PANTHEON

Community-Based Smart City Digital Twin Platform

for Optimised DRM operations and Enhanced Community

Disaster Resilience

D3.6

USE CASE SCENARIOS

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TASK ABSTRACT

The present Deliverable "Use Case Scenarios" is the outcome of T3.6 "Project use case specification and scenarios". The aim of this Deliverable is to provide the selected disaster and usage scenarios along with their respective use cases to the technical partners of the project and thus enable them to formulate system specifications and the design of the high-level reference architecture of PANTHEON. Specifically, the work done was based on the regulatory framework in the under-study regions (T2.1), the hazards analysis based on literature (T2.2), the community characteristics and capacities (T.2.3), the ethical and legal considerations (T3.5), the feedback of stakeholders based on guidelines for participatory governance (T2.5, T2.6 and T3.2), the technical capabilities and the preliminary technical designs (T2.4, T3.1, T3.3 and T3.4). An iterative approach was followed in order to arrive to prioritise specific hazards based on a number of criteria and discussions between technical and end-user organisations.

[1] **Please indicate the type of the deliverable using one of the following codes**:
R = Document, report
DEM = Demonstrator, pilot, prototype, plan designs
DEC = Websites, patents filing, press & media actions, videos
DATA = data sets, microdata
DMP = Data Management Plan
ETHICS: Deliverables related to ethics issues.
OTHER: Software, technical diagram, algorithms, models, etc.

[2] **Please indicate the dissemination level using one of the following codes**:
PU = Public
SEN = Sensitive

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
A-SIT	Austrian Secure Information Technology Centre
AI	Artificial Intelligence
APCIP	Austrian Programme for Critical Infrastructure Protection
API	Application Programming Interface
C3S	Copernicus Climate Change Service
CBDRM	Community-based Disaster Risk Management
CBSCDT	Community Based Smart City Digital Twin
CERT.at	Computer Emergency Response Team Austria
DESFA	Hellenic Gas Transmission System Operator S.A.
DRM	Disaster Risk Management
E.P.P.O	Earthquake Planning and Protection Organisation
ECMWF	European Centre for Medium-Range Weather Forecasts
EKAB	National Centre of Emergency Assistance
ELSTAT	Hellenic Statistical Authority
EMS	Emergency Medical Services
EOSDIS	Earth Observing System Data and Information System
ESA	European Space Agency
EVI	Enhanced Vegetation Index
FWI	Fire Weather Index
G.S.C.P.	General Secretariat of Civil Protection
GDAL	Geospatial Data Abstraction Library
GFS	Global Forecasting System
GHCN	Global Historical Climatology Network

GIS	Global Forecasting System
HEDNO	Hellenic Electricity Distribution Network Operator
HPOL	Hellenic Police
IR	Infrared
ISO	International Standard Organisation
IT	Information Technology
JUH	Johanniter Unfall Hilfe
LiDAR	Light Detection and Ranging
LST	Land Surface Temperatures
NCEI	National Centers for Environmental Information
NDVI	Normalized Difference Vegetation Index
NGOs	Non-Governmental Organizations
NWS	National Weather Service
OCG	Austrian Computer Society
OSCS	Austrian Cyber Security Strategy
OSS	Austrian Security Strategy
OTE	Hellenic Telecommunications Organization
PSSUQ	Post-Study System Usability Questionnaire
QGIS	Quantum Geographic Information System
RGB	Red Green Blue
SAR	Synthetic Aperture Radar
SCDT	Smart City Digital Twin
SKKM	National Crisis and Disaster Management strategy
SUS	System Usability Scale

UAV	Unmanned Aerial Vehicle
ZAMG	Central Institute for Meteorology and Geodynamics

EXECUTIVE SUMMARY

<table>
<tr><th>Background</th><th>Goals</th></tr>
<tr><td>To define the system specifications and the high-level reference architecture, a selection of disaster and usage scenarios along with specific use cases has been defined and described in detail. The work also constitutes a basis for consolidating, testing, evaluating and refining the results by various work tasks throughout the project.</td><td>The aim of this Deliverable is to provide the selected disaster and usage scenarios along with their respective use cases to the technical partners of the project and thus enable them to formulate system specifications and the design of the high-level reference architecture of PANTHEON, to be presented in D3.7. Specifically, the work done was based on the regulatory framework in the under-study regions (T2.1), the hazards analysis based on literature (T2.2), the community characteristics and capacities (T.2.3), the ethical and legal considerations (T3.5), the feedback of stakeholders based on guidelines for participatory governance (T2.5, T2.6 and T3.2), the technical capabilities and the preliminary technical designs (T2.4, T3.1, T3.3 and T3.4). An iterative approach was followed in order to arrive to prioritised specific hazards based on a number of criteria and discussions between technical and end-user organisations.</td></tr>
<tr><th colspan="2">Approach and course of action</th></tr>
<tr><td colspan="2">Utilise work achieved in previous work packages and previous tasks:
• WP2 PANTHEON Approach for Building Disaster-Resilient Communities
• WP3 PANTHEON Requirements, Participatory Design Process and Pilot Use-Cases Specifications
A multi-criteria and iterative approach was followed, including four two-hour (2h) workshops with the relevant partners for prioritising specific hazards and determining the potential applications of the SCDT, actors, disaster and usage scenarios and use cases.</td></tr>
<tr><th colspan="2">Findings and results</th></tr>
<tr><td colspan="2">Herewith the results of the approach are presented. The four disaster scenarios along with their potential applications to be used in PANTHEON are:
• Wildfire in the Region of Attica, applying PANTHEON in planning and early warning according to simulations.
• Earthquake in the Region of Attica, applying PANTHEON in training and exercises.
• Heatwave in Vienna, applying PANTHEON in planning and early warning according to simulations.
• Man-made disaster in Vienna, applying PANTHEON in training and exercises.</td></tr>
<tr><th>Impact</th><th>Planned dissemination and exploitation</th></tr>
<tr><td>A selection of disaster and usage scenarios has been finalised and can be utilised for system specifications and the definition of the high-level reference architecture.</td><td>Public</td></tr>
</table>

1. INTRODUCTION

This deliverable extends the work done previously in WP2 and prior tasks in WP3 (T3.1, T3.2, T3.3, T3.4 and T3.5), by considering:

- previous work in the regulatory framework in the under-study regions (T2.1),
- the hazards analysis based on literature (T2.2),
- the community characteristics and capacities (T.2.3),
- the ethical and legal considerations (T3.5),
- the feedback of stakeholders based on guidelines for participatory governance (T2.5, T2.6 and T3.2),
- the technical capabilities and preliminary technical designs (T2.4, T3.1, T3.3 and T3.4),

eventually linking this work with the selection and design of representative disaster/usage scenarios and use cases that meet several criteria based on a methodological framework. This process is highlighted in Figure 1.

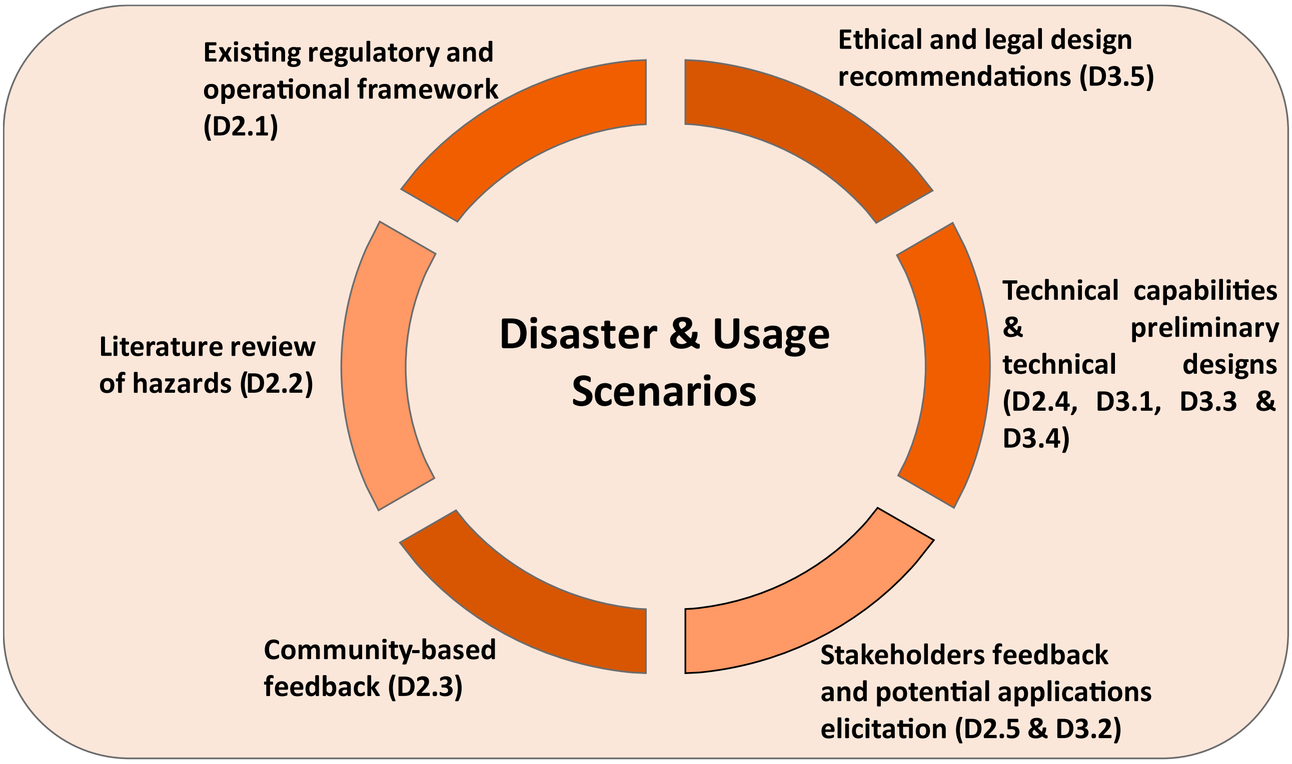

Figure 1 The PANTHEON circular process to arrive to Disaster and Usage scenarios.

These scenarios and use cases present the PANTHEON functionalities and features that will be used as a basis for the system requirements definition and the overall system design (T3.7). Thus, this deliverable connects the previous work done in WP2 and WP3 with the system specifications and high-level architecture, and therefore facilitates the transition from the user world to the developer one, placing user needs at the centre of all technical decisions. The elaborated disaster/usage scenarios and use cases will serve as a baseline for the testing of the technology enablers in the different pilot settings.

1.1. Deliverable Structure

- In Chapter 2 we describe the methodology followed to arrive to specific hazards and potential applications and the work done that starts from specific hazards and ends into specific use cases.
- In Chapter 3 we introduce the disaster and usage scenarios that were selected and analysed based on the previous work and the discussions among technical partners and end-user organisations.
- In Chapter 4 we further elaborate on the usage scenarios regarding specific use cases that provide a functional-driven approach and will result in specific features that will be included in the system architecture definition (D3.7).
- In Chapter 5 we apply the user requirements as compiled in T3.2, to the specific usage scenarios and potential applications selected from the PANTHEON partners.
- In Chapter 6 we conclude with the work done and provide a preliminary insight on how the results from this deliverable will be useful for the future tasks and the overall project.

2. METHODOLOGY FOR THE PANTHEON SCDT USE CASE DEFINITION

One of the primary challenges in PANTHEON lies in the development of features and services that align with user needs. Meeting the diverse range of end-user requirements while providing functionality and services that surpass their initial expectations can be a daunting task. Hence, it is essential to employ an iterative approach to solution development, accompanied by the utilization of usage scenarios, use cases, and features, all of which contribute to gaining a comprehensive understanding of user needs. A scenario serves as a narrative that highlights the problem at hand and subsequently presents a potential resolution. This methodology enables the identification and prioritization of key user needs for specific user groups, serving as a foundation for the subsequent development of software, hardware, and service functionalities, which, in turn, will undergo testing. By following this approach, there is no requirement to outline all the needs of every individual user prior to initiating the specification and development of the PANTHEON solution and services. With reference to Figure 2, the related work will give the input to the creation of Scenarios, Use Cases and Features. This is described in detail in the next sections. This will in turn be an important input for the Test Specifications. In the pilot validations we will test the use cases like specified in this document. The PANTHEON project follows an iterative process, where Scenarios, Use Cases and Features will be created in parallel, and they will all give input to each other (Figure 2).

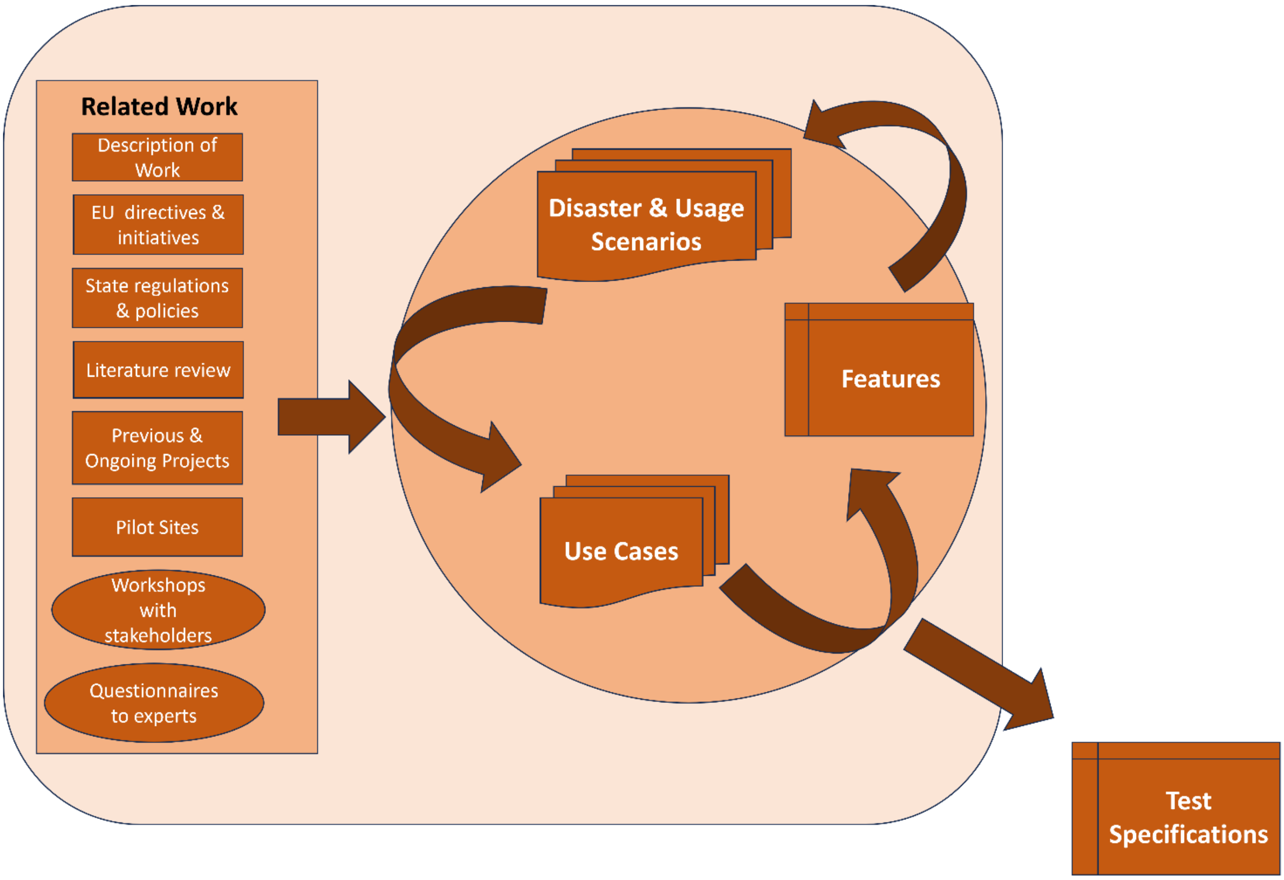

Figure 2 PANTHEON's iterative approach for the definition of Disaster and Usage Scenarios, Use Cases and Features.

2.1. Use Case Outcomes as Baseline for Technology Enablers

This section presents the methodology for leveraging use cases in the development and evaluation of technologies within the PANTHEON project. It introduces the theoretical and practical approach to designing use cases and evaluating system usability through them. It also includes the possible evaluation process to be followed, as well as the different methodologies and methods to be used for this purpose.

2.1.1. Usability and user satisfaction as a key factor for system success

Technological systems are often developed based solely on technological or technical merits. However, research has shown that such practices are often less successful than expected [1]. Measuring the success of a system is a complex task. Nevertheless, end-user satisfaction has recently become one of the most important variables, representing a reliable indicator of success [1], [2], [3].

End-user satisfaction is often integrated within a broader concept known as 'usability' of the system. According to [4], usability can be broken down into five elements:

- **Learnability** refers to how easily users can learn the basic functions of the system. It can be measured by calculating the time it takes a user to complete a given task.
- **Efficiency** can be quantified by the number of tasks per unit time that a user can perform using the system.
- **Retention capacity** refers to the user's ability to remember the basic operation of the system over time.
- **Error rate** refers to the number of errors made by a user while performing a task. A low error rate indicates good usability.
- **Satisfaction** measures the user's subjective impression of the system.

In the same vein, ISO 9241-11 proposes three parameters for measuring system usability: effectiveness, efficiency, and satisfaction. **Effectiveness** refers to the ability of users to complete a task using the system and the quality of its output; **efficiency** refers to the level of resources consumed to perform the task; and **satisfaction** refers to the users' subjective reactions to the use of the system [5].

As it is one of the most critical factors in determining a system’s success or failure, it is crucial to consider user satisfaction when developing any technological product. Therefore, it is important to consider the various variables involved in the notion of end-user satisfaction. In [1] is presented a precise meta-analysis of the empirical literature on this subject (see Figure 3).

Three main domains are presented, bringing together several variables. Within the domain of perceived benefits, we find user expectations, ease of use and perceived usefulness. Regarding the domain of organisational support, we find the user's attitude towards information systems, the support provided by the organisation and the perceived attitude of the organisation's top management. Finally, the last domain, user background, considers user experience with technological systems, user skills, and user involvement in system development.

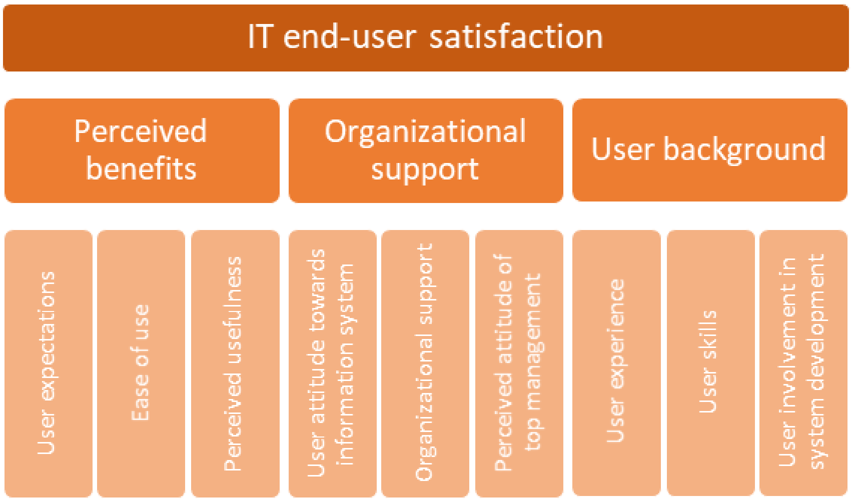

Figure 3 Factors affecting IT end-user satisfaction [1].

Regarding the first item, perceived benefits, it was found that user satisfaction is strongly influenced by the user's perception of the benefits of the system, especially regarding characteristics such as perceived usefulness, ease of use and user expectations. Although ease of use is a significant factor, the system's usefulness is even more critical. Users are more likely to accept technology and be satisfied with it if they perceive it as useful for their work tasks, which can be improved in terms of performance and productivity. While a user-friendly interface and ease of use can increase acceptance, [6] found that users are willing to tolerate difficulties if they believe the system will benefit them. Conversely, if users do not perceive a system as useful, they will not use it, regardless of its ease of use. Meeting users' needs by providing good support for their tasks is crucial to achieving the main objective of building software [4]. Therefore, the perceived usefulness of a system is a crucial determinant of users' intentions to use it, with ease of use being a significant but secondary factor [1], [3], [6]. It is worth noting that users who have unrealistic expectations of the system are likely to be less satisfied with it and, as a result, use it less [3].

Secondly, regarding organisational support, it has been argued that creating and implementing a training programme for users on how to use the system plays a crucial role in the success of IT. Some users may experience difficulties when using the system, so a training programme is a good measure to alleviate frustrations arising from perceived poor control of a system's functionalities [1], [3].

Finally, user background has also been identified as a factor in user satisfaction with technology systems. Variables such as user experience, user skills, and user involvement in technology development have been found to affect user satisfaction. According to [1], there is no significant correlation between users' experience and skills with computers and their level of satisfaction (p. 765). As discussed in the previous paragraph, user skills can be managed with a training programme aimed at teaching users how to use the system. However, involving users in the development of the system has been found to increase its acceptance. This is due to issues such as a feeling of ownership of the system and a better understanding of its capabilities. Users who participate in the development of a software system tend to be more satisfied with it. Their involvement in the design, development, and deployment process has a positive effect on satisfaction and, consequently, on their willingness to use it [2], [7], [8].

Designers need to predict whether a new system will be acceptable to users when planning its development. Similarly, it is important to diagnose the reasons why a user may be unwilling to accept the technology and take corrective measures to increase its acceptability. In [6] conducting this evaluation process from the beginning of the project as it is easier and more cost-effective to address usability issues that may arise (p. 999) is suggested. Research has shown that involving end-users in the design process can improve product quality by providing more accurate requirements and avoiding the implementation of unnecessary features [2]. However, usability-related work is often only undertaken at the final stage of developing a system. Usability problems are less expensive to solve if they are identified early in development [9].

The involvement of users should not be restricted to merely collecting their feedback. Instead, system designers and developers must comprehend the needs of users and translate them into innovative solutions [10]. Undoubtedly, software end-users are a crucial source of information for the development of applications [2]. All applications are intended to be tools that assist users in completing specific tasks in a more efficient manner. Detailed information is necessary regarding the end users of the system, their goals, and how the system can assist them in achieving these [4].

2.1.2. The role of Use Cases in technology development

Usability engineering, which involves assessing usability with real users from the early stages of development, is a widely accepted practice. The term 'participatory design' is also commonly used to refer to this approach [4]. The participatory design process has been developed since month 1 through task 1.2 on engaging and involving CBDRM stakeholders. Specifically, during task 3.2 on participatory design process, the results of which can be found in the respective deliverables [11]. The methodology has been divided into three main phases:

1. **Understanding**: this was the process of gathering information about potential end-users and their contexts to comprehend their needs. This has been achieved through several workshops aimed at identifying the different requirements for the system, using methods such as brainstorming, timelines, visioning using the Walt Disney method, as well as questionnaires and semi-structured interviews.
2. **Conceptualisation**: this process was used to develop the main ideas and concepts to meet the needs identified in the previous phase. This phase resulted in the creation of use cases.
3. **Evaluation**: this will be the process which will involve testing the product for usability problems by users and/or experts, and it will be covered in WP8.

The work presented in [5] highlights the importance of defining the end-users, their tasks, and the physical, organizational, and social context in which the technology will be used when assessing the usability of a system (p. 189). Measuring usability is a complex task that depends on multiple variables [12]. Scenario-based use cases have been proven to be an effective tool for assessing and integrating usability during the early stages of software system development, as they provide concrete examples of system use that encompass space, time, actors, and system characteristics [4], [9], [12], [13]. Use cases can be utilised for planning, developing, designing, and evaluating software[14].

A use case is a description of the requirements and functionalities of a system [14]. It describes the behaviour of a system as it responds to the requests of an actor seeking to achieve a particular goal [9]. Scenarios, on the other hand, are narratives that describe in detail the interactions a user has with a system or application [13]. In addition to the narrative, scenarios should also include information on the relevant actors, context, task goals, system effects, and consequences of use [13]. Considering the importance of scenario-based use cases for designing, developing, and evaluating technological systems, as well as their impact on product quality, it is vital to design both use cases and scenarios correctly [14]. Otherwise, designers and developers may deviate from their main goal of creating a useful tool for their users. Customers and end-users want to be sure that the systems that are built based on their needs have the functionalities they really need, which in terms of use cases implies the following [14]:

- The right actors must be identified and described.
- The right use cases must be identified and describe the way by which the goals of each use case can be achieved.
- The flow of events must be realistic in terms of achieving the objectives set by the use case.
- The descriptions of the use cases must be simple for users who are not familiar with these models, which implies describing them at a high level of detail.
- Functionality must be correctly delimited using pre- and post-conditions.

Given the role of the quality of use cases in the successful development of technological systems, it is highly desirable to ensure the quality of these use cases. To this end, the authors of [9] have developed a method for evaluating use cases that is divided into three distinct phases:

1. **Inspection of use cases**: this consists of compiling a collection of use cases that describe the purpose of the system and give a brief description of the context in which it is to be used. After carrying out creative exercises to determine the use case, a systematic inspection of the usability issues that may arise should be carried out. It is useful to consider the guidelines in Table 1.

Table 1 Guidelines for Use Case Evaluation [9].

Guideline	Description
Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
Match between system and the real world	The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-specific terms. Follow real-world conventions and make information appear in a natural order.
User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
Error prevention	Even better than good error messages are a careful design which prevents a problem from occurring in the first place. Eliminate error-prone conditions or handle them gracefully.
Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another.
Flexibility and efficiency of use	Accelerators - unseen by the novice user - may often speed-up the interaction for the expert user such that the system can cater to both inexperienced and experienced users.
Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Avoid hard mental operations and lower workload	Do not force the user into hard mental operations and keep the user's workload at a minimum.
Avoid forcing the user to premature commitment	Do not force the user to perform a particular task or decision until it is needed. Will the user know why something must be done?
Provide functions that are of utility to the user	Consider whether the functionality described is likely to be useful to users and whether functions/data are missing

2. **Use case evaluation**: once the use cases have been inspected, an evaluation of the use cases is highly recommended. One of the most used methodologies for this is checklists such as those presented in Table 2.

Table 2 Checklist for inspections of use case model (Anda & Sjøberg, 2002).

	Yes	No
2.1.2.1. Actors		
Are there any actors that are not defined in the use case model, that is, will the system communicate with any other systems, hardware or human users that have not been described?		
Are there any superfluous actors in the use case model, that is, human users or other systems that will not provide input to or receive output from the system?		
Are all the actors clearly described, and do you agree with the descriptions?		
Is it clear which actors are involved in which use cases, and can this be clearly seen from the use case diagram and textual descriptions? Are all the actors connected to the right use cases?		
2.1.2.2. The use cases		
Is there any missing functionality, that is, do the actors have goals that must be fulfilled, but that have not been described in use cases?		
Are there any superfluous use cases, that is, use cases that are outside the boundary of the system, do not lead to the fulfilment of a goal for an actor or duplicate functionality described in other use cases?		
Do all the use cases lead to the fulfilment of exactly one goal for an actor, and is it clear from the use case name what is the goal?		
Are the descriptions of how the actor interacts with the system in the use cases consistent with the description of the actor?		
Is it clear from the descriptions of the use cases how the goals are reached, and do you agree with the descriptions?		
2.1.2.3. The description of each use case		
Is expected input and output correctly defined in each use case; is the output from the system defined for every input from the actor, both for normal flow of events and variations?		
Does each event in the normal flow of events relate to the goal of its use case?		

Is the flow of events described with concrete terms and measurable concepts and is it described at a suitable level of detail without details that restrict the user interface or the design of the system?		
Are there any variants to the normal flow of events that have not been identified in the use cases, that is, are there any missing variations?		
Are the triggers, starting conditions, for each use case described at the correct level of detail?		
Are the pre- and post-conditions correctly described for all use cases, that is, are they described with the correct level of detail, do the pre- and post-conditions match for each of the use cases and are they testable?		
2.1.2.4. Relation between the use cases		
Do the use case diagram and the textual descriptions match?		
Has the include-relation been used to factor out common behaviour?		
Does the behaviour of a use case conflict with the behaviour of other use cases?		
Are all the use cases described at the same level of detail?		

3. **Documentation of the evaluation**: the results of the evaluation should be compiled into a report for later consideration in the design of the final product.

The purpose of this report is to explain the process of use case selection in the PANTHEON project. The use cases and scenarios were not chosen arbitrarily but were based on research and a participatory design process. After studying the end-users and their needs, and developing ideas and concepts to meet these needs, the final step is to create the product - a Community-Based Smart City Digital Twin (CBSCDT) - and test it with real users to identify any usability issues. The process for testing the technology is detailed in the next section and will be further explained in WP8.

2.1.3. PANTHEON APPROACH TO EVALUATING AND INTEGRATING RESULTS

The previous subsections have emphasised the importance of usability to determine the success of a technological system. User satisfaction is a fundamental variable for system usability. Therefore, the usability of the system and the involvement of end-users in its development are key factors in ensuring user satisfaction with the final product.

The participatory design process carried out in the PANTHEON project enabled close collaboration between consortium partners and potential system users, resulting in the use cases presented in this report. The final step of the participatory process is evaluation, which involves testing the product to be developed in WP4, WP5, WP6, and WP7 with real end-users to identify any usability issues. The aim of testing is to deploy developed concepts and technologies and run pilots to obtain feedback from end-users. The objective is to identify possible modifications needed to improve the system's quality and implement them if necessary.

The evaluation of the system and the use cases will be based on the four scenarios that have been developed. The evaluation process will follow a cyclical dynamic consisting of three distinct phases, which have been taken from the DUET project [15], which also developed a product based on digital twin technology, and adapted to PANTHEON (see Figure 4). The evaluation cycle is initiated upon delivery and implementation of the first results for each use case and scenario.

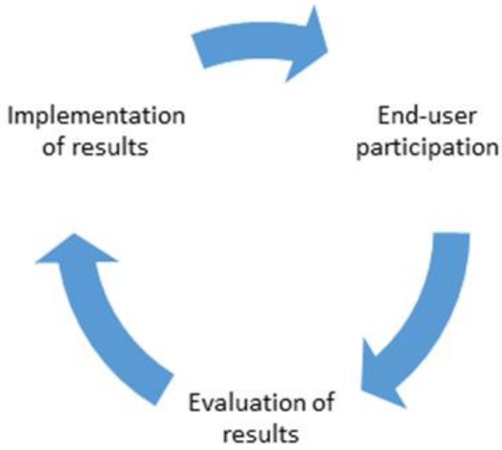

Figure 4 PANTHEON evaluation cycle. The cycle is started after the development implementation and delivery of the first results for each use case and scenario.

In the first phase, end-users will take part in pilot tests developed for each specified use case and scenario. Prior to system use, end-users will undergo a training programme to become familiar with the system's features and functionalities. The second phase will involve evaluating the results, which will produce a report for each use case scenario. The report will contain pertinent information from each pilot test, including the user type, number of participants, evaluation methods and tools, and results such as user opinions, comments, and recommendations. The implementation phase aims to confirm the findings and, if possible, integrate them into an improved version of the system. Considering that the pilot tests are scheduled for the final five months of the project and that the PANTHEON system's Technological Readiness Level (TRL) has been established in 5 (validated in a relevant environment), any feedback collected from the pilot tests will not be incorporated into a new version of PANTHEON. Nevertheless, the value of the results obtained from the pilot tests will not be diminished in any way.

The strategy to improve user involvement in the pilot tests, is based on the methodology of the DUET project [15]. PANTHEON's strategy can be divided into the following five phases:

1. **Identification of potential users:** for each use scenario, the most relevant actors will be identified. There is a possibility that for a particular scenario there are different actors that fit. In any case, it will be decided in the near future whether the tests will be carried out jointly or separately.
2. **Contacting potential users**: the leaders of each pilot test, after identifying the relevant users, will contact them to explain the project and the PANTHEON system. If they agree to participate in the pilot tests, they will be sent the corresponding informed consent form, which must be signed prior to the start of the tests.
3. **Training of participants** (T8.3): end-users who have agreed to participate in the pilot tests will participate in a training programme that will be developed with the objective of familiarising participants with the features and operation of the system.
4. **Pilot testing** (T8.4): This is the phase in which end-users who have agreed to participate in the test and have completed the corresponding training programme will interact with the PANTHEON system.

5. **Feedback collection and results** (T8.5): following each pilot test, the evaluators will employ various methods of collecting feedback from the end users who participated in the tests, and then refine this feedback into recommendations that will help to improve the system.

Different methods can be used to collect feedback from users about the usability of the system and their satisfaction with it. Usability testing is a common method that includes both quantitative and qualitative approaches. It can add value to technological systems by reducing the gap between product quality and user satisfaction. Comprehensive user experience measurements are essential for system development and the feedback obtained from the evaluation process will serve as the basis for improving the technological product [8], [10]. Evaluations are typically conducted after the participant has interacted with the system, and there are various research methods addressing them.

In terms of quantitative methods, questionnaires tend to be the most used approach. There is a wide variety of questionnaires that can be used to measure the usability of technological systems. For example, [16] developed and validated a twelve-question instrument that can be used to evaluate applications with end-users (see Appendix 8.1). The test consists of five dimensions: content, accuracy, format, user-friendliness, and timeliness, each of which has several questions that enable measurement. Apart from an overall assessment, this test is useful in comparative terms, as it allows for a comparison of end-users' satisfaction with the specific elements mentioned. While it is true that, as the authors admit, it may be necessary to add more questions depending on the application to be tested, the generic nature of the test makes it suitable for all types of applications, including the PANTHEON system.

In the same vein, [12] developed and validated the Post-Study System Usability Questionnaire (PSSUQ), which is a 19-item instrument to assess user satisfaction with the usability of the system (see Appendix 8.2). Participants will only need 10 minutes to complete the test, which can provide an overall assessment of the PANTHEON system. Finally, [5] developed the System Usability Scale (SUS), a 10-item usability scale that seeks to provide the subjective perspective of users regarding usability evaluation (see Appendix 8.3). In fact, the SUS has been used in recent studies to measure usability and user experience with digital twins [17], so it could be a good fit for the PANTHEON system.

Regarding qualitative methods, interviews and/or focus groups are the most commonly used approach. This methodology enables us to identify which characteristics and elements of the system can be improved and how. [13] created an interview guide to evaluate use case scenarios that could serve as a basis for PANTHEON interviews (see Appendix 8.4). [17] used open-ended questions in addition to the SUS to evaluate the usability of their system (see Appendix 8.5). This approach could also be applied to assess the usability of the PANTHEON system.

The authors of [4] also propose the think-aloud method. This involves the participants speaking their thoughts aloud during the test, thus providing an insight into possible usability problems. For instance, if the user is unable to locate a specific functionality, they should explicitly state so, highlighting any difficulties they may encounter when using the PANTHEON system.

These evaluation strategies and methods offer a preliminary perspective on the approach to be used in PANTHEON. The tasks related to evaluating the usability of the PANTHEON system will take place during WP8. Therefore, the issues discussed in this report will be continued in the deliverables and reports corresponding to WP8, particularly D8.1 and D8.2.

2.2. Prioritisation of Hazards

The methodology for prioritising the hazards that the PANTHEON project is considering is presented in Figure 5 and is based on the input from WP2. This contains the results gathered during the regulatory and DRM analysis as presented in [18], the results from the Hazard Analysis and Risk Assessment as presented in [19] and the Community Vulnerabilities feedback as presented in [20]. All these inputs were finally structured by the partners of the consortium (as shown in Figure 5) to prioritise specific hazards in disaster scenarios. Ultimately this will help showcase the PANTHEON system's added value in DRM operations while incorporating the needs of the communities in the pilot regions and the stakeholders' input.

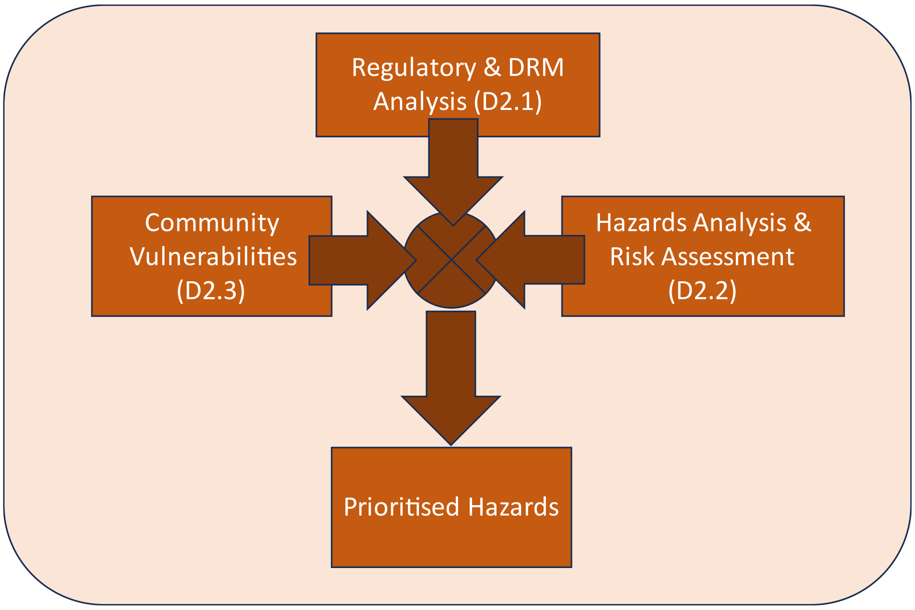

Figure 5 Methodological process for prioritising hazards.

2.2.1. Results from the Regulatory & DRM analysis

The results of the regulatory & DRM analysis as presented in [18] are briefly summarised below. The Attica region is exposed to various natural and man-made hazards. The design of civil protection and disaster management plans and strategies, targeting specific hazards, is crucial to define stakeholders' roles and responsibilities and to lay out measures to be taken for each phase of the disaster management cycle. DRM strategies are implemented on a national basis; however, each region adapts these plans to its specific vulnerability and exposure against hazards. In the context of the PANTHEON project, two scenarios were selected for the region of Attica, in which the nascent SCDT system will be tested and evaluated. These include the occurrence of an earthquake and of a wildfire.

In January 2020, the General Secretariat for Civil Protection of Greece issued "Egkelados", a national plan for the management of disasters related to the occurrence of earthquakes. The plan was updated in early 2022 and encompasses actions to be implemented for all four phases of disaster management. As described above, the region of Attica developed its own plan, adjusting the "Egkelados" national strategy and adapting it to the features of the area. The compilation of the regional plan was also deemed necessary due to the catastrophic 1999 event, which had devastating impact on residents, infrastructure and households.

In addition to the "Egkelados" plan, the Earthquake Planning and Protection Organisation developed, in 2000, the national map for seismic risk, based on which, structures and buildings should be constructed according to specific guidelines and indices, to withstand specific values of seismic accelerations. According to the map (Figure 6), Attica is divided between zones I and II, which represent specific seismic acceleration values and corresponding construction guidelines. It should be noted that the E.P.P.O. regulation is in accordance with Eurocodes 7 and 8.

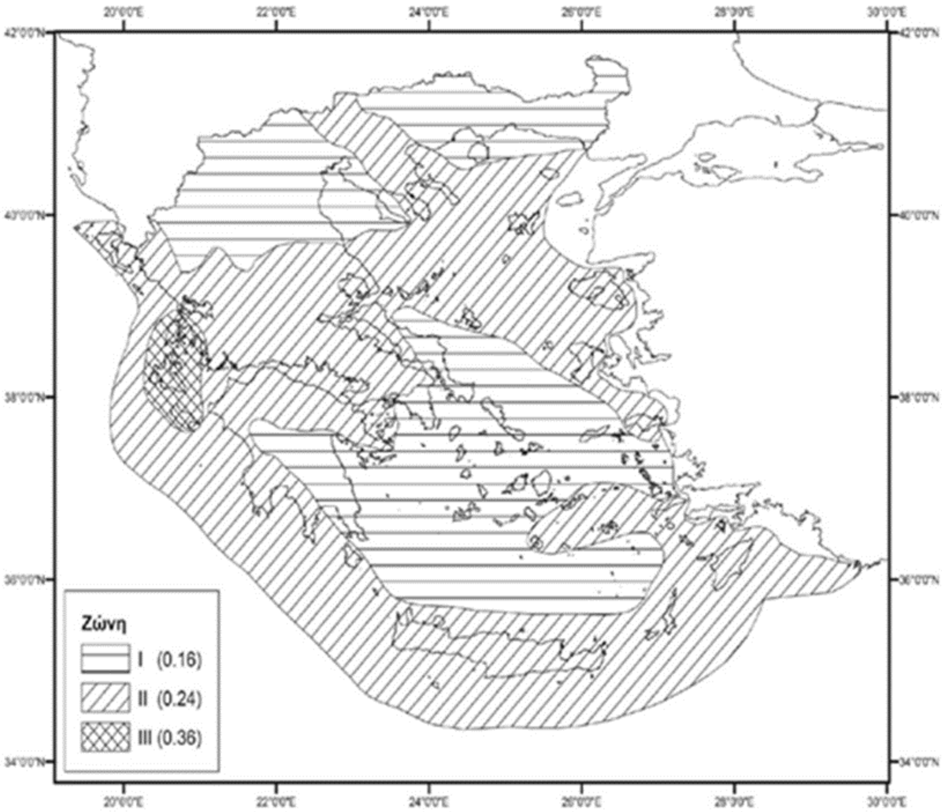

Figure 6 Map of seismic zones in Greece as provided by E.P.P.O.

In Greece, areas susceptible to wildfires represent a large proportion of the country's overall territory, as shown in Figure 7.

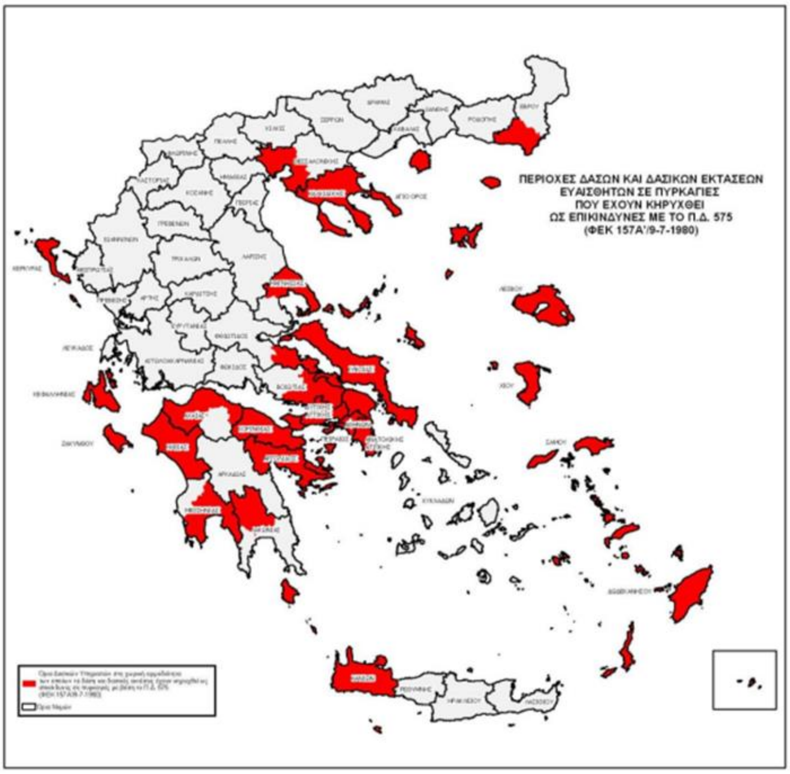

Figure 7 Map for areas susceptible to wildfires, as provided by G.S.C.P.[3]

Therefore, the G.S.C.P. developed, in 2010, the "Iolaos" national plan to manage disasters occurring from wildfires. The plan was updated several times, the latest being published in April 2023. The plan takes into consideration various factors, that play a significant role for the occurrence of a wildfire, such as vegetation, land use and meteorological patterns among others, and is valid during the fire season, which, in Greece, lasts from 1st of May till the 31st of October. The scope of the strategy is to provide measures for an effective management of wildfires and to assist first responders by laying out roles and responsibilities. Similarly to the "Egkelados" national plan for the management of earthquakes, the regions adopt and adapt the "Iolaos" plan according to their needs and their specificities. The specific action plan of Attica includes measures to secure forests, ensure interoperability among different first responders as well as measures for the recovery phase e.g., reforestation.

The fire danger prediction map, which is published daily during the fire season, and provides an overview of the fire danger of the following day, is a significant tool for the management of resources and the elevation of the alert level. According to the map in Figure 8, different colours depict different alert levels, i.e., green is low fire danger level, blue is moderate, yellow is high, orange is very high and, finally, red represents the alarm level.

[3] https://civilprotection.gov.gr/sxedia-politikis-prostasias/geniko-shedio-antimetopisis-ektakton-anagkon-exaitias-dasikon-0

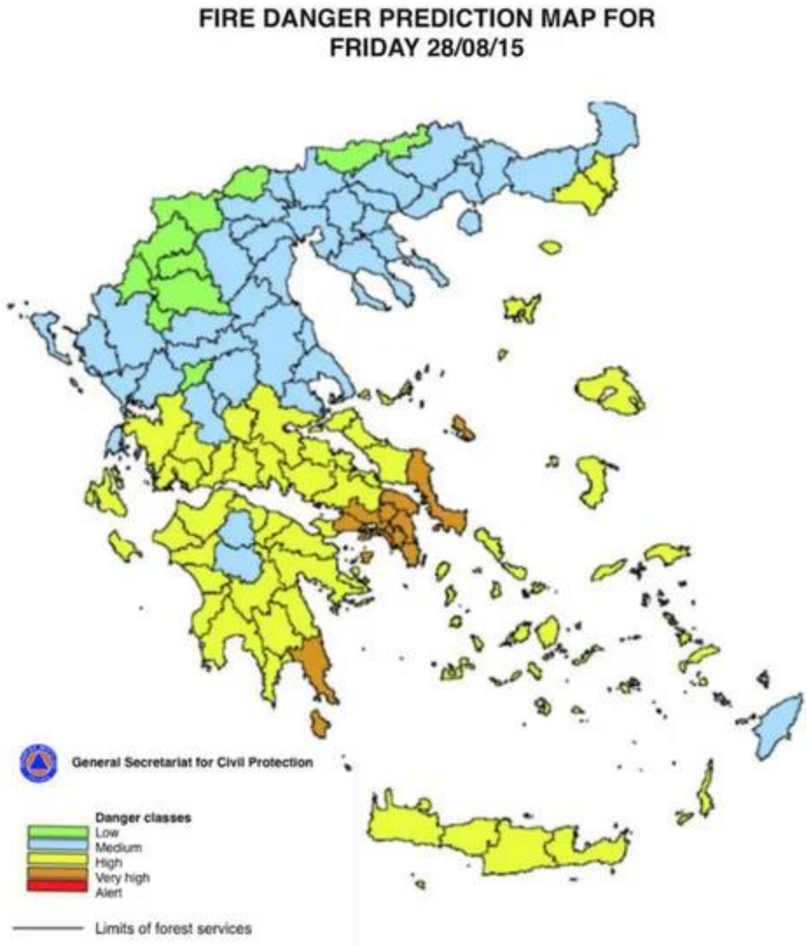

Figure 8 Fire Danger Prediction Map for a specific date issued by G.S.C.P.[4]

Austria and specifically the Federal State of Vienna is not exposed to natural hazards to the same extent as Greece and Attica, the threat of a natural disaster cannot however be completely ruled out. The danger of man-made disasters including terrorism is particularly categorised high. For that reason, the Federal Ministry of Interior has developed plans for the management of such disasters.

As part of the Austrian Security Strategy, the Austrian Programme for Critical Infrastructure Protection (APCIP) was developed on the basis of the European Programme for Critical Infrastructure Protection. The aim of the Programme is to foster resilience in the critical infrastructure domain and focuses on the sectors of transportation, energy, telecommunications, food supply and economy. Each Federal State must adapt this plan, taking into consideration local specificities and features. Furthermore, the Austrian Cyber Security Strategy (OSCS) formulates the cybersecurity policy of the country. The strategy aims to facilitate interoperability and collaboration among agencies engaged in the cybersecurity domain, analyse potential risks, both for individual users as well as for critical infrastructures and public bodies, and set strategic goals fostering secure data exchange. The Cyber Security Steering Group and the Cyber Security Platform are also established through the OSCS. Both the APCIP and OSCS strategies create a framework for the protection from and response to physical or cyber emergencies that have an impact on infrastructure and the public domain.

[4] https://civilprotection.gov.gr/sites/default/files/150828.gif

The Austrian Security Strategy (OSS), adopted in 2001 and updated in 2011, considers natural and man-made disasters as significant threats and provides measures for their prevention and the management of their impact. The National Crisis and Disaster Management strategy (SKKM) is shown in Figure 9 and identifies five main pillars of disaster management: emergency organisations, national authorities, the population, the science and research domain, and the economy. Each Federal State is responsible for the adoption and adaptation of the strategy according to its specific needs and characteristics. In addition, volunteer organisations play a crucial role in firefighting and first aid operations, whereas the general public is responsible to implement measures for self-protection and awareness of potential threats.

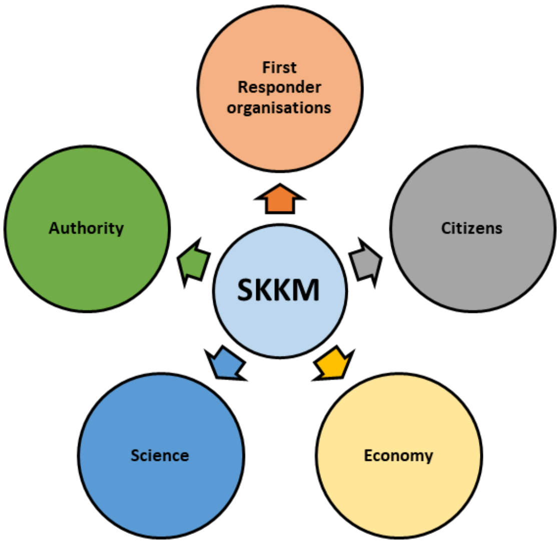

Figure 9 Depiction of the National Crisis and Disaster Management strategy in Austria.

Austria, and Vienna in particular, are becoming increasingly susceptible to heatwaves. The absence of open and green spaces and excessive urbanisation have significantly increased the level of the heat island effect. To mitigate the impact of heatwaves, the Ministry of Social Affairs, Health, Care and Consumer Protection issued the National Heat Protection Plan in 2017. The plan provides information regarding early warning for imminent heatwaves and the impact they might have on the population. Moreover, the Ministry of Interior of Austria has published guidebooks to raise citizen awareness, inform and provide guidance to prepare the public against specific hazards e.g., earthquakes, wildfires, weather and climate-related phenomena and radiation propagation.

2.2.2. Results from the Hazards Analysis & Risk Assessment

The results of the hazards analysis and risk assessment as presented in [19] are briefly summarised below. Both Greece and Austria generally, as well as the regions of Attica and Vienna specifically, are affected by a plethora of hazards, both natural and man-made. Extensive desktop research was conducted, under the framework of WP2, to identify and organise these hazards. The interrelation between them was examined with the aim of understanding how different hazards might interact and the impact they might have on various exposed assets e.g., population, physical and built environment as well as critical infrastructures, was assessed. Among the objectives of WP2 was to produce a qualitative risk assessment for the areas of interest, taking into consideration the likelihood of occurrence for each of the identified hazards as well as the total impact these hazards have on the two regions. Furthermore, the general civil protection and disaster management strategies, initiatives and plans were examined in order to map potential hazards for the two pilot areas, and have an overview of existing strategies for the management of disasters deriving from these.

This chapter provides an overview of the findings of WP2 for the two areas under examination i.e., the region of Attica and the Federal State of Vienna.

The region of Attica, which also encompasses the metropolitan area of Athens is affected mainly by natural hazards, including earthquakes, floods, wildfires, landslides and heatwaves. Earthquakes have frequently occurred either within or in the proximity of the region. Although their majority did not have significant impact, there are occasions on which earthquakes led to serious damage and casualties, such as the 1938 event in eastern Attica, the 1981 event with an epicentre at the eastern parts of the Corinthian Gulf and, finally, the 1999 earthquake of Parnitha.

In addition, floods are another hazard that has continuously concerned Attica due to two main reasons i.e., the increasing frequency of torrential rains, which is abetted by climate change, as well as urbanisation, that reduces the capacity of water absorption by the soil. Flood events with significant impact on the region include the 1977 and the 2017 floods, which both resulted in serious damages and a considerable number of casualties.

Wildfires, although not uncommon in the region, have increased in both frequency and severity, resulting in vast environmental degradation. Similarly to floods, wildfires are affected by climate change, considering that the climate in Attica becomes warmer and drier during summer, with long lasting periods of droughts and increased temperatures. This, combined with the flammable vegetation of the area and the susceptibility to high velocity winds, can lead to extreme forest fires such as the 2007, 2018 and 2021 events which, apart from environmental degradation and infrastructure disruptions, took a heavy toll on human lives as well.

Heatwaves are another meteorological phenomenon which is frequent in Greece, and Attica in particular. In highly urbanised areas, such as Athens, heatwaves are amplified by the heat island effect, which results in high temperatures not only during the day but also during nighttime. There are occasions with severe impact on infrastructures and citizens e.g., the 1987 and 1958 heatwaves, however the population has become more resilient due to the repetitive nature of the phenomenon.

Although natural hazards are the main source of threat for the region of Attica, man-made hazards cannot be disregarded. Terrorism is experienced mainly in the form of individual attacks on politicians by radical terrorist organisations, and not in the form of mass shootings or direct hits of specific industries or infrastructure. In addition, public bodies and organisations have been the target of cyber-attacks. Table 3 depicts the risk assessment for the region of Attica in terms of likelihood of occurrence and impact.

Table 3 Qualitative Risk Assessment for Attica.

Impact / **Likelihood (Hazard)**	Very Low	Low	Moderate	High	Very High
Almost certain - Very High			Heatwave		Wildfire
Likely-High					
Possible-Medium			Cyber Attack	Earthquake / Flood	
Unlikely-Low		Landslide	Terrorist Attack		

Rare-Very Low					

Risk	Low	Moderate	High	Very High

Austria in general and Vienna specifically is less prone to natural hazards, although disasters are not implausible. Austria has been at the epicentre of earthquake activity; however, the majority of seismic events is not strong and the impact on the country is moderate. Damaging earthquakes in Vienna are scarce, while construction follows specific rules and standards for the building of structures which are less vulnerable. A strong earthquake in the mid-term future cannot however be ruled out.

Floods have had a very large impact on the province of Vienna since its very early days. The recurrent phenomenon, which continuously resulted in serious damage, led officials to take measures, which, time and again, proved to be insufficient. However, in 1981 the regulation of the Danube River, with the excavation of a large canal and the formation of the Danube Island between the canal and the actual river, was concluded, a measure that is considered among the best flood protection structures globally. The regulation of the Danube is expected to withstand a flood of a 10,000-year return period, significantly increasing the overall resilience of the province.

Landslides and avalanches are of lower concern for Vienna. The reason is that the area has a lower attitude, and as a result is not affected by severe snowstorms. Moreover, the terrain is smooth, and the slope is low, therefore neither avalanches nor landslides can be triggered. Earthquakes, which could be triggering factors are not strong enough to create avalanches, whereas earthquake-induced landslides usually occur in the mountainous parts of the country, far from Vienna.

Wildfires have not been a major concern for Austria until recently. Although a large number has occurred, wildfires are typically not severe and rarely incinerate areas larger than 1 ha. Climate change, however, poses a significant threat, leading to an increase of wildfire occurrence and overall wildfire risk in the country. The impact of a wildfire increases when it affects WUI (wildland urban interface), as in the surrounding area of Vienna a large number of installations and infrastructure exists. This is the reason why the overall wildfire risk in Vienna is considered moderate and not low, because although the likelihood is itself low, the impact, in the case of an occurrence, would be moderate.

Heatwaves, on the other hand, are considered a major threat for Vienna. Climate change has increased the frequency, intensity, and duration of heatwaves, while city expansion and urbanisation increase the heat-island effect, especially in areas without open spaces and air corridors. Moreover, due to the fact, that in the past the phenomenon was rare, the population and infrastructure is ill-prepared and thus quite vulnerable in particular as heat stress increases health risks of the ageing population.

Regarding human-induced hazards, technological accidents and also terrorism are considerable threats, mainly in terms of potential damage and impact. In Austria there is a large number of SEVESO sites. Though technological accidents do not occur on a regular basis, the impact can be considerable, especially regarding the population, environment and even economy. Additionally, terrorist attacks are a significant threat, taking into consideration that the headquarters of many international agencies and organisations are situated in Vienna. Extremism is the main threat for the province, with a massive shooting taking place in November 2020. Cyber-terrorism is a hybrid cyber-physical threat that could severely damage critical infrastructure and disrupt the city's normal operations. Table 4 presents the qualitative risk assessment conducted for the province of Vienna.

Table 4 Qualitative Risk Assessment for Vienna.

Impact / Likelihood (Hazard)	Very Low	Low	Moderate	High	Very High
Almost certain - Very High					
Likely-High				Heatwave	
Possible-Medium		Earthquake / Flood	Wildfire	Technological Accident / Terrorist Attack / Cyber-attack	
Unlikely-Low					
Rare-Very Low		Landslide / Avalanche			

Risk	Low	Moderate	High	Very High

2.2.3. RESULTS FROM THE COMMUNITY VULNERABILITIES ASSESSMENT

The results of the community vulnerabilities assessment as presented in [20] were outcome of common efforts in T2.2 and T2.3 – they are briefly summarised below. To evaluate the vulnerabilities and capacities regarding certain hazards within the communities of the pilot regions, qualitative and quantitative data was collected in T2.2 and T2.3. Three interviews were conducted with Greek experts, stakeholders, and community representatives, and four interviews with comparable people active in Austria. In addition, an online survey was circulated among a similar demographic, which was filled out by 26 respondents from Greece and 32 from Austria.

Interview participants were asked to list the most relevant hazards in their region. During the interviews, the experts listed a great variety of hazards relevant to Athens and Vienna. For the region of Attica and Athens, the most emphasized hazards were earthquakes, floods, landslides and ground movements, cyber threats, fires (especially wildfires), tsunamis, as well as migration and refugee crises, an overload of the public health system, pandemics, and nuclear risks. For Vienna, a big emphasis was placed by the interview partners on the danger of heatwaves, due to the increasing severity and frequency caused by climate change, as well as epidemics and pandemics. In addition, the experts listed landslides, storms, floods (mostly because of heavy rain), droughts, forest-/wildfires, snowstorms/ blizzards, terrorist attacks and cyber threats.

The results of the survey complemented their outcomes with quantitative data. The respondents to the online questionnaire were asked to list the top five most relevant hazards for their region, the results of which were evaluated and are presented in Table 5. The results show that there are two very clear favourites for Greece, namely earthquakes and wildfires, followed at a considerable margin by floods, which also fits well with the interview data. Man-made hazards were only chosen by few respondents as highly relevant. For Austria, the opinions were more divergent. Heatwaves and epidemics/pandemics were considered the most important hazards by the survey participants, similarly to the interviewees. This was followed by storms, technological accidents, cyber threats, floods, and terrorist attacks. In conjunction with the interview data, this suggests that of the natural hazards, heatwaves and epidemics/pandemics are considered the most relevant by experts in the community. Regarding man-made hazards, technological accidents, cyber threats, and terrorist attacks are deemed approximately equally relevant.

Table 5 Responses regarding the top five most relevant hazards for Greece and Austria.

Selectable hazards	Total times the hazard was listed among the top 5	
	Greece	*Austria*
Blizzard	1	5
CBRNe malicious act	1	1
Cyber Threat	1	15
Drought	1	2
Earthquake	26	8
Epidemics/Pandemics	14	22
Flood	17	14
Heatwave	15	22
Landslide	0	3
Storm	10	19
Technological Accident	5	16
Terrorist Attack	2	11
Tsunami	0	0
Wildfire	22	3

Based on the gathered inputs the PANTHEON consortium partners devised the following prioritisation:

For Attica/Greece the disasters that have been prioritised are Wildfires and Earthquakes. These two disasters combined the highest risk scores (probability and impact) in the relevant tables of [19] and were the most frequent disasters indicated by the community representatives' feedback, as indicated in Table 5.

For Vienna/Austria the disasters that have been prioritised are Heatwaves and Cyber Terrorism. These two disasters again combined the highest risk scores (probability and impact) in the relevant tables of [19] and were also amongst the most frequent disasters as indicated by the community representatives' feedback as depicted in Table 5.

2.3. Mapping of Potential Applications to Hazards

The work done in T3.2 and concluded in [20],included a participatory design process, consisting of several stakeholder/end-user workshops in the project's focus regions and led to the definition of several potential applications that PANTHEON could target within the disaster management cycle. These potential applications were accompanied by specific design recommendations and served as an exploratory foundation for the refinement and definition of Usage Scenarios and Use Cases in T3.6. Five potential applications resulted from the work in T3.2, as presented in Table 6.

Table 6 Potential Applications identified for PANTHEON.

Disaster phase	Code	Name	Description
Before a disaster	A	Planning and early warning according to simulations	Models and simulations based on big amounts of data are being used to estimate the evolution of disaster scenarios thus supporting the development of emergency plans, giving prognosis or serve as early warning systems through continuous monitoring.
	B	Training and exercises	Bridging the gap between expensive large-scale exercises and abstract table-top exercises, the SCDT facilitates cross-organisational trainings increasing the mutual understanding of needs during disaster response and shedding light on blind spots.
During a disaster	C	Situational picture	The system helps to shorten the initial chaos phase of a disaster and improves early orientation among emergency services by assessing the situation on site and giving an estimation of potential damage.
	D	Cross-organisational communication	Enhancing cross-organisational communication and coordination by granting shared real-time access to information provided across organisational boundaries.
After a disaster	E	Documentation and evaluation	Increasing the understanding and transparency of actions taken by emergency services through the documentation of all operations, therefore providing legal security and a foundation to evaluate operational strategies applied.

Based on this, the consortium partners discussed and decided that since the core technology of PANTHEON is the Smart City Digital Twin that could simulate disasters and cascading effects, the most appropriate potential applications that could showcase the PANTHEON SCDT capabilities are applications A (Planning and early warning according to simulations) and B (Training and Exercises). On top of this, each potential application was picked to be utilized for the prioritised disasters according to the pilot organisation's feedback. This mapping is presented in Figure 10. Potential application A was selected for Earthquakes in Attica and Heatwaves in Vienna and potential application B was selected for Wildfires in Attica and Cyber Terrorism in Vienna. Based on this mapping, disaster scenarios, usage scenarios, use cases and features are derived in the following sections.

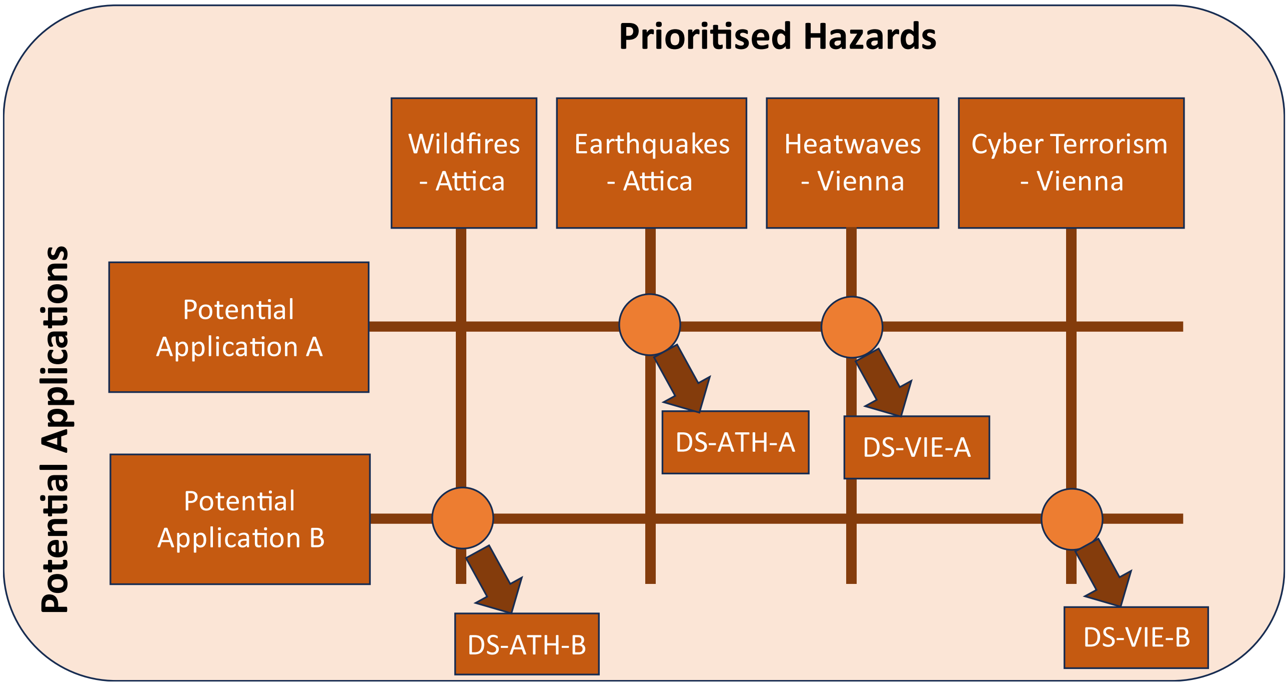

Figure 10 Mapping between potential applications to prioritised hazards.

2.4. TECHNICAL CAPABILITIES CONSIDERATIONS

Except for the feedback received by the community, the stakeholders, and the literature review, PANTHEON partners engaged in discussions for mapping between the technical capabilities and capacities of PANTHEON as described in [21], [22], [23], [24], considering the needs of each defined disaster scenario. In PANTHEON, five main technologies have been identified (SCDT/Simulations, UAV swarms, Weather IoT, Satellite Sensors and Visualisations), however not all of them add value to every disaster scenario defined. The PANTHEON partners engaged in discussions about applicability of each technology in the disaster scenarios and the outcome is summarised in Figure 11. In a nutshell, the PANTHEON SCDT along with visualisations will be present in every disaster/usage scenario defined, the UAV swarms will be absent from the Heatwave scenario in Vienna (DS-VIE-A), since partners agreed that UAV swarms wouldn't add value to this scenario and the Weather IoT will be absent from the Earthquake scenario in Athens (DS-ATH-A), since these devices couldn't contribute to the modelling of the disaster in any aspect.

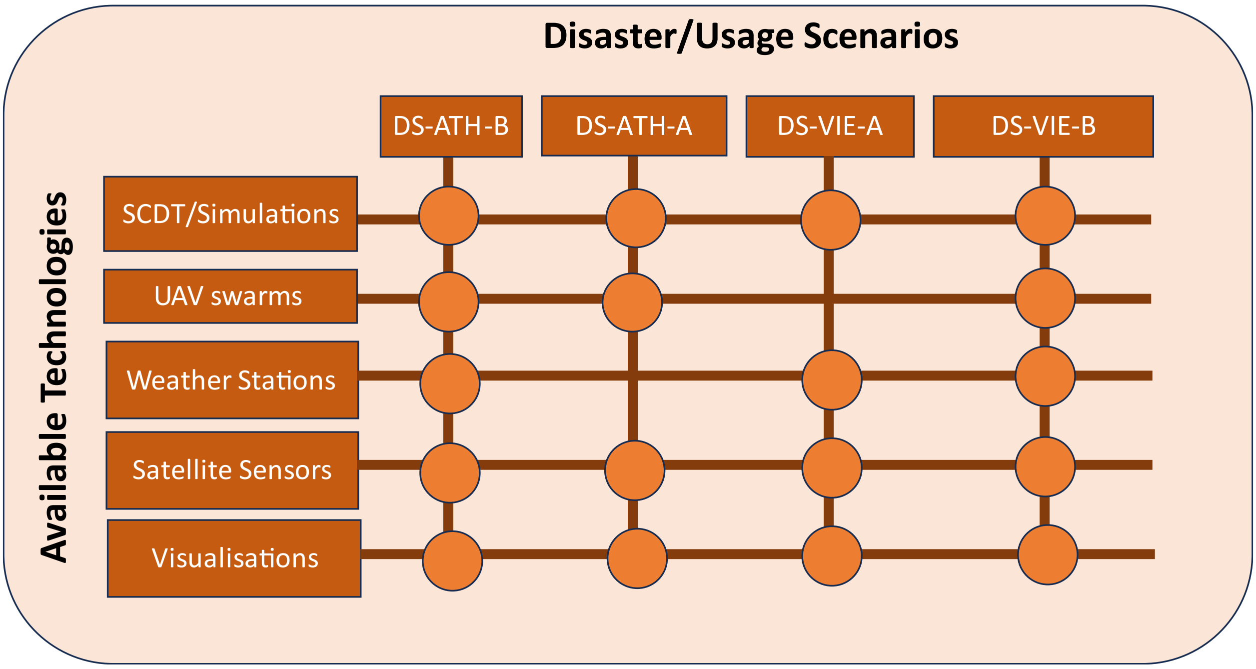

Figure 11 Mapping of available technologies to the PANTHEON Disaster and Usage Scenarios.

2.5. ETHICAL, LEGAL AND SOCIAL DESIGN RECOMMENDATIONS

In addition to the aforementioned inputs, the definition of the disaster and usage scenarios in PANTHEON considers also ethical, legal and social design recommendations as elaborated in [25]. These recommendations stem from the existing EU and national regulatory, ethical, and social framework of each pilot area of PANTHEON. The recommendations are summarised in Table 7 for conciseness.

Table 7: Ethical, legal, and social design recommendations catalogue.

Title	Description
Legal issues	
Human Rights	Consider the impact that the PANTHEON system may have on the human rights highlighted in this report, namely (1) equality, (2) non-discrimination, (3) security, (4) privacy, (5) freedom of thought, (6) freedom of opinion and expression, and (7) freedom of assembly and association. This can be done through a human rights impact assessment.
Consumer Rights	Ensure the quality of the product to be developed under the PANTHEON project by complying with the relevant specific regulations, i.e. the Consumer Rights Directive (2011/83/EU) and the Product Safety Regulation (EU Regulation 765/2008).
Climate change	Consider the environmental impact of the PANTHEON system, particularly in terms of energy consumption. It is recommended to choose energy options and consumption habits that are less harmful to the environment.
Artificial Intelligence	Consider the UNESCO and OECD recommendations on the use of AI. Consider the recently adopted EU law on artificial intelligence and the ethical recommendations of the EU High Level Group on Artificial Intelligence. At PANTHEON use cases national level, consider Greece's Law 4961/2022 and Austria's National Strategy for the Use of AI.

Safety and security by design	
Security and Accuracy of the Smart City Digital Twin	Ensure, as far as possible, that the devices and processes used to generate the Smart City Digital Twin are secure and that the data collected is accurate and confidential.
Security at the Device Layer of the IoT System	Consider and assess the attacks highlighted in D3.5 but identify potential alternative risks and vulnerabilities that have not been foreseen in this report. Risk analysis should be a constant throughout the PANTHEON lifecycle and mitigations should be implemented accordingly.
IoT System Gateway Layer Security	Consider and evaluate the attacks highlighted in D3.5, while identifying potential alternative risks and vulnerabilities not foreseen in this report. Risk analysis should be a constant throughout the PANTHEON lifecycle and mitigations should be implemented accordingly. Particular attention should be paid to DoS/DDoS and man-in-the-middle attacks.
Security at the cloud layer of the IoT system	Consider and assess the attacks highlighted in D3.5, while identifying potential alternative risks and vulnerabilities not foreseen in this report. Risk analysis should be a constant throughout the PANTHEON lifecycle and mitigations should be implemented accordingly.
Security Planning	The architecture of the PANTHEON system must be studied to identify its most vulnerable features or elements. With this in mind, both possible attacks and the different attack surfaces that a cybercriminal might target should be identified, studied and evaluated. Threats should be classified according to whether they are accepted, transferred, or mitigated. Finally, mitigation measures for the identified risks should be defined. These measures should be addressed during the design of the system, following the principle of security by design.
External security review	It is recommended that security experts who have not been involved in the security design of the architecture can review the system for potential weaknesses/vulnerabilities that may have been overlooked by the main designers. These experts may be from an organisation that is part of the PANTHEON consortium, although it is strongly recommended that experts from outside the consortium also participate.
Device authentication	Devices in the IoT system must be properly identified and authenticated with respect to the other devices in the IoT system.
Key management system	Communications and data transfers within the system must be properly encrypted.
Ensure the CIA triad	Guarantee Confidentiality through data security, Integrity through data accuracy and the establishment of measures to prevent tampering, and Availability of data only to authorised persons.
User awareness	System users should be aware of both the risks and threats to the security of the system and the corrective and self-protection measures they can take.
Updating the system	The system should be designed to allow regular updating and incorporation of security patches.
Pentesting	It is advisable to perform regular penetration tests of the system's software and hardware to identify possible vulnerabilities and implement corrective measures.
Resilient design	The design of the system should be as resilient as possible to adversities such as power outages or loss of connectivity.
Privacy by design	

Privacy Impact Assessment (PIA)	Designers should identify, examine, and assess the risks that may exist in relation to the personal data collected by the system. They should (1) identify the categories of data to be processed and (2) the type of processing they will be subject to, (3) identify, assess, and prioritise potential risks and threats, (4) adopt appropriate mitigation measures and (5) monitor the data flow. The use of the LINDDUN methodology based on data flow diagrams is strongly recommended.
Data Minimisation	The amount of personal data collected should be reduced as much as possible. Only data that is strictly necessary for the service and operation of the system should be collected.
Access controls	Restrictive permissions should be implemented so that only authorised personnel have access to files containing personal or sensitive data.
Default login	All system user accounts should require login by username and password or other verification and authentication mechanisms.
Strong passwords	Passwords should be secure and strong. The use of common or overly simple passwords should be avoided. They should be at least 8 characters long, including upper- and lower-case letters, numbers and special characters. The system should require that passwords have these characteristics and that they are changed with some frequency. Where possible, passwords should be audited to ensure they are secure.
Double authentication factor	Accounts with special privileges (e.g. access to large amounts of personal and/or sensitive data) should be protected by a double authentication factor.
Anonymisation of personal data	Personal Identifiable Information should be removed from the dataset as far as possible. This can be done by direct deletion, masking, generalisation or tokenisation.
Encryption of data and communications	Appropriate and robust cryptographic techniques should be used to ensure privacy and confidentiality of data and communications.
Data retention and disposal policies	Clear privacy policies should be implemented during design. They should define what data is collected, what data is retained and for how long.
User awareness	System users should be made aware of privacy risks and threats, as well as the corrective and self-protective measures they can take to mitigate them.
Artificial Intelligence	
Decision-making	Users should be the sole decision-makers, with the system merely a supporting tool.
Security of AI systems	AI systems should be protected against previously identified risks and threats. Containment plans should be in place in the event of adverse effects.
Data accuracy	The data on which the algorithm is trained must be accurate to avoid personal and/or material damage. Where possible, biases introduced into the system should be identified and eliminated. It is advisable to work with a culturally and academically diverse team to avoid bias.
Privacy	Protocols should be established about who can access what data and in what situations. Measures must be taken to anonymise, aggregate and encrypt data. It must be possible for humans to audit the data.
Explainability and transparency of processes	Users should know at all times that they are interacting with an AI system and, as far as possible, be able to understand the rationale behind the decisions it recommends. The objectives, limitations, benefits and risks of the system and its decisions should be communicated to the user.

Environment and social welfare	Identify, study, and evaluate the impact that the AI system may have on the environment (especially the issue of energy consumption), as well as on labour issues, institutions and democracy.
Audits	Systems should be designed in such a way that they can be audited. It should be possible to evaluate their data, their algorithms and their design process.

2.6. From Disaster Scenarios to Usage Scenarios, Use Cases and Features

In PANTHEON the usage scenarios are derived from the disaster scenarios which are in turn created from the mapping between disasters and potential applications. A usage scenario is a hypothetical story which is used to help a person think through a complex problem or system. The motivation for using usage scenarios is:

- Describe different user situation as a fundament for developing use cases and features.
- A tool for creating shared mental models of the projects aim among the different partners.
- The easy understanding for the users and developers, enabling the sharing of information in an insightful and concise way.
- The scenario is a story about someone trying to accomplish something with the product (integrated set of features) under test.

The disaster scenario describes (based on experiences) what the problem is, not yet knowing how its solution might develop. Once the problem is well formulated the next development step will be the creation of a so-called usage scenario.

- The usage scenario tells a story about a person trying to accomplish something with the product/ system in the future. It requires new ways of thinking about users' needs and how to meet them. A usage scenario can be a complex story, but it must be easy to analyse and to extract its relevant features. The strength of such a scenario is that it helps discover problems in the relationships among the features. The final characteristic of this scenario is the easiness of evaluation, important to validate if the solution and development passed or failed.
- When identifying usage scenarios, we have identified "system events", and described how the system handles them. An event is any occurrence that the system is designed to respond to. These are events that have meaning to the system, such as triggering a simulation of a disaster or receiving decision support for potential actions. For any event, it is important to understand its purpose, what the system is supposed to do with it. Describing the user interests helped identifying the events. The user will value the system if it furthers their interests. From the interests, we have identified the user objective for the system, something it can do for them. From this, we have found features that serve that objective. Special events are also important because unusual occurrences may require special handling.

Thus, after the definition of a disaster and the creation of a plausible scenario around it (disaster scenario), the intended users of the system along with the rest of the PANTHEON partners collaborate to think of ways they could use the system (usage scenarios) and define in finer detail how the users will interact with the system (use cases), as thoroughly presented in the use case methodological framework in 2.1. This collaboration will elicit use cases and system features to be developed. As shown in Figure 12, each disaster scenario can have multiple usage scenarios, however since in PANTHEON a potential application has been mapped for each disaster, each disaster scenario has one usage scenario. Then each usage scenario will have multiple use cases that correspond to single steps of functionality expected by the user which in turn will lead to specific system features that need to exist for the PANTHEON system to meet its users' needs.

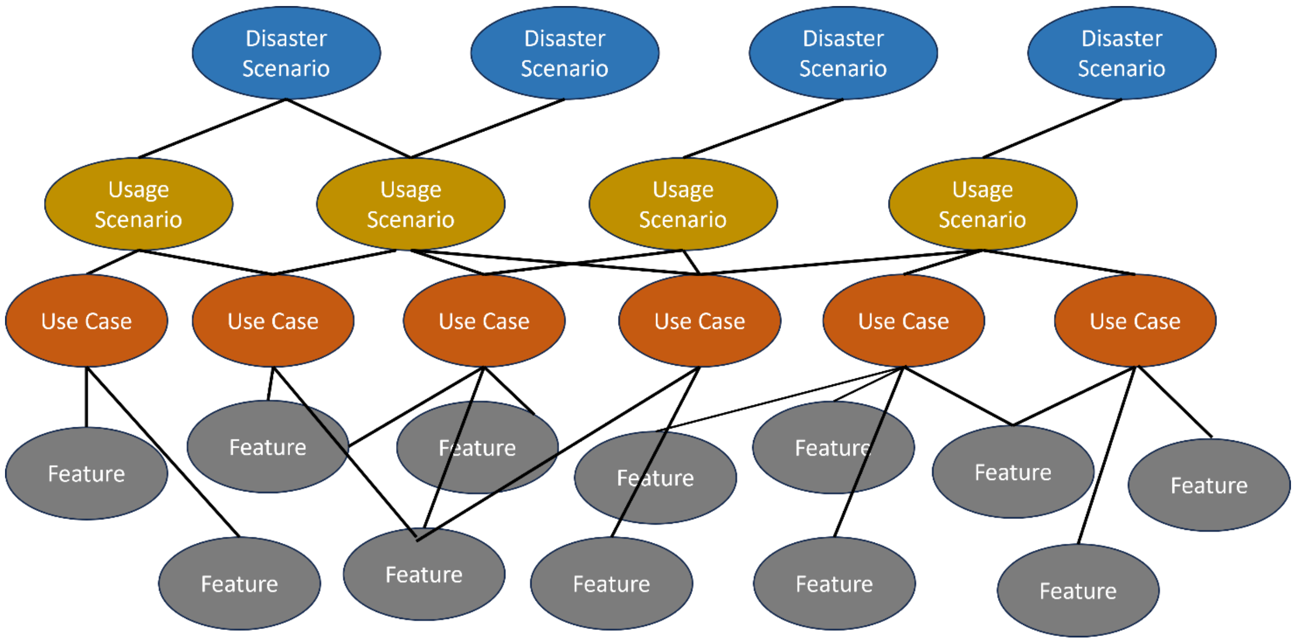

Figure 12 Relationship between Disaster Scenarios, Usage Scenarios, Use Cases and Features in PANTHEON.

3. DISASTER AND USAGE SCENARIOS

3.1. SCENARIO 1 | DS-ATH-B: WILDFIRE IN THE REGION OF ATTICA

3.1.1. WEATHER CONDITIONS

Although May and June 2024 are relatively wet months, with high precipitation in most regions, and temperatures close to and even below normal, July 2024 is a particularly warm month with temperatures well above normal and very low humidity. The Region of Attica has been suffering hot and dry conditions for more than two weeks, something that greatly increases the risk of a wildfire occurrence.

The forecast for day d_0 from the Hellenic National Meteorological Service predicts calm weather for most Regions of Greece. More specifically, in the continental parts of the country, from the Region of the Peloponnese to the south, up until Macedonia and Thrace, weather will be clear with some clouds in the central and northern parts of the country appearing during the afternoon and evening. Winds will not exceed the intensity of 5 in the Bf scale and will mostly be of a northeastern direction. Temperatures will reach 30 ^{0}C in northern Greece, 32 in the central parts and 34 in the southern.

However, in the Aegean Sea and over the easternmost parts of central Greece, including the Attica Region and Euboea Island, winds will be very strong, reaching the intensity of 8 to 9 in the Bf scale. The direction will be NE, whereas temperatures will not exceed 31 ^{0}C.

3.1.2. CIVIL PROTECTION AND PREVENTION AGAINST WILDFIRES

As described in detail in [18], a series of measures are taken by the Civil Protection Mechanism as prevention actions against wildfires. The fire season officially starts on May 1st and ends on October 31st each year. In 2010, the General Secretariat for Civil Protection issued the “Iolaos” general plan for the management of wildfires, which also dictates specific actions to be taken for all phases of disaster management i.e., prevention, preparedness, response, and recovery. One crucial aspect, which has significantly supported first responders in their operations, is the daily issue of the fire risk map, which showcases the areas colour-coded that present the highest risk for fire ignition, based on the prevailing weather conditions.

Due to the very strong northeastern winds prevailing across the eastern parts of the country, the General Secretariat issued the fire risk map shown in Figure 13:

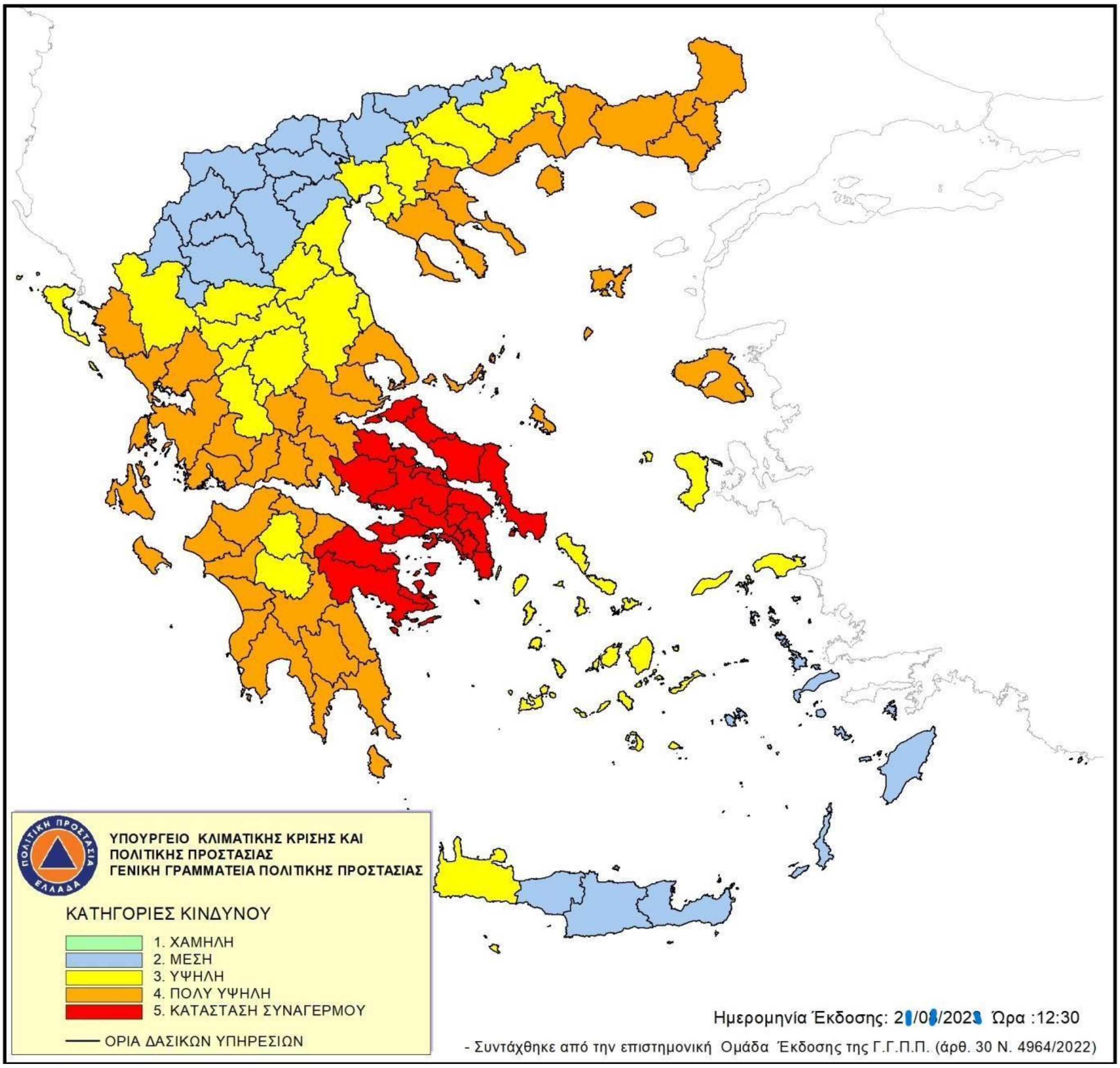

Figure 13 Fire risk map for day d_0, taken as an example from the inventory of daily maps created by G.S.C.P.[5]

It is apparent, that the eastern parts of the Region of Central Greece, the eastern parts of the Thessaly Region, the northeastern parts of the Peloponnese and the whole Attica Region present the highest risk for wildfire occurrence, during the 20th of July 2024. This is the aftereffect of a prolonged hot and dry period, which lasts more than two weeks in the area. Moreover, fire risk is increased also due to the heatwave that affected the whole country the previous days and due to the vegetation of these areas, that include highly flammable species like pines. The fire risk map is disseminated by the operational centre of the G.S.C.P. to all relevant stakeholders. Measures for high-risk areas include increased forest surveillance, curfew measures inside or in the proximity of forests, raise of public awareness, cessation of outdoor activities e.g. agricultural and even military activities [18].

[5] https://civilprotection.gov.gr/arxeio-imerision-xartwn

3.1.3. Wildfire Occurrence in NW Attica

At approximately 12:00 the 112-emergency call centre receives numerous calls from citizens reporting smoke and fire around the west-southwestern slopes of the Parnitha mountain. The Hellenic Fire Service is mobilized to the site of the forest fire. Due to the increased temperatures, low humidity and strong winds airborne forces are required. The area of ignition is depicted in Figure 14:

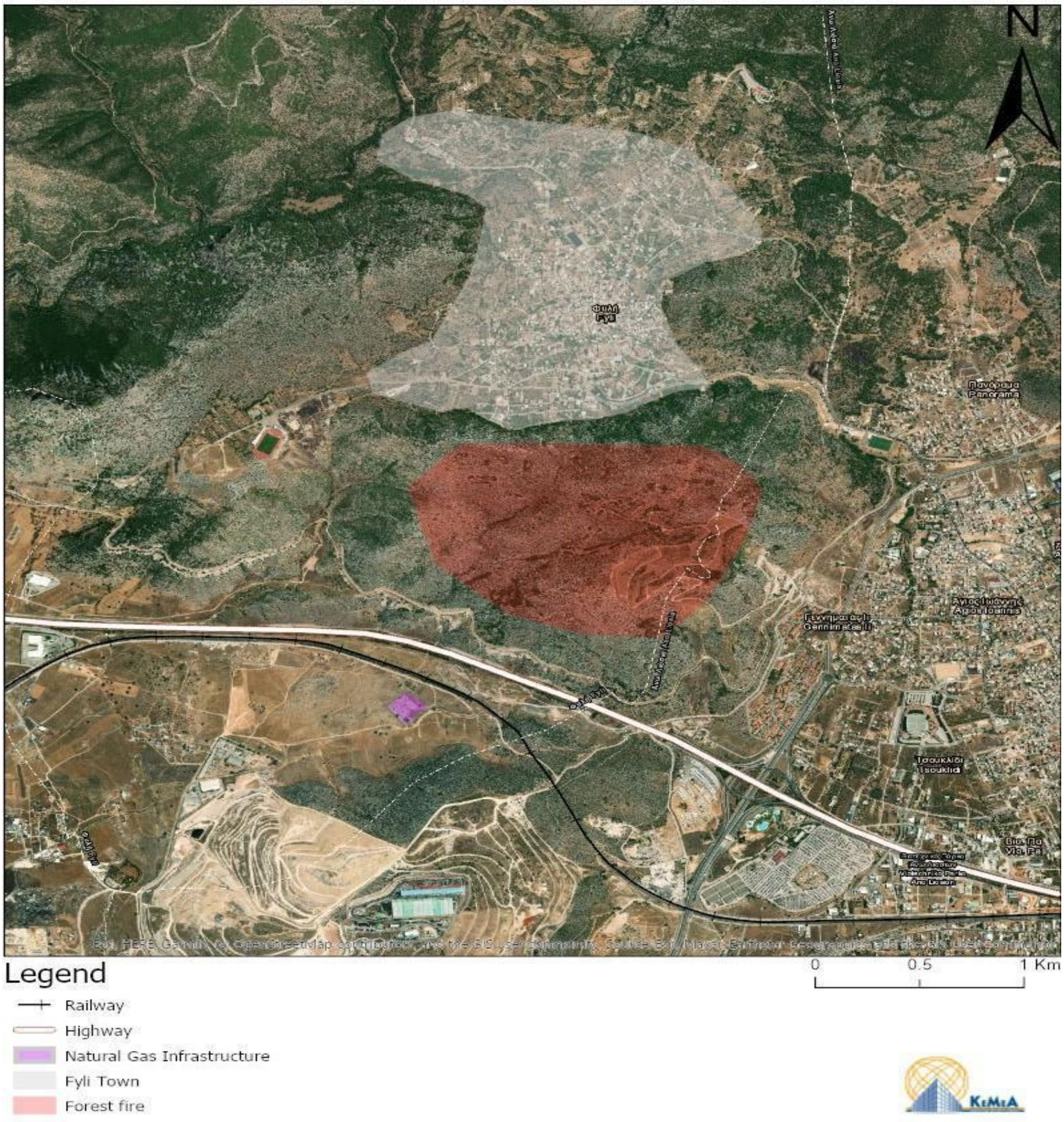

Figure 14 Map, depicting CIs around the area affected by the fire.

3.1.4. Impact on critical and other infrastructures

The wildfire is affecting a sparsely forested area, which is mainly covered with bushes and low vegetation in general. To the north lies the town of Fyli, which is not directly threatened by the fire, mainly due to the NE winds. Although the SW is not densely populated, as it lies outside of the Athens metropolitan area, it encompasses many industrial sites and critical infrastructures, that could be severely affected by the fire.

Regarding Critical Infrastructures, these include the Attiki Odos highway, the Hellenic Train railway and an installation of the National Natural Gas System Operator (S.A.). Below are presented potential cascading events, that could occur:

- Transportation hubs: The fire, driven by the very strong NE winds reaches the Attiki Odos highway and the railway, causing serious damage to the infrastructures and consequently leading to a curfew.
- Energy Grid Failure: The nearby natural gas installation is severely damaged by the fire with explosions being documented in the gas pipelines. Nearby towns suffer from gas shortages.
- Pollution from the Ano Liosia dumping ground: The fire reaches the nearby Ano Liosia dumping ground, an area which concentrates vast amounts of waste from the metropolitan area of Athens. A large plume of toxic smoke is created and heads towards the town of Aspropyrgos and the island of Salamina.
- Water and power supply: Both the water and power network of the surrounding area are damaged, and supply is suspended.

3.1.5. Stakeholders' Roles

The General Secretariat for Civil Protection: As soon as the 112-emergency call centre receives reports for fire in the area, the G.S.C.P. disseminates all information to relevant stakeholders and first responders for the management of the fire. Moreover, it issues warnings to raise public awareness and preparedness in case of evacuation. The Region will also assist the Fire Service by providing water trucks and tanks when requested by the Fire Service officer, who is responsible for the operations.

The Hellenic Fire Service is the main actor for the management of wildfires. Both land and aerial means are deployed in order to constrain the fire and prevent it from reaching the aforementioned critical infrastructures and the dumping grounds.

After the occurrence of a forest fire, the Hellenic Police (HPOL) based on the current institutional framework (L.4249/2014) is mainly responsible for:

- Implementing traffic measures to facilitate the movement of fire engines and vehicles of other agencies (ambulances, OTA vehicles, etc.) involved in the suppression.
- Implementing traffic measures. to avoid traffic congestion, both in the affected area and beyond, diversion of traffic flow of other vehicles to avoid them being caught in the fire, as well as measures to facilitate citizens moving away from the affected area.
- Implementing public order and security measures in the affected area
- Contributing to the implementation of an organized preventive evacuation of citizens due to forest fires when it is ordered by the locally competent Mayors, Regional Governors, or the General Secretary of Civil Protection.
- Guarding and safeguarding the properties destroyed or threatened by forest fires, until they are safely handed back to the owners.

The above actions are launched by the local competent Services of the Hellenic Republic of Greece according to their operational planning and intervention plans. The National Centre for Emergency Assistance is on standby for treatment of injuries and burns, as well as for the evacuation and transport of vulnerable people, who might develop respiratory issues due to smoke.

3.1.6. Actor Definition

As described above, the main stakeholder that is engaged in the management of wildfires is the Hellenic Fire Service, which mainly undertakes firefighting as well as search and rescue operations. The wildfire scenario will be used as input for training and exercises (Application B), therefore it would be important that the SCDT system provides the Fire Service and the personnel in the command post with crucial information, in order to better prepare against actual emergencies. Such data would encompass:

- Type of vegetation and land cover in the under-examination area. Vegetation is a crucial factor as it provides the needed fuel that feeds a wildfire. Different types of vegetation result in different fire behaviour.
- Topographic data, through Digital Elevation Models are essential, as the relief is a significant driver of wildfires.
- Meteorological data is also important, especially in terms of wind direction and velocity, humidity, and temperature. Combining this information with relief and land cover data, a quite accurate estimation of the fire propagation can be created.
- Historical data, such as location, size, duration, and intensity of past occurrences are important, especially when it comes to the simulation of fires, as well as resources used to suppress and extinguish them.
- Data regarding the number and location of available operational resources.
- Identification of specific routes to approach the ignition location.
- Critical Infrastructure locations, potential interlinkages between them.

The aforementioned information would be of great significance for firefighters as it would enhance situational awareness and facilitate a timely and targeted response, leading to a quick suppression and avoidance of cascading effects.

Furthermore, the Hellenic Police assists in operations, mainly through managing the traffic, by implementing curfew measures for the facilitation of the incoming flow of firefighting vehicles and the prevention of citizens approaching the incident location. In addition, the Police undertakes evacuation procedures, should the need arise. Therefore, the following information would be of great importance:

- Road network and traffic data, which would facilitate the implementation of curfew measures.
- Demographic data e.g. number of people that would potentially require evacuation.
- Data regarding the location and availability of operational resources, in terms of personnel and vehicles.
- Locations and potential interdependencies between critical Infrastructures in the affected area
- Identification of evacuation routes and open spaces for staging areas of displaced population.

3.1.7. Usage Scenario Description

Following on the wildfires disaster scenario and given that we are targeting potential application B, a Fire Service employee who creates operational response plans for their organisation would like to simulate this scenario in a system, see its cascading effects and get decision support on the possible prevention actions first responder organisations could follow to contain such a disaster and minimise its cascading effects. To do so, they log in to the PANTHEON system and input the organisation's assets. They then select ranges of values to input into the simulation (e.g. wind speed and direction, flammable materials, slope). After the simulation is created, they receive a decision support on how their organisation should place its resources to minimise the impact of the disaster and mitigate its cascading effects, while also considering community characteristics such as socio-economic factors. Moreover, the PANTHEON system should consider the assets and resources of the local municipalities and the prefectures alike, given that they represent two separate layers of elected local government and can-by law-contribute to the activities of the fire service within the context of civil protection. In terms of users, the Hellenic Fire Service would act as the user with full privileges (members - running simulations, inputting assets etc.) and the rest of the stakeholders (Hellenic Police, local municipalities and prefectures) would act as observers of the system with restricted access (possibly read only).

3.1.8. PANTHEON TECHNOLOGIES USAGE

3.1.8.1. SCDT

Addressing the wildfire disaster scenario using simulations, the PANTHEON system will leverage Neo4J graph databases, impact assessment analytics, and centrality metrics. The town of Fyli serves as the starting location, and within the Neo4J graph database, it is represented as the initiating node. This node encapsulates critical information about the geographical and infrastructural characteristics of the area (e.g., population, flammable materials etc). that affect the initiating impact and spread factors.

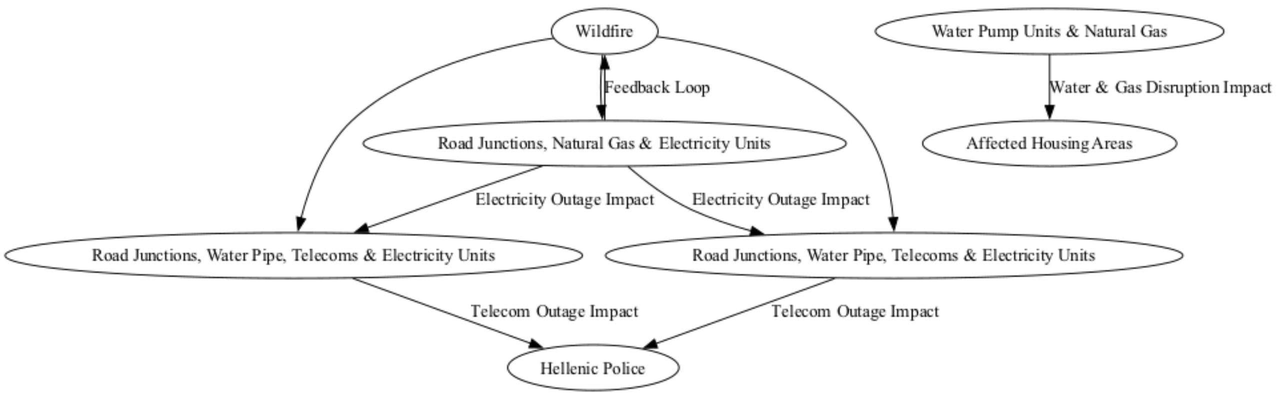

Figure 15 Overview of the wildfire disaster propagation scenario as simulated by PANTHEON platform.

The initiating event in the scenario will be the wildfire at a given geospatial point (upper node in Figure 15). The event triggers several first-order dependencies: disruption of a road junctions, disruption of natural gas pipelines that transport fuel to neighbouring civilian houses and disruptions of water pipe, telecoms (cell towers) and electricity units. As shown in Figure 15, the wildfire directly impacts the road junctions and the electricity units, which in place take out the water distribution, telecoms and the evacuation routes of civilians; three second-order dependencies. Telecom outage in turn affects the operation of the Hellenic Police, a third-order dependency, and natural gas pipes may burst, further exacerbating power problems at node A (feedback loop to the wildfire itself). Finally, the disruption of water pump units and natural gas (node H) affect housing at several areas (node I), a fourth-order dependency.

The Hellenic Police, as a key stakeholder, will input and extract valuable insights from the simulation by leveraging Neo4J's graph database capabilities to model the spatial relationships between critical infrastructures, transportation hubs, and potential evacuation routes. By incorporating impact assessment algorithms that will simulate the impact per m^2, the simulation can predict the cascading effects of the wildfire on different infrastructures such as road junctions, public gas chokepoints and other critical infrastructure, thus allowing the Hellenic Police to formulate optimal curfew measures and evacuation plans.

Centrality metrics within the graph database will identify key nodes representing critical areas requiring immediate attention, ensuring a targeted and efficient deployment of resources.

Similarly, the Hellenic Fire Service will input details about their assets, including land and aerial firefighting resources. The simulation, driven by Neo4J's graph database, can dynamically model the spread of the wildfire, considering factors such as wind direction and intensity. Impact assessment algorithms enable the Fire Service to predict potential threats to critical infrastructure and prioritize containment efforts. Centrality metrics within the graph database can identify pivotal points in the network, guiding the optimal placement of firefighting resources to control the fire's progression effectively.

After PANTHEON has evaluated all the dependency risk paths, it is possible for the Hellenic Fire Service to examine several scenarios in an efficient manner. One option is to analyse and compare all possible cascading effects. PANTHEON produces a list of all the dependency paths sorted according to their cumulative dependency risk values based on projections of wildfire routs. This helps the first responders to identify all the potential dependency risks that are above a specified threshold value, regardless of the time taken to reach the threshold. Note that first responders may project different paths using different thresholds.

Incorporating the mentioned technologies, the simulation provides decision support by offering a comprehensive view of the disaster scenario. Neo4J's graph database ensures a dynamic representation of the evolving wildfire, allowing stakeholders to visualize and analyse the complex interdependencies. Impact assessment algorithms enable the prediction of consequences, guiding stakeholders in devising preventive strategies. Centrality metrics identify critical nodes, ensuring resource allocation aligns with the most vulnerable areas.

3.1.8.2. In-Situ IoT sensors

In-situ sensors can provide valuable information and insights to a natural, weather-related disaster (such as a wildfire), mainly in the preparedness and prediction/forecasting phase. Specifically, the in-situ deployed weather station, integrated with a multiplicity of IoT-based sensors, including air temperature and moisture, solar radiation, and wind vector, can act as a local weather/environmental monitoring system providing necessary information and microclimatic parameters to a weather forecasting system. The forecasting, which can be part of the AI-supported simulations component, can correspondingly provide a priori prediction estimations about the possibility of a wildfire disaster advent, based on local weather parameters provided by the IoT sensors. Moreover, the IoT sensors may include air quality and particulate matter sensor and soil moisture sensors, which can be of major importance in the prediction phase or at the beginning of a major fire disaster event. Furthermore, the local monitoring performed by the sensor-equipped weather station can provide continuous situational awareness, even during the event (provided the equipment itself is not affected by the wildfire). Concluding, local environmental monitoring can play a vital role in the preparedness/prediction phase of a natural disaster event. This monitoring can be optimally performed by in-situ IoT sensors/stations, which can provide local weather data in real-time to a disaster risk management system, such as the PANTHEON SCDT platform.

3.1.8.3. Satellites

Sentinel satellite data is a key component of the Copernicus Programme and can be accessed through platforms provided by the European Space Agency (ESA), or other data portals such as the Copernicus Open Access Hub. Possible usage of the satellite data includes:

Prevention and Early Detection: Satellite data, particularly from Sentinel-1 and Sentinel-2, can be utilized for early detection of wildfires in Attica. Sentinel-1's Synthetic Aperture Radar (SAR) can penetrate through smoke and clouds to detect changes in vegetation cover, while Sentinel-2's optical imagery can provide high-resolution views of the landscape. By monitoring changes in vegetation health and surface temperatures, authorities can identify potential fire hotspots and take preventive measures.

Fire Behavior Monitoring: During wildfires, satellite data can be used to monitor fire behavior and progression. Sentinel-2's thermal infrared bands can track changes in land surface temperatures, helping firefighters anticipate fire spread. Additionally, combining SAR and optical data allows for real-time mapping of burned areas and assessing the extent of the fire, aiding in resource allocation and evacuation planning.

Several software technologies are commonly used for processing and analysing Sentinel data for disaster assessment as listed below; however, decision must be made on what is the technology that best suits the PANTHEON project:

a. **ESA's Sentinel Toolbox (SNAP)**: Designed for processing Sentinel data, SNAP offers a wide range of tools for reading, processing, and analysing optical, radar, and thermal imagery.
b. **QGIS (Quantum GIS)**: An open-source GIS software that supports the processing and analysis of spatial data, including Sentinel imagery, for assessing wildfires, heatwaves, and earthquakes.
c. **ENVI:** A commercial software package for processing and analysing remote sensing data, including Sentinel imagery, suitable for more specialized applications.
d. **ArcGIS**: A widely used GIS software offering powerful capabilities for managing, analysing, and visualizing spatial data, including Sentinel imagery, for disaster assessment and management.
e. **GDAL (Geospatial Data Abstraction Library)**: This is an open-source library for reading and writing raster and vector geospatial data formats. Although it is not a standalone software application like the above listed, it is commonly used as a backend library for processing Copernicus data in custom-built or specialised applications.

In the context of wildfires, fuel maps and weather forecasting are crucial components for understanding and managing the risk of wildfires. Here are some references and information that might be helpful:

- **Fuel Maps:**
  - The LANDFIRE program in the United States provides detailed fuel data, including vegetation types and fuel models. You can access their data through the official website: LANDFIRE. However, it is estimated that it will be of very limited value for the PANTEON project.
  - The European Space Agency's Climate Change Initiative Fire Disturbance project provides global fire product datasets, including fuel information: ESA CCI Fire Disturbance. This indeed provides a lot of valuable maps for various scenarios and it is estimated is quite relevant for PANTHEON.
  - Check with relevant authorities in the Athens area revealed the following entities which are likely to possess fuel maps:
    - General Secretariat for Civil Protection part of which is the Hellenic Fire Service (very likely). Today they belong to the Ministry of Climatic Change and Civil Protection as they are the main organisations for managing and preventing wildfires.
    - Hellenic Agricultural Organisation- “Demeter” which is responsible for agricultural research in Greece (less likely).
- **Weather Forecasting:**
  - The National Weather Service (NWS) in the United States provides detailed weather forecasts, including fire weather information: NWS Fire Weather. Not relevant to PANTHEON.

  - The European Centre for Medium-Range Weather Forecasts (ECMWF) provides global weather data and forecasts: ECMWF. Quite relevant for PANTHEON.
  - The Global Forecast System (GFS) is a widely used weather model that provides global weather forecasts: GFS. Recommended for PANTHEON.
- **Wildfire Prediction Systems:**
  - Systems like the Fire Weather Index (FWI) are used globally for assessing fire danger. The Canadian Forest Service provides information on the Canadian Forest Fire Danger Rating System, including FWI: Canadian Forest Service. Can be used if no similar system exists within the General Secretariat for Civil Protection and the Hellenic Fire Service
- **Satellite Imagery:**
  - Utilize satellite imagery to monitor vegetation health and potential fire hotspots. NASA's Earth Observing System Data and Information System (EOSDIS) provides access to various satellite data: NASA EOSDIS. Not recommended for PANTHEON as it is easier to use Copernicus satellite imagery.

3.1.8.4. UAVs

As explained in [26], "the growing interest in using aerial vehicles for diverse missions creates the need for higher autonomy and dexterity. Unconventional configurations can potentially satisfy such requirements, at a cost of new challenges in design and control. Simulation environments are often employed to tackle such challenges while minimizing resources expenditure. In [26], an existing simulation framework has been extended to allow for the modelling of new UAV configurations. Aerodynamic forces and moments generated by propellers and airframes are defined in separate functions to ease the understanding and allow future addition of new vehicle configurations. Different methods are implemented as vehicle agnostic control and guidance solutions. Vehicle models are extracted and implemented into Paparazzi[6] open-source autopilot system, which makes a seamless switch towards real flights and hardware in the loop tests, facilitating the development of different control schemes. The simulator can also be used within vehicle and mission design environments. With that, the entire closed loop behaviour of the system can be addressed from the design stage, allowing for the vehicle and fleet optimization while considering control and operation constraints."

As noted in [26] "Simulators have become indispensable tools in aeronautical and robotics research. Their use is one of the factors that led to the increasing interest in deploying aerial robots for real life missions. In a fully computational environment, researchers can evaluate vehicle performance and different control strategies without expending resources to manufacture and test robots. By employing a simulator to train a learning-based solution, [27] showed how quadcopters can safely and nimbly navigate through complex environments such as forests and disaster zones. [28] also used simulations to assure that two unmanned aerial vehicles (UAVs) could be used to document historical buildings without endangering them. Thanks to the successful application of UAVs in different tests or even in real life scenarios, there is an increasing interest in using them in different tasks."

In short, "The simulator [developed in [26]] is intended to be used to model new vehicle designs, develop control and guidance laws and simulate mission scenarios while testing different vehicle configurations at the same time" [26].

One of the aims of the PANTHEON platform is to provide similar technology and tools to the following use cases: wildfire in the region of Attica, earthquake in Attica, and man-made disaster in Vienna. All parameters to be considered will be subject to technical specifications to be drafted in the project's next phases.

[6] https://wiki.paparazziuav.org/wiki/Main_Page

In the context of Pantheon and large-scale fires, the deployment of drones can contribute to improving the situational awareness for rescue teams, with the potential benefit of providing data dynamically, even in real time. The study case can be summarized as follow:

- **Problem:** large-scale fires are usually occurring in large, remote areas, difficult to reach for rescue teams, and firefighters need information to improve their operations and protect themselves.
- **Drone added value:** observation drones could be deployed to augment a map of the affected areas and identify the high priority places to address with firefighting and water bombing operations.

The most classic case study involves flying over areas ravaged by flames, to map the position of the fire fronts and their evolution over time. In this context, the drone will be equipped with RGB and thermographic cameras mounted on a gimbal to allow the user to point in different directions, enabling a realistic visualization of the areas flown over that can be coupled with hot spot detection provided by the infrared sensor. Data fusion or overlay technologies will further enhance the readability of the observed situation, and the interface of a Geographic Information System may be dedicated to geolocating the fire fronts and their evolution to further improve decision-making processes.

Eventually, this type of information, combined with results coming from numerical simulations, should allow for anticipating the movement and expansion of fire fronts and enable firefighting teams to allocate available resources in the most optimal manner considering the set objectives (such as achieving the fastest possible extinguishment of fires, protecting individuals or habitations, and protecting particularly vulnerable or densely populated areas).

The main challenge for planners and rescue operators intervening in this type of crisis and wishing to assess the usefulness of deploying drone-based observation systems, remains the management of their operation considering other users of the airspace. Managing large forest fires typically involves the intensive implementation of other aerial assets besides drones. These include water bombers, observation aircrafts carrying specialized forest management teams, medically equipped transport helicopters, emergency firefighting team transport helicopters, or even the cohabitation of multiple drones or drone systems. Manned and remotely controlled systems are currently not highly interoperable, and numerous precautions must be taken to avoid collisions and system interferences.

This often leads to the implementation of operational segregation rules, either geographically (where specific areas are allocated to each system, manned or unmanned, and safety zones are established to ensure acceptable levels of security), altitude-based (where platforms operate at different altitudes, allowing, for example, water bombers to operate at low altitudes while drones are deployed above), or according to a scheduled program (where drones are used in specific time slots prohibited to other platforms, each having its own time slot; e.g., drones can be deployed at night time). In all cases, the difficulty is primarily organizational, as it involves determining all parameters of the segregation rules, possibly based on the operational characteristics of the considered aerial vehicles, and initiating the documentation and regulatory framework that will concretize these operational deployment plans for different types of vehicles (NOTAM, SORA, operational plans, and flight manuals).

Another aspect of the problems the PANTHEON platform can help mitigate concerns the definition or sizing of drone systems. This involves optimizing the size of the system to meet the objectives, while considering multiple constraints of various kinds:

- **Definition of the descriptive parameters of the crisis:** size and limits of the area concerned, types of crises to be analysed, type of actors present in the crisis zone, type of payloads to be considered, etc.
- **Characteristics of airborne vehicles:** speed, endurance, minimum and maximum altitude, maximum deployment range, loadable mass, airborne behaviour, operational limits (especially meteorological), take-off and landing constraints, etc.
- **UAV system support equipment:** ground station capabilities, positioning of the ground control station and of the data management station with respect to the area of operation, range of telecommunication C^2 and data transfer systems, characterization of necessary ground equipment such as catapults etc.
- **UAV integration characteristics:** whether the UAVs are operating as stand-alone vehicle, in a small group or in a swarm configuration will have an impact on how the impact of the UAV system is simulated.
- **Payload characteristics:** type of sensors (RGB, IR, LIDAR, Hyper-spectral etc.), payload control and associated sensor mobility (Gimbal etc), resolution, fields of view, size of data transferred, real time or not.
- **Regulatory constraints:** prohibition or limitation of flights in populated areas, avoidance of hazardous industrial zones or military zones subject to overflight bans, avoidance of protected natural areas, etc.

In the face of these constraints, the operator must be able to define their objectives and identify the added value that can be expected from the deployed systems. Through the PANTHEON platform, indicators should be simulated and quantified, focusing primarily, in the case of observing large areas affected by fires, on elements related to the aerial system's spatial coverage and payload (ability to reach all areas of interest, frequency of drone passes, sensor field of view, etc.). It will also involve determining the characteristics of the elements to be identified, located, or characterized (major fire fronts, hot spots, fire starting or residual smoke vents, etc.), as this will determine the types of payloads carried out and the distances considered optimal for operations. The system may also be required to detect people or vehicles, or to map built-up areas, which could also impact the selection of payloads or operational parameters.

Figure 16 illustrates the decision-making process that will be proposed through the PANTHEON platform, starting from the descriptive parameters of the crisis under study, the types of drone systems and available payloads, and the targeted objectives, and finishing with conclusions focusing on the sizing of the drone system and an outline of operational deployment procedures.

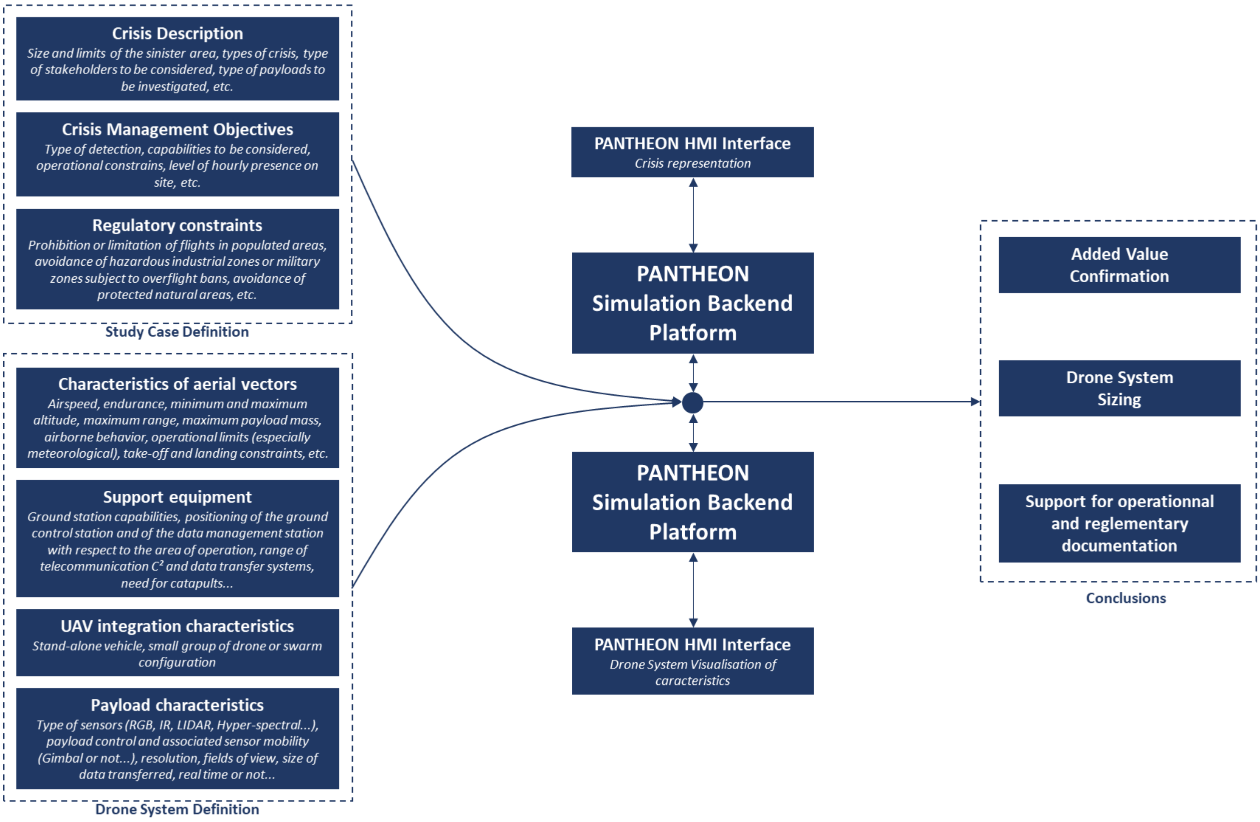

Figure 16 Overview of process dedicated to drone systems implementation as proposed by PANTHEON platform.

Figure 17 illustrates a practical case where a forest area prone to fires can be subject of firefighting intervention, in this case represented by water bombing operations. Drone deployment is considered to cover the area and identify the fire positions, which can then be transmitted in real-time to water bombers to improve efficiency of the dropping task. Since the operations of both types of aerial vehicles are thus simultaneous, spatial segregation would be established to scan the intervention area, with each vehicle having its own operating zone. Consequently, the large observation distances and the extensive area to cover will likely lead the operator to deploy multiple drones equipped with RGB and IR payloads with strong zoom capabilities. Due to the type of operation envisaged (identification of hot spots and continuous monitoring of their movement in real-time to provide the best position to the bomber just before the drop), multi-copter drones equipped with orientable high-resolution RGB and thermographic cameras will likely be the most suitable, but fixed-wing drones could be considered on account of their range and endurance advantage. However, confirming or refuting this type of conclusion precisely relies on the expected determination resulting from the use of the PANTHEON platform.

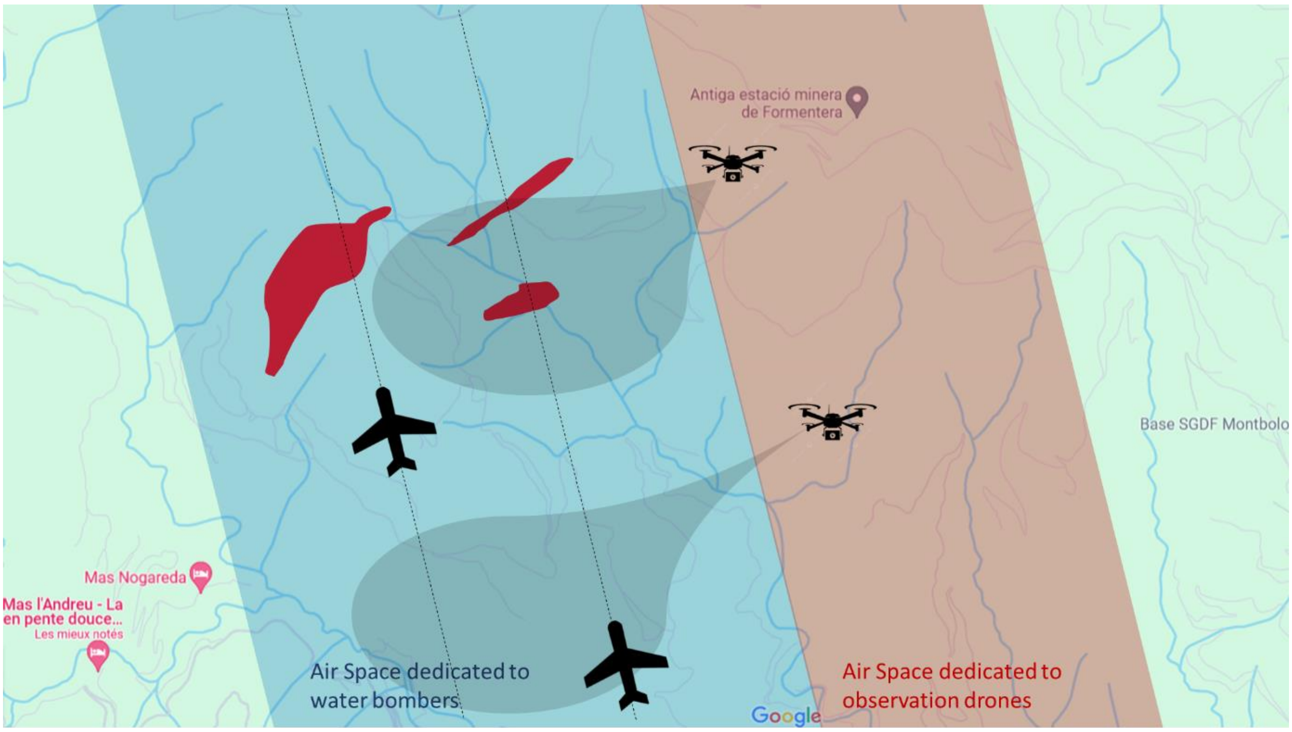

Figure 17 Illustration of a study case dedicated to firefighting in remote area and involving water bomber coordination using observation drones.

The steps described above are both generic and exhaustive. For the PANTHEON project, they are circumscribed as follows:

1. Prior to the disaster (planning)
    1. The available equipment will be simulated first – no hard limit on the number and type of drones and equipment. we shall at least retain two drones, one rotary wing and one fixed wing drone, both equipped with IR cameras.
    2. Feed this data in the SCDT, along with user inputs, and restricted airspaces, for the swarm controller to come up with an optimised swarm;
2. During the disaster (early warning simulation)
    1. Fly the swarm within the authorised zones (safety buffers included); always stay in contact with simulated other airspace users and Air Traffic Control.
    2. The aim is to detect, localise and survey the fire line and isolated hotspots with IR cameras (this objective will be confirmed with the requirements of real firefighting teams)

3.1.8.5. Data Sources Requirement & Availability

The scenario involves the usage of the PANTHEON system for addressing a wildfire disaster. To simulate and analyse this scenario effectively, various data sources would be essential (conceptualised in Figure 18) including:

Local GIS and Topographical Data: Geographic Information Systems (GIS) and topographical maps of the NW suburbs of Athens, the Parnitha mountain, Fyli town, and surrounding areas can provide detailed information about the terrain, road networks, critical infrastructures, and potential chokepoints for the natural gas supply network. This data can help in accurately modelling the fire's spread and its impact on the region.

Weather Data: Accessing historical and real-time weather data for the specific date and time of the scenario, including wind speed and direction, temperature, humidity, and precipitation, will be critical for simulating the behaviour of the wildfire under strong NE winds. Weather data can be obtained from meteorological agencies or through specialized weather APIs.

Infrastructure and Facilities Data: Detailed information about transportation hubs, highways, railways, gas installations, the dumping ground, water supply networks, and power supply networks in the area is essential. This can include infrastructure maps, network layouts, and vulnerability assessments to understand the potential impact and dependencies between these infrastructures.

Emergency Response Protocols: Gathering data on the standard operating procedures, coordination protocols, and responsibilities of relevant stakeholders, such as the Hellenic Fire Service, Hellenic Police, National Centre for Emergency Assistance, and other organizations involved in disaster response and management.

Historical Wildfire and Disaster Data: Studying past wildfire incidents in the region, including their impacts on critical infrastructures, population, and the environment, can provide valuable insights for creating realistic simulations and understanding potential cascading effects.

Population and Vulnerable Groups Data: Information about the population density, demographics, and locations of vulnerable groups in the affected area can help in assessing the potential impact on communities and planning for evacuation and medical assistance.

Risk Analysis and Dependency Data: Data sources for analysing dependencies between affected infrastructures, identifying critical nodes, and understanding the potential cascading effects, as mentioned in the scenario, can be derived from infrastructure risk assessments, network analysis, and relevant studies.

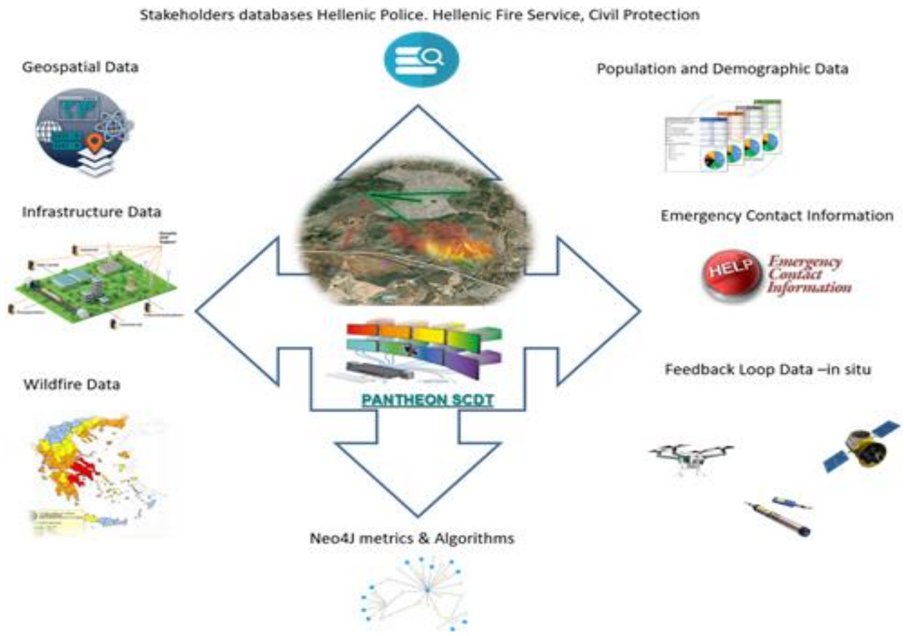

Figure 18 Data Sources in DS-ATH-B scenario.

1. Geospatial Data & Wildfire Data

Sources	Purpose	Actual Sources
GIS (Geographic Information System) databases,	Provide detailed geographic information about the town of Fyli, including topography, land use, and critical infrastructure locations.	**https://effis.jrc.ec.europa.eu/** **https://gwis.jrc.ec.europa.eu/apps/gwis_current_situation/index.html** **Global Wildfire Information System** DIAS, or Data and Information. Access Services.
satellite imagery		**NASA Earthdata:** NASA Earthdata provides access to satellite imagery and data, including information relevant to monitoring wildfires globally. **European Space Agency (ESA) - Earth Online:** ESA's Earth Online platform offers access to satellite data and tools for monitoring environmental phenomena, including wildfires.
Local government mapping data		**National Observatory of Athens - Forest Fire Monitoring System (FIRESENSE):** FIRESENSE is a project by NOA aimed at monitoring forest fires using satellite data. It offers real-time monitoring and early warning systems for wildfires in Greece.

2. Infrastructure Data

Sources	Purpose	Actual Sources
Municipal databases,	Capture information about road networks, natural gas pipelines, water distribution networks, telecom infrastructure, electricity grids, and other critical infrastructures.	**Athens Municipality Website:** The official website of the Athens Municipality may provide general information about road networks, water distribution networks, and other municipal infrastructure projects. https://www.cityofathens.gr/ **Hellenic Electricity Distribution Network Operator (HEDNO):** HEDNO manages the electricity distribution grid in Greece, including Athens. Their website may offer information about electricity grids, power outages, and maintenance schedules. https://deddie.gr/en/ **Hellenic Gas Transmission System Operator (DESFA): DESFA** operates the natural gas transmission network in Greece. While detailed information may not be publicly available, their website may provide general information about the natural gas pipeline infrastructure. https://www.desfa.gr/en/ **Hellenic Telecommunications Organization (OTE):** OTE is the primary provider of telecommunications services in Greece. Their website may offer information about telecom infrastructure, coverage maps, and services available in Athens. https://www.cosmote.gr/cs/otegroup/en/ote_ae.html **Ministry of Infrastructure and Transport:** https://www.gov.gr/en/upourgeia/upourgeio-upodomon-kai-metaphoron **Local Water Utility Companies:** Water utility companies operating in Athens may offer information about water distribution networks, treatment plants, and water quality. **Google Maps and OpenStreetMap:** Mapping services like Google Maps and OpenStreetMap provide detailed maps of road networks, landmarks, and infrastructure in Athens. While they may not provide specific information about critical infrastructure, they can offer a general overview of the area.

3. Stakeholder databases

Sources	Purpose	Actual Sources
Hellenic Fire Service Data	available firefighting resources, both land and aerial, Real-time data on the status of firefighting efforts	**Hellenic Fire Service:** Responsible for firefighting operations. It has various units and stations throughout the Athens area. https://www.fireservice.gr/ **National Center for Prevention of Fires:** Monitors, prevents, and controls fires. Maintains databases with information on weather conditions, fire risk assessment, and other relevant information. https://epadap.web.auth.gr/?lang=en **National Center for Social Solidarity (EKKA):** Contributes to coordinated response and support for disaster victims, including fires. Maintains databases with information on victims and their needs. https://ekka.org.gr/index.php/en/ **National Coordination Mechanism (ΕΣΥΜ)**: Coordinates crisis management and emergency response operations. Plays a significant role in connecting various agencies and services. https://www.preventionweb.net/national-platform/greece-national-platform
Sources: Fire service records, asset databases, weather data.		**Hellenic Police Website:** The official website of the Hellenic Police may provide updates and announcements regarding emergency measures, including evacuation plans, critical areas, and curfew measures. https://www.astynomia.gr/?lang=en **Greek Government Websites:** Government websites, such as the Ministry of Citizen Protection or the Ministry of Digital Governance, may release information regarding emergency management, including data on evacuation plans and road closures. **Civil Protection Websites:** Civil protection agencies may offer information about emergency plans, including evacuation procedures and road closures, to ensure public safety during crises. **General Secretariat for Civil Protection:** General Secretariat for Civil Protection- https://civilprotection.gov.gr/ **Emergency Management Authorities**: Local emergency management authorities, such as regional or municipal governments, may provide updates on evacuation plans, critical areas, curfew measures, road closures, and traffic management specific to their jurisdictions

4. Population and Demographic Data

Sources	Purpose	Actual Sources
Census data, demographic surveys	Provide information about the population in the affected areas, including demographics, population	**Hellenic Statistical Authority (ELSTAT):** ELSTAT is the official statistical authority in Greece, responsible for conducting census surveys and collecting demographic data. https://www.statistics.gr/en/home/ **Census Data:** Census data collected by ELSTAT provides detailed information about the population in Athens, including demographics such as age, gender, ethnicity, education level, and household composition. https://www.statistics.gr/en/2021-census-pop-hous

	density, and vulnerable populations.	**Eurostat:** Eurostat, the statistical office of the European Union, provides demographic data and indicators for member countries, including Greece and Athens. https://ec.europa.eu/eurostat **Athens Municipality:** The Athens Municipality may offer demographic data specific to the city, including population density, socioeconomic indicators, and information about vulnerable populations. **Academic Research Institutes:** Universities and research institutes in Greece may conduct demographic surveys and studies focusing on Athens and its population. Accessing academic publications and research reports can provide valuable insights into demographic trends and characteristics. **Non-Governmental Organizations (NGOs) and International Organizations:** NGOs and international organizations operating in Greece may collect demographic data as part of their humanitarian and social assistance programs. Reports and publications from these organizations may contain demographic information relevant to vulnerable populations in Athens. **Local Community Centers and Social Services**: Local community centers and social services organizations in Athens may have demographic data and insights about the population they serve, including vulnerable groups such as migrants, refugees, and low-income residents. **Public Health Authorities:** Public health authorities and healthcare organizations may maintain demographic data related to healthcare access, disease prevalence, and health disparities among different population groups in Athens

5. **Emergency Contact Information**

Sources	Purpose	Actual Sources
Emergency contact databases, local government records.	Ensure that communication channels are available, and emergency contact information for residents, businesses, and critical services is up to date.	https://civilprotection.gov.gr/112

6. **Examples of open datasets**

City of Athens Open Data main sources	https://data.gov.gr/ https://geodata.gov.gr/en/dataset
Datasets related with Transportation	map-of-the-main-road-network_greece_vector_shapefile Road traffic in Attica: 2023-10-24. Measurements of number of crossings and average speed per measurement station of the traffic monitoring network in Attica Traffic and itineraries of shipping companies: 2023-11-12. Shipping companies enter information about their itineraries (departure times, ports of call, passenger details, details of issued tickets, vehicles, etc.)

	Passenger public at OASA: 2023-11-10. Travel/transfer endorsements on fixed transit and bus routes Railway Network of Greece [EL]: Railway Network of Greece. This file does not include descriptive information, it contains only the routes of the railway network.
Datasets related with Infrastructure	Schools [EL]: This dataset contains all schools (nursery schools, primary schools, secondary schools, high schools, technical vocational schools, etc.) in Greece.
Datasets related with Environment	List of Forest Fires: 2018-12-31 Data concerning the Forest events in which the PS intervenes. Stations for the Measurement of Air Pollution [EL]: This dataset contains the data and positions of the stations for the measurement of air pollution in Greece. In part of the records the geographical position is absent. Wind map of Greece [EL] The wind map comprises the wind potential of Greek territory (except for Crete and parts of the prefectures of Kavala and Ksanthi) on a 150 x 150 m grid. Wildfire in North Attica, Greece (2023-08-22) Wildfire in western Attica, Greece (2023-07-17) Wildfire in Attica, Greece (2023-07-17) Forest fire in Lavrio, Eastern Attica, Greece (2021-08-17) Wildfires in Greece (2021-08-04) Fire in Western Attica, Greece (2021-08-17) Forest Fires in Attika, Greece (2018-07-24)
Datasets related with Demography	04. Estimated Population by sex and five year age groups on 1st January for the years (2001 - 2021)
	09. Estimated Population by sex, on the 1st January and in the middle of the year (2001 - 2021)
	10. Estimated Population on the 1st January for the years, Hellas Total, Region, Departments (2002 - 2021)
	17. Estimated Population by Sex, Group of Citizenship and Age Group At 1st January (2009 - 2021)
	18. Estimated Population by sex, Group of Country of Birth and Age Group at 1st January (2009 - 2021)

3.2. Scenario 2 | DS-ATH-A: Earthquake in the Region of Attica

3.2.1. Seismological regime in Greece

Greece is located at a highly seismically active area. The reason for this is that the country lies directly above the convergence zone between the African and the Eurasian tectonic plates, with the former dipping beneath the latter. This tectonic movement is the main cause for the seismicity observed around the area of Greece, which is among the highest in Western Eurasia [18]. Figure 19 depicts the main tectonic movements around the Mediterranean, as well as major faults, some of which led to the occurrence of catastrophic seismic events.

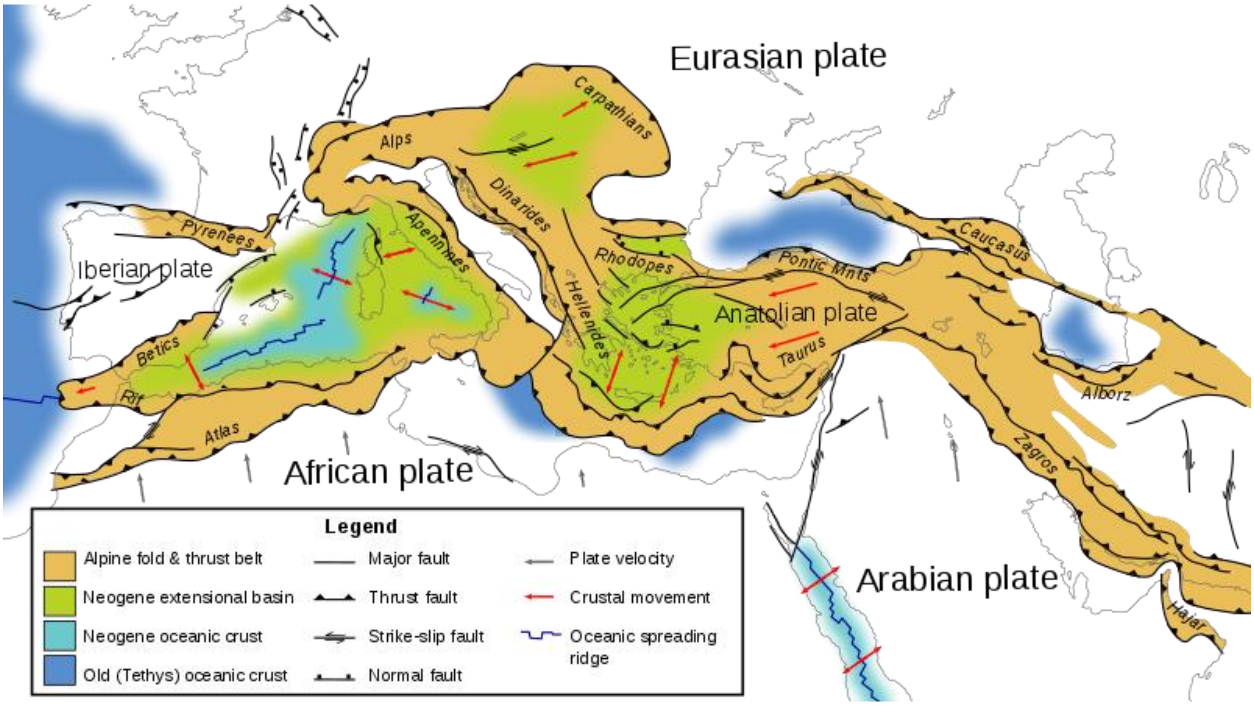

Figure 19 Tectonic movements and major faults around western Eurasia and north Africa[7]

It is apparent that the African and Arabian plates move northwardly, whereas the movement of the Eurasian plate is generally towards the south and southwest. At the same time, the Anatolian plate moves to the west. Greece is mainly affected by the major faults of the hellenic trench, a tectonic structure, which constitutes the subduction zone of the two major plates. In addition, strike slip faults to the west, beneath the Ionian Sea, and the Anatolian fault, the extension of which reaches the north Aegean Sea, are significant earthquake causing factors. Several minor neotectonic faults, located all around Greece, can also cause major earthquakes.

3.2.2. Civil Protection and Prevention against Earthquakes

Since 1900, when earthquakes have been systematically monitored with scientific instruments, several minor and major earthquakes have occurred in Greece. The permanent seismic hazard impelled the General Secretariat for Civil Protection to issue the "Egkelados" plan, which dictates a number of measures and actions to be taken for the prevention, preparedness, response and recovery from earthquakes as well as their appendant effects. In addition, the Earthquake Planning and Protection Organisation has issued the national anti-seismic code, which includes, inter alia, a seismic map of Greece, which divides the country in three zones, depending on the seismic acceleration criterion.

3.2.3. Seismicity in the Region of Attica

The Region of Attica is divided between the first and second zone of seismic acceleration, according to the zoning map of the E.P.P.O., with the central and southern part of the Region presenting relatively lower acceleration than the northern-northwestern. According to Triantafyllou et al., 2023, since 1900, four are the main catastrophic seismic events that have affected the Attica Region, occurring in 1938, 1953, 1981 and

[7] https://commons.wikimedia.org/wiki/File:Tectonic_map_Mediterranean_EN.svg

1999. These events caused several deaths, critical infrastructure disruption, damage to and collapse of buildings, as well as other natural phenomena, such as landslides and soil liquefaction.

3.2.4. Earthquake Occurrence in NW Attica

On a future t_0, at approximately 03:00 UTC an earthquake of M_w=6.3 R occurs. The National Observatory of Athens, which monitors real time seismicity, defines the epicentre at coordinates 38.08 N and 23.60 E and the focal depth at 9.5 km, something which means that the earthquake is relatively shallow. The Parnitha fault, which gave the devastating 1999 event, is again responsible for the current earthquake.

The 112-emergency call centre receives numerous calls reporting collapsed buildings. The National Coordination Centre for Crisis Management conveys the information to the Hellenic Fire Service, the resources of which are deployed to respond to hundreds of emergency calls. The occurrence of the earthquake very early in the morning significantly increases the probability of many victims and possible casualties beneath the ruins and debris. Collapses have been reported in various NW suburbs of the metropolitan area of Athens.

3.2.5. Cascading Effects

The simulated earthquake is strong and shallow. Therefore, a series of events are observed, which can be considered as cascading effects from the earthquake.

- Landslides: Landslides and rock falls are observed, mainly in the southern steeper slopes of the Parnitha mountain, leading to the blocking of the main road, which leads to the military base at the peak of the mountain.
- Soil liquefaction: Soil liquefaction is observed in the western parts of the Attica Region. The reason for this is that water saturated soils, prevailing under the aforementioned areas, lose their cohesion due to the shaking and behave as liquids.
- Ground deformation: Due to the magnitude and depth of the earthquake, ground deformations are observed, again in the western parts of the Region, which severely damage the railway and lead to building collapse.

3.2.6. Impact in Infrastructures

Both the earthquake and cascading phenomena have severely impacted several critical infrastructures, the most important of which are mentioned below:

- Transportation hubs: The Hellenic Train railway is severely damaged due to ground deformations, caused by the earthquake. The railway line close to the Aspropirgos town is broken leading to a standstill of trains going to western Attica and the Peloponnese.
- Energy failure: Deformations also affect gas pipelines. An explosion has been reported, the cause of which is suspected to be a fracture in the gas pipeline. The explosion is reported to occur at the DESFA station in the Municipality of Acharnai.
- Power supply network: Power shortages are observed in NW Athens, due to the collapse of a high voltage pillar. The disruption occurred at the power station of the Acharnai Municipality.
- Telecommunications: The telecommunications and internet network are overloaded and fail.

The map in Figure 20 depicts the epicentre of the earthquake, the earthquake-causing fault, as well as affected CIs.

Figure 20 Areas of interest for the earthquake scenario.

3.2.7. STAKEHOLDERS' ROLES

The General Secretariat for Civil Protection: As soon as the 112-emergency call centre receives reports for emergency assistance, the G.S.C.P. disseminates all information to relevant stakeholders and first responders for the management of the consequences of the earthquake.

The Hellenic Fire Service is the main actor in the management of the effects of earthquakes. More specifically, the Specialised Units for Disaster Management of the Fire Service arrive and initiate rescue operations.

The National Centre of Emergency Assistance with its Specialised Department of Disaster Medicine arrives to assist in triage and medical evacuation procedures.

The Hellenic Police is also activated and regulates traffic to facilitate the arrival of first responders' vehicles and prevent citizens from approaching dangerous buildings.

Volunteer organisations arrive and participate in rescue operations upon request from the G.S.C.P.

3.2.8. ACTOR DEFINITION

The Hellenic Police is directly involved as a stakeholder in the management of an earthquake, tasked mainly with several public order and public safety duties and responsibilities.

Per the current legislation, upon the occurrence of an earthquake, the Hellenic Police (H.POL.) based on the current institutional framework (N N.4249/2014, 5301/4/16-ρνʹ/28-8-2013 and 5301/4/14ρνʹ/25 -11-2014 documents of the Hellenic Police Headquarters) is mainly responsible for:

- Gathering information on the prevailing situation and the affected area regarding the effects caused by the earthquake event and informing the agencies involved.
- Implementing traffic measures in the affected area (traffic diversion, traffic stoppage, temporary signage, etc.)
- Implementing public order and security measures in the affected area
- Contributing to the implementation of the decision for organized preventive evacuation of citizens due to earthquakes or induced catastrophic phenomena, when it is taken in accordance with the provisions of articles 27 and 29 par. 4f of Law 4662/2020
- Guarding and safeguarding the property destroyed by earthquakes, until it is handed over to the owners.

Given that the earthquake scenario will be used as input for the simulation of real-life events, therefore it would be important that the SCDT system provides the Hellenic Police and its personnel in the command post with a number of important and necessary information, so that they can effectively prepare against an actual earthquake incident. The type of data that should be included are as follows:

- Road Network Status: Information on road closures and traffic conditions.
- Evacuation Routes: Identification of safe and efficient evacuation routes.
- Population Data: Information on population distribution to plan evacuation and security measures.
- Critical Infrastructure Data: Locations of critical infrastructure that need to be secured and potential interlinkages and interdependencies between them.
- Real-time data regarding the number and location of available operational resources.

- The aforementioned information would be of great significance for firefighters as it will enhance situational awareness and facilitate a timely and targeted response, leading to a quick suppression and avoidance of cascading effects.

3.2.9. Usage Scenario Description

To initiate the simulation, an officer logs into the PANTHEON system and inputs their organization's assets, which could include personnel details, vehicles, equipment, and other resources at their disposal. Then, they select ranges of values to input into the simulation. These values represent key variables that influence earthquake impacts, such as the depth of focus and magnitude of the earthquake. The simulation then runs, considering these variables to model the earthquake's progression and potential impact. Upon completion, the system provides decision support, offering strategic recommendations on how their organization should deploy its resources to minimize the disaster's impact and in line with the duties and responsibilities assigned to Police in the case of an earthquake (see above). These recommendations consider various factors, including the earthquake's predicted impact area, the locations of critical infrastructures, and the availability of resources. In terms of users, the Hellenic Police Officer acts as the only identified user of the system with full privileges.

3.2.10. PANTHEON Technologies Usage

3.2.10.1. SCDT

In addressing the seismic scenario using simulations within the PANTHEON system, we can draw parallels to the approach taken for wildfires, tailoring it to the unique characteristics of earthquakes. Based on the earthquake scenario described simulations within the PANTHEON system can play a pivotal role in disaster management. The Neo4J graph database will once again serve as the foundational technology for modelling the complex interdependencies within the urban area affected by the earthquake and ensure a robust simulation of a complex earthquake scenario, providing decision support for stakeholders involved in disaster response and recovery. The focus will be on addressing cascading effects and their potential impact independently.

Just as in the wildfire scenario, the town of Fyli serves as the starting point for the simulation, represented as the initiating node in the Neo4J graph database. Starting with the initiation node at the epicentre, represented in Neo4J as the point of origin, the simulation considers the cascading effects described in the scenario. Landslides, soil liquefaction, and ground deformations are modelled dynamically within the graph database, capturing the spatial relationships and potential impact on critical infrastructures.

Simulations can model the impact of landslides on transportation hubs, specifically the main road leading to the military base at the Parnitha mountain peak. Utilizing Neo4J's graph database, the simulation can represent spatial relationships between the epicentre, affected slopes, and transportation infrastructure. Impact assessment algorithms can predict the extent of road blockages, enabling the Hellenic Fire Service to strategically deploy resources for road clearance and rescue operations, while centrality metrics will assist in identifying key routes for prioritized intervention.

The western parts of the Attica Region will be simulated to experience soil liquefaction and deformations. Concerning soil liquefaction, Neo4J's graph database will dynamically model the affected areas, and impact assessment algorithms will predict the consequences on the water supply network and nearby buildings. Centrality metrics will then guide the allocation of resources to address the most vulnerable points, ensuring efficient recovery. Ground deformations in the western parts of the region can assist in understanding the impact on the Hellenic Train railway and gas pipelines. Neo4J's will again represent the spatial relationships between the earthquake epicentre, affected areas, and critical infrastructures and predict the severity of damage, guiding the Hellenic Fire Service in prioritizing response efforts.

Energy failures because of the seismic activity can be modelled as deformations affecting gas pipelines, following an initial node propagation from a reported explosion at the DESFA station in the Municipality of Acharnai. Neo4J's graph database will represent the spatial relationships, whereas impact assessment algorithms will predict the consequences regarding nearby delivery of natural gas to households, and centrality metrics will guide resource allocation for containment and recovery.

The simulation can also model the effects on the water and power supply networks, predicting shortages in NW suburbs of Athens and the Regional Unit of Western Attica. Neo4J's graph database dynamically represents spatial relationships, while impact assessment algorithms will quantify the extent of disruptions, and centrality metrics guide resource allocation for restoration. Similarly, the overload and failure of the telecommunications and internet network will be incorporated as a partial map of telecoms over the urban area, with Neo4J's graph database partially representing aspects of the network architecture around the given suburb.

In this seismic scenario, the type of data required for simulations is diverse, ranging from seismic data, building structures, transportation networks, and critical infrastructure layouts to geological information, soil properties, and population density. Drone and satellite data can play a central role in gathering crucial in situ information for simulating the real-time feedback loop of the PANTHEON cascading analysis component. Drones can be deployed for rapid assessment of building damages, identifying collapsed structures, and assessing the extent of landslides that will be used **as added data to update the graph model, as if it was real-time retraining**. Satellite data can aid in simulating the monitoring for large-scale ground deformations, identifying areas prone to soil liquefaction, and assessing the impact on transportation and energy infrastructures.

Just as in the wildfire scenario simulation, the Hellenic Police can utilize PANTHEON to input details about their assets and devise operational response plans. Neo4J's graph database represents spatial relationships between affected transportation hubs, collapsed buildings, and emergency routes. Impact assessment algorithms predict the consequences of landslides, soil liquefaction, and ground deformations, guiding the Police in formulating efficient evacuation plans. Centrality metrics identify critical nodes, ensuring a targeted deployment of resources to maintain public safety.

The Hellenic Fire Service, a key stakeholder, can input details about their assets and response capabilities into PANTHEON. Leveraging Neo4J's graph database capabilities, the simulation dynamically represents the seismic impact on transportation hubs, energy infrastructure, water supply, power supply, and telecommunications. Impact assessment algorithms within the simulation predict the severity of damage to critical infrastructures, guiding the Fire Service in prioritizing their response efforts. Centrality metrics within the graph database identify key nodes representing critical areas, ensuring an efficient deployment of resources to mitigate the impact of the earthquake and its cascading effects.

Hellenic Railways, energy operators, water supply authorities, power supply entities, and telecommunication companies can be inputted as assets and dependencies into the simulation. The Neo4J graph database will dynamically models the interactions and dependencies, allowing stakeholders to visualize and analyse the complex network of infrastructures affected by the earthquake. The execution of these scenarios can predict the impact on the Hellenic Train railway, identifying the broken railway lines and assessing the standstill of trains. Neo4J's graph database represents the spatial relationships between affected areas and transportation hubs, guiding the Hellenic Fire Service in resource allocation.

3.2.10.2. Satellites

Pre-Event Preparedness: Satellite data, especially Sentinel-1 SAR imagery processed using interferometric SAR (In SAR) techniques, can contribute to pre-event preparedness for earthquakes in Attica. By monitoring surface deformation and fault movements over time, authorities can identify areas prone to seismic activity and implement measures to strengthen infrastructure and improve disaster response plans. Sentinel-2 optical data complement SAR data by providing information on earthquake-induced changes in land cover and infrastructure.

Post-Event Damage Assessment: After an earthquake, satellite data can assist in rapid damage assessment and response efforts. SAR imagery can detect ground displacements and surface ruptures, helping prioritize search and rescue operations. Additionally, optical imagery can be used to assess damage to buildings, infrastructure, and critical facilities, aiding in recovery and reconstruction efforts.

The software technologies for processing and analysing Sentinel data for disaster assessment is already reported in chapter 3.1.8.3. As previously stated, a decision is still outstanding regarding what technology best suits the PANTHEON project.

3.2.10.3. UAVs

In the case of managing a major earthquake crisis over large areas involving a large population, considering drone systems and their added value bears many similarities to the previous scenario, which dealt with a large area affected by large-scale wildfires. Once again, one of the challenges faced by planners revolves around the ability of rescue teams to quickly understand the situation and adjust their decisions and actions based on a better awareness of the actual situation.

To characterize the situation, one of the study cases could be summarized as follow:

- Problem: large-scale earthquake means that various and numerous infrastructures could be destroyed, potentially impacting rescue team mobility, and thus their efficiency. It is therefore critical to quickly understand the status of roads, bridges, or other constructions to be able to choose backup plans.
- Drone added value: observation drones could be deployed during the first hours to reconstitute the map of the area and identify the damaged areas and assess the number of refugees to be helped.

The parallels with the previous scenario mainly concern the functionalities offered by the PANTHEON platform, which once again encompass the need to simulate and visualize the crisis situation and its impacts and integrate into this simulation the benefits that can be brought by deploying drone systems. In practical terms, it will involve deploying a multitude of drones over the disaster area and gathering and processing data and information to make them understandable for operators. The challenges are immense, primarily due to the large distances that will need to be covered, and these aspects will need to be addressed by the PANTHEON platform. For example, the dispatching and positioning of control stations should be an output of the simulators, and the conclusions drawn from the PANTHEON platform can be used to plan and organize their deployment in the early hours of the crisis.

The issue of airspace segregation will always be a major concern of crisis management planners, primarily because the crisis caused by a major earthquake will inevitably feature an intense deployment of medical rescue helicopters and possibly the airlifting of essential goods by aircraft. These types of missions, given their nature, cannot be postponed, and compromises will need to be found to authorize the operations of all aerial vehicles. Both temporal and spatial segregation will likely need to be implemented, but this will be the result of simulations from the PANTHEON platform, which should allow for defining the most effective scenario.

Once again, the PANTHEON platform will need to aid in defining and sizing drone systems. Indeed, the goal is to optimize the size of the deployed system in relation to the objectives pursued, and the constraints could be numerous and similar to those identified in the previous scenario. The challenge will be to identify the best solutions in accordance with these requirements, notably because it will once again involve the deployment of observation drones, but with a focus on mapping rather than surveillance. The main challenges will essentially be the vast distances and areas to be covered by the aerial vehicles, and the collection and processing of data that could quickly saturate telecommunication and data processing systems.

Figure 21 illustrates a study case where a large area has been struck by a major earthquake, resulting in the destruction of vast amounts of infrastructure, which could impact the deployment of rescue teams needing to reach a specific point in the area. Drone deployment is considered to cover the area and identify the position and extent of the earthquakes effect, with the data subsequently collected and processed to reconstruct the map of the disaster-stricken region. Since drone operations coincide with those of other aerial users, spatial and temporal segregation would be established to allow for scanning of successive parts of the area. In this specific case, the vast observation distances and the large area to cover will likely lead the operator to deploy multiple drones equipped with RGB payloads capable of producing georeferenced orthophotos. It is worth noting that onboard intelligence could be advantageously implemented to enable drones to detect damaged areas and temporarily divert them to provide more accurate details on specific areas of interest. Due to the type of operation envisaged (coverage of very large areas), fixed-wing drones will likely be the most suitable, but confirming or refuting this type of conclusion precisely relies on the expected output resulting from the use of the PANTHEON platform.

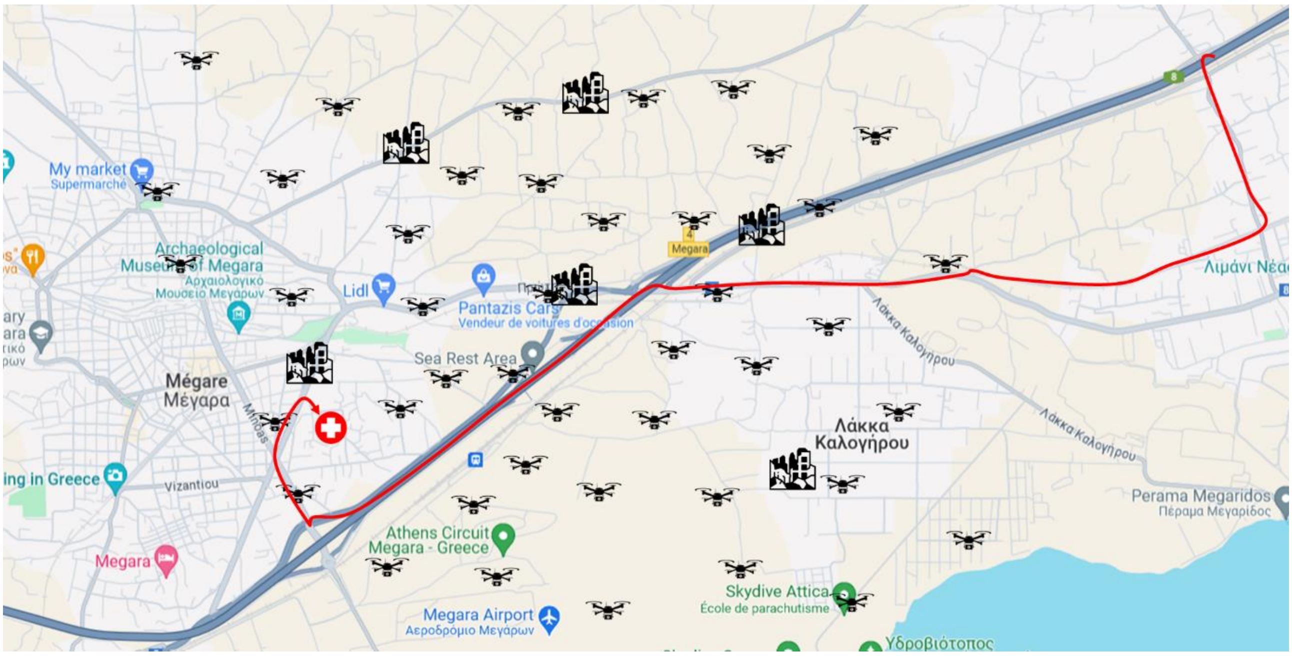

Figure 21 Illustration of a case study focused on earthquakes in large areas and requiring the remapping of transportation infrastructures.

Regarding the processes implemented within the PANTHEON platform and the architecture required to reproduce them, the concepts will be identical to those presented previously.

The steps described above are both generic and exhaustive. For the PANTHEON project, they are circumscribed as follows:

1) Prior to the disaster (planning)
   a) The available equipment will be simulated first – no hard limit on the number and type of drones and equipment. we shall at least retain two drones, one rotary wing and one fixed wing drone, both equipped with RGB cameras.
   b) Feed this data in the SCDT, along with user inputs, and restricted airspaces, for the swarm controller to come up with an optimised swarm.
2) During the disaster (training and exercise simulations)
   a) Fly the swarm within the authorised zones (safety buffers included); always stay in contact with simulated other airspace users and Air Traffic Control.
   b) The aim is to reconstruct a map of the area showing and locating the damaged infrastructure (road, bridges, buildings, etc.) and people in need of assistance (this objective will be confirmed with the requirements of real first responders' teams)

3.2.10.4. Data Sources Requirement & Availability

For the specific scenario of a strong earthquake in the Region of Attica near Athens, the required data sources to effectively model and plan for the response (conceptualised in Figure 22) include:

Seismic Data and Geological Surveys: Accessing seismic data and geological surveys of the Region of Attica and the Parnitha mountain area is essential for understanding the fault lines, seismic activity history, and the potential impact of a strong earthquake with specific coordinates and magnitude. This data is typically provided by geological and seismological institutions.

Infrastructure Mapping and Vulnerability Assessments: Detailed information about critical infrastructure in the affected area, including natural gas stations, pipelines, railways, telecommunications networks, and power supply facilities, is crucial. This data can include infrastructure maps, vulnerability assessments, and risk analysis reports.

Historical Earthquake Data: Studying past seismic events in the region, including their impacts on infrastructure, population, and emergency response, can provide vital insights. Understanding the patterns of cascading effects following earthquakes will help in accurately simulating and planning for this scenario.

Real-Time Seismic Monitoring and Early Warning Systems: Utilizing data from real-time seismic monitoring stations and early warning systems can provide immediate information about the earthquake's parameters, such as magnitude, epicentre location, and potential aftershocks. This data can aid in rapid response coordination.

Emergency Response Protocols and Stakeholder Responsibilities: Gathering data on the standard operating procedures, coordination protocols, and emergency response responsibilities of relevant stakeholders, such as the Hellenic Fire Service, Hellenic Police, National Centre for Emergency Assistance, and other organizations involved in disaster response and management.

Population Density and Vulnerable Groups Data: Information about population density, demographics, and locations of vulnerable groups in the affected area is essential for assessing the potential impact on communities and planning for effective search, rescue, and medical evacuation operations.

Soil Composition and Stability: Accessing soil properties data, including composition and stability characteristics, can help in assessing the susceptibility of different areas to ground deformations, soil liquefaction, and landslides following the earthquake. This data can be obtained from geological surveys and soil analysis reports.

Geological Information: Geological Maps and Surveys: Accessing geological maps and surveys of the Region of Attica and the Parnitha mountain area can provide insights into the underlying geological formations and fault lines. Understanding the specific geological structures and fault characteristics can aid in predicting the areas most vulnerable to seismic impact.

For both the wildfire and earthquake scenarios in the Region of Attica near Athens, the combination of various data sources and technologies will be performed effectively in each use case.

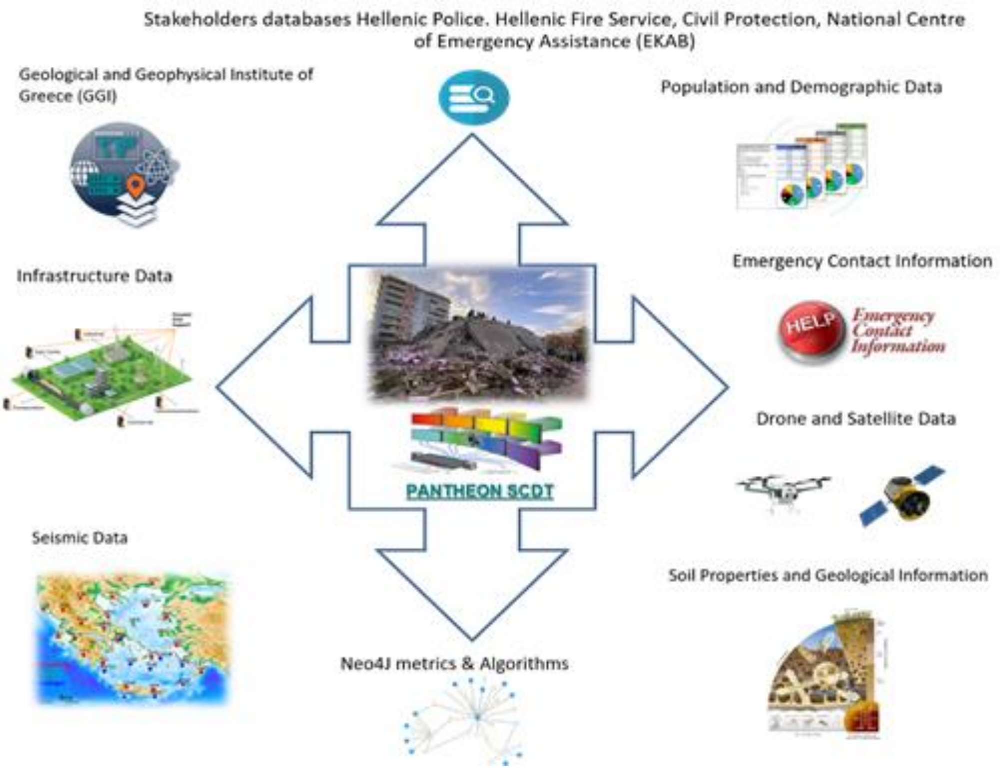

Figure 22 Data Sources in DS-ATH-A scenario.

1. **Geospatial Data & Seismic Data**

Sources	Purpose	Actual Sources
GIS (Geographic Information System) databases,	Provide detailed geographic information about the observed area Provides real-time seismic data for monitoring and studying	https://effis.jrc.ec.europa.eu/ https://gwis.jrc.ec.europa.eu/apps/gwis_current_situation/index.html **National Cadastre & Mapping Agency:** The Hellenic Cadastre provides detailed geospatial data, including cadastral maps, topographic information, and urban planning data for Athens city. https://geodata.gov.gr/en/organization/about/ekxa **Hellenic Statistical Authority (ELSTAT):** ELSTAT offers demographic and economic geospatial data, including population density, land use, and spatial distribution of various socio-economic indicators.

	earthquakes in Greece, including the Attica Region.	**OpenStreetMap**: This collaborative mapping project offers open-access geospatial data, including road networks, pedestrian pathways, and points of interest within Athens city. **Hellenic Ministry of Environment & Energy:** The ministry provides geospatial data related to environmental factors, natural resources, and geological features in Athens and its surrounding areas. https://www.gov.gr/en/upourgeia/upourgeio-periballontos-kai-energeias
satellite imagery,		Satellite imagery can be accessed through various platforms and databases, including NASA's Earth Observing System Data and Information System (EOSDIS), the European Space Agency's (ESA) Copernicus Open Access Hub, and commercial satellite imagery providers such as Maxar Technologies' DigitalGlobe and Planet Labs. These platforms offer access to satellite imagery archives, as well as real-time and near-real-time satellite data. **NASA Earth Observing System Data and Information System (EOSDIS)** - https://earthdata.nasa.gov/ **European Space Agency (ESA) Copernicus Open Access Hub** - https://scihub.copernicus.eu/ **Commercial satellite imagery providers like Maxar Technologies**' DigitalGlobe - https://www.maxar.com/
Seismic Data sources		**NOA operates the "Seismological Network of the National Observatory of Athens,"** which includes seismic data archives, earthquake catalogues, and real-time monitoring information. The data can be accessed through the NOA's official website: http://bbnet.gein.noa.gr/ **Institute of Geodynamics, National Observatory of Athens:** The institute collects and disseminates seismic data, earthquake reports, and geodetic measurements related to seismic activity in Athens and the broader region. https://bbnet.gein.noa.gr/HL/ **Hellenic Unified Seismological Network:** This network, operated by the Institute of Geodynamics, provides real-time seismic data, earthquake alerts, and seismic hazard assessments for Athens city and the surrounding regions. http://www.geophysics.geol.uoa.gr/ **European-Mediterranean Seismological Centre (EMSC):** The EMSC offers seismic monitoring data and earthquake reports, providing comprehensive information on seismic events within the European-Mediterranean region, including Athens. https://emsc-csem.org/Special_reports/ **Geological Society of Greece**: The society offers access to seismic hazard maps, geological surveys, and research publications related to seismic risk assessment and earthquake impact studies in Athens and Greece. https://gsg2022.gr/
Soil Properties and Geological Information	geological characteristics, soil composition, and potential	**Ministry of Environment and Energy, Greece:** The Ministry of Environment and Energy may provide access to geological survey reports, soil classification data, and environmental impact assessments related to Athens and its surrounding areas.

	geohazards in the region, which is essential for urban planning, construction, infrastructure development, and environmental management in the city of Athens.	**Hellenic Institute of Geology and Mineral Exploration (IGME):** IGME conducts geological surveys, research, and exploration activities in Greece. They may offer geological maps, soil studies, and reports on the geological characteristics of the Athens region. http://www.cgseurope.net/PartnerData.aspx?IdPartner=39 **National Observatory of Athens**: The National Observatory of Athens may provide resources on geological and environmental research relevant to the city of Athens. This institution often conducts studies on seismic activity, soil properties, and natural hazards. **Geological Society of Greece:** This society is dedicated to the study of geology in Greece and may offer access to geological publications, research papers, and geological survey data pertaining to the Athens region. **Universities and Research Institutes:** Academic institutions and research organizations, such as universities in Athens and geological research institutes, may conduct studies and provide access to scholarly publications related to soil properties, geological formations, and environmental geology in Athens.

2. Infrastructure Data

Sources	Purpose	Actual Sources
Local & Municipal databases,	Capture information about road networks, natural gas pipelines, water distribution networks, telecom infrastructure, electricity grids, and other critical infrastructures.	**Athens Municipality Website:** The official website of the Athens Municipality may provide general information about road networks, water distribution networks, and other municipal infrastructure projects. https://www.cityofathens.gr/ **Hellenic Electricity Distribution Network Operator (HEDNO):** HEDNO manages the electricity distribution grid in Greece, including Athens. Their website may offer information about electricity grids, power outages, and maintenance schedules. https://deddie.gr/en/ **Hellenic Gas Transmission System Operator (DESFA): DESFA** operates the natural gas transmission network in Greece. While detailed information may not be publicly available, their website may provide general information about the natural gas pipeline infrastructure. https://www.desfa.gr/en/ **Hellenic Telecommunications Organization (OTE):** OTE is the primary provider of telecommunications services in Greece. Their website may offer information about telecom infrastructure, coverage maps, and services available in Athens. https://www.cosmote.gr/cs/otegroup/en/ote_ae.html **Ministry of Infrastructure and Transport:** https://www.gov.gr/en/upourgeia/upourgeio-upodomon-kai-metaphoron **Local Water Utility Companies:** Water utility companies operating in Athens may offer information about water distribution networks, treatment plants, and water quality. **Google Maps and OpenStreetMap:** Mapping services like Google Maps and OpenStreetMap provide detailed maps of road networks, landmarks, and infrastructure in Athens. While they may not provide specific information about critical infrastructure, they can offer a general overview of the area.

3. **Stakeholder databases**

Sources	Purpose	Actual Sources
Hellenic Police. Hellenic Fire Service, Civil Protection, National Centre of Emergency Assistance (EKAB)	Provides emergency medical services, including disaster medicine, triage procedures, and medical evacuation operations during emergencies and disasters. EKAB may maintain internal databases for managing medical resources, response protocols, and patient information. Traffic regulations, road closures, and real-time traffic updates may be available through the Hellenic Police official website, government portals, or dedicated traffic management systems. Access to real-time traffic data may also be provided through mobile applications or third-party services.	**Hellenic Police Website:** The official website of the Hellenic Police may provide updates and announcements regarding emergency measures, including evacuation plans, critical areas, and curfew measures. **Greek Government Websites**: Government websites, such as the Ministry of Citizen Protection or the Ministry of Digital Governance, may release information regarding emergency management, including data on evacuation plans and road closures. **Civil Protection Websites:** Civil protection agencies may offer information about emergency plans, including evacuation procedures and road closures, to ensure public safety during crises. **Emergency Management Authorities:** Local emergency management authorities, such as regional or municipal governments, may provide updates on evacuation plans, critical areas, curfew measures, road closures, and traffic management specific to their jurisdictions

4. **Population and Demographic Data**

Sources	Purpose	Actual Sources
Census data, demographic surveys.	Provide information about the population in the affected areas, including demographics, population density, and vulnerable populations.	**Hellenic Statistical Authority (ELSTAT)**: ELSTAT is the official statistical authority in Greece, responsible for conducting census surveys and collecting demographic data. **Census Data:** Census data collected by ELSTAT provides detailed information about the population in Athens, including demographics such as age, gender, ethnicity, education level, and household composition. **Eurostat:** Eurostat, the statistical office of the European Union, provides demographic data and indicators for member countries, including Greece and Athens. **Athens Municipality:** The Athens Municipality may offer demographic data specific to the city, including population density, socioeconomic indicators, and information about vulnerable populations. **Academic Research Institutes**: Universities and research institutes in Greece may conduct demographic surveys and studies focusing on Athens and its population. Accessing academic publications and

	research reports can provide valuable insights into demographic trends and characteristics. **Non-Governmental Organizations (NGOs) and International Organizations:** NGOs and international organizations operating in Greece may collect demographic data as part of their humanitarian and social assistance programs. Reports and publications from these organizations may contain demographic information relevant to vulnerable populations in Athens. **Public Health Authorities:** Public health authorities and healthcare organizations may maintain demographic data related to healthcare access, disease prevalence, and health disparities among different population groups in Athens

5. Emergency Contact Information

Sources	Purpose	Actual source
Emergency contact databases, local government records.	Ensure that communication channels are available, and emergency contact information for residents, businesses, and critical services is up to date.	**https://civilprotection.gov.gr/112**

6. Open Data Sets for Disaster Analysis

PANTHEON will utilise all the knowledge from appropriate websites that provide datasets for data analysis related to various types of disasters:

NOAA National Centers for Environmental Information (NCEI): Website: https://www.ncei.noaa.gov/

NCEI provides access to environmental and climate data sets, which can be valuable for analysing natural disasters such as severe weather events, hurricanes, and climatological data.

EM-DAT: The International Disaster Database: Website: https://www.emdat.be/

EM-DAT is a global database providing essential data on the occurrence and effects of over 22,000 natural and technological disasters from 1900 to the present.

USGS Earthquake Hazards Program: Website: https://earthquake.usgs.gov/

The USGS provides access to earthquake data sets, seismic event information, and geospatial data related to seismic hazards and monitoring.

3.3. SCENARIO 3 | DS-VIE-A: HEATWAVE IN VIENNA

3.3.1. WEATHER CONDITIONS

Between 2000 and 2017 Vienna experienced the warmest summers in the entire measurement history of over 250 years. The Austrian central meteorological institute ZAMG (Zentralanstalt für Meteorologie und Geodynamik, recently renamed GeoSphere Austria) analysed the Kysely days for all provincial capitals in a historical comparison, i.e. the very hot days that occurred in succession during heatwaves. The results show some regional differences, but also a clear trend, according to climatologist Robert Klonner: "Heatwaves with a series of maximum temperatures around and above 30 °C have become much more frequent in Austria in recent decades. This can be clearly seen in the evaluation of weather stations with data series spanning over more than 100 years. Almost every year since the 1990s heatwaves increased."

Because of these increases the ZAMG started issuing nationwide warnings of extreme weather events for multiple warning parameters including heat stress. As can be seen in Figure 23, the intensity of a predicted event, and thus also the extent of the expected impact, is characterized by warning colours.

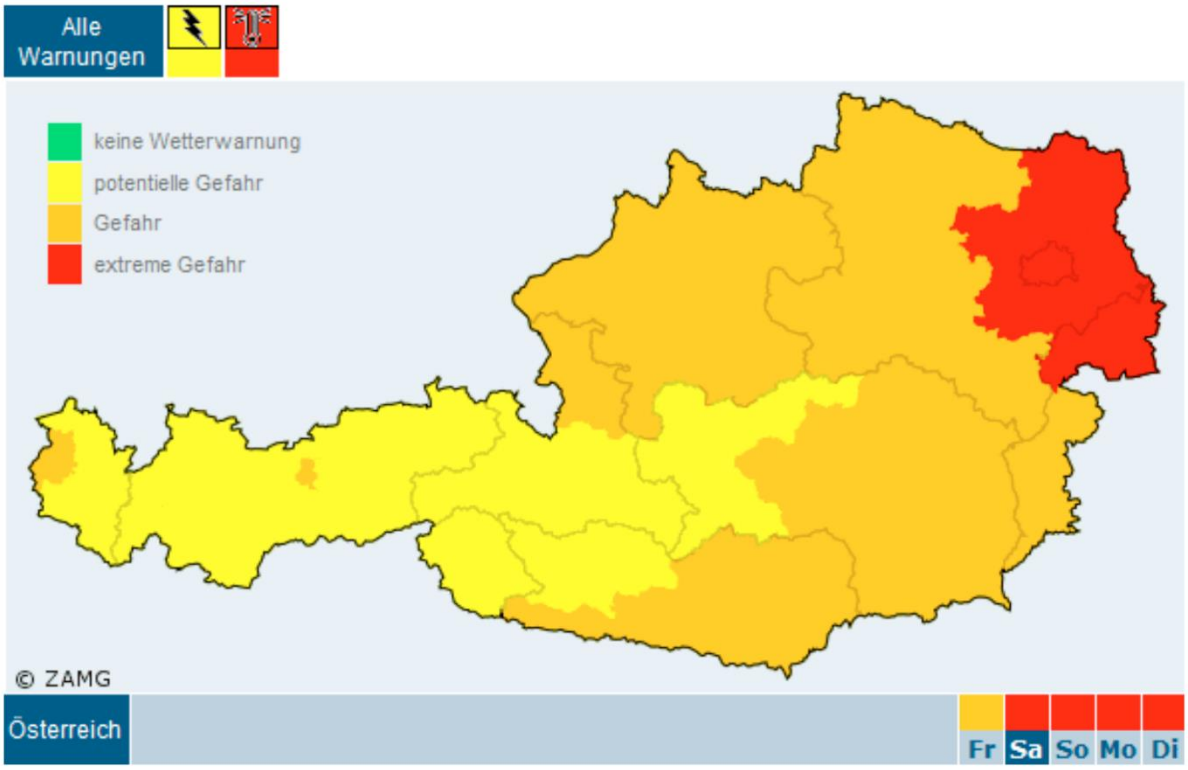

Figure 23 An example of a heatwave forecast in Austria [29].

Vienna had the record most hot days in the summer of 2015 with a total of 42 hot days and 78 summer days. Second place in the ranking goes to the summer of 2003 with 40 hot days and 102 summer days. The last summer without a single hot day was in 1975. Climate researchers therefore assume that the number of summer and hot days will increase in the coming decades. This is also shown by data from the Central Institute for meteorology. In the period from 1981 to 2010, there were 65 summer days per year in Vienna. In addition, the data projection for the period of 2071 to 2100 shows an increased 85 to 100 summer days per year.

The effects of heat waves are compounded by rapid urbanization, Vienna's population growth, and urban heat island effects.

3.3.2. Effects of heatwaves on the population and medical infrastructure

Heatwaves increase morbidity and mortality of the general population [30]. Though many of the temperature increase's effects are indirect, they still represent an added burden on health care services at all levels. This impact on the infrastructure is aggravated as heatwaves tend to present in the form of surges in demand and the effects of the first heatwave of the year will usually be stronger than those of further midsummer weather conditions so preparation is necessary before the first effects have been observed.

The specific effect relevant to the pilot in Vienna we will focus on is the increase in ambulance callouts in combination with changes in hospital occupancy.

Large overlaps between typical patient descriptions and groups particularly vulnerable to the added physiological strain caused by sustained high temperatures are very much in line with the vulnerable groups assessment described in prior deliverables and include:

- Elderly and chronically ill persons, including but not limited to patients suffering from cardiovascular disease or diabetes mellitus (this group alone represents more than 10% of the population)
- Patients taking certain medications, including but not limited to medications affecting the body's fluid balance, perfusion, temperature regulation/perception.
- Socio-economically weaker groups
- Infants and young children
- Pregnant women

3.3.3. Cascading effects

The super additive effect of events taking place in a surge-like fashion and at a scale that was unseen in years before causes a resource drain that needs long lead times for planning.

Operations centres will need good training and predictive tools to be able to handle situations that may exceed regular operational capabilities and reserves. In the coming years heatwaves will force first responder organisations to switch to the very unusual combination of using a triage system very quickly but for an extended period of time.

This uncommon problem constellation is usually not part of the basic preparedness concepts and the prioritisation of patient groups during this kind of event is not well trained for in general.

3.3.4. Stakeholder's roles

Preparing for heatwaves means that operators centres, equipment and planning regarding human resources need to be in place before heatwaves occur.

1.) Operations centre: Plans for prioritisation of patients belonging to vulnerable groups after prolonged waiting times, as well as decreased priority for transports of low urgency transports according to vulnerability assessment over a prolonged time needs to be developed. Decision support systems need to be evaluated.
2.) Equipment: Cost and potential dual use of additional equipment for a surge in demand including vehicles need to be assessed.

3.) Human resources: Main holiday seasons and heatwaves in Vienna overlap and so the deployment of volunteers as resources and the vacation block of full-time employees need to be communicated in time.

The PANTHEON system's predictive capabilities as a training tool and aid in resource management will be the main showcase of this pilot scenario. Employees of the operations centres, people responsible for fleet management and human resource planning will have to work together to react to different heatwave scenarios. The PANTHEON system needs to be able to present resource usage during heatwaves and needs to be able to consider adjustments of variables including temperature and length of heatwaves. An emphasis will be placed on simulating the breaching point of regular operational capabilities and switching to a triage system and the transition to a disaster scenario including the establishment of a crisis staff. The players in this scenario will be planning and reacting to these simulations. Specialists from first responder operations centres responsible for shutting down non-essential operations and activating emergency contingents and plans will ideally be creating a feedback loop (shown in Figure 24) to see how their plans for the next heatwave panned out thus enabling an ideal repetitive training tool.

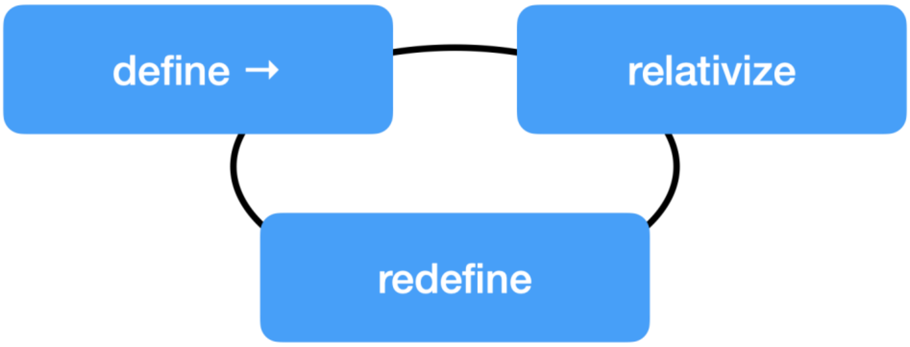

Figure 24 The feedback loop of the heatwave scenario.

3.3.5. Actor Definition

As this is first and foremost a planning & resource management scenario the main actors will be dispatchers working at the command centre, shift planners, managers of the vehicle fleet and their respective superiors. Within the scenario's simulation capabilities, the consequences of a prolonged resource sap and possible counter measures, as well as their cost-benefit ratios need to be evaluated regarding their human and monetary requirements. All parties within the organisation responsible for managing those resources need to be involved.

The early warning aspect of this scenario will include members of the disaster relief team who will need to provide input regarding the switch from regular operation towards a triage system once personnel resources start running out and a reprioritisation needs to be implemented.

3.3.6. Usage Scenario Description

For the planning scenario with a heatwave, participants will need to be able to interact with an interface that realistically allows them to simulate resource usage and drain during extended heatwaves. Members will mainly be:

- shift coordinators.
- human resources.
- volunteer coordinators.

- command centre employees.

Participants will need to be able to adjust extent and length of the heatwave to simulate the additional patient transport, hospital capacity and employee needs during such an event and see breaking points and possible mitigation measures. In terms of users, the members act as the only identified user of the system with full privileges.

3.3.7. PANTHEON Technologies Usage

3.3.7.1. SCDT

For the purposes of heatwave impact assessment, PANTHEON will integrate Google Solar API data into its system to detect the potential vulnerability of the population to heatwaves based on building exposure to solar radiation. Leveraging this API, which provides information on solar potential for individual buildings, we can assess the degree of building exposure to sunlight and thus the potential risk of heat-related issues for occupants. By incorporating this data into the simulation, we enhance our understanding of the spatial distribution of vulnerability within the urban area affected by the heatwave. By integrating Google Solar API data into the simulation, we gain valuable insights into the spatial distribution of vulnerability within the urban area affected by the heatwave. This information enhances our ability to identify high-risk areas and prioritize resource allocation for effective mitigation strategies. Additionally, it allows for a more nuanced understanding of the interdependencies between building exposure to solar radiation and the resilience of critical infrastructure, facilitating targeted interventions to protect vulnerable populations during heatwave events.

In this heatwave scenario, the type of data required for simulations is diverse, ranging from temperature data and infrastructure layouts to population density and vulnerability assessments. Satellite data can play a role in gathering information for potential choke points in the transportation infrastructure of these areas, while drone data can be utilized for assessment of road blockages due to high traffic or engineering daywork. Beginning with the initiation node at the epicentre of the heatwave, represented in Neo4J as the point of origin, the simulation will factor in building exposure to solar radiation as a key determinant of vulnerability. Buildings with high solar potential, indicating greater exposure to sunlight, are flagged as potential hotspots for heat-related risks such as overheating and discomfort. Alongside exposure to heat, the technical component can model the use of population allocation per m^2 to determine the amount of heatwave impact to specific areas. This data will allow stakeholders to prioritize areas with higher vulnerability/high impact for targeted interventions and resource allocation.

Furthermore, the simulation can analyse the impact of heatwaves on transportation, especially for reaching or evacuating locations of high vulnerability and high impact. Utilizing Neo4J's graph database, the simulation can represent spatial relationships between affected areas and transportation infrastructure. Impact assessment algorithms can predict the extent of potential population affected, enabling stakeholders to strategically deploy resources for evacuation or rapid deployment to locations.

Stakeholders can input details about their assets and response capabilities into PANTHEON. The Neo4J graph database will dynamically model the interactions and dependencies, allowing stakeholders to visualize and analyse the complex network of infrastructures affected by the heatwave. This will enable stakeholders to make informed decisions and allocate resources effectively to mitigate the impact of heatwaves on critical infrastructure and communities, especially in cases of mass evacuation or the need to reach specific areas quickly. Similarly to the earthquake scenario simulation, first responders can utilize PANTHEON to input details about their assets and devise operational response plans. Neo4J's graph database will provide information on emergency routes and assessment of areas with high vulnerability due to the exposed population. Impact assessment algorithms will predict the consequences per % of population affected guiding first responders in formulating efficient routing or evacuation plans.

3.3.7.2. In-Situ IoT sensors

Similarly to the wildfire scenario, in-situ environmental and local weather monitoring can provide critical data for the predictions/forecasting of upcoming crucial - weather caused - events and their possible effects. The weather stations, equipped with IoT-enabled temperature sensors (among others), can detect sudden or gradual rises in the ambient temperature; therefore, provide a warning about eminent heatwaves in the wider area of interest. It must be noted that other environmental parameters (such as air humidity and wind vector) can also be important in predicting heatwaves and subsequently, derive decisions about their outcomes. The corresponding IoT data is gathered in the wireless gateway (on-board) the weather station and transmitted to a proprietary cloud platform. From there, they can be accessible to the central PANTHEON platform, where the digital twin will be developed, and the simulations will be performed.

3.3.7.3. Satellites

While Sentinel satellite data is not specifically designed for monitoring heatwaves, it can still be utilized to assess and analyse various factors associated with heatwaves. Here's how we can use Sentinel data for understanding and responding to heatwaves:

a. Surface Temperature Monitoring: Sentinel-2 satellite imagery can provide data on land surface temperatures (LST) by capturing thermal infrared radiation. During heatwaves, land surface temperatures typically rise significantly, and Sentinel-2 can detect these temperature anomalies. By analysing changes in LST over time, you can identify regions experiencing heatwave conditions and assess the severity and spatial extent of the heatwave.
b. Vegetation Health Assessment: High temperatures associated with heatwaves can stress vegetation, leading to changes in vegetation health and moisture content. Sentinel-2's multispectral imagery can be used to monitor vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI). Decreases in these indices may indicate vegetation stress caused by heatwaves, providing insights into the ecological impacts of extreme heat events.
c. Urban Heat Island Mapping: Urban areas tend to experience higher temperatures than surrounding rural areas during heatwaves due to the urban heat island effect. Sentinel-2 imagery can be used to map land cover types and urban heat islands, enabling the identification of areas prone to heat-related risks. Analysing land surface temperature variations between urban and rural areas can help urban planners and policymakers implement strategies to mitigate heat stress in urban environments.
d. Water Bodies Monitoring: Heatwaves can lead to increased temperatures in water bodies such as lakes, rivers, and oceans, which can have ecological consequences and impact human activities such as fishing and recreation. Sentinel-2's thermal infrared bands can be used to monitor water surface temperatures and detect anomalies caused by heatwaves. Changes in water temperatures can inform management decisions related to water resource management and aquatic ecosystem conservation.
e. Climate Change Impacts: Sentinel data, when analysed over longer time periods, can provide insights into the trends, and impacts of climate change, including the frequency and intensity of heatwaves. By analysing historical Sentinel imagery, researchers can identify temporal trends in land surface temperatures and assess how heatwaves are changing over time, contributing to our understanding of climate change impacts and adaptation strategies.

f. Integration with Other Data Sources: Combine Sentinel data with ground-based weather observations, climate models, and socioeconomic data to enhance the understanding of heatwave dynamics and their impacts on human health, infrastructure, and vulnerable populations. Integrating satellite data with other sources can provide a comprehensive assessment of heatwave risks and support the development of targeted interventions and adaptation measures.

By leveraging Sentinel satellite data and complementary datasets, we can enhance the monitoring, assessment, and response to heatwaves, contributing to efforts to mitigate the impacts of extreme heat events on ecosystems, communities, and infrastructure.

3.3.7.4. Data Sources Requirement & Availability

Several data sources for heatwaves in Vienna provide historical weather data, climate assessments, and information specific to Vienna and the surrounding region. A depiction of these data sources is shown in Figure 25. For this case the following datasets will be required:

Meteorological Data: Historical and real-time meteorological data, including temperature records, humidity levels, and weather forecasts, is essential. This data should cover the historical trend of heatwaves, including the frequency, duration, and intensity of hot days in Vienna. The Austrian central meteorological institute ZAMG and the Central Institute for Meteorology are likely to provide this data.

Geospatial and Urban Data: Information on Vienna's urban structure, infrastructure, and urban heat island effects will be needed. This could include data on rapid urbanization, population growth, land use, vegetation cover, and infrastructure details. City urban planning and infrastructure departments, as well as geographical and environmental research institutes, may provide such data.

Demographic and Health Data: Population demographics and health statistics will be vital. This includes vulnerability assessments for different groups, hospital occupancy rates during heatwaves, ambulance call-out statistics, and community health profiles. Access to health ministries, hospitals, health research organizations, and public health agencies is crucial for obtaining this data.

Emergency Operational Data: Data on ambulance dispatches, first responder resource allocation, and emergency response plans will be required. This should cover human resource planning, equipment assessments, and the impact of heatwaves on operational functions.

Satellites and in situ sensors offer indispensable tools for comprehensive weather monitoring, forecasting, urban heat island analysis, environmental assessment, and health impact evaluations, ultimately supporting proactive and effective responses to heatwave events in urban areas like Vienna.

Simulation Input Data: To run simulations and decision support, the system will need parameters such as temperature ranges, humidity levels, and duration of the heatwave. This data input is critical for generating models, predicting impacts, and identifying preventive actions.

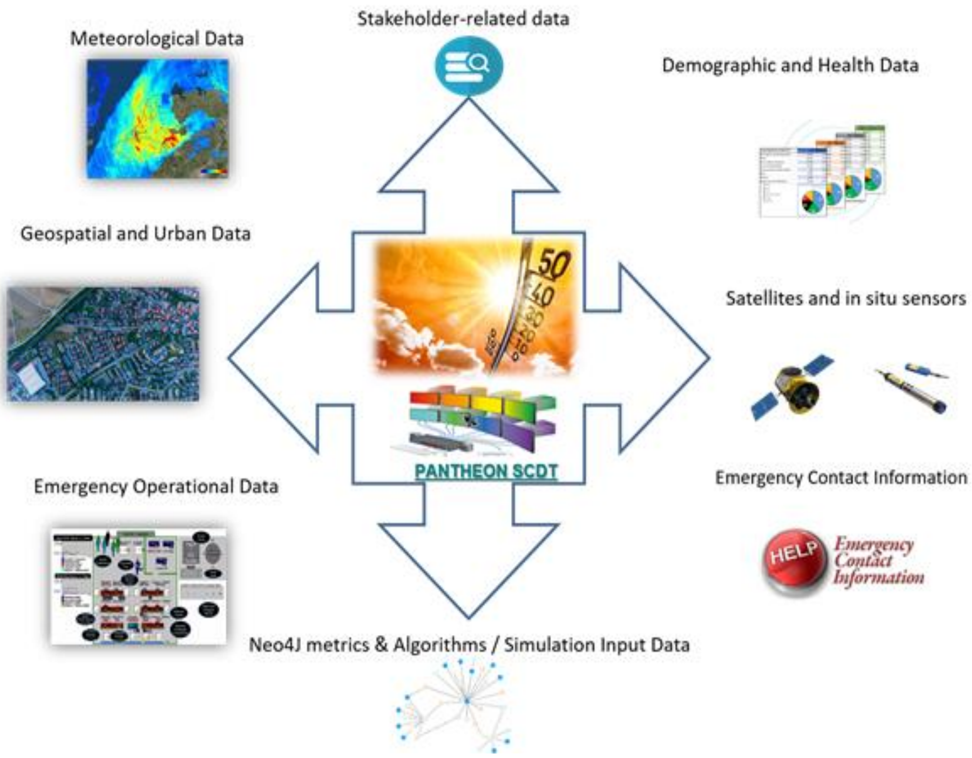

Figure 25 Data Sources in DS-VIE-A scenario.

1. Meteorological Data

Sources	Purpose	Actual source
meteorological data, including historical and real-time information, especially related to heatwaves in Vienna	analysis of historical heatwave trends, real-time monitoring of weather conditions, and the ability to make informed decisions and conduct detailed forecasting and planning related to heatwaves in Vienna.	**Zentralanstalt für Meteorologie und Geodynamik (ZAMG) -** The Austrian central meteorological institute is a primary source for comprehensive meteorological data, including historical records, real-time weather observations, and forecasts. They provide detailed information on temperature records, humidity levels, and specific data relevant to heatwaves in Vienna. **Central Institute for Meteorology** - This institute is another significant source for meteorological data, particularly concerning Vienna and the broader region. They offer historical climate data, analysis of heatwave patterns, and real-time weather forecasts to provide a holistic view of meteorological conditions. **European Centre for Medium-Range Weather Forecasts (ECMWF)** - This organization provides global atmospheric data, weather forecasts, and climate monitoring, including data relevant to the region of Vienna and its surroundings. **Global Historical Climatology Network (GHCN)** - GHCN is maintained by the National Oceanic and Atmospheric Administration (NOAA) and provides an

		extensive archive of weather and climate data from thousands of stations worldwide, including Vienna. It includes historical temperature and precipitation records, essential for studying heatwave trends. **Local Weather Stations and Observatories** - Local weather stations and observatories within Vienna and the surrounding area provide real-time meteorological data, such as temperature and humidity readings, which are critical for monitoring heatwave conditions as they unfold. **Vienna Open Data Portal:** The city of Vienna's open data portal may provide access to historical weather data, including temperature records, heatwave events, and related climate information specific to Vienna.

2. **Geospatial and Urban Data**

Sources	Purpose	Actual source
Vienna's urban landscape, infrastructure, and environmental attributes	understand Vienna's urban landscape, evaluate its environmental impact, and inform urban planning and resilience strategies to address challenges related to urbanization, infrastructure development, and the impact of heat island effects on the city	**City Urban Planning Department:** The Vienna City Administration's urban planning department may provide access to data on urban development plans, building permits, zoning regulations, and land use patterns in the city. **Vienna's Geographic Information System (GIS) Data:** The city's GIS department, or relevant municipal offices, could offer detailed spatial data on infrastructure, land cover, topography, and city development projects, which can provide insights into the urban environment. **Environmental Research Institutes:** Research institutions focused on urban environmental studies and climate research may collect and provide data on heat island effects, vegetation cover, and environmental impact assessments in Vienna. **Austrian Federal Environmental Agency (Umweltbundesamt):** This agency often provides environmental data and reports, including information on urbanization, ecological assessments, and sustainability indicators related to Vienna. **University Research Centers:** Academic institutions in Vienna with urban planning, geography, or environmental science departments may conduct research and offer access to spatial data related to urbanization and environmental characteristics. **Open Data Portals:** The City of Vienna or regional government bodies may operate open data platforms providing access to geospatial datasets, city maps,

		infrastructure details, and environmental monitoring data. **Population and Housing Census Data**: National statistical agencies often collect and provide demographic and housing data, including population density, housing characteristics, and urban growth trends.

3. **Demographic and Health Data**

Sources	Purpose	Actual source
demographic and health-related data sources in Vienna	understanding of the demographic and health impacts of heatwaves in Vienna, informing public health strategies, emergency response plans, and targeted interventions to protect vulnerable populations during extreme heat events.	**Vienna Health Authorities and Ministries:** Local health authorities and ministries are essential sources for health statistics, demographic data, and public health assessments related to heatwave impacts. These organizations may provide information on population health, vulnerability assessments, and community health profiles. **Vienna General Hospital and Medical Centers**: Hospital data, including occupancy rates during heatwaves, admission trends, and health outcomes related to heat-related illnesses, can be obtained from Vienna's hospitals and medical centers. **Vienna Health and Social Care Agencies:** Health and social care agencies play a vital role in collecting and managing demographic and health-related data. These agencies are responsible for public health assessments and vulnerability analyses related to heatwave impacts. **Vienna's Public Health Research Organizations:** Public health research institutions and organizations conduct studies on the impact of heatwaves on public health. They may provide demographic data, vulnerability assessments, and health statistics specific to heat-related illnesses. **Statistical Offices and Research Institutes:** Regional statistical offices and research institutes are valuable sources for demographic data, population health statistics, and vulnerability assessments, helping to understand the health impacts of heatwaves. **Community Health Organizations and Non-profits**: Collaborating with community health organizations and non-profits can provide local insights into community health profiles, vulnerability assessments, and neighborhood-specific health data related to heatwave impacts.

4. **Emergency Operational Data**

Sources	Purpose	Actual source
emergency response operations and resource management data during heatwave events	assessing response capacities, identifying operational challenges, and refining emergency response plans to address extreme heat conditions in Vienna.	**Vienna Emergency Medical Services (EMS) and Fire Department**: Vienna's EMS and fire department are primary sources for data on ambulance dispatches, response times, and resource allocation during emergencies, including heatwave-related incidents. **City Emergency Response Centers:** Emergency response centers and command operations play a central role in managing emergency services. They are likely to provide data on emergency call volume, resource allocations, and coordination of response efforts during heatwaves. **Vienna Hospitals and Health Facilities:** Hospitals and medical centers may offer ambulance utilization data, patient arrivals during heatwave events, and the impact on hospital operational functions during periods of heightened demand. **Vienna City Administration:** The city administration may maintain data on emergency planning, resource allocation, and operational functions during heatwave events. This could include documentation on the impact of heatwaves on operational capabilities and human resource planning during such events. **Emergency Response Training and Simulation Centers**: Institutions focused on emergency response training and simulations may provide data on operational functions, response capabilities, and resource management strategies during heatwave scenarios. **Transportation and Infrastructure Data:** Data on transportation networks, road conditions, and infrastructure performance during heatwaves can be obtained from transportation departments and infrastructure management agencies. This information is crucial for understanding the impact on operational functions during heatwave events.

5. **Satellite and in situ sensors Data**

Sources	Purpose	Actual Sources
satellite and in situ sensor data for heatwave monitoring and response in Vienna	understanding of the meteorological and environmental aspects of heatwave events, supporting proactive and effective responses to heatwaves in Vienna	**European Space Agency (ESA):** The ESA offers satellite data and Earth observation missions, including the Sentinel series, which provides detailed meteorological and environmental monitoring data for urban areas such as Vienna. **Austrian Meteorological Service (ZAMG):** ZAMG operates in situ sensors and may collaborate with

	satellite data providers to offer comprehensive weather monitoring, including temperature, humidity, and environmental analysis, particularly focused on heatwave events. **European Centre for Medium-Range Weather Forecasts (ECMWF)**: The ECMWF offers access to weather predictions, climate modelling, and data on extreme weather events, supporting comprehensive forecasts and monitoring of heatwave conditions. Institute of Meteorology at the University of Vienna: The university's meteorological institute may provide localized meteorological data, including in situ sensor readings, urban heat island analyses, and environmental assessments relevant to heatwave events in Vienna. **Copernicus Climate Change Service (C3S):** C3S offers diverse climate and environmental data, including historical and real-time information relevant for monitoring and forecasting heatwave conditions and their impact on urban areas. **Local Environmental Research Institutes:** Research institutions focused on urban environmental studies and climate research may collect and provide data on heatwave-related meteorological conditions, urban heat island effects, and environmental impact assessments in Vienna. **National Meteorological and Environmental Monitoring Agencies:** Austria's national meteorological and environmental monitoring agencies offer comprehensive meteorological, air quality, and environmental data, including satellite and in situ sensor information, related to heatwave events. **Open Data Portals and Public Research Databases**: Open data initiatives and public research databases in Austria provide access to satellite data, in situ sensor readings, and meteorological analyses relevant to understanding heatwave conditions and their impact on urban areas.

3.4. SCENARIO 4 | DS-VIE-B: MAN-MADE DISASTER IN VIENNA

3.4.1. SCENARIO BUILDING BLOCKS

The last pilot scenario is going to be modelled closely after a real-life exercise taking place mid-2024. The model for PANTHEONS final pilot will contain all the basic building blocks of a staff exercise and is aimed at showcasing the ability of the system to virtually simulate events as closely as possible to a disaster situation having been acted out in an exercise.

The pilot scenarios template will be derived from both:

- An exercise to be conducted as part of another Horizon 2020 project as a clustering effort.
- The previous pilots' disaster simulations

One of the PANTHEON systems main use-cases is as a tool usable by first-responder organisations and other actors in the field of DRR to supplement real-life exercises and possibly have a reduction of exercises needed to be organised in real-life while still presenting most of the experiences a real-life training can present. Organising real-life exercises needs enormous amounts of financial-, human- and time- resources so any reduction in effort will make an adoption as a support tool much more likely.

Putting on a full-scale staff exercise will enable feedback from all possible stakeholders jointly considering this tool's potential and ideally showcasing strengths and weaknesses regarding deployment by diverse organisations and stakeholders, representing the broad spectrum of DRR the field (shown in Figure 26).

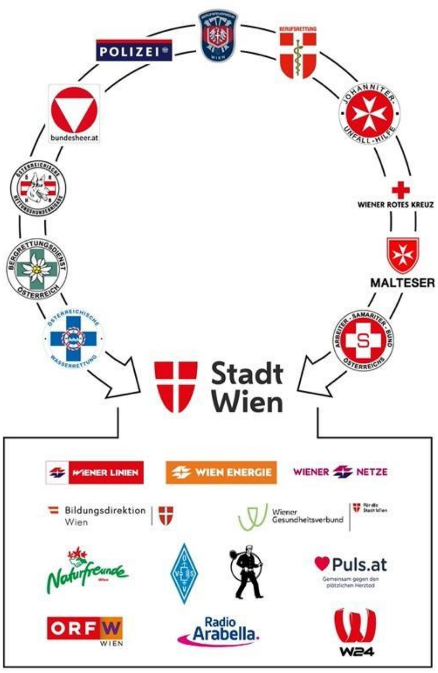

Figure 26 Organisations of the K-Kreis DRR network.

3.4.2. EFFECTS TO BE SIMULATED

The model exercise to be used as a reference, stemming from the TREEADS project, will focus mainly on wildfires, their prevention as well as the effects of one taking place in inhabited areas.

The PANTHEON narrative will include a man-made trigger stemming from an infrastructure cyber-attack targeting a powerplant and show the implication of one targeted trigger by in an arboreous area causing a forest fire spreading over a region towards and including the outskirts of Vienna, which is a densely forested area.

Having one trigger creating a cascading effect will enable the last pilot to showcase all development efforts up to this point and including a multitude of organisations in a staff exercise will facilitate including fully developed parts and excluding parts not yet ready for practical use while still collecting feedback from specialists in their respective field.

We aim to play close attention to vulnerable groups being situated in the pilot area and observe the system's ability to account for special measures needed including those regarding communication and logistics, which will be derived from the observation of first responders during the real-life exercise.

By choosing a real-life exercise as reference we have the opportunity to observe and document all relevant building blocks of a disaster relief effort while they take place and include them in the simulation for the PANTHEON project's pilot, bringing it as close to reality as possible.

Cascading effects

The man-made scenario as derived from an evacuation effort of a part of Vienna's outskirts will initially include the deployment of fire fighters, the police and medical first responder organisations, with increasing numbers of other organisations the further the effects of the initial trigger spread towards the more densely populated parts of the city. For the pilot to make sense as a staff exercise, we will have to tailor the scenario's length and extent to the systems capabilities so the final pilot can serve as a feature presentation of the whole PANTHEON development effort.

By choosing a man-made trigger such as cyber-terrorism we can realistically have a disaster start in an area usually not considered to be exceptionally threatened by disaster. Thus, having a cascade of events that are not well planned for and which usually necessitates a lot of experienced specialist to come together during the response time. This group of people is ideally suited to gauge a simulation system's capabilities during a pilot and can give competent feedback regarding possible additional application fields, quality of the simulation regarding their own experiences as a benchmark and overall scope of digital twin platforms in DRR. At the same time these partners represent the core user group and target audience of digital twin city technology.

3.4.3. Stakeholder's roles

In staff exercises[8] stakeholders from different organisations including first responders, municipal representatives, infrastructure providers, media representatives and healthcare provides come together to train their cooperation and coordinate their efforts during an emergency.

For the final pilot we will create a tabletop exercise with diverse units active in the field of DRR, cooperating to manage the effects simulated by the PANTHEON platform. The collaborative effort will enable collection of input from a wide variety of stakeholders simultaneously and simulate the effect of the PANTHEON system

[8] https://www.bmi.gv.at/204/Download/files/2020_01_22_Richtlinie_Uebungsplanung_Strahlenschutz_Druckversion.pdf

in crisis management over a period of time. The length of time to be simulated as a scenario will heavily depend on participating organisations and development status of the system but can be very flexibly adapted in the months prior to the pilot.

3.4.4. Actor Definition

As this will be the project's last demonstration it's key parameters and main actors will be dependent on the systems' capabilities at the point of implementation. The underlying idea of a staff exercise is to include as many of the principal parties coming together in a real disaster situation as possible and having them coordinate their efforts in a tabletop exercise in real time while using the PANTHEON system for the simulation of cascading effects. Participating partners from the city of Vienna's disaster relief forces, first responders, city planners, communications experts and members of civil protection authorities will be invited to take part in the exercise. For the staff exercise, which will simulate a cyber-physical threat, the internal Johanniter Unfall Hilfe (JUH) staff unit will participate and invite external experts. Users of the technologies/system will be JUH-members only. Observers will be obtained from both, JUH and external organizations. External observing experts will be able to provide feedback on the Pantheon system and the execution of the exercise. In doing so, additional knowledge can be added and used for future development. JOH staff unit: Users and observers. According to internal JOH rules of action, the following positions will be included in the JOH staff unit. Some positions will only have observing functions (i.e. using the information provided by the system), whereas other will be users (i.e. interaction with the system). The user groups will be:

- S1: Personnel and internal affairs
    - shift coordinators.
    - human resources.
    - volunteer coordinators.
    - command center employees.
- S2: Situational picture/Status Quo
    - Officers on duty.
    - Disaster relief team.
- S3: Mission
    - Incident leaders
    - Support: Disaster Relief Team
- S4: Logistics
    - Material/equipment department
    - Disaster relief team personel
- S5: Press/Media
    - Press relations officer.
- S6: Information and communication
    - Command centre.
    - Disaster Relief Team's communications dept.

<u>Observing external experts (to be defined at a later stage)</u>

The following external organizations will be invited to join the exercise as observers and external experts for supporting the JOH staff unit. The availability of the respective authorities will be requested at a later point.

First responder organizations:

- Police
- Vienna Fire Brigade
- Civil Protection Authorities
- Austrian Military
- Other medical first responder organizations

Infrastructure providers:

- Wiener Netze (power supply)
- Telecom provider
- Healthcare provider
- Vienna General Hospital
- Klinik Donaustadt

Political decision makers:

- Wr. Gesundheitsstadtrat
- Geschäftsgruppe Gesundheit und Soziales der Stadt Wien (MA70)

3.4.5. Usage Scenario Description

The main interaction with the PANTHEON system will be through large scale screens displaying a situational picture of the status quo augmented by different layers tailored to the end users. Depending on the systems' maturity and integration possibilities visualisations may include all the information already present for the heatwave scenario (though without the need for adjustments) and additionally infrastructure damage, further human- and object (e.g. vehicle) resource availability, as well as a multitude of map overlays to be determined in the upcoming months regarding user requirements. In terms of users, the JOH members would act as the user with full privileges (members - running simulations, inputting assets etc.) and the rest of the stakeholders as indicated previously will act as observers of the system with restricted access (possibly read only).

3.4.6. PANTHEON Technologies Usage

3.4.6.1. SCDT

The ICS Vienna disaster scenario is centred around a singular initiating event: a cyber-physical attack on a power plant that leads to a fire, subsequently affecting nearby habitable areas and critical infrastructure, including telecommunications towers. A suburban area of Vienna is chosen as the primary focus for this simulation. The simulation incorporates detailed information about the area's geographical layout and infrastructural characteristics (e.g., population density, proximity to the power plant, and the location of flammable materials), which are vital for assessing the initial impact of the disaster and its potential spread.

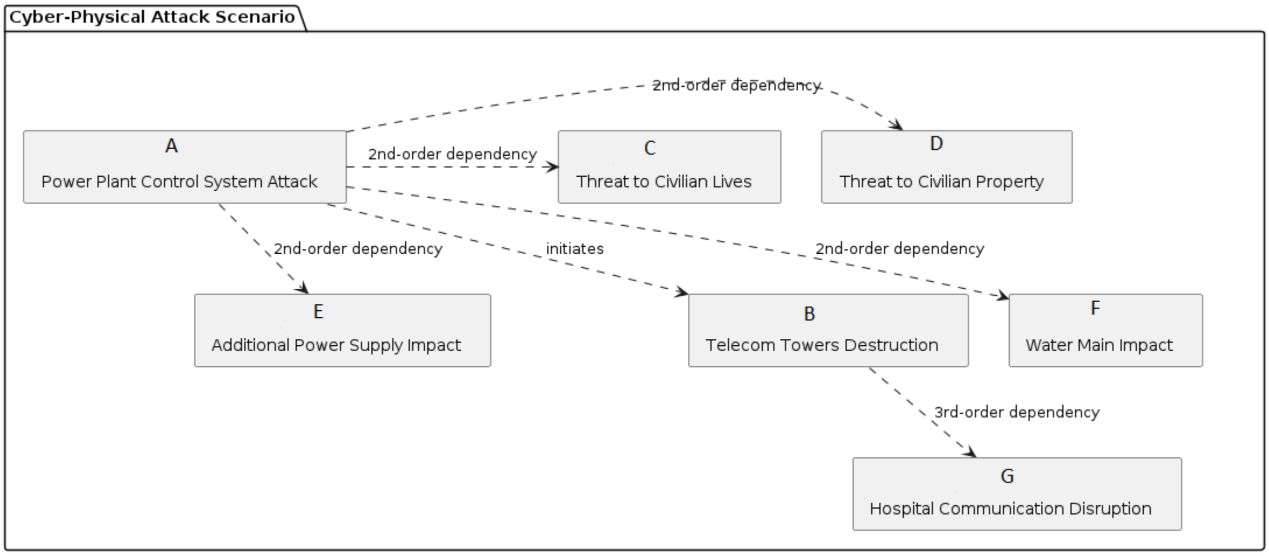

Figure 27 The Cyber-Physical Attack Scenario.

The scenario unfolds with a cyber-physical attack targeting the power plant's control systems, represented by node A in Figure 27. This assault leads to operational failures within the plant, culminating in a significant fire. This fire, in turn, poses immediate threats to adjacent residential areas and begins to impact surrounding infrastructure, including telecom towers, due to its spread (node B). The destruction of telecom towers, a result of the fire's expansion, represents a critical secondary event, severely hampering communication channels essential for coordinating first responder efforts.

The primary event, the cyber-physical attack and resultant fire (node A), initiates a series of failures to other dependencies too. The immediate threat to civilian lives and property (nodes C and D representing block houses) and the disruption of transportation channels (due to the fire impacting road junctions) are identified as second-order dependencies. Subsequent impacts on nearby critical infrastructure, such as additional power supplies, water mains and inability for hospitals to communicate (nodes E, F and G), emerge as second-order (nodes E and F) and third-order dependencies (node G) respectively. These cascading effects underscore the complexity of the disaster scenario, necessitating advanced simulation and strategic response planning.

Emergency management authorities will utilize the Neo4J graph database to model the spatial relationships among the affected infrastructure, residential zones, and available emergency resources. By focusing the simulation on the consequences of the cyber-physical attack-induced fire, the system is equipped to predict the fire's spread and its cascading effects on urban infrastructure, including the secondary impact on telecommunications. Impact assessment algorithms are employed to estimate the potential damage per square meter and the extent of the communications breakdown, enabling authorities to prioritize response efforts and formulate effective evacuation plans.

As part of the response strategy, the Fire Department, along with other emergency services, will contribute data regarding their operational capabilities and resources. Neo4J's dynamic modelling facilitates a comprehensive evaluation of the direct consequences of the fire and the indirect effects on emergency response efficiency due to compromised telecommunications. Impact assessment algorithms enhance the ability to anticipate further risks to critical infrastructure, guiding the prioritization of firefighting and rescue operations. Centrality metrics within the graph database play a crucial role in identifying key locations in need of urgent attention, directing the optimal deployment and mobilization of emergency response units to mitigate the disaster effectively and support affected populations.

3.4.6.2. In-Situ IoT sensors

As already mentioned in the two described weather/nature related disaster scenarios, local environmental monitoring plays a major role in predicting the possible disaster and its outcomes. In that sense, the utilisation of in-situ IoT sensors in the herein disaster scenario adheres to the previously described cases of wildfire and heatwave. Moreover, with respect to the cyberterrorism attack/disaster scenario, no direct exploitation of local weather monitoring data can be found. However, in the case of a cyber-attack that results in local fires in the vicinity of the deployed IoT weather station, the sudden increase in temperature can be detected and contribute to the disaster warning and mitigation actions.

3.4.6.3. Satellites

As the man-made terrorist attack finally results to a wildfire what was already reported in the Wildfires for the Attica region holds true for this case.

Although managing wildfires typically falls under the jurisdiction of firefighting agencies, forestry departments, or environmental authorities in Austria, relevant entities could include the Austrian Federal Forests (Österreichische Bundesforste), the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, or regional fire departments and emergency services. It's advisable to contact these organizations directly or check their official websites for the most current and accurate information regarding fuel maps and wildfire management in Vienna.

3.4.6.4. UAVs

Once again, this case study can be supported by observation drone systems tasked with monitoring or mapping the crisis area, aiming to improve understanding of the situation and enable rescue teams to anticipate and support their decision-making process. To explore more specific uses of drones and extend the considerations to the deployment of drone swarms, a slightly more specific case study has been identified.

In this case, the cyberattack targeted an industrial infrastructure corresponding to the Seveso European Directive. In this context, a major fire can become a hazardous emission source that may lead to the urgent evacuation of part of the population, particularly those directly exposed to toxic substances. To optimize the evacuation process and avoid saturating communication routes and hospital facilities, it is necessary to know the exact extent of the smoke plume and its concentrations at varying distances from the disaster. Numerous parameters, including meteorological factors, can influence the outcome, and only direct measurements will likely and accurately meet the need. Therefore, given the urgency of the situation and the need for rapid decision-making, deploying drones in a swarm configuration will be an effective solution. The mission will involve mapping the cloud and collecting as much information as possible about its evolution over time.

Figure 28 illustrates a practical case where an explosion has occurred in an industrial infrastructure located within an urban area, surrounded by populated zones. Evacuating and transporting people affected to hospitals must be optimized to avoid resource saturation, and the affected individuals must even be classified based on their degree of exposure to toxic substances, as this parameter can influence the medical treatment they will receive. Deployment of drones equipped with special sensors capable of sniffing and detecting chemical substances is considered to scan the smoke cloud, with swarm formation enabling the creation of a detailed map of it. The constraint will be primarily dynamic, as the shape of the cloud can evolve over time, and the onboard intelligence in the drones must allow them to define their flight plan to always remain within the area of high concentration. Due to the type of operation envisaged (local operations but highly dynamic), multi-copter drones will be chosen, but confirming or refuting this type of conclusion precisely relies on the expected conclusions resulting from the use of the PANTHEON platform.

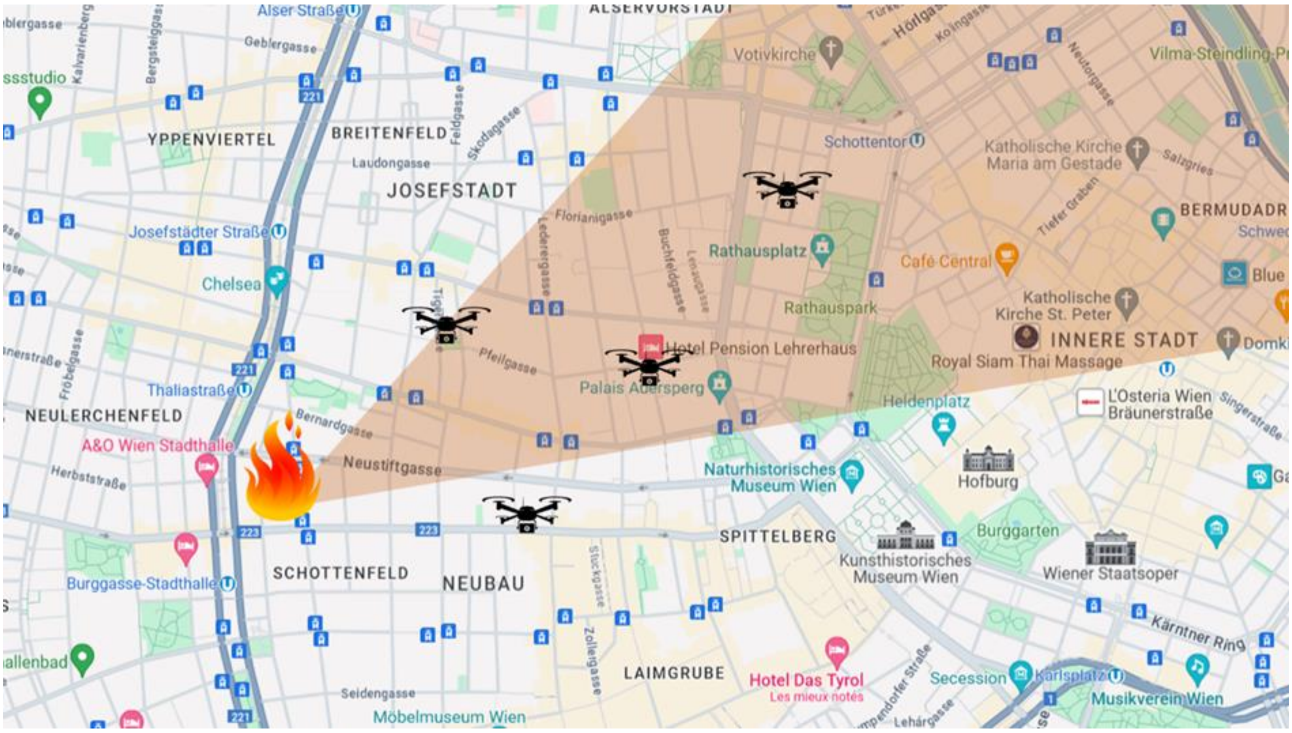

Figure 28 Illustration of a study case dedicated to large industrial fire in an urban area and requiring a dynamic mapping of the toxic plume.

Regarding the processes implemented within the PANTHEON platform and the architecture required to replicate them, the concepts will once again be identical to those presented previously.

The steps described above are both generic and exhaustive. For the PANTHEON project, they are circumscribed as follows:

1. Prior to the disaster (planning)
    1. The available equipment will be simulated first – no hard limit on the number and type of drones and equipment. we shall at least retain two rotary wing drones, both equipped with sniffer sensors (for gas and fine particle sensing)
    2. Feed this data in the SCDT, along with user inputs, and restricted airspaces, for the swarm controller to come up with an optimised swarm
2. During the disaster (training and exercise simulations)
    1. Fly the swarm within the authorised zones (safety buffers included); always stay in contact with simulated other airspace users and Air Traffic Control.
    2. The aim is to dynamically locate, follow and map the plume of toxic gas and particles

3.4.6.5. Data Sources Requirement & Availability

The fourth scenario involves a complex man-made disaster scenario modelled after a real-life exercise. The focus is on simulating a cascade of events resulting from a cyber-attack on a power plant and its subsequent effects, including the spread of a forest fire toward the outskirts of Vienna. Data sets required for this scenario:

Historical Disaster Data: Access to comprehensive historical disaster data, including records of cyber-attacks, incidents of industrial infrastructure compromise, and previous forest fires in the region.

Geographic Information System (GIS) Data: Detailed GIS data that includes infrastructure mapping, forested areas, transportation networks, and vulnerable community locations in Vienna and its surroundings.

Climate and Weather Data: Information on local weather patterns, wind conditions, temperature, humidity, and historical heatwave and fire weather indices for Vienna.

Cybersecurity Threat Intelligence Data: Data sets related to cybersecurity threat intelligence, including information on known cyber-attack tactics, techniques, and procedures, and historical attack patterns.

Environmental Monitoring Data: Real-time and historical environmental monitoring data, which includes information from in-situ IoT sensors for local environmental conditions, such as temperature, air quality, and sudden changes indicative of hazards, including potential fire outbreaks.

Urban Planning and Infrastructure Data: Data sets related to urban planning, critical infrastructure locations, transportation networks, and population density to assess vulnerability and cascade effects.

First Responder and Emergency Services Data: Information on first responder protocols, emergency response plans, and available resources for specific organizations involved in disaster response and management.

3.4.6.5.1. Specific data sources for Vienna

For specific data related to Vienna, Austria, consider starting with the following organizations and websites:

1. ZAMG - Central Institute for Meteorology and Geodynamics:
   Website: https://www.zamg.ac.at/cms/en
2. City of Vienna Open Data Portal:
   Website: https://www.data.gv.at/katalog/organisation/ddbffc36-78ae-455d-8c1f-59b2c7b344e8
3. Central Institution for Meteorology and Geodynamics (ZAMG):
   Website: https://www.zamg.ac.at/cms/en/climate
4. Austrian Cyber Security Center:
   Website: https://www.acsc.gv.at/
5. City of Vienna's Official Website:
   Website: https://www.wien.gv.at/english/

These organizations and official government websites may provide access to detailed historical, geographical, weather-related, cybersecurity-related, and emergency management-specific data pertinent to Vienna and its surroundings.

Since the data sources identified for Scenario 3 – Heatwave in Vienna are similar expect those which are cybersecurity related, the following available data sources should be further utilised in this scenario:

- **CERT.at (Computer Emergency Response Team Austria):** As the national Computer Emergency Response Team for Austria, CERT.at provides cybersecurity threat intelligence, advisories, and analysis of historical cyber-attacks and vulnerabilities relevant to organizations in Austria.
- **A-SIT (Austrian Secure Information Technology Center)**: A-SIT offers cybersecurity assessments, consulting, and research services, providing valuable insights into known vulnerabilities, attack patterns, and threat intelligence specific to the Austrian context.
- **Oesterreich Computer Gesellschaft (OCG):** OCG, the Austrian Computer Society, organizes cybersecurity events, conferences, and knowledge-sharing initiatives, offering access to industry insights and threat intelligence specific to Austria's cybersecurity landscape.
- **Austrian National Cyber Security Strategy:** The official National Cyber Security Strategy and related cybersecurity reports published by the Austrian government may include assessments of historical cyber-attack patterns and threat intelligence relevant to the nation's critical infrastructure.

4. USE CASES DESCRIPTION

The previously defined disaster and usage scenarios have been elaborated further into single functional steps (use cases) that depict the flow of operations a user will follow in the PANTHEON platform for each scenario. A summarisation of the below use cases can be seen in Figure 29.

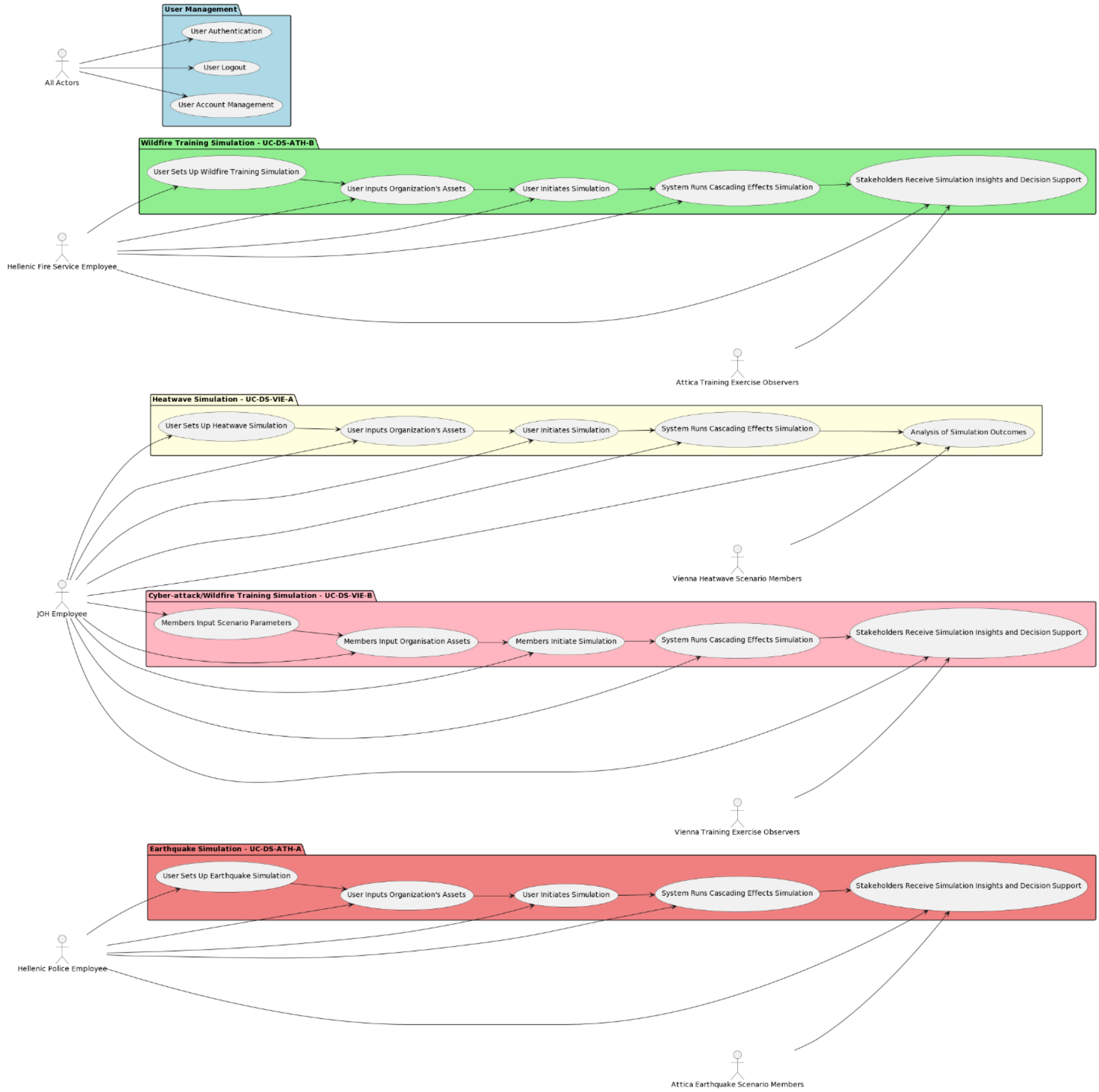

Figure 29 Summary of PANTHEON Use Cases.

In total, this section includes 23 use cases, 5 use cases for each usage scenario, and three use cases that are user management related, thus they are common for every usage scenario. Each use case has an identifier, to be easily separated from the others. The identifier of the use cases follows the following naming schema: UC-DS-{PILOT}-{APPLICATION}-{SEQUENCE}, where PILOT is in {ATH, VIE}, APPLICATION is in {A,B} and SEQUENCE is in {1,2,3,4,5}.

Identifier	UC-MGM-01
Name	User Authentication
Description	This use case involves a user attempting to log in to the PANTHEON system, verifying their identity.
Actors	All defined actors
Goals	To authenticate the user and grant access to the system.
Stakeholders	Users, System Administrators
Pre-conditions	• The user has a registered account in the PANTHEON system. • The user provides valid login credentials.
Post-conditions	• Successful: The user is authenticated and gains access to the system. • Unsuccessful: Authentication fails due to incorrect credentials or technical issues.
Dependencies from other functionalities/steps	None
Basic Flow	1. User enters their username and password. 2. Initiates the login process. 3. System verifies user credentials against stored records. 4. Grants access if credentials are correct. 5. Denies access if credentials are incorrect or technical issues arise.
Alternate path	None
Exceptions	• User provides incorrect credentials. • Technical issues prevent authentication.

Identifier	UC-MGM-02
Name	User Logout
Description	This use case involves a user logging out of the PANTHEON system, terminating their active session.
Actors	All defined actors
Goals	To terminate the user's active session and clear session data.
Stakeholders	Users, System Administrators
Pre-conditions	• The user is currently logged into the PANTHEON system.
Post-conditions	• Successful: The user is logged out, and the session is terminated. • Unsuccessful: Technical issues prevent the logout process.
Dependencies from other functionalities/steps	None
Basic Flow	1. User initiates the logout action from the system interface. 2. System terminates the user's active session. 3. Clears session data and authentication tokens. 4. Redirects the user to the login page or a designated landing page.
Alternate path	None

Exceptions	● Technical issues prevent the completion of the logout process.

Identifier	**UC-MGM-03**
Name	User Account Management
Description	This use case involves a user managing their account information, such as updating contact details or changing a password.
Actors	All defined actors
Goals	To allow users to update their account information securely.
Stakeholders	Users, System Administrators
Pre-conditions	● The user is currently logged into the PANTHEON system.
Post-conditions	● Successful: The user successfully updates their account information. ● Unsuccessful: Technical issues prevent the update process.
Dependencies from other functionalities/steps	● User needs to be logged in (UC-MGM-01)
Basic Flow	1. User navigates to the account management section in the system. 2. Edits and updates relevant account information. 3. System validates the updated information. 4. Saves the changes to the user's account. 5. Sends confirmation or error messages to the user.
Alternate path	None
Exceptions	● Technical issues prevent the completion of the account update process.

Identifier	**UC-DS-ATH-B-1**
Name	User Sets Up Wildfire Training Simulation
Description	This use case involves a Fire Service employee (member) configuring parameters for the wildfire response training simulation.
Actors	Fire Service members
Goals	To allow users to customize simulation parameters for realistic training scenarios.
Stakeholders	Fire Service Employee, System Administrators, Attica Training Exercise Observers
Pre-conditions	● The user is logged into the PANTHEON system and has access to the training simulation dashboard.
Post-conditions	● Successful: Simulation parameters are configured as per user input. ● Unsuccessful: Technical issues prevent the configuration process.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01)
Basic Flow	1. Fire Service employee navigates to the simulation setup section.

	2. Defines parameters such as fire propagation direction, weather data, and slope/elevation. 3. Submits the configured parameters to the system.
Alternate path	None
Exceptions	● Technical issues prevent the completion of the setup process.

Identifier	**UC-DS-ATH-B-2**
Name	User Inputs Organization's Assets
Description	This use case involves a Fire Service employee entering and providing essential information regarding their organization's assets into the PANTHEON system. The assets inputted are crucial for the realistic representation of available resources during the wildfire response training simulation.
Actors	Fire Service members
Goals	To capture and incorporate accurate data on the organization's assets to enhance the realism of the wildfire response training simulation.
Stakeholders	Fire Service Employee, System Administrators, Attica Training Exercise Observers
Pre-conditions	● The user is logged into the PANTHEON system and has access to the training simulation dashboard. ● Simulation parameters, such as fire propagation direction, weather data, and other relevant factors, are configured.
Post-conditions	● Successful: The system stores and integrates the inputted data on the organization's assets for use in the wildfire response training simulation. ● Unsuccessful: Technical issues or user errors prevent the successful input and storage of asset data.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01) ● Successful configuration of simulation parameters (UC-DS-ATH-B-1)
Basic Flow	1. Fire Service employee navigates to the asset input section within the simulation setup. 2. Inputs information such as the type and quantity of vehicles, equipment, personnel, and other relevant assets available for firefighting. 3. Submits the entered data to the system. 4. The system validates and stores the asset information for utilization in the upcoming simulation.
Alternate path	None
Exceptions	● Technical issues prevent the successful storage of asset data. ● User provides incomplete or inaccurate information.

Identifier	UC-DS-ATH-B-3
Name	User Initiates Simulation
Description	This use case involves a Fire Service employee starting the wildfire response training simulation based on the configured parameters.
Actors	Fire Service Employee
Goals	To initiate the simulation based on the user-defined parameters for training purposes.
Stakeholders	Fire Service Employee, System Administrators, Attica Training Exercise Observers
Pre-conditions	● Simulation parameters are successfully configured. ● The user is logged into the PANTHEON system and has access to the training simulation dashboard.
Post-conditions	● Successful: The simulation is initiated, and the system begins processing the scenario. ● Unsuccessful: Technical issues prevent the initiation of the simulation.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01) ● User has inputted simulation parameters (UC-DS-ATH-B-1) ● User has inputted her organisation's assets (UC-DS-ATH-B-2)
Basic Flow	1. Fire Service employee navigates to the simulation initiation section. 2. Initiates the wildfire response training simulation. 3. System processes configured parameters and starts the simulation.
Alternate path	None
Exceptions	● Technical issues prevent the initiation of the simulation.

Identifier	UC-DS-ATH-B-4
Name	System Runs Cascading Effects Simulation
Description	This use case involves the PANTHEON system running a real-time simulation of the disaster and predicting cascading effects based on the wildfire scenario and the received critical infrastructure data.
Actors	PANTHEON System
Goals	To simulate potential cascading effects and assess their impact on critical infrastructures.
Stakeholders	System Administrators, General Secretariat for Civil Protection, Fire Service, Hellenic Police, Collaborating Organizations
Pre-conditions	● Stakeholders have successfully inputted updated data on critical infrastructures. ● The system is in a state ready to run the cascading effects simulation.
Post-conditions	● Successful: The cascading effects simulation runs successfully. ● Unsuccessful: Technical issues prevent the simulation, or data is incomplete or inaccurate.

Dependencies from other functionalities/steps	● Stakeholders need to be logged in (UC-MGM-01) ● User has initiated simulation (UC-DS-ATH-B-3)
Basic Flow	1. System processes the inputted data on critical infrastructures. 2. Runs simulation of potential cascading effects on transportation, energy grids, pollution, and utilities. 3. Considers dynamic factors such as weather changes and terrain characteristics.
Alternate path	None
Exceptions	● Data is missing or inaccurate. ● Technical issues prevent the simulation.

Identifier	**UC-DS-ATH-B-5**
Name	Stakeholders Receive Simulation Insights and Decision Support
Description	This use case involves stakeholders (members and observers) reviewing the decision support insights and analysis provided by the PANTHEON system based on the completed cascading effects simulation.
Actors	Fire Service members, Attica Training Exercise Observers
Goals	To allow stakeholders to comprehend and utilize the simulation insights for decision-making.
Stakeholders	Fire Service members, Attica Training Exercise Observers
Pre-conditions	● The cascading effects simulation has been successfully completed. ● Relevant data logs from the simulation are available in the PANTHEON system.
Post-conditions	● Successful: Stakeholders receive and comprehend the simulation insights. ● Unsuccessful: Stakeholders encounter issues accessing or understanding the provided insights.
Dependencies from other functionalities/steps	● Stakeholders need to be logged in (UC-MGM-01)
Basic Flow	1. Stakeholders navigate to the cascading effects simulation results section. 2. System presents a comprehensive analysis of the simulated cascading effects and recommends resource deployment strategies. 3. Stakeholders review decision support insights and recommendations.
Alternate path	None
Exceptions	● Technical issues prevent access. ● Stakeholders face challenges in comprehending the insights.

Identifier	UC-DS-ATH-A-1
Name	User Sets Up Earthquake Simulation
Description	This use case involves a Hellenic Police employee configuring parameters for the earthquake simulation.
Actors	Hellenic Police Employee
Goals	To allow users to customize simulation parameters for realistic earthquake scenarios.
Stakeholders	Hellenic Police Employee, System Administrators
Pre-conditions	● The user is logged into the PANTHEON system and has access to the simulation dashboard.
Post-conditions	● Successful: Simulation parameters are configured as per user input. ● Unsuccessful: Technical issues prevent the configuration process.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01)
Basic Flow	1. Hellenic Police employee navigates to the simulation setup section. 2. Defines parameters such as earthquake magnitude, location, and duration. 3. Submits the configured parameters to the system.
Alternate path	None
Exceptions	● Technical issues prevent the completion of the setup process.

Identifier	UC-DS-ATH-A-2
Name	User Inputs Organization's Assets
Description	This use case involves a Hellenic Police employee entering and providing essential information regarding their organization's assets into the PANTHEON system. The assets inputted are crucial for the realistic representation of available resources during the earthquake simulation.
Actors	Hellenic Police Employee
Goals	To capture and incorporate accurate data on the organization's assets to enhance the realism of the earthquake simulation.
Stakeholders	Hellenic Police Employee, System Administrators
Pre-conditions	● The user is logged into the PANTHEON system and has access to the simulation dashboard. ● Simulation parameters, such as earthquake magnitude, location, and duration, are configured.
Post-conditions	● Successful: The system stores and integrates the inputted data on the organization's assets for use in the earthquake simulation. ● Unsuccessful: Technical issues or user errors prevent the successful input and storage of asset data.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01) ● Successful configuration of simulation parameters (UC-DS-ATH-A-1)

Basic Flow	1. Hellenic Police employee navigates to the asset input section within the simulation setup. 2. Inputs information such as the type and quantity of vehicles, equipment, personnel, and other relevant assets. 3. Submits the entered data to the system. 4. The system validates and stores the asset information for utilization in the upcoming simulation.
Alternate path	None
Exceptions	● Technical issues prevent the successful storage of asset data. ● User provides incomplete or inaccurate information.

Identifier	**UC-DS-ATH-A-3**
Name	User Initiates Simulation
Description	This use case involves a Hellenic Police employee starting the earthquake simulation based on the configured parameters.
Actors	Hellenic Police Employee
Goals	To initiate the simulation based on the user-defined parameters.
Stakeholders	Hellenic Police Employee, System Administrators
Pre-conditions	● Simulation parameters are successfully configured. ● The user is logged into the PANTHEON system and has access to the simulation dashboard.
Post-conditions	● Successful: The simulation is initiated, and the system begins processing the scenario. ● Unsuccessful: Technical issues prevent the initiation of the simulation.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01) ● User has inputted simulation parameters (UC-DS-ATH-A-1) ● User has inputted her organisation's assets (UC-DS-ATH-A-2)
Basic Flow	1. Hellenic Police employee navigates to the simulation initiation section. 2. Initiates the earthquake simulation. 3. System processes configured parameters and starts the simulation.
Alternate path	None
Exceptions	● Technical issues prevent the initiation of the simulation.

Identifier	**UC-DS-ATH-A-4**
Name	System Runs Cascading Effects Simulation
Description	This use case involves the PANTHEON system running a simulation of the earthquake and predicting cascading effects based on the scenario parameters and the received organisation assets data.
Actors	PANTHEON System
Goals	To simulate potential cascading effects and assess their impact on critical infrastructures.

Stakeholders	System Administrators, Hellenic Police
Pre-conditions	● The system is in a state ready to run the cascading effects simulation.
Post-conditions	● Successful: The cascading effects simulation runs successfully. ● Unsuccessful: Technical issues prevent the simulation, or data is incomplete or inaccurate.
Dependencies from other functionalities/steps	● Users need to be logged in (UC-MGM-01) ● User has initiated simulation (UC-DS-ATH-A-3)
Basic Flow	1. System processes the inputted data. 2. Runs a simulation of potential cascading effects on transportation, energy grids, pollution, and utilities.
Alternate path	None
Exceptions	● Data is missing or inaccurate. ● Technical issues prevent the simulation.

Identifier	**UC-DS-ATH-A-5**
Name	Stakeholders Receive Simulation Insights and Decision Support
Description	This use case involves stakeholders (members and observers) reviewing the decision support insights and analysis provided by the PANTHEON system based on the completed cascading effects simulation.
Actors	Hellenic Police, Attica Earthquake Scenario Members
Goals	To allow stakeholders to comprehend and utilize the simulation insights for decision-making.
Stakeholders	Hellenic Police, System Administrators, Collaborating Greek First Responders, Greek National Centre of Emergency Assistance, Greek Volunteer Organisations
Pre-conditions	● The cascading effects simulation has been successfully completed. ● Relevant data logs from the simulation are available in the PANTHEON system.
Post-conditions	● Successful: Stakeholders receive and comprehend the simulation insights. ● Unsuccessful: Stakeholders encounter issues accessing or understanding the provided insights.
Dependencies from other functionalities/steps	● Stakeholders need to be logged in (UC-MGM-01) ● Simulation has finished (UC-DS-ATH-A-4)
Basic Flow	1. Stakeholders navigate to the cascading effects simulation results section. 2. System presents a comprehensive analysis of the simulated cascading effects, including potential earthquake impacts on infrastructure, population, and critical facilities, offers recommendations for prioritising resource allocation to areas most affected by the

	earthquake and offers recommendations for safe evacuation routes identified for affected areas. 3. Stakeholders review decision support insights and recommendations.
Alternate path	None
Exceptions	● Technical issues prevent access. ● Stakeholders face challenges in comprehending the insights.

Identifier	**UC-DS-VIE-A-1**
Name	User Sets Up Heatwave Simulation
Description	This use case involves a JOH employee configuring parameters for the heatwave simulation.
Actors	JOH Employee
Goals	To allow users to customize simulation parameters for realistic heatwave scenarios.
Stakeholders	JOH Employee, System Administrators
Pre-conditions	● The user is logged into the PANTHEON system and has access to the simulation dashboard.
Post-conditions	● Successful: Simulation parameters are configured as per user input. ● Unsuccessful: Technical issues prevent the configuration process.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01)
Basic Flow	1. JOH employee navigates to the simulation setup section. 2. Defines parameters such as heatwave intensity and duration. 3. Submits the configured parameters to the system.
Alternate path	None
Exceptions	● Technical issues prevent the completion of the setup process.

Identifier	**UC-DS-VIE-A-2**
Name	User Inputs Organization's Assets
Description	This use case involves a JOH employee entering and providing essential information regarding their organization's assets into the PANTHEON system. The assets inputted are crucial for the realistic representation of available resources during the heatwave simulation.
Actors	JOH Employee
Goals	To capture and incorporate accurate data on the organization's assets to enhance the realism of the heatwave simulation.
Stakeholders	JOH Employee, Shift coordinators, human resources managers, volunteer coordinators, command center employees
Pre-conditions	● The user is logged into the PANTHEON system and has access to the simulation dashboard.

	• Simulation parameters, such as heatwave intensity and duration, are configured.
Post-conditions	• Successful: The system stores and integrates the inputted data on the organization's assets for use in the heatwave simulation. • Unsuccessful: Technical issues or user errors prevent the successful input and storage of asset data.
Dependencies from other functionalities/steps	• User need to be logged in (UC-MGM-01) • Successful configuration of simulation parameters (UC-DS-VIE-A-1)
Basic Flow	1. JOH employee navigates to the asset input section within the simulation setup. 2. Inputs information such as the type and quantity of vehicles, equipment, personnel, and other relevant assets. 3. Submits the entered data to the system. 4. The system validates and stores the asset information for utilization in the upcoming simulation.
Alternate path	None
Exceptions	• Technical issues prevent the successful storage of asset data. • User provides incomplete or inaccurate information.

Identifier	**UC-DS-VIE-A-3**
Name	User Initiates Simulation
Description	This use case involves a JOH employee starting the heatwave simulation based on the configured parameters.
Actors	JOH Employee
Goals	To initiate the simulation based on the user-defined parameters.
Stakeholders	JOH Employee, Shift coordinators, human resources managers, volunteer coordinators, command center employees
Pre-conditions	• Simulation parameters are successfully configured. • The user is logged into the PANTHEON system and has access to the simulation dashboard.
Post-conditions	• Successful: The simulation is initiated, and the system begins processing the scenario. • Unsuccessful: Technical issues prevent the initiation of the simulation.
Dependencies from other functionalities/steps	• User need to be logged in (UC-MGM-01) • User has inputted simulation parameters (UC-DS-VIE-A-1) • User has inputted her organisation's assets (UC-DS-VIE-A-2)
Basic Flow	1. JOH employee navigates to the simulation initiation section. 2. Initiates the heatwave simulation. 3. System processes configured parameters and starts the simulation.
Alternate path	None

Exceptions	• Technical issues prevent the initiation of the simulation.

Identifier	**UC-DS-VIE-A-4**
Name	System Runs Cascading Effects Simulation
Description	This use case involves the PANTHEON system running a simulation of the heatwave scenario and predicting cascading effects based on the received parameters organisation assets data.
Actors	PANTHEON System
Goals	To simulate potential cascading effects and assess their impact on critical infrastructures.
Stakeholders	System Administrators, Shift coordinators, human resources managers, volunteer coordinators, command center employees
Pre-conditions	• The system is in a state ready to run the cascading effects simulation.
Post-conditions	• Successful: The cascading effects simulation runs successfully. • Unsuccessful: Technical issues prevent the simulation, or data is incomplete or inaccurate.
Dependencies from other functionalities/steps	• Users need to be logged in (UC-MGM-01) • User has initiated simulation (UC-DS-VIE-A-3)
Basic Flow	1. System processes the inputted data. 2. Runs a simulation of potential cascading effects on transportation, energy grids, pollution, and utilities.
Alternate path	None
Exceptions	• Data is missing or inaccurate. • Technical issues prevent the simulation.

Identifier	**UC-DS-VIE-A-5**
Name	Analysis of Simulation Outcomes
Description	This use case involves users analyzing the outcomes of the heatwave resource management simulation to identify resource requirements and potential areas for improvement.
Actors	JOH employees, Vienna Heatwave Scenario members
Goals	To review simulation results and identify resource requirements and potential areas for improvement in emergency response planning.
Stakeholders	JOH Employees, Shift coordinators, human resources managers, volunteer coordinators, command center employees
Pre-conditions	• User has logged into the PANTHEON system. • Simulation process has been successfully finished.
Post-conditions	• Successful: Simulation outcomes are analysed to inform resource planning and management. • Unsuccessful: Technical issues prevent accessing the simulation results

Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01) ● Simulation has finished successfully (UC-DS-VIE-A-4)
Basic Flow	1. Users review simulation results, including resource usage, response times, and potential bottlenecks. 2. Users identify resource requirements based on simulation outcomes. 3. Users propose adjustments to resource allocation and emergency response plans based on simulation insights.
Alternate path	None
Exceptions	● System downtime prevents access to the simulation results ● Inaccurate or incomplete simulation data leads to incorrect analysis and decision-making.

Identifier	**UC-DS-VIE-B-1**
Name	Members Input Scenario Parameters
Description	Members input parameters and data into the PANTHEON system to define the characteristics of the man-made disaster scenario.
Actors	JOH members
Goals	Define scenario characteristics for simulation.
Stakeholders	JOH members, Vienna Training Exercise Observers
Pre-conditions	● The user is logged into the PANTHEON system and has access to the training simulation dashboard.
Post-conditions	● Successful: Scenario parameters inputted into the system. ● Unsuccessful: Technical issues prevent the initiation of the simulation.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01)
Basic Flow	1. User accesses the scenario planning interface within the PANTHEON system. 2. User inputs parameters such as geographical location and weather conditions. 3. User verifies the accuracy and completeness of the input data. 4. User submits the scenario parameters to the PANTHEON system for further processing.
Alternate path	If the user encounters missing or incomplete data, they may need to seek additional information from external sources or consult with other stakeholders to complete the scenario parameters.
Exceptions	● If there are technical issues or system errors during the input process, users may need to retry the input or seek assistance from technical support to resolve the issue. ● If there are disagreements among stakeholders regarding certain scenario parameters, users may need to facilitate discussions or negotiations to reach consensus on the input data.

Identifier	UC-DS-VIE-B-2
Name	Members Input Organisation Assets
Description	Members input organisation assets into the PANTHEON system to define the characteristics of the man-made disaster scenario.
Actors	JOH members
Goals	Define organisation assets for simulation.
Stakeholders	JOH members, Vienna Training Exercise Observers
Pre-conditions	● The user is logged into the PANTHEON system and has access to the training simulation dashboard.
Post-conditions	● Successful: Organisation assets inputted into the system. ● Unsuccessful: Technical issues prevent the initiation of the simulation.
Dependencies from other functionalities/steps	● User need to be logged in (UC-MGM-01) ● Successful configuration of simulation parameters (UC-DS-VIE-B-1)
Basic Flow	1. User accesses the scenario planning interface within the PANTHEON system. 2. Inputs information such as the type and quantity of vehicles, equipment, personnel, and other relevant assets. 3. User verifies the accuracy and completeness of the input data. 4. User submits the scenario parameters to the PANTHEON system for further processing.
Alternate path	If the user encounters missing or incomplete data, they may need to seek additional information from external sources or consult with other stakeholders to complete the scenario parameters.
Exceptions	● If there are technical issues or system errors during the input process, users may need to retry the input or seek assistance from technical support to resolve the issue. ● If there are disagreements among stakeholders regarding certain scenario parameters, users may need to facilitate discussions or negotiations to reach consensus on the input data.

Identifier	UC-DS-VIE-B-3
Name	Members Initiate Simulation
Description	Involves a JOH member starting the cyber-attack/wildfire response training simulation based on the configured parameters.
Actors	JOH members
Goals	To initiate the simulation based on the user-defined parameters for training purposes.
Stakeholders	JOH members, Vienna Training Exercise Observers
Pre-conditions	● Simulation parameters are successfully configured. ● The user is logged into the PANTHEON system and has access to the training simulation dashboard.
Post-conditions	● Successful: The simulation is initiated, and the system begins processing the scenario.

	• Unsuccessful: Technical issues prevent the initiation of the simulation.
Dependencies from other functionalities/steps	• User need to be logged in (UC-MGM-01) • User has inputted simulation parameters (UC-DS-VIE-B-1) • User has inputted organisation's assets (UC-DS-VIE-B-2)
Basic Flow	1. JOH member navigates to the simulation initiation section. 2. Initiates the cyber-attack/wildfire response training simulation. 3. System processes configured parameters and starts the simulation.
Alternate path	None
Exceptions	• Technical issues prevent the initiation of the simulation.

Identifier	**UC-DS-VIE-B-4**
Name	System Runs Cascading Effects Simulation
Description	This use case involves the PANTHEON system running a real-time simulation of the disaster and predicting cascading effects based on the wildfire scenario and the received critical infrastructure data.
Actors	PANTHEON System
Goals	To simulate potential cascading effects and assess their impact on critical infrastructures.
Stakeholders	JOH members, Vienna disaster management teams, Vienna city planners, all mentioned in the relevant disaster scenario.
Pre-conditions	• Users have successfully inputted updated data on critical infrastructures. • The system is in a state ready to run the cascading effects simulation.
Post-conditions	• Successful: The cascading effects simulation runs successfully. • Unsuccessful: Technical issues prevent the simulation, or data is incomplete or inaccurate.
Dependencies from other functionalities/steps	• Users need to be logged in (UC-MGM-01) • Users have initiated the training simulation (UC-DS-VIE-B-3)
Basic Flow	1. System processes the inputted data on critical infrastructures. 2. Runs a real-time simulation of potential cascading effects on transportation, energy grids, pollution, and utilities. 3. Considers dynamic factors such as weather changes and terrain characteristics.
Alternate path	None
Exceptions	• Data is missing or inaccurate. • Technical issues prevent the simulation.

Identifier	**UC-DS-VIE-B-5**
Name	Stakeholders Receive Simulation Insights and Decision Support

Description	This use case involves stakeholders (members and observers) reviewing the decision support insights and analysis provided by the PANTHEON system based on the completed cascading effects training simulation.
Actors	JOH members, Vienna Training Exercise Observers
Goals	To allow stakeholders to comprehend and utilize the simulation insights for decision-making.
Stakeholders	JOH members, Vienna Training Exercise Observers
Pre-conditions	● The cascading effects simulation has been successfully completed. ● Relevant data logs from the simulation are available in the PANTHEON system.
Post-conditions	● Successful: Stakeholders receive and comprehend the simulation insights. ● Unsuccessful: Stakeholders encounter issues accessing or understanding the provided insights.
Dependencies from other functionalities/steps	● Stakeholders need to be logged in (UC-MGM-01) ● Simulation and cascading effects analysis has finished (UC-DS-VIE-B-4)
Basic Flow	1. Stakeholders navigate to the cascading effects simulation results section. 2. System presents a comprehensive analysis of the simulated cascading effects, highlights key takeaways, successful strategies, and areas for improvement and offers suggestions for future preventive measures and resource allocation. 3. Stakeholders review decision support insights and recommendations.
Alternate path	None
Exceptions	● Technical issues prevent access. ● Stakeholders face challenges in comprehending the insights.

5. User Requirements

From [11] the design recommendations by stakeholders and end-users for the PANTHEON system have been extracted and summarized. These recommendations have been created after workshops with relevant stakeholders, with the methodology and the results of this research effort being described in more detail in the deliverable. For conciseness, the design recommendations or user requirements for the specific applications that PANTHEON is focusing on (applications A and B) have been added and indexed in Table 8.

Table 8: Catalogue of design recommendations for PANTHEON.

ID	Title	Description
General Design Recommendations (to be considered for all application options)		
UR-GEN-01	Community organisations	Locations of local NGOs, sports clubs and cultural institutions should be available and visible within the SCDT, as they might serve as useful contact points to the local community and could be able to provide a space that can be used for building emergency structures during disaster response operations.
UR-GEN-02	Data of buildings	PANTHEON should contain data of buildings on: Number of flats, floors and residents. Businesses, their employees and working times. Building fabric and entries. Further building plans could be embedded within the system, if available.
UR-GEN-03	Embedding documents	An option to embed documents within the SCDT. Therefore, building plans, emergency plans or other documents can be added to specific buildings and places, if available.
UR-GEN-04	Filtering	Both automatic and manual filters are very important to enable usability and usefulness. The vast amounts of data should not overwhelm the operators, while leaving them the option to take all data into account.
UR-GEN-05	Integrate all relevant emergency actors	The system to be developed by the PANTHEON consortium should identify and integrate all relevant emergency management actors present in the pilot region, considering both professionals and local communities.
UR-GEN-06	Legislative specifics and flexibility	The system should be adapted to the emergency plans and legislation in force in the region. However, there should be some flexibility to allow for solutions that are not covered by emergency plans, as long as this does not lead to serious breaches of law and order.
UR-GEN-07	Manual adaptability of incident data	The operator has to be able to add incidents, change times, change locations and other variable values.
UR-GEN-08	Standard interfaces	The use of normed standard interfaces is very important. There are many systems already being used by emergency organisations and these have to be able to communicate or exchange data. Also, data import and export should be as easy as possible by using standard interfaces.
UR-GEN-09	Uniform language	Clear and precise wordings and professional jargon have to be used, that are understood by all operators and emergency organisations. (Standardized vocabularies should be used, if available)

UR-GEN-10	User-friendliness	The system should be easy to use and not require significant technical or scientific expertise from the operator's side.
	Application A: Planning and early warning according to simulations	
UR-A-01	Inclusion of local communities in emergency plan development	It is recommended to include the affected local communities when creating disaster response plans according to simulations within their area. This way, local knowledge can be integrated in the plans and community members can be sensitized and empowered in the process. It is also recommended to include vulnerable groups to address their individual needs during planning.
UR-A-02	Informing citizens	Informing citizens about potential risks and emergencies is a fundamental right, and PANTHEON should thus integrate the necessary means of communication to reach as many people as possible. This communication should further include plans on how to address vulnerable groups.
UR-A-03	Prioritisation of action	According to simulation and modelling, the system might suggest a prioritisation of actions to be taken according to calculations of probable consequences (e.g., in order to bypass cascades). While this should just be supportive information without any compulsion to act accordingly, it could point to measures that otherwise might get lost or undervalued.
UR-A-04	Size detection of spaces	The system should be able to detect on-site spaces according to their size. This will lead to the quick identification of the right sites to designate and build structures (for example 25m x 25m for a helipad). There could be a set of predefined structures and their respective sizes, where suitable sites can be identified, while leaving the option to change dimension requirements.
UR-A-05	Socio-demographic data	For operations, information on the quantity as well as the quality of affected people is of high relevance. For example, the evacuation efforts are very different for a student's home and an old people's home. Therefore, socio-demographic data on population in the area might be of high importance.
UR-A-06	Warning notices for vulnerabilities	(Automatically) mark vulnerable buildings (schools, hospitals, old people homes, etc.) with according warning messages. For this, week days and day times should be factored in to draw an accurate picture of vulnerability.
	Application B: Training and exercises	
UR-B-01	Defining zones	The operators of the system should be able to mark and define zones with polygons. These should include danger zones (red, yellow, green) or also defined areas for specific purposes (e.g., patient collection, staging areas for ambulances or firefighter).
UR-B-02	Embedding instructions	For specific hazards and locations, behavioural or safety instructions should be embedded in those areas.
UR-B-03	Levels of permission	As soon as different command levels and different organisations are working with the system, there have to be different levels of permission that regulate the scope of competencies within the system. It may for example define the data and information that one can see, import, export, modify and adapt and also differences in their display.

		Since organizational structures may differ between countries, the definition of permission structures may be individually adaptable by organisation's admins.
UR-B-04	Marking resources	Function to mark resources (units, vehicles, personnel etc.) within the SCDT.
UR-B-05	No decision-making	The system should support operators by providing information but should not make the decisions for them.
UR-B-06	Parallelism of operations	When adding/depicting emergency operations within PANTHEON, it has to be clear that those do not follow strict chronology. Operations are happening in parallel in different organisations and on different levels. This has to be reflected.
UR-B-07	Prioritisation of action	According to simulation and modelling, the system might suggest a prioritisation of actions to be taken according to calculations of probable consequences (e.g., in order to bypass cascades). While this should just be supportive information without any compulsion to act accordingly, it could point to measures that otherwise might get lost or undervalued.
UR-B-08	Size detection of spaces	The system should be able to detect on-site spaces according to their size. This will lead to the quick identification of the right sites to designate and build structures (for example 25m x 25m for a helipad). There could be a set of predefined structures and their respective sizes, where suitable sites can be identified, while leaving the option to change dimension requirements.
UR-B-09	Socio-demographic data	For operations, information on the quantity as well as the quality of affected people is of high relevance. For example, the evacuation efforts are very different for a student's home and an old people's home. Therefore socio-demographic data on population in the area might be of high importance.
UR-B-10	Time-stamps	When items (zones, resources etc.) or data is added to the SCDT, they should receive a time-stamp for better traceability.
UR-B-11	Usable infrastructure on-site	Identify (ideally public) spaces and buildings in or next to the incident area, that can be used to build structures with low efforts.
UR-B-12	Warning notices for vulnerabilities	(Automatically) mark vulnerable buildings (schools, hospitals, old people homes, etc.) with according warning messages. For this, week days and day times should be factored in to draw an accurate picture of vulnerability.
UR-B-13	Zooming in and out	When zooming in and out using the SCDT, marked elements (like zones or resources) on the map should neither change their size nor their place.

6. CONCLUSIONS

This Deliverable elaborates the selection process of disaster and usage scenarios along with their respective use cases and their refinement for usage by the technical partners of the project to enable them to formulate system specifications and the design of the high-level reference architecture of PANTHEON.

Specifically, the work done was based on the regulatory framework in the under-study regions (T2.1), the hazards analysis based on literature (T2.2), the community characteristics and capacities (T.2.3), the ethical and legal considerations (T3.5), the feedback of stakeholders based on guidelines for participatory governance (T2.5, T2.6 and T3.2), the technical capabilities and the preliminary technical designs (T2.4, T3.1, T3.3 and T3.4).

An iterative approach was followed to prioritise specific hazards based on several criteria derived from the results of four two-hour (2h) workshops with technical and end-user organisations. To arrive at the specific criteria for selecting the disaster and usage scenarios for PANTHEON, the iterative approach relied on the previous work done in T2.1 (*suitable regulatory and operational framework)*, T2.2 (*high-risk hazards)*, T2.3 (*community characteristics and capacities*), T3.5 (*ethical and legal considerations*), T2.4-T3.1-T3.3-T3.4 (*technical feasibility*) and T3.2-T2.5-T2.6 (*selection of disasters based on potential applications from stakeholders)*. Based on the previous criteria and after an iterative process, the technical partners along with the pilot representatives formulated the definition of the following disasters and potential applications (two for Athens and two for Vienna) to be piloted.

For Athens, the first disaster to be piloted is a wildfire with potential application B, meaning PANTHEON should facilitate training and exercises to foster readiness of first responders when a wildfire happens in the metropolitan area of Athens. The second disaster scenario is an earthquake with potential application A, meaning PANTHEON should provide planning and early warning according to simulations of an earthquake happening in the metropolitan area of Athens.

For Vienna, the first disaster to be piloted is a heatwave with potential application A, meaning PANTHEON should provide planning and early warning tools with simulations of heatwaves happening in the metropolitan area of Vienna. The second pilot scenario will simulate the cascading-effects resulting from a cyber-terrorism attack with potential application B, meaning PANTHEON should bolster training and exercise of diverse disaster relief forces working together.

The disaster scenarios were further elaborated into storylines with the end-users at the spotlight (usage scenarios) which led to the formulation of specific functional steps (use cases). These will allow the technical partners in T3.7 to establish system specifications and the definition of the high-level reference architecture.

Finally, the user requirements emanating from D3.2 were further clarified and used to adapt the currently defined disaster and usage scenarios.

7. REFERENCES

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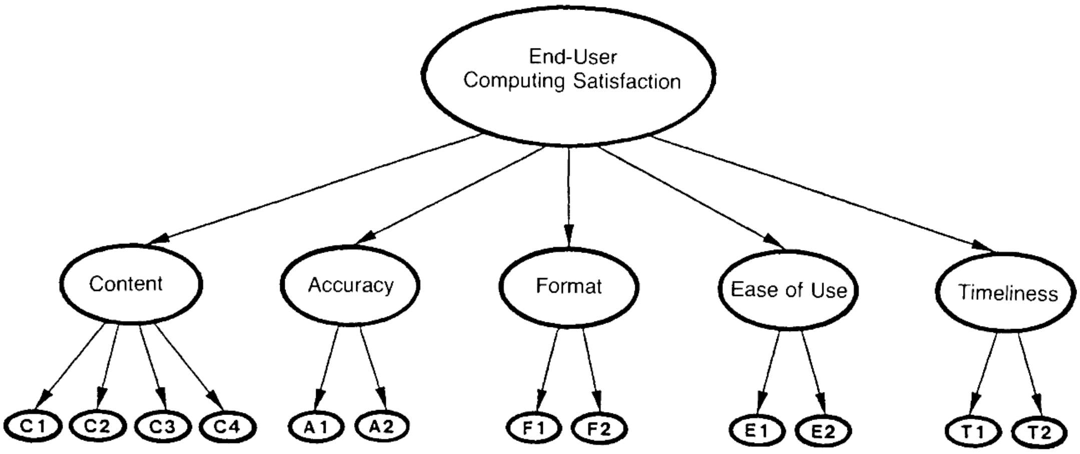
8. APPENDIX

8.1. APPENDIX I – MODEL FOR MEASURING END-USER COMPUTING SATISFACTION



CONTENT

C1: Does the system provide the precise information you need?
C2: Does the information content meet your needs?
C3: Does the system provide reports that seem to be just about exactly what you need?
C4: Does the system provide sufficient information?

ACCURACY

A1: Is the system accurate?
A2: Are you satisified with the accuracy of the system?

FORMAT

F1: Do you think the output is presented in a useful format?
F2: Is the information clear?

EASE OF USE

E1: Is the system user friendly?
E2: Is the system easy to use?

TIMELINESS

T1: Do you get the information you need in time?
T2: Does the system provide up-to-date information?

Figure 30 Model for measuring end-user computing satisfaction [16].

The evaluation is conducted using a five-point Likert scale:

- Almost never
- Some of the time
- About half of the time
- Most of the time
- Almost always

8.2. APPENDIX II – THE POST-STUDY SYSTEM USABILITY QUESTIONNAIRE (PSSUQ)

Administration and Scoring. Give the PSSUQ to participants after they have completed all the scenarios in a usability study. You can calculate four scores from the responses to the PSSUQ items: the overall satisfaction score (OVERALL), system usefulness (SYSUSE), information quality (INFOQUAL), and interface quality (INTERQUAL).

Table A1. Rules for Calculating CSUQ/PSSUQ Scores

Score Name	Average the Responses to
OVERALL	Items 1–19
SYSUSE	Items 1–8
INFOQUAL	Items 9–15
INTERQUAL	Items 16–18

Instructions and Items. The PSSUQ items use the same format as that shown for the ASQ. The questionnaire's instructions and items follow. Average (with the arithmetic mean) the scores from the three items to obtain the ASQ score for a participant's satisfaction with the system for a given scenario. Low scores are better than high scores due to the anchors used in the 7-point scales. If a participant does not answer an item or marks N/A, average the remaining items to obtain the ASQ score.

1. Overall, I am satisfied with the ease of completing the tasks in this scenario.

strongly agree <———————————> strongly disagree
1 2 3 4 5 6 7 N/A

Comments:

2. Overall, I am satisfied with the amount of time it took to complete the tasks in this scenario.

strongly agree <———————————> strongly disagree
1 2 3 4 5 6 7 N/A

Comments:

3. Overall, I am satisfied with the support information (on-line help, messages, documentation) when completing the tasks.

strongly agree <———————————> strongly disagree
1 2 3 4 5 6 7 N/A

Comments:

This questionnaire gives you an opportunity to tell us your reactions to the system you used. Your responses will help us understand what aspects of the system you are particularly concerned about and the aspects that satisfy you. To as great a degree as possible, think about all the tasks that you have done with the system while you answer these questions. Please read each statement and indicate how strongly you agree or disagree with the statement by circling a number on the scale. If a statement does not apply to you, circle N/A. Please write comments to elaborate on your answers. After you have completed this questionnaire, I'll go over your answers with you to make sure I understand all of your responses. Thank you!

1. Overall, I am satisfied with how easy it is to use this system.
2. It was simple to use this system.
3. I could effectively complete the tasks and scenarios using this system.
4. I was able to complete the tasks and scenarios quickly using this system.
5. I was able to efficiently complete the tasks and scenarios using this system.
6. I felt comfortable using this system.
7. It was easy to learn to use this system.
8. I believe I could become productive quickly using this system.
9. The system gave error messages that clearly told me how to fix problems.
10. Whenever I made a mistake using the system, I could recover easily and quickly.
11. The information (such as on-line help, on-screen messages, and other documentation) provided with this system was clear.
12. It was easy to find the information I needed.
13. The information provided for the system was easy to understand.
14. The information was effective in helping me complete the tasks and scenarios.
15. The organization of information on the system screens was clear.
16. The interface of this system was pleasant.
17. I liked using the interface of this system.
18. This system has all the functions and capabilities I expect it to have.
19. Overall, I am satisfied with this system.

8.3. Appendix III – System Usability Scale (SUS) questionnaire

Using SUS

The SU scale is generally used after the respondent has had an opportunity to use the system being evaluated, but before any debriefing or discussion takes place. Respondents should be asked to record their immediate response to each item, rather than thinking about items for a long time.

All items should be checked. If a respondent feel that they cannot respond to a particular item, they should mark the centre point of the scale.

Scoring SUS

SUS yields a single number representing a composite measure of the overall usability of the system being studied. Note that scores for individual items are not meaningful on their own.

To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1,3,5,7, and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU.

SUS scores have a range of 0 to 100.

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

8.4. Appendix IV – Interview guide

General questions: elicit roles, task goals, & setting

- What is your position?
- Describe your different roles in the [*insert name of the organisation the participant belongs to*].
- What are your key tasks and priorities?
- Who are your key collaborators?

Questions related to current system use: scenarios & claims

- Describe your scenarios of use of the PANTHEON system.
- How do scenarios of use contribute to the mission of the [*insert name of the organisation the participant belongs to*]
- What information and functions of the PANTHEON system do you find most useful/ least useful?
- How does the PANTHEON system support collaboration across different [*insert name of the organisation the participant belongs to*] roles and functions?
- What sort of manual information management processes are not supported by the PANTHEON?

Questions related to prospective system use:

- What information needs are not currently being met by the PANTHEON system?
- How could any of these unmet information needs be met by the PANTHEON system?
- Describe some work scenarios you would like supported by the PANTHEON system in the future.

8.5. APPENDIX V – OPEN QUESTIONS

Q1. How do you assess the quality of the interaction with the PANTHEON Digital Twin?

1. Very poor
2. Poor
3. Acceptable
4. Good
5. Very Good

Comments:

Q2. How do you rate the relevance of the data provided by the PANTHEON Digital Twin?

1. Very irrelevant
2. Irrelevant
3. Neutral
4. Relevant
5. Very relevant

Comments:

Q3. How do you rate the Graphic User Interface used to represent data in the PANTHEON Digital Twin?

1. Very poor
2. Poor
3. Acceptable
4. Good
5. Very good

Comments:

Q4. What are the main strengths of the PANTHEON Digital Twin?

Q5. What are the main weaknesses of the PANTHEON Digital Twin?

Q6. Can you think of any additional features to be included in the PANTHEON Digital Twin?

Q7. Would you like to include other types of data in the PANTHEON Digital Twin?