# PBE Application Summary (V3.4.0)

The Performance Based Engineering (PBE) application simulates the impact of a natural hazard event on a building or other structure. The impact is quantified in a probabilistic approach using the Pelicun damage and loss assessment engine. The modules featured in EE-UQ are integrated into PBE to enable various open-source seismic response simulation workflows. Simulations with commercial tools and other non-seismic hazards are also supported by allowing users to import external response data. Various uncertainties in damage and loss models can be represented and propagated through the analyses. Besides the built-in libraries of damage and loss models, custom user-defined models and calculation methodologies are also supported. Damage and loss results can be used in the integrated functional recovery simulation tool to simulate the repair process of a building. Detailed results are provided in a standardized format to facilitate post-processing and further calculations.

USE CASES

Perform a FEMA P-58 Seismic Damage and Loss Assessment

Leverage the built-in FEMA P-58 component library and assign component quantities to floors in the building either through the user interface or using standard input files. Calculate Engineering Demand Parameters (EDPs) with external tools or using the built-in structural response simulation workflow. Access detailed calculation data on component quantities, re-sampled EDPs, damages, and repair consequences, including environmental impact.

Seismic Performance Assessment of Buildings
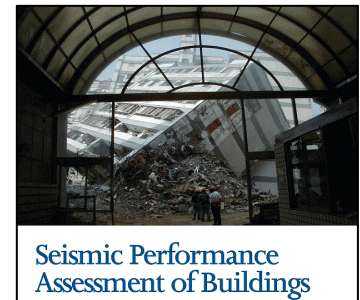
Develop and Leverage New Components and Methods

Extend the built-in libraries with your own components for vulnerability and loss assessment. Custom fragility and consequence functions can be imported, visualized, and combined with built-in libraries. Share your components with the community through the SimCenter Damage and Loss Database. Custom damage processes and loss maps support the extension of existing methodologies and the development of completely new ones. Customizations are not limited to the seismic hazard; the underlying Pelicun engine is hazard agnostic.
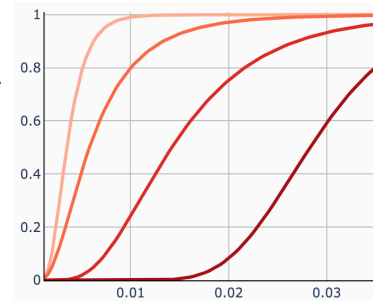
Develop Surrogate Models for Damage and Loss Assessment

Leverage the advanced surrogate modeling capabilities through built-in UQ engines to reproduce the results of complex damage and loss simulations at a fraction of the original computation time. Use PBE to perform a series of simulations that will provide training data linking demands to damage or losses. Utilize built-in surrogate modeling tools to train and export models for use in future PBE or R2D simulations.
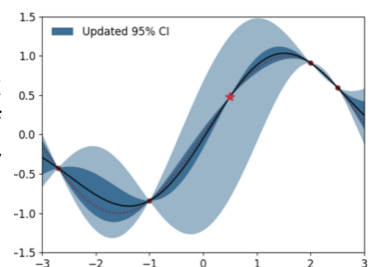
CURRENT CAPABILITIES

Structural Response: Provides a set of response quantities that are used to characterize the demands acting on the structure under the natural hazard event. The following options are available:

- Use the integrated EE-UQ modules to set up a seismic response simulation workflow. Standard earthquake EDPs are automatically prepared and passed on to the damage and loss calculation.
- Import external demand data in a tabulated format. This option supports any arbitrary hazard and corresponding EDPs as well as any calculation method performed outside of the PBE application.

Damage and Loss: Define a set of interconnected models in the Pelicun framework that describe (1) the quantities and locations of vulnerable components in a structure, (2) the demands acting on each component, and (3) the resulting damage. Then, map the damage to economic losses, repair times, and other environmental consequences. The following options are available:

- Use built-in libraries and methods for a standard FEMA P-58 or Hazus Earthquake assessment.
- Extend FEMA P-58 or Hazus analyses with additional components in your own component library.
- Develop new methods by creating your own damage process and loss map.

Functional Recovery: Use functional recovery simulation engines to estimate the recovery process and the time it takes to reach important milestones during recovery. The PBE application includes ARUP's REDi methodology for calculations based on results of a FEMA P-58 analysis, where a user-defined JSON file provides the additional inputs required for the REDi calculation. Damage and loss output data can also be integrated into workflows as input for other recovery methods.

Uncertainty Quantification: Sample the prescribed random input variables and obtain realizations of the outputs by executing the workflow with each input realization from the generated sample. The underlying UQ engines let you leverage the following techniques in your research:

- Forward propagation: Define a set of random input parameters and perform Monte Carlo simulations to obtain a corresponding sample of output parameters.
- Surrogate models: Generate training data, develop and utilize surrogate models that employ Gaussian Process and Probabilistic Learning on Manifolds techniques.

UPCOMING CAPABILITIES

- Facilitate wind damage and loss calculations by adding relevant vulnerability and loss components. The building-level components from the Hazus Hurricane Methodology will be complemented by components from recent research that support higher-resolution analyses. (Jun 2024)
- Integrate additional functional recovery simulation engines, including the ATC 138 methodology, TREADS. This will enable benchmarking and further development of these methods (Sep 2024)
- Automatic access to physics-based ground motion simulation results (Sep 2024)
- Facilitate water damage and loss calculation by adding relevant vulnerability and loss components. The building-level components from the Hazus Flood Methodology will be complemented by components from recent research that support higher-resolution analyses. (Dec 2024)

MORE INFORMATION

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