Progetto DPC-ReLUIS 2024-2026 WP 11
Task 4 – Rischio Uniforme (G. Monti)

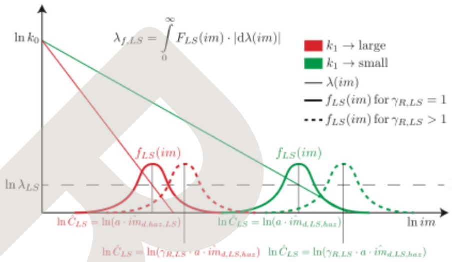
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

From Uniform-Reliability to Uniform-Risk Seismic Design

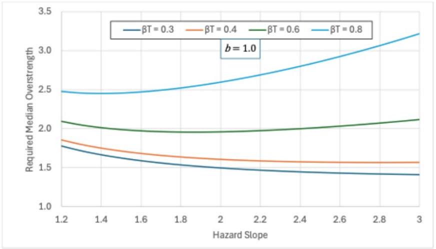
G. Monti, C. El Moussawi, R. Rahmat Rabi
Sapienza Università di Roma

Scope and Motivation

EN1998-1-1:2024 introduces reliability-based targets (Annex F).
Current formulation → uniform *reliability*, not uniform *risk*.
Hazard curve slope k is critical for real risk consistency.



Schematic of the different elements for calculating the mean annual Limit State (LS)-exceedance frequency, f_{LS}. $f_{LS}(im)$ denotes the PDF of the fragility function.

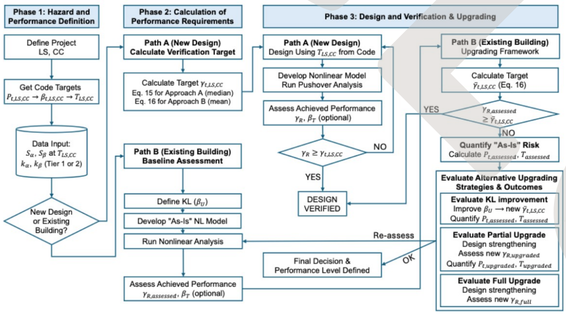


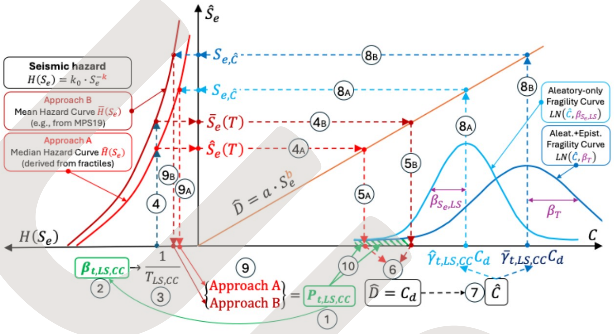
Required median performance factor $\hat{\gamma}_{t,LS,CC}$ as a function of hazard slope k for different total fragility dispersions β_T, for CC2, SD Limit State. With $b = 1.0$ (equal displacement), the reference value in Annex F ($\beta_{S_e,LS} = 0.6$, with $\beta_U = 0$) yields a slope-neutral outcome, approximating a uniform-reliability design.

Method

Simplified Workflow Diagram:
Inputs: Code targets (β, P_f), hazard slope k, fragility (β_T)
Process: Hazard & fragility → Target performance factor $\gamma_{t,LS,CC}$
Outputs: Verification KPI for design/assessment

Two Approaches:
Approach A (Median hazard):
Routine design → hazard slope + aleatory uncertainty only
Approach B (Mean hazard):
Robust → hazard slope + aleatory + epistemic uncertainty

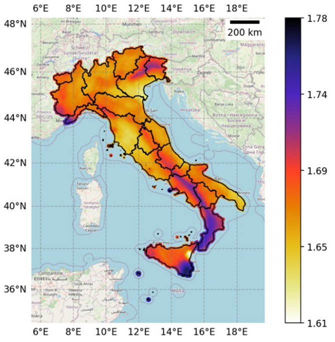


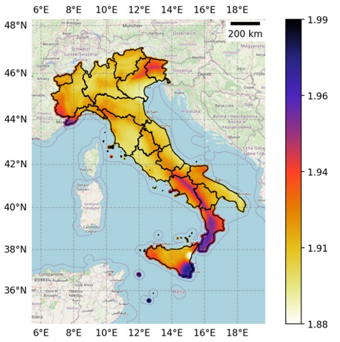


Workflow of the risk-targeted verification procedure, showing the connection between hazard curve, structural capacity, and target probability of exceedance of EN 1998-1-1:2024. The workflow proceeds from code targets (Steps 1-3), through hazard and fragility models (Steps 4-8), to final risk verification (Steps 9-10) to finally compute the factor $\gamma_{t,LS,CC}$.

Results & Insights

1. Target performance factor $\gamma_{t,LS,CC}$ is a **KPI** linking hazard, uncertainty & performance
2. Engineer checks compliance with $\boldsymbol{\gamma}$_$(\boldsymbol{t,LS,CC})$ (easier than $\boldsymbol{\beta}_{t,LS,CC}$)
3. Uniform reliability ≠ uniform risk → **local slope $\boldsymbol{k}$ matters**
4. Enables rational **design verification & retrofit strategies**





Maps of Required Target Performance Factor ($\gamma_{t,LS,CC}$) for SD Limit State, CC2, $\beta_{S_e,LS} = 0.6$.
(left) Median-Based Target ($\hat{\gamma}_{t,LS,CC}$) calculated with $\hat{k}_\alpha$.
(right) Mean-Based Target ($\bar{\gamma}_{t,LS,CC}$) calculated with $\hat{k}_\alpha$ and $\beta_U = 0.4$.

Case Study: L'Aquila retrofit path

The table shows the initial "As-Is" performance and how it is improved first by enhancing knowledge (β_U) and then by implementing physical upgrades (γ_R). The final performance is expressed in terms of the risk-consistent return period (T_{eq}).

Stage	β_U (Knowledge)	γ_R (Achieved)	γ_t (Benchmark)	Quantified Performance T_{eq}	Status
Initial Assessment	0.40 (KL2)	1.8 (As-Is)	2.20	344 years	Non-Compliant
After Improving Knowledge	0.25 (KL3)	1.8 (As-Is)	2.08	378 years	Non-Compliant, but improved
After Partial Upgrade	0.25 (KL3)	2.00	2.08	442 years	Compliant*
Full Upgrade	0.25 (KL3)	≥ 2.08	2.08	≥ 473 years	Compliant