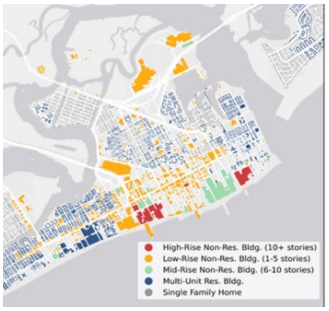
R2D Application Summary (V3.0.0)

The Regional Resilience Determination Tool (R2D) creates and launches simulation workflows to assess the regional impact of natural hazard events. Advanced capabilities facilitate high-resolution simulation. Researchers can investigate disaster scenarios or perform a probabilistic assessment by including uncertainties in both the hazard and the characteristics of the built environment. Assessments can include a comprehensive inventory of assets or focus on a distributed portfolio of structures, subjected to hurricanes, earthquakes, or other hazard events. The application integrates tools and libraries to support the creation of inventories, characterization hazard events, and simulate damage and losses on large inventories of buildings and civil infrastructure. User-defined models and calculation methodologies are also supported. Detailed results are provided in a standardized format to facilitate post-processing and further calculations to evaluate community impacts and recovery.

USE CASES

Perform a Hazus-type assessment of regional disaster risk

Leverage built-in access to building inventories from the Hazus database and the National Structures Inventory. Use machine learning models available in BRAILS to augment the available data with additional building features. Characterize hurricane and seismic events using built-in tools or import your own event data. Use the Hazus fragility curves and loss models that are integrated in R2D and complement them with custom damage and loss models. Aggregate outputs across census blocks or tracts for conveying results.

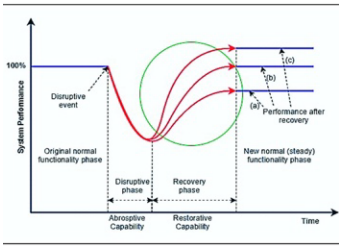


Assess portfolio risk using advanced models and methods

Import a user-defined inventory of building locations and features. Use built-in tools or external data to characterize the hazard event. Provide scripts for structural model generation that can parse those features, create models, and perform analyses to evaluate structural response. Define an auto-population script to map buildings to specific damage and loss archetypes and use rulesets to augment the inventory data. Leverage detailed simulation results in visualization and custom risk metrics.

Seed disaster studies with robust damage and loss data

Consider interventions and socioeconomic factors in generated inventories, structural models, and damage and loss estimates. Use inventories of buildings and transportation and water networks in integrated analyses, including models to capture interdependencies between these systems. Create an automated workflow by leveraging the standardized outputs of R2D in your own model.



(https://www.mdpi.com/2412-3811/4/2/30)

CURRENT CAPABILITIES

Asset Inventories: Assets are characterized by their location and a set of features used by simulation models. Buildings, as well as and transportation networks, are supported. The following options are available to define asset inventories:

- Import external inventories from files using SimCenter's standard JSON format.
- Use the integrated inventory generator module to create an inventory of assets for any location in the United States. The module uses information from federal inventories complemented by inference from machine learning models in BRAILS and data imputation methods.

Natural Hazard Events: Earthquake, hurricane or tsunami events are characterized by intensity measures and/or more refined hazard features (e.g., earthquake seismograms). The hazard measures can be specified at user-defined geographic grid locations and are automatically mapped to asset locations during the simulation. The following options are available to define natural hazard events:

- Import hazard event files using SimCenter's standard CSV format.
- Import ShakeMap ground motion intensities from USGS or hurricane wind speeds and water inundation from NOAA.
- Import ground motion seismograms from regional physics-based simulations.
- Use the integrated hurricane simulation tool to generate maps of wind speeds and water inundation.
- Use the integrated ground motion event generator tool to create a set of event files that either represent a seismic scenario or the local seismic hazard. Interfaces with OpenSHA, OpenQuake, and PEER Ground Motion Database.
- Use the site response tool to propagate ground motion time histories from a bedrock to the surface.

Structural Response: Utilizes OpenSees or Python to perform numerical simulations of models ranging from idealized shear column models to user defined models. Provides a set of response quantities to characterize the demands acting on the asset due to the natural hazard event.

Damage and Loss: Defines a set of interconnected models in the Pelicun framework that describe vulnerable components in the structure and the demands on each component. Maps demands to damage to various potential consequences. The following options are available:

- Perform a standard FEMA P-58 or Hazus assessment using the built-in libraries and methods.
- Perform a custom damage and loss assessment using your own component library and auto-population script that links buildings to archetypes.

Uncertainty Quantification (UQ): Samples the prescribed random input variables and obtains realizations of the outputs by executing the workflow with each input realization from the generated sample. The underlying UQ engines leverage Monte-Carlo and Latin Hypercube sampling techniques.

UPCOMING CAPABILITIES

- Perform Hazus level assessment for water pipeline systems. (Oct 2023)
- Incorporate surrogate models developed in EE-UQ for use in regional assessment of building damage for earthquake events (Oct 2023). Incorporate surrogate models developed in HydroUQ and WE-UQ for wind, tsunami and storm surge events (Sept 2024)
- Perform post-event transportation and buried pipeline performance simulation to study the effect of network damage on systems and subsequent impact on communities. (Mar 2024)
- Transform physics-based ground motion simulation output (e.g., SW4, SCEC BP) into acceleration time histories, using the Domain Reduction Method. (Sep 2024)
- Model recovery of households, business operations, and lifeline networks after a natural hazard event. (Sep 2024)
- Incorporate multi-fidelity simulation modeling available in EE-UQ, HydroUQ, and WE-UQ into regional simulations. (Sep 2025)
- Ability to study effects of multi-hazard events in regional simulations. (Sep 2025)

MORE INFORMATION

The software application, examples, and information about previous releases can be found in the documentation accessible from the R2D website: https://simcenter.designsafe-ci.org/research-tools/r2dtool/