



# SOLutions TESTing for Regions through Insurance for Climate Adaptation

HORIZON-MISS-2022-CLIMA-01| Project Number 101112867

## Deliverable 2.4

# Software Prototype Data Foundations and Prototype Solutions for Natural Hazard Risk Analysis

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| Dissemination Level |                                                                  |          |
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| <b>PU</b>           | Public                                                           | <b>x</b> |
| <b>SEN</b>          | Sensitive — limited under the conditions of the Grant Agreement  |          |
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| Nº | ORGANISATION                                                 | Short name | Country | Role               |
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| 7  | AQUATEC                                                      | AQUA       | ES      | Beneficiary        |
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| 9  | National Center for Scientific Research Demokritos           | DEMO       | GR      | Beneficiary        |
| 10 | Hochschule Weihenstephan-Triesdorf                           | HSWT       | DE      | Beneficiary        |
| 11 | Association for the Development of West Athens               | ASDA       | GR      | Beneficiary        |
| 12 | Behavior SMART OOD                                           | BES        | BG      | Beneficiary        |
| 13 | Conselleria de Generalitat Valenciana                        | GVA        | ES      | Beneficiary        |
| 14 | Municipality of Gabrovo                                      | MoG        | BG      | Beneficiary        |
| 15 | Empower Insight                                              | EI         | FR      | Beneficiary        |
| 16 | Stiftung Global Infrastructure Basel                         | GIB        | CH      | Associated Partner |
| 17 | Verbraucherzentrale Sachsen e.V.                             | VZS        | DE      | Associated Partner |
| 18 | Landesamt für Umweltschutz (Regional Env. Protection Agency) | LAU        | DE      | Associated Partner |
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| 23 | German Insurance Association                                 | GDV        | DE      | Associated Partner |
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| 25 | Bavarian Farmers Association                                 | BBV        | DE      | Associated Partner |
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| 28 | DZI at KBC Group (insurance)                                 | DZI        | BG      | Associated Partner |
| 29 | Caisse de Reassurance (insurance)                            | COR        | FR      | Associated Partner |
| 30 | Hellenic Association of Insurance Companies                  | HAIC       | GR      | Associated Partner |



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## Abbreviations

|                   |                                                                                   |
|-------------------|-----------------------------------------------------------------------------------|
| <b>ARIES</b>      | ARtificial Intelligence for Ecosystem Services                                    |
| <b>BSU</b>        | Basic Spatial Unit                                                                |
| <b>CINEA</b>      | European Climate, Infrastructure and Environment Executive Agency                 |
| <b>DCAT-AP</b>    | Data Catalogue Vocabulary Application Profile                                     |
| <b>DEM</b>        | Digital Elevation Model                                                           |
| <b>DSM</b>        | Digital Surface Model                                                             |
| <b>DTM</b>        | Digital Terrain Model                                                             |
| <b>ECHO</b>       | Directorate-General for European Civil Protection and Humanitarian Aid Operations |
| <b>EU</b>         | European Union                                                                    |
| <b>FAIR</b>       | Findable, Accessible, Interoperable, Reusable                                     |
| <b>GDP</b>        | Gross Domestic Product                                                            |
| <b>GDPR</b>       | General Data Protection Regulation                                                |
| <b>GeoDCAT-AP</b> | Geospatial DCAT-AP                                                                |
| <b>INE</b>        | Instituto Nacional de Estadística (Spanish National Statistics Institute)         |
| <b>JRC</b>        | Joint Research Centre                                                             |
| <b>NASK</b>       | Norwegian Natural Disaster Statistics                                             |
| <b>NBS</b>        | Nature-Based Solutions                                                            |
| <b>NOK</b>        | Norwegian Krone                                                                   |
| <b>NUTS3</b>      | Nomenclature of Territorial Units for Statistics – Level 3                        |
| <b>PFR</b>        | Property Flood Resilience                                                         |
| <b>RDH</b>        | Risk Data Hub                                                                     |



## EXECUTIVE SUMMARY

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This deliverable presents the development and demonstration of data foundations and software prototypes for natural hazard risk analysis within Task 2.5 of Work Package 2. It focuses on enabling the practical use of climate-related risk and loss data by transforming fragmented datasets into interoperable, user-oriented decision-support tools for regional authorities, municipalities and insurers. The work builds on previous WP1 (Task 1.2) and WP2 activities, including data barriers and harmonisation guidelines, and contributes to SOTERIA's expected outcomes of improving data sharing, strengthening regional data hubs, and supporting evidence-based climate adaptation and insurance solutions.

Two complementary prototypes were developed and tested in the case regions. The first is a historical loss data visualisation prototype using the Norway case, which demonstrates how harmonised insurance loss data can be integrated, analysed and visualised to support municipal planning, infrastructure prioritisation and risk management. The second is an Integrated Flood Risk Platform developed for Valencia, a web-based tool that combines hydraulic modelling, building-level exposure and social vulnerability data to assess infrastructure risk and pedestrian safety, and to support the selection and sizing of adaptation measures.

This deliverable translates user needs into practical tools for working with climate risk and loss data. It identifies relevant datasets required for risk analysis, demonstrates interoperable and scalable software prototypes, and provides a foundation for future integration with regional data hubs and European risk data initiatives. By bringing these elements together, the work moves from data and user requirements to tested, real-world solutions. Together, the results demonstrate the feasibility and value of interoperable, user-oriented tools for converting scattered risk and loss datasets into decision-ready outputs, providing a concrete basis for scaling SOTERIA's approach across European regions.

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## 1. Introduction

Climate change is increasing the frequency and intensity of natural hazards across Europe, exposing communities, infrastructure, and economies to growing levels of risk. Floods, storms, heatwaves, and other climate-related events already generate significant social, environmental and economic losses, placing pressure on public authorities, insurers, and local communities. Despite this, decision-makers often lack access to integrated, high-quality data on hazards, exposure, vulnerability, and losses, limiting their ability to plan effectively for adaptation and risk reduction.

A major challenge lies in the fragmentation of climate risk and loss data. Information is typically dispensed across institutions, stored in different formats, and described using inconsistent classifications. In particular, detailed loss and insurance data, while highly valuable for understanding real-world impacts, remain difficult to access and integrate due to privacy concerns, legal barriers, and lack of harmonisation. As a result, adaptation strategies are frequently based on incomplete evidence, reducing their effectiveness.

Within this context, one of the aims of the SOTERIA project is to improve how regions test, share, and use climate risk and loss data to support evidence-based adaptation and insurance solutions. This Deliverable (D2.4) related to Task 2.5 in Work package 2, contributes to this objective by developing data foundations and prototype solutions for natural hazard risk analysis. The focus is on demonstrating how harmonised data models and user-oriented tools can translate complex datasets into actionable insights for municipalities, regional authorities, and other stakeholders.

This deliverable has four main objectives:

- (i) to map the needs and preferences of end users in the SOTERIA pilot regions;
- (ii) to identify and assess the best available datasets for comprehensive risk analysis;
- (iii) to develop and test a prototype for visualising and analysing historical loss data; and
- (iv) to develop and test a web-based prototype for urban flood risk and adaptation analysis in the Valencia case study.



## 2. Stakeholder Needs and Preferences

Understanding user needs is critical for designing effective tools.

To inform the development of the prototype, user needs and expectations were identified through questionnaires, workshops and stakeholders meetings conducted in the three SOTERIA pilot regions (Valencia, Gabrovo, and West Athens),

The objective was to understand how different public authority actors (technicians, analysts, planners, and civil protection staff) currently access and use climate-risk and loss data, and which aspects limit their ability to apply this information in practice. Indeed, insights were collected to better understand:

- Current access to and climate risk and loss data
- Key challenges related to data availability, usability and integration
- Gaps in existing data and tools
- Desired features for an intuitive and effective platform

### 2.1 Methodology

The mapping of end-user needs was conducted through a questionnaire (see Annex A1) developed for the pilot regions, with distribution methods adapted by each pilot team.

The questionnaire was circulated in several rounds: in Valencia, an initial distribution followed a workshop in October 2024, complemented by a second round in February 2025 due to delays caused by the November 2024 DANA flood event. We received 7 responses. The respondents come from various technical and environmental roles within regional and municipal public authorities in the Valencian region (eg: Senior technical officer in civil engineering, biodiversity and protected natural areas technician, climate change representative, public works and environmental engineering technician).

In Gabrovo, the questionnaire was shared in November 2024 with participants from the Climate Resilience Dialogue, with responses received in early January 2025. A total of 14 responses were received from stakeholders in municipal administration, regional government, environmental agencies, insurance companies, and industry chambers.

In West Athens, the questionnaire was distributed after the regional Climate Dialogue in December 2024, with limited responses recorded by mid-February 2025 and therefore not included.



## 2.2 Finding from the pilots regions

### 2.2.1 Current use of climate risk and loss data

Findings from Valencia and Gabrovo show that most respondents actively work with climate risk and loss data, primarily for policy development, risk assessment, and disaster response. The data used mainly includes meteorological observations and projections, hazard maps (e.g. floods, fires), exposure and vulnerability data, and, to a lesser extent, loss and damage data.

Stakeholders rely predominantly on public datasets provided by national and regional authorities and access them through multiple existing platforms and institutional sources.

Data use is more frequent in Valencia (daily to weekly) than in Gabrovo (monthly or occasional), and work is generally conducted at municipal or regional scale, with limited use of asset-level data.

### 2.2.2. Data gaps and limitations

Despite the availability of multiple datasets, respondents in both regions reported that existing data is not always sufficient to meet their needs. In Valencia, most respondents indicated that additional data is required to comply with legal obligations, particularly higher-resolution, local-scale data and updated climate projections. In Gabrovo, around half of respondents reported similar needs, highlighting gaps in localized hazard data, future projections, and economic loss information.

Across both regions, data on losses, especially insurance-related data linked to event location, timing, and damage magnitude, was considered particularly valuable but remains limited or difficult to access.

### 2.2.3. Technical and operational challenges

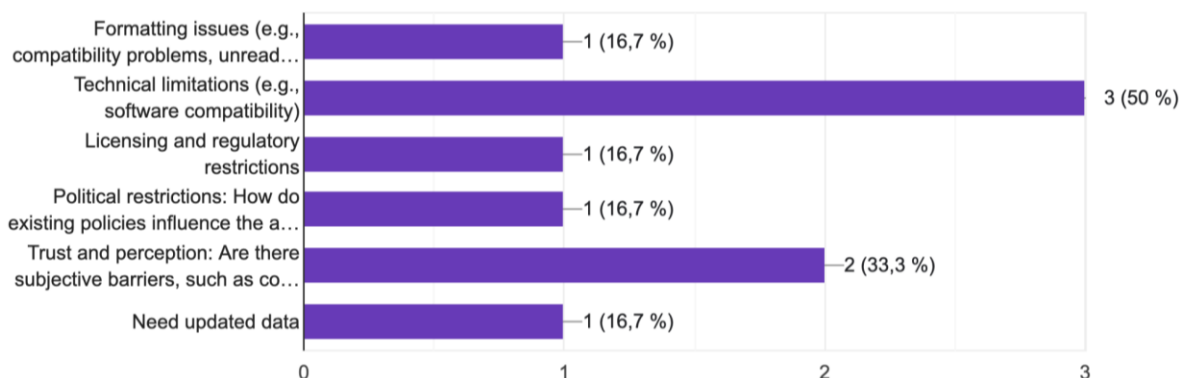
Stakeholders in Valencia and Gabrovo identified technical constraints as a major barrier to effective data use (see Figure 1).

These include difficulties related to data formats, interoperability, and integration across sources, as well as concerns about data reliability and consistency. These challenges complicate data analysis and limit the ability to combine datasets for comprehensive risk assessments.



What challenges or barriers do you face when accessing, interpreting, or using this data?

6 respuestas



12 responses

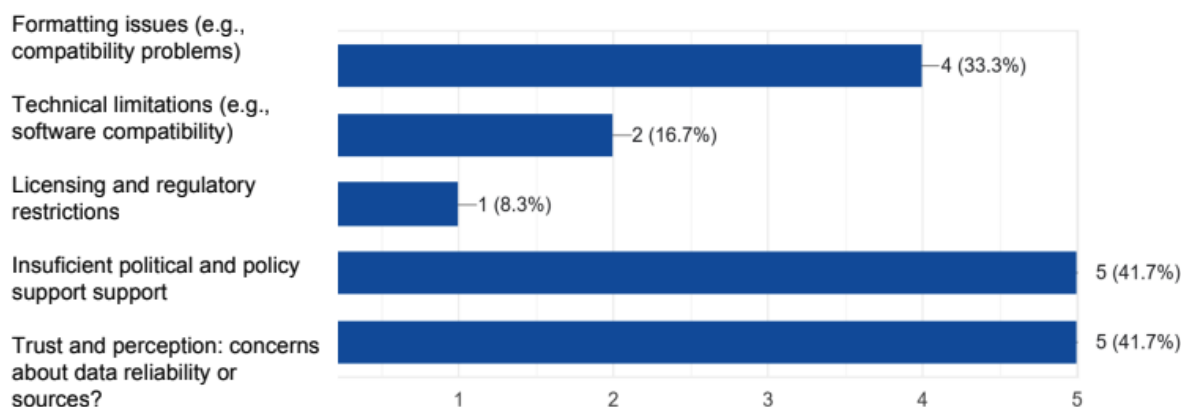


Figure 1: Challenges and obstacles encountered when accessing, interpreting and using data on climate-related risks - Valencia (purple) and Gabrovo (blue).

#### 2.2.4 Expectation for future tools and platforms

Most respondents expressed interest in improved or centralised access to climate risk and loss data. In Gabrovo, there was strong support for a centralised platform integrating multiple datasets. In Valencia, views were more mixed, with several respondents suggesting that enhancing existing tools, such as the GVA Viewer, may be preferable to developing a new platform.

Across both regions, stakeholders emphasised the importance of flexible visualisation, allowing data to be explored at different spatial scales depending on professional needs. While requirements for data granularity varied between users, the ability to access verified, up-to-date datasets from authoritative sources was consistently highlighted as essential.



### 2.2.5 Summary

Stakeholder feedback shows a strong demand for more accessible, integrated and locally relevant climate risk and loss data. The challenges identified by stakeholders provide a clear direction for the data requirements of the SOTERIA platform.

The next chapter therefore presents the key datasets available to support risk analysis and adaptation planning.



### 3. Best available data

Building on stakeholder needs, this section outlines the datasets required for effective risk analysis. Comprehensive risk assessment for climate adaptation relies on robust data inputs. Essential data include vulnerability indicators for infrastructure and communities, local climate projections, and exposure metrics. These data sets identify priority areas for adaptation by detailing heat stress patterns, flood-prone zones, and drought susceptibility. Socioeconomic data, such as insurance data losses, population demographics, economic activities, and adaptive capacities, inform assessments of community resilience and guide the design of targeted adaptation strategies. Infrastructure data, including building conditions, urban planning parameters, and critical facility locations, support the evaluation of structural vulnerabilities and adaptation planning. Integrating these diverse data sources enables decision-makers to assess the cost-effectiveness of adaptation options, prioritize interventions, and formulate evidence-based policies. Monitoring and evaluation data further track the outcomes of adaptation measures and inform adaptive management. Inadequate data inputs reduce the precision of adaptation planning and may lead to maladaptation.

Various regional, national, and European sources provide hazard data, particularly for flood-related hazards such as fluvial floods, coastal floods, and sea level rise. However, these models are generally broad in scope, utilize coarse spatial resolution, and focus on return periods derived from historical records, which limits their calibration with historical loss data. There is a notable absence of spatially explicit hazard values for individual events. Furthermore, pluvial flood maps are rarely available, despite the significant losses associated with pluvial flooding.

Publicly accessible data for other hazards, including heatwaves and wind events, remain limited. Figure 2, Figure 3 and Figure 4 highlight the information available in the main Case Studies of the SOTERIA project.



## Valencia - Spain

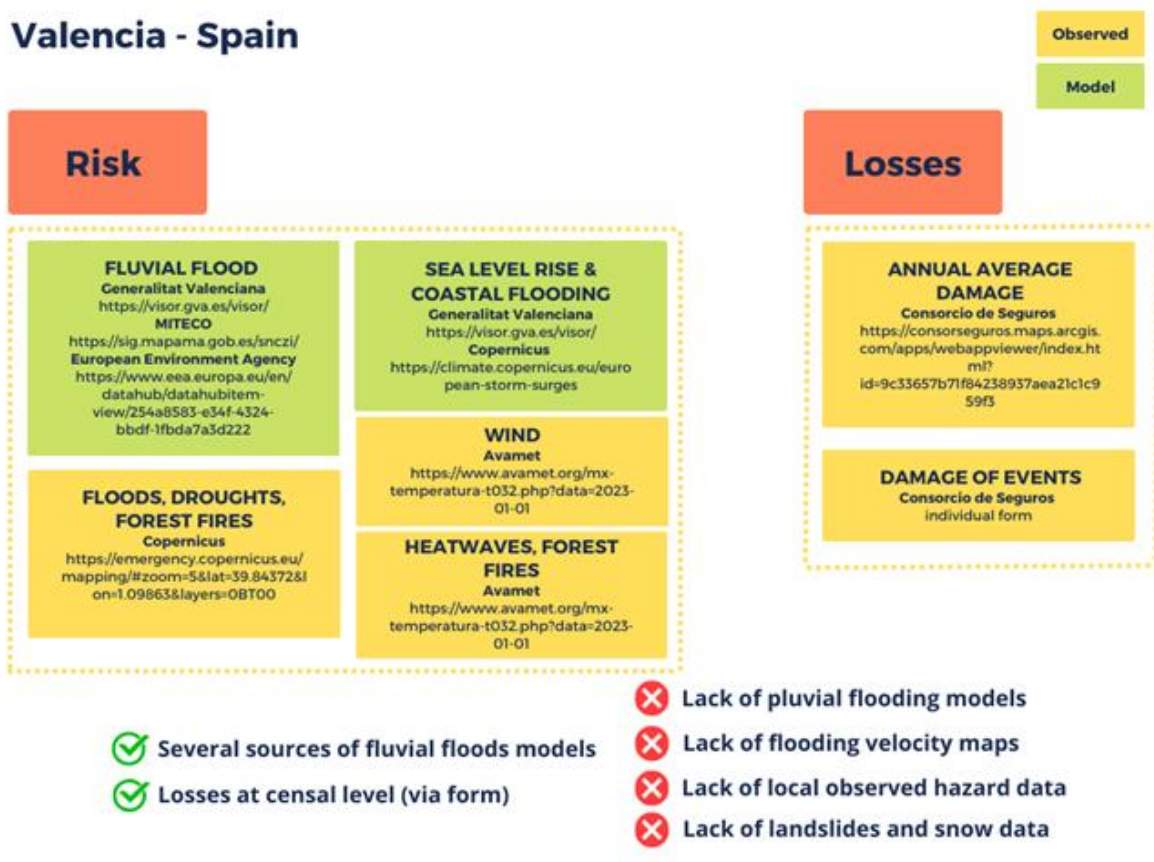
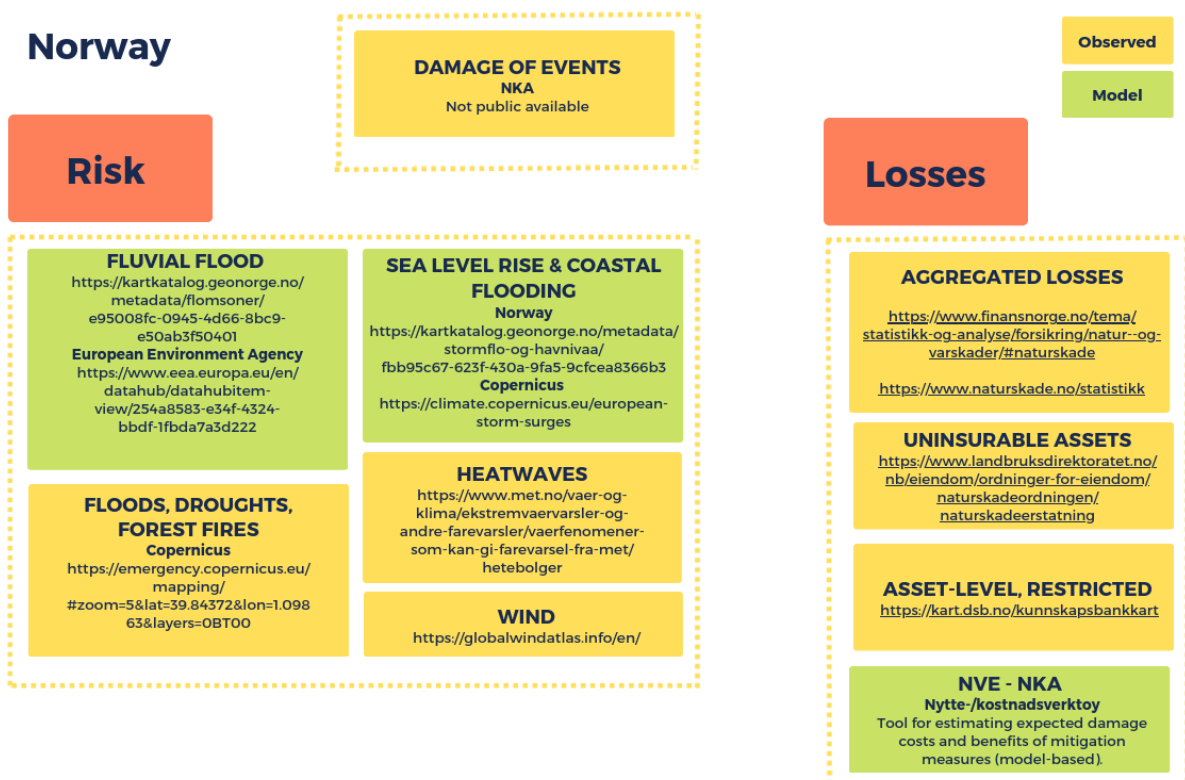


Figure 2: Available data on climate risk and losses in CS Valencia, Spain.



- ✓ Several sources of hazard maps
- ✓ Losses at high resolution level
- ✗ Lack of local observed hazard maps data

Figure 3: Available data on climate risk and losses in CS Norway.

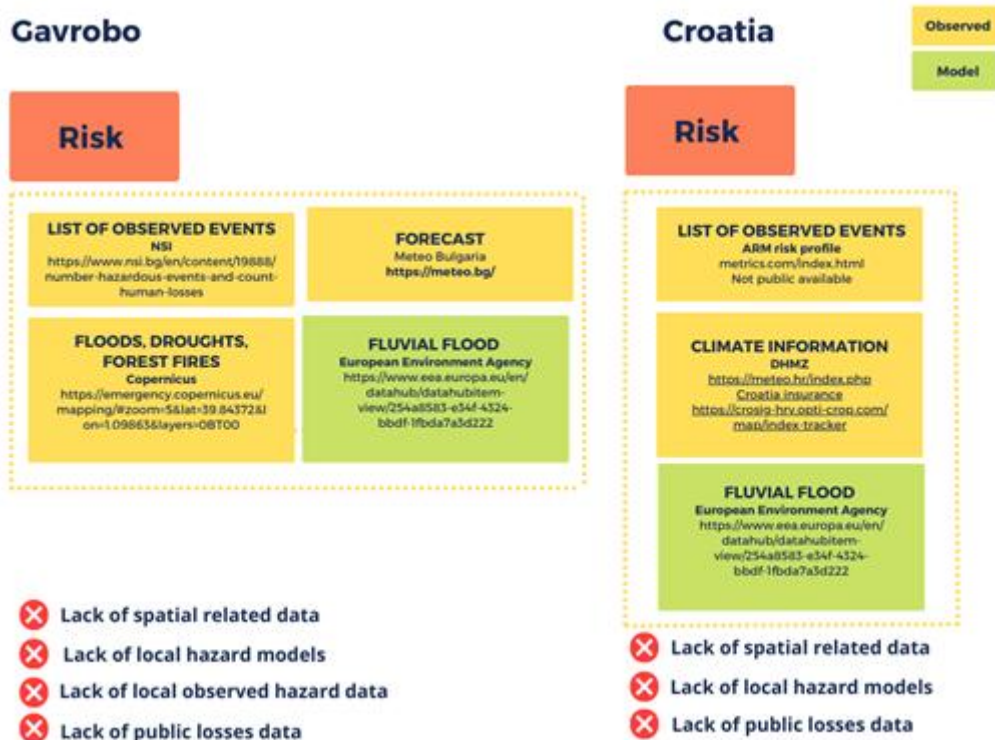


Figure 4: Available data on climate risk and losses in CS Gabrovo and Croatia.

The data required for a comprehensive risk assessment can be classified into three primary categories. Geographic data includes digital terrain models (DTM), digital elevation models (DEM), digital surface models (DSM), land use and land cover maps, infrastructure networks such as roads, utilities, and communications, urban planning maps, satellite imagery, aerial photography, and geological and soil maps. Climatic data consists of temperature records, precipitation patterns and intensity, wind speed and direction, humidity levels, historical weather events and extremes, climate change projections, return periods for extreme events, and seasonal variations. Exposure and vulnerability data comprises cadastral information, property records, building characteristics, construction types, population demographics and distribution, critical infrastructure locations, socioeconomic indicators, historical damage and loss records, insurance data, claim history, emergency response capabilities, population vulnerability factors including age, health, and income, as well as economic assets and their value.

Together, these datasets enable detailed risk analysis and guide the development of targeted adaptation strategies. Their integration with European platforms, as discussed next, is essential for ensuring consistency and interoperability.



## 4. Integration with European Risk Data Hub

To ensure interoperability and compliance, the integration of economic loss data with the European Risk Data Hub (RDH) was assessed against three core objectives: achieving technical interoperability, safeguarding privacy, and aligning with European best practices. Economic loss data was prioritized because it represents the most sensitive and heterogeneous component of regional datasets, requiring careful harmonisation to enable cross-country comparison and secure sharing. This section summarizes the barriers identified in Tasks 1.2 and 2.3, the solutions implemented in the prototype, and how lessons from work with participating regions and from surveys conducted in Task 1.2 and 2.1 informed the design.

Several challenges can be identified from the project's work with participating regions, which are also evident in recent surveys for the European Commission and in the broader literature on the sharing of detailed loss data (European Commission. Joint Research Centre. 2025; European Commission. Directorate General for European Civil Protection and Humanitarian Aid Operations (ECHO) and ICF. 2024). The first challenge relates to data quality. Many records contained incomplete or inaccurate geolocation, missing or inconclusive cause classification codes, and heterogeneous address formats. These inconsistencies required extensive preprocessing and validation before the data could be used for analysis or integration. The second challenge concerns privacy and compliance with the General Data Protection Regulation (GDPR). Granular insurance data, while highly valuable for risk assessment, raises confidentiality concerns that limit direct integration of asset-level records. These concerns can persist even after aggregation and anonymization, despite the potential benefits such data could provide to local administrations and communities (see SOTERIA Report D1.2 and D2.2, available [here](#)). A third challenge is semantic misalignment. Variations in hazard classification, asset categories, and loss indicators or accounting practices across companies and regions hinder comparability and integration. Without harmonization, datasets cannot be reliably combined or used for cross-regional analysis (Figure 5).

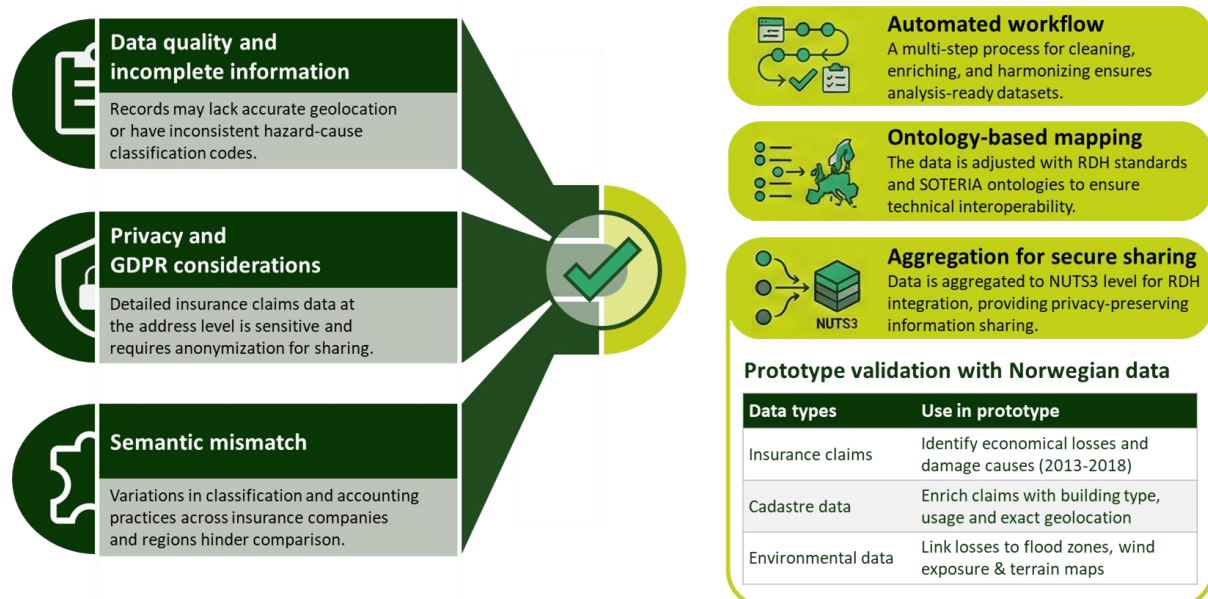


*Figure 5: Barriers to data sharing and corresponding solutions implemented in the SOTERIA prototype, validated using Norwegian insurance claims, building/address information, and environmental datasets.*

To address these barriers, as illustrated in Figure 5, the prototype presented in Section 5.1 applied a structured workflow combining data cleaning, semantic alignment, and privacy-preserving measures. Loss data was aggregated to NUTS3 level for RDH integration, while sensitive details were anonymized to ensure compliance with GDPR. Ontology-based mapping aligned all datasets with RDH hazard taxonomy and asset codes, creating a consistent semantic structure. Data quality was improved through geolocation validation against cadastral records, inference of missing municipalities from postal codes, normalization of monetary values to a 2015 baseline, and the addition of provenance tracking for transparency.

Starting from asset-level records provided a unique opportunity to verify and enrich the data by linking it with complementary datasets such as cadastral information, building types, and floor areas. Geo-references were used to couple loss data with explanatory variables describing physical characteristics, including terrain and ground conditions, distance to water bodies and river networks, and proximity to hazard maps or modelled risk areas. This approach not only improved data integrity but also enabled more advanced spatial analysis and reporting after aggregation.

The design of the prototype also integrated best practices identified in SOTERIA Report D2.2 Tech briefing on Data drivers and barriers, and governance insights from SOTERIA, and Report D1.3 Recommendation for developing regional data hubs, available [here](#). These include adherence to FAIR principles and the use of open standards such as DCAT-AP and GeoDCAT-AP for metadata interoperability. Lessons from regional hubs in Valencia, Gabrovo, and West Athens, together with the



Norwegian Knowledge Bank, informed strategies for trust-building, legal anchoring, and co-design with end users. The architecture was developed to be modular and scalable, allowing phased integration of additional hazards and climate projections. Legal compliance and institutional anchoring were prioritized, drawing on examples such as Norway's regulatory provision for insurance data sharing to ensure GDPR compliance and respect for business sensitivity.

While the loss data prototype focuses on integration with the European Risk Data Hub at NUTS3 level, the framework can support a multi-layered access model. While anonymized data aggregated to a sufficient level can be shared publicly, granular, asset-level records can remain accessible only to authorized users under controlled conditions. This approach ensures compliance with GDPR while preserving the analytical value of detailed data for municipalities and civil protection agencies.

The data delivery mechanism can also be designed to deliver so-called analysis-ready datasets or decision-ready indicators, enabling users to move from raw insurance claims data to actionable insights. By combining harmonized semantics, geospatial enrichment, and privacy-preserving measures, the prototype provides a foundation for interoperable, scalable data ecosystems that support evidence-based climate adaptation and disaster risk reduction.

This approach reflects recommendations in the SOTERIA Policy Brief on Data Sharing (included in D4.3) and the JRC report on Disaster Loss Data Management (2025), which call for harmonized standards, centralized platforms, integration of geospatial data, and legal frameworks for secure and transparent data exchange. By embedding these principles into the architecture, the prototype ensures compatibility with RDH and provides a replicable model for regional data hubs across Europe.

The following section described in more detail how these principles informed the data model used in the prototype for visualizing and analysing historical loss data.



## 5. Prototype Solutions

### 5.1 Historical Loss Data Analysis

#### 5.1.1 Using Address-Level Insurance Data to Improve Municipal Risk Assessment

Municipalities face a variety of natural disasters, ranging from floods and storms to wildfires. To effectively anticipate, plan for, and mitigate these risks, local governments need detailed, actionable data. Address-level insurance compensation data related to natural disasters, which reveals where damages actually occur and how severe they are is pivotal for identifying high-risk zones, calibrating disaster models, and driving more informed infrastructure investments. For instance, for river/coastal flooding, knowing exactly where floods incur the most damage helps urban planners make smarter zoning and permitting decisions. This may include restricting development in high-risk zones, encouraging flood-resilient building techniques, or planning evacuation routes that align with known flood pathways. The same insights can also strengthen early-warning systems by improving risk mapping, refining alert thresholds, and helping municipalities target timely warnings and evacuation guidance to the most vulnerable neighbourhoods.

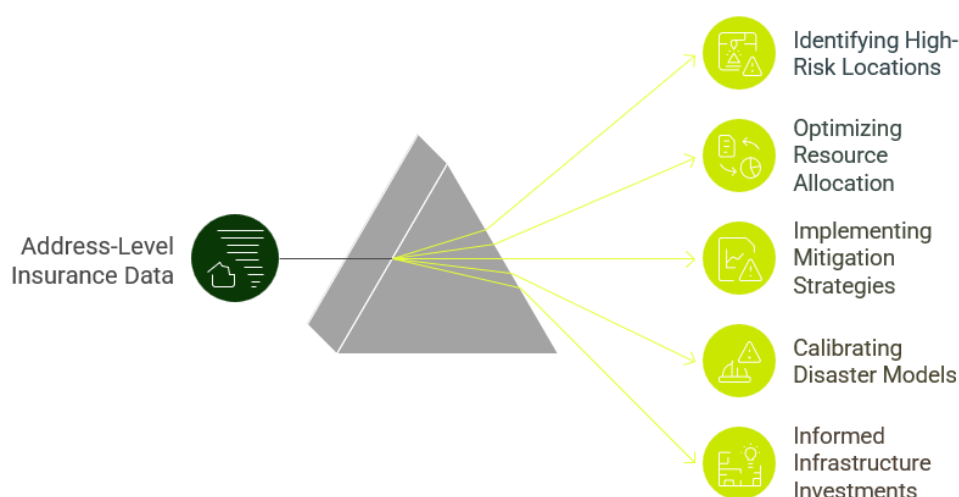


*Figure 6: Using address-level insurance data for improved risk assessment.*

Access to such detailed, address-level insurance compensation data not only highlights where losses occur but also creates opportunities for municipalities to translate this information into actionable planning tools. To demonstrate how these insights can be operationalized in practice, the following use case outlines a scenario where municipal



planners employ a dedicated prototype to visualize, analyse, and act upon this data for improved resilience and disaster preparedness.

### **5.1.2 Use case description**

Building on the value of address-level loss data outlined above, the prototype is designed to enable municipalities to visualize and analyse detailed insurance compensation records related to for instance water damage, sewage backups, and natural disasters. The aim is to translate raw claims data into actionable insights, identifying high-risk areas, prioritizing infrastructure upgrades, guiding zoning decisions, and implementing targeted resilience measures.

#### **Main Success Scenario**

##### **1. User Login & Authentication**

- Municipal planner or engineer logs into the software prototype with the appropriate permissions.

##### **2. Dataset Selection**

- User selects the relevant dataset(s) (e.g., insurance claims related to floods, sewage backup, or storms) for the region of interest.

##### **3. Visualization of High-Risk Zones**

- The system generates a city-wide map pinpointing addresses or blocks with recorded insurance losses.
- Areas with repeated flooding/sewage backup incidents are highlighted (e.g., using heatmapping or color-coded markers).

##### **4. Analysis of Historical Trends**

- User applies a time filter (e.g., the past 5 years), and the software reveals patterns in claim frequency and severity over time.
- System displays line charts or bar charts that show rising or falling trends in claim incidents.

##### **5. Drilling Down to Specific Addresses**

- User clicks on a high-risk area or address to view detailed claim information, such as claim dates, compensation amounts, and types of damages (e.g., flood damage).
- User can compare year-over-year changes in loss data for that specific address or street block.



## 6. Infrastructure Analysis

- Based on identified hotspots, the user can overlay municipal infrastructure data (e.g., sewer lines, storm drains, topographical maps) to understand potential causes (e.g., undersized sewer line, topographical low point).

## 7. Reporting and Sharing

- User exports key findings (maps, charts, summary reports) for presentation to city council or for inclusion in planning documents and budget proposals.

### Benefits and Rationale

Targeting specific addresses with frequent losses allows municipalities to allocate resources more efficiently, avoiding broad, one-size-fits-all solutions and directing limited funds to the places that need them most. Tracking how these issues change over time also supports stronger planning and adaptation efforts, revealing whether problems such as pipe deterioration or more intense rainfall are getting worse or improving.

In addition, having detailed information on areas with, for instance, high flood-related claims helps inform zoning decisions and updates to building codes so communities can better reduce future risks. These data can also highlight gaps or “blind spots” in existing hazard maps, for example, fluvial flood zones are often well mapped, while pluvial flooding is not, allowing municipalities to identify areas that may currently be under-represented in risk assessments. Finally, insights at the address level support public safety by enabling more precise evacuation planning, stronger early-warning systems, and more effective community engagement to strengthen overall resilience.

### 5.1.3 Interface prototype

Leveraging the previously described case, a prototype to analyze and visualize insurance compensation data related to natural hazards was developed. This tool is designed to support municipal planners, engineers, and disaster response teams. While the broader long-term vision includes urban flood events (e.g., water damage, sewage backups) as described in the previous use-case, the current prototype focuses exclusively on natural hazards, with the potential for future expansion.

The system supports data-driven decision-making by highlighting high-risk areas and revealing trends over time. Key features include:

- Interactive Map: Allows users to visualize where losses have occurred and how



risks are distributed across the municipality.

- Temporal Analysis Tools: Help identify recurring issues or emerging vulnerabilities.
- Incidence Ratios: Critical for risk assessment, these normalize loss data against the exposed building stock, revealing true vulnerability patterns across different areas.

Figure 7 shows the three-tier architecture of the prototype.



*Figure 7: Overview of prototype architecture.*

At the core is a Neo4j knowledge graph that implements the SOTERIA ontology introduced in [ D2.3 ] Guidelines on loss data, available [here](#). This graph stores harmonized hazard, exposure, and claims data in a structured, queryable format, creating a clear and navigable representation of relationships between buildings, events, and damages.

The presentation layer is a Plotly Dash web application, which connects to the knowledge graph via Bolt/Cypher. This interface allows users to filter data by hazard type, time period, or location. Users can move from municipal overviews to specific address-level details. Interactive maps, charts, and dashboards facilitate the identification of hotspots, the analysis of historical patterns, and the linking of observed losses to underlying assets.

The code for the presentation layer is available on GitLab: <https://gitlab.sintef.no/soteria-public/soteria-interface-prototype#>

A demonstration of the prototype, including a video overview, is available [here](#).

#### **5.1.4 Analysis of historical loss data in Norway**

To validate both the semantic model developed in Deliverable 2.3 and the usability of the interface prototype, a comprehensive test case was implemented using Norwegian data. Norway was selected because of the high quality, completeness, and regulatory



consistency of its building and insurance loss datasets, making it well suited for demonstrating the potential of ontology-based integration and analysis. The test case combined building registers, property value data, historical flood and storm loss records, and environmental exposure layers, which were ingested into the SOTERIA ontology hosted in a graph database. This allowed the project team to verify that the ontology structure correctly represents the multi-dimensional relationships between assets, hazards, and economic impacts, and that these relationships can be effectively queried and visualised through the prototype interface.

The Norway-based testbed confirmed the technical feasibility of the overall approach and provided valuable feedback on both the coverage of domain concepts in the ontology (such as building damage, agricultural losses, and claims aggregation) and the design and usability of the frontend application. The exercise also highlighted practical challenges related to data quality, geocoding, and semantic alignment, offering important lessons for future scaling to other regions and data sources.

#### Data description and preparation

In Norway, buildings or properties insured against fire damage are automatically covered against natural disasters under the Natural Disaster Insurance Act, administered by the Norwegian Natural Perils Pool, which includes all insurance companies in Norway. Within this project we got access to detailed loss data about natural disasters for Norway at address level provided by DSB's (Directorate for Civil Protection). The specific dataset covers the period 2013-2018 and includes:

##### Geographic Information:

- Property addresses
- Geographic coordinates
- Property identification numbers (g.nr/b.nr - ground number/building number)

##### Damage Information:

- Cause of damage
- Date/time of damage occurrence
- Compensation paid by insurance companies (excluding the assumed deductible)

The granular geographic detail (down to individual property level) was essential since the objective with the prototype was to demonstrate the potential of linking the insurance data with other datasets like the building registry and weather data to understand the factors influencing damage severity and patterns.

Cadastral data, which includes information on all buildings in Norway, was used to



capture relevant building characteristics. Knowing the location and features of every building makes it possible to assess what percentage of buildings with certain traits were affected by damage, providing valuable insights for the risk assessment.

Transforming raw Norwegian insurance claims data into a harmonized format required a structured, multi-step process to ensure semantic consistency, interoperability, and analytical reliability, as illustrated in Figure 8. The workflow transforms raw, asset-level records into a SOTERIA-compliant, analysis-ready dataset through a series of stages: Data Cleaning, Data Enrichment, Transformation, and Semantic Harmonization. The final output is an integrated and harmonized dataset suitable for in-depth analysis.

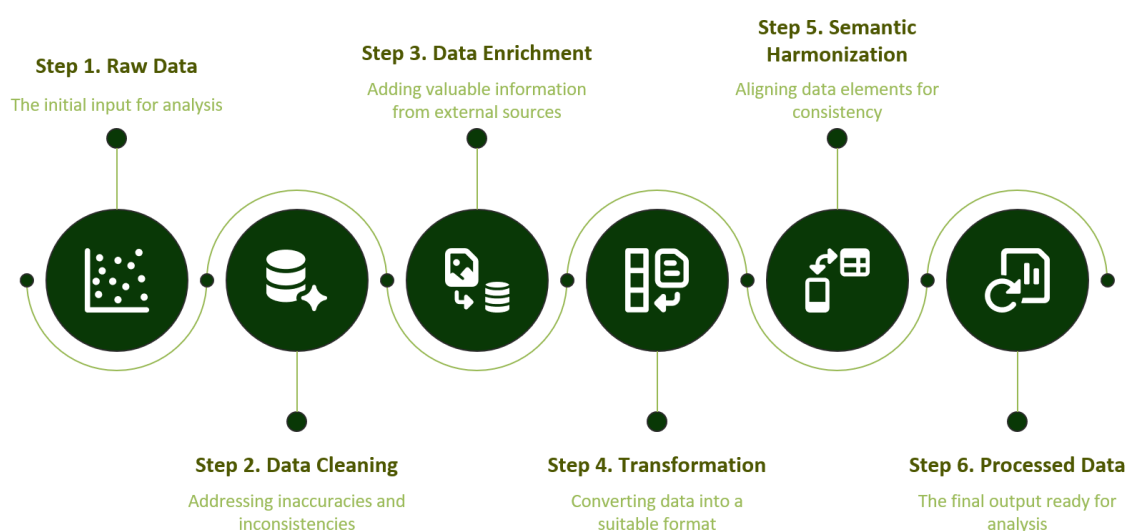


*Figure 8: Workflow for Preparing Natural Disaster Loss Data.*

## Step 1. Raw Data

The process begins with the raw dataset, which consists of Norwegian economic loss records from natural disasters between 2013 and 2018. Norway maintains a highly regulated and comprehensive system for recording natural hazard insurance losses through national mechanisms such as databases like NASK<sup>1</sup> (Norwegian Natural Disaster Statistics). Insurers are legally required to report claims data in a standardized format, including a unique claim ID, the date and location of the damage (address, municipality, postal code, and coordinates), estimated compensation, and details about the insurance product and damage type. If the damage is linked to a broader event, such as a natural disaster, the event type is also specified.

A key factor that makes Norway particularly suitable for this analysis is its high

<sup>1</sup> <https://nask.finansnorge.no/OmNask.aspx> (accessed 31.10.2025)



insurance penetration rate, which ensures that most property-related losses from natural hazards are captured in the dataset. This level of coverage provides a relatively complete and representative picture of economic impacts, reducing the bias that often occurs in countries where insurance coverage is limited. In such contexts, claims data reflect only a small fraction of actual losses, making it difficult to assess the true scale of hazard impacts.

The Norwegian dataset is characterized by its granularity, with records available at address level. This richness of detail enables advanced spatial and statistical analyses but also introduces challenges. The raw data are inherently heterogeneous and require extensive cleaning, enrichment, and standardization before they can be integrated into the SOTERIA Ontology and used for comprehensive risk assessment.

## Step 2. Data Cleaning

The second stage involves data cleaning, a crucial process for ensuring data quality and consistency. This stage comprises several key operations. It begins with duplicate removal, which identifies and eliminates repeated entries within the dataset to prevent skewed analyses and redundancy. Next, address validation verifies the accuracy and completeness of address information associated with each damage record, involving cross-referencing against authoritative address databases and correcting any inconsistencies or errors. Finally, a cadastral cross-check is performed, comparing asset locations in the damage data with cadastral records to confirm accurate spatial representation and proper alignment with property boundaries.

For claims lacking addresses, postal codes, or municipality information, the municipality was inferred from available geolocation data. Despite these efforts, some limitations persisted. For example, out of 41,330 claims, approximately 4% lacked municipality information and required inference, reducing the reliability of regional assignments. Furthermore, only 25,345 claims (about 62%) could be matched to cadastral addresses; the remaining 38% were excluded from spatial analyses, underscoring the importance of accurate address reporting.

## Step 3. Data Enrichment

Following data cleaning, the data enrichment stage aims to augment the dataset with additional contextual information. This process involves several key tasks. First, each asset record is mapped to its corresponding NUTS3 region (Nomenclature of Territorial Units for Statistics Level 3) (European Commission. Statistical Office of the European Union. 2020), a standardized geocode used for subdividing countries for statistical purposes. This mapping facilitates regional-level analysis and comparison. Next, the enrichment process links hazard dates to the relevant loss records, connecting each entry to the major natural disasters responsible for the associated economic losses and thereby enabling temporal and correlation analyses. Finally,



unique building identifiers and auxiliary data are added to each record, providing a more comprehensive representation of the assets at risk.

Several data quality challenges were identified during processing. Claim dates often reflected reporting rather than the actual damage occurrence, complicating event matching. Additionally, not all claims could be linked to major hazard events, as official registries only list significant occurrences; consequently, about one-third of claims remained unlinked. These issues highlight the need for standardized reporting practices and improved metadata capture at the source.

Cadastral data from the Norwegian national property registry<sup>2</sup> provided detailed information on building characteristics, such as footprint area and usage type. Flood zone maps, sourced from national hazard mapping authorities<sup>3</sup>, were linked to each property to evaluate exposure to riverine flooding. Similarly, wind exposure data<sup>4</sup>, derived from long-term wind speed models, were associated with building locations to assess susceptibility to storm damage. Finally, regional socio-economic data (e.g., population, GDP per capita) were incorporated to contextualize losses within broader demographic and economic conditions, supporting aggregated analyses at the municipal and NUTS3 levels.

The combination of these datasets enabled a multi-dimensional view of hazard impacts, linking physical exposure, and socio-economic context.

#### **Step 4. Transformation**

The transformation stage focuses on standardizing and aggregating the data to enable consistent analysis across regions and time periods. This stage encompasses two key operations. First, time references are standardized to ensure uniformity in date formats and temporal alignment throughout the dataset. Second, economic normalization is performed to adjust all monetary values to a 2015 base year, accounting for inflation and currency fluctuations. This allows for meaningful comparisons across different years and follows the methodology established by the RDH.

#### **Step 5. Semantic Harmonization**

The semantic harmonization stage focuses on aligning the data with a defined ontology and standardizing the terminology used throughout the dataset. This process involves

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<sup>2</sup> Property data is sourced from the Norwegian national property registry Matrikkel: <https://matrikkel.no/matrikkel/> (accessed 31.10.2025)

<sup>3</sup> Flood zones are sourced from Norges vassdrags- og energidirektorat (NVE) flood hazard area maps: <https://temakart.nve.no/tema/flomaktsomhet> (accessed 31.10.2025)

<sup>4</sup> Wind speeds are sourced from the Global Wind Atlas: <https://globalwindatlas.info/en/> (accessed 31.10.2025)



two key tasks. First, ontology alignment is carried out by mapping the data to the concepts and terms defined in the SOTERIA Ontology, ensuring semantic consistency with the broader knowledge framework. Second, attribute standardization is performed to harmonize the descriptors used across the dataset, such as naming conventions and data types, thereby enhancing consistency, comparability, and interoperability.

### Step 6. Processed Data

The final stage results in the Processed Data, which is a SOTERIA-compliant, analysis-ready dataset. This dataset is characterized as an "Integrated & harmonized dataset", meaning that it has been cleaned, enriched, transformed, and semantically harmonized to ensure consistency, accuracy, and interoperability. Despite the above-mentioned challenges, the workflow successfully produced a semantically consistent, RDH-aligned dataset suitable for populating the SOTERIA Ontology and supporting advanced analytics. This process demonstrates the feasibility of integrating insurance data into a unified framework, while also revealing critical areas for improving data governance and quality assurance in future implementations.

#### Overview of historical data

Figure 9 shows the SOTERIA prototype dashboard for exploring Norwegian loss data, combining high-level indicators, spatial hotspots, temporal accumulation and regional breakdowns in a single view. At the top, three key performance cards report: total compensation paid, total claims filed, and average claim size. Below, users can filter by hazard type, year and region to drive all visualizations.

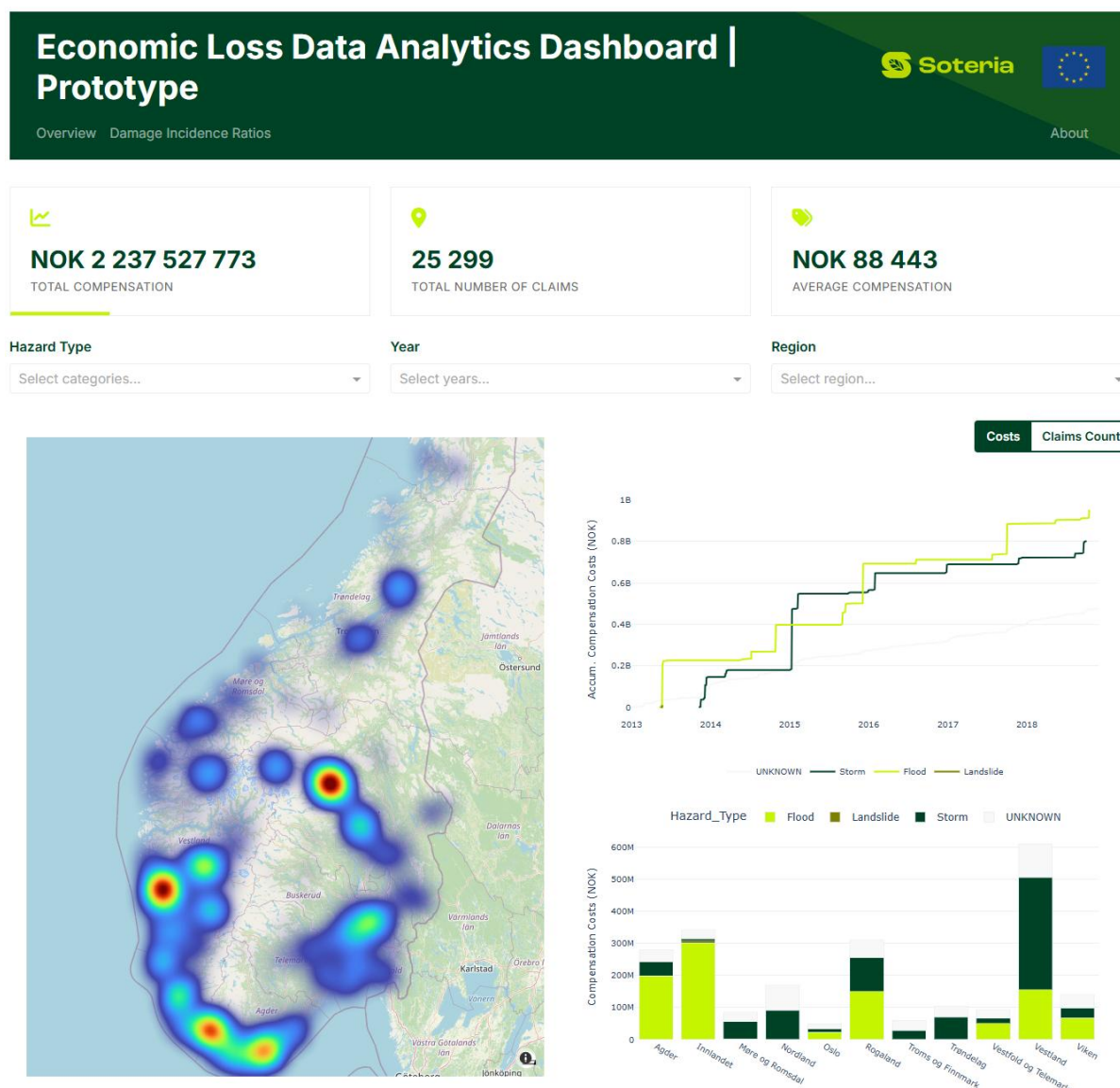


Figure 9: Overview of economic losses related to natural hazards.

On the left, a heatmap of claim locations overlays building-level compensation amounts on a basemap of Norway, instantly pinpointing where losses concentrate. At upper right, a cumulative line chart traces total payout over time by hazard (flood, landslide, storm, unknown), revealing episodic surges, e.g. major storm year in 2015. Finally, the stacked-bar chart at bottom right breaks down compensation by NUTS3 region and hazard type, highlighting which counties bear the greatest economic burden for each hazard.

By integrating these linked views (KPIs, spatial, temporal and regional) this interface empowers analysts to form and test hypotheses about loss drivers (e.g. “Do flood hotspots correspond to high-value municipalities?”), track evolving risk profiles, and prioritize resilience investments where they will yield the greatest reduction in future



claims.

#### Building damage by municipality

Figure 10 a) and b) are choropleth maps showing the share of each municipality's building stock with damages from, respectively, flood events and storm events over the study period. To create these, we aggregated all recorded building-damage incidents by municipality and then divided by the total number of buildings in each jurisdiction.

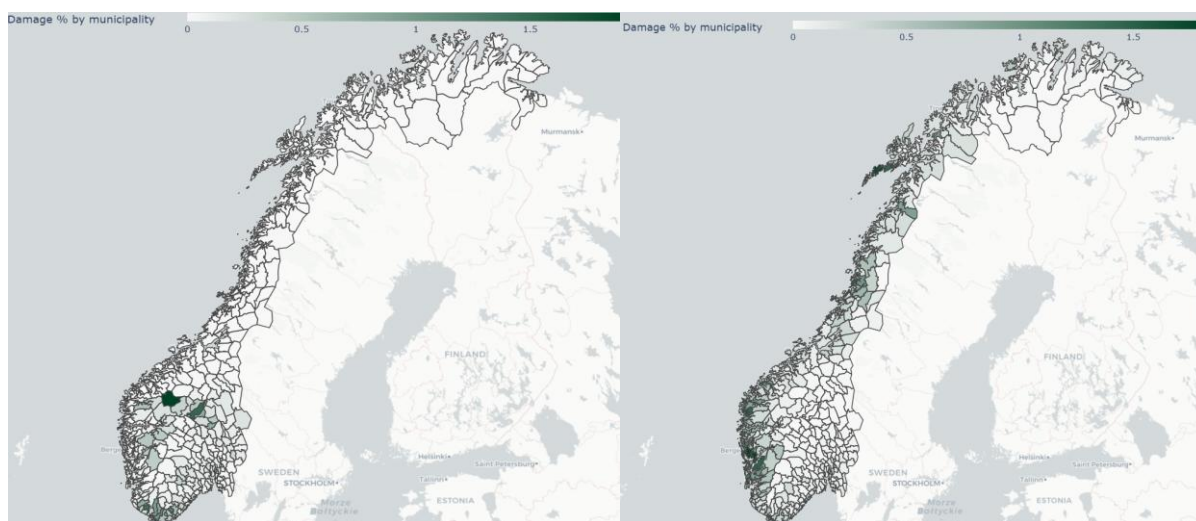


*Figure 10 a) Share of buildings per municipality with flood damages. b) Share of buildings per municipality with storm damages.*

**Flood damage (Figure 10a):** The highest damage rates, exceeding 1.5% of the local building stock, occur in low-lying, riverine municipalities in the southwest and along major river valleys. Inland municipalities farther from floodplains generally show damage rates below 0.5%, illustrating the localized nature of flood risk.

**Storm damage (Figure 10b):** By contrast, storm impacts concentrate along the exposed western and northern coasts. Many fjord-side municipalities exhibit damage rates between 0.5% and 1%, reflecting their greater exposure to wind. Interior and eastern municipalities remain largely unaffected by storms, with rates under 0.2%.

Comparing these spatial signatures underscores the need for hazard-specific resilience planning: flood mitigation (levees, river-channel restoration) should be prioritized in vulnerable communities, while wind proofing measures should be the focus in the exposed western municipalities.

#### Building damages and distance to flood zone

Figure 11 illustrates the relationship between a building's proximity to officially mapped



fluvial flood zones<sup>5</sup> and the likelihood of experiencing flood damage. Based on the working hypothesis that flood impacts attenuate with distance from inundation areas, we binned all buildings in our study region into five distance classes (0 m, 250 m, 500 m, 750 m and 1000 m) and computed the percentage of buildings within each class that sustained flood-related damage over the study period.

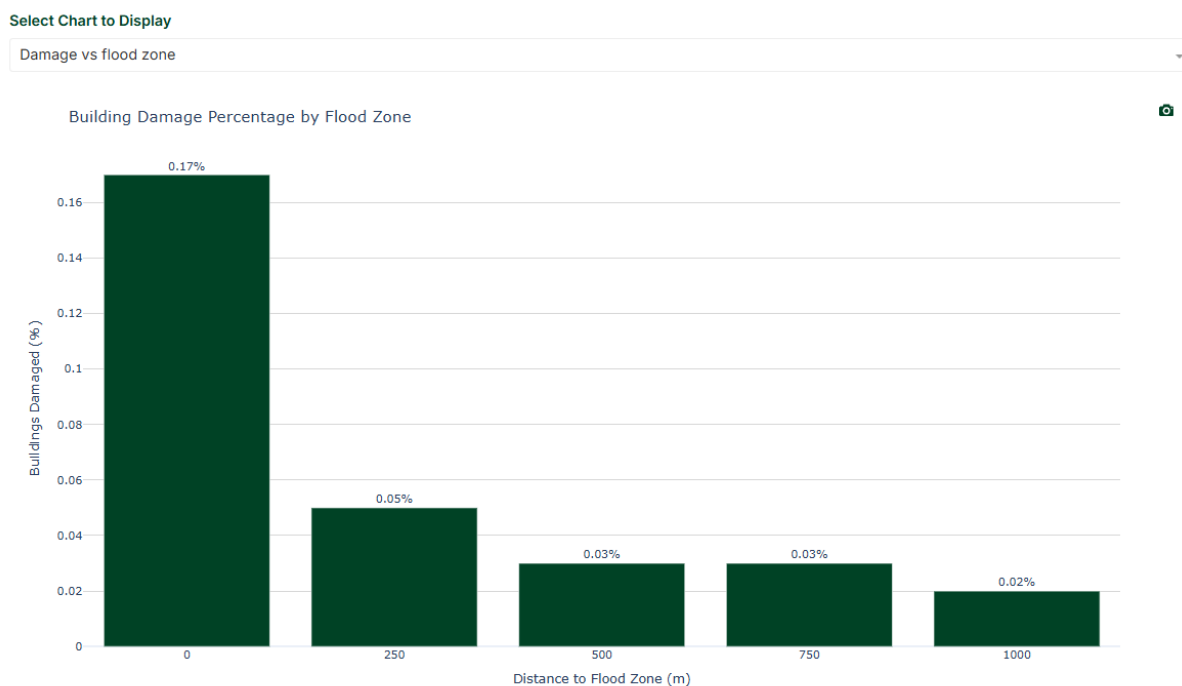


*Figure 11: Share of buildings that experienced flood damages per interval of proximity to officially mapped fluvial flood hazard areas.*

As hypothesized, the damage rate is highest for buildings located directly within the fluvial flood zone, at approximately 0.17 %. At just 250 m from the flood boundary, this rate drops by nearly two-thirds to 0.05 %. Beyond 250 m, the damage rate continues to decline more gradually, to 0.03 % at 500 m and 750 m, before reaching a minimum of 0.02 % at 1000 m. This clear negative gradient confirms that physical proximity to mapped flood extents is a robust predictor of flood damage probability.

Understanding this spatial decay of risk is critical for hazard mitigation and land-use planning. Quantifying how sharply damage likelihood falls off with distance can inform the delineation of buffer zones, guide the prioritization of flood-proofing investments, and underpin actuarial models for insurance underwriting.

#### Building damages and wind exposure

Figure 12 illustrates how a building's exposure to wind, measured by its local 10-year

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<sup>5</sup> <https://temakart.nve.no/tema/flomsone>



average wind speed<sup>6</sup>, relates to both its likelihood of wind-related damage and the abundance of buildings in each exposure class. Operating under the hypothesis that higher wind-speed zones should show elevated per-building damage rates, we grouped every structure into nine wind-speed intervals (0–1.99 m/s, 2–3.99 m/s, ..., 16–20 m/s) and computed for each cohort (a) the percentage of buildings damaged and (b) the total number of buildings.

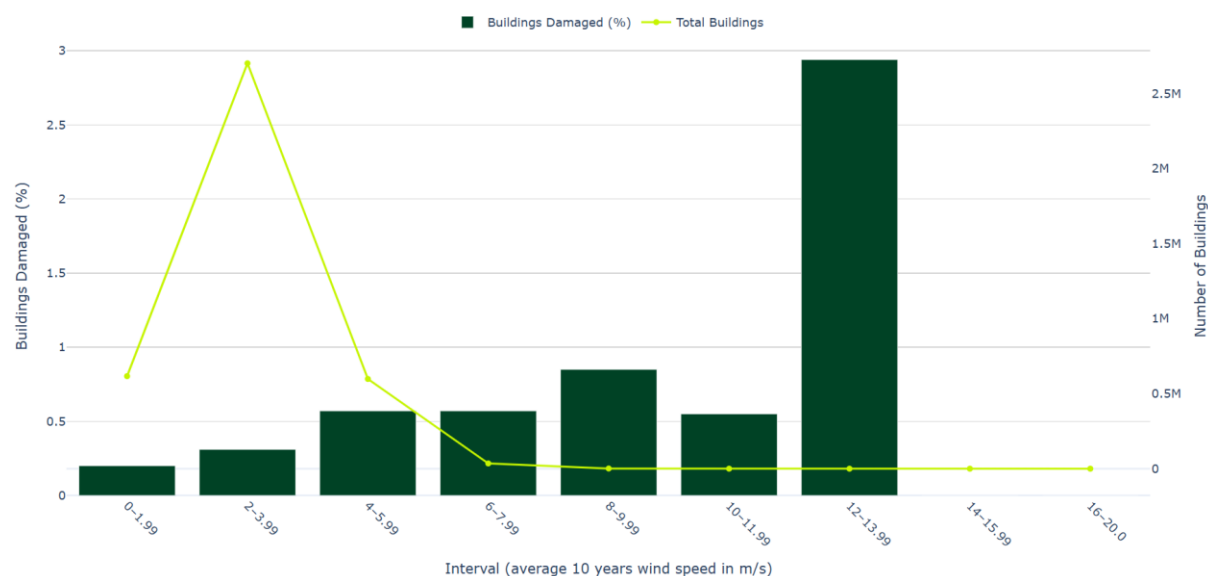


*Figure 12: Share of buildings that experienced storm damages per interval of wind exposure, grouped by its local 10-year average wind speed.*

As hypothesized, damage rates climb sharply with wind exposure. Key observations straight from the data:

- **Low wind zones (< 4 m/s):** Damage rates are very low (~0.2 % for 0–1.99 m/s, ~0.3 % for 2–3.99 m/s), yet these two cohorts together host the vast majority of buildings, over 3 million structures.
- **Moderate wind zones (4–10 m/s):** Damage rates climb steadily from ~0.55 % (4–5.99 m/s) to ~0.85 % (8–9.99 m/s), while building counts fall sharply to under 500 000.
- **High wind zones (≥ 10 m/s):** In the 12–13.99 m/s cohort, damage rates jump to nearly 3 %, but fewer than 10 000 buildings lie in this exposure class, explaining the line’s near-zero values beyond 10 m/s.

This dual perspective, per-unit vulnerability versus absolute exposure, highlights a key planning insight. Although the most extreme wind zones carry the greatest individual-building risk, the bulk of potential losses arise in the far more numerous moderate-wind

<sup>6</sup> <https://globalwindatlas.info/en/>



areas. Accordingly, resilience strategies should combine targeted retrofits for the small but highly vulnerable high-wind hotspots, with broadscale, cost-effective reinforcement measures across the moderate-wind majority to achieve the greatest aggregate reduction in wind-related damage losses.

### Building damages and construction period

Figure 13 examines how building vulnerability to flood damage varies with the era of construction. We began with the hypothesis that older buildings, typically built to less stringent design standards and with aging materials, would exhibit higher damage rates, whereas more recent construction would be more resilient. To test this, we grouped all buildings into six construction-period cohorts (1800–1949, 1950–1969, 1970–1987, 1988–1997, 1998–2007, and 2008–2025) and calculated the percentage of buildings that had flood damages. We noticed that the unusual high number of buildings with the year 2004–2007 is not due to actual construction, but because the national property registration (Matrikkel) was migrated to a new system during these years, which led to many existing buildings being registered with these dates. This anomaly may influence the conclusions drawn from the analysis.

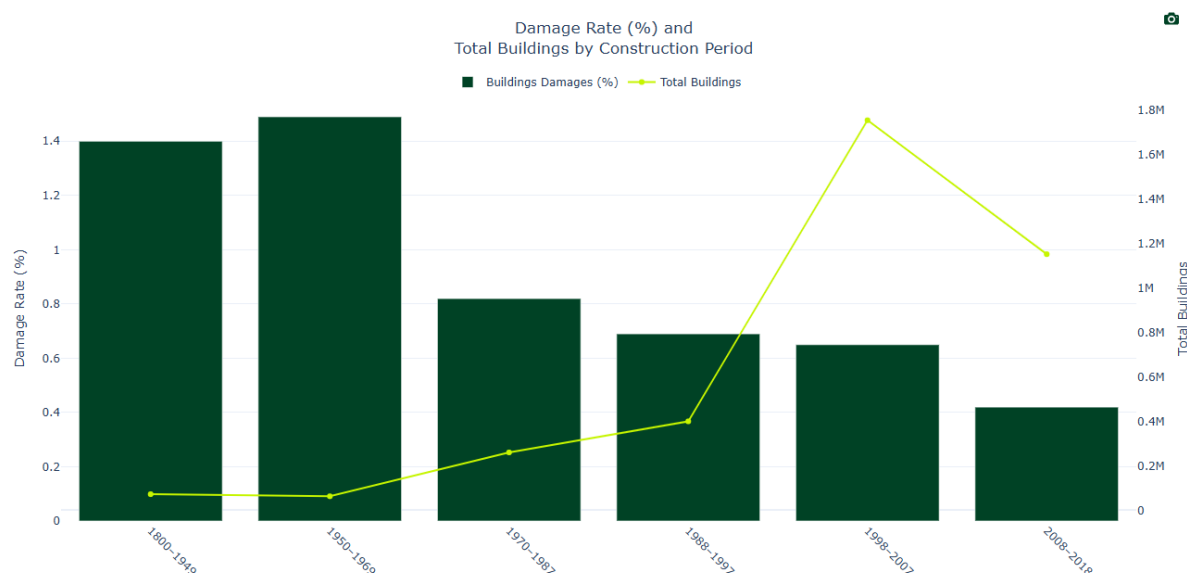


*Figure 13: Share of buildings that experienced damages due to natural hazards per construction period.*

Earliest cohorts show the highest damage rates: roughly 1.40% for 1800–1949 and peaking at about 1.48% for 1950–1969. From 1970 onward, damage rates decline steadily, to 0.82% (1970–1987), 0.69% (1988–1997), 0.65% (1998–2007), and just 0.4% for the newest stock (2008–2018). This downward trend may be related to the effectiveness of progressively stricter building codes, improved materials, and flood-



proofing practices implemented in recent decades. Quantifying how vulnerability diminishes with building age underscores the value of regulatory improvements and helps prioritize retrofit and insurance strategies by identifying the cohorts at greatest residual risk.

#### Average damage cost due to flood and building footprint area

Figure 14 presents the average flood-damage cost per building across eight building footprint intervals (0–100 m<sup>2</sup>, 101–200 m<sup>2</sup>, ..., 1001–10 000 m<sup>2</sup>).

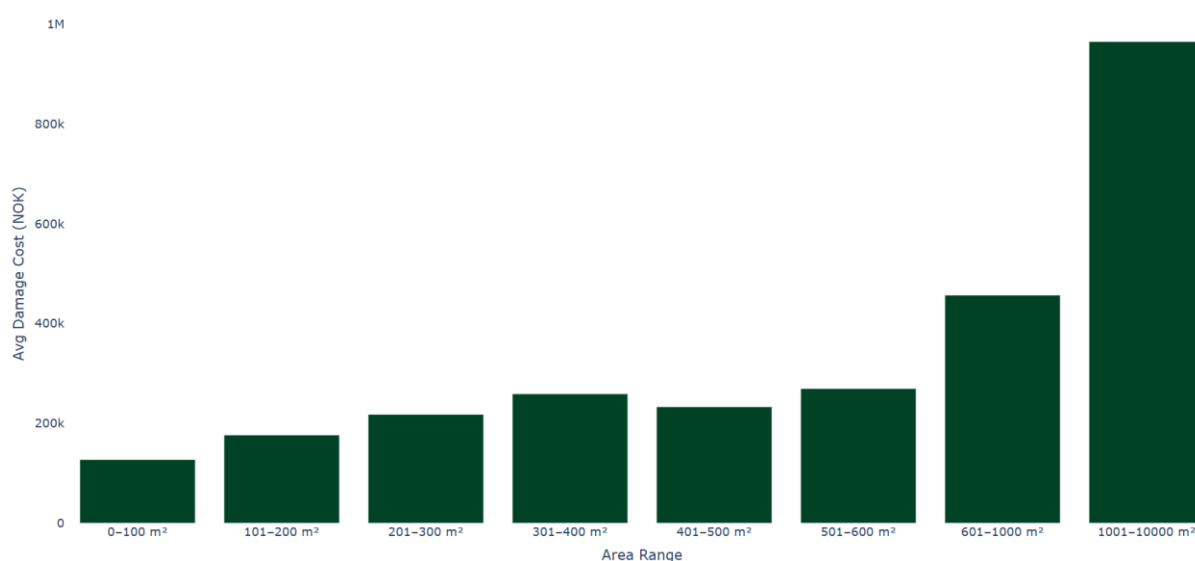


*Figure 14: Average damage cost due to flood per building footprint.*

The results show a clear, monotonic increase in average cost with building footprint. Small footprint areas under 100 m<sup>2</sup> average just over 120kNOK in repair expenses, while medium-sized footprint areas (301–400 m<sup>2</sup>) average approximately 250kNOK. Above 600 m<sup>2</sup>, mean costs accelerate sharply: buildings between 601 m<sup>2</sup> and 1000 m<sup>2</sup> average roughly 460kNOK, and the largest interval (1001–10 000 m<sup>2</sup>) approaches one million NOK per damage event. This strong positive relationship confirms that footprint-area is a critical driver of financial exposure in flood events. Incorporating area-dependent damage functions into vulnerability models can thus improve loss projections, refine insurance premium structures, and help decision-makers prioritize floodproofing investments in the most economically at-risk asset classes.

#### Median damage costs per average property price

Figure 15 illustrates the relationship between median flood-damage costs and average property prices, grouped into six market-value categories. Each flooded building is assigned to one of these categories based on the average market value per square meter in its postal-code area. For every price cohort, the midpoint of the postal-code price range



is used on the x-axis, while the median flood-damage cost per claim is plotted on the y-axis. The size of each bubble reflects the total number of recorded damage events within the corresponding cohort.

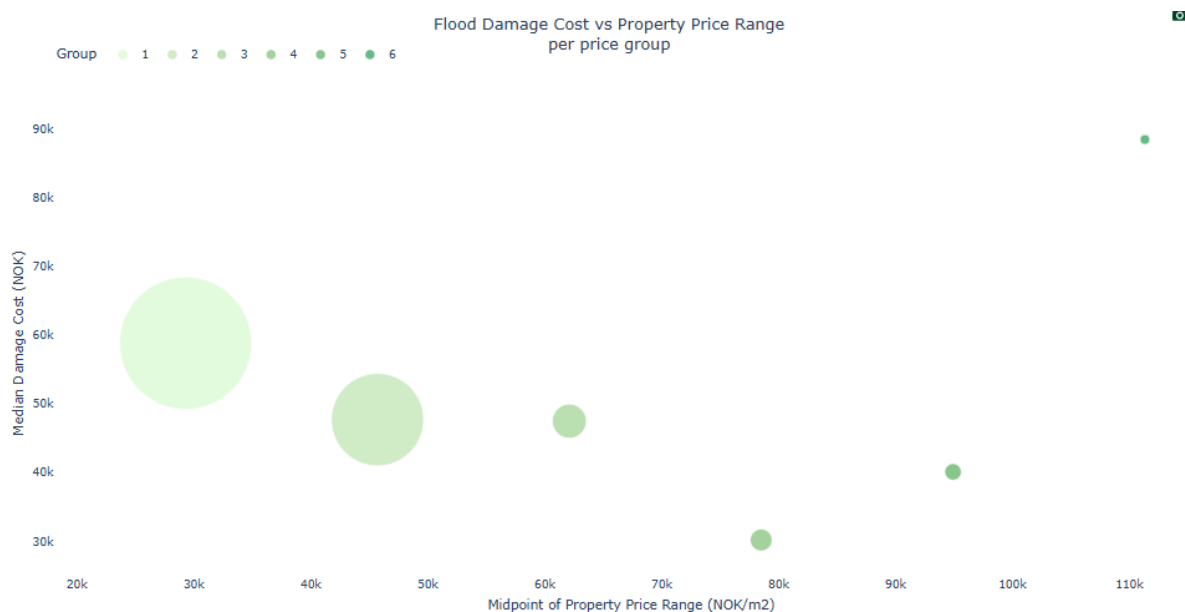


Figure 15: Median damage cost caused by natural hazards per average property price.

Rather than increasing monotonically, the relationship is U-shaped. The lowest-value cohort (Group 1, ~30kNOK) exhibits the highest claim count (largest bubble) and a relatively elevated median cost (~60kNOK), indicating that low-priced areas, where exposure patterns may differ, experience frequent and moderately severe losses. Median costs then decline through Groups 2–4, bottoming out at ~30kNOK in mid-range properties, before rising again in the top tiers: ~40kNOK in Group 5 and ~88kNOK in Group 6, despite much smaller claim volumes.

The median within each price cohort is used because damage-cost distributions are strongly right-skewed, a few very large losses would otherwise distort the mean and misrepresent the typical claim. Using postal-code averages for property price smooths local volatility, and captures neighborhood-scale clustering of market values and flood exposure.

#### Average damage costs and number of damages per building type

Figure 16 illustrates the relationship between building type, frequency of damages, and the corresponding average damage cost (NOK).

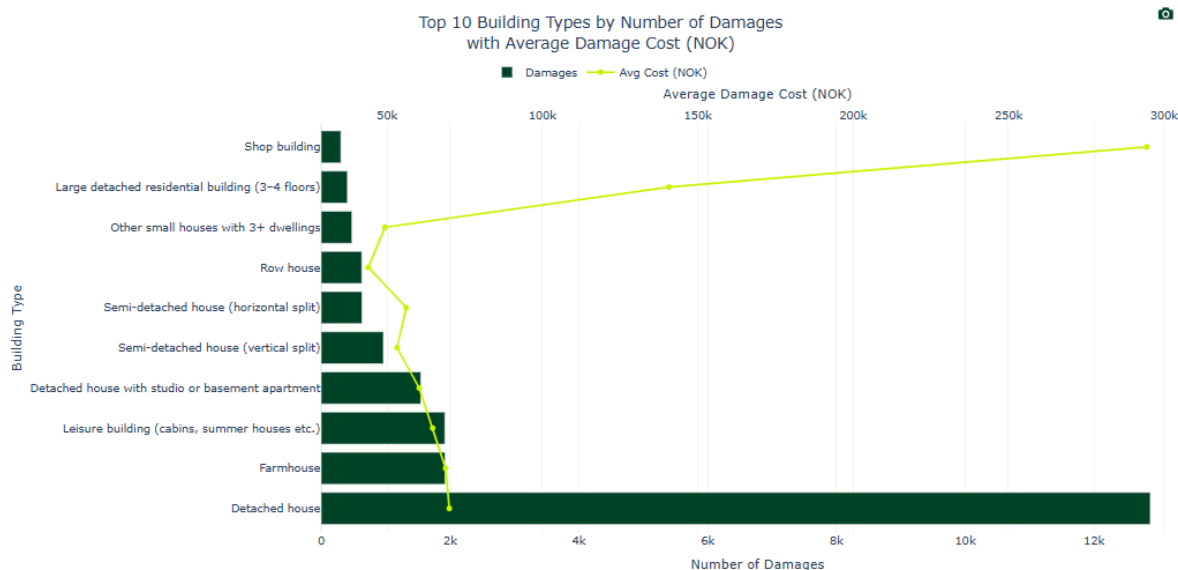


Figure 16: Top 10 building types by number of flood damages and corresponding average damage cost (NOK).

The ten most frequently affected building categories were ranked by the total number of reported losses, with a secondary axis displaying the mean loss per claim. Detached houses dominate in absolute count of damages. In contrast, multi-unit and shop buildings account for far fewer damage incidents but exhibit substantially higher average repair costs, reaching nearly 300kNOK per event. This inverse relationship between frequency and cost suggests that while common residential buildings experience more frequent minor events, less frequent damages in complex or multi-storey buildings tend to be more severe and expensive to repair.



## 5.2 Integrated flood risk management

### 5.2.1 Introduction

While historical insurance data provides a retrospective view of financial losses, effective municipal resilience requires predictive tools that model potential physical impacts before they occur. To address this, we developed a complementary Integrated Flood Risk Platform for the city of Valencia. This platform is designed to visualize and analyse the direct physical risks associated with a 20-year return period flood event, a high-probability scenario that poses significant challenges to urban management.

The platform delivers a spatially explicit assessment of flood risk by integrating high-resolution hydraulic hazard data with detailed exposure and vulnerability information. Risk is structured into two operational modules, reflecting distinct management objectives and datasets:

1. Surface water flood risk is categorised in four different risk types as following:
  - a. Runoff (Heavy rain can overwhelm soil absorption, leading to excess water pooling around the property and increasing flood chances. This water can damage the property and even affect the neighbours. The runoff risk is caused by larger area of roofs and paved surfaces in the property. The more roofs and paved areas, the higher the risk.)
  - b. Basement (The basement risk reflects how likely water gathering near the building can get inside through cracks and foundations. The closer water gathers to the property, the higher the risk.)
  - c. Obstruction (Obstruction risk arises when a construction unintentionally disrupts the natural paths of rainwater. This trapped water can then make its way into the building. The more disruption, the higher the risk.)
  - d. Inundation (Inundation means rising water levels could enter the building through ground-floor openings. The higher the water rises along the building, the higher the risk.)
2. Risk to People (Pedestrian Safety): Focusing on the safety and stability of citizens in public spaces.

The methodology for surface water flood risk is designed to address a key gap in flood risk management: the disconnect between hazard modelling, property-level vulnerability, and actionable prevention. By integrating these elements into a single, consistent framework, Mitigrate enables stakeholders to move from static risk classification to practical, decision-oriented risk reduction.



First, the methodology provides property-specific risk insight at scale. Traditional flood maps describe hazard at an area level, but do not account for how individual buildings interact with surface water through elevation, layout, soil conditions or surrounding land cover. By translating surface water dynamics into four distinct risk types at building level, the methodology captures the mechanisms of loss, not just exposure. This enables a more accurate differentiation between properties that may appear similar on conventional maps but face very different flood behaviours and impacts. Second, the methodology directly links risk assessment to prevention. Risk levels are not produced in isolation; they are explicitly designed to inform the selection, sizing and prioritisation of adaptation measures. This ensures that recommended actions are proportional to the level and type of risk, avoiding both under- and over-investment. As a result, the outputs are usable for loss prevention programmes, underwriting strategies and portfolio optimisation, rather than requiring additional interpretation or expert intervention.

### 5.2.2 Methodology

The risk assessment framework follows a spatial multi-criteria evaluation approach, integrating hydraulic hazard data with sector-specific vulnerability indicators.

#### Mitigate's risk + measures methodology

Mitigate's methodology translates surface water flood hazard into property-level flood risk and loss-reduction actions by combining hydrological modelling, high-resolution geospatial data and building-specific vulnerability proxies. Flood hazard is represented using climate-informed extreme precipitation indicators (e.g. RX1day) combined with surface flood modelling to derive spatially consistent flood depth estimates for defined return-period scenarios (typically 20-year). Surface flood depths are estimated using the Malstrøm flood model, which applies a one-dimensional (1D) surface drainage modelling approach to simulate overland flow generated by extreme precipitation events. For consistency and scalability across large areas, the flood model applies several simplifying assumptions:

- The total rainfall volume of the event is assumed to occur **simultaneously**
- The model simulates **surface flow only**, and **drainage/sewer systems are not represented**
- Hydrological losses such as infiltration or retention are not explicitly modelled
- Runoff generation is treated conservatively, effectively assuming near-total surface runoff

The approach is designed to ensure that each assessed property receives risk



classifications and mitigation recommendations that are specific, actionable and comparable across portfolios.

The methodology consists of three main stages:

1. Flood hazard modelling and geospatial analysis,
2. Calculation of property-level flood risk types and risk levels,
3. Identification, sizing, scoring and ranking of appropriate adaptation measures.

The methodology assesses four distinct surface water flood risk types, each representing a different physical mechanism of flood impact at the building scale (For explanation of the four different risk analysis read the introduction above). Surface water flood hazard is derived using a combination of Digital Elevation Models (DEM), precipitation data and rainfall scenarios, high-resolution land-cover data, soil and infiltration capacity datasets.

Risk levels are determined through a multi-parameter evaluation, not by water depth alone. The calculation considers water depth, elevation difference between water and building, distance to accumulation points, proximity to natural flow paths.

### Solution selection

Measures are screened for applicability on a property-by-property basis using geospatial suitability criteria reflecting available space, soil type, land cover, building footprint and characteristics.

Each suitability criterion is analysed spatially to ensure that only physically and contextually feasible measures are proposed for a given property. Once applicable measures are identified:

- NBS measures are sized based on their capacity to store or convey water,
- Property Flood Resilience (PFR) measures are sized based on building dimensions, characteristics and expected flood depth.

Costs are calculated from the estimated size of each measure and adjusted to local conditions using construction cost indices, inflation rates and purchasing-power parity factors.



### Pedestrian safety

The assessment of risk to the population focuses specifically on pedestrian stability: the ability of individuals to move safely through floodwaters without losing balance or suffering injury. The methodology is adapted from the framework proposed by Martínez-Gomariz et al. (2019) at RESCCUE and BINGO research projects, tailored to the specific data availability constraints of the Valencia region.

### Hazard characterization

The primary hazard input is a raster map of the Valencia area with a 1-meter resolution, representing the maximum water depth for a 20-year return period flood. While standard stability criteria often rely on the product of depth and velocity ( $D \cdot v$ ), this model utilizes depth-only stability thresholds. These thresholds define critical depths where pedestrian stability is compromised regardless of flow velocity, and are therefore used as conservative proxies, ensuring that potentially hazardous conditions are not underestimated.

Depth thresholds are derived by adapting the stability limits illustrated in Figure 3 of Martínez-Gomariz et al. (2019), excluding the velocity dimension. Based on this adaptation, flood hazard for pedestrians is classified as follows:

- **High Hazard (> 0.15 m):** Depths exceeding 15 cm are classified as High Hazard, as they pose a critical risk to vulnerable groups (children and the elderly) even under static or low-velocity conditions.

For lower water depths, hazard assessment becomes more uncertain, as pedestrian stability depends strongly on flow velocity. However, since the medium hazard range is conventionally defined between 0.09 and 0.15 m, this depth interval is conservatively classified as Moderate Hazard regardless of velocity. Water depths below 0.09 m are therefore classified as Low Hazard.

- **Moderate Hazard (0.09–0.15 m):** This intermediate range is classified as Moderate. In Martínez-Gomariz et al. (2019), risk in this zone is velocity-dependent; in the absence of velocity data, it is treated as a transitional zone of potential instability.
- **Low Hazard (< 0.09 m):** At depths below 9 cm, stability is maintained for the vast majority of pedestrians.

### Vulnerability assessment

Social vulnerability is modelled at the Census Tract (*Sección Censal*) level to capture localized demographic characteristics while maintaining consistency with publicly



available socioeconomic data. All indicators are derived from the Spanish National Statistics Institute (INE).

The vulnerability index aggregates three demographic indicators that influence susceptibility to flood-related harm:

1. **Critical age groups:**

This indicator represents the percentage of population belonging to age groups associated with reduced physical stability or mobility.

Defined as the percentage of the population aged **> 65 years** and **< 16 years**.

*Note: The upper bound for children was adjusted from 15 to 16 to align with available census cohorts.*

The thresholds used are taken from Martínez-Gomariz et al. (2019) :

- Low risk: **< 10 %**
- Moderate risk: **∈ (10,33) %**
- High risk: **> 33 %**

2. **Foreign Population:**

This indicator is used as a proxy for potential language barriers, reduced access to risk communication, and lower familiarity with local flood behaviour and emergency protocols.

Defined as the percentage of foreigners in proportion to total population.

The thresholds used are the same as in Martínez-Gomariz et al. (2019):

- Low risk: **< 10%**
- Moderate risk: **∈ (10,25) %**
- High risk: **> 25 %**

3. **Population Density:**

Population density (inhabitants per hectare) reflects the scale of potential human exposure within each census tract, amplifying the consequences of hazardous conditions.

The thresholds used are adapted from Martínez-Gomariz et al. (2019). The lower threshold is adopted directly from the Badalona case study (3.84 inhabitants per hectare), while the upper threshold is defined using the mean population density of the study area, which in this case is 57.41 inhabitants per hectare.:

- Low risk: **< 3.84%**
- Moderate risk: **∈ (3,84,57.41) %**
- High risk: **> 57.41 %**

Vulnerable infrastructures (e.g. hospitals, schools, critical facilities) are not included in



the social vulnerability index, as these belong to the infrastructure risk assessment module.

The final social vulnerability level for each census tract is defined as the arithmetic mean of the four indicators described above, all of which are assigned equal weight. The resulting average score is then classified into three vulnerability levels: Low vulnerability for mean values less than or equal to 1.5, High vulnerability for mean values greater than 2.0, and Moderate vulnerability for intermediate values.

### Overall risk

The resulting hazard and vulnerability classifications are then combined using the same risk matrix proposed by Martínez-Gomariz et al. (2019), Fig. 5.

### 5.2.3 Web Application

The Integrated Flood Risk Platform is implemented as a web-based geospatial application representing the entire municipal area of the city of Valencia. It offers an intuitive, web-based interface that makes flooding assessment accessible to everyone: from practitioners and decision-makers to individuals interested in understanding their environment. Users can obtain results for the greater area of Valencia, powered by the latest available regional or local data. Thanks to the interoperability of the ARIES system, models are automatically updated when new datasets or improved methodologies become available, ensuring that results remain accurate, consistent, and up to date for every area assessed.

#### Accessing the web application

The application is accessible at the following [link](#)<sup>7</sup>. To access the system, interested users must follow these steps:

1. Register at the Integrated Modelling Hub.

Users have to access <https://integratedmodelling.org/hub/#/register> choose a username and provide an email address to create a profile. Then check the inbox for a validation email. There will be a link to activate the new profile. Finally, a new password must be set to secure the account.

2. Request to join the SOTERIA group.

This application is only visible for users that have requested it. To do so, users need to go to their “PROFILE” page, then the “GROUPS” tab and scroll down until they can

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<sup>7</sup> <http://soteria.integratedmodelling.org/modeler/?app=aries.valencia.en>



click on the “GROUP REQUEST” button. By clicking on it and selecting “SOTERIA”, a request will be sent to our team that will review it and give permission. This is to ensure only selected users can access the application for the time being

3. Access the application.

Can be done directly from the above link.

### Navigating the application

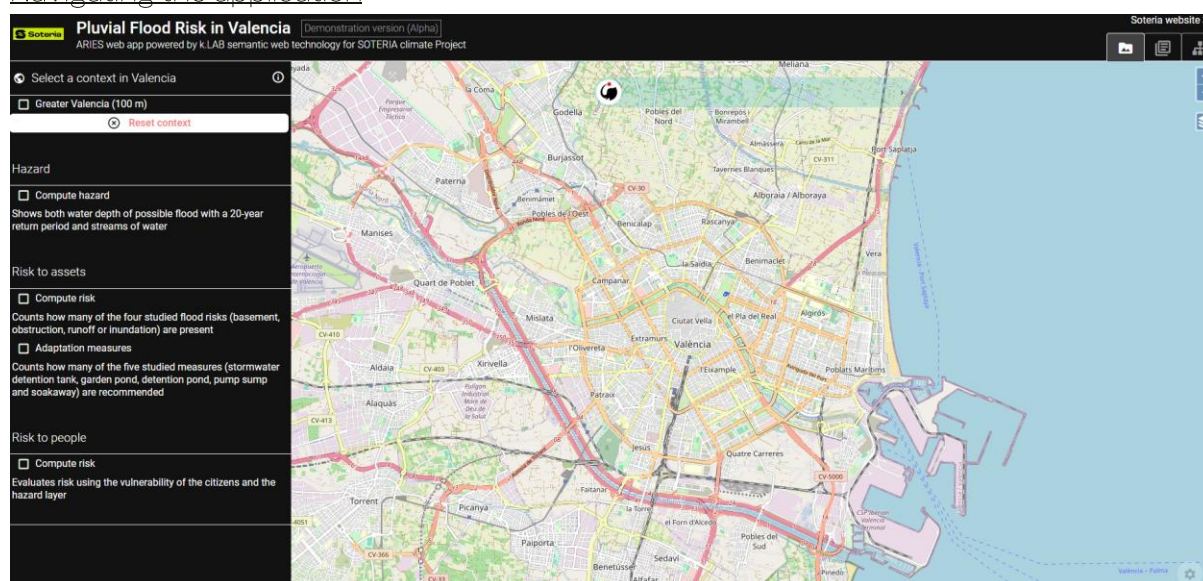


*Figure 17: The first look of the application*

Upon entering the application, users are presented with an intuitive interface, illustrated in Figure 17. The layout is structured around three main components: a side panel on the left (highlighted in green in Figure 17), where users can define the analysis context and select observations; the central map interface (outlined in yellow), where results are computed, visualized, and made available for download; and a dedicated documentation and dataflow tab (shown in blue), which provides transparency on data sources and modelling steps.

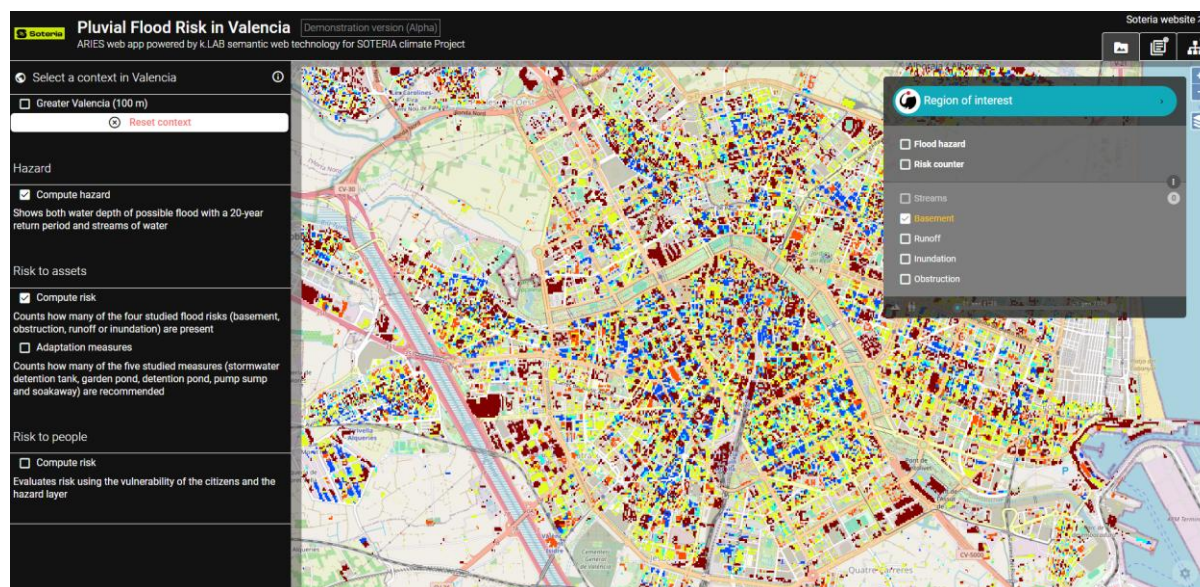


Figure 18: Layers in the app with the download button highlighted in yellow

Within the map interface, computed results are displayed as spatial layers and can be downloaded via the downward arrow icon (Figure 18). Users can retrieve the value associated with each Basic Spatial Unit (BSU) by clicking directly on the corresponding feature in the map, while the map legend can be accessed by selecting the name of the active observation (Figure 19).

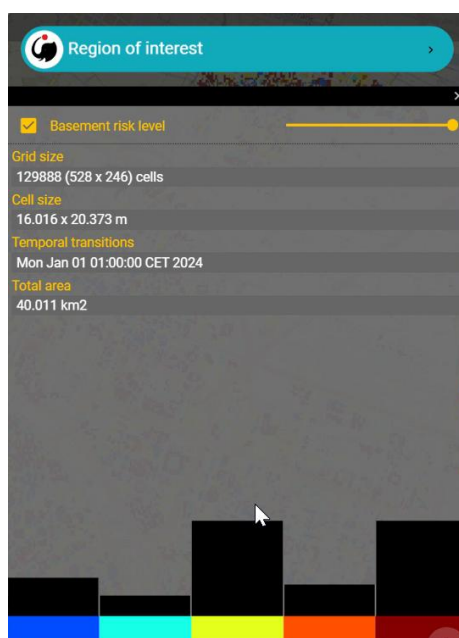


Figure 19: Legend of basement risk level, opened by clicking on the layer's name



### Context selection

Upon accessing the application, users can define the spatial context for analysis in the following ways:

- Greater Valencia: By clicking on the button, users can select “Greater Valencia”, which corresponds to the full municipal extent of Valencia.
- Custom area: After deselecting the default context, users may also define a custom area of interest by navigating, panning, or zooming within the map interface to focus on a specific neighborhood or sub-area. The entire area visible on the screen becomes the analysis context.

All subsequent analyses are dynamically constrained to the currently selected spatial context.

### Hazard layer

Users can activate the hazard layer, which displays the flood extent and maximum water depth associated with the 20-year return period event (in meters). An accompanying layer is presented as well: the routes of the water in that same scenario (the “streams” layer). These layers provide the foundational hydraulic information used by both the infrastructure and population risk modules.

### Infrastructure risk

When the “Compute risk” function is selected for infrastructure, the application calculates and visualizes a cumulative indicator representing the number of flood-related risks affecting each building. This is derived from the four distinct risk layers mentioned in the methodology:

- Risk of runoff
- Risk to basements
- Risk of obstruction
- Risk of inundation

Each layer represents a specific impact mechanism affecting buildings and urban infrastructure.

If the user selects the “Adaptation measures” option, the application computes and displays spatial layers indicating the applicability of selected flood mitigation measures. In the current implementation, and based on inputs provided by Mitigrate, the following measures are included:



- Applicability of soakaways
- Applicability of detention tanks
- Applicability of garden ponds
- Applicability of pump sumps

These layers are also aggregated to assess how many adaptation options are applicable to each building, supporting the identification of locations with greater potential for targeted risk reduction interventions.

#### Population risk

For the assessment of risk to people, the user can activate the “Compute risk” function, which triggers a multi-step modelling workflow. This workflow integrates several intermediate layers, including hazard classification, social vulnerability indicators, and exposure metrics.

All intermediate outputs generated during the model execution are visualized within the application interface, and individually accessible and downloadable by the user, ensuring transparency and reproducibility of the assessment.

#### Features of the application

The Integrated Flood Risk Platform is designed around a modular, model-driven dataflow that prioritizes transparency, reproducibility, and interoperability. For each user request, the system dynamically assembles a modelling workflow (Figure 20) based on the selected spatial context, the chosen risk module, and the requested outputs. Rather than relying on a single precomputed model, the platform orchestrates a sequence of interconnected models that progressively transform input data into intermediate and final risk indicators. These transformations include hazard reclassification, vulnerability scoring, spatial aggregation, and rule-based risk combination. All intermediate layers generated during model execution are explicitly produced, preserved, and made accessible within the application, allowing users to inspect and download them individually. This approach ensures full traceability of results and avoids black-box interpretations of flood risk.

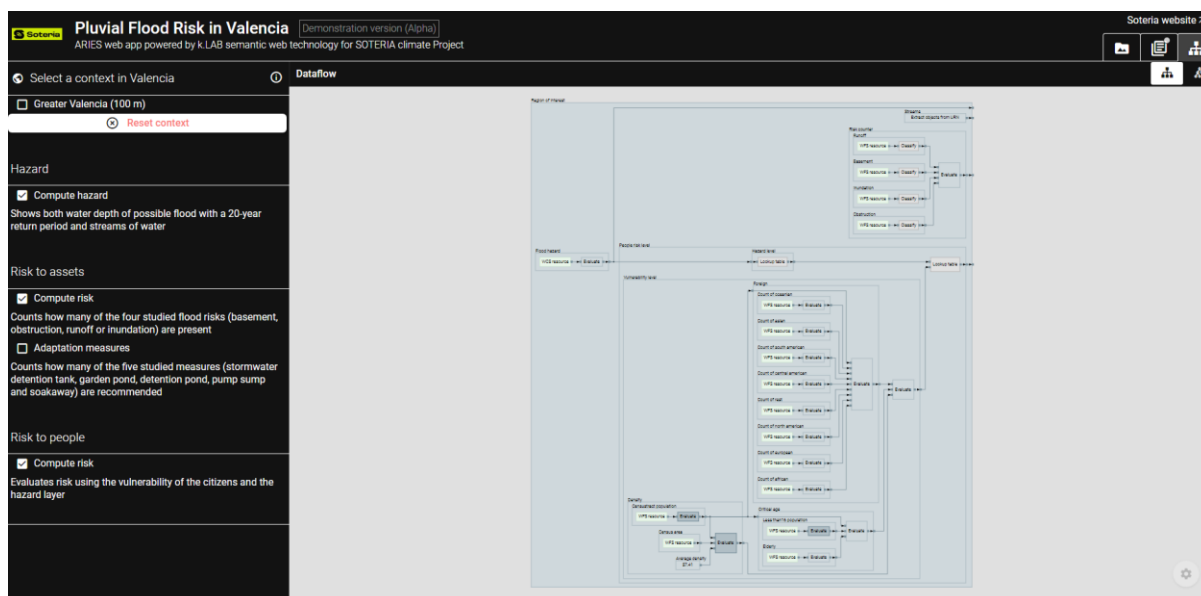


Figure 20: Dataflow tab

Each model within the platform is associated with structured, human-written documentation describing its conceptual basis, inputs and outputs, assumptions, and limitations. During execution, a Machine Reasoning component records which models and datasets are used, how they are parameterized, and how their outputs are combined. At the end of each analysis, this information is automatically compiled into a single downloadable report (Figure 21) that accompanies the spatial results and provides a transparent narrative of the dataflow and modelling logic. This documentation framework supports the FAIR (Findable, Accessible, Interoperable and Reusable) principles by ensuring that data and models are findable through explicit metadata, accessible via downloadable layers and reports, interoperable through standardized spatial formats, and reusable through clearly documented assumptions and workflows. Together, these design choices enable the platform to function not only as a visualization tool, but as a robust and interpretable decision-support system for integrated flood risk management.

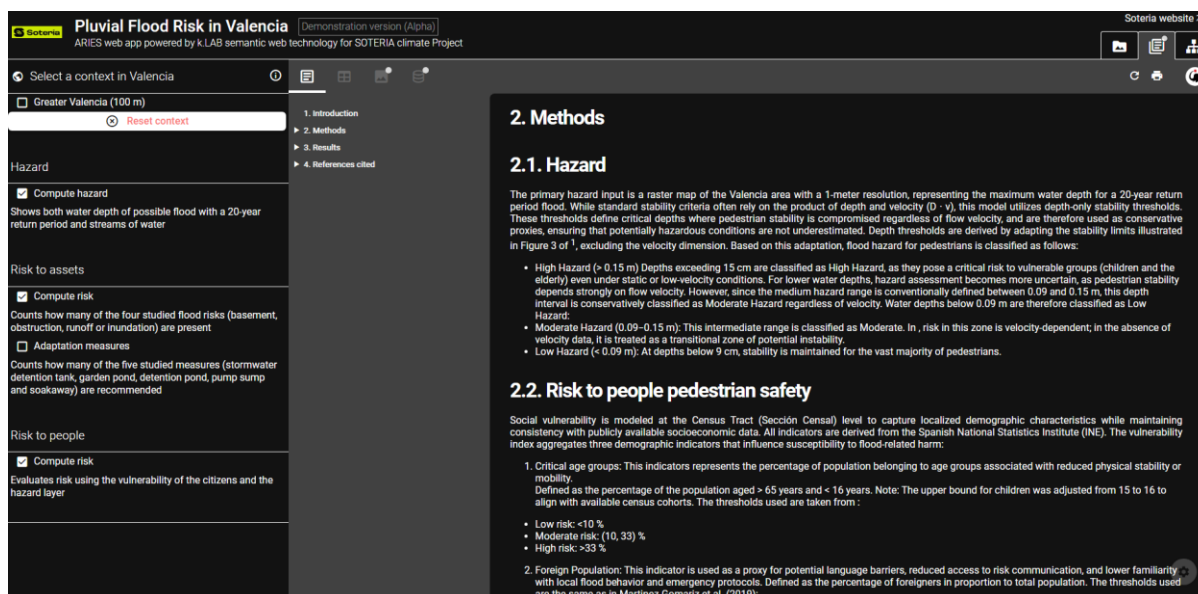


Figure 21: Documentation tab

A presentation of all the previous steps with videos to make matters cleaner can be downloaded in [here](#). The repository with the code can be found [here](#).

## 5.2.4 Results

Figure 22a illustrates the spatial distribution of the Pedestrian Risk Index. A clear center-periphery gradient is observable, with the dense urban core exhibiting significantly higher risk levels compared to the surrounding suburban belts. This pattern is largely attributable to population density, a heavily weighted factor in the vulnerability model, which amplifies the exposed population in the central districts (e.g., L'Eixample, Ciutat Vella).

However, the specific 'hotspots' of critical risk (shown in dark red) do not strictly follow density alone; they show a strong spatial correlation with the high-intensity flood zones depicted in the Hazard Map (Figure 22b). This indicates a compounding effect: while high social vulnerability exists throughout the city center, critical risk emerges specifically where this vulnerability intersects with hydraulic extremes.

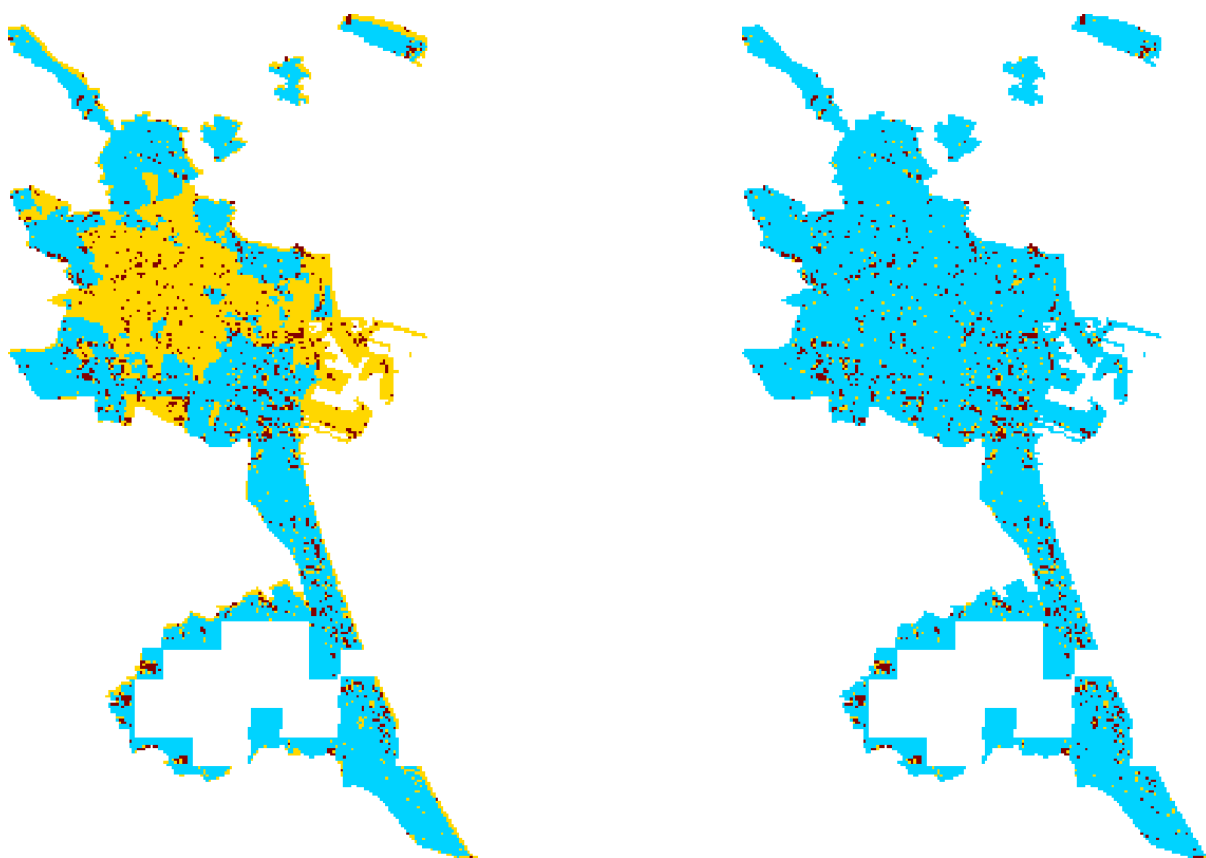


*Figure 22: a) Pedestrian risk level (left) and b) hazard level (right) for the study area. Blue represents Low, yellow Moderate and red High*

Figure 23 illustrates properties classified as having high or very high risk of inundation and surface runoff. As discussed in the previous sections, inundation risk is primarily controlled by local topography, particularly surface depressions and the relative elevation difference between properties and surrounding water accumulation zones. Properties located in low-lying areas or near natural or artificial depressions are therefore more susceptible to inundation during intense rainfall events.

In contrast, runoff risk is mainly influenced by the proportion of impermeable surfaces within each property and the characteristics of the surrounding ground, including soil type and infiltration capacity. Areas with a high coverage of sealed surfaces, such as buildings, roads, and paved spaces, tend to generate greater surface runoff due to reduced infiltration.

As evident from the figures, the central parts of Valencia city, characterised by a higher density of buildings and urban infrastructure, exhibit a greater runoff risk compared to inundation risk. This pattern reflects the dominance of impermeable surfaces in these areas, which significantly increases surface runoff generation while limiting water infiltration. Conversely, inundation risk is comparatively lower in these central zones, indicating that topographic depressions and elevation-driven water



accumulation play a less dominant role there than surface sealing.

Overall, the spatial distribution of risks highlights the strong influence of urbanisation patterns on runoff processes, while inundation risk remains more closely linked to local topographic conditions.

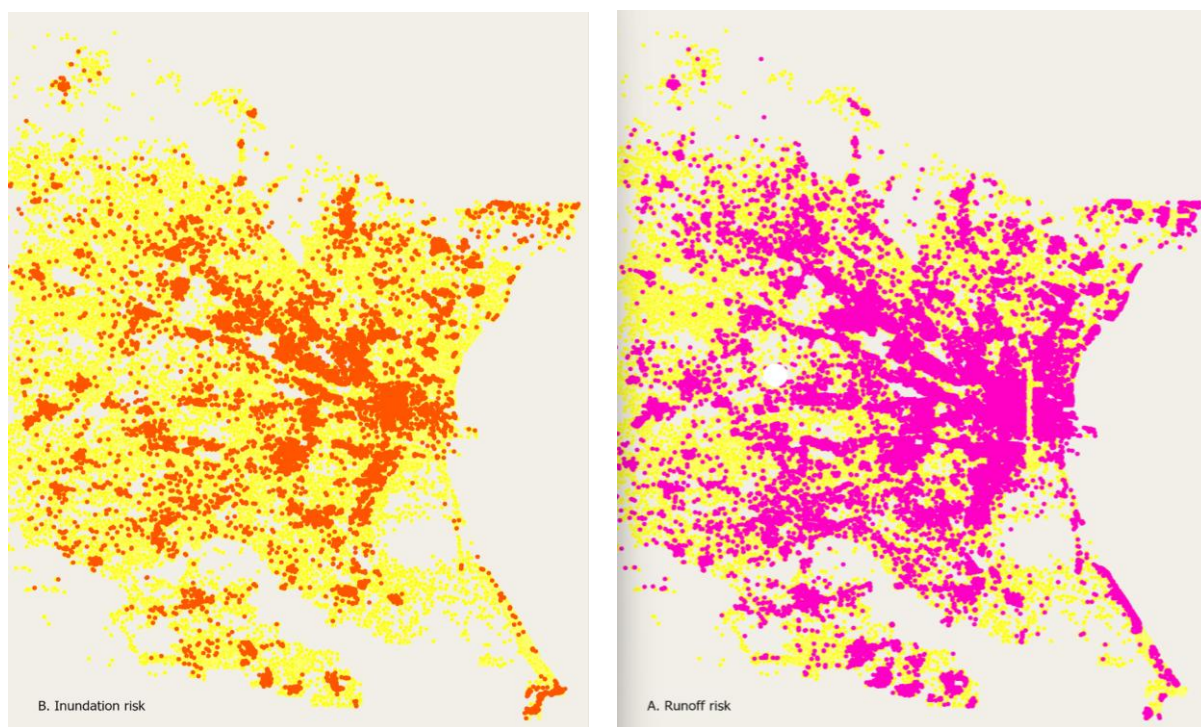


*Figure 23: Properties with high or very high inundation and runoff risk.*



## 6. Conclusion

### 6.1 Data availability, user needs and systemic gaps

Across the SOTERIA pilot regions, stakeholders actively use climate risk data to support policy development, risk assessment, spatial planning, and disaster response. The most commonly used sources are public datasets, including meteorological observations, hazard maps, and basic exposure information. However, the analysis clearly shows that existing data ecosystems remain fragmented and insufficient to support comprehensive, forward-looking climate risk management.

Significant gaps persist in high-resolution local data, future climate projections, and, in particular, detailed loss and insurance data. While such data are widely recognised as highly valuable for understanding real-world impacts and prioritising interventions, they remain difficult to access due to legal, institutional, and technical barriers. In addition, stakeholders consistently reported challenges related to poor interoperability, inconsistent formats, and variable data quality, which limit their ability to integrate datasets and conduct robust multi-hazard assessments.

Overall, the findings confirm strong interest in improved and more centralised data platforms that facilitate access, harmonisation, and visualisation of climate risk and loss information. They also highlight the need for better integration of geographic, climatic, exposure, and vulnerability data, as well as more detailed, event-based hazard and loss records, particularly for pluvial floods, heatwaves, and wind events.

### 6.2 Key Insights from the Prototypes

#### 6.2.1 Visualising historical loss data related to Natural Hazards

The software prototype developed in this study demonstrates how climate-related economic loss data can be operationalized to support climate adaptation planning, insurance modelling, and disaster risk management. By integrating harmonized loss datasets into a functional, user-oriented interface connected to back-end analytical tools, the prototype illustrates the practical value of accessible, high-quality data for understanding hazard impacts at multiple spatial and temporal scales.

Stakeholder feedback highlighted the system's strengths, particularly its ability to visualize losses, filter by hazard type and location, and provide address-level insights that are directly relevant for municipal planning and infrastructure prioritization. The prototype also showed strong performance in querying and exploring complex



datasets in real time, demonstrating that when data are sufficiently structured and quality-controlled, detailed loss analyses can offer meaningful support for resilience-building efforts.

At the same time, the implementation process exposed several limitations that must be addressed before such a system can be applied operationally. The available dataset (2013–2018) is limited in both scope and timeliness, reducing its relevance for assessing current climate-related challenges. Data inconsistencies, such as incorrect geocoding, incomplete cause codes, and heterogeneous address formats, required substantial preprocessing, echoing findings from recent European assessments that emphasize the need for improved reporting standards and clearer institutional responsibilities (European Commission. Joint Research Centre. 2025). Privacy requirements also necessitated aggregation and anonymization measures that can diminish spatial precision, highlighting a continued need for robust privacy-preserving techniques that safeguard confidentiality without compromising analytical value.

Despite these challenges, the prototype demonstrates the feasibility and value of harmonized loss data from multiple sources, showing how clear spatial and temporal patterns emerge when data quality and analytical workflows are well managed. Looking ahead, progress could include integrating hazard event catalogues and meteorological layers and improving data quality through standardized reporting and validated geocoding. Overall, the prototype illustrates how high-quality, interoperable loss data, paired with effective analytical tools, can strengthen Europe's capacity for evidence-based adaptation and disaster risk reduction.

### ***6.2.2 Urban flood risk and mitigation measures***

The platform developed for Valencia can be used to enhance urban resilience. By synthesizing high-resolution hydraulic models with sociodemographic and infrastructure data, the platform bridges the critical gap between abstract hazard maps and actionable, property-level adaptation strategies. It illustrates the practical value of a modelling approach where transparent workflows allow stakeholders to understand the specific drivers of risk, whether they are physical mechanisms (e.g., runoff, basement seepage) or social vulnerabilities (e.g., aging populations in high-density zones).

The system's primary strength lies in its ability to disentangle complex risk factors into operational insights. For infrastructure, the differentiation into specific risk types moves beyond simple "flood extents" to inform targeted engineering solutions like Nature-Based Solutions (NBS). For pedestrian safety, the platform successfully identifies high-risk "trap zones" by overlaying depth thresholds with vulnerable



demographic clusters. The modular architecture, supported by the Integrated Modelling Hub, proves that complex, multi-criteria evaluations can be delivered through an accessible web interface without sacrificing scientific rigor, ensuring that results are traceable and reproducible via the FAIR principles.

At the same time, the implementation highlights challenges inherent in high-resolution risk modelling. The assessment of pedestrian stability was constrained by the absence of flow velocity data, necessitating the use of conservative "depth-only" thresholds (0.15m) to ensure safety margins for vulnerable groups. Furthermore, while hazard data is available at 1-meter resolution, social vulnerability metrics rely on Census Tract aggregation to respect privacy standards. This resolution mismatch requires careful interpretation at the street level, emphasizing the continued need for richer hydraulic datasets and more granular, anonymized demographic records to fully capture micro-scale risk dynamics.

Despite these constraints, the platform validates the feasibility of an interoperable, model-driven approach to urban flood management. Looking ahead, the platform's integration with the ARIES ecosystem ensures adaptability; as new velocity data or updated census figures become available, models can be automatically updated.



## 7. References

- European Commission. Directorate General for European Civil Protection and Humanitarian Aid Operations (ECHO). and ICF. 2024. *Interim Evaluation of the Implementation of Decision No 1313/2013/EU on a Union Civil Protection Mechanism, 2017-2022*. Publications Office. <https://data.europa.eu/doi/10.2795/389073>.
- European Commission. Joint Research Centre. 2025. *Disaster Loss Data Management: Current Practices, Challenges, and Opportunities in Europe: Survey Results & Recommendations*. Publications Office. <https://data.europa.eu/doi/10.2760/8144782>.
- Martínez-Gomariz, Eduardo, Luca Locatelli, María Guerrero, Beniamino Russo, and Montse Martínez. 2019. 'Socio-Economic Potential Impacts Due to Urban Pluvial Floods in Badalona (Spain) in a Context of Climate Change'. *Water* 11 (12): 2658. <https://doi.org/10.3390/w11122658>.



## Attachments

### Questionnaires sent to the three pilot regions (Valencia, Gabrovo and West Athens) on use cases.

#### Questionnaire 1 - June 2024

| Job title :                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Main functions : | Organization |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------|
| <p><b>1. Understanding current climate-related risk data applications</b></p> <p><i>This section focuses on how you currently use climate-related risk and loss data in your work. We aim to understand the types of data you rely on, the specific purposes for which you use it, and any barriers you face in accessing, analyzing, or utilizing it. The insights gathered here will help us tailor the data hub to meet the real-world needs of stakeholders at various levels.</i></p> <p><i>Current use of climate-related risk data</i></p> <ol style="list-style-type: none"><li>1. What types of climate-related risk and loss data do you currently use in your work? (e.g., hazard data, vulnerability assessments, loss data, etc.)</li><li>2. For what purposes do you use this data? (e.g., policy-making, risk assessment, disaster response, urban planning, etc.)</li><li>3. How often do you use climate risk-related data ? (e.g., daily, weekly, monthly, etc.)</li><li>4. At what geographic or administrative level do you primarily work? (e.g., asset-level, municipal, regional, national, or global)</li><li>5. Are there specific geographic areas where you require more detailed climate-related data? If yes, please specify the regions or locations.</li><li>6. What type of data is most needed for these geographic areas? (e.g., hazard data, vulnerability assessments, loss data, etc.)</li><li>7. Are there specific time periods for which you need more detailed climate-related data? If yes, please indicate the time periods and the types of data needed.</li><li>8. Do you rely on climate-related risk and loss data that is sector-specific? (e.g., health, agriculture, infrastructure)</li></ol> <p><i>Data accessibility and sources</i></p> <ol style="list-style-type: none"><li>9. Where do you typically source your climate-related risk and loss data from? (e.g., national databases, regional hubs, international organizations, academic institutions)</li></ol> |                  |              |



10. Do you use any specific platforms to visualize, analyze, or download climate-related risk and loss data? If yes, which platforms do you use?
11. What challenges or barriers do you face when accessing, interpreting, or using this data?
  - Data formats: Are there any issues related to the formats in which data is provided? (e.g., compatibility issues, unreadable formats)
  - Technical limitations: Are there technical issues, such as software compatibility or data interoperability, that hinder your access or use of the data?
  - Licensing and regulatory restrictions: Do you face challenges due to licensing agreements or regulatory constraints?
  - Policy Constraints: How do existing policies affect your ability to utilize this data?
  - Trust and Perception: Are there any subjective barriers, such as concerns about the reliability of the data or its sources?

#### *Data gaps and needs*

12. What types of climate-related data do you find missing and/or insufficient for your work?
13. Are there specific indicators or datasets that would enhance your risk and loss assessments?
14. Are there specific hazards or climate events for which loss data is particularly lacking?

#### 2. Establishing a regional data hub

*The development of a Regional data hub relies on collaboration between different institutions and stakeholders. This section seeks to identify the key players necessary for establishing the hub, the types of data they can contribute, and the potential challenges or strategies for building a shared data environment. Your input will help shape the structure and governance of the hub to ensure it is inclusive and efficient.*

1. Do you currently collaborate with other institutions or departments to obtain relevant climate-related data? If yes, please specify which institutions and the nature of your collaboration.
2. In your opinion, which institutions or actors would be essential for developing a regional data hub? Consider those with the mandate, resources, or data that is crucial for the hub.
3. Why do you believe these actors are key? Are they responsible for setting up, running, or funding the hub? Do they have access to the necessary data for the region and municipalities?
4. How do you suggest we start a climate resilience dialogue among these key stakeholders? What approaches would facilitate effective discussions about establishing a regional data hub? (e.g., workshops, working groups, roundtable)



*discussions, etc.)*

5. Should the data hub be regional or national in scope? What are the advantages of following the model used in Norway to create a national data hub?

### 3. Development of the software for the data hub

*The successful implementation of a regional data hub also depends on the development of user-friendly software that allows stakeholders to access, analyze, and visualize climate-related risk and loss data effectively. This section seeks to gather insights on the functionalities and features that would enhance the usability of such a platform.*

- Data integration and usability
  1. How important is it to have a single platform where all relevant climate-related risk data (including risk and loss data) is available? *(Consider examples like the Norwegian platform (Knowledge Bank) that shares public risk and loss data with local authorities.)*
  2. What functionalities would make such a platform more useful for you? *(e.g., custom reports, data visualization tools, scenario modeling, etc.)*
  3. How do you prefer to export or visualize data? *(e.g., dashboards, raw data exports, GIS maps)*
  4. Would you prefer a platform that allows integration with other tools or systems you already use? *(e.g., geographic information systems, risk management software)*
  5. Who/which institutions should run this platform?
- Interface functionalities propositions
  6. Do you think it would be useful to have software that displays aggregated loss data per hazard type? If yes, which types of hazards would be most useful to include?
  7. What type of visualizations would be most helpful for exploring risk and loss data? *(e.g., interactive maps, bar charts for comparisons, time series, etc.)*
  8. Would you find it helpful to download filtered data in formats like CSV or Excel?
  9. Do you think it would be useful to have a platform that provides quick access to public datasets relevant to climate-risk assessment organized by hazard type? *(e.g. table or cards with quick access links) ?*
- Existing solutions
  10. Are there any examples of best practices from other platforms, regions, or countries that should be considered in the development of this software?
  11. What examples of successful climate-related data platforms or tools do you know of that could inform the development of this prototype?
  12. Are there features or approaches from these tools that should be integrated into the prototype?



#### 4. *Additional Suggestions*

Do you have any additional suggestions, comments, or specific needs related to the use of climate-related risk and loss data that you'd like to share?



## Questionnaire 2 - October 2024

### Questionnaire:

#### Identifying needs for climate-related risk and loss data

##### Purpose:

As part of the European Horizon project SOTERIA, this questionnaire aims to gather insights from public authorities and key stakeholders regarding the collection, access, and use of climate-related risk and loss data.

This questionnaire explores your existing use of climate-related data, the gaps or challenges you face, and the functionalities you require in a user-friendly software platform for accessing and analyzing this data.

##### Context

Loss data is crucial for identifying areas vulnerable to and exposed to climate risks, enabling the planning and implementation of adaptation measures. For instance, Norway's Knowledge Bank has allowed municipalities to pinpoint highly vulnerable areas, supporting informed decisions on adaptation strategies. By understanding the costs of damages, countries can prioritize investments in risk reduction measures and risk transfer mechanisms, contributing to building climate resilience.

There are various types of risk and damage data (see annexes), some of which come from insurers who record and analyze damages. **This information is not only vital for local decision-making but also supports international frameworks** such as the Paris Agreement and the Sendai Framework for Disaster Risk Reduction. The OECD highlights the importance of public-private collaboration in collecting and making available data on assets, vulnerabilities, and past losses. Consistent post-disaster loss assessments and the harmonization of data at national, regional, and international levels are essential for effectively managing disaster risks.

##### Questions



| Job title :                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Main functions : | Organization |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------|
| <p><b>1. Current use of climate-related risk data</b></p> <p><i>This section focuses on how you currently use climate-related risk and loss data in your work. We aim to understand the types of data you rely on, the specific purposes for which you use it, and any barriers you face in accessing, analyzing, or utilizing it. The insights gathered here will help us tailor the data hub to meet the real-world needs of stakeholders at various levels.</i></p> <p>1. Do you work with climate risk and loss data?</p> <ul style="list-style-type: none"><li>• Yes</li><li>• No (If you select "No", it is not necessary to continue with the questionnaire.)</li></ul> <p>2. What types of climate-related risk and loss data do you currently use in your work?(e.g., flood data, storms, economic damages, etc.)</p> <p>3. What is the purpose of using this data? (e.g., policy formulation, risk assessment, disaster response, urban planning, etc.)</p> <p>4. How often do you use climate risk-related data?</p> <ul style="list-style-type: none"><li>• Daily</li><li>• Weekly</li><li>• Monthly</li><li>• Occasionally</li></ul> <p>5. At what administrative level do you primarily focus on?</p> <ul style="list-style-type: none"><li>• Asset level (infrastructure or properties)</li><li>• Municipal</li><li>• Regional</li><li>• National</li><li>• Global</li></ul> |                  |              |



6. What types of areas do you primarily work in?

- Coastal areas
- Urban areas
- Rural or agricultural areas
- Mountainous areas
- Forest areas
- Other: specify

7. What data sources and platforms do you use to access and visualize climate risk and loss information?

## 2. Data Needs

*This section focuses on identifying barriers and the need for additional data, as well as understanding what would be useful to meet legal objectives.*

8. What challenges or barriers do you face when accessing, interpreting, or using this data?

- Formatting issues (e.g., compatibility problems, unreadable formats)
- Technical limitations (e.g., software compatibility)
- Licensing and regulatory restrictions
- Political restrictions: How do existing policies influence the ability to use these data?
- Trust and perception: Are there subjective barriers, such as concerns about data reliability or sources?
- Other. (please specify)

9. Would you need additional data to comply with your legal obligations?

- Yes
- No (If you select "No", you can proceed to the next section.)

10. Are there specific data you need for particular geographic areas (e.g., certain municipalities or regions)? If so, what type of data is needed, and for which areas?

11. Do you need more detailed data (e.g., at a finer geographic scale, such as community, neighborhood, or asset level)? If so, what type of data and what



level of detail is required?

12. Do you need projected data, such as long-term climate scenarios? If so, what specific data do you need and what time scale is required?

13. Do you find the data from insurers useful on the following aspects?

- Cause of damage (e.g., type of hazard like storm, earthquake)
- Natural damage (e.g., river floods, landslides)
- Water-related damage (e.g., flash floods, sewage backups)
- Economic losses (e.g., compensation paid to policyholders)
- Business impacts (e.g., indirect economic costs due to interruptions)
- Date, time, and location of the damage

### 3. Need for a centralized climate Risk Data Platform

*This section aims to understand the usefulness of developing a single platform or integrating climate risk data into an existing platform, similar to Norway's Knowledge Bank. This platform would provide local authorities and other relevant stakeholders with access to crucial climate risk data, including:*

- *Database: Information on climate events, losses, and vulnerabilities.*
- *Interactive visualization: Maps and charts to identify vulnerable areas.*
- *Assessment tools: Analysis to help prioritize adaptation investments.*
- *Educational resources: Reports and case studies on adaptation strategies.*
- *Continuous updates: Regularly updated data*

14. Do you think it would be useful to have a single platform for various climate risk data? Do you already use or know of a similar platform?

15. Below is a list of suggested functionalities. What are your thoughts on these?

- Do you think a tool that displays aggregated loss data by hazard type would be useful? If so, what types of hazards would be most relevant to include?
- Would it be useful to have a platform that provides quick access to relevant public datasets for climate risk assessment, organized by hazard type? (e.g., tables or cards with quick access links)



| Potential Interface features                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <div>Loss Data Visualization</div> <ul style="list-style-type: none"><li>● Feature: Display loss data per hazard type (adjusted to 2015 Euro values).</li><li>● Functionality:<ul style="list-style-type: none"><li>○ Filter by region, year, and hazard type.</li><li>○ Aggregated loss data with regional breakdown.</li></ul></li><li>● Download: Option to download filtered data in CSV/Excel.</li><li>● Visual Suggestion: Interactive map and bar charts for loss data comparison.</li></ul> | <div>Public Datasets for Risk Assessment</div> <ul style="list-style-type: none"><li>● Feature: List of public datasets organized by hazard type.</li><li>● Functionality:<ul style="list-style-type: none"><li>○ Links to dataset sources.</li><li>○ Brief descriptions of each dataset and relevance for risk assessment.</li></ul></li><li>● Visual Suggestion: Table or cards with quick-access links.</li></ul> |
| <div>4. Additional Suggestions</div> <p>Do you have any additional suggestions, comments, or specific needs related to the use of climate-related risk and loss data that you'd like to share?</p>                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                      |



# End Page



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