Understanding Disaster Risk

3 - Cross-Sectoral and Multi-Risk Approach to Cascading Disasters

Key words: cascading risk, cascading disasters, cascading effect,

This section presents an operational framework for a cross-sectorial and multi-risk assessment of cascading disasters. First, the distinguishing elements of cascading risk are explained. Secondly, the role of critical infrastructure is related to national risk assessments. Some practical suggestions are advanced for adapting scenario building and contingency planning to rapid change and complex situations. In conclusion, the essential concepts are clarified with examples, and attention is drawn to some online resources and tools for further information.

An introduction to cascading risk and cascading disasters

From utilities to the Internet, over the last two decades technological networks have increased in interdependency and level of integration with society. They have also become more unstable and their behaviour has become harder to predict. Critical infrastructure (CI) is defined as those assets or systems that are vital to the maintenance of the socio-economic functions of society. It is also an essential pillar that supports the provisions of the Sendai Framework for Disaster Risk Reduction. CI can be conceptualised as nodes in the built environment which group together physical, functional and organizational attributes. With the increased complexity of the built environment, the definitions and sectors have evolved in concert with one another. They incorporate lifelines for the delivery of resources and services, essential sites for communities, and assets such as chemical plants that are potentially vulnerable to self-standing hazards.

A causal chain generates secondary disasters from the interaction between anthropogenic and ecological systems. Despite major efforts by the international community, many challenges are still present in efforts to mitigate such phenomena. For example, current risk management strategies are insufficient for estimating the probability of rare events and coincidences, and also for understanding cascades and event trees[1]. In order to improve the operational management of complexity, a system-wide approach to resilience is needed that embraces new forms of analysis, new methods and new tools[2]. Cascading disasters and risks present substantial challenges to both citizens and the emergency management community.

The emerging nature of the field implies that for a long time it has remained ill-defined, and only recently has there been substantial investment by the European Commission, in the form of Seventh Framework Programme and Horizon 2020 projects, which have enabled concept and practices to be defined better. Starting from the idea that cascades could be modelled as a dendritic structure of evolving secondary events[3], it has been suggested that cascading disasters reveal complex risks, where the effects of primary triggers are amplified by the non-linear progression of the crisis over time[4]. In other words, the consequences of the initial or trigger impact becomes the primary sources of further crises, which, instead of decreasing as time progresses, become larger and require more resources to bring

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them under control. The primary effects of the physical trigger are amplified by the disruption of entire sectors of critical infrastructure, such as air transportation and energy supply, and often by the hazardous components of CI, such as nuclear plants. The path of cause and effect exploits vulnerabilities that accumulate at different scales. They are manifest in unexpected events that escalate into full-blown cross-sectoral disasters[8]. The vulnerabilities can be accumulated in macroscopic dynamics, such as the technological drivers of globalization, or micro dynamics such as local CI management or decision making for land-use control.

Cascades are different from other topics analyzed in the literature and new instruments are needed to mitigate them. This is because sectors of CI influence each other. For example, losses in the energy sector can disrupt the water sector, which depends on electricity for pumping and other functions. The connections are complex and dynamic. Similarly, cascades differ from compound disasters, because the latter are more focussed on the concurrent and combined nature of climate extremes, such as flooding that occurs during a cold wave or heat waves that contribute to wildfires[5]. What is particularly needed to address cascading risk is to create scenarios, tools and information that could join the triggers with their patterns of consequences and thus help visualize the potential structure of secondary emergencies. In this respect, the following examples will clarify the most salient issues for national risk assessments

Examples of cascading risks and disasters

It must be noted that the literature on critical infrastructure has analysed many examples of cascades in areas defined by high concentrations of technology, such as the energy shortage that followed Hurricane Sandy in 2012 in the USA, and the distributed effects of the 2015 floods in York, UK. Much less evidence has been provided for developing countries. In 2007, Cyclone Sidr struck the southwest coast of Bangladesh with 240 km/hr winds and a six-metre storm surge. Water and sanitation infrastructure were heavily damaged, including 11,612 tube wells, 7,155 ponds, and over 55,000 latrines. Human waste was generally not treated, and waterborne diseases became a major public health concern. In many communities, drinking-water sources (tube wells and ponds) were contaminated with salt water and debris[6]. Further research is needed to understand how the specific needs and strategies at the local level can affect broader strategies for mitigating cascades.

BOX 1 - Eruption of Eyjafjallajökull volcano

The eruption of the Icelandic volcano Eyjafjallajökull in April 2010 is one of the events that have raised the tone of the debate about cascading risks. Its direct physical damages were limited, but it released an ash cloud that temporarily stranded 8.5 million airline passengers[7]. This disruption of the aviation sector became the main vector of the crisis. It showed that the dependency of modern society upon functioning global networks is both broad and deep. The temporary cessation of civil aviation increased the pressure on other forms of transportation, revealing its fundamental role in ordinary activities, from the delivery of perishable goods to air freight transportation of medical supplies, including organs for transplant. Despite many precursors, volcanic ash clouds were not considered in the risk registers of countries that were involved in the 2010 crisis, such as the UK. One wonders what other, unconsidered triggers could cause high levels of disruption to CI.

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BOX 2 - Tōhoku earthquake

The triple disaster in Japan that started with the Tōhoku earthquake of 11th March 2011 had serious consequences in term of loss of life and long-term impacts on the environment. The consequences included a boost to the worldwide debate on nuclear safety. Although only about 100 people died as a direct result of the primary trigger, namely the earthquake, about 18,000 were killed by the ensuing tsunami, and there was uncertainty about the consequences of the radioactive contamination resulting from the Fukushima Dai'ichi nuclear meltdowns. The interaction between natural and technological hazards was amplified by local vulnerabilities, and the Fukushima nuclear accident was considered "a profoundly man-made disaster – that could and should have been foreseen and prevented"[8]. Other critical infrastructure in the affected area was broadly compromised, which constrained efforts to contain the cascading effects of the primary disruption. It prompted the creation of new data sets to improve deployment in secondary disasters[15].

Implications of cascading risk and disasters for national risk assessments

Cascading risk and cascading disasters have serious implications for national risk assessment processes. It is vital, not only to understand and assess cascades in critical infrastructure, but also to know how to stop cascades from escalating. In order to address the possible impact of disruption, the United Kingdom and United States ranked elements of CI according to their importance[9][10]. In the Netherlands, an area-based approach is used because it enables the interdependencies of critical infrastructure elements to be mapped and assessed[11]. International work has striven to address the relationship between CI and society. When Peru estimated the resources that are essential to emergency response and recovery if an earthquake or tsunami were to strike the metropolitan areas of Lima and Callao, a high likelihood of poor functioning or paralysis of vital services was identified. This required new maps to be produced and alternative supply routes to be planned[12]. However, there is still no coherent and fully coordinated approach that respond properly to the provisions of the Sendai Framework for DRR. Risk maps that include loss of CI and its impact are generally unavailable or lack uniformity. In Europe, natural and technological hazards tend to be separated or overlain without an accompanying context[13]. Even when risk registers and national strategies are implemented, the tendency is to focus heavily on the impacts that are deemed most likely to happen, not those with the most complex consequences.

New strategies have been employed to address cascading failures, increase resilience and share information on possible common paths for the disruption of infrastructure. First, in recent years constant technological and scientific progress has led to cross-domain modelling of interdependent systems and economic impact assessment of critical events[14]. Together with research on empirical approaches, agent-based models, and interoperability input–output models, there has been an evolution in network-based approaches that aim to describe the connections and interlinkages between nodes of critical infrastructure (Ouyang 2014). The new resources available from geospatial technologies and computational tools have been integrated into digital support tools that consider local, regional national and international interdependencies, for example the Geospatial Risk and Resilience

Assessment Platform (GRRASP) reported in the resource section, below. It is also possible to find new methods for improving training for disaster management in complex environments, such as fault trees, root causes, and wider impact-tree analyse[15]. In order to improve the anticipation of crises, the PANDORA project initiated by the Danish Government has developed its 'forward-looking cells strategy'[16]. A key driver is to approach complexity before possible events occur, involving different stakeholders in the promotion of awareness, in information sharing and in planning. For example, in the UK, London Resilience has produced a general model called 'Anytown' which could easily be replicated in other urban environments. In the USA, the National Institute of Standards and Technology (NIST) has defined a step-by-step process to integrate buildings and infrastructure systems into community resilience (see resources section).

A complementary approach suggests that the paths of cascades can be understood in advance of the triggering events by identifying sensitive nodes that generate secondary events and rapidly scale up a crisis. Risk scenarios based on hazard can be integrated with corresponding vulnerability scenarios based on escalation points that could be used to represent unknown triggers[17]. This approach was tested with two different studies. First, empirical comparisons showed that the disruption of critical infrastructure can orient international relief in terms of the goods and expertise needed in the emergency phase. Priorities can change as the cascade evolves, secondary emergencies escalate and new datasets are required for the optimization of deployment[18]. Secondly, the technological motivations of CI disruption can raise the emergency to larger geographical and temporal scales, which have not yet been included in legislation on cross-border and cross-sectoral crises[19]. Knowledge of such cases could be improved with multi-level scenarios based upon vulnerability frameworks that are already available[20]. Distributed systems characterized by modular design and digital technologies could be used to increase the resilience of communities and emergency services[1].

The involvement of emergency managers, associations and representatives of the business community could help determine which consequences of a disaster could become the principal drivers of cascades. A practical example illustrates this point. Europe's biggest training event to date ("Exercise Unified Response", www.london-fire.gov.uk) took place in London in February 2016. The exercise lasted four days and simulated a building that collapsed onto an underground railway station, with over 1000 casualties. It involved all the major authorities in London and special rescue teams from Hungary, Italy and Cyprus. Although the consequences of a loss of transportation for London were considered, promoting a wider focus on secondary emergencies and escalation points could help to improve the strategic framework for the future, whatever the nature of the primary trigger. In an increasingly interconnected world, emergency planning needs to consider the existence of intersectoral factors and identify the less evident connections that could modify the need for assistance and coordination[21]. In this sense, the International Risk Governance Council (IRGC) developed an approach to risk governance that could be a step forward because it integrates cascading risk into resilience-driven strategies. Of particular relevance is the application of a tiered approach that supports the assessment of resilience and its translation into applied management actions[22]. This kind of information may be critical to the work of emergency managers and the development of situational awareness tools at the operational, strategic and policy levels. This is particularly relevant for developing countries, where increasing the awareness of new strategies and support for the training of local people could make a significant difference by increasing the flexibility of response and matching it more closely to local needs.

Resources for further information

Various resources are available online that help improve knowledge on of cascading risk.

The Research Group on Cascading Disasters at University College London is developing a series of guidelines written for non-academic users to improve the understanding of cascading risk. The documents and other papers are available at: www.ucl.ac.uk/rdr/cascading. Similarly, the International Centre for Infrastructure Futures is releasing policy briefs and presentations on critical infrastructure interdependencies and societal resilience. The documents are available at: www.icif.ac.uk. Other international sources provide information and guidance outside academia. The IRGC produced policy recommendations on "Managing and Reducing Social Vulnerabilities" from coupled critical infrastructures, while their "Resource Guide to Resilience" is focused on the governance of risks distinguished by high uncertainties. These and other reports can be downloaded free of charge at: www.irgc.org. Finally, other resources and compilations of lessons learned have been produced by initiatives such as the Rockefeller Foundation's One Hundred Resilient Cities (www.100resilientcities.org)

A wide range of methods and digital tools could be used to address cascading failures. The Joint Research Centre of the European Commission created the GRRASP platform, based on open source technologies, to support the analysis of cross-sectoral interdependencies and critical infrastructure disruptions, see: www.ec.europa.eu/jrc/en/grrasp. The European Commission has also funded projects on cascading effects that produced methodologies and software for modelling cascading effects, such as FORTRESS (www.fortress-project.eu), CIPRnet (www.ciprnet.eu), CascEFF (www.casceff.eu), PREDICT (www.predict-project.eu) and SnowBALL (www.snowball-project.eu). The websites of these projects have made different resources available for download, including decision-support systems and deliverables. Finally, it must be noted that the interaction between cascading risk and compounding drivers can be widely explored by accessing the resources provided by the US Climate Resilience Toolkit, which includes a catalogue of more than 200 digital tools for building resilience (www.toolkit.climate.gov).

Different resources are available in open access for supporting the training and preparedness of stakeholders. London Resilience, which acts on behalf of the Mayor of London, London's local authorities and London Fire Brigade, has developed 'Anytown', a conceptual model designed "to improve the understanding of infrastructure interdependencies by non-experts". The model is generic and has been developed to be used easily in different urban contexts. This and other information can be found at www.londonprepared.gov.uk. In the USA the NIST developed the Community Resilience Planning Guide for Buildings and Infrastructure Systems. The document aims to support the prioritization and management of resources to improve preparedness and recovery by using a practical six-step process to identify the linkages and dependencies between the social dimensions and the vital services provided by infrastructure (www.nist.gov). On the same website, the NIST provided standards and guidelines on cyber security for critical infrastructure.

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