Cascading effects in crises: categorisation and analysis of triggers

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ABSTRACT

The analysis of cascading effects in crisis situations can enhance crisis managers' understanding of how crises unfold and what prominent triggers of cascading effects are. By identifying and categorising triggers of cascading effects, a greater understanding of critical points in crisis situations can be reached, which can contribute to strengthening practices of crisis management, including preparedness and response. Accordingly, this paper provides an insight into triggers of cascading effects, gained through the analysis of six case studies of crises that took place between 1999 and 2014. The analysis produced six categories of triggers, which are discussed here: the disruption of pre-existing relations of information, organisation, and supply, disturbance relations, pre-disaster conditions, and the malfunctioning of legal and regulatory relations. Authors argue that the categorisation of triggers aids anticipating cascading effects, along with predicting risks and planning for potential bottlenecks in crisis management.

Keywords

Cascading effects, crisis management, critical infrastructure, triggers, risk management.

INTRODUCTION

Cascading effects in crises refer to a situation where a disruption of one element, such as infrastructure, causes a sequence of disruptive events, which can cause deleterious impacts far beyond the initial impacts of the crisis (Little, 2010). For instance, a power outage can impact on the quality or safety of drinking water and consequently the consumption of contaminated drinking water could lead to detrimental large-scale health impacts. Critical infrastructure systems, such as water systems, transport, or communication, are frequently highly interconnected and embedded in socio-economic systems (Labaka et al. 2014). Because of this interconnectivity, it is often difficult to predict how a crisis will unfold, what it will affect, and how effects further shape the unfolding of the crisis. The unpredictability and uncertainty commonly contribute to the magnitude of the catastrophic consequences a crisis can have.

However, as this paper will show, the analysis of cascading effects, and the identification of their triggers, can contribute to enhancing the understanding of the complexity of cascading crisis situations. It is important for such triggers to be mapped in order to generate knowledge that can be used in preparing for and responding to cascading effects in crisis situations. This paper presents an analysis of triggers of cascading effects from six case studies of crises that occurred between 1999 and 2014. During the analysis, triggers were categorised and

discussed with the aim of providing further insights into the processes of cascading crises.

This working paper stems from work conducted in the European Commission (EC) funded FORTRESS project (Foresight tools for responding to cascading effects in a crisis). FORTRESS aims to develop a scenario builder and decision-support tool that assists decision makers in preparing for and addressing cascading effects in crisis situations. The research presented in this paper was carried out with the purpose of providing an empirical basis for the technical development of these tools at a later stage in FORTRESS.

METHODOLOGY

The selection of case studies was in-part informed by an analysis of the Emergency Events Database (EM-DAT) crisis data (focusing on European crises between 2003 and 2013) that was carried out as part of the EC funded COSMIC project (The Contribution of Social Media In Crisis management).

The selection was also based on examining more recent and non-European case studies to ensure that our analysis met the needs of FORTRESS (i.e., an inclusion of cross-border crises) and is thus a non-representative sample of cases. As required by the project, which seeks to understand cross-border cascading effects (in addition to localised cascading effects), cross-border aspects were also important for selecting case studies in Europe. Within the current paper, the analysis concerns the following case studies: the Galtür avalanche (Austria, 1999), the fireworks factory explosions in the city of Enschede (the Netherlands, 2000), the European Heatwave (with a focus on France, 2003), the London attacks (UK, 2005), the Fukushima nuclear disaster (Japan, 2011), and the MH17 plane crash (Ukraine, 2014).

The analysis is based on an analysis of existing academic literature, event related research and evaluation reports, and news articles. Each of the crisis situations were analysed by the means of completing a visual overview consisting of seven columns: 1) Triggers of cascading effects, 2) Time (on relevant time scale), 3) Unfolding of events in crisis management (individual category and level of authority), 4) Unfolding of the physical event over time, 5) Negative effects, 6) Sectors directly affected, and 7) Sectors indirectly affected. An impression of what the visual overviews looked like is presented in Figure 1 which was taken from the case study of the avalanche disaster of Austrian Galtür (note: this overview is presented for illustrative purposes only).

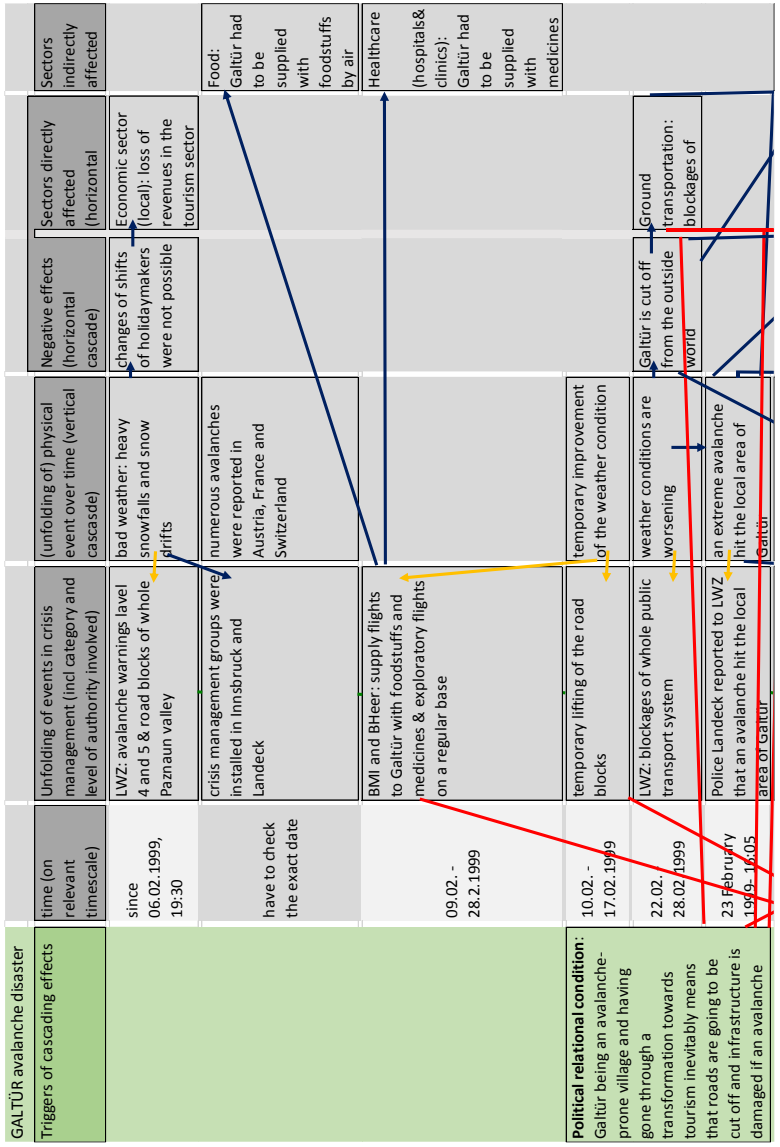

Figure 1. Example of visual overview

In each overview, information on the crisis was placed in boxes in the appropriate column. As illustrated in Figure 1, arrows and lines were used to connect the boxes and provide an indication of causal relations and influences. A blue arrow indicated a direct causal relation (e.g., A causes B), a yellow arrow indicated an influence on a causal relation (e.g., X influences how A causes B), a green line indicted subsequent steps but not a causal relation, a red line connected a trigger listed in column 1 to the cascade it caused.

Triggers of cascading effects in crisis situations were identified in two ways. Firstly, a deductive approach was chosen and categories of triggers derived from prior research conducted by Rinaldi (2001) and Voogd (2004). Secondly, an inductive, data-driven way enabled to expend the deductively developed categories by adding triggers while going through the material of each case study. Cascading triggers were added to the deductively developed categorisation when they emerged in at least two different cases. The varying natures of the case studies at times resulted in the identification of new triggers, and the creation of categories was therefore a process of discussion and revision. The final categorisation used to identify and label all case studies' triggers of cascading effects is presented in Figure 2.

Categories of triggers	**Further explanation and/or example**
Disruption of an information relation	Refers to a relation in which system elements or actors are dependent on the communication of information.
Disruption of a supply relation	Refers to a relation in which system elements or actors are dependent on supply activities by other system elements.
Disruption of an organisational relation	Refers to a relation of organising, making decisions, and making different people or things work. It is the case when actor X is dependent on decisions made by actor Y and not only on information.
Malfunctioning of a legal and regulatory relation	When regulations are not respected or legal responsibility are not acted upon. Triggers of cascading effects that fall in this category largely concern the malfunctioning of this relation in a pre-disaster stage.
Disturbance relation	Refers to unintended relations of interference that only come into being in a crisis. Unlike the categories above, where pre-existing relations were disturbed, disturbance relations did not exist before.
Pre-disaster conditions	Conditions (e.g., cultural, political or economic trends) that contributed to the occurrence of cascading effects. This commonly concerns pre-crisis conditions.

Figure 2. Triggers of cascading effects

ANALYSIS OF TRIGGERS

In each of the six case studies various triggers of cascading effects were identified by using the above-described categorisation. This process revealed eleven triggers of cascading effects in the category 'Disruption of information relations' and ten triggers in the category 'Disruption of organisational relations'. Seven triggers were categorised under 'Disruption of supply relations', and six in in 'Disturbance

relations'. The category 'Pre-disaster conditions' accounted for five triggers, and three triggers were placed in 'Legal and regulatory relations'. In this order these categories of triggers of cascading effects are discussed below.

Disruption of information relations

The disruption of information relations refers to flaws in the functioning of a relation in which actors or system elements are dependent on the communication of information. Such disruptions were identified eleven times, in five of the six case studies. With the exception of the Fukushima nuclear disaster, this trigger of cascading effects was addressed in all case studies. The Galtür avalanche provides a descriptive example of a disruption of information relations. Landline and mobile phone networks were congested, which made communication among first responders more difficult during the first hours after the avalanche took place (Thaler, 1999). This disruption of information also affected the communication between first responders in Galtür and crisis management groups that were installed in the nearby capital of the district. The communication problem was solved by an improvised radio network connection (Thaler, 1999). Moreover, the London attacks illustrate another aspect of malfunctioning information relations. The coverage of mobile networks in the London underground system is often lacking. Therefore, when the attacks occurred on the London underground network, passengers and drivers on the trains were largely unable to use their phones to call for help to emergency services (London Assembly, 2006). These two examples illustrate the importance of the availability of reliable communication systems for an immediate deployment of resources to the scene when managing a crisis.

Disruption of organisational relations

The disruption of organisational relations as triggers of cascading effects is often related to disruption of information relations but is more than that. Organisational relations regard organising, making decisions, and making different people or things work in emergency management. Disruption of such relations were identified nine times across five case studies. Only the case study on the avalanche disaster of Galtür did not identify this trigger of cascading effects. This is contrasted by the MH17 plane crash in Ukraine, which provides an example of a disruption of organisational relations. The political and armed conflict in Eastern Ukraine interfered with the work of the international investigation team on MH17 plane crash. Due to a tense security situation, the Dutch government leading the investigation team made the decision not to deploy an international military mission to secure the crash site (Government of the Netherlands, 2014). Rather, the Dutch government prioritised the recovery and identification of the victims and decided to do what they could to prevent an escalation of the tensions in the area. As the leader of the investigation team feared that a military mission could increase the risk of becoming directly involved in the civil warfare, resulting in a possible escalation of international dimensions, the investigation team cooperated with the self-declared Donetsk People's Republic in searching for and recovering victims' remains (Government of the Netherlands 2014a). The named disruption of an organisational relation led to restrictions and delays in the search operation at the crash site. Furthermore, the London attacks provided another clear example for the disruption of organisational relations. A meeting of the Gold Coordination Group was relocated to a remote area in North London because of its good facilities and prior use for running emergency preparedness (London Assembly, 2006). However, the underground was closed and traffic congested because of the attacks. Consequently, it took the group members longer than planned to get to the new location which impacted the coordination of responding to the attacks. These two examples illustrate how disruptions of organisational relations triggered decisions taken that later turned out to be erroneous, impacting negatively on the crisis response.

Disruption of supply relations

Supply relations are characterised by system elements or actors that are dependent on supply activities by other system elements. A disruption of a supply relation may cause a cascading effect but the relation of dependency already existed before that. Disruptions were addressed in all of the six case studies and identified seven times. An example for a disruption of supply relation provides the lack of supply of water during the heatwave in France. While there is a regular dependency on the supply of water for cooling of power plants, it was disrupted during the heatwave when the water level in rivers reached a critical level and left insufficient water for cooling nuclear power stations (UNEP, 2004). Due to the reduced supply of water and the threat of overheating, several nuclear power stations were shut down (Ibid.). To ensure the energy supply of the French population, electricity exports to other European countries were cut by more than 50% (Ibid., 3). A lack of supply of water as a trigger of cascading effects was also identified in the case study on the fireworks factory explosions in the city of

Enschede. The large amounts of water used to extinguish any fire related to the explosions impacted negatively on the region's drinking water reservoir. Although it took the water supplier five days to solve the problem, any further negative consequences in relation to the lack of water were prevented (Doorn, 2001). Both examples illustrate how a disruption of supply relations causes cascading effects to occur and gives particular attention to the role of natural resources and infrastructures.

Disturbance relations

Crises are commonly characterised by a degree of unpredictability. This regards the magnitude of the event, as well as the unintended relations of interference that come into being during a crisis. These 'disturbance relations' concern connections between systems or stakeholders involved in crisis management, in which the functioning of one becomes dependent on the other, whilst this was previously not the case. Such relations were identified in six instances, in four of the six case studies, namely the London attacks, the Galtür avalanche, the heatwave in France, and the Fukushima nuclear disaster. The latter provides an illustrative example of a disturbance relation. As the supply of cooling water to the power plant's reactors was lost immediately following the tsunami, alternative means of cooling had to be generated. Consequently, firemen were charged with the task of providing water injections, by means of fire engines (Blandford and Ahn, 2012). These new responsibilities were characteristic of the disturbance relation between the nuclear reactors and the firemen that arose during the course of the crisis. Furthermore, the case of the Galtür avalanche shows the example of how local emergency personnel present in the Austrian village of Galtür became responsible for search and rescue on their own, whereas a large-scale response operation with much more personnel was required. Only when the adverse weather conditions improved the day after the avalanche, the external assistance this crisis demanded could be flown in (Thaler, 1999). These two examples illustrate how new or increased responsibilities can come into being during a crisis, which can considerably reduce the speed of managing the emergency.

Pre-disaster conditions

Pre-disaster conditions as triggers of cascading effects have their roots in pre-crisis developments and events that led to cascading effects during the crisis. They were identified five times, in four of the six case studies. For example, the management of the heatwave in France was hindered by the shortage of staff in emergency services, as it was summer and many had taken annual leave (Lagadec 2004, 162). Public authorities were understaffed and responsibilities were not clearly defined (World Health Organization 2004, 27). This contributed to a lack of information sharing, which negatively impacted the organisation of emergency management. Pre-disaster conditions of a more long-term nature were seen to cause cascading effects in crises as well. The Fukushima nuclear disaster provides an example of this. Over the years leading up to the event, nuclear power had become less profitable in Japan. Tokyo Electric Power Company (TEPCO), the owner of the Fukushima nuclear power plant, had therefore begun to place more emphasis on cost cutting at the expense of safety measures (Kurokawa, Kyoshi, Ishibashi, Oshima, Sakiyama, Sakurai and Tanaka, 2012). This could be seen in shortcomings in diagrams and documents outlining the venting procedures, and accident manuals not being up to date (Kurokawa et al., 2012). This caused a delay in releasing accumulated hydrogen gas in the reactor buildings (Funabashi and Kitazawa, 2012), which contributed to overheating and subsequent hydrogen explosions in the reactors. These two examples thus illustrate how pre-disaster conditions can be of considerable influence on how a crisis unfolds.

Malfunctioning of legal and regulatory relations

The malfunctioning of legal and regulatory relations can also be seen to occur in the pre-disaster stage. This involves regulations not being respected or acted upon, which impacts on the way a crisis unfolds. Such instances were identified three times, in two case studies: the Enschede fireworks factory explosion and the Fukushima nuclear disaster. The former provides an example of how pre-crisis legal and regulatory relations between local government, national government and industry contributed to the cascading effects in a crisis. Smallenbroek Enschede (SE) Fireworks, the owner of the fireworks factory, had not met its legal obligations with regards to fire-safety in various ways, including the storage of fireworks of a more explosive nature than permitted and storing fireworks in areas where they should not be stored. However, they had been able to get away with this as inspections were not carried out sufficiently by the local government. The combination of these factors enabled the fire that started in the factory to spread rapidly and subsequent explosions to cause extensive damage (Voogd 2004).

CONCLUSION

Cascading effects in crisis situations can increase the negative impacts of disastrous events far beyond their initial impacts. The analysis of how such cascading effects are triggered, can contribute to providing a better understanding of these effects, and can be beneficial for the development of tools and procedures in crisis management. This paper has briefly discussed the analysis of cascading effects and their triggers in six historical crises. The analysis revealed that the disruption of information relations and organisational relations were most commonly identified as triggers of cascading effects. These triggers concern relations that should have been functioning, but failed to do so, leading to cascading effects. Disruptions of supply relations, concerning the dependency on the supply of materials or resources, and disturbance relations, unintended relations of interference, were less frequently identified but were still prominent triggers of cascading effects. Pre-disaster conditions and legal and regulatory relations were least frequently identified.

In line with Voogd's (2004) argument that flaws not dealt with in advance can turn into disasters, the analysis presented here showed that triggers of cascading effects can have their roots in the turn of events during crises, as well as in pre-disaster conditions. The latter illustrates that everyday conditions in a given situation should be considered when preparing for crises. In particular with regard to crises that frequently occur in a particular area, (e.g., avalanches in mountains) pre-disaster conditions should play an important role in disaster preparedness. Having regulations in place, and enforcing these regulations, is one such measure that is relatively easy to address. More difficult are pre-crisis conditions that relate to long-term societal developments, as these triggers of cascading effects commonly concern multiple events of causes.

Regarding triggers that originated during crises, the two most commonly identified triggers were often related, as the flow of information not only concerns information relations but also organisational relations crucial for crisis management. More extensive preparedness measures regarding having pre-established plans of approach and divisions of responsibility, as well as separate communication systems and back-up lines, have the potential to improve the organisational response to crises and limit cascading effects.

The findings presented in this working paper will feed into the development of a list of nodes regarding connections between systems and sectors of society. This will contribute to the assessment of the criticality of individual elements in a crisis situation, and will subsequently provide a basis for the technical development of a scenario builder and decision-support tools at a later stage in FORTRESS.

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