

Towards a Pan-European Harmonized Exposure Database of Critical Infrastructure for Multi-Hazard Risk Assessment

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1 INTRODUCTION & SCOPE OF WORK

Critical Infrastructure (CI) systems - such as transport, energy, healthcare, education, and telecommunications form the backbone of modern societies, supporting economic activity, security, and public health. When natural hazards occur, disruptions in these systems can lead to severe socio-economic consequences and cascading effects across interconnected networks. Despite their importance, the exposure of CI assets to natural hazards remains inconsistently documented across Europe. Existing datasets differ substantially in spatial coverage, resolution, accessibility, and attribute completeness, which limits their direct applicability in large-scale multi-hazard risk assessment.

This study addresses this gap by reviewing key European and global datasets related to CI exposure and by proposing a methodology for the development of a harmonized pan-European exposure database. The proposed approach relies primarily on OpenStreetMap (OSM), an open and continuously updated geospatial dataset that provides extensive spatial information on infrastructure systems. An automated geospatial workflow was developed to systematically extract, process, and standardize CI assets across multiple sectors using OSM as the primary data backbone. By harmonizing infrastructure data across countries, the database provides open-access coverage of CI systems across Europe and supports multi-hazard risk assessment and resilience planning at both national and continental scales. This work has been developed within the Horizon Europe project MIRACA (Multi-hazard Infrastructure Risk Assessment for Climate Adaptation, Grant Agreement No. 101093854). MIRACA aims to strengthen the resilience of critical infrastructure in Europe by advancing harmonized exposure mapping and multi-hazard risk methodologies under current and future climate scenarios.

2 REVIEW OF CI EXPOSURE DATASETS

Several global and European initiatives provide spatial datasets describing the distribution of critical infrastructure (CI) assets. These datasets differ significantly in terms of geographic coverage, accessibility, spatial resolution, and attribute completeness. While some datasets focus on specific infrastructure sectors, others provide broader geospatial information on multiple asset types. However, data availability remains fragmented and inconsistent across infrastructure systems and countries.

A review of existing exposure datasets was conducted in order to identify the most suitable sources for large-scale infrastructure exposure mapping. Table 1 summarizes the datasets considered most appropriate for each CI network in terms of spatial coverage, accessibility, and data completeness. These datasets represent the most reliable sources currently available for supporting European-scale analyses.

Table 1. Overview of exposure datasets for critical infrastructure systems

System	Network	Exposure datasets
Energy	Electric power network	OpenStreetMap (OSM), EuroRegionalMap (<i>EuroGeographics, 2023a</i>), PyPSA-Eur (<i>Hörsch et al., 2018</i>), SciGRID (<i>Medjroubi et al., 2017</i>)
	Natural gas network	OSM, IGGIELGN dataset (<i>Pluta & Lünsdorf, 2020</i>), OGIM (<i>Environmental Defense Fund, 2023</i>)
	Oil network	OSM, EMODnet (EMODnet, 2023), OGIM
Transportation	Roadway network	OSM, EuroGlobalMap (<i>EuroGeographics, 2023b</i>), EuroRegionalMap
	Railway network	
	Port network	
	Airport network	OSM, EuroGlobalMap
Telecommunications	Telecommunication	OpenCellID (<i>Unwired Labs, 2023</i>), OSM, EuroRegionalMap
Healthcare	Healthcare facilities	OSM , Global Healthsites Mapping Project (<i>Healthsites.io, 2023</i>)
Education	Educational facilities	OSM, RiskSchools (<i>Karafagka et al., 2024</i>)

Among the datasets reviewed, OpenStreetMap (OSM) stands out as the only openly accessible geospatial database providing consistent coverage across all infrastructure sectors considered in this study. Its global coverage, frequent updates, and open licensing make it particularly suitable for large-scale exposure mapping. For this reason, OSM was selected as the primary backbone for the development of the harmonized exposure database.

3 METHODOLOGY

The exposure database was developed through an automated geospatial workflow designed to extract and harmonize critical infrastructure assets across Europe using OpenStreetMap as the primary data source. Infrastructure elements were organized into thematic networks including transportation, energy, telecommunications, healthcare, and education. Assets were identified using a predefined tagging scheme based on selected OSM key-value pairs corresponding to each infrastructure type.

The workflow was implemented in a Python environment using Jupyter Notebook, allowing automated processing of country-level OSM extracts in *.osm.pbf format. Open-source geospatial libraries were used to perform data extraction, geometry validation, duplicate removal, and geometry harmonization to ensure consistent spatial representation across countries. Figure 1 illustrates the main steps of the workflow used to construct the harmonized exposure database.

Following preprocessing, infrastructure assets were spatially linked to administrative units (LAU and NUTS regions) to support spatial aggregation and analysis. The final datasets were exported in GeoParquet format using a standardized naming convention by infrastructure type and country, enabling efficient storage and integration with hazard and risk assessment workflows.

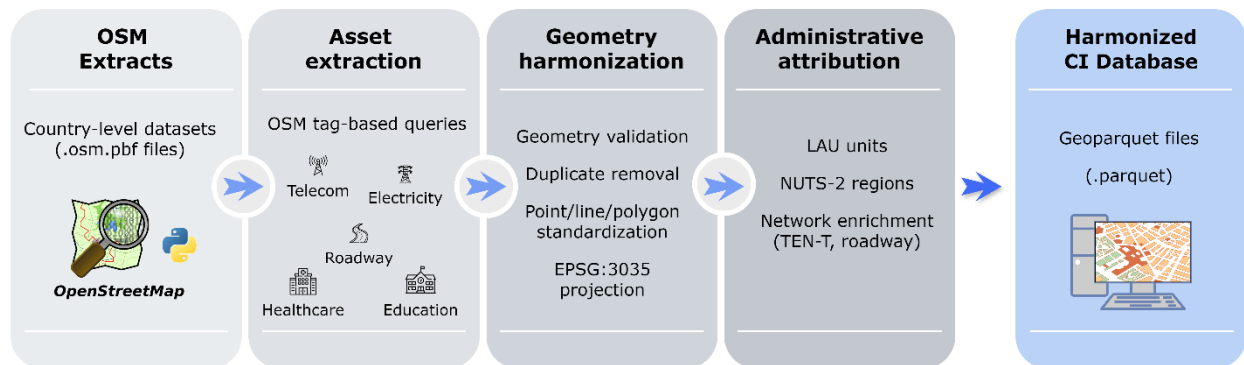


Figure 1. Automated workflow for the construction of the harmonized critical infrastructure exposure database using OpenStreetMap data.

The resulting harmonized exposure database covers 37 European countries and includes multiple critical infrastructure sectors, namely transportation, energy, telecommunications, healthcare, and education. The datasets are organized using a standardized structure by infrastructure type, geometry representation, and country code, enabling consistent cross-country comparisons and facilitating direct integration into hazard and risk assessment workflows. Overall, the proposed database provides an open, consistent, and scalable basis for large-scale exposure assessment of critical infrastructure systems across Europe and supports multi-hazard risk analysis at both national and continental scales.

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