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Guideline document for integration of risk forecasting tool for different flooding scenarios into existing CPAs' procedures

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Executive Summary

A set of guidelines on integration of risk forecasting tool for different flooding scenarios into existing CPAs emergency procedures is presented in this deliverable. The risk tool outputs are integrated into the existing prefectural emergency management plans for case study areas. Different flooding scenarios developed through WP2 are considered, in order to enhance the civil emergency for the monitoring and response coordination for the minimisation of the flood risk. The guidelines are adapted to specific needs of different European CPAs.

Keywords: guidelines, civil emergency, flood risk, emergency management plan

Table of Contents

Project Information 2

Partner Information 2

Document Information 3

Executive Summary 4

Table of Contents 5

1 Introduction 7

2 Integration of the risk-forecasting tool by CPA's 8

2.1 Risk assessments and CPA's 8
2.2 Conclusion of integrating the risk forecasting tool of oVERFLOw 19
2.3 Integration in Crisis management 21

5 Guidelines for Civil Protection Agencies 23

5.1 Prevention 23
5.2 Mitigation 23
5.3 Preparedness 24
5.4 Response 25
5.5 Recovery 25

6 References 26

Abbreviations and Acronyms

Abbreviation / Acronym	Description
ACPDR	Government of the Republic of Slovenia - Administration of the Republic of Slovenia for Civil Protection and Disaster Relief
CI	Critical infrastructure
CPA	Civil protection authority
DARS	Slovenian motorway company
GIS	Geographic Information System
IPPC	Integrated pollution prevention and control Directive

1 Introduction

This deliverable is a report on integration of the risk-forecasting tool by CPAs. The deliverable provides guidelines on how to adapt the tool outputs to specific needs of different European CPAs. Within the oVERFLOw project we have improved the existing methodology with the focus on the quantification of direct and indirect impacts using higher resolution data and improved damage curves. Besides that, the existing expert judgment methodology for the vulnerability assessment of critical infrastructure has been improved using novel in-situ data collection methods (i.e. drones, thermal cameras, geophysical methods) and improved numerical models for bridges and embankments. The aim of the proposed methodology is to integrate probabilistic vulnerability assessment of flood protection system into the existing GIS platform and improved prediction of the flood impacts related to the population and built environment, namely to support decision making at the Infrastructure Managers and Civil Protection Agencies.

2 Integration of the risk-forecasting tool by CPA's

Project oVERFLOw developed a methodology that takes real-time and predicted data about river water levels to develop a better system for evacuation response. The methodology is supporting an information driven approach in Risk and Crisis management. It gives insight in the vulnerability of the dyke, embankments and bridges, the actual situation, impact of the dynamic water rise and the probability and impact of the hazards.

2.1 Risk assessments and CPA's

From 2011 onwards, in The Netherlands the 25 so-called Safety Regions (see Figure 1) are by law required to develop a regional risk assessment, also referred to as 'regional risk profile'. To assist the regions in this endeavour and realize a common practice and understanding, in 2009 a 'National Guideline on Regional Risk Assessment' has been developed, as a joint initiative of the Dutch Association for Firefighting and Disaster management, the Dutch Association for Medical Emergency Management, the Council of Chief Constables and the Council of Municipal Disaster Management, in close cooperation with the Ministry of the Interior and Kingdom Relations and experts from nearly all Dutch Safety Regions.

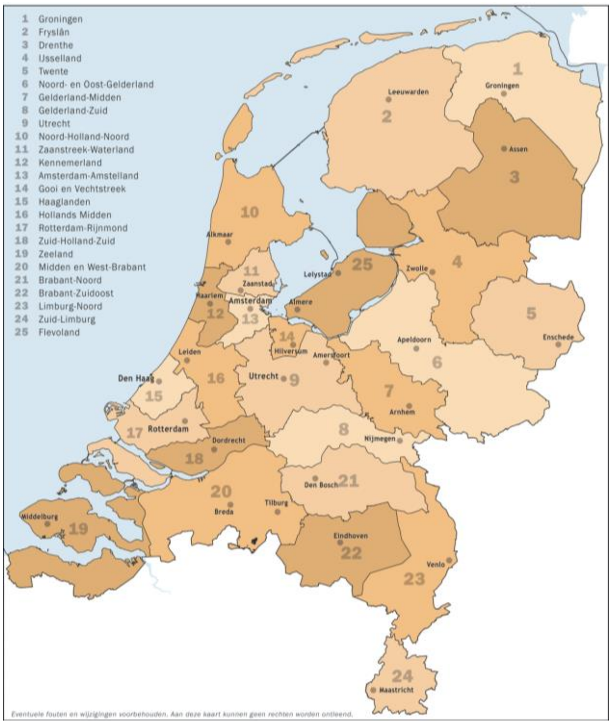

Figure 1: Safety regions in the Netherlands[1]

In this guideline the way how the regions can identify hazards, analyse them, and support the process of political decision making on risk management policies is described. It enables a

[1] https://en.wikipedia.org/wiki/Safety_region#/media/File:2019-Veiligheidsregio-1200.png

comparison between the regional risk assessments and ensures a close connection between the regional assessments and the national risk assessments, the method as described in the national guideline is based upon the method used by the Dutch central government.

2.1.1 Organization of public safety and security in The Netherlands

The Dutch constitution distinguishes 3 government levels: the central government, the provinces and the municipalities. The central government consists of the parliament and the cabinet, headed by the prime minister.

However, the main responsibility for safety and security, and risk management policies, is dedicated to the so-called 'de-centralized governments': primarily to the municipalities and secondary to the 12 provinces. The municipalities are responsible for firefighting, police and security, risk management and disaster preparedness. The provinces are responsible for risk policies only concerning issues that transcend the level of the municipalities. While the formal responsibilities for safety and security are mainly concentrated in the 344 municipalities, effectively the main government authorities for safety and security are, however, organized on the level of 25 regions.

Formally the Dutch constitution does not recognize these 'regions' as a fourth government level, separate from the central, provincial and municipal governments. However, to ensure that safety en security policies are corresponding between municipalities, instead of depending on the coordinating role of the 12 provinces, by law the 344 municipalities are clustered into 25 Police Regions (since 1993) and 25 corresponding Safety Regions (since 2010). The mayors of the municipalities within these 25 regions together are the management of the Police and the Safety Regions. This ensures that these supra-municipal regions execute the policies the municipalities demand.

The 25 Safety Regions are, on behalf of the municipalities, responsible for the fire services, the medical emergency management, the joint emergency room of police, fire services and ambulance services (112), and the disaster preparedness and response. Furthermore, the Safety Regions give advice to the municipalities and provinces on risk reduction policies. Implementation of risk reduction policies, however, effectively remains a responsibility of the municipalities and provinces itself.

Also, The Netherlands is divided into 26 Regional Water Authorities, the eldest form of Dutch government administration, because of the significant risk of flooding. They are responsible for the management of water barriers, water ways, water quantity (ensuring a correct water level) and water quality. The borders of the 26 Regional Water Authorities follow the dimensions of the water risk areas (water basins). This means they are completely different from the borders of the 25 Safety Regions.

2.1.2 Risk assessment methodologies

The United Nations defines risk assessment or analysis generically as a method for determining the nature and extent of risk "by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.”

The main objectives of risk assessment, require the method for risk assessment to enable a ranking of risks. Only on the basis of this ranking, in combination with political preferences, strategic choices on the risk policies can be made. The Dutch method offers the ingredients to rank risks from a multi-disciplinary perspective, leaving scope for administrative input about what is considered important and for other aspects of policy judgement.

The concept of ‘risk’ is defined as “a composition of the ‘impact’ (total of the consequences) and ‘probability’ or likelihood (a forecast about the occurrence) of a disaster or crisis”. This means the ranking of risks has to consist of these two separate dimensions.

In risk assessment impact and probability cannot be interchangeable because they are not always weighed equally. Depending on the political agenda and the risk consciousness of the inhabitants either the impact or the probability can have a deciding influence on the policy priorities. For example, in the Netherlands traditionally floods (from rivers and the sea) have had much attention. As a result, the probability of floods is very low, because the safety measures have a calculated failure risk of once in a thousand or ten thousand years. The impact, however, of such an occurrence remains very high, resulting in continual attention from policymakers for this particular kind of risk. On the other hand power failures have a far greater occurrence, but mainly a lesser impact than floods, in this case leading to far less attention from policymakers.

Shifting political preferences could, however, in the future lead to a reversal of the opinions on the risks in this example. For example, when the economic cost of a long-term power disruption are taken into account, policymakers might want to give this risk more attention as opposed to lowering the attention for floods

Hazard identification is the starting point for any risk assessment. It concerns the identification of the natural, technological and manmade hazards that can affect our region or municipality.

2.1.2.1 Dutch approach

The starting point of the Dutch approach is that in analysing safety and security risks all kinds of hazards have to be taken into account. In the Netherlands the width of an all-hazard analysis contains issues ranging from natural disasters (like floods, extreme weather and earthquakes) to technological driven disasters with hazardous materials (e.g. explosions, toxic fumes) or transport (e.g. planes, trains, pipelines) and ultimately also man-made disasters like terrorism. Moreover, an all-hazard approach brings together all these kinds of ‘classical’ disasters with ‘modern’ crises (e.g. long-term failures of utility supplies, political instability, polarization of populations and health crises like the flu pandemic). To be able to compare totally different risks in an all-hazard approach, as a basis for strategic policy choices, some sort of ‘yardstick’ is needed: a predefined model that makes it possible to measure risks in a comparable manner. In order to compare the completely different kinds of risks, that ‘yardstick’ needs to distinguish between the different sorts of consequences. In terms of the before described definition of a ‘hazardous situation’, the impact analysis needs to distinguish between the various kinds of consequences for the ‘recipients’ of a risk. The method for impact analysis therefore needs to recognize the different sorts of impacts of a disaster or crisis. In The Netherlands these different sorts of impacts are clustered in six so-called ‘vital interests of the society’.

In the Dutch approach a hazardous situation consists of two components. Firstly a 'source' with an inherent risk of the occurrence of a disastrous incident, like for example industries, transportation and natural disasters. The other component defining a 'hazardous situation' are the 'recipients' or, in the terminology of the United Nations, 'conditions of vulnerability', that bear the consequences of a disastrous incident, like inhabitants, housing, cultural heritage and the environment. Only the combination of 'source' and 'recipient' make a hazardous situation. For example, an industry with toxic materials will only lead to a considerable risk if there are people living or working nearby. This definition of hazardous situations in itself presents a possible solution for risks: separating the source from the recipient, in other words mitigation.

Based upon the 25 types of disasters and crises the Safety Regions make an inventory of all 'hazardous situations', from which one of them is flooding. The municipalities and provinces are by law required to provide data on all relevant industries, buildings and infrastructures. In the future possibly also, cultural heritage will be added, as an extra vital interest of society. These data are presented on the so-called 'provincial risk map', a digital database which is accessible from the internet (www.risicokaart.nl). The Safety Regions use this system to generate maps for every type of disaster or crisis with a geographical component. Because hazards are not limited to manmade borders, the Safety Regions jointly analyse risks that are 'border crossing', like cyber, terrorist attacks, pandemic and recently the refugee crisis.

The second step in risk assessment is the actual risk analysis. In the Dutch approach the risk analysis constitutes an analysis of disaster and crisis scenarios on the two dimensions of risk: impact (or vulnerability) and probability.

Insight in actual and future hazardous situations does not automatically translate into a risk analysis. It is impossible to try to separately analyse the hundreds or even thousands identified hazardous situations. In the Dutch approach this is considered not only impossible, but even useless, because the risk assessment needs to be directed to strategic policy making. In order to enable politicians to choose between strategic policy options rather than concrete measures for individual hazards, it is important to abstract the hazard identification to a strategic level.

The Dutch method for risk assessment therefore presupposes that threats to the safety and security are described in scenarios. Dutch risk analysis in fact is an example of scenario analysis. In international literature the accepted definition by Wilkinson states a scenario is "a tool for ordering one's perceptions about alternative future environments in which today's decisions might be played out."

For the use of scenarios in risk assessment the more precise Dutch definition is as follows: "a scenario is the expected development of a disaster or crisis, described in terms of principle causes, concrete triggers and the final consequences for the vital interests of society". The main reason for the use of scenarios as an instrument for risk assessment is the possibility to define the critical elements in the development of a disaster or crisis, as a basing for strategic policies. A scenario analysis enables the identification of the most important factors with which the outcome of a disaster or crisis can be influenced positively.

This means in one case risk reduction (meaning either reduction of the impact or of the probability) needs the most attention, while in another case disaster preparedness is most important. The risk assessment therefore enables a tight correlation between risk management and disaster preparedness.

To enable a scenario analysis the identified hazards have to be described in terms of potential disaster or crisis scenarios. For every of the 25 types of disasters and crises the experts of the Safety Regions have to determine which scenarios could realistically occur on their territory. This is called the first 'funnel': from many hazardous situations to a limited number of scenarios. The actual method for analysing scenarios corresponds directly with the before mentioned two dimensions of risks: impact and probability. In the following sections the method for impact and probability analysis is described.

Impact is defined as "the total of the consequences of a risk scenario". Because the risk assessment consists of an all hazard approach, various kinds of consequences have to be taken into account. For example, an explosion has consequences which are completely different from the pandemic outbreak of flu or social unrest. When one wants to compare the impact of such different scenarios a multi criteria analysis is needed. The Dutch all hazard approach to measuring the consequences of risk scenarios is therefore based upon the principle of so-called 'vital interests', namely in the impact analysis consequences which inflict direct damage to the vital interests of society are taken into account. In The Netherlands for the regional risk assessment six vital interests are defined, of which the first five are also used for the national risk assessment. Each of these vital interests is measured by means of 1 to 3 criteria. For methodological reasons the total of impact criteria is set to ten.

The risk analysis, based upon the hazard identification, leads to insight in the objective 'ranking' of risks. When the hazards are identified and the risks are analysed, the results are presented to the political decision makers. The final step in risk assessment is to determine the significance of the analysed risks for those who are affected. This step puts the objective analysis within the framework of the subjective political opinions. In this stage of so-called 'risk evaluation' the decisions are made about the priorities in the risk policies. Interpretation of the risk diagram In the Dutch approach the first step in risk evaluation is to present the risk diagram in a manner that enables better understanding and interpretation. This means categorizing of the plotted risk scenarios in different priorities.

The approach enables politicians to better understand the risk analysis and thus enable the decision making process on policy priorities. Disasters which could be catastrophic in consequence simply have more political attention, even if they are very unlikely to occur. In order to facilitate a transparent political decision making process, in The Netherlands the Safety Regions are by law required to present the risk assessment to all municipal councils. In the end the mayors, in their role of management of the Safety Regions, decide upon the actual policies. This process of political decision making is different in every country, but at the same time shows many similarities.

It is important for the safety and security professionals to allow the political authorities to define their own set of preferences with which they decide on the future risk policies. Political decision making is more about subjective preferences than objective risk diagrams.

These preferences could include factors like:

- public risk awareness and concerns of inhabitants
- existing policy priorities and political programs
- instructions from higher government levels

- prestigious projects (like new housing or industries)
- a disbalance between the risk level and the actual disaster preparedness.

In this first stage of political consultation, the main question is: which of the analysed risks demand more attention? This phase therefore is about strategic priorities, rather than elaborate policy options.

In the Dutch approach this is called the second 'funnel': from a wide scope of analysed scenarios to a limited set of priority risks. These priorities are the basis for further research into concrete policy options.

Having concluded the process of actual risk assessment, the next step is to define risk related policy options. Like mentioned before, this phase needs to address three questions:

- What are we already doing about the risks? (capability identification)
- What more can we do? (capability analysis)
- What more do we want to do? (setting objectives)

Capability of the CPA is a very broad term, which stands for all possible factors with which the final outcome of disasters and crises can be influenced positively. This varies from mitigation policies to prevent and constrain the possible impact and decrease the probability, to policies to improve disaster preparedness.

A (non exhaustive) summary of the suggested capabilities is

- Risk management;
    - Risk awareness of inhabitants, corporations and politicians
    - Mitigation of hazardous situations (separation of risk source and risk recipient)
    - Reduction of probability (making industries inherently safe)
    - Prevention of consequences (preventive measures to minimize the consequences)
- Disaster preparedness and response;
    - Contingency planning
    - Quantity and quality (competence) of disaster relief personnel
    - Quantity and quality of disaster relief materials
    - Command and control
    - Information management
- Recovery
    - Interconnection between disaster relief and recovery

To be able to identify the capabilities that influence a risk the most, it is necessary to analyse the developed priority scenarios once more. For every aspect of the scenario (causes, triggers, consequences) solutions can be identified. In order to finally set the objectives a cost-benefit analysis can be performed on the identified measures. On the other hand, political decisions on concrete policy measures are governed by political preferences, just like the prioritization of risk scenarios. A cost benefit analysis cannot always provide all the decisive answers.

In response to flood events The Netherlands has built strategic large flood defence schemes based on dike rings and developed a sophisticated flood risk management system VNK2 (Rijkswaterstaat, 2014). Dike-rings surround flood-prone areas and are constituted by connected embankments and other flood protection structures. The dike-rings protect the flood-prone areas against flooding according to pre-defined protection levels, ranging from 1:10 000 per year along the coast to 1:1250 per year along the rivers for the major dike-rings. (Klijn et al., 2012)

2.1.2.2 Slovenian approach

The Administration for Civil Protection and Disaster Relief is a body within the Ministry of Defence that carries out administrative and expert tasks regarding protection, rescue and disaster relief. The tasks pertain to the management, preparation and operation of the system for protection from natural and other disasters; the provision of assistance to affected local communities; monitoring, notification and warning; communications and the information system; the assessment of damage caused by natural and other disasters; fire protection and the operation of general rescue services; the organisation and operation of the Civil Protection Service and the preparation and operation of the Civil Protection Headquarters; the preparation and execution of national programmes in the field of protection from natural and other disasters; and disaster relief and post-disaster remediation.

National competence encompasses the management of the system, research and development work, drafting and implementing the national program, the elaboration of risk assessment and national emergency response plans, organization and equipment of national response units and services, on-site leadership of units and services in the event of a major disaster, organization of information and communication systems, damage assessment, assistance in reconstruction and recovery in order to prevent further damage and provide basic living conditions, drafting education and training program, inspections and international cooperation.

Local community competencies encompass: monitoring of danger and the provision of information and warnings in the event of danger, provision of communication means for local units and services, elaboration of local risk assessment and emergency response plans, implementation of protective measures in the event of a disaster, organization of individual and group protection for the population, organization and equipment of CP and other local response units and services, provision of emergency accommodations, training of local units and services, provision of on-site leadership for local units and services, disaster recovery efforts.

For the safety and management of roads and there are a few stakeholders responsible in Slovenia depending on the roads level. For the state roads there is Ministry of infrastructure, for highways Slovenian motorway company (DARS) is responsible and for municipal roads local communities. State concessionaires are in charge for the maintenance of state roads.

Additionally, the dams and embankments are under the jurisdiction of Ministry of infrastructure, Ministry of environment and infrastructure owners and operators.

Slovenian Environment Agency oversees the national network of hydrological and weather stations.

Response units dealing with flooding events in Slovenia are mostly firefighters (at the local level) as first responders and regional/national high-capacity pumping teams.

For flood hazard monitoring the ACPDR uses GIS application SMOK system[2] for monitoring of water levels. The application is used as a tool and support for decision makers in disaster response. In addition to the mentioned application, the hydrological warnings and reports

[2] https://smok.sos112.si/Voda/PostajaMap/Map?Alarm=True&Narasca=True&Pada=True&Ustaljen=True&Brez=False

compiled and published by Slovenian environment agency are used. These warnings and reports are published in written and graphic form, which show current hydrological situation and forecast for the current and the next day, including alarm levels for individual areas.

Parameters used are water level and water flow. Both values are acquired from the national network of hydrological stations maintained by Slovenian environment agency (Agencija Republike Slovenije za okolje, 2021). Data is interpreted with Rules on methodology to define flood risk areas and erosion areas connected to floods and classification of plots into risk classes. Flood risk map, flood hazard map and map of areas of significant flood impact are also used.

2.1.2.3 Croatian approach

In Croatia a document entitled "Preliminary Flood Risk Assessment" is prepared every six years and serves as a basis for River Basin Management Plan for Croatia (Croatian Waters, 2013). The first one was published in 2013 using available information and data which identifies all areas where potentially significant flood risks exist or are likely to occur. This document identified areas of potentially significant flood risk according to the following criteria: recorded significant floods, frequently flooded areas, potentially flooded areas, areas affected by floods caused by failure of flood defences and areas affected by flash (torrential) floods. It was developed by Croatian Waters and has the characteristics of an expert assessment, using the available data. Another Preliminary Flood Risk Assessment was published in 2019 for the planning period of 2022-2027. The document has significantly wider range of collected data, and it also includes new thematic units such as climate change, cultural heritage or future economic development activities.

The preliminary risk assessment contains the following:

- Maps of the river basin district at the appropriate scale, with the boundaries of the river basin districts and coastal areas, showing the topography and land use,
- Description of historic floods which had an adverse impact on people, environment, cultural heritage and economy, as well as assessment of probability that a similar scenario may occur in the future,
- Assessment of potential adverse impact of future floods on population (life and health), environment, cultural heritage and economy taking into consideration topographic, hydrological and geomorphological characteristics. Here are also included flooding areas and natural retention areas, efficiency of existing flood defense structures, location of settlements and industrial zones, as well as long-term development plans and effect of climate change on floods).

Based on the preliminary flood risk assessment, flood hazard maps and flood risk maps for each river basin district were prepared in cooperation with experts from the Netherlands, Austria and France in the Twinning project "Development of flood hazard maps and flood risk maps". During the implementation of the Twinning project, flood hazard maps and flood risk maps were developed for three flood scenarios, namely floods of high, medium and low probability of occurrence. Maps were subsequently made for the whole Croatian territory and are available online[3] (Croatian Waters, 2013).

Flood risk maps have the following content:

- Number of endangered populations by settlements (up to 100, from 100 to 1,000, more than 1,000 persons) – source Central Bureau of Statistics.
- Data on land use (populated areas, areas of economic use, intensive agriculture, other agriculture, forests and low vegetation, wetlands and sparse vegetation, water areas) according to CORINE Land Cover 2006 taken from the Environmental Protection Agency.
- Infrastructure data (airports, railway stations, river and sea ports, bus stations, hospitals, schools, kindergartens, retirement homes, water intakes, substations, railways,

[3] http://korp.voda.hr/

embankments, highways, other roads) taken from competent institutions and / or collected from public data sources, and from the archives of Croatian Waters.

- Data on environmental protection taken from competent institutions and / or collected from the archives of Croatian Waters, i.e. from the Register of Protected Areas (habitat or species protection areas, national parks, water protection areas, bathing areas, IPPC / SEVESO II plants, waste water treatment).
- Data on cultural heritage taken from the competent institutions (UNESCO sites).

Consequences of the flood hazard are determined based on the methodology presented in “Disaster risk assessment for Republic of Croatia”, developed by Main working group of the Croatian Platform for Disaster Risk Reduction (2019). In this document different risks are identified and with each risk a preliminary scenario is associated. Consequences of events are evaluated by impacts on the following three categories: Human Life and Health, Economy and Social Stability and Politics. Some impacts are easily quantified while others require a qualitative approach. For the purposes of selecting priority risks for processing in the first National Assessment, the categories are developed only as having a small, moderate or large impact and a small, moderate or high probability. This is the approach also adopted in the oVERFLOw to make it applicable with already existing practices and strategies.

2.2 Integration of the oVERFLOw risk forecasting tool

In the Deliverables 5.1 and 5.2 (Skaric Palic & Stipanovic, 2022) risk assessment methodology and the application on case study areas are presented, which aim to improve decision making during the flood risk management stages and planning of the investments to increase the resilience of the critical infrastructure. Flood risk assessment methodology is based on the intersection of flood hazard scenario for certain return period with the affected area, for which vulnerability or damage functions are developed. Results of the vulnerability analysis are combined with possible consequences of a flood in the developed GIS-based risk forecasting tool. The risk forecasting tool provides valuable information for infrastructure managers and civil protection agency, namely it predicts the consequences of different flood scenarios in the affected area. oVERFLOw methodology for quantification of flood impacts includes:

i. The quantification of impacts in monetary value to show direct flood damage to different assets, which can be used by infrastructure managers, owners or local authorities. This information can support decisions such as the prioritization of assets which need to be upgraded, identification of possible needed interventions and investments for flood protection system, transport infrastructure or any other endangered asset. The model is used in final risk assessment and can be also used for cost benefit analysis.

ii. Mapping of vulnerability of critical infrastructure, flood water levels and population density in the affected area, which gives the insights into the safe evacuation routes and the number of people who need to be evacuated. This information is especially important for CPAs and first responders about the endangered population, areas with low rise buildings or buildings with people without self-sufficiency (preschools, schools, old-people homes etc.) where their immediate attention is needed in case of floods. It also provides the information about safety evacuation routes so they can reach certain areas without delay or endangerment.

Results of the implementation of the risk forecasting tool model are presented for two case studies, City of Karlovac in Croatia and Oostmolendijk in the Netherlands. In both cases we have shown the benefits of the integration of the improved risk assessment methodology into the existing tools and procedures, thus revealing the information about the areas with the highest potential risk enabling prioritization of the investments and evacuation planning. The methodology of the risk assessment of oVERFLOw provides the information which can be used on the Risk analysis part with the Water authorities and Municipality in charge, , and is input for the risk reduction possibilities. The Waterboard is the partner to work on the mitigation of the hazardous situation and the municipality should be cooperating with the Waterboard and is ultimately responsible for the prevention of consequences. The CPA can advise the municipality in this case.

The tool provides quantification of the flood consequence analysis, which includes direct and indirect impacts. The outputs of the tool can be used as a support for the decision making, based on the cost-benefit analysis of flood protection systems vs. direct impacts and prioritization of human lives and societal aspects.

However, a critical note in the cost benefit analysis is that the effect of a flooding is not locally but regional and even more in case of the Dutch situation ‘Oostmolendijk’ national, due to the port of Rotterdam and the hinterland meaning the rest of Western Europe.

A CPA can take its leading role in the capability identification and analysing. By showing the impact of a flooding in the area, on the embankments and bridges, the CPA can use it in its preparedness actions (like e.g. raising the risk awareness of inhabitants via communication, preferably together with the Waterboards, Critical Infrastructure stakeholders and the municipality) and in preparedness planning as well as response integration in crisis management and exercises.

2.3 Integration in Crisis management

In Crisis management there are five phases to be distinguished, namely Prevention, Mitigation, Preparedness, Response and Recovery.

Prevention focuses on preventing hazards from occurring, whether they are natural, technological, or caused by humans. Not all hazards are preventable, but the risk of loss of life and injury can be limited with environmental and spatial planning and design standards.

The oVERFLOw outcome of the risk assessment shows the impact of a breach of failure of embankments in the affected area. This means that when new investments are planned, the flood hazard maps and impact analysis should be taken into account during the planning process and the decision making by the authorities, in order to prioritize the investments into critical infrastructure.

Mitigation is the effort to reduce loss of life and property by lessening the impact of disasters and emergencies. It refers to measures or actions that can prevent an emergency, reduce the chance of an emergency or reduce the damaging effects of unavoidable emergencies. The establishment of building codes and zoning requirements or the creation of defensible space around homes to protect them from the hazard impacts are examples of mitigation efforts.

The project oVERFLOw shows the critical areas and measures that can be taken either on restructuring or redesigning existing situations in spatial planning or other initiatives in the area. In case of the Dutch situation Oostmolendijk, it offers suggestions how to reconstruct the dyke so that the vulnerability level can be lowered. But also, for existing houses, industries, critical infrastructure it is good to raise awareness and think about mitigation measures which can be taken by the owners of properties. The authorities which are responsible for the critical infrastructure should think about barriers and adjustments to lower the vulnerability.

For the Karlovac case study calculation of direct damage to transport infrastructure, buildings and land type is summed up in million € for three different flood scenarios. Based on the performed analysis it can be concluded that the total damage costs are increasing with the increase of the return period, or the extent of the flood event. These results support Infrastructure Managers decision making regarding investments and mitigation measures for flood protection systems and other infrastructure based on the insight into areas with the highest risk.

Preparedness is a continuous cycle of planning, organizing, training, equipping, exercising, evaluating and taking corrective action. Training and exercising plans of CPAs is the cornerstone of preparedness. Training and emergency preparedness plans increase the ability to respond when a disaster occurs. Typical preparedness measures include contingency plans, evacuation plans, training for response personnel on different levels, educational and awareness raising campaigns for affected citizens or vulnerable groups, conducting disaster exercises to reinforce training and test capabilities.

The outcome of the oVERFLOw risk forecasting tool gives the input for review and adjustment of evacuation plans, action perspectives when the dynamic systems show changes in the colour of warning signal.

In preparation phase it is necessary to involve the stakeholders of CI, but also the adjacent municipalities and Safety Regions, as flooding and its impact is not likely to be just locally, but more regional and inter-regional.

The **response** phase is a reaction to the occurrence of a catastrophic disaster or emergency. It consists of actions which are aimed at saving lives, reducing economic losses and alleviating suffering. The response phase comprises the coordination and management of resources utilizing the Incident Command System.

In case of flooding, the response actions will include activating the emergency operations centre, decision making whether to evacuate threatened populations, opening shelters and providing mass care, emergency rescue and medical care, fire fighting, and urban search and rescue for example with the National Rescue Fleet.

oVERFLow will help us to locate the properties which are flooded and to what extent. It will also give insight during the decision making process what the impact and possibilities of evacuation will be (e.g. safety of the bridges to be used during the evacuation) and to determine what area should be evacuated first. GIS layer with critical infrastructure such as hospitals, schools, kindergartens, shelters etc. enables CPAs to prioritize evacuation and also have the information where it is possible to take the evacuated population. Another GIS layer is provided with the information on safe evacuation routes (flooded roads, safe and available bridges and embankments), location and number of most vulnerable population regarding type of buildings (low rise buildings-no dry floors).

Recovery consists of those activities that continue beyond the emergency period to restore critical community functions and begin to manage stabilization efforts. The recovery phase begins immediately after the threat to human life has subsided. The goal of the recovery phase is to bring the affected area back to some degree of normalcy, including the restoration of basic services and the repair of physical, social and economic damages. Typical recovery actions include debris clean-up, financial assistance to individuals and governments, rebuilding of roads and bridges and key facilities, and sustained mass care for displaced human and animal populations.

The outcome of the oVERFLOw project does not have a direct input for the recovery plans in the area.

3 Guidelines for Civil Protection Agencies

As determined in the previous chapters the outcome of the oVERFLOw project can be used by the Civil Protection Agencies in the various phases of Crisis management. In this chapter the use per phase is summarized.

3.1 Prevention

Based on the oVERFLOw outcome of the risk assessment, the impact of a breach of failure of embankments in the affected area needs to be updated and predicted based on the actual water levels. Therefore CPA should establish regular meetings with the several stakeholders. The stakeholders can be defined by the municipality, waterboard and the authorities of the Critical Infrastructure objects.

On a regular basis a meeting should be organised with the above-mentioned stakeholders and the topics on the agenda should be at least the following:

- Current situation
- Spatial developments
- Measures to reduce of probability (making it inherently safe).

3.2 Mitigation

Mitigation measures are most important for the increase of the resilience of critical infrastructure such as embankments, dykes and bridges. Maintenance and reconstruction planning are under the responsibility of the infrastructure owners and authorities, and not under direct authority of CPAs. Vulnerability assessment methodology for embankments and bridges developed in oVERFLOw is used to reduce known uncertainties regarding the response and behaviour of critical infrastructure during flood events. The results are used to highlight critical sections of infrastructure or parts of structures with the highest probability of failure depending on the water height during a flood. Connecting these results with potential consequences of a flood event gives the infrastructure managers and CPAs risk values for certain area. Based on that outcome, possible mitigation measures are proposed, that can be taken in order to decrease the vulnerability of the critical infrastructure and reduce the risks for the affected area. These measures should be also discussed between CPAs and stakeholders, as they can be used for the mitigation of hazardous situations.

Calculation of direct damage to transport infrastructure, buildings and land type support Infrastructure Managers decision making regarding the prioritization of the investments into flood protection systems and other infrastructure.

CPAs are provided with the information on safe evacuation routes (flooded roads, safe and available bridges and embankments), location and number of most vulnerable population regarding type of buildings (low rise buildings-no dry floors). GIS layer with critical structure such as hospitals, schools, kindergartens, shelters etc. enables CPAs to prioritize evacuation and also have the information where it is possible to take the evacuated population.

Therefor the topics to discuss on a regular basis between CPAs, municipality, responsible authorities and / or CI stakeholders are:

- Current situation
- Spatial developments
- Measures to reduce of probability (making it inherently safe);
- Mitigation of hazardous situations (separation of risk source and risk recipient)
- Financial impact and benefits.

3.3 Preparedness

The risk forecasting tool is input for optimising the contingency planning, evacuation plans, as well as raising awareness in campaigns for the citizens, decision making authorities and professionals.

As explained in Chapter 2.3, crisis management involves development of preparedness plans, trainings and exercises for different scenarios and tools. Therefore the GIS layers from oVERFLOw risk forecasting tool should be used regularly during the exercises. If not, it most probably will not be used during a real incident because personnel is not familiar with it and will not be able to use and interpretate the content.

Also very important is the expert-interpretation of the water and embankment situation, therefore the experts (water authorities) should always be trained and have a role in the exercises as well.

Based upon the insight from the risk forecasting tool, people can also see whether they are safe or whether their house will be flooded (e.g. one, two or three stories). They themselves can use this information for mitigation purposes but can also prepare themselves e.g. making sure they can move their valuable household items a story higher. This can be used in communication campaigns.

Secondly oVERFLOw forecasting tool gives the insight in the kind of impact on locations where vulnerable groups are located. CPA's can use this information for evacuation plans, but also to discuss this with the institutions and organisations who facilitate these vulnerable people.

A summary for the guidelines for preparedness:

- Integration into the existing GIS system
- Input for actualisation of the existing contingency and evacuation plans
- Involvement of water authorities about the integration of outputs into the planning procedures
- Training and exercises for emergency professionals and water authorities using the tool outputs
- Awareness raising through communication campaigns, citizens and professionals
- Communication campaign or meetings with stakeholders, like healthcare institutes, elderly homes and other vulnerable groups
- Regular evaluation of situation and use of risk forecasting tool (updates).

3.4 Response

The response phase is a reaction to the occurrence of a catastrophic disaster or emergency. The oVERFLOw tool gives the insight in the actual situation of the object (bridge or embankment) and the impact of its failure. When the integration of the tool has taken place in the preparation phase the scenarios in the contingency plans and the adjusted evacuation routes can be updated. This information should be always checked with the water authorities and municipalities as they are expert on either the water management (water level monitoring system) and the local urban situation.

The GIS layer (when checked with the experts) should give an overview of the actual operational picture and should improve the decision making by the emergency services and authorities. It should give insight in the involved stakeholders CI, and an overview of the number of affected citizens and the expected impact on the area.

A summary for integration of the risk forecasting tool in the response phase:

- When there is a threat check of the GIS layer with the actual situation
- Ask advice and interpretation of water authorities before decision making
- Contact with adjacent municipalities and regions and share advice water authorities
- Define the impact on the several locations, CI, citizens and vulnerable groups before decision making

3.5 Recovery

Recovery consists of those activities that continue beyond the emergency period to restore critical community functions and begin to manage stabilization efforts. Proposed mitigation measures (D6.4) can be also used as recovery measures.

6 References

Agencija Republike Slovenije za okolje, (2021) Program hidrološkega monitoringa površinskih voda, http://www.arso.gov.si/vode/poro%c4%8dila%20in%20publikacije/ (in Slovenian)

Bau V., Kosic, M., Anzlin, A., Bacic, M. (2022). oVERFLOw Deliverable 6.4 Development of the strategy for adaptation measures to flood events.

Croatian Platform for Disaster Risk Reduction - Main working group, Republic of Croatia, 'Disaster risk assessment for Republic of Croatia', 2019.

Croatian Waters, 'Preliminary Flood Risk Assessment – Republic of Croatia: Danube river basin district and Adriatic water area', 2013

Croatian Waters, 'Water area management plan 2022 – 2027', Flood risk management, Preliminary Flood Risk Assessment 2018.', published July 2019

Dottori, F., Kalas, M., Salamon, P., Bianchi, A., Alfieri, L., & Feyen, L. (2017). An operational procedure for rapid flood risk assessment in Europe. Natural Hazards and Earth System Sciences, 17(7), 1111–1126. https://doi.org/10.5194/nhess-17-1111-2017

EEA. (2016). Flood risks and environmental vulnerability - Exploring the synergies between floodplain restoration, water policies and thematic policies. In EEA Report No 1/2016. (Issue 1).

Jorissen, R. E., & van Noortwijk, J. M. (1998). Instrumenten voor optimaal beheer van waterkeringen. Het Waterschap, 83, 6–12 & 42–47.

Klijn, F. & De Bruijn, Karin & Knoop, J.M. & Kwadijk, Jaap. (2012). Assessment of the Netherlands' Flood Risk Management Policy Under Global Change. Ambio. 41. 180-92. 10.1007/s13280-011-0193-x.

Kolen, B., & van Gelder, P. H. A. J. M. (2018). Risk-Based Decision-Making for Evacuation in Case of Imminent Threat of Flooding. Water, 10(10), 1429. https://doi.org/10.3390/w10101429

Krzhizhanovskaya, V. V., Shirshov, G. S., Melnikova, N. B., Belleman, R. G., Rusadi, F. I., Broekhuijsen, B. J., Gouldby, B. P., Lhomme, J., Balis, B., Bubak, M., Pyayt, A. L., Mokhov, I. I., Ozhigin, A. V., Lang, B., & Meijer, R. J. (2011). Flood early warning system: design, implementation and computational modules. Procedia Computer Science, 4, 106–115. https://doi.org/10.1016/j.procs.2011.04.012

National Guideline on Regional Risk Assessment (Handreiking Regionaal Risicoprofiel), Dutch Association for Fire fighting and Disaster management, the Dutch Association for Medical Emergency Management, the Council of Chief Constables and the Council of Municipal Disaster Management, 2009

Pruyt, E. and D. Wijnmalen, National Risk Assessment in The Netherlands. A MultiCriteria Decision Analysis Approach, 2010

Regional Risk Assessment in The Netherlands An introduction by Ruud Houdijk 1 st MiSRaR seminar 27th May 2010

Rijkswaterstaat (n.d.) [Waterberichtgeving Dordrecht (Oude Maas)] https://waterberichtgeving.rws.nl/wbviewer/maak_grafiek.php?loc=DORD&set=Eindverwachting-RMM&nummer=1 Accessed on 27-01-2022.

Rijkswaterstaat VNK Project Office (2014) The National Flood Risk Analysis for the Netherlands, https://www.helpdeskwater.nl/onderwerpen/waterveiligheid/programma-projecten/veiligheid-nederland/

Skaric Palic, S., Stipanovic, I. (2022). oVERFLOw Deliverable 5.1 Quantification framework for direct and indirect impacts of flooding hazards.

Skaric Palic, S., Stipanovic, I. (2022). oVERFLOw Deliverable 5.2 D5.2 Report on risk forecasting tool applied on case study areas.

Speijker, L. J. P., Van Noortwijk, J. M., Kok, M., & Cooke, R. M. (2000). Optimal maintenance decisions for dikes. Probability in the Engineering and Informational Sciences, 14(1), 101–121. https://doi.org/10.1017/s0269964800141087

Stoutjesdijk, C. (2015). Gebiedsanalyse 'peilgebied 27A.'

United Nations International Strategy for Disaster Risk Reduction, UNISDR Terminology on Disaster Risk Reduction, UN ISDR, Geneva, 2009.

Working with scenarios, risk assessment and capabilities, Dutch Ministry of the Interior and Kingdom Relations, 2009

World Economic Forum. (2019). Global Risks Report 2019, 14th Edition. World Economic Forum.

Zhang, W., Zhou, J., Liu, Y., Chen, X., & Wang, C. (2016). Emergency evacuation planning against dike-break flood: a GIS-based DSS for flood detention basin of Jingjiang in central China. Natural Hazards, 81(2), 1283–1301. https://doi.org/10.1007/s11069-015-2134-7