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Search & Rescue

Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations

D4.3 Design of SOT DSS components

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Partners

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	ENOSI PTYCHIOYCHON AXIOMATIKON YPAXIOOMATIKON PYROSVESTIR OY SOMATEIO (EPAYPS)	Greece
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Executive Summary

This document aims to identify and design the SOT decision support tool. This DSS module will be used in the S&R operations for real-time resource allocation following the strategic, operational and tactical level of decision making in crisis situations.

The DSS component is designed in order to address the following services:

- Recommended (optimal) allocation of available EMS units to incidents, depending on estimated needs
- Recommended (optimal) allocation of patients to transport vehicles and first receivers (hospitals), based on given order of evacuation and triage results for present injuries
- Recommended (optimal) allocation of tasks to available actors on the field, given demand pre-defined by the field commander.
- Estimation of expected casualties and demanded resources (EMS units), given historical data on emergency incident recordings

As an outcome, "D4.3 Design of SOT DSS components" provides:

- The design specifications of the Decision Support System in strategic, operational and tactical levels
- The services of DSS and the implementation methodology
- The overall technical approach for the design of SOT DSS services

A second attempt will be held in "D4.9 Design of SOT DSS component, V2" at M22, in order to enhance and fulfil the design of the SOT DSS component that will guarantee the smooth management of resources in a real crisis situation and help the First Responders to make fast and accurate decisions during the disaster responses.

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1 Introduction

1.1 Objectives

The aim of D4.3 is the description of the design of the DSS components which are necessary to guarantee an efficient resource allocation during the emergency operation. The DSS modules are designed to address the following three levels of decision making in crisis situations:

1. Strategic Level (allocation of resources, interoperability with different countries)
2. Operational Level (communication among organizations, planning and data warehousing, logistic models)
3. Tactical Level (ambulance, field teams, EU modules, Physiological status, communication protocols, transmission of medical patient data)

The first attempt is focused on the implementation of an effective SOT Decision Support System in order to support users on decision-making procedures through designed models of linear programming. As a next step, D4.9 – 'Design of SOT DSS components, V2' will further extend the functionality and the reliability of the models, utilizing more data and validating the results.

1.2 Scope of SOT DSS Components in the S&R project

During a crisis, First Responders have to make fast and accurate decisions. The large amount of data coming from various sources of the field are impossible to be handled during an emergency situation. The S&R project aims to improve the management of a crisis with better and more efficient decision-making. For this reason, SOT DSS should be an effective management system to allocate the resources where they are needed.

The aim of the design of the SOT Decision Support System is to support the users regarding the decision-making procedures. The functionalities of the SOT DSS are:

- **Service 1,** recommendation of the most efficient allocation of resources to incidents,
- **Service 2,** recommendation of the most efficient allocation of patients to hospitals using optimization techniques,
- **Service 3,** recommendation of allocation of tasks to available actors on the field, given demand pre-defined by the field commander
- **Service 4,** the estimation of casualties during the incident using Machine Learning Algorithms.

The SOT DSS will be a data and model-driven DSS that utilizes historical and real-time data to achieve the goals above.

The final scope of SOT DSS is to give the capability of simulations to the user scenarios in order to have realistic decisions based on the needs of the incidents and the existing information about the resources. The ultimate goal of the SOT DSS is to be able to give fast and accurate decisions in a time of crisis.

The first version of SOT DSS will have the actual techniques which will be used in its second version. As a result, the present document aims to present the overall architecture of the SOT components and the initial functionalities which will be enriched during the S&R project.

1.3 Relationship with Other Documents

The current deliverable is the preliminary document addressing the design of the SOT DSS components. The document provides inputs to other S&R components, therefore is linked to the following deliverables:

- D3.1 Requirements to knowledge management and SA Model
- D3.7 Requirements to knowledge management and SA Model, V2
- D4.1 Data aggregation
- D4.2 Situational Analysis & Impact Assessment
- D4.4 Design of PHYSIO DSS component
- D4.5 Development of SOT DSS component
- D4.8 Data aggregation, V2
- D4.9 Design of SOT DSS components, V2
- D4.10 Design of PHYSIO DSS component, V2
- D4.11 Development of SOT DSS component, V2
- D4.12 Development of PHYSIO DSS component, V2
- D7.2 Architecture and Design Specifications of S&R platform
- D7.3 Component interface specifications for interoperability within S&R
- D7.4 Adapted S&R components and services

1.4 List of Abbreviations

Abbreviation	Explanation
API	Application Programming Interface
APP	Application
D	Deliverable
DSS	Decision Support System
EMS	Emergency Medical Services
EU	European Union
ICAO	International Civil Aviation Organization
GPS	Global Positioning System
NOAA	National Oceanic and Atmospheric Administration
PSAP	Public safety answering point
SA	Situation Awareness
S&R	Search & Rescue
SOT	Strategic Operational and Tactical
UC	Use Case
US	United States

Table 1-1: List of Abbreviations

2 Functionality Description of the SOT DSS Components

2.1 Scope of the Decision Support System

A “Decision Support System” (DSS) is an interactive computer-based system or subsystem intended to help decision-makers use communications technologies, data, documents, knowledge, and/or models to identify and solve problems, complete decision process tasks, and make decisions [1]. There are five main categories of Decision Support Systems [2]:

1. Communication-driven
2. Data-driven
3. Document-driven
4. Knowledge-driven
5. Model-driven

Communications-driven DSS use network and communications technologies to facilitate decision-relevant collaboration and communication. In these systems, communication technologies are the dominant architectural component.

Another approach is a data-driven DSS which highlights access to and manipulation of internal data and sometimes external and real-time data. By given to a Data-Driven DSS the functionality of On-line Analytical Processing [3], can provide the decision support that is linked to the analysis of large collections of historical data. Executive Information Systems are examples of data-driven DSS [2]. Initial examples of these systems were called data-oriented DSS, Analysis Information Systems [4] and retrieval-only DSS by Bonczek, Holsapple and Whinston (1981) [5].

Also, there is the document-driven DSS which utilizes computer storage and processing technologies in order to make easier and manageable the document recovery and analysis. It is focused on the recovery and management of unstructured documents by searching for keywords. These could be large document databases that may contain scanned documents, hypertext documents, images, sounds and video. Examples of documents that might be accessed by a document-driven DSS are policies and procedures, product specifications and historical documents. A search engine is a primary decision-aiding tool related to a document-driven DSS [2].

In addition, a knowledge-driven DSS can suggest or recommend actions to managers [6]. These DSS use person-computer systems with particular problem-solving expertise. The "expertise" consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems [2]. The decisions provided by a knowledge-driven DSS are aided by facts, rules, and procedures based on similar problems. These systems have been entitled suggestion DSS [4] and knowledge-based DSS [7]. Goul, Henderson, and Tonge (1992) [8] examined Artificial Intelligence (AI) contributions to DSS.

Last but not least, there is the model-driven DSS which emphasizes to optimization and/or simulation models. Quantitative models provide the simplest level of functionality to solve semi-structured problems. Model-driven DSS use limited data and parameters provided by decision-makers to aid decision-makers in examining an occasion, but in general large databases are not needed for model-driven DSS [2]. Early versions of model-driven DSS were called model-oriented DSS by Alter (1980), computationally-oriented DSS by Bonczek, Holsapple and Whinston (1981) [5] and later spreadsheet-oriented and solver-oriented DSS by Holsapple and Whinston (1996) [6].

2.1.1 Human Factor

Disaster management can face an emergency situation without any pre-sign and even if it has a prediction, they can meet the requirements of improvisation making their decision. Improvisation can be taken at any level of the management (strategic, operational, and tactical), but at the tactical level the time press is certainly the biggest problem [9]. In these situations, humans are typically confronted with severe threats, uncertainty, and time pressure [10].

A DSS provides helpful support to manage all these. First of all, the creation of a quick response plan helps the actors to avoid possible threats which maybe occurs from inexperience. Moreover, in difficult situations, the actors maybe feel uncertain about the correct response. Here, the DSS which is based on past similar situations can provide an accurate response plan to help with the decision making. It will help the users to be more confident in decision-making and also sharpen their perception [11]. Also, a quick response plan provided by DSS will help the actors to decrease the response time. Thus, the actors have more time to think about the best response actions.

However, a DSS could not be effective without considering the human factor. The DSS provides a possible response plan based on the occasion, but the users are those who choose and apply response actions. In this case, education and training are probably the most appropriate available solutions. Decision-making requires quick decisions to be effective. Time pressure puts a great strain on the human information processing system, which may affect the decision-making process. The actors fail to move quickly in order to mitigate the damage. The DSS should provide accurate information in order to help actors to make decisions during the time of the incident and also create the know-how for future incidents. This way, users can react quickly and effectively in future incidents. This process will also help in avoiding some human errors during the operation.

2.1.2 Failure factors of Decision Making

One of the biggest challenges in decision-making in crisis situations is the high pressure for the decision which might require accepting low precision information instead of losing valuable time to wait. Refusing to take decisions in the absence of reliable information can be regarded as an avoidable failure. The lack of reliable information is a major failure factor in responding particularly to a major crisis. Additionally, crisis management organizations sometimes face difficulties in sharing information with others, mainly due to legal or organizational/procedural constraints. In this respect, a failure factor in decision-making stems from challenges in coordinating and communicating with other actors.

Moreover, the lack of information from the incident and inadequate planning of the rescue plan (e.g., non-use of information about the situation) lead to bad decision making and consequently to failure of the rescue plan. Furthermore, insufficient training leads to insufficient knowledge of the procedures in a crisis. The actors will fail to act following regularly practiced and procedures. Thus, bad decisions are a common result in these situations. All these factors affect the quality of the rescue plan and must be taken into consideration in all procedures.

2.2 Use Cases of SOT DSS in S&R operations

The S&R's Decision Support System offers four Services. Three of the Services exploit optimisation techniques to recommend allocation of some supplied resources to relevant demand, while the last one predicts/estimates the number of casualties and the required resources in an emergency incident.

An important part of SOT DSS Services is to list the actors involved in each Service separately. First, Service 1 and Service 2 are addressed to the High Commander, Field Commander & PSAP. Service 3 can be used mainly by the Field Commander by creating polygons in the map, defining which task should be performed, and allocating the task to the available actors. Service 4 results can be accessible and visible to everyone but mainly are used by the High Commander.

Figure 1 shows the above description:

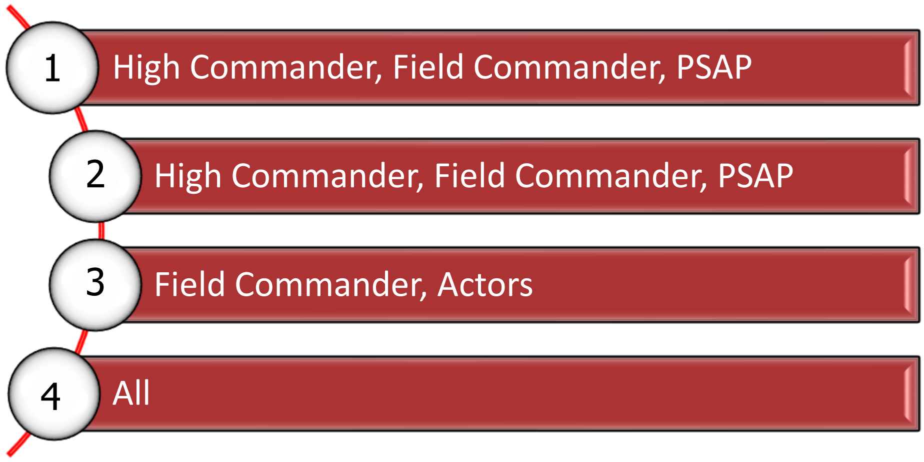

Figure 2-1: The end-users of the SOT DSS operations

2.3 The overall architecture of the SOT DSS Components

The SOT DSS includes four Services as it mentioned in chapter 1. Initially, there is a two-way communication between SOT DSS and COncORDE. COncORDE sends data to SOT DSS to execute its algorithms and send the results back to COncORDE. An abstract architecture behind the communication of other components in S&R project with SOT DSS is also described below.

The process starts when a component within S&R requests the necessary information from SOT DSS through COncORDE. Then, COncORDE calls SOT DSS, the latter runs its algorithms based on the requested information, and sends the results. Finally, COncORDE takes the information and sends it back to the requested component. Simultaneously, COncORDE requests the physiological state of the actors or patients from the PHYSIO DSS, required by the SOT DSS. In addition, SOT DSS communicates directly with external web services in order to get third-party information, for example, weather forecast.

Figure 2 shows the overall architecture described above.

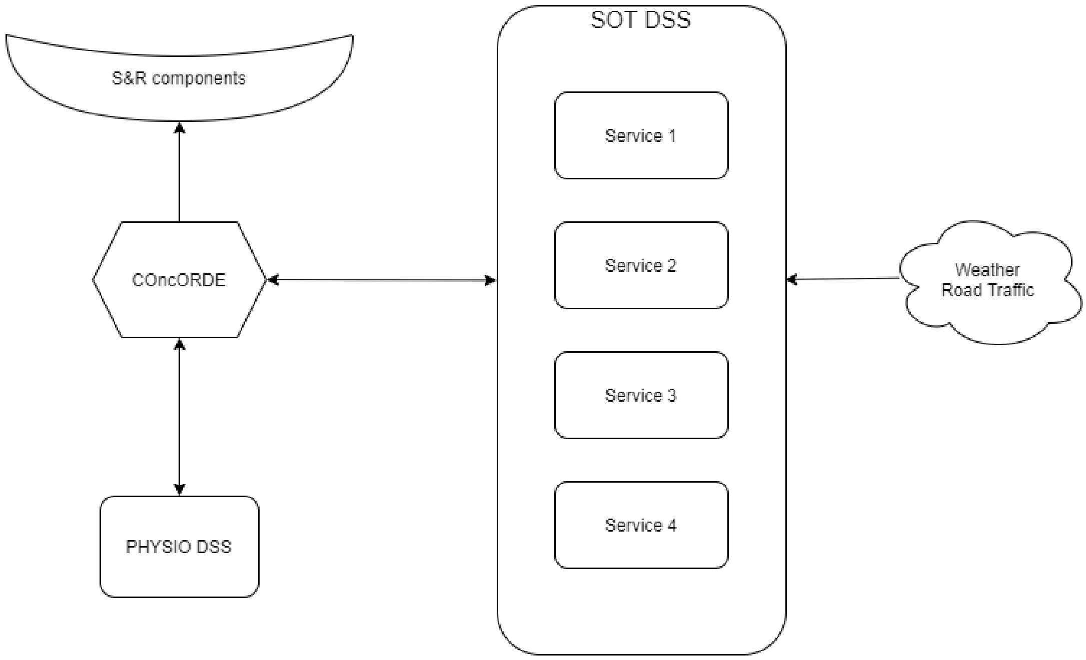

Figure 2-2: Overall Architecture of SOT DSS

This is an abstract and high-level architecture of the DSS's interconnection to other SnR components (and only), in order to place the DSS to SnR's technical perspective and probably will change in the future.

2.4 Proposed Methodology

Most of the SOT DSS services rely on Linear Programming (LP) techniques. Linear programming is a mathematical technique to achieve the best outcome in a mathematical problem by depicting the complex requirements of it through linear functions and then finding the optimum points.

In linear programming, a real-life problem is formulated into a linear mathematical model. It involves an objective function, linear inequalities or equations, subject to constraints. For the SOT DSS problem, LP is used for obtaining the most optimal solution for the three of four Services with given constraints. An analytical view of these is given in the next chapters.

The main steps to create and solve a LP problem are listed below:

1. **Identification of decision variables.** In this step, the decision variables will be defined. The decision variables are the variables that will decide the final output.
2. **Definition of the objective function.** The objective function is defined as the objective of making decisions. An objective function is a single scalar value that is formulated from a set of design responses. More generally, optimization includes finding the "best available" values of some objective function given a defined domain (or input), including a variety of different types of objective functions and different types of domains. Thus, the ultimate goal is to minimize or

maximize the value of objective function. For example, Service 1 model uses the *transportation problem* objective function which will be analyzed in the following chapters.

3. **Identification of constraints**. In this step, the analyst defines the restrictions of the problem. Every real-life problem has some restrictions. In LP, these restrictions are taken into consideration in the solution of the problem.
4. **Explicit state to the limitation of non-negativity.** In this step, it should be strictly modelled that the decision variables should always take non-negative values. This means the values for decision variables should be greater than or equal to 0.

In the linear programming problem, the decision variables, objective function, and constraints all have to be linear functions. When the above steps are completed, the LP problem can be solved using a LP solver tool.

3 External Inputs and SOT DSS Modules Description

3.1 Data sources

A Decision Support System receives data from a variety of sources. It is able to include data internal to the organizations, data produced by several apps and external data acquired from third-party applications. Such internal and external resources are possible for a DSS to meet its needs. Thus, by using a wide variety of data sources, the DSS might provide better accuracy and reliability in the results, meaningfully reducing the probability of an error. This statement depends on the selected models and the data utilization.

More specifically, in the S&R, the Decision Support System receives data from direct and indirect sources. The sources from which the DSS receives data directly are COnCORDE and various third-party APIs. The COnCORDE provides EMS data (e.g., organization name, location, availability of EMS, etc.), Hospital data (e.g., trauma operating theatres, etc.), Patient data (e.g., injury description, etc.), First Responder data, and the High Commander's tasks data (e.g., incident details, etc.). The external APIs may be Weather API and Road Traffic API, among others.

Figure 3-1: Direct Sources of Data

On the other hand, the sources from which the SOT DSS receives data indirectly are field sensors, drones, smartphones, etc. Another indirect data source is the PHYSIO DSS component since it communicates with COnCORDE, and then the data is sent to SOT DSS. The drones provide video data to object detection algorithms of S&R and the results are utilized by the DSS. The components of PHYSIO DSS will be able to provide data for the physiological state of the patients and the First Responders. All this indirect data first is sent to the Data Lake, with the exception of PHYSIO DSS, then to the COnCORDE, and finally ends up in the DSS.

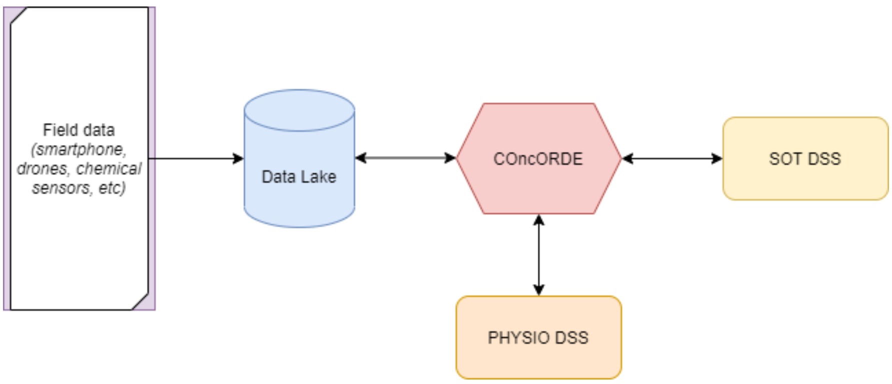

Figure 3-2: Indirect Sources of Data

3.2 SOT DSS Modules Description

3.2.1 Service 1 - Allocation of available EMS units to incidents, depending on estimated needs

While in crisis, multiple incidents may have been initiated around the local or surrounding area. High Commanders must decide which EMS station will send EMS units and how many, to each incident. For this task, Service 1 of the DSS will support its decisions utilizing the most data coming from COncORDE. This data may be EMS availability, demand, distance from the incidents, severity, potential hazards etc.

Service 1 depends mostly on the number of the demand of EMS units from the incident, the number of supply of EMS units (fleet size) from EMS stations and the location of the incident and EMS stations. In order to give an accurate allocation, Service 1 follows the philosophy below.

3.2.1.1 The Transportation Problem

The Transportation Problem aims to fulfil the demand of n demand points using capacities of m supply points, in an optimal way. For instance, transportation of goods from warehouses to retail stores while minimizing the transport cost. The Transportation Problem was first formalized by the mathematician Gaspard Monge. The problem can be written as a Linear Programming problem as:

$$\min z = \sum_{i=1}^{m} \sum_{j=i}^{n} c_{ij} \cdot x_{ij}$$

$$s.t.$$

$$\sum_{j=1}^{n} x_{ij} = a_i, \quad i = 1, 2, \dots, m$$

$$\sum_{i=1}^{m} x_{ij} = b_j, \quad j = 1, 2, \dots, n$$

$$x_{ij} \in \mathbb{Z}^{0+} \ \forall i, j$$

Where a_i the supply of supply point i, b_i the demand of demand point j, x_{ij} the quantity of goods shipped and c_{ij} the cost of transportation of a unit from supply point i to demand point j.

In general, the variables' domain is $\mathbb{R}^{0+}$ but the problem consists of units. In this case, the domain is $x_{ij} \in \mathbb{Z}^{0+}$.

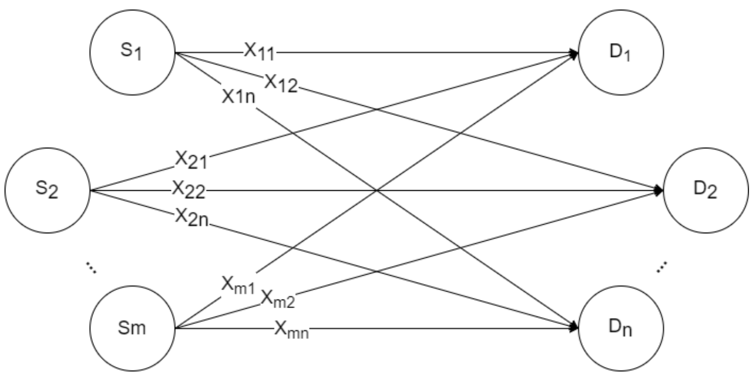

Figure 3-3: Generic formulation of Transportation problem. S_i *node ships* x_{ij} *amount of goods to* D_j *node*

If the total demand is equal to the total supply, i.e., $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$, then the transportation problem is said to be balanced. In this case, each of the constraints is an equation:

$$\sum_{j=1}^{n} x_{ij} = a_i, i = 1, \ldots, m$$

$$\sum_{i=1}^{m} x_{ij} = b_j, j = 1, \ldots, n$$

Otherwise, the problem is said to be unbalanced. There are various techniques to balance an unbalanced problem. One way is directly adding a fictitious supply (res. demand) point with zero costs and the excess amount of goods as supply (res. demand) amount. Others are domain-specific, like storing the excess goods, resulting in additional costs, or excess type-specific, i.e., excess demand or excess supply.

3.2.1.2 Problem modelling

The Service 1 of the S&R DSS recommends the optimal allocation of EMS units to incidents, based on the estimated needs. One can understand that the EMS stations and EMS units constitute the supply points and the "goods" to be shipped, respectively. The fleet size of each station is the supply of each supply point. Furthermore, the incidents are the demand points, and the estimated needs describe the demand of each incident, in means of EMS units. The output of Service 1 is the recommendation of the optimal allocation of the necessary number of EMS units to the incidents based on the demand and the supply of EMS units.

Another problem lies in finding a proper cost function, as it is domain-specific. For this version, the haversine distance function will be used.

The haversine formula is a quite accurate way of calculating distances between two points on the surface of the Great Sphere using the latitude and longitude of the two points. A problem that arises with this approach of the cost function is that the allocation of units depends on the distances and nothing else. Thus, a scenario with an incident will have fulfilled its demand by the nearest hospital, ignoring the others. Hence, the demand is not distributed to more hospitals, resulting in a high workload for the allocated hospital. However, the cost function can be more complicated and exploit much more data. Candidates may be:

- Actual road distance & road traffic
- Weather conditions
- The severity of the incident
- Probability of disaster worsening
- The patients' state

3.2.1.3 Dealing excess demand and supply

In a crisis, the total demand of EMS may exceed the total supply that is the number of available EMS units is not sufficient. This situation is said to be unbalanced, as described above. S&R's approach for the excess demand, considering the ethics behind the allocation of EMS units in crisis situations, is to proportionally reduce the demand of each incident by $\left(1 - \frac{\sum_{i=1}^{m} a_i}{\sum_{j=1}^{n} b_j}.\right) \cdot 100\ \%$. This fair reduction may lead to demand nodes with a demand less than 1. So, the new demand is calculated as:

$$b_j'' = \begin{cases} \lfloor b_j' \rfloor, & b_j' > 1 \\ 1, & b_j' \le 1 \end{cases}, \qquad b_j' = \frac{\sum_{i=1}^{m} a_i}{\sum_{j=1}^{n} b_j} \cdot b_j$$

Still, the rounding may lead to excess demand or supply, so the total demand must be decreased (res. increased). Therefore, the maximum demand of the demand points is reduced by 1, iteratively, until there is no excess demand.

$$b_{k_{t+1}}^* = b_{k_t}^* - 1,$$

Where $k_t = argmax\{b_1'', b_2'', \dots, b_n''\}$ at iteration $t = 1,2 \dots$, and $b_{j_0}^* = b_j''\ \forall\, j$.

The same applies in the case of excess supply, but this time, the minimum demand is increased by 1.

$$b_{k_{t+1}}^* = b_{k_t}^* + 1,$$

where $k_t = argmin\{b_1'', b_2'', \dots, b_n''\}$ at iteration $t = 1,2 \dots$, and $b_{j_0}^* = b_j''\ \forall\, j$.

Finally, the transportation problem becomes:

$$min\ z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} \cdot x_{ij}$$

$$s.t.$$

$$\sum_{j=1}^{n} x_{ij} \le a_i, \quad i = 1, \dots, m$$

$$\sum_{i=1}^{m} x_{ij} \ge b_j^*, \ \ j = 1, \dots, n$$

$$x_{ij} \in Z^* \ \ \forall i, j$$

where b_j^* the demand of node j after the iteration process.

To summarize, Service 1 is a Transportation Problem which exploits Linear programming techniques and using meaningful data to provide an optimal allocation of available EMS units to incidents to support the decision making.

In future work, the approach will also consider the Governance Model and the end-user requirements to address its limitations.

3.2.2 Service 2 - Allocation of patients to transport vehicles and first receivers (hospitals), based on given order of evacuation and triage results for present injuries

This Service tries to solve the problem of allocation of patients to transport vehicles and then the allocation of transport vehicles to first receivers. In a crisis, multiple patients need to be transported to hospitals, but the limitation of resources (EMS units), as well as the injury severity of each patient makes the allocation a difficult task for the operational management. That is, a decision maker must consider many factors, such as the number of available resources, the distance between patients, EMS units and hospital, traffic, the physiological state of the patients etc.

The problem behind this Service is the Transportation Problem of LP. The tricky part is to define the suitable cost function that models the cost of allocating a patient to a vehicle. For this version, evacuation order, physiological score and location of the patient are used, while in the last version, the types of traumas will be utilized. Thus, the allocation and the routing of EMS, to hospitals, does not depend on the trauma specialization of the hospital.

The output of Service 2 is the recommendation of the optimal allocation of the patients in the incident to the EMS units based on the aforementioned characteristics. In case that the patients are more than EMS units the allocation will occur only for the number of patients that the EMS Units can serve. The extra number of patients won't be allocated.

In this document two cost functions are proposed, the experimental results are presented in D4.5. The former constitutes a mathematical formula and the latter utilizes the multi-criteria decision analysis method, UTA (UTilités Additives) proposed by Siskos and Yannacopoulos [12].

Before we define the allocation models, a mathematical formulation of the data must be defined. Let $e_i \in E$ a transport vehicle (ambulance/EMS) with an attribute l_i the location (longitude and latitude) of the vehicle. Let $p_j \in P$ a patient as quadruplet $p_j = (r_j, t_j, l_j, c_j)$, where $r_j \in \mathbb{N}^*$ the order of evacuation, $t_j \in \mathbb{N}^*$ the physiological score, l_j the location of the patient and $c_j = 1$, if the patient is child, $c_j = 0$ otherwise. It has to be mentioned that the psychological score has an increasing monotony sense, i.e., the larger the values of the psychological score, the worse his/her physiological state, the faster it he/she must be transported.

3.2.2.1 Patient allocation using Patient cost formula

Following the proposal, the allocation must consider the order of evacuation and the physiological state. Thus, patients with higher physiological scores must be allocated prior to others. The same applies to the evacuation order. In addition to these attributes, the DSS must consider other factors, like the distance between patients and transport vehicles, as well as the fact that a patient is a child or not. So, order of evacuation and distance are proportional to the cost value. On the contrary, physiological score and the child factor are inversely proportional. Besides that, each factor affects the cost value based on each significance. For example, a seriously injured patient, who is last in the order of evacuation and is far from the transport vehicle must be transported prior to a patient who has been evacuated before the former and has minor injuries. Similarly, a child with mild traumas should get treated before other patients with the same traumas. So, the proposed cost value is:

$$cost_{ij} = \frac{r_j \cdot \sqrt{1 + d_{ij}}}{t_j^{2+c_j}}, \qquad i = 1, 2, \dots, n \quad j = 1, 2, \dots, m$$

Where d_{ij} the distance between EMS units i and patient j. Nonetheless, this approach constitutes the first version of Service 2, so it can be upgraded. In the future, the cost formula will take into account the governance model and protocols of patient transportation, described in WP1, in the second version. After all, the results of Service 2 will not be the real allocation, but they will support the decision-maker to take the final allocation.

3.2.2.2 Patient allocation using UTA

The second approach exploits the ranking, produced by UTA, to create the cost values. UTA is a multi-criteria decision analysis method which aims at inferring one or more additive value functions for the alternative solutions, from their given ranking. Specifically, the patients are modelled as alternative solutions, having a set of criteria (physiological score, distance from vehicle, child/adult) and a subjective rank (order of evacuation). Then, for each vehicle, solving the LP a new ranking of the alternative solutions is obtained, as consistent as possible with the subjective one. The UTA method is defined as:

Denote $A = \{1, \dots, j, \dots n\}$ the set of the alternative solutions, $C = \{1, \dots, i, \dots m\}$ the family of criteria and $g_j = (g_{j1}, \dots, g_{ji}, \dots, g_{jm})$ the multi-criteria profile of the alternative solution j. The utility function of the alternative solution j is:

$$u(g_j) = \sum_{i=1}^{m} u_i(g_{ij}) + d_j^- - d_j^+$$

where $u_i(g_{ij})$ is the marginal utility, d_j^-, d_j^+ the underestimation and overestimation errors, respectively. Note here that u_i is monotonically non-decreasing and every decreasing criterion must be inverted. Also, let $A_R = \{1, \dots, j, j+1, \dots, s\}$ the set of the alternative solutions, which w.l.o.g. it is ordered by the preference of the analyst. The following properties hold for the utility function:

$$jPj + 1 \Leftrightarrow u(g_j) - u(g_{j+1}) > 0 \; (Preference)$$

$$jIj + 1 \Leftrightarrow u(g_j) - u(g_{j+1}) = 0 \; (Indifference)$$

To approximate the value of the marginal utility, we have to define a set of intervals, for each criterion and use linear interpolation. Let $[g_{i*}, g_i^*]$ the range of possible values for the criterion i, which is divided into $(a_i - 1)$ equal-width intervals $[b_i^q, b_i^{q+1}]$ $q = 1,2 \dots, a_i$. We calculate the endpoints as:

$$b_i^q = g_{i*} + \frac{q-1}{a_i - 1}(g_i^* - g_{i*})$$

For each interval, we define a variable $w_{iq} = u_i(b_i^{q+1}) - u_i(b_i^q) \geq 0$, that is the increase of the utility function between the endpoints of the interval $[b_i^q, b_i^{q+1}]$.

Thus, the marginal utility of $g_{ij} \in [b_i^q, b_i^{q+1}]$ is calculated as:

$$u_i\left(g_{ij}\right) = w_{i1} + \dots + w_{iq-1} + \frac{g_{ij} - b_i^q}{b_i^{q+1} - b_i^q} w_{iq}$$

Finally, the estimation model of the additive utility function is:

$$\min z = \sum_{j \in A} d_j^+ + d_j^-$$

$$s.t.$$

$$u(g_j) - u(g_{j+1}) \geq \varepsilon \;\; If \; jPj + 1 : j = 1, \dots, n-1$$

$$u(g_j) - u(g_{j+1}) = 0 \;\; If \; jIj + 1 : j = 1, \dots, n-1$$

$$\sum_{i=1}^{m} \sum_{q=1}^{a_i - 1} w_{iq} = 1$$

$$w_{iq} \geq 0 \; \forall i, q$$

$$d_j^+ \geq 0, d_j^- \geq 0 \; \forall j \in A$$

Solving the above linear program, the optimal weights w_{iq} are obtained and then the utility function of each alternative solution is calculated. Finally, the alternative solutions are sorted based on the utility values and get the final ranking. It is important to note that if the objective function is zero, i.e., the overestimation and underestimation errors are zero, the model is in agreement with the subjective preferences of the analyst.

As mentioned above, the patient allocation to transport vehicles lies on the transportation problem. The final problem lies in finding a suitable cost matrix for our application. For this method, UTA is used in order to calculate this matrix and then find an optimal solution. The intuition behind this method is that UTA is let to infer the "transport" ranking of patients for each vehicle. Thus, the higher the ranking, the lower the cost of transportation, i.e., the patient must be transported as soon as possible.

First, define the alternative solutions and their criteria. Let a_j be a patient (alternative solution), with $g_j = \left(inv.d_{jk}, t_j, c_j\right)$ his multi-criteria profile and r_j his rank, where $inv.d_{jk}$ the inverted distance between jth patient and the kth vehicle, t_j the Physiological score, $c_j = 1$ if his child, $c_j = 0$ otherwise and r_j the order of evacuation. It is important to note that the inverted distance is used since the criteria must be non-decreasing. The lower the distance, the higher priority a patient must have. Using the inverse transformation, the lower the distance, the greater the inverted distance, the higher the priority. Thus, one must solve the LP for each vehicle to get the patients' ranks. Finally, the cost matrix is created using the resulted ranks in order to solve the transportation problem and return the recommended allocation, as described before.

3.2.3 Service 3-Allocation of tasks to available actors on the field, given demand pre-defined by the field commander

Managing a team of people in the field might be very risky, especially when the number of tasks increases and the overall performance of the actors decreases through time. Before the assignment of a task, Field Commander must monitor the state of the actor, his/her expertise and skills, as well as the needs of the tasks. The goal of the third service is to provide decision support in these cases, utilizing the available field data.

Considering the COncORDE functionality, Field Commander creates a polygon on an interactive map and assigns a pre-defined task for this area. Then, the SOT DSS should recommend the most suitable actors for that task.

The output of Service 3 is a recommendation for the allocation of tasks to available actors based on the skills, the state of the actor and the needs of the task. In case of excess demand of actors, the Service will allocate at least one actor to each task.

As it was mentioned in the previous chapter, the linear problem behind this Service is a transportation problem with a suitable cost function, as described before. Following the concept of Service 2, two methods of cost matrix calculation are proposed, Task Cost Formula and UTA.

Before diving into these methods, symbology must be defined. Denote $a_i \in A$ *an actor as a triplet* $a_i = (s_i, r_i, l_i)$ *where* $s_i \in N^*$ *the physiological score,* $r_i \in B$ *the role and* B *a set of roles,* l_i *the location of the actor. Also, let* $t_j \in T$ *a task as a triplet* $t_j = (r_j, d_j, l_j)$ *where* $r_j \in B$ *the demand role of the task,* d_j *the demanded number of actors and* l_j *the location of the task.*

3.2.3.1 Role distance function

While in operation, there might be a lack of certain roles, but every task must be assigned to actors even if they do not have that role, otherwise, the task will not be completed at all. In these cases, the assignment must be done to the "nearest" role.

Consider a tree of roles $G = (V, E)$, where nodes are roles and children-nodes are sub-roles. Assume that each actor is assigned to a node v_i (role of the actor) and a task is assigned to a node v_j (demanded role of the task). The role distance function $\varphi(v_i, v_j)$ is defined as the shortest path length between v_i and v_j.

For example, denote R the first-order role (all actors), R_i the second-order roles (e.g., firefighters, medics, etc.) and R_{ij} the third-order roles (e.g., sub-roles of firefighters). The role distance between R_{11} and R_{21} is $\varphi(R_{11}, R_{21}) = 4$.

Based on Figure 6, a S&R instance here is that R could be any role, R_1 could be medics or R_2 firefighters etc. and R_{11} could be a Retriever, R_{12} could be a Runner and R_{13} could be a Rescuer etc.

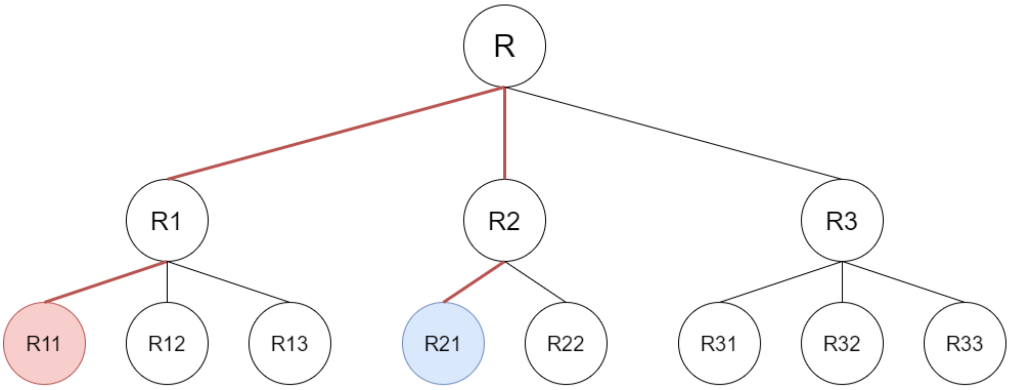

Figure 3-4: Roles tree

3.2.3.2 Patient allocation with Task Cost Formula

Following the concept of Patient Cost Formula, the transportation cost of an actor to a task is proportional to his/her physiological state, geographic distance, and role distance. That is, an actor with the low physiological score and high physiological state/performance has a low cost of transportation. The same applies to distances, the lower the value, the lower the cost. Although, geographic distance should have a smaller impact on the overall cost than the other factors. Likewise, role distance should have greater impact. Finally, the Task Cost Formula is defined as:

$$cost_{ij} = \varphi^2(r_i, r_j) \cdot s_i \cdot \sqrt{1 + d_{ij}}, \qquad i = 1, 2, \ldots, n \quad j = 1, 2, \ldots, m$$

Where d_{ij} the distance between actor i and task j. The transportation problem is solved using the above costs, with actors as suppliers with 1 unit of supply, tasks as demanders with d_j units of demand.

As mentioned in the previous chapter, there are cases that a firefighter might be assigned to a task that requires medics if there are not any available medics, or the medics' cost is higher than other actors. Still, the output of these Services remains a simple recommendation and it will be evaluated by the decision-maker.

3.2.3.3 Patient allocation with UTA

This method follows the concept of UTA being used to infer rankings of tasks for every actor and finally use these rankings as cost matrix for the transportation problem.

UTA was analyzed in Service 2 chapter, so this chapter is a straight-forward application of UTA. For every task t_i, an actor a_j is modelled as an alternative solution with criteria $(inv.d_{ij}, inv.s_j)$ and subjective rank $\varphi(r_i, r_j)$, where $inv.d_{ij}$ and $inv.s_j$ are the inverse distance between i and j and the inverse physiological score of j. The inverse transformation is used to change the monotonicity of the criteria, that is the lower the physiological score, the greater the inverted physiological score, the greater the prioritization.

3.2.4 Service 4 - Estimation of expected casualties and demanded resources (EMS units), given historical data on emergency incident recordings

Estimating the number of casualties, and therefore the needed resources, in disasters is not a trivial task. Especially, when the disasters may vary by type, location, emergency responses and many other factors.

For example, in July 2018 a large wildfire at Eastern Attica, caused 102 deaths and 148 injuries, burning 13.000 acres of land. Another wildfire in August 2009 at Eastern Attica too, caused no deaths but burned 210.000 acres of land. That is, the same disaster type, in similar locations resulted in a different number of casualties, due to the variation in population density, cover land, weather conditions and emergency operations. Probably, one can estimate the casualties in case of wildfire, having this information, still, in most cases, the estimation will be inaccurate. The reason is the complex nature of the problem.

In S&R project, the goal is to minimize the error of the prediction. A wrong prediction may lead to waste (overestimation) or lack (underestimation) of resources. The number of fatalities for each disaster type has different prediction factors, i.e., the number of fatalities in earthquakes depends on the shake intensity, but in wildfires, the number of houses in the forest and the flora have a great impact. That is, Service 4 must be constituted by a model for each disaster type. Analysing the UCs of the project and the WP8 deliverables, the disaster types are:

Use Case	Disasters
UC1 – Victims trapped under rubbles (Italy)	Earthquake
UC2 – Plane crash, mountain rescue, non-urban (Greece)	Plane Crash
UC3 – Heavy storms between Vienna Rail Station & Kufstein railway station heavy damages in the rail station (Cross-border pilot, Austria-Germany)	Derailing, Explosion
UC4 – Forest fire expanded and threat to industrial zone (Greece)	Wildfire, Chemical spill
UC5 – Victims trapped under rubbles (France)	Earthquake
UC6 – Resilience Support for Critical Infrastructures through Standardized Training on CBRN (Romania)	Chemical spill
UC7 – Chemical substances spill (Spain)	Earthquake, Explosion, Chemical Spill

Table 3-1: Disasters per Use Case

The above table depicts that a main disaster may be followed by secondary hazards, which cause additional fatalities and injuries.

The ultimate goal of this service is to continuously update its estimations by collecting new data from the field and the general situation. Nevertheless, this requires the existence of the proper historic field data or the involvement of a domain expert. Still, this is not a trivial task, so other approaches must be followed for each event type separately.

3.2.4.1 Earthquake

An analysis of the existing databases, which were collected in D4.1 & D4.8, was held and showed that only these data are not enough for an earthquake incident. Major attributes, that are contributing factors in casualty prediction, were missing, such as epicenter, depth and in many cases, magnitude. An attempt of aggregating other factors, like intensity per region, building condition index and land cover, was made and many machine learning models were tested without the requested success.

Considering these limitations and in order to enhance the current historical data with new additions, the proposed solution is the exploitation of a worldwide real-time earthquake catalog, such as *Advanced National Seismic System (ANSS)*[1] *Comprehensive Earthquake Catalog (ComCat)*[2]. ComCat contains earthquake source parameters (e.g., hypocenters, magnitudes, phase picks and amplitudes) and other products (e.g., moment tensor solutions, macroseismic information, tectonic summaries, maps) produced by contributing seismic networks. Also, ComCat provides the onePAGER[3] product, which is a summary document of the earthquake with estimated fatalities, economic losses, Modified Mercalli Intensity Map and other information useful for the end-users.

[1] https://pubs.er.usgs.gov/publication/fs07500

[2] "https://earthquake.usgs.gov/data/comcat/"

[3] https://earthquake.usgs.gov/data/pager/onepager.php

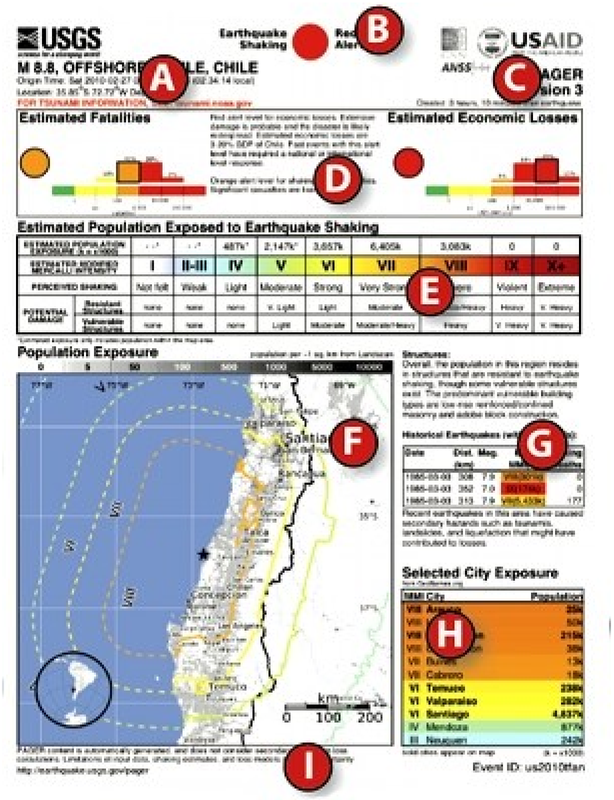

Figure 3-5: one PAGER sample

More specifically, the onePAGER provides:

A. **Summary of the basic earthquake parameters**, including origin time, local time, magnitude, hypocenter, and the name of the region where the earthquake took place. For events with a high likelihood of a tsunami, a link to the NOAA tsunami Web page is provided (bold red text).

B. **Earthquake Impact Scale summary alert level.** The higher of the two alert levels (D) is shown as the summary alert at the top-center of the page.

C. **The version of the PAGER alert and the time the alert was created**. New versions of the alert are generated when the earthquake information is improved as supplemental ground-shaking constraints become available.

D. **Earthquake Impact Scale alert levels** for fatalities (left) and economic losses (right). The alert levels are based on the range of most likely losses; the uncertainty in the alert level can be gauged by the histogram, depicting the percent likelihood that adjacent alert levels (or fatality/loss ranges) occur. Accompanying text clarifies the nature of the alert based on experience from past earthquakes. If the economic alert is yellow or greater, the text will also give a range of economic losses in terms of the country's Gross Domestic Product. The higher level of the two alerts is shown as the summary alert at the top-centre of the page (B).

E. **Table showing population exposed** to different Modified Mercalli Intensity (MMI) levels and the possible damage at different intensity levels for resistant and vulnerable structures. MMI describes the severity of an earthquake in terms of its effect on humans and structures and is a rough measure of the amount of shaking at a given location. Unlike earthquake magnitude, intensity varies with distance from the fault. Population outside the map bounds are not included in the totals.

F. **Map of MMI contours** plotted over the Landscan (Oak Ridge National Laboratory) population base map. The regions labelled with Roman numeral MMI values are separated by half intensity unit contour lines, e.g., 5.5, 6.5, 7.5. The total population exposure to a given MMI value is obtained by summing the population between the thick contour lines. This total is shown in the population exposure table (E).

G. **Region-specific structure and earthquake commentary**. The Structures comment may contain the most vulnerable building type(s) in the region or a general description of the vulnerability of the buildings in the region. The Historical Earthquakes section includes a table of population exposure and fatalities for three previous nearby earthquakes and, in some cases, the potential for fires, landslides, liquefaction, or other hazards, based on past earthquakes in the region, will be noted.

H. **Table of MMI estimates for selected settlements**. A maximum of 11 settlements that fall within the map boundary are included in the table. The table contains country capitals and the six settlements with the highest estimated intensity. The remaining settlements listed are selected by population. Settlement name, location and population are obtained from the freely-available GeoNames geographical database.

I. **Footer**, including a link to the PAGER web page, event identification information, and a disclaimer noting that the content was automatically generated, and has additional sources of uncertainty. All possible uncertainties are not considered in the determination of estimated earthquake fatalities and economic losses; the actual impact of the earthquake may differ from PAGER's automatically generated estimate.

3.2.4.2 Plane Crash

In the 21st century, plane crashes remain extremely rare, and planes are considered one of the safest transportation modes. ICAO provides accident statistics and shows that in 2020 there were 4 fatal accidents and 297 fatalities. The COVID-19 had a big impact on aviation but the differences in accidents are not significant, comparing the year 2019.

Figure 3-6: Accident statistics by ICAO. https://www.icao.int/Pages/default.aspx

In spite of the fact that the chances of dying in air travel are pretty low [13], the chances of dying in a falling plane are quite high.

Considering the above sentence and the lack of plane crash data, the proposed approach for the estimation of fatalities requires the exploitation of an aviation API. That is, having the location of the crash by the caller, a spatial search of planes that flew that time in a specified radius will return the crashed plane data. So, the estimation of these services will be the capacity of the plane. In case of multiple planes passed, that time by the area, an average of the capacities may constitute the result of the DSS. The advantage of this approach is that there is no need for information about the existence of the plane, but the crashed location.

However, it is possible to consider the plane crash's consequences as incidents, such as explosion and a possible fire. In this case, sub-chapters 3.2.4.5 and 3.2.4.6 describe how to approach these possible incidents.

3.2.4.3 Derailing

Trains are characterized as a safe option for transportation, along with airplanes. The number of rail accidents and fatalities is decreasing in the last few years, in EU[4] and US[5]. Still, railway accidents may cause a large number of injuries and fatalities due to massive public transport systems. The collected databases contain 529 records of rail accidents, but there is no information about the conditions under which the accident happened. In order to create the desired model, attributes like speed before the accident, number of wagons, type of area, capacity, etc. are required.

The proposed approach for this case follows the idea of plane crash casualty prediction. A railway API could be used in order to predict the number of casualties, based on the train capacity. Otherwise, the SOT DSS could use information from the incident details form of COncORDE, such as the number of wagons derailed.

3.2.4.4 Chemical spill

Chemical accidents often occur in industrial zones, where dangerous substances are used, transported or stored. Examples of vulnerable sites are [14]:

- Fuel storage sites, tank farms
- Waste storage sites
- Gas and oil pipelines
- Tailing dams
- Petroleum or petrochemical industries
- Acid mine drainage
- Chemical factories
- Transport: railways, roads, rivers, sea
- Food processing plants
- Hospitals, laboratories, pharmacies
- Pesticide storage depots
- Metallurgical industries

Common factors that cause a chemical accident have been identified [15]:

- Inadequate hazard review or process hazards analysis
- Installation of pollution control equipment
- Use of inappropriate or poorly designed equipment
- Inadequate indications of process condition
- Warning went unheeded

[4] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Railway_safety_statistics_in_the_EU#Persons_killed_in_railway_accidents

[5] https://oli.org/track-statistics/collisions-casualties-year

One can understand the large variety of parameters that are involved in a chemical accident and complicate the task of casualty estimation. Also, many factors are unknown prior to the incident, such as industrial equipment conditions, immediate response, people in building, etc, thus a machine learning process may include data leakage and lead to an overly optimistic model. To this end, chemical spills may cause other hazards, such as explosions and fires. Thus, casualty assessment to an event type is more complicated, and many records can be misleading.

For this case, data from chemical sensors on the field will be used, which will be implemented in the second version and after the integration phase.

3.2.4.5 Explosion

An explosion is a rapid expansion in volume associated with an extremely vigorous outward release of energy, usually with the generation of high temperatures and the release of high-pressure gases. The causes of explosions vary, but generally they are related to other disasters, for instance, fire, chemical spill, earthquakes. Furthermore, there are site-related factors, which contribute to the scale of the explosion, as described in the chemical spill section. Industrial zones seem to be fertile ground for such incidents. In 2020, a fire broke out at the port of Beirut, triggering a small explosion reaction and finally, causing a devastating explosion. Finally, explosions may be caused by terrorist attacks. These attacks are usually occurring in residential areas and high population density areas.

The lack of contributively attributes in the gathered data and the uncertainty of the field sensors specifications do not allow the construction of a machine learning model. The complex nature of the disaster, the variety of the impacts and the relationship with other disasters make the task of estimation more difficult.

3.2.4.6 Wildfire/Residential fire

Fires are another threat for Europe, especially for the Mediterranean countries in the summer periods. Fires burn large forest areas, destroy the flora and fauna of the region, and damage properties. Wildfires generally occur in rural areas burning large areas, but they result in a low casualty number. On the contrary, residential fires occur in urban areas, often in structures and buildings. They are smaller in size but may lead to an extreme number of casualties. The common factors of mortality in fire cases are easily identified but they may differ between wildfires and residential fires. The following table shows some common factors.

Wildfire	Residential Fire
Weather	
Landcover	
Fuel type	
Preparedness measures	
Access	
Tree height	Building condition
Drought	Population density
Rate of spread	Other hazards, e.g., explosions

Table 3-2: Common factors in the fire incidents

The European Forest Fire Information System (EFFIS)[6], along with the EU Copernicus program, publishes Fire Danger Forecast maps every day, indicating the probability of ignition, fire danger, fuel, etc.

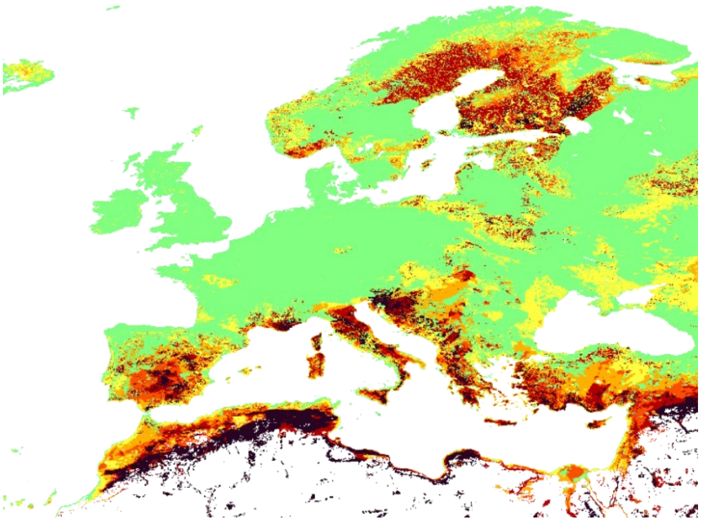

Figure 3-7 Ignition probability map for 28/06/2021.
https://effis.jrc.ec.europa.eu/applications/data-and-services

Other services provide data that help in fire prediction too, for example, weather APIs, land cover maps, and census data.

However, in a wildfire or a residential fire, the number of casualties is on a scale of 0 to 3. Thus, in this case, the prediction of the number of casualties has no actual value for the operation. Moreover, the historical data provided by Task 4.1 offer the number of resources needed and the burnt area in a wildfire. Considering these available data and services, the model for the disaster will predict the burnt area and the resources needed.

[6] https://effis.jrc.ec.europa.eu/

In the second version of the current deliverable, for the above disasters will be used as many as possible historical data from the task 4.1 in order to cover as many use cases as possible.

4 Conclusions

In this deliverable, the design of the SOT DSS modules were described. The scope of SOT DSS design was analyzed and the five categories for the general term of DSS were also mentioned. The human factor and the possibilities of failures in the decision-making were also analyzed.

Furthermore, the proposed methodology for the design of the SOT DSS was described. Linear Programming techniques were used to solve the problems of the three of the Services of SOT DSS. Also, for the fourth Service, various approaches were described for a number of disasters based on the use cases.

In terms of general architecture, SOT DSS connects to COncORDE with two-way communication. As a result, the COncORDE receives data which it then distributes to the other S&R components. Moreover, the external input and the SOT DSS Modules description were presented.

In the D4.5 "The development of SOT DSS Component" the technical details of the development of SOT DSS are presented.

In the second version of the deliverable, an enhanced version of the SOT DSS will be presented. Extensions based on the functionality and the reliability of the models will be implemented, by utilizing more data and validating the results. Moreover, Service 4 will be enhanced with more and better inputs in order to provide better and more accurate results.

D4.3 and D4.5 must also stay close to the end-users' needs, in order to address the SOT DSS component to the most suitable and possible way and deliver accurate recommendations to the S&R operations.

Annex I: References

[1] Power, D. J. (2001). Supporting decision-makers: An expanded framework. *Informing Science*, *1*, 1901-1915.

[2] Power, D. J. (2002). *Decision support systems: concepts and resources for managers*. Greenwood Publishing Group.

[3] Codd, E. F. (1993). Providing OLAP (on-line analytical processing) to user-analysts: An IT mandate. *http://www. arborsoft. com/papers/coddTOC. html*.

[4] Alter, S. (1980). *Decision support systems: current practice and continuing challenges* (No. 04; HD30. 23, A5.).

[5] Bonczek, R. H., C.W. Holsapple, and A.B. Whinston. (1981). Foundations of Decision Support Systems, New York: Academic Press.

[6] Holsapple, C. and A. Whinston, (1996). Decision Support Systems: A Knowledge-Based Approach, Minneapolis/St. Paul, MN: West Publishing

[7] Klein, M. R., & Methlie, L. B. (1995). *Knowledge-based decision support systems: with applications in business*. John Wiley & Sons, Inc..

[8] Goul, M., Henderson, J. C., & Tonge, F. M. (1992). The emergence of artificial intelligence as a reference discipline for decision support systems research. *Decision Sciences*, *23*(6), 1263-1276.

[9] Restas, A. (2016). Effect of Time Pressure at Tactical Level Managing Disaster. *World Journal of Engineering and Technology*, *4*(3), 93-100.

[10] Schraagen, J. M., & van de Ven, J. (2011). Human factors aspects of ICT for crisis management. *Cognition, Technology & Work*, *13*(3), 175-187.

[11] Bohanec, M. (2009). Decision making: A computer-science and information-technology viewpoint. *Interdisciplinary Description of Complex Systems: INDECS*, *7*(2), 22-37.

[12] Jacquet-Lagreze, E., & Siskos, J. (1982). Assessing a set of additive utility functions for multicriteria decision-making, the UTA method. *European journal of operational research*, *10*(2), 151-164.

[13] Jozwiak, Ireneusz & Marianski, Aleksander & Cwik, Michal. (2015). The probability of dying in a plane crash or having a safe flight. Aviation. 19. 1-6. 10.3846/16487788.2015.1015287.

[14] World Health Orgnatzation. (2018). Chemical releases caused by natural hazard events and disasters – information for public health authorities. ISBN: 978-92-4-151339-5

[15] Belke, James. (2001). Recurring causes of recent chemical accidents. Loss Prevention Bulletin. 159. 6-10. 10.1205/026095701750285490.