

Learning from flood events on Critical Infrastructure: Relations and Consequences for Life and Environment (Circle)

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Circle - Critical Infrastructures Relations and Consequences for Life and Environment

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Introduction

It becomes more and more clear that when a natural disaster occurs in modern society, the direct effects to the single critical infrastructure networks are not the only effects to deal with. Dependencies and interdependencies between different networks, like the energy network (figure 1a), transport network (figure 1b) and communication network (figure 1c), can cause unexpected consequences. Next to this, indirect effects and cascading effects may have a larger impact over a longer period of time than the direct effects. In 2014 the minister of Infrastructure and the Environment of The Netherlands wrote a letter to the Dutch parliament concerning awareness on Critical Infrastructures when dealing with climate change related topics like floods and droughts (Rijksoverheid, 2014). She was not just mentioning awareness among the stakeholders concerned with the CI, but the inhabitants of the Netherlands as well. The interactive Circle tool that is recently developed will be able to contribute to these goals by analysing and visualising cascading effects of critical infrastructure networks.



Figure 1 a, b and c: Electricity network, road transport network and communication network.

Cascading effects

A simple example of a cascading effect due to a flood is when at certain locations the water depth reaches 25 cm. In this case the substations of the electricity network will flood and there will be outages in the areas connected to these substations. Usually these areas will be flooded as well. These substations are connected to the main stations of the electricity network. When a certain percentage of substations is flooded, the entire main station and all the connected substations are not working anymore and electricity outages are experienced in non-flooded areas. This is a cascading effect within one network. An example of a cascading effect between two different networks could happen when communication substations are flooded with a water depth of about 50 cm. The consequence is that all communication within a certain area is affected. This includes radio towers of the waterboards that are needed to operate water pumps in the area. The pumps of the waterboards and pumps for tunnels in the area will stop functioning and could worsen the effects of flooding in the area.

Until now connections between critical infrastructure networks, are hardly identified. Critical infrastructures are dealt with separate from each other, even though different parties are aware of their interdependencies and possible cascading effects. Especially when recurrences are involved these effects become unclear. Furthermore, data is hardly available and dependencies are even less documented, which makes it difficult to determine the effects on a certain location. For that reason it also may hinder an adequate coordination and disaster management.

In flood risk management there are concerns on the indirect impacts. Because of the lack of quantitative research a certain factor per region times the total of the direct impact is used to calculate the indirect impact (Jonkhoff, 2012). There are qualitative studies indicating that the indirect impact could be much more than that and other studies indicating that it is likely to be much less than that (Luijf, 2009). Provinces,

WaterBoards and safety regions are aware of these uncertainties and in need of more decision-support. They need to know:

- What the weakest links are;
- How to protect the weakest links and minimise damage;
- Where to evacuate people (non-flooded area but with working drinking water, energy and wastewater facilities);
- If it is possible to take last-minute measures and what these measures could be.

Open Data

It is not always possible to access detailed network information. This information is quite often seen as vulnerable to terrorist attacks, especially for the energy networks. Because it is important to have easy access to network data and to analyse cascading effects quickly and real-time in order to be helpful for stakeholders, open data is chosen instead of fictive network models. This open data needs to be combined with knowledge and experiences of the networks: at what water-depth will the network experience problems and what type of problems are they?

Two studies in Groningen and West-Friesland in the Netherlands have shown that the availability of useful open data is good enough for cascading effects analyses. Although the data was not as detailed as the data the network owners have themselves, they did indicate that the effects that were calculated were very close to reality and detailed enough for crisis management operations and decision-making during events.

The abovementioned example of the electricity network is derived from these case-studies. The contacts at the electricity network indicated the water depth of 25 cm although often 50 cm is used (Royal HaskoningDHV, 2012).

Causal relationships

Although there is a lot of open data available and useful for cascading effects analyses, the data alone is not enough. How a network is affected, exactly when and how it interacts with other networks is not directly clear from the data alone. During meetings with different network owners it became clear that many outages and other effects can be described as causal relationships:

- When during a flood the water depth reaches 25 cm, the electricity substations stop functioning (see Figure 2).
- When electricity falls out, our industry relies on temporary measures for 3 days.

- When water levels reach 30 cm, the gas network is damaged but can still be repaired (also present in Figure 2).

With these types of relationships for different networks, it is possible to use open data for real-time cascading effects predictions. Figure 2 shows a screenshot of an automatic GIS-analysis of cascading effects for a part of Groningen, made entirely with open data and gathered causal relationships.

Cascading effects of Critical Infrastructure due to coastal flooding - A flood scenario in Groningen

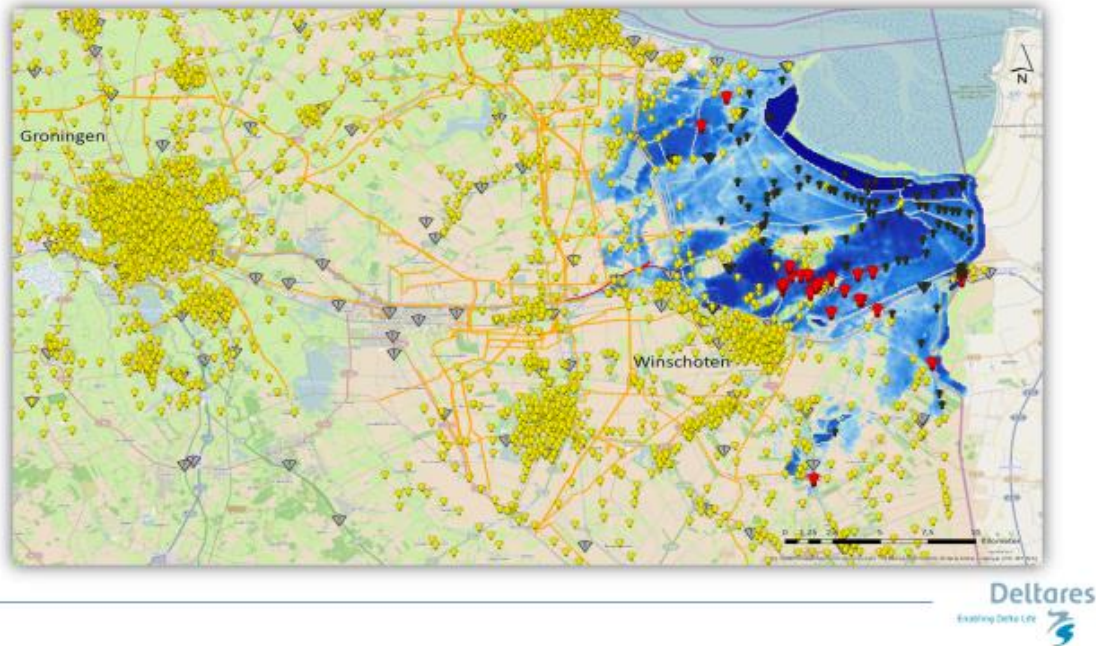


Figure 2: Screenshot of an automatic GIS-analysis of cascading effects for which only open data and causal relationships have been used.

Figure 3 shows an overview of threatened pumps of the Waterboard in West-Friesland, based on open data. The flood scenario shown occurs after thirty hours of flooding based on a 3Di simulation, from a breach location at Wijdenes (see arrow in Figure 3). The effect of an outfall of the pumps is that the regulated water levels of the corresponding canals is not regulated anymore, probably causing more flooding. As an extra result of the outfall of pumps in this area, also drinking water distribution may be threatened since the pumps are fed with electricity from the Wervershoof area and it's pumps close to Andijk (i.e. red circle in Figure 3) is directly threatened as well. This will lead to an effect that is much larger than the shown area of West-Friesland, because the whole east side of the province of North Holland is depending on the water supply from Andijk.

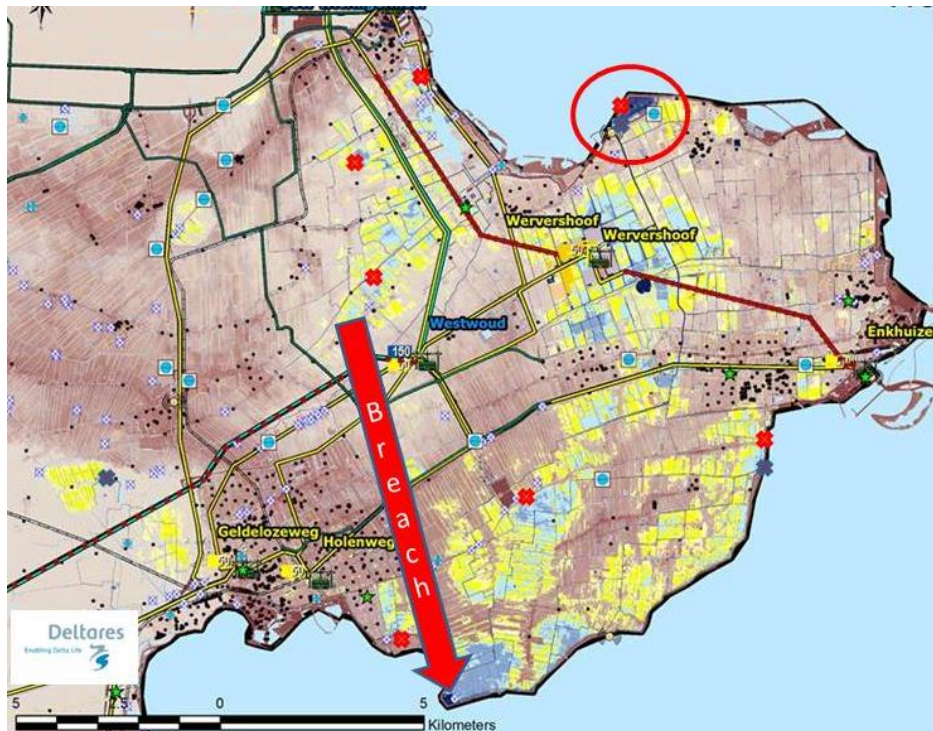


Figure 3: Threatened pumps of the responsible waterboard in West-Friesland, after 30 hours of flooding from a breach location as indicated; based on open data and a 3Di flood scenario. In the red circle the drinking water supply in Andijk is indicated.

Circle – interactive stakeholder tool

With Circle (the tool for Critical Infrastructure: Relations and Consequences for Life and Environment), knowledge and experiences of the different network owners and experts are gathered, discussed and combined to visualise and analyse cascading effects. In this way consequences for people and environment will become clear.

The idea behind Circle is the sharing of knowledge during workshops. Participants of the workshops will typically be stakeholders in crisis management or owners of networks (such as pipes, roads, cables, etc.). All parties, including the coordinator of the workshop will sit round the Circle touch table. All of the parties can share their knowledge on the components of their own (part of the) CI. For example, the water pump of a waterboard which influences the water level of a watercourse depends on electricity supply to this particular pump. In case of emergency it may be dependent on the road leading to the pump as well when back-up power units need to be started up. On the touch table application this will be drawn by the participants as an arrow between the pump and the substation and the road and the pump. By mentioning this dependency, the electricity distributor as well as the road owner will clarify how they take care of the required need of the waterboard. The waterboard or province may know that a certain substation will be renewed and can ask for special measures. Since Circle is based on equality and is used as a circle of trust resulting in

awareness it helps connecting knowledge on CI, by connecting people in the process and connecting technical knowledge.

Figure 4 shows Circle during a session where connections are drawn. Circle is used as a discussion tool. When during the discussion knowledge is shared on direct effects and cascading effects, this can be entered into the system at each network block or at each connection. The entered data and information is gathered in an Excel-file. Some data is directly written down as a causal relationship, others might be more qualitative but important as well. The causal relationships are directly used in the automated GIS analysis to show results when for instance electricity sub stations can manage 50 cm of water instead of 25 cm of water in a certain area.

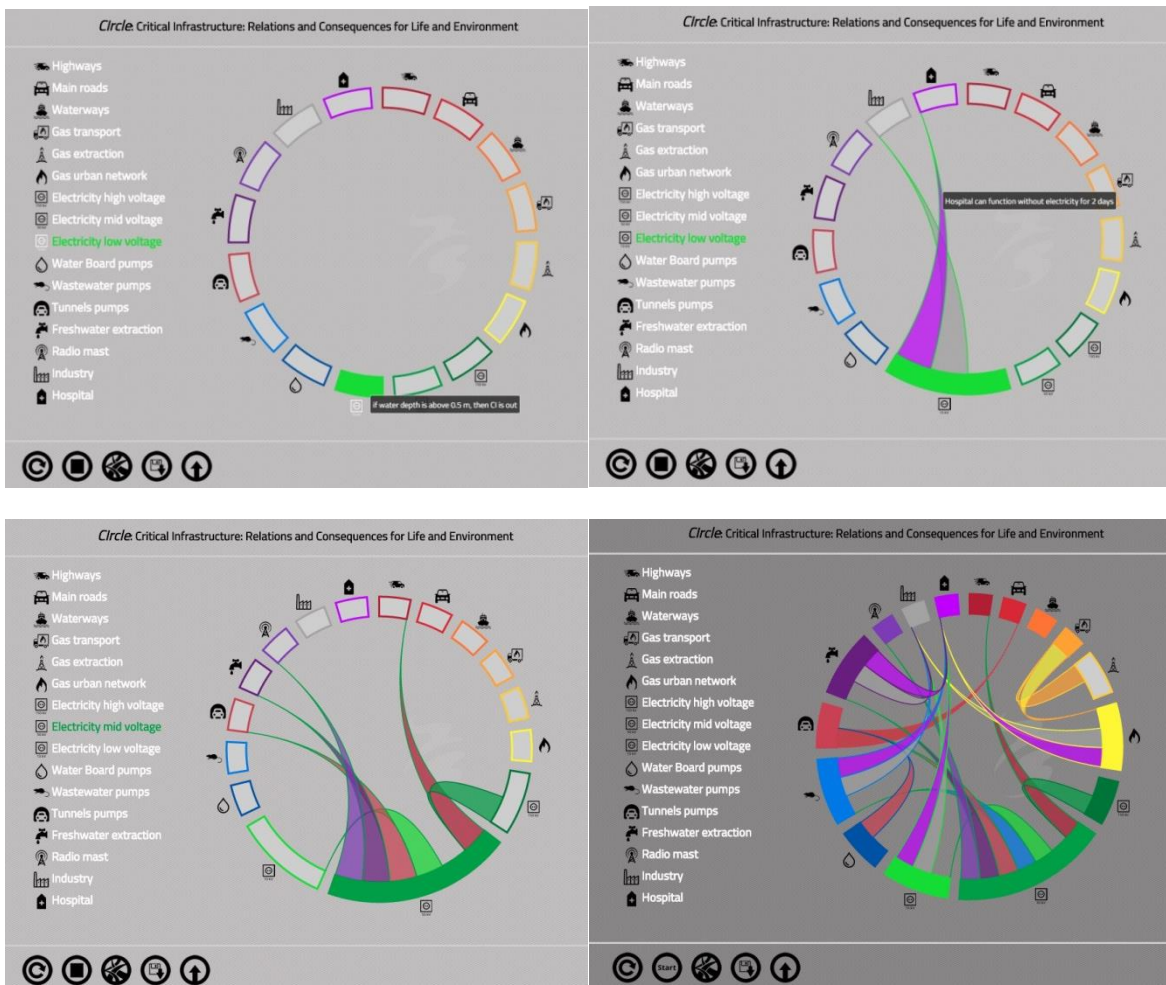


Figure 4a, b, c and d: Circle during a workshop session where in 4a a direct effect is added to the system and in 4b an indirect effect is entered into the system. 4C shows the gathering of different dependencies and 4d shows an end-result of a session where all discussed connections are shown.

Workshops

Sharing knowledge is crucial for the workshops as for critical infrastructures and cascading effects the combined knowledge tells us more than knowledge of just one network. Because it is not necessary to have all the information of the different

networks beforehand, network owners will not feel they have to share secret information and they can decide for themselves what how much they would want to share. The visual and interactive techniques of Clrcle help to understand cascading effects and exchange important information on causal relationships, making stakeholders aware of their vulnerability, direct or by their network interdependencies.

These causal relationships are collected in a database and shown in a time-dependent GIS analysis in order to visualise the shared knowledge immediately. Because the application has the ability to store the knowledge on interdependencies gathered in the workshops, it will grow in each workshop and will become more powerful and more valuable to different parties. Such a well-documented library of interdependencies and covariance between the risks affecting different infrastructure assets will be interesting to all participants, but to other parties like insurance companies as well.

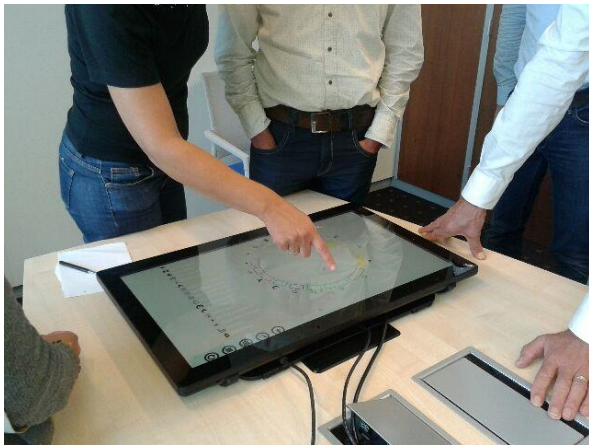


Figure 4: Clrcle on a mini touch table during a workshop.

For the case area West-Friesland, several workshops were organised during which different stakeholders and network owners discussed critical infrastructures and its vulnerability and possible cascading effects. They were all very willing to share knowledge during discussions. All the participants were somewhat surprised to find out how interdependent they were in a small area like the case area. They also wondered how their networks could be protected best as everybody understood that increasing heights of our dikes was not the ultimate solution. It is because of these workshops that Clrcle was created to be able to gather more data and to use the knowledge in such a way that every case and every workshop will get better and that after each workshop a better prediction can be given when there is a need for actual data and information during an event.

Learning from flood events

There are many ways in which we can learn more from flood events. Good visualisation to enhance understanding of what actually happens during an event is

one of the most important keys here. With Circle different stakeholders are able to learn from fictive or actual flood events in the following ways:

1. Participants of a work-shop learn from each other's knowledge and the combined knowledge in cascading effects
2. Flood experts learn from the combined knowledge gathered in Circle on direct and indirect flood impact and will be able to quantify flood impact better
3. With Circle you can replay actual events and check whether the network knowledge can predict outages and dependencies properly.
4. Crisis management organisations can predict better where the safe areas are to evacuate people to.
5. For other events than flood events the knowledge gathered in these workshops provides insight in cascading effects after an outage by another source. Some interdependencies are more universal than others and generically usable.

Future work

The coming months will be used to organise different workshops in order to gather as much data and knowledge as possible. After enough workshops more data analysis can be performed to find solutions for combining qualitative knowledge and causal relationships. At the moment they will be used separately: the causal relationships in the automated GIS-analysis and the qualitative knowledge to learn more about the impact for inhabitants and to find ways to quantify this qualitative knowledge. Over time it will become clear what causal relationships can be generally applied to other cases and what relationships are specific to a certain case or an event.

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