Disaster Risk Assessment
Decision-making process to reduce risk
The case of Peru

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Outline

1. Seismic risk background and baseline
2. Probabilistic risk assessment
3. Seismic risk mitigation plan

1. Seismic risk background and school infrastructure baseline

Schools damage and cost in recent earthquakes

DATE	EARTHQUAKE	MAGNITUDE M_W	TOTAL AFFECTED SCHOOLS	FATALITIES WITHIN EDUCATIONAL INFRASTRUCTURE	COST ESTIMATE (US$ M)
16/04/2016	Ecuador (Muisne)	7.8	280 Schools collapsed 1000 affecteted	No fatalities 120,000 children temporarily out of school	1.4
25/04/2015	Nepal (Khudi)	7.8	5,000 schools collapsed 16,000 schools have been damaged 50% Nation's educational infrastructure	Not specified	944,0
03/08/2014	China (Wenping)	6.1	10 collapsed 1000 buildings damaged	Not specified	0.7
24/09/2013	Pakistan (Awaran)	7.7	170 collapsed	No fatalities 75% non attendance to school	1.1
22/02/2011	New Zealand (Christchurch)	6.3	Several school buildings of timber construction	No fatalties or injuries in schools	1.8
04/09/2010	New Zealand (Canterbury)	7.1	144 Schools out of 179	No fatalities	10.5
27/02/2010	Chile (Offshore)	8.8	Several school buildings offshore populations	Earthquake ocurred on vacation period	2.1
12/01/2010	Haiti Region	7.0	1350 collapsed 80% National's educational Infrastructure	4,000 students and 700 teachers	1000,0
08/10/2005	Pakistan (Kashmir)	7.6	8,000 schools destroyed 10% National's educational Infrastructure	17,000 children and 853 teachers	472,0

Seismic hazard

Zones in Perú

Reglamento Nacional de Edificaciones (RNE -2015)

Schools Damaged by Earthquakes

SCHOOL INFRASTRUCTURE CENSUS

In 2014 the Ministry of Education carries out 1st School Infrastructure Census (CIE) generating the following basic information:

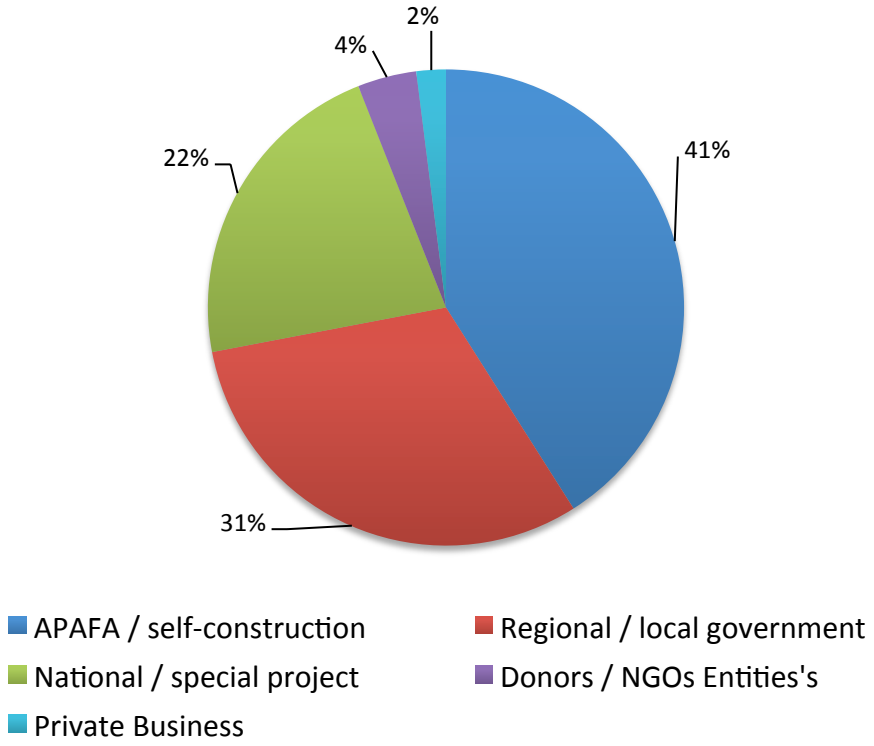
For each building:

- Location
- Number of classrooms, construction area
- Number of students
- Construction typology (visual screening by technicians)
- Approximate date of construction
- Functional information (architectural, utilities, accessibility, etc.)

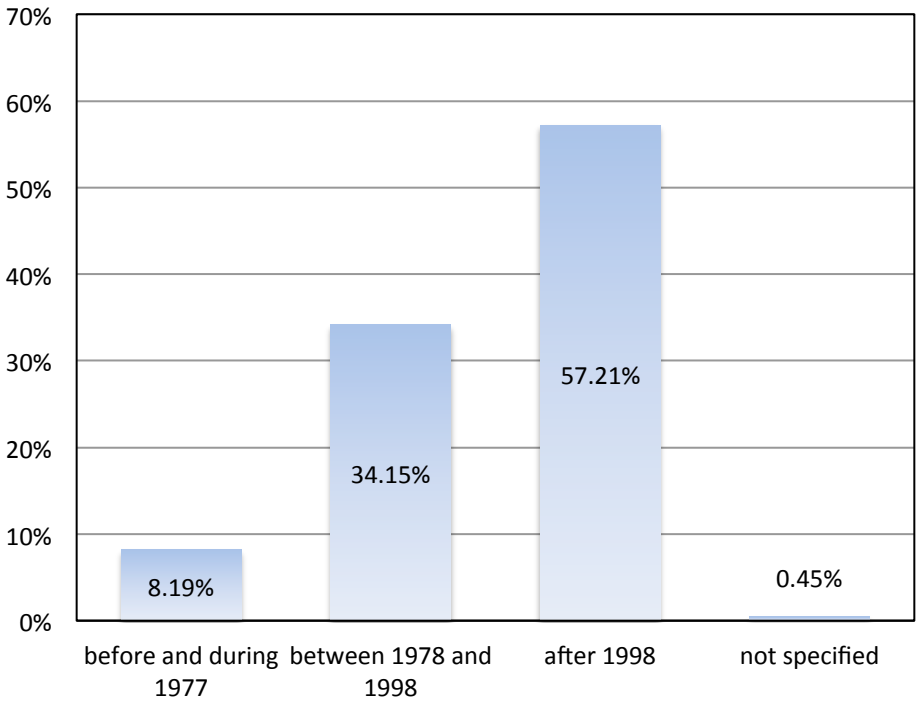
Peru's Public School Infrastructure in numbers

- **~ 50,000** school facilities
- **~ 200,000** school buildings
- School community: **6.5** million students
- Distribution: **35%** urban, **65%** rural

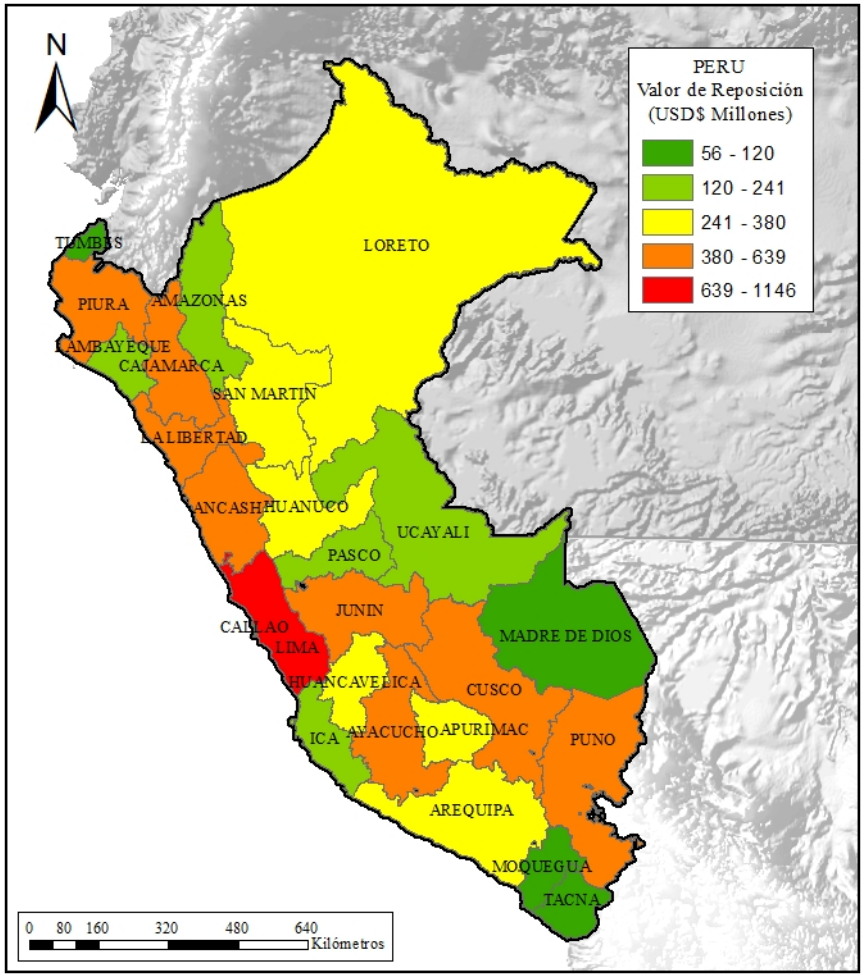
Who builds ?



Building's age



Geographical distribution of exposed values (USD millions)



RISK MITIGATION

MAIN OBJECTIVES:

1. Reduce the risk of **loss of lives** and potential **injured**
2. Reduce **damage potential** in the school infrastructure
3. Reduce the **disruption time**
4. Improve the **general conditions** of the infrastructure

NON-ENGINEERED STANDARD LINES OF INTERVENTION

1. **Replacement**: very old, vulnerable and/or damaged buildings
2. **Retrofitting**: update existing building to the seismic code level
3. **Rehabilitation**: functional intervention only
4. **Maintenance**: usually mandatory for functionality
5. **No intervention**: good condition, limited budget

Hands-on session

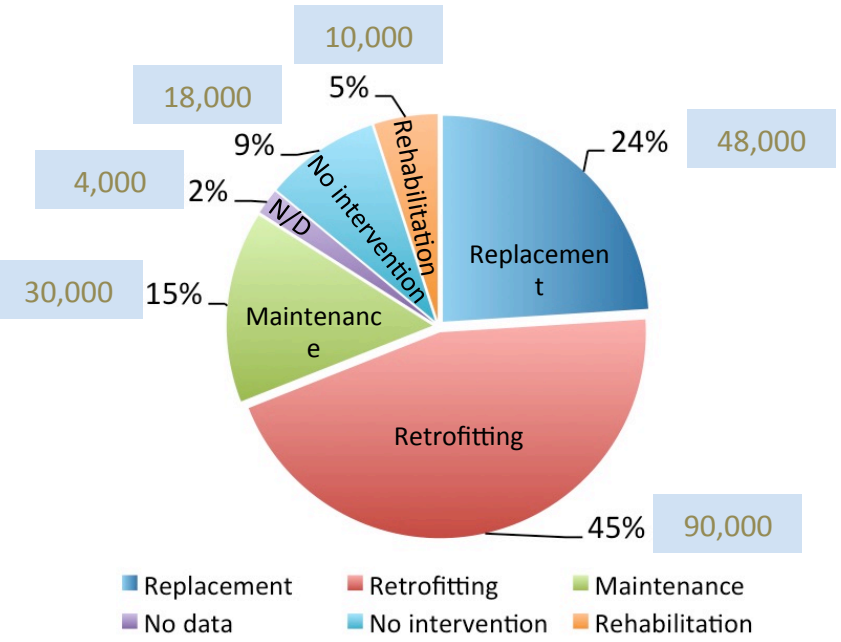
Seismic risk background and school infrastructure baseline

Question No. 1:

Prioritization of interventions based on *number of school buildings*

Prioritization of interventions based on number of school buildings

Lines of intervention



Number of buildings

Select the first priority line of intervention:

- ❑ 1. Replacement
- ❑ 2. Retrofitting
- ❑ 3. Rehabilitation
- ❑ 4. Maintenance

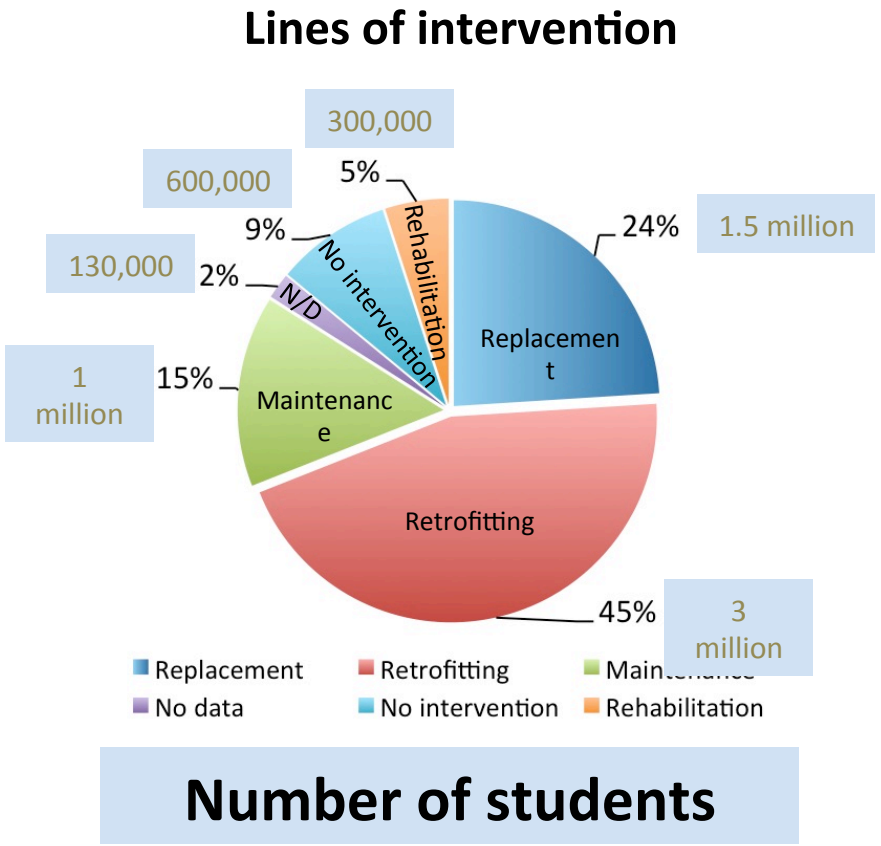
Hands-on session

Seismic risk background and school infrastructure baseline

Question No. 2:

Prioritization of interventions based on *number of students*

Prioritization of interventions based on number of students



Select the first priority line of intervention:

- ❑ 1. Replacement
- ❑ 2. Retrofitting
- ❑ 3. Rehabilitation
- ❑ 4. Maintenance

Hands-on session

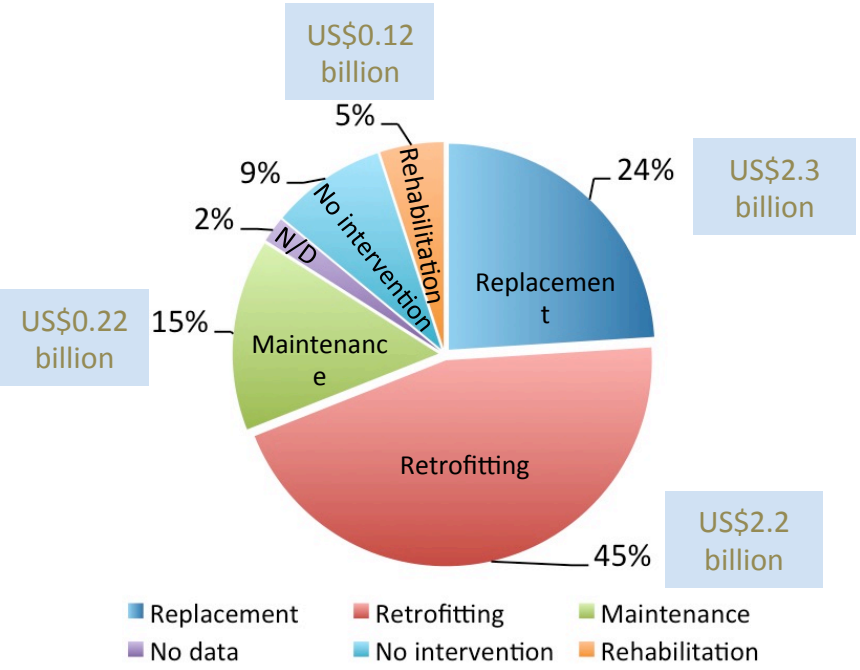
Seismic risk background and school infrastructure baseline

Question No. 3:

Prioritization of interventions based on replacement cost

Analysis of Census Results – Prioritization of interventions

Lines of intervention



Background:

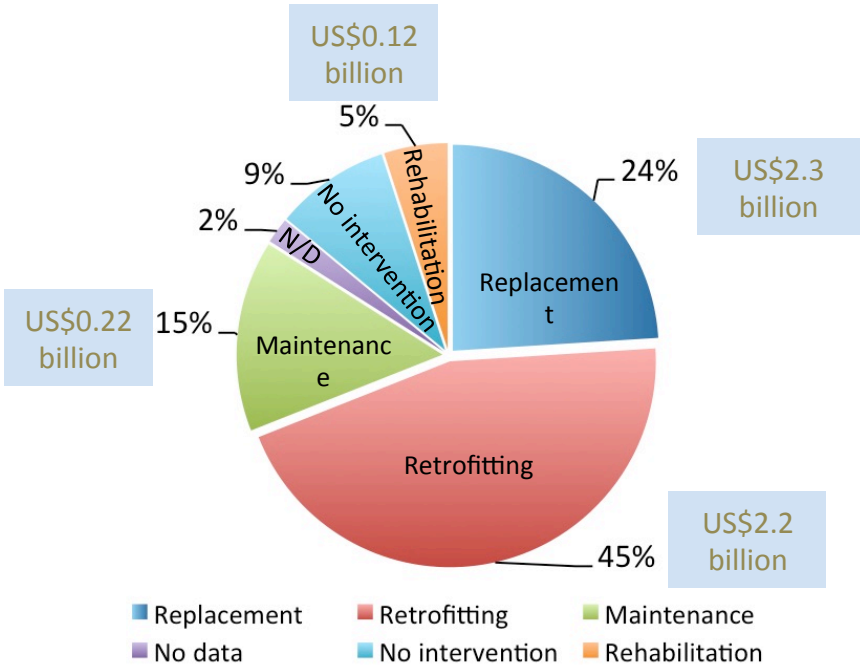
- 15% of spending is allocated for replacement and retrofitting of existing schools

US$ billion	2010	2011	2012	2013	2014	2015
Spending in school infrastructure	0.9	1.0	1.4	1.4	1.4	1.5
Proportion (Total spending in school infrastructure/GDP)	0.8%	0.7%	0.9%	0.8%	0.8%	0.8%

Replacement cost

Analysis of Census Results – Prioritization of interventions

Lines of intervention



Replacement cost

Select one of the following:

- ❑ 1. 50% Replace + 50% Retrofit
- ❑ 2. 80% Replace + 20% Retrofit
- ❑ 3. 20% Replace + 80% Retrofit

SEISMIC SCHOOL SAFETY: THE PROBLEM

- **TOTAL** buildings: **~** 200,000
- **TOTAL** replacement value of portfolio: **USD$ 9,0 Billion**
- **TOTAL** number of buildings to be intervened: **140,000**
- **TOTAL** estimated intervention costs: **USD$ 6,0 Billion (3% GDP)**
- **From 2006 – 2015 (10 years) only 220 schools retrofitted (< 0.15%)**
- **Investment budget of MINEDU in 2015: USD$ 1.5 Billion in school infrastructure, USD$0,5 Billion for construction of new schools**
- **It will take 24 years for a full mitigation project using 50% of the budget for new constructions**

Change the strategy in order to scale the impact:

Seismic risk mitigation plan

Main aspects of the seismic risk mitigation plan

1. **What to do**: type of intervention according to building typologies
2. **Optimization of interventions**: reduce costs, maximize benefits
3. **Prioritization scheme**: controlling parameters
4. **Budget requirements:** in order to balance objectives and include DRM in government agenda

2. Probabilistic risk assessment of school infrastructure

Probabilistic risk assessment

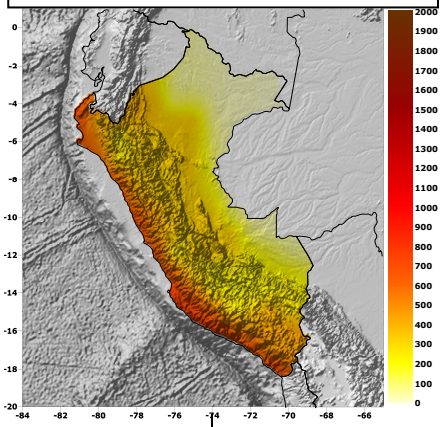
Answer to fundamental questions

1. Magnitude of losses
2. Frequency of occurrence of different level of losses
3. Expected annual losses for each individual component and the portfolio
4. Distribution of losses by typologies and geographic locations

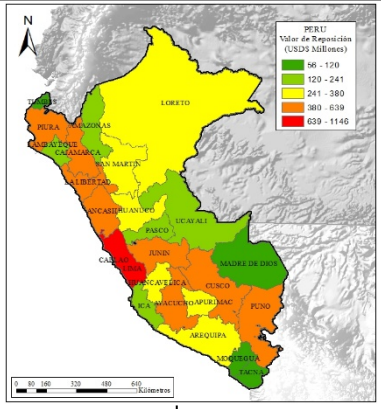
CAPRA is a multi-hazard, non licensed, open-source risk assessment platform (www.ecapra.org)

Probabilistic risk assessment: general methodology

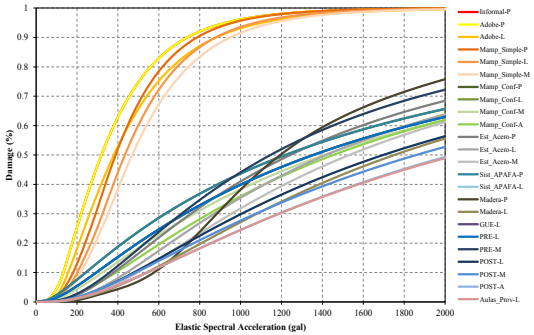
Hazard



Exposed Assets



Vulnerability

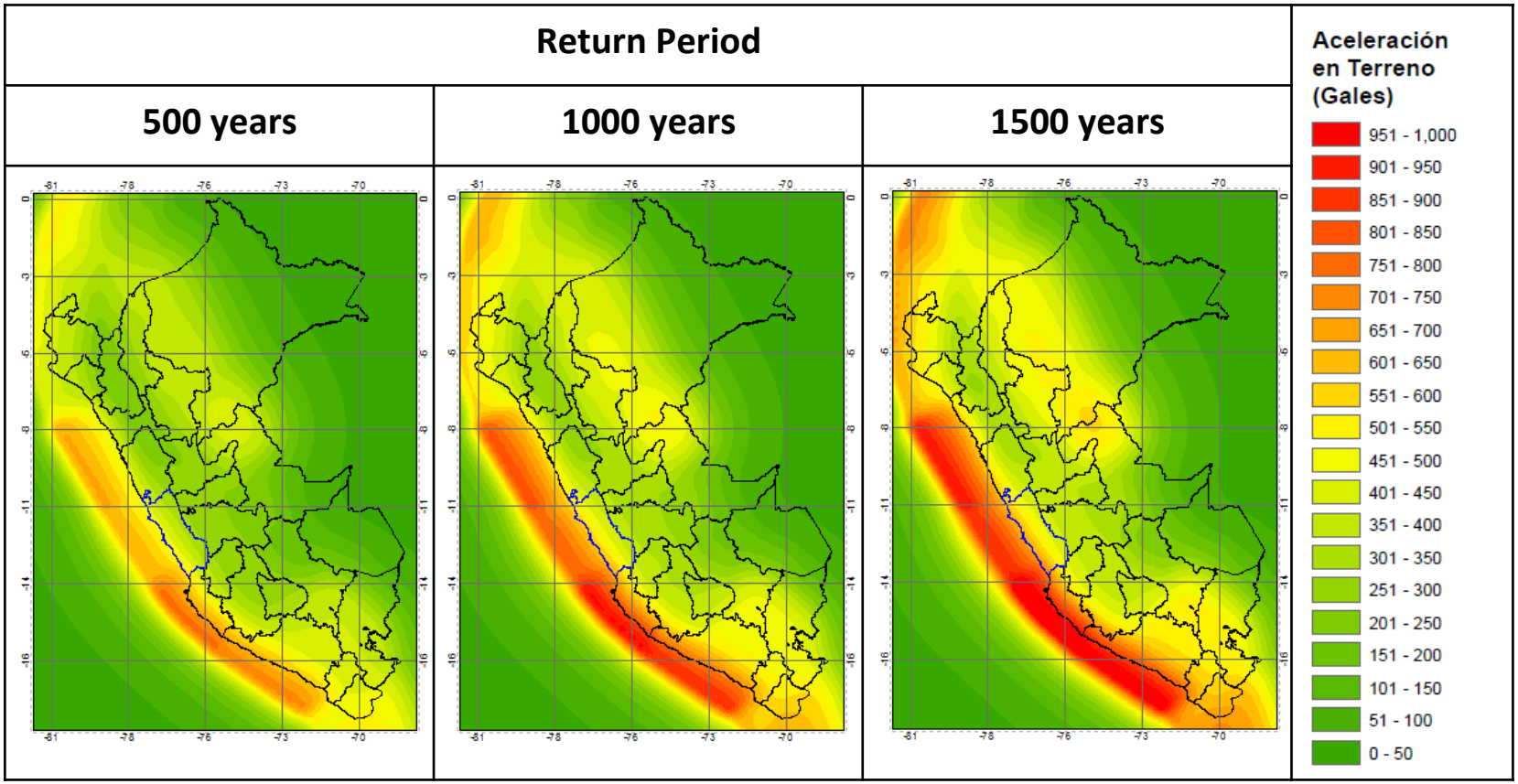


Probabilistic risk assessment

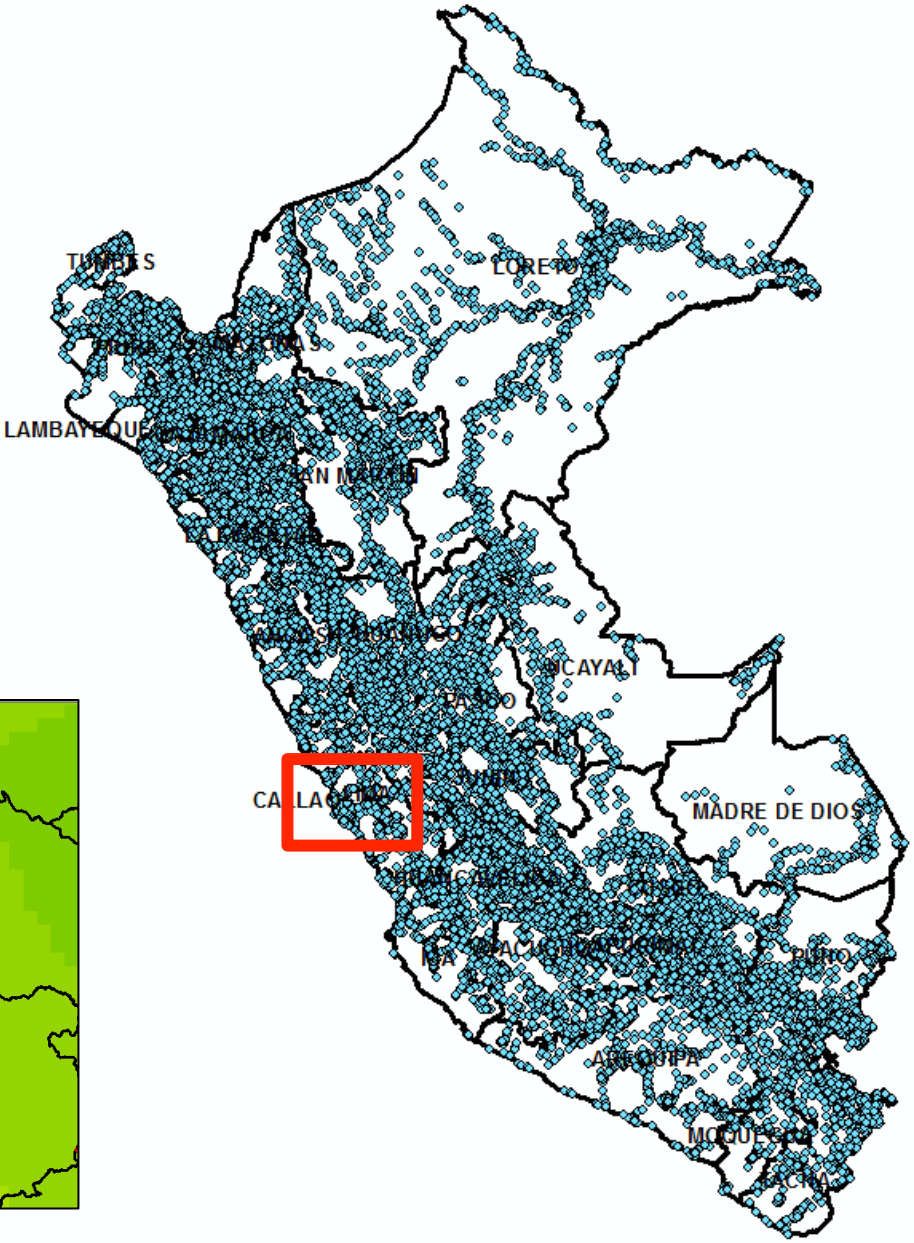
Risk mitigation plan

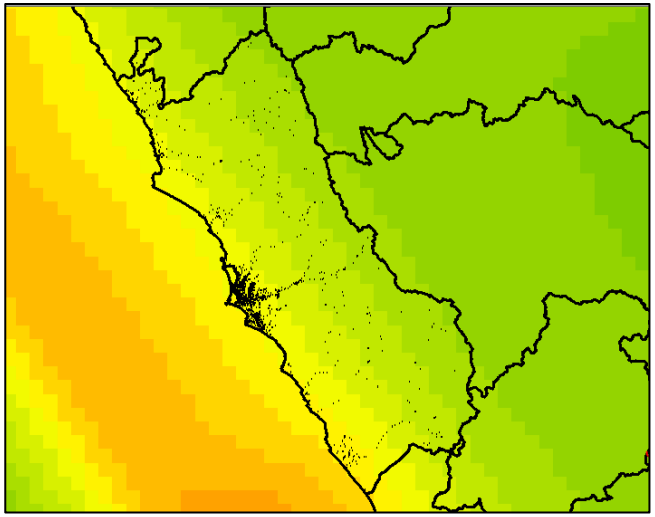
Probabilistic seismic hazard

National- CAPRA AME file



Exposed assets





Exposed assets

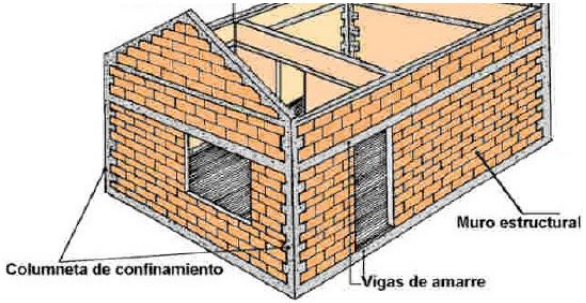
Structural typologies

Adobe

Unconfined masonry (ASC)

Steel Frame (EA)

Confined masonry (AC)

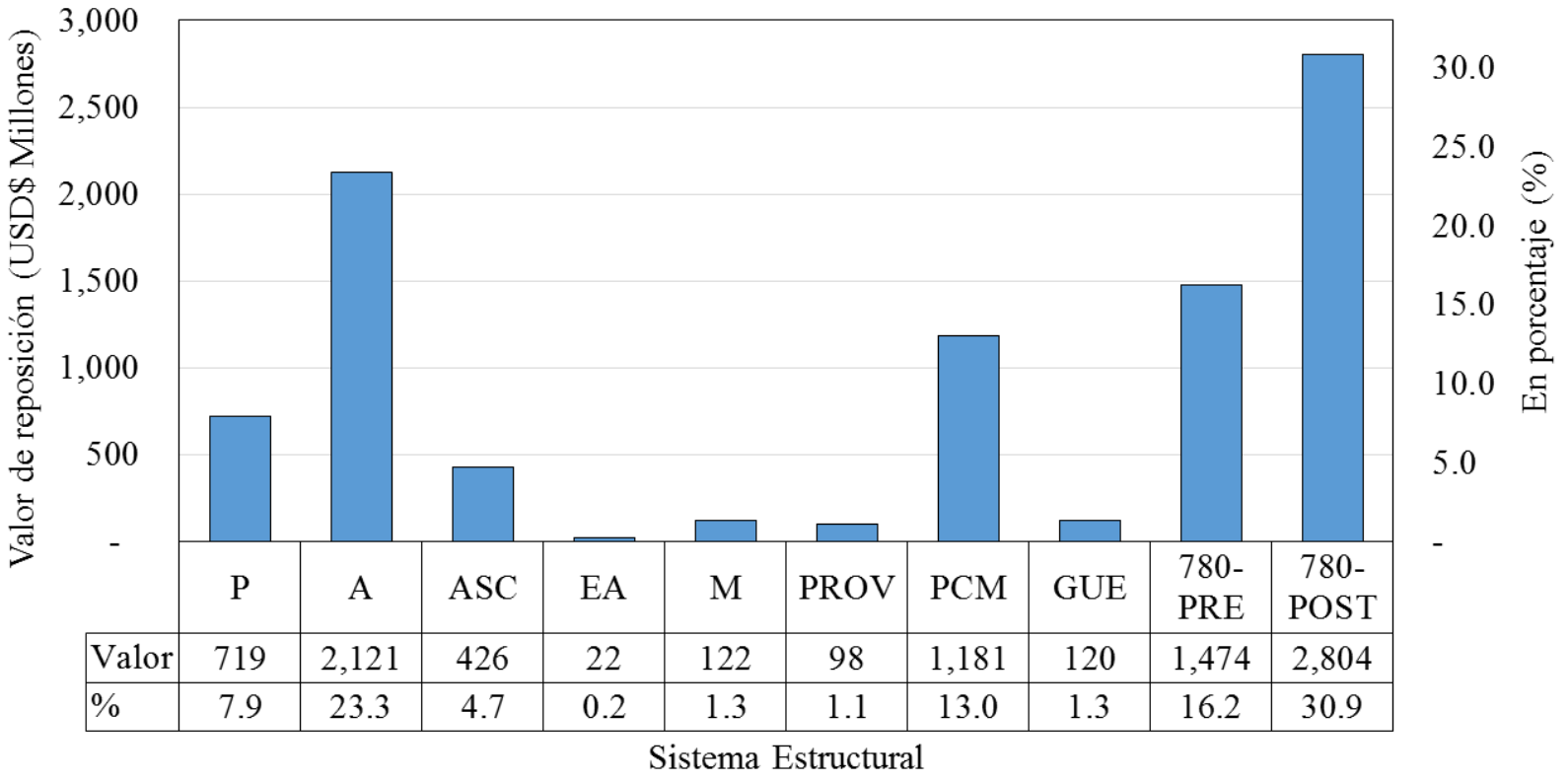


Temporary Classrooms

Complex Buildings (GUE)

Exposed assets

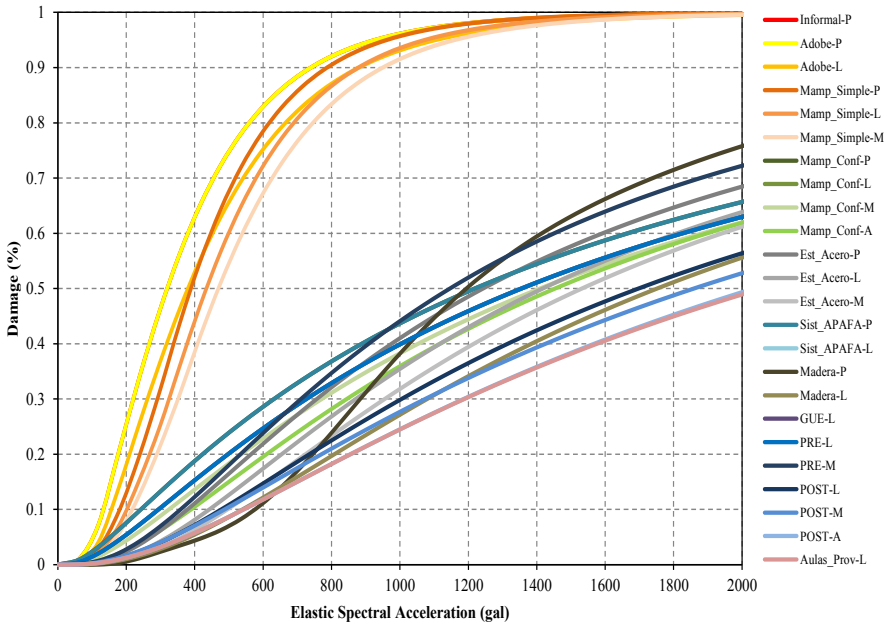
Distribution of replacement cost by typology



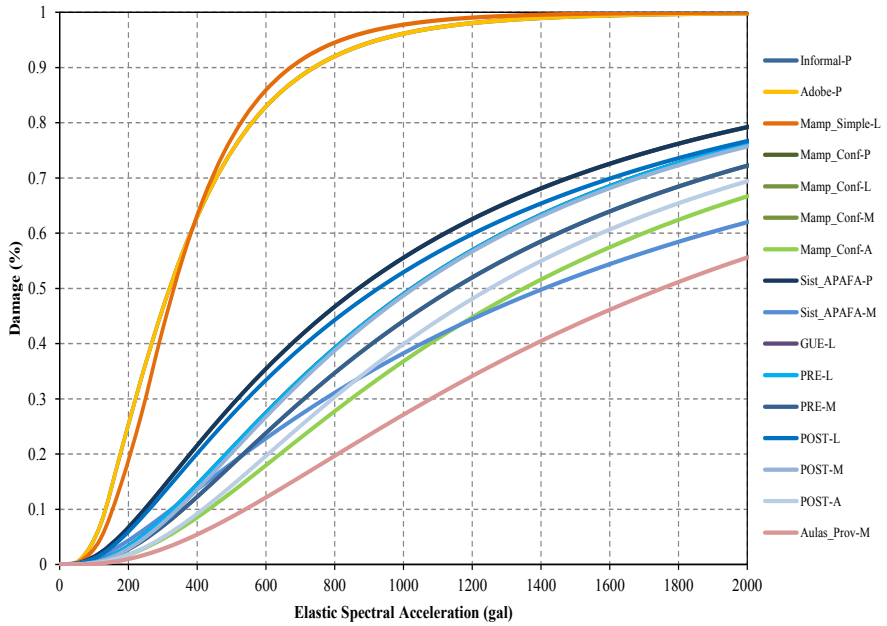
	P	A	ASC	EA	M	PROV	PCM	GUE	780-PRE	780-POST
Valor	719	2,121	426	22	122	98	1,181	120	1,474	2,804
%	7.9	23.3	4.7	0.2	1.3	1.1	13.0	1.3	16.2	30.9

Vulnerability functions

Low rise buildings



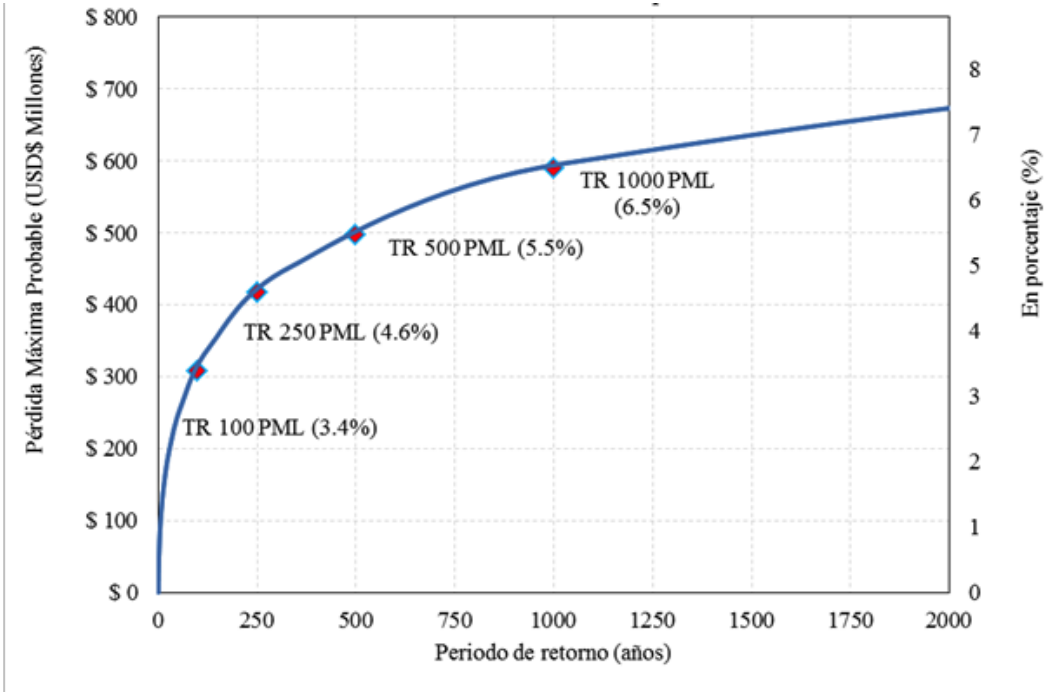
Medium rise buildings



Risk assessment results

Losses and frequency of occurrence

	Value USD$ million	Percentage
Total Exposed Value	9,000	100%
Annual expected loss	190	0,21 %

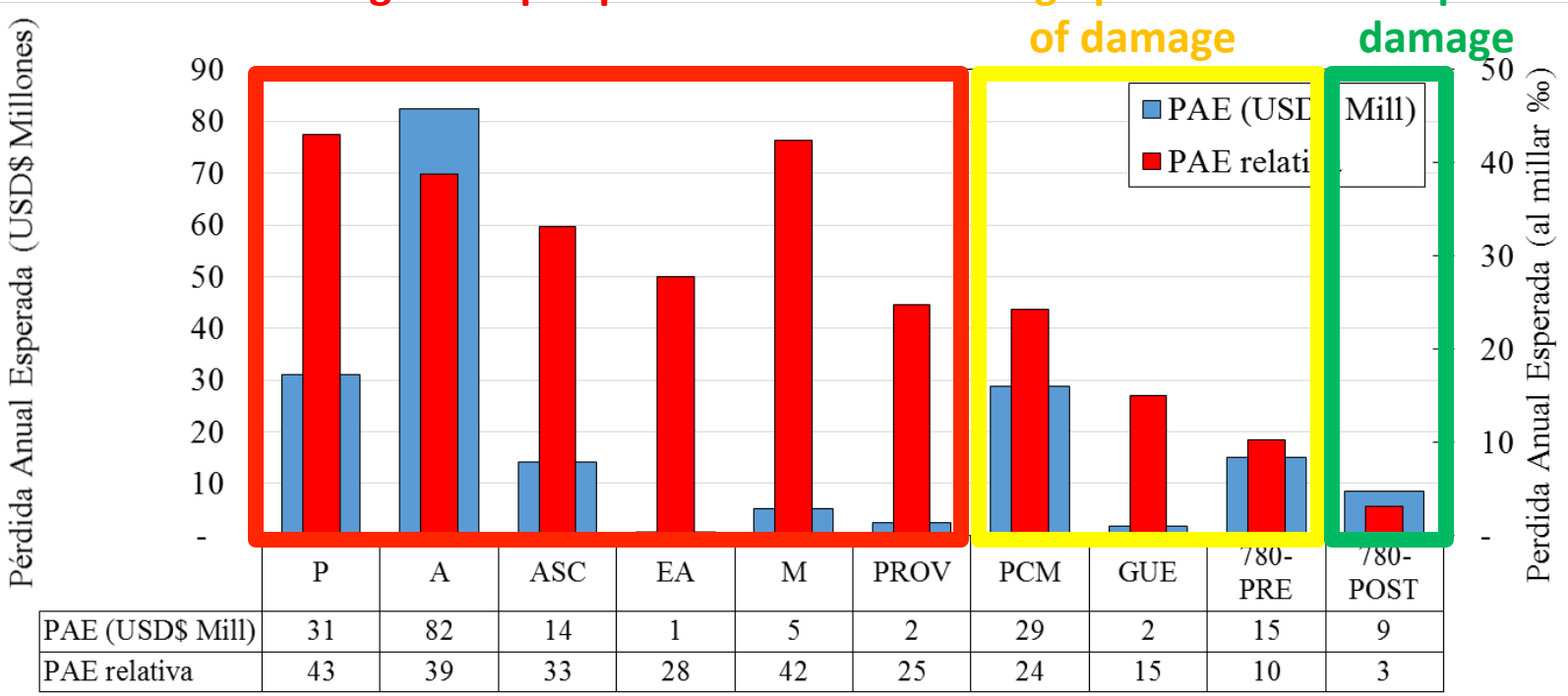


Expected annual losses for each individual component and the portfolio

High collapse potential

High potential of damage

Low expected damage

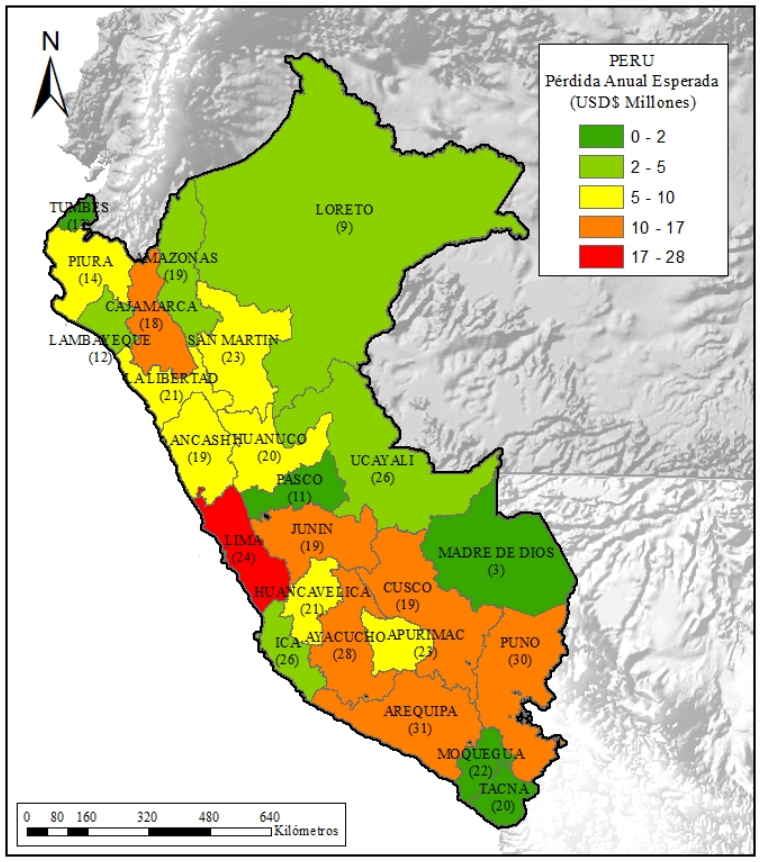


	P	A	ASC	EA	M	PROV	PCM	GUE	780-PRE	780-POST
PAE (USD$ Mill)	31	82	14	1	5	2	29	2	15	9
PAE relativa	43	39	33	28	42	25	24	15	10	3

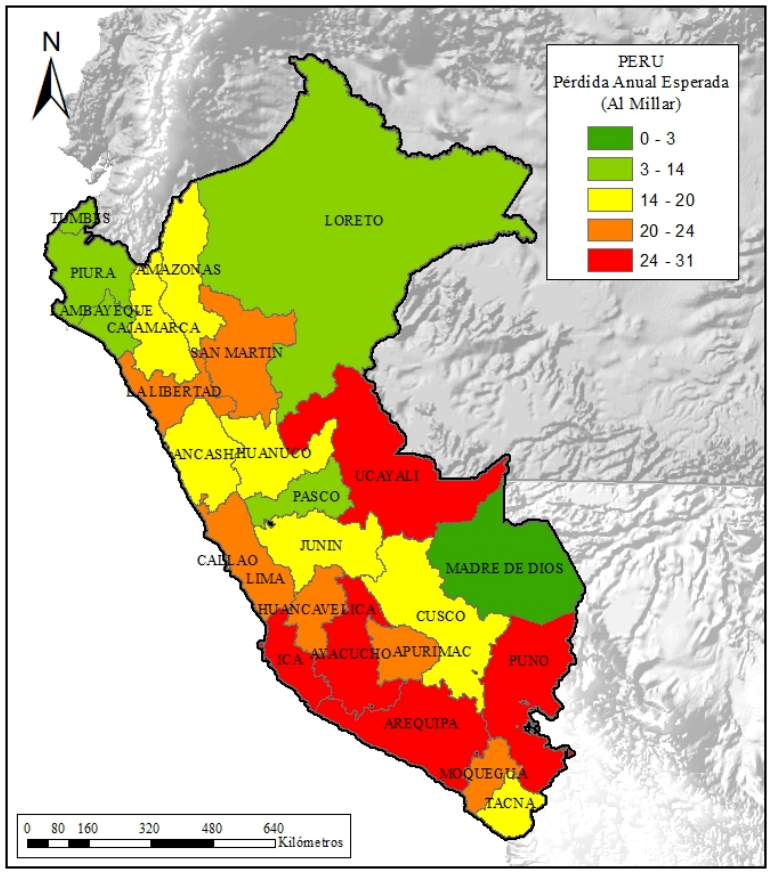
AAL by structural type

Expected annual losses for each individual component and the portfolio

Average Annual Loss (USD$ Millions)



Average Annual Loss (relative)



SEISMIC SCHOOL SAFETY

PROBABILISTIC RISK ASSESSMENT
NEW INFORMATION AVAILABLE

1. More reliable replacement value for each building component
2. Risk indicator for each individual building and for each building typology
3. Geographic distribution of losses

Hands-on session

Probabilistic risk assessment

Question No. 4:

Select the best way to *focus the investment* (optimization)

- ❑ 1. Only buildings in high hazard zones
- ❑ 2. Only buildings with high vulnerability
- ❑ 3. Only buildings with high risk
- ❑ 4. Only buildings where intervention generates an important risk reduction
- ❑ 5. A combination of the above

Hands-on session

Probabilistic risk assessment

Question No. 5:

Select the best criteria to define a *sequence of interventions* (*prioritization of buildings*) :

- ❑ 1. Line of intervention
- ❑ 2. Geographic location
- ❑ 3. Intervention cost
- ❑ 4. Effective risk reduction in each building
- ❑ 5. Number of students benefitted
- ❑ 6. Combination of some of the above

3. Risk mitigation plan

Main components:

1. Identify intervention options according to different typologies and level of risk
2. Assess the total expected cost of interventions
3. Optimization of resources (focus the investment)
4. Prioritization of interventions (sequence of interventions)
5. Disaggregate by activities and regions for implementation

1. Identify interventions options

1. Conventional reinforcement: full seismic code level

2. Incremental retrofitting: level of intervention: CP, LS, DC, IO

3. Complete replacement

4. Contingent intervention to reduce collapse potential in non-critical cases

5. Maintenance: to guarantee functionality

1. Select an intervention according to the building risk category:

1. Buildings with <u>High Potential of Collapse</u> (HPC):

2. Buildings with <u>High Potential of Damage</u> (HPD)

3. Buildings with <u>Low Expected Damage</u>: low seismicity or low vulnerability

2. Assess the total expected cost of interventions

- **Buildings with a High Potential of Collapse (*HPC*):**
  - ✓ **97,110** buildings to be demolished and reconstructed
  - ✓ Substitution cost= [300,450] USD/m2 + 25% (Temporary classrooms) + 10% (demolition)

- **Buildings with a High Potential of Damage (*HPD*):**
  - ✓ **39,933** buildings to be retrofitted
  - ✓ Total Retrofit cost = 50% replacement value

- **Buildings with Low Expected Damage:**
  - ✓ **2,689** buildings undergo maintenance
  - ✓ Maintenance cost = 15% Replacement value

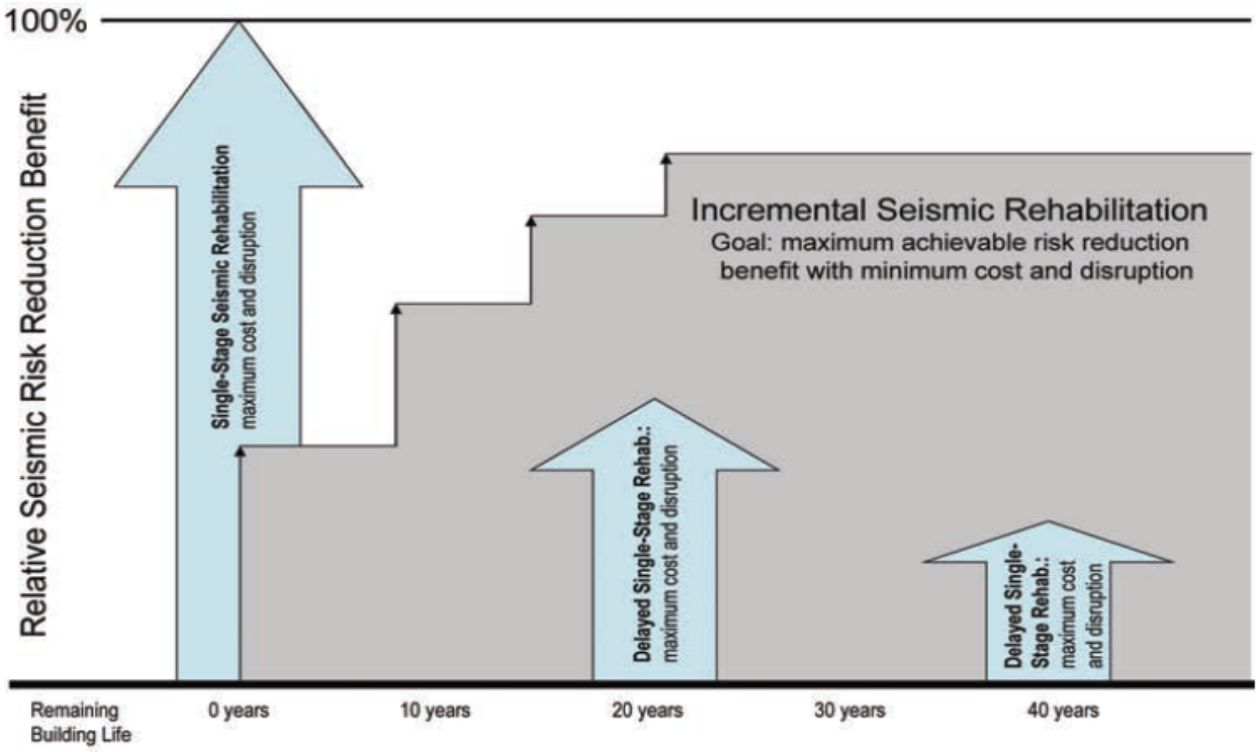
2. Assess the total expected cost of interventions

No.	Intervention program	Number of buildings	USD$ (millions)
1	Replacement of high risk of collapse buildings in High seismic hazard zones	97,110	4,660
2	Conventional reinforcement of high potential of damage buildings in High seismic hazard zones	39,933	1,353
3	Contingent intervention of buildings with low expected damage	2,689	19
	TOTAL INTERVENTION PROGRAM	**139,732**	**6,032**

3. Establish the optimization and prioritization criteria

Incremental retrofitting: discrete steps over a period of time

Acceptable risk reduction with less initial resources



Source: FEMA P-420

3. Establish the optimization and prioritization criteria

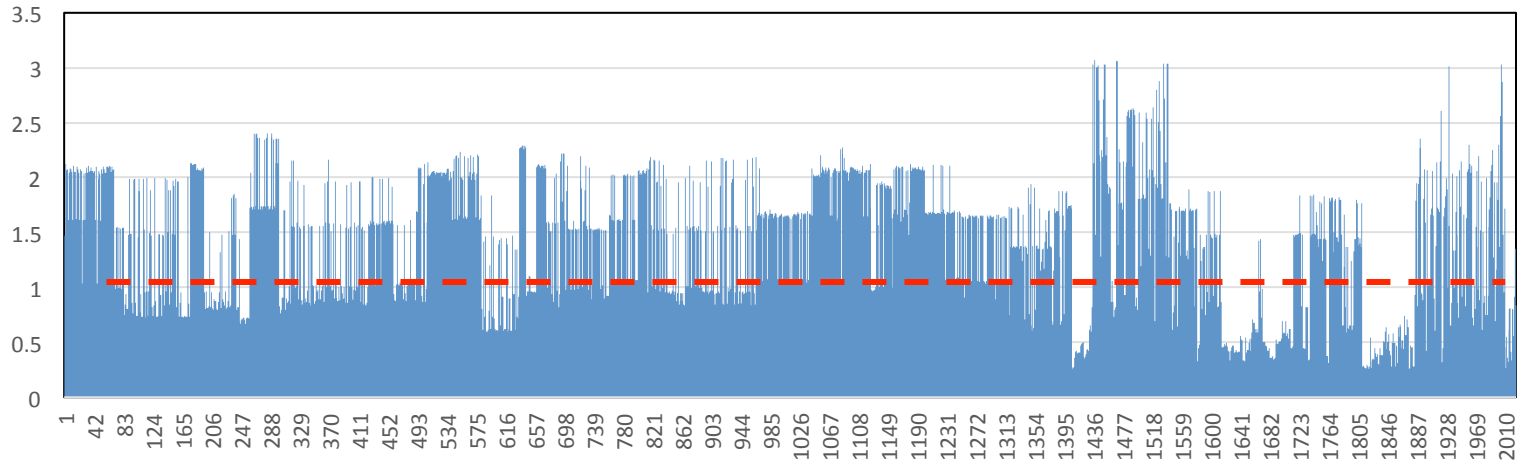
EFFICIENCY/COST INDICATOR

E/C prioritization of building intervention:

Criteria: maximize the effectiveness-cost ratio of the proposed interventions

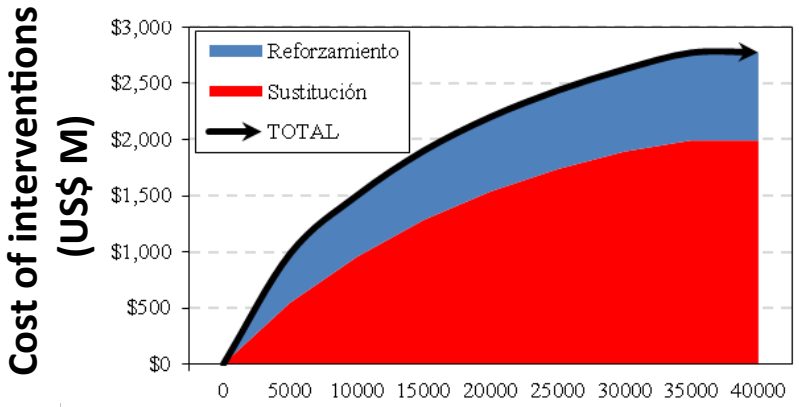
$$E/C = Students{\downarrow}school * (EAL\,\%{\downarrow}\,before\,damage - EAL\%{\downarrow}\,after\,intervention)/Cost\,of\,intervention * i{\downarrow}annual\,discount\,rate$$

E/C for Lima and Callao

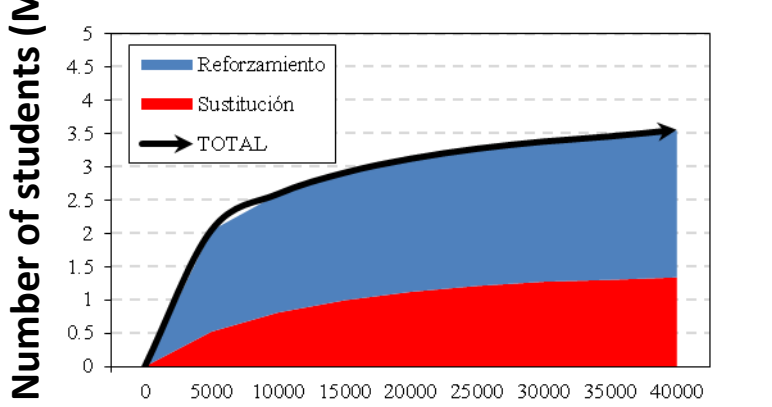


3. Establish the optimization and prioritization criteria

Cost of interventions



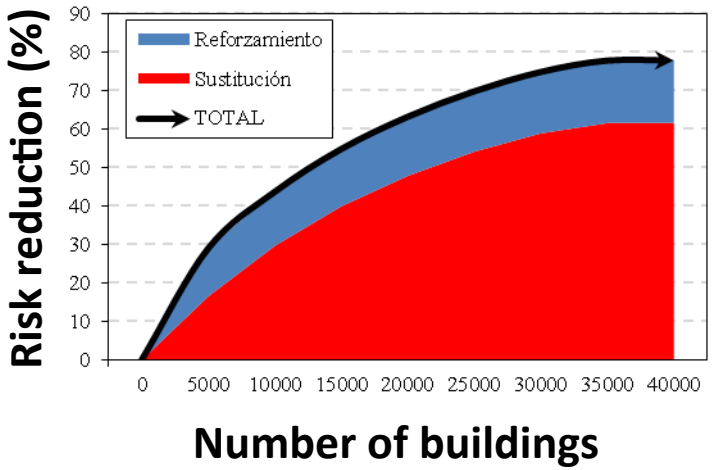
Number of students benefitted



Retrofitting

Replacement

Risk reduction (%)



4. Disaggregate the intervention plan by activities and regions for implementation

1. Critical programs:
   - ***Replacement of high risk of collapse buildings*** in High seismic hazard zones
   - ***Incremental retrofitting*** of high potential of damage buildings in High seismic hazard zones

2. Critical regions:
   - ***High seismic hazard*** zones
   - ***High risk concentration*** zones

4. Disaggregate the intervention plan by activities and regions for implementation

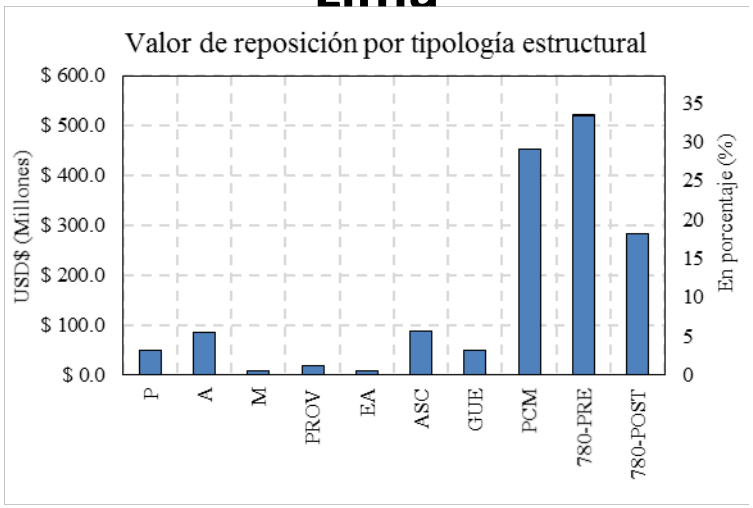
No.	Critical Intervention program	Number of buildings	USD$ (millions)
1	Replacement of high risk of collapse buildings in High seismic hazard zones	73,645	1,990
2	Incremental retrofitting of high potential of damage buildings in High seismic hazard zones	34,984	783
	TOTAL INTERVENTION PROGRAM	**108,629**	**2,778**

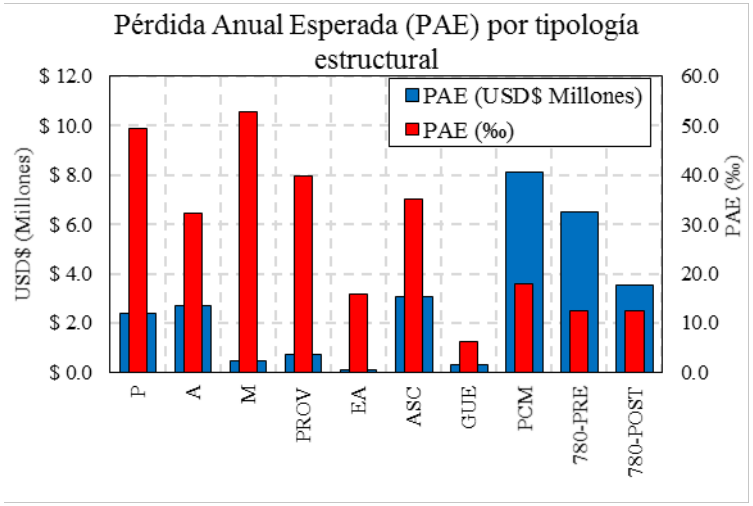
Total new gap: ***USD$ 2,8 Billion***

1.3% National GDP

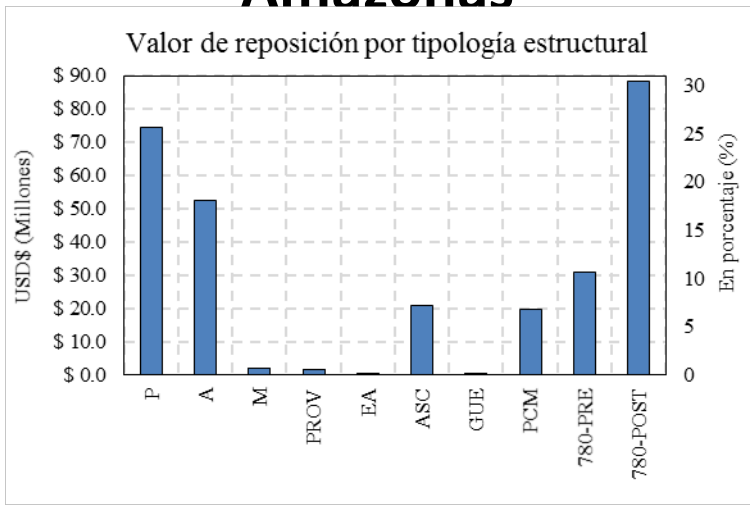
A comparative example for regional mitigation programs

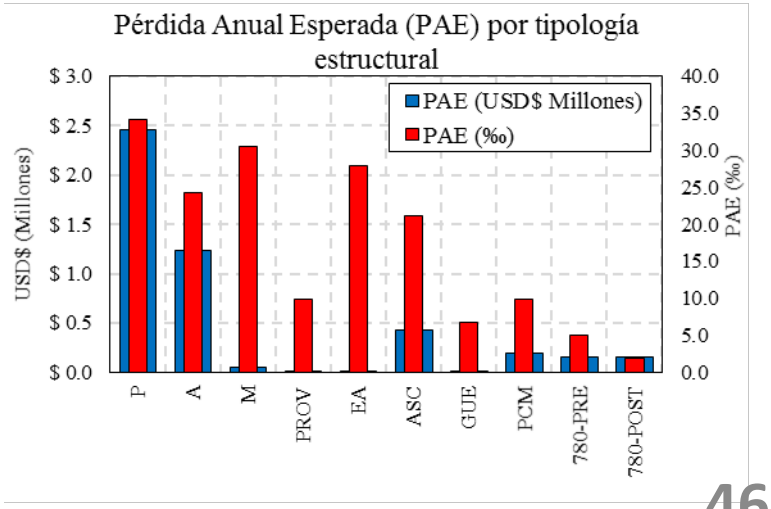
Lima





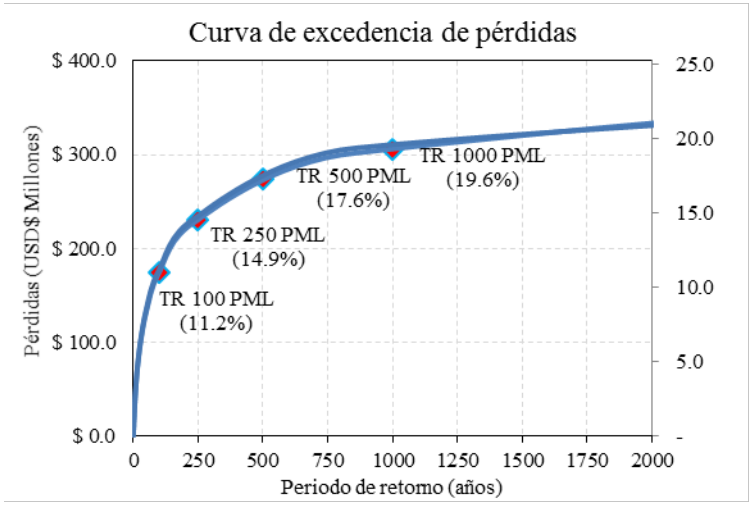
Amazonas

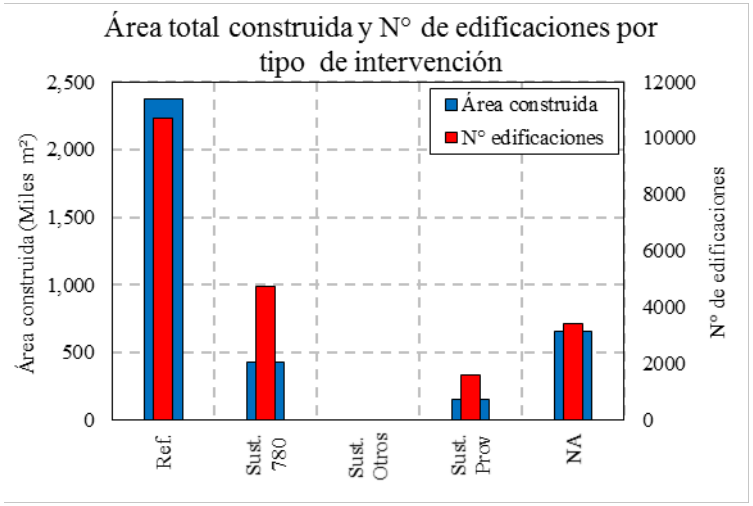




Comparison between the two regions

Lima





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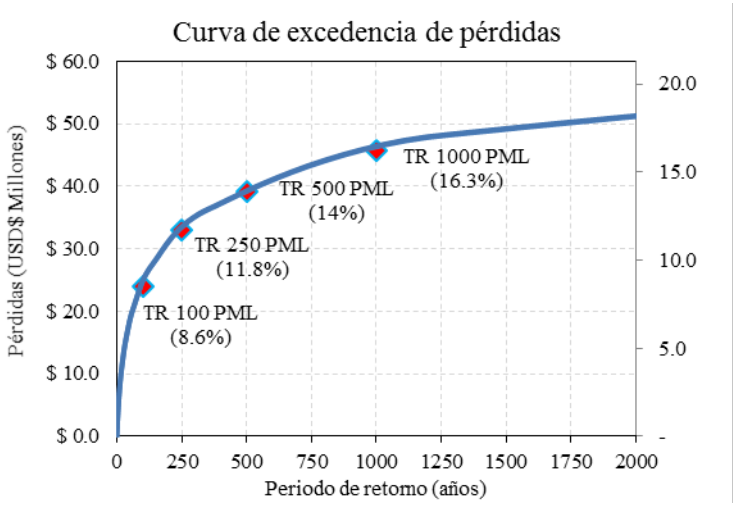
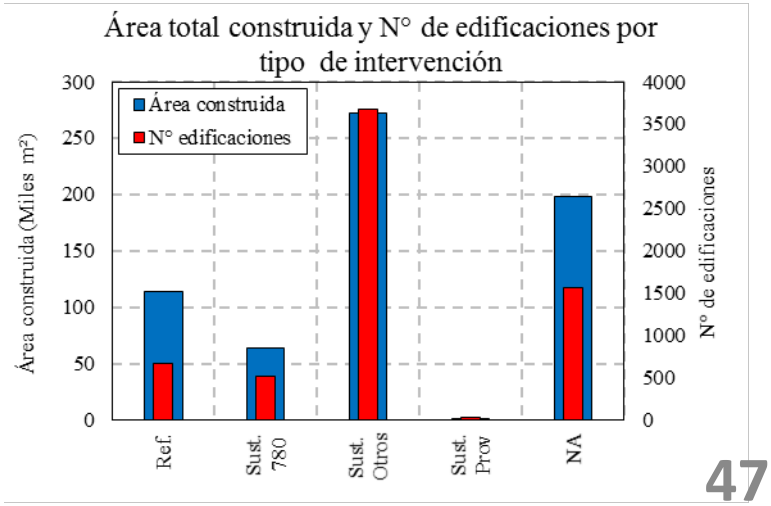
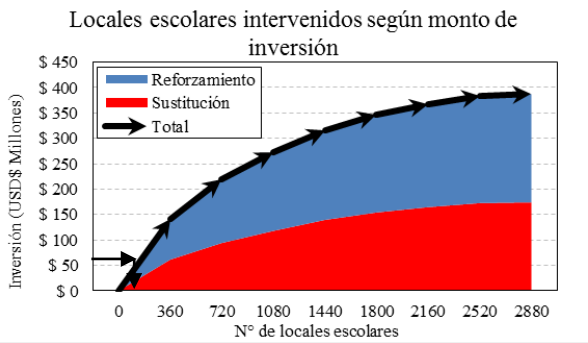
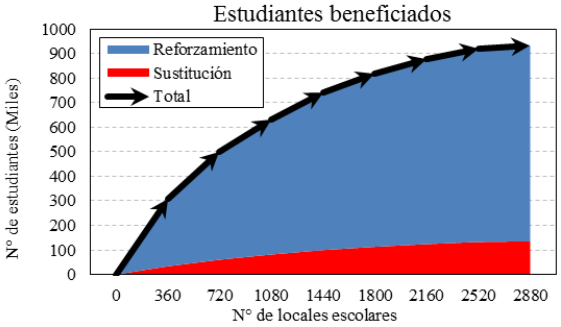
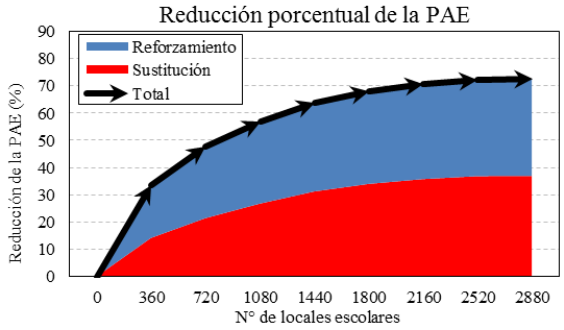




Lima







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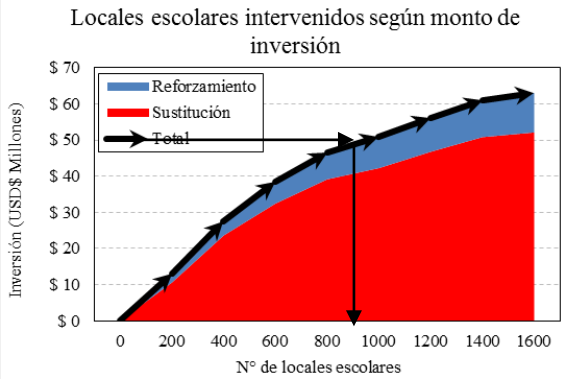

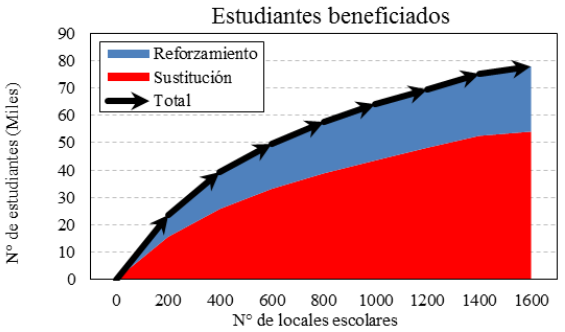

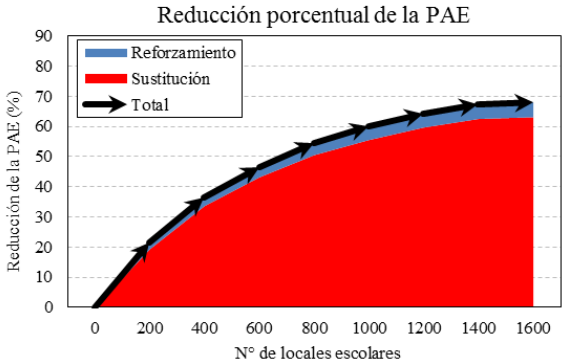

PERU – National School Infrastructure Plan 2025

PROGRAMS	SUBPROGRAMS	Total GAP (USD billions)	Natl Plan (USD billions)
P1. Risk reduction	S1.1 Incremental retrofitting	1.2	1.2
	S1.2 Demolition and temporary classrooms	2.1	2.1
	S1.3 Conventional retrofitting	0.1	0.1
	Subtotal	3.4	3.4
P2. Furniture and equipment		2.2	1.4
P3. Maintenance of school infrastructure		2.3	2.3
P4. Improvement and expansion of existing school facilities		10.0	5.6
P5. New school infrastructure	S.5.1 Plan Selva	0.4	0.4
	S.5.2 Replacement of school buildings	7.3	7.3
	S.5.3 New school facilities	6.3	2.5
	Subtotal	13.9	10.1
ET. Building capacity for school infrastructure management		0.9	0.8
TOTAL		32.7	23.6

Hands-on session

RISK MITIGATION PLAN

Question No. 6:

If you use this approach in your country, what will be the greatest challenge?

- ❑ 1. To build a good inventory
- ❑ 2. To develop a hazard model
- ❑ 3. To quantify risk
- ❑ 4. To integrate risk data into long-term planning
- ❑ 5. Government engagement and leadership of the process
- ❑ 6. Other

Thank you

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