, 3.1.3 ISO 37123:2019, 3.6 |
| | fault tolerance resilience | ability of a functional unit to continue to perform a required function in the presence of faults or errors | ISO/IEC 2382:2015, 2123055 |
| resilience | capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation | ISO 14080:2018, 3.1.3.6 | |

According to the ISO OBP, there are currently some 320 standards in which reference is made to resilience, by title and/or content, although often without defining what is meant by the term. Below are some examples of ISO standards which explicitly focus on resilience. Two of these relate to mechanical resilience and one to functional resilience of systems:

- ISO 8307, prepared by ISO/TC 45, Rubber and rubber products;
- ISO 4662, prepared by ISO/TC 45, Rubber and rubber products;
- ISO 28002, prepared by ISO/TC 292, Security and resilience.

The following standard is concerned with mechanical resilience but refers to it as "elastic recovery":

- ISO 7389, prepared by ISO/TC 59/SC 8, Sealants.

5 Disaster risk

5.1 General

Since resilience is the ability to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard^[10], it is necessary to understand the status of disaster risks, which is a prerequisite for the development of resilience standards for buildings and civil engineering works.

This document collects three categories of disaster risks closely related to buildings and civil engineering works: climate-induced, earthquake-induced and human-induced, and indexes some related reports and data sets of these disaster situations. Since the life of a building or civil engineering

work will be tens or even hundreds of years, it is also necessary to pay attention to future possibilities of disaster risks.

5.2 Climate-induced

For climate-induced disaster risks, this document mainly collects some typical reports and data. From them, the following can be seen:

- 1) **The frequency and economic losses of global meteorological disasters have increased:** Under the background of global climate change, the frequency and economic losses of meteorological disasters have an obviously upward trend, being detrimental to the safety of human life and property and the sustainable economic and social development.
- 2) **The global climate risks will continue rising:** Looking ahead to the coming decades of the 21st century, global climate risks will continue rising due to climate change and increased exposure and vulnerability brought about by urbanization. Among them, changes of risks such as **high temperature, low temperature, heavy precipitation, tropical cyclone, drought and sea level rise** can have certain impact on buildings and civil engineering works. These impacts have important implications for considering the resilience standard of buildings and civil engineering works in the long term. [Table 3](#) shows projected changes of global annual mean temperature, high temperature, low temperature, heavy precipitation, tropical cyclone, drought and sea level rise in the 21st century, extracted from the collected data.

Table 3 — Projected changes of global annual mean temperature, high temperature, low temperature, heavy precipitation, tropical cyclone, drought and sea level rise in the 21st century under different emission scenarios [30],[31],[32],[33]

| Annual mean temperature | RCP2.6 | | RCP4.5 | | RCP8.5 | |
|----------------------------|---|-------------------|------------------|-------------------|------------------|-------------------|
| | Mid-21st century | Late 21st century | Mid-21st century | Late 21st century | Mid-21st century | Late 21st century |
| | (1,0 ± 0,3) °C | (1,0 ± 0,4) °C | (1,4 ± 0,3) °C | (1,8 ± 0,5) °C | (2,0 ± 0,4) °C | (3,7 ± 0,7) °C |
| High temperature | The 1-in-20-year extreme daily maximum temperature will likely increase by about 1 °C to 3 °C and 2 °C to 5 °C by the mid- and late 21st century respectively, depending on different regions and emission scenarios. A 1-in-20-year hottest day is likely to become a 1-in-2 and 1-in-5-year event by the end of 21st century for the high and low emission scenarios respectively. The heat related risks increase with greater degrees of warming. 13,8 % of the world population would be exposed to severe heat waves at least once every 5 years under 1,5 °C of global warming, with a threefold increase (36,9 %) under 2 °C warming. | | | | | |
| Low temperature | Cold days and cold nights are very likely to become much less frequent. Further decreases in the number of cold days/nights and an increase in overall temperature of cold extremes would occur under 1,5 °C of global warming compared to under the present-day climate (1 °C of warming), with further changes occurring towards 2 °C of global warming. And in some regions, cold-related mortality is projected to decrease with increasing temperatures. | | | | | |
| Heavy precipitation | A 1-in-20-year annual maximum daily precipitation amount is likely to become a 1-in-5 to 1-in-15-year event by the end of the 21st century in most regions under higher emission scenarios. Projected increase in heavy precipitation will contribute to rain-generated local flooding in some catchments or regions. Over the global land monsoon region, an estimated 25 % (18 % to 41 %) and 36 % (22 % to 46 %) of area and population, respectively, could be relieved from the baseline 1-in-20-year events over the present-day level, if global warming were limited to 1,5 °C instead of 2 °C. | | | | | |
| Tropical cyclone | The global frequency of tropical cyclones will either decrease or remain essentially unchanged in 21st century. Average tropical cyclone maximum wind speed will likely increase, although it is possible that increases will not occur in all ocean basins. There is limited evidence that the global number of tropical cyclones will be lower under 2 °C of global warming compared to under 1,5 °C of warming, but with an increase in the number of very intense cyclones. In coastal regions, increases in heavy precipitation associated with tropical cyclones combined with increased sea levels can lead to increased flooding. | | | | | |

Table 3 (continued)

| | | | |
|-----------------------|--|---|---|
| Drought | Droughts will intensify in the 21st century in some seasons and areas, and extreme drought is projected to act as the normal climatological state by the end of the 21st century under the high emission scenarios in many mid-latitude locations. Duration of droughts are also projected to increase in some regions of the world. | | |
| Sea level rise | 0,4 m (0,26 m to 0,55 m) rise by the late 21st century | 0,47 m (0,32 m to 0,63 m) rise by the late 21st century | 0,63 m (0,45 m to 0,82 m) rise by the late 21st century |

Meanwhile, there are some online map tools for visualizing global or national climate projections. Some of them show changes in risks such as temperature, precipitation and sea level rise in different periods of the 21st century under different emission scenarios. These projections can play a supporting role in the decision-making of investment, standards and design for the resilience of buildings and civil engineering works.

Some countries and organizations have proposed initiatives and action plans to address climate change, targeting parts of cities, communities, buildings, infrastructure, etc., which can have certain implications for the resilience of buildings and civil engineering works.

5.3 Earthquake-induced

For earthquake-induced disaster risks, this document mainly collects some typical data on seismic risk. From them, the following can be seen:

- 1) **The global seismic risk remains severe:** Earthquake is one of the most catastrophic natural hazards to human beings. With rapid urbanization in recent years, an increasing amount of population as well as property will be exposed to seismic risks. At the same time, aging and changes in strength and stiffness can also impair the seismic safety and serviceability of the existing engineering structure.
- 2) **It is challenging to meet the demand for resilience via traditional seismic resistance methods:** In certain recent earthquakes, although some buildings did not collapse, they could hardly be repaired due to the severe damage, causing enormous economic loss and substantial social impact. For example, after the Christchurch earthquake in New Zealand in 2011, none of the 51 tallest buildings in the city collapsed owing to the rigorous seismic standards of New Zealand. Nonetheless, 37 of these tall buildings had to be demolished due to their severe damage and potentially high costs to repair^[34]. Furthermore, other seismic resilience issues also occurred in the Great East Japan earthquake in 2011, and in the Haiti earthquake in 2010.

These issues indicate that resilience enhancement of buildings and communities is essential, which is illustrated in [Figure 1](#).

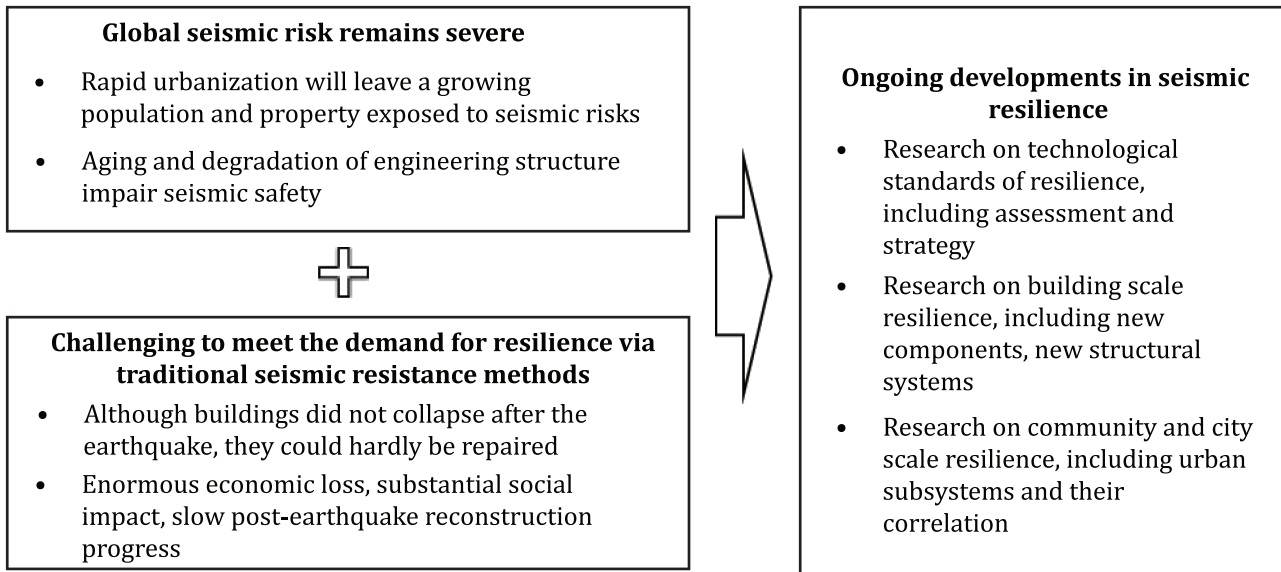


Figure 1 — Seismic resilience is essential

Meanwhile, some online map tools have been developed for the visualization of global or national seismic risk. They can support decision-making for investment, standardization and design related to seismic resilience of buildings and civil engineering works.

5.4 Human-induced

For human-induced disaster risks, this document focuses on collecting relevant information on global terrorist attacks. From them, the following can be seen:

- 1) **Global terrorist attacks are increasing:** Incidents involving hostage-taking, assassination, and attacks on facilities or infrastructure all increased over tenfold in the past two decades^[35].
- 2) **Counter-terrorism engineering design is increasingly important for buildings and communities:** Some countries are now beginning to consider how building and engineering professionals can assist in reducing the impact of terrorism through design.

6 Countermeasure

6.1 Strategy

At present, practice and research on the resilience strategy of buildings and civil engineering works have progressed to a certain extent. The collected data shows the following characteristics:

In different forms: Some strategies are relatively mature, refined into systems such as standards and guidelines; some are implemented in cases; and some are still at the research stage.

For different types of disaster risks: Some systems are broad-spectrum, targeting multiple types of disaster risks, while some focus on one type.

Consider the future: For the sake of the future, some climate related strategies consider the impact of climate change on buildings and civil engineering works.

Table 4 sorts out some typical sources of these strategies according to the two dimensions of disaster risk categories (climate-induced/earthquake-induced/human-induced) and forms (system, case, research).