CDRI
Coalition for Disaster Resilient Infrastructure

# INFRASTRUCTURE STANDARDS - BUILDING BLOCKS FOR A RESILIENT FUTURE

## Technical Note


By
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Under CDRI Young Professionals Programme

## Coalition for Disaster Resilient Infrastructure

The Coalition for Disaster Resilient Infrastructure (CDRI) is a global multi-stakeholder partnership of national governments, UN agencies, programmes, multilateral development banks financing mechanisms, private sector, academic and knowledge institutions. CDRI is committed to working with various stakeholders to promote the resilience of infrastructure globally.

## CDRI Young Professionals Programme

CDRI hosts Young Professionals Programme as part of its overall strategy to address the challenges of building resilience into infrastructure systems and associated development globally. Under the guidance of identified mentors, the Young Professionals participate in the implementation of projects by contributing to methodological soundness, rigour, validation, and timely achievement of the goals of CDRI. The Young Professionals Programme is designed as an immersive learning experience to enable young professionals to pick up critical knowledge and skills for taking forward the disaster resilient infrastructure agenda through their professional journeys. Young minds from leading institutions across the globe gain a practical understanding of formulating and implementing initiatives that promote resilient infrastructure through their involvement in CDRI's programmes.

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# EXECUTIVE SUMMARY

Increasing frequency and severity of disasters and extreme weather events affect the planning, development and construction of infrastructure as well as investment decisions. It is the need of hour to build infrastructure in a way to withstand the present and future disaster and climate risks. Technical standards play a crucial role in ensuring that built infrastructure is technically sound and financially feasible. However, limited attention is given to existing standards towards incorporating disaster and climate risks and building in resilience. Gaps in implementation of standards in planning, implementation and management phases of the entire lifecycle of infrastructure indicate wide scope for incorporating principles of resilience in technical standards.

This technical note intends to build a case for identification of gaps in existing set of requirements of technical standards for development of disaster resilient infrastructure. Landscape review of existing standards highlight the efforts undertaken by some countries in revising and updating their existing technical standards to address the challenges of disaster and climate risks as well as the current limitations in adoption of standards in infrastructure development. Further, the note emphasizes the need for international organizations as the Coalition for Disaster Resilient Infrastructure (CDRI) to facilitate multi-stakeholder collaborations for effective implementation of technical standards for building disaster resilient infrastructure.

# ACRONYMS & ABBREVIATIONS

| | |
|---|---|
| AISI | Aligned Indicators for Sustainable Infrastructure |
| BDN | Blue Dot Network |
| BIS | Bureau of Indian Standards |
| BMVBS | Federal Ministry of Transport, Building and Urban Affairs, Germany |
| BSI | British Standards Institution |
| CARICOM | Caribbean Community |
| CCBFC | Canadian Commission on Building and Fire Codes |
| CDRI | Coalition for Disaster Resilient Infrastructure |
| CEEQUAL | The Civil Engineering Environmental Quality Assessment & Award Scheme |
| CEN | European Committee for Standardization together |
| CENELEC | European Committee for Electrotechnical Standardization |
| Climate-KIC | Climate – Knowledge and Innovation Community |
| CMSI | Climate Measurement Standards Initiatives |
| CRED | Centre for Research on the Epidemiology of Disasters |
| CROSOQ | CARICOM Regional Organisation for Standards and Quality |
| DIS | Draft International Standard |
| DRI | Disaster Resilient Infrastructure |
| DWD | Deutscher Wetterdienst |
| EM-DAT | Emergency Events Database |
| ETSI | European Telecommunications Standards Institute |
| EU | European Union |
| GIH | Global Infrastructure Hub |
| GRESB | Global Real Estate Sustainability Benchmark |

| | |
|---|---|
| IDB | Inter-American Development Bank |
| IEC | International Electrotechnical Commission |
| IMF | International Monetary Fund |
| IRC | Indian Road Congress |
| ISO | International Organization for Standardization |
| ITU | International Telecommunication Union |
| LEED | Leadership in Energy and Environmental Design |
| NISI | Northern Infrastructure Standardization Initiative |
| NIST | National Institute of Standards and Technology |
| QII | Quality Infrastructure Investment |
| RDSO | Research Design and Standards Organisation |
| SDG | Sustainable Development Goal |
| SDO | Standard Developing Organization |
| SFDRR | Sendai Framework for Disaster Risk Reduction |
| SSO | Standard Setting Organization |
| SuRe | Standard for Sustainable and Resilient Infrastructure |
| UNDRR | United Nations Office for Disaster Risk Reduction |
| USA | United States of America |

# 1 | INFRASTRUCTURE STANDARDS - BUILDING BLOCKS FOR A RESILIENT FUTURE

## Need for Disaster Resilient Infrastructure

Infrastructure projects are key drivers of economic growth. For infrastructure, aging assets as well as increasing demand and investment gaps exacerbate the physical risks of disasters and climate change at an unprecedented rate. The Emergency Events Database (EM-DAT) estimates that the total damages from disasters over the last two decades were US$2.83 billion and that these disasters affected more than 4.2 billion people (CRED-EMDAT, 2021)[1]. To reduce economic losses and damages due to disruption of infrastructure, it is imperative to safeguard the resilience of infrastructure to disasters and extreme weather events.

The rationale for disaster resilient infrastructure (DRI) reflects the need to protect infrastructure assets from damages due to disasters and climate extreme events as shown in Figure 1. The need of infrastructure assets for protection of society during disasters and in ensuring continuity of service during post disaster recovery is crucial. Hence, DRI is the key by which individuals, communities, government and private organizations can structure themselves to learn from past disasters to reduce future risks. There is an urgent need to make infrastructure systems further resilient to the physical impacts of natural hazards and extreme climate related events. Estimates suggest that by 2030, infrastructure development will need an investment of around $80 trillion (Bhattacharya et al., 2016). The urgency for development of resilient infrastructure for sustainable development is also addressed in United Nation's

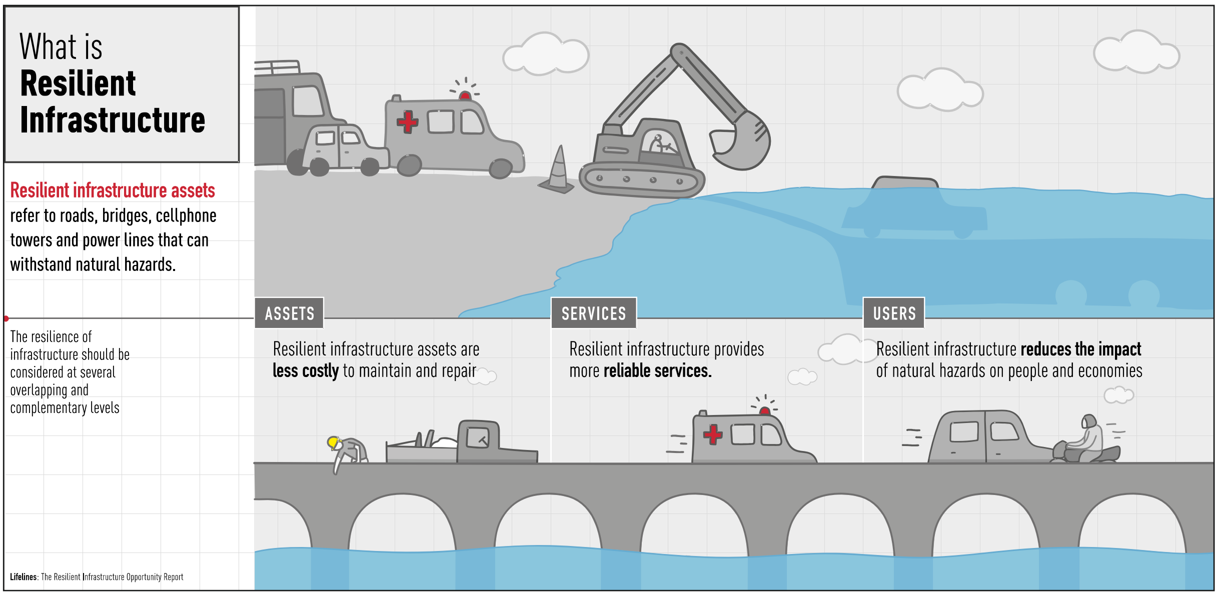


**Figure 1:** Need for disaster resilient infrastructure

*Source: Prepared by CDRI*

[1]*The Centre for Research on the Epidemiology of Disasters - Emergency Events Database (EM-DAT), 2021. Accessed from https://www.emdat.be/ on 10 October 2021.*

Sustainable Development Goals (Figure 2). This reflects a need to strengthen infrastructure resilience to disasters and climate impacts by considering resilience from the beginning, rather than take the risk of locking in vulnerability for many decades to come.

*Improved decision making for disaster resilience and climate change adaptation requires in-depth knowledge of existing standards.* Additionally, it is important to understand the pre-conditions for effective utilization of existing standards. Hence, a focus on standards complements other aspects such as financial incentives for project developers to improve asset resilience, effective use and development of enabling technology, and promotion of effective risk governance.


**Figure 2:** Sustainable Development Goals (SDGs) from targets related to resilient infrastructure

*Source: Compiled by author from United Nations, 2021*

# 2 | ABOUT THIS NOTE

Given the current pace and wide scale of investments in infrastructure, there is a strong urgency to achieve infrastructure resilience. Such investments will define the future path for years to come. This will impact either in addressing disaster risks to develop sustainably or locking in to unsustainable development and wasting resources on inadequate infrastructure (Rydge et al., 2015). Estimates suggest that the current trend of infrastructure investments is 19 percent lower than the global infrastructure investment needs by 2040, amounting to an average of $3.7 trillion per year (GIH, 2017). Consistent codes, standards, guidelines and rating systems strengthen efforts to ensure the quality and consistency of infrastructure and services. Standards assist the infrastructure development process in various ways by outlining a systemic approach for identifying and managing risks. Additionally, standards set planning, design, technical, management and operation norms to attain the anticipated outcome in most circumstances. These standards must be informed by disaster, resilience, and climate change concepts such as uncertain nature of present and future climatic conditions, infrastructure systems' ability to withstand various climate change impacts and their capacity to adapt to new circumstances and reduce vulnerability to disasters, among others.

*This technical note intends to build the case for developing and updating of technical standards to build the principles of resilience – robustness, redundancy, resourcefulness, responsiveness, flexibility, good governance and recovery across the entire lifecycle of infrastructure systems. It identifies the challenges in current standards and suggests ways to address them to enhance the resilience of infrastructure to disaster and climate extreme events.* The note navigates through the typology of standards and global landscape of standard developing organizations (SDOs)/ standards setting organizations (SSOs) to map various actors working towards integrating disaster resilience in different phases of the lifecycle of infrastructure. Enhancing nationally and regionally context-specific standards, codes, specifications and guidelines for planning, design and management of infrastructure systems is one of the strategies for promoting DRI. This document is aligned with the mission of the Coalition for Disaster Resilient Infrastructure (CDRI) to support countries in upgrading their systems towards disaster and climate resilience of existing and new infrastructure systems.

# 3 | TYPOLOGY OF STANDARDS

*"The term 'standards and codes' refers to sets of provisions relating to the institutional environment—the 'rules of the game'—within which economic and financial policies are devised and implemented."*

*International Monetary Fund, 2021*

**Table 1**: Typology of standards

| No. | Typology of Standards | Details | Nature of Document |
|---|---|---|---|
| 1. | Codes | ▪ Standards synthesized by legislation and/ or regulation at appropriate jurisdictional level<br>▪ Usually refers to the minimum technical requirements for ensuring the safety of infrastructure delivery<br>E.g., Eurocodes, International Building Code 2018 (USA), and National Model Construction Codes 2015 (Canada) | Mandatory |
| 2. | Standards | ▪ Technical and/ or managerial definitions outlining specifications, guidelines, and toolkits to encourage consistent use of a specific topic at one or more stages of the infrastructure lifecycle<br>E.g., ISO 37123:2019, ISO 37122:2018, ISO/DIS 14097, ISO/DIS 14091, ISO 14080:2018, etc. | Voluntary |
| 3. | A. International Standards | ▪ Developed by global SDOs such as International Organization for Standardization (ISO), International Telecommunication Union (ITU) and International Electrotechnical Commission (IEC) for countries to adopt for national use | Voluntary/ Mandatory |
| | B. Regional Standards | ▪ Prepared by a specific region<br>E.g., European Union's EU standards, CARICOM Regional Organisation for Standards and Quality (CROSOQ) | Voluntary/ Mandatory |

| No. | Typology of Standards | Details | Nature of Document |
|---|---|---|---|
| | C. National Standards | ▪ Developed either by a national SDO/ body or other accreditation bodies<br>E.g., Bureau of Indian Standards (BIS) for India, Standards Australia for Australia | Mandatory |
| 4. | Guidelines | ▪ Recommendations or research to assist in developing standards. It may also include infrastructure development best practices.<br>E.g., Sustainable Framework from IDB (2018), Disaster Resilience Scorecard for Cities (UNDRR, 2017), etc. | Voluntary |
| 5. | Rating systems | ▪ Frameworks including metrics from standards, codes, and guidelines for evaluating infrastructure projects based on performance levels from planning to management phases<br>E.g., LEED, SuRe ®, CEEQUAL, Envision, IS Rating Tool, GRESB[2] | Voluntary |

*Source: Compiled by author from various sources such as Standards Australia, ISO and GCA*

Most of the standards, rating systems, and guidelines are voluntary, whereas codes are governed by law and thus, mandatory. International standards are voluntary for countries to adopt, whereas regional standards are either voluntary or mandatory in nature. Majority of national standards are mandatory to adopt for infrastructure development in the respective countries. Standards assist in formulating technical regulations which may be termed as 'codes', and are, hence, compulsory for implementation in infrastructure development (Cançado and Mullan, 2020).[3]

*[2]Some rating systems are also considered standards/ have standards built within. E.g., SuRe is a voluntary standard enabling rating of infrastructure, while GRESB is a benchmarking tool, that includes GRESB standards within it.*
*[3]While Table 1 provides typology of standards, codes, rating systems and guidelines, these will be collectively referred to as 'standards' throughout this document.*

# 4 | GLOBAL LANDSCAPE OF STANDARD DEVELOPING ORGANIZATIONS IN INFRASTRUCTURE

Key international organizations involved in developing standards for infrastructure sectors include: (i) International Organization for Standardization (ISO); (ii) International Telecommunication Union (ITU); and (iii) International Electrotechnical Commission (IEC). Also, the European Committee for Standardization (CEN) together with European Committee for Electrotechnical Standardization (CENELEC) and European Telecommunications Standards Institute (ETSI) are officially recognized by the EU Regulation (1025/2012) as competent authorities in the domain of voluntary technical standardization. Several national standards development organizations have developed risk management guidelines including climate change and disaster resilience considerations for infrastructure. For example, Community Resilience Planning Guide for Buildings and Infrastructure Systems developed by the US National Institute of Standards and Technology (NIST) (2015), Climate Change Adaptation—Adapting to Climate Risks Using ISO 9001, ISO 14001, BS 25999, and BS 31100 developed by British Standards Institution and Council of Standards Australia's Climate Change Adaptation for Settlements and Infrastructure: A Risk based Approach (2013), etc.

Some recent initiatives of multi-stakeholder collaborations promoting the development of consistent and comparable disclosures, as well as the adoption of reliable standards for global infrastructure development in an inclusive framework include the Blue Dot Network (BDN), Quality Infrastructure Investment (QII), Climate Measurement Standards Initiatives (CMSI) by Climate-KIC, and the Aligned Indicators for Sustainable Infrastructure (AISI).

Many international standards, which are voluntary for countries to adopt, have already incorporated resilience elements, towards achieving targets of the Sendai Framework for Disaster Risk Reduction (SFDRR) (2015-2030) and contribute to the achievement of SDGs. For example, the ISO inventory of existing guidelines and approaches on sustainable development and resilience in cities (2017), ISO 14090 adaptation to climate change - principles, requirements and guidelines (2019), ISO 37123 for measuring cities performance on resilience indicators (2019) and the European civil engineering technical standards developed by CEN — the Eurocodes, especially for energy and transport infrastructure (European Commission, 2014), etc.

In recent decades, technical standards and regulatory codes are being revisited and revised to achieve disaster resilience in view of increased frequency and severity of extreme climate events. For instance, in 2014, the New York state utilities regulator (Public Service Commission) approved a settlement requiring power utility Con Edison to employ cutting-edge measures to anticipate and protect its electric, gas, and steam frameworks from the effects of climate change (Vicaud and Jouen, 2015).

Also, there are multiple SDOs, including governmental and private entities in countries. For example, in the Indian context, consistent standards for planning, design and construction of sector-specific infrastructure are developed by various bodies, including the national standard body, Bureau of Indian Standards (BIS), established for the harmonious development of standardization practices, marking, and quality certification of goods, as well as for other related matters. The recent standard, IS 17000: 2019 on Sustainable Development of Habitats — Indicators, identifies core and supporting indicators for 16 essential infrastructure sectors in terms of directing and evaluating the performance management of city services and quality of life. However, this does not take disaster and climate risks into account. Other entities include the registered society of Indian Road Congress (IRC), for developing and updating standards, codes of practice and guidelines under the road sector and the Research Design and Standards Organisation (RDSO) — a government organization under the Ministry of Railways, developing standards and specifications for the Indian railways.

The process for developing technical standards for infrastructure is not uniform across several sector-specific SDOs globally, resulting in lack of quality assurance and appropriateness of the standards themselves (Sapatnekar et al., 2018). This calls for developing performance-based design and construction standards (incorporating operation and maintenance [O&M] aspects) through improved regulations, cutting-edge technologies, financial and non-financial incentives and innovations.

The following table gives examples of revision of standards undertaken by multiple countries to address climate change and disaster resilience.

**Table 2:** Revision of standards by countries to address climate change and disaster resilience

| Country | Revision of standards/guidelines/codes to address climate change and disaster resilience |
|---|---|
| Australia (Engineers Australia) | • Australian Rainfall and Runoff handbook<br>• Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering (2017) |
| Australia (Austroads) | • Australian Transport Assessment and Planning Guidelines to cover public, road and rail transport |
| Canada (Canadian Commission on Building and Fire Codes [CCBFC]) | • National Building Code of Canada (2015) |
| Canada (Standards Council of Canada, Indigenous and Northern Affairs Canada) | • Northern Infrastructure Standardization Initiative (NISI) Standards |
| Germany | • Technical rule on precipitation and flooding for flood safety of plants subject to the German Major Accidents Ordinance in 2011 (The Commission on Process Safety)<br>• Climate data standards for buildings and infrastructures (BMVBS/DWD and the German Institute for Standardization) |
| Korea | • Revision of the design requirements for drainage capacity, bridge design and embankment slopes (The Korea Expressway Corporation) |
| Netherlands (Delta Commission) | • Design guidelines for infrastructure to account for changing characteristics of rain showers |
| Norway (Transport agencies) | • Handbook on the design of road drainage structures (2011) |
| Sweden | • Design rules for road drainage (VVMB 310 Hydraulisk dimensionering, 2008:61) |

*Source: Adapted from Vallejo and Mullan, 2017*

# 5 | ROLE OF STANDARDS IN ACHIEVING DISASTER RESILIENCE

Standards are critical for ensuring that infrastructure can withstand current and future climate scenarios. Infrastructure resilience to disasters takes into account not only climate risks, but also resilience to other shocks, stresses, or changes such as demographic shifts, seismic events, technological shifts, pandemics, and other aspects not related to climate. Standards assist stakeholders in incorporating such risks, resilience, and adaptation measures into infrastructure planning, implementation, and management. Standards play a critical role in anchoring efforts to strengthen infrastructure resilience and mobilizing finance. There is an opportunity to achieve greater consistency by integrating standards with the needs of the various stakeholders (Cançado and Mullan, 2020).

## Lifecycle Approach to Infrastructure

The infrastructure lifecycle involves three main phases: planning, implementation and management. The significance of standards differs in each phase (Figure 3) as does the engagement of stakeholders.

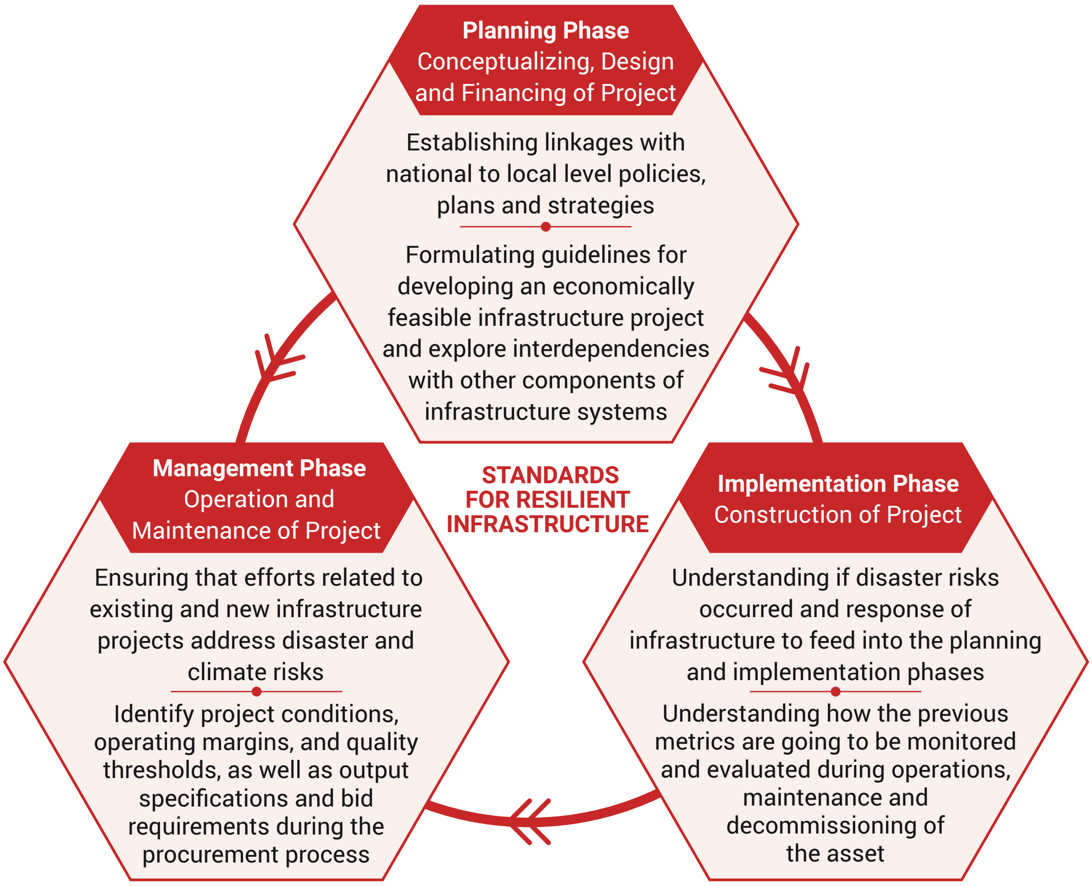


**Figure 3:** Importance of standards in project lifecycle of infrastructure

*Source: Adapted by author from Cançado and Mullan, 2020*

Risk and vulnerability assessments based on up-to-date climate data at the local level are critical factors in planning for uncertain future scenarios. Risk assessments can assist to identify and decide on projects that will improve resilience to disasters and climate change and address specific vulnerabilities of site selection. During the implementation phase for construction of the project, infrastructure must be considered with a long-term perspective to adequately incorporate concepts and principles of resilience. Since typical infrastructure investment decisions are often based on a return on investment period, which is short in comparison to the infrastructure lifetime, the technical design solutions and financial analysis usually do not necessarily take into account anticipated future risks, including longer term impacts of climate change (Gallego-Lopez and Essex, 2016). This emphasizes *the importance of taking a whole-lifecycle approach to infrastructure, so that the impacts and benefits can be properly costed throughout the infrastructure's lifetime.*

The identification of gaps in standards as per different lifecycle phases of infrastructure is imperative to understand the needs for revising or updating standards for development of DRI.

**Table 3:** Gaps in standards per infrastructure lifecycle phase

| Infrastructure Lifecycle Phase | Gaps in Standards |
|---|---|
| Planning | *Lack of guidance towards standards in the very early stages of budget development*<br>Despite the relative abundance of tools, guidance and standards to aid the assessment and definition of sustainability and resilience in infrastructure, these standards focus largely on the development phase or later. Guidance and standards are rarely used in the needs assessment phase. |
| Implementation | *Lack of support for sustainable and resilient procurement for infrastructure across all stages of the project lifecycle*<br>Guidance is available but more detailed information and examples are needed e.g., clauses in term contracts and procurement guidelines. |
| Management | *Less practical support available to infrastructure practitioners to help them integrate resilient and sustainable practices into the operation and maintenance of the project lifecycle* |

*Source: Complied by author*

The overview of different types of standards across the lifecycle of infrastructure indicates following needs that should be addressed more prominently in standards:

- **Planning phase:** Consider various disaster and climate change scenarios and integrate a systems approach to infrastructure development for incorporating disaster resilience from the conceptualization and design phase.
- **Implementation phase:** Adopt a longer-term perspective and incorporate specifications in project conditions during construction to procure assets that account for disaster and climate change risks and promote resilience.
- **Management phase:** Ensure tools to measure the performance of disaster and climate change resilient projects are used to assess and showcase the achieved benefits.

## Mapping of Stakeholders

Consistent standards are the foundation for ensuring DRI. The crucial window of opportunity for integrating disaster resilience into standards is dependent on significant mainstreaming, which necessitates the collaboration of a diverse range of stakeholders, ranging from international and national governments, SDOs (global/ regional/ national) to public and private financiers, academia and end-users, as highlighted in Figure 4.

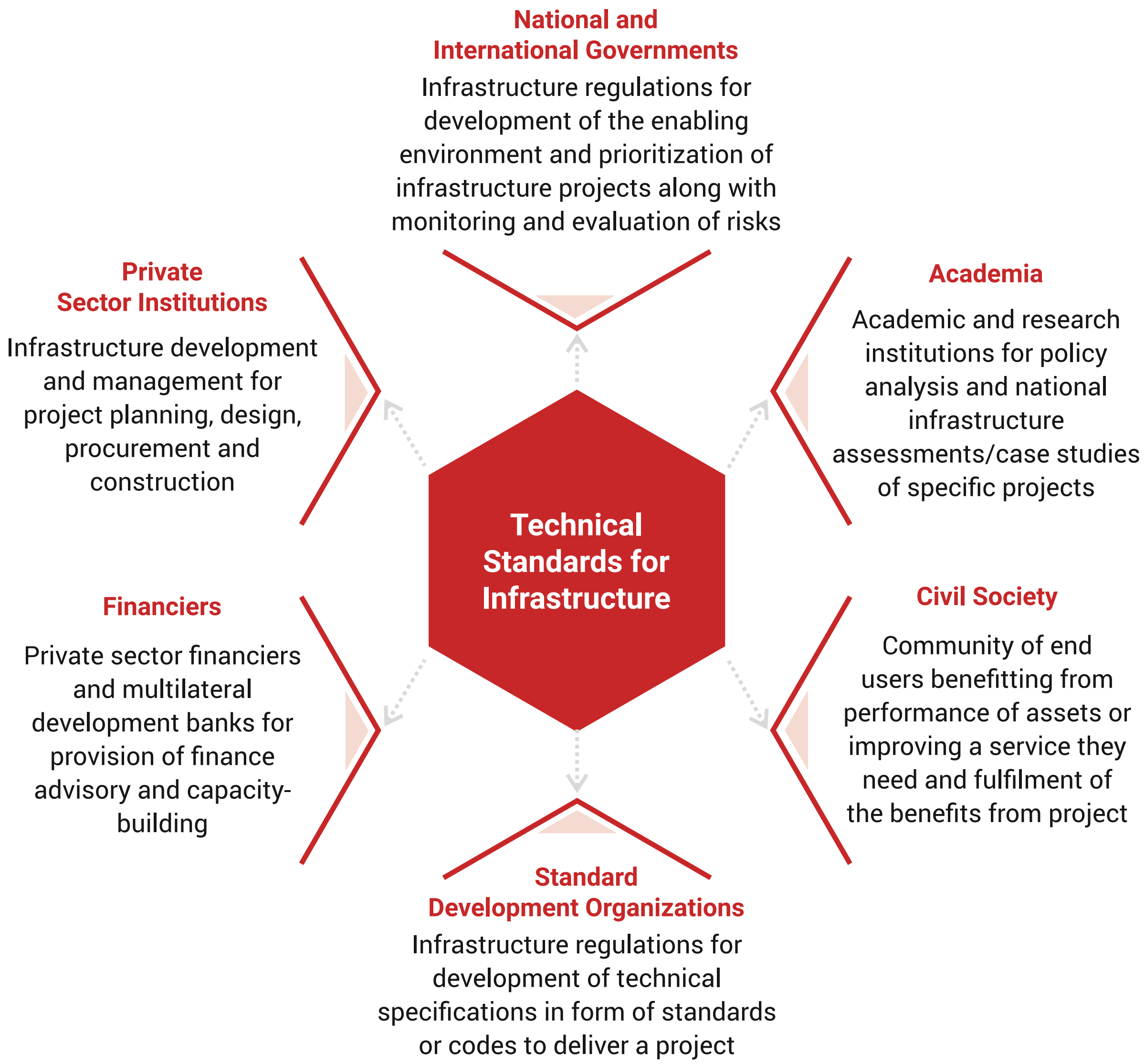


**Figure 4:** Relationship between stakeholders and standards for incorporating resilience in infrastructure development

*Source: Compiled by author*

# 6 | LIMITATIONS IN ADOPTION OF STANDARDS IN INFRASTRUCTURE DEVELOPMENT

Technical standards are crucial in enhancing disaster resilience in investment decisions for infrastructure and ensuring that the developed infrastructure is built to survive the shocks of present disasters and future climate change scenarios. Standards must take into account a variety of factors, including geophysical hazards, climate conditions, environmental and socio-economic trends, availability of resources, local construction practices, supply chains, and policy priorities, in order to have optimal impact (Hallegatte and Rentschler, 2019). They need to be revised regularly as well as applied consistently with support of training mechanisms and enforcement capacity, considering the trends of disasters, climate change, and other long-term environmental impacts. It is also imperative to consider the evolving understanding of natural hazards and recent advancements and innovations in engineering technology. Also, governments need to ensure a holistic approach for aligning the international, national and local approaches in order to facilitate resilience in infrastructure investments made by public and private sector.

*Infrastructure standards for disaster and climate change apply uniformly across varying contexts while aiming to address uncertain issues*. However, for contextual specific risks, such approaches of implementation could lead to systematic over- or under-investment in infrastructure resilience (Vallejo and Mullan, 2017). This dissonance can challenge the positive impacts of standards.

*The regulatory regime under which the standards are implemented, i.e., prescriptive-based or performance-based, has a significant impact on their effectiveness*. Prescriptive-based regulatory regimes, usually based on past experiences, are easy to follow and measure. These require adherence to mandated actions and have potential to hinder innovation. Hence, such systems can act as a hurdle to disaster and climate resilience as exceeding the current standards with higher levels of resilience is not required under existing practices. Performance-based regulatory regimes set objectives and allow flexibility on achieving compliance. The development of regulatory regime involves maintaining a balance between prescriptive and more flexible performance-based approaches.

*Another limitation of codes and regulations is that regulators and governments may not have detailed cost benefit assessment mechanism of all options for building resilient infrastructure*. Incentives such as rewards and penalties can be used for infrastructure providers and developers to go beyond the obligatory standards and implement innovative cost-effective solutions to enhance resilience (Rodriguez Pardina and Schiro, 2018). International and national governments could use their purchasing power to improve the resilience of their infrastructure investments (Lu, 2019). National or subnational governments, for example, could encourage exceeding the code compliance in government-funded infrastructural development, where standards surpass the minimum life safety requirements as per local building codes. Also, another limitation of existing standards is the lack of incentives for project developers to adopt voluntary standards. Most project developers are incentivized to minimize cost, at the expense of quality and resilience of infrastructure. An approach for delimiting this may be adopted by adding tender evaluation points to more resilient projects or projects that achieve a rating and/ or to provide financial incentives such as better loan conditions, lower interest rates, etc.

# 7 | CONCLUSION

Resilience of infrastructure to disasters depends on the technical standards, codes, and practices used throughout their development and subsequent lifecycle phases. To achieve long-term performance of infrastructure systems, it is essential to ensure disaster resilience of factors considered for infrastructure development, e.g., the target community, desired levels of functionality before, during, and after disruptive hazard events, and prioritization of steps among others. It is imperative to focus on developing a coordinated approach for DRI to benefit from the efficiency gains and from quick turn-around to meet the fast-growing demands of user ecosystem. Not only is it important to factor in the physical risks associated with the infrastructure asset, but also the risks posed by extreme climate events on supporting infrastructure to ensure availability and reliability of infrastructure systems in the times of disaster and extreme events.

For an integrated approach on enhancement of infrastructure resilience, technical design standards and building codes must be reviewed and updated in a timely manner, considering the changing climate. The development and revision of standards is typically a slow process and requires a plethora of resources. *While much disaster and climate science appropriately inform infrastructure development decisions, a crucial aspect is to mainstream this process in engineering practices.* Key adjustments in existing engineering design standards are required to inform different phases of the infrastructure lifecycle. *Multilateral institutions can play an important role in encouraging the use of engineering design practices that are informed by climate and disaster risk considerations.* For example, there is significant potential for mainstreaming resilience into infrastructure development through co-development and adoption of revised design standards during sector-specific strategic planning. Standards and codes also play a vital role in creating incentives for private sector participation in initiatives to improve infrastructure resilience, as well as in adoption of resilience measures in commercial bank lending (Lu, 2019).

It is important to *develop a holistic approach across the entire lifecycle of infrastructure systems and consider the impact of infrastructure projects on the wider system.* Despite the abundance of guidance documents and standards, most of these relate to the design phase of the infrastructure lifecycle, compared to the implementation and management phases. Resiliency in standards formation needs development of standard interface considering automation and autonomy, integrating resiliency within stakeholders (such as utility providers, application and network providers, local authorities, financiers, etc.) and considering weather forecasts. Lifecycle perspective for infrastructure systems requires an end-to-end approach to reduce fragmentation and provide clarity. It also needs thinking aligned with systems approaches as well as practical and actionable guidance through standards which form critical building blocks for resilient future.

# 8 | WAY FORWARD

Effective implementation of technical standards is crucial for enhancing resilience of existing and new infrastructure systems to disasters and climate extreme events. Extensive research on the inclusion of principles of resilience in standards formation can guide the way for addressing the identified gaps. There is a need for analysis of effectiveness of new standards formulated, considering the increased severity and frequency of disasters and extreme events. The assessments for revisiting and updating existing standards may contribute to building integrated resiliency of infrastructure systems, which will help reduce the cascading impacts of extreme events. Research on geography-specific requirements is essential to bring consistency between global, regional and national standards. To collectively raise awareness on the importance of resilience standards, it is imperative to reinforce adherence to a set of requirements and interoperability amongst the community of users, including infrastructure developers, private sector institutions, etc.

There is a clear need for resilient technical standards with a systems perspective to maximize the lifecycle of infrastructure assets while minimizing their impacts on the surrounding environment. Having a collaborative process for all stakeholders to agree on resilience measures and codes would encourage ownership amongst stakeholders and ensure smoother and wider adoption. This will lead to better sharing of existing information and good practices, enhanced capacity building and support for multi-stakeholder participation in the process. In order to do so, international institutions such as CDRI can facilitate multi-stakeholder collaborations between international and national governments, SDOs, academia, private sector institutions, financiers and civil society to strengthen setting and implementation of global norms and standards enabling development of resilient infrastructure.

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