Seismic Assessment of Reinforced Concrete Buildings based on Fatality Risk

QuakeCoRE DT2 – **Workshop**
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BACKGROUND

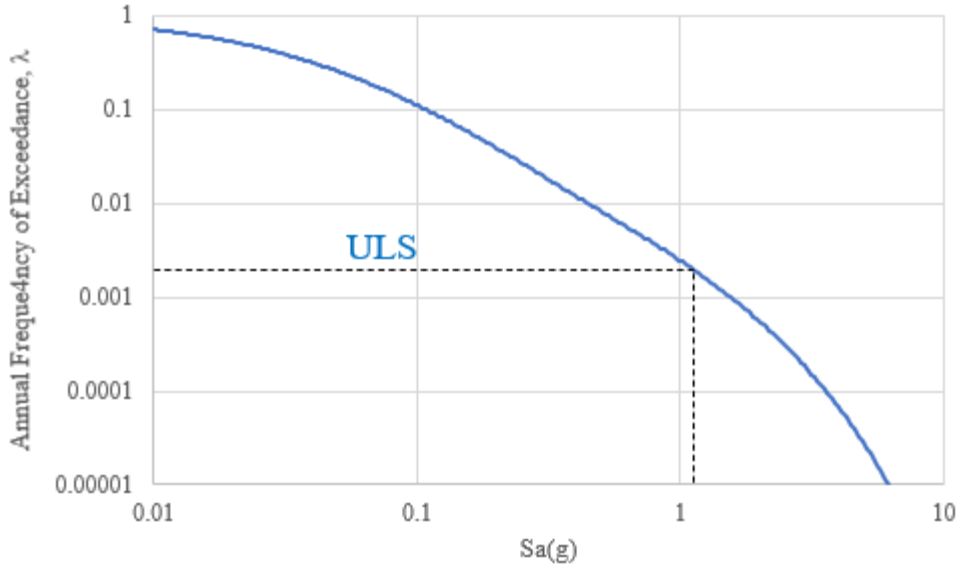
NZ ASSESSMENT GUIDELINES

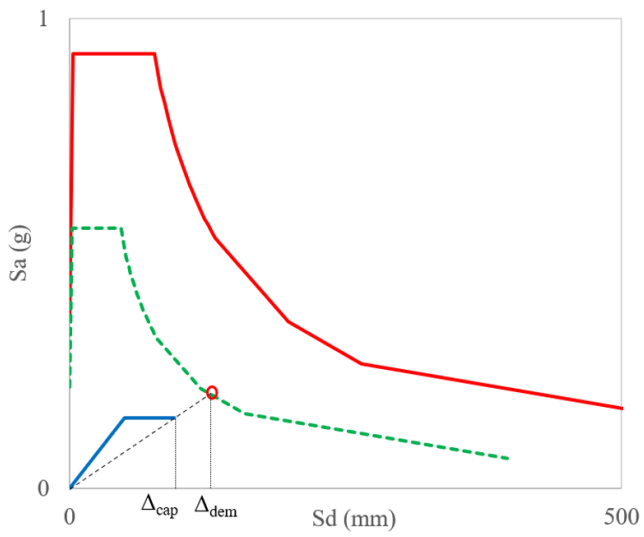
*"The rating provides a measure of the expected performance from a **life safety** point of view, compared with the minimum required by the Building Code for new buildings."*

$$\%NBS = \frac{\text{Ultimate Capacity (Seismic)}}{\text{ULS Seismic Demand}} \times 100$$

Significant Risk to Life Safety - Subjective

Not expressed in terms of risk metric





BACKGROUND

BUILDING CLOSURES

Te Awamutu Museum and staff building closed due to seismic risk

Waikato Herald

25 Oct, 2022 12:05 PM · 3 mins to read

Save Share

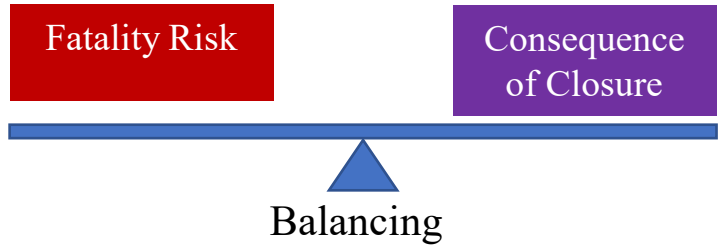
Hastings District Council staff to vacate earthquake-risk building

Georgia-May Gilbertson · 17:05, Jun 27 2020

Wellington Central Library to close indefinitely due to earthquake concerns

Felix Desmarais and Andre Chumko · 19:51, Mar 19 2019

Building closure has consequences

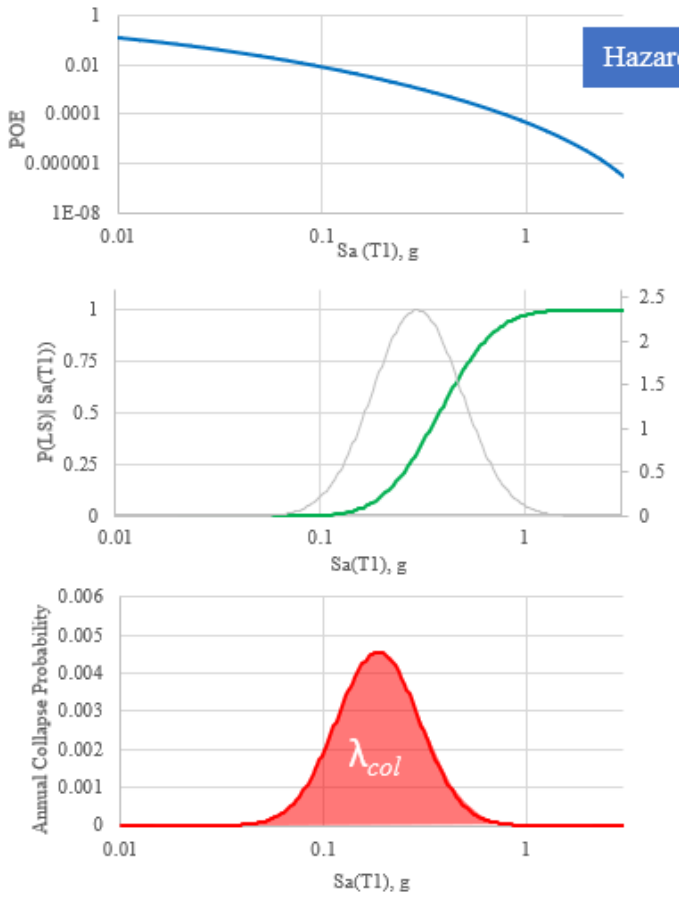


BACKGROUND

DESIRED

- Probabilistic Framework – Account for uncertainties
- Consideration of different levels of shaking – Full Hazard Curve
- Risk Metric – Fatality Risk
- Objective decision making post seismic assessment – Based on risk to life safety

RISK BASED FRAMEWORK



Hazard Curve

Fragility PDF

$$\lambda_{col} = \int_0^{\infty} P(IM > im). \left| \frac{d(LS_{col})}{dIM} \right| dIM$$ (Risk Integral)

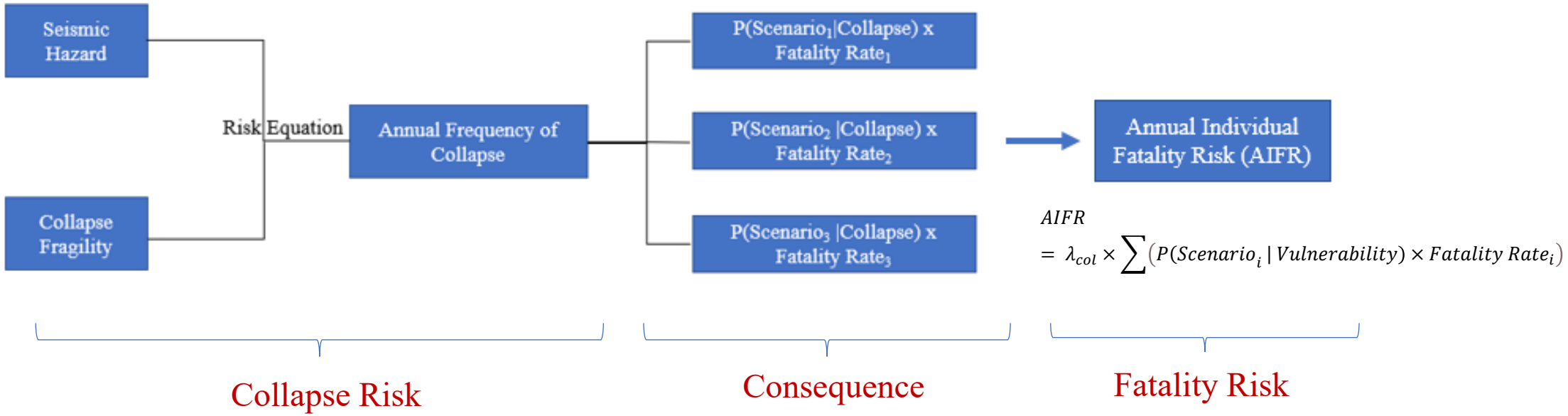
Mean Annual Frequency of Collapse

- Full hazard curve
- Capacity as a fragility function

Luco et. al. (2007)

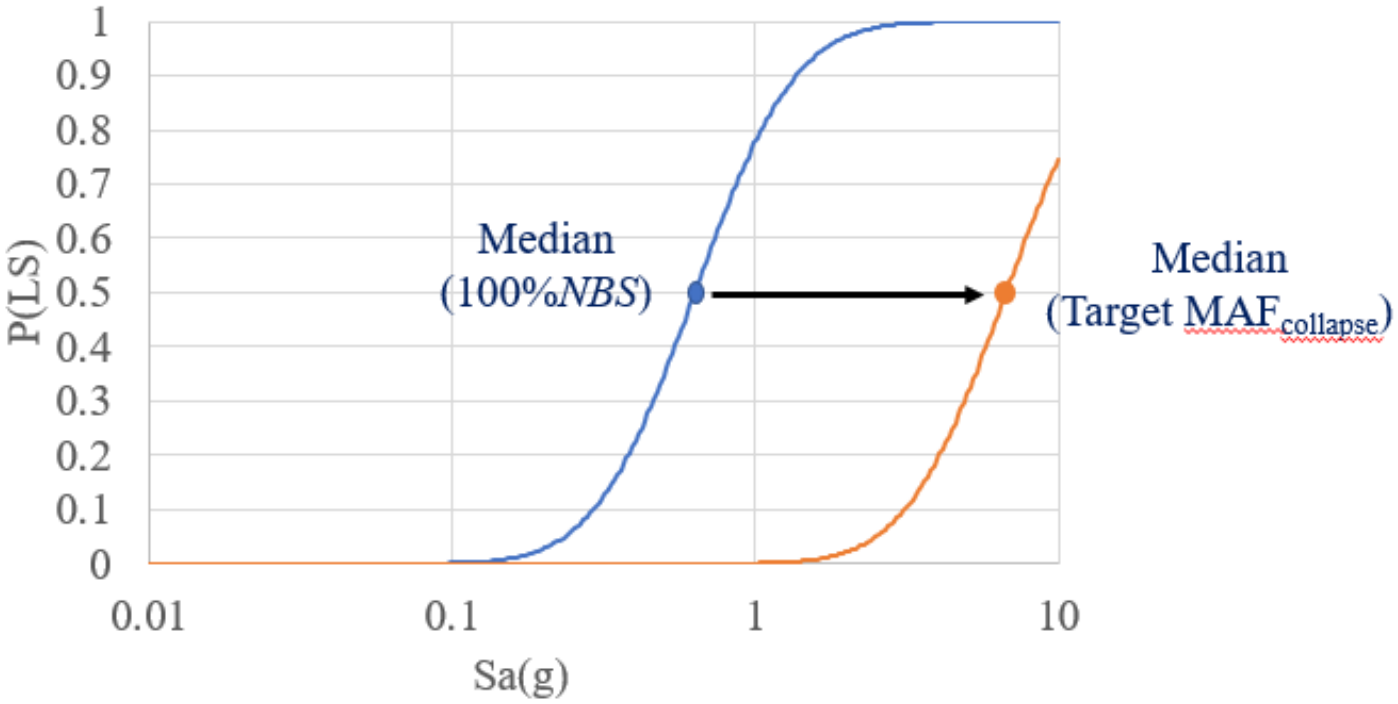
RISK BASED FRAMEWORK

- Collapse (Severe Damage State) fragility curves for identified vulnerabilities
- Recognizing variabilities in consequences of failure



RISK BASED FRAMEWORK

- Linking %*NBS* to Collapse Risk



- Collapse capacity is higher than assessed capacity for %*NBS*.
- Capacity represented by generic fragility curves / depending on vulnerabilities
- Target Mean Annual Frequency of Collapse ($MAF_{collapse}$) for building with 100%*NBS* ($= 10^{-5}$?)
- Collapse fragility$_{100\%NBS}$ λ_{col} = Target $MAF_{collapse}$

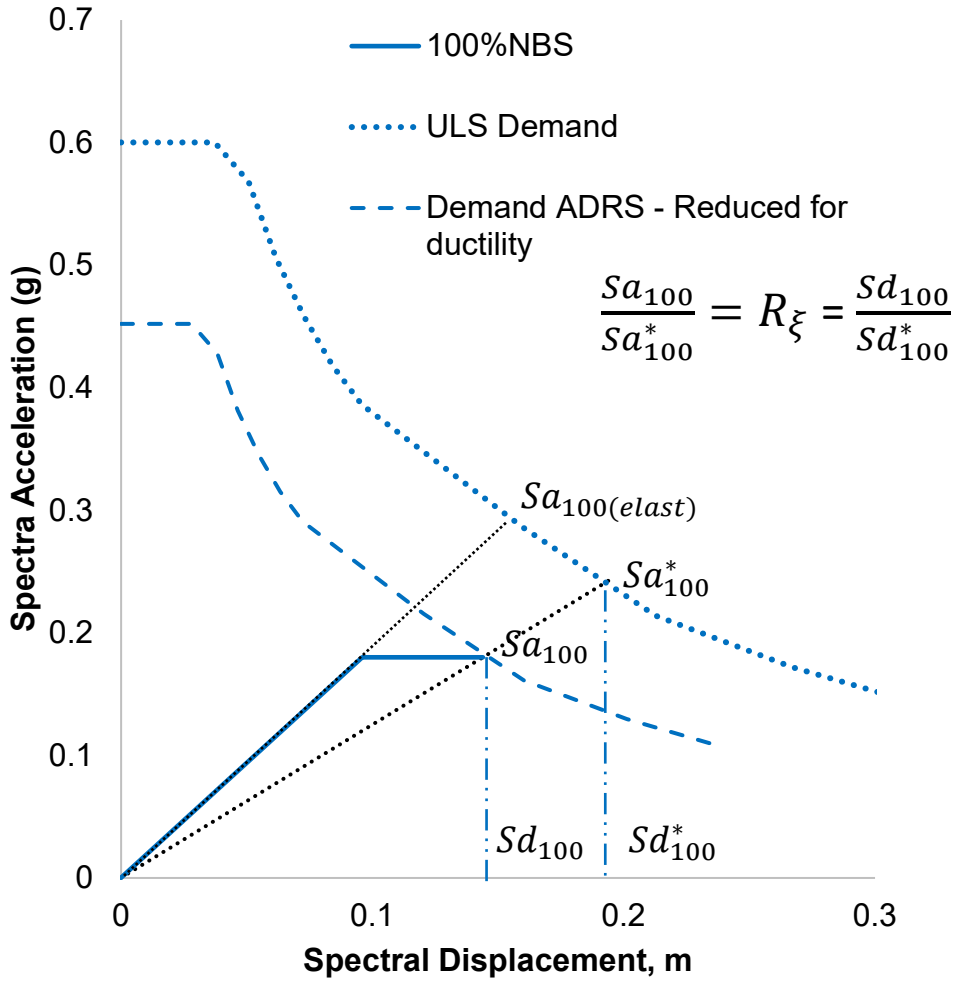
RISK BASED FRAMEWORK

- Assuming Median Sa(Collapse) scales linearly with *%NBS*

$$\frac{XX\%NBS}{100\%NBS} = \frac{Sa_{XX(elast)}}{Sa_{100(elast)}}$$

- Capacity of building *XX%NBS* - Generic fragility curve with median $Sa_{XX\%}$

- $\lambda_{col\ XX\%NBS}$ - Integration of hazard and fragility for building with *XX%NBS*



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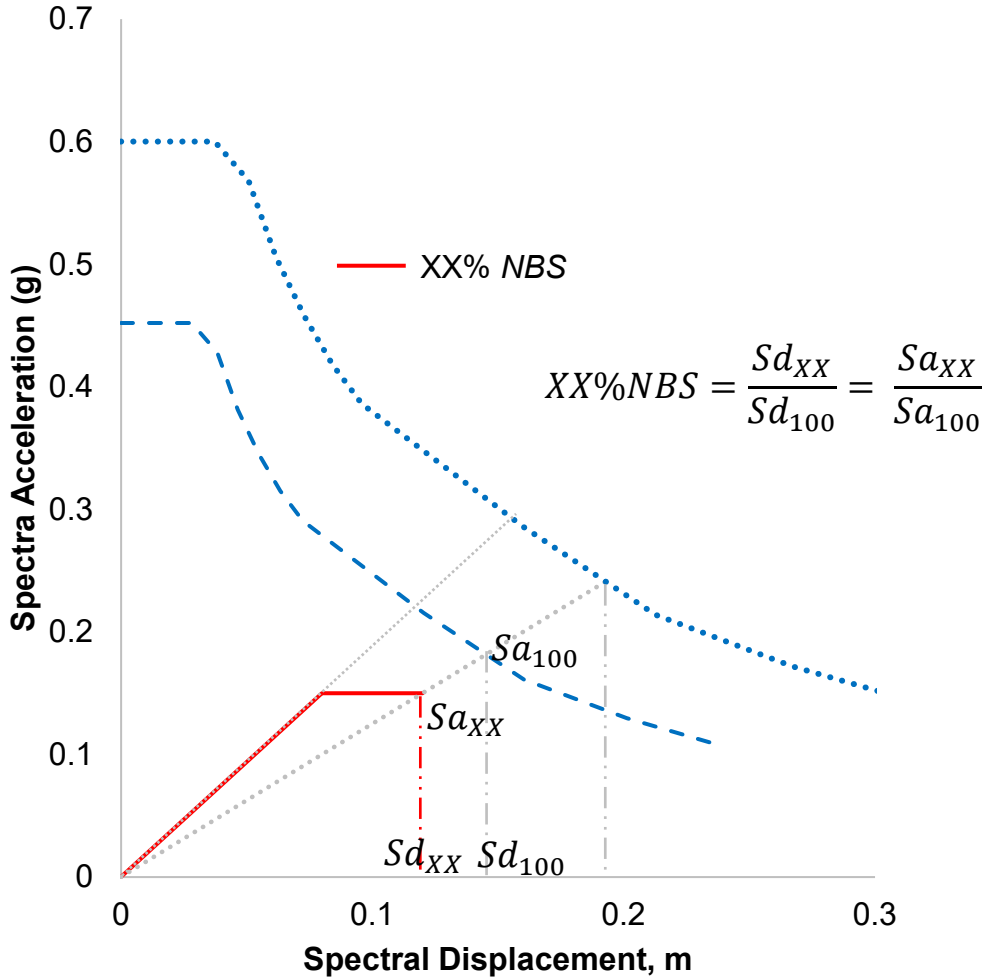

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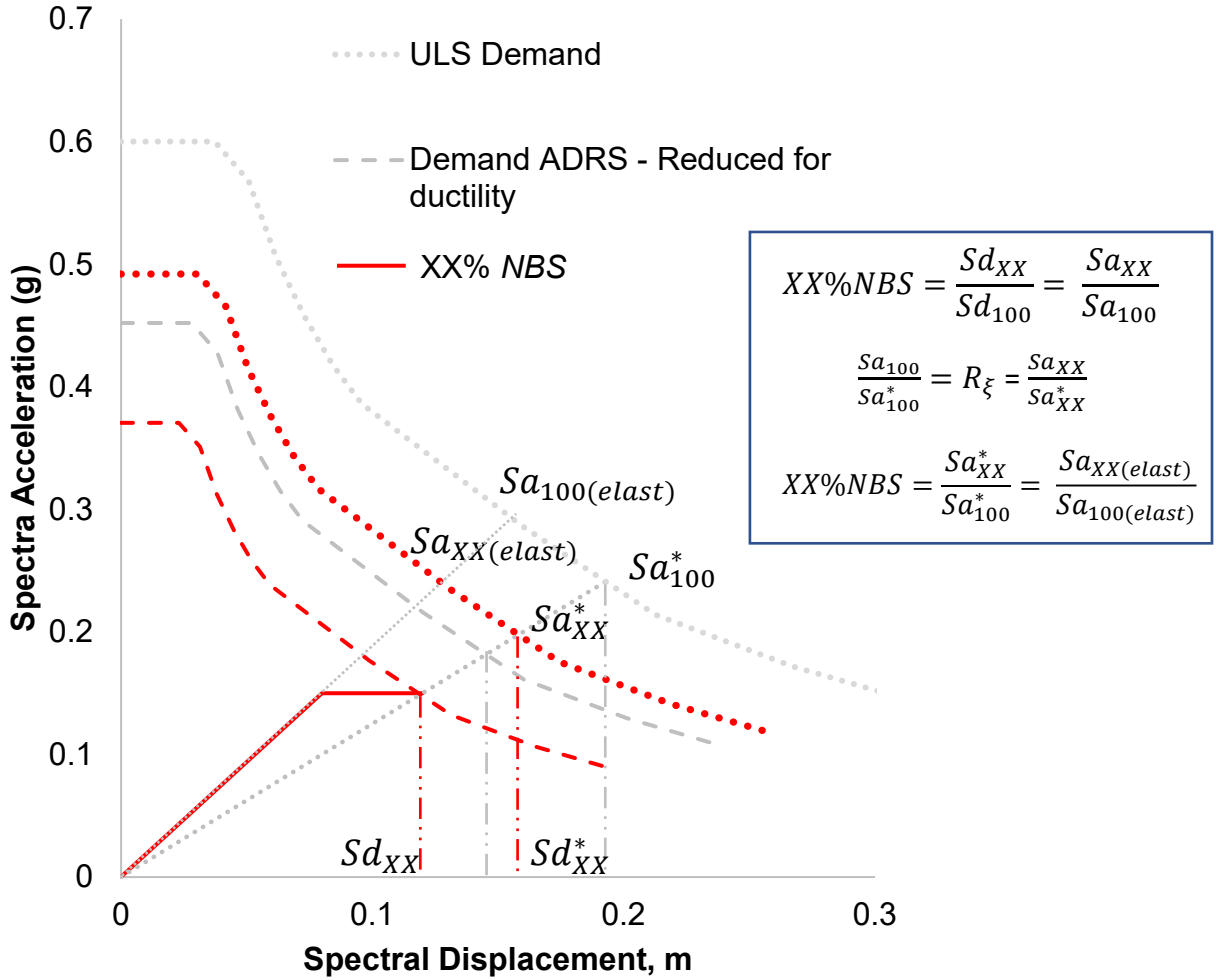
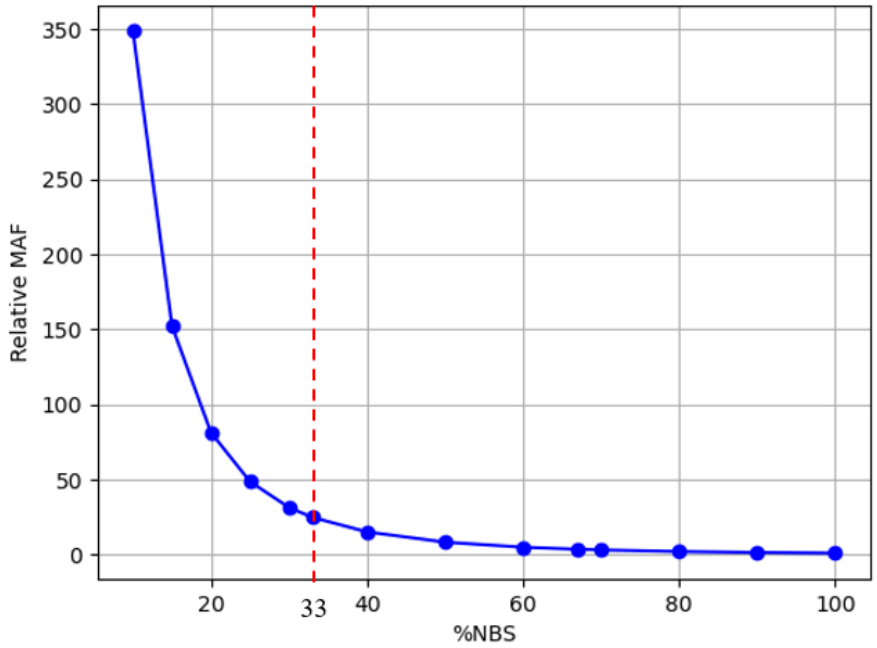


RISK BASED FRAMEWORK

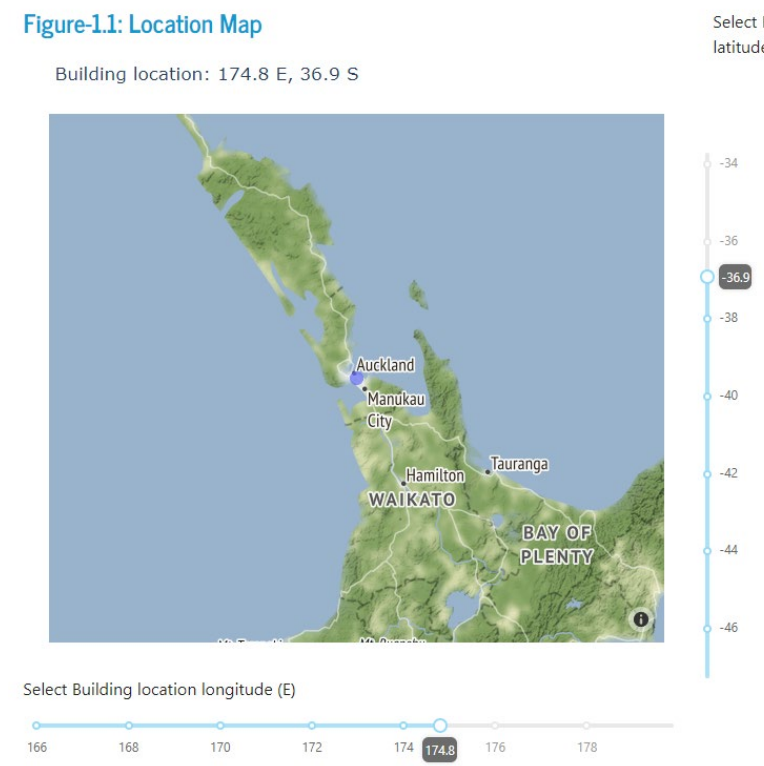
MAF collapse can be represented relative to a new building.

%NBS	NZSEE (2017) Table A3.1	Target MAF collapse $1x10^{-5}$	Target MAF collapse $2x10^{-4}$
>100	Less than or comparable to	Less than or comparable to	Less than or comparable to
80 to 100	1-2 times greater	1-2 times greater	1-2 times greater
67 to 79	2-5 times greater	2-4 times greater	2-3 times greater
34 to 66	5-10 times greater	4-27 times greater	3-13 times greater
20 to <34	10-25 times greater	27-53 times greater	13-22 times greater
<20	25 times greater	>53 times	>22 times



RESEARCH TOOL

- Fatality Risk Assessment Tool - Web Based Application



- Estimation of Fatality Risk
- Post Assessment Decision Making
- Vulnerability Information from Seismic assessment
- Realtime visualization of change in risk reduction based on retrofitting strategy

Building Information → Hazard Curve → Vulnerabilities and Fragilities → Risk Calculation → Risk Mitigation / Reduction → Retrofitting

RESEARCH TOOL

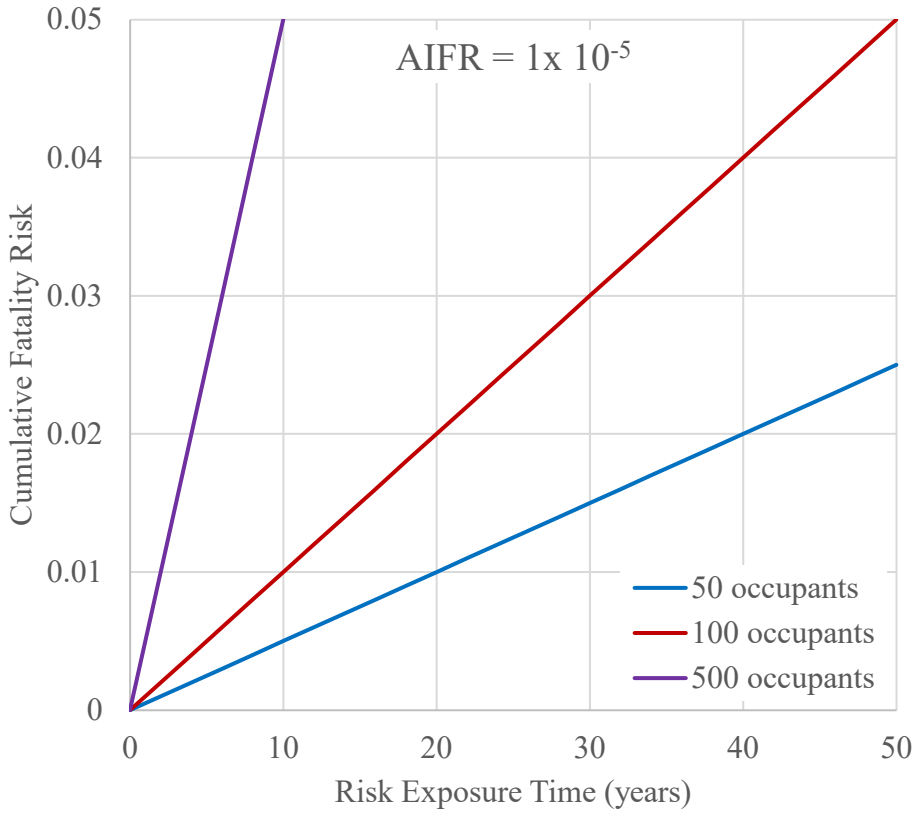
Mean Annual Frequency (MAF) of Collapse
Integration of hazard curve with fragility

$$\times \sum \left(P(Scenario_i \mid Vulnerability) \times Fatality\ Rate_i \right)$$

Annual Individual Fatality Risk (AIFR)

$$\times\ Occupancy_{avg} \times Exposure\ time$$

Cumulative Fatality Risk (CFR)



RESEARCH TOOL

Retrofitting:

- Retrofitting can be executed in many stages
- Each intervention tackles one or a few vulnerabilities
- Improvement in fragility and possible reduction in fatality rate
- Tracks risk reduction at the end of each stage

RESEARCH TOOL

Retrofit Execution Stage	Start Time from current date D(years)	End Time from current date D(years)	AIFR-Rel (End of Stage)	CFR (End of Stage)	Governing Vulnerability
RDM	0	0.1	16.2	0.00037	Vul. No. 1
PDR	0.1	0.6	16.2	0.0019	Vul. No. 1
1	0.6	1.6	3.2	0.00464	Vul. No. 6
2	2.1	2.6	3.2	0.0053	Vul. No. 6

Figure-4.1: AIFR reduction during retrofitting

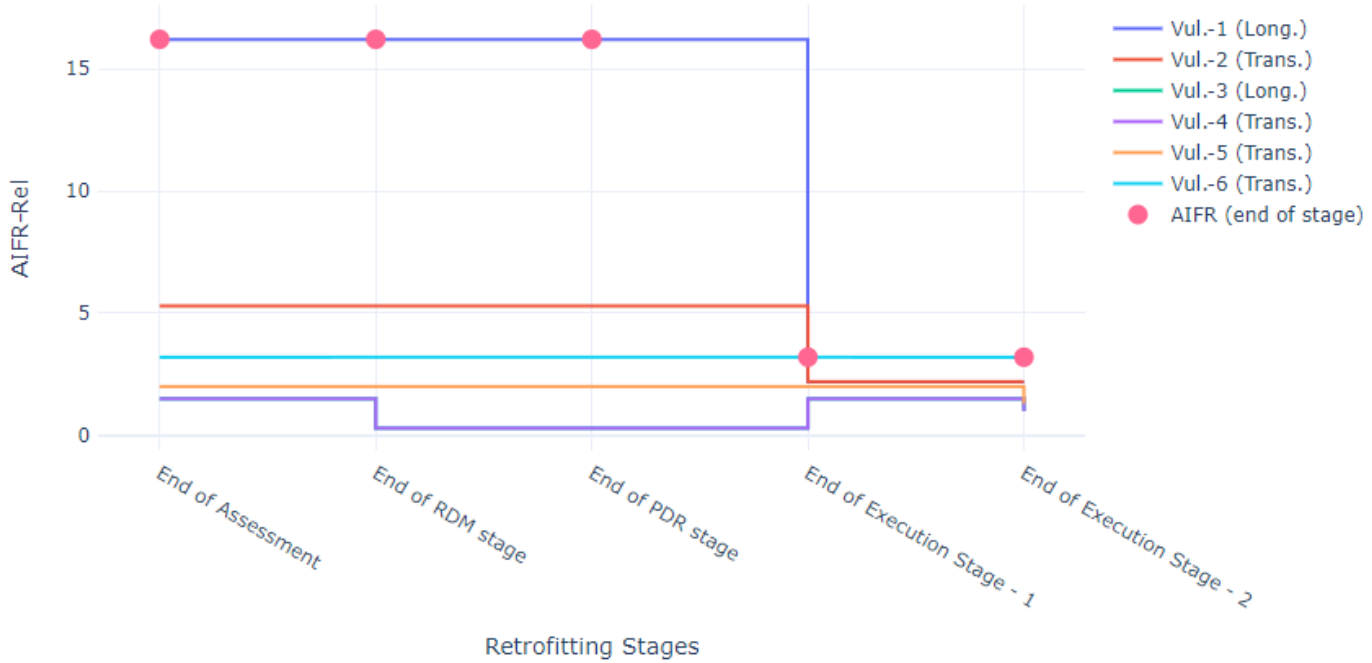
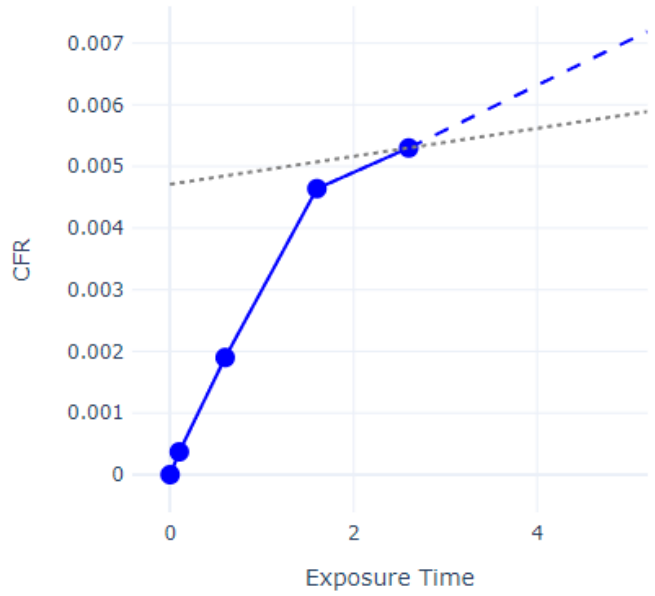
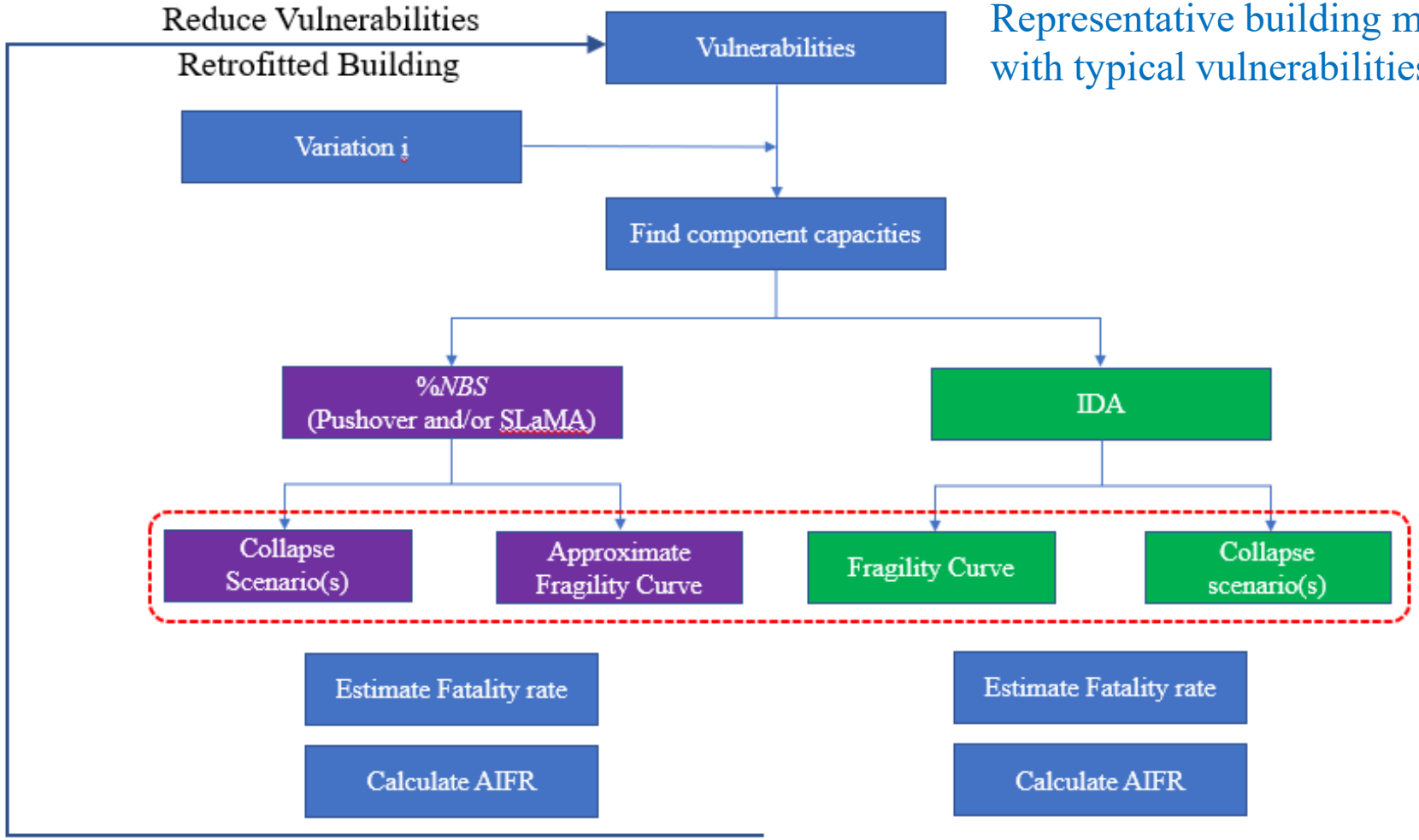


Figure-4.2: Risk accumulation during retrofitting



NON-LINEAR ANALYSIS



Representative building models with typical vulnerabilities

Appropriateness of %NBS linked fragility determination

Effect of vulnerability accumulation – Weighing of Vulnerabilities for risk calculation

Variation in collapse(scenarios)

Appropriate generic fragility curves

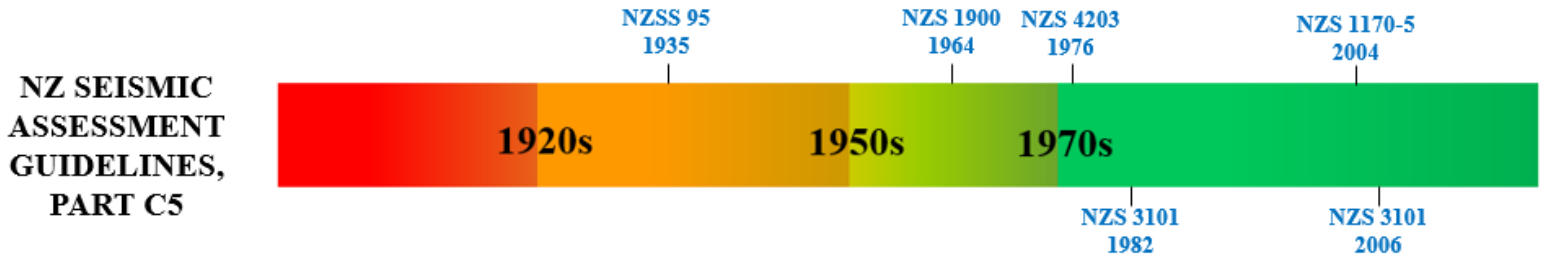
LARGE SCALE TESTING

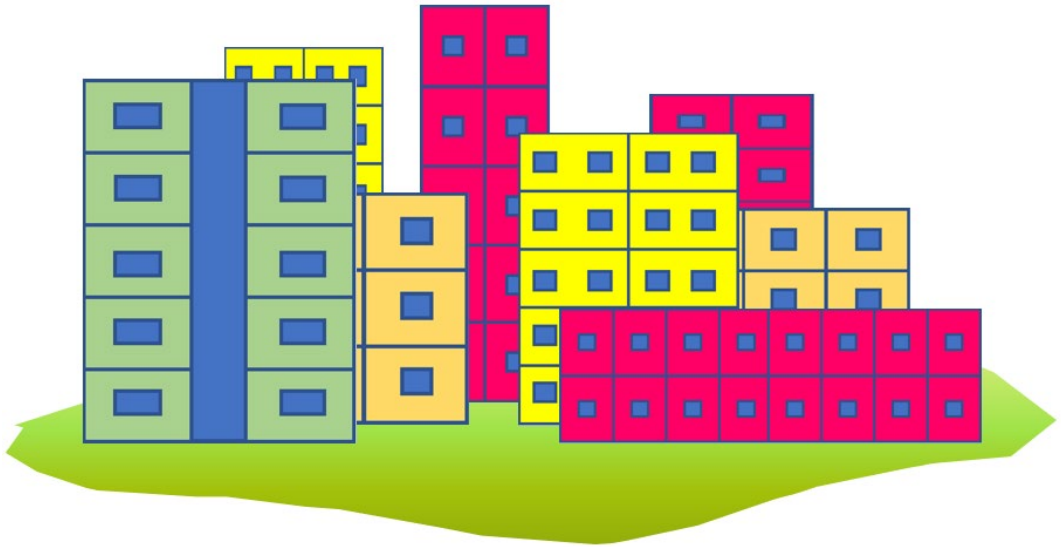
- Linking performance to fatality risk
- Assessment (%*NBS*) based on Component vulnerability
- Affect of component vulnerability on system performance
- Studying failure mechanism to infer fatality risk

THANK YOU

BACKGROUND

EVOLUTION OF SEISMIC DESIGN PROVISIONS





Large inventory of buildings designed and constructed before significant advancements in seismic design provisions