



Training Module

Critical Infrastructures and Disaster Risk Reduction

(in the Context of Natural Hazards)

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Dr. Dieter Mutz

Director

Indo-German Environment
Partnership (IGEP)
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GIZ-Germany India Office
New Delhi, June 2013

Message from GIZ-IGEP

Since 2010, GIZ has been collaborating with the National Institute of Disaster Management for implementing the “Environmental Knowledge and Disaster Risk Management” (ekDRM) project, aimed at strengthening capacity building initiatives in knowledge management and risk reduction for disasters caused by natural hazards, such as floods, cyclones, drought, or manmade disasters caused by industry. The design and development of training tools, such as an internet based training and knowledge management system and blended learning training methodology and the development of training materials are important activities under this project.

It gives me great pleasure to introduce these training modules to help trainees in developing knowledge and skill in specific thematic areas, to reduce the risk of disasters.

I take this opportunity to express appreciation of the commitment of NIDM, Ministry of Home Affairs, Govt of India, New Delhi, the Institute for Environment and Human Security of the United Nations University and ifanos Germany who extended their support and cooperation to this effort. I wish that such modules are used extensively by all stake holders across the country.



Prof. Dr. Jakob Rhyner
Director

United Nations University
Institute for Environment
and Human Security
(UNU-EHS),

Bonn, Germany, June 2013

Message from UNU-EHS

The mission of UNU in a changing world is to contribute, through research and capacity building, to the efforts to resolve pressing global issues that are of concern to the United Nations, its Peoples, and Member States. Besides its research, the United Nations University Institute for Environment and Human Security (UNU-EHS), together with a worldwide system of UNU research and training institutes and programs (RTC/P), focuses on postgraduate education and conducting research.

With regard to capacity development, UNU-EHS aims to strengthen the institutional capacities of academic institutions in developing and transitional countries. This includes the development of a modular curriculum on Disaster Risk Management (DRM), thereby strengthening universities' teaching capacity. On the other hand, research includes investigation of root causes, factors, and processes contributing to the generation and/or increase of human insecurities and risk management practices, as well as promoting the use of innovative technologies to help improve the work of DRM researchers and professionals.

The UNU-Vice Rectorate in Europe and UNU-EHS are pleased to have partnered with GIZ and are delighted that the dedication and input provided by the faculty members of NIDM, Ministry of Home Affairs, Government of India, New Delhi and ifanos Germany, will ensure a broader spectrum of expertise and will sustain implementation of such postgraduate education, research and professional training in the future. I congratulate the ekDRM team and especially to Dr. Anil K. Gupta, Sreeja S. Nair and Florian Bemmerlein-Lux for this initiative, and to Claudia Bach, the principal author of this module, for taking the lead.



Dr. Satendra, IFS,
Executive Director,
NIDM
New Delhi, June 2013

Foreword

Knowledge of environmental systems and processes are crucial in the management of disasters, particularly the hydro-meteorological ones. Climate-change is the challenge of modern times known to aggravate natural hazards like floods, drought, cyclone, landslides and forest fires, and on the other hand it also intensifies people's vulnerability by affecting their resources and capacities. Environmental conditions including climatic and topographic factors also determine the impact of various natural disasters on infrastructure and resources including critical ones. In the recent disaster in Uttarakhand (June 2013) the power generation and distribution was directly affected with damage to hydro-power plants, reservoirs, and gridlines, which in turn affected communication and other key resources needed for emergency and relief operations.

Sustenance of social well being and developmental activities needs a diverse set of infrastructure for various supplies and services, out of which some are of critical importance. These are, for example, water supply, electricity, health care, communication, etc. which if impacted by a disaster of natural or man-made origin, society's normal activities come to a halt calling for emergency assistance. Electricity is crucial service, and therefore, electricity generation and distribution units are Critical Infrastructure. When affected by an earthquake, tsunami, flooding or water scarcity, it aggravates disaster situation and adversely affects rescue and relief of the people also.

NIDM and GIZ Germany, under the aegis of Indo-German Environment Partnership Programme (IGEP) with Indian Ministry of Environment and Forests, implemented a joint project entitled "Environmental Knowledge for Disaster Risk Management (ekDRM)" wherein development of case studies and training modules are among the key activities. This module's special focus on electricity as a Critical Infrastructure system, developed by the faculty members of UNU-EHS and NIDM, is a praiseworthy effort.

The module is ready for wider use by trainers and scholars of various courses at different levels. I am sure, the module shall be of significant contribution in the capacity building and training related programmes within the country and outside. I would welcome any suggestions of the readers for future improvements.

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1

Introduction

1.1 Context

The massive Tohoku Earthquake and the following tsunamis which hit Japan on March 11th 2011 revealed how severely the destruction of Critical Infrastructure (CI) can affect societies. The indirect effects caused by the damage to the Fukushima nuclear power plant with the widespread losses and the threat to the urban area of Tokyo caught major attention. At the same time also the effects of the earthquake and tsunami such as the destruction of housing and infrastructure services caused exceptional problems. Even one month after the earthquake, 430,000 households were out of gas and electricity besides 150,000 people living still in shelter (SEEDS Asia 2011, p. 2). Other disasters in the recent times i.e. the Haiti earthquake (2010), the Sichuan earthquake (2008), Cyclone Nargis (2008), the Indian Ocean tsunami (2004), the Pakistan earthquake (2005), Hurricane Katrina (2005), the Bam earthquake (2003), the European Floods (2002), the Bhuj earthquake (2001), or the Orissa Super Cyclone (1999) resulted in huge damage to CI. During the 2002 flood in Germany, e.g., municipally-owned and federal infrastructure damages amounted up to 50% of the overall damage caused and accounted for almost 5 billion (Mechler & Weichselgartner 2003, p.18).

Although definitions of CI differ among countries (see Chapter 2), their importance for the functioning of societies is widely recognized. Particularly highly industrialized societies heavily depend on the functioning of infrastructure services such as electricity or telecommunications technology which also facilitate the operation of e.g. transport, health systems or sewage treatment. Infrastructure systems can be interrupted or destroyed by a variety of threats such as natural hazards,

human failure or terror attacks. Hence, the vulnerability assessment of Critical Infrastructures and the dependency of different population groups on these infrastructure services are essential. The vulnerability of CIs towards natural hazards which are in the specific focus of the module necessitates thorough measures to reduce disaster risk. In order to increase disaster resilience, vulnerability assessments are to be made an integral part of the disaster risk management process to natural hazards. As a step towards this goal, vulnerability assessment methods will be introduced within the scope of this booklet. Besides prevention and preparedness, also reconstruction and recovery processes offer opportunities to reduce infrastructure vulnerability and to build back better and safer.

Focusing on Critical Infrastructure protection as part of the core strategy to disaster management is relevant for India due to its proneness to a wide range of natural hazards. India witnessed several hazard events such as earthquakes in Uttarkashi, Bhuj, Kashmir, floods as recurring in almost all hilly states, landslides, dry spells, which led to serious impacts on the Critical Infrastructure and thereby on the functioning of the society. Additionally, the country is characterized by high economic growth rates and infrastructure sectors are constantly expanding. It is important to account for infrastructure vulnerability when investing and extending these systems in order to improve their resilience since they are key for further socio-economic development. A safe electrical energy supply plays a crucial role in this development. Therefore this module has a particular focus on electricity infrastructure and the methodological perspectives for assessing its vulnerability.

1.2. Structure of the Module

This module provides an introduction to disaster risk reduction of Critical Infrastructures (CIs) in the context of natural hazards and an overview on the key issues in CI vulnerability reduction. The module is structured in four Learning Units (LU), as listed below:

Learning Unit A: Understanding Critical Infrastructure

Learning Unit B: Vulnerability of Critical Infrastructure to natural hazards

Learning Unit C: Methods of Critical Infrastructure vulnerability assessment

Learning Unit D: Addressing Critical Infrastructure vulnerability

Learning Unit A deals with definitions of Critical Infrastructures, underscores the relevance of this sector and gives first examples of indicators for Critical Infrastructure vulnerability. Learning Unit B offers a closer look at natural hazards and their specific effects on CIs. Concepts for vulnerability assessments are presented and discussed in Learning Unit C and the relevance of CI vulnerability for India in particular is brought in the perspective. Learning Unit D finally gives some examples on vulnerability reduction strategies for CIs.

Although this publication covers a variety of important factors of Critical Infrastructure which itself is a complex topic due to interdependencies of different sectors, the limited extent of this series does not allow providing details about each and every CI sector and their vulnerabilities. The module also provides hazard specific assessment examples and outlines some potential adaptation strategies. Overall, the publication is meant to provide an overview of the importance of infrastructure services and their consideration in disaster risk reduction to natural hazards while also presenting potential assessment methods and frameworks.

2

Learning Unit A: Understanding Critical Infrastructure

Learning objectives

1. To develop a sound understanding about the infrastructures to be considered as critical.
2. To discuss the increasing complexity of infrastructures and their interconnectivity.
3. To contextualize the electric power supply in India as a Critical Infrastructure and its vulnerability to natural hazards.

Certain types of infrastructure play vital roles in underpinning our economy, security and way of life. These complex and often interconnected systems have become so ubiquitous and essential to day-to-day life that they are easily taken for granted. Often it is only when the important services provided by such infrastructure are interrupted – when we lose easy access to electricity, health care, telecommunications, transportation or water, for example – that we are conscious of our great dependence on these networks and of the vulnerabilities that stem from such dependence. In order to assess the vulnerability of such Critical Infrastructures (CI), it is important to understand and define it. Therefore, common CI definitions are introduced and aspects of criticality will be discussed in the following section.

2.1 Critical Infrastructure Definitions

There is no universal definition of Critical Infrastructure. CIs include a range of engineered systems, assets and facilities which are essential for day-to-day societal functions, as well as continued economic and societal functioning in the aftermath of a disaster event. A variety of CI definitions given in Table 1.

Table 1: National definitions of Critical Infrastructure

Australia	“Critical Infrastructure is defined as those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact on the social or economic well-being of the nation, or affect Australia’s ability to conduct national defence and ensure national security.” (Australian Government 2010, p.8)
Germany	“Critical Infrastructures are organisations and facilities of major importance to the community whose failure or impairment would cause a sustained shortage of supplies, significant disruptions to public order or other dramatic consequences.”(German FMI 2009, p. 4)
European Union	“Critical Infrastructure means an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions” (Art. II a, 2008/ 114/ EC)
United States	“Critical” Infrastructure is defined as systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (Sec. 1016(e) of The USA PATRIOT and Homeland Security Acts, 2001)” (United States: Department of Homeland Security 2009, p.109)

Source: illustration based on OECD 2008, p. 4.

Although definitions differ among countries (see Table 1), major consistencies and key similarities can be found in terms of CI definition. Accordingly, CIs are characterized in many countries by the following attributes:

- Facilities/ systems/ organizations that have an essential meaning for the functioning of societies;
- their breakdown/ failure could cause significant disruption of societies.

One of the most encompassing definitions which will also be used within this report was developed by the United Nations International Strategy for Disaster Reduction (UN/ISDR).

Critical facilities are thereby :

“the primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency. [...] Critical facilities are elements of the infrastructure that support essential services in a society. They include such things as transport systems, air and sea ports, electricity, water and communications systems, hospitals and health clinics, and centres for fire, police and public administration services” (UN/ISDR 2009, p. 8 f).

Critical Infrastructures are usually divided into physical and socio-economic infrastructure systems. Physical CI encompasses all basic services such as electricity and water supply, waste (water) management, transport or information and telecommunication technologies. Socio-economic infrastructures instead include facilities such as hospitals and schools but also public administration, disaster management services and recreational areas (see e.g. IRP n.a., p. 2 or FMI 2009, p. 7). They may exist in public or private sectors, depending on how they are owned, managed and regulated. In some cases, CIs are managed with shared competences between public and private sectors. Finally, the degree of criticality of an infrastructure is determined by its significance in relation to the effects on society in case of its failure (Lenz 2009, p.19).

2.2 Complexity of CIs

As described by the definitions above, CIs are of essential importance for the functioning of societies; their interruption or destruction might have major effects on societies which can be explained by two main reasons: an increasing complexity of infrastructures and a growing dependency of the population on the infrastructure services (see also example in Box 1)¹.

Complexity can be understood as the “difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects” (IRGC 2006) and is characterized by two major developments. First, different types of infrastructure are increasingly dependent on each other (level of interdependency) (compare Figure 1). Electricity can thereby be seen as a basic

¹ Civil coping capacity towards blackouts decreases with an increasing supply security due to a lack of awareness of potential shortfalls (compare FMI 2009).

infrastructure, for information and communication technology as well as for transport or financial services. Second, the integration of markets and the privatization of companies led to a restructuring in the provision of services, resulting in a scattered market with an increased number of actors operating in a geographically extended area (IRGC 2006, Kröger 2008)².

BOX 1: Münsterland, Germany 2005 blackout

The region of Münsterland in Germany experienced a major blackout in winter 2005. Due to heavy snowfall, strong wind and temperatures around 0°C leading to especially wet and heavy snow, several transmission lines and power poles were broken. Consequently, about 250,000 people were without electricity for up to five days. Emergency generators were flown in from the whole Federal Republic to maintain infrastructure services such as hospitals or retirement homes (Bundesnetzagentur 2006; THW 2005).

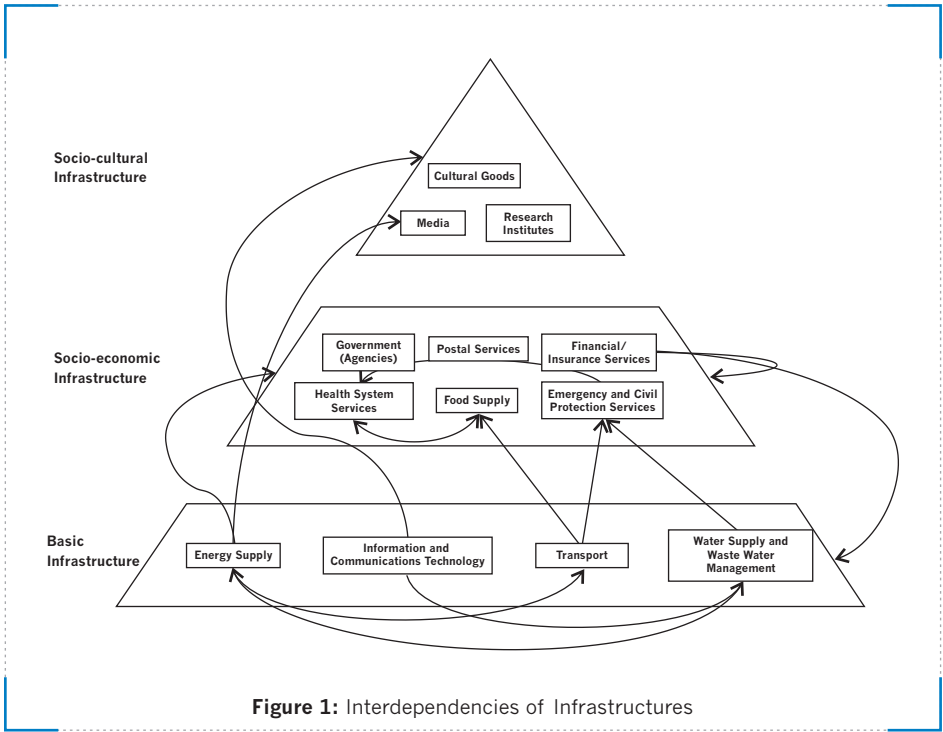


Figure 1: Interdependencies of Infrastructures

Source: Lauwe & Riegel 2008.

²The latter finding does at least account for the European context.

Complexity thus implies a loss of linear cause-effect chains. Instead, failures may lead to (unforeseen) effects that can lead to cascading effects impacting further infrastructure sectors. Besides changes of the system itself (e.g. technique), the dependency of the population on system services also changed over time and still varies among developing and developed countries. Whereas 100 years ago the absence of electricity was a normal condition in today's developed countries, the evolution of electricity grids and increased provision shaped technical and social processes in such a way that their dependence on an uninterrupted electrical power supply grew dramatically (Lorenz 2010; Nye 1990). At the early phase of this process of electrification (around the 1930s), blackouts did not pose a threat towards society. Pre-electrification processes and structures were still in place and people were used to their handling in case of a shortfall (Nye 2007). With the increasing and more reliable use of electricity in everyday life however, the knowledge about the use and the availability of alternative sources slowly disappeared as they were hardly needed anymore. Today there is hardly any buffer in case of a blackout – neither between infrastructures themselves nor between infrastructure and the population in many industrialized countries and countries in transition (Perrow 1992, p. 131; Perrow 2007).

BOX 2: Secondary effects of natural hazards caused by infrastructure failure

Safe drinking water was a serious concern in the aftermath of Cyclone Aila in the Sundarbans. Following cyclone Aila, the Sundarban area, West Bengal, India, reported an increased number of diarrhoea cases at the end of May 2009. A study performed to identify the agent and source of the outbreak as well as to propose control measures was carried out by the Department of Health and Family Welfare, South 24 Parganas District. In total, 1076 probable case patients and 14 deaths were identified. The outbreak started in the fourth week of May, with two peaks in the second and fourth weeks of June, and lasted until August 2009.

Since the supplies were inadequate, villagers broke the water pipelines near their houses for easy access to water. Piped water specimens and stored drinking water were found positive for faecal contamination. Contaminated drinking water was the probable source of the cholera outbreak. Repairing the pipelines, chlorination at household level and educating villagers regarding the danger of breached water pipe connections controlled the outbreak. Tube wells constructed as



Figure 2: Tube well with raised platforms

Source: photo by S.S. Nair 2012.

a part of the Aila recovery programme in affected villages incorporated the DRR considerations by installing wells with raised platforms (see Figure 2). These tube wells serve as a means of clean drinking water in the affected area.

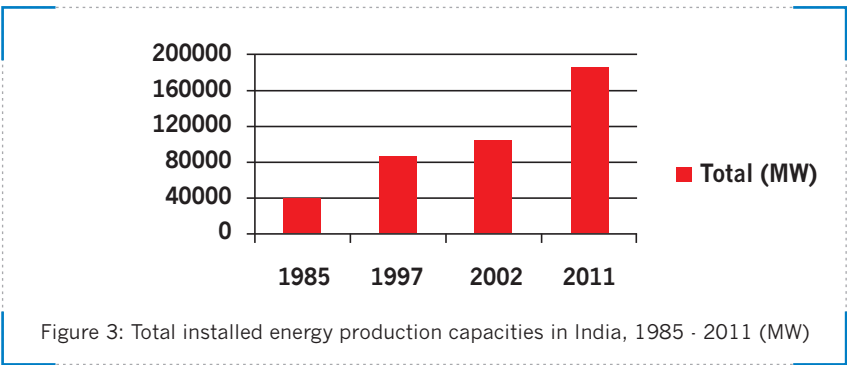
Constructed as a part of Cyclone Recovery Programme by CARE India and Human Development Centre (HDC) in Gangapur Village, West Bengal in India.

Source: Bhunia, R. and S. Ghosh (2011): Waterborne cholera outbreak following Cyclone Aila in Sundarban area of West Bengal, India, 2009, in: Transactions of the Royal Society of Tropical Medicine and Hygiene, Vol. 105(4), pp. 201-219.

At the same time, for many countries, supplying electricity and other infrastructure services to major parts of the population remains still a challenge. Thus, some of the developments described might seem to be of less relevance at first sight. However, infrastructures are expensive and long-lasting investments which are hard to restructure once built. It is thus important to consider the vulnerability which might result from pathway decisions on their development now. Consequently, we take a closer look at infrastructure developments in India with the example of electricity supply.

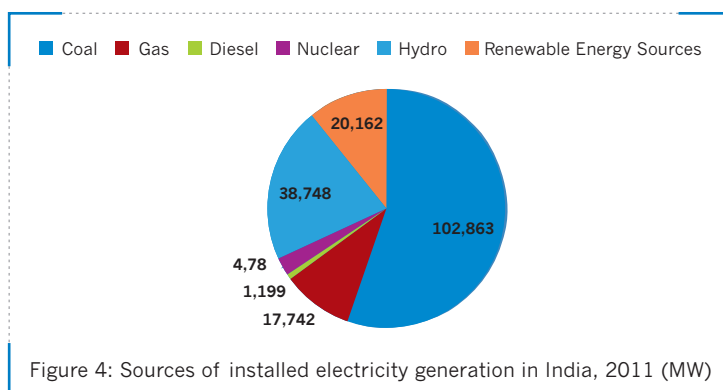
2.3 Development of Infrastructure Sectors in India: The Power Sector

India's infrastructure is constantly growing. Taking the example of the electricity supply sector, in 1997 twice the amount of generation capacity was available compared to 43,000 MW in 1985. Since 2002 the electricity generation capacity almost doubled again from 105,000 MW to 185,000 MW in 2011 (also see Figure 3).



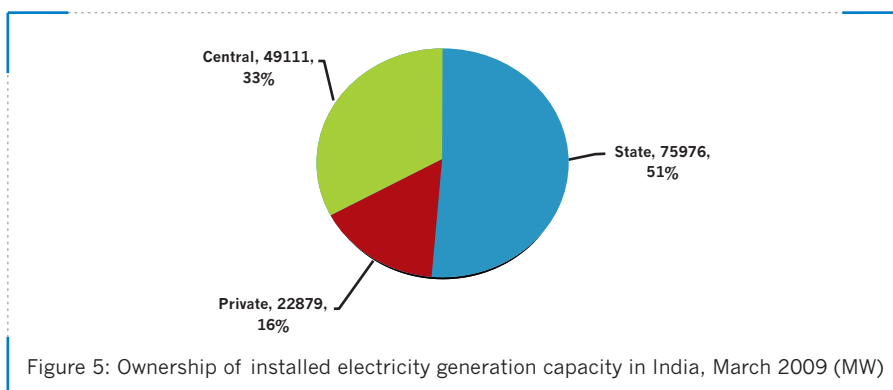
Source: own illustration based on Central Electricity Authority, India 2011.

India's aspiration to become a globally leading economy with low poverty and high growth rates of 8 to 10% per year requires the further extension of the energy sector (Bhattacharyya, 2010). As will be outlined also in Learning Unit B, the overall setup of the system partly determines its overall vulnerability. It is thus important to have a closer look at it. Today, the sector is characterized by the use of high amounts of coal for electricity generation (Figure 4).



Source: own illustration based on Central Electricity Authority, India 2011.

For these supply structures, resource availability and potential price volatilities have to be considered for future developments. India is, however, highly self-reliant and its dependency on imports is low. Major parts of the sector are still controlled by the state (Figure 5) although private participation has been allowed in 1990. As a result, energy prices are not market-based but decided through administrative processes leading to subsidized energy prizes. Side effects of this policy according to Bhattacharyya (2010) are a rather wasteful consumption of energy and a serious financial distress to state-owned electricity supply companies.



Source: own illustration based on Central Electricity Authority, India 2011.

Besides average generation and consumption patterns, it is also useful to derive information about peak demands which have to be covered. For India, around the year different demand peaks have to be considered across the regions which can cause shortages of about 10 to 25% (Table 2).

Table 2: Power supply positions in different regions 2008-2009

Region	Peak demand (GW)	Peak supply (GW)	Peak shortages		Energy demand (GW)	Energy supply (GW)	Energy shortages		Occurrence of peak
			(GW)	(%)			(GWh)	(%)	
Northern	33.034	29.504	3.530	10.69	224.218	199.928	24.290	10.83	June, July and August
Western	37.240	30.154	7.086	19.03	254.486	213.724	40.762	16.02	December
Southern	28.340	26.244	2.096	7.40	204.086	183.865	15.221	7.46	March and October
Eastern	12.901	11.689	1.212	9.39	82.127	78.370	3757	4.57	March
North-eastern	1.820	1.358	0.462	25.38	9407	8134	1273	13.53	January
All India	109.809	96.685	13.124	11.95	774.324	689.021	85.303	11.02	March and October

Source: Shukla and Thampy 2011, based on data of the Central Electricity Authority, India.

The Indian electricity grid is characterized by its three-tier structure comprising distribution networks, state grids as well as regional grids. State grids are thereby interconnecting through high-voltage transmission lines in order to facilitate the transfer of electricity between neighbouring states. Figure 6 shows the five regional grids for India. As indicated, regions vary among their electricity supply capacities and their demand. Accordingly, major amounts of electricity are wheeled through inter-state and inter-region transmission grids (Shukla and Thampy 2011).

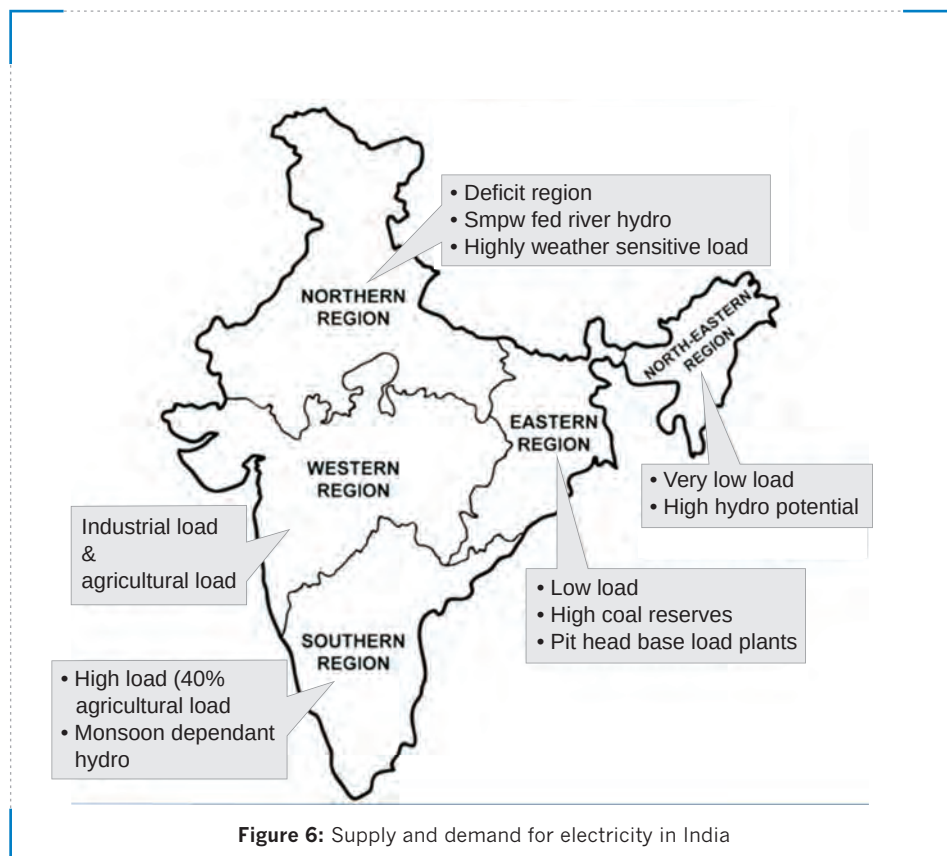


Figure 6: Supply and demand for electricity in India

Source: figure adapted from Shukla and Thampy, 2011 p. 2702, based on CEA India 2007 and Soonee 2008.

This knowledge is important since the overall infrastructure setup has an influence on CI vulnerability, e.g. in terms of maintaining supply levels during heat waves or the geographic extension of blackouts as will be outlined in the following Chapters.

Natural hazards can however affect infrastructures in various ways as also shown by the examples in Boxes 3 to 6. Hazard specific vulnerability assessment methodologies have thus to be applied for the implementation of encompassing risk reduction strategies. Respective examples are outlined in the following Chapters.

BOX 3: Water infrastructure failure effects on response after hurricane Katrina

"Hurricanes Katrina and Rita demonstrated the consequences of mankind's failure to reduce the vulnerability of physical infrastructure. The physical and human toll of these recent disasters and the slow and ineffective initial response efforts are connected to the near total failure of the city of New Orleans' critical public infrastructure. This has intensified the problems and suffering of victims, and impaired the capability of responders to react. The failure of the levee system left New Orleans under floodwater, the destruction of road systems severely limited access to the city and the ability to evacuate stranded residents, and has prevented the delivery of critical relief and energy supplies during the most critical stages of the disaster. The inadequate federal preparation for and execution of the response to Katrina has been severely criticized and led the FEMA director to resign" (Tanali and Harrauld 2006).

"In the case of city's drinking water infrastructure, within a few days after the hurricane, the Environmental Protection Agency (EPA) estimated that 1,220 water systems in Louisiana, Mississippi, and Alabama were inoperable due to power loss. Both of New Orleans' major water treatment plants were inoperable due to excessive wind damage and floodwater inundation. Additionally, since potable urban water systems consist of pressurized pipelines with associated pumps, the power loss rendered pumps inoperable and the pumping stations were buried under floodwater. Even when the power was restored using generators, water was unsafe due to contamination and inadequate hydrostatic pressure caused by excessive cracks in water pipelines. Two weeks after Hurricane Katrina, only 30% of the affected drinking water and 40% of affected wastewater facilities were restored" (Copeland, 2005, p 71).

3

Learning Unit B: Vulnerability of Critical Infrastructures (CIs) to Natural Hazards

Learning objectives

1. Defining vulnerability, its components and its characterization with respect to CI.
2. Understanding the threats to Critical Infrastructure, their specific significance and characteristics.
3. Assessing system vulnerability.
4. Reviewing infrastructure system characteristics influencing the vulnerability to natural hazards.

3.1 Vulnerability of Critical Infrastructures

In the context of vulnerability research, a variety of concepts and definitions exists (for example, Turner et al. 2003; Wisner et al. 2004; Birkmann 2006, and Thywissen 2006). It is therefore essential to clarify how vulnerability is defined within the scope of this publication. The understanding refers to the definition by the United Nations International Strategy for Disaster Reduction (UN/ISDR). Accordingly, vulnerability is characterized by “the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of “hazards.” (UN/ISDR 2004, p. 7)

Following this definition and according to Borgardi and Birkmann (2004) and Cardona (1999/2001), vulnerability is shaped by mainly three components: exposure, susceptibility and coping capacity. Exposure can be defined as the

“elements at risk, an inventory of those people or artefacts that are exposed to a hazard” (UNDP-BCPR 2004, p.136).

Whereas susceptibility describes the likelihood of suffering harm from a hazard, coping capacity can be depicted as

“the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster” (UN/ISDR 2004, p.2).

Vulnerability can thus be described by the following function:

$$f(\text{Vulnerability}) = \text{Exposure} \times \text{Susceptibility} \times \text{Coping Capacity}$$

These definitions show that vulnerability towards natural hazards is to large amounts socially constructed. Hence, social, economic and environmental factors heavily determine the impacts of a hazard. With respect to Critical Infrastructures, vulnerability assessment approaches considering the effects of their shortfall are, however, basically lacking. Although there have been some attempts to conceptualize Critical Infrastructures and their vulnerabilities (see e.g., Rinaldi 2001, IRGC 2006, Hellström 2007, Lauwe and Riegel 2008, Kröger 2008, Lenz 2009), most of these approaches remain at a very general level or focus on specific details, without showing a systematic overview of the overall vulnerability of the system, its components and processes. Nevertheless, the application of vulnerability assessment frameworks in order to develop a basis for planning is feasible and will be shown in Chapter 4.

3.1.1 Exposure

Critical Infrastructures can be exposed to a variety of Hazards. In this regard, hazards are defined as

“potentially damaging physical event[s], phenomenon[s] and/or human activity[ies], which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro meteorological and biological) and/or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability” (UN/ISDR 2004).

Hazards can be grouped into natural events, technical failure and terrorism, crime and war (Table 3).

Table 3: Threats towards Critical Infrastructure

Natural events	Technical failure/ human error	Terrorism, crime, war
Hydro-meteorological hazards	System failure (e.g. insufficient or excessive complexity of planning or defective hardware)	Terrorism
Geological hazards	Negligence	Sabotage
Epidemics and pandemics (in man, animals and plants)	Accidents and emergencies	Other forms of crime
Cosmic events (e.g. meteorites or energy storms)	Failures in organizations (e.g. shortcomings in risk and crisis management or inadequate coordination/ cooperation)	(Civil) Wars

Source: adapted from FMI 2009.

The overview shows that natural hazards, technical failure/ human error as well as terrorism, crime and war have to be considered as causes for severe infrastructure disruption. In the context of this material, hydro-meteorological and geological hazards are particularly relevant.

Hydro-meteorological and geological hazards can be specified as follows:

Hydro-Meteorological hazards (processes or phenomena of atmospheric, hydrological or oceanographic nature):

- floods, debris and mud floods
- tropical cyclones, storm surges, thunder/hailstorms, rain and wind storms, blizzards and other severe storms
- drought, desertification, wild-land fires, temperature extremes, sand or dust storms
- permafrost and snow or ice avalanches

Geological hazards (internal earth processes or tectonic origin):

- earthquakes, geological fault activity, tsunamis, volcanic activity
- external processes such as mass movements:
 - o landslides, rock slides, rock falls or avalanches
 - o surfaces collapses, expansive soils and debris or mud flows

These hazards can vary in terms of intensity, frequency, duration, area of extent, speed of onset, spatial dispersion and temporal spacing. They can be differentiated into slow and sudden onset hazards which have different impacts on systems regarding time and geographical scale. Sudden onset hazards such as flooding are rather limited in their geographical extension and time scale (Gaume et al. 2004). These hazards can have devastating physical effects on infrastructure components, e.g. by water intrusion. Slow onset hazards such as (combined) heat waves/ dry spells instead are much more expansive in their geographical extension, hard to limit and might last up to several weeks (Mc Gregor et al. 2005). They do not necessarily affect infrastructure components physically but lead to the malfunction of processes such as energy generation which depends on water availability. For the distribution of natural hazards in India, see Box 4.

BOX 4: Natural hazards in India

India is prone to natural hazards of hydro metrological and geological origin. The Building Material Technology Promotion Council (BMTPC) of the Ministry of Urban Development and Poverty Alleviation published the “Vulnerability Atlas of India” which provides a broader analysis of the hazard profile at national and state levels for earthquake, cyclone, flood and landslides (see Figures 7a to 7d).

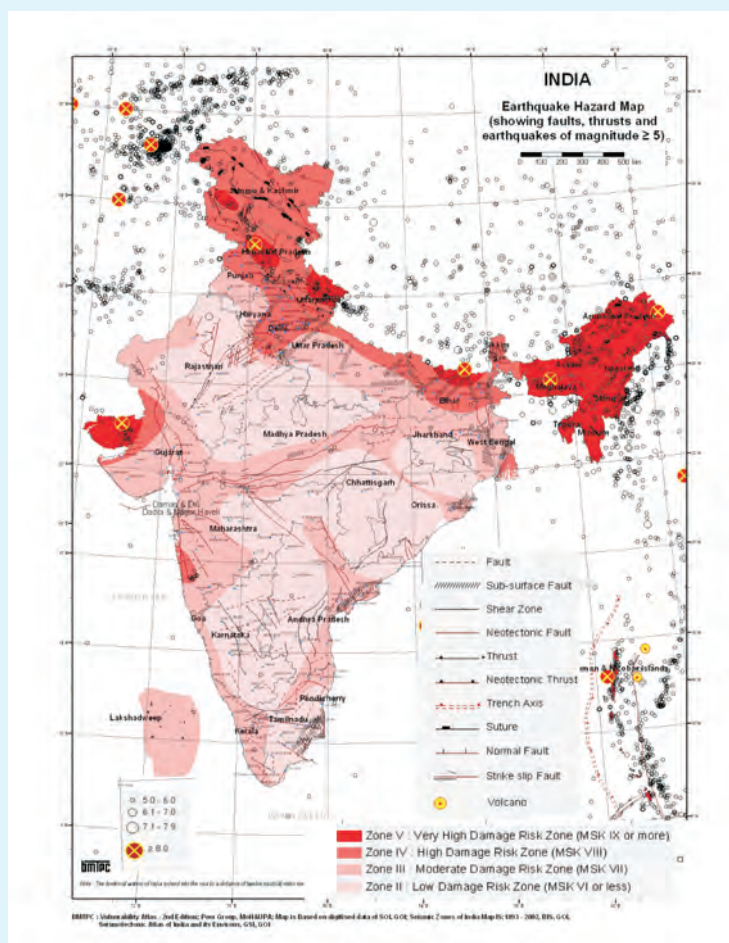


Figure 7a: Seismic zoning map of India

Source: <http://www.downtoearth.org.in> (viewed on 15.11.2012)

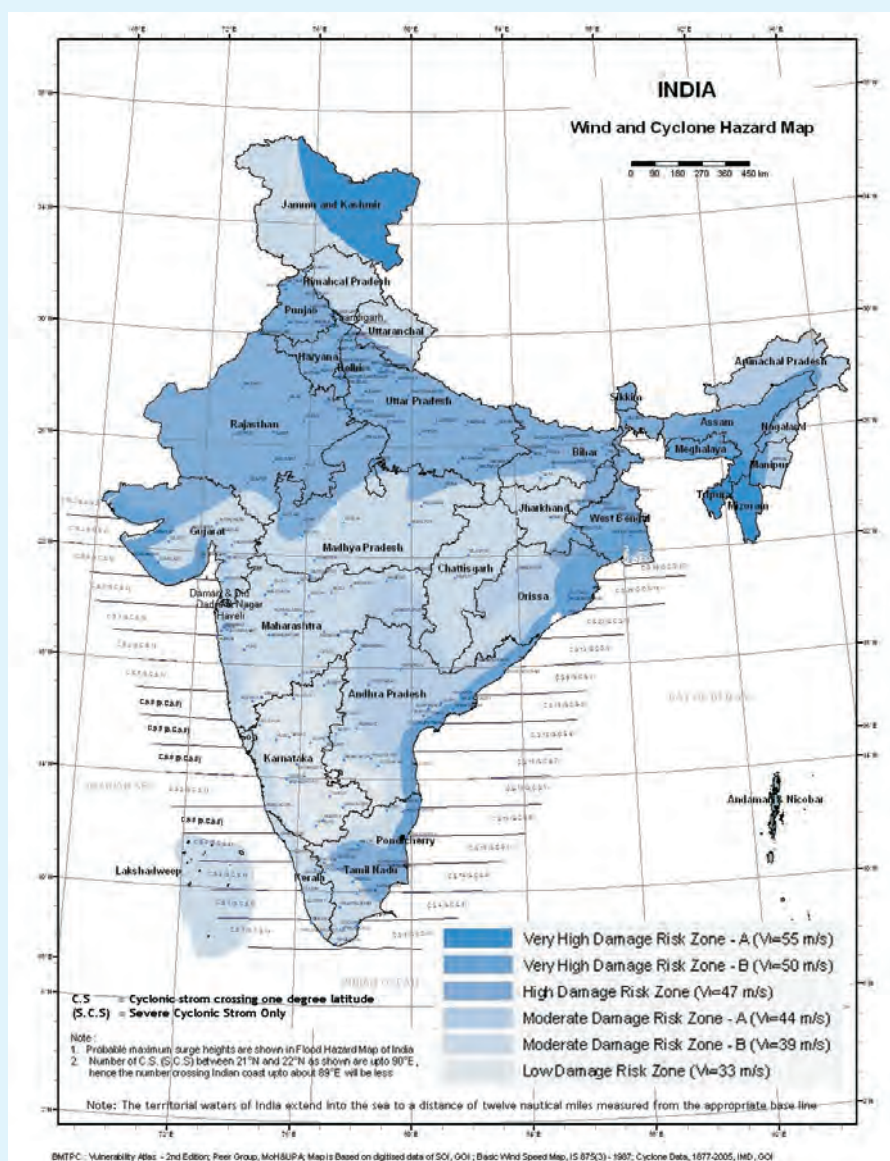


Figure 7b: Wind and cyclone hazard map of India



Figure 7c : Flood hazard map of India

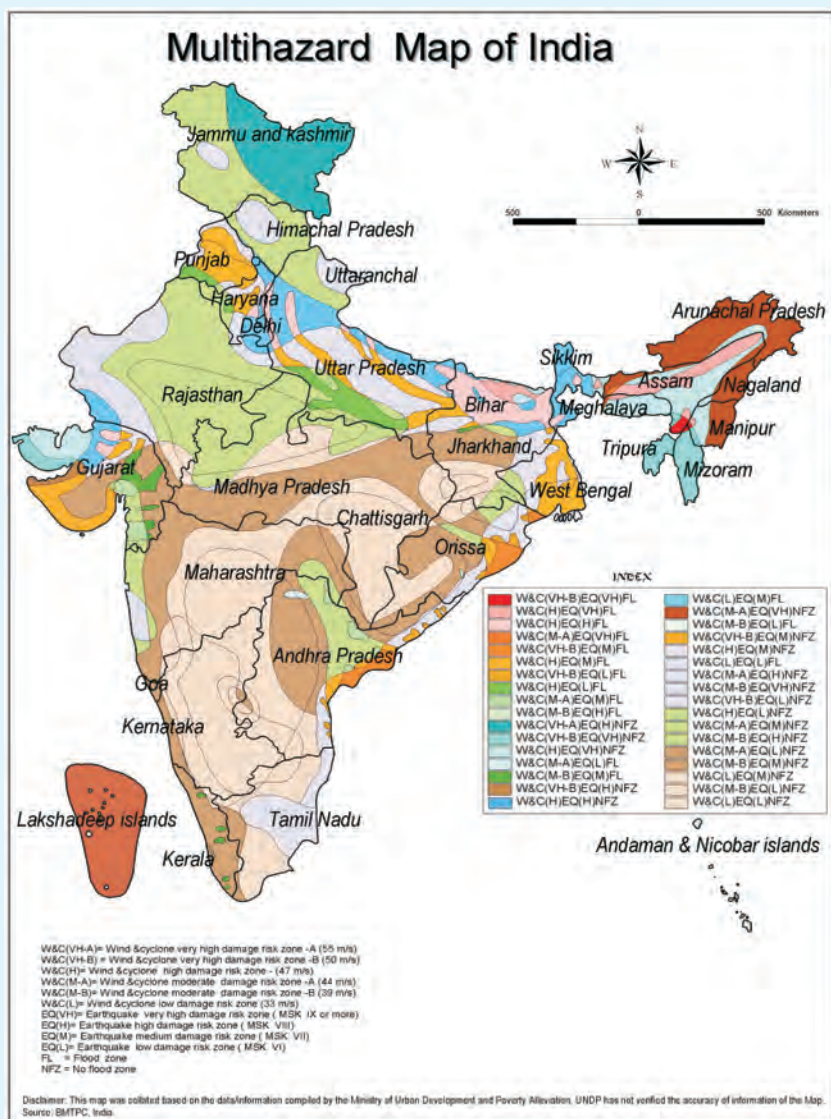


Figure 7d: Multihazard map of India



Figure 8: Main power plants in India

Source: IEA (2002), p. 35

Due to the different effects that natural hazards can have on infrastructure systems and their differences in distribution amongst countries, hazard-specific assessment methods have to be applied for an in depth analysis. Nevertheless, a set of core indicators for susceptibility and coping capacity exist that give an overview of the system vulnerability irrespective of the hazards as will be outlined in 3.3 and 3.4.

In order to determine exposure, susceptibility and coping capacity, information about the location of infrastructure components is an inevitable prerequisite. Figure 8 and 9 as well as Box 5 depict exemplarily the location of important power plants and allow for an understanding of their exposure to different natural hazards.

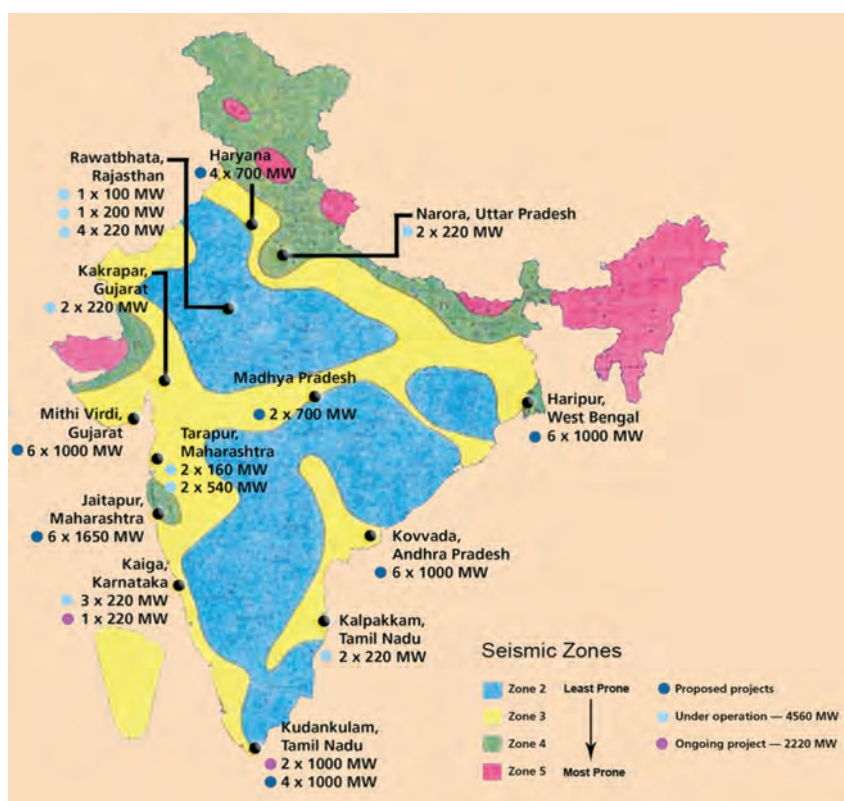


Figure 9: Vulnerability of nuclear power plants towards earthquakes in India

Source: http://www.downtoearth.org.in/dte/userfiles/images/Earth_quake_map.jpg (viewed on 15.09.2013)

BOX 5: Nuclear power and tsunamis: The case of Kalpakkam

"India's Kalpakkam nuclear power plant withstood the giant waves, which engulfed its small township, home to India's centre for atomic research. Battered but safe, the plant shut down automatically after detectors tripped it as the water level rose. There was no release of radioactivity. The reactor was restarted 1 January 2005, six days after the catastrophic waves struck India's east coast" (IAEA 2011). Although plant designers had not planned for a tsunami, they had taken cyclone storm surges into account and thus estimated comparable inundation levels (Sacchetti 2008). However, design structures and their robustness towards the spectrum of plausible natural hazards should be reviewed and adopted where necessary."

3.1.2 Susceptibility

Regarding infrastructure susceptibility, three main characteristics are of particular relevance:

- Dependencies on other infrastructures
- Dependencies on specialized staff
- Dependencies on environmental services

An infrastructure is increasingly vulnerable when it needs the input of another infrastructure to function. Most infrastructures such as transport, waste water management, telecommunications etc. are dependent on electricity as input and are thus negatively affected in case of electricity supply failure. The autonomous functioning of infrastructures components from electricity supply or information and telecommunication technology however can be realized only to a limited extent.

The same accounts for specialized staff and environmental services: The more dependent an infrastructure is on staff and environmental services (e.g. the availability of water), the more vulnerable it tends to be towards hazards affecting these factors. A hazard might prevent employees from coming to work or reduce environmental services. A drought/dry spell for example might reduce the availability of water significantly (Lenz 2009). Additionally, conflicting uses of environmental

services can arise through natural hazards, e.g., when water availability is reduced due to heat waves/dry spells – see also Box 6.

BOX 6: Water crisis in India's capital after supplies cut in searing heat-wave

India is suffering from severe water shortages in many states although being comparatively rich of precipitation which encompasses an average of about 120 cm per year. However, the precipitation is unevenly distributed and in New Delhi, although being India's richest city, most middle-class households do not have a dependable source of clean water (Rodell et al. 2009).



This situation is being exacerbated by extreme weather events such as heat waves. During June 2012 for example, 16 million people in New Delhi were sweltering in 43 °C (109.4 F) while one of the biggest supplying neighboring states, Haryana, cut its flow to the city and about three million people were suffering shortages or were completely cut off (The Extinction Protocol 2012). While generally demand patterns are rapidly changing, the competition for the available sources is increasing (World Bank 2005).

3.1.3 Coping Capacity

As described in section 3.1, coping capacity is the “[...] resources and abilities to face adverse consequences that could lead to a disaster”. But how are these resources characterized and how could they be measured? Basically four main general characteristics describe the coping capacity of a Critical Infrastructure system: preparedness, redundancy, replaceability and robustness (Lenz 2009) which can be accomplished by hazard specific indicators.

Preparedness describes the level of preparation for the maintenance or rapid restoration of services affected by a hazard. It includes emergency plans, training of employees and emergency drills as well as back-up systems.

Redundancy describes the multiple existences of certain components or services which are able to replace or to take over the function of another component. Redundancies allow for the maintenance of a service under the malfunction of certain components. Redundant components might be used in every-day-live such as additional railroads or electricity lines but they might also be available for a worst-case scenario (back-up systems).

Replaceability depicts the effort needed to re-establish a service or component after its break-down. It thereby includes resources such as time and budget. The faster services can be restored the less vulnerable they are towards natural hazards.

Robustness describes the ability of a service or component to withstand the effects of one or multiple hazard(s) without losing its function. The robustness determining the maintenance of services depends on the severity of a hazard as well as on the configuration of components including building standards and protection measures.

3.2 Entry Points for Infrastructure Vulnerability Reduction

Assessing the vulnerability of CIs is a prerequisite for "systematically developing" protection or adaptation strategies that can reduce the hazard impact and the potential losses due to a breakdown of the CIs. Such plans might also be helpful to ensure prompt resumption of these services in the aftermath of a natural hazard or a disaster (UN/ISDR 2007, pp. 101 f).

Against this background, the following section will deal with the presentation of selected assessment methodologies for the vulnerability of CIs using the example of electricity supply. In this context, two ways of considering CI vulnerability assessments exist. First, Critical Infrastructures are cost-extensive and long-lasting infrastructures. In order to avoid major losses and failures, vulnerability assessments can help to improve the resilience and robustness of such structures in the medium and long-run if being taken into account in planning processes already. Second, vulnerability analysis can be used in the aftermath of a destructive event where also budgets might increase due to relief

funding. Infrastructure might then be built up in a more resilient way or at new locations where they could be less exposed. Consequently, in some cases, crises or disasters might also provide an opportunity for societies and provinces or communities to revisit existing Critical Infrastructures and adapting them to new challenges. In this context, UN/ISDR recommends to select sites for more resilient and efficient infrastructures (constantly as well as temporarily for the direct aftermath of an event) and to identify contractors from around the country which can help to rebuild infrastructures as well as the development of management mechanisms (UN/ISDR 2007, pp.82 ff).

4

Learning Unit C: Methods of CI Vulnerability Assessment

Learning objectives

1. Getting to know different approaches and methods for CI vulnerability assessment to selected natural hazards.
2. Understanding the challenges of respective assessments and ways of reducing CI vulnerability.

4.1 Assessing Vulnerability of Critical Infrastructures

Supplementary to the characteristics influencing CI vulnerability introduced in Chapter 3, hazard specific indicators and methods are needed to implement vulnerability assessments which help to monitor longer-term developments and to consider regional specifications. Accordingly, one example will be given for pluvial flooding and for heat waves/dry spells respectively.

BOX 7: Tropical Cyclone Nilam: Maldives, Sri Lanka and India situation report (SR-1) 01 November 2012

Severe weather conditions on Monday 29 October, including a tornado and heavy rain, have resulted in flooding of up to five feet in the Maldives, affecting 24 islands. When passing through north-eastern Sri Lanka near Trincomalee on 30 October, Tropical Cyclone Nilam affected 16 out of 25 districts on the island. The storm later intensified and hit the Indian states of Tamil Nadu and Andhra Pradesh. It made landfall on 31 October, 2012. Winds of a speed of up to 101 km/h were reached. The capital of Tamil Nadu, the coastal city of Chennai which is home to 4.5 million people, was largely spared.

Water and sanitation problems affected 12 islands and required for immediate attention. Although no diseases outbreaks were reported, assistance was requested to avoid epidemics. While in India over 100 trees were uprooted, as well as several telephone and lamp posts, the main damage experienced in the Maldives was caused by the disruption of water supply and sanitation systems.

Source: World Health Organization (WHO) (2012): Tropical Cyclone Nilam: Maldives, Sri Lanka and India, Emergency and Humanitarian Action (EHA) Unit, Regional Office for South-East Asia (SEARO).

4.2 Flooding (Surface Water)

Exposure

Whereas the exposure towards flooding can be defined by choosing a specific flood scenario, e.g. HQ-100³, the exposure assessment for pluvial floods is more complex. For the latter, a digital land model (DLM) has to be used in order to define depressions in which water would gather during a surface water flood. Figure 10 shows the example of sinks in Wuppertal, Germany which were intersected with electricity supply components. The intersection of a Geographic Information System (GIS) map encompassing the locations of Critical Infrastructure components (and respective processes) with a map of the flooding scenario/ depressions allowed for the detection of those components and processes potentially experiencing disruptions (being exposed to pluvial flooding).

³Flooding scenario representing a flood that statistically occurs once in 100 years.

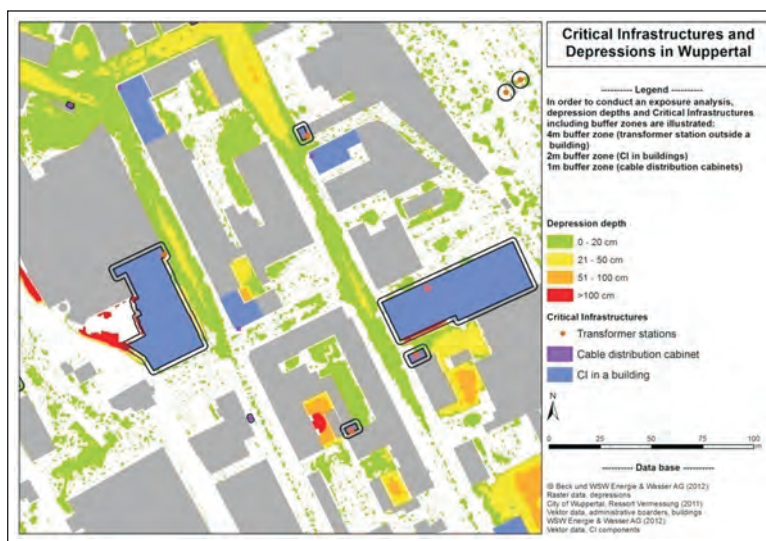
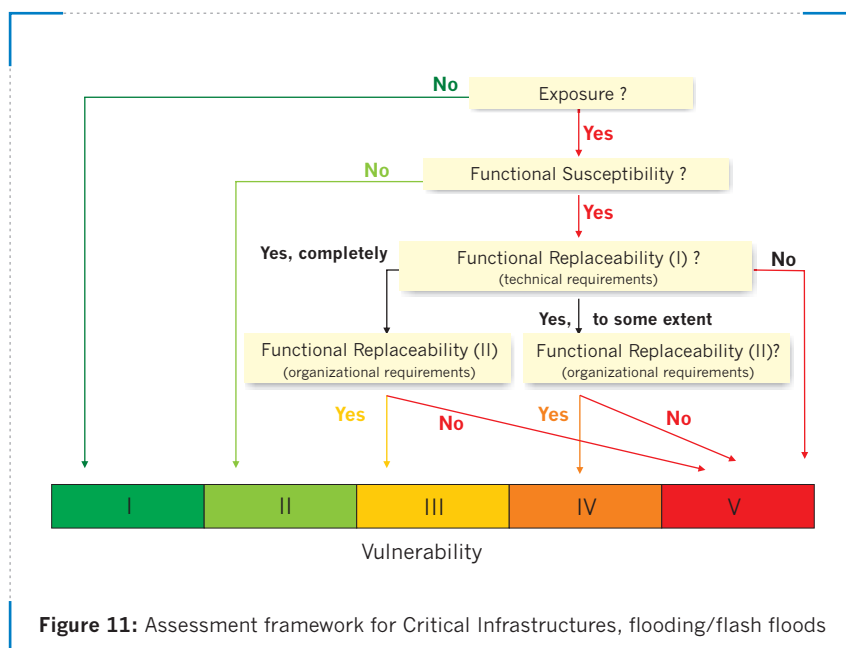


Figure 10: Depressions and respective depths in the City of Wuppertal, Germany

Source: own figure based on data of the WSW Energie und Wasser AG, the engineering office Reinhard Beck GmbH & Co. KG as well as the City of Wuppertal.

Susceptibility and Coping Capacity

In a second step, the susceptibility of components when inundated is analyzed. In this context, semi-quantitative assessments can be applied (see Figure 11). These assessments are based on questionnaires capturing core factors of vulnerability of CIs such as exposure, susceptibility and coping capacity (see Krings 2010; Birkmann et al. 2012). Expert interviews can provide important information about the functionality of a component within the electricity network/system when inundated and about the maintenance of its operation during adverse events. Finally, questions about the coping capacity of processes have to be handled by focusing on two major issues: a) the technical redundancy and b) the organizational and institutional preparedness within CIs. While the technical redundancy examines whether another component would be able to replace the susceptible component, organizational and institutional preparedness issues deal with the question whether also personnel is available to manage such shifts and to undertake the changes necessary in the situation of a crisis (Krings, 2010, p. 25 ff.).

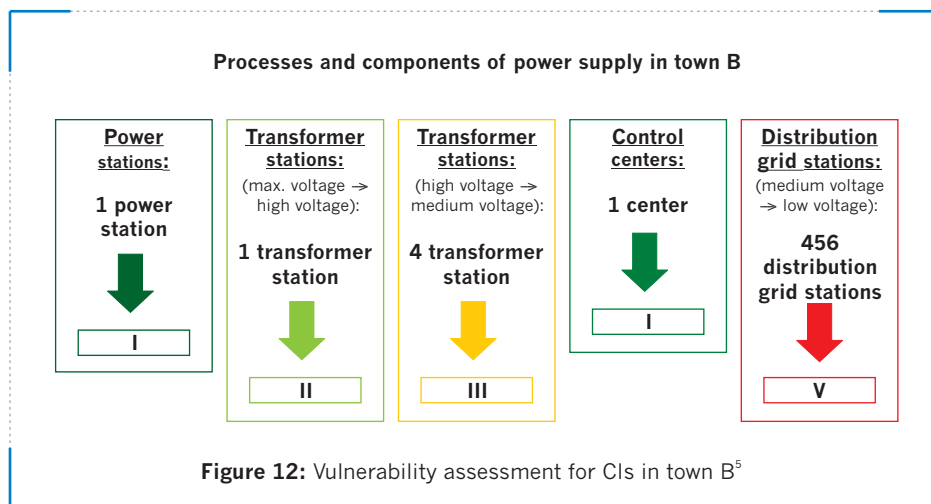


Source: own illustration based on Krings 2010, p. 25.

If a component or network is not exposed to the flood scenario it is automatically classified as not vulnerable⁴. Compared to that, a system component that is exposed, susceptible and has a low coping capacity, is judged to be very vulnerable using an ordinal classification scale (Figures 11 and 12).

The analysis of the vulnerability of the overall system by looking step by step at individual components is the basis for an integrated analysis that can also inform respective protection and adaptation strategies. Potential measures could encompass the relocation of important infrastructure components or the specific modification of the network, e.g. decentralization in order to keep the cascading effect of a breakdown of one component at a more local scale. The shift of local distribution stations to higher ground has been one strategy that was conducted after the major flood experiences on the Rhine and Elbe in Germany. Particularly, the (re)location of different key components of such Critical Infrastructure networks or the development/conservation of redundant structures has great planning relevance and should thus be considered when developing infrastructure systems.

⁴ Although components might in some cases breakdown without being directly exposed for complexity/coupling reasons, this was assumed in order to operationalise the assessment.



Source: own illustration based on Krings 2010, p. 173.

⁵ Each process is classified according to the component with the highest vulnerability. Whereas the components of power generation and control centers are not exposed, transmission from maximum voltage to high voltage is exposed but would continue working when flooded due to flood protection measures. Two of the four transformer stations from high to medium voltage are susceptible to flooding but redundant (class III). Most of the distribution grid station are susceptible to flooding but not redundant and are therefore classified in the highest vulnerability class (V).

BOX 8-A: 2012 Himalayan flash floods

Flash floods occurred on August 3rd 2012 in the Himalayan region of the states of north India having the following impacts:

Himachal Pradesh

Two bridges and a road which connects Manali to Rohtang in the Palchan region were washed away on the night of August 4th 2012. About 120 people have been evacuated from the affected areas. A government school, an under construction hydropower project and many electricity poles were washed away in the floods.

Other effects

Business Standard reported that the Northern Grid, which tripped on 30 and 31 July, would be likely to come under renewed pressure as the power generation in Uttarakhand was stopped due to flash floods. The major hydro power projects were shut down following torrential rains that hit the state. In Uttarkashi district, flash floods have caused damage to three state-run small hydro projects, resulting in their shut down. Due to the shut down, Uttarakhand would fall short of 18-20 million MW per day during a monsoon season.

Sources:

1. Business Standard (2012): Floods in Uttarakhand: Fresh burden for Northern grid, Article of 4th August 2012. Available via: http://www.business-standard.com/article/economy-policy/floods-in-uttarakhand-fresh-burden-for-northern-grid-112080502011_1.html, last accessed: 02.09.2013.
2. IBNLive (2012): Flash floods in Uttarakhand, Himachal Pradesh, Over 30 feared dead, Article of 5th August 2012. Available via: <http://ibnlive.in.com/news/flash-floods-in-uttarakhand-himachal-pradesh-jammu-over-30-feared-dead/278619-3-243.html>, last accessed: 02.09.2013.
3. IBNLive (2012): Heavy rains create havoc in U'Khand, Chardham Yatra suspended, Article of 4th August 2012. Available via: <http://ibnlive.in.com/news/heavy-rains-in-uttarakhand-chardham-yatra-suspended/278383-3-243.html>, last accessed: 02.09.2013.
4. NDTV (2012): 31 dead, 40 missing in Uttarkashi flash floods, Article of 5th August 2012. Available via: <http://www.ndtv.com/article/india/31-dead-40-missing-in-uttarkashi-flash-floods-251351>, last accessed: 02.09.2013.

BOX 8-B: Uttarakhand 2013 torrential rain impacts on power generation

The torrential rain and landslides have stranded pilgrims at four revered Hindu shrines, washed away bridges and roads and caused other damage like impact on power generation and power plants in Uttarakhand state of India. The monsoon arrived 15 days early in Uttarakhand with continuous rainfall along with cloudburst between 16 to 19 June this year.

Massive floods and heavy rains in Himachal Pradesh and Uttarakhand have taken a toll on power generation. As per the Business Standards magazine, more than 26 per cent of the combined power capacity in the two states has been forced shut, including the country's largest hydro power project, the 1,500-Mw plant at Nathpa Jhakri and the largest private sector plant, the 1,000-Mw Karcham Wangtoo project run by Jaypee Group in Himachal.

On 1st July 2013, silt levels at Nathpa Jhakri crossed 4,000 parts per million (ppm), against the normal average of 1,500 ppm, leading the operator to shut the plant. It supplies power to nine states, including Himachal, Rajasthan, Uttar Pradesh, Uttarakhand, Punjab, Haryana and Chandigarh.

Himachal has an installed hydro power generation capacity of 4,883 MW. Of this, 1,524 MW were down. The projects being impacted include a few small sized plants of Government-run National Hydroelectric Power Corporation Limited. Three of NHPC's plants – 280 MW Dhauliganga, 120 MW Tanakpur and 390 Mw Dulhasti — have been forced shut.

The two states together meet over a tenth of the northern India's monthly power demand. The shutdown in capacity has brought down daily power availability for the national capital to 150 MW from 450 MW.

In Uttarakhand, the devastating floods and landslides have damaged a series of under construction projects on the Mandagini River in the Rudraprayag district.

Source: Business Standard (2013): Floods hit power output in Himachal, Uttarakhand, Article of 20th June 2013. Available via: http://www.business-standard.com/article/current-affairs/floods-hit-power-output-in-himachal-uttarakhand-113061900805_1.html, last accessed: 02.09.2013.

Business Today (2013): Jaiprakash Power shuts down plant in Uttarakhand, shares tank 15%, Article of 24th June 2013. Available via: <http://businesstoday.intoday.in/story/jaiprakash-power-shares-on-bse-nse-june-24-2013/1/196100.html>, last accessed: 02.09.2013.

Livemint (2013): Heavy rains disrupt electricity generation at hydropower projects, Article of 19th June 2013. Available via: <http://www.livemint.com/Industry/7Kr4ks7O9bj20q19hb1T2N/Heavy-rains-disrupt-electricity-generation-at-hydropower-pro.html>, last accessed: 02.09.2013.

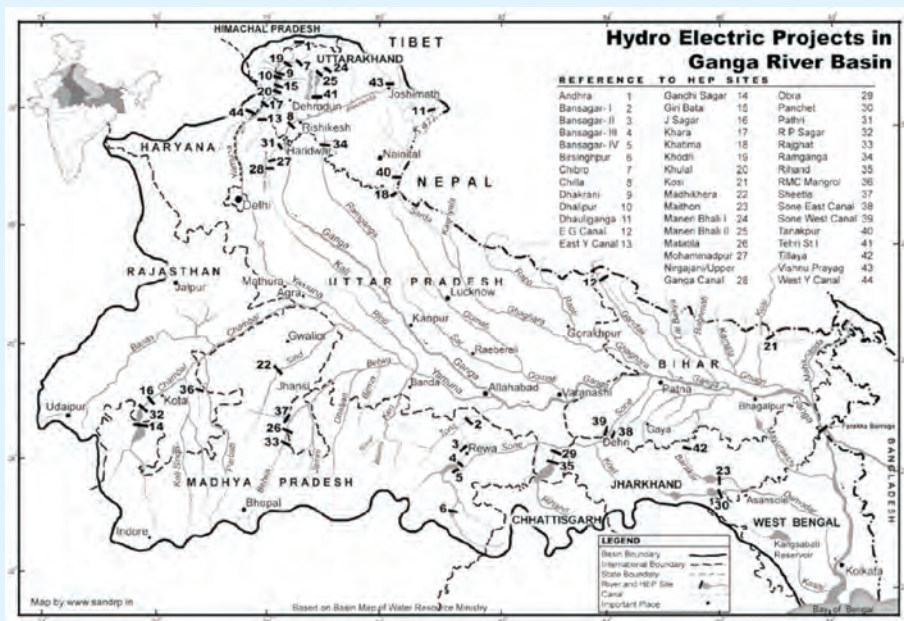


Figure 13: Hydroelectric projects on the river Ganga

Source: Image courtesy: www.sandrp.in

4.3 Heat Waves/Dry Spells

For heat waves/dry spells, methods which do not focus on the physical destruction of components are needed. Hence, indicators for the vulnerability of certain processes such as electricity generation which is mainly affected through heat waves/dry spells (see Box 9) have to be used.

BOX 9: Heat wave Western Europe 2003

During a heat wave in Europe in 2003 basically the whole continent was exposed to heat stress which occurred in combination with a dry spell. It caused approximately 70,000 deaths (MunichRE 2011) and severely affected the electricity production and the energy sector. Due to low river tides, the production capacity of hydro-electric power plants was decreased and problems in the shipment of coal to supply coal fired power plants arose. Especially on Rhine, Danube and Elbe, ships could only load 20 to 30 % of their capacity (BAG 2003).

In general, water is needed for the cooling of coal fired and nuclear power plants. To protect aquatic organisms however, river water temperatures have to be kept below certain thresholds. Since water temperatures were already high due to low tides and high temperatures in 2003, the use of river water for cooling purposes and the discharge of heated water into rivers had to be limited (BfG 2006). Resulting, nuclear and coal fired power plants had to reduce their capacities between 20 and 100 % (Lönker 2003).

Exposure

The geographical extension of heat waves/dry spells can be relatively vast, encompassing numerous countries and almost continents as demonstrated during the European heat wave in 2003. Compared to sudden onset hazards such as floods the exposure assessment of certain elements at risk during a heat wave is challenging and also not of big relevance since components are not physically affected in terms of destruction/impairment. Accordingly, we will focus particularly on susceptibility and coping capacity of CIs in order to determine their vulnerability to heat waves/dry spells.

Susceptibility

Nuclear and coal-fired power plants as well as hydroelectric plants which highly depend on water for their cooling and functioning are susceptible in times of river water shortages and low water levels. A lack of water was (besides the physical limitations) caused by environmental regulations limiting the water temperature to protect aquatic ecosystems and thus not permitting its use for cooling purposes anymore. As a result, severe reductions in the production capacities of large power plants along major rivers in Germany were caused particularly where alternative cooling options were lacking. Hence, a limited water level can lead to deficiencies in power generation by water, coal and nuclear power plants (BfG 2006). At the same time, during a combined heat wave and dry spell phase, the demand for electricity might be higher due to an increased demand for air conditioning and other

cooling devices (German Federal Government 2008, Hekkenberg et al. 2009). For India, several demand peaks occur during the year in the different regions (compare Chapter 2.3).

Accordingly, the share of river water dependent⁶ power plants in the overall electricity generation influences the susceptibility of the system towards heat waves/dry spells. On the contrary, power plants using ambient air for their cooling instead of, or supplementary to, river water cooling, are less dependent on this natural source and thus less vulnerable towards heat waves (BfG 2006). This indicator thereby takes up the dependency on environmental services also suggested in Chapter 3.

Coping capacity/ Adaptation

Coping capacity is, compared to adaptation, an immediate response and reaction to a hazardous event. Adaptation instead is “characterized by medium and long-term strategies that imply or lead to change and often require changes in institutional frameworks” (Birkmann 2011, p. 815). In terms of the assessment of the vulnerability of electricity infrastructure threatened by heat waves/dry spells, however, there is often only one measure that can be taken when energy generation does not meet the demand – the cut-off of major consumers. This strategy is often unavoidable in order to support the stabilization of the grid in terms of voltage and can thus be understood as a coping strategy. At the same time, it also has negative side-effects such as economic losses, particularly when companies or households are not informed about this cut-off beforehand.

Most of the features reducing electricity supply vulnerability towards heat waves concern intrinsic characteristics of the system, such as the setup of electricity generation facilities and demand patterns. Accordingly, characteristics decreasing CI vulnerability regarding heat waves/dry spells are referred to as adaptation measures.

One of the indicators reducing vulnerability pointing towards an increased adaptation is the diversification of the electricity supply. The number and share of alternative generation sources can decrease the dependency single sources of energy generation and raw materials such as coal. Additionally, the diversification of generation sources could come along with the decentralization of the system. A decentralized organization is thereby not only relevant for a lower susceptibility to heat waves/dry spells but generally reduces the dependency of centralized services. In case of the breakdown of the supply systems or a shortage in power generation, the effects would rather be limited to a local level (Alanne and Saari 2006; Sperling et al. 2011; van Vliet et al. 2012). Both, diversification and decentralization of energy systems might also contribute to the mitigation of

⁶ Many nuclear power plants are also located at the sea and are thus less susceptible to water shortfalls. However, their exposure, e.g. to tsunamis, might be higher (Rübelke & Vögele 2011; IAEA 2004; BfG 2006).

greenhouse gas emissions. Consequently, such transformations can constitute win-win situations as they not only enhance the possibilities to react to the impacts of heat waves/ dry spells but also reduce the probable increase of such events in the future.

However, long-distance transport of electricity and resources can be reduced only to a limited amount due to geographical locations of domestic resource centres and demand. Nevertheless, Bhattacharyya (2010) recommends a decentralized generation in combination with a demand side management for India. A demand side management offers the possibility to regulate the demand in times of low generation capacity. By means of intelligent meters, energy providers could offer their customers load-dependent tariffs. Additionally, increasing energy efficiency can contribute to a higher coping capacity as decreasing amounts of energy are needed. For India, Bhattacharyya (2010, p. 4179) argues in favour of the consideration of energy efficiency measures, especially when big investments for persistent components such as power plants are made. He argues that the “energy-intensive western lifestyles by the richer section of the population propagates to the other sections of the population” leading to future energy demands which “could grow much faster than has been observed in the past” (ibid.). During heat waves/dry spells this mismatch could additionally highly increase. Although attempts towards increasing energy efficiency have been made e.g. through the Energy Conservation Law of 2001 or the creation of the Bureau of Energy Efficiency in 2002, the potential for an increase in energy efficiency mainly in lightning as well as in industrial and agricultural consumption still amounts up to 70% of the saving potential through efficiency measures (Delio et al. 2009 and Natarajan 2008). At the same time, barriers to a reduction in energy consumption such as misplaced incentives, financing or mispricing of energy could hamper this development (see also Chapter 2.3).

BOX 10: Sea Level Rise – Impact on major infrastructure, ecosystems and land along the Tamil Nadu coast

The Tamil Nadu coastline is about 1,076 km long, encompassing thirteen coastal districts. It forms a fairly large and narrow coastal strip dotted with fragile ecological features and intense development activities. There are major, existing and proposed, economic and infrastructure developments, including ports, power plants, highways and even airports, which are being planned very close to the shoreline along India’s coast.

At the same time, sea level rise could affect the coastline in India in a variety of ways, including inundation, flood and storm damage associated with severe cyclones and surges, erosion,

saltwater intrusion, and wetland loss. Some of the specific points of concern according to the Centre for Developing Finance (IFMR) and the Indian Institute of Technology Madras (IIT) (2011) are the following:

- The area at risk from sea level rise is much larger than the area that would actually be inundated since storm surges have to be taken into account. Accordingly the area at risk for a 1 m rise in mean sea level is identified on a district-level basis:
- For five coastal districts (Nagapattinam, Thiruvarur, Thanjavur, Pudukottai, and Ramanathapuram), the area along the coast that is below 10 m above current mean sea level is estimated to be at risk from a 1 m sea level rise, because of the very high storm surges that already affect them.
- For the remaining coastal districts, the coastal area that lies below 5 m elevation relative to current mean sea level is estimated to be at risk from a 1 m sea level rise.
- A 1 m rise in average sea level would permanently inundate about 1,091 km² along the Tamil Nadu coast, but the total area at risk would be nearly six times as much.

The study estimates the total replacement value of infrastructure (ports, power plants and major roads) impacted by sea level rise to be between Rs. 47,418 (7760 million USD) and Rs. 53,554 (8764.9 million USD) crores (in 2010 terms).

5

Learning Unit D: Addressing CI Vulnerability

Learning objectives

1. Understanding Critical Infrastructure protection in the context of Disaster Risk Reduction (DRR) and the different dimensions of vulnerability reduction at which action is possible.
2. Provide an overview of the proactive planning for climate change adaptation by increasing infrastructure resilience.

The increasing awareness of the importance of Critical Infrastructures for Disaster Risk Reduction (DRR) and their potential shortfall due to e.g. natural hazards was facilitated by a number of events. Two examples are the European Floods in 2002 or the relatively recent Tohoku Earthquake which hit Japan in March 2011 giving examples on the vulnerability of infrastructures and societies. The impact of infrastructure failure is thereby to a large extent influenced by the complexity and interdependency of infrastructure systems as well as by the dependency of the population on the functioning of these services. Whereas developing countries still face challenges in supplying major parts of their population with infrastructure services, many developed countries and countries in transition are characterized by high supply levels and by an increasingly dependent society on Critical Infrastructure services, such as energy supply.

BOX 11: Critical Infrastructure Protection (CIP) Framework

Much has been written in the past 20 years about the deteriorating condition and quality of the nation's roads and bridges and its power and water systems and about the trillions of dollars that it will take to fix them. The issues, however, are much more complex: How we as a nation choose to renew our infrastructure systems in the coming years will help determine the quality of life for future generations. It will also help determine our success in meeting other national challenges, including those of remaining economically competitive and reducing our dependence on imported oil, and of dealing with issues related to global climate change, national security, and disaster resilience.

Significantly reducing greenhouse gas emissions will require that power and mobility be provided in new ways using new systems and technologies. Limiting deaths and injuries, property losses, impacts on ecosystems, and recovery time after natural or human-made hazards requires robust and resilient infrastructure systems. Every year public- and private-sector organizations spend hundreds of billions of dollars to operate and maintain power, water, waste water, transportation, and telecommunications systems.

A framework is needed to structure these efforts so that ongoing activities, knowledge, and technologies can be aligned and leveraged to help meet multiple national objectives. The essential components of the needed framework are as follows:

- A broad and compelling vision that will inspire individuals and organizations to pull together to help meet the imperatives by renewing the nation's Critical Infrastructure systems. Such a vision would focus on a future of economic competitiveness, energy independence, environmental sustainability, and quality of life.
- A focus on providing the essential services involving water and waste water, power, mobility, and connectivity – in contrast to upgrading individual physical facilities – to foster innovative thinking and solutions.
- Recognition of the interdependencies among Critical Infrastructure systems to enable the achievement of multiple objectives and to avoid narrowly focused solutions that may well have serious, unintended consequences.

- Collaborative, systems-based approaches to leverage available resources and provide for cost-effective solutions across institutional and jurisdictional boundaries.
- Performance measures to provide for greater transparency in decision making by quantifying the links among infrastructure investments, the availability of essential services, and other national imperatives.

Source: Excerpt from National Research Council (NRC) of the National Academies (2009): *Sustainable Critical Infrastructure Systems: A Framework for Meeting 21st Century Imperatives, Report of a Workshop, Washington D. C.* Available via: http://www.nap.edu/catalog.php?record_id=12638, last accessed: 02.09.2013.

Additionally, Critical Infrastructures (such as electricity and water supply, transport or telecommunication) are also of great importance during and in the aftermath of natural hazard events. Consequently, Critical Infrastructures have to be considered in the field of disaster risk reduction more systematically. In close cooperation with suppliers and planning agencies, the vulnerability of CIs should be assessed and taken into account. This is especially true for rapidly growing economies such as India which are shaping the set-up of cost-extensive and long-lasting infrastructures now. Vulnerability assessments for Critical Infrastructures can help to improve planning processes and adaptation strategies. A schematic of the Critical Infrastructure Protection in the context of DRR is suggested in Figure 14. It stresses assessments as the basis for effective DRM.

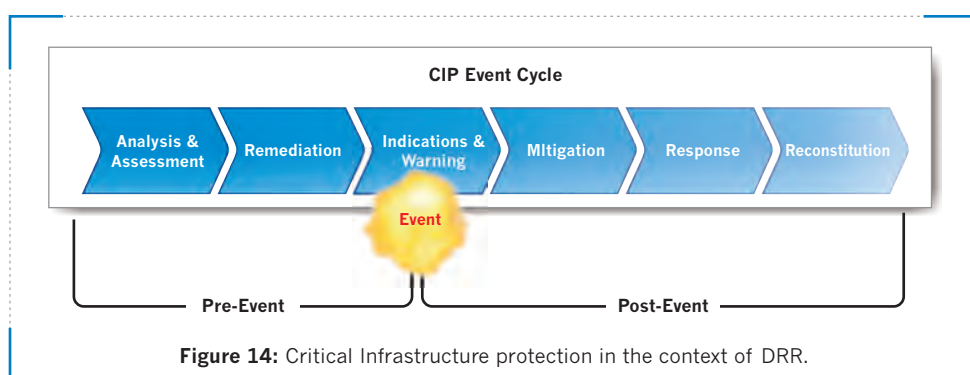


Figure 14: Critical Infrastructure protection in the context of DRR.

Source: NRC 2009.

When conducting vulnerability assessment of CIs to natural hazards, methodologies are determined by the hazard type: slow- and sudden-onset hazards and the vulnerability of the system. Whereas sudden onset hazards tend to physically destroy infrastructure components, slow onset hazards rather affect processes such as electricity generation in terms of energy supply. Two potential methods were introduced providing examples for CI vulnerability assessments for each hazard type which can be seen as a starting point to improve the consideration of Critical Infrastructure vulnerability. The assessment methods might be further developed and operationalized as well as mainstreamed into a variety of sectors such as energy supply or land use planning for different natural hazards. When conducting vulnerability assessments and implementing measures to decrease disaster risk, also overall trends in changes of the average climate should be considered since respective measures can have effects on short term (towards natural hazards) as well as on long-term resilience (towards gradual change) (see also Hallegatte 2011).

BOX 12: Infrastructure resilience building in coastal zones

Some measures to increase infrastructure resilience in India have been already developed and implemented by GLZ-Adapt Cap - Local Adaptation Projects for Climate Proofing Vulnerable Coastal Communities in India which is mainly considered with coastal communities who are increasingly facing environmental and socio-economic pressures exacerbated by global climate change as well as a growing need to reduce the vulnerabilities of coastal communities. The capacities of local authorities and the population on climate change adaptation, climate change mitigation and disaster risk reduction are strengthened. These infrastructure pilot projects encompass amongst others:

- Coastal Bund Construction at Perumalpettai, Nagapattinam District, Tamil Nadu
- Solar Power Backup for Reverse Osmosis Plant at VengamukkaPalem, Prakasam District, Andhra Pradesh
- Pond Renovation, Bund and Shutter Construction at Kadapakkam, Thiruvallur District, Tamil Nadu
- Cyclone Resistant Causeway over the Buckingham Canal and Fishing Equipment Shed at Ramudupalli Palem and Sri Ramapuram, Nellore District, Andhra Pradesh
- Road Side Channel Bund Construction at Kaduvetti, Cuddalore District, Tamil Nadu

Policies to decrease system vulnerability can thereby be developed in five categories (Hallegatte 2011, p. 5f):

- (1) Information-based policies,
- (2) Regulation-based policies,
- (3) Market or incentive-based policies,
- (4) Institution-based solutions and
- (5) Direct investments which can be
 - (i) investments to retrofit existing infrastructure;
 - (ii) additional costs of new infrastructure to increase their resilience;
 - (iii) investments to duplicate infrastructure and augment redundancy and resilience.

Referring to this, Hallegatte (2011) offered several explicit examples (ibid. p. 8):

- Increased infrastructure robustness to extreme events (e.g., bridges designed to cope with 120km/h winds instead of 100 km/h winds; or drainage systems able to cope with higher extreme runoffs);
- Improved retrofit capacity (e.g., dikes systems that can be heightened at lower cost);
- Change in building norms for buildings and infrastructures (e.g., all new buildings should be made able to cope with 120 km/h winds, or built on stilts);
- Retrofit program to make all buildings and infrastructure more robust (e.g., all (new and old) buildings should be made able to cope with 120 km/h winds);
- Systematic information of investors about long-term natural risks where and when they build infrastructures;
- Implementation of forecast and early warning systems (e.g. to use sandbags in metro station entrance);

- Change in network structure to increase redundancy (e.g., build two smaller bridges instead of a large one over a river; or multiply the electricity network high-voltage lines);
- Organize emergency response to extreme events (e.g., implement a system to mobilize retired workers at electricity providers to speed up recovery, create special work permits for foreigners to help reconstruct);
- Avoid to develop infrastructure in potentially at-risk areas (e.g., in flood plain or in low-lying coastal areas), to avoid promote investment and settlement in these areas;
- Strategic retreat, i.e. infrastructure removal in high-risk areas, and environment restoration (e.g., restoration of marshlands and mangroves).

Further appropriate policies, plans and implementation strategies need to be developed at various levels to improve the resilience of Critical Infrastructure. For India, one example for such policies is the standard operating procedure (SOP) for drinking water supply and sanitation services during natural hazards which was released by the Department of Drinking Water and Sanitation, under Ministry of Rural Development in Government of India released in 2011 (see also Box 13).

BOX 13: Natural hazards – rural drinking water supply and sanitation

STANDARD OPERATING PROCEDURE

The Department of Drinking Water and Sanitation, under the Ministry of Rural Development in Government of India, in 2011, released the standard operating procedure (SOP) for drinking water supply and sanitation services during natural hazards. "Safe drinking water" is one of the basic needs and without it's availability in adequate quality and quantity, there could be serious impacts on human and animal health.

Drought could lead to scarcity of water due to depletion of ground water table and/or drying up of surface water sources. Natural hazards such as flood, tsunami, avalanche, landslide, or hailstorm could result in wash-off/damage of water supply assets, thus resulting in disruption of supply of safe drinking water. Therefore in any type of crisis, proper management of drinking water supply to the affected people on an "immediate basis" is an essential requirement. Maintaining environmental sanitation and individual hygiene are also equally important to reduce/eliminate chances of disease prevalence/outbreak of epidemics.

The SOP manual is prepared in order to assist everyone in the rural water and sanitation department and State Water and Sanitation Mission (SWSM), District Water and Sanitation Mission (DWSM), NGOs and the community, whether at the national, state, district or at other levels. It also indicates actions that need to be taken in collaboration with other departments at various levels. This document explains, for each category of staff, what they are responsible for, and what steps they should take before, during and after a natural hazard.

Source: Government of India (2011): Standard Operating Procedure for Responding to Natural Disasters – Rural Drinking Water Supply and Sanitation, Ministry of Rural Development, Department of Drinking Water and Sanitation. Available via:

http://www.indiawaterportal.org/sites/indiawaterportal.org/files/Standard_operating_procedure_for_responding_to_natural_disasters_Rural_drinking_water_supply_and_sanitation_DDWS_2011.pdf, last accessed: 02.09.2013.

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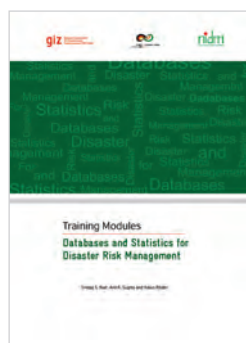
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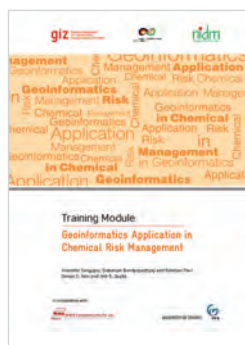
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