Driving Innovation in Crisis Management for European Resilience

REAL TIME FLOOD RISK ASSESSMENT AND EXPERT JUDGEMENT METHOD

FINAL REPORT

CMINE TASK GROUP FLOODS

The aim of the CMINE Task Group Floods was to develop an internationally-recognised approach to quantify the effectiveness of flood measures and bring about an effective and efficient use of open data (such as water levels, levee information, flood scenarios, alarm levels, critical moments, possible risk reduction measures per zone or area).

The specific outputs of the Task Group Floods are:

- **Real Time Flood Risk Assessment (RTFRA):** It is 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).
- **Expert Judgement Method:** The method is a stepwise elaboration of the assessment of effectiveness of measures to the flood risk, with the help of "expert judgement sessions", inspired by a Delphi approach

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February 2020

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EXECUTIVE SUMMARY

The Crisis Management Innovation Network Europe[1] (CMINE), which is one of the outputs of DRIVER+ (Driving Innovation in Crisis Management for European Resilience)[2], 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. Different task groups have been set up to develop approaches aimed at resolving current issues in different Crisis Management domains.

In the Task Group Floods, we have created a method called Real-Time Flood Risk Assessment (RTFRA), included in which is an expert judgement process which can be used reproducibly, and which in practice estimates the impact of a measure, based on the expert knowledge. The RTFRA method thereby improves the quantification of flood risk reduction and support emergency personnel and decision-makers.

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The specific outputs of the Task Group Floods are:

- **Real-Time Flood Risk Assessment (RTFRA):** It is an interactive viewer, in which the conditional flood probability and flood risk are demonstrated using forecast and prepared scenarios (based on the EU Flood Directive). Measures can be selected and immediately their effect or impact on the flood risk can be cross-checked and shown. This viewer can be used in operations and/or as a decision and support information system. In the event of no available water level measurements, a demonstration is available to show the possible use of the viewer, for future reference.
- **Expert Judgement Method:** The method is a stepwise elaboration of the assessment of the effectiveness of measures to the flood risk, with the help of "expert judgement sessions", inspired by a Delphi approach[3].

The following conclusions and recommendations follow from the cases carried out by the Task Group Floods in the Netherlands, Germany and Hungary:

1. The methodology in Real-Time Flood 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. Preparedness is an answer to uncertainty. In this method, everyone involved, from experts to decision-makers, are invited to reflect on the impact of all possible measures simultaneously.
2. The Real-Time Flood Risk Assessment viewer supports expert judgement. Basic information (i.e. real-time risk information) is suitable and can be made visible with the help of the Real-Time Flood

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[1] https://www.cmine.eu/.

[2] Launched in May 2014, DRIVER+ is a project funded under the 7th Framework Programme of the European Commission, whose main aim is to cope with current and future challenges due to increasingly severe consequences of natural disasters and terrorist threats, by the development and uptake of innovative solutions that are addressing the operational needs of practitioners dealing with Crisis Management.

[3] https://en.wikipedia.org/wiki/Delphi_method.

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. Therefore, some fine-tuning is still required in some countries to reach harmonisation across the board.

3. The advantages of the flood risk assessment method and the impact of assessing possible measures in an expert group, via ”expert judgement sessions” are:
    - Time available: Faster decision-making; more time available for operations
    - Time needed: High quality of preparation measures
    - Interpretability: Decisions are supported by expert opinion
4. The Crisis Management team is not losing time by asking for expert judgement on a proposed measure, because the expert team works in 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 judgement on hand.
5. The timing of the expert judgement meeting in the Crisis Management procedure is extremely important. Code red is too late to weigh up the effects of measures properly and to include them in decision-making. A crisis team will certainly be able to apply this method well in the run-up to a code red.

The composition of the expert judgement 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 an expert judgement session, this provides useful information to operational leaders or the "water advisor" in the regional operational team.

ACKNOWLEDGEMENTS

The Final Report builds on the insights, experience and expertise of a large group of experts.

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Task Group Composition and Rationale
The composition of the task group has been chosen in order to attain a geographical spread of members across Europe, thereby creating the possibility of having a diversity of cases in different countries and further, to involve the water authorities in the development of the method. All of the task group members share a strong track record in Crisis Management relating to floods. The task group is an assortment of people with a research background, practitioners and crisis managers. Despite the participation of a large number of Dutch representatives, an EU perspective has been maintained by selecting and organising cases in three different countries. The task group members started their collaboration by sharing their knowledge, thoughts and experience related to the task. After this kick-off, three cases were prepared. A suitable group of interested people were matched and assigned to each of the cases. The Dutch members participated in two local meetings for the Dutch case, which was of assistance to the task group, as it enabled members to elaborate the methodology and the RTFRA viewer.

INTRODUCTION

BACKGROUND OF THE NEED TO IMPROVE REAL-TIME FLOOD RISK MANAGEMENT

Different approaches to 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 flooding threat, emergency measures can be taken to reduce the probability of an occurrence and its consequences. Forecasts of water levels and the strength of levees or dams are prepared and distributed during the threat, which might increase in accuracy when the time to take action reduces. More frequent inspections can be implemented to monitor levees and dams. When weak spots are detected, flood fighting measures can be implemented. In circumstances where there is a potential failure of levees or dams, warnings and evacuations 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 a lot of uncertainties and grave consequences of their decisions (including a delay of decisions) (Kolen & van Gelder 2018), such as:

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

When the time needed to execute the measures is limited, or when the necessary 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, these models also 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 of these models gives a better view of the potential impact of measures.

In the Task Group Floods, we have created a method called Real-Time Flood Risk Assessment (RTFRA) and added expert judgement to create a concise method that can be used reproducibly, which in practice estimates the impact of a measure, on the basis of the expert knowledge; thereby improving the quantification of flood risk reduction and support emergency personnel and decision-makers.

GOAL OF THE TASK GROUP

The Crisis Management Innovation Network Europe (CMINE), which is one of the outputs of DRIVER+, 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.

CMINE comprises of an online community platform, face-to-face meetings and workshops, all of which aims to tackle current and future challenges and facilitate 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 the Task Group Floods, Task Group Wildfires and Task Group Volunteer Management. CMINE is designed to evolve continuously through collaboration, with the aim of becoming a pan-European platform, which is centred on exchanges between various Crisis Management professionals.

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

In DRIVER+, a series of trials have been conducted in different countries, focused on various crises types. Their aim was to investigate innovative solutions under simulated crisis conditions, by gradually adapting them to operational constraints, as well as by creating acceptance among users 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 visualise and improve the effectiveness of emergency measures related to flood risk management. In future, the elaborated and tested expert judgement method can be used by crisis teams in order to determine the effectiveness, advantages and accountability of centralised or regional investment on flood risk management measures.

The Task Group Floods aimed to develop an internationally-recognised approach to quantify the effectiveness of flood measures and bring about effective and efficient use of open data (such as water levels, levee information, flood scenarios, alarm levels, critical moments, possible risk reduction measures per zone or area).

The specific outputs of the Task Group Floods are:

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- **Expert Judgement Method:** The method is a stepwise elaboration of the assessment of the effectiveness of measures to the flood risk, with the help of “expert judgement sessions”, inspired by a Delphi approach[4].

[4] https://en.wikipedia.org/wiki/Delphi_method

The method and the results of the testing session can be found in chapters **EXPERT JUDGEMENT METHOD** and **EXPERT JUDGEMENT MEETINGS: CASES AND RESULTS** of this report. A list of *recommendations* for further development and issues to be elaborated, can be found in chapters **CONCLUSIONS AND RECOMMENDATIONS** and **WAY FORWARD**.

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

The challenge of the Task Group Floods has already been mentioned as one of the DRIVER+ gaps (see D922.11, gap number 1, p. 6, with a more detailed description on pp. 35-36). The 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 cases 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 improvements in:

- Fast and accurate assessment is provided by the expert judgement 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 judgement 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 judgement), more time is available for the implementation of the measure, with a greater chance of a successful outcome.

EXPERT JUDGEMENT METHOD

This chapter describes the expert judgement method, which has been developed and tested in the Task Group Floods.

PREFACE

Although many Crisis Management teams have the legitimate feeling that they are well prepared for facing and fighting a flood, there may be little or no experience with extreme situations, such as (natural) disasters. As a result, when experts express their recommendations on what should be done at a specific moment in the crisis, this expert's judgement 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.

An expert is someone who, through years of training and experience, is extremely adept at solving problems in a certain problem area. An expert is supposed to have a lot of knowledge and experience in a certain field. The expert is used here as a source of knowledge, and for unlocking professional knowledge and new developments. Experts are the persons who can assess and judge exceptional situations, he/she never experienced before.

In the development of this procedure, the state of the art insights has 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. This translation can be performed through quantitative analysis (calculations) and knowledge (expert judgement). 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 the expert's knowledge.
- Annual expert judgements that lead to the adoption of basic data for operational use.

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

USUAL OPERATIONAL PROCEDURE FLOOD CRISIS MANAGEMENT

A flood risk management strategy can consist of measures which can be categorised in multiple layers, like prevention using levees, land use planning, building codes, insurance and emergency management. Flood risk (probability x consequences) distinguishes the probability of flooding as well as the consequences.

Society as a whole is considered as a system in which all stakeholders (professionals, authorities, and citizens) can interact. Structures exist that describe the relationship between these stakeholders and other stakeholders that 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, p. 10). The possibility of implementing measures depends on, for example, the following factors:

- The availability, lead time and quality of forecasts,
- The available infrastructure (roads and buildings),
- The available equipment (fire trucks, police vehicles, trucks, buses 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 all the required activities necessary to reduce loss of life and damage to zero.

The criteria to activate emergency planning and identify different phases that indicate the status of flooding and mass evacuation are in many cases based on forecasts for expected weather conditions, rain rates or duration, water levels or expected flooding. Thresholds (e.g. water levels) are defined to determine when to inform and alert the decision-makers and to form Crisis Management teams for decision making on operational, tactical and strategic levels.

For example, level 1 (low risk) is used to alert crisis teams, ensuring 24 hours monitoring. In level 2 (medium risk), flood defences will be strengthened, or mobile flood defences will be put in place. Level 3 (high, critical risk) means 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 of when to warn different stakeholders and in 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, for example humans are more important than economy, emergency planning only describes procedures on how to make these choices. The decisions are made in a crisis team where trade-offs are made for the costs and expected benefits, taking 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 circumstances where there is an imminent threat of flooding, reference is made to the conditional[5] or real time risk, which is the level of risk given the actual forecasted water levels and potential consequences during the days following 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 (e.g. water levels). These scenarios do not describe the reduction of risk. Also for measures taken to implement mobile flood defences or flood fighting, they are not related to a reduction of the probability of failure. The impact on risk reduction, by lowering the probability of flooding or a reduction in the consequences of a flood, are however key. Sunstein (Sunstein 2002) states that quantitative analysis of risks is indispensable to genuine deliberative democracy. Risk analysis can compare different and competing strategies.

Different and competing strategies or measures can be compared in a rational approach, which may be risk-seeking or risk-averse, based on the benefits, such as risk reduction and the costs or investments of these alternatives (Benjamin and Cornell 1970).

The expert judgement method 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.

INNOVATION: REAL-TIME FLOOD RISK ASSESSMENT

The Real-Time Flood Risk Assessment viewer 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 and 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; i.e. the working processes.

The risk information developed for supported flood risk management strategies (as contained in the EU Flood Directive) is used in an operational context. Therefore, we do not speak about 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[6] (see Figure 1):

1. **Data**: the data describe the characteristics of levees, geotechnical parameters and flood scenarios.
2. **Knowledge**: the knowledge converts data into information. This can be done by models based on algorithms but also by expert judgement (i.e. human assessment) to correct biases and unforeseen consequences. With knowledge, data can be combined, and information is generated.
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.

[5] The conditional flood risk is based on the conditional probability, which is the probability of an event occurring with some relationship to one or more other events.

[6] Conditional probability of failure is the probability that a specific item, such as a piece of equipment, material or system fails at a certain time interval. This is with the condition that the item has not yet failed at the current time (source: www.corrosionpedia.com).

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 following days and the relevant mechanisms of failure (e.g. seepage or overtopping).

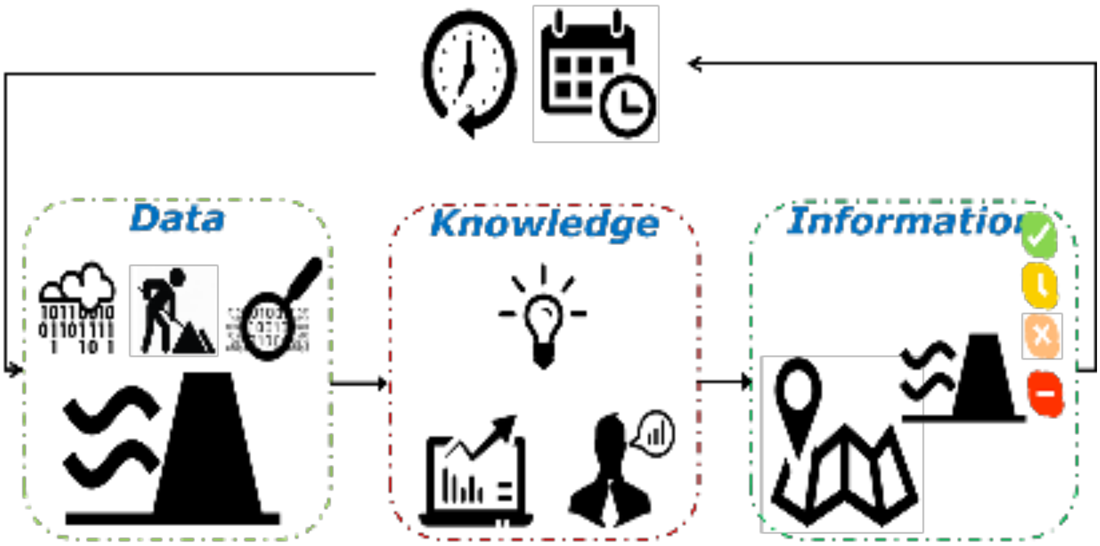


Figure 1. Real-Time Flood Risk Assessment (from Conditional flood risk management, ICOLD, 2019)

In the Real-Time Flood Risk Assessment viewer risk information is presented for the actual situation (using measurements) and the upcoming day's 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 into different sections based on common characteristics. For each levee section, the characteristics are described which 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.

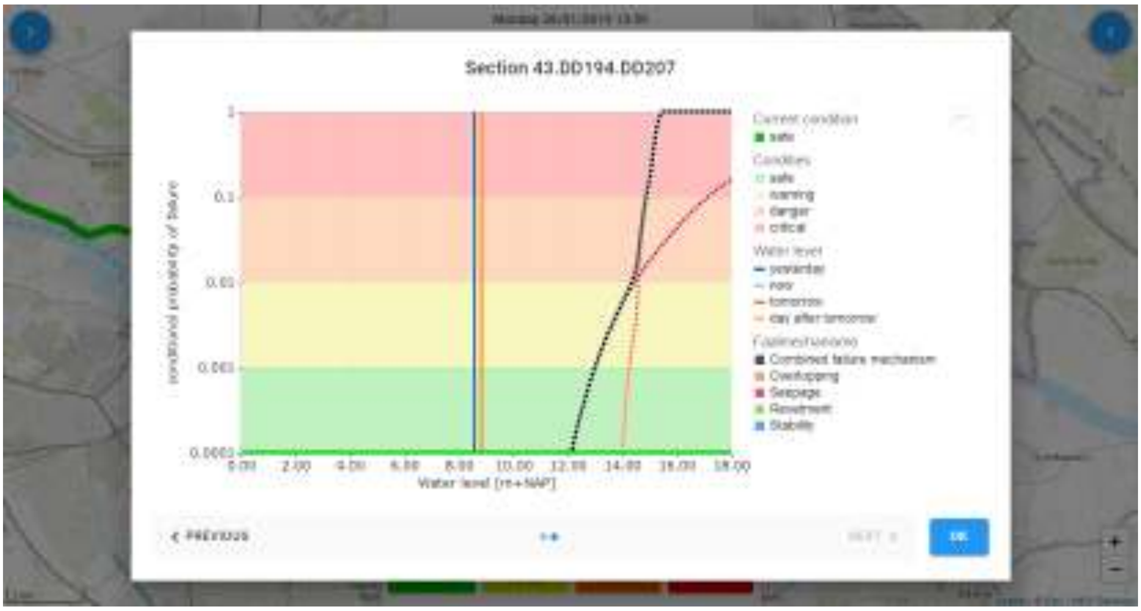


Figure 2. Fragility curve

Figure 3. Conditional probability of failure of flood defences (extracted from Dutch Case)

- **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 a zip code. The conditional risk is quantified as a conditional risk of economic damage, conditional risk of people at risk or conditional fatalities and local probability of exposure to a flood. Figure 4, shows an example of the conditional risk per zip code.
- **Measures: F**or each levee or dam, there is also a library of different fragility curves, which describes the effectiveness of measures that can be prepared in advance. For example, the height of the levee

can be corrected, as can 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, dam or zone, the contribution of the risk per levee section can also be ranked from high to low to support decision-makers to prioritise measures. Also for zones, measures or actions can be taken to reduce the consequences. Also a database of possible flood scenarios can be prepared.

- **Human assessment (expert judgement):** The probability of failure and the consequences/impact of flooding, can be corrected for biases by human assessments. Therefore measurements and field inspections can be used, as well as remote sensing and data science techniques.

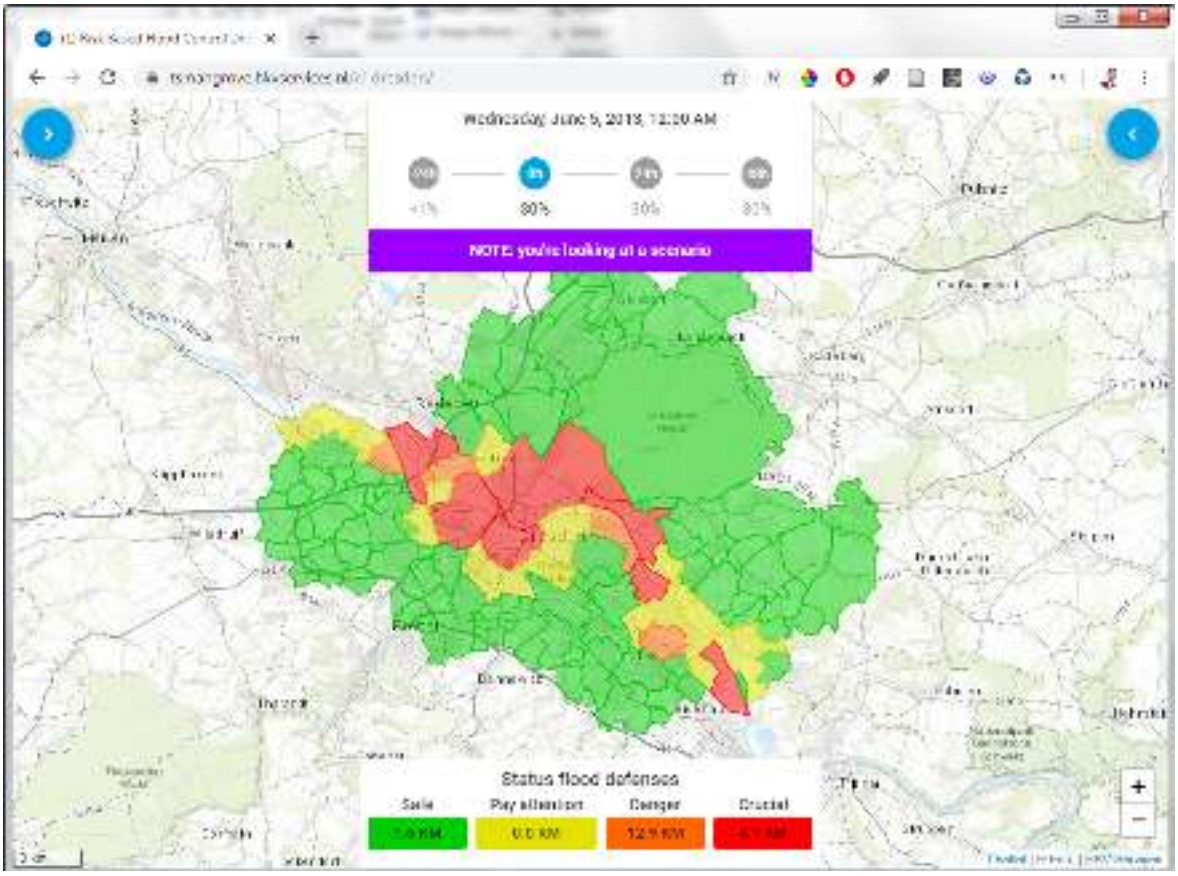


Figure 4. Example of conditional risk per zip code

For the purposes of learning, validation and asset management also 'what if' events (water levels) can be defined. These synthetic events can be described as 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 flood scenarios. Other emergency managers are responsible for warning or evacuation and deal with 'summarised' information. In these cases, only the probability of a flood is needed and not the contribution of different mechanisms relating to the failure probability. A flood fighter, however, needs more information about the relevant failure mechanism (such as seepage or overtopping), because the flood-fighting measure is related to the failure mechanism.

The Real-Time Flood Risk Assessment viewer offers information about water levels, the conditional probability of failure and conditional risks in particular zones, which are presented in different levels of detail. Information can be viewed and extracted from the interactive Real-Time Flood Risk Assessment viewer (see Figure 5, Figure 6 and Figure 7). In the 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, which relate to the level of alarm, for the conditional probability of the failure of a levee[7]:

- **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 (e.g. location, levee or area) on the map, more detailed information is presented using descriptions, graphs and numerical time series.

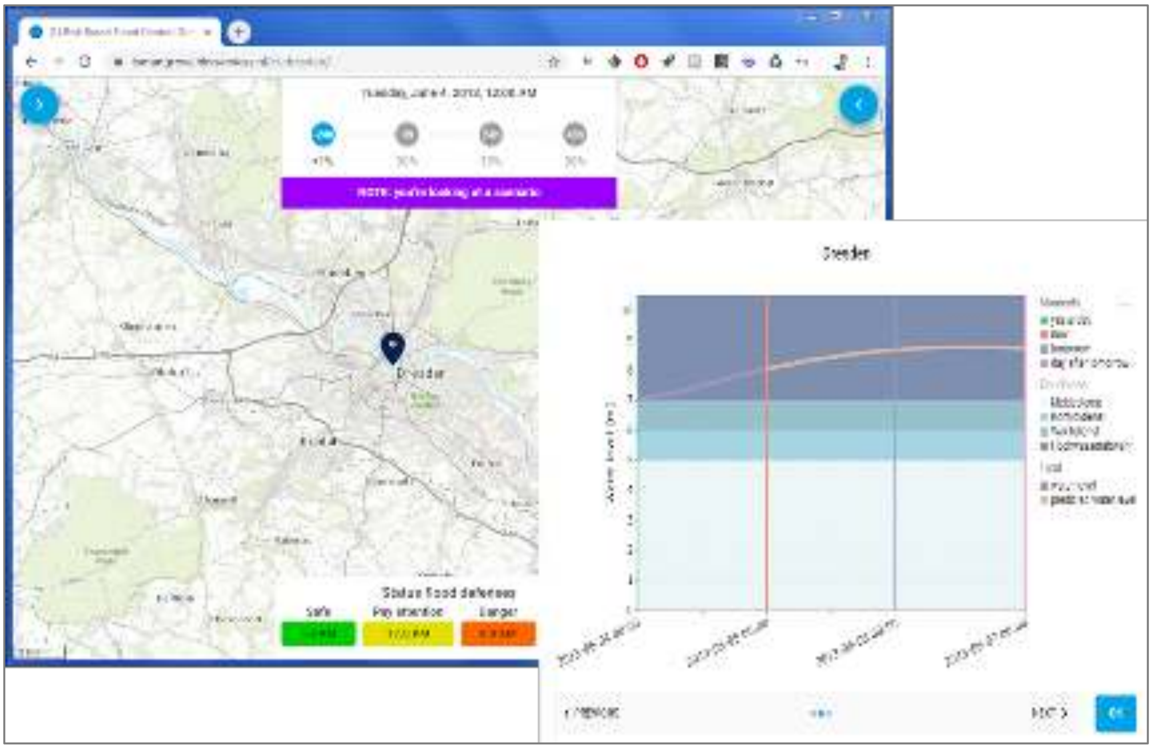


Figure 5. Example of detailed information about the expected water level. The conditions are indicated in German: Meldedienst (reporting), Kontroledienst (inspection), Wachtdienst (standby), Hochwasserabwehr (flood defence)

[7] Lendering, K. & Schweckendiek, Timo & Kok, Matthijs. (2018). Quantifying the failure probability of a canal levee. Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards. 1-15. 10.1080/17499518.2018.1426865.

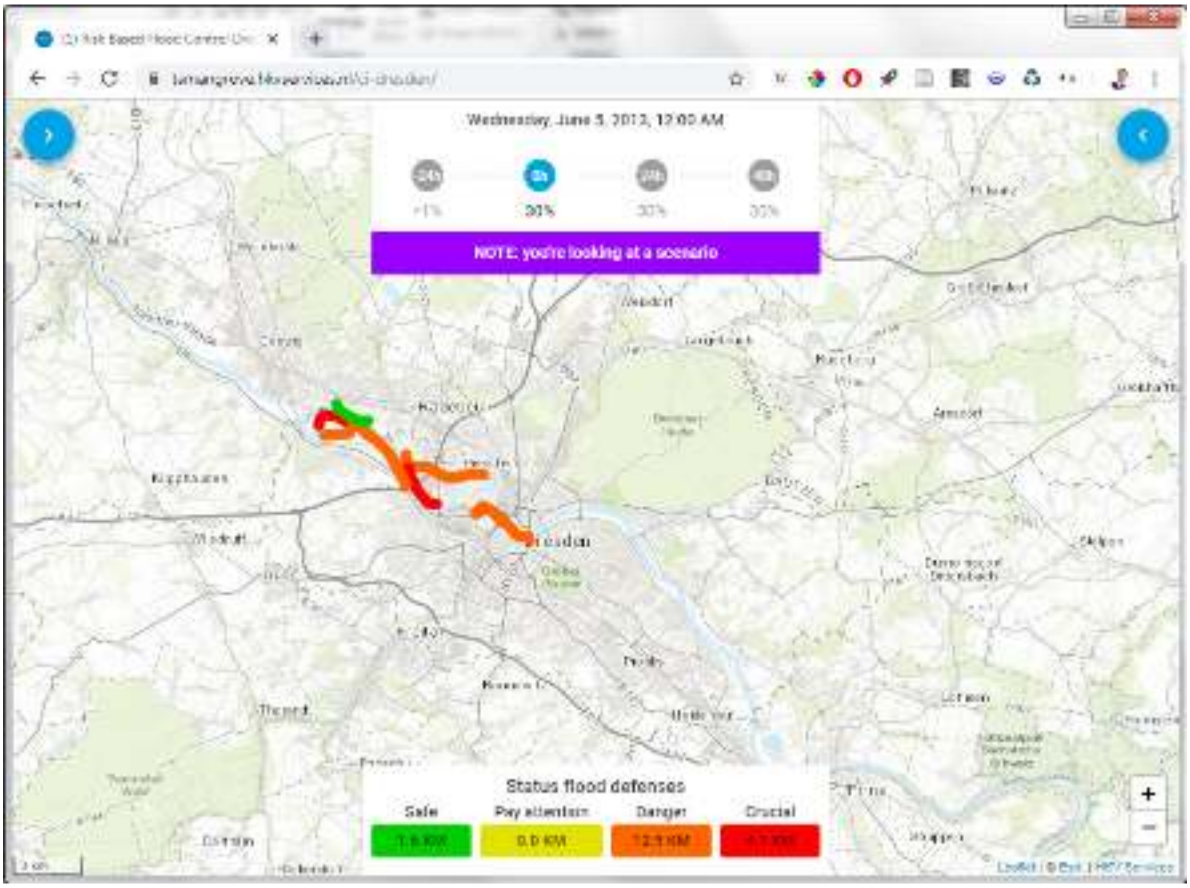


Figure 6. Example of detailed information about the status of flood defences

EXPERT JUDGEMENT PROCEDURE

Because of the low frequency of events and the lack of experience and uncertainties in data; models are used to describe probabilities and consequences. These models consist of algorithms which describe physical processes. In addition, uncertainties can be taken into account using probabilistic approaches.

However, during an event, incidents can occur which are not foreseen. During an event, levees will be inspected more frequently by dike control teams, remote sensing and other sensors. This information is used to evaluate the need for flood fighting measures. In order to arrive at the most appropriate response decision, weak spots must first be identified and factored in. It is only then that measures can be executed (Lendering et al, 2015).

The Real-Time Flood Risk Assessment viewer offers information on where (and which) failure of the levee is most likely to occur. This 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 enabling inspectors and crisis managers to set priorities.

The algorithms used in the Real-Time Flood Risk Assessment and the detection of information by humans and remote sensing (and other sensors) are presented in models. A validation of the outcome of these models is done by human assessment. The outcomes of the model can be fine-tuned, as it is possible to correct biases and to add new information. 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 judgement procedure has been developed using case studies. The role of this procedure is also to validate the final risk assessment and actual alarm categories collated by all the stakeholders, thereby leading to acceptance by all.

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

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

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

As a consequence of flood events occurring with a low frequency, the availability of expert experiences and information to calibrate models is limited. However, when an event occurs, new information might arrive relating to a particular set of conditions (such as measurements or inspection results). This new information gives model experts the opportunity to correct models' outcomes, especially when underperformance or inaccuracies are known to be recorded for these conditions. For example, an incidence of melting snow might assist an expert who is aware that the calculated water levels during/after melting snow are always 10 cm too low, to correct the model outcomes with his/her expert opinion, based on the findings of the event.

There is limited time available to develop new and trusted models and run calculations during times of crisis. Therefore, expert judgement has the benefit of being used to adjust model outcomes in order to improve information for emergency management. When the expert judgement is prepared in advance of an event, the greater will be the acceptance of the flood risk information.

As regards the process involved in the elaboration of the expert's opinion, a distinction is made between the process and support tools.

PROCESS

The expert-judgement procedure is based on the standard Delphi method and can be utilized for continuous updates and semi-dynamic updates. This method gives group processes an effective structure, which enables 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).

As regards the 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 undertaken prior to an event. Hence, it is called step zero.
- **Step 1.** First individual assessment by 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 results in a probability distribution of estimations and an expected value.

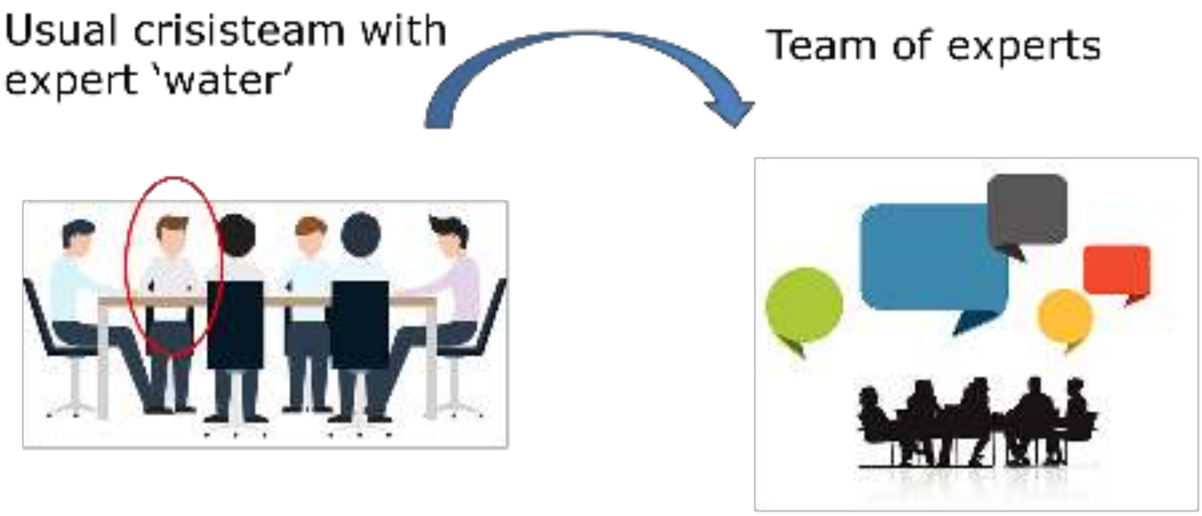


Figure 7. Team of experts additional to the crisis team

The selection of experts in Step 0 is determined by the alarm phase and the impact of an alarm phase to society. Therefore, lessons have been learned from responses to weather warnings and alarms in the Netherlands by the public, media and politicians. A warning is issued when there is a relative low probability of an event occurring in an area. The warning is issued after consultation with weather experts. An alarm is issued when there is a relative high probability of extreme weather, which also takes into account the potential impact of the extreme weather (KNMI 2015). For example, an incidence of extreme rainfall or fog during rush hour might result in an alarm, whereas the same event occurring during a weekend or evening, may only result in the issuing of a warning.

During a code yellow or green (see Figure 8 below), all efforts are focused on the prevention of a flood and implementing flood-related defence measures. In these instances, only flood risk experts will participate in the expert team. During a code orange, emergency managers, including a representative of emergency services, also participate because of the increase of flood risk, potential warnings and impact to society. During a code red, decision makers also participate because of issues of evacuation and business interruption.

The existing crisis management organisation remains intact. An expert team will support the water advisor, who informs others about flood risk and potential measures, in the emergency teams on an operational or strategic level. The experts in the expert team are carefully selected, which means that the assessment of the expert team will have broad-spectrum support.

The procedure to be followed depends on the class of risk that is being faced, the type of weather warning and the weather alarm. Before announcing a weather warning (for example in the Netherlands the warning is released with a 60% chance of its occurrence somewhere in an area), an assessment is made by various meteorologists in a 'weather room'. External stakeholders are also involved in the weather alarm, commensurate with the impact and extent of the alarm. The following experts participate in the expert judgement process:

- In low risk cases (code green or yellow, extra monitoring): 3 water experts,
- In medium risk cases (code orange alert for possible danger): 3 water experts and 1 or 2 (intended) operational emergency planners from the water authority,
- In critical or high risk cases (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.

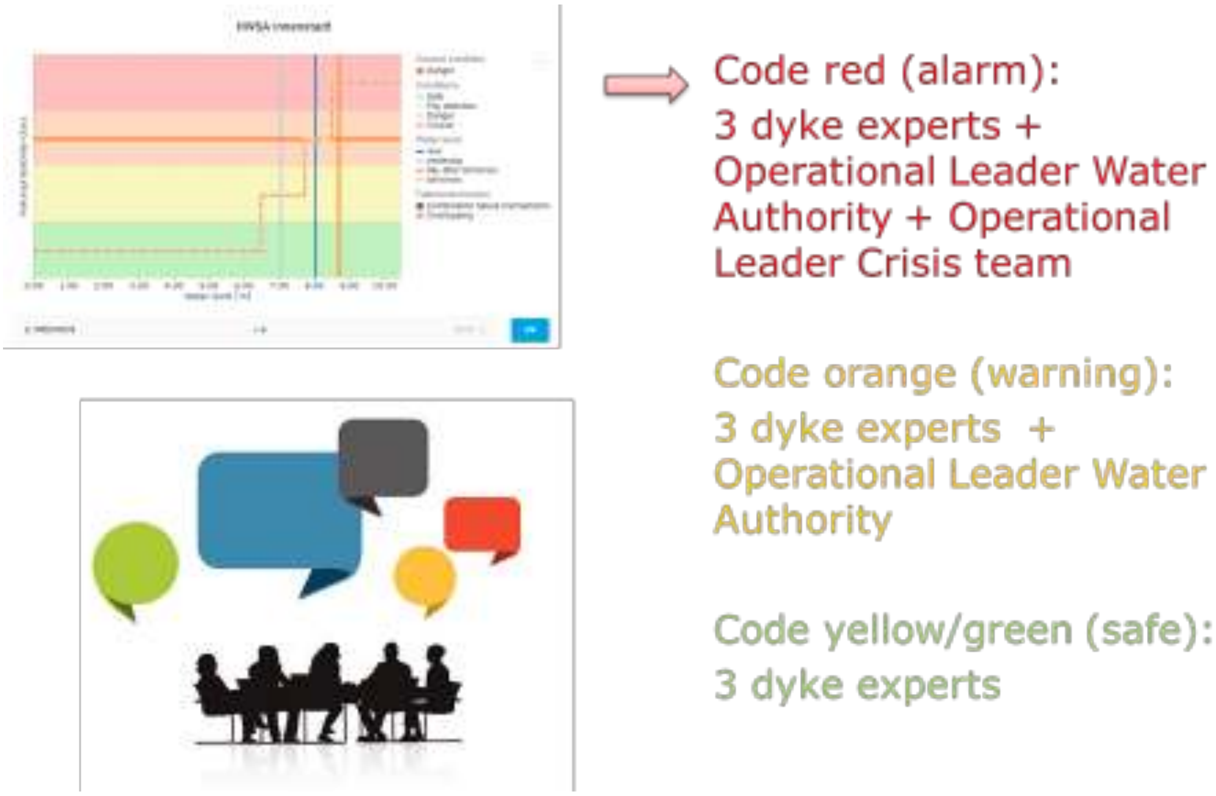


Figure 8. Composition of the expert team

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, thereby making it possible to make a better estimate about the flood probability. This also involves understanding flood consequences and the impact of potential measures to reduce the extent of the flood, 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 9 for piping). Piping under dikes occurs due to the entrainment of soil particles by the erosive action of seepage flow. 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 (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 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 Risk Assessment can support human assessment during operational flood risk management.

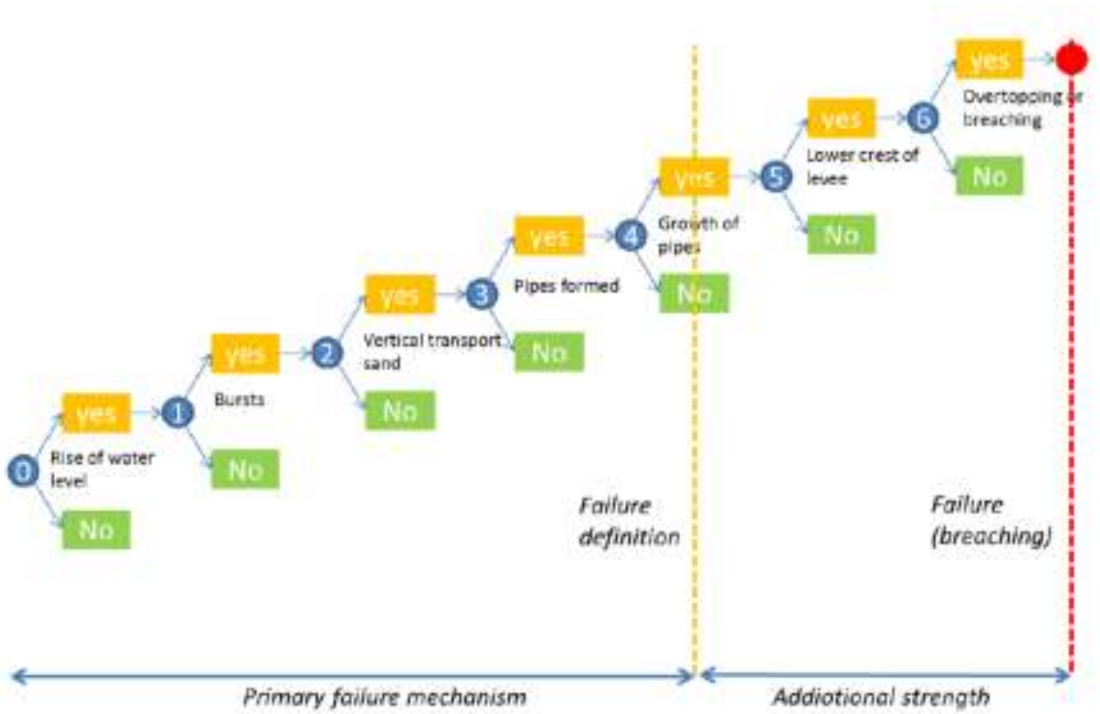


Figure 9. Failing definition for the example of piping

The definition of failure, 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 *10*). However, in reality, only an erosion process starts, leaving residual strength. Calculation tools are available for this process; which 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 *11*).

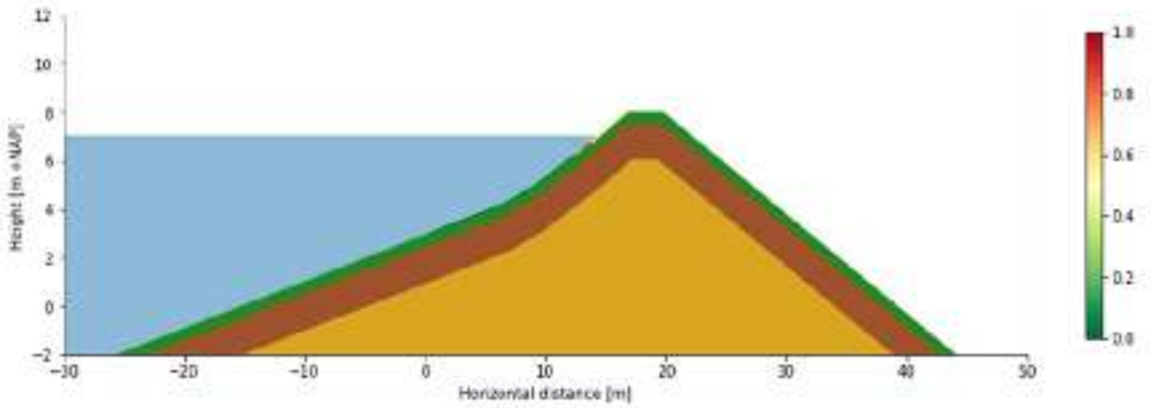


Figure 10. Failures of the dike coating in accordance with failure definition with the occurrence of critical values

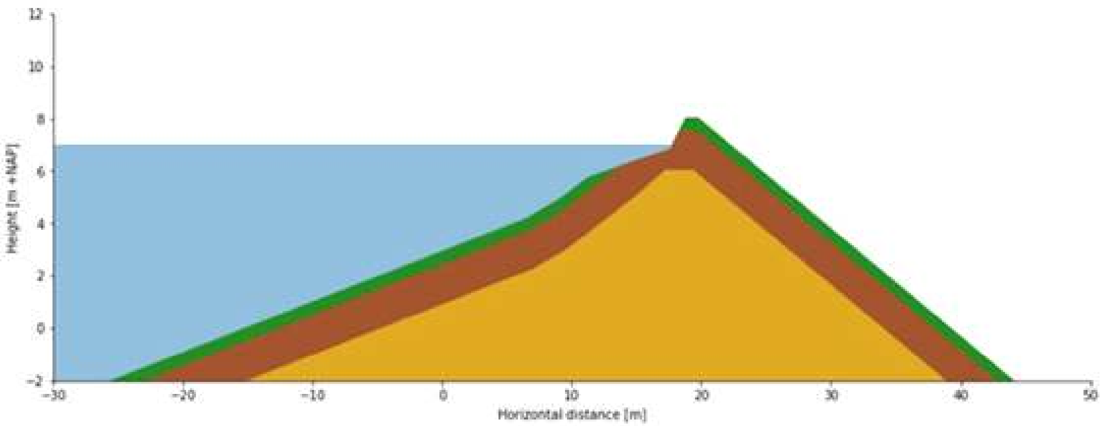


Figure 11. Further elaboration of the erosion process that makes it plausible that the probability of failure is smaller than with the use of conservative calculation rules, due to residual strength

PREPARATION: ANNUAL EXPERT'S ASSESSMENT AS A PRE-CONDITION FOR USER ACCEPTANCE

It is important that the data that is eventually used in the expert judgement method is trusted by the decision-makers (i.e. the crisis team and the end users). In addition, it is important to include lessons from the past regarding the basic data, such as user experiences or completed, scientific or non-scientific projects. The expert's opinion, which is given on an annual basis, can be seen as a process in itself, which improves the content for technical readiness. However, the expert's annual assessment is also a method to accept and bed down the results in the crisis organisation. Users of the results will know that use has been made of the most up-to-date data and knowledge and are thus prepared to adopt the insights. There is also room for asking questions, which creates trust.

For the annual expert's opinion, a step-by-step approach is proposed, as has already been described in the expert judgement procedure. The first step is to improve the content of data. The second step involves obtaining social acceptance by decision-makers, because of the participation of representatives of the other stakeholders) from within their own management structure, along with an operational manager.

EXPERT JUDGEMENT MEETINGS: CASES AND RESULTS

EXPERT JUDGEMENT MEETINGS SETUP

AIMS

The following are the aims needed to be achieved at the expert judgement meetings:

1. Test the method, developed in the Task Group Floods
2. Estimate the risk of failure of the flood defence,
3. 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 or damage, etc.

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

PARTICIPANTS

Participants of the expert judgement team include: flood and levee experts (i.e. flood defence experts), who are invited in their capacity as experts, operational leaders working for the water authority and a liaison officer of the safety region. Furthermore, participation can also extend to other experts with knowledge of the risks in the area; for example, a person with knowledge about resilience and recovery. Even experts from outside the region could be included, who not only have substantive knowledge, but can look at the area and the possible measures with an open mind.

MEETING SET-UP

All available information is gathered in a Real-Time Flood Risk Assessment viewer, to be used to determine the chances of dike failure and connected risks, including their impact. After a short introduction of the participants, the aim of the meeting is explained; to realise and test a method to estimate the effects of measures devised from their expert judgement. The goal of this method is flood risk reduction. The participants duplicate the steps of the method, in order to use and test the method in the same meeting.

REAL-TIME FLOOD RISK ASSESSMENT

The types of input gathered for expert judgement meetings, which are shown on a map include: damage, casualties and victims per neighbourhood. The purpose of the procedure is then to estimate the reducing effect of measures. This allows experts to assess all kinds of organisational measures based on their effectiveness, including cost-effectiveness.

HEADLINES OF THE CASES

In all scenarios, the same structure is followed. The procedure is followed to determine at a specific moment the probability of failure in the proceeding days. The experts look ahead for two or more days and in this way, they also run through an assessment of the probability of failure over time.

Figure 12. Options for probability of failure.

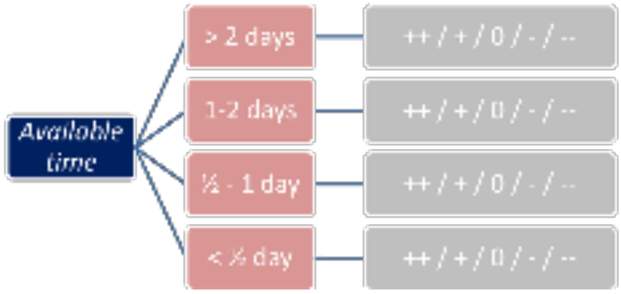


Figure 13. Options for available time before failure

Session 1: Chance and moment of dike failure

In a specific section, given the rising water levels, the probability of failure can be determined. In the expert meeting, the focus is on a crisis situation; e.g. 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 percentage terms. The information can be conveyed via a classification (see figure above), which is developed as part of the process, which also means that it is not necessary to have exact numbers.

Session 2: Impact and consequences

For this expert session, two different options are being elaborated:

- **Option 1:** flood threat and Crisis Management. The possibility of influencing the consequences of the flood is estimated. In the event of a levee breaking through at a specific location, the experts might look for a high line element in the flood patterns. The issue to determine is whether the positive and negative effects can be estimated if a temporary barrier with big bags and/or other heavy items is constructed. 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 issue at hand is knowing as accurately as possible, about effects of various measures, which will enhance faster decision-making. One question needs to be answered by the participants: if faster decision-making would provide half a day more time to implement the measures (and perhaps to do additional things), what would the effect be on the victims and the damage?

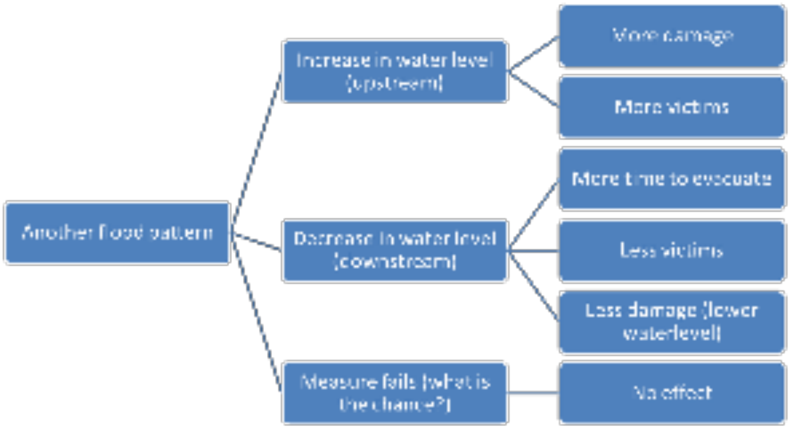


Figure 14. Possible options if the flood pattern changes

CASE THE NETHERLANDS

Expert-judgement 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.

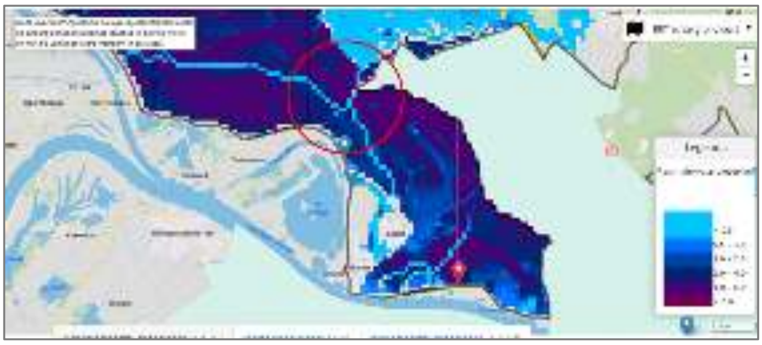
Step 2: A round of expert contribution bring arguments to the table, and new information is introduced, such as:

- How conservatively do you enter this? We may miss a weak spot (e.g. piping, digging).
- 1% chance of failure seems to be a very small chance in comparison with the cross-border situation in Germany, some kilometres upstream from Lobith (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 step-by-step approach has not been followed, but the situation has been discussed, with the following results:



- The place for big bags is also the evacuation route. Therefore, adopting 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 it will not stop the water.
- 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 adopt the measure, it must be well prepared, also for 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 state that placing big bags over a large length is not realistic.

General output

The purpose of this session was to test the expert judgement method to provide input to the regional operational team as an expert team in the form of balanced measures. Has it passed the test? Is the method useful for the Dutch Crisis Management organisation?

- It is difficult to decide on this kind of measure 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 of this) and that is why you use expertise to make a proper assessment.
- This is a good method to reduce the bandwidth in situations where there are uncertainties. This places demands on the presence of sufficient expertise 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 making an 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 methods, for example, those employed 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 including a supervisor or facilitator who can ask the right questions and guide the process in the right direction.

CASE HUNGARY

Expert judgement 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) and Waterboard Brabantse Delta (The Netherlands)

Situation 1: Water level rising in the Danube

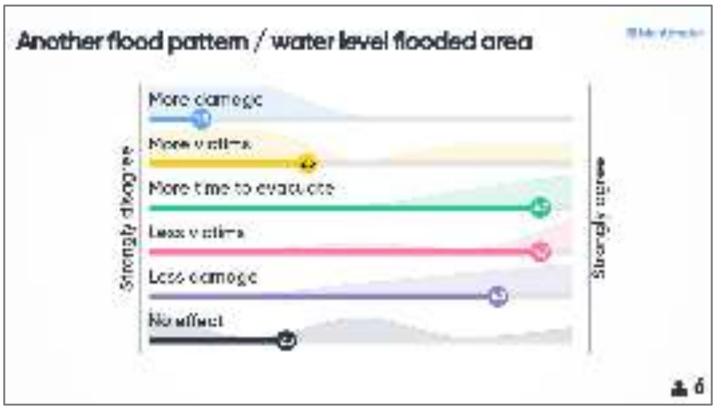
Step 0: The selected experts are sitting at a table. The first question is: what is the probability of failure and what is the available time before failure?

Step 1: All experts provide an individual estimate.

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

- In this situation, the national operational staff will be at the location. This bend is the most critical point in the Danube River, so monitoring 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 snowfall and melting snow. In these cases, the amount of water is not easy to regulate.
- Small dam breaches have taken place historically, with similar water levels as in this scenario. The locations are well-known and will be monitored according to a strict procedure.
- Around Gyor, tributaries of the Danube River could realise a coincidental peak.
- When the levee will fail, is full of uncertainties. In real-time, the expert judgement 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 expressing it will have an increased probability of failing.

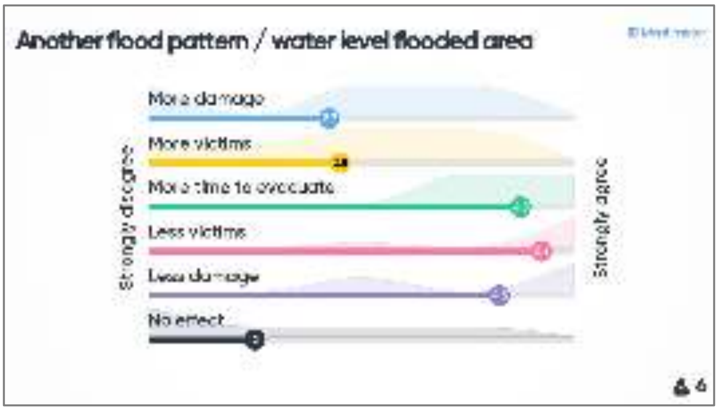


Situation 2: Measure planned to protect the city of Gyor

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 expert contribution 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 sandbags and helping people to evacuate.
- Combination of firefighters 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 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 endangered 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 an adjustment of the advice. It has been found that after the discussion in step 2 that the experts expect more damage and slightly more victims than in the first estimation. The possibility of failure is estimated as 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 it passed the test? Is the method useful for the Hungarian Crisis Management organisation?

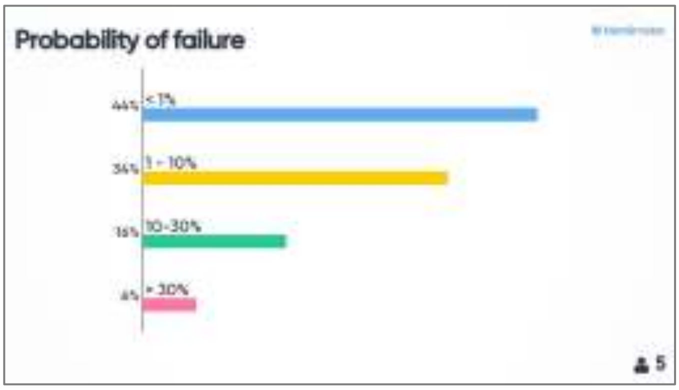
- In this case, cross-border expert judgement was tested. In reality, experts from neighbouring countries (Slovakia and Austria) would have been invited to the expert team. In the test experts from the Netherlands and Bulgaria were present. It is quite obvious that in this kind of cross-border cooperation, it is important to know and recognise 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 towards a full integration in the Crisis Management system, 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 (e.g. percentages), interpretation is needed on behalf of decision making.

CASE GERMANY

Expert judgement 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 Standardisation 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 expert contribution 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, i.e. overtopping.
- In the system, the water level expectations are being displayed. Uncertainties should also be shown to be able to judge the probability of failure.

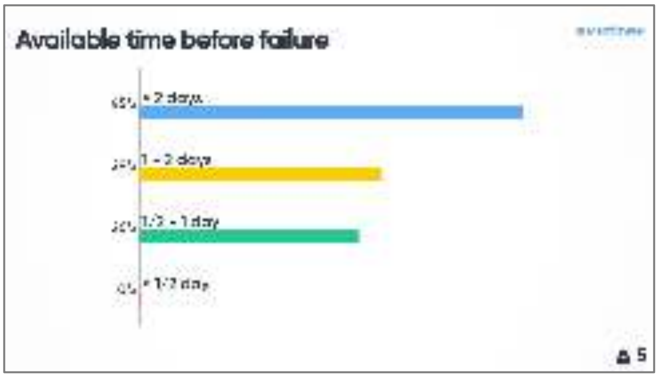
Step 3: All experts provide a new estimate; this leads to the adjustment of the advice. It has been found that more experts estimate the chance of failure as lower after the discussion. Also the available time before failure is estimated as longer.

Situation 2: Measure planned to protect the city centre

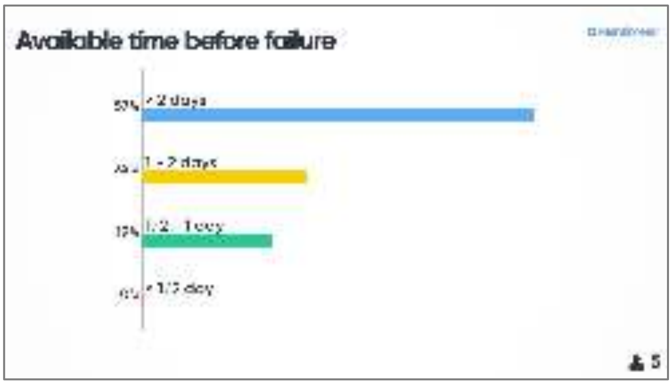
Step 0: The selected experts are sitting at the table. The first question is: what is the impact of the measure?

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 or fall out due to the floods, it might have a larger impact than expected.
- Same question for sewage systems. Is it more worthwhile protecting 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 as 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 at 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 it passed the test? Is the method useful for German Crisis Management organisations?

- The Real Time Flood Risk Assessment viewer presented is useful to facilitate the discussion on possible measures. It helps the expert to explicitly state 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 to know how this knowledge could benefit in the crisis situation.
- The way of presenting is working well, using simple colour codes and the clearly stated fragility curves. Nevertheless, preparation and good facilitation during the expert judgement sessions is necessary.

- In the test, the open tool Mentimeter8 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-up results. It facilitates the discussion and shows the differences between the two expert judgements 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 judgement.
- Step 3 is important; the expert team should give useful advice to the crisis team. To provide the results of step 2 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 had not been tested.

The question was raised whether this method will work in cross border Crisis Management. On one hand, the experts from both sides of the border will be able to exchange knowledge, expertise and arguments about specific measures. On the other hand, a good 'dictionary' or glossary/thesaurus is needed, to be sure that that they are speaking the same language (use the same words and definitions for specific actions, materials and terms).

[8] www.mentimeter.com is presentation software for leaders, educators, and speakers that's interactive and engaging. The audience uses their smartphones to connect to the presentation where they can answer questions. Their responses are visualized in real-time.

CONCLUSIONS AND RECOMMENDATIONS

The methodology for Real-Time Flood 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, are invited to spend some thoughts on the impact of all possible measures.

The Real-Time Flood Risk Assessment viewer is supportive for the expert judgement. The basic information (real time risk information) is suitable and can be made visible with the help of the Real Time Flood 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 Flood Risk Assessment. Advantages of the method of flood risk assessment and the impact of measure in a separate expert group are:

- 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 losing time by asking for expert judgement 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 judgement.

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 Flood Risk Assessment viewer is helpful in this situation. For example, in DRIVER+ Trial the Netherlands the risk assessment sessions more or less took place, but unguided and without structure.

Timing of the expert judgement meeting in the Crisis Management procedure is extremely important. Code red is too late to weigh the effects of measures properly 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 judgement, this provides useful information to the operational leader or the "water advisor" in the Regional Operational Team. By placing the operational leader in the expert team, this person also becomes associated with the advice, and he or she can provide immediate interpretation. The Crisis Management team can thus gain more confidence in the judgement. It is then no longer under discussion in the operational or strategic team, so it increases the speed of decision making.

WAY FORWARD

LIMITATIONS OF THE TASK GROUP AND FINDINGS

The Task Group Floods 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 tabletop 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 Flood Risk Assessment viewer on a 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 and/or possible small scale crisis.

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, the impact is known in a more or less in a hypothetical situation, but we need adjustments 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 such as 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, policymakers, crisis managers, water authorities, but also companies and industry,
- Standardisation of wording regarding emergency plans - not only a glossary but also an overview of emergency measure, a thesaurus),
- Elaboration of expert judgement on other types of floods, for example those caused by heavy rains, flash floods, coastal flooding and snow melts etc.,
- Share experiences about repair and recovery after real flood events.

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LIST OF ABBREVIATIONS

CM	Crisis Management
CMINE	The Crisis Management Innovation Network Europe
CoPCM	Community of Practice in Crisis Management
DRIVER+	Driving Innovation in Crisis Management
EU	European Union
KNMI	Royal Netherlands Meteorological Institute
PoS	Portfolio of Solutions
RTFRA	Real-Time Flood Risk Assessment Methodology
SIA	Societal Impact Assessment
SP	Subproject

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