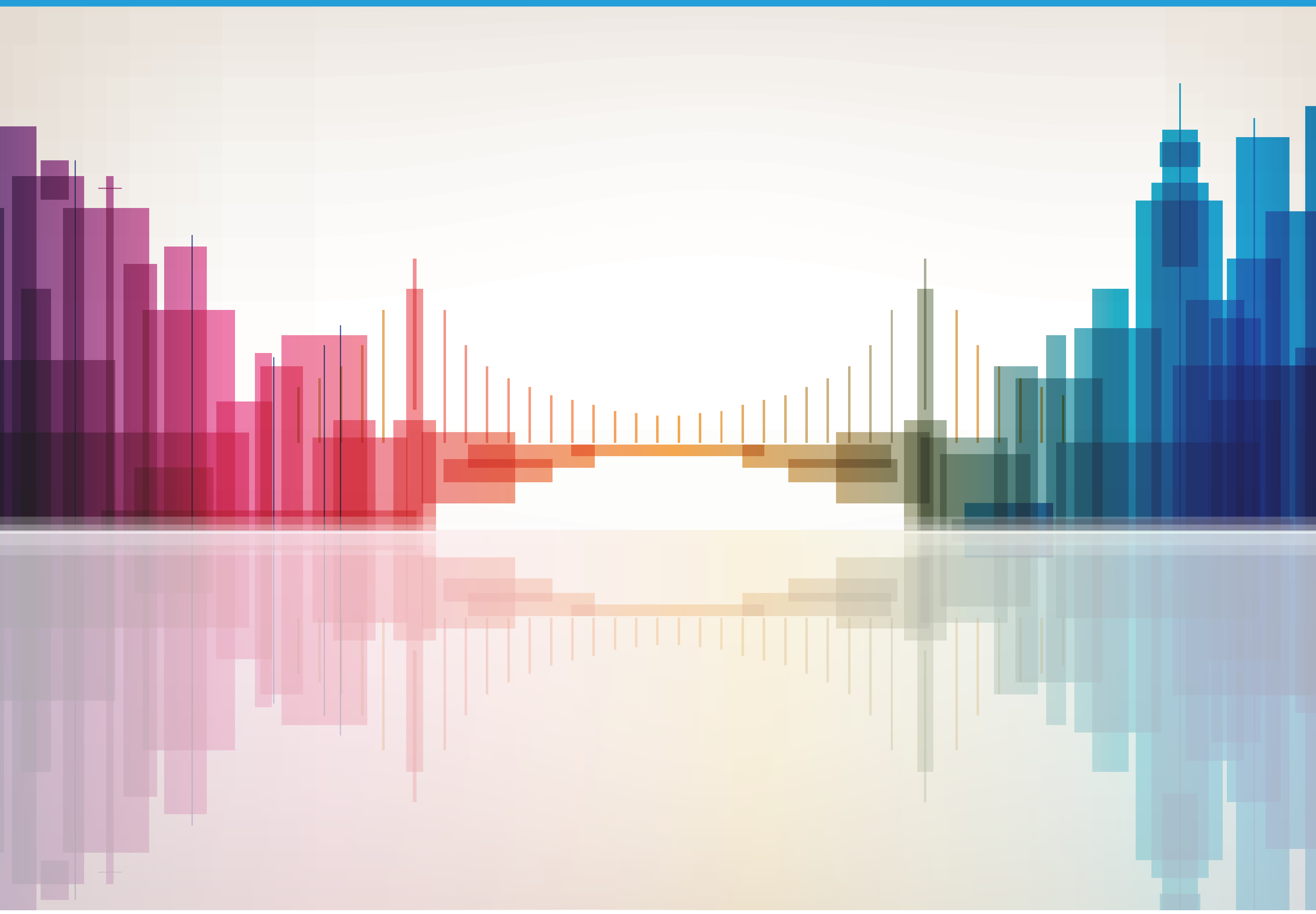
United 4 Smart Sustainable Cities

Identifying cascading effects on vital objects during flooding

Case study of the U4SSC City Science Application Framework



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Case study: Identifying the cascading effects on vital objects during flooding

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Foreword

This publication has been developed within the framework of the United for Smart Sustainable Cities (U4SSC) initiative.

Acknowledgements

The development of the Case study: Identifying cascading effects on vital objects during flooding has been researched and written by Ban Al-Bakri and MeadowCom and has been edited and revised by Okan Geray (Smart Dubai Office).

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United 4 Smart Sustainable Cities

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1. Introduction

1.1. Background

Towards Adaptive Circular Cities, Concepts for a sustainable urban environment:

The research project "Adaptive Circular Cities" in which the institutes LEI Wageningen UR, Alterra, Deltares, ECN and TNO worked together in collaboration with the Dutch Ministry of Economic Affairs to bring knowledge aiming to make cities more adaptive, circular and more sustainable. Several stakeholders from the Amsterdam Living Lab Buiksloterham acted as a discussion partner or "launching customer", and in addition, the district is used as test case for the solutions offered.

- The project addressed major challenges for urban areas[1]:
- Implementing climate change mitigation
- Adaptation to climate changes and sea level rise
- Sustainable use of natural resources and ecosystems
- Finding alternatives for valuable resources
- Transition to circular economies.

Figure 1: Towards Adaptive Circular Cities[2]

Identifying cascading effects on vital objects during flooding is a case study under the **Adaptive Circular Cities** project. Increasingly we see flood-related events and these will intensify in the future due to climate change and social-eco development, especially in coastal cities (high-tides, storms, hurricanes, tsunamis) as well as pluvial flooding (heavy rain or long rainy periods) and fluvial flooding (in river deltas).

1.2. Challenge and response

Identifying cascading effects on vital objects during flooding

Flood related events can cause enormous damage to cities if not controlled. The first stage is the flood itself and the second stage is the cascading effect on the city infrastructure that can potentially paralyze the entirety of a city.

It is essential to understand the short-term and long-term effects of flooding in order to be able to improve the resilience of the impacted cities and control the cascading effect.

Different challenges and measures for urban areas are to be considered, which include: implementing climate change mitigation and adaptation actions, rising sea level, sustainable use of natural resources and ecosystems, finding alternatives for valuable resources, and transition to circular economies.

In response, a tool has been developed to build a model (3Di) that allows a detailed analysis of cascading effect, called Circle knowledge. It is performed on critical infrastructure where information can be gathered from different stakeholders in an area. In combination with the high-resolution hydraulic model, 3Di is capable of stimulating a flooding scenario by making use of a variable-size computational grid combined with high-resolution underlying input data. The results are based on a combination of information from the stakeholders and the high spatial and temporal resolution of the model.

3Di is a state-of-the-art computational model to simulate flooding, both fluvial and pluvial (*see reference 2 and 5 for details*). The 3Di instrument is based on detailed hydraulic computations. The computations are extremely fast and therefore allow for interactive modelling, with multiple stakeholders, on a touch-table.

3Di is a process-based, hydrodynamic model for flooding, drainage and other water management studies. It can be used for the computation of water flow in 1D and 2D. The software is developed by a consortium of Stelling Hydraulics, Deltares, TU Delft and Nelen & Schuurmans. With 3Di it is possible to make fast simulations while using a high level of detail. 3Di allows the user to interact with the model during a simulation. One can interactively influence the simulation by changing the rainfall, wind force and model components like cross-sections, breaches and pump capacities. Deltares also has developed a fully open source model to complement 3Di, called Delft3D Flexible Mesh. More information about that model can be found here[3].
The first analysis has been conducted in North Rotterdam followed by several cities around the world.

2. The smart project(s)

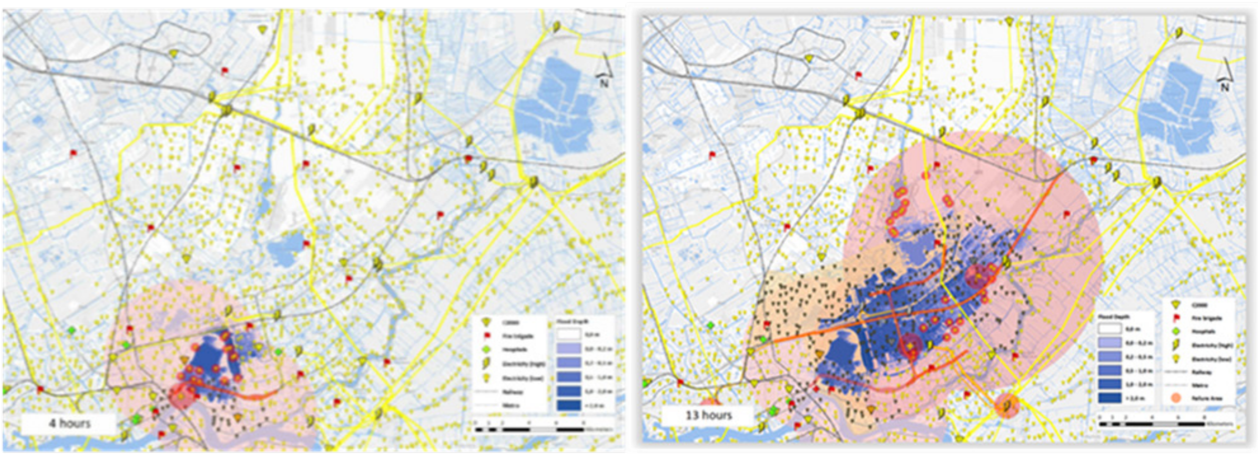
2.1. Vision and content

"**Identifying cascading effects on vital objects during flooding**" is conducted using cases within the Dutch cities (Utrecht, Amsterdam, Almere, Duiven and Rotterdam) in collaboration with the Dutch Ministry of Economic Affairs. The leading Dutch institutes for applied research Deltares, TNO, Wageningen UR and ECN combined forces in the 2015 project Adaptive Circular Cities.

The project investigated and experimented with methods for interdisciplinary research and development to tackle multifactorial challenges.

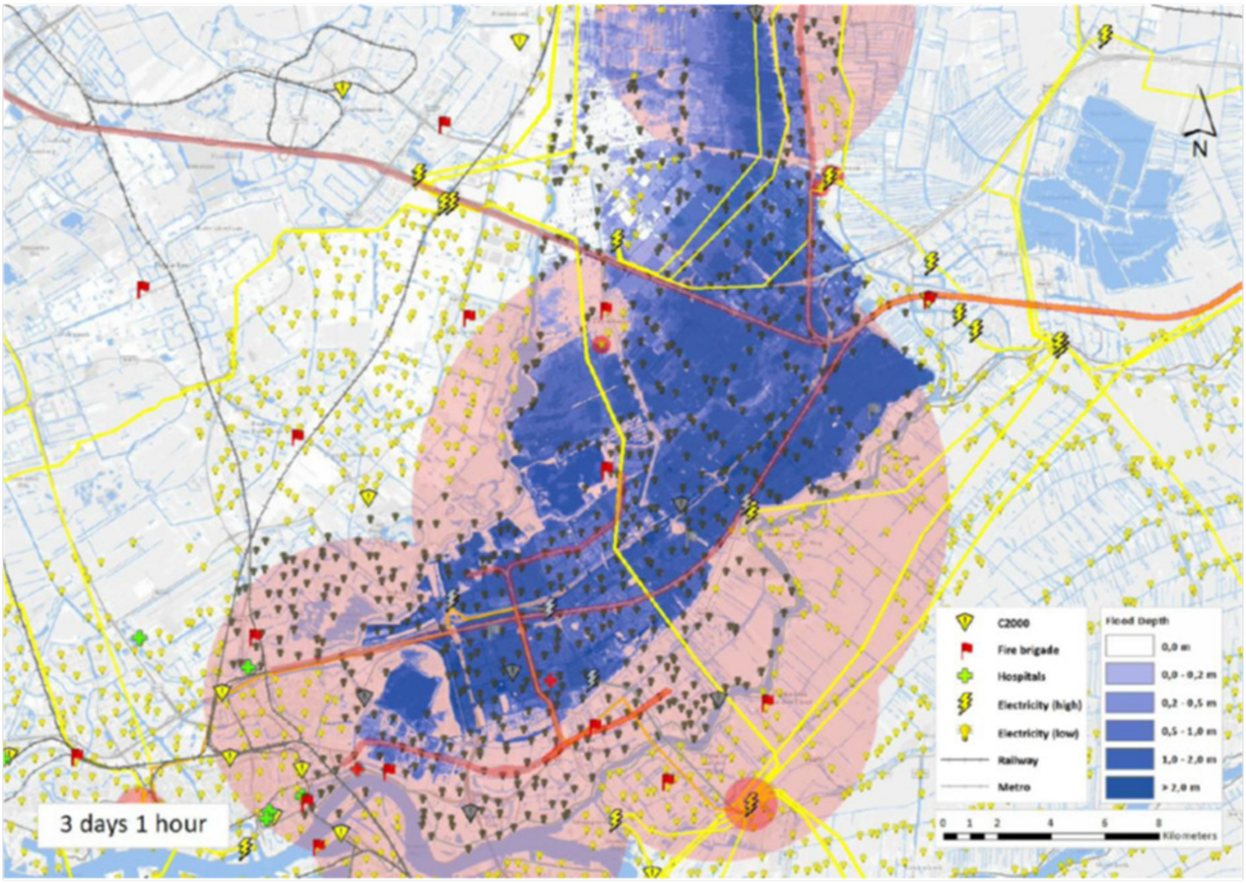
Looking into the content of this case study, "Identifying cascading effects on vital objects during flooding" addresses what happens if a dike breaches in Rotterdam.

Figure 2a: Visualization of Impact in Rotterdam in the first 4 and 13 hours[4]



As seen in Figure 2a, it models and identifies the direct and indirect impact of flooding in the city.The aforementioned 3Di tool allows visualization of these impacts over time; i.e. it displays how the flooding progresses over time in the city and how different city infrastructures will be affected if they are within the range of impacts. The image on the left side of Figure 2a shows the impacts in the first 4 hours, whereas the image on the right side shows the impact in 13 hours. As expected, the impact range (shown by the shaded orange area) has significantly increased in 9 hours. We can see as indirect and cascading impact of the flood effects, as the metro network and the railway network that cannot be used due to embankment instability. The C2000 emergency communications network is also affected. Additionally, power outage (largely outside the flooded areas) is expected to take place and will have direct impacts on hospitals and other public establishments (needs to be evacuated).

Figure 2b: Visualization of Impact in Rotterdam after 3 days



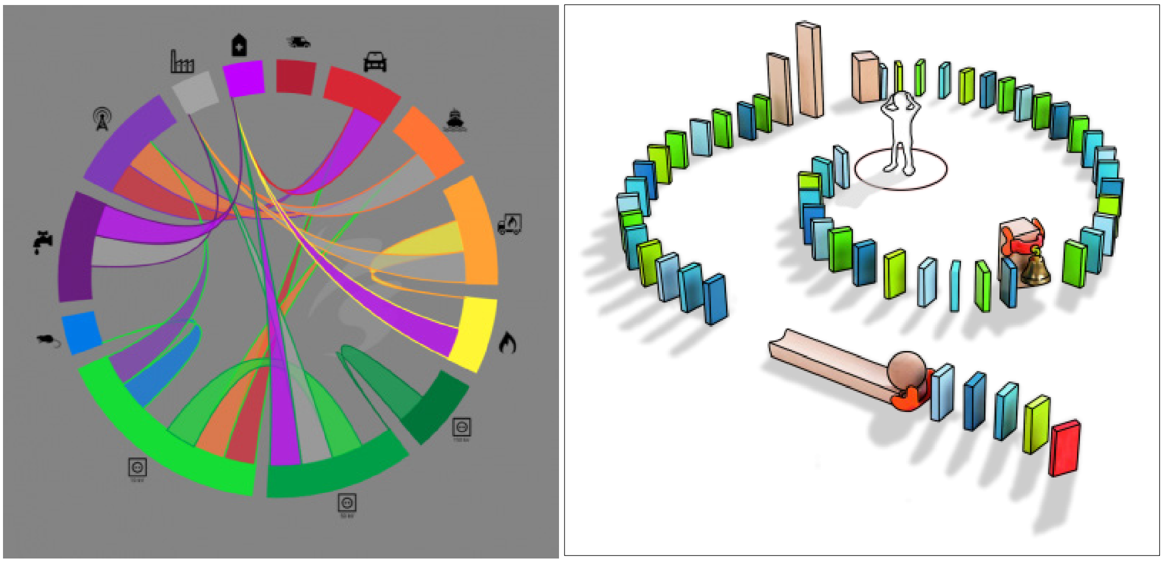
Few days following the incident, the flood and the outages moves north as shown in Figure 2b, making the evacuation process significantly more challenging. Without electricity, water pumps around the city will stop working, directly affecting the availability of drinking water. The lack of drinking water will potentially damage the health of the entire population, which is particularly devastating in a highly populated area like Rotterdam. The cascading effect of flooding will continue to spread until the city has sufficiently responded to the situation.

2.2. Implementation

As mentioned earlier, it is important to understand the short-term and long-term impacts of such events in order to improve the resilience of cities and to better understand the impacts of flooding. To that end, we need to be able to distinguish between direct and indirect impact.

The first step to identify indirect impacts is to understand the cascading effect that is often larger than the initial direct damage. That is, flooding can set in motion a cascade of effects influencing many other features. For example, flooding can trigger outages in the electricity infrastructure. That in turn may cause water and sewage pumps to fail leading to water and sewage system outages.

Figure 3: Impact and Cascading Effects



The flood scenario for Rotterdam was used to calculate direct damages to critical infrastructure networks caused by the flood, as this damage can expand to other dependent networks.

Stakeholder workshops were conducted to assess direct and indirect impacts including the cascading effects. The matters discussed includes and not limited to the relationship between electricity and: emergency communications (can last 4 to 8 hours), the railway transport and how to communicate with the operators, hospitals, etc. Analysis can be found here[5] which simulates the cascading effects for Rotterdam in a short movie with respect to time frame.

Another example of the cascading effect can be found on Cork- an Ireland city. The video is available here[6].

Figure 4: An Excerpt from the Video Simulating the Impact on City Critical Infrastructures – City of Cork, Ireland

Other tools are developed to control the city and prevent it from flooding, such tools application example can be found here[7].

Figure 5: An Excerpt from the Video Simulating City Impact – Deltares Animation RTC Tools for Smart Water Management

2.3. Results

Rotterdam flood scenario has been calculated with the hydrodynamic 3Di model. The tool can be considered as a new versatile water management instrument that supports operational water management, calamity management and spatial planning design.

The potential benefits of such a predictive tool to cities and communities are multi-fold. Simulations allow increasing the preparedness and hence the resilience of cities to various unexpected yet disastrous events. Precautions and safeguards that can be taken as a result of understanding the potential impact of such events could save human lives. They can also help preparing communities and informing them in advance what to do in such circumstances. Additionally, rescue efforts can be organized better and more efficient. Requisite resources such as equipment, personnel, etc. can better be distributed and utilized by predicting their needed quantities and locations.The project has now also an analogue version of Circle, called Circle BAO. This was made for use in areas where there is no digital information available. This method focusses on bringing together stakeholders and identify what the possible impacts of flooding are. A description of the workshop format can be found here[8] and a video can be found here[9] for cascading effects on critical infrastructure in Tanzania.

Further planned development is to look at how these tools can be integrated in 'digital twins' of cities. These are virtual reality copies of cities that are used for urban planning.
It is useful to know that the Circle method is not limited to use for assessing the effects of flood events. It can also be used for other natural hazards or man-made events that lead to failure of critical infrastructure.

3. Conclusions

Citizens are more and more dependent on technologies and information systems that are run by the cities. This socio-technical system interdependency has had significant impacts on the way in which cities response to disaster situations. However, in the case of technological failure (such as that caused by flooding), it is important to understand the cascading effects on the critical infrastructures of a city. Therefore, conducting studies and developing methodologies to better understand risks propagation and the cascading effects of natural disaster are fundamental building blocks to improve disaster responses and create a more resilient urban infrastructure.

The key factors to be considered here include the probability of failure of a given critical infrastructure and the time required for repairing a damaged critical infrastructure before it spreads to another critical infrastructure, through cascading effect. There are methods, tools and models being developed to achieve simulation of flooding effect using information provided by stakeholders. Workshops are arranged to allow stakeholders to share their knowledge and devise a coordinated plan when disaster strikes.
It is expected that new tools and models that incorporate other frontier technologies will be further developed over time. This may include virtual reality, IoT devices to collect information, automation, etc. to facilitate an automated control on such incidents.

A. References

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http://www.3di.nu/

https://oss.deltares.nl/web/delft3dfm

B. List of discussion partners/interviews

Email exchange with Mr. Marco Hoogvliet / Deltares – Holland. He provided further information on the project development and status.

This case study has been prepared by:

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Endnotes

1 Source: http://www.adaptivecircularcities.com/towards-adaptive-circular-cities/

2 http://www.adaptivecircularcities.com/

3 https://oss.deltares.nl/web/delft3dfm

4 http://www.adaptivecircularcities.com/wp-content/uploads/2016/03/Description-of-CIrcle-method-and-combination-with-flood-modelling.pdf

5 https://www.youtube.com/watch?v=7N3SXMXAszw&feature=youtu.be

6 https://www.youtube.com/watch?v=9tISZo8cmMY

7 https://www.youtube.com/watch?v=GAuQ5ft8vr4

8 https://www.deltares.nl/app/uploads/2015/04/Particpatory-CIrcle-Bao-Workshop_Guideline_Final.pdf

9 https://www.youtube.com/watch?v=uNccvrk3MuA

Digital manipulation of flooded Rotterdam downtown skyline, Netherlands

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