D6.11

Decision Support Specification and Implementation Report - Final

Instrument	Collaborative Project
Call / Topic	H2020-SEC-2016-2017/H2020-SEC-2016-2017-1
Project Title	Multi-Hazard Cooperative Management Tool for Data Exchange, Response Planning and Scenario Building
Project Number	740689
Project Acronym	HEIMDALL
Project Start Date	01/05/2017
Project Duration	42 months
Contributing WP	WP 6
Dissemination Level	PU
Contractual Delivery Date	M38
Actual Delivery Date	30/06/2020
Editor	Monika Friedemann (DLR)
Contributors	Christian Böhnke, Martin Mühlbauer, Nico Mandery (DLR-DFD), Benjamin Barth (DLR-KN), Bruce Farquharson (SFRS)

Document History			
Version	Date	Modifications	Source
0.1	22/06/20	First draft	DLR
0.2	26/06/20	QA-reviewed version	SFRS
1.0.D	03/07/20	First Issue	DLR
1.0.F	21/07/20	Approval for submission	DLR

Table of Contents

List of Figures

List of Tables

List of Acronyms

AB	Advisory Board
API	Application Programming Interface
AOI	Area of Interest
C&C	Command & Control Centre
CDM	Change Detection Module
CIMA	Centro Internazionale in Monitoraggio Ambientale – Fondazione CIMA (CIMA Foundation)
DB	Database
DES	Decision Support Service
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DLR-DFD	Deutsches Zentrum für Luft- und Raumfahrt e.V.; German Remote Sensing Data Center
DLR-KN	Deutsches Zentrum für Luft- und Raumfahrt e.V.; Institute of Communications and Navigation
DS	Decision Support
DSS	Decision Support System
ELSI	Ethical, Legal and Social Issues
EO	Earth Observation
EUW	End User Workshop
FCP	Forward Command Post
GOI	Geographical Object of Interest
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
IPsec	Internet Protocol Security
ISA	Impact Summary
ISAS	Impact Summary Generation Service
JSON	JavaScript Object Notation
LULC	Land Use and Land Cover
OGC	Open Geospatial Consortium
PE	Plan Execution
PF	Plan Formulation

REST	Representational State Transfer
RVA	Risk and Vulnerability Analysis
SA	Situation Assessment
SAW	Situation Awareness
SITREP	Situation Report Generation Service
SMAC	Scenario Matching Service
SMES	Scenario Management Service
SP	Service Platform
TOC	Table of Contents
TR	Technical Requirement
UI	User Interface
URL	Uniform Resource Locator
VM	Virtual Machine
VPN	Virtual Private Network
WP	Work Package

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Executive Summary

This document presents the HEIMDALL decision support concept and technical component design. The concept has been elaborated in close collaboration with the end users, the project lead and the Ethical, Legal and Social Issues (ELSI) research partners in order to ensure an appropriate and desired degree of decision support by technology.

Thus, the first of the two main objectives of this document is to provide an overview over the different decision support approaches developed and implemented by WP6 suitable for strategic response planning.

The second objective is to present a technical specification which enables technical contributors and partners to understand how to develop, deploy, configure and use the decision support components developed and implemented in T6.4. Therefore, topics include the external and internal architecture design, interfaces, data structures, formats, functionality, methods, configuration and software issues.

The main task contributing to this deliverable is T6.4 – Decision Support Services. However, significant contributions were made by tasks T3.1 – Stakeholder Management, WP8 – Ethics Requirements and T2.4 – Service Concept Specification and System Architecture as tool-assisted decision making is a pivotal concept in the HEIMDALL system. The overall HEIMDALL situation assessment and decision support approach has been elaborated together with task T6.3. Scenario management and matching concepts are contributed by task T6.5.

The two decision support functionalities described in this deliverable are provided by the Decision Support Service (DES). The DES generates for a user-specific area of interest (AOI) for a specific hazard situation aggregated information on 1) safe strategic areas and points and 2) safe roads. The resulting so-called DES information supports end users in Command and Control Centres (C&C), Forward Command Posts (FCPs) and in the field to identify options and contingencies and to decide on the path to follow to achieve the desired outcome.

1 Introduction

This document describes efforts performed and results produced in the HEIMDALL project in finding and designing technical solutions which provide decision support to the different groups of end users during the strategic response planning process. In particular, solutions are highlighted which support the end users' contingency planning activities, suitable to all involved perspectives. The document focuses on the Decision Support Service (DES) and the different types of generated information products, the so-called DES information. The HEIMDALL project aims at a collaborative design which is a methodology that involves people who will be affected by new technologies throughout all design phases [1]. Unlike traditional approaches to develop information systems of having a fixed product and/or system idea that does not change or evolve as the development process take place, an agile approach is a response to the need for a flexible and iterative process to be able to consider unexpected changes [2]. For example, intermediary results of system developments have been presented at the End User Workshops (EUWs) and iterated together with the end-user partners. This deliverable poses an update of the first version D6.10 [3] and presents the mature DES component design together with a detailed technical specification, the test plan and implementation report.

Since the first documentation of the DES in D6.10 (M18), end users have been able to trial and evaluate the maturing HEIMDALL system during the EUWs. Hereby, EUWs served on the one hand to determine the validity of the implemented products and services when used in a real-world situation by decision makers, who are the potential user of the system. On the other hand, EUWs made it possible for the end user partners to discuss common and specific procedures and constraints and to identify needs and gaps based on a visual and functional system prototype. Based on these insights user requirements have been updated, most recently in D2.9. The technical requirements, concepts and specifications in this document reflect these updates.

As a matter of fact, the final system release does cater mainly to user requirements identified in the first phase of the project including prioritized refinements after EUWs 1-4. However, the system development could not include all evolving user requirements and concepts from the later phases due to the prioritisation of other modules.

In particular, D6.11 updates concern:

- Technical requirements in section 2 have been refined and newly added based on updated system requirements in D2.9.
- DES products respectively outputs have been narrowed down to specific GOIs such as safe areas and safe roads
- In D6.10 throughout the document reflections on the Change Detection Module (CDM) have been documented. The CDM assists decision makers in the identification of changed land cover and land use over time in the area of interest and has been intended to be used as an add-on to scenario matching. Due to shifts of priority during the main implementation and integration phase before the final release the CDM description has been removed from this deliverable. However, the CDM concept will be moved to an additional deliverable on updated Situation Assessment, Decision Support and Scenario Matching concepts scheduled for the end of the project.
- As explained later in this document, the Scenario Matching Module (SMAC) has been designed and implemented as a further decision support tool. The successive efforts made towards refined SMAC criteria and metrics will be specified in detail in D6.15 [13] and in the additional deliverable on updated Situation Assessment, Decision Support and Scenario Matching concepts
- The DES specification, in particular the REST API and implementation details have been updated
- The test plan and results have been added in section 6

The document is organised as follows:

- Section 2 specifies the technical requirements for the DES component.
- Section 3 describes the DES in the context of the overall HEIMDALL system, inputs and outputs and interfaces with other HEIMDALL components.
- Section 4 starts with background on tool-assisted decision support. Then, the section elaborates how HEIMDALL aims to support decision making in strategic response planning of the involved end users. The section concludes with an overview of DES building blocks, functionalities and workflows.
- Section 5 presents the detailed DES specification including the description of criteria and metrics, results, REST API, configuration and implementation details.
- Section 6 contains the test plan and results carried out for releases C and final.
- Finally, section 7 summarizes the work carried out so far and gives an outlook to future work.

2 Technical Requirements

This section includes the list of technical requirements for the DES module. Requirements for the SMAC apply (see D6.15 [13]).

Since the first specification of technical requirements in D6.10 (M18), end users have been able to trial and evaluate the maturing HEIMDALL system during the EUWs. Hereby, EUWs served on the one hand to determine the validity of the implemented products and services when used in a real-world situation by decision makers, who are the potential user of the system. On the other hand, EUWs made it possible for the end user partners to discuss common and specific procedures and constraints and to identify needs and gaps based on a visual and functional system prototype. Based on these insights user requirements have been updated, most recently in D2.9. The technical requirements in this section reflect these updates in the form of refined as well as newly added requirements.

2.1 Interface Requirements

2.1.1 **Hardware Interfaces**

The DES shall be accessible via Ethernet. If a Virtual Private Network (VPN) is used it must offer IPSec compatibility.

2.1.2 **Software Interfaces**

The DES shall be deployed as Linux-based container and/or virtual machine (VM).

2.1.3 **Communication Interfaces**

The DES shall be connected to the other HEIMDALL components through the Service Platform (SP).

The DES component shall be designed as RESTful web service allowing clients to communicate with it using common HTTP methods (e.g. GET, PUT) and/or for georeferenced data OGC methods (based on HTTP).

Focused on providing a lightweight and easily consumable output format, the data shall be exchanged using JSON serialization and the formats specified by the respective OGC standards.

2.2 Functional Technical Requirements

2.2.1 **Short-Term Features**

Table 2-1: Technical Requirement TR_DS_1

Requirement ID:	TR_DS_1
Related SR(s):	• Sys_SADS_24
Description: The DES shall generate and return on request a list of potentially safe emergency response infrastructure/GOIs (e.g. C&C sites) per selected AOI. For each GOI in the list a timestamp with the validity of the safe status shall be provided. DES information is compiled by intersecting the outputs of the simulation modules, impact assessment (RVA) information and pre-defined geographical base. No further data enrichment shall be performed.	
Rational: The user shall be supported in contingency planning by DES information generated	

by the system. DES information shall not infer possible decisions. Instead, decisions are solely taken by the user. DES information generated by the system enables the user, upon modifying inputs and conditions, to better anticipate which emergency response infrastructure would most probably remain safe (i.e. not affected by a hazard).
Stimulus: After running a simulation and RVA the SP requests the generation of DES information for the selected scenario, the generated simulation results and impact assessment information.
Response: The DES returns DES information for the selected AOI, e.g. for display in the UI or for inclusion in a situation report.
Verification Criterion: DES information for a scenario AOI can be requested
Notes: none

Table 2-2: Technical Requirement TR_DS_2

Requirement ID:	TR_DS_2
Related SR(s):	• Sys_SADS_13
Description: The DES shall provide means for configuring thresholds for the generation of DES information which describes potentially safe emergency response infrastructure (e.g. C&C sites). Configuration shall be done before the system is started (configuration file) or with each request.	
Rational: The users shall be able to configure rules and thresholds for DES processes according to their individual and organizational needs.	
Stimulus: Rules and thresholds shall be set and modified through configuration in a text file.	
Response: -	
Verification Criterion: Rules and thresholds shall be able to be set and modified through configuration before the system is started. Configuration changes shall be visible in DES process results.	
Notes: none	

2.2.2 **Mid-Term Features**

Table 2-3: Technical Requirement TR_DS_3

Requirement ID:	TR_DS_3
Related SR(s):	• Sys_SADS_24
Description: The DES shall generate and return on request a list of potentially safe environmental assets/GOIs (e.g. sand pits) per selected AOI. For each GOI in the list a timestamp with the validity of the safe status shall be provided. DES information is compiled by intersecting the outputs of the simulation modules, impact assessment (RVA) information and pre-defined geographical base. No further data enrichment shall be performed.	

Rational: The user shall be supported in contingency planning by DES information generated by the system. DES information shall not infer possible decisions. Instead, decisions are solely taken by the user. DES information generated by the system enables the user, upon modifying inputs and conditions, to better and anticipate which environmental assets should remain safe (i.e. not affected by a hazard).
Stimulus: After running a simulation and RVA the SP requests the generation of DES information for the selected scenario, the generated simulation results and impact assessment information.
Response: The DES returns DES information for the selected AOI, e.g. for display in the UI or for inclusion in a situation report.
Verification Criterion: DES information for an AOI can be requested
Notes: none

Table 2-4: Technical Requirement TR_DS_4

Requirement ID:	TR_DS_4
Related SR(s):	• Sys_SADS_13
Description: The DES shall provide means for configuring thresholds for the generation of DES information which describes potentially safe environmental assets (e.g. sand pits). Configuration shall be done before the system is started (configuration file) or with each request.	
Rational: The users shall be able to configure rules and thresholds for DES processes according to their individual and organizational needs.	
Stimulus: Rules and thresholds shall be set and modified through configuration in a text file.	
Response: -	
Verification Criterion: Rules and thresholds shall be able to be set and modified through configuration before the system is started. Configuration changes shall be visible in DES process results.	
Notes: none	

Table 2-5: Technical Requirement TR_DS_5

Requirement ID:	TR_DS_5
Related SR(s):	• Sys_SADS_15
Description: The DES shall provide means for adding and modifying the DES information.	
Rational: The user shall be enabled to add or modify DES information according to his/her knowledge, role and goals.	
Stimulus: The user updates existing DES information for a selected scenario over the UI.	
Response: Status OK if modification successful, otherwise error status message	

Verification Criterion: DES information referring to a scenario can be modified at any time
Notes: none

Table 2-6: Technical Requirement TR_DS_6

Requirement ID:	TR_DS_6
Related SR(s):	• Sys_SADS_35
Description: The DES shall allow the user to identify safe and unsafe roads either in a list or a map.	
Rational: Users shall be able to distinguish safe and unsafe roads for their strategic planning.	
Stimulus: The system client (e.g. SP or GUI) specifies the AOI, the road network to be assessed and the hazard for which the assessment has to be performed.	
Response: Status OK if modification successful, otherwise error status message	
Verification Criterion: A system client can request safe and unsafe roads.	
Notes: The hazard area must intersect the AOI and the road network. Otherwise, the result could be empty.	

2.3 Other Requirements

2.3.1 **Short-Term Requirements**

2.3.2 **No short term requirements have been identified.Mid-Term Requirements**

Table 2-7: Technical Requirement TR_DS_7

Requirement ID:	TR_DS_7
Related SR(s):	• Sys_SADS_17
Description: The DES shall be transparent on the mechanisms and used criteria.	
Rational: The user is the one liable so all decisions presented by the system must be transparent to the user and the underlying criteria.	
Stimulus: -	
Response: -	
Verification Criterion: All thresholds are accessible through configuration and visible.	
Notes: none	

3 Reference Architecture

This section describes the DES component in the context of the overall HEIMDALL architecture. Afterwards, the different inputs and outputs expected from the component are listed. Finally, the section describes the interfaces needed to allow the component communicate with the other components.

3.1 HEIMDALL Overall Architecture

Figure 3-1 illustrates the HEIMDALL overall architecture highlighting the DES and the SMAC components. The DES as well as its sub-modules is treated as a “black box” within the overall architecture. As can be observed in the diagram the DES performs all communication and interactions with the other components of HEIMDALL through the SP. Interface 4 (I4) serves as the general interface.

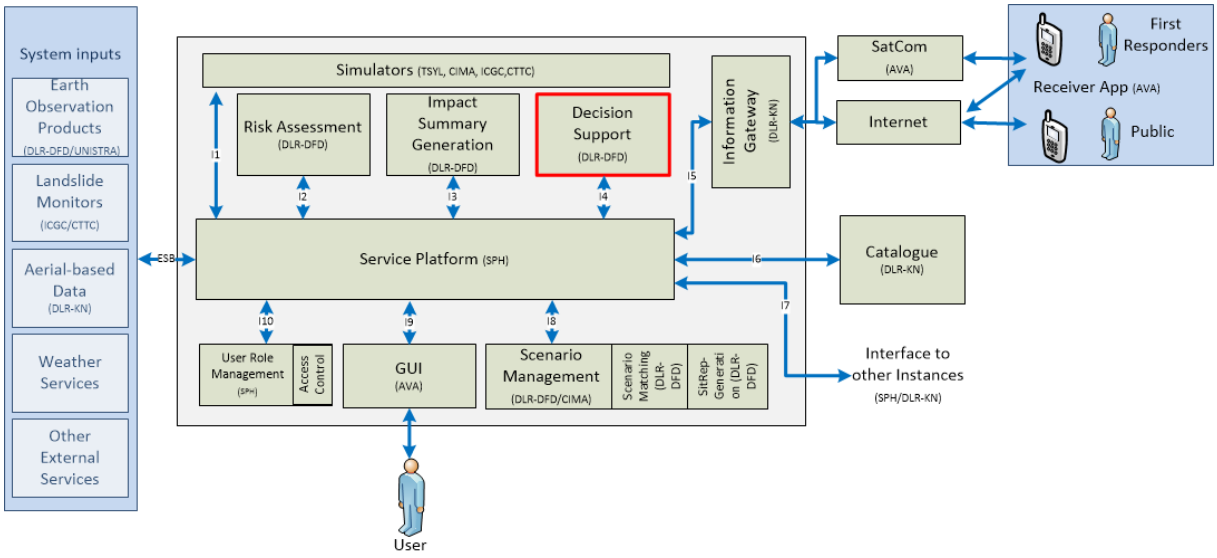

Figure 3-1: HEIMDALL overall architecture

The DES enables clients (e.g. the UI) to generate DES information for a specific scenario. This DES information will support end users in C&C, FCPs and in the field to identify options and contingencies and to decide on the path to follow to achieve the desired outcome.

Other components communicate with the SMAC over interface 8 (I4). As part of the scenario management the final SMAC specification is described in D6.15 [13].

3.2 Inputs and Outputs

Table 3-1 gives an overview of DES inputs and outputs with a short description respectively. A detailed description of DES inputs, outputs and formats can be found in the API specification in section 5.1.4.

Table 3-1: DES inputs and outputs

Output	Short description	Inputs needed	Format
Information about safe, strategic areas and points (i.e. GOIs)	List of potentially safe GOIs until time x in AOI (e.g. safe shelter, safe evacuation area, safe FCP) which can be displayed as a list or as styled elements on a map.	Pre-defined list of GOIs to be assessed. The API accepts polygons (i.e. areas) and points. Expert configuration (e.g. maximum hours to be considered) Hazard information (i.e.	Descriptive GEOJSON format with georeferenced objects

		simulation results per requested hours)	
Information about safe roads	List of safe roads in AOI which can be displayed as a list or as styled roads on a map.	Transportation network dataset reference Expert configuration Hazard information (i.e. simulation results) Impact assessment (RVA) information (affected roads dataset)	Descriptive GEOJSON format with georeferenced objects

3.3 Interfaces with other HEIMDALL components

The DES provides access to its data resources and functionality by use of a RESTful web service interface. Figure 3-1 shows I4 as the major interface connecting the SP with the DES (see Table 3-2 for details on I4).

Table 3-2: Interfaces with other components

Interface	**Short description**	**Methods**	**Protocol**
I4	RESTful web service interface	GET, POST, PUT, DELETE	HTTP(S)

The DES as a web service provides a REST API for accessing and creating its data resources. Any input needed by the component must be attached as a data resource by the client to the request.

4 Module Functionality

For many decades, Decision Support Systems (DSS) have been developed and employed in the field of disaster management in order to “complement the cognitive processes of humans in their decision making” [4]. In the German-Indonesian Tsunami Early Warning (GITEWS) project DLR has designed and developed a situation assessment and decision support workflow (DSS workflow) for the DSS of the Indonesian Tsunami Early Warning System InaTEWS [5][6]. In the Project on a Multi-Hazard Open Platform for Satellite Based Downstream Services (PHAROS) the DSS workflow has been refined and applied to the wildfire domain [7]. Based on the overall HEIMDALL service concept [8] we have elaborated a service-based, multi-hazard approach to the DSS workflow which fosters customized utilization and combination of the different DSS building blocks in different contexts. D6.7 [9] describes the background and the HEIMDALL approach to tool-assisted situation assessment and decision support in detail.

4.1 Contextual, Ethical, Legal and Social Considerations

It strongly depends on the processes to be supported, their legal and organizational context, their degree to which they are structured and the existence of best practices and SOPs that may be automated whether DSS leave the generation of situational awareness (SAW) on the different levels to the user (less automatic) or whether they provide fully automatic decision options among which the user has just to choose. In sudden-onset types of disasters such as tsunami events in Indonesia authorities are forced to disseminate an appropriate warning at the earliest point in time under pressure to respond to dynamic uncertain conditions. With these circumstances in mind, the InaTEWS DSS has been designed to provide a high degree of computerized situation assessment and decision support. For example, the DSS automatically selects a “preferred” simulated tsunami propagation and inundation scenario based on an aggregation of the best-matching scenarios under consideration of quality and error measures. While this type of automated support has proven to be helpful in numerous operational tsunami early warning situations [5] [15], long-term response planning activities identified so far in the HEIMDALL context [10] require a much more data-driven approach without decision automation. In the field of data-driven DSS the key is having easy and rapid access to a large amount of accurate, well-organized multidimensional data [11]. Based on this data users are able to perform situation and risk analysis, assessment and strategic planning more efficiently. This applies particularly for wild fire and flood hazards which are challenging to forecast and at first can happen without much notice, thus they require a high degree of user expertise in their management and monitoring of conditions triggering such a hazard.

Also from an Ethical, Legal and Social Issues (ELSI) perspective data-driven decision support has been assessed to be more appropriate and desired. Two major categories of ELSI issues have been identified by WP8 as critical for tool-assisted decision support in HEIMDALL: respect for autonomy and integrity. The respect for autonomy might be restricted if decision support is implemented against the will or not reflecting the internal diversity of end-users. In order to prevent this restriction it has been advised to identify and select important characteristics the tools aim at based on end-user needs, social acceptability, social acceptance and technological safety. Integrity issues might come up if responsibility structures for tool-assisted decision-making were neglected. As a measure of prevention critical discussions of technological risks, of the need and wishes for decision support with the end users and of the ethical issues arising from decision support have been proposed [12] and conducted. As a result of these discussions between the project lead, the ELSI research partners and the end-users the focus of computerized decision support has been shifted from automated system actions (e.g. decision proposals for routes of actions, tasking of models and simulations) to the preparation and provision of relevant SAW information. In particular, these design decisions have been made:

- The system does not infer and propose decisions or routes of actions. Instead, decision support is provided in the form of goal-oriented SAW and decision support information which users can base their decisions on (e.g. safe road until time x, safe alternative FCP site, etc.).
- Decisions are taken solely by users in the C&C or FCP according to their individual knowledge, and their individual and organizational responsibility, needs and goals
- Users always have the possibility to add and modify information according to their individual knowledge, and their individual and organizational responsibility, needs and goals
- Criteria and thresholds for decision support processes are configurable for users according to their individual knowledge, and their individual and organizational responsibility, needs and goals
- The user is the one liable so all decisions and the underlying criteria and thresholds presented by the system must be visible to the user
- Information supporting decision making is integrated into standardized situation reports as far as possible to facilitate the distribution of information products to the relevant stakeholders (e.g. for staff meetings, publishing on the web, transfer between incident commanders and field resources, transfer to other C&Cs and organizations, etc.)

4.2 Decision Support Features of HEIMDALL

Together with the end-user partners, a major objective of the first project phase was the definition of the different activities in their response planning process mentioned before and how HEIMDALL can technically support these activities (see D2.11 [8] and [10]). In D6.7 [9] the term SAW information encompasses different types of information relevant to the decision maker in the three phases of the decision making process, Situation Assessment (SA), Plan Formulation (PF), and Plan Execution (PE). In the SA phase, situation and impact assessment information helps the different involved stakeholders to identify risks to people, property and environment and to decide on the working strategy for the response planning to come. In the PF phase, information on options and contingencies is needed: if the fire escalates, what is required? If a FCP is at risk, where in the vicinity can another one be set up? If casualties are recovered, is there somewhere to take them? In the PE phase decisions and measures taken need to be tracked for future reference. WP6 contributes the information products and functionalities listed in Table 4-1 implemented to support decision making in strategic response planning.

Table 4-1: WP6 decision support products and functionalities

HEIMDALL product	**Decision-making Phase**	**Supports stakeholders in activity**	**HEIMDALL tool (functionality)**	**Deliverable**
Impact assessment	SA	Risk and impact assessment: analysis of the consequences of a situation at hand resp. scenario Analysis of possible future scenarios: planning and assessment of different future scenarios with alternative conditions and situational parameters	RVA module (situation assessment)	D6.5
ISA information – aggregated impact summary for an AOI; total	SA	Risk and impact assessment: analysis of the consequences of a situation at hand resp. scenario in an AOI	ISAS	D6.8

numbers for an AOI as well as list of affected strategic GOIs (human, physical, economic damage per GOI)		Analysis of possible future scenarios: planning and assessment of different future scenarios with alternative conditions and situational parameters		
DES information - safe strategic areas and points in an AOI	**PF**	**Contingency management: Analysis of contingencies and options, e.g. identification of safe shelters and material storages**	**DES**	**D6.11 (this deliverable)**
DES information - safe roads in an AOI	**PF**	**Contingency management: Analysis of contingencies and options, e.g. identification of safe transportation routes**	**DES**	**D6.11 (this deliverable)**
Similar scenarios	SA	Scenario matching: Analysis of similar situations in the past	SMAC	D6.15
Changes in LULC over time	SA	Scenario matching: LULC change detection as additional indicator for similarity of scenarios.	CDM (EO-based change detection module)	D6.19 (new deliverable to come)
ISA information - total economic damage in similar scenarios	SA	Cost analysis	ISAS	D6.8
Decisions and measures taken, lessons learnt in similar scenarios	PF	Adaptive emergency management: Analysis of decisions and measures taken and lessons learnt in similar scenarios as potential decision options for the situation at hand	SMES	D6.15
Impact assessment for hypothetic measures	SA/PF	Risk and impact assessment of possible future scenarios: analysis of the consequences of hypothetical prevention and mitigation measures	RVA/ISAS/SMES	D6.5/D6.8/D 6.15
Situation report	SA	Cross-stakeholder cooperation and communication: Utilization of emergency management message standards such as the EDXL (Emergency Data eXchange Language) group of standards (see D6.8) which includes decision support information to overcome the problems of interoperability and semantic heterogeneity and to	SITREP	D6.8

		ensure the optimal provision of disaster-related information for fast decision-making in a highly coordinated manner		

4.3 Functionality of the DES Module

In this deliverable two of the above presented products provided by the **Decision Support Service (DES)** are specified:

- Identification and listing of safe strategic areas and points in an AOI , e.g. safe shelters, evacuation areas and FCPs until a specific time
- Identification of and listing of safe roads in an AOI until a specific time

DES information on potentially safe (potentially not affected for a given time) task-oriented infrastructure, customized towards the addressing organization, is generated based on a fusion of expert, scenario, simulation, and impact assessment information for real and fictional scenarios. Examples for DES information are locations of accessible response materials, safe roads and bridges, alternative locations for C&Cs and FCPs and possible target areas for evacuation. When included in a situation report, this information can help the decision maker to decide on the path to follow to achieve the desired outcome. We expect the combination of this intelligence and the efficient use of means for standards-based communication and information sharing to eventually foster decision making based on informed collaborative reasoning and contingency planning.

In order to reflect the internal diversity of end users in terms of different legal frameworks, national, regional and organizational strategies, roles and profiles, end users are able to customize infrastructure such as potential shelter locations and FCP sites which will be considered for the generation of DES information. In addition, decision makers can configure rules and thresholds and modify DES information according to their individual and organizational needs and knowledge.

4.4 Architecture

The DES module consists of the actual web service in cooperation with the SP and GUI. Interaction of these three components happens through WFS or the exchange of JSON formatted data.

The DES as a RESTful web service provides a HTTP-based REST API which allows clients such as the HEIMDALL SP to communicate with the service.

We have decided not to persist any data in the module directly in order to foster scalability towards different organizational contexts. User management and customization are established centrally in the SP of each HEIMDALL unit. Pre-filtering is performed by specification in the DES request and DES results are directly handed back to the SP. Figure 4-1 outlines the approach.

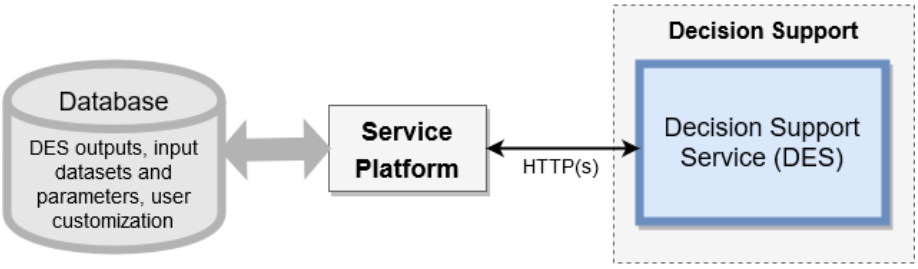

Figure 4-1: DES building blocks

4.5 REST API Conventions

The DES REST API communicates using JSON and WFS as data-interchange format. The formats will be based on shared conventions for designing web APIs, e.g. the JSON API conventions [14] and the WFS specifications [16]. Based on common procedures and technologies in web development the DES API documentation will be built and deployed together with every software release. This way, the API documentation shall remain always up-to-date.

The DES module is installed in the HEIMDALL VPN and is therefore accessible over an URL like this:

http://esb.heimdall.sp/services/des/

Therefore, all URLs used in the examples in the following part of this document refer to this global URL. For example, the request

```
POST process-safe-roads
```

Would be resolved to

```
POST http://esb.heimdall.sp/services/des/process-safe-roads
```

4.6 Workflows

This section describes the general workflow in order to foster a deeper understanding of how the DES works. In addition, workflows for the two types of DES products, safe areas and safe roads, are shown.

4.6.1 General DES Information Generation Workflow

DES information is generated in the PF phase of the decision making process when the end user needs this information as a basis for decision making on options and contingencies. Figure 4-2 outlines the general workflow.

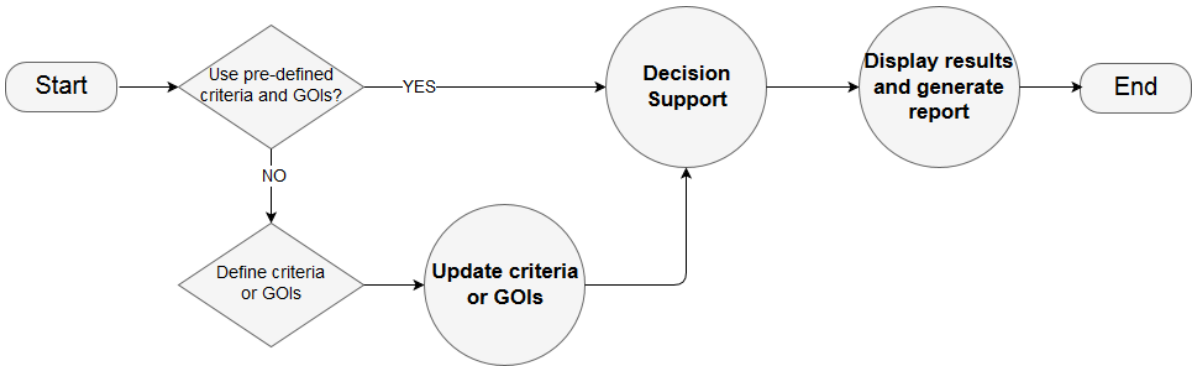

Figure 4-2: General decision support workflow

The workflow is started on demand, either by the end user or by a workflow component. It makes sense to collect first all input data and configure the needed criteria and pre-defined GOIs before starting the DES information generation. DES information can be used to display it in the UI and to list it in a situation report in an additional information block.

4.6.2 Workflow for Safe Areas

The workflow starts on request once simulation results are available for the scenario at hand and the user has defined an AOI. The “safe areas” functionality accepts a collection of GOIs (areas or points) which are assessed as safe or not from the simulated hazard. Areas may be pre-defined evacuation areas, FCPs or potential shelter locations. A system client such as the GUI provides these GOIs and the simulation perimeters to the DES. After process completion the DES returns the same list with an assessment whether and for how long the respective GOIs are safe or not from the hazard. In addition, the DES provides a legend for

styling the areas according to their DES assessment in the map in the GUI. For example, areas which are not safe will be coloured red.

4.6.3 **Workflow for Safe Roads**

The workflow starts again on request once simulation results are available for the scenario at hand and the user has decided on an AOI. The “safe roads” functionality accepts two references: 1) reference to the applicable transportation network and 2) reference to simulated impact relevance results. A system client such as the GUI provides these references to the DES. After process completion the DES returns the list of roads with an assessment whether and for how long the respective roads are safe or not from the hazard. In addition, the DES provides a legend for styling the roads according to their DES assessment in the map in the GUI. For example, roads which are not safe will be coloured red.

5 Technical Specification

5.1 Decision Support Service Specification

5.1.1 **Information Fusion**

The DES aggregation process makes use of the information fusion strategies described for the ISAS in D6.8. Hazard information and impact assessment information are intersected and aggregated using configured expert criteria and metrics with pre-selected GOIs defined by the user.

5.1.2 **DES Information**

In contrast to the ISAS, the DES identifies for a given AOI infrastructure, in particular response infrastructure, which won't be affected within a specific period of time according to the given hazard information. For an AOI the following DES information is generated:

- List of safe areas and points of interest for response planning
- List of safe roads relevant for response planning

Use cases include:

- List of potentially save (potentially not affected for a given time) alternative FCP sites in the area which, when included in a report, can help the decision maker to meet the best possible contingencies in case that a forward command post need to be moved.
- List potential sheltering options in the area (potentially not affected for a given time)
- Find water reservoirs for firefighting or sand pits for filling sandbags in the area

5.1.3 **Multi-criteria Decision Support**

A major task performed in T6.4 in the first period of the project has been to collect and compile hazard- and task-specific domain knowledge in the form of user requirements and expert criteria and metrics, in particular from the different groups of emergency management experts in the consortium and AB from different countries and disciplines. This domain knowledge has been used to shape design, assessment, processing and fusion techniques of the different situation assessment and decision support components on a **per hazard type** basis. For example, depending on the hazard type, the level of detail in hazard information can be different and therefore hazard-specific impact assessment concepts have been elaborated either working with simulated or observed hazard information (see D6.1). Accordingly, different impact classifications apply to each hazard type and impact assessment concept. DES aggregation and fusion techniques must consider these specifics. As to task-specific decision support, different levels of responsibility, legal frameworks and organizational procedures require flexible solutions for the specification of criteria and weights that are applied to the scenario matching process. Identified rules, thresholds, workflows or other appropriate means of customization are transformed into an appropriate service configuration.

In a second step, we identified **common, cross-domain aspects** in the domain knowledge and applied these aspects to the high-level information fusion processes performed by situation assessment and decision support services. In these processes the disjoint hazard-specific pieces of information are related to each other, compared to user goals and objectives and mapped to generalized data models and terminologies. Examples are the harmonized scenario, response plan, and lessons learnt data models and the GOI entity as a means for specifying a target area of interest for the information aggregation. At the same time, these common concepts have been designed to always provide means for a certain degree of customization.

As a possible way of finding criteria and metrics that produce the most promising results out of criteria-based processes such as scenario matching, ISA and DES information generation

is to perform **system trials** with the end users in training sessions. In such trials end users are presented with the tool and a **default configuration of criteria and metrics** (based on identified needs and assumptions). In consecutive trials users **fine-tune the configuration** so that the produced results are assessed as appropriate. The more training data (e.g. scenarios) is available the better the results. The finalized configuration is used for immediate response situations. For the time being, the consortium has agreed upon performing trials for the scenario matching component.

5.1.3.1 Criteria and Metrics

The DES makes use of pre-defined criteria and metrics in order to generate the most useful DES information as a basis for decision making in contingency management. Through the diversity of end users in terms of different legal frameworks, national, regional and organizational strategies, roles and profiles, these criteria and metrics depend strongly on the stakeholders which shall be addressed. Therefore, it is fundamental to identify common and individual criteria and metrics for the different stakeholders to be supported by the DES. These criteria and metrics have been incrementally developed and evaluated in collaboration with the end user partners. Discussions have revealed a need for the consideration of the following criteria and metrics which will be refined in future discussions:

- Different selections and pre-definitions of relevant response-oriented infrastructure, e.g. safe roads
- Pre-definition of potential alternative FCP sites
- Different prioritizations of infrastructure
- Single-hazard vs. multi-hazard impact assessment
- Different DES information products of interest, different product attributes of interest
- Different temporal horizons of interest (e.g. not safe, safe until time x)
- Transparency of data source whereof the end user might pre-select
- Visibility of configuration and pre-selection
- Visibility of limitations (e.g. in data resource)

5.1.3.2 Configuration of Criteria and GOIs

In order to reflect the internal diversity of end users the DES provides the possibility to customize criteria, rules and other definitions of process behaviour which are considered during the generation of DES information. The DES API offers the possibility to pre-filter the desired information by explicitly selecting the AOI and GOIs in the GUI. If the user is interested in roads being safe until a certain time, these specific roads of interest are selected with a bounding box and retrieved from the exposure layer.

5.1.4 REST API

The DES provides a REST API. The REST API enables clients such as the SP or UI to trigger the DES information generation process and to access and modify DES information products. The specification in this chapter describes the API in more detail.

Using WFS or JSON directly depends on the object of investigation, i.e. processing on safe roads requires the SP to provide the data with WFS whereas processing on safe areas requires the SP to provide the data as JSON objects following a custom API. The user will be able to call the DES module with the RESTful POST command. The user decided either to process on safe roads or safe areas.

If the user is interested in safe roads, the basic command is:

```
POST http://esb.heimdall.sp/services/des/process-safe-roads
```

```
Content-Type: application/vnd.api+json
```

With the body:

```
{
    "aoi": {
        "type": "Polygon",
        "coordinates": <coordnate list>
    },
    "impact_assessment":
"http://esb2.heimdall.sp/services/rest/simulations/transportation?simid=425
b6e5f-bfd6-41bb-ac9f-b7e9f796c9f5",
    "exposure_data":
"http://esb.heimdall.sp/services/ogc/heimdall/ows?service=WFS&version=1.0.0
&request=GetFeature&typeName=heimdall:cataloniaTransportation2&outputFormat
=application/json"
}
```

If the user is interested in safe areas, the basic command is:

```
POST http://esb.heimdall.sp/services/des/process-safe-areas
Content-Type: application/vnd.api+json
```

With the body:

```
{
    "type": "FeatureCollection",
    "features": {
        "area": [{
                "type": "Feature",
                "properties": {
                    "heimdall_id": "7d8e05e7-3cc0-47c0-9230-9e6983be66a2",
                    "area_type": "fcp"
                },
                "geometry": {
                    "type": "MultiPolygon",
                    "coordinates": <coordnate list>
                }
            }
        ],
        "per": [{
                "type": "Feature",
                "properties": {
                    "heimdall_id": "03bd2277-51f6-4fbd-b5a7-510c021a72df",
                    "perimeter": <perimeter value>,
```

```
                    "area_type": "per"
                },
                "geometry": {
                    "type": "MultiPolygon",
                    "coordinates": <coordnate list>
                }
            }
        ]
    }
}
```

The response looks like:

```
[
  {
    "area_safe_until": 20.0,
    "area_type": "eva",
    "heimdall_id": "7d8e05e7-3cc0-47c0-9230-9e6983be66a2",
    "area_not_safe": 50.0
  }
]
```

The results are stored in a list. The list contains all GOIs (also non-safe). The keyword `area_safe_until` states the area is at least safe for the indicated time. The keyword `area_not_safe` states the area is affected within the indicated time.

Table 5-1: Functionality of the DES module

ID	Functionality	Interface method	Data exchanged and data representations
DES_A_01	Compute safe areas	HTTP POST / des/process-safe-areas	Request body: JSON resource with basic parameters. Response body: JSON
DES_R_02	Compute safe roads	HTTP POST / des/process-safe-roads	Request body: JSON resource with basic parameters. Response body: JSON

5.1.5 **Visualization of DES Information in the GUI**

DES information can be displayed in a map as the results are provided as a list of geolocations (i.e. GEOJSON FeatureCollection).

In the map areas and roads can be highlighted according to the provided legend and to their assessment as “safe until some specific time” (yellow) or “not safe” (red):

```
[
    {
        "label": "safe_until",
        "value": "#73ff00"
    },
    {
        "label": "not_safe",
        "value": "#ff0000"
    },
    {
        "label": "unknown",
        "value": "#000000"
    }
]
```

In Release C, the label “safe” has been provided by the DES with a green color code. Figure 5-1 shows a screenshot of DES results in the HEIMDALL GUI taken during EUW4. Safe areas are shown in green colour, areas that are safe until a specific time in yellow colour; popup shows DES information for a selected area, e.g. the area is assessed to stay safe from flooding for 20 hours.

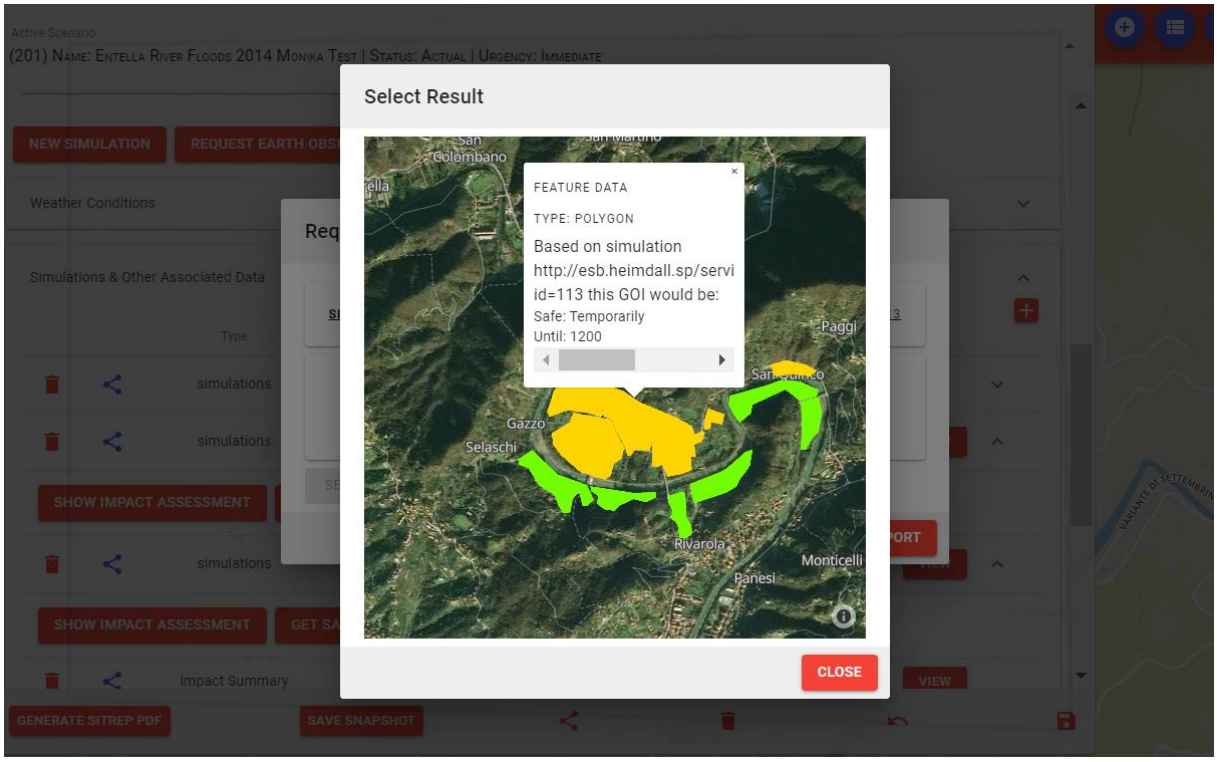

Figure 5-1: DES information visualization in the map of the Release C system release

In the final release the “safe” assessment has been removed as the DES cannot state that an element is safe. The only time information we have are the fire resp. flood perimeters. Thus, the element will not be affected until being reached by a fire resp. flood perimeter. The

output value will be the perimeter time itself (e.g. 6 hours) so the element will be safe for six hours. If the element won't be reached by the maximum fire perimeter this does not mean that it won't be reached by the fire resp. flood at all.

Upon clicking on an area or road DES information for that specific element can be displayed in descriptive form in a popup like the one shown in Figure 5-1. Descriptive information may be the assessment itself (i.e. safe or not safe) and the time until the assessment is valid. The time can be displayed as relative information (e.g. hours) or as a timestamp. The latter has been identified by the end users as more useful.

5.1.6 **Implementation Details**

The DES is implemented using the same technologies as the ISAS module. For further information refer to the section on implementation details in D6.8 [9].

The implementation language of the DES component is the general purpose, high-level language Python. This language focuses on high productivity, code readability and offers a wide variability of supporting software libraries.

The language is built on a dynamic type system and offers automatic memory management which makes is resilient against a wide range of common errors like buffer overflows or memory leaks.

While the language supports multiple programming paradigms the implementation of this module mostly follows an object-oriented approach with occasional usages of functional elements.

5.1.6.1 Implementation framework and software libraries

The Web API will be implemented using the Django framework, an open source web application framework which follows the Model-View-Controller pattern. The framework includes geographic datatypes and functions following the Simple features specification of the Open Geospatial Consortium (OGC).

In addition to the generic Django framework the "Django REST Framework" shall be used as a toolkit to implement the REST API.

As mentioned in section 2.1.3 JSON is the preferred format for exchanging data and generating output information.

The module was developed in multiple iterative steps with every stage being managed with the versioning system Git which is commonly used in the software development community.

5.1.6.2 Hardware

The hardware used for the implementation of this module are two virtual machines based on a 64bit Linux distribution. As the first VM is for testing the second VM is for developing. Both VM's have 4 CPU cores each as well as 1 TB disk memory and 32 GB RAM. A proper Ethernet connection is crucial as well as a connection to the HEIMDALL VPN.

6 Test Plan

6.1 DES Verification

The DES can be tested by directly calling its web services with a REST client to verify the correct triggering of the DES functionalities and receiving the appropriate DES information products. For both functionalities specified in section 5.1.4, safe areas and safe roads, a test was performed using a correct and an incorrect input. In the *correct* case, the DES shall perform the specified action and return the specified reply. In the *incorrect* case, the DES shall reply with the specified error message.

Test ID	*TS_DS_01*
Requirements to be verified	• TR_DS_01 • TR_DS_03
Test objective	Verify that the DES generates and returns on request DES information that describes list of potentially safe areas/GOIs (e.g. C&C sites, evacuation areas, sand pits, shelters) per selected AOI. Verify that for each GOI in the list a timestamp with the validity of the safe status is provided.
Test procedure	1. The user connects to the HEIMDALL VPN. 2. The user starts a REST test client (e.g. Postman). 3. Using the test client the user creates and submits a POST request to the DES service URL and specifies in the request body a list of areas, simulation perimeters (from an actual simulation result) and an AOI
Test prerequisites/ configuration	• DES connected to the HEIMDALL system
Success criteria	The user receives a POST response with the DES result in the body. For each GOI in the list it is visible whether and until which perimeter it will be safe from the hazard
Results analysis	The test has been performed and passed with different types of GOIs namely evacuation areas (Release C), FCPs (Release C) and shelter locations (final release) and with forest fire (final release) and flood perimeters (Release C).
Success	PASSED

Test ID	*TS_DS_02*
Requirements to be verified	• TR_DS_02 • TR_DS_04
Test objective	Verify that the DES can be configured with thresholds for the generation of DES information.
Test procedure	1. The user connects to the HEIMDALL VPN. 2. The user starts a REST test client (e.g. Postman). 3. Using the test client the user creates and submits a POST request to the DES service URL and specifies in the request body the maximum perimeter to be considered for assessment.
Test prerequisites/ configuration	• DES connected to the HEIMDALL system
Success criteria	The user receives a POST response with the DES result in the body. For each

	GOI in the list it is visible whether and until which perimeter it will be safe from the hazard. The maximum perimeter shown is the pre-configured maximum perimeter.
Results analysis	The test has been performed and passed with forest fire (final release) and flood perimeters (Release C).
Success	PASSED

Test ID	*TS_DS_03*
Requirements to be verified	• TR_DS_05
Test objective	Verify that the DES information can be added and modified.
Test procedure	1. The user connects to the HEIMDALL VPN. 2. The user starts a REST test client (e.g. Postman). 3. Using the test client the user creates and submits a POST request to the DES service URL and specifies in the request body a list of areas, simulation perimeters (from an actual simulation result) and an AOI 4. Then, the user generates and submits the same request and adds another GOI in the list 5. After submission the user modifies DES information in the result.
Test prerequisites/ configuration	• DES connected to the HEIMDALL system
Success criteria	For both requests the user receives a POST response with the DES result in the body. The second response contains the added GOI with its safe status.
Results analysis	The test has been performed and passed with different types of GOIs namely evacuation areas (Release C) and shelter locations (final release) and with forest fire (final release) and flood perimeters (Release C).
Success	PASSED

Test ID	*TS_DS_04*
Requirements to be verified	• TR_DS_06
Test objective	Verify that the DES generates and returns on request safe and unsafe roads either in a list or a map.
Test procedure	1. The user connects to the HEIMDALL VPN. 2. The user starts a REST test client (e.g. Postman). 3. Using the test client the user creates and submits a POST request to the DES service URL and specifies in the request body the reference to the transportation network, to the forest fire simulator impact relevance results and an AOI
Test prerequisites/ configuration	• DES connected to the HEIMDALL system • Transportation networks (exposure datasets) available and accessible on the SP • FFS Impact Relevance Results available and accessible on the SP
Success criteria	The user receives a POST response with the DES result in the body. The

	response contains a list of safe roads. The response body can be displayed in a map.
Results analysis	The test has been performed and passed with different transportation networks (exposure datasets) available on the SP and different impact relevance results.
Success	PASSED

7 Conclusion

This document provided an overview of work conducted in task 6.4 in close collaboration with the other tasks in WP6, with the end user and ELSI partners in the project consortium. The overall HEIMDALL decision support concept has been highlighted under consideration of multi-hazard, cross-domain, and ELSI aspects.

In the specification part, the Decision Support Service (DES) has been presented in detail. The DES identifies and lists save strategic geolocations such as shelters, FCPs and roads in an AOI which supports the identification of options and contingencies.

Before documenting the DES specification in D6.11 it has been uploaded to the HEIMDALL developer wiki. On the basis of this specification the involved technical partners have been able to develop Release C and the final release of the component and to integrate it in the overall HEIMDALL system. Release C has been successfully integrated in the GUI so that end users have been able to use the module and to display DES results in the user interface and provide feedback to the developers. However, due to prioritization of the end user and technical partners the updates of the DES considering the feedback could not be integrated in the GUI for the final demonstration. Nevertheless, the component has been successfully tested in interaction with the Service Platform and is accessible from within the HEIMDALL VPN using any HTTP client.

The component design is based on concepts developed in close collaboration with end users from different countries and disciplines, which namely are Fire and Rescue Services (FRS), Police, Medical Services (MS), Civil Protection (CP) and Command and Control Centres (C&C). Requirements and solutions evolve through collaborative design and the HEIMDALL agile system development considers the needs of end users and other stakeholders. Intermediary system releases based on the case studies developed by the end users have been demonstrated in real-environment conditions, for example during EUW4 in October 2019. These demonstrations and exercises have given the end users the possibility to reflect on intermediary solutions, to validate these and to identify problems and further needs. User feedback has been acquired during demonstrations and exercises. This information has led to re-iterations of technical requirements and the component design. Furthermore, in in-depth discussions, expert criteria and metrics for the different decision support products have been refined.

As a matter of prioritization, the system development could not include all evolving user requirements and concepts. A cost-neutral extension of the project lifetime will enable us to take on these requirements. Not in the form of full-fledged functionalities but in the form of concepts for future research and development and experimental proof-in-concept implementations, fine-tuning of expert criteria and methods. We believe that some of these activities will improve the HEIMDALL modules to be verified in a final demonstration. We plan to promote these current developments and to document them in the additional deliverable D6.19 Situation Assessment, Decision Support and Scenario Matching – Updated Concepts at the end of the project.

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