Driving Innovation in Crisis Management for European Resilience

CMINE TASK GROUP FLOODS FINAL REPORT

SP95 - IMPACT, ENGAGEMENT AND SUSTAINABILITY

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The DRIVER+ project

Current and future challenges due to increasingly severe consequences of natural disasters and terrorist threats require the development and uptake of innovative solutions that are addressing the operational needs of practitioners dealing with Crisis Management. DRIVER+ (Driving Innovation in Crisis Management for European Resilience) is a FP7 Crisis Management demonstration project aiming at improving the way capability development and innovation management is tackled. DRIVER+ has three main objectives:

1. Develop a pan-European Test-bed for Crisis Management capability development:
    - Develop a common guidance methodology and tool (supporting trials and the gathering of lessons learned
    - Develop an infrastructure to create relevant environments, for enabling the trialing of new solutions and to explore and share CM capabilities
    - Run trials in order to assess the value of solutions addressing specific needs using guidance and infrastructure
    - Ensure the sustainability of the pan-European Test-bed
2. Develop a well-balanced comprehensive Portfolio of Crisis Management Solutions:
    - Facilitate the usage of the portfolio of solutions
    - Ensure the sustainability of the portfolio of tools
3. Facilitate a shared understanding of Crisis Management across Europe:
    - Establish a common background
    - Cooperate with external partners in joint trials
    - Disseminate project results

In order to achieve these objectives, five Subprojects (SPs) have been established. **SP91 *Project Management*** is devoted to consortium level project management, and it is also in charge of the alignment of DRIVER+ with external initiatives on crisis management for the benefit of DRIVER+ and its stakeholders. In DRIVER+, all activities related to SIA (from the former SP8 and SP9) are part of SP91 as well. **SP92 *Testbed*** will deliver a Guidance methodology and guidance tool supporting the design, conduct and analysis of trials and will develop a reference implementation of the test-bed. It will also create the scenario simulation capability to support execution of the Trials. **SP93 *Solutions*** will deliver the Portfolio of Solutions (PoS) which is a database driven web site that documents all the available DRIVER+ solutions, as well as solutions from external organisations. Adapting solutions to fit the needs addressed in trials, will be done in SP93. **SP94 *Trials*** will organize four series of trials as well as the final demo. **SP95 *Impact, Engagement and Sustainability***, is in charge of communication and dissemination, and also addresses issues related to improving sustainability, market aspects of solutions, and standardization.

The DRIVER+ trials and the Final Demonstration will benefit from the DRIVER+ Test-bed, providing the technological infrastructure, the necessary supporting methodology and adequate support tools to prepare, conduct and evaluate the trials. All results from the trails will be stored and made available in the Portfolio of Solutions, being a central platform to present innovative solutions from consortium partners and third parties and to share experiences and best practices with respect to their application. In order to enhance the current European cooperation framework within the Crisis Management domain and to facilitate a shared understanding of Crisis Management across Europe, DRIVER+ will carry out a wide range of activities, whose most important will be to build and structure a dedicated Community of Practice in Crisis Management (CoPCM), thereby connecting and fostering the exchange on lessons learnt and best practices between Crisis Management practitioners as well as technological solution providers.

Executive summary

<To be elaborated>

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1. Introduction

1.1 Background of the need to improve real time flood risk management

Different approaches for flood risk management have been adopted in various parts of the world. Flood risk management strategies can contain different measures to reach and maintain an acceptable level of risk. Possible measures are the reduction of the probability of failure of levees or dams, but also measures to reduce the consequences of a flood, like building codes, warning systems and evacuation protocols (Kolen & Kok 2011). Risk can be defined as the probability of the event multiplied by the consequences of the event. This definition is commonly accepted in the flood risk literature (Vrijling 2009; ten Brinke et al. 2008). The consequences are often expressed in economic damages or loss of life in the flooded area. Alternative definitions describe the risk in terms of hazard, vulnerability and exposure (Kron 2002; Gendreau et al. 1998). Both approaches for defining risk lead to similar outcomes, as they both consider the occurrence of a hazard (the probability) and the consequences (vulnerability, exposure) of a given occurrence.

In case of a threat for flooding, emergency measures can be taken to reduce the probability of occurrence and the consequences. Forecasts of water levels and the strength of levees or dams are made during the threat event and might become more certain when the lead time reduces. More frequent inspections can be implemented to monitor levees and dams. When weak spots are detected, flood fighting measures can be implemented. In case a potential failure of levees or dams warning and evacuation can be considered. These measures can be costly with respect to time, money, and credibility (Bourque et al. 2006). Decision makers have to deal with uncertainties and great consequences of their decisions (including a delay of decisions) (Kolen & van Gelder 2018):

- The probability of flooding.
- The positive consequences of measures (as reduction of failure probability of levees, reduction of damage or loss of life in case of a flood).
- The negative consequences of measures (as the costs, potential loss of life because of evacuation and the economic damage because normal economic processes are disrupted).
- Postponing a decision is already a decision because the effectiveness of measures might decline.

When the time needed to execute the measures, is limited, or when the available resources are not available, priorities have to be set as well.

To compare different strategies and to evaluate decisions, risk analysis can be used in a rational approach (Benjamin and Cornell 1970). Costs and benefits of measures can be defined and the optimal decision can be selected resulting in the lowest total (social) costs. The impact can be described using hydrologic and hydraulic models. But the quality of these models depends on the assumptions in the model. Because we focus on extreme events also these models have their limitations. Therefore we combine the results of models with the experience of experts (which can also be seen as a model). The combination these models gives a better view of the potential impact of measures.

In the Task Group Floods we have elaborated a the method Real Time Flood Risk Assessment (RTFRA) and added expert judgment as a concise method to reproducibly and recognizably estimate the impact of a measure on the basis of expert knowledge, and thus improve the quantification of the flood risk reduction and support emergency personnel and decision makers

1.2 Goal of the Task Group

The Crisis Management Innovation Network Europe (CMINE) is a Community of Practice that fosters innovation and enhances a shared understanding in the fields of Crisis Management and Disaster Risk Reduction in Europe. CMINE is creating an umbrella network of stakeholders active in Crisis Management by linking existing projects, networks and initiatives. By doing so, CMINE reduces fragmentation, generates ideas and helps to identify innovative solutions to improve European resilience. CMINE comprises an online community platform and face to face meetings and workshops with the aim of tackling current and future challenges and facilitating the uptake of research and innovation by practitioner organisations. Different Task Groups have been set up to develop approaches aimed at resolving current issues in different Crisis Management domains, such as Floods, Wildfires or Volunteer Management. CMINE is designed to evolve continuously through collaboration with the aim of becoming a pan-European platform, which is centred on the exchanges between various Crisis Management professionals.

A Task Group Floods, consisting of representatives of European and International organizations working on flood related topics, has been established to develop and demonstrate a Real Time Risk Assessment methodology for different countries on predictive operational information for conditional flood risk management.

In the DRIVER+ a series of Trials has been conducted in different countries, focused on various crises types. Their aim was to investigate innovative solutions under simulated crisis condition, by gradually adapting them to operational constrains, as well as creating acceptance among user through their active involvement, and by providing evidence to decision-makers that they are cost-effective. The Task Group Floods has provided a way to visualize and improve the effectiveness of emergency measures related to flood risk management. In the future the elaborated and tested expert judgment method can be used by crisis teams to be able to determine the effectiveness, advantages and accountability of centralized or regional investment on flood risk management measures.

The aim of the Task Group was to develop an international worldwide approach to measure the effectiveness of flood measures and an effective and efficient use of open data (like water levels, levee information, flood scenarios, alarm levels, critical moments, possible risk reduction measures per zone or area).

The specific output of the Task Group Floods is:

- *Real Time Flood Risk Assessment (RTFRA)*: An interactive viewer in which the conditional flood probability and flood risk is demonstrated using forecast and prepared scenarios (based on the EU Flood Directive). Measures can be selected and immediately the effect/impact on the flood risk is shown. This viewer can be used in operations and/or as a decision support information system. In case no water level measurements are available, a demo is available to demonstrate the possible use of the viewer.

- *Expert Judgment Method*: A description of the stepwise elaboration of the assessment of effectiveness of measures to the flood risk, with the help of expert judgment sessions, inspired by a Delphi approach. The method and the results of the testing session can be found in this report, see chapter 3 and 4.

- A list of *recommendations* for further developments and issues to be elaborated, see chapter 5 and 6.

This output of the Task Group Floods contributes to the domain of floods, because the topic of the assessment of effectiveness of measures is still underexposed.

The challenge of the Task Group has already been mentioned as one of the DRIVER+ gaps (see D922.11, gap # 1, p. 6, with more detailed description on pp. 35-36). This gap is related to the challenge to reduce the risk by assessing the effects of measures: "To enhance response operations […], there is a need for fast and accurate assessment of the concerned territory at the pre-event and response phase (for the incident-specific attributes that cannot be anticipated at the planning phase). Detailed forecasts and models (predictive modelling capabilities) need to be produced in real time with incident-specific variables. The incident commander needs to understand both the current situation, and how it will evolve (crisis dynamic). Time is a critical factor." Although the focus in this gap is on decision making in case of chemical threats where preparation time is not available, it is also relevant for floods, because time is also critical and modelling and risk assessments play an important role in evolving crises.

The Task Group Floods has realised improvement in:

- 'Fast and accurate assessment' is provided by the expert judgment method to improve basic information.

- ‘At the pre-event and response phase’: the expert group is a supportive addition to the crisis team.
- ‘For the incident-specific attributes that cannot be anticipated at the planning phase’: expert judgment is being performed on the actual measurements, results of inspection, and the impact on real time flood risk.
- ‘Detailed forecasts and models’ are provided by the real time flood risk assessment viewer.
- ‘The incident commander needs to understand both the current situation and how it will evolve’: the crisis management team is provided with expert information.
- ‘Time is a critical factor’: if decision making can be faster and more efficient (with the support of expert judgment), more time is available for the implementation of the measure, with a greater chance of a successful outcome.

2. Task Group composition and rationale

The Task Group Floods is composed as followed:

Management:

- Hanneke Vreugdenhil (The Netherlands): HKV Consultants, Organisational Chair Task Group Floods
- Bas Kolen (The Netherlands): HKV Consultants, Theme Chair Task Group Floods
- Todor Tagarev (Bulgaria): Head, Centre for Security and Defence Management, Head Chair CMINE Task Groups

Active members:

- Leskó György (Hungary): Doctoral School of Military Engineering, National University of Public Service, researcher
- Ralf Hedel (Germany): Fraunhofer Institute, Head of Team Risk modelling, researcher
- Orlin Nikolov (Bulgaria): Director of Crisis Management and Disaster Response Centre of Excellence, practitioner
- Marcel van der Doef (The Netherlands): Waterboard Brabantse Delta, practitioner
- André de Rond (The Netherlands): Safety Region Haaglanden, DRIVER+ Trial 4 Host, practitioner
- Roelof Moll (The Netherlands): TU Delft, H2020 BRIGAID, researcher
- Jaap van der Veen (The Netherlands): Waterboard Zuiderzeeland, WAVE2020, practitioner
- Martin Nieuwenhuis (The Netherlands): Waterboard Rijn and IJssel, WAVE2020, practitioner
- Jan van der Lingen (The Netherlands): Waterboard Hollands Noorderkwartier, Asset management, practitioner

Internal reviewers:

- Antoni Rifa Ros (Spain): Chief of the Catalan Fire Service Brigade, Girona, practitioner
- Carmen Castro (Spain): Centre of Security and Emergencies and Valencia Local Police (emergency management), policy maker
- Kim Lintrup (Denmark): Fire and Rescue Service Frederiksborg, Executive director and Chief Fire Officer, practitioner
- Evert Hazenoot (The Netherlands): Waterboard Rivierenland, practitioner
- Ludolph Wentholt (The Netherlands): STOWA, policy maker
- Raymond de Landmeter (The Netherlands): Waterboard Hollands Noorderkwartier, Crisis management, practitioner

External reviewers:

- Massimo Lanfranco (Italy): Senior Technical Officer Regione Liguria, practitioner
- Leo van Nieuwenhuijzen (The Netherlands): Waterschap Rijn en IJssel, flood defence expert, practitioner
- Marco van Ravenstein (The Netherlands): Safety Region Gelderland-Midden, crisis manager, practitioner

This composition has been chosen because of the geographical spreading around Europe, the possibility to have completely different cases in different countries and to involve the water authorities quite strong in the development of the method. The Task group members all have a strong track record in crisis management related to floods. The Task group is a mix of people with a research background, practitioners and crisis managers.

The Task group members started with sharing their knowledge, thoughts and experience related to the task. After this kick off three cases have been prepared. A logical group of interested people have been gathered around this cases. The Dutch members have participated in two local meetings around the Dutch case, to enable us to elaborate the methodology and the viewer. The communication was organised exclusively by mail. The CMINE platform has not been used, until the end for review purposes.

To populate the CMINE platform effectively there should be more content and task related information available and ready to be produced and to share. Experts and specialist should have the feeling that they miss the discussion on relevant topic if they are not involved in CMINE. Although we know that this is a chicken-or-egg dilemma, the experience so far is that there is still too little reason to participate.

3. Method Expert Judgment

This chapter describes the Method Expert Judgment as has been developed and tested in the Task Group Floods.

3.1 Preface

Although many crisis management teams have the legitimate feeling that they are well prepared for fighting a flood, there may be little or no experience with extreme situations. As a result, when experts express their recommendation on what should be done at a specific moment in the crisis, this expert's judgment can be difficult to reproduce. That is why in the CMINE Task Group Floods a procedure has been developed to make the expert's opinion transparent and more reproducible. In the development of this procedure, state of the art insights have been used in which the (failure) behaviour of flood defences can be described more precisely. In addition, process-based techniques were used to unlock information from various experts. Use was also made of experiences gained during the drafting of weather warnings and weather alarms and how flood defences are assessed in the USA.

The Task Group focused on the requirement that knowledge needs to be translated into information through calculation and knowledge. In this method the centre of attention is on the role of the expert, expressed in the ‘expert's opinion’. Two situations are distinguished:

- A regular expert's assessment that is taken at the time of daily work. This assessment is based on expectations of water levels. (Interim) results are adjusted based on expert’s knowledge.

- Annual expert judgments that lead to the adoption of basic data for operational use.

With the expert's opinion the expert's knowledge can be combined with expertise with the knowledge in calculation rules. The information approved by the expert is ultimately leading in flood risk management.

3.2 Usual operational procedure flood crisis management

A flood risk management strategy can consist of measures which can be categorised in multiple layers, like prevention with levees, land use planning, building codes, insurance and emergency management. Flood risk distinguishes the probability of flooding as well as the consequences. Therefore, the risk as the probability x consequences is the central element, and such an approach can be used to evaluate flood risk management.

The whole society is considered as a system in which all stakeholders (authorities, citizens) can interact, structures exist that describe the relation between these stakeholders and stakeholders might be confronted with the consequences of measures by others. All stakeholders function inside a network with formal and informal relationships. It is assumed that the responsibilities of a government are spread over several organisations over several levels as a federal, national, regional or local level. This is the case in most democracies.

If disturbances cause consequences that cannot be controlled or minimised by working processes of authorities, then these processes can be changed by the implementation of crisis management structures. The decision-making process for mass evacuation is characterised by short reaction times and requires consideration of the probability of a certain impact, possible life-and-death situations and the economic impact. Therefore the situation has to be considered a crisis. A crisis is defined as ‘a serious threat to the basic structures or the fundamental values and norms of a system, which under time pressure and highly uncertain circumstances necessitates making vital decisions’ (Rosenthal et al. 1989, p10)’. The possibility of implementing measures depends on, for example, the following:

- The availability, lead time and quality of forecasts;
- The available infrastructure (roads, buildings);
- The available equipment (fire trucks and police vehicles, trucks and ambulances);
- Emergency personnel;

- Equipment and personnel in the private sector;
- Self-response (or citizen response);
- Ability to adapt the infrastructure and equipment or reallocate them;
- Fallibility of emergency management and evacuation planning.

The capacity of rescue services will never fit to all required activities to reduce loss of life and damage to zero.

Criteria to activate emergency planning and different phases that indicate the status of the situation of flooding and mass evacuation are in many cases based on forecast about expected weather conditions, water levels or expected flooding. Thresholds (as water levels) are defined to determine when to inform and alert the decision makers and to form crisis management teams for decision making on operation, tactical and strategic levels. For example, level 1 (low risk) to alert crisis teams, level 2 (medium risk) to strengthen flood defences or put mobile flood defences in place and level 3 (high, critical risk) for evacuation because of the probability of flooding and limitations in the measures available to reduce the probability. These thresholds are in many cases designed based on the philosophy of 'better safe than sorry'. Because of the extreme consequences of a flood, measures are taken in advance to reduce the probability and consequences of a flood. The thresholds in emergency planning describe procedures when to warn different stakeholders and some cases when to implement flood fighting measures or close barriers.

In case of limited resources or time priorities have to be set. Although some criteria are available (as humans are more important than economy) emergency planning only describes procedures how to make these choices. The decisions are made in a crisis team where trade-offs are made for the costs and expected benefits (taken the probability of flooding into account as well as the consequences).

It is important for decision makers in emergency response situations to know how to determine the scope, scale, timing, path and resettlement area of an evacuation decision, when there is an imminent threat of flooding. In case of an imminent threat for flooding we are referring to the conditional or real time risk, which is the risk given the forecasted water levels and potential consequences during the next days of the event. Given the threat and potential costs and benefits, evacuation decisions have to mitigate this conditional risk. The costs refer to the investments required by the measures, and the benefits correspond to the reduction in the flood risk.

The current information for emergency planners and decision makers is mainly based on (deterministic) flooding scenarios. These flooding scenarios for example describe the consequences of a flood, or the consequences of measures in terms of a reduction of flood impact (water levels). These scenarios do not describe the reduction of risk. Also for measures taken to implement mobile flood defences or flood fighting are not related to a reduction of probability of failure. The impact on risk reduction (by a lower probability of flooding or a reduction of the consequences of a flood) are however key. Sunstein (2004) states that quantitative analysis of risks is indispensable to a genuine deliberative democracy. Risk analysis can compare different (competing) strategies. Different competing strategies or measures can be compared in a rational approach (which may be risk-seeking or risk averse) based on the benefits (as risk reduction) and the costs (investments) of these alternatives (Benjamin and Cornell 1970).

The method conditional (or real time) flood risk assessment offers the flood risk information to emergency planners and decision makers (using the prepared scenarios and forecasts). The method is the next step from a scenario driven response to a risk reduction driven response.

3.3 Innovation: Real Time Flood Risk Control

The viewer 'Real Time Flood Risk Control' uses a single point of truth of information for all the daily operational working processes of water authorities e.g. inspection, maintenance, operational management, flood fighting, emergency management (including warning and evacuation). The data, knowledge and information of levees, dams developed for risk assessments of levees are used during daily activities: the working processes.

The risk information developed for flood risk management strategies supported (as the EU Flood Directive) is used in an operational context. Therefore we do not speak of the risk per year but the conditional risk during the current event. We distinguish three steps to define conditional risk and the conditional probability of failure (see Fig. 1):

1. Data: the data describes the characteristics of levees, geotechnical parameters and flood scenario's.

2. Knowledge: the knowledge transfers data into information. This can be done by models based on algorithms but also by expert judgment (the human assessment) to correct for biases and unforeseen consequences. With knowledge, data can be combined and information is generated. The procedures for human assessment are described in chapter 3.4.

3. Information: this is the result and input for daily flood control. Because of the different stakeholders involved in operational flood risk control, the presentation of the information differs per end user. A decision maker for evacuation for example, is interested in the actual probability of failure of levees, while a flood fighter is more interested in the conditional probability of failure for the next days and the relevant mechanisms of failure (e.g. seepage or overtopping).

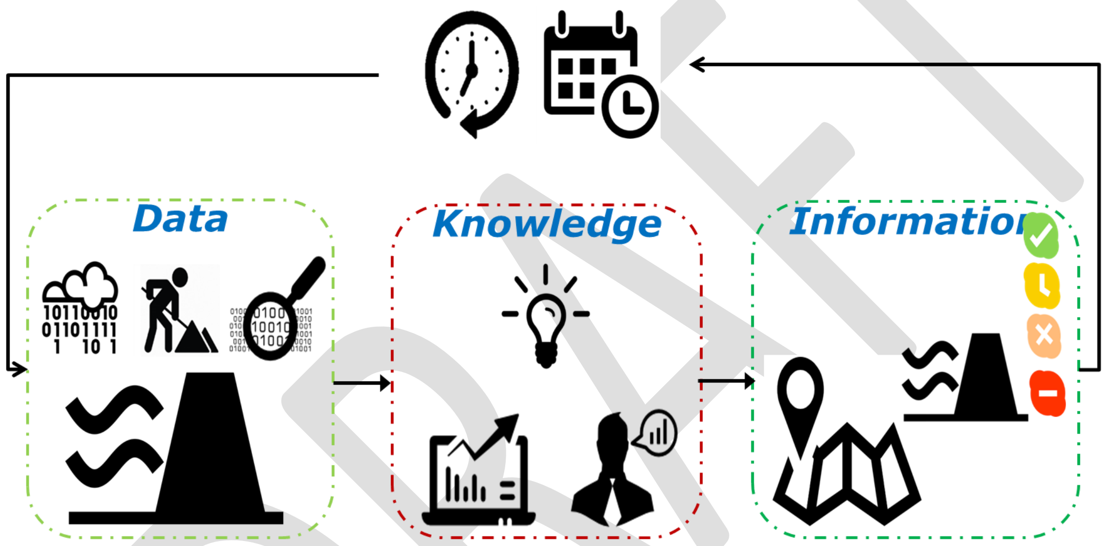

Figure 1. Real Time Flood Risk Control

In 'Real Time Flood Risk Control' risk information is presented for the actual situation (using measurements) and upcoming day's using forecasts. Information is clustered into:

- Water levels: Measured and forecasted water levels at different locations, and the translation of these water levels to the hydraulic load (including wind and waves) to a levee or dam at a certain location.
- Levees: A levee can be divided in different sections based on common characteristics. For each levee section the characteristics are described that determine the strength of the levee. Given these characteristics the relation between the hydraulic load and the probability of failure is described by a fragility curve for each levee section (see Figure 2). The fragility curve is the result of the contribution of the relevant mechanism of failure. For each mechanism a specified fragility curve is available. Combining the measured or forecasted water levels with the fragility curve results in the conditional probability of failure of the levee or dam (see Figure 3). Using forecasts the expected probability of failure can be shown for multiple days.

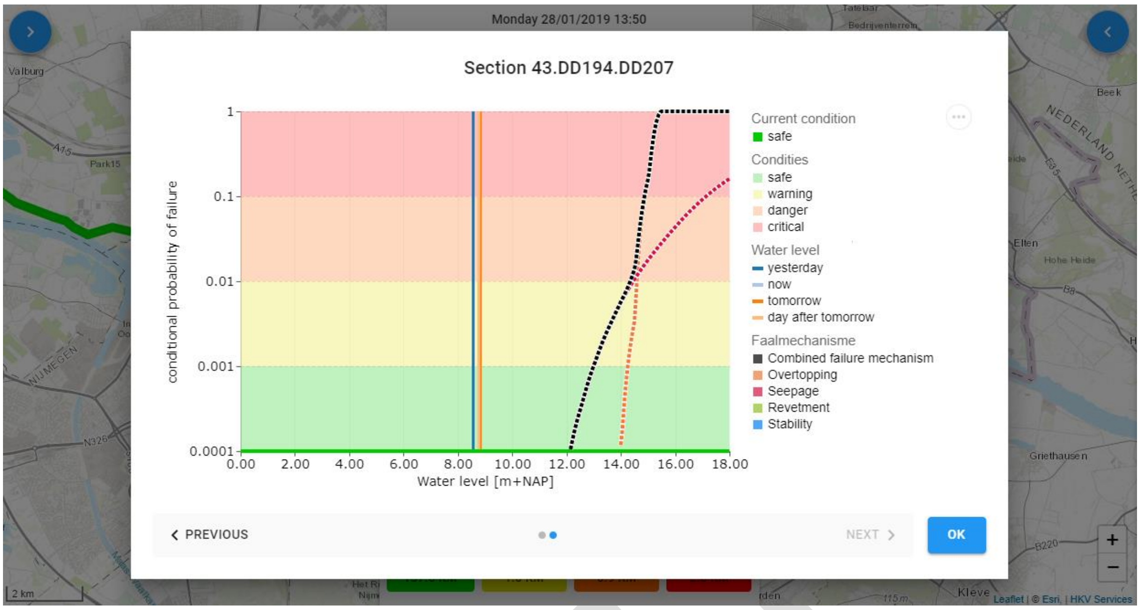

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Figure 2: Fragility curve

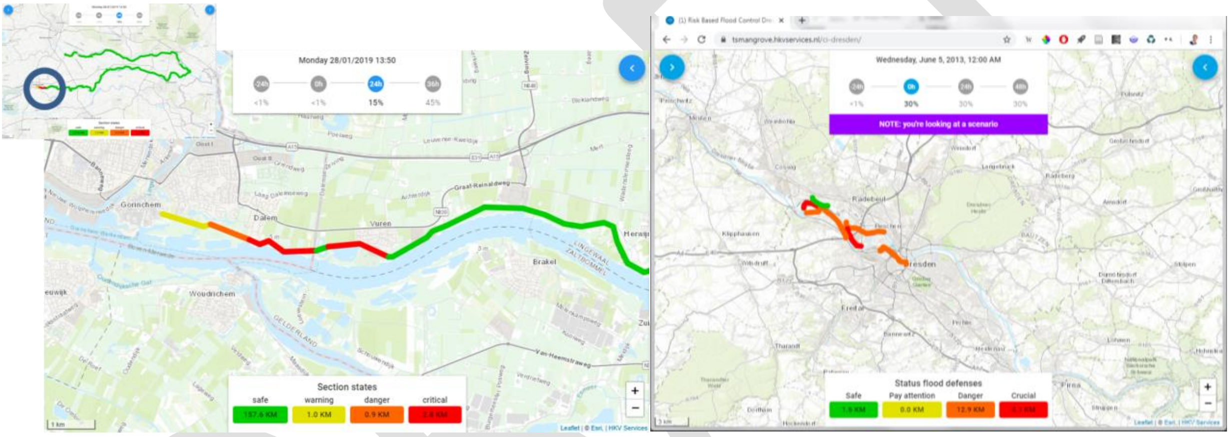


Figure 3: Conditional probability of failure of flood defenses (left: Dutch Case, right: Case Dresden)

- Zones: the conditional risk in an area is quantified using flood scenarios and the probability of failure. An area can be divided in different zones for example based on zip code. The conditional risk is quantified in a conditional risk of economic damage, conditional risk of people at risk and conditional fatalities and local probability of exposure to a flood. In Figure 4 we show an example of the conditional risk per zip code.
- Measures: For each levee or dam also a library of different fragility curves, which describe the effectiveness of measures, can be prepared in advance. For example the height of the levee can be corrected, as the states of the grass revetment etc. When a measure is selected the fragility curve used to define the conditional failure probability and conditional risk will be updated. For each section of a levee or dam or zone also the contribution of the risk per levee section can be ranked from high too low to support decision makers to prioritize measures. Also for zones measures can be taken to reduce the consequences. Also a database of possible food scenarios can be prepared which also holds measures.
- Human assessment (expert judgment): The probability of failure, as the consequences of flooding, can be corrected for biases by human assessments. Therefore measurements can be used, field inspections as well as remote sensing and data science techniques.

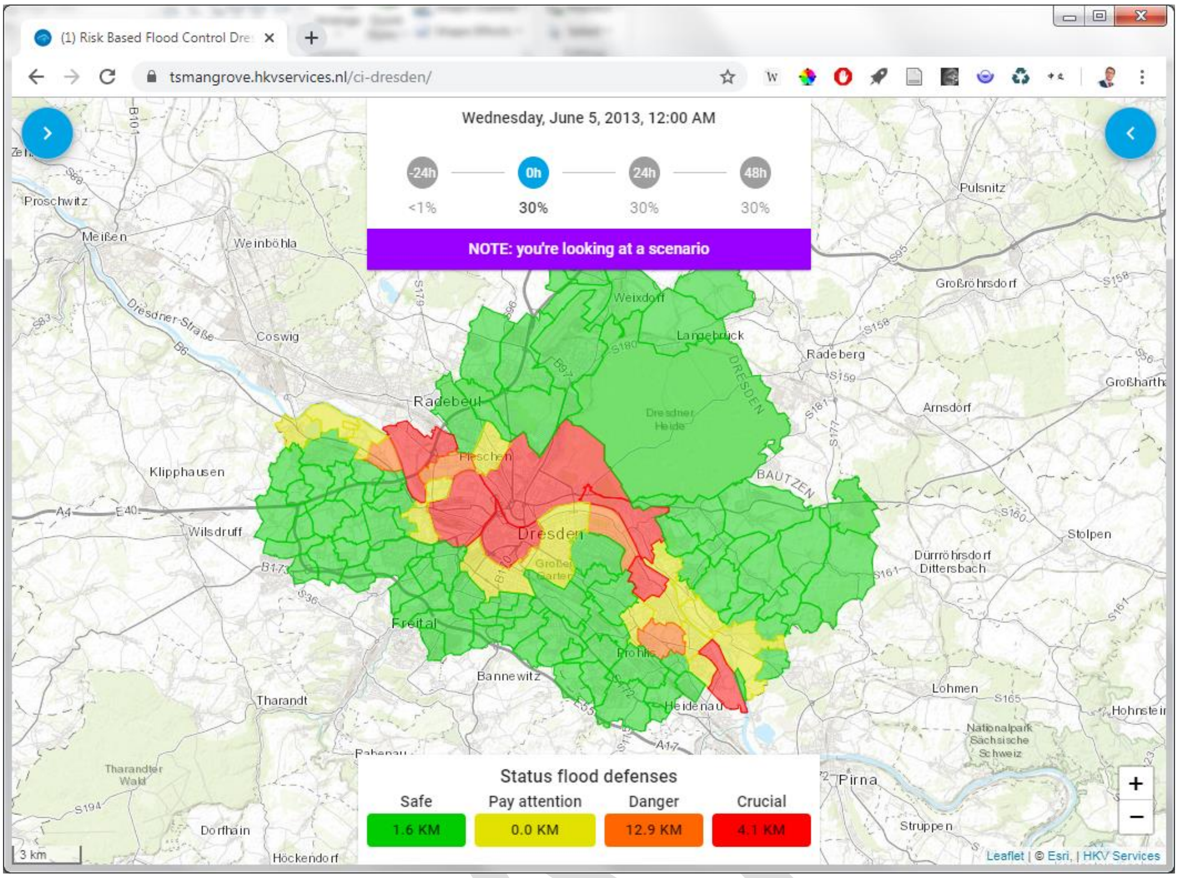


Figure 4: Example of conditional risk per zip code

For purposes of learning, validation and asset management also synthetic 'what if' events (water levels) can be defined. These synthetic events can describe potential or historic flood events.

During operational flood risk management different types of stakeholders are involved. The flood risk expert has a background in the assessment of levees and the flood scenarios. Other emergency managers, for example responsible for warning or evacuation, deal with 'summarized' information. In that case only the probability of a flood is needed, and not the contribution of different mechanism to the failure probability. A flood fighter however needs more information about the relevant failure mechanism (as seepage or overtopping) because the flood fighting measure is related to the failure mechanism. The viewer therefore offers information about water levels, conditional probability of failure and conditional risk in zones which is presented in different levels of detail. Information can be viewed and extracted by an interactive viewer (see fig. 5, 6 and 7). In this viewer the status of measured and forecasted water levels, the conditional probability of failure of levees and the conditional risk in zones is presented in categories and maps. For each parameter these categories can be defined. For example the following four categories are distinguished (related to the level of alarm) for the conditional probability of failure of a levee:

- 'Code red' (critical, high risk) when the conditional probability of failure is > 10%.
- 'Code orange' (danger, medium risk) when the conditional probability is between 1% and 10%.
- 'Code yellow' (warning, low risk) when the conditional probability is between 0,1% and 1%.
- 'Code green' (normal) when the conditional probability of failure is < 0,1%.

After selecting an object (location, levee or area) on the map more detailed information is presented using descriptions, graphs and numerical time series.

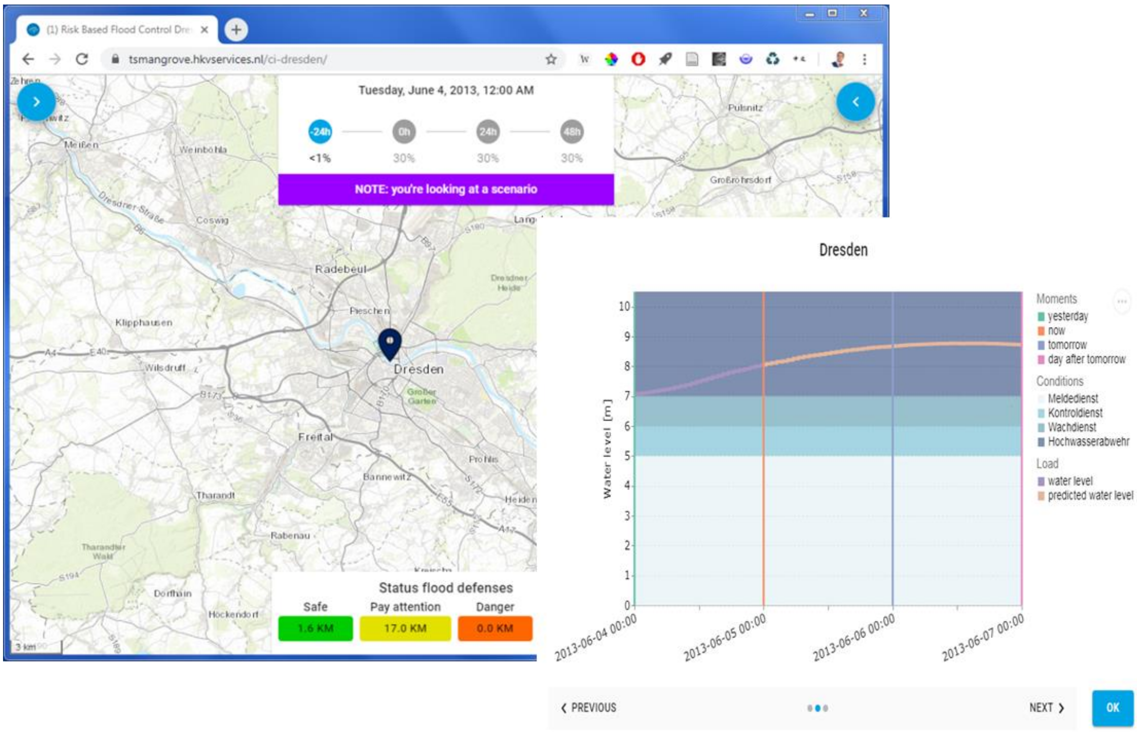


Figure 5: Example of detailed information about expected water level

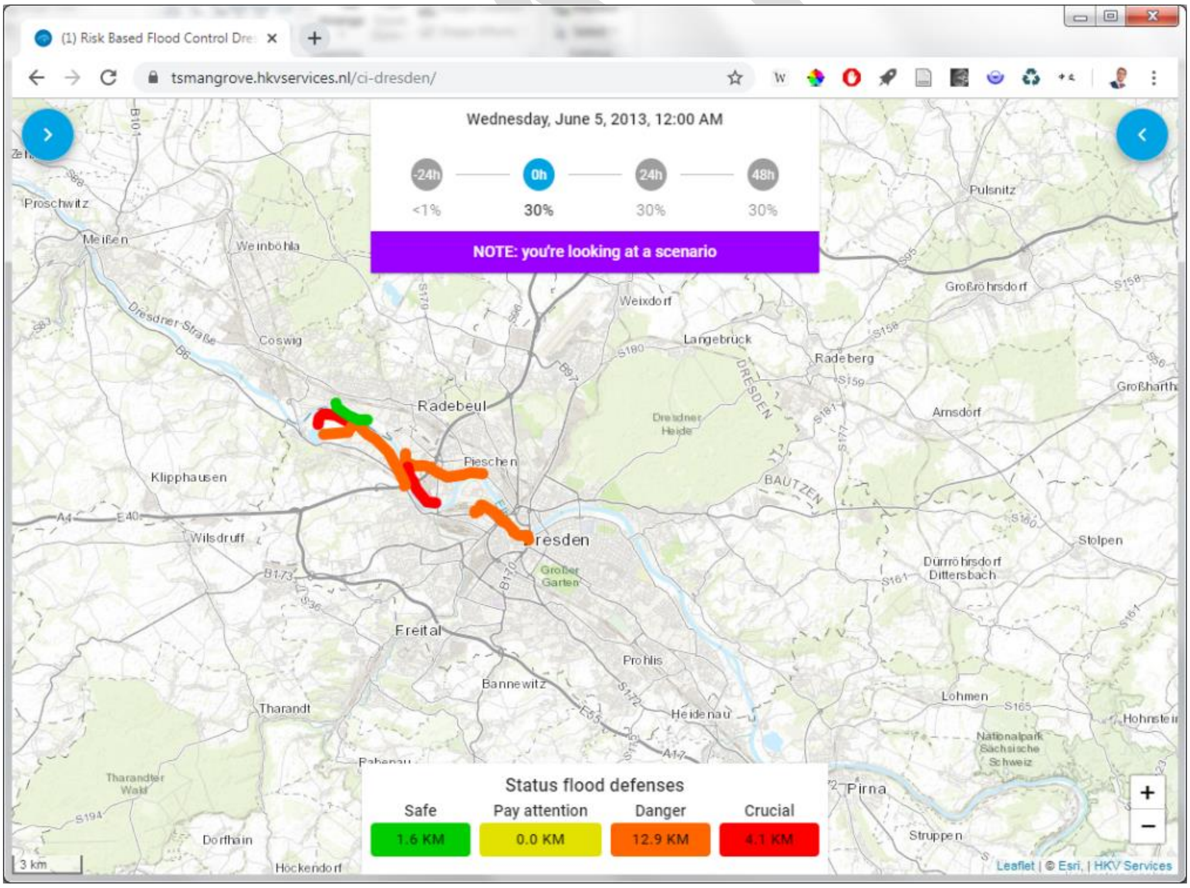


Figure 6: Example of detailed information about the status of flood defenses

3.4 Procedure expert judgment

Because of the low frequency of events and the lack of experience and uncertainties in data, models are used to describe the probabilities and consequences. These models consist of algorithms which describe physical processes. Also uncertainties can be taken into account using probabilistic approaches. However during an event mechanisms can occur which are not foreseen. During an event levees will be inspected more frequent by dike control teams, by remote sensing and other sensors. This information is used to evaluate the need for flood fighting measures. To select measures however weak spots have to be detected first, than choices have to made on how to act, and finally the measures can be executed (Lendering et al 2015). The Real Time Flood Risk Assessment viewer offers information where (and which) failure of the levee is most likely to occur. The viewer can be used to increase the effectiveness of inspection during high water levels. The increase of effectiveness of inspection is the result of a better understanding of the levee so inspectors and crisis managers can set priorities.

Both the algorithms used in Real Time Flood Risk Assessment as the detection by humans and remote sensing (and other sensors) are based on models. A validation of the outcome of these models is the human assessment part. The outcomes of the model can be fine-tuned because outcomes can be corrected for biases and new information can be added. After an event this knowledge can be used to improve basic information or models. The human assessment is a measure to reduce so called blindness (Boin et al 2005). For a transparent and reproducible human assessment, an expert judgment procedure has been developed using case studies. The role of this procedure is also to create acceptance of the final risk assessment and actual alarm categories by all the stakeholders.

The time for these adjustments however is limited. It is recommended to train and validate the expert team with these skills and to prepare basic data (as measurements, flood scenarios and failure paths for levees and timelines for evacuation). Taking into account the limited time available, consideration can be given to prioritizing:

- By forming clusters of comparable dyke sections or areas as zip codes (in terms of structure and risk class).
- By zooming in on only those dyke sections or areas as zip codes that may need adjustment.
- By zooming in on dyke sections or areas as zip codes with a high risk that contribute most to the risk.

The procedure of expert judgments aims to enrich and improve model outcomes. A model is a schematic (simplified) description of the reality. Models can be calibrated to be applicable to describe the consequences in certain conditions. When more details are added to the models it does not necessarily mean that the quality will increase because more uncertainties are added as well. Models can be based on physics (hydraulic or hydrologic models) but also based on human assessments.

Flood events happen with a low frequency, therefore experiences by experts are limited as well as information to calibrate models. However in case of an event new information might become available (like measurements or results of inspection) and because of the current conditions model experts can correct models outcomes when underperformance is known in these conditions. For example an expert might know that the calculated water levels in case of melting snow are always 10 cm too low and therefore will be able to correct the model outcomes with his/her expert opinion.

In case of a crisis time is limited to develop new (trusted) models and run (trusted) calculations. Therefore expert judgment can be used to adjust model outcomes so information is improved for emergency management. When the expert judgment is prepared in advance the acceptance of the flood risk information increases.

For the procedural elaboration of the expert's opinion, a distinction is being made between the process and support tools.

3.4.1 Process

The expert judgment procedure is based on the standard Delphi method and can be used for continuous updates and semi dynamic updates as well. This method structures group processes so that the process is effective in allowing a group of individuals as a whole, to address complex problems (Linstone and Turoff 1975). This method is further described and analysed by Rowe and Wright (1999). For Real Time Flood Risk Assessment the following steps are defined:

Step 0. Selection of experts. The selection of experts depends on the alarm phase and is done prior to an event. Therefore this is called step zero.

Step 1. First (individual) assessment of each expert using:

- Level 1 state of information
- Results of inspection (from dike control teams, remote sensing, etc.)
- Technical background information

Step 2. Discussion of estimation among the experts and exchange of arguments.

Step 3. Final estimation by the experts which result in a probability distribution of estimations and an expected value.

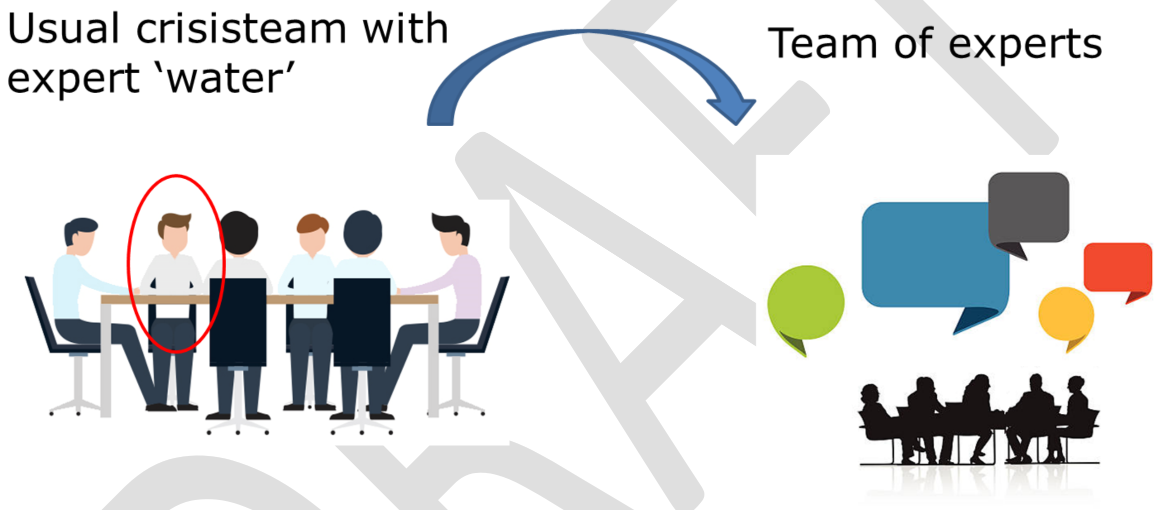


Figure 7: Team of experts additional to the crisis team

The selection of experts is based on the alarm phase, because of the impact of an alarm phase to the society. Therefore we used the lessons learned with weather warnings and alarms in the Netherlands and the response of the public, media and politicians to these warnings and alarms. A warning is issued given a relative low probability for an event in an area. The warning is issued after consultation of weather experts. An alarm is issued given a relative high probability of extreme weather but also the potential impact of the extreme is taken into account (KNMI 2015). For example in case of extreme rainfall or fog during rush hour might result in an alarm, while on a weekend evening only a warning is issued.

In code or phase yellow/green the focus is on the prevention of a flood and related flood fighting measures. Therefore only flood risk experts participate. In code or phase orange also emergency managers (including a representative of emergency services) participate because of the increase of flood risk, potential warnings and impact to the society. In code or phase red also decision makers participate because of issues of evacuation and business interruption.

With this method the existing organization remains intact. An expert team will support the water advisor (who informs others about flood risk and potential measures) in the emergency teams on Operational or

Strategic level. The experts in the expert team are actively selected, which means that the assessment of the expert team will be broadly supported.

The procedure to be followed depends on the risk class as with the weather warning and the weather alarm. Before announcing a weather warning (in the Netherlands the warning is released with a 60% chance of occurring somewhere in an area), the assessment is made by various meteorologists in the 'weather room'. External stakeholders are also involved in the weather alarm because the impact of the alarm is also taken into account. The following experts participate in the expert judgment process:

- In case of low risk (code green/yellow extra monitoring): 3 water experts;
- In the case medium risk (code orange alert for possible danger): 3 water experts and 1 or 2 (intended) operational emergency planners from the water authority;
- In case of critical or high risk (code red high potential of danger): 3 water experts, 1 or 2 operational leaders of the water board and a liaison officer of the safety region.

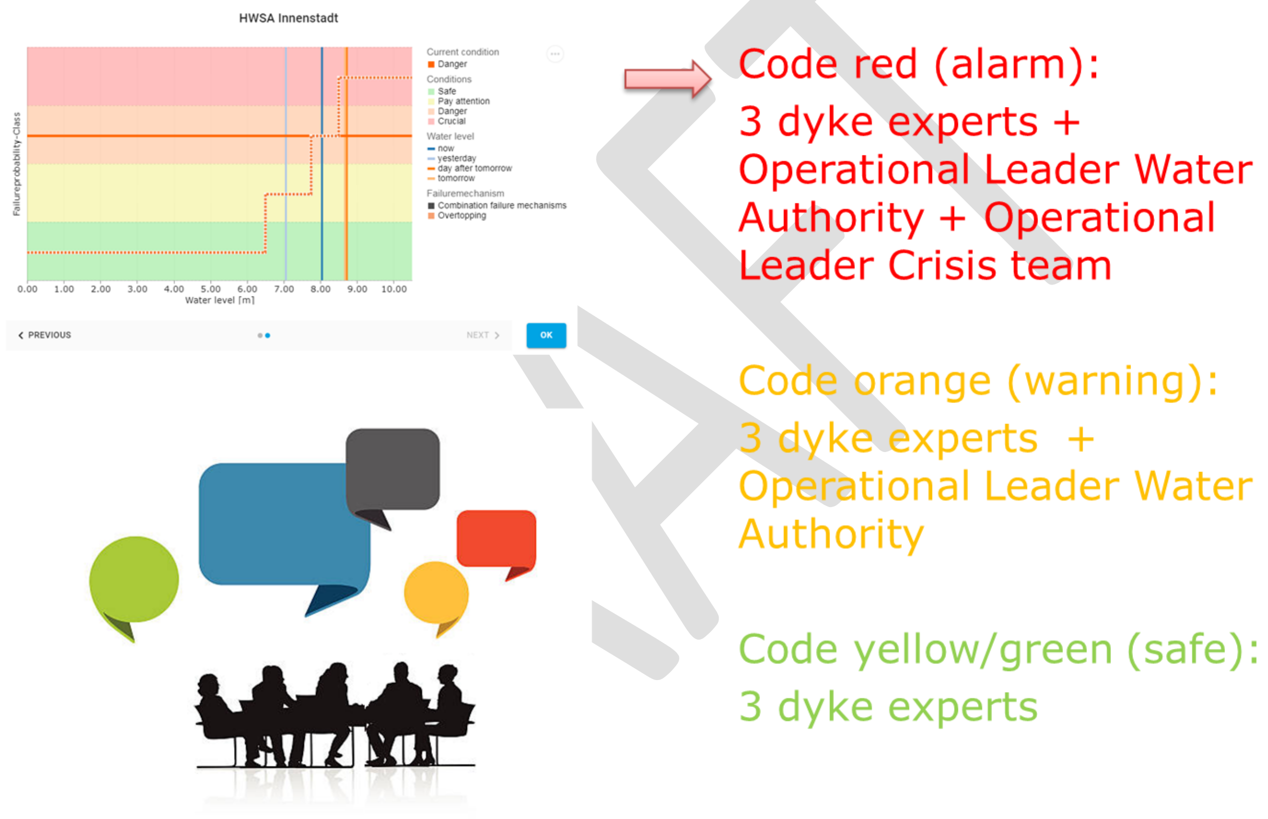


Figure 8: Composition of the expert team

3.4.2 Support tools

Technical background information of levees and dams and flood consequences can be prepared to support decision makers. The fragility curves describe the probability of failure given a definition of failure (see Figure 2). The technical elaboration concerns information that is made available to the experts. This mainly involves understanding the dike failure behaviour better and making it possible to make a better estimate about the flood probability. This also involves understanding the flood consequences and impact of potential measures to reduce the flood extent, economic damage or loss of life (evacuation).

Example: Piping

In the Netherlands specific calculation rules are being used, mainly to describe the start of a flood defence failure (on the basis of a failure path and failure definition, see Figure 1 for piping). The definition of failure is related to a critical length of a pipe which is not by definition breaching. This definition is used in the standardized procedures for the 6 yearly assessment of levees (`t Hart et al 2016). After reaching the critical length of a pipe the levee has to decrease in height before it breaches. This means that the probability of breaching is less than the probability of failure, this is called additional strength. In case of a levee assessment in the Netherlands this additional strength can be taken into account when additional research is done. For operational flood risk management this additional strength can also be taken into account, but also a better understanding of a more detailed description of the process of failure for each mechanism can be used to validate model outcomes or correct for biases.

A pathway of failure for a mechanisms describes the different phases to breaching of a levee. The pathway describes the possible conditions which are required using fault trees. Using probabilities the most significant pathways can be selected and the probability of failure can be updated, also the effectiveness of measures can be defined using pathways.

Preparation of the pathways as part of the knowledge in Real Time Flood Risk Control can support human assessment during operational flood risk management.

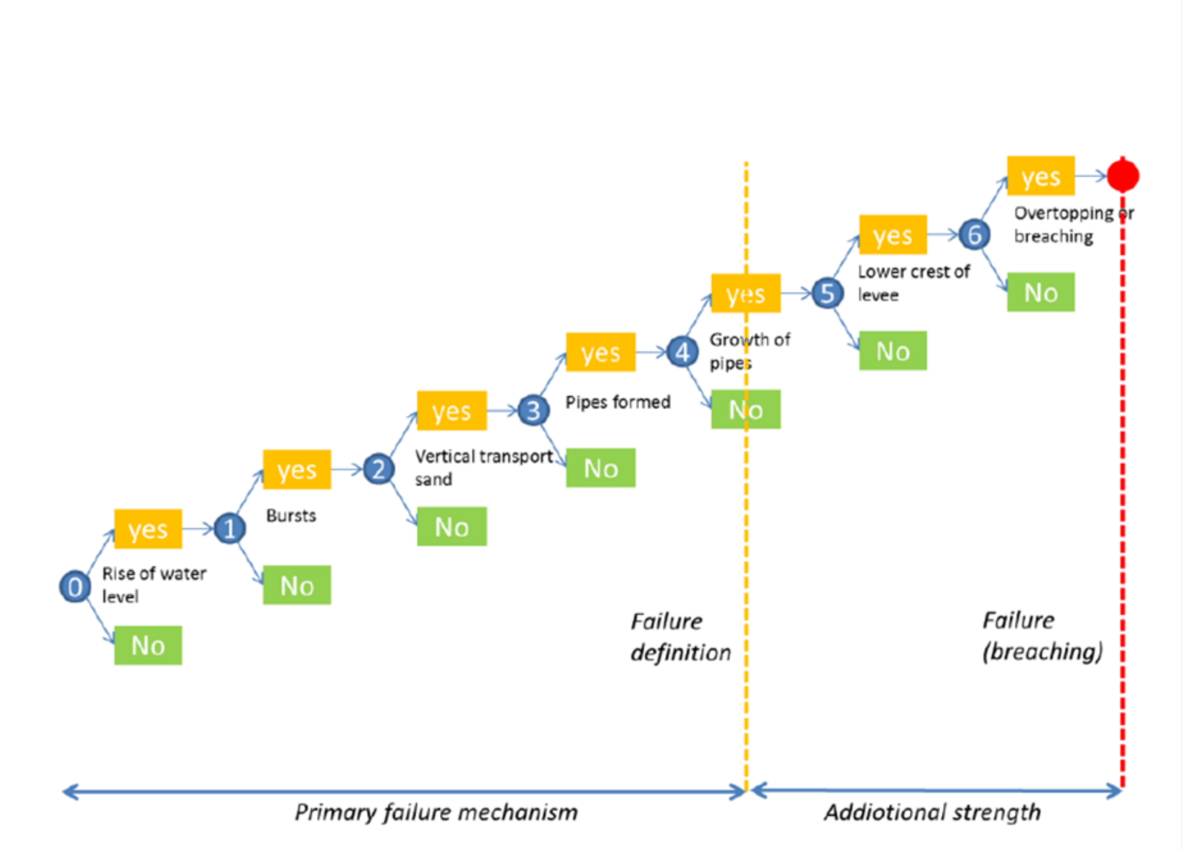


Figure 9: Failing definition for the example of piping

The failure definition therefore does not mean that failure will actually already occur. To be able to translate this effect into a new probability of failure, including the contributions of the failure mechanisms, failure paths can be used as an aid. These failure paths can be prepared in advance for different failure mechanisms.

As an example we can look at the failure of the grass cover of a dike and how it can be described more accurately. Now, as a result of wave impact and wave run-up, as soon as a part of the covering fails, the barrier is assumed to fail, according to the usual calculation rules (Figure 2). However, in reality, only an erosion process starts, leaving residual strength. Calculation tools are available for this process, tools that can be used to determine the probability of failure on the basis of the erosion process for a certain situation and therefore also to take into account the residual strength (Figure 3).

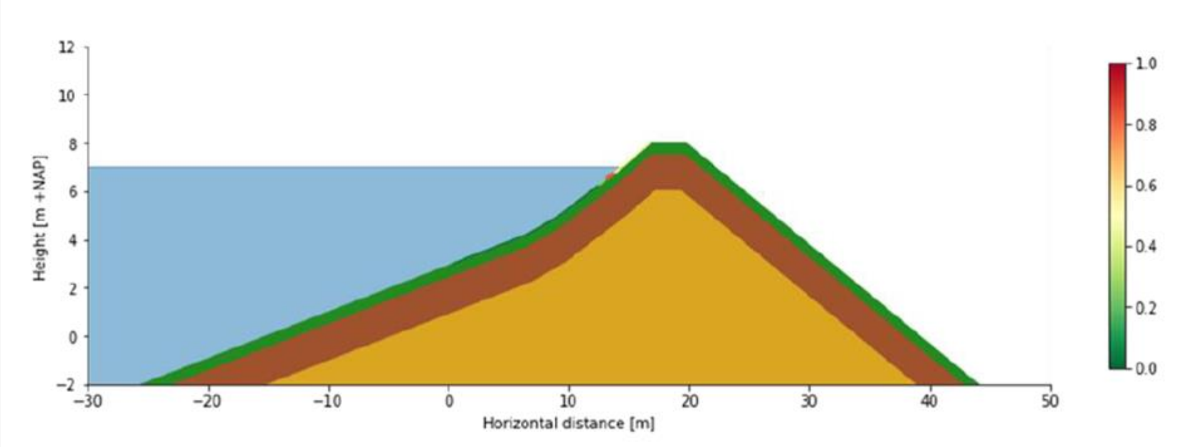


Figure 10: Failures of the dike coating in accordance with failure definition with the occurrence of critical values

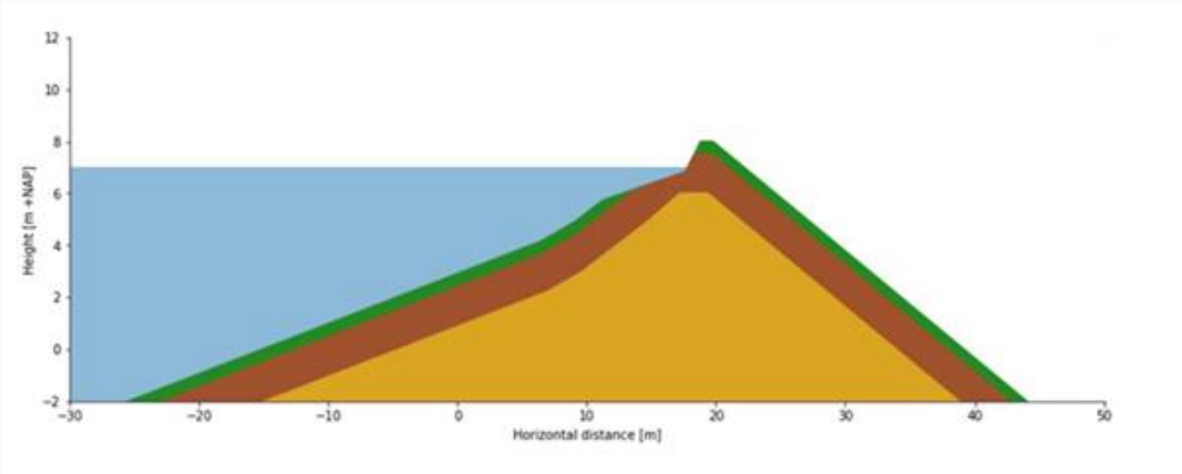


Figure 11: Further elaboration of the erosion process that shows that the probability of failure is smaller than with the use of conservative calculation rules

3.5 Preparation: Annual expert's assessment as a precondition for user acceptance

It is important that the data used in the expert judgment method is trusted by the end users. In addition, it is important to include lessons from the past in the basic data, such as user experiences or completed (scientific) projects. The annual expert's opinion can be seen as a process to improve the content (technical readiness). However, the expert's assessment is also a method to accept the results in the (crisis)organization. Users of the results know that use has been made of the most up-to-date data and knowledge and are thus prepared to adopt the insights. There has also been room for asking questions that create trust.

For the annual expert's opinion, a step-by-step elaboration is proposed as already described in the procedure. The first step is to improve the content. The expert's judgment in accordance with ‘code yellow’ can be applied here. The second step is obtaining social readiness from the end users. The elaboration of the ‘code orange’ is suitable for this, in which a representative of the other end users within the own management organization participate in addition to the operational manager.

4. Expert judgment meetings: Cases and results

4.1 Expert judgment meetings

4.1.1 Aims

In the expert judgment meetings the following aims need to be achieved:

1. Test the method, developed in the Task Group Floods
2. To estimate the risk of failure of the flood defence
3. To explore the effect of impact-limiting measures, in which two variants are elaborated:
    a. Effect of interventions to redirect flood
    b. Effect of faster decision making on evacuation / victims / damage

In the CMINE Task Group it is important to clearly formulate the expert judgment method and make it reproducible.

4.1.2 Participants

As experts for the expert judgment meeting flood and levee experts (flood defence expert) are being invited, but operational leaders working for the water authority and a liaison officer of the safety region. Furthermore, the expert team could also include experts who know the risks in the area, a person with knowledge about resilience and recovery. Even an experts from outside the region could be added, who has substantive knowledge, but look at the area with an open mind and the possible measures.

4.1.3 Meeting setup

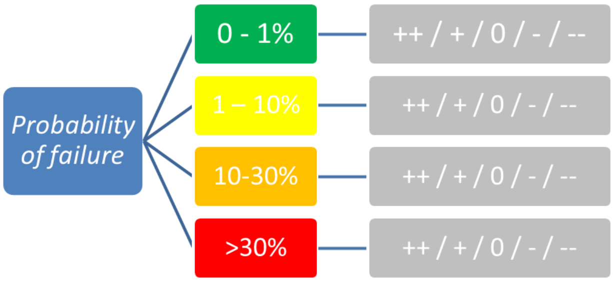
All available information has been gathered in a viewer, to be used to determine the chances of dike failure and connected risks (impact). After a short introduction of the participants (names and organizations) the aim of meeting should be explained: to realize and test a method to estimate the effects of measures through expert judgement. The goal of this method is flood risk reduction. The participants follow the method twice, in order to use and test the method in the same meeting.

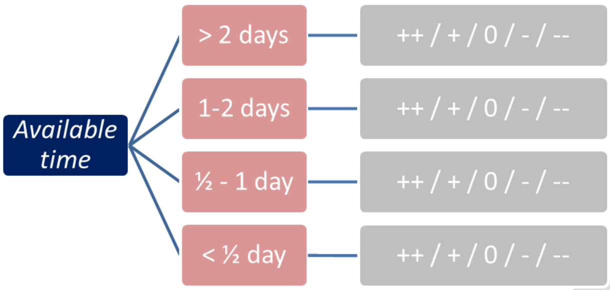
4.1.4 Real Time Risk Assessment

As input for the expert judgment session, the damage, casualties and victims per neighbourhood are demonstrated on a map. The purpose of the procedure is then to estimate the (often reducing) effect of these measures. This allows us to assess all kinds of organizational measures based on their (cost) effectiveness.

4.1.5 Headlines of the cases

In all cases the same structure has been followed. The procedure has been followed to determine at a specific moment the probability of failure in the coming days. The experts look ahead for two or more days and in this way the also get a probability of failure over time.





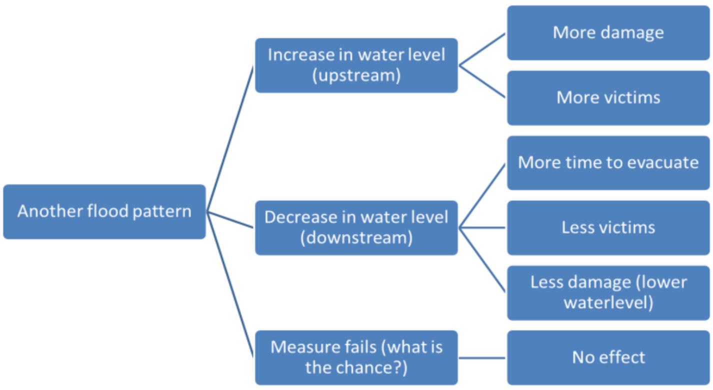
Session 1: Chance and moment of dike failure

In a specific section, given the rising water levels, the probability of failure is determined. In this session the focus is on a crisis situation: the water level rises and reaches the top of the dike section. The expert judgement result should be the estimated probability of failure for a few moments in time, preferably in%. Classes are being made so that it is clearly not necessary to have the exact number.

Session 2: Impact and consequences

For this session two different options are being elaborated:

- Option 1 (water- and crisis management). The possibility of influencing the consequences of the flood will be estimated. In the event of a levee breakthrough at a specific location, the experts might look for a high line element in the flood patterns. The question in the session is whether the effects can be estimated if a temporary barrier here with bigbags will be established and/or with other heavy items (Defence will have to carry out this action). Two questions need to be answered by the participants:
  a. What is the effect on the damage and victims (both downstream and upstream)?
  b. What is the chance of failure of this measure itself?
- Option 2 (evacuation and mitigation measures). The main question is the effect of various measures to enable faster decision making. One question need to be answered by the participants: If faster decision making would provide half a day more time to implement the measures (and perhaps do additional things), what will be the effect on the victims and the damage (or the chance of failure).

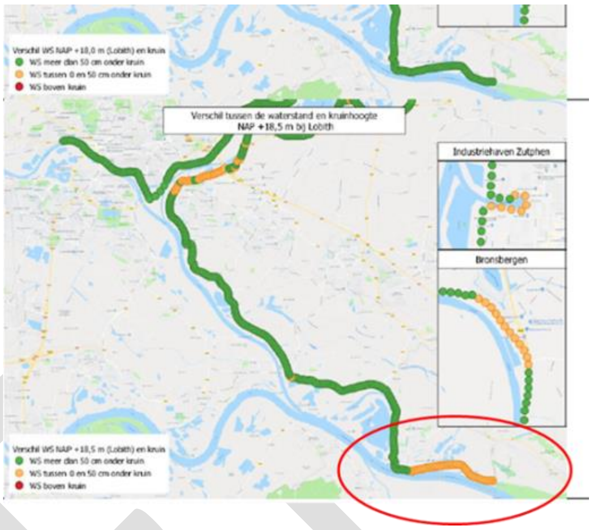


4.2 Case The Netherlands

Expert judgment meeting: September 24th 2019 (Amersfoort).

Participants from Water Authorities, University of Delft, Safety Region.

Situation 1: Water level rising at Lobith (river Rhine)



Step 0: The selected experts are sitting at the table. The first question is: what is the chance of failure?

Step 1: All experts provide an individual estimate.

Step 2: A round of experts brings arguments to the table, and even new information, such as:

• How conservatively do you enter this? We may miss a weak spot (piping, digging).

• 1% chance of failure seems to be a very small chance in connection with the situation in Germany (lower defences, including excavations).

• The previous flood situation has not failed and there have been no wells in the last 30 years (situation is similar) - we are talking about proven strength.

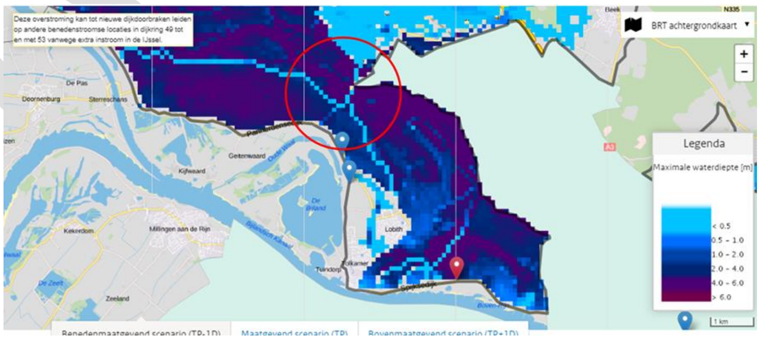
• This situation is not entirely comparable with previous events, because the predicted water level is higher. There is probably a fairly high chance of failure.

• The dike has also been raised since the last high water. This again provides a considerably smaller chance of failure.

Step 3: All experts provide a new estimate; this leads to the adjustment of the advice. Ultimately, the advice is formulated. It does not have to be unanimous, but it must have a good interpretation.

Situation 2: Placement of big bags at strategic places.

In this second situation the method has not been followed, but the decision tree has been discussed, with the following results:



• The place for big bags is also the evacuation route. Therefore, taking the measure may increase the number of people affected than without the measure.

• The question is whether there are positive effects of the measure. At most it can slow down a little, but stopping the water will not work.

• Think in advance of the meeting of mayors: they will cooperate, because the dilemma is about sacrificing one area as opposed to saving another. It is a delaying measure, but you might make the final consequences greater. A 'good decision' is almost impossible. If you want to take the measure, it must be well prepared, also towards the population. The discussion properly reflects the dilemma for administrators and decision makers.

• When weighing costs and benefits, it is important to include the costs and benefits for the surrounding areas.

• Experts with area knowledge say that placing big bags over a large length is not realistic.

General output

The purpose of this session was to test the method to provide input to the Regional Operational Team as an expert team in the form of balanced measures. Has the test passed? Is the method useful for the Dutch crisis management organisation?

• It is difficult to decide on this kind of measures during a crisis. Such situations could be prepared with experts. It also helps the crisis team to assess measures in advance as feasible or not.

• This method is meant for an exceptional situation (no person has personal experience with this) and that is why you use expertise to make a proper assessment.

• This is a good method to reduce the bandwidth in situations with uncertainties. This places demands: sufficient expertise should be available in the expert team. The crisis team must also have a perspective for action so that the water advisor can actually use the information for decision making. The question is therefore: can the expert team deliver counsel that is needed in due time.

• It is an interesting method, because it offers the opportunity for a short while to stand next to the acute problem and look at it from all sides, before the actual decision.

• With regard to the composition of the team: the role of the Safety Region in the expert team does have added value, by being able to put forward arguments other than water-technical ones. This does not have to be someone from your own region. Furthermore, the expert team should not only include flood defence managers, but also area managers, a recovery coordinator and experts from outside the region.

• It is recommended to compare the method with other method, for example for hazardous substances or water shortage. They have a large network and many experiences.

• The method can certainly also be used to improve scenario thinking (for planning or exercises).

• Consider seniority and dominance in the composition. If everyone looks at the same person, don't let this person dominate the discussion. The expert group must therefore practice. You can also think of a supervisor / facilitator who asks the right questions and guides the process in the right direction.

4.3 Case Hungary

Expert judgment meeting: November 29th 2019 (Budapest).

Participants from Crisis Management and Disaster Response Centre of Excellence (Bulgaria), Hungarian Disaster Management Training Centre (Hungary), Hungarian Civil Protection Association (Hungary), National University of Public Service (Hungary), Waterboard Rijn & IJssel (The Netherlands), Waterboard Brabantse Delta (The Netherlands)

Situation 1: Water level rising in Danube

Step 0: The selected experts are sitting at the table. The first question is: what is the probability of failure and what is the available time before failure?

Step 1: All experts provide an individual estimate.

Step 2: A round of experts brings arguments to the table:

- In this situation the national operational staff will be at location. This bend is the most critical point in the Danube river, so the monitoring of the water level is extremely tight.
- Information about the water level is received from Germany and Austria. Normally this information flow works well.
- Upstream from Gyor is a dam, used to regulate the water level in the river Danube. The most critical situation is the period after snow fall and snow melt. In that case the amount of water is not easy to regulate.
- Small dam breaches have taken place in history, with the presented water level. The locations are known and will be monitored according to a strict procedure.
- Around Gyor tributaries to the Danube river could realise a coincidental peak.
- When the levee will fail is full of uncertainties. In real-time the expert judgment would depend on the technical analysis but also on information from the field.

Step 3: All experts provide a new estimate; this leads to the adjustment of the advice. Mainly the experts indicate the dike won't breach, but there are also some voices it will have an increased probability of failing.

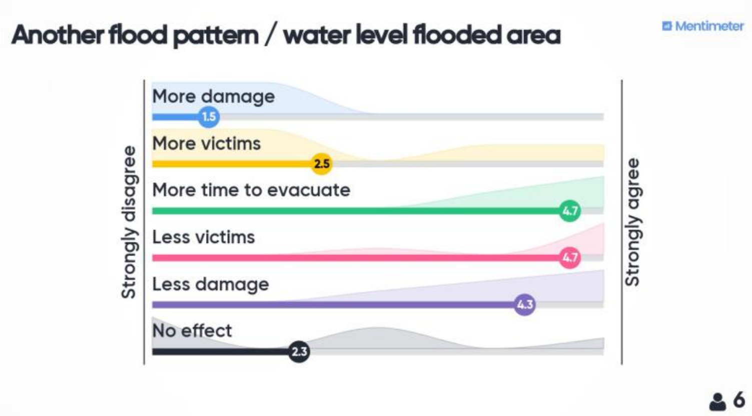
Situation 2: Measure planned to protect the city of Gyor

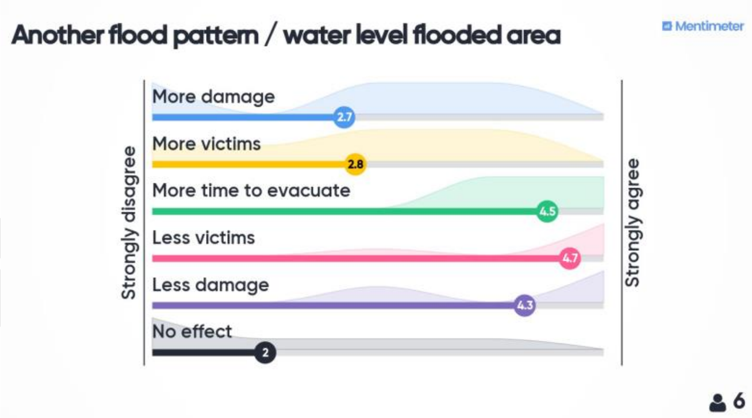
Step 0: The selected experts are sitting at the table. The question is: what is the impact of the measure?

Step 1: All experts provide an individual estimate.

Step 2: A round of experts brings arguments to the table:

- Inhabitants are normally already warned to evacuate in a situation like this. This may reduce the number of affected people and casualties. In 2008 about 3000 people were evacuated in one night. Over 10.000 volunteers were assisting in placing sand bags and helping people evacuating.
- Combination of fire fighters and police.
- Is the measure planned at the right place?
- Is it possible to place sandbags over 50 kilometres? Are other materials available and usable? In the city of Gyor there is a mobile dam protection. This is an aluminium structure, connected with a concrete wall.
- Are any vital objects (schools, nursing homes, power supply, etc.) in danger?
- The endanger region is a Natura 2000, so we face a dilemma of people against nature.





Step 3: All experts provide a new estimate; this leads to the adjustment of the advice. It has been found that after the discussion in step 2 the experts expect more damage and slightly more victims than in the first estimation. The possibility of failure is estimated lower than in the first estimation.

General outcome

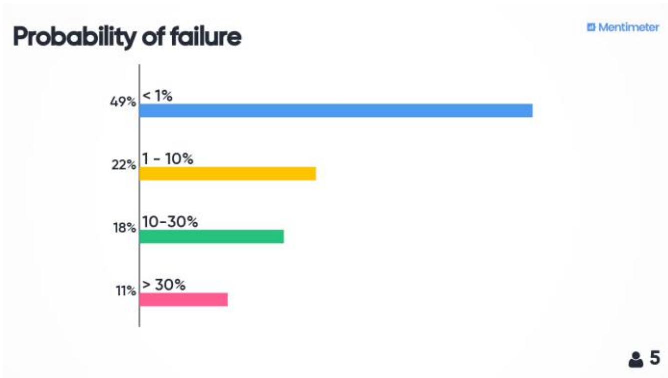
The purpose of this session was to test the method to provide input to the crisis team. Has the test passed? Is the method useful for the Hungarian crisis management organisation?

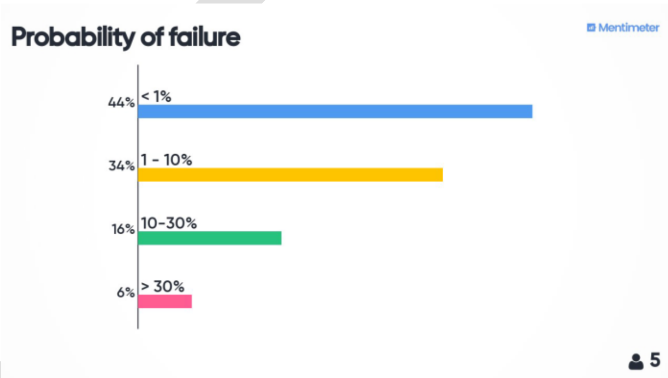
- In this case cross border expert judgment was tested. In reality experts from the neighbouring countries (Slovakia and Austria) would have been invited in the expert team. In the test experts from the Netherlands and Bulgaria were present. It is quite obvious that in this kind of cross border cooperation it is important to know and recognize the national crisis management structure and organisation. It could be a standard step in the method to explain not only the scenario and the situation, but also the actual crisis management setup.
- This method could be an important step toward fully integrated crisis management, in which the decision making on crisis measures and action needs to be done consciously with active participation from the right persons. Decision makers from the crisis team should somehow be incorporated in preparing the advice.
- The presentation of the expert judgement outcome is still under discussion. The decision maker needs more than just the numbers (percentages), interpretation is needed on behalf of decision making.

4.4 Case Germany

Expert judgment meeting: December 4th 2019 (Dresden).

Participants from Safety Region Haaglanden (The Netherlands), Fraunhofer Institute (Germany), Leibniz Institute of Ecological Urban and Regional Development (Germany), DIN Standardization Institute (Germany) and Centre for Security and Defence Management (Bulgaria).





Situation 1: Water level rising in Elbe

Step 0: The selected experts are sitting at the table. The first question is: what is the probability of failure and what is the available time before failure?

Step 1: All experts provide an individual estimate.

Step 2: A round of experts brings arguments to the table:

- Failure is defined as breaching of the levee and occurs when the load exceeds the resistance. In this test case we have only one failure mechanism: overtopping.
- In the system the water level expectations are being displayed. Uncertainties should also be shown to be able to judge about probability of failure.

Step 3: All experts provide a new estimate; this leads to the adjustment of the advice. It has been found that more experts estimate the chance of failure lower after the discussion. Also the available time before failure is estimated longer.

Situation 2: Measure planned to protect the city centre

Step 0: The selected experts are sitting at the table. The first question is: what is the impact of the measure?

Step 1: All experts provide an individual estimate.

Step 2: A round of experts brings arguments to the table:

- Think about the cascading effects. If a power station in the city centre would malfunction of fall out due to the floods, it might have a larger impact than expected.
- Same question for sewage systems. Is it worth to protect those vital systems more, compared with other parts of town. This creates dilemmas.

Step 3: All experts provide a new estimate; this leads to the adjustment of the advice. It is interesting that the experts are quite neutral about the possibility that the measure itself will fail. The experts judge the effect of the measure quite helpful. Extra time, for example to evacuate the area is the most valuable effect, according to the experts. More damage and more victims in other areas are not to be expected, although the probability is never zero. This is interesting information for the crisis team, although it must be accompanied by an explanation.

General outcome

The purpose of this session was to test the method to provide input to the crisis team. Has the test passed? Is the method useful for German crisis management organisations?

- The presented Real Time Risk Assessment viewer is useful to facilitate the discussion on possible measures. It helps the expert to explicit their opinion and it provides insight in a complex system with interdependencies. Knowledge could be available in their heads and in this way, while presenting and discussing the options with the help of the map, it is also visible for the other experts in the expert team how this knowledge could benefit in the crisis situation.
- The way of presenting is working well, using simple colour codes and the clear stated fragility curves. Nevertheless preparation and good facilitation during the expert judgment sessions is necessary.
- In the test the open tool 'Mentimeter' was used to collect the expert judgements and directly present them on the screen. Any other tools can provide the same type of results. But the good thing about this way of working is that it enables the participants in the meeting to see directly the summed result. It facilitates the discussion and shows the differences between the two expert judgments rounds.
- The question from the crisis management team should be completely clear. In this case no options were asked, only an expert opinion on one possible measure. In reality a range of options, a package would be prepared for expert judgment.
- Step 5 is important; the expert team should give useful advice to the crisis team. To provide the results of step 4 is not sufficient. The advice should be clear, descriptive, argued and focused on the original question. In the tests the formulation of the final advice has not been tested.
- The question was raised whether this method will work in cross border crisis management. At one hand the experts from both sides of the border will be able to exchange knowledge, expertise and arguments for typical measure. At the other hand a good 'dictionary' is needed, to be sure that that they speak the same language (use the same words and definitions for specific actions, materials and terms).

5. Conclusions and recommendations

The methodology Real Time Risk Assessment helps to make better and faster choices. Decision makers often want to be sure before they decide, but during a flood threat or crisis they will never reach that stage. To be prepared is the answer to uncertainty. In this method everyone involved, experts and decision makers, is invited to spend some thoughts on the impact of all possible measures.

The Real Time Risk Assessment viewer is supportive for the expert judgment. The basic information (real time risk information) is suitable and can be made visible with the help of the Real Time Risk Assessment viewer. To be of added value there should be no confusion about anything that is presented in the viewer, not even about colour encodings. Some fine-tuning is needed for different countries.

Main advantages of Real Time Risk Assessment. Advantages of the method of flood risk assessment and the impact of measure in a separate expert group:

- Time available: Faster decision making - more time available for operation
- Time needed: Quality of preparation measures
- Interpretability: the decision is supported by arguments from experts

No loss of time because the expert team works parallel to the crisis team. During the test the question about time pressure was raised. The crisis management team is not loosing time by asking for expert judgment on the considered measure, because the expert team works parallel and is additional to the crisis team. It is not a separate step in the crisis management operation but the reliability of the information increases due to the expert judgment.

Preparation of the expert team is crucial. Consensus is not needed; a facilitator might be helpful to prevent domination by specific experts. Mainly the team composition is important (not only expert itself, but also the desire to cooperate). There should be ground rules for the experts. The expert team should practice regularly. Visualisation with a data viewer is anyhow helpful in decision making.

Attention is needed to translate the result of the expert team into the crisis team. During Trial the Netherlands (DRIVER+) observations indicated that the Waterboard had troubles to translate the technical water related information to the crisis teams. A risk difference map as in the Real Time Risk Assessment viewer is helpful in this situation. In Trial the Netherlands the risk assessment sessions more or less took place, but unguided and without structure.

Timing of the expert judgment meeting in the crisis management procedure is extremely important. Perhaps code red is too late to properly weigh the effects of measures and to include them in decision-making. A crisis team will certainly be able to apply this method well in the run-up to code red.

The composition of the expert team can vary depending on the type of crisis and the urgency. If there is a discussion between the experts after the first round of expert judgment, this provides useful information to operational leader or the "water advisor" in the Regional Operational Team. By placing the operational leader in the expert team, this person also becomes "complicit" in the advice, and he or she can provide immediate interpretation. The crisis management team can thus gain more confidence in the judgment. It is then no longer under discussion in the operational or strategic team, so it increases the speed of decision making.

6. Way forward

6.1 Limitations of the Task Group and Findings

The Task Group has worked with a strong focus on developing and testing the expert judgement method. Three cases in different countries have been organised and passed. For the local experts and Task Group members it was a challenge to provide the required data and to involve the local experts. These difficulties were caused by the project related setting: a table top test with limited data and not related to a real crisis situation.

Improvements could be made on three levels of the method:

- Improve the content of the Real Time Risk Assessment viewer on local level, when it would be possible to include and elaborate the detailed locally available data.
- Form an expert team and practice the method for many different scenarios. Appoint a facilitator.
- Organise dry runs with the experienced expert team during real (possible small scale) crisis.

6.2 Way forward

In the Task group a method has been developed and tested to estimate risks in case of a flood threat and to estimate the impact of measures. An expert team has been looking for a well considered probability of failure and flood risk, based on the combination of water level, dyke strength and impact of failure, including possible measures. Usually this is known well in a more or less in a hypothetical situation, but we need adjustment for an actual situation, with measures discounted.

The Task Group has identified other challenges that need to be addressed in the future:

- Flexible and standardised data that can be used in other EU-countries (open, GIS-based, including metadata like definitions, boundary conditions, etc.
- To create a common risk based vision on flood information to serve different user groups, like practitioners, inhabitants of threatened areas, policy makers, crisis managers, water authorities, but also companies and industry.
- Standardization of wording regarding emergency plans (not only a glossary, but also an overview of emergency measure)
- Elaboration of expert judgment on other types of flood, for example due to heavy rains, flash floods and snow melts
- Share experiences about repair and recovery after real flood events

7. References

Kolen, B. & Kok, M. Optimal investment in emergency management in a multilayer flood risk framework. In Proceedings of the 5th International Conference on Flood Management (ICFM5), Tokyo, Japan, 27–29 September 2011.

Vrijling J.K. 2009. The lesson of New Orleans. In Risk and decision Analysis in maintenance optimization and flood management, edited by M.J. Kallen, Kuniewski, S.P. Amsterdam: IOS press.

ten Brinke W.B.M., Bannink B.A. & Ligtvoet W. 2008. The evaluation of flood risk policy in The Netherlands. Journal on Watermanagement Volume 151 (Number 4):181-188.

Kron. W. 2002. Keynote lecture: Flood risk = hazard x exposure x vulnerability. In Proceedings of the flood defence 2002 conference, edited by Wu et al. Being, China.

Gendreau N., Longhini M. & Combe P.M. 1998. Gestion du risque d'inondation et méthode inondabilité: une perspective socio-economique. Ingenieurs EAT 14:3-15.

Bourque L.B., Siegel J.M., Kano M. & Wood, M.M. 2006. Weathering the Storm: The Impact of Hurricanes on Physical and Mental Health. The annals of the American Academy of Political and Social Science 604:121-159.

Kolen B. & Gelder P.H.A.J.M. 2018. Risk-Based Decision-Making for Evacuation in Case of Imminent Threat of Flooding. Water. 10. 1429. 10.3390/w10101429.

Benjamin J.R., Cornell C.A. 1970. Probability, statistics and decision for Civil Engineers: McGraw Hill Book co.

U. Rosenthal, M.T. Charles and P. 't Hart. 1989. Coping with crisis: the management of disasters, riots and terrorism: Springfield: Charles C. Thomas.

C.R. Sunstein. 2022. Risk and reason: safety, law, and the environment. Cambridge, Massachusetts: Harvard University Press.

Lendering K, Schweckendiek T. & Kok M. 2015. Quantifying the failure probability of a canal levee, Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards, (1).

Boin A., 't Hart P. Stern E. & Sundelius B. 2005. The politics of crisis management. Public leadership under pressure. UK: Cambridge University Press.

Linstone H.A. & Turoff M. 1975. The Delphi method: techniques and applications. Reading: MA: Addison-Wesly Publishing Company.

Rowe G. & Wright G. 1999. The Delphi technique as a forecasting tool: issues and analysis. International journal of forecasting 15:353-375.

`t Hart, R. De Bruijn H. de Vries G. 2016. Fenomenologische beschrijving Faalmechanismen WTI. Deltares.

KNMI 2015. Herijking Waarschuwingssytematiek

Conditional flood risk management. Kolen, B. et al: ICOLD, 2019