

Critical Infrastructures: Risk, Vulnerability and Coping Capacity

Susanne Lenz

UNITED NATIONS UNIVERSITY – Institute for Environment and Human Security (UNU-EHS), UN Campus, Hermann-Ehlers-Str. 10, D-53113 Bonn, Germany, E-Mail: lenz@ehs.unu.edu, phone: +492288150230

1 Introduction

Critical infrastructures provide essential goods and services for the daily needs of modern societies. Growing dependency on critical infrastructures also implies increasing susceptibility to their failure. In the scope of preventive civil protection, measures that minimise the risk of critical infrastructure failure are of high relevance to ensure the supply of essential goods and services. Consequently, critical infrastructure protection is an important task on national and international levels.

In order to take adequate protective measures, a detailed assessment is required to determine which infrastructure assets exhibit high criticality and thus need to be protected most urgently. Additionally, risk assessments can help to identify areas that are threatened by certain hazards and especially vulnerable with regard to damage and failure.

As climate change has the potential to change the frequency and intensity of natural hazards like storms, heavy rainfall and heat waves, critical infrastructures in their current status might experience increasing vulnerability to the impacts of such events in future. Thus, adequate measures of mitigation and adaptation are needed within the frame of preventive risk management.

2 Risk of critical infrastructure failure

The term risk is a theoretical construct, generally referring to negative consequences of a potential hazardous event to a specific element at risk. With regard to critical infrastructures, individual infrastructure assets (e.g. a power supply line, a railway station) as well as entire infrastructure systems (e.g. the energy supply system, the railway system) can be considered as elements at risk.

By its spatial location, an element at risk can be exposed to different kinds of hazards of natural or human-induced origin. The realisation of a hazard results in an event that might have negative consequences for the element at risk, if it is exposed and vulnerable. Therefore, the risk of critical infrastructure failure results from the interaction of three basic components of risk: hazard, vulnerability and exposure. Theoretically, an element that is exposed to a hazardous event without being vulnerable has no risk of being damaged by this specific event. Likewise, an element that is vulnerable to a certain type of hazard but cannot not be exposed due to its spatial location has no risk of being damaged by this specific hazard, either. In reality, however, probabilities and intensities of hazards as well as degrees of exposure and vulnerability vary widely between individual elements at risk, consequently necessitating more or less complex risk analyses.

Depending on the kind of risk one wishes to assess, the basic risk components hazard, exposure and vulnerability have to be supplemented by additional components. Therefore, the first step in a purposeful risk analyses should be the definition of the kind of risk that is to be analysed. Figure 1 exemplarily demonstrates different kinds of risk that can be analysed with regard to critical infrastructures. Their general risk of failure is, for example, determined by hazard, exposure and vulnerability and can be assessed by an analysis of these components. If, however, the temporal dimension of a potential failure is to be included in the risk assessment, it has to be added by the component coping capacity as this is of relevance with regard to the duration of restoration in the aftermath of a destructive event. Moreover, the analysis of the risk of failure with serious consequences for society additionally demands the integration of the component criticality into the risk assessment.

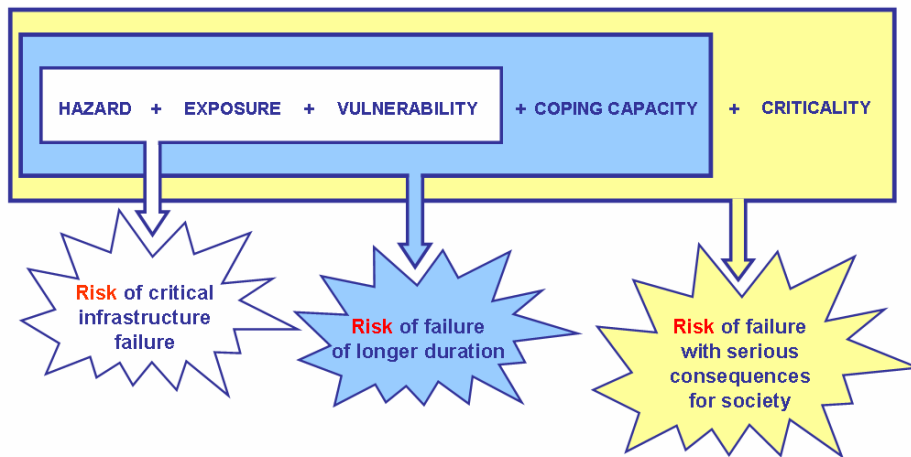


Figure 1: Risk components related to different kinds of risks.

3 Indicators for vulnerability and coping capacity

Whereas hazardous events like earthquakes or technological accidents can hardly be influenced in their occurrence and intensity in advance, vulnerability and coping capacity are those risk components that can well be modified by concerted actions. Criteria and indicators can help to assess vulnerability and coping capacity of elements at risk in order to provide a basis for decision about appropriate preventive actions.

With regard to critical infrastructures, the following attributes have been identified as relevant indicators to assess vulnerability¹:

- **physical robustness** as a relative measure for the ability of a critical infrastructure (element) to withstand the physical impact of a hazardous event,
- **buffer capacity** as a relative measure for the duration that a critical infrastructure (element) can absorb the impact of a hazardous event without being affected in its functionality,
- **dependency on other infrastructures** as a relative measure for the degree to which a critical infrastructure (element) is reliant on the services of other infrastructures to perform its service,

¹ These indicators are based on a research project of the German Federal Office of Civil Protection and Disaster Assistance (BBK). A final project report will be published in the near future (see Lenz 2007).

- **dependency on specialised personnel** as a relative measure for the degree to which a critical infrastructure (element) is reliant on the availability of specialised personnel to perform its service,
- **dependency on specific environmental conditions** as a relative measure for the degree to which a critical infrastructure (element) is reliant on specific environmental conditions to perform its service,
- **ability to adapt** as a relative measure for the ability of a critical infrastructure (element) to adapt to changing surrounding conditions to avoid negative effects on its functionality,
- **level of quality** as a relative measure for the current qualitative condition of a critical infrastructure (element),
- **level of protection** as a relative measure for the current status of protection of a critical infrastructure (element) with regard to a specific hazard.²

Additionally, the following attributes are considered as relevant indicators for the coping capacity of critical infrastructures:

- **preparedness** as a relative measure for the degree to which preparations are taken for the handling of disruptions or damages to ensure rapid restoration and maintenance of the functionality of a critical infrastructure (element),
- **redundancy** as a relative measure for the existence of multiple structures to perform the same service,
- **substitutability** as a relative measure for the substitutability of the service of a critical infrastructure (element) by another critical infrastructure (element),
- **transparency** as a relative measure for the traceability of the composition and mode of operation of a critical infrastructure (element),
- **reconstruction effort** as a relative measure for the temporal and financial effort related to the reconstruction of a critical infrastructure (element) and its functionality in case of damage or destruction.

The United Nations University Institute for Environment and Human Security (UNU-EHS) currently develops a method for an indicator-based assessment of vulnerability and coping capacity of population, environment, economy and critical infrastructures in urban areas with regard to floods. Within the project, the aforementioned indicators are further operationalised and will be exemplarily applied to critical infrastructures in Cologne and Dresden, two major urban areas that have been seriously affected by floods in recent years. Additionally, comparable sets of indicators are developed and tested to assess social, environmental and economic vulnerability and coping capacity. The results of their combined application are supposed to reveal potentials for purposive actions in policy making, civil protection and planning to effectively reduce vulnerability and enhance coping capacity. A GIS is established to visualise the results by supportive maps.

4 Climate change and critical infrastructure security

Consequences of climate change include changes in the spatial distribution, frequency and intensity of meteorological extreme events with serious consequences for human-environmental systems. As existing adaptive measures are currently concentrated in flood defence, there is considerable need and

² These indicators are based on a research project of the German Federal Office of Civil Protection and Disaster Assistance (BBK). A final project report will be published in the near future (see Lenz 2007).

potential for adaptation planning and implementation in other areas like human health care, water supply, energy production and transportation (see also European Environmental Agency 2005: 6).

The increased probability of heat waves will, for example, lead to water scarcity, especially in eastern parts of Germany (Umweltbundesamt 2005: 46). With regard to critical infrastructures, reduced water availability will negatively affect fresh water supply, electricity production (due to lack of cooling water) and inland water navigation. Unfortunately, the water supply sector is currently rarely adapted to impacts of climate change and especially not prepared for water scarcity, resulting in high vulnerability if no additional measures for adaptation are taken (Umweltbundesamt 2005: 46). Moreover, high temperatures during heat waves will challenge energy supply by changes in daily peak power demands, especially due to increased use of air conditioning (European Environmental Agency, 2005: 25). And the health care sector will probably have to cope with increasing numbers of heat-related illnesses like heat exhaustion and heat stroke, especially in urban areas (Government of Canada, 2004: xxi). Consequences of an increase in the frequency and intensity of heavy precipitation events are, for example, severe flood hazards (especially in densely populated and highly sealed areas), capacity problems for sewage water systems and problems for inland water navigation.

Concerning preventive measures to protect critical infrastructures against potential negative impacts of climate change, their dependency on specific environmental conditions and their ability to adapt are of special relevance. The following steps are suggested for critical infrastructure protection with regard to climate change:

- spatially differentiated **hazard analyses** for critical infrastructures concerning potential consequences of climate change,
- assessment of expected **changes in demand** of products and services provided by critical infrastructures,
- determination of the **functionality and performance capability** of critical infrastructures under changing conditions,
- identification of relevant **interdependencies** between critical infrastructures and sectors on national and trans-national levels,
- assessment of **possibilities and limits of adaptation** for existing infrastructures,
- consideration of potential hazards related to climate change and adaptive measures in the **planning process** for new infrastructures,
- establishment of **action plans** for the case of critical infrastructure failure,
- development and implementation of an **integrative protection strategy** involving actors from science, governmental institutions and critical infrastructure operators.

Finally, it has to be realised, that adaptation to climate change cannot take place without consideration of basic social and political-economic conditions (Dietz, 2006: 48). And surely, it should be complemented by strong actions for **mitigation**.

Literature

- Dietz, K. (2006): Vulnerabilität und Anpassung gegenüber Klimawandel aus sozial-ökologischer Perspektive. Aktuelle Tendenzen und Herausforderungen in der internationalen Klima- und Entwicklungspolitik. Diskussionspapier 01/06 des Projektes „Global Governance und Klimawandel“. Berlin.
- European Environmental Agency (2005): Vulnerability and adaptation to climate change in Europe. EEA Technical report No. 7/2005. Copenhagen.
- Government of Canada (2004): Climate Change - Impacts and Adaptation: A Canadian Perspective. Ottawa.
- Lenz, S. (2007): Vulnerabilität Kritischer Infrastrukturen. Schriftenreihe Zivilschutzforschung (in preparation).
- Umweltbundesamt (ed.) (2005): Klimawandel in Deutschland. Vulnerabilität und Anpassungsstrategien klimasensitiver Systeme. Forschungsbericht 201 41 253. UBA-FB 000844. Dessau.