D6.4

Technical Specifications on Hazard, Scale and User-Specific Risk Assessment Information, Products and Service Workflows - Draft

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List of Acronyms

ALS	Airborne Laser Scanning
API	Application Programming Interface
BBOX	Bounding Box
CI	Critical Infrastructure
CIESIN	International Earth Science Information Network
CIMA	Centro Internazionale in Monitoraggio Ambientale – Fondazione CIMA (CIMA Foundation)
CPU	Central processing unit
CLC	Corine Land Cover
CSV	Comma-separated values
CTTC	Centre Tecnològic de Telecomunicacions de Catalunya (Catalan Tecnological Telecommunications Centre)
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center)
DB	Database
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
DSS	Decision Support System
EO	Earth Observation
EEA	European Environment Agency
EMS	Emergency Management Service
ESS	European Statistical System
FTP	File Transfer Protocol
FUA	Functional Urban Area
EEA	European Environmental Agency
GHS-POP	Global Human Settlement Population Grid
GIS	Geographic Information System
GUI	Graphical User Interface
GHS-POP	Global Human Settlement Population Grid
HR	High-Resolution

HTTP	Hyper Text Transfer Protocol
HTTPS	Hyper Text Transfer Protocol sECURE
ICGC	Institut Cartogràfic I Geològic de Catalunya (Catalan Institute of Cartography and Geology)
IT	Information technology
IS	Impervious Surfaces
ISA	Impact Summary Generation
LAN	Local Area Network
LIDAR	Light Detection and Ranging
JSON	Javascript Object Notation
LiDAR	Light detection and ranging
LULC	Land use land cover
MIR	Middle Infrared
MTBF	Mean time between failures
nDSM	Normalized Digital Surface Model
NUTS	Nomenclature des unités territoriales statistiques
OGC	Open Geospatial Consortium
OS	Operating System
OSM	OpenStreetMap
SRTM	Shuttle Radar Topography Mission
PC	Personal Computer
RAID	Redundant Array of Independent Disks
RAM	Random Access Memory
REST	Representational State Transfer
ROM	Read-only memory
RVA	Risk and Vulnerability Analysis
SP	Service Platform
TanDEM-X	TerraSAR-X add-on for Digital Elevation Measurement
ToC	Table of Contents
TSYL	Tecnosylva S.L.
UA	Urban Atlas
UNISTRA	Université de Strasbourg (University of Strasbourg)
VGI	Volunteer Geographic Information

VHR1	Very High Resolution (< 1m spatial resolution)
VHR2	Very High Resolution (1m > spatial resolution < 4m)
VPN	Virtual Private Network
WMS	Web Map Service
WFS	Web Feature Service
WCS	Web Coverage Service
WP	Work Package
XML	Extensible Markup Language

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Executive Summary

This document provides the first documentation (draft) of the technical specifications for the implementation of the methodological concepts on risk and vulnerability analysis in HEIMDALL (RVA) specified in deliverable D6.1 "Concept design for risk analysis methods and components – Detailed concept design and documentation of methods on risk analysis". Based on the identified technical requirements the RVA module functionality is described explaining the existing sub modules, their purpose and function inside the module, the main components of each sub module, as well as how these sub modules interact and exchange information among them. Accordingly, four different sub modules are defined and specified, namely the human exposure and physical exposure sub modules which generate the physical and human exposure products and the Earth-Observation impact assessment and the Simulation based impact assessment sub modules that generate the impact assessment products. Each of these sub modules are then further specified detailing the process of generating the corresponding products, the used data as well as the methods planned to be used to implement and integrate these sub modules in HEIMDALL.

1 Introduction

This document addresses the work carried out so far in task T6.2 and aims at providing a first component design with a basic specification of the technical details of the RVA module following the methodological concepts on risk and vulnerability that are specified in deliverable D6.1. These concepts constitute the basis for the technical specifications of the module and corresponding sub modules in this document. Due to the V-model development approach this module in a similar way than the other components of HEIMDALL will be designed and implemented in a progressive way, following several iterations with the end-users and Advisory Board during the several scheduled demonstrations of the System. The first implementations of the RVA module is planned to be performed for release B, therefore the test plans and corresponding tests and implementation details are expected to be provided during the follow-up version of the document in deliverable D6.5.

The RVA module shall be comprised of two main sub modules, on one hand the Exposure sub module that calculates the human exposure and physical exposure through the corresponding exposure sub modules, and on the other hand the impact assessment module that comprises the “Simulation based impact assessment” and “Earth Observation based impact assessment sub modules (see Section 4) according to the specifications and needs identified and described in deliverable D6.1.

In particular, the document is organised as follows: Section 2 specifies the technical requirements based on the identified system requirements of HEIMDALL in what concerns the risk and vulnerability assessment functionalities and interfaces expected in HEIMDALL. These requirements are specified for the short-term, mid-term and long-term versions of the HEIMDALL system according to the planed releases of the system throughout the project.

Section 3 illustrates the role of the RVA module inside the HEIMDALL system as well as the relations and dependencies with the other modules of the System.

Section 4 describes how the RVA module works and how it is designed from the inside. In particular, it describes the existing sub modules, their purpose and function inside the module, the main components of each of these sub modules, as well as how these sub modules interact and exchange information among them and among the HEIMDALL modules external to the RVA module.

Section 5 presents the detailed technical specification of each of the RVA sub modules, specifying the base data use by each of these, the necessary input data, the created outputs and results as well as the methods used to implement or integrate the corresponding sub modules in the HEIMDALL system.

Finally, Section 6 summarises and concludes the document.

2 Technical requirements

2.1 Interface Requirements

2.1.1 Hardware Interfaces

DLR will generate the exposure products from its premises in Oberpfaffenhofen, Germany. All data is stored on internal data servers of DLR, which will be backed up frequently. The exposure data is created using the following hardware interfaces:

- Intel(R) Xeon(R) CPU E5-2687W v2 @ 3.40GHz, 3401 MHz, 8 Cores, 16 logical processors
- 32 GB RAM
- x64-Windows 7 Enterprise

UNISTRA/SERTIT will generate the EO based impact assessment products from its Strasbourg/Illkirch premises, France. Its premises have a crisis mapping room that has 5 dedicated PCs having the following minimum configuration:

- 3+GHz dual/quad-core CPU
- 16 Go RAM
- 2+To Disks RAID 1 (mirror)
- Enterprise/RAID Disks (24/7 high MTBF level)
- Reliable PC power supply (Gold 80+)
- Reliable and robust motherboards
- 64 bit
- Double screens HD (1920x1080)

UNISTRA/SERTIT uses state of the art industrial standard hardware regarding its IT hardware infrastructure with a data-server “cluster” of 2 servers with server breakdown protection and synchronous duplication of data, a 1 Gb full duplex LAN with back-up network. Below is the description of the servers:

- Professional material high reliability and duplication
- Bi quad-core CPU at 3.3 GHz
- 64 Go RAM
- ~50 TB of ROM (logic) for rack data (with RAID 6 back-up disks. These disks are made to function 24/7 and are Enterprise standard)
- Network switches 2x40 GB (interconnection between 2 switches) with 10 GB links between racks and servers.
- Windows 2012 Server OS

UNISTRA/SERTIT’s internet connection is via the University of Strasbourg to the extremely high broadband 10 Gb shared Osiris/RENATER network which is the high-performance network infrastructure linking French universities.

CIMA will generate the simulation-based impact assessment products in its premises in Savona (Italy); the server that will be used in order to provide the service will have the following characteristics:

- FUJITSU PRIMERGY TX300 S8 4U
- Dual 8 core Intel(R) Xeon(R) CPU E5-2640 v2 @ 2.00 GHz
- 64 Gb RAM DDR3
- 10 TB disk space

2.1.2 **Software Interfaces**

The RVA module shall be connected to the following services of HEIMDALL:

- Service Platform,
- User interface (through the SP),
- EO services (through the SP),
- Modelling and simulation products (through the SP),
- Situation Assessment,
- Decision Support.

The exposure and simulation-based components of the RVA shall interface with the SP using RESTful web services whereas the EO-based impact assessment component shall interface the SP through FTP connection.

2.1.3 **Communication Interfaces**

Depending on the corresponding sub module the RVA shall use HTTP / HTTPS and FTP to connect to the HEIMDALL network and to interface with it.

The connections will be done using the Virtual Private Network (VPN) managed by SPH to allow a secure connection.

2.2 Functional Technical Requirements

2.2.1 **Short-Term Features**

Table 2-1: Technical Requirement TR_Risk_01

Requirement ID:	TR_Risk_01
Related SR(s):	• Sys_Risk_9 • Sys_Risk_8
Description: The RVA module shall be able to extract built-up area from EO data or integrate the information from external databases for the exposure estimation.	
Rational: Built-up area has to be extracted in order to perform impact assessment based on expected building damage and number of affected people.	
Stimulus: The process will be triggered by the user or the SP.	
Response: The RVA module will extract built-up area information from EO data.	
Verification Criterion: That the RVA is able to extract built-up area from EO data.	
Notes: The quality of the EO data (cloud cover, geometric resolution, number of points per unit) has to be sufficient. In case external databases provide appropriate information, the module shall be able to integrate external data sets.	

Table 2-2 Technical Requirement TR_Risk_02

Requirement ID:	TR_Risk_02
Related SR(s):	• Sys_Risk_9
Description:	

The RVA shall be able to identify affected buildings and other infrastructure components.
Rational: Identification of affected elements is the necessary input for the impact assessment.
Stimulus: The process will be triggered by the user or the SP.
Response: RVA module will perform geometric operations to identify the affected elements
Verification Criterion: Given the necessary input affected/exposed elements can be identified by the module.
Notes: Detected or simulated hazard extent must be provided in order to identify the affected/exposed elements.

Table 2-3 Technical Requirement TR_Risk_04

Requirement ID:	TR_Risk_04
Related SR(s):	• Sys_Risk_9 • Sys_Risk_11
Description: The RVA shall be able to estimate the number of affected people.	
Rational: Affected population shall be used as an impact indicator.	
Stimulus: The process will be triggered by the user or the SP.	
Response: The RVA module estimates the number of affected people.	
Verification Criterion: The RVA module provides an estimate of the affected population.	
Notes: In case no damage functions are available this indicator will serve as the impact assessment.	

Table 2-4 Technical Requirement TR_Risk_05

Requirement ID:	TR_Risk_05
Related SR(s):	• Sys_Risk_9 • Sys_Risk_11
Description: The RVA shall be able to integrate information on monetary values and based on this estimate the impact expressed in the potential loss of monetary values.	
Rational: Economic losses shall be used as an impact indicator.	
Stimulus: N.A.	
Response: Using the hazard information and the information about the monetary values the RVA will provide an impact estimate expressed in monetary values.	
Verification Criterion: RVA can estimate loss of monetary values as indicator for the impact.	
Notes: Standardized information on monetary values of the affected areas must be present in	

an external data sources. The information on monetary values will be stored and on request used for the impact assessment as an indicator. Since the calculation is not performed on-the-fly, no stimulus is defined.

2.2.2 Mid-Term Features

Table 2-5 Technical Requirement TR_Risk_03

Requirement ID:	TR_Risk_03
Related SR(s):	• Sys_Risk_9 • Sys_Risk_11
Description: The RVA shall be able to estimate the expected impact based on the identified affected components, damage/vulnerability functions and the simulation/EO products.	
Rational: Impact Assessment is the main output from the RVA module.	
Stimulus: The process will be triggered by the user or the SP.	
Response: The RVA module estimates the expected impact on the affected components.	
Verification Criterion: The RVA module provides the Impact Assessment product.	
Notes: With regard to specific hazards suitable vulnerability/damage functions must be available in order to calculate the expected damage.	

Table 2-6 Technical Requirement TR_Risk_06

Requirement ID:	TR_Risk_06
Related SR(s):	• Sys_Risk_7
Description: The RVA shall be able to integrate preliminary risk information products provided by the end users based on their expert knowledge. For example, map products showing critical infrastructures and flood prone areas identified based on experience by the end-users and first responders should be integrated into the RVA module.	
Rational: Integration of preliminary risk information enables the RVA to assess risk without triggering the creation of simulation or observation products.	
Stimulus: The user has to import the products and request it.	
Response: The RVA module displays preliminary risk information products.	
Verification Criterion: Preliminary risk information products can be integrated into the platform.	
Notes: The preliminary risk information must be provided in a standardized format in order to be integrated into the platform.	

Table 2-7 Technical Requirement TR_Risk_07

Requirement ID:	TR_Risk_07
Related SR(s):	• Sys_Risk_1 • Sys_Int_9
Description: RVA module shall be able to provide the hazard extent to be displayed by the GUI without including the generation of impact information.	
Rational: In case the necessary input data for detailed risk assessment is not available the module supports the user with hazard information.	
Stimulus: The user or the SP requests the hazard information.	
Response: RVA provides the hazard information provided by sensor or simulation data.	
Verification Criterion: Hazard information can be requested and is displayed by the GUI without the triggering of risk assessment information.	
Notes:	

Table 2-8 Technical Requirement TR_Risk_08

Requirement ID:	TR_Risk_08
Related SR(s):	• Sys_Risk_2
Description: RVA module shall be able to generate risk assessments for forest fires, floods and landslides.	
Rational: Risk information products concerning the respective hazards are mandatory input for the situation assessment and the DSS component.	
Stimulus: The process will be triggered by the user or the SP.	
Response: Risk information products will be calculated.	
Verification Criterion: RVA module is able to estimate the risk concerning the hazards forest fires, floods and landslides.	
Notes: Depends on hazard extent detected by analysis of sensor or simulations data.	

Table 2-9 Technical Requirement TR_Risk_09

Requirement ID:	TR_Risk_09
Related SR(s):	• Sys_Risk_4
Description: RVA module shall be able to consider cascading effects on vulnerability.	
Rational: In case of multi-hazard risk assessment the cascading effects on vulnerability have to be addressed by the RVA.	
Stimulus: Risk assessment process regarding multiple hazards is triggered by the user or the	

SP.
Response: Cascading effects on vulnerability are estimated by the RVA during risk assessment.
Verification Criterion: The cascading effects on vulnerability are considered during the risk assessment process.
Notes:

Table 2-10 Technical requirement TR_Risk_10

Requirement ID:	TR_Risk_10
Related SR(s):	• Sys_Risk_5
Description: RVA module shall be able to integrate national datasets of critical, and if available significant, infrastructures that will be provided by the respective institutions over external data sources.	
Rational: National data sets of critical and significant infrastructures shall be integrated in order to further improve the exposure data set.	
Stimulus: The process will be triggered by the user.	
Response: The provided data set will be integrated into the exposure data set.	
Verification Criterion: Critical, and if available significant, infrastructures from external sources can be integrated into the RVA exposure data set.	
Notes: Critical infrastructure data sets have to be up-to-date and provided in a standardized format.	

Table 2-11 Technical requirement TR_Risk_11

Requirement ID:	TR_Risk_11
Related SR(s):	• Sys_Risk_5
Description: RVA module shall be able to identify infrastructures not affected by the hazard and the potentially not affected.	
Rational: Identification of not affected infrastructures can be used for shelter identification.	
Stimulus: The process will be triggered by the user or the SP.	
Response: Location of potentially safe infrastructures.	
Verification Criterion: The RVA module identifies potentially safe infrastructures with respect to the disaster event extent.	
Notes:	

Table 2-12 Technical requirement TR_Risk_12

Requirement ID:	TR_Risk_12

Related SR(s):	• Sys_Risk_6
Description: RVA module shall be able to estimate the vulnerability of the population.	
Rational: The assessment of the vulnerability of the population will lead to more precise risk assessment.	
Stimulus: The process will be triggered by either by the user or directly by the SP.	
Response: Vulnerability assessment in the human domain will be performed by the RVA.	
Verification Criterion: RVA module provides an estimate of the vulnerability of the population.	
Notes:	

Table 2-13 Technical requirement TR_Risk_13

Requirement ID:	TR_Risk_13
Related SR(s):	• Sys_Risk_10
Description: RVA module shall be able to share the risk assessment products with other services.	
Rational: Sharing of RVA information is mandatory for other services, e.g. during the situation assessment process.	
Stimulus: RVA information is requested by the user or directly by the SP.	
Response: The created RVA information products are either provided or transformed to a standardized exchange format.	
Verification Criterion: RVA information can be shared among other HEIMDALL services.	
Notes:	

Table 2-14 Technical requirement TR_Risk_14

Requirement ID:	TR_Risk_14
Related SR(s):	• Sys_Risk_9 • Sys_Risk_8
Description: The RVA module shall be able to extract relevant land use land cover (LULC) information from EO data or integrate the information from external databases for the exposure estimation.	
Rational: LULC information has to be extracted in order to perform impact assessment based on expected damage on the LULC classes (e.g. agricultural fields, vegetation classes).	
Stimulus: The process will be triggered by the user or the SP.	
Response: The RVA module will extract LULC information from EO data or integrate information from external databases.	
Verification Criterion: That the RVA is able to provide LULC information.	

Notes: The quality of the EO data (cloud cover, geometric resolution, number of points per unit) has to be sufficient. In case external databases provide appropriate information the module shall be able to integrate external data sets.

Table 2-15: Technical Requirement TR_RiskWF_1

Requirement ID:	TR_RiskWF_1
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2
Description: The RVA module shall be able to estimate the human exposure on demand.	
Rational: The user shall be able to trigger the estimation of the human exposure for a certain area; this estimation can be based on a simulation perimeter or a hazard extension obtained from EO imagery.	
Stimulus: The user through the GUI or the SP shall be able to trigger the assessment of the human exposure for an existing hazard extension or simulation perimeter of a given scenario.	
Response: Creation and storage of the human exposure results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: External human exposure datasets can be integrated.	

Table 2-16: Technical Requirement TR_RiskWF_2

Requirement ID:	TR_RiskWF_2
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2
Description: The RVA module shall be able to carry out the estimation of the physical exposure on demand.	
Rational: The user shall be able to trigger the estimation of the physical exposure for a certain area; this estimation can be based on a simulation perimeter or hazard extension obtained from EO imagery.	
Stimulus: The user through the GUI chooses to run the physical exposure for an existing hazard extension or simulation perimeter.	
Response: Creation and storage of the physical exposure results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-17: Technical Requirement TR_RiskWF_3

Requirement ID:	TR_RiskWF_3
Related SR(s):	• Sys_Risk_1

	• Sys_Risk_2 • Sys_Risk_4 • Sys_Risk_11
Description: The RVA module shall be able to carry out the assessment of the human impact on demand.	
Rational: The user shall be able to trigger the estimation of the human impact for a certain area based on a simulation perimeter or a hazard extension obtained from EO	
Stimulus: The user through the GUI or the SP shall be able to trigger the human impact assessment for a given hazard extension or simulation perimeter.	
Response: Creation and storage of the impact results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-18: Technical Requirement TR_RiskWF_4

Requirement ID:	TR_RiskWF_4
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2 • Sys_Risk_4 • Sys_Risk_11
Description: The RVA module shall be able to carry out the assessment of the physical impact on demand.	
Rational: The user through the GUI or the SP shall be able to trigger the estimation of the physical impact for a certain area based on a simulation perimeter or a hazard extension obtained from EO	
Stimulus: The user through the GUI or the SP triggers the physical impact assessment for a given hazard extension or simulation perimeter.	
Response: Creation and storage of the impact results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-19: Technical Requirement TR_RiskWF_5

Requirement ID:	TR_RiskWF_5
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2
Description: The RVA module shall be able to estimate the human exposure automatically based on the existence of a new EO image or the creation of a new simulation perimeter.	

Rational: The RVA module shall estimate the human exposure for a certain area which is triggered based on the creation of a new simulation perimeter or a new hazard extension obtained from EO
Stimulus: New simulation perimeter, new EO based hazard extent.
Response: Creation and storage of the human exposure results
Verification Criterion: Results are retrieved to the service(s) that request them.
Notes: none

Table 2-20: Technical Requirement TR_RiskWF_6

Requirement ID:	TR_RiskWF_6
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2
Description: The RVA module shall be able to carry out the estimation of the physical exposure automatically based on the obtaining of a new EO image or the creation of a new simulation perimeter.	
Rational: The RVA module shall estimate the physical exposure for a certain area which is triggered based on the creation of a new simulation perimeter or a new hazard extension obtained from EO	
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.	
Response: Creation and storage of the social exposure results.	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-21: Technical Requirement TR_RiskWF_7

Requirement ID:	TR_RiskWF_7
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2 • Sys_Risk_4 • Sys_Risk_11
Description: The RVA module shall be able to carry out the physical impact assessment automatically based on the obtaining of a new EO image or the creation of a new simulation perimeter.	
Rational: The RVA module shall estimate the physical impact for a certain area which is triggered based on the creation of a new simulation perimeter or a new hazard extension obtained from EO	
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.	
Response: Creation and storage of the impact assessment results	

Verification Criterion: Results are retrieved to the service(s) that request them.
Notes: none

Table 2-22: Technical Requirement TR_RiskWF_8

Requirement ID:	TR_RiskWF_8
Related SR(s):	• Sys_Risk_1 • Sys_Risk_2 • Sys_Risk_4 • Sys_Risk_11
Description: The RVA module shall be able to carry out the human impact assessment automatically based on the obtaining of a new EO image or the creation of a new simulation perimeter.	
Rational: The RVA module shall estimate the human impact for a certain area which is triggered based on the creation of a new scenario, a new simulation perimeter or a new hazard extension obtained from EO	
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.	
Response: Creation and storage of the impact assessment results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

2.2.3 **Long-Term Features**

Table 2-23 Technical Requirement TR_Risk_15

Requirement ID:	TR_Risk_15
Related SR(s):	• Sys_Risk_3
Description: RVA module shall be extendable to create information products for other hazards like e.g. earthquakes, storm events and man-made disasters.	
Rational: The user should have the possibility to extend the platform functionality.	
Stimulus: The process will be triggered by the user or the SP.	
Response: Respective RVA information products are created.	
Verification Criterion: RVA module can create information products for hazards other than forest fires, floods and landslides.	
Notes:	

Table 2-24 Technical Requirement TR_Risk_16

Requirement ID:	TR_Risk_16
Related SR(s):	• Sys_Risk_8
Description: RVA module shall be able to identify possible evacuation areas based on hazard information and exposure data set.	
Rational: The end user shall be provided with possible evacuation areas to support tactical decisions.	
Stimulus: The process will be triggered by the user or the SP.	
Response: Evacuation areas are identified by the RVA module.	
Verification Criterion: The RVA module can identify evacuation area information products.	
Notes:	

Table 2-25: Technical Requirement TR_RiskWF_9

Requirement ID:	TR_RiskWF_9
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to calculate the human exposure on demand for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The user shall be able to trigger the calculation of the human exposure for a certain area based on a simulation perimeter or a hazard extension obtained from EO imagery.	
Stimulus: The user through the GUI or the SP shall be able to trigger the human exposure for an existing hazard extension or simulation perimeter.	
Response: Creation and storage of the human exposure results.	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-26: Technical Requirement TR_RiskWF_10

Requirement ID:	TR_RiskWF_10
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to carry out the calculation of the physical exposure on demand for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The user shall be able to trigger the calculation of the physical exposure for a certain area based on a simulation perimeter or hazard extension obtained from EO imagery.	

Stimulus: The user through the GUI or the SP shall be able to trigger the physical exposure for an existing hazard extension or simulation perimeter.
Response: Creation and storage of the social exposure results.
Verification Criterion: Results are retrieved to the service(s) that request them.
Notes: none

Table 2-27: Technical Requirement TR_RiskWF_11

Requirement ID:	TR_RiskWF_11
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to carry out the assessment of the human impact on demand for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The user shall be able to trigger the calculation of the impact for a certain area based on a simulation perimeter or a hazard extension obtained from EO	
Stimulus: The user through the GUI or the SP shall be able to trigger the human impact assessment for an existing hazard extension or simulation perimeter.	
Response: Creation and storage of the human impact results.	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-28: Technical Requirement TR_RiskWF_12

Requirement ID:	TR_RiskWF_12
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to carry out the assessment of the physical impact on demand for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The user shall be able to trigger the calculation of the physical impact for a certain area based on a simulation perimeter or a hazard extension obtained from EO	
Stimulus: The user through the GUI or the SP shall be able to trigger the physical impact assessment for an existing hazard extension or simulation perimeter.	
Response: Creation and storage of the physical impact results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-29: Technical Requirement TR_RiskWF_13

Requirement ID:	TR_RiskWF_13
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to calculate the human exposure automatically for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The RVA module shall calculate the social exposure for a certain area which is triggered based on the existence of a new simulation perimeter, a new hazard extension obtained from EO	
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.	
Response: Creation and storage of the social exposure results.	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-30: Technical Requirement TR_RiskWF_14

Requirement ID:	TR_RiskWF_14
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to calculate the physical exposure automatically for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The RVA module shall calculate the physical exposure for a certain area which is triggered based on the existence of a new simulation perimeter, a new hazard extension obtained from EO	
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.	
Response: Creation and storage of the physical exposure results	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

Table 2-31: Technical Requirement TR_RiskWF_15

Requirement ID:	TR_RiskWF_15
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to calculate the human impact assessment automatically for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The RVA module shall calculate the human impact for a certain area which is triggered based on the existence of a new simulation perimeter, a new hazard extension	

obtained from EO
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.
Response: Creation and storage of the impact assessment results.
Verification Criterion: Results are retrieved to the service(s) that request them.
Notes: none

Table 2-32: Technical Requirement TR_RiskWF_16

Requirement ID:	TR_RiskWF_16
Related SR(s):	• Sys_Risk_1 • Sys_Risk_3
Description: The RVA module shall be able to calculate the physical impact assessment automatically for other risks e.g. earthquakes, storm events, man-made disasters.	
Rational: The RVA module shall calculate the physical impact for a certain area which is triggered based on the existence of a new simulation perimeter, a new hazard extension obtained from EO	
Stimulus: Creation of a new simulation perimeter, new EO based hazard extent.	
Response: Creation and storage of the impact assessment results.	
Verification Criterion: Results are retrieved to the service(s) that request them.	
Notes: none	

3 Reference Architecture

3.1 HEIMDALL overall architecture

This subsection illustrates the HEIMDALL overall architecture highlighting the module addressed in the current technical specification. The RVA module is treated as a “black box” within the overall architecture, receiving requests through the SP to carry out the corresponding operations. As can be observed in Figure 3-1, the RVA module performs all the communications and interactions with other components of HEIMDALL through the Service Platform using RESTful web services and FTP connections. Clients can communicate with the SP by making use of the HTTP protocol methods, GET, POST, PUT, PATCH and DELETE as well as of FTP connection to share data between some sub modules and the SP. The SP is the element that orchestrates the triggering of the exposure and impact assessment sub modules. On the one hand it provides the necessary input parameters and data coming from other modules for the RVA module to process the corresponding products and an on the other hand retrieves the data and results from the module that need to be provided to other components of the system.

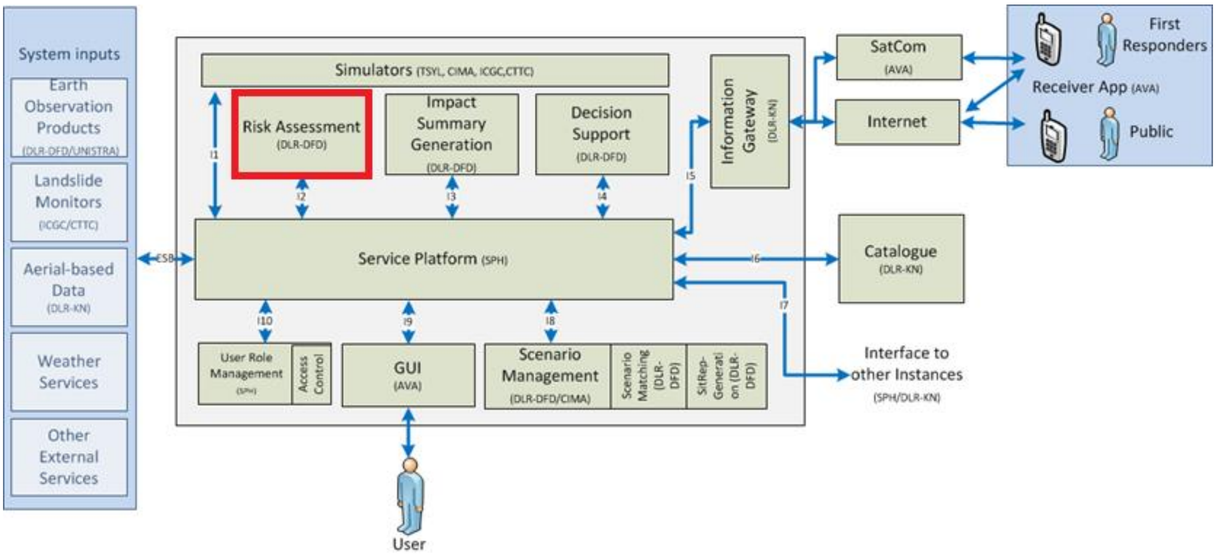

Figure 3-1 Placement of the RVA module inside the HEIMDALL overall architecture

4 Module Functionality

This section describes the functionality and the design of the RVA module. With this aim, it describes the existing sub modules, their purpose and function inside the module, the main components of each of these sub modules as well as how these sub modules interact and exchange information among them and among the HEIMDALL modules external to the RVA module. The design of the RVA module follows the risk assessment concepts defined and described in D6.1. These concepts together with the related technical requirements set the basis for the technical specifications and design of the RVA module.

4.1 Overview

The RVA module has the purpose of processing and providing exposure and impact assessment products inside the HEIMDALL system. With this in mind it is designed with two main sub modules: the Exposure assessment sub module and the Impact assessment sub module (section 4.2). The first identifies exposed elements, i.e. elements that could be adversely affected (including life and property) by the hazard(s), whereas the second provides an impact estimation of the hazard(s) on people and assets. The outputs and results of the exposure sub modules will serve as input for the impact estimation sub modules (section 4.4.), accounting for the expected losses and adverse effects in relation to a specific hazard.

The Impact Assessment sub module is comprised of two main sub modules: Simulation based impact assessment and Earth Observation based impact assessment. Each of these follows a different approach in calculating the estimated human and physical impact due to the different nature of the used input data (i.e. simulated data vs pre-event and post event imagery data). As has been described in D6.1, the first performs a probabilistic impact assessment based on simulated hazard information such as hazard extent and intensity outputs generated during a pre-event or during an event by the Simulation and Modelling module whereas the second carries out a deterministic impact assessment based on EO based hazard information generated after the event has occurred, comparing post-event with pre-event images and crossing it with exposure data. Separated assessment of the impacts is necessary according to the nature of the input information available to be used (simulated vs EO imagery data) as well as according to the differences in the level of detail of the input data of hazard information.

Two different sub module impact assessment sub modules are described in sections 4.4.14.4.2 and 4.4.2 Section 4.4.1sub module describes the impact assessment sub module based on simulated hazard information, reflecting the estimated pre-event and operational impacts. Section 4.4.2 describes an impact assessment sub module based on hazard information reflecting the post-event impacts estimated from earth observation imagery data.

The outputs generated by the RVA module can be used to improve the resource allocation in the field during disaster response, response training and post-disaster (for the case of EO based impact assessment). In addition, the information provided could help to communicate the financial needs of the respective emergency response organisations to cope with the number of affected people and assets.

4.2 Module description

The diagram of Figure 4-1 presents the overall functionality of the RVA module, illustrating the main sub modules of the module and the way they are related to each other. Furthermore, it shows the interfaces of these elements with the other modules of HEIMDALL specifying the main inputs and outputs coming from and going to each of those modules. This data exchange is further specified in Table 4-4-1, as well as in the following subsection.

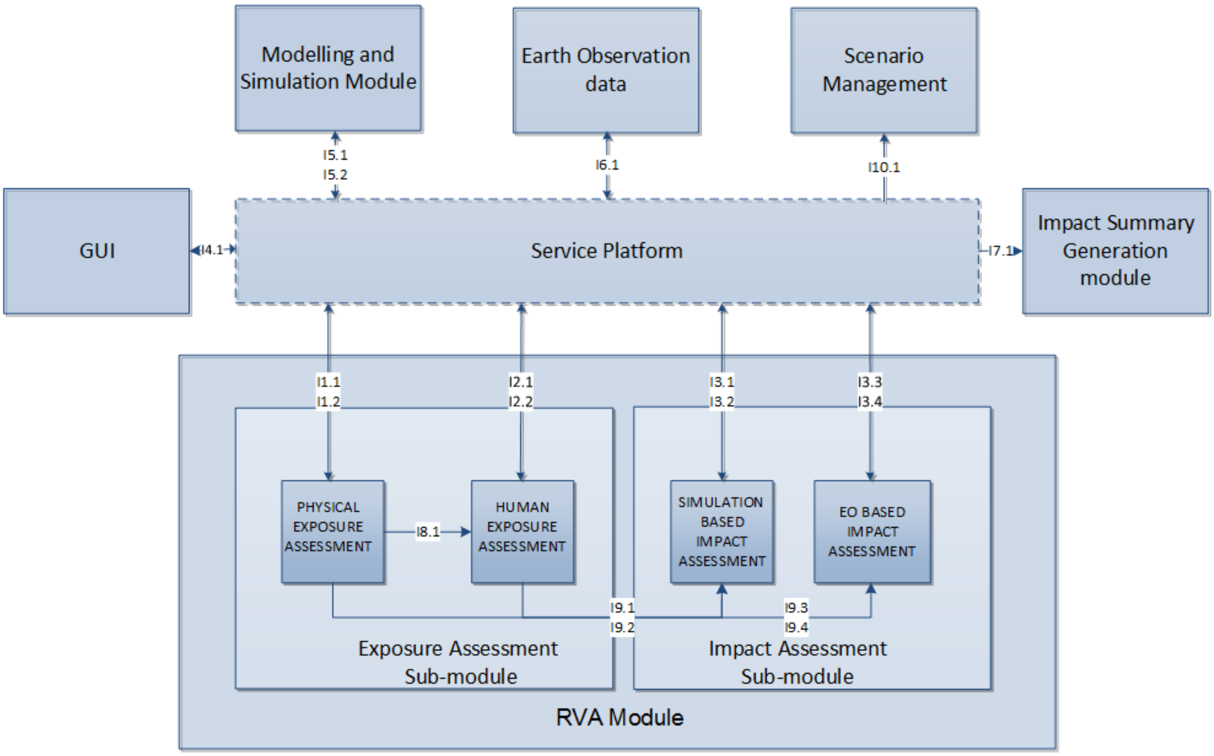

Figure 4-1 General RVA module architecture showing the relations with the other sub modules of the module

Table 4-4-1 Main interfaces between the RVA sub modules, as well as between these and the Service Platform

Interface	Involved modules / sub modules	Description
I1.1	Physical exposure assessment sub module and SP	• SP triggers the physical exposure sub module and provides simulation extent calculated in the Modelling and Simulation module. • Physical Exposure sub module provides the physical exposure outputs to the SP.
I1.2	Physical exposure assessment sub module and SP	• SP triggers the physical exposure sub module and provides EO imagery-based hazard extent. • Physical Exposure sub module provides the physical exposure outputs to the SP.
I2.1	Human Exposure Assessment, Physical Exposure Assessment and SP	• SP triggers the human exposure sub module and provides the simulation extent calculated in the Modelling and Simulation module. • Human Exposure sub module provides the human exposure outputs to the SP.
I2.2	Human Exposure Assessment, Physical Exposure Assessment and SP	• SP triggers the human exposure sub module and provides EO based hazard extent. • Human Exposure sub module provides the human exposure outputs to the SP.
I3.1	Simulation Based Impact Assessment and SP	• SP triggers the Impact assessment sub module and provides hazard intensity or extent results coming from the Modelling and Simulation module. • Impact assessment sub module provides the physical impact results to the SP.

I3.2	Simulation Based Impact Assessment and SP	• SP triggers the Impact assessment sub module and provides hazard intensity or extent results coming from the Modelling and Simulation module. • Impact assessment sub module provides the human impact results to the SP.
I3.3	EO Impact assessment and SP	• SP triggers the EO based impact assessment sub module and provides the physical and human impact results.
I3.4	EO Observation Impact assessment and SP	• SP triggers the EO based impact assessment sub module and provides the EO images. • The EO based impact assessment module provides the human impact results to the SP.
I4.1	GUI and SP	• The SP provides the exposure and impact results to the GUI to be displayed to the user. • The GUI provides input parameters to the exposure and/or impact assessment sub modules.
I5.1	Modelling and Simulation Module and SP	• The Modelling and Simulation Module provides the simulation extent to the Exposure and Simulation based Impact Assessment sub modules. • The Modelling and Simulation Module provides the simulation intensity/extension outputs to the simulation-based Impact assessment.
I6.1	Earth Observation data and SP	• The Earth Observation data module provides EO based event extent (and severity in case of fire) to the SP.
I7.1	Impact Summary Generation module and the SP	• The SP provides the Exposure and Impact assessment results to the Impact Summary Generation module.
I8.1	Physical Exposure Assessment and Human Exposure Assessment sub modules	• The Physical exposure assessment sub module provides the 3D buildings model to the Human Exposure assessment sub module.
I9.1	Physical Exposure Assessment and Simulation based Impact Assessment sub modules	• Physical Exposure Assessment sub module provides the physical exposure results to the Simulation based impact assessment sub module.
I9.2	Human Exposure Assessment and Simulation based Impact Assessment sub modules	• Human Exposure Assessment submodule provides the human exposure results to the Simulation based Impact Assessment sub module.
I9.3	Physical Exposure Assessment and EO Based Impact Assessment sub modules	• Physical Exposure Assessment sub module provides the physical exposure results to the EO Based Impact Assessment sub module
I9.4	Human Exposure Assessment and EO Based Impact Assessment sub modules	• Physical Exposure Assessment sub module provides the physical exposure results to the Human Exposure Assessment and EO Based Impact Assessment sub module
I10.1	Service Platform and Scenario Management	• The exposure and impact results are associated to a given scenario.

4.2.1 RVA module inputs and outputs

Table 4-4-2 provides an extensive list of the inputs that shall be provided to several RVA sub modules to trigger the corresponding services as well as the outputs that shall be generated by each of these sub modules.

Table 4-4-2 Inputs and outputs to be received and generated by each of the RVA sub modules

Module/ Sub module providing inputs	***Module/Sub module receiving inputs***	***Inputs***			***Outputs***	
		Product	**Short description**	**Format**	**Product(s)**	**Format**
Forest Fire Simulation (Modelling and Simulation module)	Human exposure assessment	Fire perimeter	Isochrones of the arrival time of the fire. Each line represents one hour of fire spread	Vector GeoJSON	Population density product, accounting for the number of people per grid cell dedicated to each fire perimeter	Raster, GeoTIFF
	Physical exposure assessment	Fire perimeter	Isochrones of the arrival time of the fire. Each line represents one hour of fire spread	Vector GeoJSON	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and Raster, GeoJSON and GeoTIFF
	Simulation based Human impact assessment	Fire intensity and flame length	Layer of the Fire intensity in kW/m Layer of flame length of the fire in meters	Raster GeoTIFF	Hazard levels and location and number of the affected people	Vector or raster GeoJSON or GeoTIFF
	Simulation based Physical impact assessment	Fire intensity and flame length	Layer of fire intensity in kW/m Layer of flame length of the fire in meters	Raster GeoTIFF	Hazard levels and location and number off affected assets	Vector or raster GeoJSON or GeoTIFF
Flood Simulation (Modelling and Simulation module)	Human exposure assessment	Flood extension	Map of flood maximum extension	Raster of binary values (flooded vs not flooded) GeoTIFF format.	Population density product, accounting for the number of people per grid cell dedicated to the flood extent	Raster, GeoTIFF
	Physical exposure assessment	Flood extension	Map of flood maximum extension	Raster of binary values (flooded vs not flooded) GeoTIFF format.	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	Simulation based Human impact	Water depth	Map of maximum water depth in the	Rasters of water depth and	Number of people in the hazard zones	Raster in GeoTIFF

Module/ Sub module providing inputs	***Module/Sub module receiving inputs***	***Inputs***			***Outputs***	
		Product	**Short description**	**Format**	**Product(s)**	**Format**
	assessment	Water velocity	flooded areas Map of water velocity in the flooded area	water velocity in GeoTIFF format		
	Simulation based Physical impact assessment	Water depth	Maps of maximum water depth in the flooded areas	Raster of water depth in GeoTIFF format	Percentage of damage for each building Loss in monetary value	Vector in GeoJSON
Landslide Simulation (Modelling and Simulation module)	Human exposure assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area, grouped in classes	GeoTIFF	Population density product, accounting for the number of people per grid cell dedicated to the landslide extent	Raster, GeoTIFF
	Physical exposure assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area, grouped in classes	GeoTIFF	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	Simulation based Human impact assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area, grouped in classes	ESRI Shapefile	Number of people in each susceptibility area	Raster, GeoTIFF
	Simulation based Physical impact assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area, grouped in classes	GeoTIFF	Qualitative risk associated to single buildings	Vector, GeoJSON
EO module (Forest Fire)	Human exposure assessment	Burn scar	Burnt areas binary mask	GeoTIFF and ESRI Shapefile	Population density product, accounting for the number of people per grid cell dedicated to each fire perimeter	Raster, GeoTIFF
	Physical exposure assessment	Burn scar	Burnt areas binary mask	GeoTIFF and ESRI Shapefile	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	EO based Human impact	Burn scar	Burnt areas	GeoTIFF and ESRI	Impact on population (number	ESRI

Module/ Sub module providing inputs	Module/Sub module receiving inputs	Inputs			Outputs	
		Product	Short description	Format	Product(s)	Format
	assessment	Human exposure	binary mask Population density	Shapefile	of people per affected building)	Shapefile
	EO based Physical impact assessment	Burn scar Fire severity Physical exposure	Burnt areas binary mask Layer with 4 levels of fire severity Road network, buildings, and LULC layers	GeoTIFF and ESRI Shapefile	Impact on road network (inside / outside burnt area) Impact on buildings (inside / outside burnt area, by function and number of stories) Impact on LULC classes by severity level	ESRI Shapefile
EO module (Flood)	Human exposure assessment	Flood extent	Flood binary mask	GeoTIFF / ESRI Shapefile	Population density product, accounting for the number of people per grid cell dedicated to the flood extent	Raster, GeoTIFF
	Physical exposure assessment	Flood extent	Flood binary mask	GeoTIFF and ESRI Shapefile	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	EO based Human impact assessment	Flood extent Human exposure	Flood binary mask Population density	GeoTIFF and ESRI Shapefile	Impact on population (number of people per affected building)	ESRI Shapefile
	EO based Physical impact assessment	Flood extent Physical exposure	Flood binary mask Road network, buildings, and LULC layers	GeoTIFF and ESRI Shapefile	Potentially impacted road network (inside / outside flood affected area) Potentially impacted buildings (inside / outside flood affected area, by function and number of stories) Impact on LULC classes (inside / outside flood affected area)	ESRI Shapefile
EO module (Landslide)	Human exposure assessment	Landslide mask	Binary mask of abrupt landslide affected areas	GeoTIFF and ESRI Shapefile	Human exposure: Population density product, accounting for the number of people per grid cell	Raster, GeoTIFF

Module/ Sub module providing inputs	*Module/Sub module receiving inputs*	*Inputs*			*Outputs*	
		Product	**Short description**	**Format**	**Product(s)**	**Format**
					dedicated to the landslide extent	
	Physical exposure assessment	Landslide mask	Binary mask of abrupt landslide affected areas	GeoTIFF and ESRI Shapefile	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	EO based Human impact assessment	Landslide mask Human exposure	Binary mask of abrupt landslide affected areas Population density	GeoTIFF and ESRI Shapefile	Impact on population (number of people per affected building)	ESRI Shapefile
	EO based Physical impact assessment	Landslide mask Physical exposure	Binary mask of abrupt landslide affected areas Road network, buildings, and LULC layers	GeoTIFF and ESRI Shapefile	Potentially impacted road network (inside / outside landslide affected area) Potentially impacted buildings (inside / outside landslide affected area, by function and number of stories) Impact on LULC classes (inside / outside landslide affected area) Impact on CI classes (inside / outside landslide affected area)	ESRI Shapefile
GUI (Flood)	Human exposure assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no flood perimeter necessary)	Vector/Raster	Human Exposure Population density product, accounting for the number of people per grid cell dedicated to the flood extent	Raster, GeoTIFF
	Physical exposure assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no flood perimeter necessary)	Vector/Raster	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	EO based Human impact	Area of Interest	Area of interest defined by the	Vector/Raster	Impact on population	ESRI Shapefile

Module/ Sub module providing inputs	***Module/Sub module receiving inputs***	***Inputs***			***Outputs***	
		Product	**Short description**	**Format**	**Product(s)**	**Format**
	assessment		user, triggers sub module (no flood perimeter necessary)			
	EO based Physical impact assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no flood perimeter necessary)	Vector/Raster	Potentially impacted road network (inside / outside flood affected area) Potentially impacted buildings (inside / outside flood affected area, by function and number of stories) Impact on LULC classes (inside / outside flood affected area)	ESRI Shapefile
	Simulation based Human impact assessment	Water depth Water velocity	Map of maximum water depth in the flooded areas. Map of water velocity in the flooded area,	Raster files of water depth and water velocity	Number of people in the hazard zones	Raster in GeoTIFF
	Simulation based Physical impact assessment	Water depth	Maps of maximum water depth in the flooded areas	Raster of water depth in GeoTIFF format	Percentage of damage for each building. Loss in monetary value. Impact on the asset functionality.	Vector in GeoJSON
GUI (Forest fire)	Human exposure assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no fire perimeter necessary)	Raster, GeoTIFF	Human Exposure Population density product, accounting for the number of people per grid cell dedicated to the flood extent	Raster, GeoTIFF
	Physical exposure assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no fire perimeter necessary)	Raster, GeoTIFF	Location, height and function of the affected building stock Affected road network Affected LULC Affected CI	Vector and raster, GeoJSON and GeoTIFF
	EO based Human impact assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no fire perimeter	Raster, GeoTIFF	Impact on population	ESRI Shapefile

Module/ Sub module providing inputs	*Module/Sub module receiving inputs*	*Inputs*			*Outputs*	
		Product	**Short description**	**Format**	**Product(s)**	**Format**
			necessary)			
	EO based Physical impact assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no fire perimeter necessary)	Raster,GeoTIFF	Potentially impacted road network (inside / outside burnt area) Potentially impacted buildings (inside / outside burnt area, by function and number of stories) Impact on LULC classes by severity level Impact on CI classes by severity level	ESRI Shapefile
	Simulation based Human impact assessment	Fire intensity and flame length	Layer of the Fire intensity in kW/m. Layer of flame length of the fire in meters.	Raster GeoTIFF	Hazard levels and location and number of the affected people.	Vector or raster GeoJSON or GeoTIFF
	Simulation based Physical impact assessment	Fire intensity and flame length	Layer of fire intensity in kW/m. Layer of flame length of the fire in meters.	Raster GeoTIFF	Hazard levels and location and number off affected assets.	Vector or raster GeoJSON or GeoTIFF
GUI (Landslide)	Human exposure assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no landslide extent necessary)	Raster,GeoTIFF	Human Exposure Population density product, accounting for the number of people per grid cell dedicated to the flood extent	Raster,GeoTIFF
	Physical exposure assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no landslide extent perimeter necessary)	Raster,GeoTIFF	Physical Exposure Location, height and function of the affected building stock. Affected road network. Affected LULC.	Vector and raster, GeoJSON and GeoTIFF
	EO based Human impact assessment	Area of Interest	Area of interest defined by the user, triggers sub module (no landslide extent necessary)	Raster,GeoTIFF	Impact on population	ESRI Shapefile
	EO based Physical	Area of	Area of interest defined by the	Raster,	Potentially impacted road network (inside	ESRI

Module/ Sub module providing inputs	*Module/Sub module receiving inputs*	*Inputs*			*Outputs*	
		Product	**Short description**	**Format**	**Product(s)**	**Format**
	impact assessment	Interest	user, triggers sub module (no landslide necessary)	GeoTIFF	/ outside landslide affected area) Potentially impacted buildings (inside / outside landslide affected area, by function and number of stories) Impact on LULC classes (inside / outside landslide affected area) Impact on CI classes (inside / outside landslide affected area)	Shapefile
	Simulation based Human impact assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area.	GeoTIFF	Qualitative risk for population living in the specific building	Vector GeoJSON
	Simulation based Human impact assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area, grouped in polygons.	ESRI Shapefile	Number of people in each susceptibility area	Raster, GeoTIFF
	Simulation based Physical impact assessment	Terrain moveme nt susceptib ility map	Susceptibility of the terrain to landslide failure within a selected area.	GeoTIFF	Qualitative risk associated to single buildings.	Vector, GeoJSON

4.3 Exposure assessment sub module

The exposure assessment sub module will be interconnected with the other HEIMDALL services as described in Table 4-4-1 and Figure 4-1 using the interfaces I1.1, I1.2 as well as I2.1 and I2.2. The underlying concepts of the exposure estimation are presented in [1] and will be used as a reference during the technical specification. Those interfaces will be used to provide the hazard information coming from either the Modelling and Simulation or Earth observation modules to the physical and human exposure assessment components. Hazard extent calculated in the Modelling and Simulation module will be provided through the SP in vector format through interfaces I1.1 and I2.1 whereas the Earth Observation data exchange will be synchronized through interfaces I1.2 and I2.2 using vector formats.

4.3.1 **Components**

The Exposure Assessment sub module is separated in two main component blocks, (1) the physical exposure component generating information on the physical elements (building stock, transportation network, critical or significant infrastructure elements and land use land cover information) and (2) the human exposure component using the physical exposure information for the quantification and localization of possible adversely affected population.

Even though both components are closely related, the information generated by the exposure component can be used separately, forwarding the information through the SP to the other modules (GUI, Simulation, ISA, Impact assessment modules). Details about the general concept are outlined in [1].

4.3.1.1 Physical Exposure

The physical exposure component will generate a SpatiaLite database of physical elements situated in the respective hazard prone areas, collecting the information from various sources [1].The database can be used to create a textual summary of the present elements as foreseen in the Impact Summary Generation (ISA) module (I7.1) and to run the impact assessment sub module using the hazard extent.

The physical exposure component is organized in several sub-components that address different methodologies in order to generate an up-to-date data set with the highest possible spatial and semantic resolution:

- External data import sub-component,
- ALS point cloud building detection sub-component,
- VHR building detection sub-component,
- OSM extraction sub-component.

External datasets will be queried, transformed if needed and imported into a SpatiaLite database. Very high-resolution digital elevation models created from ALS point cloud data are stored internally in GeoTIFF format and used for the generation of ground-based elevation models (nDSM) in order to complement the building stock information. EO imagery is processed using state-of-the-art object detection algorithms ([2], [3]). OpenStreetMap (OSM) data is queried using python libraries (e.g. [4]) to integrate VGI data for the generation of the exposure data set.

The resulting information is stored in a SpatiaLite database:

- Building geometries extracted from the various sources (national datasets, OSM buildings, building footprints detected in ALS point clouds, building footprints from VHR imagery). The characteristics of each building (e.g. height, stories and function) is stored in the same database.
- Transportation networks (Primary, Secondary, Tertiary and Local),
- LULC information according to the highest level of detail available for the respective area (CLC; UA).

GIS-Operations using python libraries are used to assure the quality of the listed database inputs. The data is stored in OGC conform formats and can be visualized using WMS and WFS standards. Data exchange is performed using HTTP/HTTPs requests.

4.3.1.2 Human Exposure

The human exposure component generates an estimation of the location and quantities of people in hazard-prone areas using the population census counts available on administrative level and building stock information from the physical exposure component. The function information (residential vs. non-residential) and other properties of the database of physical elements [1] created from the physical exposure component will be used. The generated product will be shared with the SP via interfaces I2.1 and I2.2 (Table 4-4-1) and can be queried by the GUI and ISA module (I4.1, I7.1, and compare Figure 4-1).

Technically the human exposure uses the following components:

- External database in CSV holding the official census counts per municipality or NUTS region,

- Administrative boundaries vector data,
- Building stock information queried from the SpatiaLite database.

4.3.2 **Internal interfaces**

Both human exposure and physical exposure components are closely related, since the building stock information from the physical exposure component is used for human exposure generation. Therefore, internal interfaces between the components are needed. sub module. The internal interface I8.1 will be an OGC-conform Web Feature Service (Table 4-4-1), serving as the interface for the exchange of information internally (3D building model: e.g. number of stories, building footprint, gross floor area).

Within the physical exposure sub module building height information is retrieved from the nDSM using zonal raster calculations. The height information is used to calculate the total volume of a building. If building storey information is present (e.g. from external datasets), linear regressions tasks can enable the derivation of storey numbers from building height. In this case generation of gross floor area is possible. The created information is internally exchanged with the SpatiaLite database.

Within the human exposure sub module information on the total building gross floor area per municipality is requested from the 3D building model within the physical exposure data set. The information is transmitted via standard exchange format and used for the calculation of building type specific population density measures. Those density values are used in the generation of the multi-temporal population estimates. Official census data prepared by the European Statistical System (ESS) is queried from the Eurostat Census Hub (https://ec.europa.eu/CensusHub2) and transformed according to the information provided in the administrative boundaries vector file. The successful join of census data per municipality or NUTS region with the spatial representation of the municipality or NUTS region may require modification of the key-value representations in the corresponding sub-components.

4.3.3 **Workflows**

The exposure sub module is triggered by the SP through the generation of the new simulation and observation products, with the simulated or observed hazard information respectively. If hazard information is provided, first the physical exposure database will be identified using the hazard information. In case of multiple hazards occurring, the hazard extent information will be used for each of the hazard to perform exposure estimation dedicated to each single hazard. The identified exposed elements (critical infrastructures, number of buildings, transportation network, and LULC) are input to the human exposure component. The exchanged data exposed physical elements will be used to estimate the number of people that could be adversely affected (simulation) or are affected by an event (observation) in the area defined by the hazard extent. The information on physical and human exposure will serve as input for the impact assessment and is forwarded to the impact assessment sub module.

4.4 *Impact assessment*

4.4.1 **Simulation based Impact assessment**

Figure 4-2 shows the overall structure of the simulation-based impact assessment sub module. The module is hazard-independent, providing information on direct impact to assets due to the occurrence of an event.

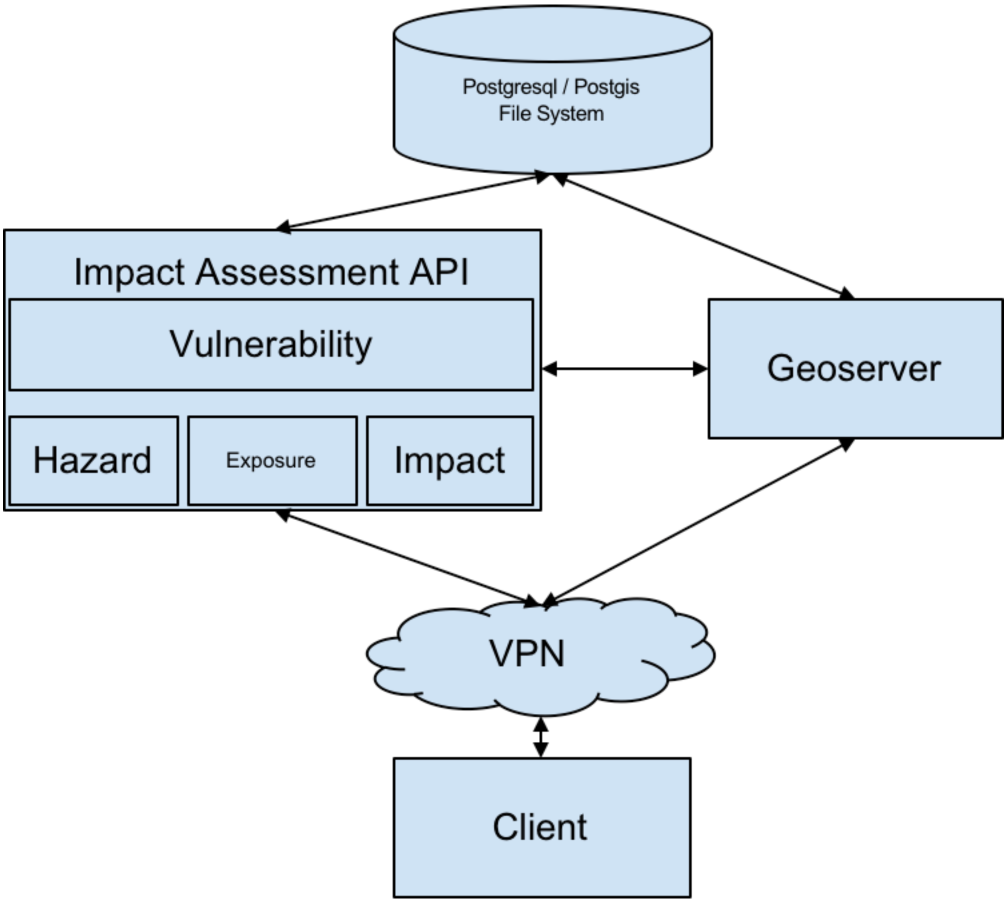

Figure 4-2 Architecture of the simulation-based impact assessment sub module

4.4.1.1 Components

The main components of the simulation-based impact assessment sub module are:

- The PostgreSQL/Postgis database,
- The Geoserver,
- The impact assessment API.

Some sub components can be identified within the overall process and furthermore developed across the main impact assessment module: hazard, exposure, vulnerability and impact.

In the database, the following information are stored:

- For the hazard, the hazard type (e.g. floods, landslides, forest fires) and the hazard forcings (e.g. water level, fire length, etc.),
- For the exposure, the exposure categories (e.g. building, population), the exposure attributes (e.g. building usage, median age), the exposure values (e.g. residential, industrial),
- For the vulnerability, the curves (univocally identified for given forcing and combinations of exposure values),

- For the impact, the indicators (e.g. damage percentage).

The Geoserver is used to collect geographic data on hazard, exposure and impact. Requests for data (uploaded by the user or created within the platform through the simulation models) can be performed through WMS, WFS and WCS.

The impact assessment API can be used to upload hazard and exposure data and to compute impact assessment.

4.4.1.2 Internal interfaces

The Impact Assessment API framework is connected to:

- Postgres for the management of:
    - Data for the system configuration,
    - Vulnerability functions,
    - Vector data on exposure/hazard/impacts,
- Geoserver for the OGC standard publication of:
    - Exposure,
    - Hazard,
    - Impacts.

In order to clarify the communication among the components composing the simulation-based impact assessment module, the use case for the impact assessment evaluation is reported.

User asks to evaluate the impact specifying:

- The hazard layer,
- The exposure layer,
- The vulnerability function library.

Hazard loads all the intensity measures (forcings) in the hazard layer.

Vulnerability loads all the vulnerability functions that can be used for the specific hazard forcings and the specific category of exposed elements.

Impact executes the calculation of the impact by performing the following actions for each feature in the exposure layer:

- It assigns a value for each forcing to the feature,
- It asks to Vulnerability to find a curve suitable for that feature,
- It executes the function, using as parameters the values of the forcing and the other attributes of the feature (if any),
- It calculates all the possible indicators,
- It saves the indicators of the feature in the output layer.

Impact publishes the obtained layer on the Geoserver.

4.4.1.3 Workflows

The simulation-based impact assessment sub module is triggered by the SP when new modelling and simulation products are available. Through the SP, hazard intensity and/or extent results coming from the Modelling and Simulation sub modules are provided.

When hazard information is provided, the corresponding data on exposure (physical and/or human) is retrieved. Such an information can be already present in the Geoserver, otherwise it has to be provided by the exposure sub module. Then, the simulation-based impact assessment module assigns vulnerability curves to each exposed element, and the impact associated to the given hazard conditions is evaluated; the corresponding data is stored in the Geoserver, and from here it is made available to the SP.

4.4.2 **EO imagery-based Impact assessment**

4.4.2.1 Flood impact estimation

The concept of the EO based flood impact estimation is presented in D6.1 and is based on the standard procedures of the Copernicus Emergency Management Service – Rapid Mapping [5], as well as on the International Working Group on Satellite-based Emergency Mapping's guidelines [6] but the extraction of the flood extent is more automated.

This sub module will be interconnected with some of the other HEIMDALL services, in particular with Earth Observation data module and Exposure Assessment sub module. EO based flood extent will be provided through the SP in vector and raster formats as well as physical and human exposure assessment databases.

4.4.2.1.1 Components

The EO based flood impact estimation is separated in two main sub components, the physical impact assessment and the human impact assessment.

Physical impact assessment

The physical impact assessment sub component provides information on the flood affected physical elements (buildings, road network, land use land cover etc.). It is derived from the intersection of physical exposure data with EO based flood extent.

Impact assessment on road network is performed using the flood binary mask. The binary flood mask is automatically generated from the intersection of pre- and post-event water bodies layers based on pre- and post-event EO images, leading to a binary impact classification. This binary mask is used to cookie cut the roads that intersect with the flood mask. The result highlights the impact assessment per road type.

Impact assessment on buildings and LULC follows the same methodology as for roads. For the buildings located in the flooded area, the result highlights the impact assessment per use type (residential / non-residential).

For the LULC, the result is an impact classification per LULC type.

Human impact assessment

The human impact assessment provides information on the potentially flood affected population. It is derived from the intersection of human exposure data with EO based flood extent, leading to a classification of affected / not affected buildings with the associated number of people per building.

4.4.2.1.2 Internal interfaces

Both physical and human impact assessment components are closely related to Earth Observation data and physical plus human exposure components, since they are built using the products derived from these components. Therefore, internal interfaces between the components are needed. The internal interfaces I3.3, I3.4, I9.1, I9.2, I9.3 and I9.4 will be an OGC-conform Web Mapping or Feature Service, serving as the interface for the exchange of information internally.

4.4.2.1.3 Workflows

The EO based impact assessment is triggered both by EO products related to the flood extent and the exposure products of the RVA, orchestrated by the SP. The occurrence of a real event or a past real event, chosen for a demo, is needed to trigger this sub module.

Flood mask and physical plus human exposure data are retrieved from their respective modules, and then combined to provide separate flood impact layers on road network, buildings, LULC and population.

The results are delivered to the GUI through the Service Platform.

In case of cascading effects, such as a landslide causing a flood, or flooding generating landslides, physical and human impact assessment is performed using the inputs layers of both disaster types (flood mask, landslide mask). The origin of the road/building/LULC impact (flood or landslide) is indicated in a field in the layers' attribute table.

4.4.2.2 Forest fire impact estimation

The concept of the EO based forest fire impact estimation is presented in D6.1 and is based on the standard procedures of the Copernicus Emergency Management Service – Rapid Mapping [5], as well as on the International Working Group on Satellite-based Emergency Mapping's guidelines [6] but the extraction of the burnt areas is more automated.

This sub module will be interconnected with some of the other HEIMDALL services, in particular with Earth Observation data module and Exposure Assessment sub module. EO based fire extent and severity will be provided through the SP in vector and raster formats as well as physical and human exposure assessment databases.

4.4.2.2.1 Components

The EO based forest fire impact estimation is separated into two main sub components, the physical impact assessment and the human impact assessment.

Physical impact assessment

The physical impact assessment sub-component provides information on the fire affected physical elements (buildings, road network, land use land cover etc.). It is derived from the intersection of physical exposure data with EO based fire extent and severity/damage grade).

Impact assessment on road network is performed using the burn scar binary mask automatically generated from pre and post-event EO images, leading to a binary impact classification. This binary mask is used to cut / extract the roads intersecting with the burn scar. The result highlights the impact assessment per road type. Impact on road network cannot be estimated according to the fire severity/damage grade because the only parameter used in fire severity calculation is the difference of pre and post-event vegetation indexes. Moreover, roads can be located within a burnt area without being destroyed (but only impracticable during the fire event).

Impact assessment on buildings follows the same methodology as for roads. The result highlights the impact assessment per use type (residential / non-residential). Here again, the fire severity/damage grade is not used as whatever the severity, a building can be totally destroyed.

Impact assessment on LULC is performed using the fire severity/damage, generated from change detection between pre and post-event EO images, leading to an impact classification by LULC type and severity level.

Human impact assessment

The human impact assessment provides information on the fire affected population. It is derived from the intersection of human exposure data with EO based fire extent, leading to a classification of affected / not affected buildings with the associated number of people per building.

4.4.2.2.2 Internal interfaces

Both physical and human impact assessment components are closely related to Earth Observation data and physical plus human exposure components, since they are built using the products derived from these components. Therefore, internal interfaces between the components are needed. The internal interfaces I3.3, I3.4, I9.1, I9.2, I9.3 and I9.4 will be an OGC-conform Web Mapping or Feature Service, serving as the interface for the exchange of information internally.

4.4.2.2.3 Workflows

The EO based impact assessment is triggered both by EO products related to the fire extent and severity / damage grade and the exposure assessment. The occurrence of a real event or a past real event, chosen for a demo, is needed to trigger this sub module.

Burn scar, fire severity/damage grade and physical plus human exposure data are retrieved from their respective modules, and then combined to provide separate fire impact layers on road network, buildings, LULC and population.

The results are delivered to the users via the GUI through the Service Platform.

In case of cascading effects, such as a forest fire causing a landslide because of soil erosion susceptibility, physical and human impact assessment is performed using the inputs layers of both disaster types (burn scar mask, landslide mask). The origin of the road/building/LULC impact (fire or landslide) is indicated in a field in the layers’ attribute table.

4.4.2.3 Landslide impact estimation

The concept of the EO based landslide impact estimation is presented in D6.1 and is based on the standard procedures of the Copernicus Emergency Management Service – Rapid Mapping [5], as well as on the International Working Group on Satellite-based Emergency Mapping’s guidelines [6]. The processing is more dependent on automatic processing than in operational rapid mapping.

This sub module will be interconnected with some of the other HEIMDALL services, in particular with Earth Observation data module and Exposure Assessment sub module. EO based landslide extent will be provided through the SP in vector and raster formats as well as physical and human exposure assessment databases.

4.4.2.3.1 Components

The EO based landslide impact estimation is separated in two main sub components, the physical impact assessment and the human impact assessment.

Physical impact assessment

The physical impact assessment sub-component provides information on the abrupt landslide affected physical elements (buildings, road network, land use land cover etc.). It is derived from the intersection of physical exposure data with EO based abrupt landslide extent.

Impact assessment on road network is performed using the abrupt landslide binary mask automatically generated from a change detection method applied between the pre- and post-event EO images, leading to a binary impact classification. The result highlights the impact assessment per road type.

Impact assessment on buildings and LULC follows the same methodology as for roads. For the buildings located in the landslide affected area, the result highlights the impact assessment per use type (residential/non-residential). For the LULC, the result is an impact binary classification per LULC type.

Human impact assessment

The human impact assessment provides information on the landslide affected population. It is derived from the intersection of human exposure data with EO based abrupt landslide extent, leading to a classification of affected / not affected buildings with the associated number of people per building.

4.4.2.3.2 Internal interfaces

Both physical and human impact assessment components are closely related to Earth Observation data and physical plus human exposure components, since they are built using the products derived from these components. Therefore, internal interfaces between the components are needed. The internal interfaces I3.3, I3.4, I9.1, I9.2, I9.3 and I9.4 will be an OGC-conform Web Mapping or Feature Service, serving as the interface for the exchange of information internally.

4.4.2.3.3 Workflows

The EO based impact assessment is triggered both by EO products related to the abrupt landslide extent and the exposure products of the RVA, orchestrated by the SP. The occurrence of a real event or a past real event, chosen for a demo, is needed to trigger this sub module.

Landslide mask and physical plus human exposure data are retrieved from their respective modules, and then combined to provide separate landslide impact layers on road network, buildings, LULC and population.

The results are delivered to the users via the GUI through the Service Platform.

In case of cascading effects, such as a landslide causing a flood, flooding generating landslides, or a forest fire causing a landslide, physical and human impact assessment is performed using the inputs layers of both disaster types (flood mask, fire mask, landslide mask). The origin of the road/building/LULC impact (flood, fire or landslide) is indicated in a field in the layers' attribute table.

5 Technical Specification

5.1 Exposure estimation

5.1.1 **Input data**

The exposure estimation sub module requires the simulated or observed hazard information from the simulation module or Earth Observation module. The extent of the hazards covered within HEIMDALL will be used to identify the exposed elements. The hazard extent enables the generation of an up-to-date exposure data set that will be used during the impact assessment, base data is needed. In case of multi-hazard exposure estimations, the combined hazard extents will used for the identification of the exposed elements.

5.1.2 **Base data**

In order to generate an up-to-date exposure data set used during impact assessment outlined in section 0, base data is required. The following section lists the mandatory, recommended and optional base data that will be used if available during the preparation of the exposure data set.

5.1.2.1 Physical exposure component

This section describes the mandatory, recommended and optional base data inputs for the generation of the physical exposure information in the physical exposure component. For the generation of the building stock information OSM buildings are mandatory input. The OSM database holds one of the largest building data sets with nearly global coverage. The database is used as a basis within the HEIMDALL project for the generation of the building stock layer. Nevertheless, the database is not always up-to-date nor complete and therefore additional base data will be integrated.

The analysis of VHR imagery enables the module to complement the building stock information where necessary using novel object detection algorithms such as [2], [3] Either VHR satellite borne imagery or airborne orthophotos will be used. The preferred data format is GeoTIFF, in order to assure easy WMS integration.

Airborne Laser Scanning (ALS) point cloud data in LAS/LAZ format will be used to generate very high resolution Normalized Digital Surface Model (nDSMs) in GeoTIFF format. This base data is used for the extraction of building footprints and for the determination of the building height for building footprints extracted from other base data sets.

If available for the demonstration areas selected within the project, national building datasets shall be integrated into the physical exposure data set. The preferred format is ESRI shapefile but it depends on the provided national data.

Table 5-1 Required base data for the generation of the building stock information within the physical exposure estimation.

Component	Comment	Format/ Service	Requirement
OSM buildings		Shape File/WFS	Mandatory
VHR image data		GeoTIFF/WMS	Recommended
ALS point cloud data		LAS/LAZ	Recommended
National building datasets		Shape File/WFS	Optional

Table 5-2: Required base data for generation of the transportation network database

Component	Comment	Format/ Service	Requirement

National roads network	Down to agricultural roads with attributes type (Local, Primary, Secondary and Tertiary) condition, trafficability and tonnage (up to x tons)	Shape File/WFS	Recommended
OSM roads	Down to agricultural roads with attributes type (Local, Primary, Secondary and Tertiary)	Shape File/WFS	Optional
Bridges	with attributes trafficability and tonnage	Shape File/WFS	Optional
Railway network		Shape File/WFS	Optional
Airports		Shape File/WFS	Optional

Table 5-2 lists the required base data for the generation of the transportation network. The database of transportation networks mainly relies on national datasets, since it provides the highest level of detail in terms of data quality and semantic resolution. In case national data sets cannot be integrated, one option is the OSM roads network that will be queried and integrated into the database. Other components of the transportation network such as bridges, railways and airports will be included in the database, if covered by the base data. The standard input data format for the generation of the transportation network is ESRI Shapefile.

Table 5-3: LULC products used for the generation of the land use land cover data set.

Component	Comment	Format/ Service	Requirement
CORINE Land Cover	Provided by European Environment Agency (EEA); Documentation	Shape File/WFS	Mandatory
National LULC products		Shape File/WFS GeoTIFF/WMS	Recommended
European Urban Atlas	Provided by European Environment Agency (EEA); Documentation	Shape File/WFS	Optional
Global Urban Footprint (GUF)	Provided by German Remote Sensing Data Centre; Documentation	GeoTIFF/WMS	Optional
Global Human Settlement Layer (GHSL)	Provided by EC Joint Research Centre (JRC); Documentation	GeoTIFF/WMS	Optional

Land use/land cover (LULC) information can be used during the creation of the 3D building model if the information on building function is not present in the building base data components listed in Table 5-3. The information of LULC will be joined by location to the building stock layer and allow the identification of predominant function information (residential, commercial, and industrial) that will be stored per building or building block. In addition, the information is used during impact assessment. The LULC information is stored in the SpatiaLite database and can be requested by the impact assessment modules over the SP.

Table 5-4: Required base data that will be used for the preparation of the critical infrastructure database.

Component	Comment	Format/ Service	Requirement
Hospitals	-	Shape File/WFS	Mandatory
Schools	-	Shape File/WFS	Mandatory
Police	-	Shape File/WFS	Mandatory

Electric supply network	-	Shape File/WFS	Optional
Supply stations	-	Shape File/WFS	Optional
Pipeline network	-	Shape File/WFS	Optional
Important industries/tanks/ refineries	-	Shape File/WFS	Optional
Water supply network	-	Shape File/WFS	Optional

The critical infrastructure (CI) database mainly relies on the generated building stock layer, which identifies CI buildings that are relevant. Those include but are not limited to hospitals, schools and police stations. In addition, other CI components important for the electricity and water supply shall be imported from external data sources if available. Further refinement of the requirements regarding CI, will lead to reworking of the CI database in the upcoming releases B and C.

5.1.2.2 Human exposure component

Census data provided by the respective national statistic bureaus is required to produce an estimate of the human exposure which will refine the spatially coarse information on administrative unit to building or building block units. Therefore, the estimation of human exposure requires the 3D building model generated from the physical exposure component. The quality and timeliness of the available census data as well as the thematic and spatial accuracy of the building model are the main drivers for an accurate assessment of the human exposure.

Official Census counts will be integrated into the human exposure component in CSV format and combined with the administrative boundaries using join by attribute operation. The resulting administrative boundaries in vector format contain the total population counts within each exposed municipality.

In case of unavailability of the listed base data for the human exposure estimation (Table 5-5), population density grids can be used to retrieve coarser estimates of the human exposure. One example is the Global Human Settlement Population Grid (GHS-POP) created and offered free of charge by the European Commission Joint Research Centre (JRC). The Global Human Settlement Population Grid (GHS-POP) dataset depicts the distribution and density of population, expressed as the number of people per cell. Population estimated for the year 2015 provided by CIESIN GPWv4 [12] were disaggregated from census or administrative units to 250m grid cells. Those products are usually distributed in GeoTIFF raster format and will be used throughout the project for data-poor regions as fall-back human exposure information.

Table 5-5: Required base data for generation of human exposure data

Component	Comment	Format/ Service	Requirement
Census counts	Census count per municipality/NUTS region	CSV/XLS	Mandatory
Administrative boundaries	Geographical extent of municipality/NUTS region	Shape File/WFS	Mandatory
Urban areas	Containing population numbers	Shape File/WFS	Recommended
3D building model	Number of stories, building function	Shape File/WFS	Mandatory

Table 5-6: Population grid products used for human exposure estimation in case necessary base data for the generation of high spatial-temporal resolution products is unavailable

Component	Comment	Format/ Service	Requirement
LandScan (LSCAN)	Provided by: US Oak Ridge National Laboratory (ORNL); Documentation	GeoTIFF/WMS	Optional
GHS Population Grid (GHS-POP)	Provided by: EC Joint Research Centre (JRC); Documentation	GeoTIFF/WMS	Optional

5.1.3 **Outputs and results**

This section describes the outputs and results of the exposure module in detail. The description of the outputs is separated into physical exposure outputs and human exposure outputs.

5.1.3.1 Physical exposure component

The physical exposure component is going to provide an estimate of the exposed building stock, including information about building height, number of stories, footprints and building function type. The level of detail of the building stock depends on the availability and quality of the input data. In addition, high-detail information on transportation networks, land use and land cover and critical and significant infrastructure including for example educational and health facilities will be provided. LULC information will be created using the generated information provided in vector format whereas the level of detail (e.g. building or building block level) depends on the quality of available base data. Main components of the physical exposure data set their attributes and additional metadata are provided in Table 5-7.

Table 5-7: Outputs and attributes of the physical exposure estimation sub modules

Component	Attributes	Format	Notes
3D building model	• Building height • Number of Stories • Hierarchical Building function • Assigned population	GeoJSON/ESRI Shapefile	Identification of through the building function taxonomy • Residential, • Non-Residential • Educational Buildings • Buildings for Transport • Buildings for Religion • Buildings for Leisure and Sport • Administration Buildings
Transportation network	• Road type	GeoJSON/ESRI Shapefile	Primary, Secondary Tertiary and Local roads
Land use land cover	• According to the Corine Land Cover nomenclature [18]	GeoJSON/ESRI Shapefile	

5.1.3.2 Human exposure component

The human exposure component will provide information on the number of exposed human elements, i.e. people that could be adversely affected from a hazard. This information will be provided on building or building block aggregation level, depending on the level of detail of the building stock information. The human exposure information can be provided in vector format (building or building block level) describing the quantities per unit or in an aggregated format in raster format, describing population density per raster cell. Main components of the human exposure data set their attributes and additional metadata are provided in Table 5-8.

Table 5-8: Output generated by the human exposure estimation sub module. Two product formats will be provided, either raster or vector format.

Component	Attributes	Format	Notes
Day-time Human exposure	People per grid cell	GeoTIFF	Aggregated to 20m spatial resolution
Night-time Human exposure	People per grid cell	GeoTIFF	Aggregated to 20m spatial resolution
Day-time Human exposure	People per building	GeoJSON	
Night-time Human exposure	People per building	GeoJSON	

5.1.4 **REST API's documentation**

Two main RESTful services are provided in order to access the information generated by the exposure sub module in a standardised way. The service related to the human exposure specified in Table 5-9 will enable the SP and the connected modules to access the gridded population density products as well as the population estimated per building or building block in vector format. Two main parameters can be included in the request, namely the bounding box parameter specifying the area of interest and the product type parameter, specifying the desired return format.

Table 5-9: Specification of the human exposure service API

Service ID	**human-exposure-get**
Assumed consumers (via reference point)	SP, Impact assessment modules, ISA
Data exchanged	• Gridded population density product (Raster) • Population per building level/building block (Vector)
Operations	Conditions, history, forecast
Main parameters	**bounding box, product type** <raster/vector>
Data representation protocol	ESRI SHP, GeoJSON, GeoTIFF
Communication protocol	WFS, WMS, HTTP
Response	Requested data
Notes	-

Table 5-10 specifies the service related to the generated physical exposure information. This service is designed to query the SpatiaLite database, holding the information on the physical exposure information. Two main parameters determine the returned data: the bounding box (bbox) parameter specifying the area of interest and the component parameter. The component parameter is used to request a subset in the physical exposure data set. In case no component parameter is submitted, all components will be returned.

Table 5-10: Specification of the physical exposure service API

Service ID	**physical-exposure-get**
Assumed consumers (via reference point)	SP, Impact assessment modules, ISA
Data exchanged	3D building model: • Building height, • Number of stories, • Building function, • Assigned population transportation-grid: • Road type lulc: • According to CLC nomenclature
Operations	Conditions, history, forecast
Main parameters	**bounding box, component** <transportation-grid, 3D building model, lulc>
Data representation protocol	ESRI SHP, GeoJSON
Communication protocol	WFS, HTTP
Response	Requested data
Notes	If the component parameter is not included in the query, the service will return all components within the bounding box.

5.2 Simulation based Impact assessment

5.2.1 **Flood impact assessment**

5.2.1.1 Base data

The base data for the sub module is constituted only by the vulnerability curves set, saved in CSV format in the DB. Curves link the hazard intensity to an esteemed percent damage.

5.2.1.2 Input data

The flood impact assessment requires as input data information relevant to: hazard extension and/or intensity, exposure.

For flood impact assessment, information relevant to hazard is constituted by raster data of maximum water level (coming from the simplified flood simulation module), or the combined information on maximum water level and velocity in distinct raster files or two-band raster file (coming from the complete flood simulation module). Also, information already present in the Geoserver can be used (i.e. information directly uploaded by the user).

Analogously, information relevant to exposure can be produced within the system by the exposure estimation module, or it can be uploaded by the user directly into the Geoserver.

5.2.1.2.1 Human impact

Input data can be:

- Distribution of the population – typically raster files; it can be obtained by the human exposure module, expressing day-time and night-time number of people per grid cell (GeoTIFF); otherwise, analogous input can be provided by the user through the SP;

- People living within single features; it can be obtained by the physical exposure module, and more precisely from the 3Dbuilding model, "Assigned population" attribute; otherwise, analogous input can be provided by the user through the SP.

5.2.1.2.2 Physical impact

Input data can be:

- Characteristics of exposed buildings, coming from the physical exposure module, and more precisely from the 3D_building model, "number of stories" and "Building function" attributes; otherwise, analogous input can be provided by the user through the SP;
- Characteristics of exposed transportation network, coming from the physical exposure module, and more precisely from the transportation network component, "Road type" attribute; otherwise, analogous input can be provided by the user through the SP;
- Characteristics of exposed LULC, coming from the physical exposure module, and more precisely from the Land use land cover component, Corine Land Cover" attribute; otherwise, analogous input can be provided by the user through the SP.

5.2.1.3 Outputs and results

5.2.1.3.1 Human impact

Output provided by the human impact service:

- Number of people in the different hazard zones, evaluated on the basis of maximum water depth (simplified flood simulation model) or of maximum water depth and velocity (complete flood simulation model); the format is raster (GeoTIFF) if the human exposure input is raster, or vector (GeoJSON) if the input comes from the 3D building model exposure component.

5.2.1.3.2 Physical impact

Outputs provided by the physical impact service:

- Percentage damage of each asset; the output is provided in vector format (GeoJSON);
- Loss in monetary value of each asset; the output is provided in vector format (GeoJSON).

5.2.2 Forest fire impact assessment

5.2.2.1 Forest fire impact assessment

5.2.2.1.1 Base data

The base data for the sub module being it for the human or physical impact is formed only by the vulnerability curves set, saved in CSV format in the DB. Curves link the hazard intensity to an esteemed percent damage.

5.2.2.1.2 Input data

The forest fire impact assessment requires as input data information relevant to hazard and exposure.

For forest fire impact assessment, information relevant to hazard is constituted by raster data of fire intensity [kW/m] and flame length [m]. Also, information already present in the Geoserver can be used (i.e. information directly uploaded by the user).

Analogously, information relevant to exposure can be produced within the system by the exposure estimation module, or it can be uploaded by the user directly into the Geoserver.

5.2.2.1.2.1 Human impact

Input data can be:

- Distribution of the population – typically raster files; it can be obtained by the human exposure module, expressing day-time and night-time number of people per grid cell (GeoTIFF); otherwise, analogous input can be provided by the user through the SP,
- People living within single features; it can be obtained by the physical exposure module, and more precisely from the 3D_building model, "Assigned population" attribute; otherwise, analogous input can be provided by the user through the SP.

5.2.2.1.2.2 Physical impact

Input data can be:

- Characteristics of exposed buildings, coming from the physical exposure module, and more precisely from the 3D_building model, "number of stories" and "Building function" attributes; otherwise, analogous input can be provided by the user through the SP.

5.2.2.1.3 Outputs and results

5.2.2.1.3.1 Human impact

Output provided by the human impact service:

Number of people at different level of hazard, evaluated on the basis of fire intensity and flame length; the format is raster (GeoTIFF) if the human exposure input is raster, or vector (GeoJSON) if the input comes from the 3D building model exposure component.

5.2.2.1.3.2 Physical impact

Output provided by the physical impact service:

- Number of assets at different level of hazard, evaluated on the basis of fire intensity and flame length; the format is vector (GeoJSON).

5.2.3 **Landslide impact assessment**

5.2.3.1 Base data

The base data for the sub module is constituted only by the vulnerability curves set, saved in CSV format in the DB; in this specific case, curves link the probability of occurrence of an event (landslide/rockfall / debris flow) to a qualitative estimation of risk for given assets.

5.2.3.2 Input data

The main input data that will be used for impact estimation is the potentially affected area provided by the landslide simulator. More specifically, the output of the model that will be used is a GeoTIFF file. Such a file provides the susceptibility of each pixel of the DEM, so each unit of the terrain (resolution depends on the DEM resolution), to become unstable and slide, given the conditions that the user provides to the simulator. Three susceptibility classes (plus the 0 = no data) can be identified, starting from 1 (Low susceptibility) to 3 (high susceptibility); such a susceptibility measures the likelihood of the area to become unstable and slide.

An analogous scale is defined in case of rockfall/debris flow, in this case the susceptibility indicating the likelihood of the area to be reached by a rockfall or debris flow.

Also, information already present in the Geoserver can be used (i.e. information directly uploaded by the user). Analogously, information relevant to exposure can be produced within the system by the exposure estimation module, or it can be uploaded by the user directly into the Geoserver.

5.2.3.2.1 Human impact

Input data can be:

- Distribution of the population – typically raster files; it can be obtained by the human exposure module, expressing day-time and night-time number of people per grid cell (GeoTIFF); otherwise, analogous input can be provided by the user through the SP,
- People living within single features; it can be obtained by the physical exposure module, and more precisely from the 3D building model, “Assigned population” attribute; otherwise, analogous input can be provided by the user through the SP.

5.2.3.2.2 Physical impact

Input data can be:

- Characteristics of exposed buildings, coming from the physical exposure module, and more precisely from the 3D building model, “number of stories” and “Building function” attributes; otherwise, analogous input can be provided by the user through the SP.

5.2.3.3 Outputs and results

5.2.3.3.1 Human impact

Output provided by the human impact service:

- Qualitative risk for population living in the buildings (output is in this case vector, GeoJSON);
- Number of people in each susceptibility area, characterized in terms of different probability of occurrence of an event (output is in this case a raster, GeoTIFF).

5.2.3.3.2 Physical impact

Output provided by the physical impact service:

- Qualitative risk associated to each single asset (output is in this case vector, GeoJSON).

5.2.4 REST API documentation

The REST API described in this section – namely the ones used in connection to the simulation-based impact assessment module – are common for all the hazards considered in HEIMDALL. For this reason, a common description is provided below.

5.2.4.1 Common methods

In this subsection, the documentation relevant to the general REST API is reported. These API are used to manage (upload, search for, delete) all types of layers used within the module, regardless their specific function (e.g., exposure layers, hazards layers, impact layers).

Table 5-11: Specification of the search layer service API

Service ID	**layers-search**
Assumed consumers (via reference point)	*layers/*search
Data exchanged	

Operations	This API takes as input the search parameters and returns the list of all layers that satisfy the filters
Main parameters	Type = <EXPOSURE/ HAZARD / IMPACT..> bbox = <bounding box>
Data representation protocol	JSON, binary file
Communication protocol	HTTP (GET)
Response	JSON list of layers
Notes	-

Table 5-12: Specification of the upload layer service API

Service ID	**layer-upload**
Assumed consumers (via reference point)	/tools/upload
Data exchanged	
Operations	This API takes as input the search parameters and returns the list of all layers that satisfy the filters
Main parameters	
Data representation protocol	JSON, binary file
Communication protocol	HTTP (POST)
Response	Information about the received files if they are recognized as a GeoTIFFor a shape file.
Notes	-

Table 5-13: Specification of the delete layer service API

Service ID	**layer-delete**
Assumed consumers (via reference point)	/layer/delete
Data exchanged	
Operations	remove a layer
Main parameters	layename
Data representation protocol	JSON
Communication protocol	HTTP (DELETE)
Response	
Notes	-

5.2.4.2 Hazard methods

This section describes the hazard API used to manage hazard data.

There are different types of hazard (such as flood, forest fires, landslides) and different forcings for each type; for example, for flood one can consider: water depth and/or water velocity.

Table 5-14: Specification of the hazard forcings service API

Service ID	**hazard-forcings**
Assumed consumers (via reference point)	/hazard/hazardswithforcings
Data exchanged	
Operations	obtain hazard system information
Main parameters	
Data representation protocol	JSON
Communication protocol	HTTP (GET)

Response	json list of json objects describing the hazard
	[
	{
	id: 1,
	name: "Flood"
	descr: "Flood",
	forcings:
	[
	{
	descr: "Water Depth",
	id: 1,
	measure_unit: "m",
	name: "WD"
	},
	{
	descr: "Water Velocity",
	id: 4,
	measure_unit: "m/s",
	name: "WV"
	},
	]
	}
	]

Notes	-

Table 5-15: Specification of the hazard forcing type service API

Service ID	**hazard-forcing-type**

Assumed consumers (via reference point)	/hazard/forcings
Data exchanged	
Operations	This API obtains hazard system information
Main parameters	
Data representation protocol	JSON
Communication protocol	HTTP (GET)

Response	dictionary indexed by the hazard type of hazard forcings
	{
	"flood":
	{
	1: "water depth",
	2: "water velocity"
	...
	}
	...
	}

Notes	-

Table 5-16: Specification of the hazard import service API

Service ID	**hazard-import**
Assumed consumers (via reference point)	/hazard/import

Data exchanged	{
	"layername": <name of the layer to create>,
	"filename": <name of previously uploaded file>,
	"mapping": <mapping of the uploaded data in the rasor hazard schema… see notes for details>
	}

Operations	This API creates a new hazard layer
Main parameters	
Data representation protocol	JSON
Communication protocol	HTTP (POST)
Response	operation result
Notes	The mapping object should be:

	• for geotiff: a dictionary indexed by the band number of hazard forcing id. In this way each band is interpreted as a rasor forcing

5.2.4.3 Exposure methods

This section describes the exposure API used to manage exposure data.

Exposures data are organized in categories (such as buildings, population, lifelines…).

Each category has a list of attributes that can be used to describe the asset (i.e. for the buildings: building_usage, replacement cost etc.).

An attribute can assume free values or a value from a predefined set; for example, the attribute "building usage" can be: medical_clinic, kindergarten, library, while the attribute "replacement cost" can be any number.

Table 5-17: Specification of the exposure category service API

Service ID	**exposure-category**
Assumed consumers (via reference point)	/exposure/categories
Data exchanged	
Operations	This API obtains exposure category information
Main parameters	
Data representation protocol	JSON
Communication protocol	HTTP (GET)
Response	json list of json objects representing the categories [{ id: 1, name: "buildings" }, ...]
Notes	-

Table 5-18: Specification of the exposure attributes type service API

Service ID	**exposure-attributes**
Assumed consumers (via reference point)	/exposure/attributes
Data exchanged	
Operations	This API obtains exposure attribute information

Main parameters	category=<category_id>
Data representation protocol	JSON
Communication protocol	HTTP (GET)
Response	json list of json objects representing the attribute [{ category: 1, descr: "foundation_type", id: 8, long_name: "foundation_type", name: "found_type" }, ...]
Notes	-

Table 5-19: Specification of the exposure values service API

Service ID	**exposure-values**
Assumed consumers (via reference point)	/exposure/values
Data exchanged	
Operations	This API obtains exposure value information
Main parameters	attribute=<attribute_id>
Data representation protocol	JSON
Communication protocol	HTTP (GET)
Response	json list of json objects representing the attribute [{ descr: "The foundations are less than 1m deep below grade, and they have no lateral capacity. Foundations with no lateral capacity include piles without lateral bracing support.", id: 911, name: "shallow_foundation_no_lateral_capacity" },

	{
	descr: "The foundations are 1m deep or more below grade, and they have lateral capacity. Foundations with lateral capacity include tie-beams, foundation walls, inclined piles, piles or piers on wide spread footings.",
	id: 912,
	name: "deep_foundation_with_lateral_capacity"
	},
	{
	descr: "The foundations are 1m deep or more below grade, and they have no lateral capacity. Foundations with no lateral capacity include piles without lateral bracing support.",
	id: 913,
	name: "deep_foundation_no_lateral_capacity"
	},
	{
	descr: "The foundations are less than 1m deep below grade, and they have lateral capacity. Foundations with lateral capacity include tie-beams, foundation walls bracing in the direction of their lengths, inclined piles, piles or piers on wide spread footings, cantilevered or braced piles, and slabs on grade.",
	id: 910,
	name: "shallow_foundation_with_lateral_capacity"
	}
	]

Notes	-

Table 5-20: Specification of the exposure import service API

Service ID	**exposure-import**
Assumed consumers (via reference point)	/exposure/import

Data exchanged	{
	“layername”: <name of the layer to create>,
	“category”: <exposure category id>,
	“schema”: <mapping of the uploaded data in the rasor exposure schema… see notes for details>
	}

Operations	This API allows the user to insert an exposure layer in the platform

Main parameters	
Data representation protocol	JSON, binary file
Communication protocol	HTTP (POST)
Response	

Notes	the schema object should be:
	
	for geotiff:
	
	{
	  “band”: <band identifier>,
	  “attr”: <exposure attribute identifier>
	}
	
	for shp:
	
	[
	  {
	    “id”: <exposure attribute identifier>,
	
	    // for attribute with “free” values
	    “mappedBy”:
	    {
	      “name”: <column name in the source shp>
	    },
	
	    // for attribute with “enumerative” values
	    “mappedByEnum”:
	    {
	      “enum”:
	      [
	        “id”: <attribute value identifier>
	        “name”: <attribute value name>
	        “mapping”:
	        [
	          {
	            “value”: <column value inf the source shp>
	            “col”:

	{
	"name": <column name in the source shp>
	}
	}
	]
	
	]
	}
	}
	]

5.2.4.4 Vulnerability methods

This section describes the vulnerability API used to manage vulnerability functions. Vulnerability functions are hazard-specific.

Table 5-21: Specification of the vulnerability library service API

Service ID	**vulnerability-library**
Assumed consumers (via reference point)	/vulnerability/libraries
Data exchanged	
Operations	
Main parameters	hazard = <hazard type filter>
Data representation protocol	JSON
Communication protocol	HTTP (GET)
Response	json list of json objects representing the curve
Notes	-

5.2.4.5 Impact methods

This section describes the impact API, used to manage impact data. Impact can be represented in different ways according to: hazard type, exposure category and vulnerability library used to obtain the impact.

Table 5-22: Specification of the impact compute service API

Service ID	**impact-compute**
Assumed consumers (via reference point)	/impact/compute
Data exchanged	{ "exposure": <exposure layer name> "exposurecategory": <exposure category> "hazard": <hazard layer name>

	"library": <vulnerability library used for damage computation> "layer": <result layer name> }
Operations	This API launches the computation in a separate thread and return immediately.
Main parameters	
Data representation protocol	JSON
Communication protocol	HTTP (POST)
Response	
Notes	-

5.3 EO imagery-based Impact assessment

5.3.1 **Flood impact assessment**

5.3.1.1 Base data

Pre- and post-event satellite images are mandatory data for performing the EO based flood impact assessment.
EO images acquired before the flood event are used to generate a reference water bodies mapping in order to have an idea of the situation before the disaster Pre-event images should be recent, not older than 3 years before the event, as specified within Copernicus EMS - Rapid Mapping [5], and should consider the season in some specific areas. Alternatively, static reference water masks such as the SRTM Water Body Data (SWBD) are used.
Satellite images acquired during/after the flood event are used to generate the crisis water bodies mapping. Several acquisition dates can be necessary to completely cover the flood event, because of the topography (plain flood can move from upstream to downstream in several days) and of the cloud coverage often present during flood events. The acquisition of satellite images covering a flash flood event is a real challenge Anticipating satellite acquisition can improve the chance of having an exploitable image, but the daily revisit of satellites still does not ensure the acquisition of a good image.

5.3.1.1.1 Pre-event satellite imagery

Optical data is the best option for the pre-event satellite imagery, in particular sensors having a Middle Infrared (MIR) spectral band which highlights very well water bodies and ensure the water detection in urban areas. The only remaining limitation is the water detection under vegetation, especially under dense vegetation like forested areas.
The HEIMDALL EO data module will concentrate on the following satellite sensors for pre-event observations:

- Optical High Resolution (HR): Sentinel-2
  Sentinel-2A/B satellites cover wide areas at a spatial resolution of 10 m, with MIR bands, on a systematic mode (every 5-6 days). Images are available for free.
- Optical Very High Resolution (VHR): SPOT6/7 and Pléiades-HR

SPOT6/7 satellites cover wide areas at a spatial resolution of 1.50 m, whereas the coverage of Pléiades-HR satellites is more limited but the resolution is higher (50 cm). Both of them are commercial satellites.

As satellite images are regularly acquired over the globe, in a systematic mode for some of them, pre-event optical data can be selected within the existing archive imagery catalogues, considering the cloud coverage, the date, the season if needed, and the spatial resolution. Higher resolution is useful in dense urban areas.

5.3.1.1.2 External databases

The use of national data, if available, is another option for the pre-event water bodies mapping, as well as Open Street Map databases, if good and complete.
Digital Terrain Model (SRTM, EU DEM or national DTM if available such as IGN BD TOPO in France) are used for geometric purposes (reference elevation information for satellite imagery orthorectification) and for steep slopes exclusion from automatically extracted water bodies. SRTM DTM (30 m) is integrated by default in the water bodies' automatic extraction tool but it can be replaced by a more precise source if available.
Static reference water masks such as the SRTM Water Body Data (SWBD) are mainly used in fully automatic processors to differentiate between flood surfaces and permanent water areas.

5.3.1.1.3 Post-event satellite imagery

Both radar and optical data are needed in case of flood events. Radar data is essential as it is independent of the cloud coverage (often present during a flood event). However, optical data are the most pertinent data in urban areas, but also for flash flood events (if not acquired too late and if flood traces are still present).
The acquisition date should be as close as possible to the flood peak. To monitor the evolution of major, long lasting plain flood events over time multiple acquisitions are necessary. To obtain optimal imagery the anticipation of satellite acquisitions is an important criterion in obtaining useful images, and multi-temporal observations should to be planned. To obtain optimal coverage, the combination of several satellites, both optical and radar, have to be envisaged to cover as best as possible the extent, dynamics and impact of a flood event. According to the size of the flood event and to the type of LULC affected (urban, suburban, rural, etc.), the use of HR and/or VHR data is another important parameter, as HR data cover wide areas, whereas VHR data are useful to map flood extents in complex urban areas.
The HEIMDALL EO data module will concentrate on the following satellite sensors for post-event observations:

- Radar HR: Sentinel-1
  Sentinel-1A/B satellites cover wide areas at a spatial resolution from 10 to 20m, with the C-band, on a systematic mode (every 5-6 days); data is available for free.
- Radar HR/VHR: TerraSAR-X
  The TerraSAR-X satellites cover areas with different swath widths at a spatial resolution between 1 o 30m, with the X-band. This is a commercial satellite. However, for scientific applications the data are free.
- Optical HR: Sentinel-2
  Sentinel-2A/B satellites cover wide areas at a spatial resolution of 10 m, with MIR bands, on a systematic mode (every 5-6 days); images are available for free.
- Optical VHR: SPOT6/7, Pléiades-HR

SPOT6/7 satellites cover wide areas at a spatial resolution of 1.50 m, whereas the coverage of Pléiades-HR satellites is more limited but the resolution is higher (50 cm). Both of them are commercial satellites.

5.3.1.2 Input data

5.3.1.2.1 Flood extent product

Pre-event and post-event satellite images are used to generate an observed flooded extent product, which is one of the input data of the flood impact assessment module.
A reference water bodies' binary mask is automatically extracted from the pre-event satellite image, using the dedicated developed processing chain. Alternatively, static nearly global available reference masks is used. In case an accurate reference water layer is available in the national database or OSM, they are used instead of satellite imagery.
The reference water extracted from EO imagery will lead to a result without specific attributes whereas national databases and OSM data will provide results with details on the type of water body.
A crisis water bodies' binary mask is automatically extracted from the post-event satellite image, using the dedicated developed processing chain (varying according to the sensor/sensor type). A crisis water body mask is generated for each observation date. The result contains both reference and event water bodies. It cannot be used as such for the flood impact assessment.
The flood extent product is generated by intersecting the crisis water mask with the reference water bodies. The reference water is then removed and only the flooded areas remain in the output layer. The result is composed of two classes (flooded/not affected area) but can be completed by a third class (potentially flooded area) in some specific cases (flash flood, visible flood traces, etc.) by photo-interpretation of optical images.

Table 5-23 Description of EO based flood extent products

Component	Classes	Format	Notes
Reference water bodies	Water body/Other	ESRI Shapefile GeoTIFF	-
Flood extent	Flooded area/Unflooded area	ESRI Shapefile GeoTIFF	A 3rd class called "Potentially flooded area" can be exceptionally added in some cases

5.3.1.2.2 Physical and Human Exposure data

Physical and Human Exposure data, which identify the buildings, critical infrastructures, transportation networks, LULC and population at risk, exposed to the hazard, are the second input to derive the flood impact assessment product. They are retrieved from the service platform and combined with the EO based flood extent product in order to generate the EO based impact assessment output.

5.3.1.3 Outputs and results

EO based impact assessment leads to two main products: physical impact and the human impact assessments.
The EO based Physical Impact Assessment product highlights the buildings, critical infrastructure, transportation networks and LULC affected by the flood event as detected on

the post-event satellite imagery, with reference waterbodies removed. A separate output is generated for each assets type with its own attributes.
The EO based Human Impact Assessment product highlights the population affected by the flood event as detected on the post-event satellite imagery.
Each of the products is composed of a binary classification “Affected/Not Affected” but a third class “Potentially affected” can be added in case of flash flood events.
The results will include geo-spatial layers that are going to be made available through the service platform in vector ESRI Shapefile format.

Table 5-24 Description of EO based flood impact assessment products

Component	Attributes	Format	Notes
Impact on road network	- Impact - Road type	ESRI Shapefile	-
Impact on buildings	- Impact - Height - Number of Stories - Function - Volume - Population	ESRI Shapefile	-
Impact on LULC	-Impact -Type	ESRI Shapefile	-
Impact on population	-Impact -Number of people	ESRI Shapefile	-

5.3.1.4 Methods documentation

The input data (flood extent product plus exposure data) are manually retrieved by an UNISTRA/SERTIT operator from the Service Platform as soon as a new flood layer is made available in vector shapefile and/or raster GeoTIFF formats. These input data are then internally combined by a semi-automatic procedure in order to derive the EO based flood impact assessment. The output layers are provided in vector shapefile compressed format, at the EPSG 4326 – WGS84 decimal degrees projection, with the following naming convention: source.productname.namespace.layername.date.zip, where:

- source: is the source of your original EO image,
- productname: is how the product/category of output is called (has to do with the rapid mapping process that produces that product),
- namespace: our choice. Something meaningful for the project (event location etc.),
- layername: our choice. Has to do with what the layer actually contains,
- date: yyyyMMddTHHmmss.

Moreover, the output layers contain a specific QGIS file (.sld) providing the features' symbology.

When ready, these EO based flood physical and human impact assessment layers are manually uploaded by an UNISTRA/SERTIT operator onto the dedicated FTP server (ftp:\\esb.heimdall.sp) hosted by Space Hellas, through the HEIMDALL Virtual Private Network (VPN). When available on the FTP, the EO based flood impact assessment products are automatically uploaded and made available onto the Service Platform.

5.3.2 **Forest fire impact assessment**

5.3.2.1.1 Base data

Pre- and post-event satellite images are mandatory data for performing the EO based forest fire impact assessment.
EO images acquired before the fire event are used to give an idea of the situation before the disaster, and to generate the fire severity/damage grade product. Pre-event images should be recent, not older than 3 years before the event, as specified within Copernicus EMS Rapid Mapping [5].
Satellite images acquired during/after the fire event are used to generate the burn scar mapping, the fire severity/damage grade products and the hot spot data. Several acquisition dates can be necessary to completely cover the fire event, especially when the fire is still active, in order to monitor the evolution of the burnt area and because of the smoke coverage often present during active fire events.

5.3.2.1.2 Pre-event satellite imagery

Optical data is the best option for the pre-event satellite imagery, in particular sensors having a Middle Infrared (MIR) spectral band which highlights very well the vegetation and allows to generate a more accurate severity/damage grade product. Pre-event images are also useful to remove uncertainties on the burnt areas extent: past burnt areas can be present in the area of interest and have to be removed from the new burn scar mask if not reactivated. The pre-event image should be as close as possible to the fire event.
The HEIMDALL EO data module will concentrate on the following satellite sensor for pre-event observations:

- Optical High Resolution (HR): Sentinel-2
  Sentinel-2A/B satellites cover wide areas at a spatial resolution of 10 m, with MIR bands, on a systematic mode (every 5-6 days); images are available for free.

As Sentinel-2 images are regularly acquired over the globe in a systematic mode, pre-event data can be selected within the existing archive imagery catalogues, considering the cloud coverage and the acquisition date.

5.3.2.1.3 Post-event satellite imagery

Optical images are the most pertinent data for the detection of burn scars, hot spots (without thermal infrared) and for fire severity/damage grade mapping. Even if visible spectral bands are able to highlight the burnt areas, infrared spectral band enable the removal of uncertainties, especially areas covered by shadows. MIR spectral band is particularly useful for the fire severity/damage grade product, and is widely used in the scientific community.

Multi-temporal observations have to be planned in case of active fires, whereas a unique acquisition can be used in case the fire event is rapidly under control.
The HEIMDALL EO data module will concentrate on the following satellite sensors for post-event observations:

- Optical HR: Sentinel-2
  Sentinel-2A/B satellites cover wide areas at a spatial resolution of 10 m, with MIR bands, on a systematic mode (every 5-6 days); images are available for free.
- Optical VHR data such as SPOT6/7 (1.50 m) or Pléiades-HR (50 cm) could be added when fires threaten urban areas.

- Optical Low Resolution (LR): TERRA MODIS
  MODIS satellite cover very wide areas, with well targeted bands, at a spatial resolution from 1000 to 250 m, on a systematic mode (1-2 per day); images are available for free. Its set of spectral bands is particularly useful for hotspots detection and from this rough fire delineation.

For the demonstrator Release A, the fire related modules are adapted to data acquired to map past event, not Sentinel-2, as it was launched not so long ago.

5.3.2.2 Input data

5.3.2.2.1 Burn scar mapping and fire severity

Pre- and post-event satellite images are used to generate an observed burnt area product as well as a fire severity (also called damage grade) which are two of the input data of the forest fire impact assessment.
The burn scar mapping is automatically extracted from the pre and post-event satellite image, using the dedicated developed processing chain. A burn scar mask is generated for each observation date. The result is two classes: burnt area/not affected area.
The fire severity is calculated by a change detection method between the pre- and post-event satellite images. Different levels of change are detected on vegetation according to its photosynthetic response, leading to 4 classes (at maximum) of fire severity.

Table 5-25 Description of EO based forest fire products

Component	Classes	Format	Notes
Burn scar / Extent of burnt area	Burnt area/Unburnt area	ESRI Shapefile GeoTIFF	-
Fire severity	Unburnt/Possibly damaged/Damaged/Destroyed	ESRI Shapefile GeoTIFF	-

5.3.2.2.2 Physical and Human Exposure data

Physical and Human Exposure data, which identify the buildings, critical infrastructures, transportation networks, LULC and population at risk, exposed to the hazard, are the second input to derive the forest fire impact assessment product. They are retrieved from the service platform and combined with the EO based burn scar mapping or with the severity product in order to generate the EO based impact assessment output.

5.3.2.3 Outputs and results

EO based impact assessment leads to two main products: physical impact and human impact assessments.
The EO-based Physical Impact Assessment product highlights the buildings, critical infrastructures, transportation networks and LULC affected by the fire event as detected on the post-event satellite imagery. A separate output is generated for each assets type with its own attributes.
The EO-based Human Impact Assessment product highlights the population affected by the fire event as detected on the post-event satellite imagery.
Roads and buildings are intersected with the burn scar mask leading to binary impact classifications (inside / outside burnt area) whereas LULC is combined with the fire severity product in order to derive an impact classification by LULC and severity level.
Population data are also intersected with the burn scar to derive a binary impact product “Affected/Not Affected”.

The results will include geo-spatial layers that are going to be made available through the service platform in vector ESRI Shapefile format.

Table 5-26 Description of EO based forest fire impact assessment products

Component	Attributes	Format	Notes
Impact on road network	- Impact - Road type	ESRI Shapefile	-
Impact on buildings	- Impact - Height - Number of Stories - Function - Volume - Population	ESRI Shapefile	-
Impact on LULC	-Impact -Type	ESRI Shapefile	-
Impact on population	-Impact -Number of people	ESRI Shapefile	-

5.3.2.4 REST API documentation

The input data (fire extent and severity products plus exposure data) are manually retrieved by an UNISTRA/SERTIT operator from the Service Platform as soon as a new fire layer is made available in vector shapefile and/or raster GeoTIFF formats. These input data are then internally combined by a semi-automatic procedure in order to derive the EO based fire impact assessment. The output layers are provided in vector shapefile compressed format, at the EPSG 4326 – WGS84 decimal degrees projection, with the following naming convention: source.productname.namespace.layername.date.zip, where:

- source: is the source of your original EO image;
- productname: is how the product/category of output is called (has to do with the rapid mapping process that produces that product);
- namespace: our choice. Something meaningful for the project (event location, …);
- layername: our choice. Has to do with what the layer actually contains;
- date: yyyyMMddTHHmmss.

Moreover, the output layers contain a specific QGIS file (.sld) providing the features' symbology.

When ready, these EO based fire physical and human impact assessment layers are manually uploaded by an UNISTRA/SERTIT operator onto the dedicated FTP server (ftp:\\esb.heimdall.sp) hosted by Space Hellas, through the HEIMDALL Virtual Private Network (VPN). When available on the FTP, the EO based fire impact assessment products are automatically uploaded and made available onto the Service Platform.

5.3.3 Landslide impact assessment

5.3.3.1 Base data

Pre- and post-event satellite images are mandatory data for performing the EO based landslide impact assessment.
EO images acquired before the landslide event are used to give an idea of the situation before a disaster, and to generate the landslide extent product; pre-event images should be recent, not older than 3 years before the event, as specified within Copernicus EMS Rapid Mapping [5].

Satellite images acquired during/after the landslide event are used to generate the landslide extent mapping.

5.3.3.1.1 Pre- and post-event satellite imagery

Abrupt landslides are detectable both on optical and radar data. Landslide extraction is based on a change detection method, between pre- and post-event images, coming from the same type of sensors, radar or optical. These will be used to establish pre-event and the post-event situations. The pre-event image should be from a date as close as possible to the landslide event, as well as the post-event image.
The HEIMDALL EO data module will concentrate on the following satellite sensor for pre-event observations:

- Optical High Resolution (HR): Sentinel-2
  Sentinel-2A/B satellites cover wide areas at a spatial resolution of 10 m, with MIR bands, on a systematic mode (every 5-6 days); images are available for free.
- Radar HR: Sentinel-1
  Sentinel-1A/B satellites cover wide areas at a spatial resolution from 40 to 5 m, with the C-band, on a systematic mode (every 5-6 days); images are available for free.
- Optical VHR data such as SPOT6/7 (1.50 m) or Pléiades-HR (50 cm) could be added when landslides are small and/or urban areas are threatened.

As Sentinel images are regularly acquired over the globe in a systematic mode, pre-event data can be selected within the existing archive imagery catalogues, considering the cloud coverage for Sentinel-2 and the acquisition date.

5.3.3.1.2 External databases

Digital Terrain Models are used for geometric purposes (reference elevation information for satellite imagery orthorectification). SRTM DTM (30 m) is integrated by default into the landslide automatic extraction tool but it can be replaced by a more precise source if available.

5.3.3.2 Input data

5.3.3.2.1 Landslide extent

Pre- and post-event satellite images are used to generate an observed landslide extent product which is one of the input data of the landslide impact assessment.
The landslide extent is automatically extracted thanks to a change detection method applied between the pre- and post-event EO images, using the dedicated developed processing chain. The result is composed of two classes (landslide affected area/not affected).
This procedure can be also supported by the analysis of a wider area, where close, and similar landslides can be present. To provide information related to the behaviour, i.e. velocity, acceleration, of the observed landslide, the analysis of the Sentinel1 SAR images-derived PS long temporal series of the surroundings, can provide statistical estimates to be integrated. This can sometimes improve the reliability of the Optical and simple radar interferometric product, i.e. the interferogram calculated between the pre and post event SAR images, especially in landslides with significant percentage of vegetated areas. Through the SP the user can decide if deepen the analysis of the standard change detection, and try to improve the estimate of the extent.

Table 5-27 Description of EO based landslide extent products

Component	Classes	Format	Notes
Landslide extent	Landslide affected area/No landslide	ESRI Shapefile GeoTIFF	-

5.3.3.2.2 Physical and Human Exposure data

Physical and Human Exposure data, which identify the buildings, critical infrastructure, transportation networks, LULC and population at risk, exposed to the hazard, are the second input in deriving the landslide impact assessment product. They are retrieved from the service platform and combined with the landslide extent product in order to generate the EO based impact assessment output.

5.3.3.3 Outputs and results

EO based impact assessment leads to two main products: physical impact and the human impact assessments.

The EO-based Physical Impact Assessment product highlights the buildings, critical infrastructures, transportation networks and LULC affected by the landslide event as detected on the post-event satellite imagery. A separate output is generated for each assets type with its own attributes.

The EO-based Human Impact Assessment product highlights the population affected by the landslide event as detected on the post-event satellite imagery.

Each of the products is composed of a binary classification “Affected/Not Affected”, but a third class “Potentially affected” can be added in case of doubt or in case of slight or not clear damage.

The results will include geo-spatial layers that are going to be made available through the service platform in vector ESRI Shapefile format.

Table 5-28 Description of EO based landslide impact assessment products

Component	Attributes	Format	Notes
Impact on road network	- Impact - Road type	ESRI Shapefile	-
Impact on buildings	- Impact - Height - Number of Stories - Function - Volume - Population	ESRI Shapefile	-
Impact on LULC	-Impact -Type	ESRI Shapefile	-
Impact on population	-Impact -Number of people	ESRI Shapefile	-

Table 5-29 Description of EO based landslide impact assessment products

5.3.3.4 Methods documentation

The input data (landslide extent product plus exposure data) are manually retrieved by an UNISTRA/SERTIT operator from the Service Platform as soon as a new landslide layer is made available in vector shapefile and/or raster GeoTIFF formats. These input data are then internally combined by a semi-automatic procedure in order to derive the EO based landslide impact assessment. The output layers are provided in vector shapefile compressed format, at the EPSG 4326 – WGS84 decimal degrees projection, with the following naming convention: source.productname.namespace.layername.date.zip, where:

- source: is the source of your original EO image;
- productname: is how the product/category of output is called (has to do with the rapid mapping process that produces that product);
- namespace: our choice. Something meaningful for the project (event location, …);
- layername: our choice. Has to do with what the layer actually contains;
- date: yyyyMMddTHHmmss.

Moreover, the output layers contain a specific QGIS file (.sld) providing the features' symbology.

When ready, these EO based physical and human landslide impact assessment layers are manually uploaded by an UNISTRA/SERTIT operator onto the dedicated FTP server (ftp:\\esb.heimdall.sp) hosted by Space Hellas, through the HEIMDALL Virtual Private Network (VPN). When available on the FTP, the EO based landslide impact assessment products are automatically uploaded and made available onto the Service Platform.

6 Conclusion

This deliverable provided the preliminary documentation of the technical implementation of the methodological concepts on risk and vulnerability analysis in HEIMDAL which are specified in deliverable D6.1. The presented work constitutes a first design of the components with a basic specification of the technical details that is expected to evolve throughout the project and throughout the different releases of the system and iterations with the end-users and Advisory-Board members from release B to C. The definitive specification shall be provided in M38 in deliverable D6.5. The current version of the document specified the structure of the RVA module describing its sub modules, their components and the interfaces between sub modules as well as between the RVA module and the other components of HEIMDALL, specifying workflows and necessary interactions. In order to address the needs of the specified methodological concepts different sub modules shall be implemented in the RVA module. An exposure sub module with a component dedicated to generate the physical exposure and another one dedicated to process the human exposure of the affected areas (either based on simulation perimeters of the hazard or on hazard masks obtained from EO-imagery). The corresponding outputs shall feed the two-impact assessment sub modules to generate impact assessment results. One of these sub modules performs impact assessment based on the outputs generated by the simulators of the modelling and simulation module such as hazard perimeters and hazard forcings (i.e. hazard measurements such as hazard intensities) for pre-events impact estimations and in some cases operational (i.e. during the incident lifetime) impact assessments. This sub module shall be based on the RASOR project [13] impact assessment APIs for the calculation of the physical and human impact for floods, forest fires and landslides. With regard to the simulation-based impact assessment for landslides, the performed impact assessment is expected to follow a more qualitative approach when compared to the other hazards addressed by HEIMDALL, this limitation is due to the fact that the outputs provided by the landslide simulator follow a more qualitative assessment approach and do not provide hazard forcings as in the other hazards' cases. The other impact assessment sub module focuses on the calculation of post-incident impact assessment through the analysis of pre-event with post-event EO-imagery and crossing this with the exposure data. The former sub module shall be based on the already operational Rapid Mapping service from the Copernicus Emergency Management [5].

Since the implementation of the specified services will start with the implementation of the release B of the HEIMDALL system the next iteration of the document shall provide the definitive and extensive technical documentation as well as the tests that shall validate the technical requirements and technical specifications.

7 References

[1] Christian Knopp (DLR), Cláudia Abanco (ICGC) Monika Friedemann (DLR) Roberto Rudari, Eva Trasforini (CIMA) Stéphanie Battiston, Stephen Clandillon (UNISTRA) Guido Luzi (CTTC), "Concept design for risk analysis methods and components – Detailed concept design and documentation of methods on risk analysis - Draft," H2020-Project HEIMDALL, 2018.

[2] W. Abdulla, "Mask R-CNN for object detection and instance segmentation on Keras and TensorFlow," *GitHub repository*. Github, 2017.

[3] K. He, G. Gkioxari, P. Dollár, and R. B. Girshick, "Mask R-CNN," *CoRR*, vol. abs/1703.06870, 2017.

[4] G. Boeing, "OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks," *Computers, Environment and Urban Systems*, vol. 65, pp. 126–139, 2017.

[5] EC, "Emergency Management Service - Rapid Mapping Product Portfolio [http://emergency.copernicus.eu/mapping/ems/ems-rapid-mapping-products]." European Commission, 2015.

[6] International Working Group on Satellite-based Emergency Mapping (IWG-SEM), "Emergency Mapping Guidelines, Version 1.0." Dec-2015.

[7] EEA, "CLC 2012 — Copernicus Land Monitoring Service." 2016.

[8] EEA, "Urban Atlas 2012 — Copernicus Land Monitoring Service." 2016.

[9] T. Esch, M. Marconcini, A. Felbier, A. Roth, W. Heldens, M. Huber, M. Schwinger, H. Taubenböck, A. Müller, and S. Dech, "Urban Footprint Processor – Fully Automated Processing Chain Generating Settlement Masks from Global Data of the TanDEM-X Mission," vol. 10, no. 6, pp. 1617–1621, 2013.

[10] M. Pesaresi, G. Huadong, X. Blaes, D. Ehrlich, S. Ferri, L. Gueguen, M. Halkia, M. Kauffmann, T. Kemper, L. Lu, M. A. Marin-Herrera, G. K. Ouzounis, M. Scavazzon, P. Soille, V. Syrris, and L. Zanchetta, "A Global Human Settlement Layer From Optical HR/VHR RS Data: Concept and First Results," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 6, no. 5, pp. 2102–2131, 2013.

[11] S. Freire and M. Pesaresi, "GHS population grid, derived from GPW4, multitemporal (1975, 1990, 2000, 2015)," *European Commission, Joint Research Centre (JRC). PID: http://data. europa. eu/89h/jrcghsl-ghs_pop_gpw4_globe_r2015a*, 2015.

[12] SEDAC, "Gridded Population of the World." 2015.

[13] F. N. Koudogbo, J. Duro, L. Rossi, R. Rudari, and A. Eddy, "Multi-hazard risk analysis using the FP7 RASOR Platform," vol. 9239. p. 92390J–92390J–15, 2014.