

# SuPeRBE Training Material

Macro Area of Expertise AD5:

**Risk Assessment At Small Urban Scale**

**Hazard: FLOODS (B)**

Area of Expertise AD5.5:

**Urban Sector: EMERGENCY SERVICES (B9)**

**Risk Category: Efficiency risk for civil protection service (B9.1)**

**Level of competence: 3**

# FLOODS

## General Information

Floods happen when water overflows onto normally dry land, caused by heavy rain, river overflow, storm surges, or melting snow and ice. They are one of the most frequent and damaging climate-related hazards.

### Why does it happen?

- **More extreme rainfall** from climate change overwhelms rivers and drainage.
- **Sea-level rise** increases coastal flooding and storm surge impacts.
- **Urbanization** (paved surfaces, poor drainage) makes cities more flood-prone.
- **Deforestation and land use change** reduce natural water absorption.

### How frequent or severe?

Floods are happening **more often** and are becoming **more intense**, affecting millions of people annually.

Some regions see **1-in-100 year floods** occurring far more frequently.



# FLOODS AND HEALTH

The impacts of floods extend beyond immediate physical damage, creating long-term health risks.

Vulnerable populations, including older adults, children, people with disabilities, and low-income communities, are disproportionately affected due to limited resources, difficulty accessing safe shelter, and pre-existing health conditions.

Exposure to floods can lead to:

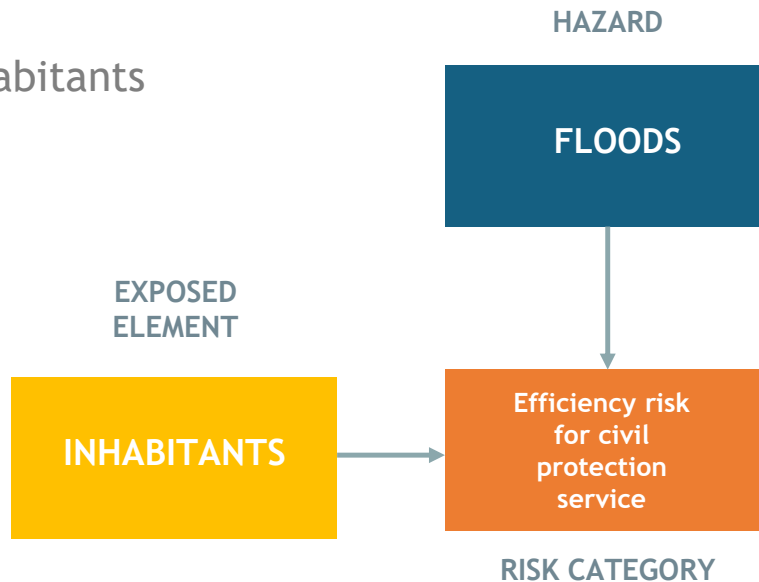
- **Waterborne and vector-borne diseases**, caused by contaminated water, sewage overflow, and increased mosquito breeding.
- **Injuries and trauma** from swift waters, debris, or building collapse.
- **Mental health challenges**, including post-traumatic stress disorder (PTSD), anxiety, and depression.
- **Disruption of healthcare access**, as flooding can damage infrastructure, limit transportation, and interrupt medical services.
- **Long-term impacts**, such as mold exposure, chronic respiratory conditions, and economic hardship that worsens health inequalities.



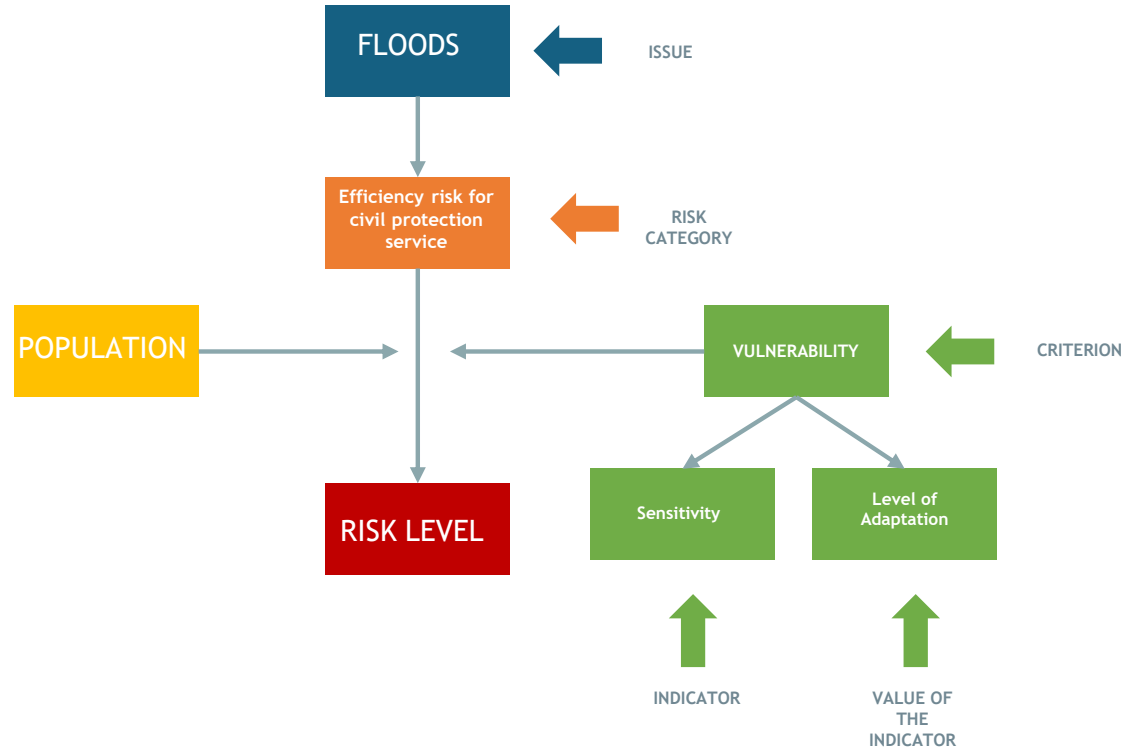
# RISK ASSESSMENT FOR THE HEALTH OF INHABITANTS

Hazard: Floods

Exposed Element: Inhabitants

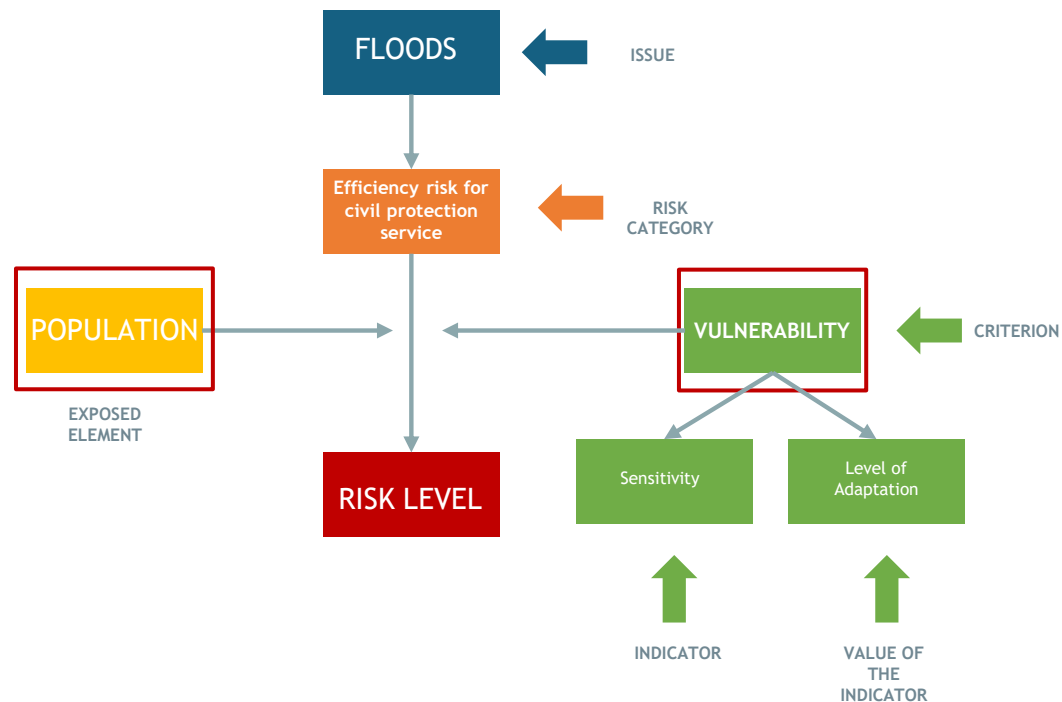


# IMPACT CHAIN



# VULNERABILITY AND EXPOSURE CRITERIA

| CRITERIA                                                                                   |
|--------------------------------------------------------------------------------------------|
| VULNERABILITY                                                                              |
| Trained civil protection staff                                                             |
| Knowledge of the territory by the civil protection staff                                   |
| Organized Volunteer Work                                                                   |
| Civil Protection Plan                                                                      |
| Availability of emergency protocols accessible during crises in relation to the flood risk |
| Areas with a high probability of flooding                                                  |
| Flood incidence on major road connections                                                  |
| Availability of civil protection vehicles                                                  |
| Travel times for Aid                                                                       |
| Alert system (sirens) installed in the flood risk investigated area                        |
| Vulnerable public buildings connected to the Civil Protection Radio channel                |
| Amount of economic aids                                                                    |
| Informative campaigns performed                                                            |
| EXPOSURE                                                                                   |
| Population density                                                                         |



## B9.1. Indicators

| VULNERABILITY |                                                                                            |                                                                                                                                                                                                                     |
|---------------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Code          | Criterion                                                                                  | Indicator                                                                                                                                                                                                           |
| B9.1.1        | Trained civil protection staff                                                             | Number of trained civil protection staff on flood risk in relation to the population density in the investigated area per year                                                                                      |
| B9.1.2        | Knowledge of the territory by the civil protection staff                                   | Number of training exercises performed on flood risk in the investigated area per year                                                                                                                              |
| B9.1.3        | Organized Volunteer Work                                                                   | Number of organised volunteer workers available in the investigated area per year                                                                                                                                   |
| B9.1.4        | Civil Protection Plan                                                                      | Year of the Civil Protection Plan contents update in relation to the year in which the last flood event happened in the area                                                                                        |
| B9.1.5        | Availability of emergency protocols accessible during crises in relation to the flood risk | Percentage of high-risk flood zones with updated contingency plans on the overall high-risk flood zones                                                                                                             |
| B9.1.6        | Areas with a high probability of flooding                                                  | Extent of the areas with a high probability of flood in relation to the investigated area                                                                                                                           |
| B9.1.7        | Flood incidence on major road connections                                                  | Length of the major roads with high risk of flooding in relation to the overall length of the major roads in the investigated area                                                                                  |
| B9.1.8        | Availability of civil protection vehicles                                                  | Number of civil protection vehicles properly equipped for flood risk in relation to the investigated area                                                                                                           |
| B9.1.9        | Travel times for Aid                                                                       | Average of travel times between the centre of the inhabited reference locality and the civil protection headquarters                                                                                                |
| B9.1.10       | Alert system (sirens) installed in the flood risk investigated area                        | Number of alert systems (sirens) concerning flood risk installed on the total extension of the investigated area                                                                                                    |
| B9.1.11       | Vulnerable public buildings connected to the Civil Protection Radio channel                | Proportion of public buildings in flood-risk areas equipped with operational, well-maintained, and regularly tested radio communication systems integrated into civil protection emergency protocols on the overall |
| B9.1.12       | Amount of economic aids                                                                    | Amount of economic refunds received per year in relation to the natural disasters that occurred related to flood                                                                                                    |
| B9.1.13       | Informative campaigns performed                                                            | Number of informative campaigns performed in the investigated area in relation to flood risk, during the year                                                                                                       |
| EXPOSURE      |                                                                                            |                                                                                                                                                                                                                     |
| B9.1-E1       | Population density                                                                         | Total number of inhabitants divided by the dimension of the investigated area                                                                                                                                       |

## B9.1.1. Trained civil protection staff

### Description:

This indicator measures the number of civil protection staff specifically trained on flood risk in relation to the inhabitants of the investigated area, on a yearly basis.

### Objective:

To evaluate whether the number of staff trained on flood risk is adequate compared with how densely populated the territory is, ensuring that exposed people can be assisted effectively during a flood event.

### Relevance:

In densely populated areas, more people are exposed to flood impacts. A higher number of trained staff per population density improves coverage of the territory, coordination of emergency actions, and overall safety during flood events.



## B9.1.1 Trained Civil Protection Staff

### Indicator

Number of trained civil protection staff **per 1000 inhabitants**, on a yearly basis.

**Unit:** #staff/1000 inhabs. year

**Type of value:** High is better

Critical value (1) = 0 staff/1000 inhabs. year)

Optimal value (0) = To be defined for each local context



$$X = \frac{\text{Trained Staff}}{\left(\frac{\text{Population}}{1000}\right)}$$

## B9.1.1 Trained Civil Protection Staff

### CALCULATION: STEP BY STEP

$$X = \frac{\text{Trained Staff}}{\left(\frac{\text{Population}}{1000}\right)}$$

#### Step 1

Collect data on trained municipal civil protection staff (formal, certified, active members).

#### Step 2

Obtain the total population of the investigated area.

#### Step 3

Convert population to “per 1000 inhabitants” and divide trained staff by that value.

Example: Trained Civil Protection Staff in  
Comune di Brunico, Bolzano, Italy

Trained civil-protection staff (COC members): 9  
Population (2025): 17182

Calculation:

$$\frac{17182}{1000} = 17.18$$

$$X = \frac{9}{17.18} = 0.52$$

Result:

0.52 trained civil protection staff / 1000 inhabs. year

– **Comune di Brunico (2023).** Comitato Operativo Comunale per la Protezione Civile – Composizione.  
[https://www.comune.brunico.bz.it/it/Amministrazione/Organi\\_di\\_governo/Comitato\\_operativo\\_comunale\\_per\\_la\\_protezione\\_civile?utm\\_source=chatgpt.com#Membri424075](https://www.comune.brunico.bz.it/it/Amministrazione/Organi_di_governo/Comitato_operativo_comunale_per_la_protezione_civile?utm_source=chatgpt.com#Membri424075)

– **Comune di Brunico (2025).** Popolazione residente nel Comune di Brunico (17.435 abitanti).  
[https://www.comune.brunico.bz.it/it/Novita/Notizie/Brunico\\_in\\_cifre](https://www.comune.brunico.bz.it/it/Novita/Notizie/Brunico_in_cifre)

## B9.1.1 Trained Civil Protection Staff

### CALCULATION: STEP BY STEP

#### Normalize the result:

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

Where:

$X_i$  =observed trained staff ratio (0.52 staff / 1000 inhabs.)

$X_{min}$  =critical value (0 staff/1000 inhabs. → score 1)

$X_{max}$  =optimal value (To be defined based on local context → score 0)

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.2. Knowledge of the territory by the civil protection staff

### Description:

This indicator measures the number of flood-risk training exercises conducted annually in the investigated area, normalized by territorial extent. Exercises strengthen operational familiarity with rivers, critical zones, and evacuation routes.

### Objective:

Assess the extent to which civil protection staff actively train on local flood-risk scenarios to maintain readiness and territorial awareness.

### Relevance:

Field exercises improve response coordination, validate alarm and communication systems, and enhance operational capacity during real flood events.



– Comune di Chiavari (2024). *Esercitazione di Protezione Civile*.  
<https://www.comune.chiavari.ge.it/it/news/esercitazione-protezione-civile>

## B9.1.2. Knowledge of the territory by the civil protection staff

### Indicator

Number of flood-risk training exercises per  $\text{km}^2 \cdot \text{year}$

Unit: #exercises/ $\text{km}^2 \cdot \text{year}$

Type of value: High is better

Critical value (1) = 0 exercises/ $\text{km}^2 \cdot \text{year}$

Optimal value (0) = To be defined based on the context of the territory



Levante News (2024). Chiavari, nuova esercitazione di protezione civile.

<https://www.levantenews.it/2024/09/24/chiaivari-nuova-esercitazione-di-protezione-civile/>

$$X = \frac{\#_{\text{exercises}}}{\text{Area}}$$

## B9.1.2. Knowledge of the territory by the civil protection staff

### CALCULATION: STEP BY STEP

$$X = \frac{\#_{\text{exercises}}}{\text{Area}}$$

#### Step 1

Collect data on flood-risk training exercises performed annually in the investigated area (full-scale drills, evacuation simulations, alarm tests).

#### Step 2

Obtain the territorial extension of the investigated area (km<sup>2</sup>).

#### Step 3

Divide the number of exercises by the area in km<sup>2</sup>.

### Example: Flood-Risk Training Exercises in Chiavari, Liguria, Italy

Data (Chiavari):

Number of flood-risk exercises (2025): 4

Area: 12.27 km<sup>2</sup>

Population (2025 est.): 28,000 (not required, just contextual)

Calculation:

$$X = \frac{4}{12.27} = 0.33$$

Result:

0.33 flood-risk training exercises/km<sup>2</sup>·year

## B9.1.2. Knowledge of the territory by the civil protection staff

### CALCULATION: STEP BY STEP

#### Step 4: Normalize the result

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

Where:

$X_i$  = measured value (0.33 exercises per km<sup>2</sup> per year)

$X_{min}$  = critical value (0 exercises per km<sup>2</sup> per year)

$X_{max}$   
= optimal value (To be defined based on each local context)

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.3 Organized Volunteer Work

### Description:

This indicator measures the number of organized civil protection volunteers active in the investigated area per year, in relation to the territorial extent. Organized volunteers support institutional protection services during flood emergencies by providing manpower, logistics, and local operational knowledge.

### Objective:

To assess whether the number of organized civil protection volunteers is sufficient to support flood-related emergency response across the territory, increasing operational coverage and reducing vulnerabilities linked to limited staff availability.

### Relevance:

Organized volunteer groups significantly enhance emergency response capacity, especially in municipalities where professional staff numbers are limited. A higher number of trained volunteers per km<sup>2</sup> improves territorial coverage, evacuation assistance, resource distribution, and post-event support, ultimately reducing vulnerability and improving community resilience during flood events.



## B9.1.3 Organized Volunteer Work

### Indicator

Number of organized civil protection volunteers per  $\text{km}^2$

Type of value: High is better

Units: #volunteers/ $\text{km}^2 \cdot \text{year}$

Critical value (1) = 0 volunteers/ $\text{km}^2 \cdot \text{year}$

Optimal value (0) = To be defined by the context of analysis



$$X = \frac{\# \text{Volunteers}}{\text{Area}}$$

## B9.1.3 Organized Volunteer Work

### CALCULATION: STEP BY STEP

$$X = \frac{\# \text{ Volunteers}}{\text{Area}}$$

#### Step 1

Collect data on organized municipal civil protection volunteers (active, certified, officially registered).

#### Step 2

Obtain the territorial extension of the investigated area (km<sup>2</sup>).

#### Step 3

Divide the number of volunteers by the area in km<sup>2</sup>.

#### Example: Organized Volunteer Civil Protection Forces in Turin, Piedmont, Italy

Data:

Number of registered organized volunteers: 600

Area: 130 km<sup>2</sup>

Population (2023): 847,287

Calculation:

$$X = \frac{600}{130} = 4.6 \text{ volunteers/km}^2$$

Result:

4.6 organized civil protection volunteers/km<sup>2</sup>·year

## B9.1.3 Organized Volunteer Work

### CALCULATION: STEP BY STEP

#### Step 4: Normalize the result:

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

Where:

$X_i$  = observed volunteer density (4.6 staff/km<sup>2</sup>)

$X_{min}$  = critical value (0 staff/km<sup>2</sup> → score 1)

$X_{max}$   
= optimal value (To be defined by the context of analysis → score 0)

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.4. Civil Protection Plan

### Description:

This indicator measures whether the Civil Protection Plan of a municipality is updated after the last severe flood event. A more recent update, aligned with past events, indicates improved preparedness and risk knowledge.

### Objective:

Assess if the Civil Protection Plan incorporates lessons learned from the most recent flood event, ensuring updated procedures, mapping, emergency routes, and response coordination.

### Relevance:

Updating the Civil Protection Plan after major events enhances institutional readiness, supports accurate flood-risk zoning, and improves response effectiveness by integrating new data, infrastructure changes, and revised emergency protocols.



## B9.1.4. Civil Protection Plan

### Indicator

Year of Civil Protection Plan update relative to last major flood event

Units (-)

Type of value: High is better

**Critical value (1)** = If the civil protection plan update was done before the last severe event happened (Indicator < 1)

**Optimal value (0)** = If the civil protection plan was updated after the last severe event happened (Indicator ≥ 1)

$$X = \frac{Year_{plan\ update}}{Year_{last\ flood}}$$



## B9.1.4. Civil Protection Plan

### CALCULATION: STEP BY STEP

$$X = \frac{Year_{plan\ update}}{Year_{last\ flood}}$$

#### Step 1

Identify the year of the most recent update of the Civil Protection Plan.

#### Step 2

Identify the year in which the last severe flood event occurred in the investigated area.

#### Step 3

Divide the plan update year by the flood event year.

#### Example: Civil Protection Plan Update in Turin, Piedmont, Italy

Data (Torino):

Year of Civil Protection Plan update: 2020

Year of last severe flood: 2016

Calculation:

$$X = \frac{2020}{2016} = 1.04 \rightarrow 4\ years\ later$$

Result:  $1.04 > 1 \rightarrow 4\ years\ later$  (Plan updated after major flood event)

Interpretation:

Updated following major flood  $\rightarrow$  **Lower vulnerability**

-Comune di Torino (2020). Piano Comunale di Protezione Civile – Aggiornamento 2020.

<https://protezionecivile.comune.torino.it/piano-comunale-di-protezione-civile/>

-ARPA Piemonte (2017). Rapporto sull'evento di piena del 21–25 novembre 2016.

<https://www.arpa.piemonte.it/publicazione/eventi-alluvionali-piemonte-evento-21-25-novembre-2016>

-Regione Piemonte (2016). Evento alluvionale 21–25 novembre 2016.

<https://www.regione.piemonte.it/web/temi/protezione-civile-difesa-suolo-opere-pubbliche/calamita-naturali/evento-alluvionale-21-25-novembre-2016-piemonte>

## B9.1.4. Civil Protection Plan

### CALCULATION: STEP BY STEP

#### Step 4: Normalize the result

The value is normalized applying the following logic:

If  $X_i \geq 1 \rightarrow X_{\text{norm}} = 0$  (Optimal)  
If  $X_i < 1 \rightarrow X_{\text{norm}} = 1$  (Critical)

Example:

$$X = \frac{2020}{2016} = 1.04$$

$X_i > 1 \rightarrow X_{\text{norm}} = 0$       **Optimal**

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.5. Availability of emergency protocols accessible during crises in relation to the flood risk

### Description:

This indicator measures the percentage of high-risk flood zones in the investigated area that are covered by updated emergency protocols and operational contingency procedures. Protocols include activation workflows, evacuation routes, staging zones, and inter-agency communication plans specific to hydraulic risk.

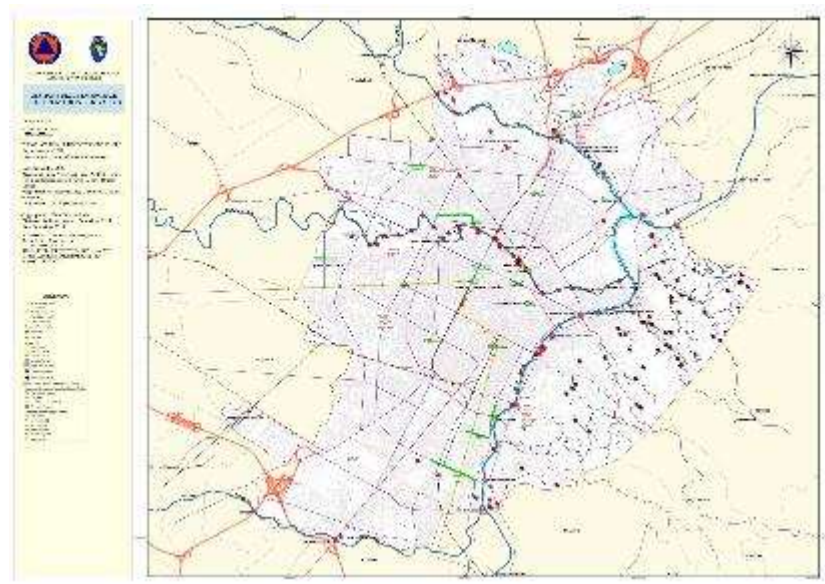
### Objective:

To evaluate the degree of preparedness and operational organization for emergency response to floods. A higher percentage of covered high-risk zones indicates better crisis management capabilities, clearer intervention procedures, and improved population safety.

### Relevance:

Emergency protocols are essential to minimize response time, coordinate rescue forces, activate emergency areas, issue public warnings, and reduce casualties and infrastructure damage during flood events.

This indicator supports strategic planning and decision-making by identifying gaps in emergency procedures across flood-exposed territories.



## B9.1.5. Availability of emergency protocols accessible during crises in relation to the flood risk

### Indicator

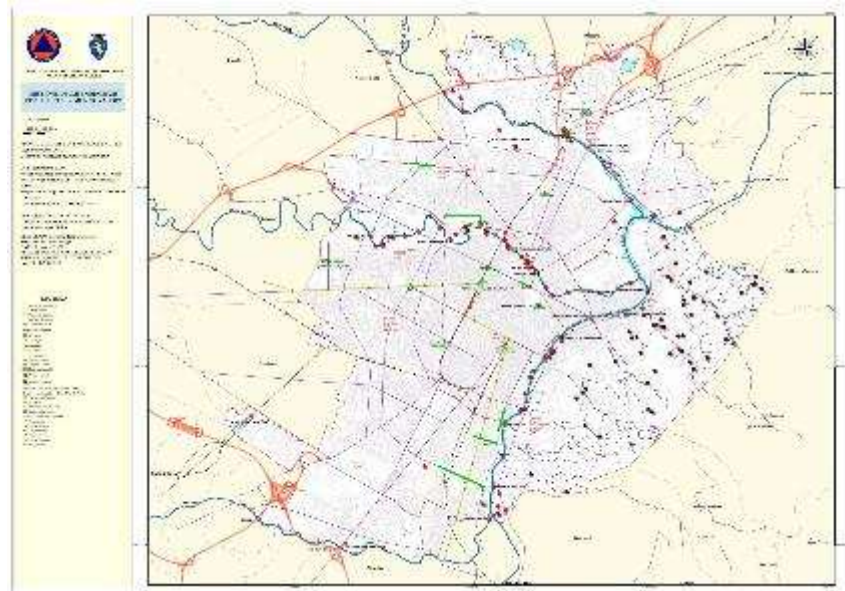
Availability of official, municipality-approved flood-risk emergency protocols covering the identified flood-prone zones of the study area.

Units: %

Type of value: High is better

Critical value (1) = 0%

Optimal value (0) = 100%



$$X = \frac{N_{updated}}{N_{total}} \times 100$$

## B9.1.5. Availability of emergency protocols accessible during crises in relation to the flood risk

### CALCULATION: STEP BY STEP

$$X = \frac{N_{updated}}{N_{total}} \times 100$$

#### Step 1

Identify high-risk flood zones in the municipality.

#### Step 2

Check whether each zone has an associated operational protocol (evacuation routes, emergency areas, activation procedures).

#### Step 3

Evaluate the following:

- Total number of high-risk flood zones ( $N_{total}$ )
- Number of high-risk zones with updated contingency plans ( $N_{updated}$ )

#### Step 4

Calculate the percentage following the formula of the indicator

### Example (Torino): Coverage of High-Risk Flood Zones with Emergency Protocols

- Total high-risk flood zones: 4  
(Po, Dora Riparia, Stura di Lanzo, Sangone corridors)
- High-risk zones with updated contingency plans: 4  
(All covered by PCPC 2020 operational procedures + emergency areas)

$$X = \frac{4 \text{ contingency plans}}{4 \text{ Flood risk zones}} \times 100 = 100\%$$

Result:

100% of mapped high-risk flood zones have contingency protocols.

– PCPC 2020 operational procedures of commune di torino

– **Note:** Torino's four river corridors and the PCPC 2020 are used as **illustrative flood-risk references** for this example.

## B9.1.5. Availability of emergency protocols accessible during crises in relation to the flood risk

### CALCULATION: STEP BY STEP

#### Step 5: Normalize the result:

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

where:

$X_i$  = measured value (% of high-risk flood zones covered)

$X_{max}$  = 100 → optimal (full coverage)

$X_{min}$  = 0 → critical (no coverage)

#### Example Torino: Normalize the result

$$X_{norm} = \frac{100 - 100}{100 - 0} = 0.00$$

Normalized value: 0.00

**Optimal**

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.6. Areas with a high probability of flooding

### Description:

This indicator measures the extent of land areas classified as high flood-probability zones within the investigated territory. It quantifies exposure by comparing the surface of flood-prone zones to the total area.

### Objective:

To assess the level of exposure to flood hazard by determining the proportion of land with frequent or severe flooding potential.

### Relevance:

A higher percentage of flood-prone land indicates greater operational challenges for civil protection services, highlighting areas where response time, evacuation, and accessibility could be compromised during flood events.



Google Earth Pro (2025), satellite imagery of the investigated area.



## B9.1.6. Areas with a high probability of flooding

### Indicator

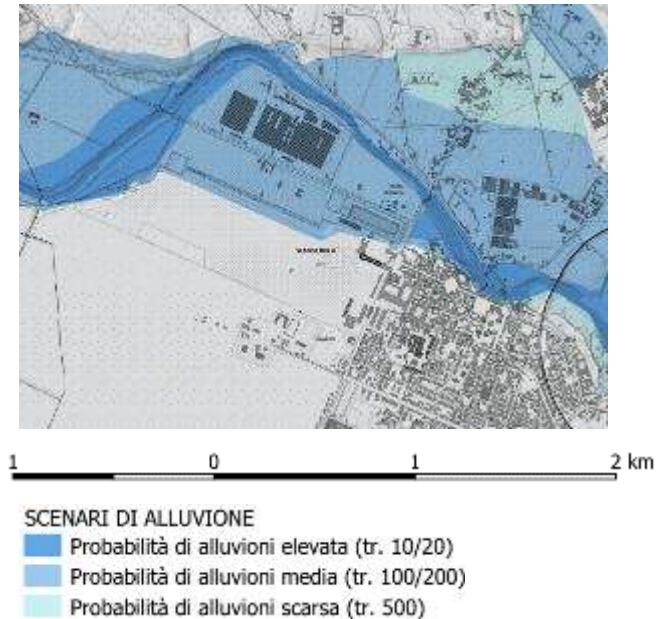
Percentage of the investigated area classified as high-probability flood zone

Units: %

Type of value: Low is Better

Critical value (1) = 100%

Optimal value (0) = 0%



$$\text{Flood Area \%} = \frac{A_{\text{flood}}}{A_{\text{total}}} \times 100$$

## B9.1.6. Areas with a high probability of flooding

### CALCULATION: STEP BY STEP

$$\text{Flood Area \%} = \frac{A_{\text{flood}}}{A_{\text{total}}} \times 100$$

#### Step 1

Obtain the flood hazard map for the study area (e.g., from Civil Protection Plan or SECAP).  
Identify zones marked as High Probability of Flooding

#### Step 2

Define the total investigated area ( $A_{\text{total}}$ ) – usually the municipal or district boundary.

#### Step 3

Measure the area of all HIB zones ( $A_{\text{flood}}$ ) within that boundary.

#### Step 4

Compute the percentage of flood-prone area, and normalization:

$$\text{Flood Area \%} = \frac{A_{\text{flood}}}{A_{\text{total}}} \times 100$$

#### Example: High-Risk Flood Area in Venaria Reale, Piedmont, Italy

The total investigated area is 2.90 km<sup>2</sup>, and the estimated surface of the high-probability flood zones is 1.70 km<sup>2</sup>\*.

Using the formula:

$$\text{Flood Area \%} = \frac{1.70}{2.90} \times 100 = 58.6\%$$

we obtain:

$$\text{Flood Area \%} = 58.6\%$$

## B9.1.6. Areas with a high probability of flooding

### CALCULATION: STEP BY STEP

#### Step5: Normalize the result:

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

where:

$X_i$  :calculated flood area percentage (58.6%)

$X_{min}$  :optimal(0%)

$X_{max}$  :critical(100%)

Example: Venaria Reale - Normalize the result:

$$X_{norm} = \frac{58.6 - 0}{100 - 0} = 0.586$$

Normalized Value: 0.59

Rather negative

| Normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.7. Flood incidence on major road connections

### Description:

This criterion assesses the length of the major roads with high risk of flooding in relation to the overall length of the major roads in the investigated area. Flooding poses a significant hazard to road safety; know the high-risk areas can contribute to the proactive flood management, to improve driver safety, and to keep communities informed.

### Objective:

Evaluate the proportion of the road infrastructure exposed to flood events

### Relevance:

Measuring the proportion of major roads at high flood risk helps prioritise interventions and improve road safety. It supports proactive flood management, ensures communities are informed, and enhances the resilience and reliability of transportation infrastructure in flood-prone areas.



## B9.1.7. Flood incidence on major road connections

### Indicator:

Length of the major roads with high risk of flooding in relation to the overall length of the major roads in the investigated area

Type of value: Low is better

Units: %

Critical value (1)= 100 %

Optimal value (0)= 0%



$$\text{Indicator} = \frac{\text{Lenght of roads under risk of Flood}_{\text{Interest Area}}}{\text{Total lenght of roads}_{\text{Interest Area}}}$$

## B9.1.7. Flood incidence on major road connections

### CALCULATION: STEP BY STEP

$$\text{Indicator} = \frac{\text{Length of roads under risk of Flood}_{\text{Interest Area}}}{\text{Total length of roads}_{\text{Interest Area}}}$$

#### Step 1: Data Collection

- Set the boundaries of the area of analysis (City, Neighborhood, District)
- Retrieve the data about the road infrastructure in the area
- Retrieve the Flood hazard map in the area of analysis

e.g. Statistical zone 22, Turin, Piedmont, Italy.  
Flood Hazard ([ISPRA, 2024](#))

The areas within the Flood hazard surface (low, medium and high) according to the presented map, are considered as the Flood incidence area on the road segments.



## B9.1.7. Flood incidence on major road connections

### CALCULATION: STEP BY STEP

$$Indicator = \frac{Length\ of\ roads\ under\ risk\ of\ Flood_{Interest\ Area}}{Total\ length\ of\ roads_{Interest\ Area}}$$

#### Step 2: Calculate the total length of roads in the area of analysis (Denominator)

Using the retrieved GIS data:

- Clip the layer of the road infrastructure with the boundaries layer of the area of analysis
- Calculate the total length of the road segments in the area of analysis

#### Step 3: Calculate the length of roads within the area of flooding (Numerator).

Using the retrieved GIS data:

- Intersect the map of high-risk areas and the layer containing the road segments within the area of analysis (Tool - Intersect/Clip).
- Calculate the total length of the road segments clipped within the flood area.

e.g. Statistical zone 22, Turin, Piedmont, Italy.

Flood Hazard ([ISPRA, 2024](#))

Total length of roads in the area of analysis (Statistical zone 22, Turin) = 18.15 km

Length of roads within the flooding area (Statistical zone 22, Turin) = 15.45 km

#### Step 4: Indicator Calculation:

Divide the length of roads within the flood area by the total length of roads in the area of analysis

$$Indicator = \frac{15.45\ km}{18.15\ km} = 0.851 = 85.1\%$$

## B9.1.7. Flood incidence on major road connections

### CALCULATION: STEP BY STEP

#### Step 3: Normalize the result:

The value is normalised applying the following formula (For Indicators where Low Value is Better):

$$X_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

where:

$x_i$ : value of the indicator

$x_{min}$  = optimal indicator's value (corresponding to score 0)

$x_{max}$  = critical indicator's value (corresponding to score 1)

e.g. Venaria Reale, Piedmont, Italy

$$X_{norm} = \frac{85.1\% - 0\%}{100\%} = 0.85$$

$$X_{norm} = \mathbf{0.85}$$

**Critical**

| Normalisation values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.8 AVAILABILITY OF CIVIL PROTECTION VEHICLES

### Description:

This indicator measures the density of civil protection vehicles properly equipped for flood response within the investigated area.

### Objective:

To evaluate the operational readiness and territorial coverage of emergency services in case of flood events.

A higher number of available vehicles per km<sup>2</sup> implies better efficiency and faster response capacity.

### Relevance:

Vehicle availability is a key component of response efficiency, affecting rescue time, accessibility, and the ability to reach flooded zones rapidly.

The indicator supports planning decisions for improving fleet distribution and resource allocation.



## B9.1.8 AVAILABILITY OF CIVIL PROTECTION VEHICLES

### Indicator

Vehicle density of civil protection vehicles properly equipped for flood response

Type of Value: High is Better

Units: #veh/km<sup>2</sup>

Critical value (1) = 0 veh/km<sup>2</sup>

Optimal value (0) = To be defined based on the context of analysis



$$\text{Indicator} = \frac{\#_{\text{vehicles}}}{A_{\text{total}}}$$

## B9.1.8 AVAILABILITY OF CIVIL PROTECTION VEHICLES

### CALCULATION: STEP BY STEP

$$\text{Indicator} = \frac{\#_{\text{vehicles}}}{A_{\text{total}}}$$

#### Step 1

Collect data on civil protection vehicles that are flood-ready (boats, trucks, amphibious units, emergency vans).

#### Step 2

Determine the total number of equipped vehicles ( $N_{\text{vehicles}}$ ) within the investigated area.

#### Step 3

Obtain the area of the municipality ( $A_{\text{total}}$ ) in  $\text{km}^2$ .

#### Step 4

Calculate the vehicle density, and normalization:

### Example: Civil Protection Fleet for Flood Emergencies - Vaiano, Tuscany, Italy

**Identify Flood-Ready Vehicles:** From the municipal vehicle list, the following units can realistically serve in flood emergency operations (transport, evacuation, logistics, debris removal, access support):

#vehicles identified: 17\*

**Municipality Area**

$A_{\text{total}} = 34.19 \text{ km}^2$

**Vehicle Density Calculation**

$$\text{Vehicles per km}^2 = \frac{17}{34.19} = 0.50$$

**Result:**

The municipality has 0.50 civil protection vehicles per  $\text{km}^2$  available for emergency operations.

\*The Vaiano vehicle list refers to **all-hazard civil protection vehicles**, not flood-specific ones; used as an **illustrative example**. Retrieved from: Piano Comunale di Protezione Civile (Adopted Plan). Official documentation and vehicle inventory (Allegato 4 – Utility). Available at: <https://www.comune.vaiano.po.it/amministrazione/uffici/piano-comunale-di-protezione-civile/piano-di-protezione-civile-comune-di-vaiano-adozionato>

## B9.1.8 AVAILABILITY OF CIVIL PROTECTION VEHICLES

### CALCULATION: STEP BY STEP

#### Normalize the result:

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

where:

$X_i$  :calculated vehicle density (e.g., 0.5 veh/km<sup>2</sup>)

$X_{min}$  :critical value ( 0 veh/km<sup>2</sup> → score 0)

$X_{max}$  :optimal value (1 veh/km<sup>2</sup> → score 1)

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.8 AVAILABILITY OF CIVIL PROTECTION VEHICLES

### CALCULATION: STEP BY STEP

Normalize the result:

$$X_{norm} = \frac{1.0 - 0.50}{1.0 - 0.0} = 0.50$$

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

Normalized Value: 0.50

**Neutral**

Civil protection coverage is acceptable but not strong.

Increasing the number of specialized flood-ready units (boats, amphibious vehicles, 4×4 rescue trucks) would improve preparedness.

## B9.1.9. Travel times for Aid

### Description:

This criterion assesses the necessary travel time from the civil protection facilities to reach the inhabited zone of the investigated area. Less time is taken to reach the inhabited zone, less vulnerable the area is

### Objective:

To assess the travel time to reach civil protection aid facility from the inhabited areas during an extreme event.

### Relevance:

A low travel time to reach the civil protection aid facilities during Flood events in the area of analysis will represent a low level of vulnerability to extreme events in the area.



## B9.1.9. Travel times for Aid

### Indicator

Average of travel times between the centre of the inhabited reference area and the civil protection facilities

Type of value: Low is better

Units: minutes.

Critical value (1) = 20 minutes.

Optimal value (0) = 8 minutes.



*Indicator = Average travel time*

## B9.1.9. Travel times for Aid

### CALCULATION: STEP BY STEP

*GIS-based estimation of the travel times for aid*

#### Step 1: GIS Data Collection

- Retrieve GIS feature layers of:
  - Location of Civil Protection Aid facilities/buildings serving the area of analysis (city, metropolitan area)
  - Boundaries of the area of analysis (neighborhood, district, etc.)
  - Road network data

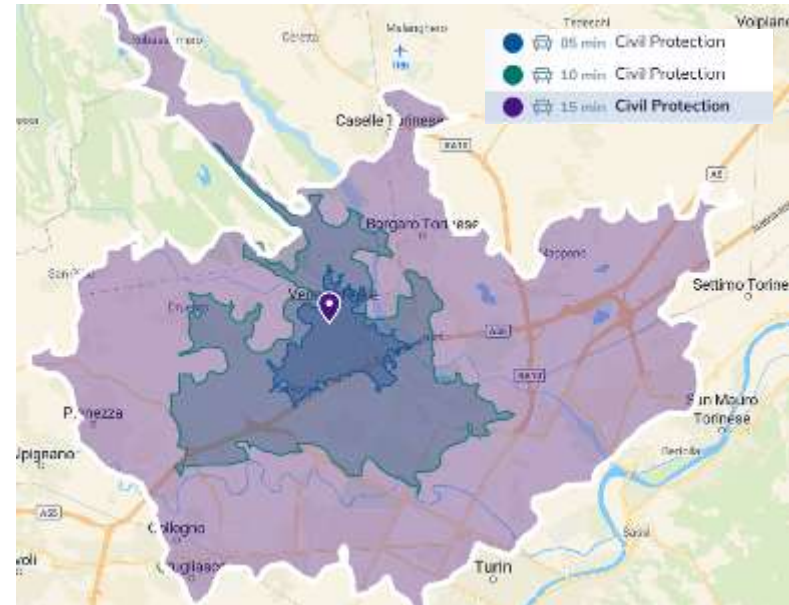
Data sources: Municipal/Regional GeoPortal – OpenData portal;  
Open Street Map

#### Step 2: Generate Isochrones (travel-time polygons) for Aid facilities

- Using GIS Network Analyst tools, calculate *Service Area* for the Health aid facilities serving the area of analysis
- Network: Roads of the city of analysis
- Travel mode: car (av. Speed dense urban area: 30km/h)
- Input locations: Civil protection aid facilities
- Breaks: 0-5 min; 5-10 min; 10-15 min; 15-20 min; 20-30 min

#### e.g. Venaria Reale, Piedmont, Turin

Travel Times by Car to the Aid in the case of emergencies.  
Venaria Reale Civil Protection “*Centro Operativo Misto*”



## B9.1.9. Travel times for Aid

### CALCULATION: STEP BY STEP

*GIS-based estimation of the travel times for aid*

#### Step 3: Clip the Isochrones for the area of analysis:

Since the isochrones can extend beyond the study area, clip the Isochrones to keep the part of each travel-time polygon that lies inside the boundaries of the area of analysis.

#### Step 4: Calculate the average-travel time for the area of interest:

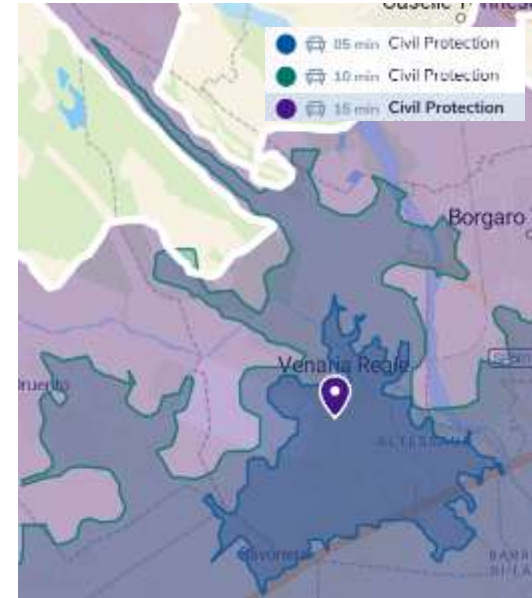
Calculate the area covered ( $A_i$ ) for each travel time interval ( $t_i$ ) within the area of analysis.

$$\begin{aligned}\text{Average travel time} &= \frac{\sum A_i * t_i}{\sum A_i} = \frac{\sum A_i * t_i}{A_{tot}} \\ &= \frac{(A_{0-5} * 5 \text{ min}) + (A_{5-10} * 10 \text{ min}) + (A_{10-15} * 15 \text{ min}) + (A_{15-20} * 20 \text{ min}) + (A_{20-30} * 30 \text{ min})}{A_{tot}} \\ &= \frac{8.7 \text{ km}^2 * 5 \text{ min} + 8.1 \text{ km}^2 * 10 \text{ min} + 2.4 \text{ km}^2 * 15 \text{ min}}{19.2 \text{ km}^2} = \frac{160.5 \text{ min} * \text{km}^2}{19.2 \text{ km}^2} = 8.35 \text{ min} \\ \text{Average travel time} &= 8.35 \text{ min}\end{aligned}$$

**e.g.** Venaria Reale, Piedmont, Turin

Travel Times by Car to the Aid in the case of emergencies.

Venaria Reale Civil Protection “Centro Operativo Misto”



## B9.1.9. Travel times for Aid

### CALCULATION: STEP BY STEP

#### Step 5: Normalize the result:

The value is normalised applying the following formula (For Indicators where Low Value is Better):

$$X_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

where:

$x_i$ : value of the indicator

$x_{min}$  = optimal indicator's value (corresponding to score 0)

$x_{max}$  = critical indicator's value (corresponding to score 1)

e.g. Venaria Reale, Piedmont, Italy

$$X_{norm} = \frac{8.35 - 8}{20 - 8} = 0.03$$

$$X_{norm} = 0.03$$

**OPTIMAL**

| Normalisation values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.10. Alert system (sirens) installed in the flood risk investigated area

### Description:

This criterion assesses the number of alert systems concerning flood risk installed on the total extension of the area investigated. Alert systems facilitate risk detection and provide early warning towards the inhabitants, contributing to their protection

### Objective:

Evaluate the availability of flood-risk alert systems within the area of analysis.

### Relevance:

Flood alert systems play a crucial role timely communication to residents. Assessing their presence helps determine the area's capacity to warn and protect inhabitants during flood events, supporting more effective emergency preparedness and reducing vulnerability.



## B9.1.10. Alert system (sirens) installed in the flood risk investigated area

### Indicator

Number of alert systems (sirens) concerning flood risk installed on the total extension of the investigated area

Type of value: High is better

Units: #sirens/km<sup>2</sup>

Critical value (1) = 0.

Optimal value (0) = 0.32 sirens/km<sup>2</sup>  
(1 sirens/π km<sup>2</sup>)



$$\text{Indicator} = \frac{\text{Number of alert systems}_{\text{interest area}}}{\text{Area of analysis}}$$

## B9.1.10. Alert system (sirens) installed in the flood risk investigated area

### CALCULATION: STEP BY STEP

$$\text{Indicator} = \frac{\text{Number of alert systems}_{\text{interest area}}}{\text{Area of analysis}}$$

#### Step 1: Data Collection

- Retrieve the number of sirens for alert systems available in the area of analysis
- Boundaries of the area of analysis (neighborhood, district, etc.)

Data sources: Municipal/Regional Administration; Civil Protection;  
Municipal/Regional GeoPortal

**e.g. Venaria Reale, Piedmont, Italy**

**Number of Alert Systems:**

10\*

**Area:**

20.3 km<sup>2</sup>

**Population:**

32462 inhabitants (ISTAT, 2021)

#### Step 2: Calculate the indicator:

Divide the number of alert systems available by the total area of the evaluated territory.

**e.g. Venaria Reale, Piedmont, Italy**

$$\begin{aligned}\text{Indicator} &= \frac{\text{Number of alert systems}_{\text{interest area}}}{\text{Area of analysis}} \\ &= \frac{10}{20.3 \text{ km}^2} = 0.49 \text{ sirens of alert systems/km}^2\end{aligned}$$

$$\text{Indicator} = 0.49 \text{ sirens of alert systems/km}^2$$

## B9.1.9. Travel times for Aid

### CALCULATION: STEP BY STEP

#### Step 3: Normalize the result:

The value is normalised applying the following formula (For Indicators where High Value is Better):

$$X_{norm} = \frac{x_{max} - x_i}{x_{max} - x_{min}}$$

where:

$x_i$ : value of the indicator

$x_{max}$  = optimal indicator's value (corresponding to score 0)

$x_{min}$  = critical indicator's value (corresponding to score 1)

| Normalisation values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

e.g. Veneria Reale, Piedmont, Italy

Period of study - January 2025

$$X_{norm} = \frac{0.32 - 0.49}{0.32 - 0} = -0.53$$

$$X_{norm} = -0.53 \rightarrow 0$$

The indicator value is higher than the optimal value

Optimal

## B9.1.11. Vulnerable public buildings connected to the Civil Protection Radio channel

### Description:

This indicator measures the percentage of public buildings located in flood-risk areas that are equipped with operational, well-maintained, and regularly tested radio communication systems connected to civil protection protocols.

### Objective:

To evaluate whether critical public buildings exposed to flood hazards can maintain stable, immediate communication with the Civil Protection network during emergencies.

### Relevance:

Ensures rapid alerting, supports coordinated evacuation, reduces communication failures, and strengthens overall municipal resilience during flood events.



## B9.1.11. Vulnerable public buildings connected to the Civil Protection Radio channel

### Indicator:

Percentage of public buildings in flood-risk areas equipped with an operational Civil Protection radio system.

Type of values: High is better

Units: %

### Reference values

Critical (1): 0% of buildings connected

Optimal (0): 100% of buildings connected



$$I = \frac{N_{radio}}{N_{total}} \times 100$$

## B9.1.11. Vulnerable public buildings connected to the Civil Protection Radio channel

### CALCULATION: STEP BY STEP

$$I = \frac{N_{radio}}{N_{total}} \times 100$$

#### Step 1:

Identify all public buildings located inside the mapped flood-risk area of the municipality.

#### Step 2:

From this subset, check which buildings are equipped with operational Civil Protection radio systems (Emercomnet fixed or mobile units).  
Use official radio distribution lists.

#### Step 3:

Evaluate

- $N_{radio}$  = number of public buildings in flood-risk areas with operational radio
- $N_{total}$  = total public buildings in flood-risk areas
- Compute the indicator following the proposed formula

#### Step 4:

Assign the result as % of flood-risk public buildings connected to the radio network, then proceed to normalization.

## B9.1.11. Vulnerable public buildings connected to the Civil Protection Radio channel

### CALCULATION: STEP BY STEP

#### Step 5: Normalize the result

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

Where:

$X_i$  =observed % of vulnerable buildings equipped with radio

$X_{min}$  =critical condition → highest vulnerability

$X_{max}$  =optimal → all buildings connected

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.11. Vulnerable public buildings connected to the Civil Protection Radio channel

### Example CALCULATION STEP BY STEP: Venaria Reale, Piedmont, Italy

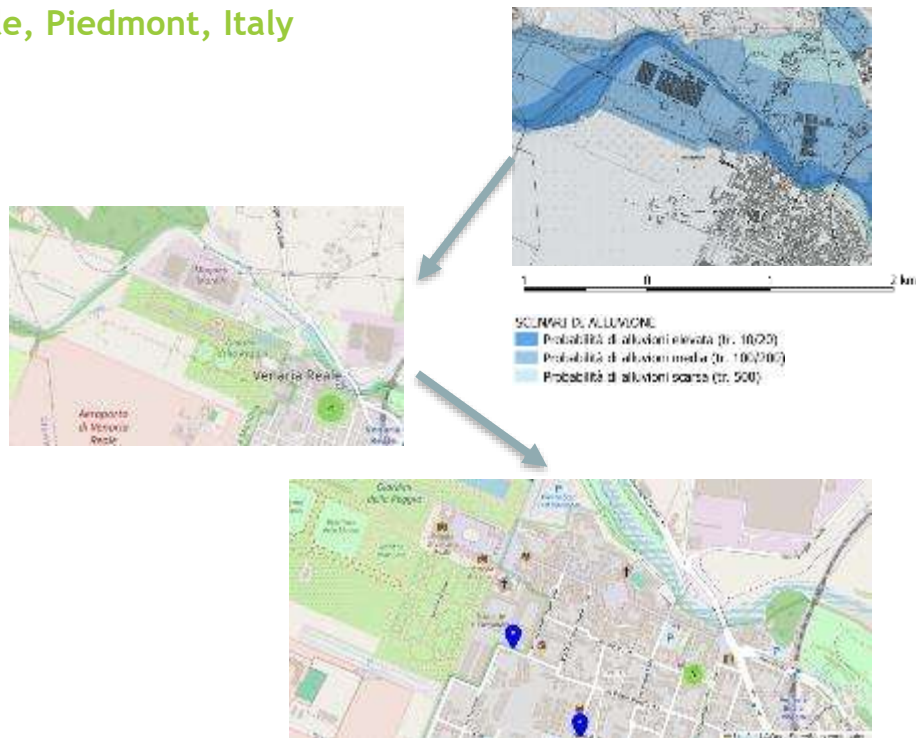
Public buildings in flood-risk area (approx.): 5

- Consorzio Residenze Sabaude - heritage office
- Biblioteca “T. Milone” - library/cultural center
- GE.S.IN Srl - mobility & infrastructure services
- Centro per le Famiglie - community support
- Municipio - main municipal offices

(Approximate location in flood-risk zone based on map.)

Radio equipment

Fixed Emercomnet radio in Venaria Reale: 1  
(Assumed installed in one of the 5 buildings.)



– Regione Piemonte – Protezione Civile (2020).  
Piano di Emergenza di Protezione Civile – Linee guida e scenari di rischio idraulico.

Available at: <https://www.regione.piemonte.it/web/media/47319/download>

– Regione Piemonte – Protezione Civile (2024).

EmercomNet – Distribuzione apparati fissi e veicolari, rubrica operatori del sistema radio regionale di emergenza.

Available at:  
<https://www.regione.piemonte.it/web/temi/protezione-civile-difesa-suolo-opere-pubbliche/protezione-civile-logistica/emcomnet-distribuzione-apparati-rubrica-operatori>

– Regione Piemonte – Protezione Civile (2024).

EmercomNet – Sistema informativo di telecomunicazioni per la Protezione Civile regionale.

Available at:

<https://www.regione.piemonte.it/web/temi/protezione-civile-difesa-suolo-opere-pubbliche/protezione-civile-telecomunicazioni-sistema-informativo/emcomnet>

– Comune di Venaria Reale (2025).

Luoghi e servizi pubblici – Elenco sedi comunali e strutture di interesse pubblico.

Available at: <https://www.comune.venariareale.to.it/it/luoghi/313941>

– All maps and locations are used for research and educational purposes within the SuPerBE project context.

## B9.1.11. Vulnerable public buildings connected to the Civil Protection Radio channel

### CALCULATION: STEP BY STEP

If 1 building out of 5 in the flood-risk zone is equipped with an operational radio system:

$$I = \frac{1}{5} = 0.20(20\%)$$

Result:

0.20 → 20% of vulnerable public buildings are connected to the Civil Protection radio network.

**Normalize the result:**

$$X_{norm} = \frac{1 - 0.20}{1 - 0} = 0.80$$

Normalized value: 0.80

**Rather Negative**

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

## B9.1.12. Amount of economic aids

### **Description:**

This indicator measures the total economic aids and refunds received per year in response to flood events. It includes public financial support aimed at recovery and mitigation.

### **Objective:**

To assess how effectively the territory secures financial resources for managing flood damages and supporting recovery. Higher annual aids indicate stronger capacity to respond and adapt.

### **Relevance:**

Economic support is essential for restoring services, protecting communities, and reducing future flood impacts. The indicator helps evaluate whether available funds match the territory's flood-risk exposure.



## B9.1.12. Amount of economic aids

### Indicator

Amount of economic funds received per year in relation to the natural disasters that occurred related to flood

**Type of Value:** High is Better

**Units:** € /year

Critical value (1) = *To be defined in the context of analysis*

Optimal value (0) = *To be defined in the context of analysis*



$$\text{economic aids (€/year)} = \sum \text{Refunds related to flood events}$$

## B9.1.12. Amount of economic aids

### CALCULATION: STEP BY STEP

$$\text{economic aids (€/year)} = \sum \text{Refunds related to flood events}$$

#### Step 1

Collect data on economic refunds allocated to the municipality for flood damages (national funds, regional funds, emergency allocations, civil protection reimbursements).

#### Step 2

Identify which refunds are specifically linked to the flood event(s) of the reference year.

#### Step 3

Sum all validated refunds to obtain the total annual amount of economic aids  
 $A_{\text{refunds}}(\text{€/year})$ .

#### Step 4

Normalize the value if required by the analysis (e.g., per km<sup>2</sup> or per capita).

### Example: Flood-Related Hydraulic Interventions Macugnaga, Piedmont, Italy

#### Identify Flood-Related Economic Refunds (Macugnaga)

From the official national funding list (Decreto 3/05/2021 - Allegato 1), the following refunds were allocated to Macugnaga after the October 2020 flood:

Refunds considered flood-related:

- Torrente Anza hydraulic safety: €20,824.49
- Torrente Tambach hydraulic safety: €126,661.77
- Conoide Pecetto hydraulic restoration: €47,580.00

**Total economic aids identified:**  
**€195,066.26**

Ministero dell'Interno (2021). *Decreto 3 maggio 2021 – Allegato 1. Elenco dei finanziamenti per interventi di messa in sicurezza a seguito degli eventi alluvionali di ottobre 2020.*

Available at: <https://dait.interno.gov.it/finanza-locale/documentazione/decreto-3-maggio-2021>

## B9.1.12. Amount of economic aids

### CALCULATION: STEP BY STEP

#### Step 5: Normalize the result

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

where:

$X_i$ : total economic aids received (e.g., €195,066.26)

$X_{min}$ : minimum value (To be defined by context of analysis → score 1 for “no refund aid”)

$X_{max}$ : maximum value (To be defined by context of analysis → score 0 for “high refund aid”)

## B9.1.13 Informative Campaigns Performed

### Description:

This indicator measures the number of informative campaigns performed annually by civil protection staff to increase population awareness regarding flood risks in the investigated area.

### Objective:

To assess the capacity of civil protection to promote education, awareness, and preparedness among residents—key for improving community resilience to flood hazards.

### Relevance:

It enhances citizens' understanding of flood risks, improves public response and evacuation behavior, and reduces social vulnerability while facilitating better coordination during emergencies.



## B9.1.13 Informative Campaigns Performed

### Indicator

Informative campaigns carried out annually to improve community preparedness.

**Type of Values:** High is Better

**Units:** campaigns/year

### Reference values

Critical (1): 0 campaigns/year

Optimal (0): 2 campaigns/year



## B9.1.13 Informative Campaigns Performed

### CALCULATION: STEP BY STEP

#### Step 1:

Collect data on all awareness or educational campaigns organized for one year (seminars, school programs, public drills, etc.).

#### Step 2:

Define the reference year for evaluation (1 year).

#### Step 3:

Count the total number of campaigns ( $N_{\text{campaigns}}$ ) and calculate the annual frequency:

$$I = \frac{N_{\text{campaigns}}}{\text{Year}}$$

#### Step 4:

Assign the result as number of campaigns per year (n/year) and normalization.

### Example: Turin, Piedmont, Italy

Campaigns considered:

2024

“Io Non Rischio - Torino 2024”

National civil protection awareness campaign held in major public squares.

$I_{2024}$  : 1 campaigns/year

2025

“Io Non Rischio - Torino 2025”

Confirmed presence in the Piemonte regional program (Piazze Io Non Rischio 2025).

“Settimana della Protezione Civile 2025 - Torino”

Official event organized by the Prefettura di Torino, “Prevenzione della resilienza e riduzione dei rischi” (Auditorium Città Metropolitana, Corso Inghilterra 7).

$I_{2025}$  : 2 campaigns/year

## B9.1.13 Informative Campaigns Performed

### CALCULATION: STEP BY STEP

#### Step 5: Normalize the result:

The value is normalized applying the following formula:

$$X_{norm} = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

Where:

$X_i$  =observed number of informative campaigns per year

$X_{min}$  =critical value (0 campaigns/year → highest vulnerability)

$X_{max}$  =optimal value ( maximum 2 number of campaigns/year  
→ lowest vulnerability)

| normalization values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

**EXAMPLE: Turin, Piedmont, Italy - Normalize the result:**

$$X_{norm\ 2024} = \frac{2 - 1}{2 - 0} = 0.5$$

$$X_{norm\ 2025} = \frac{2 - 2}{2 - 0} = 0$$

Normalized Value 2024: 0.5 → **Neutral**  
(moderate awareness; improvement recommended)

Normalized Value 2025: 0.0 → **Optimal**  
(full outreach achieved relative to the selected benchmark)

## B9.1-E1. Population density

### Description:

This criterion assesses the element exposed to the flood risk in relation to the civil protection services: the population. If the area is densely populated, the exposure value is higher

### Objective:

Evaluate the population density in the area of analysis

### Relevance:

Areas with higher population density face greater potential impacts during flood events, as more people may require evacuation, assistance, and emergency response. Understanding population exposure helps civil protection services prioritize resources, improve preparedness, and reduce risk to human life..



## C9.4-E1. Older and younger people

### Indicator:

Population density of the area of analysis.  
Total number of inhabitants divided by the dimension of the investigated area.

Type of value: Low is better

Units: #Inhabitants.

Critical value (1)= 10000 inhabitants/km<sup>2</sup>.

Neutral value (0,5)=6000 inhabitants/km<sup>2</sup>.

Optimal value (0)= 3000 inhabitants/km<sup>2</sup>.



$$\text{Indicator} = \frac{\text{Population}_{U10} + \text{Population}_{065}}{\text{Area of analysis}}$$

## B9.1-E1. Population density

### CALCULATION: STEP BY STEP

$$\text{Population Density} = \frac{\text{Population}}{\text{Area of analysis}}$$

#### Step 1: Data Collection

- Set the boundaries of the area of analysis (City, Neighborhood, District)
- Retrieve the data about the total population in the area of analysis

**e.g.** Venaria Reale, Piedmont, Italy

**Area:**

20.3 km<sup>2</sup>

**Population:**

32462 inhabitants (ISTAT, 2021)

#### Step 2: Indicator Calculation:

Divide the total number of inhabitants (numerator) by the area of the case study in km<sup>2</sup> (denominator)

**e.g.** Venaria Reale, Piedmont, Italy

$$\begin{aligned}\text{Population density} &= \frac{32462 \text{ inhabitants}}{20.3 \text{ km}^2} \\ &= 1599 \text{ inhabitants/km}^2\end{aligned}$$

**Population density = 1599 inhabitants/km<sup>2</sup>**

## B9.1-E1. Population density

### CALCULATION: STEP BY STEP

#### Step 3: Normalize the result:

The value is normalised applying the following formula (For Indicators where Low Value is Better):

$$X_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

where:

$x_i$ : value of the indicator

$x_{min}$  = optimal indicator's value (corresponding to score 0)

$x_{max}$  = critical indicator's value (corresponding to score 1)

| Normalisation values | Description                                  |
|----------------------|----------------------------------------------|
| 0.1                  | Optimal (No improvement necessary)           |
| 0.3                  | Rather positive                              |
| 0.5                  | Neutral                                      |
| 0.7                  | Rather negative                              |
| 0.9                  | Critical (Could lead to severe consequences) |

e.g. Veneria Reale, Piedmont, Italy

Period of study - January 2025

$$X_{norm} = \frac{1599 - 3000}{10000 - 3000} = -0.20$$

$$X_{norm} = -0.20$$

(The value of the indicator is lower than the optimal value)

**OPTIMAL**