FORTRESS

Foresight Tools fo Responding to cascading effects in a crisis

Final Publishable Summary Report

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1 EXECUTIVE SUMMARY

The capability project “Foresight Tools for Responding to cascading effects in a crisis” (FORTRESS) is an EU-funded research project. FORTRESS seeks to increase understanding of cascading effects and to strengthen the capabilities of crisis managers and infrastructure providers to identify and analyse cascading effects that may evolve during crises. This was achieved through developing two user friendly tools that build on each other: the FORTRESS Model Builder (FMB) and the FORTRESS Incident Evolution Tool (FIET). The philosophy guiding the project is to improve inter-sectoral crisis scenario planning by strengthening cooperation and information exchange between crisis managers, first responders and critical infrastructure providers. The FMB is a tool for the modelling of cross-system / cross-stakeholder dependencies and relations in crisis scenarios. The tool is designed as a collaborative modelling platform. Experts from different organisations login to the platform and indicate their dependency relations with other organisations. While the FMB provides the modelling basis for a scenario, the FIET offers a range of instruments to analyse how a crisis scenario might evolve. Using the tool cooperatively across different organisations facilitates inter-sectoral cooperation and raises awareness of the manifold dependencies and risks that can evolve during crises.

The project team consists of an inter-disciplinary consortium from eight European countries, and includes social scientists, practitioners in the field of crisis management and IT-specialists. The first phase of the project (WP1-2) started with a review of literature and research concerned with crises and the development of theoretical concepts. In phase 2 (WP3–5) an empirical basis for the development of the two FORTRESS tools was developed. In phase 3 (WP6–8), the software was designed, iteratively developed and tested with end users.

2 SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES

FORTRESS seeks to increase understanding of cascading effects and to strengthen the capabilities of crisis managers, first responders and infrastructure providers to identify and analyse cascading effects that may evolve during crises. This was achieved through the development of two user friendly tools that complement each other: the FORTRESS Model Builder (FMB) and the FORTRESS Incident Evolution Tool (FIET). The overall philosophy is to improve scenario planning by strengthening cooperation and information exchange between crisis managers, first responders and critical infrastructure providers. Such an approach has increased mutual awareness of the organisational structures and processes between different stakeholder groups. While the FMB provides the modelling basis for a scenario, the FIET offers a range of instruments to analyse how a crisis might evolve.

The project team consists of an inter-disciplinary consortium from eight European countries, made up of: social scientists, practitioners in the field of crisis management and IT-specialists. The social sciences are represented by the Technische Universität Berlin, Center for Technology and Society / TUB (DE), Trilateral Research & Consulting / TRI (UK), the University College of London / UCL (UK), Ritchey Consulting / RCAB (SE), the Higher Institute on Territorial Systems for Innovation / SiTi (IT), Vienna Centre for Societal Security / VICESSE (AT) and Dialogik / DIA (DE). The end users / practitioners in the consortium are the Service Départemental d'Incendie et de Secours des Alpes de Haute-Provence / SDIS 04 (FR), Electricité de France / EDF (FR), the Berliner Wasserbetriebe / BWB (DE) and the Nederlands Instituut Fysieke Veiligheid / IFV (NE). Two IT-companies participated in the project: Treelogic / TREE (ES) and GMV Sistemas S.A.U. / GMV (ES). The above consortium is actively supported by a wide range of stakeholders from the community of end users.

Given the increasing interdependencies between different infrastructural sectors and between different countries, FORTRESS aims to improve crisis management by identifying the diversity of cascading effects that can arise as a result of the multiple interrelations of systems and systems of systems. In response, FORTRESS designed a Model Builder (FMB) that allows a collaborative mapping of interdependencies involving practitioners from different sectors and organisations. Based on these models, the FORTRESS Incident Evolution Tool (FIET) allows for the identification of critical entities in networks of interconnected infrastructures, as well as to analyse different scenarios of cascading effects. Using the tools collaboratively in the preparedness phase before a crisis will enable a better *common* understanding of risks of cascading effects that may evolve in a given scenario. This collaborative process will raise awareness of dependencies and risks and thus *enhance the capability of crisis managers* to analyse and forecast potential cascading effects in the "hot phase" of a critical event. Here, crisis management refers to a process of actions, decisions and communications that are implemented when an organisation has to cope with a major event with consequences beyond its means to cope. A common understanding of a situation status, unfolding events, structures and processes is essential in order to achieve coordinated action and to avoid misunderstandings in a moment of crisis, given the diversity of organisations involved.

Two main innovations for inter-sectoral risk management can be expected from FORTRESS. First, understanding the inter-connectedness of infrastructure systems and the necessity to map these connections in a proper way is at the centre of FORTRESS' approach. FORTRESS takes into account that infrastructures are complex systems consisting of multiple inter-

connected sub-systems. Furthermore, infrastructures are conceptualised as socio-technical systems consisting of technological systems, human actors and organisational and communicational processes. Thus, FORTRESS is taking into account different types of sub-systems (technical infrastructures, operational units as well as management) and different kinds of relations (resource, service, communication, jurisdiction, interferences) between them. Second, FORTRESS assumes that the practitioners themselves (CI operators, crisis managers) will readily indicate their relevant sub-systems, objects, criticalities and relations. The FORTRESS tools enable to develop user-centric models and simulations. Apart from fostering inter-organisational communication pre-crisis, this approach ensures that national, local, sector-specific particularities, both in the technical systems and their interconnections as well as in the organisational field, are reflected in the models to be used for training or even during crises.

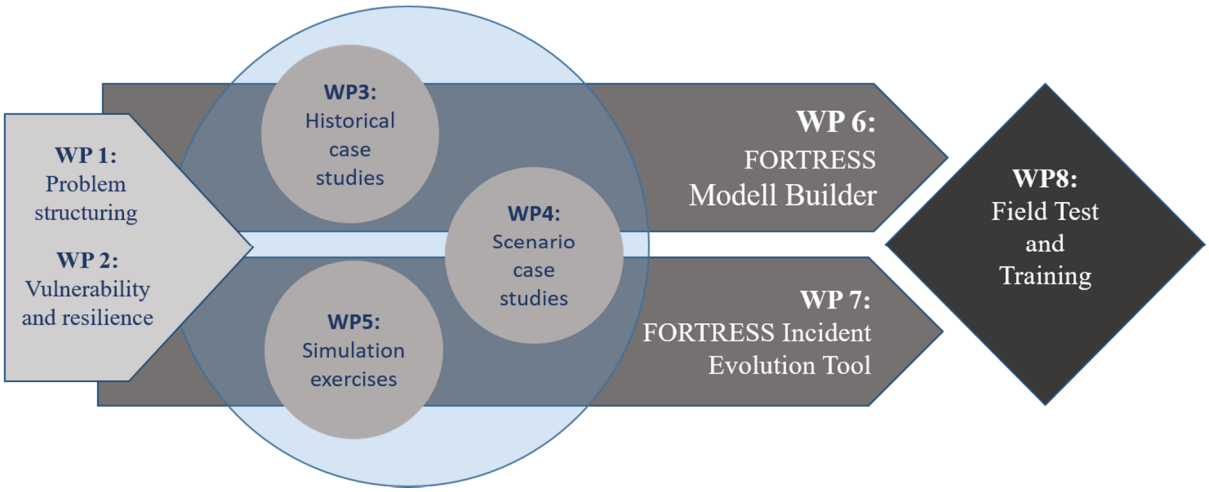

Figure 1: The FORTESS Work Plan

FORTRESS is divided into three phases. Phase 1 of the project started with a knowledge review around crisis situations and the development of theoretical concepts. First, an analysis of the "problem space of the project" has been conducted (WP1). This addresses the problems of current understanding of cascading and cross-border effects, and related problems of crisis management and limits of existing tools used in crisis management. Second, a conceptual framework for understanding interdependencies and cascading effects have been developed, based on an in-depth review of current knowledge on vulnerability and resilience (WP2). In phase 2 of the project, an empirical database for the development of the two FORTRESS tools was developed. To do so, we have combined case studies of historical crises (from both Europe and International cases) (WP3) with four real-time scenario case studies (WP4): 1) A dam disruption in the border region of France and Italy, 2) multiple infrastructure breakdowns due to a pan-European blackout in Berlin, 3) a flooding scenario in the Netherlands and 4) a flooding scenario in France. Partners have mapped systems and sub-systems involved in each of these scenarios, identified mutual interdependencies and cascading paths and assessed the cross-impacts between all nodes in terms of a sensitivity analysis.

In phase 3 of the project, the software is designed and iteratively developed. The results of WP3 and WP4 were used to develop a taxonomy of the FORTRESS Model Builder (FMB) (WP6) and to create a test data set for developing and testing the different features. Resulting from three main workshops of end user engagement (London in April 2015, Zwijndrecht in May 2015, Berlin in October 2015), the following features of the FMB were implemented in

the final version and tested in the field trials: scenario setup, system setup, object identification, relations modelling and criticality analysis. The three main end-user engagements were also used to sketch main features for the FORTRESS Incident Evolution Tool (FIET) (WP7). These main features are the identification of cascading paths in the network view, the geographical mapping of these paths, the generation of a list of affected entities, and the timeline functioning enabling to simulate specific scenarios of cascading effects. A main trial of both tools was conducted in the Netherlands in Tiel in September 2016. Three parallel trials at a smaller scale were conducted in Italy (Turin, November 2016), France (Paris, October 2016) and Germany (Berlin, December 2016), primarily focused on a shorter demonstration and test approach to confirm and validate the FMB/FIET results. In Tiel, five EU Cascade projects met for a knowledge exchange and tools comparison, followed by the joint final conference of FOTRESS, CASCeff, PREDICT, SNOWBALL and CIPRENet in Brussels 16-17 March 2017. This joint Cascading Effect Conference was coordinated by FORTRESS and hold under the umbrella of the Community of Users (CoU).

The final results of the FORTRESS project are demonstrations of the two field-tested tools (FMB and FIET). The FORTRESS Model Builder (FMB) is a web-based tool to be used by CI-operators and crisis managers prior to a crisis to establish criticalities and inter-dependencies between their systems. The result of this collaborative work is a relation graph model that maps system elements, risk objects and their mutual relations. By collaboratively mapping their mutual dependencies, the involved organisations will increase awareness about dependencies and risks beyond the own system borders. Furthermore, the models are used by the FORTRESS Incident Evolution Tool (FIET) to analyse possible cascading paths and to create crisis scenarios. For this purpose a timeline of cascading effects can also be simulated. The FIET enables the user to consider *what* happens *if* a certain entity fails when mitigation measures are not available. The expected impact of the FIET is to raise awareness of CI-operators and crisis managers about dependencies and criticalities between infrastructures by providing analyses drawn from models generated by the FMB.

3 DESCRIPTION OF THE MAIN RESULTS

3.1 WP1: PROBLEM STRUCTURING AND CONCEPTUAL MODEL

The first Work Package (WP1) reviewed existing knowledge on cascading effects in order to structure the project's problem space and to develop a conceptual model for the understanding of cascading effects.

The work undertaken for D1.1 began with developing an agreed definition of cascading effects.

FORTRESS DEFINITION OF CASCADING EFFECTS
"Cascading effects are the dynamics present in disasters when the impact of a physical event or the development of a principal technological or human failure generates a sequence of events in human subsystems that result in physical, social or economic disruption. Thus, an initial impact can trigger other phenomena that lead to consequences with higher magnitudes. Cascading effects are complex and multi-dimensional and evolve constantly over time. They are associated more with the magnitude of vulnerabilities more than with that of hazards."

This view embraces the multidimensional and complex nature of cascades. The different possible failures that can generate chain effects are integrated, while the idea of progression and magnitude becomes a distinctive element. Vulnerability is considered critical, as a vehicle for the spreading of cascading effects in space and time. In contrast, the analogy of toppling dominoes that is often used to explain the cascading phenomena is misleading: intuitively, it refers to linear events that involve no process of amplification.

Typology of Dependency Relations and cascading effects

To develop a better understanding of cascading effects different types of vulnerabilities need to be taken into account. FORTRESS is focussing on vulnerabilities that result from interdependencies between infrastructure systems and their sub-systems in a network of interconnected systems. The whole range of infrastructures is taken into account including for example first responders or civil protection authorities who are considered to be an important part of the infrastructure network during crises. Building the baseline for the modelling taxonomy (see WP6), FORTRESS has developed a taxonomy of dependency relations differentiating between resource relations, communication relations, service relations, interference relations and rule-based relations (see Figure 2).

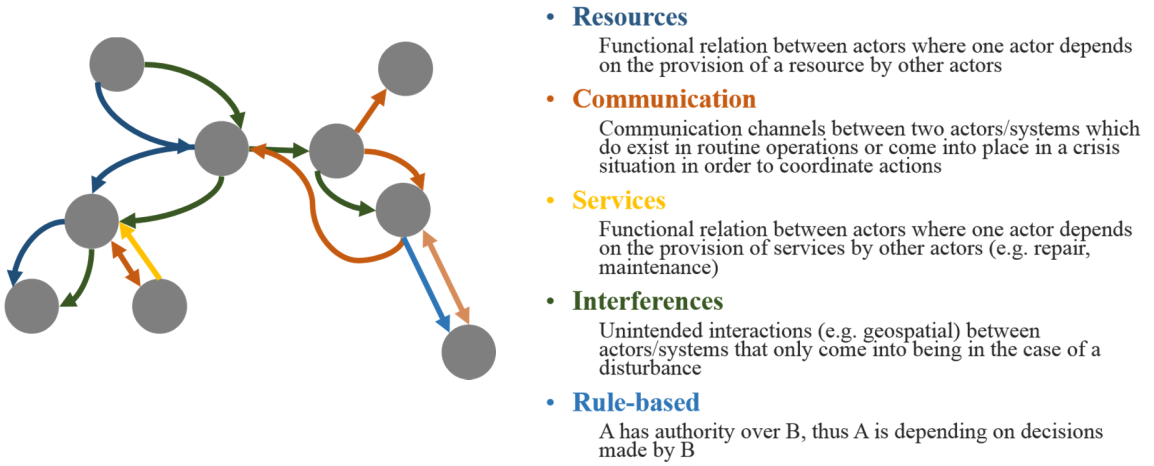

Figure 2: The FORTRESS typology of dependency relations

Cascading effects occur due to interdependencies between infrastructure systems. Mapping these interdependencies allows us to better understand cascading effects. Infrastructure systems consist of multiple sub-systems such as technical facilities and material resources, operational units and management divisions. For example the power distribution system consists of a power-grid (technical facility) but also control rooms (operational units). De-aggregating systems into sub-systems allows us to make visible multiple and different types of relations between infrastructure-systems. We gain a complex picture of dependencies and thus of vulnerabilities that cause cascading effects during crises. The dependency models raises awareness of different triggers of cascading effects and related dependencies that may be overlooked in crisis management:

Triggers of cascading effect	Description
Spatial proximity	A spatial cascade may occur between geospatially related entities
Time	A system is dependent on resources or services provided by another system that is affected by an incident. A cascading effect occurs when the recovery time of the affected system lasts longer than the buffer time of the dependent system
Failed resource allocation	The resources of an affected system are running short (e.g. diesel). Although there are sufficient resources available in the infrastructure network, crisis managers fail to distribute them properly
Escalation	An incident causes a cascading effect (e.g. time or spatial cascade) that triggers further multiple cascading effects due to the high cascading impact of the affected system on further systems
Loss of overview	Due to a limited exchange of information or an information overload, crisis managers are not aware of a critical process that is culminating in a cascading

	effect

Table 1: Triggers of cascading effects

3.2 WP2: BALANCING VULNERABILITY AND RESILIENCE

This Work Package had the aim of examining factors that contribute to the construction and amplification of vulnerability (e.g., lack of preparedness) in a system or 'system of systems' and the manner in which they relate to cross-border and cascading effects in crisis situations. As a major outcome of this WP a GAP analysis model of the interactions between resilience and vulnerability in crisis situations was developed. The model identifies discrepancies ("gaps") between pathogenic factors (vulnerabilities) and factors contributing to resilience and vulnerability reduction, taking into account systemic, organisational and human factors. This was done by using evidence-based information from the historical case studies (WP3). In the figure below (see figure 3) the discrepancies between vulnerability and resilience factors found in the case studies are mapped out and displayed by way of Vulnerability-Resilience (V-R) GAP matrix.

Vulnerability factors: Aggragates	Aspects of resilience										
	Capacity for successful response to chronic risk or sudden onset of disaster. (Risk dimension)	Capacity for overall functioning of people, communities, organisations or constituencies post-disaster.	Capacity to deal with surprise in cascading events.	Capacity for understanding the scope and magnitude of disaster effects(Salutogenesis & Sense of	Capacity for psychological resilience and integration of SoC scales in the routines	Flexibility of international diplomacy.	Capacity to mobilize effectively many resources with short time notice.	Capacity to address latent vulnerabilities and limit the spread of cascading.	Existence of an effective legal/political/administrative framework	**Totals RED & BLUE**	**Totals assess-ments**
Production pressures(take over safety)										RED: 0 BLUE: 0	**0**
Failure of the regulatory/control authorities.	3 1	3 1	2 1	2 1		2 0	1 3	2 1	2 3	RED: 17 BLUE: 11	**28**
Weakness of the organisational safety culture.	2 0	0 1	0 1	0 1	1 0		0 2	1 2	1 1	RED: 5 BLUE: 8	**13**
Limits of operational feedback.	2 1	1 0	1 2	1 2		3 0	0 4	1 2	2 3	RED: 10 BLUE: 14	**24**
Flawed management of organizational complexity	1 1	2 0	1 0	1 0		1 0	1 0	1 0	1 1	RED: 9 BLUE: 2	**11**
No consideration about a whistle-blower										RED: 0 BLUE 0:	**0**
Wrong design of mitigation measures / models.	2 0	1 1	1 1	0 1		1 0	1 1	2 0	2 1	RED: 10 BLUE: 5	**15**
Social dependency on most interconnected sectors (eg. Energy, Transportation,	2 2	2 1	2 0	0 2		1 0	1 2	1 1	1 3	RED: 10 BLUE: 11	**21**
Geographic concentration of Critical Infrastructures	1 3	0 1	2 0	0 1			0 3	2 0	1 2	RED: 6 BLUE: 10	**16**
Structural weakness of Critical Infrastructures	2 1	1 1	2 0	1 0			2 1	2 0	1 1	RED: 11 BLUE: 4	**15**
Unsustainable development	3 1	3 0	3 0	0 1		1 0	2 0	3 0	3 1	RED: 18 BLUE: 3	**21**
Totals RED & BLUE	RED: 18 BLUE: 10	RED: 13 BLUE: 6	RED: 14 BLUE: 5	RED: 5 BLUE: 9	RED: 1 BLUE: 0	RED: 9 BLUE: 0	RED: 8 BLUE: 16	RED: 15 BLUE: 6	RED: 14 BLUE: 16		
Total assessments	**28**	**19**	**19**	**14**	**1**	**9**	**24**	**21**	**30**		

Figure 3: GAP Analysis Model

For each of the 11 Vulnerability factors, it was shown: 1) which resilience and vulnerability factors were present at the outset; 2) of those present, which could be improved or extended, and 3) which of the factors not present would have had important positive effects on the course of the crisis.

Although the aggregation (total assessments) has no statistical value we can see that the *vulnerability factors* that had the most RED assessments (not effectively present) were

- Unsustainable development
- Failure of the regulatory/control authorities.

Those *aspects of resilience* that had the most RED assessments (not effectively present) were

- Capacity for successful response to chronic risk or sudden onset of disaster.
- Capacity to address latent vulnerabilities and limit the spread of cascading events.
- Capacity to deal with surprise in cascading events.
- Existence of an effective legal/political/administrative framework.

A first conclusion highlights the role of governance and government institutions in the reduction, management, recovery and even inadvertent amplification of disaster situations. The presence of effective legal, protective, and administrative frameworks, as well as a coordinated development and land planning policy appears to be central to the prevention and effective anticipation of critical events. Similarly, effective regulatory bodies operating through regularised procedures and feedback loops for learning, with the capacity to mobilise resources at short notice and in a context-appropriate manner appear to be at the root of several of the vulnerability reduction and resilience factors underlined in the GAP analysis of the historical case studies. This serves to underscore the critical role played by government during disaster situations, especially as a transmission agency for reducing or amplifying both system vulnerability and resilience, and its impact on potential cascading effects during a crisis situation.

Another theme emerges around the interconnected nature of current social systems and the relationship between resilience and vulnerability in networks of interconnected infrastructure. It can be argued that the development of complex and co-producing organisations, together with social dependency on infrastructure are the primary underlying factors behind the spread of cascading events in a system with pre-existing vulnerabilities. The interconnected nature of social, ecological and technological systems also highlights the need for effective cross-system communication, which is an underlying theme behind several of the vulnerability and resilience factors identified in the Gap Analysis, not least of which involves capacity for coordination, management, response and operational learning.

3.3 WP3: RECONSTRUCTION OF CRISES AND CRISES DECISION PROCESSES

The overall objective of work package three was to identify, understand and structure major challenges in decision making during crises. Nine case studies of historical crises were used to identify the consequences of decisions taken on the development of crises and to identify possible cascading effects that could result. Key decision makers and decision making processes were extracted from the case studies of past crises, identifying actors and places of decision-making interventions. Activities in this task were driven by four core questions:

1) Who is responsible for the management of each aspect of a crisis?
2) How are decisions taken?
3) What exceptions can be observed?

4) What were the repercussions of decisions taken?

Answering these questions in the context of the relevant actors allowed partners to pin point the existing networks of power and decision making during each phase of a crisis.

As shown in Figure 4 below, the 9 case studies analysed in this work package informed many developments in later work packages. For each case study, the FORTRESS team listed the sequence of events, the people involved, the places affected and the results of decisions and actions throughout the timeline of the disaster. Partners had the opportunity to interview some of the key actors and decision makers involved in three of the crises case studies:

- the Enschede fireworks factory explosion (the Netherlands);
- Galtür avalanche (Austria); and
- the Eyafjallajökull volcanic eruption (Iceland, but with a focus on consequences for the UK).

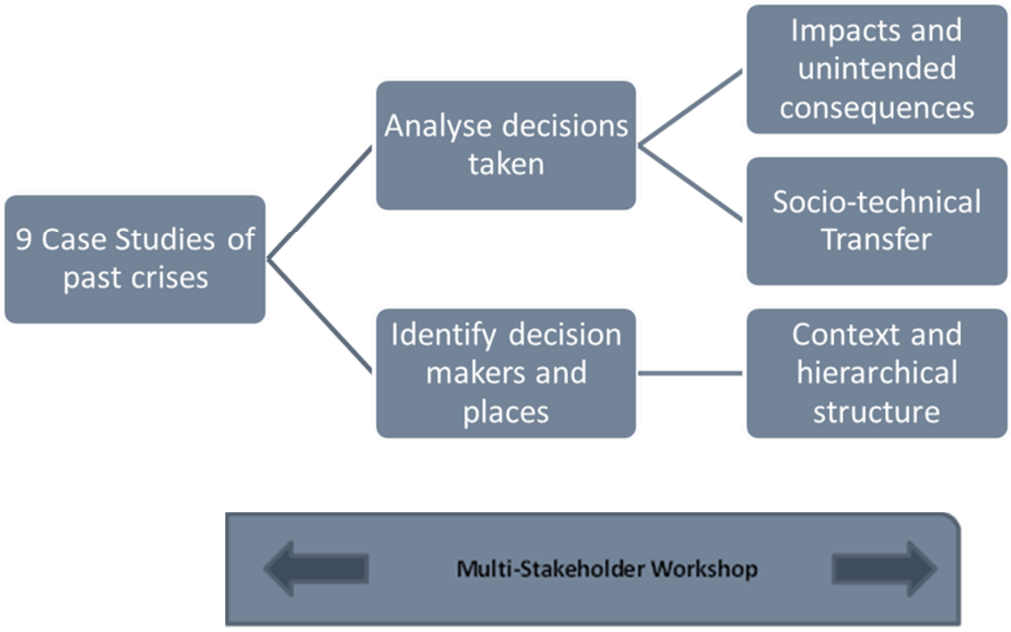

Figure 4: The structure of WP3 displaying the data that was extracted from the case studies. The multi-stakeholder workshop allowed stakeholders that were present during some of the crises to comment, provide recommendations and validate what had been observed

The close involvement of stakeholders across the activities in this work package is reflective of the overall scope of the project which seeks to incorporate stakeholder input at every stage. In keeping with this line, the interviews with crisis managers and first responders provided first hand input into the decision processes during actual crises and allowed partners greater insight into the reasoning behind decisions taken. The organisation of a multi-stakeholder workshop where results from the analysis of decisions taken during past crises were presented and participants provided input and their own recommendations. This workshop and participatory approach formed the basis for a first draft of policy recommendations based on direct stakeholder input.

Recommendations and observations gathered from the stakeholder workshop and interviews allowed partners to define user requirements for the FORTRESS tools (WP6 and WP7). In this regard the knowledge gained from stakeholder interviews and the workshop in London

allowed partners to receive first hand feedback on initial designs of the tool, where stakeholders recommended cutting back on some of the tools proposed functionalities. This engagement with stakeholders throughout the project ensured stakeholders' 'buy in' to the tools and allowed technical partners to clearly identify user requirements in real terms.

Some of the most significant findings were:

- Triggers of cascading effects can have their roots in the outcome of events both during a crisis or prior to a crisis;
- Appropriate regulations and sanctions in a pre-disaster stage have the potential to reduce cascading effects in a crisis;
- Pre-crisis conditions, such as economic and political developments, contributing to cascading effects are more difficult to address by means of preparedness measures;
- Having separate communication systems as well as pre-established plans of approach and clear division of responsibilities could improve the organisational response to crises;
- Cascading effects are not merely related to flaws in interdependent infrastructure, but can be a result of various other factors such as human errors or a lack of resources.

3.4 WP4: SYSTEMS ANALYSES

In the analysis of past crises, dependencies between infrastructures are only evident if a break in that relation triggers cascading effects. Subsequently, only a small subset of potential cascades become visible, whereas a whole range of possible cascading paths remain invisible. For this reason, the focus of this work package shifted from analysing cascading effects in past crises to real-time analysis of the connections between infrastructures during crises, as well as under everyday conditions. For example, how does the health sector connect to the power sector? How is the emergency call system connected to the police? If a disaster struck the power supply, in what ways would this affect the communication between the different first responders? This line of questioning allows for the identification of manifold interdependencies between infrastructures and other actors who become involved in crises. These dependencies were described in detail on the level of systems or sub-systems and modelled as a network graph of nodes and relations. Sensitivity and network analyses were conducted to identify critical nodes whose disruption or failure could lead to multiple cascading effects. This analysis was carried out through four case study scenarios:

1) A cross border power outage in parts of the European transmission grid causing a black out in the city of Berlin. Restoration of the transmission grid requires coordination between different countries' Transmission System Operators (TSO), local Distribution System Operators (DSOs) as well as authorities and first responders (German Case study, TUB);
2) A massive flooding in the Paris area with the consequence of multiple infrastructure disruptions (power production and distribution, public and private transportation, IT system, food and water supplies…) which may lead to disturbances in the power exchanges with French border countries as well as isolating EDF-headquarters from its subsidiaries abroad (French case study, EDF);

3) A Dam disruption/collapse on the boundaries between Italy and France. Major consequences are a blackout in the power distribution networks on both sides of the border, the need for evacuation, pollution due to flooded industrial sites and the breakdown of transportation networks and telecommunication networks (Italian Case study, SiTI);
4) A cross-border flooding in the Netherlands and Germany. Major consequences are the need for evacuation of the affected areas, blackouts, breakdown of transportation networks, telecommunications affected by flood, economic damage to the port of Rotterdam and the Dordrecht shipyards (Dutch Case study, IFV).

Based on this analysis FORTRESS developed the methodology of *dynamic criticality analysis* which has been implemented in the FORTRESS tools. Identifying risk objects, determining probability of failure and the consideration of time are all crucial factors in understanding cascading effects. A power breakdown, for example, may happen in an urban area. The capacity of emergency power for different infrastructures may last 48 hours. The distribution system operator expects the restoration of the power grid within a maximum of 96 hours, so there is a critical time window of another 48 hours. Given such an operational picture, crisis managers are facing problems related to resource distribution. To support decision-making in this situation, a dynamic criticality model is needed that indicates which systems will be affected within this decisive time frame, and if any of those systems may trigger a further cascading effect. Thus, a core element of a dynamic criticality modelling is the buffer time of an entity. It defines how long the entity can ensure system continuity on its own after a certain relation is disrupted such as a supply source (e.g. water or power provider).

The dynamic criticality model of FORTRESS is based on a weighted network graph of nodes and relations. The weights are outcomes of an impact assessment for each relation. The impact is quantified by using a simplified scoring system on a scale of 0, 1, 2, and 3 (no impact, weak impact, medium impact, strong impact). The formal network analysis provides several graph measures that are of interest and can be used as quantitative indicators to assess the criticality before and during crises. Of particular interest are the following two centrality measures (grey box below) whose objective is to determine how central or important each node in the graph is:

OUTDEGREE CENTRALITY
The outdegree centrality of a node is the number of its outgoing relations, including weighted influences, the measure indicates how many and how much other nodes are directly influenced by this given node. A node with a high outdegree-centrality can be interpreted as a node with a high cascading impact on other nodes in the network. The higher the outdegree-centrality, the more effects can be triggered or transmitted along this node.

BETWEENESS CENTRALITY
Betweenness centrality measures the number of times a node connects shortest paths between other nodes. Thus, it is a measure of the potential for control. A node with a high betweenness is able to act as a gatekeeper controlling the flow of effects. In other words: The betweenness degree indicates how much of the effects / information flow through the network is transmitted / mediated by this node. These nodes can thus be interpreted as transmission-nodes which are important facilitators of the propagation of a cascade through the network. If a node has a high betweenness centrality, it is very likely that a cascading effect will propagate through this node.

Below are some important lessons learned from the dependency and criticality analysis that need to be highlighted:

- Infrastructures consist of different socio-technical components, which might be or become critical in certain situations: technical facilities, but also operational centres, repair services and management boards.
- Differentiation between different types of relations, especially between resource and interference relations on the one hand and information relations on the other hand enables the analysis of different types of cascading effects and thus to identify different types of criticality.
- The methodology of formal network analysis proved to be valuable to identify paths of cascading effects and to reveal paths that wouldn't have otherwise been identified.
- In particular "betweeness"-centrality analysis provides useful indicators for critical hubs or transmitters of cascading effects.
- In addition to centrality measures of formal network analysis, the sensitivity analysis provides a specific benchmark for assessing the complexity of a certain node. Whereas nodes with a high active but low passive sum are suitable for interventions into a complex network, nodes with both, a high active and high passive sum, are different to control and thus to mitigate during crises.
- However, it needs to be highlighted that critical infrastructures were analysed on different aggregation levels. All quantitative figures, presented in the scenario case studies are, to different degrees, the outcome of aggregation and thus, must be treated as artificial. This doesn't mean that these measures are useless, but rather that they need to be interpreted in the context of their methodological genesis.
- Both, the interpretation of system and sensitivity analysis findings require methodological reflections with regard to the chosen aggregation level, the involved nodes and infrastructures, but also the mathematical and statistical underpinnings (esp. in the case of network analysis).

3.5 WP5: BEHAVIOURAL ANALYSIS: ACTIVITIES, COMMUNICATION AND DECISION POINTS

Accompanying the identification of relations between infrastructures and sectors, partners sought to identify the communication flows, demands and requirements between responders, public authorities and the media (WP5). What information needs to be provided to whom to successfully mitigate cascading effects during crises?

The following table (see table 2) represents the typology of communication challenges before, during and after a crisis. Who needs to know what and when is the primary concern outlined by these challenges. The questions outlined in the typology represent real concerns by stakeholders, end-users, first responders, crisis managers, critical infrastructure providers, the media and the public. Data to inform the table was collected through simulation exercises with risk managers as well as workshops with journalists and the public as part of the FORTRESS project and represent pertinent and persistent concerns on the availability of information before, during and after crises. The challenges outlined also complement and run parallel to the observations and conclusions drawn out in WP2, WP3 and WP4. Highlighted in the final column are requirements that apply to each set of communication challenges. These requirements are translated into detailed policy recommendations in the next section.

	Pre-crisis	During crisis	Post-crisis	Requirements
General crisis information	- Information on what to expect in terms of citizens and material values to be protected	- Information on actual data, e.g. number of citizens affected, cause of the crisis and means to resolve	- Information on casualties and losses and ease of recovery	- Clear outline of jurisdictional relations and who is responsible for what prior to, during and after a crisis
Specific crisis information				
Information on critical infrastructures and critical sectors	- What critical infrastructures / sectors are in which area and how are they connected	- What critical infrastructures / sectors are in the affected area?	- What are the damages on critical infrastructures? - What are lessons learned in the management of critical infrastructures?	- Sharing of lessons learnt and experience gained in joint expertise sharing and training between first responders, crisis managers and critical infrastructure providers.
Information on critical zones	- Can the area be divided into safety zones of different character: what is going to be submerged and what is not?	- Can the area be divided into safety zones of different character: what is going to be submerged and what is not?	- How long will it take to restore the area?	-
Information on crisis management	- Responsibility and means for providing information	- Responsibility and means for providing information	- Agreements or procedures required looking back at the scenario?	- Joint scenario planning between first responders, crisis managers, critical infrastructures

							providers and transport agencies.
Information on public's information needs	-	What are the characteristics of the public and how do we need to communicate to them?	- Indications of state of mind of the public through social media? - Which health related information is available? - Which security related information is available?	-	How to organize preparedness for future events? - How to evaluate the incidents to prepare the preparation? - How to change communication tools, if necessary?	-	A common standard for communication systems
Information on media's information needs	-	Information on preparedness measures - Information on emergency planning - Information on specific information sources / organisations in case of emergency	- Information on current threats - Information on uncertainties - Information on future measures	-	Information on evaluation measures - Information on mitigation measures - Lessons learned	-	A common directive to decide on information that is provided to the media and the public, ensuring that information released does not compromise response procedures or national security.
Information on stakeholders' information needs	-	Assessing stakeholders' vulnerabilities - Assessing stakeholders' resilience	- Information on current threats - Information on uncertainties - Information on future measures	-	Information on evaluation measures - Information on mitigation measures - Lessons learned	-	

Table 2: typology of communication challenges before, during and after a crisis

The constant interactions with stakeholder groups throughout the workshops and exercises conducted in WP5 provided the basis for policy recommendations (WP5) that draw on the experience and expertise of a wide range of pan-European stakeholders. Thus, the policy recommendations emerge from real concerns and represent commonly acknowledged communication challenges.

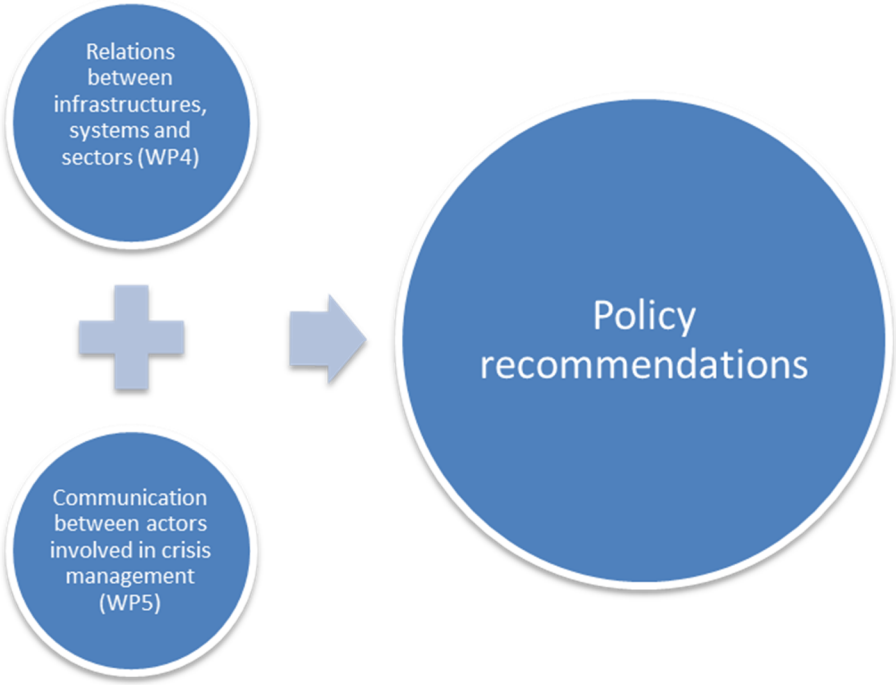

Figure 5: How the policy recommendations are informed by the infrastructure and communication requirements

Policy recommendations

The following policy recommendations build on the communication gaps identified in WP2 and WP3 and reflect the needs of various stakeholders outlined in the typology of communication challenges.

Issue

Cross-border communication: first responders and crisis managers across Europe use different terms and indicators of risk. Such a situation increases the likelihood of miscommunication and the prolonging of appropriate response procedures during crises. Although a common standard (European Tetra standard) does exist, it is not actively enforced and still results in communication issues.

Recommendation

Semantic interoperability: create a European library/repository of terms that feed icons on maps

Rationale

Given that the stated aim of the European Civil Protection Legislation (EU CPL) is to tackle common challenges in the border regions of Europe, the European repository that feed into icons on maps would go some way in achieving this aim. For example, although

the European Tetra-standard is meant to assure that national systems are compatible, communication problems still arise.

Issue

Cross-border communication: The European continent is composed of a variety of languages and dialects that intersect at the borders between countries. For countries sharing a border it is essential that due emphasis is placed on knowledge of languages on both sides of the border and for first responders and crisis managers to have the opportunities to have access to and understand terms employed across the border in crisis response scenarios. It has also been noted that in some cases preference is attributed to one language over another leading to miscommunication.

Recommendation

Semantic interoperability : create a European library of terms that feed maps and applications in multi-lingual settings

Rationale

The 38 border regions of the EU are marked by geographic and linguistic barriers, as well as by contextual differences in response procedures and warning signals during crises. First responders and crisis managers who are involved in cross-border crises require information on the linguistic and contextual differences of the scenarios they operate or *could* operate in to minimise the risk of miscommunication, the assignment of responsibility during a crisis scenario and the identification of risk objects and latent vulnerabilities.

Issue

Cross-border communication: As outlined in WP2 and WP3 as well as in the typology of communication challenges, establishing a hierarchy of responsibilities and jurisdictional relations in cross-border crisis response scenarios is essential for the smooth running of operations during a crisis (as well as prior to and after). *Who* is in charge should be clearly established, as evidenced by the case studies in WP3 where uncertainty over who was responsible for running response procedures created confusion (see example of Enschede fireworks factory explosion and Galtür avalanche).

Recommendation

Introducing definitions of jurisdictional relations between actors involved in crises. Hold cross-border workshops with crisis managers and infrastructure providers to foster knowledge about each other's jurisdictional relations as well as a common understanding of communication relations and needs.

Rationale

Research conducted in WP 3 on past crises revealed that 'disrupted or even failed coordination of actors during crisis management is an important trigger for cascading effects'. A lack of coordination of crisis plans and agreements on organisational

responsibilities were found to have led to cascading effects in these crises. The establishment of clear jurisdictional responsibilities and a clear definition of relations between actors involved would facilitate the execution of crisis response responsibilities. Additionally, in order to facilitate coordination, inter-organisational and cross-sector communication, first responders, crisis managers and critical infrastructure providers need to be able to discuss issues, procedures and response plans in order to gain an understanding of the full operational picture during a crisis and actors' specific responsibilities and roles.

Issue

Cross-border communication: Although the Monitoring and Information Centre (MIC) provides a centralised European communication node for the transfer of crisis related information, this is focused on communicating needs and assistance between national points of contact. Regional authorities for cross-border relations are required to manage the flow of information from a crisis scenario to the relative media and general public on both sides of the border. As outlined in WP2, the maintenance of a relationship of trust between the media, public and first responders and crisis managers is essential for the smooth response to a crisis. Mishandling of information during a crisis can foster distrust and further misinformation.

Recommendation

Common cross-border directive for the provision of information to the media and the public

Rationale

Past crisis scenarios (WP3) have revealed that during a crisis, differing levels of information from responsible authorities on an unfolding crisis may cause uncertainty, suspicion and even panic. In order to avoid contradictory information emerging from various responsible authorities and to enhance public trust in the responsible authorities, it is recommended that a single common cross-border authority be attributed with the responsibility for dispensing and managing information to the public and the media, in order to limit impediments to first responders and crisis managers from carrying out their duties.

3.6 WP6: THE FORTRESS MODEL BUILDER (FMB)

FORTRESS designed and developed two different tools that work in tandem, the FORTRESS Model Builder (FMB) and the FORTRESS Incident Evolution Tool (FIET). Both are meant to be used in the preparation and planning phase before a crisis. The overall philosophy is to improve scenario planning by strengthening cooperation and information exchange and to enable stakeholders involved in a crisis to coordinate better. While the FMB provides the modelling basis for a scenario, the FIET offers a range of instruments to analyse how a crisis scenario may evolve.

The FORTRESS Model Builder (FMB) is a tool for the modelling of cross-system / cross-stakeholder dependencies and relations in crisis scenarios. The design of this tool directly builds on the analyses Work Packages 1 to 5, and incorporates the dynamic criticality analysis in its design. The FMB is first of all an editing tool (see figure 6). It allows to systematically describe any entity that may become relevant or affected during a crisis.

Geographical representations of these entities can be edited in the graphical map editor. Second, it enables to model and define the relations between these entities. There can be multiple connections between two or more entities and different types of connections can be taken into account. Step by step a network develops, including the various entities, their mutual relations and their possible impact. However, the FMB should not to be used by a single organization only but is designed as a collaborative modelling platform. Experts from different organisations login to the platform and indicate their dependency relations with other organisations.

In detail the FMB provides the following features:

- **[1] Scenario setup**: includes the basis functionality for the Scenario Coordinator to login, create a new scenario, and identify the relevant organisations, systems, or sectors to be involved in the scenario definition, inviting then other authorised representatives as System Expert users to join the scenario development.
- **[2] System setup**: once invited by the Scenario Coordinator, a System Expert is allowed to login, join the scenario, in order to define at lower level what is relevant (components / sub-systems) within their own system in the particular scenario to be analysed.
- **[3] Object identification**: The System Expert is be able to define, when relevant, specific objects of their systems (either geo-located objects or not). When necessary, geo-editing features on a map, provided by the tool, can be used to define geo-located objects.
- **[4] Relations model**: as the core modelling feature, cooperative online identification of cross-system / cross-stakeholder relations and potential links and implications is enabled. All the users having been invited to join a given scenario are allowed to, cooperatively, identify relations between existing entities on a graphical way.

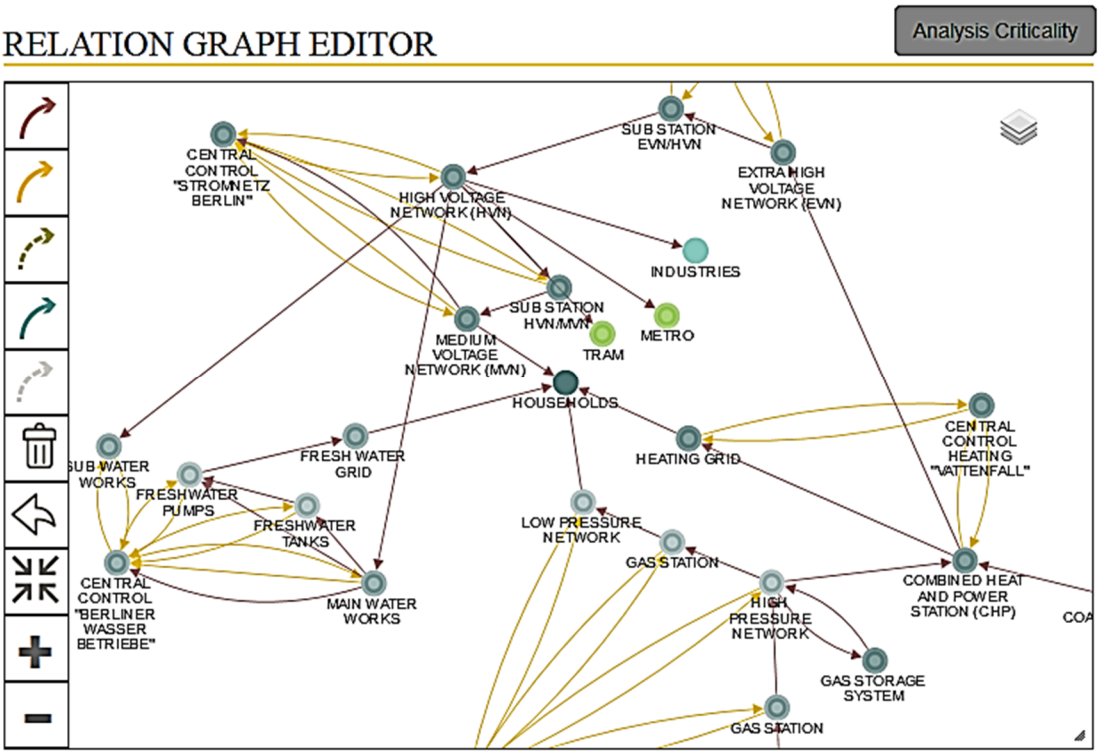

Figure 6: FSB screenshot (overview, main scenario editing view; beta version)

- **[5] Personal dashboard**: the FMB provides communication features in the form of a notifications dashboard. This enabled the different users involved in the modelling stage to stay up-to-date with the changes and updates of the scenarios in which they are involved. A log of changes/updates is provided to users involved in a given scenario in the form of a dashboard. Each message provides the information for the change performed by other users in a scenario where the user is participating. The user can mark the messages as read/unread. The messages are classified according to 3 different categories of changes, either they affect: 1) Changes in the SSM (System Scenario Map); 2) Changes in the graph (relations and nodes); 3) Changes in the GIS editor (geo positioned elements).
- **[6] Impact, criticality, sensitivity and risk estimation models**: the main advancements in the final version was the criticality analysis. Based on the theoretical basis as developed and defined in WP4 for system analysis (in particular, see deliverable D4.2), the FSB provided the mathematical models to compute risk estimation attributes through graph analytics indicators. The following indicators were defined to express different criticality views:
    - Cascading effects potential: calculated through the *Out-degree centrality* of a node in the network, it measures the strength of the effects that a node can cause within the network considering the number of outgoing relations and their impacts.
    - Transmission capacity: calculated through the *Betweenness centrality* of a node in the network, it measures the degree to which effects flow through the network is mediated by one particular node. This might indicate facilitators of cross-sectorial cascading effects, as well as intervention points to intervene on the cascade.
    - Supply cascading effects potential: calculated through the *Out-degree centrality* for resource & interference relations only (subgraph), it measures the strength of the supply effects that a node can cause within the network, considering the number of resources and interference relations and their impact.
    - Resource transmission capacity: calculated through the *Betweenness centrality* for resource & interference relations only (subgraph), it measures how many of the resources flow through the network is mediated by one particular node, taking into account potential interferences.
    - Information transmission capacity: calculated through the *Betweeness centrality* of a node, but considering information relations only (subgraph), it measures how much of the information flow through the network is transmitted by one particular node. Nodes with high values can be seen as information hubs.
    - Information bottlenecks: calculated through the *Bicomponent* estimation, considering undirected information relations; it identifies elements that might isolate others in the information flow. For this reason, these elements can be seen as bottlenecks in the information flow.

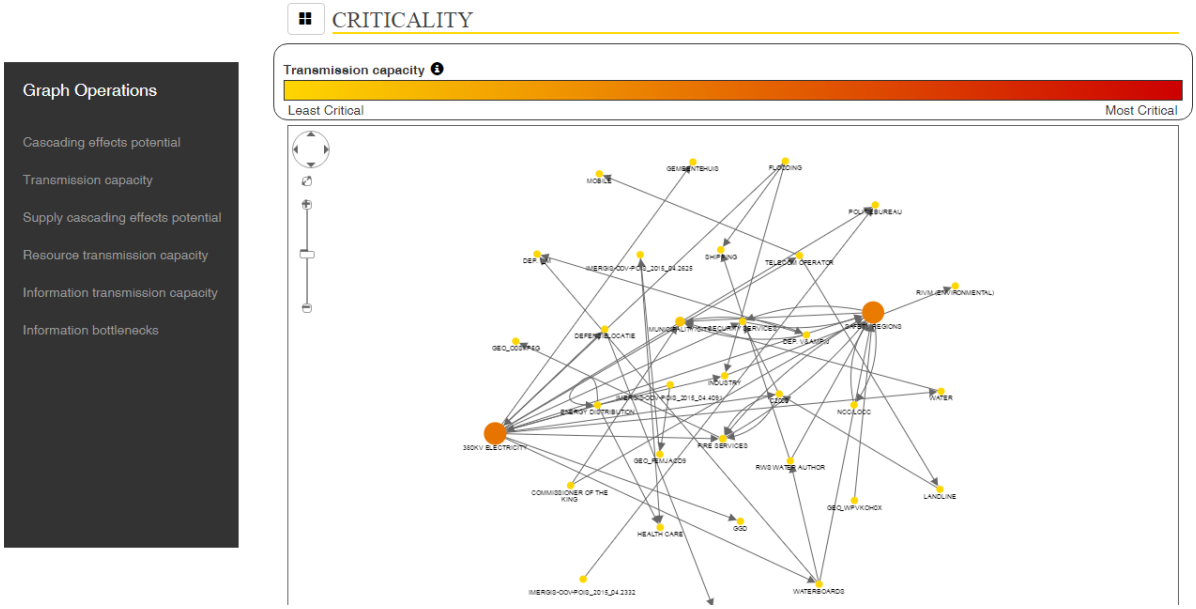

Figure 7: Criticality Analysis by the example of the Berlin case study. Here: Inbetweeness (Ressource Transmission Capacity)

The FMB aims to overcome static notions of criticality which are of limited use in process-based scenario approaches. A consequence-based approach is combined with a systemic approach of criticality where each node is defined by its individual impact (high, medium, low) and by its position respectively by its incoming and outgoing relations within the network as whole. With every failure of an entity the criticality of any other entity in a given scenario model changes as well.

3.7 WP7: THE FORTRESS INCIDENT EVOLUTION TOOL (FIET)

The FIET builds on the FMB. It allows importation of models to analyse diverse pathways of a crisis scenario as well as to assess prioritization and mitigation measures. Just as in the FMB, the modelled entities are displayed in a network view. The user can choose an entity which is disrupted. It becomes possible to assess certain scenarios within the overall relations graph enabling the user to consider *what* happens *if* a certain entity fails when mitigation measures are not available (figure 8).

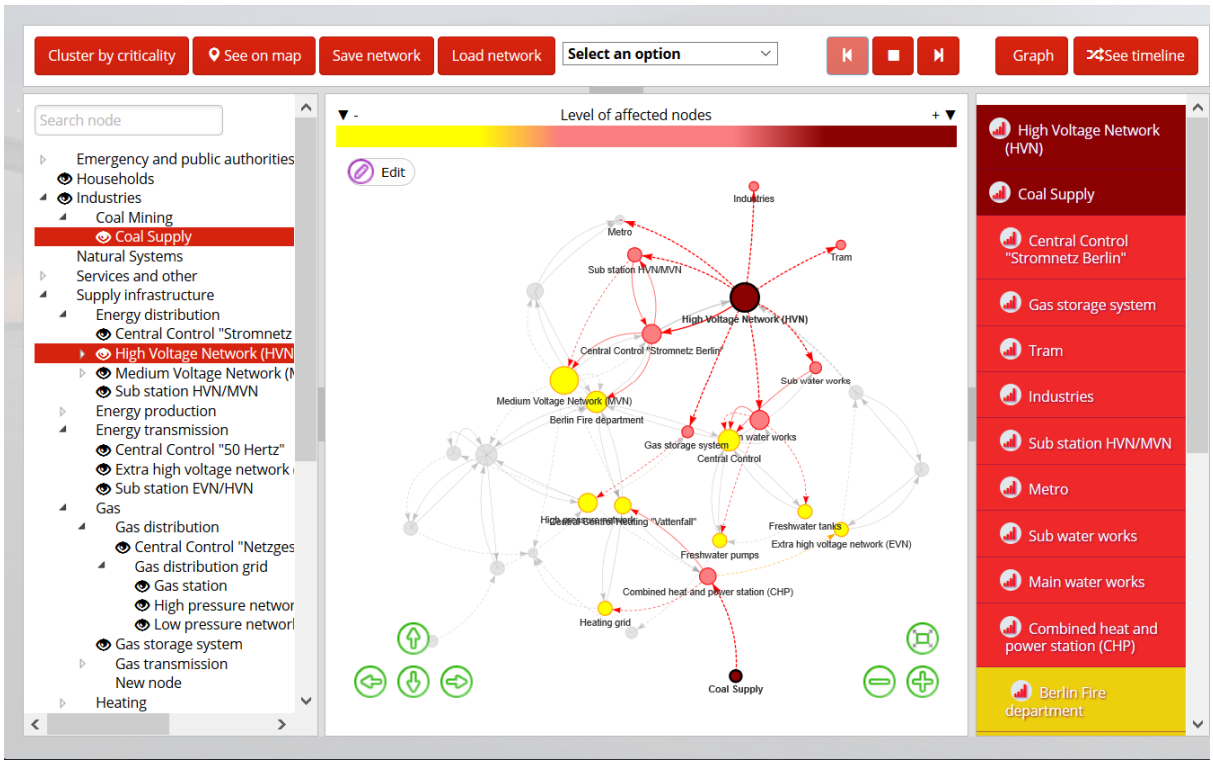

Figure 8: The user clicks on one or more trigger nodes. All directly (red nodes) and indirectly (yellow nodes) connected entities are depicted in the network view as well as in the list view on the right hand side.

As each interconnected entity includes a buffer and a recovery time, the FIET enables users to follow the evolution of a crisis. An automated timeline demonstrates how cascades spread over time and across sectors (see figure 9). An incident first affects one or more entities that – depending on their relation – triggers further incidents and so on.

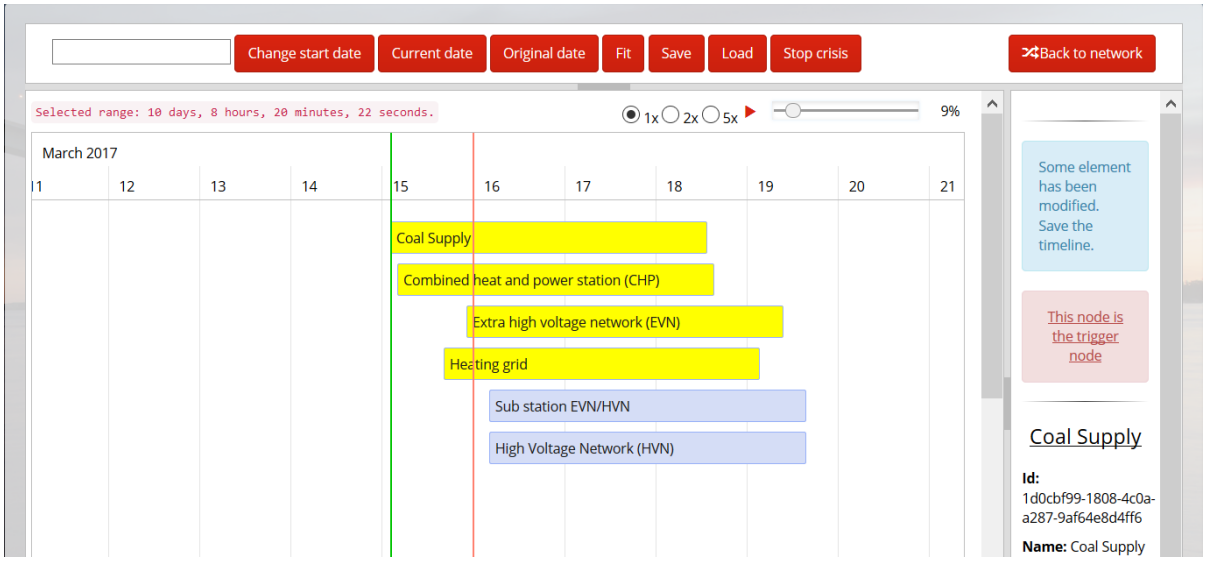

Figure 9: All nodes that can become affected in a scenario through the initially selected trigger node(s) will automatically be included in the timeline. The user can edit the timeline, e.g. change names, include or exclude further entities, indicate starting and end date as well as buffer time and recovery time.

With every failure of an entity the criticality of any other entity in a given scenario model changes as well. This criticality assessment, indicated using different colours, thus allows to

prioritize within a time frame where more action is actually required due to shrinking buffer capacities or temporary shortcomings. Finally, the FIET allows for the removal of entities in order to consider what would happen if a certain entity fails and what mitigation measures could be reasonable to prevent this.

The FIET also can leverage on the spatial information provided by the model generated by the experts on the FMB. The FIET offers a map where the different elements of the model that have an associated geolocation and / or area of influence. They can be selected on the map according to their geographical location, and it also allows the experts to the experts can check the position of the nodes geographically in the map to be able to identify possible problems by proximity to the geographical position of the nodes (indistinctly of the logical relationships already included) and evaluate the impact of the cascading incident from a spatial point of view (affected area, possible population, non-modelled infrastructures visible on the map, etc).

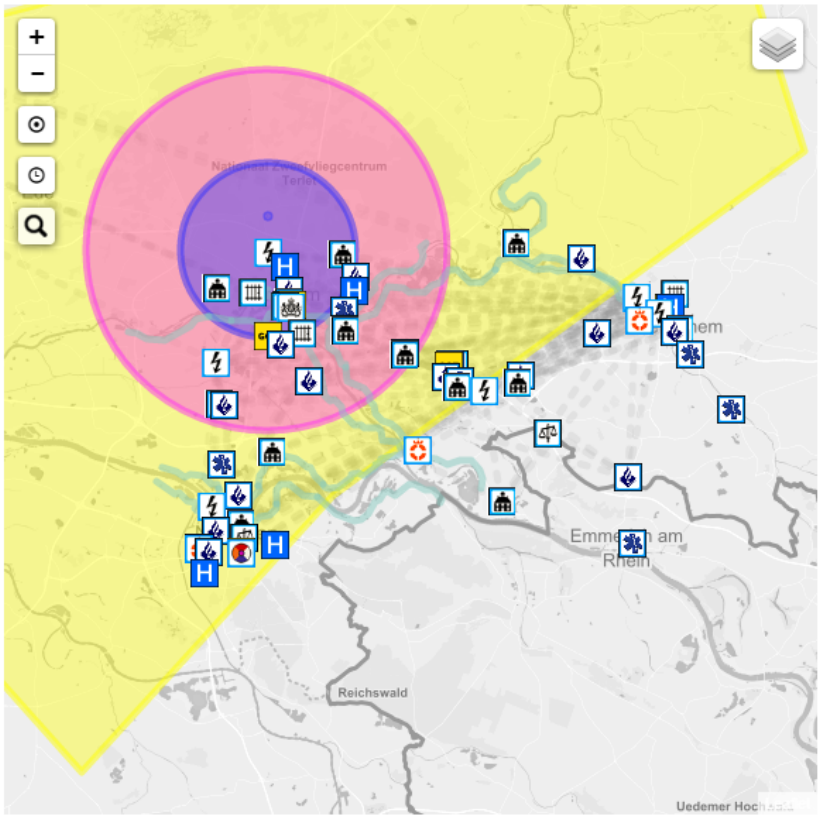

Figure 10: Map view

By specifying different sets of parameters in the simulation, modifying the starting nodes, changing the relationships among network elements, removing non-relevant nodes from the network, altering the timeline to reflect new buffer and recovery times, or creating spatial annotations, the user can generate multiple different scenarios from an initial model.

FMB and FIET are flexible tools that are designed to be used in the pre-crisis phase to support cross-sectoral scenario discussions and planning and thus to increase the awareness on the interdependencies of interconnected infrastructures and of the different types of cascading effects that may come into place during crises.

3.8 WP8: FIELD TESTS AND TRAINING

The FORTRESS consortium heavily involved end users in the research and development process. This means both tools have been iteratively developed with Dutch, German, Italian and French end users in our consortium and have been validated early on with further stakeholders during a whole range of workshops: An early validation of the modelling concept was conducted at a workshop in London in April 2015. A first field test was conducted in Zwijndrecht, the Netherlands in May 2015, involving Dutch and German crisis managers and responders to take part in demonstrations and tests of prototypes for the FMB and FIET. The event also involved 5 EU Cascade projects in a joint comparative exercise (approaches). As a result, user requirements of the FMB and FIET were clarified, guiding the development activities in WP6 & 7. Following the Zwijndrecht field tests, a technical requirement workshop with Dutch end users was conducted in Berlin in October 2015, discussing how the FMB and FIET could be connected with the Dutch crisis management system: LCMS. Finally test protocols for four field tests were prepared.

The main trial was held in Tiel, the Netherlands in September 2016. The event involved training of crisis management team members in the use of the FMB. Users collectively created the operational scenarios in the FMB and exported them to the FIET for the trial. Three parallel trials at a smaller scale were conducted in Italy (Turin, November 2016), France (Paris, October 2016) and Germany (Berlin, December 2016), and focused primarily on a shorter demonstration and test approach to confirm and validate the FMB/FIET results. In Tiel, German and Dutch cross-border crisis teams worked together on a joint scenario, and set the scene for acceptance of the FORTRESS approach, and the initiation of policy-changing discussions concerning cross-border data exchange in crises. Also in Tiel, the 5 EU Cascade projects (CascEff, CIPRNet. FORTRESS, SECTOR, PREDICT) met once again for a knowledge exchange and tools comparison event that informed all of the associated community of users.

The following provides a short list of key recommendations and open topics for future deployment of the FMB/FIET and for associated research based on the conclusions emerging from WP8:

1. Cascade modelling supports reasoning about likely crisis events and planning for crisis management. Methods for deploying such tools in training exercises should be explored with crisis management teams.
2. Crisis management teams are varied in makeup, requiring tools to be designed and adapted to support a range of user types (multidisciplinary and co-creation approach).
3. Cascade modelling only makes sense in relation to highly specific reference scenarios. Crisis teams need to identify which risks in their region are prone to cascades and develop models for these. Crisis teams also need to engage the relevant actors to tackle a cascade risk to learn from them and re-define their crisis management plans and approach.
4. Results show that using modelling tools can facilitate engagement between crisis experts and analysts, often remotely, to provide access to knowledge and insights of high value for modelling, as well as for subsequent crisis management planning. These experts react better to specific scenarios and can help detail them to enrich the common picture. Tools therefore need to be deployed in an inter-organisational and inter-disciplinary context.
5. Scenario builder / cascade modelling tools require acquisition of new skills, and not all crisis experts are comfortable. We need to identify “modelling champions” – people who are able to use tools well and who also provide a natural focus for the

team (coordinating model building). This is a new role and a new challenge to be explored.

6. Modellers should be crisis team members, not external technology experts, since the main task is coordinating, understanding and building a shared scenario and model. Technical support can be provided, but acknowledged as just that (help when needed).
7. It was observed that teams work differently and so no fixed approach is recommended. Instead, teams need to explore ways to establish the initial scenario (brainstorming, world café, etc.). This basic scenario can be adopted via tools to then elaborate on the required detail.
8. Teams must decide which entities are relevant to their scenario. Not fixed.
9. Different organisations and teams have different terminology, icons, etc. Bringing them together emphasises these differences and standardisation or translation of terms and icons has to be made an agenda item (information exchange / semantics).
10. A European level repository of terms and icons, supported by EU countries with experience in the actual take up of such facilities should support the harmonisation effort, whereas at the moment these efforts are 'tribal', monodisciplinary or technology driven.
11. An agreed model must be linked to an agreed and common crisis response plan and regularly updated as part of that review process. This may require new joint planning protocols among the stakeholders that are involved in incident management.
12. New ways of collaborating will challenge existing arrangements and so Governance and Policy issues need to be identified and solved at regional level.
13. Crisis teams must be given training to help team building, as well as opportunities to gain consensus on new risks / review known risks (training and review).
14. Weather and crisis know no borders – cross border risks should be addressed and are easier to address using the FORTRESS tools (new teams, new protocols).
15. Initiatives for integration of European and local geographical content, such as satellite imaging, base registries, aerial photography and object databases should be supported, whereas INSPIRE (EU spatial data infrastructure) is now too much focused on environmental control.

4 DISSEMINATION ACTIVITIES, POTENTIAL IMPACT AND EXPLOITATION

4.1 DISSEMINATION ACTIVITIES

The FORTRESS dissemination strategy (D9.1) provided the basis for engaging with stakeholders (crisis managers, first responders and critical infrastructure providers) through a stakeholder identification and interaction process. The intent was to create an impact (socio-economic and policy) that will outlive the duration of the project by making the results of the research known to those who could benefit from them. This was made possible through partners' close engagement and communication with first responders prior to, as well as during the course of the project, collaboration that was facilitated by end user involvement in the project as associate partners (e.g. SDIS, BWB) and full partners (EDF; IFV). This approach enabled FORTRESS to strengthen the research and knowledge base of stakeholders by facilitating the presentation of the work and results of FORTRESS precisely and effectively to as wide a stakeholder audience as possible.

This objective was achieved through: (1) the identification of a wide stakeholder audience and the compilation of a contact list of persons interested in FORTRESS and its findings, and (2) the development of differentiated and targeted communication approaches for different categories of stakeholders.

Given that stakeholders are so central to the outcomes of the FORTRESS project, more specific objectives were required to ensure that dissemination activities complemented the development of the FORTRESS tools in order to identify pathways for the exploitation and further development of the tools' capacities. The following are specific dissemination objectives for the FORTRESS project:

1. ***To use dissemination activities as a way to stimulate feedback on the results of our research, to invite critique and the validation of the methodologies being employed, as well as the tools being developed.***

Given the pan-European approach of the project and the centrality of stakeholders to provide specific requirements for the FORTRESS tools, dissemination and communication are of key importance to the FORTRESS project. Project deliverables and case studies were used as a basis for discussion with a broad range of stakeholders in interviews, focus groups and face-to-face in workshops, the outcomes of which contributed to the consortium's research, analyses and the requirements for the FORTRESS tools.

2. ***To initiate a collaborative and communicative approach with stakeholders and end-users to parallel the objectives of the FORTRESS tools and ensure an immersive engagement (buy in) in the development of the tools.***

FORTRESS built up a consistent following of stakeholders involved in crisis management and representing critical infrastructure from countries across Europe, inviting them to participate in FORTRESS events and share their experiences of crisis mitigation. The objective of this approach was intended to mirror the objectives of the FORTRESS tools (FMB and FIET); to stimulate conversation and communication among and between stakeholders and to explore the factors generating cascading effects during crises.

3. ***To promote our findings and recommendations, especially those with regard to options for enhancing social, economic and institutional resilience.***

Effective dissemination results in the establishment of contacts and interconnection of networks – a legacy that often outlives the project. The FORTRESS dissemination and exploitation strategy aimed at identifying and establishing contacts with other relevant projects and studies, to increase awareness of the consortium's work and research results. A further objective of the strategy was to facilitate collaboration among different groups of stakeholders to enhance uptake of the project's results and integrate different and diverse end-user knowledge. The consortium placed particular emphasis on facilitating this collaboration, establishing important links and closely integrating with other organisations carrying out similar or related research and analysis.

4. ***To promote widespread use of the FORTRESS policy recommendations to facilitate and encourage cross-border and cross-sector communication and collaboration.***

The consortium used the language skills of different project partners to organise events that employed other European languages such as Dutch, French, German, etc. This enabled partners to reach stakeholders outside of those who traditionally participate in European projects, which are almost exclusively focused on communication in English. In addition, two Domino conferences organised in conjunction with FORTRESS, featured between 100 and 150 participants from across Europe, where talks and discussions were carried out in Dutch, German and English. Such events served to discuss key issues and gaps in policies related to crisis management and cross-border collaboration in the EU in an inclusive way, as well as to collectively draft alternative recommendations.

5. ***To illustrate the benefits of the FORTRESS tools (FMB and FIET) for use in training related to the mitigation of cascading effects during crises***

The creation of a project video and training tutorial video for the FORTRESS tools provided an easy and accessible medium for stakeholders, end-users and the general public to understand the FORTRESS concept and to understand the benefits and potential benefits of the FORTRESS tools for training purposes. Ensuring that stakeholders were kept up to date with progress in the development of the tools allowed them to share their input and shape the functionalities offered by the tools. In this case end-user comments and feedback actually resulted in partners altering the design of the tools to fit with end-user requirements. This approach facilitated the buy-in of stakeholders and end-users in the final product.

4.1.1 FORTRESS stakeholders and the socio-economic impacts of the projects

The FORTRESS project draws from a wide range of stakeholder groups (see Table 3) that seek to benefit from the research and technological outputs of the project. Understanding why these research outputs are important to stakeholders and end users is an integral part of the FORTRESS dissemination strategy that will allow the consortium to intensify the long term socio-economic impact of the project. Crucially, FORTRESS seeks to spread awareness of the project outcomes so that they may benefit further research. Tied in with the latter is the aim to affect current policy and practice for cross-border communication and collaboration during crises but even in the pre-crisis or cold phase. In this regard, the FORTRESS workshops and conferences (Knowledge sharing workshop in Tiel and the DOMINO 1 and

DOMINO 2 conferences) encouraged cross-border communication and problem solving between crisis managers, first responders and critical infrastructure providers from Germany and the Netherlands. This reflects the FORTRESS ethic of meeting the project's objectives through the tools and knowledge generated, as well as through the day to day running of the project activities. Close engagement with stakeholders during events and providing the space for stakeholders to work together provided opportunities for partners to better identify the most appropriate policy recommendations for affecting change at a pan-European level. Table 3 below illustrates which stakeholder groups were targeted, why they were targeted and what impacts such engagement will have.

Stakeholder type	**Why we want to reach them**	**What will stakeholders gain (impact of the engagement)**
Government • Policy makers at European and Member State level • Members of the European Parliament and national parliaments • Emergency management agencies • Local authorities	• To inform them about emergency response issues addressed by the consortium and the FIET • To engage them in a dialogue about these issues • To invite them to consider recommendations made by the consortium, notably with regard to the use of the FIET • To encourage them to adopt the FIET • To assist them in the ongoing development of institutional guidelines in the complex nature of cascading effects and the need for coordinated and collaborative cross-border decision making during a crisis	• The opportunity to develop the technologies and knowledge for building capabilities needed to ensure the security of citizens from threats such as terrorism, natural disasters and crime, while respecting fundamental human rights including privacy; to ensure optimal and concerted use of available and evolving technologies to the benefit of civil European security, to stimulate the cooperation of providers and users for civil security solutions, improving the competitiveness of the European security industry and delivering mission-oriented research results to reduce security gaps. • Develop collective capacity among Member States, promote international, cross-border partnerships in crisis response and facilitate European co-operation in disaster situations with cascading effects.
Emergency Managers and First Responders	• To inform them about emergency response issues addressed by the consortium and the FIET • To engage them in a dialogue about these issues • To invite them to consider recommendations made by the consortium, notably with regard to the use of our FIET • To encourage them to adopt the FIET • To assist them in the ongoing development of institutional guidelines	• Assist with the implementation of a decision support system in the form of an incident evolution tool (the FIET) to optimise decision-making and minimise the cascading effects of a cross- border crisis. This will ensure that optimal use of available and evolving technologies and research practices (such as foresight tools) are benefiting European society by positively enhancing the modelling ability of dependencies in a complex crisis situation to help support decision-makers to prepare and respond to potential cascading effects in a cross border crisis, both in terms of preparation and training and real-time

		decision-making.
Media • Newspapers • Journals • Blogs • Social networks	• To encourage the media to raise the awareness of stakeholders, notably relevant organisations, about how important collaboration is to effective decision making to enhance emergency response. Media attention will help raise issues of concern to the consortium on the public and policy-makers' agendas. • To stimulate critical debate and information sharing about the various interdependencies between critical infrastructure and human behaviour as a result of cascading effects in a crisis.	• Making the results of the project known to those who could benefit from them, i.e. policy-makers and government agencies dealing with crisis preparedness, management and response issues and making specific investment decisions, as well as first responders and emergency managers who will need information regarding the prediction and modelling of the various dependencies in crises with cascading effect.
Academia • Universities • Research institutes	• To inform them about emergency response issues addressed by the consortium and the FIET • To encourage the use of our policy guidelines and good practices in respect of scientific research. • To encourage academics to provide their views with regard to the consortium's findings and recommendations as they are being developed as well as once they have been formulated. • To encourage academic organisations and researchers to conduct further research in regard to the issues of concern to the project's themes.	•The opportunity to apply for EC funded research and projects. FORTRESS addresses a number of issues related to physical and human interdependencies during cross-border crises, an aspect that the EU commission has expressed a clear interest in. The outcomes of the FORTRESS project provide the basis for developing this research further and exploring new avenues in this respect. •Knowledge gained and the collaborations forged through the project will enhance the current research and ideas related to cascading and cross-border effects of crises.
Civil society organizations (CSOs)	• To encourage civil society to lobby policy-makers to consider the recommendations made by the consortium. • To encourage CSOs to raise awareness of their members on these issues.	•Strengthen European values towards engagement and collaboration between different European states thereby contributing to social and territorial cohesion across Europe.
Industry • Hardware and software designers and developers • Service Providers • Technicians • Industry associations	• To inform them about emergency response issues addressed by the consortium and the FIET • To encourage the use of our policy guidelines and good practices in respect of scientific research. • To encourage industry to provide its views with regard to the consortium's findings and recommendations as they are being developed as well as once	•It creates increased collaboration and communication between researchers and industry and provides an example of how research into crises may be applied to more tangible aims and the creation of state-of-the-art tools. It accomplishes one of the main project goals of using the project as a platform for communication between industries, stakeholders and researchers working

	they have been formulated.	towards the same aim.
Project partners	• To draw the attention of partners in other EC projects to the activities of the FORTRESS consortium. • To exchange information and views with those other project partners. • To leverage the activities of other projects.	•The knowledge gained can inform other projects dealing with similar issues, promote discussion and pave the way for future collaborations in this area. It also widens the network of researchers and practitioners debating these issues.
The public	• To raise the awareness and understanding of the public with regard to the emergency response issues addressed by the consortium. • To encourage the public to lobby their political leaders in support of the consortium's recommendations.	•Inspiring government and public discourse about disaster preparedness and response that provides better insight into the information needs of emergency managers and other decision-makers and the difficulties associated with unreliable or misleading information in times of crisis, particularly those crises with the possibility of cascading effects.

Table 3: FORTRESS stakeholders, why we want to reach them and the potential impacts of their engagement with the project

4.1.2 Main Dissemination Activities

FORTRESS used a variety of different methods to disseminate the project outputs, from online material and regular tweets to academic and non-academic publications, videos and through events (confereces, workshops, pilot tests). The FORTRESS website provides news and updates on the project's activities and outputs, upcoming events, links to related projects, publications and project deliverables. In addition the website links up to FORTRESS' social media accounts and allows visitors to comment on new material. The project's website is one of the main and versatile sources of information about the project available to stakeholders. The website was established immediately after the project's kick-off in April 2014 and will be maintained for at least one year after the project ends. The FORTRESS website can be accessed via the world-wide web at the following address: http://fortress-project.eu/.

4.1.3 FORTRESS Video

Partners produced three videos to generate further interest in the project, visually present the outcomes and to provide guidance on the use of the tools (Figure 11, below).

Figure 11: Screenshot still of the FORTRESS kick off film, available at http://fortress-project.eu/

4.1.4 Publications

As part of its efforts to disseminate the project results to the scientific community, the FORTRESS consortium has published the following publications. A number of publications are in the process of being published in the course of the coming year (2017).

- Nones, M; Pescaroli, G; (2016) Implications of cascading effects for the EU Floods Directive. *International Journal of River Basin Management* , 14 (2) pp. 195-204
- Pescaroli, G. and Kelman, I. (2016), How Critical Infrastructure Orients International Relief in Cascading Disasters. *Journal of Contingencies and Crisis Management.*
- Pescaroli, Gianluca and David Alexander, "Critical infrastructure, panarchies and the vulnerability paths of cascading disasters", *Natural Hazards*, 12 February 2016, p. 1-18
- Hagen, Kim, "The 2007 Solomon Islands earthquake and tsunami: cascading effects and community resilience", *SECED 2015 Conference – Earthquake Risk and Engineering towards a Resilient World*, Cambridge, UK, July 2015.
- Watson, Hayley, Kim Hagen and Tom Ritchey, "Experiencing GMA as a means of developing a conceptual model of the problem space involving understanding cascading effects in crises". *Proceedings of the 12th International ISCRAM Conference*, Kristiansand, Norway, May 2015.
- Hagen, Kim, Meropi Tzanetakis and Hayley Watson, "Cascading effects in crises: categorisation and analysis of triggers", *Proceedings of the 12th International ISCRAM Conference*, Kristiansand, Norway, May 2015.
- Watson, Hayley, Kim Hagen, Susan Anson & Kush Wadhwa, "Working with emergency responders across Europe to enhance crisis communication practices", *British APCO Journal*, Volume 21, Issue 1, March 2015, p.22-23

- Pescaroli, Gianluca and David Alexander, "A definition of cascading disasters and cascading effects: Going beyond the 'toppling dominoes' metaphor", *Planet@Risk*, Vol. 3, No. 1, 2015.
- Hagen, Kim, Hayley Watson & Kush Wadhwa, "FORTRESS", *The International Emergency Management Society Newsletter*, Issue 21, August 2014, pp. 21.

4.1.5 Twitter

Twitter served as the project's everyday conduit to the outside world, enabling regular dissemination and communication with a growing following of stakeholders. Since November 2014, the total number of FORTRESS tweets have reached 155, 600 other Twitter accounts (Figure 12), where 60,400 accounts were reached in the period April to June 2016 alone. This could be explained by a notable increase of tweets being scheduled for this period to promote project deliverables, updates and events (such as the DOMINO conference and workshop) that coincided with this period.

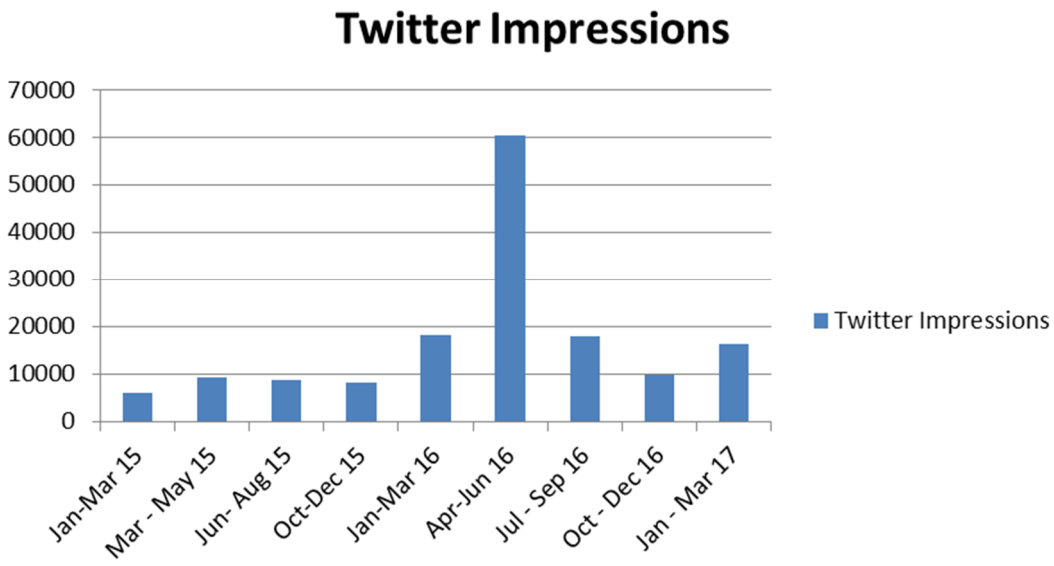

Figure 12: Twitter engagements over the lifetime of the project

4.1.6 Workshops and Events

Direct engagement with stakeholders and end-users (first responders, crisis managers and critical infrastructure providers) has been central to achieving the project outcomes. This engagement has taken the form of participation at external events such as conferences and workshops related to crisis management where partners engage with various audiences and promote the FORTRESS research. More directed engagement was achieved at events organised by the FORTRESS consortium to: gather feedback on user requirements, learn from experienced end-users, share the knowledge gained with other EU projects and researchers, and shape and promote policies to enhance cross-border communication. The following are the main events organised as part of the FORTRESS project:

Event: Multi-stakeholder workshop

Date: 10/04/2015

Location: London, UK

Participation: 12

Aim: Gain feedback and input into the development of models from external participants who have knowledge and experience of preparing for or managing crises.

The multi-stakeholder workshop (Box Above) served as a first opportunity to discuss preliminary versions of the FORTRESS tools with a small group of first responders. Participants discussed the FORTRESS Model Builder (FMB) and the FORTRESS Incident Evolution Tool (FIET), which were being developed to aid decision-makers and crisis responders in reducing cascading effects both prior to and during crisis events. The workshop was aimed at gaining feedback and input into the development of these models from external participants who have knowledge and experience of preparing for or managing crisis situations.

Event: DOMINO workshop

Date: 20/05/2015 – 22/05/2015

Location: Zwijndrecht, the Netherlands

Participation: ~200

Aim: To debate and reach agreement on future requirements for crisis management systems.

FORTRESS partner IFV co-organised the DOMINO conference (Box above) and workshop series in Zwijndrecht, the Netherlands, from 20th to 22nd May 2015. The event focused on a flooding scenario and attracted almost 200 domain experts who are active in crisis management. It included demonstrations of crisis management systems in mobile field command centers for realism, and exposed participants to frontline users and their working situations. Presentations were made by DG-ECHO, Dutch Ministry of Security, and Dutch Water Board to set the scene on EU Security Policy and its implementation at various governmental levels.

Event: Knowledge-sharing workshop

Date: 20/09/2016 – 21/09/2016

Location: Tiel, the Netherlands

Participation: 35 (workshop), ~130 (DOMINO)

Aim: (1) to share research results with other EU projects focused on cascading effects during crises, (2) to demonstrate the functions of the tools to end-users and collect their feedback

On 20 September 2016, the FORTRESS consortium together with six other EU projects (INTACT, PREDICT, SECTOR, CIPRNET, CASCEFF and DRIVER) focused on mitigating cascading effects during crises, held a knowledge-sharing workshop in Tiel (Box above), the Netherlands. The workshop provided a platform for the exchange of research outcomes

between related European projects. The workshop had two overarching themes: 1) empirical findings for reducing cascading effects in crises and enhancing resilience, and 2) tools for supporting decision making before and during crises. The workshop provided an opportunity to discuss the latest empirical findings in the field of crisis management, resilience and the curbing of cascading effects during crises.

Event: Cascading effects conference (joint final conference)
Date: 16/03/2017 – 17/03/2017
Location: Brussels, Belgium
Participation: ~135
Aim: To share the final research results and present the FORTRESS tools to stakeholders, other EU projects, the European Commission and the community of users (CoU).

The FORTRESS final conference involved a joint conference (Box above) between other EU FP7 projects focused on the mitigation of cascading effects during crises. The joint conference of projects funded by the European Union's Seventh Framework Programme included the following projects: CascEff, CIPRNet, FORTRESS, PREDICT and SnowBall. The conference focused on four main themes related to cascading effects during crises and featured presentations of the foresight tools developed by each of the projects.

4.2 EXPLOITATION - RESEARCH

Process and Plans

The FORTRESS consortium have identified four main target areas for expanding on the research conducted as part of the project (Table 4), all of which are interconnected. Partners TRI, UCL, DIA and TUB have plans to publish between one and two articles in journals related to disaster management, resilience and emergency response. UCL and TUB have submitted a proposal for the International Journal of Disaster Risk Reduction on "Understanding and mitigating cascading crises in the global interconnected system". RCAB plan to publish an article in the Journal of Disaster Management which will concern the use of morphological analysis and Bayesian Networks for modelling the societal consequences of natural disasters, as was conducted during the FORTRESS project.

Exploitation Targets	Partners involved
1. **Produce publications**	TUB, TRI, UCL, DIA, RCAB
2. **Apply for further research funding**	TUB, TRI, IFV, TREE, SiTi
3. **Continued discussion and collaboration**	All partners
4. **Develop seminars and workshops on the use of the tool**	TUB, TREE, GMV, EDF

Table 4: Consortium exploitation objectives with regards to research

Various FORTRESS partners (TUB, TRI, IFV, and TREE) have worked together outside of the project to develop a funding proposal that builds on the work conducted in FORTRESS and seeks to continue the development of the tools and research. This has ensured that the issues raised through FORTRESS will continually be discussed following the end of the project. An example of this effort has been the signing of the joint declaration (see D9.8)

between FORTRESS and other project partners and stakeholders. The Joint Declaration represents a common understanding of the main issues in effective crisis management, as well as a commitment to continued collaboration beyond the project. This initiative has led to fruitful opportunities that saw FORTRESS partners organise a workshop, entitled '**User-based Field Test Framework'** at the upcoming 2017 ISCRAM (Information Systems for Crisis Response and Management) in May 2017 in France.

Partners GMV and TREE will host the FORTRESS tools (FMB and FIET) on their websites for a minimum of three years following the end of the project, and will not be available to the public. The tools will be freely accessible to consortium members to use for research purposes and analysis, as well as for partners to use for their own exploitation goals. For example, TUB, GMV and TREE have agreed to continued cooperation following the project in the form of collaborative scenario workshops using the tools which will be directed at two audiences: critical infrastructure representatives and post-graduate students researching the mitigation of cascading effects during crises. Seminars and workshops using the tools will be held at the Technical University of Berlin (TUB), and will begin within the first six months from the end of the project. It has not yet been decided how long this will carry on for.

4.3 TECHNOLOGY DEVELOPMENT

The core outputs of the FORTRESS project are the two tools, the FMB and FIET. GMV and TREE are continuing to work *pro bono* on the further adaptation and refinement of the tools, by integrating further the user requirements into the tool. One such addition has been the inclusion of a timeline in the FIET that allows users to play a crisis scenario and identify the amount of time it would take for cascading effects to take place. This refinement will adapt the tools further to user requirements and make the tools more useable.

Exploitation Targets	Partners involved
1. Integrate further user requirements	GMV, TUB, IFV, TREE, SiTi
2. Identify interested customers	TUB, TREE, GMV
3. Continued discussion and collaboration	All partners
4. Develop seminars and workshops on the use of the tool	TUB, TREE, GMV, EDF

Table 5: Consortium exploitation objectives with regards to technological outputs

Although the tools are meant to provide the basis for training and preparedness in crisis scenarios, their ultimate aim is to enhance wider inter-sectoral and cross-border communication and collaboration. At the joint final conference on cascading effects, one FORTRESS presenter (Marcos Sacristan, TREE) noted that the tools will function fine for these stated purposes but are still reliant on the quality and extent of data available.

Conditions for facilitating transfer of data and the creation of conditions that would allow for the collection of such data are reflected in the policy recommendations proposed by the project and presented at the final conference. Many of the policy recommendations were also presented at the workshop in Tiel and adapted according to the feedback received. The policy recommendations will be presented to key policy makers at the European Commission, as well as future events such ISCRAM 2017, and meetings with the Community of Users (CoU). Policy recommendations deal with increased training, communication activities and relationship building between end-users sharing a border. Such a policy would allow for more

integration of crisis-relevant information in different contexts and improve the quality and quantity of data available to be processed by the tools. In many respects the FORTRESS project has succeeded in initiating this flow of communication. However, the enactment of the proposed policy recommendations remains a factor that will affect the future marketability and usability of the tools across a pan-European context.

4.4 APPLICATION IN TRAINING AND PREPAREDNESS (CONFIDENTIAL)

As part of their involvement in the project, EDF developed a baseline scenario of a major flooding of the Parisian region leading to a potential flooding of an EDF R&D site located on an island along the Seine River. Participants (i.e. stakeholders) to the test had faced several challenges such as continuing activities which cannot be shut down (despite the crisis) while mitigating potential cascading consequences such as avoiding pollution of the river caused by release of "toxic" wastes stored in the EDF site.

Results of the test showed that the main contribution of the tools lies in their added value during preparation (and/or training) phase of the crisis management. During this phase stakeholders have to share their different visions, to make efforts to understand each other, in other words to create an atmosphere enabling an efficient and relevant cooperation as a condition to cope with unexpected cascading effects of such a crisis scenario.

Use of the tools during preparation/training phase allows collaboration between stakeholders and therefore sharing of visions, an improved understanding of each other's roles, and taking into account unforeseen developments during a crisis. As a result, the tools are to be presented to different EDF branches such as the hydraulic branch. EDF envisages using both tools: FMB and FIET for internal purposes. The following issues are now under consideration:

- To enhance risk acceptability: using these tools in focus groups will enable EDF to put the question of risks and resilience under discussion. As stakeholders build a common vision of risks and resilience, their understanding of risks in their specific contexts will improve
- To enhance safety culture: simulating crisis management to be better prepared, enabling past crisis simulations and replays in order to train managers and show internally that cascading effects during a crisis can be mitigated.

Exploitation Targets	Partners involved
1. Use the tools for training purposes	IFV, EDF, SiTi
2. Use the tool to develop contingency plans	SiTi, EDF, IFV
3. Continued discussion and collaboration	All partners
4. Develop seminars and workshops on the use of the tool	TUB, TREE, GMV, EDF

Table 6: Consortium exploitation objectives with regards to application in training and preparedness

Partners IFV are in discussions to continue using the tools with first responders and crisis managers in the Netherlands. They plan to promote the use of the tools further especially during training and preparedness phases, to learn from past crises scenarios and to formulate contingency plans for future crises. IFV plans to utilise the FORTRESS tools within this context to refine current crisis contingency plans and to provide training for crisis management and first response based on the modelling of crisis scenarios.