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Comparison of Modeled Seismic Loss against Historical Damage Information

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Seismic risk modelling:

Hazard
- The frequency and severity of ground shaking levels generated by future earthquakes

Vulnerability
- The physical loss ratio of exposed elements against ground shaking level

Exposure
- Replacement value of exposed buildings

Risk
- The economic loss to be caused by future earthquakes

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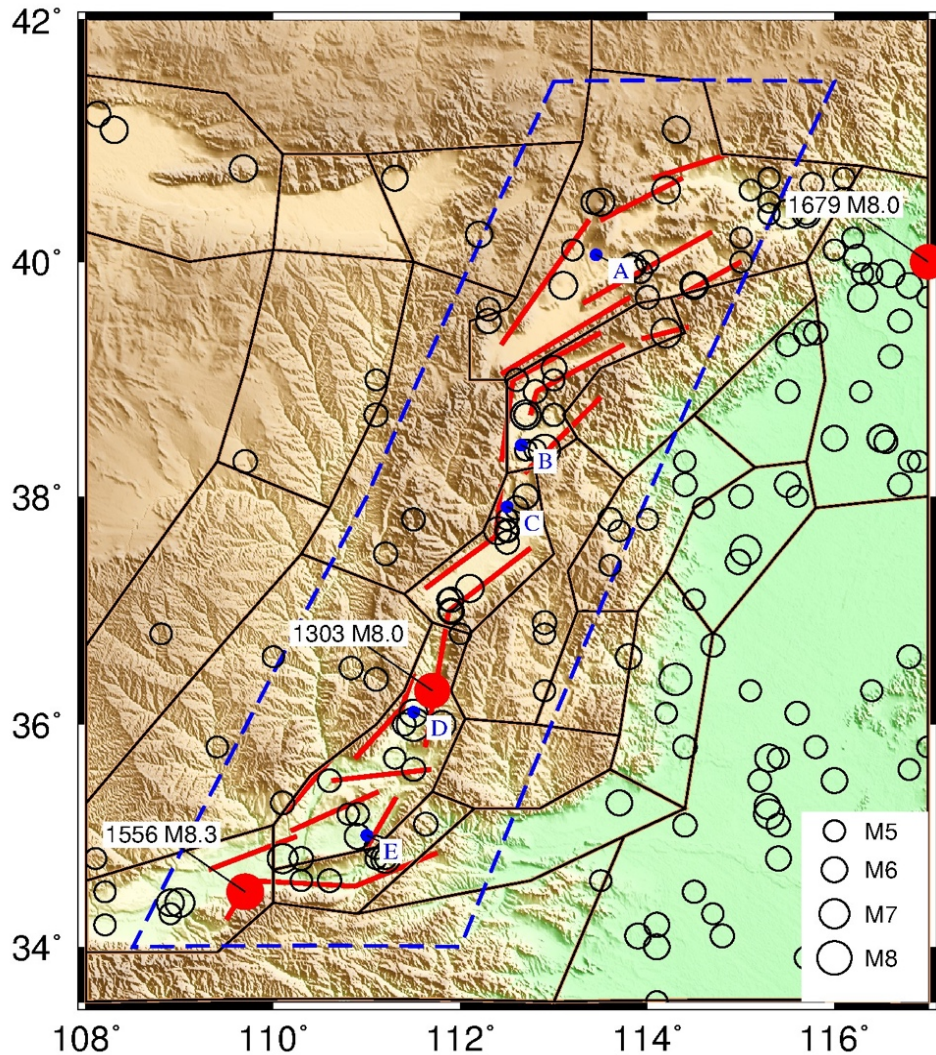
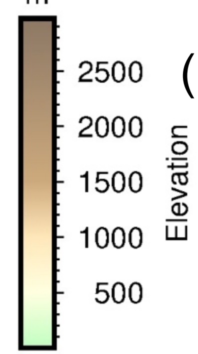
Research Question:

- To what extent is the modelled loss consistent with historical damage information? How to measure it?

Test region: Shanxi Rift System

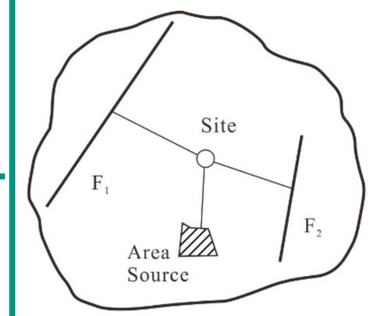




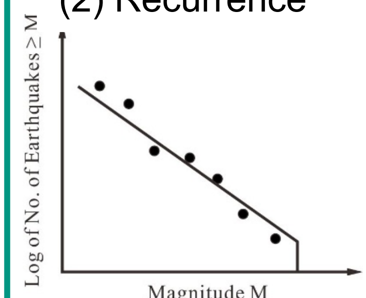
- 21 fault sources
  - Max≥mag≥6.0
- 28 area sources
  - 5≤mag < 6

(Li, 2015)

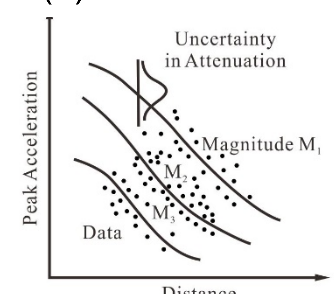
(1) Sources



(2) Recurrence



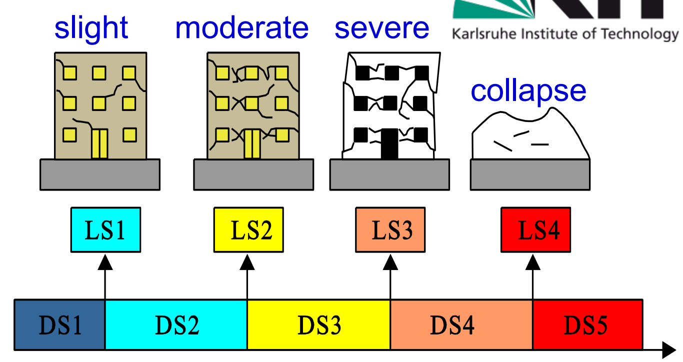
(3) Ground Motion



Yu et al. (2013)

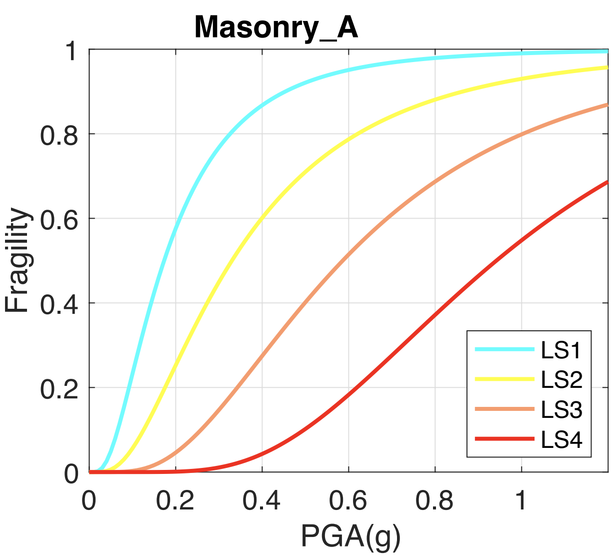
9501 sites in total with dimensions of 5km×5km

Fragility and Vulnerability:



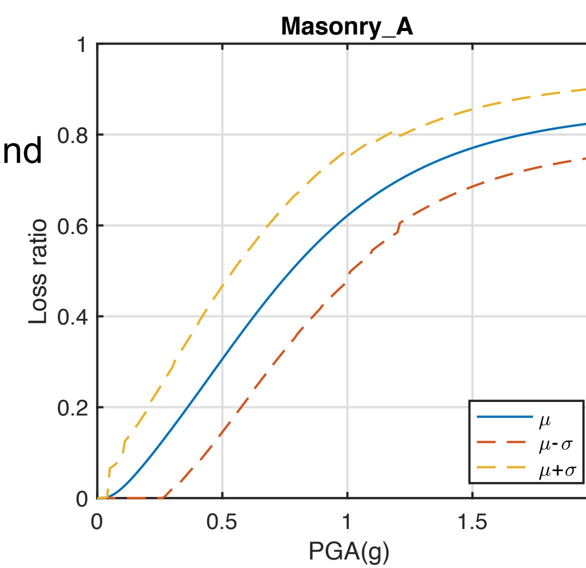
- Building fragility is described by several damage states – none, slight, moderate, severe and collapse.
- Fragility curve: describes the probability to exceed each damage limit state at specific ground motion level.
- Vulnerability curve: describes the relation between ground motion level and loss ratio.

Fragility curve:



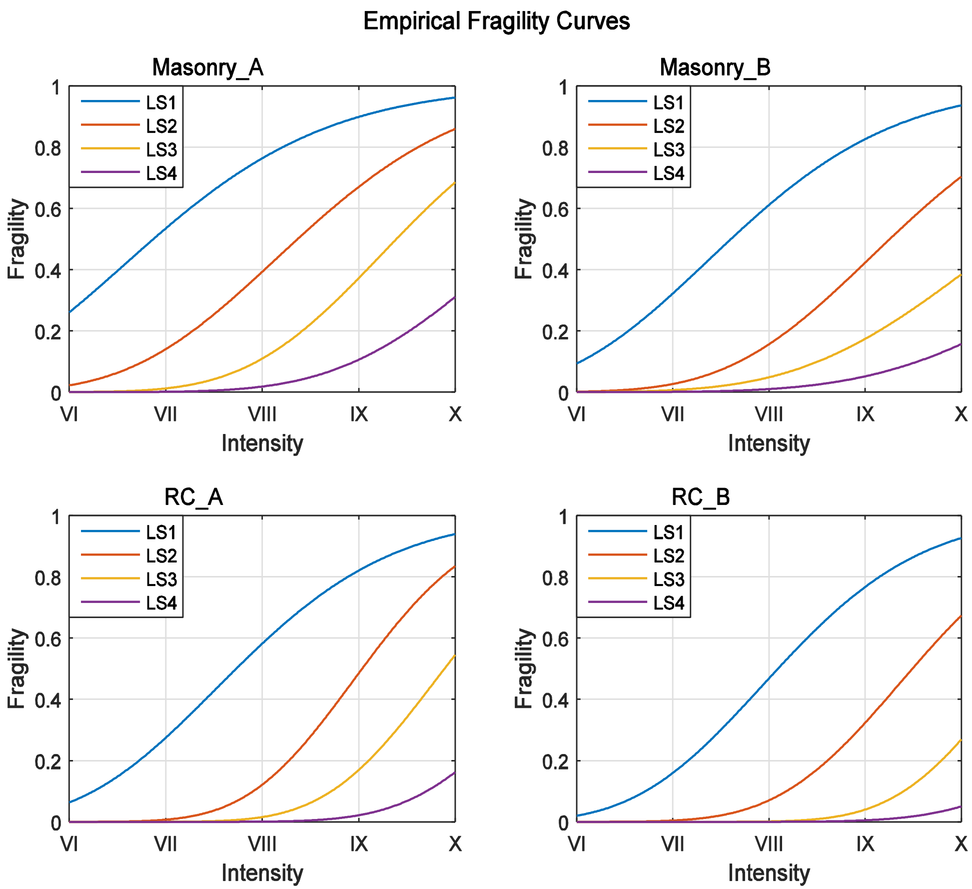
relation between damage state and loss ratio (consequence model)

Vulnerability curve:



Empirical fragility curves:

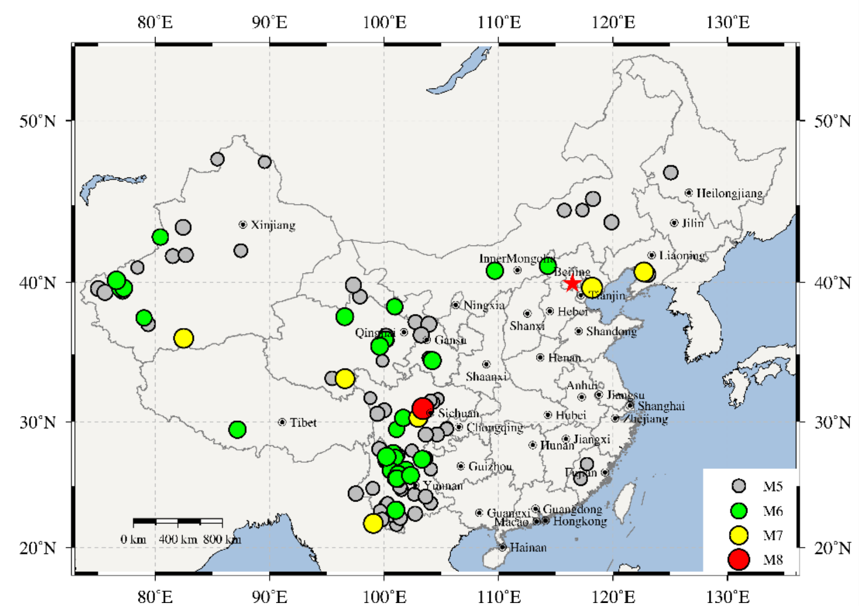
(Masonry_A, Masonry_B, RC_A, RC_B)



Fragility VS intensity

From 69 papers and theses;
For groups of masonry and RC buildings in the field;

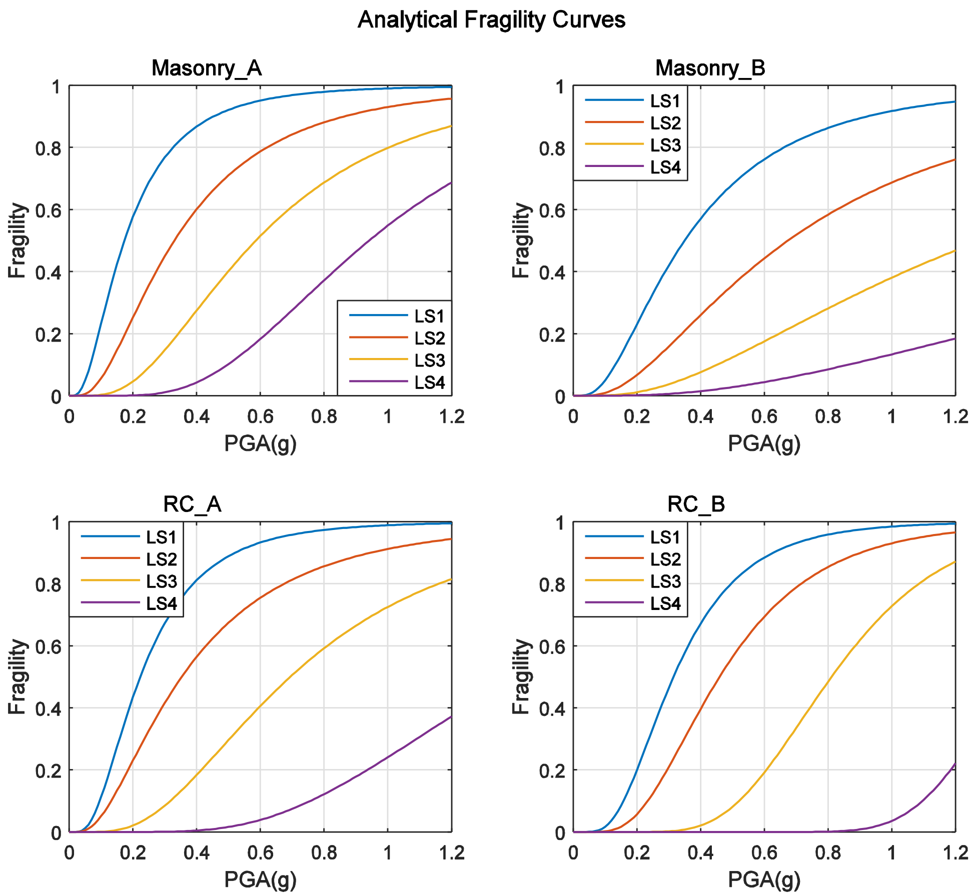
based on post-earthquake surveys



The distribution of 112 earthquakes since 1975 Haicheng EQ, for which post-earthquake surveys were conducted.

Analytical fragility curves:

(Masonry_A, Masonry_B, RC_A, RC_B)



Fragility VS PGA

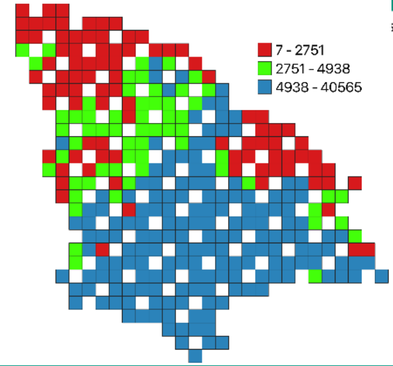
From 18 papers and thesis;
For modelled masonry and RC structures.

based on non-linear analysis

High resolution residential building stock modelling:

What we need:

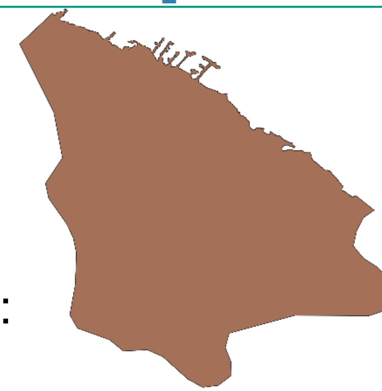
- <u>in each grid</u> (e.g. 1km*1km resolution), the building types used in loss modelling and their values
    - Masonry_A, Masonry_B, RC_A, RC_B



1km*1km

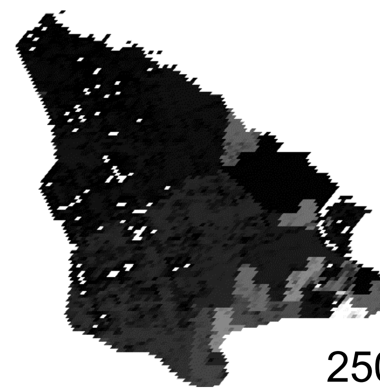
What we have:

- The 2010 national census (<u>urban, township, rural</u>):
    - Size of family
    - average floor area per capita
    - number of families living in buildings classified by:
        - Storey (1,2-3,4-6,7-9,≥10)
        - Occupancy (living, commercial, mixed)
        - Construction material (steel/RC, masonry, brick-wood, others)



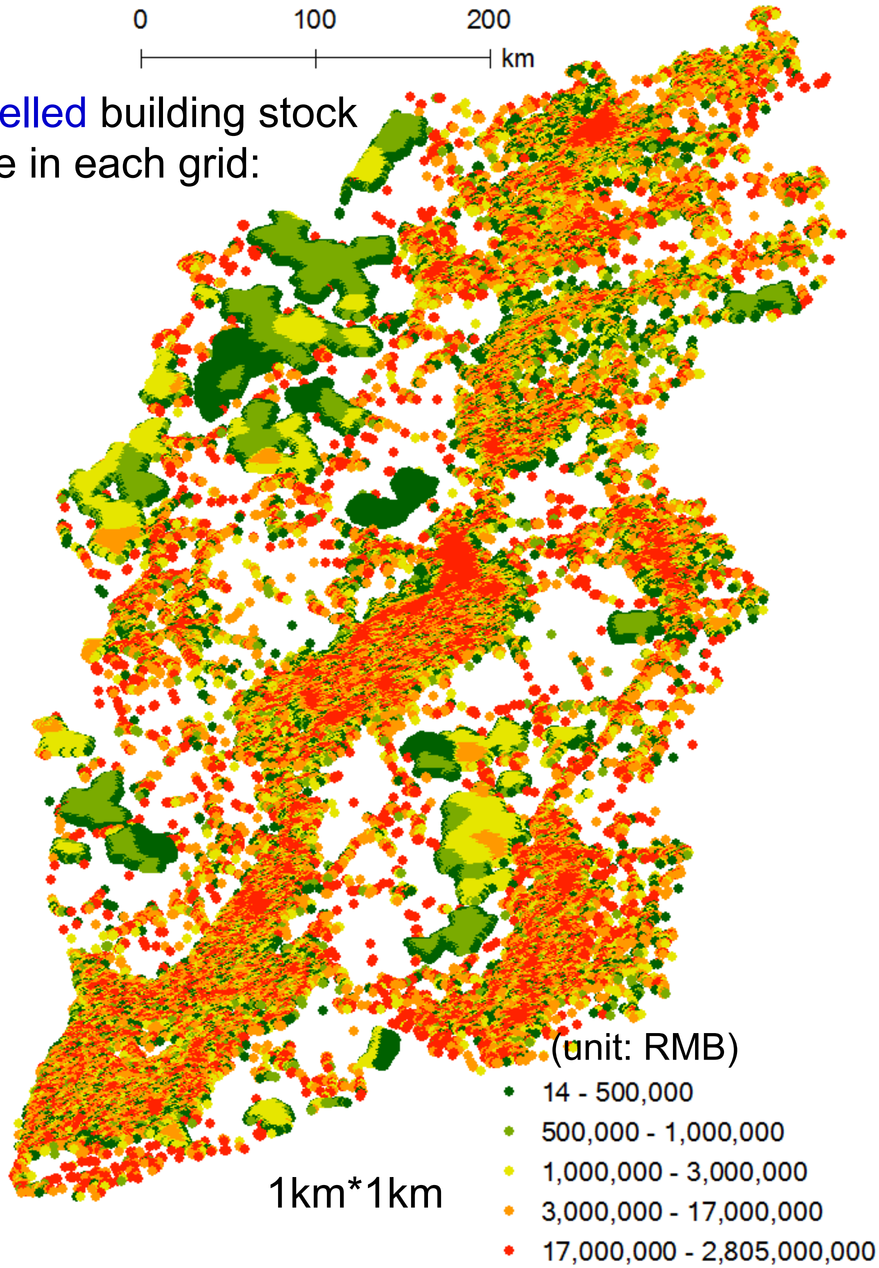
Urbanity level

- The population density profile, developed by Global Human Settlement (GHS) project

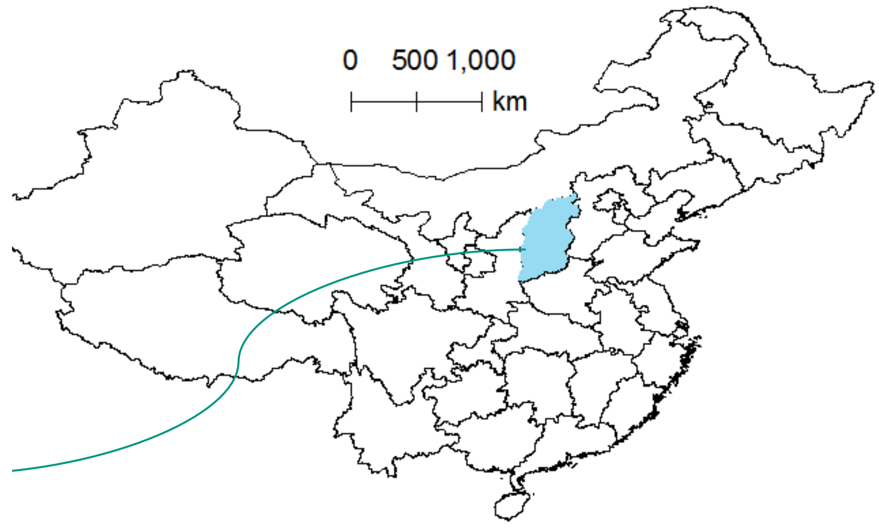


250m*250m

Modelled building stock value in each grid:



1km*1km



The overall modelled residential building stock value in Shanxi Province (in 2015 current price) is:

1603.5 billion RMB (~**200** billion Euro)
2.04% of mainland China;

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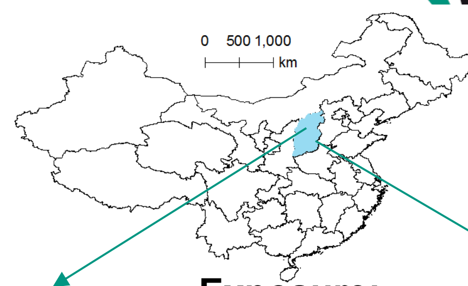
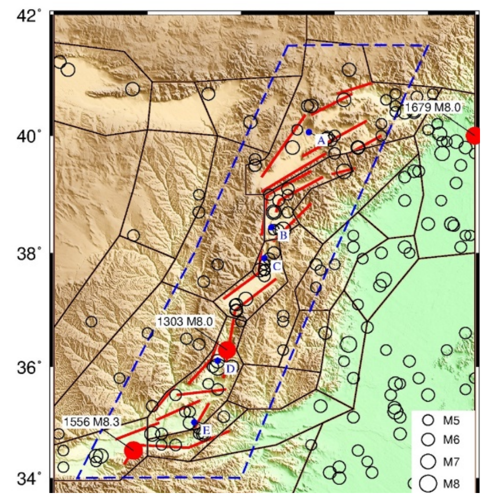
Engineering loss modelling in CAPRA:



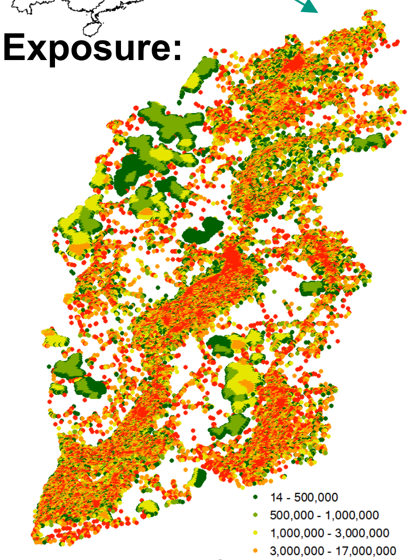
- Hazard: in terms of PGA
- Exposure: value of each building type
- **Vulnerability**: derived from fragility curve for each building type

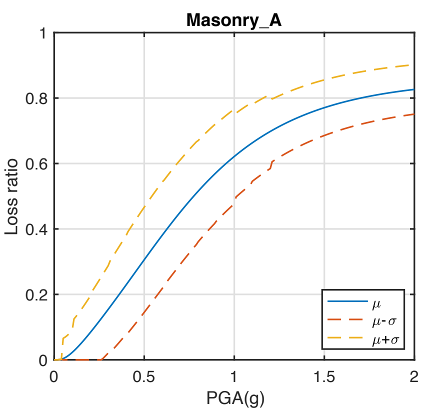
(Masonry_A, Masonry_B, RC_A, RC_B)

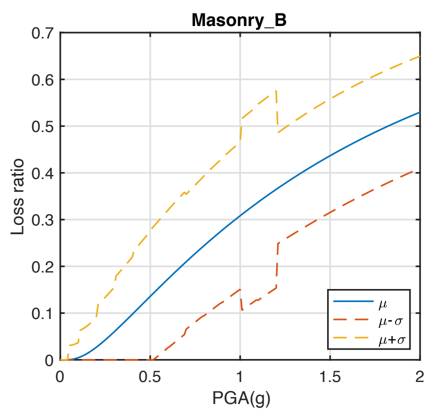
Hazard:

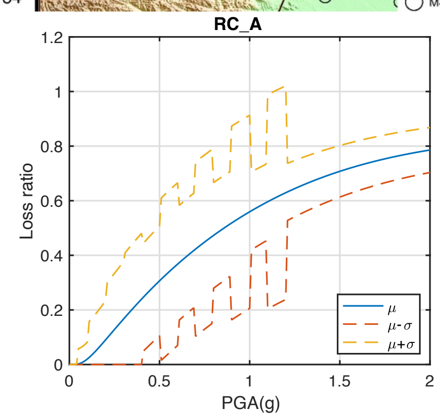


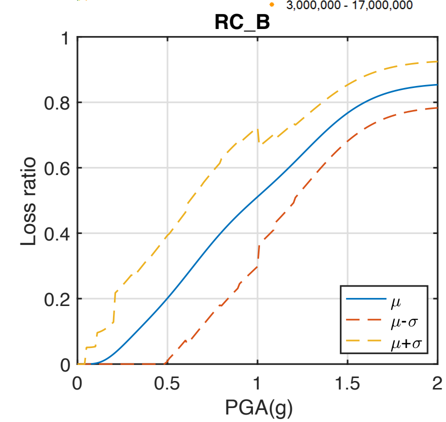
Exposure:





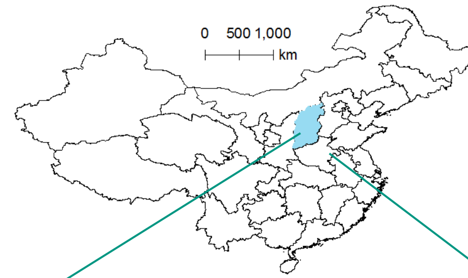




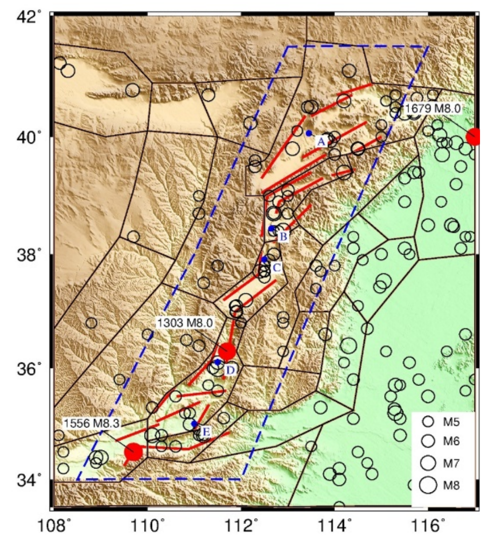


Empirical loss modelling method:

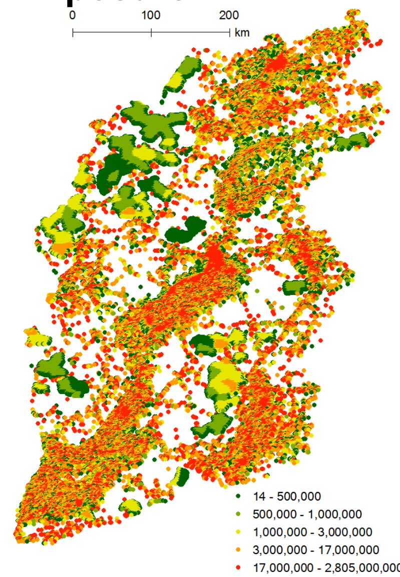
- Hazard: in terms of intensity
- Exposure: the overall value of all building types
- **Vulnerability**: one empirical loss function derived from historical damage information



Hazard:



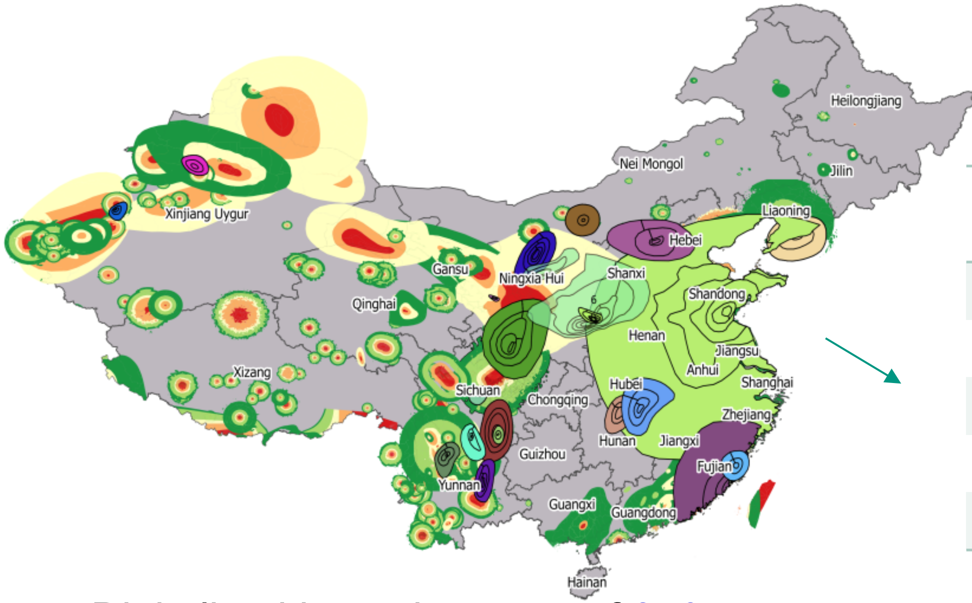
Exposure:



+

intensity-PGA relation

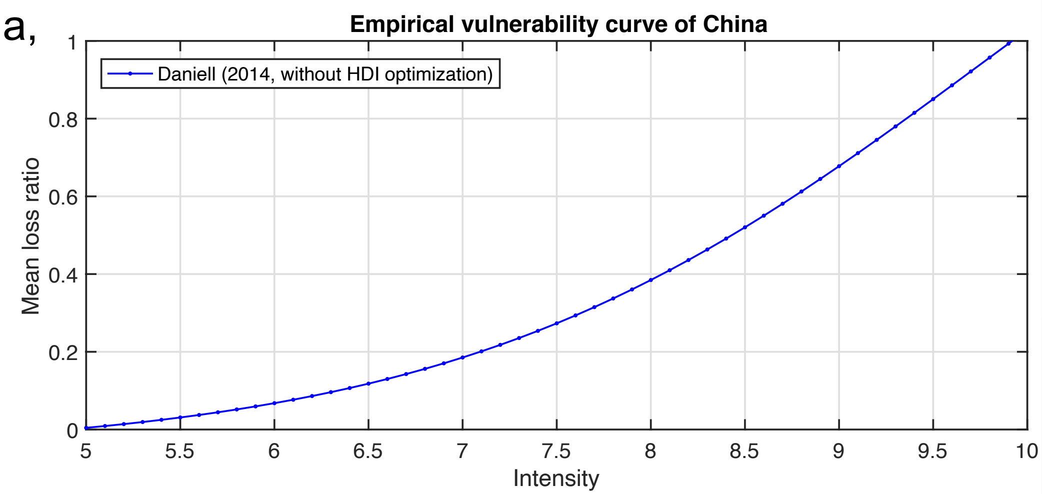
Empirical vulnerability curve derivation:



Digitalized intensity maps of **350+** historical earthquakes in mainland China, 85% occurred after 1970s

For each historical event:

intensity	year	population	exposure	loss	Mean loss ratio
VI					
VII					
VIII					
IX					
X					



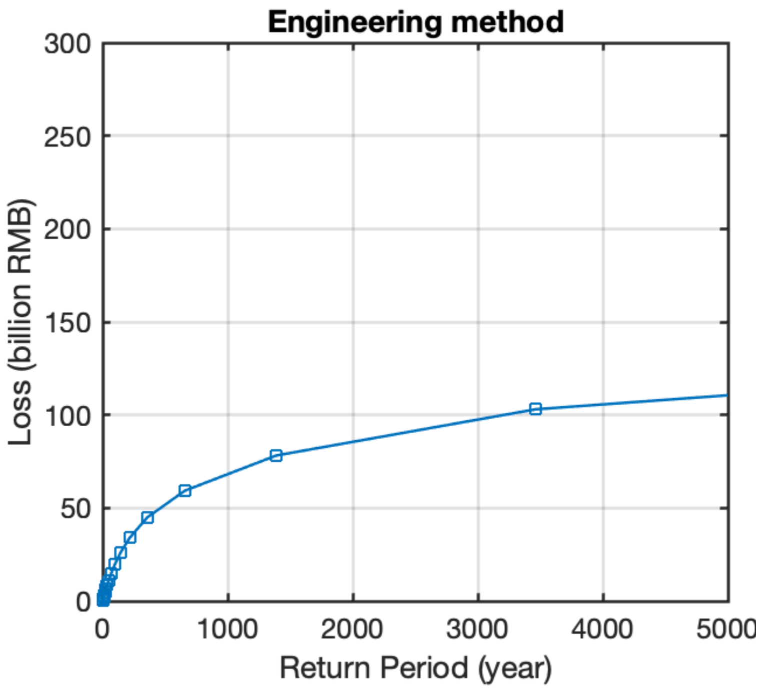
Note: empirical vulnerability curve is exclusively derived from historical damage information.

(Daniell, 2014)

Metrics used to measure loss compatibility:

- For individual scenario (deterministic):
  - compare modelled loss with surveyed loss

- For all scenarios (probabilistic):
  - AAL: Average Annual Loss
  - LEC: Loss Exceedance Curve:
    - the return period to exceed different losses for a given portfolio

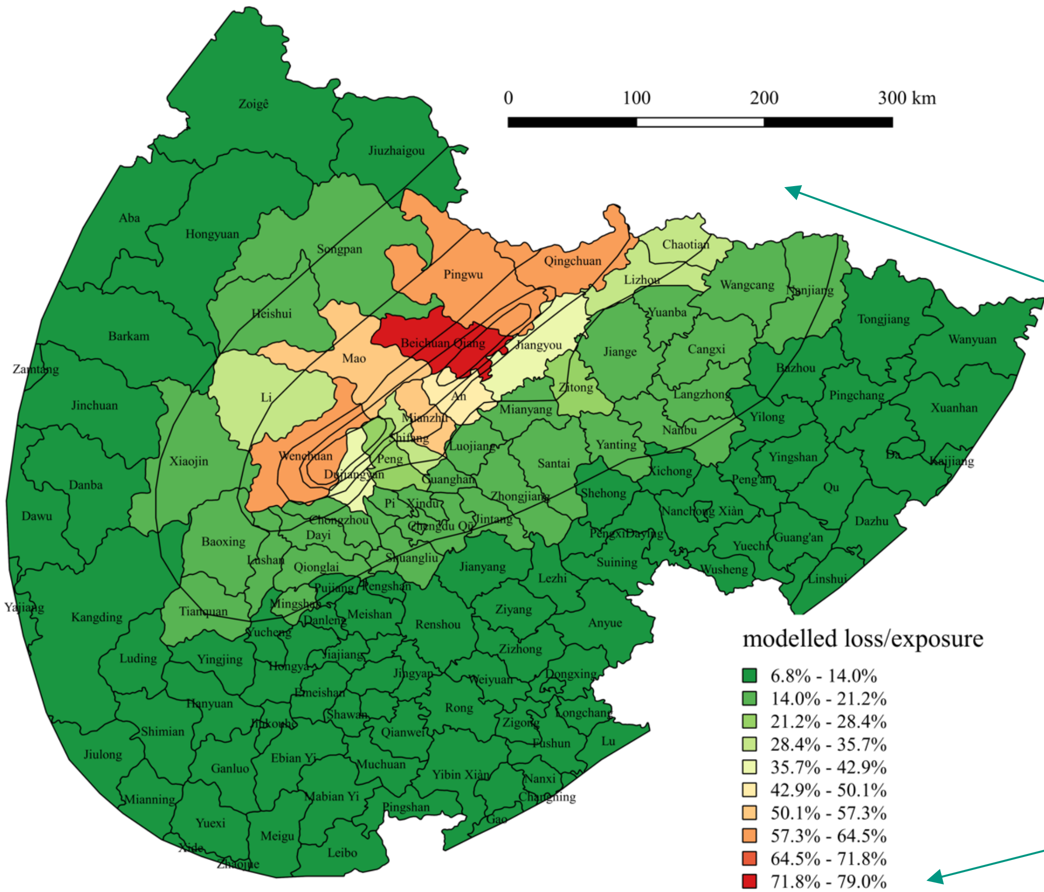


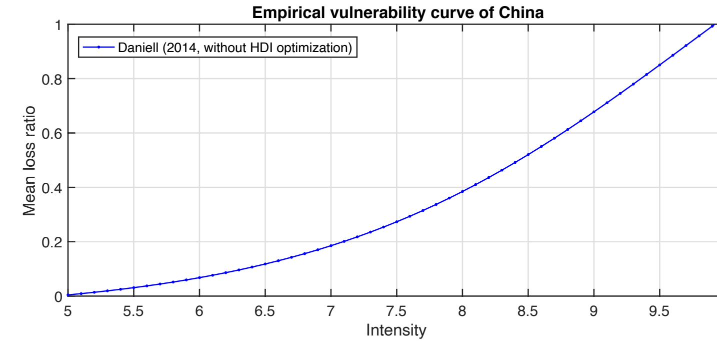
An example of Loss Exceedance Curve.

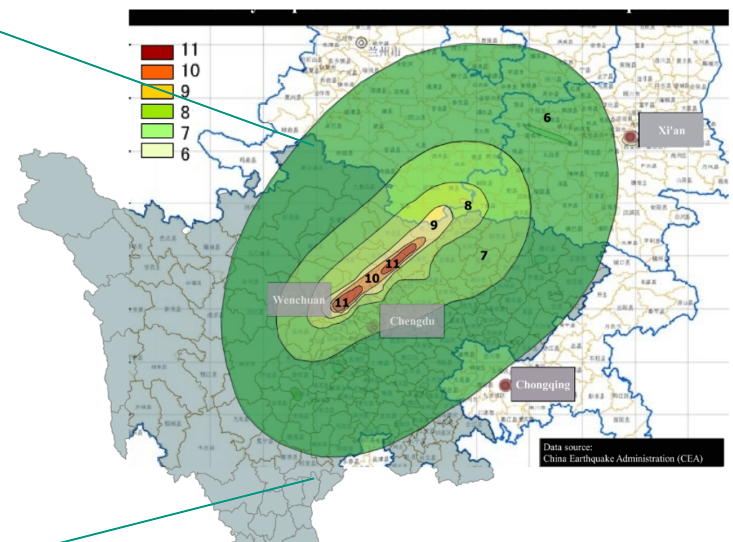
❖ Application of modelled results in Wenchuan EQ loss estimation:

Officially estimated lossbased on post-earthquake surveys: around **98.3-435.4** billion RMB, with the median around **212.32-247.25** billion RMB (in 2008 current price);

The loss estimated in this study is around **144-288** billion RMB







2008 Wenchuan Ms8.0 earthquake

Loss estimated based on damage reports:

County-level based damage reports of Wenchuan Ms8.0 earthquake in Sichuan, China:

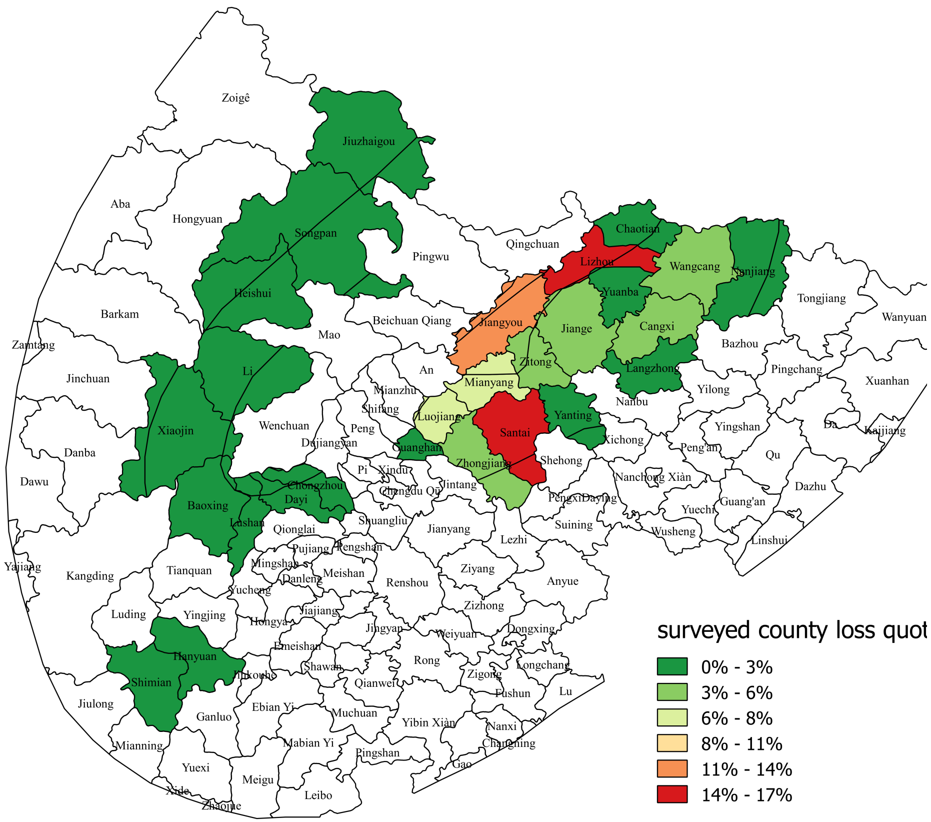
adm2_name	adm3_name	number of damaged township/urban buildings (unit: m²)			number of damaged rural buildings (unit: room, 1 room=15m²)			loss estimated from the damage reports (RMB)
		D4/D3	D2	D1	D4/D3	D2	D1	
Abazhou	Lixian	785700	77700	0	31306	16038	0	2.41E+09
Mianyang	Jiangyou	1470904	7018450	4032820	434096	354136	49212	2.17E+10
Guangyuan	Lizhou	6482800	4659400	0	422800	253500	0	2.80E+10
Guangyuan	Chaotian	485400	121300	0	27816	19555	5478	1.77E+09
Guangyuan	Wangcang	1577200	223000	0	84949	101918	170686	5.99E+09
Mianyang	Zitong	498000	1092000	827100	251687	235582	21525	7.89E+09
Mianyang	Youxian	903448	3018480	491760	161380	183697	95836	9.63E+09
Deyang	Jingyang	616300	396300	10491000	221100	147300	0	8.59E+09
Abazhou	Xiaojin	271000	61700	353100	40854	47377	0	1.68E+09
Mianyang	Fucheng	230194	1363295	2044943	28298	69664	29865	3.68E+09
Deyang	Luojiang	529400	260753	1171247	67100	134800	0	3.73E+09
Abazhou	Heishui	166300	10900	367900	27384	41327	0	1.16E+09
Chengdu	Chongzhou	13112	176749	373693	76040	151970	140000	2.72E+09
Guangyuan	Jiange	1491500	1012900	0	143100	341800	0	9.12E+09
Mianyang	Santai	1177820	5642140	5060860	427933	842074	561383	2.39E+10
Nanchong	Langzhong	525000	1120000	2630000	32554	0	0	3.68E+09
Mianyang	Yanting	320178	787212	707516	36448	62516	72111	2.95E+09
Abazhou	Songpan	84800	243300	360000	11808	64894	0	1.23E+09
Guangyuan	Cangxi	331600	1372400	0	145772	251692	176496	6.58E+09
Ya'an	Lushan	1680	12480	1062600	2300	44700	0	6.51E+08
Deyang	Zhongjiang	55160	247100	4012750	83498	202552	762188	5.23E+09
Guangyuan	Zhaohua	170600	235600	279200	48483	182925	30595	2.82E+09
Chengdu	Dayi	325000	347000	799000	5160	12445	27350	1.57E+09
Ya'an	Baoxing	4286	32467	173462	5300	36200	0	4.37E+08
Bazhong	Nanjiang	191300	106500	0	35300	46300	0	1.39E+09
Deyang	Guanghan	22400	126100	541547	65400	404900	0	4.26E+09
Ya'an	Hanyuan	115555	70935	180830	192100	76600	0	3.56E+09
Ya'an	Shimian	152600	167300	0	7500	22500	0	8.22E+08
Abazhou	Jiuzhaigou	167700	263100	543700	11291	55357	0	1.41E+09
In total:		19166937	30266561	36505028	3128757	4404319	2142725	1.69E+11

Source: Sichuan Earthquake Administration (2018)

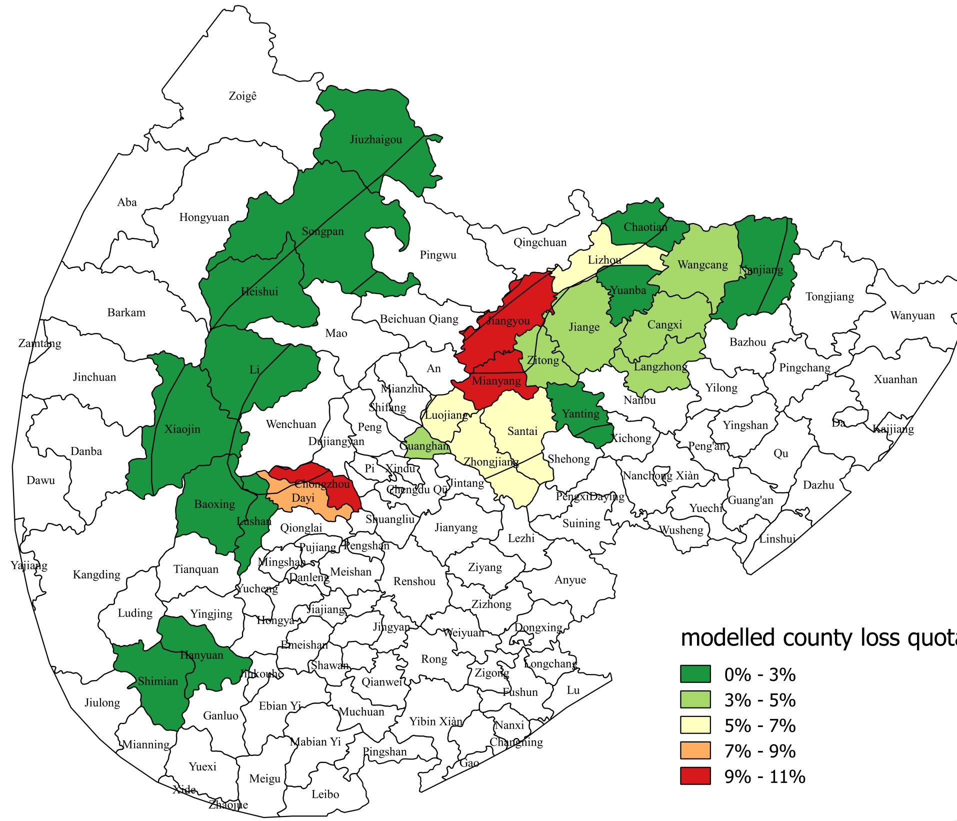
Compare modelled loss ratio with surveyed loss:

Karlsruhe Institute of Technology

Survey loss based on damage reports:



Modelled loss using empirical method:

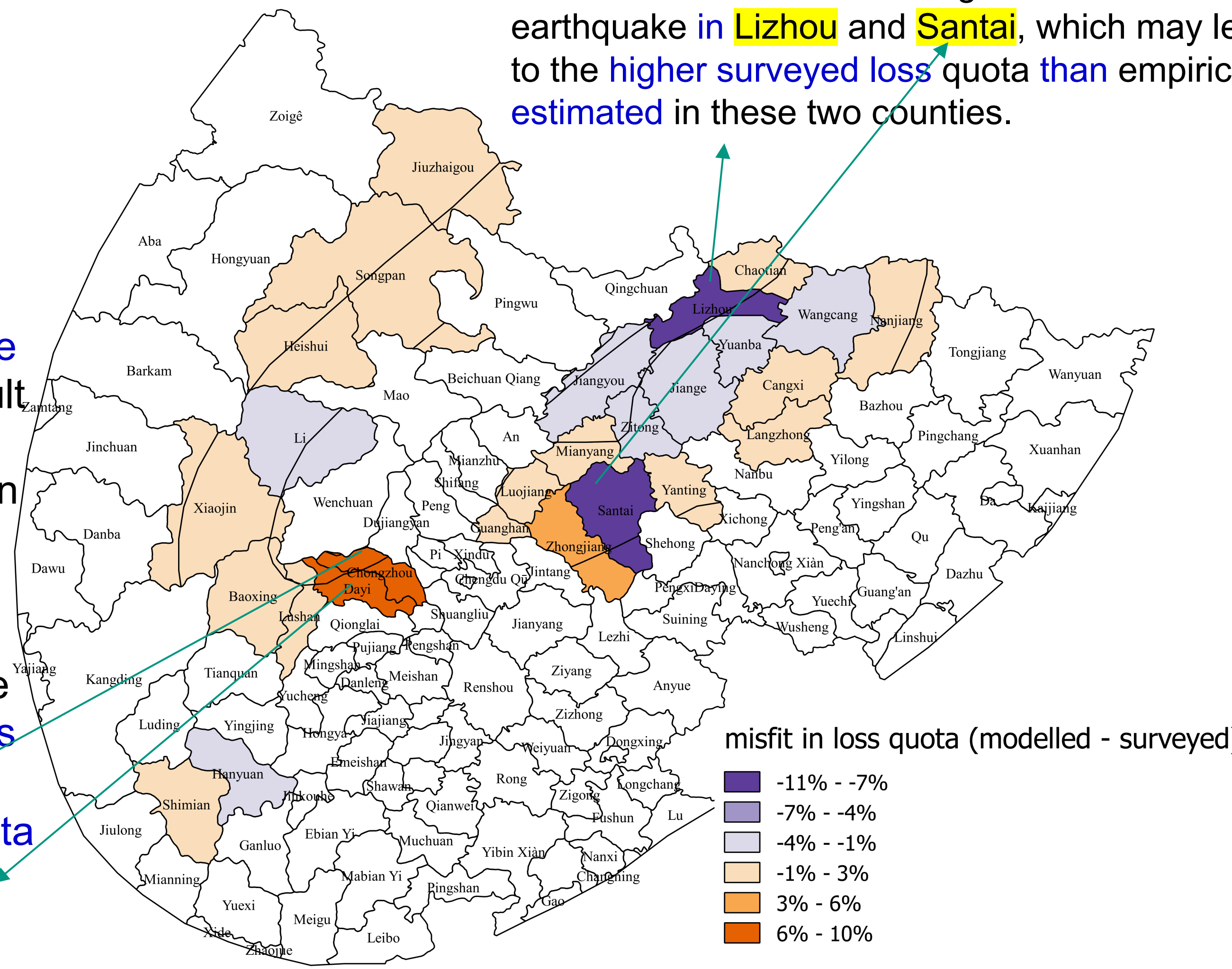


Difference in loss proportion (modelled - surveyed):

Karlsruhe Institute of Technology

According to Ding (2017), abnormal high ground motions were recorded during Wenchuan earthquake in Lizhou and Santai, which may lead to the higher surveyed loss quota than empirically estimated in these two counties.

The southwestern rupture of the Longmenshan Fault stopped at the intersection area between Chongzhou and Dayi, so the damage to buildings also stopped in between. This may explain why the empirically estimated loss quota is **higher** than the actual surveyed loss quota in Chongzhou and Dayi.

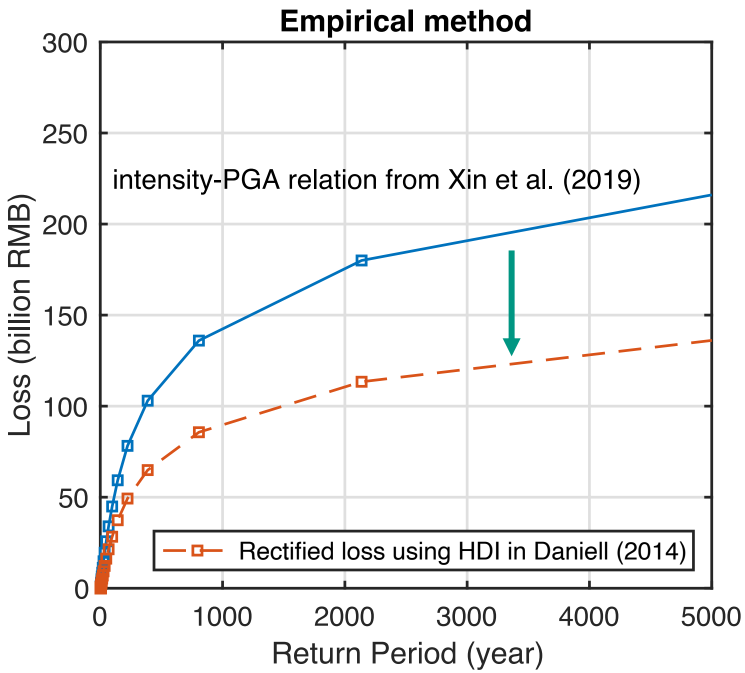


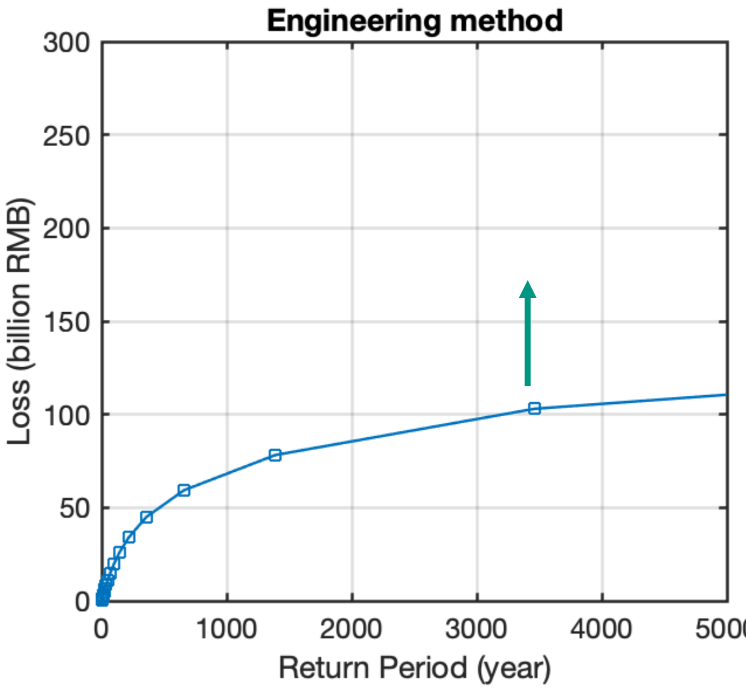
Comparison of modelled probabilistic loss:

Empirical Average Annual Loss (AAL):
2.57 billion RMB, **1.61‰** of exposed value.

Engineering Average Annual Loss (AAL):
1.02 billion RMB, **0.64‰** of exposed value.

Empirical loss ≈ 2 * Engineering loss





In empirical loss modelling:

- No building vulnerability change with time is considered (will decrease the empirical loss)

In engineering loss modelling:

- No soil amplification effect is included (will increase the engineering loss)

Research Questions & Conclusion:

➢ To what extent is the modelled loss compatible with historical damage information? How to measure it?

- Method: calculate loss using two methods
- Result: Engineering loss is essentially compatible with empirical (historical) loss

Thanks for your attention!

Two key concepts in exposure:

Difference between Gross Capital Stock and Net Capital Stock:

- Gross capital stock == replacement expense
- Net capital stock == repairment expense
  (the depreciation of capital stock over time is considered)

Difference between GDP and Capital Stock:

- In the 2013 Global Assessment Report on Disaster Risk Reduction, capital stock (a ‘stock’ indicator) has been used to replace GDP (a ‘flow’ indicator) to represent economic exposure to natural disasters;

- Because a natural disaster could cause asset damage greater than the annual GDP, such as the 2010 Haiti earthquake (Bilham, 2010)

- Instead, GDP is regarded as the indicator of indirect loss due to the interruption of econimicial activities.

Assumptions in exposure model construction：

- The urbanity (city/town/village) level is judged from population per grid (1 km^2)：**village**：≤1300 **town**：1300 ~ 6577 **city**：≥6578
- Statistical ratio between agriculture, industry, service: 41.6:19.9:38.5 (sum=1)

- Updated agriculture, industry, service: ag = 0.8*ag; ind = 1.3*ind; sevice = 1.1*service

- sum(agriculture, industry, service) stock = gross capital stock – building stock

- For detailed building types with different material and height:
  BRIWOMC1, BRIWOMC23,
  STLRCMC1, STLRCMC23, STLRCMC46, STLRCMC79, STLRCMC10,
  MIXEDMC1, MIXEDMC23, MIXEDMC46, MIXEDMC79, MIXEDMC10,
  OTHERMC1, OTHERMC23, OTHERMC46, OTHERMC79, OTHERMC10

- Average net capital stock per capita: 110480
- Gross capital stock/net capital stock: 1.64
- …

Loss validation using historical loss database:

calculated by CAPRA-GIS: **predicted based on historical database:**

Daniell (2014, thesis)

- input datasets:
  - intensity map (historical observation)
  - current population
  - current capital stock
- process:
  - intensity - loss relationship was established based on historical loss data
  - the change of vulnerability in capital stock was indicated by HDI index
  - Given an intensity map, population, capital stock info and current HDI index of research area, the potential loss can be predicted instantly
    - input datasets:
      - PGA, SA (instrumental records)
      - current population
      - current building structure information
    - process:
      - different building vulnerabilities should be developed
      - detailed building assets should be given

PGA-intensity transformation can be based on our relationship developed in fragility work