Deployment of civil engineering expertise during crises – Experiences in the Netherlands

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ABSTRACT

Modern societies are complex and depend largely on the proper functioning of the Critical Infrastructure (CI). A crisis is an unpredictable event that can lead to a disruption of CI and the functioning of society. In order to save lives and limit damage, decisions have to be taken under stress and time pressure while the situation is still very uncertain and so require a special approach to answering the relevant civil engineering questions. In the Netherlands, Deltares is on 24/7 stand-by to provide this technical assistance. The introduced SQD procedure is an approach for crisis management meetings that makes it possible to quickly get a mobilized expert team into the action phase to answer these questions. This is illustrated by two examples. The main conclusion is that deploying civil engineering expertise rapidly, as part of the crisis management, contributes significantly to limit the consequences for society.

INTRODUCTION

Modern societies are complex and depend largely on the proper functioning of the Critical Infrastructure (CI). A nation's CI provides the essential services that underpin society and serve as the backbone of the economy, security and health. Overall, 16 types of CI sectors can be delineated that compose of assets, systems and (physical and virtual) networks. The interdependencies between CI can cause so-called cascading effects, where for example a disaster like a local dike failure results in flooding of a high voltage transformer unit which then causes power blackout in a whole region leading to disruptions of telecommunication, transport and public services.

In this paper, the focus will be on four sectors that show the most civil engineering challenges, i.e. the water, energy, urban and transport sectors. These CI are all either built on the subsurface or in the subsurface and often also use material from the subsurface as building material. The subsurface itself can also be part of potential hazards, e.g. in case of landslides and earthquakes.

Table 1 presents an overview of the CI considered and the possibility of impact of natural disasters, extreme weather events and man-made hazards.

Table 1. Possibility of impact (x) of hazards on Critical Infrastructure

		Natural disasters			Extreme weather events			Man-made hazards		
	Critical Infrastructure (CI):	Flooding	Landslides	Earthquakes	Coldwaves, icing, snow	Heat waves, droughts	Storms, tornadoes	Fire and explosion	Crime and terrorism	Construction failure
Energy	Oil and gas production	X	X	X			X	X	X	X
	Electricity generation and transmission	X	X	X			X	X	X	X
	Distribution electricity, oil, gas	X	X	X			X	X	X	X
Water	Drinking-water and sewage system	X	X	X	X	X	X	X	X	X
	Surface waters	X	X	X	X			X	X	X
Urban	Public buildings, offices	X	X	X				X	X	X
	Monuments, historic buildings	X	X	X	X	X	X	X	X	X
	Resident housing	X	X	X				X	X	X
	Underground construction	X	X	X				X	X	X
Transport	Road & Rail	X	X	X	X	X	X	X	X	X
	Airports	X	X	X	X	X	X	X	X	X
	Ports and inland waterways	X	X	X	X	X	X	X	X	X
	Pipelines	X	X	X				X	X	X

The water, energy, urban and transport sectors are essential for the quality of life and vital for the competitiveness of Europe. In 2006 the European Commission adopted the European Program for Critical Infrastructure Protection (CIP), to support the member states in building a more resilient society and to improve on contingency planning. This resulted in 2008 in the Council Directive on the identification and designation of the European critical infrastructures and the assessment of the need to improve their protection. Building a more disaster resilient society is a major task for the European countries. For example the Netherlands alone are already planning to invest € 20 billion in the next 30 years (Delta Program) to maintain safety against flooding.

In order to stimulate knowledge development on Critical Infrastructure Protection, the European Commission has developed research programs on this topic. In several of these projects Deltares is involved, one of them being the INTACT project (2014-2017). INTACT addresses these challenges and demonstrates in five countries, methods to assess the impact of natural disasters and extreme weather events, the design of protective measures and the crisis response & recovery capabilities. Findings of the project will accumulate in the INTACT Reference Guide, that will support decision makers, owners and operators to protect their CI.

These ongoing developments increase not only the need to mitigate the impact of hazards but also require capabilities for immediate action in case of an emergency in order to save lives, limit the damage and return to the normal operational state effectively and as soon as possible.

CRISIS MANAGEMENT

A crisis can occur as a result of an unpredictable event (e.g. a natural disaster) that within a small time frame leads to a disruption of the functioning of society. It requires decisions on remedial actions to be taken quickly to save lives, to limit the damage and return to the normal state effectively. These decisions are taken under stress and time pressure, while the situation is still very uncertain and only limited information is available. Technical expertise is needed to answer the civil engineering questions, which are often very relevant during a crisis caused by a natural disaster, extreme weather event or failure of a construction.

Crisis management is the application of strategies designed and prepared to help an organization deal with a sudden and significant negative event. In crisis management theory, four stages are delineated, see Figure 1:

1. ***Mitigation***: this is the stage where measures are designed and implemented to prevent a crisis from happening, thus increasing societal resilience.
2. ***Preparedness***: during this stage the responsible organization develops effective action plans to execute when a disaster strikes. The action plans are based on scenarios describing possible crises and are detailed accordingly to support the staff during the crisis situation. Crisis response (mock up) exercises are also important for this stage to train staff and to test and improve the action plans. Details (e.g. alarm procedures, names of key staff, telephone numbers and access codes to information) in the action plans are aging so regular updating is required to stay prepared.
3. ***Response***: in this stage one responds to a crisis by mobilizing key resources, emergency services and first responders to deal with the situation, focusing on saving lives and limiting damage. Each team has specific tasks at different levels in the crisis management organization and is led by a team leader. Especially the collaboration between different response teams from different organizations and adequate communication of information is crucial and challenging given the stress and (time) pressure the teams face.
4. ***Recovery***: after response, this stage deals with restoring the original situation. In practice the distinction between the response and recovery stage can be vague. Many issues can come up during the recovery stage involving many more parties, for example because of investigation into the cause of the incident, liability issues and the cost of recovery. While response is often a fast stage, the recovery stage may take a long time depending on the scale and complexity of the crisis at hand.

Figure 1. Four stages of crisis management

24/7 EMERGENCY RESPONSE

As part of an agreement with the Dutch Ministry of Infrastructure and the Environment, Deltares is on 24/7 stand-by for emergency response. Should a crisis arise within the Deltares fields of expertise (i.e. water, subsurface and infrastructure), experts are available to provide technical assistance. The Deltares team is part of a much larger crisis management organization that, depending on the scale of the crisis, is activated on a local, regional or national level.

Within an hour after the alarm, a small Deltares team is formed consisting of a team leader, a department manager, a communication officer and a supporting secretary. This small team performs a first assessment of the situation and the questions that need answering. In the next phase the team is scaled up bringing in Deltares staff that has the expertise and (local) experience to deal with the identified civil engineering questions and recommend on measures to be taken. In a crisis, several groups of experts can be mobilized to work simultaneously on different questions. The team leader is responsible for the organization of this process and delivering results (i.e. advice on technical questions) within the given time period, sometimes only a few hours. The major dilemma is that on the one hand the results needs to be accurate and boundary conditions well defined but on the other hand the given time deadline has to be met under all circumstances. Each year several mock exercises are conducted to train Deltares staff and maintain a sense of vigilance.

One of the facilities used during crisis is the iD-lab (see Figure 2), an interactive data research laboratory, which combines and displays big amounts of data and brings together models, visualization techniques and expert knowledge. A major advantage is that the available information can be presented quickly to the whole team for a common analyses of the situation.

Figure 2. The iD-Lab: a Deltares facility on handling big data and operational forecasting

Next to that, the team uses the practical **SQD** procedure: a 3-step method of **S**ituation assessment, **Q**uestion analyses and **D**ecision taking. The SQD procedure is our standard approach for a crisis management meeting that, when trained well, makes it possible to get a mobilized expert team into the action phase within 30 minutes. In the action phase the team will work out advices on the formulated civil engineering questions and report about that. After quality control this advice is communicated to the crisis management organization.

In the SQD meeting the team will (i) acquire a **common** understanding of the crises situation based on controlled information, (ii) identify and prioritize the civil engineering questions and (iii) the team experts will know when they have to deliver advice about these questions. The Deltares team consists, next to the team leader, of a plotter, a communication officer and several experts. The team is arranged in the meeting in a half circle setting that allows easy contact between team members while facing the iD-lab screens and three white boards, entitled: **S**ituation, **Q**uestions and **D**ecision. The iD-lab screens are used to display maps, weather and flood forecasting and a communication channel with the crisis management organization (InfraWeb).

In Table 2 the main discussion items for the meeting are presented. During the meeting chaired by the team leader, the plotter will visualize the information on the appropriate whiteboard to help create a common understanding, to structure the discussion and to focus towards the goal of the meeting. The communication officer will keep a log, monitor incoming information and after the meeting prepare outgoing communication with the team leader.

Table 2. SQD procedure for a crisis management meeting

Situation assessment	**Question analyses**	**Decision taking**
▪ Current and expected situation (including timeline) ▪ Network analyses (who is involved?) ▪ Problem definition and prioritization ▪ Immediate no-regret measures	▪ Question 1 (facts, measures) ▪ Question 2 (facts, measures) ▪ Question 3 (facts, measures) ▪ …….. ▪ Resources check: do we need more experts, information, etc.?	▪ What questions to answer? ▪ Remaining questions ▪ Actions ▪ Communication ▪ Team check: does everybody know what to do next?

CASE HISTORIES

From the various crisis situations of the past years that have helped to shape and improve the presented SQD procedure and iD-Lab, two are highlighted here.

Flooding of an urban area at Wilnis.

On the 26th of August 2003, in the middle of the night, a sudden breach occurred in a regional dike in the village of Wilnis, close to Amsterdam. The failure of this 6 m high dike, mainly consisting of peat, flooded an urban living area and emptied the canal in front of the dike. By rapid response, a dam was constructed by dumping clay from a nearby bridge, within two hours after the breach. This prevented the inflow of some 250,000 m^3 of water from a nearby lake, which would have caused much more damage and also casualties, which were now prevented. At daylight, the following morning, the damage caused by the breach became more clear (Figure 3).

Figure 3. Aerial view of the dike breach at Wilnis

Over a length of about 1 km, the canal had been emptied, resulting in secondary stability failures towards the canal along the sides and on-going settlements in the area. This area is highly sensitive to even subtle changes in the groundwater table because of the thick underlying peat layer. The settlement process endangered further the already damaged gas and electricity utilities. After the immediate response to close the canal as quickly as possible, the emergency team therefore decided to:

- Monitor deformations and pore water pressures on both sides of the breach 24/7 to detect any impending additional failures;
- Cut off gas and electricity along the damaged canal section, investigate local damages and restore services as quickly as safely possible;
- Close the breach with a temporary measure to enable the safe restoration of the water level in the canal, mitigating further settlements;
- Investigate the root cause of this sudden breach.

Within a few days, a supporting bank was raised behind the dike sections next to the breach location. In about one week time, a sheet pile wall was constructed alongside the breach and the canal could be carefully refilled while monitoring deformation and pore water pressure. No further damages occurred. The cause of the breach turned out to be an exceptional dehydration of the peat dike during the previous extremely dry period and the complex geo-hydrological situation. Details on the root cause analysis are given by Bezuijen et al. (2005).

Piercing a naphtha pipeline near a canal

In the late afternoon of August 6, 2013, a drilling rig used for soil investigations near the village of Born pierced an underground naphtha pipeline between the Port of Rotterdam and a large chemical plant in the south of the Netherlands. This 10 bar pressure pipeline was not in use at that time because of maintenance, but it still contained naphtha, which is a poisonous fluid. A vapor of naphtha escaped to the surface, creating a dangerous situation in the immediate area around the rig. After several hours of deliberations on how to handle this situation, with a pressing economic damage in mind because management of the chemical plant demanded repair of the pipeline within 48 hours, claiming millions of euros of damage per day, the authorities realized that the incident location was very close to a canal. This canal, the Julianakanaal, is constructed above the original surface level, with steep embankments on both sides. Repair works planned could undermine the embankments and cause a flooding of the area. Next, an emergency response team was called for, which was formed according to the SQD procedure described.

A member of the team investigated the situation at the location (Figure 4), which was complicated by the presence of the vapor and the brushwood, obstructing a clear view on the situation, including lack of information on the actual distance from the incident to the dike. Yet, the information that could be obtained was sufficient to enable a supporting team to quickly perform stability calculations, indicating how to proceed with this situation. Another supporting team gave advice on how to deal with the environmental issues, affecting a large area because of the high velocities in the groundwater in the gravel layers, presumably reached already by the naphtha.

Within the required time period a practical advice could be given on how to proceed with this situation: a phased excavation of the affected area after removal of the rig by heavy lift equipment operating from outside of the vapor-affected area, repair of the pipeline and backfilling including periodic 24/7 visual inspection of the embankments. Meanwhile, an alternative route had been found to provide the chemical plant with naphtha.

Afterwards, it was found out that the rig had been operating outside its designated area: the drilling location actually used, about 10 m away, allowed for much easier access.

Figure 4. Location of the incident showing the drilling rig and the brushwood (left) and an aerial overview after clearing during refilling (right)

CONCLUSIONS

Natural disasters, extreme weather events and man-made hazards can disrupt the Critical Infrastructure and the functioning of society. It is shown that deploying civil engineering expertise rapidly, as part of the crisis management, contributes significantly to limit the consequences for society. In the Netherlands, the 24/7 stand-by of technical assistance by Deltares provides support during the response and recovery stage of a crisis. From the cases the following lessons are learned:

- Crisis management procedures are important, but also improvisation capacity is needed.
- Preparation (action plans) and training is very important to maintain vigilance.
- During a crisis, many organizations with different interests become involved. A clear mandate and proper communication is crucial.

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