NIPFP Working paper series

# Regulating Infrastructure Development in India

No. 230
15-May-2018

Sanhita Sapatnekar, Ila Patnaik and Kamal Kishore

National Institute of Public Finance and Policy
New Delhi

# Regulating infrastructure development in India

May 15, 2018

Sanhita Sapatnekar
Ila Patnaik
Kamal Kishore

India has been rapidly urbanising. Much of this has been unplanned, with regulation left to catch up to what has already been implemented. This leaves room for improving the legal framework in terms of what role is played by each level of government, as well as the process for setting standards for each type of infrastructure. Regulation of the professionals involved (including town planners and engineers) is missing, resulting in implementation issues. Further, this regulatory framework is still evolving in India. There are systemic issues to consider, such as the level of prescription a standard should have, identifying critical infrastructure, and whether to retrofit existing infrastructure. This paper reviews the existing framework for infrastructure development and the associated standards in India, and identifies areas for concern. Rather than deeply analysing any one standard, this paper analyses the ecosystem for standard setting in India's infrastructure development from a risk perspective.

The authors thank Professor Bilal Ayyub (University of Maryland) and Professor C.V.R. Murty (Indian Institute of Technology, Jodhpur) for insightful inputs into this work. They also thank Itishree Rana for valuable research support.

# 1 Introduction

Adopting safety standards when developing infrastructure is one mere element of ensuring a safe built environment. Time-varying factors coupled with geographical considerations take the notion of safety far beyond simply adopting technical standards. For example, every location has a different mix of materials that can be used to build infrastructure. Over time, changes in material science interact with locally available raw materials to create new ones.

Solid mechanics problems in designing structures are largely non-time-varying and globally applicable. Yet the solutions to these problems are steadily evolving through improvements in mathematics and numerical computation. Similarly, engineering finds cost-minimising tradeoffs. As relative prices change over time and differ across locations, feasible and optimal designs also change. Further, the shocks that a built structure may face are an integral part ensuring structural soundness. This threat perception also varies by location and changes over time.

The price of time and the price of risk are critical inputs that shape design, each of which is determined by finance. For example in terms of time, when the cost of capital decreases, the net present value is influenced by events over a longer future time horizon. At this point, low probability events become more important. Similarly in terms of risk, the optimal structures in a country maintaining an inflation target of four per cent will be cheaper and more unsafe than in a country targeting inflation at two percent.

Engineering design encompasses tradeoffs that yield cost-minimising solutions for each geography and point in time. Hence, drafting standards in civil engineering requires deep experiential local knowledge of the engineering tradeoffs prevalent as a function of time. Merely copying of a standards document that is well established elsewhere does not suffice.

These factors are particularly critical in India today, as the country is rapidly urbanising. Current infrastructure investment (which stands at an annual 118 USD billion) will increase by a further 112 USD billion if the country is to maintain its growth agenda. The population as a whole is increasing, as is rural-urban migration. Existing rural settlements are being reclassified to urban areas, and boundaries of existing urban settlements are expanding over time. 70% of the total urban population live in settlements with a population of 100,000 or more, while 42.6% of the total urban population live in cities with a population of over one million.[1]

[1] Ministry of Urban Development, Government of India, 2015b.

New towns are developing very fast and many are yet to be notified as statutory towns. For example in 2011, the census captured 7933 urban towns in India. Of these, only 4041 were statutory towns and the remaining 3892 were classified as *"census towns"*, as they met the minimum criteria for an urban town with the exception that they were not notified as such.[2] Between 2001 and 2011, the number of statutory towns increased marginally by 6.4% (from 3799 to 4041).[3] Non-statutory towns, however, increased by an alarming 186% in the same period (from 1362 to 3892), reflecting large amounts of unplanned urbanisation.

This becomes a problem as the *Constitution of India*, which details the distribution of legislative powers between the centre, states and local bodies, allows for devolution of urban and town planning to notified towns (known in India as *"municipalities"*). As a result, census towns are neither responsible for planning their urbanisation, nor do they have to power to do so. Even from the municipalities and above, different levels of governance are responsible for providing specific types of infrastructure as detailed in the *Constitution of India*. The quality of this infrastructure and the extent to which it adheres to the adopted standards may vary due to the capacity (or lack thereof) of the governing body involved.

These standards for infrastructure are developed by various sector-specific standard setting bodies. However, the process for developing them is not standardised across sectors, nor is it streamlined with the process followed by international standard setting bodies. As a result, the adequacy of these standards for mitigating the risk they are set out to is also a concern. Once these standards are adopted by each governing body, implementation requires a clear process for the steps in infrastructure development, and accountability of the relevant professionals if this process is not followed.

This process is often well defined in India across sectors. However, accountability of professionals is missing. While architects are regulated by a statutory regulator, there is no such regulator for engineers or town planners in India and implementing quality infrastructure development may therefore be hindered. Engineers play a crucial role in the design, planning and constructing stages of infrastructure projects to ensure safety. Further, competent engineers are required for providing education and developing infrastructure standards. Without a statutory regulator for engineering education and conduct, safety in infrastructure development may be compromised. In this paper, we explore established mechanisms to increase compliance to standards in infrastructure development, such

[2] i.e. places with a minimum population of 5000 and a density of at least 400 per square km, and at least 75% of the male working population engaged in non-agricultural pursuits. See Government of India, 2011b.

[3] Ministry of Urban Development, Government of India, 2015b.

as utilising the private sector on third-party review or the scope autonomous accreditation.

Further, as India's regulatory framework for infrastructure development and safety standards is still evolving, there are systemic considerations that, if addressed appropriately, could also reduce risk. For example, while there is merit in moving towards a performance-based standards regime, prescriptive standards are used when there is lacking competence to convert descriptive requirements into quantitative specifications. As a result, an appropriate balance between the two regulatory frameworks should be considered when developing a regulatory framework for standards, one that encourages compliance and allows for its measurement. Similarly, the question of whether to retrofit existing infrastructure (and to what extent and level of safety) is an important one for India. This paper explores these and several other systemic considerations.

Based on this review, this paper identifies areas for concern while moving forward in India's high-paced urbanisation context. Rather than focussing deeply on any one standard, this paper analyses the ecosystem for standard setting in India's infrastructure development from a risk perspective. The rest of this paper is structured as follows: Section 2 gives an overview of trends in India's infrastructure development and urbanisation landscape. Section 3 reviews the legal framework for infrastructure development, as detailed by the *Constitution of India*. Section 4 explores how infrastructure standards are developed, both internationally and in India. It also details the implementation process for developing infrastructure as per pre-defined standards, and addresses accountability of professionals involved in this process, along with possible incentive mechanisms to increase compliance to these standards. Section 5 explores systemic considerations when developing a framework for standards, such as the importance of developing standards for operating and maintaining infrastructure once its built. Section 6 concludes by highlighting some areas for concern in the current framework.

## 2 The Indian context

India's infrastructure has been rapidly expanding over the last two decades (see Figure 1). Current annual investment for 2016-2020 is estimated at 118 USD billion.[4] To meet its growth agenda, the country requires a further annual investment of 112 USD billion for this period.[5] By 2025, based on projects that have already been commissioned, electricity generation capacity will almost double. Similarly, highway and metro length will increase by 1.5 and 6 times, respectively (See Figures 2, 3 and 4).

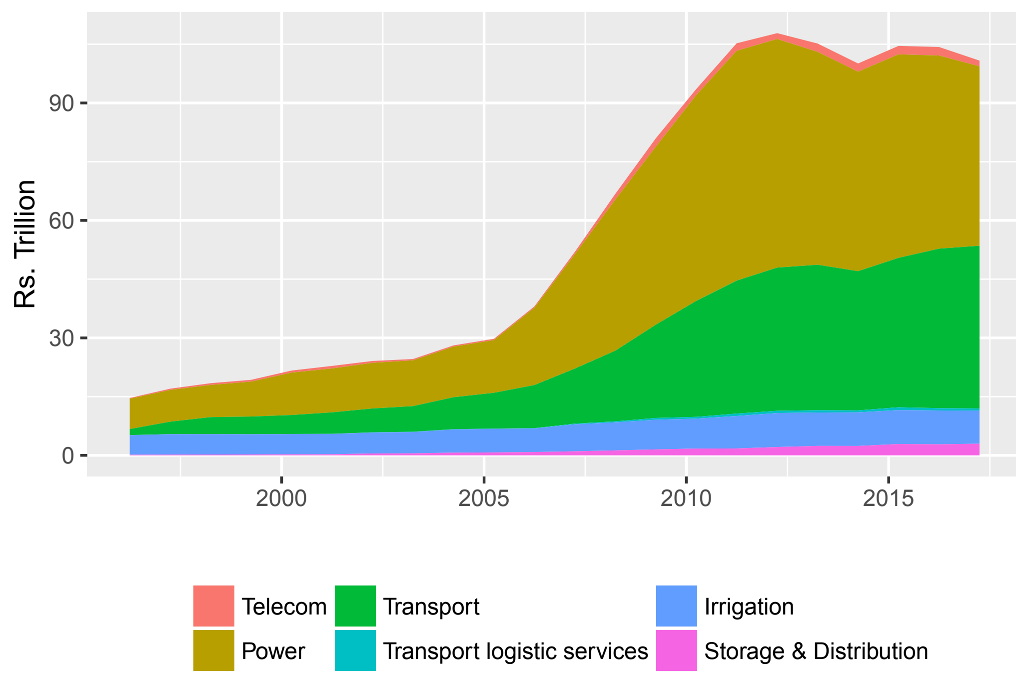



**Figure 1:** Rapid expansion in India's infrastructure
Source: Projects announced and under-implementation, CMIE Capex database

[4]Asian Development Bank, 2017.
[5]Ibid.

Projected increase in infrastructure by 2025, based on project commissioning dates. Source: CMIE Capex database

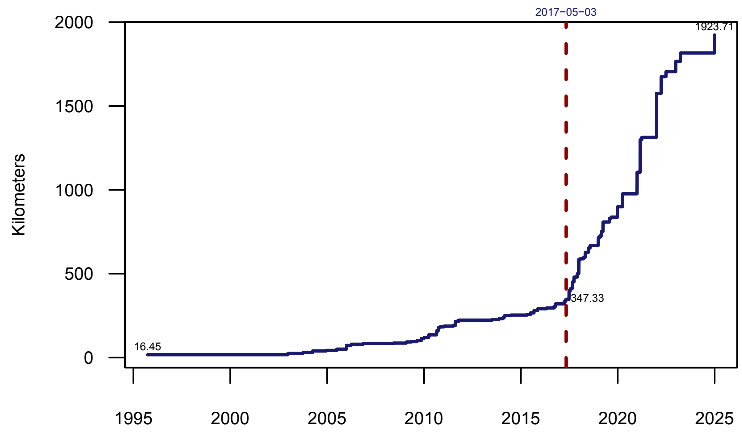



**Figure 2:** Metro lines

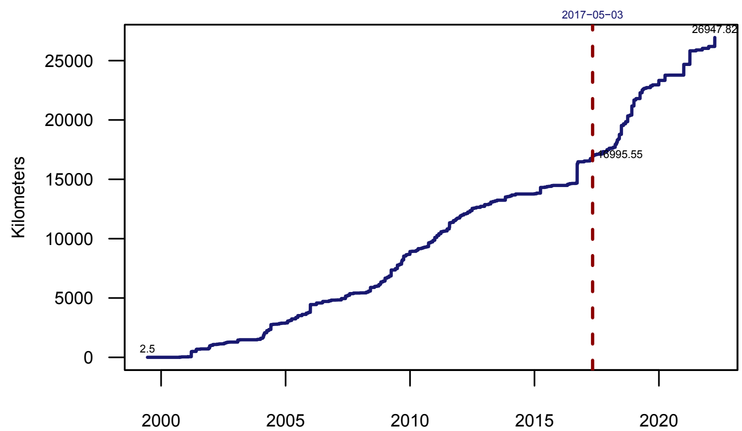
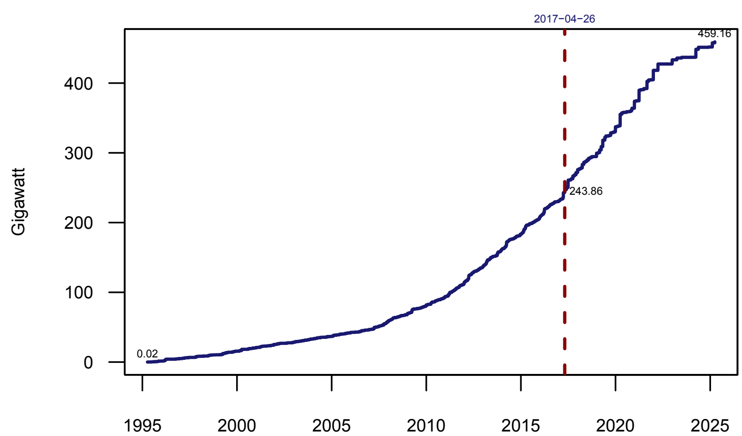



**Figure 3:** National highway length




7

**Figure 4:** Electricity generation

## 2.1 India's urbanisation

India's recent urbanisation has been rapid, and remains an integral element of the country's growth process. India's population, currently the second largest in the world at 1.32 billion in 2017, is expected to overtake that of China by reaching 1.52 billion by 2030.[6] While the national population in India is growing, its urban population is growing faster than its rural population. Data from the latest two national censuses (2011 and 2001) provide insights into India's population-based urbanisation trends.

In 2011, India's total population was 1.21 billion, an increase of 0.18 million from 2001.[7] While the overall population growth rate for 2001-2011 was 17.7%, the urban population growth rate was much high than rural, at 31.8% and 12.3%, respectively.[8] The urban population increased by 3.4% from 2001-2011, to 31.2%, with large disparities across the country.[9] For example, 90% of Himachal Pradesh remained rural in 2011, in contrast to Delhi which had an urban population of 97.5%.[10]

In addition to the increasing national population, other factors such as rural-urban migration also play a role. Further, with sufficient increase in population, some rural settlements are reclassified to urban areas, and boundaries of existing urban settlements may expand over time. Census data indicates that, between 2001-2011, the number of urban settlements with a population of over one million increased from 35 to 53.[11] Of these, five cities (namely Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune) had populations exceeding 5 million. The three largest cities, namely Greater Mumbai, Delhi and Kolkata, have populations of more than 10 million.[12] 70% of the total urban population live in settlements with a population of 100,000 or more, while 42.6% of the total urban population live in cities with a population of over one million.[13]

Based on census classification and states' experiences, the Ministry of Urban Development has (within its guidelines for urban and regional development plans) classified urban settlements in India as depicted in table 1.

[6] United Nations Department of Economic and Social Affairs, 2017.
[7] Government of India, 2011a.
[8] Ibid.
[9] Ibid.
[10] Ibid.
[11] Ministry of Urban Development, Government of India, 2015b.
[12] Ibid.
[13] Ibid.

**Table 1:** Classification of urban settlements. Source: URDPFI Guidelines

| | Classification | Sub-category | Population Range | Cities (Census 2011) |
|---|---|---|---|---|
| 1. | Small Town | Small Town I | 5,000-20,000 | |
| | | Small Town II | 20,000-50,000 | 7467 |
| 2. | Medium Town | Medium Town I | 50,000-1,00,000 | |
| | | Medium Town II | 100,000-500,000 | 372 |
| 3. | Large City | N/A | 500,000-1 million | 43 |
| 4. | Metropolitan City | Metropolitan City I | 1-5 million | 45 |
| | | Metropolitan City II | 5-10 million | 5 |
| 5. | Megapolis | N/A | More than 10 million | 3 |

The Government of India has initiated steps to help ensure that urbanisation, while rapid, happens in a planned and sustainable way. For example in 2015, the government anticipated that urban areas will contain 40% of India's population and contribute to 75% of national GDP by 2030.[14] In this context, the Government launched its flagship Smart Cities Mission to *"drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology"*.[15] This mission aims to facilitate India's urbanisation so that existing urban areas are transformed into better functioning ones, and new areas are developed around cities to accommodate expanding population.[16]

However, given the pace and scale of urban growth in India, current efforts may be insufficient to ensure planned urbanisation across the country. Existing schemes might be able to target planning in towns and cities that have been legally notified and therefore have a system for governance and planning in place. Many new towns in India develop very fast and are yet to be notified as statutory towns. For example in 2011, the census captured 7933 urban towns in India. Of these, only 4041 were statutory towns and the remaining 3892 were classified as *"Census Towns"*, as they met the minimum criteria for an urban town with the exception that they were not notified as such.[17]

Between 2001 and 2011, the number of statutory towns increased marginally by 6.4% (from 3799 to 4041).[18] Non-statutory towns, however, increased by an alarming 186% in the same period (from 1362 to 3892), reflecting large amounts of unplanned urbanisation. This type of haphazard growth hinders sustainability and may introduce new risk to its environment, as unplanned urbanisation may

[14] Ministry of Urban Development, Government of India, 2015a.

[15] Ibid.

[16] Ibid.

[17] i.e. places with a minimum population of 5000 and a density of at least 400 per square km, and at least 75% of the male working population engaged in non-agricultural pursuits. See Government of India, 2011b.

[18] Ministry of Urban Development, Government of India, 2015b.

not be built with adequate resilience or to the standards required for the region. In addition, even if the urbanisation is planned, existing infrastructure standards may not factor in resilience adequately, and can also potentially increase risk. While urbanisation (and the resultant increased concentration of population and assets) poses challenges for disaster risk management, it also offers opportunities to better manage growth and mitigate risk.

# 3 Legal framework

The *Constitution of India* details the distribution of legislative powers between the centre and the states.[19] While the Parliament of India has exclusive power to make laws on some items (such as national highways), the legislature of any state can make laws on others (such as water supply).[20] Further, the legislature of a state has power to constitute municipalities and panchayats and may, by law, endow them with certain powers and authority.[21] This section highlights the distribution of legislative powers for infrastructure related items.

## 3.1 Central level

Items on which the Parliament of India has exclusive power to make laws include:

1. Railways[22]
2. National highways[23]
3. Major ports[24]
4. Airports[25]
5. Telecommunication[26]

Developing infrastructure under these sectors is the responsibility of the Centre, and is administered through statutory bodies or through ministries. For example, the National Highways Authority of India (NHAI) is the nodal agency responsible for developing, maintaining and managing Indian national highways, and was established through the *The National Highways Authority of India Act, 1988*.[27] Similarly, the *Airports Authority of India Act, 1994* established the Airports Authority of India (AAI), which is responsible for *"establishing or assisting in the establishment of airports"*.[28]

[19] See part VI chapter I of Government of India, 1949.
[20] See article 246 of part VI chapter I of ibid.
[21] See Item 5 List II (State List) of the seventh schedule (Article 246), and Articles 243W and 243G of ibid.
[22] Item 22 List I (Union List) of the seventh schedule (Article 246) of ibid.
[23] Item 23 List I (Union List) of the seventh schedule (Article 246) of ibid.
[24] Item 27 List I (Union List) of the seventh schedule (Article 246) of ibid., Note, ports other than those declared by or under law made by Parliament or existing law to be major ports come under Concurrent List (Item 35 of List III)..
[25] Listed as *Airways* in Item 29 List I (Union List) of the seventh schedule (Article 246) of ibid.
[26] Item 31 List I (Union List) of the seventh schedule (Article 246) of ibid.
[27] The Gazette of India: Extraordinary, 1988.
[28] The Gazette of India: Extraordinary, 1994.

Each of these statutory bodies adopts appropriate standards for design and construction of sector-specific infrastructure. These standards are developed by various bodies, some governmental and some private entities. For example, the Indian Road Congress (IRC) is a registered society of highway engineers established for developing and updating standards, codes of practice and guidelines for the road sector.[29] While this society is not a government entity, NHAI regularly uses IRC standards for construction. In contrast, the Research Design and Standards Organisation (RDSO) is a government organisation under the Ministry of Railways that develops standards and specifications for materials and products for Indian Railways. The centre may also adopt and apply international standards in some cases (as discussed in section 4).

## 3.2 State level

Items on which the legislature of any state has power to make laws include: [30]

1. Roads, bridges, ferries, and other means of transportation not under the Centre's jurisdiction[31]
2. Water supplies, drainage and embankments, water storage and water power[32]
3. Land rights, tenures and revenue[33]

Within a state, every metropolitan area is required to have a committee to prepare a draft development plan for the area as a whole.[34] Also, states are responsible for the constitution of municipal corporations and other local authorities for the purpose of local self-government or village administration.[35]

The *Constitution of India* defines three types of municipalities:[36]

1. Nagar Panchayats for areas in transition from a rural area to urban area;
2. Municipal Councils for smaller urban areas; and
3. Municipal Corporations for larger urban areas.

[29] Indian Roads Congress, 2018.

[30] Note: this is subject to the provisions in Article 243M of the Government of India, 1949, which excludes certain states (Nagaland, Meghalaya and Mizoram) and parts of certain states (e.g. hill areas in the State of Manipur for which District Councils exist under any law) from this system of governance

[31] Item 13 List II (State List) of the seventh schedule (Article 246) of ibid.

[32] Item 17 List II (State List) of the seventh schedule (Article 246) of ibid.

[33] Items 18 and 45 List II (State List) of the seventh schedule (Article 246)of ibid.

[34] Article 243-ZE of ibid.

[35] Item 5 List II (State List) of the seventh schedule (Article 246) of ibid.

[36] See Article 243Q of the ibid.

Establishment of municipalities is done by public notification by the Governor of the state.[37] States may, by law, endow municipalities with the functions and implementation of certain items within their jurisdiction, including:[38]

1. Urban planning including town planning[39]
2. Regulation of land-use and construction of buildings[40]
3. Roads and bridges[41]
4. Water supply for domestic, industrial and commercial purposes[42]
5. Slum improvement and upgradation[43]

### 3.2.1 Municipal level

Municipalities develop legal tools in the form of "*Building Bye-Laws*" for structural design and construction (including that of public infrastructure such as roads), to achieve orderly development of an area.[44] These bye-laws are developed while keeping the local geography in mind, such as seismic zones and flooding risk. They incorporate standards developed by the Bureau of Indian Standards (BIS). This is the national standard setting body in India, established under *The Bureau of Indian Standards Act, 1986*.[45] Some BIS standards are made mandatory through building bye-laws within the jurisdiction of the municipality, though these bye-laws vary with each municipality.

### 3.2.2 Panchayat level

Village panchayats are rural local bodies responsible for some of the governance functions in their locality, as defined by Article 243B of the *Constitution of India*. The states may (by law) endow panchayats with the functions and implementation of:[46]

[37]See Article 243Q of the Government of India, 1949.
[38]Article 243W of ibid.
[39]Item 1 of the 12th Schedule (Article 243W) of ibid.
[40]Item 2 of the 12th Schedule (Article 243W) of ibid.
[41]Item 4 of the 12th Schedule (Article 243W) of ibid.
[42]Item 5 of the 12th Schedule (Article 243W) of ibid.
[43]Item 10 of the 12th Schedule (Article 243W) of ibid.
[44]For example, the Municipal Corporation Jalandhar was established through the *Punjab Municipal Corporation Act, 1976*. This municipality developed and adopted the *Municipal Corporation Jalandhar Building Bye-Laws, 2010* to govern construction within the municipality.
[45]The Gazette of India: Extraordinary, 1986.
[46]Article 243G of Government of India, 1949.

1. Roads, culverts, bridges, ferries, waterways and other means of transportation[47]
2. Rural electrification, including distribution of electricity[48]
3. Minor irrigation, water management and watershed development[49]
4. Drinking water[50]

For example, *The Maharashtra Village Panchayats Act* gives a panchayat established under this act responsibility over the *"construction, maintenance and repair of public roads, drains, bunds and bridges: Provided that, if the roads, drains, bunds and bridges vest in any other public authority such works shall not be undertaken without the consent of that authority"*.[51]

As a result, the central government is responsible for some of the infrastructure (such as national highways), which run through municipalities. Other roads within the municipality boundary are the responsibility of the Corporation. Outside of the boundary, the *The Maharashtra Village Panchayats Act* applies for the construction of public roads.

However, there are still many small and medium sized towns without appropriate bye-laws as they have not formed a municipality.[52] For example, *"census towns"* are those defined in the 2011 census as places that satisfy the criteria of a town, but are not statutory towns.[53] These are not regulated by municipality level bye-laws. Table 2 shows the division of responsibility for infrastructure in India.

**Table 2:** Division of responsibilities given in the *Constitution of India*

| **Sector** | **Centre** | **State** | **Municipality** | **Panchayat** |
|---|---|---|---|---|
| National highways | | | | |
| Railways | | | | |
| Major ports | | | | |
| Airways | | | | |
| Telecom | | | | |
| Other roads and bridges | | | | |
| Regulating/constructing buildings | | | | |
| Water management and/or supply | | | | |
| Urban/town planning | | | | |
| Rural housing | | | | |
| Rural electricity | | | | |

[47] Item 13 of the 11th Schedule (Article 243G) of Government of India, 1949.
[48] Item 14 of the 11th Schedule (Article 243G) of ibid.
[49] Item 3 of the 11th Schedule (Article 243G) of ibid.
[50] Item 11 of the 11th Schedule (Article 243G) of ibid.
[51] See item 40 of schedule I (Village List) of Government of Maharashtra, 1959.
[52] Ministry of Urban Development, Government of India, 2016.
[53] i.e. places with a minimum population of 5000 and a density of at least 400 per square km, and at least 75% of the male working population engaged in non-agricultural pursuits.

The following two issues can be observed from the current legal framework in India:

1. **Urban and town planning**
   Urban and town planning are state subjects. States may, by law, endow notified municipalities with these functions. However, the *Constitution of India* does not empower states to endow panchayats with these functions. This is significant in India's current urbanisation context, where many areas meet the minimum criteria for an urban town with the exception that they were not notified as such, i.e. census towns. These areas made up 3892 of 7933 urban towns in the 2011 census, and do not have powers or responsibilities to undertake urban or town planning.
   Similarly with water, census towns are empowered to provide drinking water, minor irrigation, water management and watershed development. They are not empowered with the responsibility of water supply. There is therefore a risk that the pipes and drainage systems developed in these areas will not be regulated for as long as the areas are not notified as municipalities.
2. **Levels of government developing infrastructure**
   Developing infrastructure in India is the responsibility of authorities across different levels of governance. As a result, certain types of infrastructure that are the responsibility of the central government may be developed with consistent capacity across the country. However, where sub-national authorities are responsible, infrastructure provision may vary across depending on state capacity, even if the same standards are adopted. Similarly, based on a state's budget, level of urbanisation and its development indicators, other public goods such as education or health may be prioritised at the expense of large infrastructure provision.

# 4 Developing and implementing standards

With developments in technology and a growing body of multi-disciplinary research, the understanding of nature of hazards is continuously evolving. To increase resilience to these hazards when building new infrastructure, standards for design and risk management practices have to keep pace. New technologies such as remote sensing and Geographic Information Systems (GIS) mapping could help in tracking the existing and emerging patterns of hazard risks and exposure to hazards on a large scale. Standards need to be reviewed and updated to incorporate advancements in these mapping and engineering technologies, where possible.

The global framework for setting standards comes in the form of the World Standards Cooperation (WSC), a high level collaboration between the three leading international standards setting bodies, namely the:

1. International Organization for Standardization (ISO);
2. International Telecommunication Union (ITU); and
3. International Electrotechnical Commission (IEC).

Together, they develop standards for many sectors, including infrastructure. These standards are regularly reviewed (at least every five years), and are already incorporating elements of the Sendai Framework for Disaster Risk Reduction (2015-2030). For example, in 2015, the United Nations Office for Disaster Risk Reduction (UNISDR) established an engagement with ISO to develop new standards for resilient and sustainable cities. ISO is currently in the process of developing the new *"Indicators for Resilient Cities under their Sustainable Development in Communities"* project. Meanwhile, an *"Inventory of existing guidelines and approaches on sustainable development and resilience in cities"* was published by ISO in January 2017.[54]

Standards developed by these international organisations are market driven. Hence, the first step of the standards development process is establishing whether the standard is needed, i.e. whether there is market demand and relevance. Countries can voluntarily incorporate some or all of these standards into their national frameworks. The key steps in the process for developing these international standards is given in Box 1.

[54] International Organization for Standardization, 2018.

**Box. 1: Development process for international standards**

1. The proposed standards is submitted for a vote to establish whether it is needed;
2. Upon establishing that the standard is needed, a working group of subject-relevant technical experts is created (by the relevant parent committee) to build technical consensus;
3. The parent committee then develops it further until reaching committee-consensus which is formalised through a vote;
4. This draft is then distributed widely for comments to all members and the wider community;
5. Taking these comments into account, the standard is finalised based on consensus and pre-defined parameters for voting; and
6. All standards are regularly reviewed.[a]

[a]For example, see International Organization for Standardization and International Electrotechnical Commission, 2017.

## 4.1 Developing Indian standards

India adopts standards from all three of these international organisations. While BIS adopts ISO and IEC standards (some of which could be made mandatory through municipal bye-laws), various Indian bodies such as the Ministry of Communications and Information Technology have ITU membership. The Indian government also adopts standards developed by various national bodies. Some of these are private entities (such as IRC) that prescribe their own process for developing standards.[55] The government also adopts standards developed by statutory bodies (such as BIS) whose process is formalised through legislation. For example, BIS is established through the *The Bureau of Indian Standards Act, 1986*, under which subordinate legislation can be created, such as the *The Bureau of Indian Standards Rules, 1987*.[56] These rules contain provisions for the *"Procedure for Establishment of Indian Standards"*.[57]

The process for developing infrastructure standards is not consistent across the multiple sector-specific standard setting bodies in India. As a result, quality assurance and appropriateness of the standards themselves is therefore missing. The value of streamlining the standards development process to well-established

[55]As the process is not formalised through legislation, it need not be made public.
[56]See The Gazette of India: Extraordinary, 1986 and The Gazette of India: Extraordinary, 1987
[57]See section (6) of ibid.

best practices is recognised worldwide. In many countries, this streamlining is achieved through accreditation of Standard Development Organisations (SDOs). For example in the USA, there are hundreds of SDOs in operation, with an estimated 20 of the largest producing 90% of standards.[58] The American National Standards Institute (ANSI) offers voluntary accreditation of the standard making process followed by these SDOs. All SDOs that receive accreditation from ANSI follow *"essential requirements for openness, balance, consensus and due process"*, which include:[59]

- Consensus on a proposed standard by a group including representatives from affected and interested parties;
- Broad-based public review and comment on draft standards;
- Consideration of and response to comments submitted by voting members of the relevant consensus body and through public review;
- Incorporation of approved changes into a draft standard; and
- Right to appeal by any participant that believes that due process principles were not sufficiently respected in according with procedures.

Similarly in Canada, the Standards Council of Cananda (SCC) provides accreditation of the standard making process for SDOs in Canada. Its requirements for accreditation include all these elements that the US system requires.[60] The Quality Council of India (QCI) was established along these lines as a joint effort from the Government of India and the industry, to *"develop, establish and operate national accreditation programmes in accordance with the relevant international standards & guides"* across various sectors.[61] The QCI has recently developed its own "*Accreditation Programme for Standards Development Organizations*", effective June 2017. While new in India, this voluntary accreditation program includes process requirements similar to those of the USA, Canada and ISO.[62] If incentives for accreditation under this program emerge, India could also use the accreditation of SDO processes to streamline the way standards are developed across various bodies.

When comparing the BIS standard setting process to that of ISO, there are many similarities. For example, both take a technical-committee based approach when developing standards, which are also reviewed regularly.[63] There is scope to fur-

[58] American National Standards Institute, 2018.

[59] Ibid.

[60] Standards Council of Cananda, 2018.

[61] Quality Council of India, 2018b.

[62] Quality Council of India, 2018a.

[63] See Bureau of Indian Standards, 2018a. Through the process defined in *The Bureau of Indian Standards Rules, 1987*, BIS has recently updated the IS 13920:2016 for *"Ductile Design And Detailing Of Reinforced Concrete Structures Subjected To Seismic Forces - Code Of Practice (First Revision)"*, as

ther streamline these processes. For example, even though there is a provision in *The Bureau of Indian Standards Rules, 1987* to widely circulate the draft standard for public comments, this step can be waived when *"the matter is urgent or non-controversial"*.[64]

## 4.2 Implementing Indian standards

When developing infrastructure, the construction agency has information on the process undertaken and the materials used during construction. At times, this allows for information asymmetry between the purchaser of infrastructure and the provider. Many mechanisms can overcome this issue, such as peer reviews, third party design audits, quality audits during construction. Without these checks and balances in place, there is a risk that the infrastructure developer could cut corners and the purchaser of infrastructure would be burdened with the resultant risk. Two components that could help address this issue are:

1. A clear process for the steps in infrastructure development; and
2. Accountability of the relevant professionals if this process is not followed.

### 4.2.1 Process of infrastructure development

Once standards are adopted and made mandatory, the next step in reducing risk is ensuring their compliance. When developing new infrastructure, there are four broad stages to comply with.

1. **Planning:** This involves submission of project application to relevant the authority. The application includes details of who will perform the work and how, plans for construction and land use etc., as prescribed by the authority.[65]
2. **Design:** This involves a review to check that all codes and other relevant requirements are met. This is the first compliance check (at the design stage), and also cover regular on-site inspections. It can be done by the authority itself or by an accredited third party.[66] Once the review proves satisfactory, the authority approves the application and issues the permit,

well as the IS 1893:Part1:2016 for *"Criteria For Earthquake Resistant Design Of Structures - Part 1 : General Provisions And Buildings"*. See Bureau of Indian Standards, 2018c and Bureau of Indian Standards, 2016

[64]See section (6)(e) of The Gazette of India: Extraordinary, 1987.

[65]Global Facility for Disaster Reduction and Recovery (GFDRR), 2016.

[66]Ibid.

usually with a fee reflective of the costs associated with the time spent in the review process.[67]

3. **Construction:** Inspections by external engineers (either those within the authority or those appointed by the authority) are critical at each major stage of construction. The number of inspections required varies by project.[68] A final certificate of compliance can be issued following a successful final inspection, to certify compliance of construction to all relevant codes.[69]
4. **Installation and commissioning:** This involves installing safety features as per municipal requirement, such as those to provide for fire; lift; and power safety. Only once these are met should the infrastructure be commissioned for use.

In India, these steps in the process of construction are clearly defined, in detail, for building large economic infrastructure. For example, the *National Highways Authority of India Works Manual* gives a well developed and competitive bidding process for submission of application.[70] Project preparation and approval processes are also defined, as are the processes for land acquisition and acquiring environmental and forest clearances.[71]

Pre-feasibility studies, and preliminary as well as detailed project reports that contain engineering and construction plans are also required.[72] In addition, projects are subject to various "*Environmental Impact Assessments*" conducted by the Ministry of Environment and Forests, based on their size. Inspections are conducted through third party reviews at various stages, and completion of projects is defined in the bid document.[73]

Similarly, these key steps are often also detailed by various state and municipal authorities. For example, the *Municipal Corporation Jalandhar Building Bye-Laws, 2010* detail these steps, whereas for large scale projects in metropolitan cities such as Mumbai; Chennai; Kolkata; and Delhi, many clearances are required in addition to those mandated by relevant bye-laws. These additional clearances are classified along the same steps.[74] While the process for construction in India is clearly defined and in line with well established norms, compliance during implementation may depend on the capacity of the local governing

[67] Global Facility for Disaster Reduction and Recovery (GFDRR), 2016.
[68] Ibid.
[69] Ibid.
[70] Government of India, 2006.
[71] Ibid.
[72] Ibid.
[73] Ibid.
[74] Central Public Works Department, Ministry of Urban Developmen, 2013.

body involved.

### 4.2.2 Accountability of relevant professionals

One key element to assure safety standard compliance is the capacity of professionals involved in the planning, design and construction of infrastructure. In India, many professions are self-regulated, where the professional group enters into a formal agreement with the government that allows them to formally regulate the activities of its members.[75] This formal body established through central legislation is responsible for regulating the profession, allowing for activities such as:

1. Maintaining a register of professionals;
2. Standard setting and regulation of professional education;
3. Prescribing the code of ethics;
4. Regulating continuous improvement (e.g. through licensing); or
5. Allowing for a dispute resolution mechanism.

The three main professionals involved in developing infrastructure are town planners, engineers and architects.

**Architects**

Architects focus on the design aspects of infrastructure development. In India, they are regulated by the Council of Architecture (CoA), a statutory regulator established through the *The Architect's Act, 1972*. This act defines what constitutes an architect and provides for COA to maintain a register of architects. This act also allows COA to notify which qualifications (and from which institutions) are recognised, and provides for a dispute resolution mechanism.

**Engineers**

For engineering, some of these functions are currently performed by the Engineering Council of India (ECI).[76] However, ECI is not a statutory body. In 1970, the Committee on Technical Consultancy Services set up by the Planning Commission recommended developing an All India Institute/Association of Engineers for regulating the profession of engineering.[77] The Committee also recommended this body be given the responsibility of laying down *"standards for education, experience, capability, capacity, etc"*, and to prepare a code of conduct.[78]

[75] Balthazard, 2016.
[76] Engineering Council of India, 2018.
[77] Planning Commission, Government of India, 1970.
[78] Ibid.

Since then, at least four draft Engineering Bills have been circulated, but none have been enacted.[79] As a result, regulation of the engineering profession and its education is weak. This causes a hindrance not only in quality infrastructure development, but also when competent engineers are required for roles outside of infrastructure development, such as providing education and standard setting.

For example, BIS takes a committee based voting approach in decision making when developing standards. However, the final draft can be approved by either *"the Section Committee or its Chairman"*.[80] As a result, even when a committee approach is taken, the Chairman has the power to solely decide on approving or rejecting the standard in question. In contrast, the ISO process is based strictly on a voting system. As mentioned in section 4.1, there is value in streamlining the process of developing standards. However, given the lacking regulatory framework, the number of competent domain experts required may be inadequate.[81]

If the BIS committee itself does not have the required number of competent and subject relevant domain experts, streamlining this process to ISO may be harmful as the committee may not have the required competence to vote correctly.[82] In the case where only a few or even only the Chairman is adequately qualified, a strictly voting based process would not be suitable. In this case, investing in technical human resources and competencies for creating, updating and implementing is both important and cost-effective in India, considering the cost and amount of large infrastructure yet to be built.[83]

In addition, competent engineers are required to give approvals in the design, planning and constructing stages of infrastructure projects. If in-house capacity to undertake such detailed work is limited, individual faculty members of various engineering colleges could take on this responsibility. Doing so, however, would be at the expense of the education of current engineering students.[84]

**Town planners**

*"Town planning"* is a state subject, one that can be (by law) endowed to municipalities.[85] However, the profession of town planning (and its education) is not regulated in India, and in many places even the definition of what constitutes a town planner may vary.

[79]Consulting Engineers Association of India, 2017.
[80]See section (6)(f) of The Gazette of India: Extraordinary, 1987.
[81]Based on discussions with subject matter experts.
[82]Based on discussions with subject matter experts.
[83]Based on discussions with subject matter experts.
[84]Based on discussions with subject matter experts.
[85]Item 1 of the 12th Schedule (Article 243W) of Government of India, 1949.

For example, the *Municipal Corporation Jalandhar Building Bye-Laws, 2010* define a town planner as *"a person holding postgraduate degree or equivalent diploma in City/Town Planning or Regional Planning and recognized by the "Institute of Town Planners" (India) for its associated membership"*, where the Institute of Town Planners is a private (non-statutory) entity, and not a regulator. In contrast, the *Maharashtra Regional and Town Planning Act, 1966* states that *"Town Planning Officer means the officer appointed for the time being to be the Town Planning Officer for all or any of the provisions of this Act"*.

In addition, the capacity of the local body itself, and the technology they use for town planning, may result in inconsistencies even within a state. For example, a municipality using GIS technology could capture low lying areas and thereby prevent development of critical infrastructure in such areas. Another municipality with the state that is not using GIS technology could not accomplish this to the same extent.

There are also areas governed by overlapping town planning bodies, making it difficult for planning to be efficiently integrated into the infrastructure development process. For example in Jaipur (Rajasthan), the Jaipur Municipal Corporation (established under the *Rajasthan Municipality Act 1959*) is responsible *" for maintaining the city's civic infrastructure as well as carrying out associated administrative duties"*.[86]

The Jaipur Development Authority (established under the *Jaipur Development Authority Act 1982*) is responsible for the *"urban development of Jaipur ... [and] ... to create basic infrastructure to meet the needs of the ever-increasing population and also for the required expansion of the city ... with effective monitoring and regulation"*.[87]

As a result, town planning in Jaipur is governed by overlapping statutory bodies. A comprehensive and coordinated framework for standards could overcome these issues, and reduce risk by holding professionals accountable.

## 4.3 Mechanisms to improve compliance

Compliance with the stages of development, and therefore the prescribed building standards, is critical to reducing risk in new infrastructure. Even when new infrastructure is built as per the prescribed safety standards, it may encourage additional developments around it. Hence, compliance to standards for the addi-

[86] Jaipur Municipal Corporation, 2018.
[87] Jaipur Development Authority, 2018.

tional developments is also important. For example, all of Delhi's metro stations are situated in earthquake prone areas, and one station in the flood plains of the Yamuna river.[88] Though available codes were incorporated to avoid direct risk to these stations, it is not known whether the surrounding construction of buildings led by transit oriented development complies with suitable standards and codes.[89]

The following mechanisms can be developed to increase compliance:

1. **Transparency in building code administration:** Full and easily available disclosure on building requirements facilitates better compliance. In India, this includes the availability of requirements in relevant local languages.[90] Further, reducing the number of steps to become process compliant (without compromising on achieving the level of requirements) could increase the likelihood of the right processes being followed. Doing so might also be cost-effective.[91]
2. **Utilisation of private sector in compliance checks:** Third-party review is a tool not only to increase compliance but also expand the quantity and quality of manpower. Specialised technical inspectors can supplement the work of the authority. This can be done through private engineering and architectural firms certified by the authority to carry out reviews and inspections, based on approved third party review processes. An insurance-inspired model for monitoring can also be adopted, where insurance firms engage private inspection firms for third-party review.[92] Third party peer review and proof checking is critical for fast paced infrastructure development and risk mitigation.[93] India is already utilising this mechanism for compliance in some cases (see Box 2), and its use could be further expanded.

[88] The stations are exposed to earthquakes of upto 8 magnitude and high flood for a short return period of 1 to 10 years. See UNISDR, 2013

[89] Ibid.

[90] Global Facility for Disaster Reduction and Recovery (GFDRR), 2016.

[91] Ibid.

[92] Ibid.

[93] Indian Association of Structural Engineers, 2018.

**Box. 2: Third-party reviews in India**

For NHAI projects, third party reviews are used at various stages. Pre-feasibility studies, and preliminary as well as detailed projects reports containing engineering and construction plans are required.[a] These are done by a consultant hired through a bidding process, and include detailed survey results, investigations and records technical data for design and suitability. Supervision Consultants are also hired through a bidding process. Quality audits are also done independently by external agencies.[b]

Similarly for the construction of rural roads under the Pradhan Mantri Gram Sadak Yojana (PMGSY), a three tier *Quality Management system* is adopted. The second tier involves independent quality management to ensure that the *Quality Management System* at the site is functioning as it should. As this is crucial during the construction stage, these independent Quality Monitors carry out inspections at appropriate stages of work under progress. This includes conducting independent quality assurance tests and reporting on any systemic flaws in the quality control process.[c] However, these quality monitors are usually not employed full time, and many are faculty members otherwise employed for teaching and research. Using them for inspections may be coming at the expense of their primary role of delivering quality education and research.

While yet to be implemented, the latest 2016 draft of the National Building Code (NBC) has strengthened mechanisms to ensure certification for structural safety of buildings by proficient experts and peer review of building design.[d]

[a] Government of India, 2006.
[b] Planning Commission, Government of India, 2008.
[c] National Rural Roads Development Agency, 2007.
[d] Bureau of Indian Standards, 2018b.

3. **Risk-based implementation:** Some structures (such as nuclear power plants) come with higher potential risk than others. Identifying these structures, and targeting appropriately higher review and inspection requirements for them, could help manage the risks better. This is particularly

useful in developing countries with limited resources at local levels.[94]

4. **Conflict resolution mechanisms for permit process:** Access to conflict resolution in the permit process would help increase transparency across various issues, such as interpretation of technical requirements and sufficiency of compliance.
5. **Autonomous mechanisms for accreditation:** In addition to using accreditation as a tool to streamline the process of developing standards (as discussed in section 4.1), autonomous accreditation can help determine if an infrastructure provider is meeting a quality level higher than the required minimum. This is a powerful tool, as with a well functioning mechanism for accreditation, infrastructure companies have an incentive to get accredited. It is in their interest to do so as accreditation sends out a market signal of quality for future potential clients. As more providers get accredited, more are encouraged to meet at least the minimum standards, if not more. This, in time, decreases risk.
   For example in India, the National Accreditation Board for Hospitals & Healthcare Providers (NABH) operates accreditation programmes for healthcare organisations. It is supported by all stakeholders including the industry, consumers and the government while maintaining full autonomy.[95] The government could play a role in facilitating similar mechanisms for accreditation in the infrastructure sector. The government could play an important role in setting up regulatory bodies to register and license both professionals and institutions for engineering and town planning, making accreditation more feasible (for example, see *Engineers Canada* in the Box 3).

[94] Global Facility for Disaster Reduction and Recovery (GFDRR), 2016.
[95] National Accreditation Board for Hospitals and Healthcare Providers, n.d.

**Box. 3: Examples of accreditation**

**Environmental Management System (EMS) certification for construction tenders in Northern Ireland**
In Northern Ireland, all contractors bidding for a construction tender procured by the Centre of Procurement Expertise (CoPE) must have an EMS certified by an accredited third party. The certification is approved only if required standards are adopted, site inspections are incorporated and the third party certification body is accredited.[a]
**Qualification of construction companies in Italy**
In Italy, only the organisations with accredited ISO 9001 certification can bid for construction work. This criteria helps the state in saving cost, while checking that the participating companies fulfill specified standards approved by a third party. Every year, about 30,000 audits are carried out without any expenditure by state.[b]
**Engineers in Canada** Canada has a system of provincial and territorial engineering regulatory bodies. *Engineers Canada* is an accreditation agency for those engineers that are regulated.[c] It maintains autonomy and positive relations with the federal government and policy makers, e.g. through meetings with members of Parliament and public servants.[d]

[a]Public Sector Assurance, 2018.
[b]Ibid.
[c]Engineers Canada, 2018.
[d]Ibid.

6. **Building incentives for compliance:** Building resilience in infrastructure involves multiple stakeholders. Policies, regulations, and financing, that prioritise risk reduction are key to increasing investment in risk reduction, but there may also a role for incentives to encourage investment in resilience. Incentives can be provided to stakeholders to take suitable steps for reducing vulnerability and exposure to the catastrophic hazards.[96] These incentives can be both financial and non-financial.
   In India, this concept of incentives for behaviour change already exists and can be expanded to the area of disaster resilience. For example, under the *National Solar Mission*, the Cabinet Committee on Economic Affairs (CCEA) of India has sanctioned a budget of Rs 5000 crore as funding subsidy for rooftop solar installations. For general category states/UTs, a capital subsidy of 30% will be provided and 70% for special category States.[97]

[96]Asian Development Bank, 2016.
[97]North-Eastern States including Sikkim, Uttarakhand, Himachal Pradesh, Jammu and Kash-

Box 4 gives examples of incentives for disaster resilience in the Philippines and Nepal.

**Box. 4: Examples of incentives for disaster resilience**

In the Philippines, local governments are awarded the Performance Challenge Fund (PCF), which is an incentive program to promote good governance. Naga City was awarded USD 64,000 from the PCF to implement the Lined Canal Project, a project aimed to prevent local areas from flooding. The Seal of Good Local Governance, a *non-financial incentive*, is awarded to cities for good governance in the Philippines. This Seal helps cities to access concessional loans. Disaster preparedness is one of the core criteria to measure the performance of local governments. The Seal was awarded to Naga city, through which it received the PCF to invest in disaster risk reduction.

The Government of Philippines provides Disaster Management Assistance Fund to the local governments to access concessional loans for disaster risk reduction. The loans are provided for structural and non structural interventions at 0%-1.5% interest rate, which is lower than the market rate. To promote investment in risk reduction measures, the city governments are rewarded by getting access to the subsidised loans.[a]

In Nepal, the city government and municipalities adopting minimum building performance measures are awarded intergovernmental grants and cash awards as financial incentives. A cash award of USD 900 is received by top three performing municipalities for adopting 15 indicators of minimum conditions and 40 indicators of performance criteria. A cash award of USD 700 is awarded to the next 3 municipalities. These performance criteria are related to disaster resilience design, good governance, transparency, etc.[b]

[a]Asian Development Bank, 2016.
[b]Ibid.

mir and Lakshadweep, Andaman and Nicobar Islands. See Press Information Bureau, 2015

# 5 Systemic considerations

Infrastructure standards and building codes are integral to safety. Minimum standards for infrastructure aim to ensure structurally sound (and therefore safe to use) built environments. But, when developing a national framework for standards, there are systemic considerations:

1. Balancing regulatory regimes;
2. Adjusting for levels of disaster risk;
3. Standards for Operation and Maintenance (O&M);
4. Identifying critical infrastructure;
5. Anticipating future risk;
6. Option to retrofit;
7. Governing responsibilities of professionals; and
8. Interconnected systems and cascading effects.

## 5.1 Balancing regulatory regimes

The regulatory regime within which the standards fall plays an important role in their effectiveness. Regulatory frameworks for infrastructure standards fall broadly into two categories, namely goal-based (sometimes called performance-based) regulation, and prescription-based regulation.[98] A goal-based regulatory regime sets objectives, and allows flexibility on how to achieve compliance. For example, when building a bridge, a goal-based standard would state that "*cars shall be prevented from falling over the edge of the bridge.*"[99] The equivalent prescriptive standard would specify how to achieve compliance to this objective, such as *"you shall install a 1 meter high rail at the edge of the bridge"*.[100]

One advantage of prescriptive standards are that they are easy to follow and measure. It is therefore easy from the service provider's perspective to demonstrate compliance, and from the regulator's perspective to measure it. But, there are several disadvantages to prescriptive regulations:

1. Prescriptive regulations are usually based on past experience. These can be insufficient for technically innovative industries and may not keep up with the diversity of design solutions.[101] They therefore have the poten-

[98] Industry Standards Group, 2012.
[99] Penny et al., 2001.
[100] Ibid.
[101] Ibid.

tial to hinder innovation.[102] Unless updated regularly, such standards may actually prevent the service provider from adopting current best practice (for example, see Box 5).[103]

**Box. 5: Example of outdated prescriptive standards**

The 2001 Gujarat earthquake resulted in complete demolition of the Bhuj Civil Hospital. The importance of using advanced technologies such as base-isolation was acknowledged after this event. This hospital was the first building in India to be reconstructed using New Zealand developed base-isolation technology. The 300 bedded hospital was fitted with lead rubber bearing for base isolation. While base-isolation exists in India now, Indian standards for base-isolation still do not exist.[a]

[a]See Gujarat State Disaster Management Authority, 2018, Patel, 2014 and Arya, 2015.

2. Prescriptive regulation is a potential barrier to open markets and trade, as it could be restrictive in terms of international agreements that promote equivalent safety across countries.[104]
3. Prescriptive regulations only require adherence to mandated actions. If these prove to be insufficient to prevent a subsequent accident, the regulations and those that set them are held responsible, making safety the responsibility of the regulator and not the service providers.[105]
4. Adhering to prescriptive regulations could prove to be more expensive than existing alternative solutions.[106]

On the other hand, prescriptive standards are used when there is lacking competence to convert descriptive requirements into quantitative specifications. This could be due to an insufficient number of competent professionals; a small number of academic bodies imparting such attitude, skill and knowledge; or lack of regulatory bodies with the capacity to ensure performance objectives are met. As a result, an appropriate balance between the two regulatory frameworks should be considered when developing a regulatory framework for standards, one that encourages compliance and allows for its measurement.

[102]Industry Standards Group, 2012.
[103]See Penny et al., 2001 and Industry Standards Group, 2012
[104]See Penny et al., 2001 and Industry Standards Group, 2012
[105]Penny et al., 2001.
[106]Ibid.

## 5.2 Adjusting for levels of disaster risk

Risk is a function of hazard, exposure and vulnerability.[107] Construction standards have to ensure (as far as possible) that infrastructure survives any projected demands, such as earthquakes of a certain intensity in high seismic zones.

India has already taken steps to incorporate levels of hazard when developing standards. For earthquakes, the *IS 1893 (Part 1): Indian Standard Criteria for Earthquake Resistant Design of Structures* groups the country into four seismic zones based on past seismic history. Each zone has been allocated a *"Zone Factor"* that is used to account for the effects of peak ground acceleration during the maximum considered earthquake ground motion in that zone, and to use it while making structural designs.[108] As a result, while the procedure for structural design of a particular type of building remains the same across the country, the final design and dimensions of the building will vary based on the zone.

India has reviewed and updated these classifications (and the standards assigned to them) over time. For example, the 1993 Killari Earthquake of 6.6 magnitude occurred in a region classified then as Zone 1 (i.e. least prone to seismic activity). One of the built components that collapsed was a 100,000 litre water tank. Its failure has been attributed to its fullness at the time of the earthquake which added to inertial forces, along with improper or inadequate tying of pillar reinforcement. These issues could have been compounded by a spiral staircase against the tank.[109] But, most other engineered structures in the region survived the earthquake with minor damages.[110] This raised concerns about the appropriateness of existing standards: why they served well for some infrastructure but not others, and whether they are inappropriately high for a defined zone, given that most structures built for a Zone 1 region survived a 6.6 magnitude earthquake. Standards have since been updated. This best practice of review and update could be further expanded not just by type of hazard, but also by type of infrastructure, such as dams or bridges.

Another important reason to update standards is the constant technological improvements in risk assessment, structural and material engineering, and new information that allow improvements that might have been prohibitively costly once, to be reasonably affordable today. In this respect, setting standards is a form of cost benefit analysis. A country does not adopt very costly standards that could make the infrastructure unaffordable to build. The choice of how safe

[107] UNISDR, 2009.
[108] Bureau of Indian Standards, 2002.
[109] Narula et al., 1996.
[110] Ibid.

a structure should be is determined by whether it can be built at reasonable cost, and should be based on engineering rigour rather than intuition.

## 5.3 Standards for Operation and Maintenance (O&M)

The notion of standards goes beyond the structural engineering aspect of infrastructure, to also include O&M. If standards for O&M are inadequate, this can increase the impact of hazardous events or even trigger new ones, such as urban floods due to inadequate maintenance of urban drainage systems (for example, see Box 6). Standards for infrastructure resilience should therefore include best practices for O&M. Many such standards already exist in India.[111] Reviewing these regularly and making them comprehensive would reduce the risk of and from hazards.

**Box. 6: Chicago 1992 flooding: example of O&M failure**

Chicago experienced floods in 1992 due to a crack in a freight tunnel, allowing the river flowing through the city to pour into the building basements. This affected all the critical service systems, leading to shut down of one of the main economic centres of the US. About 100 buildings connected with the tunnels were flooded, resulting in evacuation of more than 250,000 people and accounted for $40 million to pump water from the tunnel system, which took five and a half weeks. The damage could have been minimised and the leak could have been repaired easily, if it had been done in time. [a]

[a] Inouye and Jacobazzi, 1992 Martinez et al., 2012

In India, since a large stock of the physical infrastructure is yet to be built, there are opportunities to reduce O&M costs, by building new infrastructure in more efficient ways. Improving project selection, delivery, and management of existing assets could translate to 40% savings.[112] As India progresses in augmenting its physical infrastructure, it could save costs by factoring in efficient O&M techniques. In some cases, O&M costs are estimated to be as much as 60% of total expenditure requirement; savings can therefore come from improved management systems.[113] For example in the case of dams, inadequate maintenance despite serious defects pointed out by expert committees placed the safety of the dams and

[111] For example, the Ministry of Railways specifies O&M standards for all railway stations. See Ministry of Railways, Government of India, 2009

[112] McKinsey Global Institute, 2016.

[113] See Yepes, 2008, stated in Estache, 2010 and McKinsey Global Institute, 2016

the surrounding population at risk. As per the minutes of the 3rd meeting of the National Committee on Dam Safety (NCDS), pre and post monsoon inspections for large dams were to be carried out by the dam safety organisation of each state. Out of 17 states and union territories audited in 2017, only two states had fully carried out these inspections, three had carried out the inspections partially and the remaining 12 had not carried them out at all.[114]

## 5.4 Identifying critical infrastructure

Certain types of infrastructure provide essential services. In the event of a disaster, resilience in this type of *"critical infrastructure"* is crucial for minimising the impact of the disaster.[115] These include hospitals, fire stations, infrastructure for power and water supply, and transport networks. This infrastructure is integral to the functioning of society, and a disruption has significant negative implications. Inadequate resilience in these structures could increase loss of life.[116] Further, critical infrastructure (such as a school) often hosts a large number of people. The potential loss is therefore greater if the infrastructure were to fail. For example, 18,000 children died in schools during the 2005 Kashmir earthquake; 971 students and 31 teachers died in the 2001 Gujarat earthquake, which also destroyed about 227 health facilities.[117]

The Bhuj Civil Hospital (Gujarat) has since been identified as critical infrastructure and was built in compliance with more resilient infrastructure standards.[118] In some cases (e.g. earthquakes), Indian standards have also taken steps towards identifying critical infrastructure. For example, the *IS 1893 (Part 1): Indian Standard Criteria for Earthquake Resistant Design of Structures* provides for an Importance Factor *"I"*, which is determined by the functional use of the structure in question, characterised by negative consequences of its failure, post-earthquake functional needs, historical value and economic importance.[119] The standard notes that buildings may be designed for a higher value of *"I"* depending on economic and strategic decisions. India's framework for standards can build on this in order to comprehensively identify all critical infrastructure. It can also be developed so that in the event that infrastructure fails due to a hazard, it does so

[114] Comtroller and Auditer General of India, 2017.
[115] See Bach and Gupta, 2013, Steering Committee of the Tsunami Global Lessons Learned Project, Asian Disaster Preparedness Center, 2015
[116] Ibid.
[117] Ibid.
[118] Gujarat State Disaster Management Authority, 2018 Patel, 2014 Arya, 2015
[119] Bureau of Indian Standards, 2002.

in a way that minimises damage and loss as far as possible (see Box 7).[120]

**Box. 7: Minimising damage and loss: Allowing for safe-to-fail infrastructure**

In the past, a *"fail-safe"* approach to urban planning was incorporated to provide resilience, where infrastructure is built to a certain standard to withstand hazards to a certain level.[a] However, while infrastructure can be made disaster resilient, it cannot be made entirely disaster proof for all possible disaster scenarios. Low frequency, high impact events (or in some cases, cascading events that are hard to predict or model) can challenge even the most well designed infrastructure. The notion of *"safe-to-fail"* infrastructure has therefore emerged where, in the event that infrastructure fails due to a hazard, it does so in a way that minimises damage and loss as far as possible, i.e. when an extremely rare hazard event occurs, the consequences can be managed and the effects are not disproportionately catastrophic.[b] For example, the new Surajbadi Highway Bridge in India was nearing completion when an 2001 Gujarat earthquake occurred. This bridge was being built with reinforced concrete stoppers to limit lateral seismic displacement. While most of these stoppers were damaged, having them in place kept the bridge deck intact. The bridge was completed five weeks after the earthquake.[c]

[a] Ibid.
[b] Ibid.
[c] Hengesh et al., 2002.

## 5.5 Anticipating future risk

With improvements in technology, our understanding of risk and therefore standard requirements is improving. But, for large infrastructure, it is likely that the nature of risk itself will evolve over the life cycle of the infrastructure, due to emerging factors such as climate change (for example, rising sea levels may impact the effectiveness of current coastal zone regulations). Therefore, before building new large infrastructure, different risk scenarios (e.g. climate change scenarios) or models for design, maintenance or planning should be considered, so that the new infrastructure can be built in a way that can accommodate future upgrades and facilitate cost-effectiveness.[121]

[120] Ahern, 2011.
[121] International Institute for Sustainable Development, 11-2013.

## 5.6 Governing responsibilities of professionals

The model for governing responsibilities in each step of the building and maintenance process will impact the extent to which standards are adhered to. For example, if the infrastructure builder is also responsible for its long term O&M, he has an increased incentive to adopt the appropriate standards for reducing risk at the point of construction. In contrast, if the designer of infrastructure is also responsible for its construction, the incentive is to over-design the infrastructure as the builder is paid a proportion of the total cost of construction. An appropriate governance model that takes these incentives into account is required when assigning responsibility to professionals.

## 5.7 Interconnected systems and cascading effects

Economic infrastructure is often part of a larger interconnected system of other similar infrastructure, or dependent infrastructure belonging to a different sector. For example within the transport sector, a bridge serves as a pathway between two roads and in the event of bridge failure, the connecting roads are also disrupted. On the other hand, the communication sector relies on electricity generating infrastructure for cell towers to run. As a result, when infrastructure fails, it could create cascading effects for other dependent infrastructure. For example, a storm that destroys power pylons disrupts not only power supply, but also traffic signals, or food and fuel distribution that require power to function.

These cascading effects can emerge due to spatial interconnectedness, i.e. when the failing infrastructure is in close proximity of other infrastructure.[122] For example, in the event a large dam breaches, all downstream infrastructure is at risk of damage. Similarly, when a bridge falls, the debris may damage any infrastructure under it. Cascading effects can also occur when there are functional dependencies, such as with the case of cell towers relying on electricity generating infrastructure to function.[123] When building new infrastructure and identifying critical infrastructure, opportunities arise to address these interdependencies. Development can therefore be planned in a way that minimises the potential for cascading effects. Further, identifying these interdependencies allows for better prepared contingency plans and continuity processes to be established for dependent infrastructure. Zimmerman and Restrepo highlight some of these interdependencies across infrastructure sectors, as shown in the Annex.

[122] Zimmerman and Restrepo, 2009.
[123] Ibid.

## 5.8 Option to retrofit

While a large amount of infrastructure is yet to be built in India, any existing infrastructure that has not been built to the required standards can either be demolished and rebuilt to the required standards, or retrofitted to higher (or, if possible, required) standards. For each individual item of infrastructure, a cost-benefit analysis could be used to determine which option is more cost-effective. This could also help establish whether achieving the same standards required for new infrastructure through retrofitting is cost-effective. Other key elements of the infrastructure in question can also be factored into this analysis.

For example in Italy, a country faced with earthquake risk, efforts to retrofit heritage buildings are taken in order to improve their cultural heritage.[124] However, difficulties in doing this analysis may arise from trying to understand what standards were used in the first place. Another option would be to retrofit an entire area for better planning and land-use.

In 2015, the Indian government launched its Smart Cities Mission.[125] One main aim of this mission is to facilitate India's urbanisation so that existing urban areas are transformed into better functioning ones through retrofitting specific areas and planning them more efficiently.[126] The government could consider developing a quantitative risk assessment tool towards monitoring the reduction in risk under this program, which may also provide some incentives towards retrofit project funding.

[124] Frumento et al., 2006.
[125] Ministry of Urban Development, Government of India, 2015a.
[126] Ibid.

# 6 Conclusion

India is set to build a large stock of infrastructure in the next two decades. As a result, the country is well placed to incorporate disaster risk resilience while building its new and additional urban landscape in the coming years. It will benefit from developing a comprehensive national framework for standards. Yet, there are many challenges in this task. When developing infrastructure standards, India's regime is still catching up to international best practice. This regime is not factoring in the dynamic nature of the country, such as the current and future population or traffic growth. Developing and adopting new standards is difficult enough, but implementing them and monitoring that implementation is perhaps one of most difficult challenges facing India today.

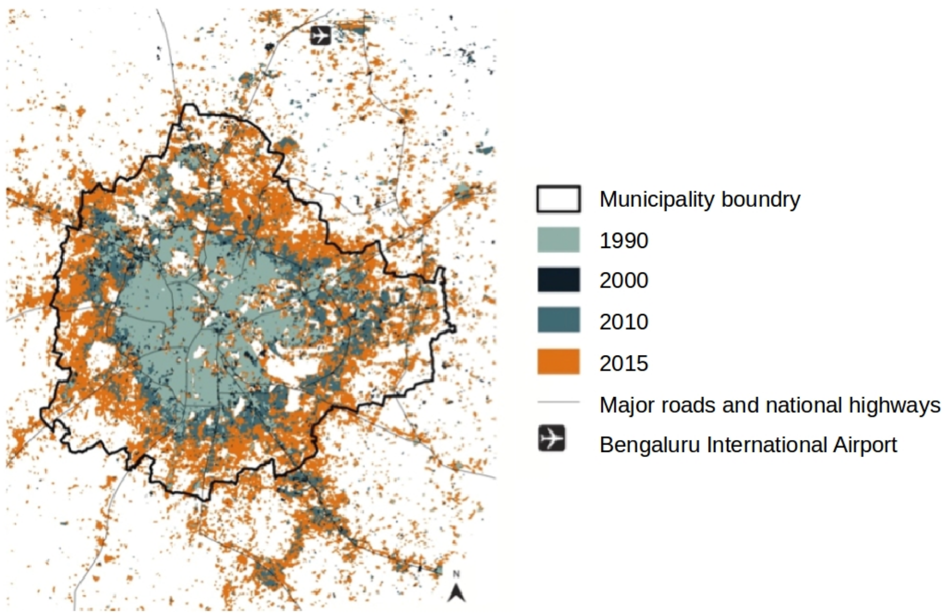
As standards improve, as land use planning adjusts to the upward pressure of hazards (e.g. increased occurrence of Hoghest Flood Levels (HFLs) or newly declared Coastal Regulation Zones (CRZs)), as our understanding of geophysical hazards becomes more sophisticated and location specific, there may be a need to upgrade the existing stock of infrastructure in accordance with new standards. Modelling and anticipating how risk itself will evolve in the coming decades (for example, due to climate change in coastal areas) will better guide how new infrastructure should be built. Doing so would also indicate whether new infrastructure should be built in a way such that future upgrades are easily facilitated to absorb this evolving risk. Based on a review of India's framework for building infrastructure, and developing and implementing standards, the following areas for improvement could be considered.

1. **Streamlining development of standards**
   Standards for infrastructure are developed by multiple bodies. Some are government bodies governed by law, while others are private entities with no legal mandate detailing the process of developing standards. As a result, the process of developing and systematically reviewing these standards is likely to vary. Streamlining both types of processes could help assure that all appropriate risk is factored in when the standard is adopted.
2. **Expanding coverage of standards**
   A municipality's building bye-laws apply only within the jurisdiction of that municipality. As a result, even if all building bye-laws are developed and enforced well, urbanisation in areas not within a municipal boundary (e.g. unplanned urbanisation that has crossed over geographical boundaries of a municipality, or a census town) remains as per the panchayat level regulations, which may increase risk for those areas.[127] For example,

[127] Ministry of Urban Development, Government of India, 2016.

Figure 5 shows urbanisation in Bengaluru that has crossed over the geographical boundaries of the municipality.[128] Similarly in 1991, the Municipal Corporation of Greater Mumbai lowered its Floor Space Index (FSI), i.e. the permitted ratio of a building's floor area to the total area of that plot. This pushed businesses and people out of the municipality boundary, due to the resulting increase in property prices within the city.[129] Addressing this issue to allow for sufficient enforcement of infrastructure development could also be done in coordination with land policies.[130]

**Figure 5:** Urbanisation in Benglauru beyond municipality borders (1990-2015). Source: WRI India, Dhindaw, 2016




3. **Minimising gaps and overlaps**
   The current framework allows for gaps and overlaps in standards. For example, there are overlapping codes for laying the foundation for a bridge in India, in the case where the bridge accommodates both a road as well as a railway (e.g. part of the Nagpur Metro is being constructed as both a flyover and a metro line).[131] IRC 6 requires the seismic load for the bridge

[128] Dhindaw, 2016.
[129] Vishwanath et al., 2013.
[130] Ibid.
[131] The Times of India, 2018.

should be taken as 1.35 times the forces transmitted by the substructure.[132] But, RDSO guidelines specify this value to be 1.25.[133] Similarly, codes do not exist in some areas and therefore need to be created or formally adopted. For example, when constructing a bridge, detailed provisions are needed for ductile detailing. A review of standards to identify these gaps and overlaps would help reduce risk during implementation.

4. **Improving coordination**
   As seen with IRC standards, there are national-level sectoral standards that can be applied across jurisdictions that overlap with local bodies. These bodies may have their own standards for similar types of infrastructure, such as for roads within a municipality. Coordination plays an important role here. The road network needs to be observed as a whole rather than in isolated components. The effectiveness of national highways in serving the people they were built for depends to an extent on the quality of roads at lower levels of governance. Even if these are built with different standards, a dialogue between the governing bodies is needed to ensure coherence across the system. Well-designed and thought out coordination could help achieve this coherence and reduce risk.
5. **Adopting suitable international standards**
   When adopting international standards, India chooses which relevant standards are incorporated into its national framework. A system of reviewing which standard is more appropriate when there is a choice (such as cost-benefit analysis of options) could help identity the standard that is most suitable to reduce risk while still being feasible to implement in India.
6. **Developing standards for planning systems**
   Ensuring adequate resilience in individual infrastructure assets may not always translate to systemic risk reduction, unless processes for town planning are also developed and implemented. When building the same infrastructure (e.g. a bridge) in two geographically different locations, both the built and natural environment at each location plays an important role in terms of whether the infrastructure chosen standards are sufficient. An integrated approach is therefore needed, where both the type of infrastructure as well as the environment it is being built in, is considered. Here, developing the capacity and regulatory framework for town planners and the profession is a prerequisite.
7. **Regulation of professionals**
   While there is a statutory regulator for architects in India, there is no such corresponding regulator for the education and profession of engineers and

[132]Indian Roads Congress, 2014.
[133]Research Designs and Standards Organisation, Ministry of Railways, 2015.

town planners. Developing these would help reduce risk by setting educational requirements and developing systems for licensing professionals. Licensing would allow for vetting the skills of the professionals, and continuous updates of these skills. This would, in turn, increase accountability of safety outcomes.

In this paper, we present an overview of infrastructure standards for India. Moving forward, a deeper analysis by sector in terms of how standards are developed, implemented and updated is needed in order to guide specific sector-wise recommendations.

# Annex: Interdependencies across infrastructure sectors

**Table 3:** Generic interdependencies among infrastructure sectors.
Source: Zimmerman and Restrepo

| | Oil and gas | Electricity | Transport | Water | Communication |
|---|---|---|---|---|---|
| **Oil and gas** | - | Fuel to operate power plant motors and generators | Fuel to operate transport vehicles | Fuel to operate pumps and treatment | Fuel to maintain temperatures for equipment and for backup power |
| **Electricity** | Electricity for extraction and transport (pumps, generators) | - | Power for overhead transit lines | Power to operate pumps and treatment | Energy to run cell towers and transmission equipment |
| **Transport** | Delivery of supplies and workers | Delivery of supplies and workers | - | Delivery of supplies and workers | Delivery of supplies and workers |
| **Water** | Production water | Cooling and production water | Water for vehicle operation;cleaning | - | Water for equipment cleaning |
| **Communication** | Breakage and leak detection; remote control of operations | Detection and maintenance of operations and electric transmission | Identification and location of disabled vehicles, rails and roads; provision of user service information | Detection and control of water supply and quality | - |

## References

Ahern, Jack F. (2011). "From fail-safe to safe-to-fail: sustainability and resilience in the new urban world". In: *Landscape Architecture and Regional Planning*.

American National Standards Institute (2018). *Domestic Programs (American National Standards) Overview*. URL: https://www.ansi.org/standards_activities/domestic_programs/overview?menuid=3 (visited on 03/17/2018).

Arya, Anand Swarup (2015). "Reducing Earthquake Losses - A Lesson from Kachchh Experience". In: *Journal of Earthquake Science and Engineering* 2.1, pp. 25–34. URL: http://www.joes.org.in/openaccess/P12_A.S.ARYA.pdf.

Asian Development Bank (2016). *Incentives for Reducing Disaster Risk in Urban Areas, Experiences From Da Nang (Viet Nam), Kathmandu Valley (Nepal), and Naga City (Philippines)*. URL: https://www.adb.org/sites/default/files/publication/185616/disaster-risk-urban.pdf.

– (2017). *Meeting Asia's Infrastructure Needs*. Manila, Philippines. URL: https://www.adb.org/sites/default/files/publication/227496/special-report-infrastructure.pdf.

Bach, Claudia and Jorn Gupta Anil K. Birkamnn (2013). *Training Module: Critical Infrastructures and Disaster Risk Reduction (in the Context of Natural Hazards)*. URL: http://nidm.gov.in/PDF/modules/cric%20infra.pdf.

Balthazard, Claude (2016). *What does it mean to be a regulated profession? HRPA Series on Governance for Professional Regulatory Bodies*. Tech. rep. Human Resources Professionals Association.

Bureau of Indian Standards (2018a). *How Indian standards are made?* URL: http://www.bis.org.in/sf/pros_setting_std.asp (visited on 03/17/2018).

– (2018b). *SP 7:2016 National Building Code of India 2016 (NBC 2016)*. URL: http://bis.org.in/sf/nbc.asp (visited on 03/17/2018).

– (2018c). *Synopsis of Indian Standard- IS 1893 (Part 1): 2016, Criteria For Earthquake Resistant Design Of Structures - Part 1: General Provisions And Buildings*. URL: http://www.standardsbis.in/Gemini/scoperef/SR1893_1.pdf (visited on 03/17/2018).

– (2002). *IS 1893 (Part 1): Indian Standard Criteria for Earthquake Resistant Design of Structures*.

– (2016). *IS 13920: 2016, Ductile Design and detailing of reinforced concrete structures subjected to seismic forces-Code of practice*. URL: https://www.nicee.org/BIS/.

Central Public Works Department, Ministry of Urban Developmen (2013). *Various local approvals and clearences required for large scale project in metro cities*. Tech. rep. National Infrastructure Unit, The Treasury, New Zealand.

Comtroller and Auditer General of India (2017). *Performance audit of Union Government Schemes for Flood Control and Flood Forecasting Reports of Ministry of Water Resources, River Development and Ganga Rejuvenation: Report No. 10 of 2017*. Tech. rep. URL: http://www.im4change.org/siteadmin/tinymce//uploaded/Report%20of%20the%20CAG%20on%20Schemes%20for%20Flood%20Control%20and%20Flood%20Forecasting.pdf.

Consulting Engineers Association of India (2017). *Need for legislation*. URL: https://ceai.org.in/engineers-bill/engineering-associations/ (visited on 06/20/2017).

Dhindaw, Jaya (2016). *Unlock Bengaluru: Five Things the City Needs to Get Right*. URL: http://wri-india.org/blog/unlock-bengaluru-five-things-city-needs-get-right.

Engineering Council of India (2018). *Why Engineering Council of India (ECI)?* URL: http://www.ecindia.org/default.htm (visited on 03/17/2018).

Engineers Canada (2018). *About Engineers Canada*. URL: https://engineerscanada.ca/about/about-engineers-canada (visited on 03/17/2018).

Estache, Antonio (2010). "Infrastructure finance in developing countries: An overview". In: *EIB Papers* 15.2, pp. 60–88.

Frumento, S et al. (2006). "Seismic retrofitting of unreinforced masonry buildings in Italy". In:

Global Facility for Disaster Reduction and Recovery (GFDRR) (2016). "Building Regulation for Resilience - Managing Risks for Safer Cities". In: URL: https://www.gfdrr.org/sites/default/files/publication/BRR%5C%20report.pdf.

Government of India (1949). *Constitution of India*. URL: http://lawmin.nic.in/coi/coiason29july08.pdf (visited on 10/20/2017).

– (2006). *National Highways Authority of India Works Manual*.

– (2011a). *Census of India. Primary Census Abstract (Data Highlights)*. Tech. rep.

– (2011b). *Census of India 2011: Provisional Population Totals. Some concepts and definitions*.

Government of Maharashtra (1959). *The Maharashtra Village Panchayats Act*.

– (1966). *Maharashtra Regional and Town Planning Act, 1966*.

Government of Punjab (1976). *Punjab Municipal Corporation Act, 1976*.

Government of Rajasthan (1959). *Rajasthan Municipality Act 1959*.

– (1982). *Jaipur Development Authority Act 1982*.

Gujarat State Disaster Management Authority (2018). *Gujarat Emergency Earthquake Reconstruction Project (GEERP)*. URL: http://www.gsdma.org/Content/geerp-gerrp-4216 (visited on 03/18/2018).

Hengesh, JV et al. (2002). "Bhuj, India Earthquake of January 26, 2001 - Reconnaissance report". In:

Indian Association of Structural Engineers (2018). *Recommended Guidelines on Proof Consultancy Services for Highway Bridges*. URL: http://www.iastructe.co.

in/Recommended-Guidelines-on-Proof-Consultancy-Services-for-Highway%20Bridges.pdf (visited on 03/17/2018).

Indian Roads Congress (2018). *Apex Committees of IRC*. URL: http://www.irc.nic.in/index1.aspx?lsid=152&lev=2&lid=154&langid=1 (visited on 03/17/2018).

– (2014). *IRC:6- 2014, Standard Specifications and Code of Practice for Road Bridges, Section II - Loads and Stresses (Revised Edition)*. Tech. rep.

Industry Standards Group (2012). *Specifying Successful Standards. An industry enquiry into how standards and specifications can enable the UK to innovate, lower costs and improve whole life value of our infrastructure assets: Infrastructure Cost Review*. Tech. rep.

Inouye, Randall R and Joseph D Jacobazzi (1992). "The great Chicago flood of 1992". In: *Civil Engineering* 62.11, p. 52. URL: http://cedb.asce.org/CEDBsearch/record.jsp?dockey=0079566.

International Institute for Sustainable Development (11-2013). *Climate Change Adaptation and Canadian Infrastructure. A review of the literature*. Tech. rep.

International Organization for Standardization (2018). *ISO/TR 37121:2017. Sustainable development in communities - Inventory of existing guidelines and approaches on sustainable development and resilience in cities*. URL: https://www.iso.org/standard/63790.html (visited on 03/17/2018).

International Organization for Standardization and International Electrotechnical Commission (2017). *ISO/IEC Directives, Part 1. Consolidated ISO Supplement - Procedures specific to ISO*.

Jaipur Development Authority (2018). *Jaipur Development Authority*. URL: http://jda.urban.rajasthan.gov.in/content/raj/udh/jda---jaipur/en/home.html# (visited on 03/17/2018).

Jaipur Municipal Corporation (2018). *Jaipur Municipal Corporation*. URL: http://urban.rajasthan.gov.in/content/raj/udh/jaipur-nagar-nigam/en/home.html (visited on 03/17/2018).

Martinez, Xavier et al. (2012). "Inflatable plug for threat mitigation in transportation tunnels". In: URL: http://barbero.cadec-online.com/Proceedings/2012/2316.pdf.

McKinsey Global Institute (2016). *Bridging the Infrastructure Gap*. Tech. rep.

Ministry of Railways, Government of India (2009). *Manual for standards and specifications for railway stations*. Tech. rep.

Ministry of Urban Development, Government of India (2015a). *Smart Cities. Mission Statement and Guidelines*. Tech. rep.

– (2015b). *Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines Volume I*. URL: http://moud.gov.in/upload/uploadfiles/files/URDPFI%5C%20Guidelines%5C%20Vol%5C%20I(2).pdf.

– (2016). *Model Building Bye-Laws, 2016*.

Municipal Corporation Jalandhar (2010). *Municipal Corporation Jalandhar Building Bye-Laws, 2010.*

Narula et al. (1996). *Macroseismic surveys and source mechanims of Latur eathquake of 30 September 1993, Peninsula India.* Tech. rep. 1765. Geological Survey of India. URL: http://www.iitk.ac.in/nicee/wcee/article/11_1765.pdf.

National Accreditation Board for Hospitals and Healthcare Providers. *National Accreditation Board for Hospitals and Healthcare Providers.* URL: http://www.nabh.co/.

National Rural Roads Development Agency (2007). *Quality Assurance Handbook for Rural Roads.* URL: http://pmgsy.nic.in/downloads/QAHVolI.pdf.

Patel, Nirav G (2014). "Study on a Base Isolation System". In: *International Journal of Innovative Science, Engineering & Technology* 1.8, pp. 2348–7968. URL: http://www.ijiset.com/v1s8/IJISET_V1_I8_33.pdf.

Penny et al. (2001). "The practicalities of goal-based safety regulation". In: *Redmill and Anderson [27]*, pp. 35–48.

Planning Commission, Government of India (1970). *Committee on Technical Consultancy Services.*

– (2008). *Report of the Inter Ministerial Committee: Restructuring of National Highways Authority of India.* URL: http://planningcommission.gov.in/sectors/ppp_report/3.Reports%20of%20Committiees%20&%20Task%20force/Power/12.Report-on-Restructuring-of-NHAI.pdf.

Press Information Bureau, Government of India (2015). *A Big Boost for Solar Rooftops in India.* URL: http://pib.nic.in/newsite/mbErel.aspx?relid=134026.

Public Sector Assurance (2018). *Construction: Case Studies.* URL: http://www.publicsectorassurance.org/topic-areas/construction/#case-studies-tab (visited on 03/17/2018).

Quality Council of India (2018a). *Accreditation Programme for Standards Development Organizations (SDOs).* URL: http://www.qcin.org/Standard-development-Organization.php (visited on 03/17/2018).

– (2018b). *Quality Council of India: Introduction.* URL: http://www.qcin.org/about-qci.php (visited on 03/17/2018).

Research Designs and Standards Organisation, Ministry of Railways (2015). *RDSO Guidelines on Seismic Design of Railway Bridges.* Tech. rep.

Standards Council of Cananda (2018). *Requirements and Guidance - Accreditation of Standards Development Organizations.* URL: https://www.scc.ca/en/about-scc/publications/criteria-and-procedures/requirements-guidance-accreditation-standards-development-organizations (visited on 03/17/2018).

Steering Committee of the Tsunami Global Lessons Learned Project, Asian Disaster Preparedness Center (2015). *Disaster Recovery Toolkit: Guidance on Critical Facilities.* URL: http://www.recoveryplatform.org/assets/tools_guidelines/Critical%20Facilities.pdf.

The Gazette of India: Extraordinary (1972). *The Architect's Act, 1972.*
– (1986). *The Bureau of Indian Standards Act, 1986.*
– (1987). *The Bureau of Indian Standards Rules, 1987.*
– (1988). *The National Highways Authority of India Act, 1988.*
– (1994). *Airports Authority of India Act, 1994.*
The Times of India (2018). *Metro will run 4-storey high over new Wardha Road flyover.* URL: http://timesofindia.indiatimes.com/city/nagpur/Metro-will-run-4-storey-high-over-new-Wardha-Road-flyover/articleshowprint/48992696.cms (visited on 03/18/2018).
United Nations Department of Economic and Social Affairs (2017). *World Population Prospects.* URL: https://esa.un.org/unpd/wpp/.
United Nations International Strategy for Disaster Reduction (2009). *UNISDR Terminology on Disaster Risk Reduction.* URL: https://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf.
– (2013). *Global Assessment Report on Disaster Risk Reduction.* URL: http://www.preventionweb.net/english/hyogo/gar/2013/en/gar-pdf/GAR2013_EN.pdf.
Vishwanath, Tara et al. (2013). *Urbanization beyond municipal boundaries: Nurturing metropolitan economies and connecting peri-urban areas in India.* 75734.
Yepes, Tito (2008). "Investment needs for infrastructure in developing countries 2008-15". In: *World Bank, unpublished draft.*
Zimmerman, Rae and Carlos E Restrepo (2009). "Analyzing cascading effects within infrastructure sectors for consequence reduction". In: *Technologies for Homeland Security, 2009. HST'09. IEEE Conference on.* IEEE, pp. 165–170.

MORE IN THE SERIES

- Choudhury, M., and Mohanty, R.K. (2018). A critique of the Aadhaar legal framework, WP No. 229 (May).
- Malhotra, S., and Roy, S. (2018). Fair play in Indian Health Insurance, WP No. 228 (May).
- Choudhury, M., and Mohanty, R.K. (2018). Utilisation, Fund Flows and Public Financial Management under the National Health Mission, WP No. 227 (May).

Sanhita Sapatnekar, is Consultant, NIPFP
Email: sanhita.sapatnekar@nipfp.org.in

Ila Patnaik, is Professor, NIPFP
Email: ila.patnaik@nipfp.org.in

Kamal Kishore, is Member, National Disaster Management Authority
Email: kkishore@ndma.gov.in

National Institute of Public Finance and Policy,
18/2, Satsang Vihar Marg,
Special Institutional Area (Near JNU),
New Delhi 110067
Tel. No. 26569303, 26569780, 26569784
Fax: 91-11-26852548
www.nipfp.org.in