Preparedness against hazardous events: A novel tool for water utilities

Christina Tsouti
DRAXIS Environmental SA
chtsouti@draxis.gr

Eleni Ntzioni
DRAXIS Environmental SA
entzioni@draxis.gr

Efstathia Tsarouchi
DRAXIS Environmental SA
etsarouchi@draxis.gr

Dimitris Sakellariou
DRAXIS Environmental SA
dsakellariou@draxis.gr

Marios Kotoulas
DRAXIS Environmental SA
mkotoulas@draxis.gr

Christina Papadaskalopoulou
DRAXIS Environmental SA
chpapadaskalopoulou@draxis.gr

Katerina Valta
DRAXIS Environmental SA
katvalta@draxis.gr

Anastasios Karakostas
DRAXIS Environmental SA
akarakos@draxis.gr

ABSTRACT

Various terms and approaches currently exist on outlining the constituent components of crisis management as well as their interrelations, focusing mainly on the effective communication between the members of the crisis management unit. A gap emerges regarding a high-level and holistic approach on crisis management that will have the organization's preparedness as its main pillar. In this work, crisis is organized into three macro-stages, i.e., pre-crisis, crisis, post-crisis. Preparedness is conceptualized as an overarching concept that frames an organization's crisis management approach to reduce its vulnerability in a potential crisis. The study focuses on developing a high-level tool to enhance the preparedness of water utilities. The tool aims to serve as a holistic crisis management framework to support stakeholders in qualitatively assessing and improving their level of preparedness. The "Preparedness against hazardous events" tool was the result of this work, which was positively assessed through experts' evaluation.

Keywords

Crisis management, tool, preparedness, assessment.

INTRODUCTION

Background

Both at the international and the European level there are several regulations and guidelines that turn the spotlight on drinking water and water security issues, linking them with environmental protection and preservation as well as human rights. At the European level, in general, the legislative framework does not directly address the topic of crisis management in water supply infrastructures, with the Floods Directive (2007/60/EC) being slightly closer to this concept by introducing preliminary flood risk assessment, flood hazard and risk maps and flood risk management plans. Additionally, in 2004 the European Commission (EC) has proposed to develop and implement a concerted EU Action Programme on flood risk management, where the concepts of "preparedness", "emergency response" and "recovery" shall be incorporated (COM (2004) 472 final). In 2009 the World Health Organization (WHO) and the International Water Association (IWA) published the *"Water Safety Plan Manual: step-by-step risk management for drinking-water suppliers"* to be used as a practical guide for the development of water safety

plans (WSP) in water supply systems managed by water utilities or relevant entities.

It is therefore evident that the EU legislative framework, as well as the international guidelines, cannot support per se the water utilities in perceiving the concept and developing concrete crisis management plans for future events to enhance their preparedness. On the contrary, standards proved to be valuable in supporting an organization in such activities and processes. There are several standards that are related specifically to water security and crisis management in water supply infrastructure: *EN/TS 17091 Crisis Management –Developing a Strategic capability*, *EN 15975 Security of drinking water supply – Guidelines for risk and crisis management,* and in particular part 1 which refers to crisis management is of great relevance, *ISO/DIS 24518: Activities relating to drinking water and wastewater services — Crisis management of water utilities* and *ISO 24520: Service activities relating to drinking water supply systems and wastewater systems — Crisis management — Good practice for technical aspects*. These four standards adopt the three-phase approach for the characterization of crisis management, i.e., pre-crisis, (during) crisis and post-crisis. Another point that all four standards agree on, is the identification of preparedness as a key component in the crisis management framework, along with response and recovery. Finally, it is highlighted that there are three key elements when it comes to crisis management, and these are people/staff, processes and resources.

Terminology

Crisis management

Two crucial aspects are encompassed within "crisis management", i.e., the term crisis and the term management. Both terms have a wide range of interpretations and definitions in literature and thus need to be perceived through their complexity and multiplicity. In ISO 22300:2021, a great overview and variety of terms on security and resilience, along with their definitions, is provided, covering not only crisis and risk, but also disaster and emergency definitions. The crisis management concept is closely associated with emergency management, based on the definitions given. Interestingly, there is a significant differentiation in wording in the case of crisis management and emergency management, where one can start perceiving the concept behind crisis management. Additionally, as Albtoush, Dobrescu, and Ionescou (2011) state, crisis management is differentiated from risk management in the fact that the latter *"involves assessing potential threats and finding the best ways to avoid those threats"*, while *"crisis management involves dealing with threats after they have occurred"*. Furthermore, they continue with saying that crisis management *"is a discipline within the broader context of management consisting of skills and techniques required to identify, assess, understand, and cope with a serious situation, especially from the moment it first occurs to the point that recovery procedures start"* (Albtoush, Dobrescu, and Ionescou, 2011).

Regarding the term "crisis" alone, apart from the international standards, several definitions of the term are also available in the literature. One of the main characteristics of a crisis seems to be its predictability, since it usually occurs suddenly and requires immediate action. Moreover, immediate, and effective response is crucial since a crisis can have severe impact on an organization or/and the environment and society. The same pattern, i.e., various approaches, is observed also in perceiving the various stages within a crisis. Several frameworks have been proposed during the years, which divide crisis into different stages with specific characteristics. The division of a crisis into stages or phases is based on the conceptualization of the crisis life cycle. During the years several frameworks have been proposed including 3-stage (Smith, 1990, Richardson, 1994, Crandall, Parnell, and Spillan, 2009, Frandsen and Johansen, 2017), 4-stage (Myers, 1993 and Fink, 1996) and 5-stage crisis approaches (Pearson and Mitroff, 1993). In this work, the 3-stage approach is adopted.

Preparedness

Crandall Parnell, and Spillan (2009) state that for many organizations a crisis is directly linked with catastrophic events and thus many of them adopt *an "it can't happen to us" mentality*. They also conclude that a crisis will occur in most organizations during their lifetime, and for this reason, crisis management should focus on *not only preventing a crisis from reoccurring, but also in mitigating its impact once it has occurred* (Crandall Parnell, and Spillan, 2009**)**. So instead of focusing on if and when a crisis will occur, one should focus on if one is prepared for when a crisis hits.

In Table 1, some indicative definitions on the concept of preparedness are presented, as found in the relevant literature. The aim is to perceive the essence of the term and not provide an exhaustive list of definitions.

Table 1. Indicative definitions on the concept of Preparedness

Authors	Definition

World Health Organization (WHO, 1995)	*A programme of long-term development activities whose goals are to strengthen the overall capacity and capability of a country to manage efficiently all types of emergency and bring about an orderly transition from relief through recovery, and back to sustained development.*
Alexander (2002)	*Preparedness. Actions taken to reduce the impact of disasters when they are forecast or imminent.*
Danish Emergency Management Agency (DEMA, 2009)	*Preparedness planning is about preparing for extraordinary incidents that cannot be managed with ordinary resources and routines alone. In other words, preparedness planning is about creating resilient organizations.*
Baubion (2013)	*Preparing for crisis has traditionally consisted in developing capacities and tools to prepare for crises that occurred in the past. Preparing for the new landscape of crises requires adapting approaches that enable preparation for response to the unknown.*

All the definitions mentioned above, seem to agree that preparedness involves a set of actions/activities that can help an organization respond effectively to a potential crisis or event, prevent specific incidents that might occur, and reduce their impact both on the organizations and its surroundings. Since preventing a crisis is not always feasible, reducing the organization's vulnerability through enhanced preparedness is a crucial issue.

Research gap

There is a great variety of terms used to describe an abnormal operational situation, the meaning of which is closely linked, complements, or even overlaps with each other. Crisis, risk, disaster, emergency, impact, hazards, and hazardous events are the most common terms when it comes to the occurrence and management of an event that may or does disrupt the normal operational procedures of a system. The situation is the same when one focuses on crisis management. Various terms, definitions and approaches exist on the constituent components of crisis management, as well as their interrelations. Furthermore, there is a variety of guidelines providing information on crisis management approaches, definitions, and constituent components focusing mainly on the existence, structure, and effective communication between the members of a crisis management unit.

A gap emerges regarding a high-level approach on crisis management that will have preparedness as its main pillar. In this work, preparedness is not perceived as one of the structural components of crisis management stages, but becomes a key concept that runs through all the various stages of crisis management. In other words, preparedness is not only found in the pre-crisis stage, but also in the crisis and post-crisis ones. Furthermore, preparedness is conceptualized as a holistic approach that frames the crisis management approach of an organization, to reduce its vulnerability in a potential crisis. The aim is for an organization to expand its understanding of preparedness in actions other than specific mitigation measures.

To this end, this paper presents a tool to support the stakeholders who are responsible for a water infrastructure in assessing their preparedness level against a series of hazardous events. Moreover, the tool provides high-level recommendations to help organizations improve their level of preparedness. The primary end user is the asset owner and/or operator, however, the use can be extended to broader stakeholder groups, that involve actors engaged in some capacity in the crisis management chain of actions in water utilities. At this point, it should be made clear that the tool's scope is not specialized risk assessment; such assessments are carried out by specific simulation software, e.g., hydrological modelling, seismic modelling etc. SCADA (Supervisory Control and Data Acquisition) is a key example of these simulation software tools, that monitors, gathers and processes real-time data. Such functionalities are not offered by the developed tool, as its main goal is to inform the users on the variety of areas and actions that crisis management can encapsulate for an effective crisis management approach within an organization. More specifically, the tool aims to deliver a high-level analysis to inform users about potential gaps in their established crisis management approach, in order to create or update their crisis management plan. In more detail, the tool will allow the end users to identify areas of strength and weakness to improve preparedness. Preparedness refers to both infrastructural capacities (e.g., a warning system) but also to organizational arrangements supporting response.

METHODOLOGY

To begin with, it is important to mention that the several methodological steps presented below should not be considered to be strictly incrementally implemented, as continuous feedback took place between the various steps.

In more detail, the first step was to conduct a thorough literature review. Literature review included the study of scientific papers and book chapters, standards, national and international guidelines, project's deliverables, online tools, etc. Several key words were used to explore literature, such as: preparedness, crisis management, disaster, emergency management, risk assessment, water utilities, hazardous events, water safety plans, mitigation actions, etc. The purpose of the review was to gain comprehensive insight on crisis management domain and crisis management in water supply systems in particular, as well as other closely linked domains, such as risk management and assessment. As a second step, a questionnaire was distributed to domain experts, serving as end users of the tool, to gain a deeper understanding of the unique characteristics of their infrastructure and established crisis management approach. The third step was to formulate the concept and the content of the tool. This was a dynamic process, and domain experts were actively involved. Having outlined the concept of the tool, the actual content of the tool was structured. Once the main concept and content of the tool have been formulated, the fourth step was to go through a validation procedure with the domain experts. The concept and content of the tool were presented to the experts, so as for them to provide comments and feedback.

The contribution of domain experts was also requested for the formulation of the preparedness assessment model. The assessment model for the tool is simple, rather than a multiparametric algorithm. Domain experts contributed in the formulation of the assessment model by providing their input on determination of weighing factors, regarding selected crisis management actions, and impact level of hazardous events on water utilities components. Regarding the weighing factors, the domain experts were provided with excel spreadsheets that included all the information, and were requested to rank each action using an integer from one (1) to five (5), with number one (1) indicating an action of very low importance, while number five (5) indicates an action of very high importance. Contributors were encouraged to go through this exercise in a collaborative way with any personnel they considered appropriate. For determining the qualitative high-level impact of the included hazardous events on the water supply system components, the domain experts were provided with an excel spreadsheet and were requested to indicate the level of potential impact of each of the hazardous events on the system components. Three were the possible options for indicating the high-level impact of the various hazardous events, i.e., "High", "Medium", and "Low". Domain experts were requested to not take into consideration the implementation of mitigation actions in their answers.

Based on the received input, content adjustments and modifications were considered and implemented. The preliminary design of the tool, first in the form of wireframes and then mockups, was the fifth step. Mockups were presented to the domain experts, so as for them to have a clear perception of what the tool's functionality and feedback was also requested. The sixth step was the finalization of the preparedness assessment model. Nevertheless, the finalization process came after receiving feedback from the domain experts in previous steps. Finally, having finalized the concept, the content and the assessment model, the development of the *"Preparedness against hazardous events"* tool was initiated.

RESULTS

The *"Preparedness against hazardous events"* tool is divided in four sections, as depicted in **Error! Reference source not found.**.

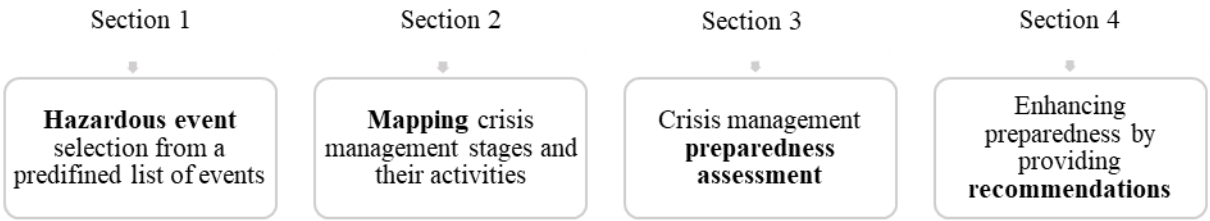


Figure 1. The tool's four sections

Content

Section 1: Hazardous events

In this first section of the tool, sixteen hazardous events are included for the user to select from and proceed with the assessment, and are presented in Table 2.The hazardous events that have already been experienced by the domain experts are indicated with a grey color, while hazardous events taken from literature are indicated with white.

Table 2. The selected hazardous events

Hazardous events			
Algae bloom	Flood	Color/Odor/Taste	Mechanism failure/ Malfunction
Earthquake	Ammonium pollution	Water stress	Cyber Attack
Severe weather	Microbiological pollution	Oil spill	Terrorism
Drought	Over chlorination	Chemical pollution	Fire

It must be noted that different hazards occurring due to specific hazardous events were not taken into consideration. Dealing with the specific hazards caused, depends on the water utility infrastructure and service area, which goes beyond the purposes of this study.

Section 2: Crisis management

Each crisis stage is divided into relevant functional areas, which are different for each of the three stages. Consequently, each functional area consists of a list of actions that can be implemented by the organization. Actions are predefined and users can select the ones that they already implement in case of crisis, due to a specific hazardous event.

Table 3. Key components of the pre-crisis macro stage

Stage	Functional area	Action
Pre-crisis	Capacities	Alternative water sources
		Alternative power sources
		Alternative distribution networks
		Interdependencies
		Primary & alternate personnel
	Training & simulations	Tabletop exercises
		Written instructions
		Foresight tools
		Evaluation & feedback
		Hazard mapping
	Planning	Risk & vulnerability assessment
		Hazard specific Crisis Management Plans (CMPs)
		Concrete data management plan
		Mitigation actions
		Incident Command System (ICS)
	Detection / Warning	Event detection & early warning systems
		Non-sensor systems
		Real-time data
		Crisis Management Unit (CMU)
	Roles & Responsibilities	Chain of command

		Responsible parties
		Trans-boundary cooperation
	Communication & Information management	Reporting rules
		Events records
		Back up key utility info
		Available communication channels
		Communication protocols

Table 4. Key components of the crisis macro stage

Stage	Functional area	Action
Crisis	State analysis	Nature of crisis
		Damage assessment team
		Priorities definition
		Resources assessment
		Situation reports
	Response	Access to utility data
		Support operations team
		Damage control operations
		Continuous documentation
		Logistics
		Personnel safety
	Recovery	Restore operations
		Immediate relief
		Long-term recovery
	Communication & Information management	Information collection & management
		Public communication
		Interoperable communication

Table 5. Key components of the Post-crisis macro stage

Stage	Functional area	Action
Post-crisis	Feedback	Post crisis analysis
		Damage assessment
		Post crisis reports
		Lessons learned
	Demobilization plan	Establish demobilization priorities
		Coordinated release of resources & personnel
	Improvement actions	Update plans & procedures
		Update chain of command
		Rethink established mitigation measures

	Rethink established policies
Communication & Information management	Public communication
	Update key response partners contact info
	Information records & storage

Section 3: Preparedness assessment

Given the high-level information and approach used in the tool, it would be misleading to provide quantitative results when it comes to management approaches. The aim of the tool's qualitative information is for the user not to rest on an increased level of preparedness, especially in cases where a high impact is possible, due to a specific hazardous event.

Based on the selections made in Section 2 and the weighing factors attributed to each action, preparedness assessment is presented both per crisis stage and per functional area. For both the overall, and the per crisis stage preparedness assessment, four levels of preparedness status are foreseen, as presented in Table 6.

Table 6. Overview of preparedness status categorization

Preparedness status	Corresponds to
Highly prepared	Very good performance, keep it up
Moderately prepared	Doing well, but can improve
Slightly prepared	Inadequate performance, need to do better
Unprepared	Immediate action is required

It was decided that the four levels of preparedness should not be of the same range. This is mainly in order to highlight the fact, that to be either "Moderately" or "Highly" prepared, one needs to implement a variety of actions. Setting a scale of differentiated range, helps to draw the attention of the user in the fact that increased preparedness against a crisis needs a holistic approach. The performance status scale and the range selected for each preparedness level, are presented in Table 7.

Table 7. Preparedness status scale and respective performance score correspondence

Preparedness status scale	Performance score correspondence
Highly prepared	>80%
Moderately prepared	(50-80%]
Slightly prepared	(0-50%]
Unprepared	0%

Two are the factors that the model is based upon:

- The user input, i.e., the actions selected by the user in Section 2. Selected actions are scored with one (1) and non-selected actions with zero (0). One (1) refers to "yes, this action is implemented in the crisis management approach" and zero (0) refers to "no", this action is not implemented in the crisis management approach".
- The weighing factors that were attributed to each action. Weighing factors were calculated as the median of the answers given by the domain experts.

Furthermore, based on the domain experts' answers and the weighing factors that occurred, the maximum score that can be reached per functional area, as well as per crisis stage, i.e., the case that the user implements all the included actions and thus scores "1" for each one of them, was calculated. The final performance of the user is calculated through a simple equation as follows:

$$User\ performance\ score = \frac{Actual\ score}{Ideal\ score} x100\%$$

Moving on, regarding the impact of a hazardous event, this does not refer to quantitative information, as it only aims to draw the attention of the user to the potential level of harm that could occur, because of the hazardous event they have selected.

An aggregation of the domain experts' answers was necessary, however the variation across the answers did not facilitate the extraction of one simple "rule" to follow when attributing the level of impact to a hazardous event. For this purpose, a matrix with all the possible combinations of the experts' answers was prepared, to extract "rules" to present the impact level of each hazardous event, in a more unified but yet representative way. In Table 8, the defined verbal codification to represent the impact level of the hazardous events on the water supply system components is presented, along with a brief explanation to highlight how they are differentiated.

Table 8. Verbal codification attributed to the impact level of the hazardous events

Verbal codification	Explanation
High	All experts indicate a high-level impact.
Expected high	The majority of the experts indicate a high-level impact.
Expected high*	Most experts indicate a high-level impact, but there is a significant variation among the experts' opinions.
Medium	All experts indicate a medium level impact.
Expected medium	The majority of the experts indicate a medium level impact.
Expected medium*	Most experts indicate a medium level impact, but there is a significant variation among the experts' opinions.
Low	All experts indicate a low-level impact.
Expected low	The majority of the experts indicate a low-level impact.
Expected low*	Most experts indicate a low-level impact, but there is a significant variation among the experts' opinions.

Section 4: Recommendations

Recommendations follow the conceptual approach of the tool, serving as a preliminary guidance for the user on the concept of crisis management and preparedness and acting as complementary material to the results of the assessment. It is important to mention that the recommendations provided, cannot replace national guidelines and standards, but they can highlight areas of intervention for future planning. In particular, users receive recommendations only for the actions they have not selected in Section 2 of the tool. The are two ways to access the recommendations, which are presented in Table 9 below.

Table 9. Available options regarding provided recommendations

"On screen"	"On paper"
Maximum of 12 recommendations are displayed in the tool's UI.	Full list of recommendations is provided in a form of downloadable report.
Recommendations are sorted by weighing factor and displayed in a descending order.	Recommendations are sorted by weighing factor and displayed in a descending order.
Top priority recommendations are provided first and crisis stage is mentioned.	Recommendations are provided per crisis stage and functional area.
No available recommendations, in case all actions are selected in Section 2.	No available recommendations, in case all actions are selected in Section 2.

Features

As mentioned above, the tool comprises four different sections. Section 1 facilitates the selection of a specific hazardous event, Section 2 displays the different actions that an organization can implement, Section 3 provides the assessment evaluation and Section 4 generates a list of recommended actions. The tool's first page is an introductory one, where additional information about the tool can be found. In this page, the user has the option to create a new session or select a previous one.

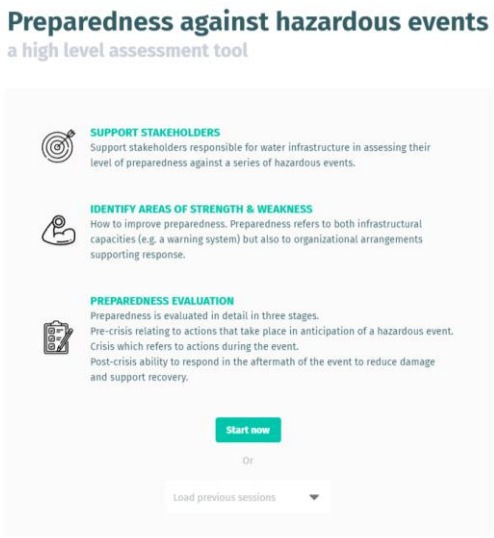


Figure 2. Tool's introductory page

Section 1: Hazardous events

The first page of the tool allows for a hazardous event selection, by providing the user with a list of predefined hazardous events to choose from (**Error! Reference source not found.**). In particular, these events have been either frequently experienced by relevant entities or being added as an option to be assessed (Table 2). As a result, the tool enables end users to assess their level of preparedness against a hazardous event or even evaluate the impact that a never before experienced event might have on their system's components.

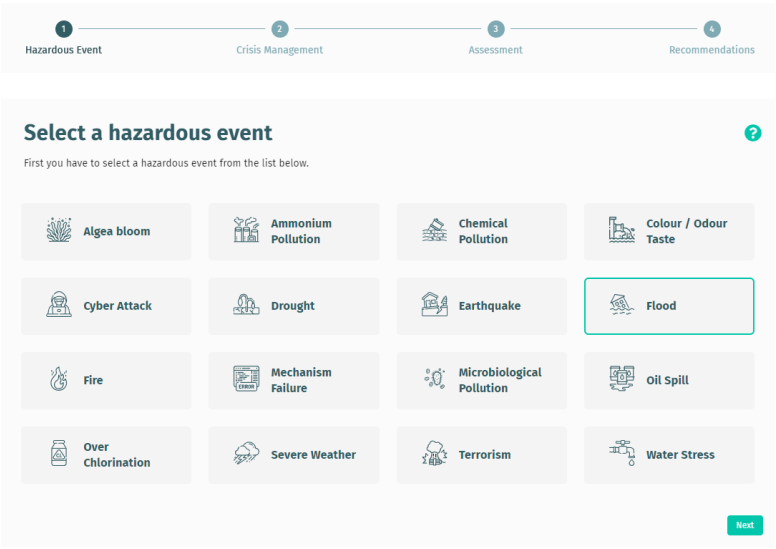


Figure 3. Hazardous event selection section

Section 2: Crisis Management

The crisis management section is divided into the aforementioned crisis stages (pre-crisis, crisis and post-crisis). Each stage consists of a number of predefined functional areas and actions (Table 3, Table 4 and Table 5). In this section, the different actions, that can be part of a crisis management plan, should be selected in order for the assessment to be produced. This functionality provides the ability for either (i) assessing the actions that are part of an organization's current crisis management plan against a specific hazardous event or (ii) including some actions to the crisis plan, that are not currently implemented, so their contribution to the organization's overall level of preparedness can be examined. It should be noted that by clicking on an action, a pop-up window with the form of a "prompt" appears, so that a short but detailed description of the action can be provided to the user (**Error! Reference source not found.**).

After the completion of the crisis management section, a verification is required through a pop-up window, which informs the user that by proceeding to the assessment, the non-selected actions would not be considered as part

of the crisis management approach.

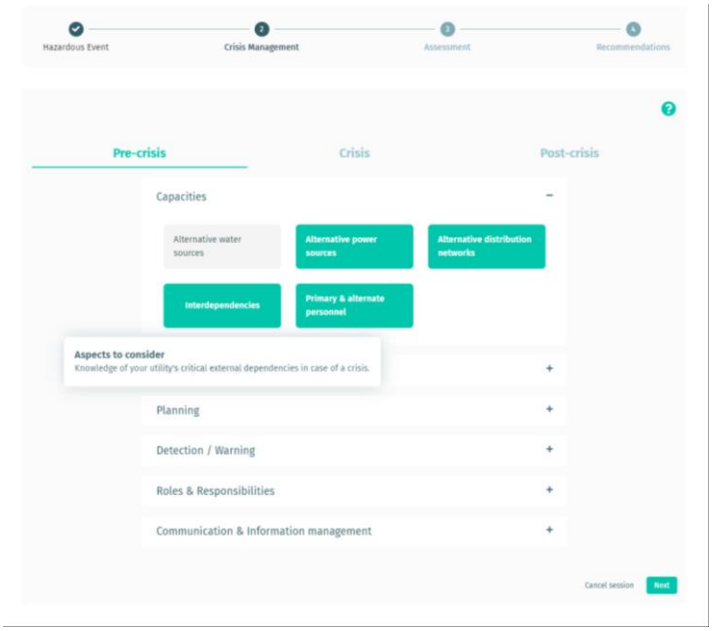


Figure 4. Crisis management section

Section 3: Preparedness assessment

In the next section, the high-level qualitative evaluation of the level of crisis management preparedness is provided. The level of preparedness against a hazardous event is assessed: overall, per crisis stage and per functional area. The results are illustrated by utilizing both verbal expressions and visualizations (color coding and graphical figures), as shown in **Error! Reference source not found.**. This section also informs, in a high-level, about the interrelation between the water supply system's components and the examined hazardous event. Additional information about the estimated levels of the potential impact of the event on the system components can be found by clicking on the help modal.

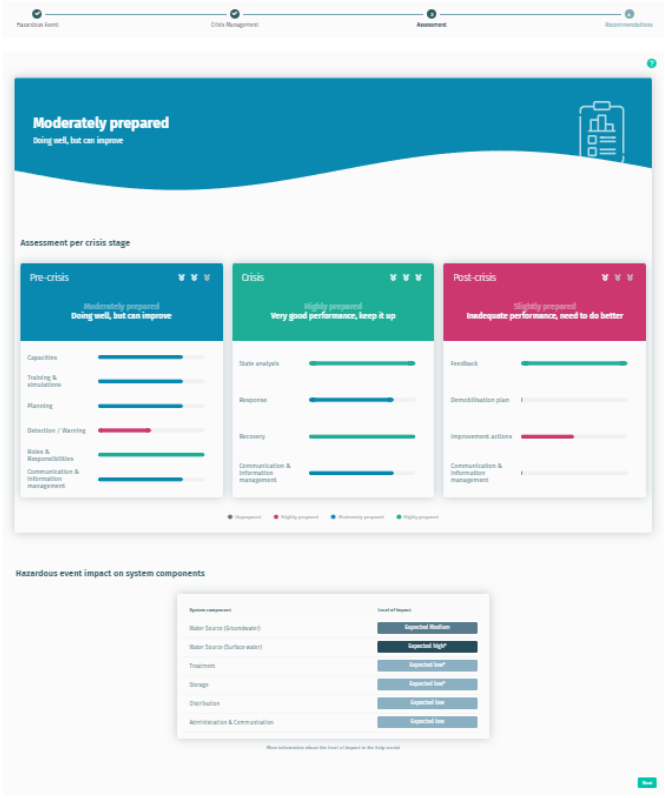


Figure 5. Assessment section

Section 4: Recommendations

The tool's last section provides a summary of suggestions that can serve as a guidance on some key aspects of crisis management (**Error! Reference source not found.**). The proposed recommendations are aiming to help the user review the actions that are not part of the organization's current crisis management approach and could improve the overall level of preparedness. It should be noted that the recommendations are ordered by higher to lower priority, based on their weighing factor, and the 12 most important ones are presented in the tool's interface. Finally, the tool enables the end users to download the full list of recommended actions, the crisis management guide and the assessment report, so that the analysis, review and decision making can be performed outside the tool's environment.

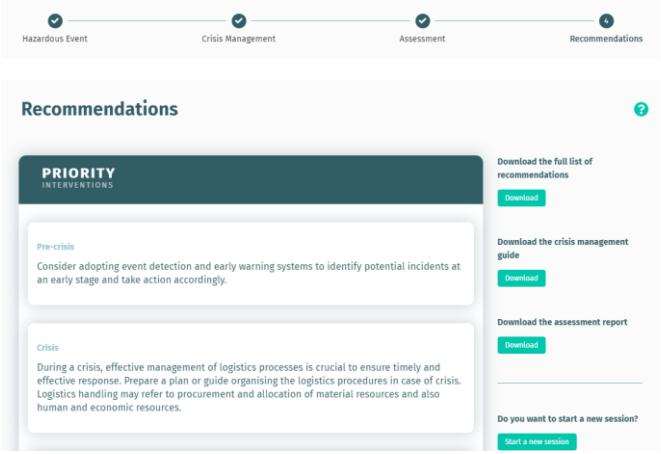


Figure 6. Recommendations Section

Evaluation

The "Preparedness against hazardous events" tool aims at providing a user-friendly environment for stakeholders, responsible for a water infrastructure, to assess their preparedness level against a hazardous event. The tool's primary end user is the owner and/or operator of a water infrastructure, however the use can be extended to broader stakeholders' groups, that involve actors engaged in a crisis management plan.

In order to evaluate the tool's functionalities and overall user experience, questionnaires were distributed and answered by eight domain experts. The distributed questionnaire was developed based on the System Usability Scale (SUS) guidelines. In particular, the experts come from four different domains (Figure 7), which are part of the crisis management chain of actions in water utilities i.e., water utilities, healthcare/rescue providers, crisis management authorities and technical institutes. The questionnaire is divided into two main sections, (i) KPIs: in this section the experts provide their feedback about the tool's usefulness as a preparedness assessment tool, based on their domain expertise and (ii) Tool usability: in this section, the experts, as end users now, provide their opinion on the tool's usability (UI, UX).

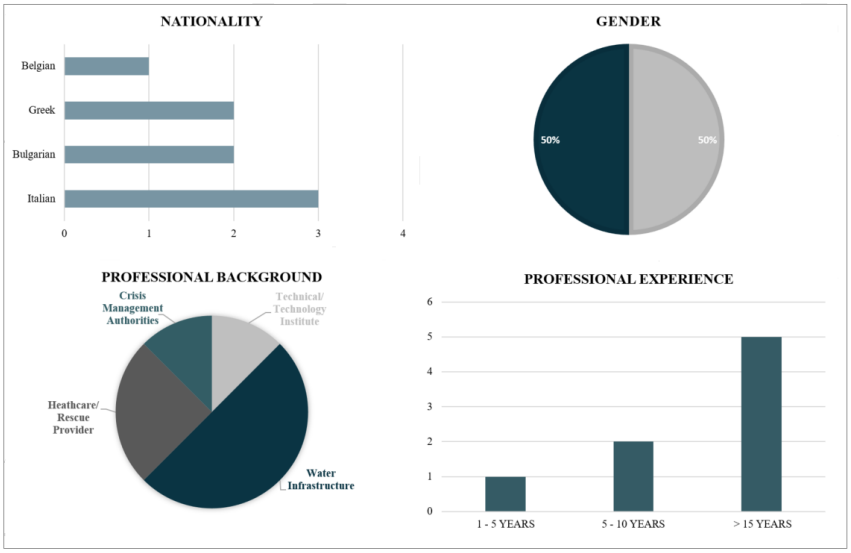


Figure 7. Domain expert's demographics

Evaluation of tool's functionalities

In the questionnaire's first section, the experts provided their input, by validating and evaluating specific KPIs, regarding the tool's different functionalities, as shown in Figure 8.

Key Performance Indicators

KPI	Validation [Pass/Fail/NA]	Satisfaction [1-5]	Comment
As a manager with strategic responsibilities for delivering crisis management plans, the tool assists me in creating or updating the crisis management plan for a specific hazardous event.			
The information presented in the tool regarding the crisis management preparedness actions and the impact of the hazardous events is accurate.			
The tool provides ample options regarding the crisis management preparedness actions, in a way that the user can sufficiently outline the actions in their crisis management approach.			
The assessment results and the recommendations are consistent with the user's options in the crisis management stage.			
The consequent steps followed by the user in the tool are coherent and consistent.			
The assessment and the recommendations provided by the tool are aligned with the results expected by the users who are interested in the tool.			
The tool presents all available information in a simple and understandable fashion.			
The tool includes the ability to be adapted to different scenarios beyond the aqua3S project (additional hazardous events that have not occurred in the pilot cases of aqua3S project).			
The tool with all its functionalities is successfully incorporated in the inclusive Interactive User Interface.			

Figure 8. Evaluation questionnaire: Key performance indicators section

The water utility experts, which are the key users of the tool, assessed that the tool can be used, by the water utility manager, in creating and updating the organization's crisis plan. Moreover, they evaluated that the information presented in the tool is accurate, the options provided are ample and the assessment report, as well as the suggested recommendations, are consistent and aligned with the user's options.

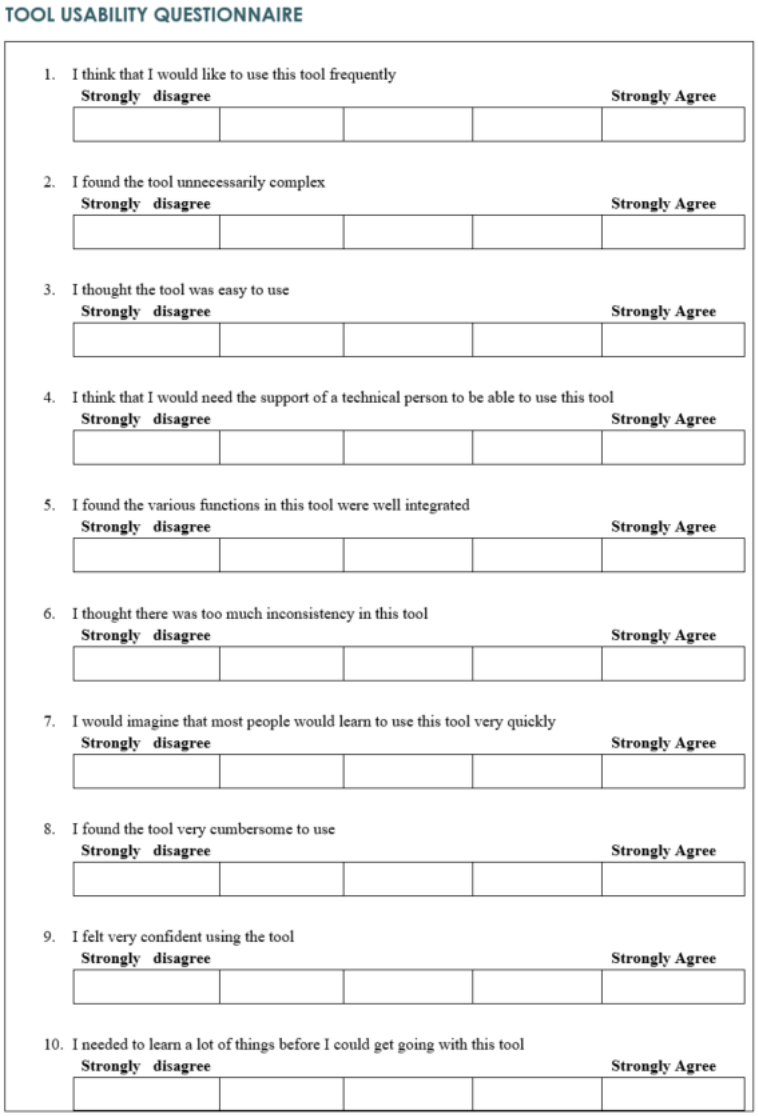
The healthcare/rescue authority experts evaluated that the tool can be useful for managing a crisis in water utilities, but it is not generally applicable for their level of activities. Having in mind that the tool's main target is water infrastructures, they mentioned that the information provided is coherent and presented in a simple manner so that any user, coming from any background, can use the tool efficiently.

The experts from crisis management authorities or a technical institute, assessed that the tool can successfully provide an environment for the evaluation of an organization's preparedness level. More specifically, they find that the steps that a user needs to follow are coherent and the resulted report can be used to further improve a crisis management plan.

Summing up, all experts agreed that the necessary information is presented in a simple and understandable fashion, so that a user can efficiently use the tool for assessing their organization's level of preparedness. In addition, they estimated that the tool could possibly adapt different crisis scenarios, such as additional scenarios that could be more useful for the healthcare/rescue authorities.

Evaluation of tool's User Experience

The questionnaire's tool usability section focus on the tool's user interface and the overall user experience. The end users indicated their level of satisfaction for given statements, as shown in Figure 9.



TOOL USABILITY QUESTIONNAIRE

1. I think that I would like to use this tool frequently
   Strongly disagree | | | | | Strongly Agree
2. I found the tool unnecessarily complex
   Strongly disagree | | | | | Strongly Agree
3. I thought the tool was easy to use
   Strongly disagree | | | | | Strongly Agree
4. I think that I would need the support of a technical person to be able to use this tool
   Strongly disagree | | | | | Strongly Agree
5. I found the various functions in this tool were well integrated
   Strongly disagree | | | | | Strongly Agree
6. I thought there was too much inconsistency in this tool
   Strongly disagree | | | | | Strongly Agree
7. I would imagine that most people would learn to use this tool very quickly
   Strongly disagree | | | | | Strongly Agree
8. I found the tool very cumbersome to use
   Strongly disagree | | | | | Strongly Agree
9. I felt very confident using the tool
   Strongly disagree | | | | | Strongly Agree
10. I needed to learn a lot of things before I could get going with this tool
    Strongly disagree | | | | | Strongly Agree

Figure 9. Evaluation questionnaire: Tool Usability Section

Based on this approach, the results of the evaluation indicated that the end users strongly agreed upon the fact that the tool is not unnecessarily complex and that the support of a technical person is not needed. Also, they agreed on the tool's quick learning curve and ease of use, the good integration of various functions and the information consistency.

It needs to be mentioned that the end users find, the frequency of use and the confidence gained from the tool's use, to be two indicators that they have a neutral opinion about. These indicators might change as the tool is utilized, by the end users, in their everyday professional life and its functionalities are being implemented in action. Therefore, a new questionnaire could be distributed, after a few months of use, in order to assess if their opinion has changed.

Lastly, a useful suggestion, for the tool's further improvement, derived from the crisis management domain experts, who suggested that further downloadable templates and extended reports could be included, at the last section of the tool, such as management and communication plans.

CONCLUSION

Several terms and approaches, regarding the components of a crisis management plan, exist and mainly focus on the actions that should be carried out during a crisis, rather than provide a holistic approach for the overall

management of a hazardous event. After a thorough literature review it was clear that the recommended way to perceive the various stages within a crisis is a three macro-stage approach: (i) pre-crisis, (ii) crisis and (iii) post-crisis, and these stages should be considered as the key aspects of a crisis management plan. The aforementioned literature review confirmed that a research gap emerges in the area of the assessment of preparedness against a hazardous event, that takes into consideration all three stages. In order for a holistic approach to be developed, the findings of the literature review were enhanced with input of active domain experts, aiming to bridge the existing research gap. As a result, the conceptual approach was formulated and it served as the core of the "Preparedness against hazardous events" tool implementation. The tool was tested both by experts and end users from different domains. Their evaluation was overall encouraging and by assessing their feedback we can conclude that the tool would be useful, in particular, for stakeholders in the crisis management domain. Suggestions for future enhancements of the tool include the addition of scenarios more suited to each stakeholders' organization or water utility.

ACKNOWLEDGMENTS

This work has been produced under research and innovation project Horizon 2020, Grant Agreement Nº 832876, "Enhancing standardization strategies to integrate innovative technologies for Safety and Security in existing water networks.", under the acronym "aqua3S".

REFERENCES

Albtoush, R., Dobrescu, R. & Ionescou, F. (2011). A hierarchical model for emergency management systems. U.P.B Scientific Bulletin, Series C, 73(2), 53-62.

Alexander, D. (2002). Principles of emergency planning and management. New York: Oxford University Press.

Baubion, C. (2013). OECD Risk Management: Strategic Crisis Management. OECD Working Papers on Public Governance. No. 23. Paris: OECD Publishing.

Commission of the European Communities (2004). Communication from the commission to the council, the European parliament, the European economic and social committee and the committee of the regions – Flood risk management – Flood prevention, protection and mitigation. Available Online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52004DC0472&from=EN

Crandall, W., Parnell, J. & Spillan, J. (2014). Crisis management in the new strategy landscape. 2nd ed. Los Angeles: SAGE.

Danish Emergency Management (2009). Comprehensive Preparedness Planning. Birkerød

Driver+. Driving Innovation in Crisis Management for European Resilience. Available Online: https://www.driver-project.eu/

European Council (2007). Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. Available Online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007L0060

European Standard (2011). EN 15975-1:2011. Security of drinking water supply – Guidelines for risk and crisis management – Part 1: Crisis Management.

European Standard (2013). EN 15975-2:2013. Security of drinking water supply – Guidelines for risk and crisis management – Part 2: Risk Management.

Fink, S. (1996). Crisis management: Planning for the inevitable. New York: American Management Association.

Frandsen, F. & Johansen, W. (2017). Organizational crisis communication: A Multivocal Approach. London: SAGE Publications.

ISO 22300:2021(en) Security and resilience – Vocabulary, Available at: https://www.iso.org/obp/ui/#iso:std:iso:22300:ed-3:v1:en

Myers, K. (1993). Total contingency planning for disasters: Managing risk . . .minimizing loss . . . ensuring business continuity. New York: John Wiley.

Myer, J., Kincaid, R., Wilmot, K., Novick, K., Long, M., Nikolas, M. & Shadden, M. (2013). Business Continuity Planning for Water Utilities: Guidance Document. Water Research Foundation.

Pearson, C., & Mitroff, I. (1993). From crisis prone to crisis prepared: A framework for crisis management.

Richardson, B. (1994). Socio-technical disasters: Profile and prevalence. Disaster Prevention & Management, 3(4), 41–69.

Smith, D. (1990). Beyond contingency planning: Towards a model of crisis management. Industrial Crisis Quarterly, 4(4), 263–275

World Health Organization. Division of Emergency and Humanitarian Action (1995). Coping with major emergencies: WHO strategy and approach to humanitarian action.

World Health Organization & International Water Association (2009). Water safety plan manual: step-by-step risk management for drinking-water suppliers. World Health Organization. https://apps.who.int/iris/handle/10665/75141