

Accounting for structural response correlation in EDP-based scenario seismic risk assessment

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Two identical buildings, same street, same contractor, same year

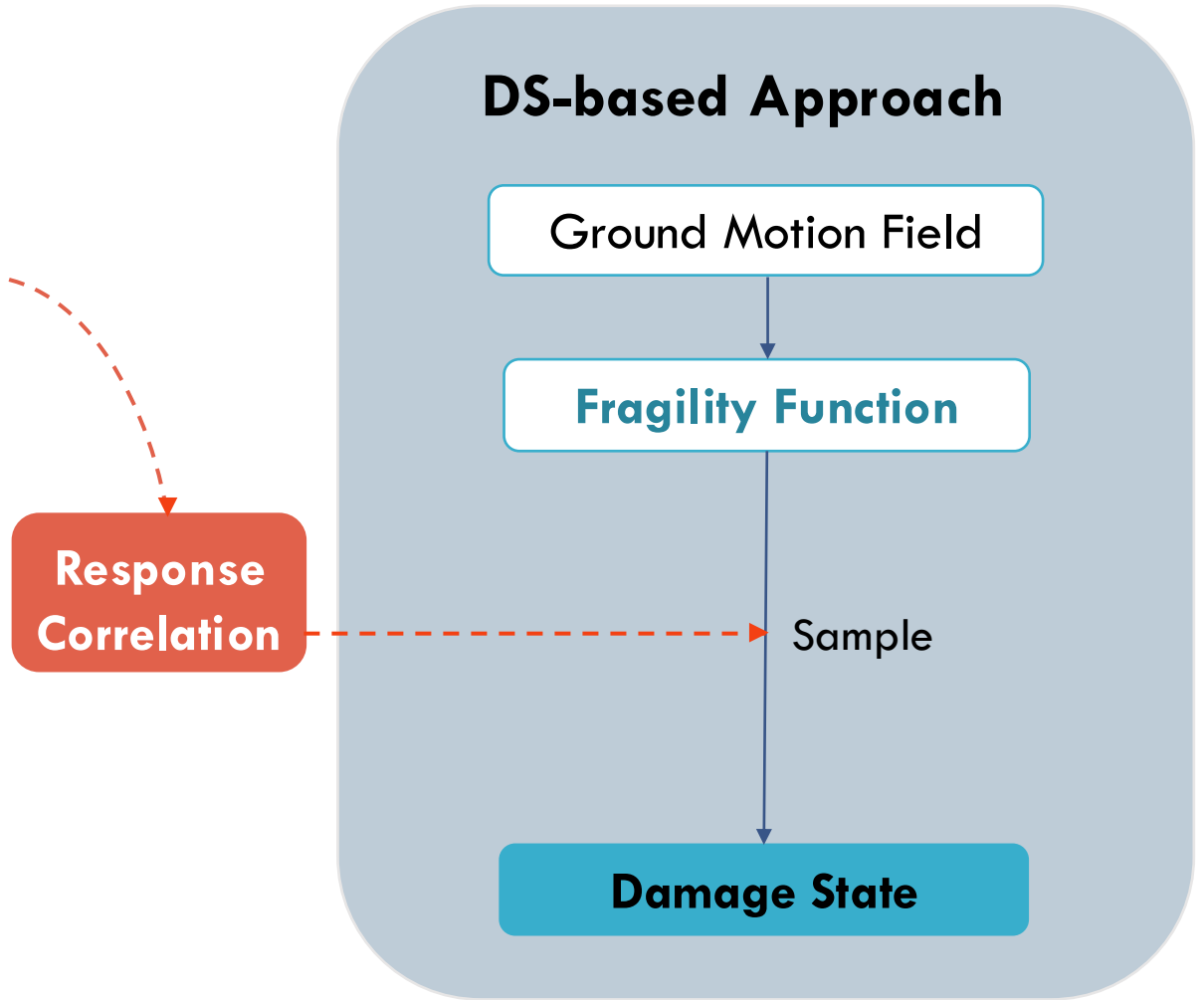
One of them has not collapsed

Does that tell you anything about the other?

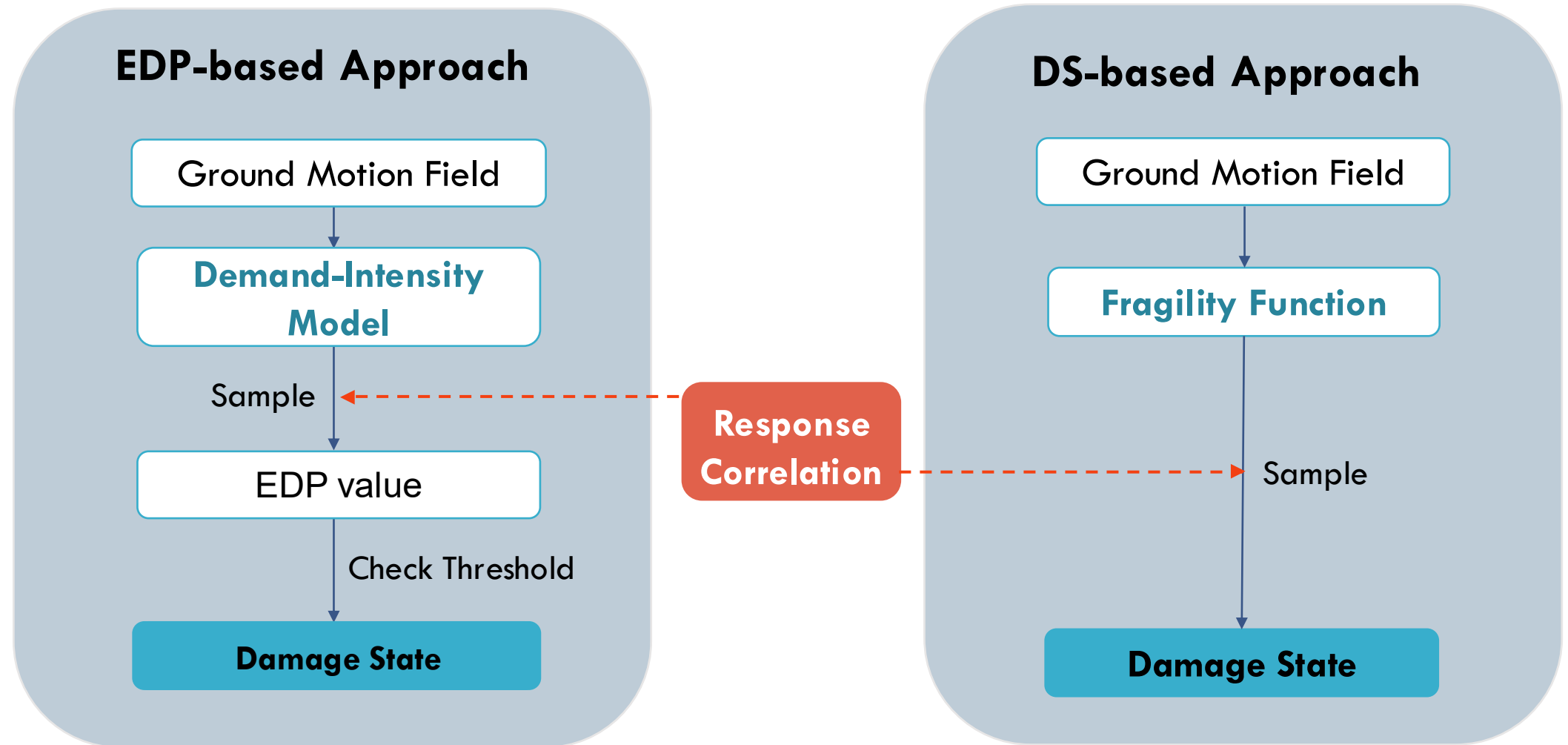


Using the typical approach can become very complex

$$\Sigma_X = \left[\begin{array}{c} \begin{array}{cc} \text{Class } t & \dots \\ \hline \text{Bdg. } a & \dots & \text{Bdg. } b \\ \hline \{ \text{DS}_k \dots \text{DS}_l \} & \{ \text{DS}_k \dots \text{DS}_l \} \\ \left[\begin{array}{cc} \delta_{a,a}^{k,k} & \dots & \delta_{a,a}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{a,a}^{l,k} & \dots & \delta_{a,a}^{l,l} \end{array} \right] & \left[\begin{array}{cc} \delta_{a,b}^{k,k} & \dots & \delta_{a,b}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{a,b}^{l,k} & \dots & \delta_{a,b}^{l,l} \end{array} \right] \\ \vdots & \vdots \\ \left[\begin{array}{cc} \delta_{b,b}^{k,k} & \dots & \delta_{b,b}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{b,b}^{l,k} & \dots & \delta_{b,b}^{l,l} \end{array} \right] & \vdots \\ \vdots & \vdots \end{array} & \begin{array}{cc} \text{Class } u & \\ \hline \text{Bdg. } c & \dots & \text{Bdg. } d \\ \hline \{ \text{DS}_k \dots \text{DS}_l \} & \{ \text{DS}_k \dots \text{DS}_l \} \\ \left[\begin{array}{cc} \delta_{a,c}^{k,k} & \dots & \delta_{a,c}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{a,c}^{l,k} & \dots & \delta_{a,c}^{l,l} \end{array} \right] & \left[\begin{array}{cc} \delta_{a,d}^{k,k} & \dots & \delta_{a,d}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{a,d}^{l,k} & \dots & \delta_{a,d}^{l,l} \end{array} \right] \\ \vdots & \vdots \\ \left[\begin{array}{cc} \delta_{b,c}^{k,k} & \dots & \delta_{b,c}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{b,c}^{l,k} & \dots & \delta_{b,c}^{l,l} \end{array} \right] & \left[\begin{array}{cc} \delta_{b,d}^{k,k} & \dots & \delta_{b,d}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{b,d}^{l,k} & \dots & \delta_{b,d}^{l,l} \end{array} \right] \\ \vdots & \vdots \\ \left[\begin{array}{cc} \delta_{c,c}^{k,k} & \dots & \delta_{c,c}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{c,c}^{l,k} & \dots & \delta_{c,c}^{l,l} \end{array} \right] & \left[\begin{array}{cc} \delta_{c,d}^{k,k} & \dots & \delta_{c,d}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{c,d}^{l,k} & \dots & \delta_{c,d}^{l,l} \end{array} \right] \\ \vdots & \vdots \\ \left[\begin{array}{cc} \delta_{d,d}^{k,k} & \dots & \delta_{d,d}^{k,l} \\ \vdots & \ddots & \vdots \\ \delta_{d,d}^{l,k} & \dots & \delta_{d,d}^{l,l} \end{array} \right] & \vdots \end{array} \end{array} \right]$$



There is an alternative



EDPs are sampled from Demand-Intensity models

- It is considered that:

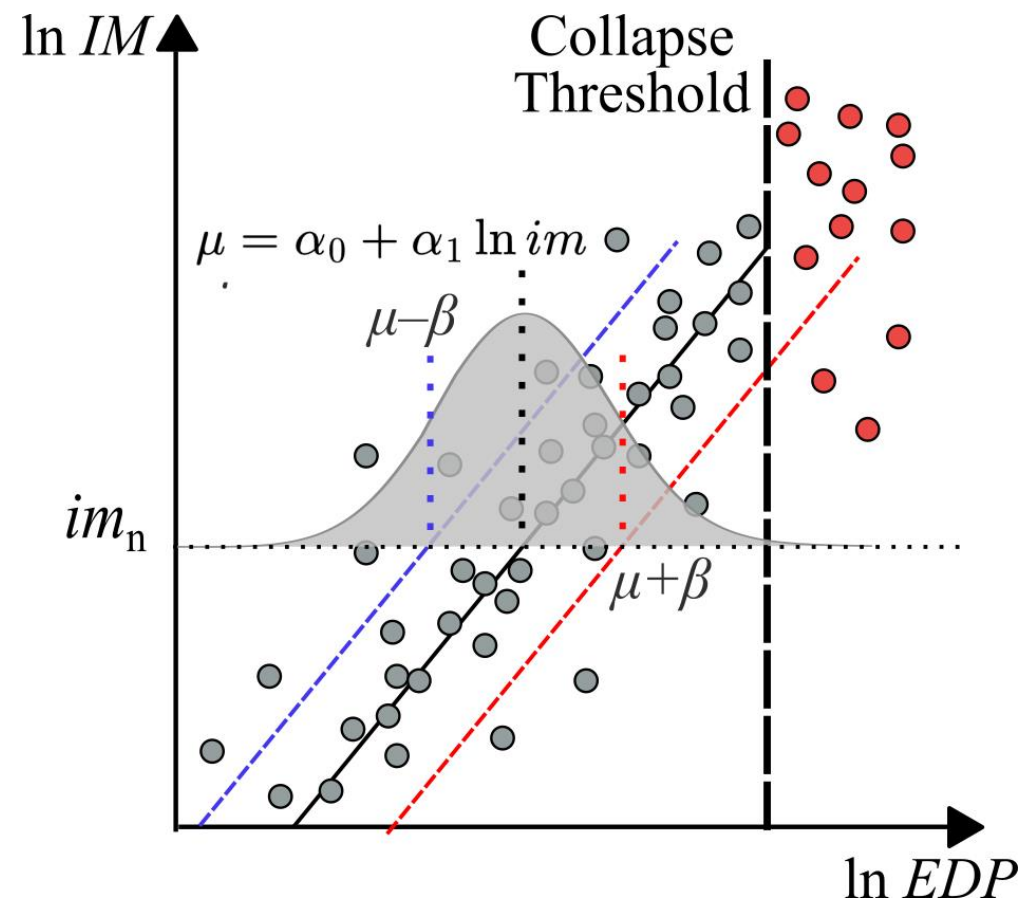
$$\ln EDP \mid \ln IM \sim N(\mu_{\ln EDP \mid \ln IM}, \beta)$$

- To sample:

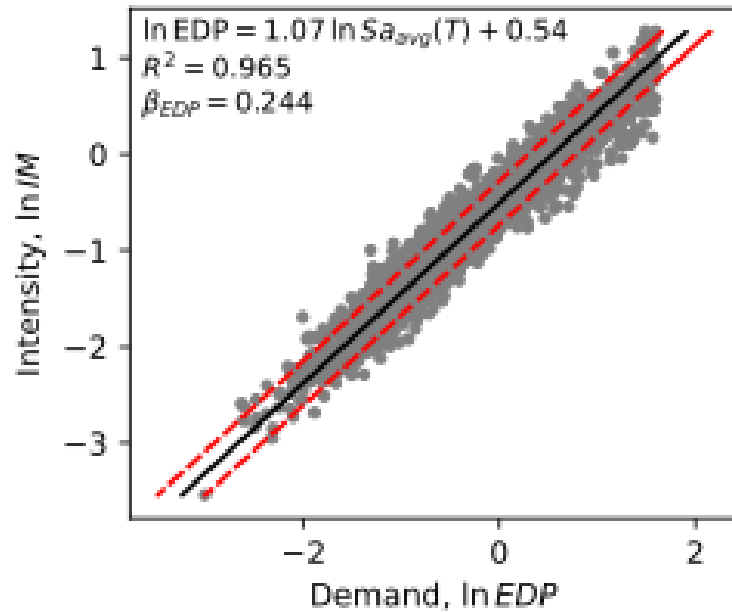
$$\ln EDP \mid \ln IM = \mu_{\ln EDP \mid \ln IM} + \varepsilon \beta$$

with:

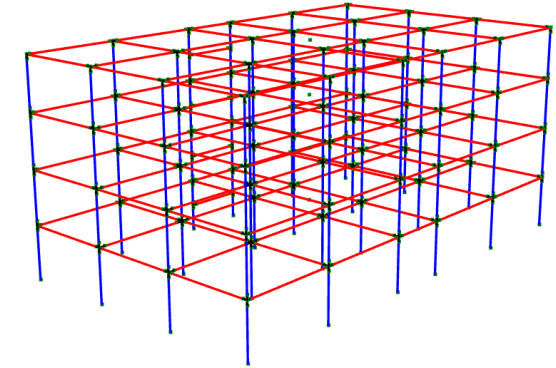
$$\varepsilon \sim N(0,1)$$



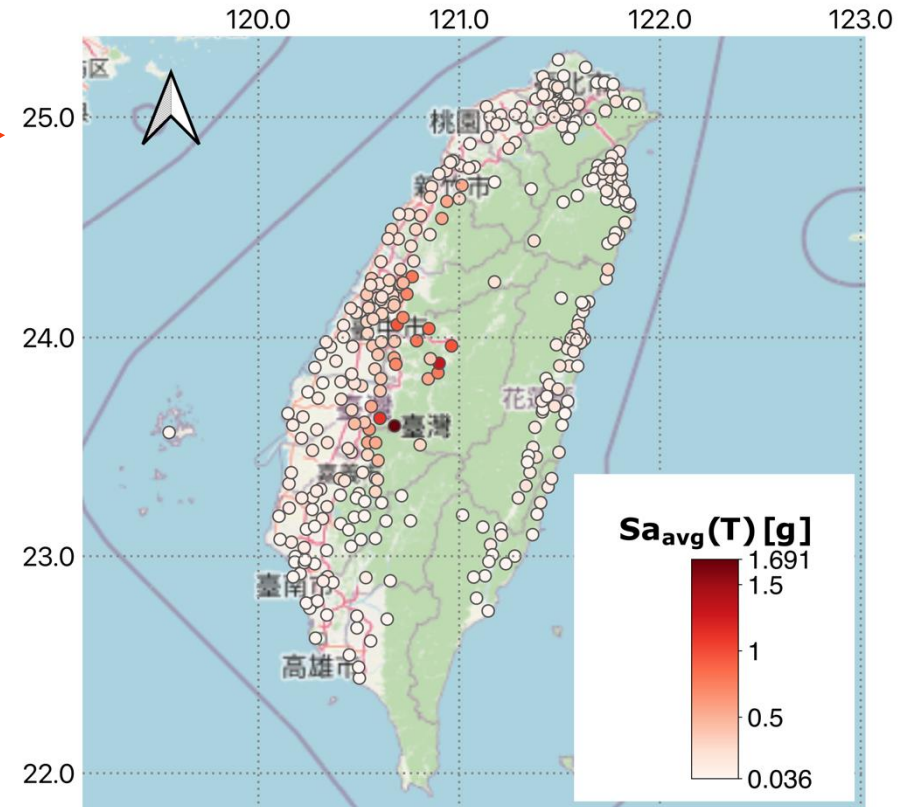
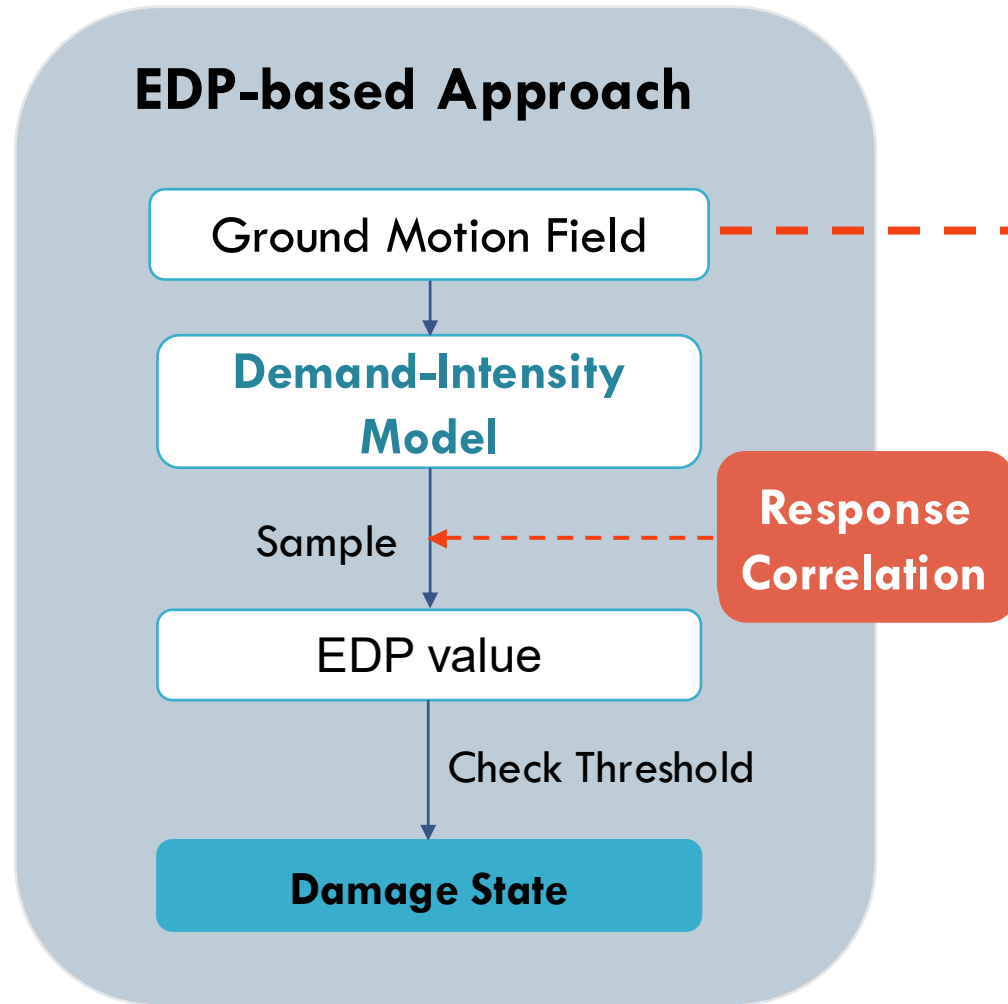
Let's test it with an example



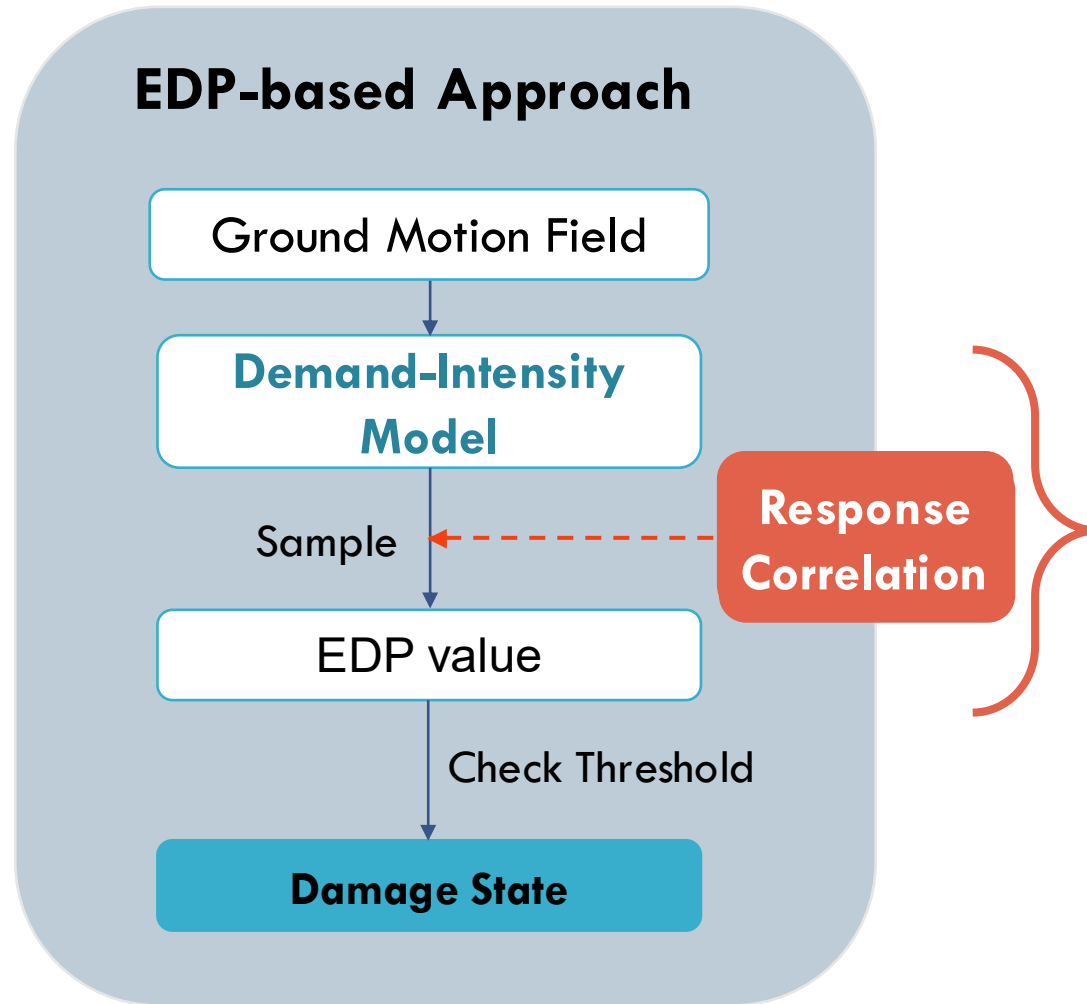
- Openses model of 80 buildings generated with **BED's simulated Design** for a common building class
- **Cloud analysis** on **equivalent SDOF** oscillator of each building
- **500 records** selected with an unconditional approach
- Determination of building specific and typology's Demand-Intensity models



Now, for the actual EDP-based assessment...



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$$1) \mu_{\ln EDP | \ln IM}^{\text{typ}} = 1.06 \cdot \ln Sa_{\text{avg}}(T) + 0.57$$

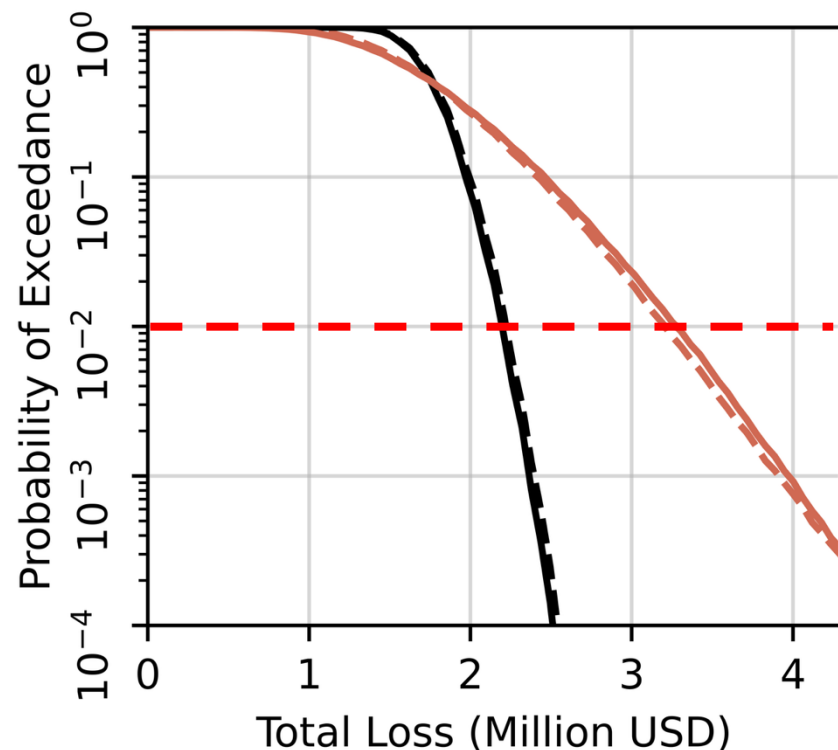
2) Sample a set of correlated or uncorrelated EDP residuals for all buildings

- Correlation calculated for **building a** and **building b** as:

$$\rho_{a,b}(h, \Delta T, \Delta Sa_y) = \underbrace{e^{\left(-\frac{h}{c_2}\right)^{c_1}}}_{\text{Spatial Component}} \underbrace{\left(c_3 \cdot e^{\left(-\frac{\Delta T}{c_4}\right)} + (1 - c_3) e^{\left(-\frac{\Delta Sa_y}{c_5}\right)} \right)}_{\text{Structural Component}}$$

$$3) \ln EDP | \ln IM = \mu_{\ln EDP | \ln IM}^{\text{typ}} + 0.282 \varepsilon$$

Repeat 500,000 times to get loss exceedance curves



--- DS-based: Independent — EDP-based: Independent
--- DS-based: Correlated — EDP-based: Correlated

Loss with 1 % probability of exceedance:

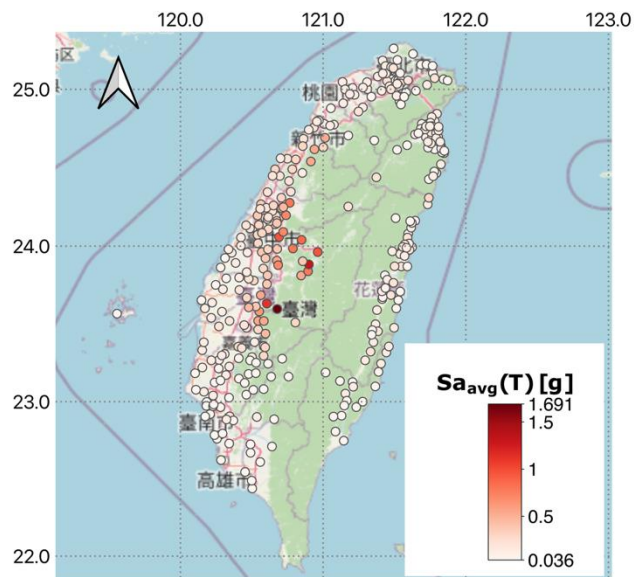
- Independent: **2.20 M USD**
- Correlated: **3.28 M USD**

+49%

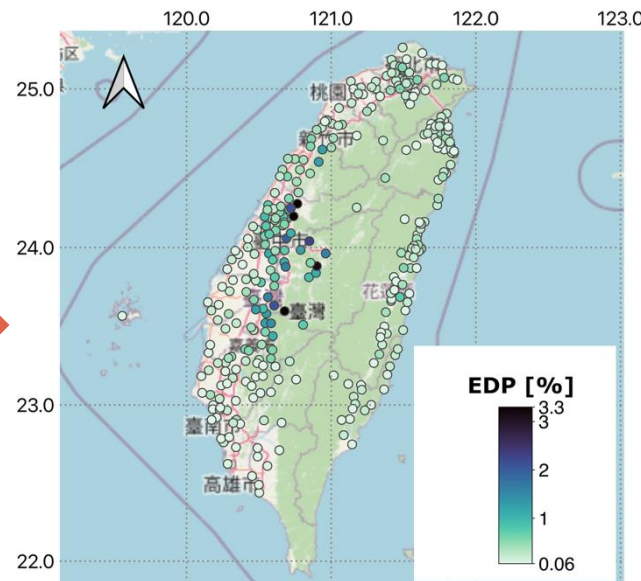
in total loss when considering response correlation

How realistic are this results?

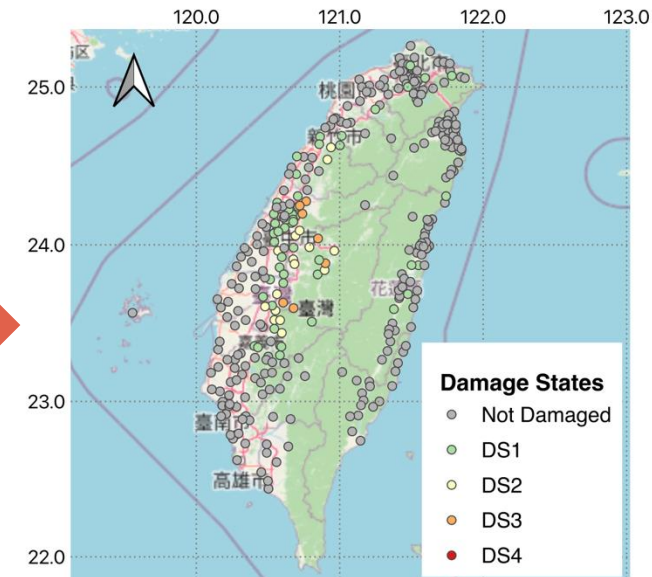
Use as-recorded ground motions



Assign a random building and perform NLTH analyses



Check actual damage states



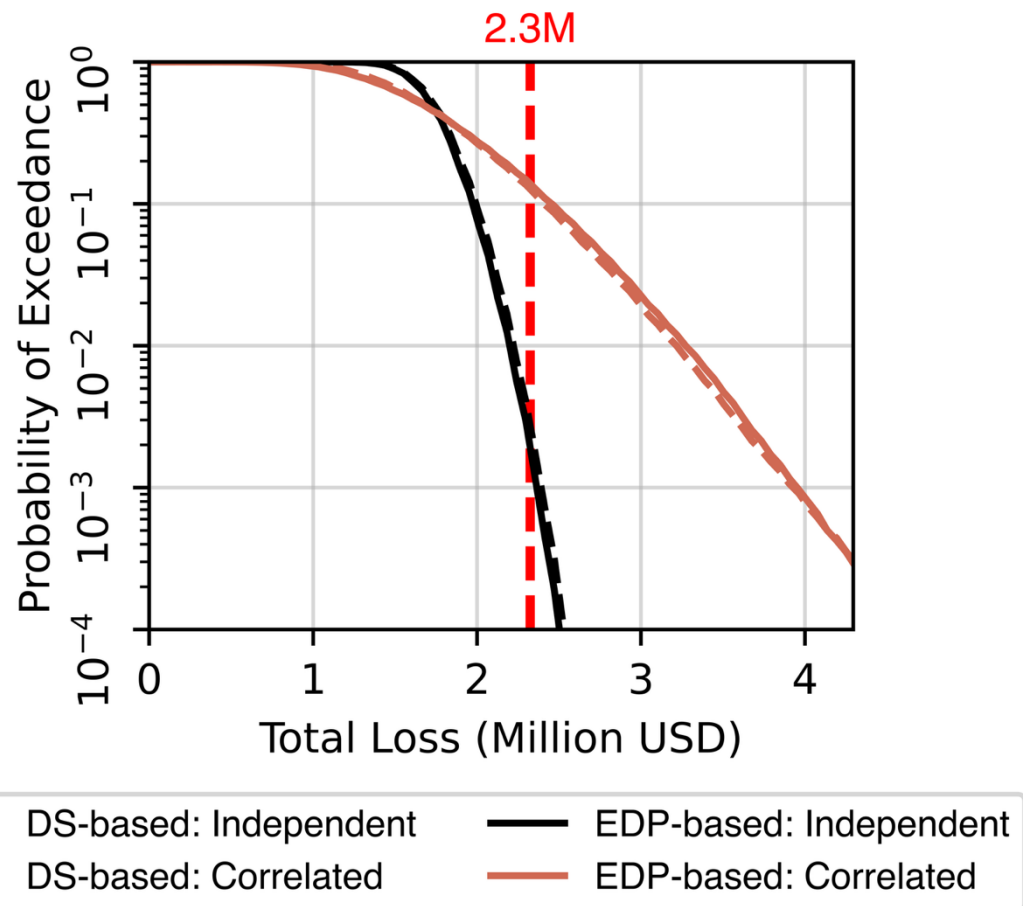
75 buildings

result in the exceedance of DS_1

2.3 M USD

is the estimated “real” loss

Much more realistic!



Probability of exceeding real loss (2.3M USD):

- Independent: **0.2%**
- Correlated: **14.3%**
- It was verified the source was not a biased demand-intensity model
- The incorporation of the response correlation yields a result closer to what was expected

Conclusions

- Incorporate the response correlation at an **EDP level is simpler** than at a DS level
- Results of both approaches can be **analogous** if done rigorously
- Response correlation can **significantly impact** the results of the assessment
- Incorporating Response correlation results in more **reliable loss-distribution tails**



Mejia, Tomas; O'Reilly, Gerard J. (2026) "Accounting for Structural Response Correlation in EDP-Based Scenario Seismic Risk Assessment", 18th European Conference on Earthquake Engineering, Berlin Germany.