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MULTI-RISK ANALYSIS AND INFORMATION SYSTEM COMPONENTS FOR THE ANDES REGION

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Development of multi-hazard exposure models from individual building observations for multi-risk assessment purposes

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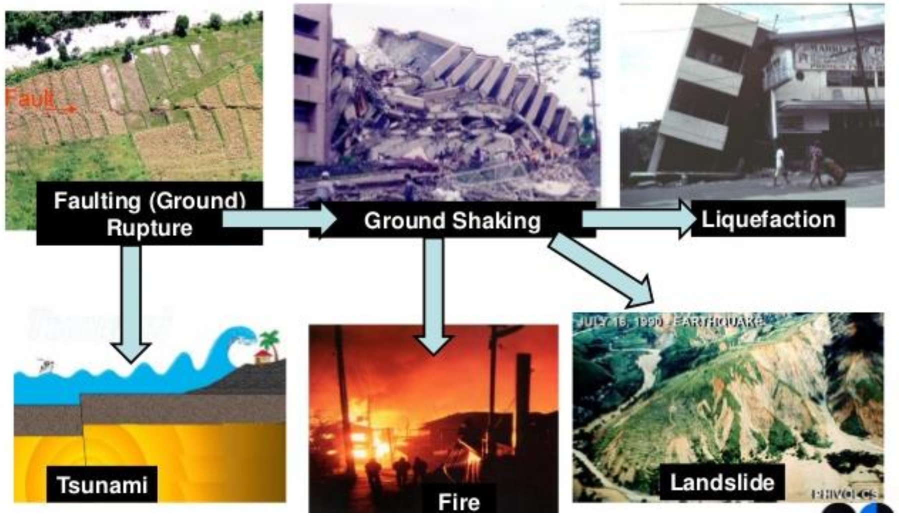
DLR GFZ Helmholtz-Zentrum Potsdam AWI TUM 52north exploring horizons geomer EOMAP plan + risk DIALOGIK

Multi- hazard- building

In recent decades, the risk to society due to natural hazards has increased globally. To counteract this trend, an efficient risk management is necessary, for which reliable information is essential.



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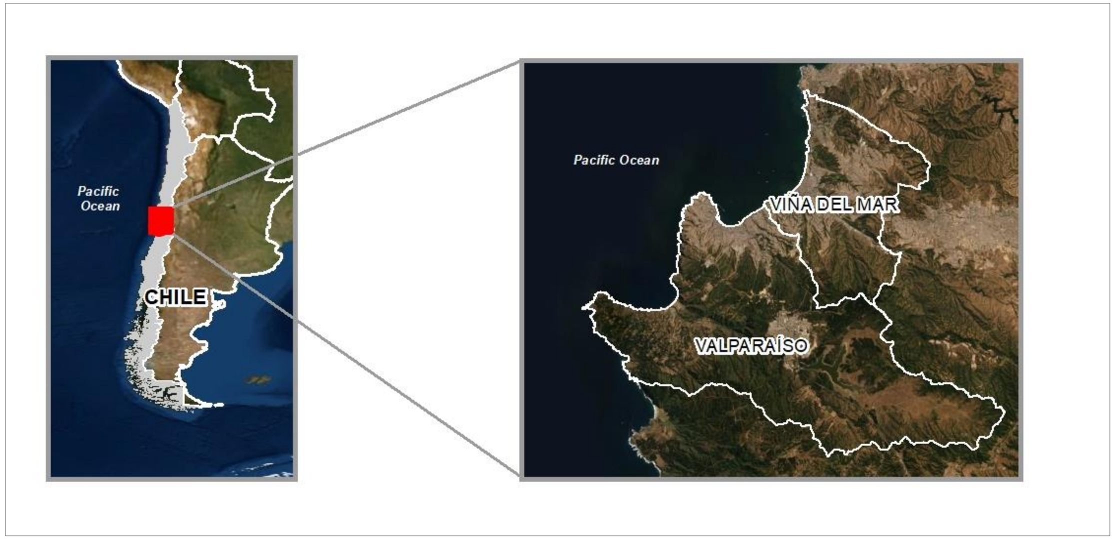
Finding a single risk- oriented taxonomies to classify a building with a single label under several hazards (with different controlling vulnerabilities) is a daunting task. Thus, implementing an approach similar to HAZUS-MH will not be any more feasible to be implemented in areas with non-calibrated exposure compositions nor expected intensities (sensitively different than the expected in the US).

Motiviation: Classifying the built environment for hazard- risk- loss assessment



How to classify a building stock into mutually exclusive, collectively exhaustive (MECE) building classes?

How can we “safely” assign a fragility function to certain building sample if most of the individual information from OSM address unstructured formats?

Typical features of masonry buildings in Valparaíso, Chile. Courtesy of Jimenez et al, 2018

Sotomayor square and Cerro Alegre and Cerro Concepción. Courtesy of Jimenez et al, 2018

Typical reinforced concrete buildings in Valparaíso. Courtesy of Jimenez et al, 2018

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A multi- hazard- building taxonomy (MHBT)

Seismic- oriented faceted GEM building taxonomy

GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

Brzev et al, 2013

Are there any other controlling building attributes that may drive the building's vulnerability towards other hazards?

e.g. Charvet et al, 2017
Blanco-Voigt, 2015

The RIESGOS Multi- hazard- faceted building taxonomy

GED4ALL RIESGOS

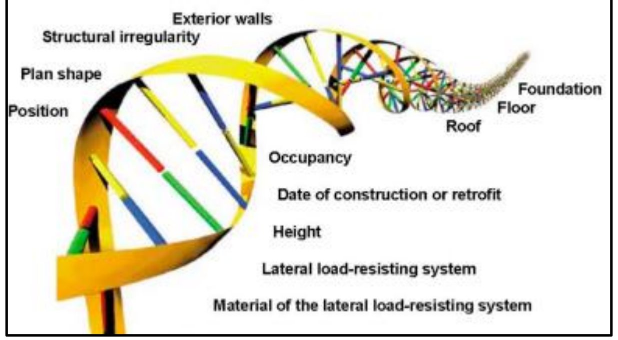
Silva et al, 2018

Building's structural and non-structural properties on a global scale.

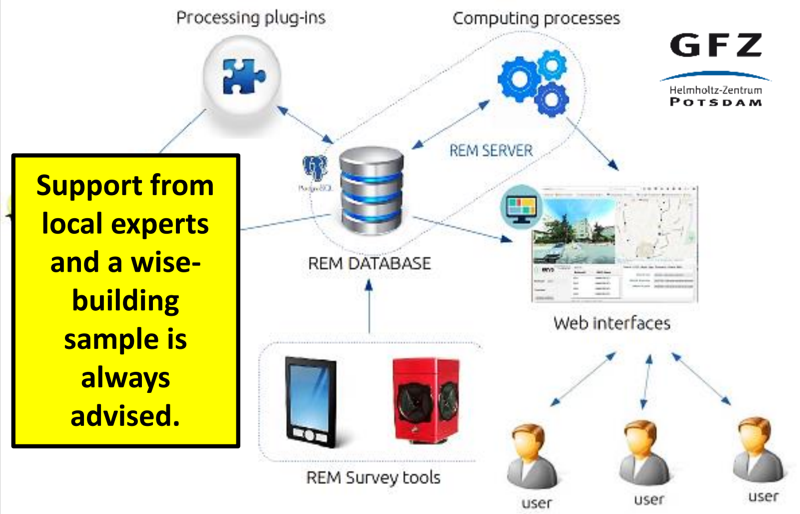
(this work after Haas et al, 2016 and (Pittore et al., 2017)

A comprehensive multi-hazard facted building taxonomy able to address most of the building attributes driving the vulnerability with respect to different hazards

Standard classification system
- Risk-oriented (e.g. EMS-98, Hazus)
- Faceted (e.g. GEM v2.0)

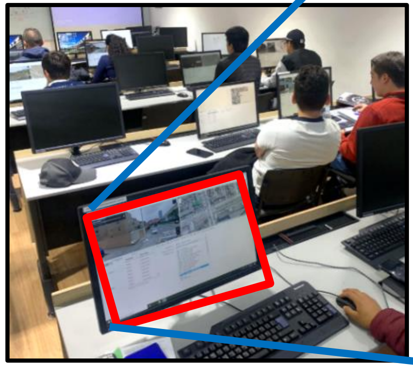


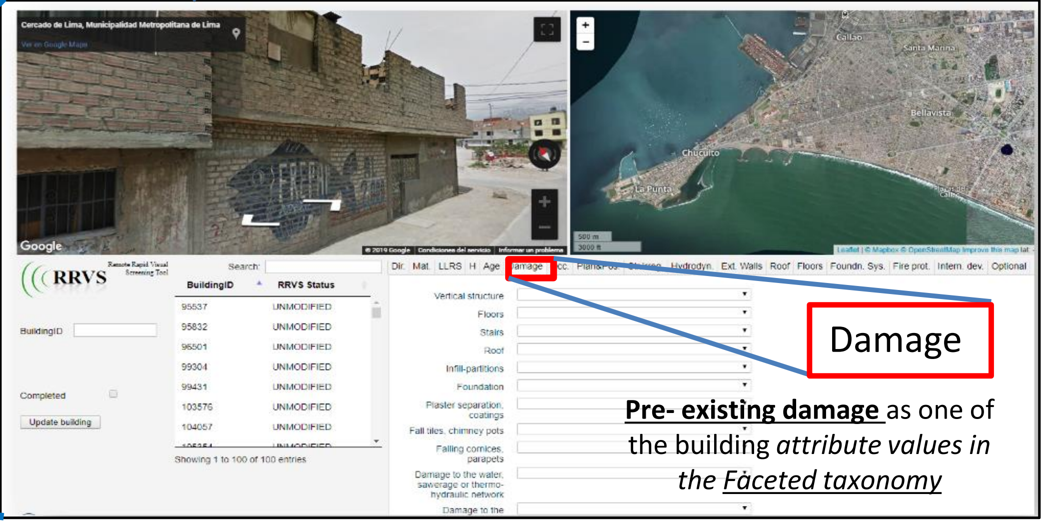
The RRVS system (Rapid Remote Visual Screening)



Support from local experts and a wise- building sample is always advised.

Thousands of collected individual observations from sampled buildings





Pre- existing damage as one of the building *attribute values in the Faceted taxonomy*

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Translating every Building schema to a faceted taxonomic description

The fuzzy compatibility scores per class

Example: EMS-98 (Grünthal, 1998)

After Pittore et al (2018)

'RC3':

- {'floor_mat': {'FC': '+++','F99':'0'},
- 'floor_conn': {'FWCP': '+++','FWC99':'0'},
- 'mat_prop': {'MOC': '++', 'MOCL': '++','MATP99':'0'},
- 'llrs': {'LFINF': '+++'},
- 'llrs_duct': {'DNO': '+', 'DUC': '+++','DU99':'0'},
- 'height_1': {'H_MIN': 1, 'H_MAX': 99},
- 'floor_type': {'FC1': '+', 'FC2': '+++', 'FC3': '+', 'FC4': '+', 'FC99': '+' ,'FT99':'0'},
- 'mat_type': {'SRC': '++', 'CR': '+++', 'C99': '++', 'CU': '-', 'M99': '--', 'MUR': '---', 'MR': '-','W':'---','MATT99':'---','MCF':'---','S':'---'},
- 'mat_tech': {'CIP': '+++','MATT99':'0'}},

'MUR1':

- {'floor_mat': {**'FW':** '+++', 'FC':'+','F99':'0'},
- 'floor_conn': {'FWCN': '+++','FWC99':'0'},
- 'mat_prop': {'MON': '+', **'MOM':** '+++', 'MOL': '+', 'MOC': '+', 'MOCL': +', 'MATP99':'0','MO99':'+'},
- 'llrs': {**'LN': '+++', 'LWAL': '++'},**
- 'llrs_duct': {'DNO': '++', 'DU99':'0'},
- 'height_1': {'H_MIN': 1, 'H_MAX': 99},
- 'floor_type': {'FW4': '+', 'FW99': '+', 'FW3': '+', 'FW1': '+++', 'FW2': '+' ,'FT99':'0'},
- 'mat_type': {'M99': '+', 'MUR': '+++','MR': '-','SRC': '--', 'CR': '---', 'C99': '--', 'SRC': '--', 'CR': '---', 'C99': '--', 'CU': '-',
- 'W':'---','MAT99':'---','MCF':'+','S':'---'},
- 'mat_tech': {'STDRE': '++', 'ST99': '+', 'STRUB': '+++', 'MUN99': '+', 'MATT99':'0'}, },

Building type	Description	GEM taxonomy string
ADO	Adobe/Earth bricks	MUR+ADO+WWD+MOM/LN+LWAL/FW+FW1+FWCNH:99,1
*MUR1**	Rubble stone	MUR+STRUB+MOM/LN+LWAL/FW+FW1+FWCNH:99,1
MUR2	Simple stone	MUR+ST99+MOL/LN+LWAL/FW+FW1+FWCNH:99,1
MUR3	Massive stone	MUR+ST99+STDRE+MOL/LN+LWAL/FW+FW1+FWCN/H:99,1
MUR4	Unreinforced masonry with manufactured stone units	MUR+ST99+MOCL/LN+LWAL/FW+FW1+FWCN/H:99,1
MUR5	Unreinforced masonry with RC floors	MUR+MO+MOC/LN+LWAL/FC+FWCP/H:99,1
MR	Reinforced or confined masonry	MR+MCF+M99/LN+LWAL/FC+FC2+FWCP/H:99,1
RC1	Reinforced concrete frame without earthquake-resistant design (ERD)	CR+CIP/LN+DNO/FC+FC2+FWCP/H:99,1
RC2	Reinforced concrete frame with moderate earthquake-resistant design (ERD)	CR+CIP/LFM/FC+FC2+FWCP/H:99,1
*RC3***	Reinforced concrete frame with high level of earthquake-resistant design (ERD)	CR+CIP/LFINF+DUC/FC+FC2+FWCP/H:99,1
RC4	Reinforced concrete walls without ERD	CR+CIP/LWAL+DNO/FC+FC2+FWCP/H:99,1
RC5	Reinforced concrete walls with moderate level of ERD	CR+CIP/LWAL/FC+FC2+FWCP/H:99,1
RC6	Reinforced concrete walls with high level of ERD	CR+CIP/LDUAL+LFM+DUC/FC+FC2+FWCP/H:99,1
STEEL	Steel structures	S+SO+S99/LFINF+DUC/H:99,1
WOOD	Timber structures	W/DUC/FW+FW1/H:99,1

MUR = Masonry, unreinforced, ADO = Adobe blocks, WWD = Wattle and daub [WWD], MOM = Mud mortar, W = WOOD, DUC = Ductile, FW = Wooden floor, FW1 = Wooden beam or trusses and joists supporting heavy flooring, S = STEEL, SO = Steel, other, S99 = Steel, unknown, LFINF = Infilled frame, CR = Concrete, reinforced [CR], CIP = Cast-in-place concrete [CIP], LFM = Moment frame, LDUAL= Dual frame-wall system [LDUAL], FC2 = Cast-in-place beam-supported reinforced concrete floor [FC2], FWCP = Floor-wall diaphragm connection present [FWCP], LWAL = Wall [LWAL], DNO = Non-ductile [DNO], MR= MASONRY REINFORCED, MCF = Masonry confined, M99 = Masonry, unknown reinforcement [M99], ST99 = Stone, unknown technology [ST99], MOCL = Cement: lime mortar [MOCL], FWCN = Floor-wall diaphragm connection not provided [FWCN], , STRUB = Rubble (field stone) or semi-dressed stone [STRUB]

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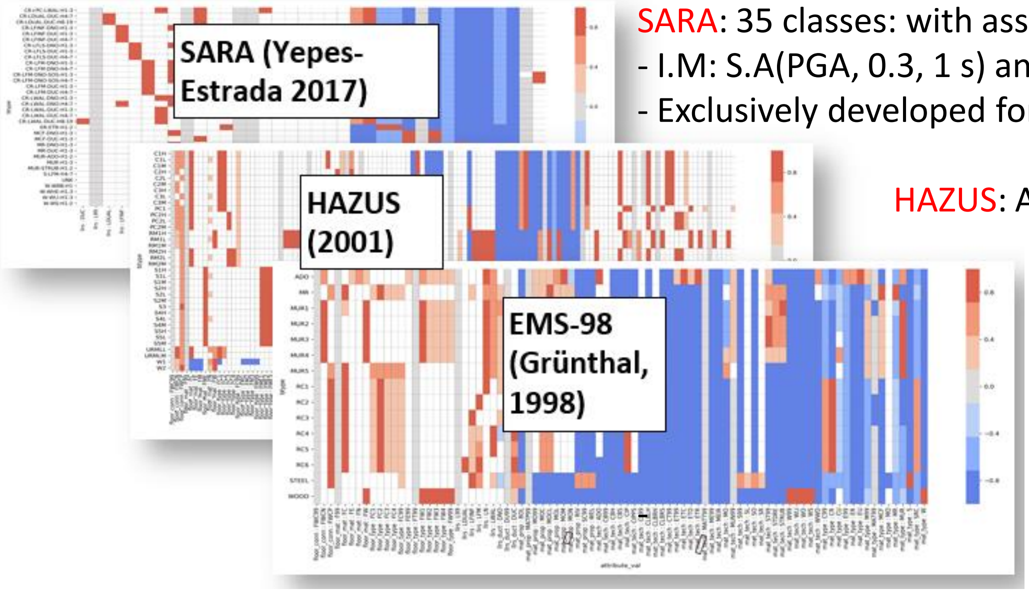
Single- hazard- building schemas: The fuzzy compatibility-scores representation

Graphical representation of the fuzzy scores *After Pittore et al (2018)*

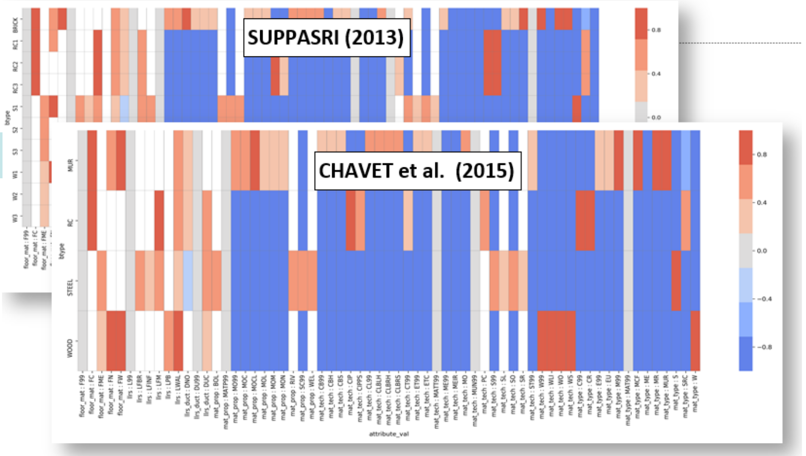
Independent classification per reference hazard of individual building observations



SARA: 35 classes: with associated **analytical** fragility functions.
- I.M: S.A(PGA, 0.3, 1 s) and 4 damage states.
- Exclusively developed for South-America!

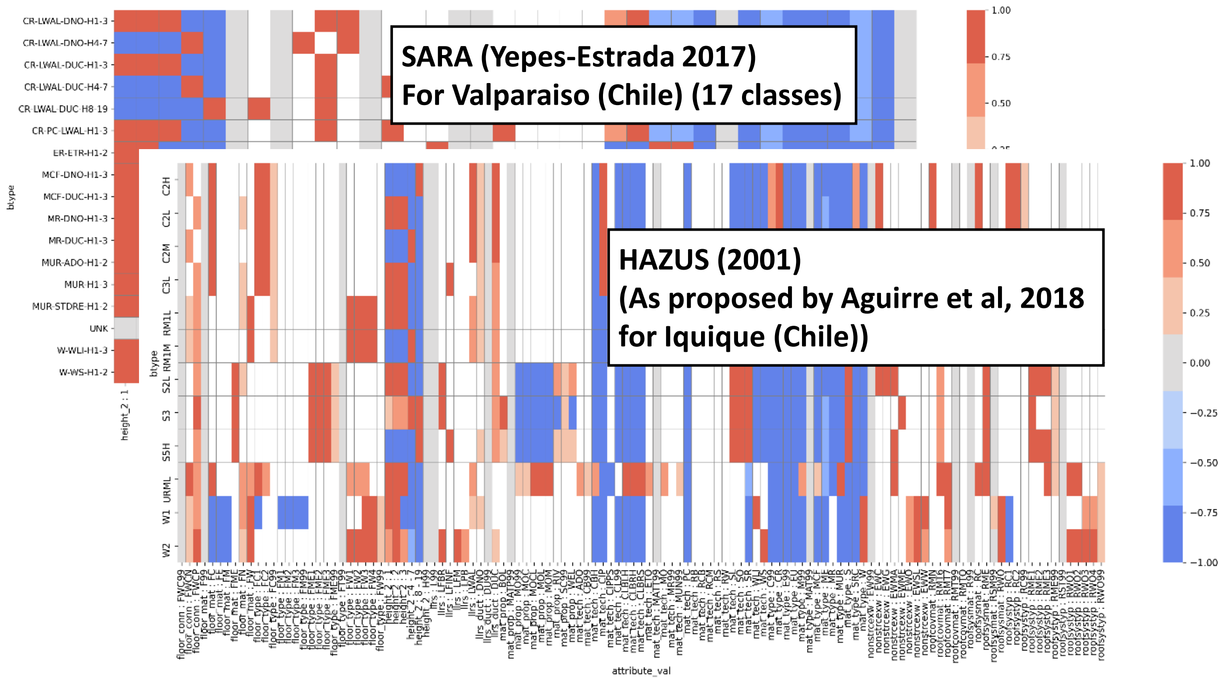
HAZUS: Around 36 classes per code- compliance level with associated **analytical** fragility functions
- I.M: S.A(PGA, 0.3, 1 s) and 4 damage states.
- Exclusively developed for USA!

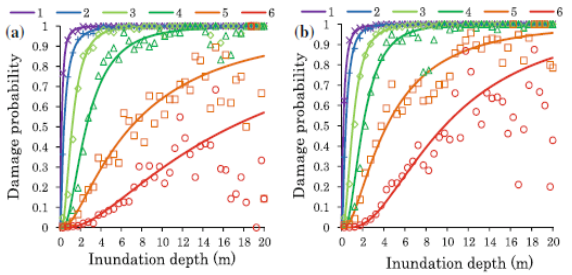
EMS-98: 15 classes. **No associated analytical** fragility functions.
- I.M: Macroseismic intensity and 5 damage states
- Recent proposal in RISK-EU model (ELER)has mixed them up with HAZUS in order to obtain *semi-empirical* functions in terms of the spectral displacement.
- Exclusively developed for Europe!



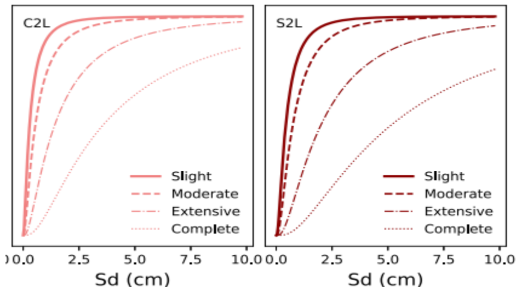
Both schemas offer empirical fragility functions and are obtained after the great 2011 Great East Japan tsunami event. Only material and height were inspected. I.M: inundation height . Suppasri: 6 damage states; Charvet: 5 damage states. Their corresponding curves have been used to assess the expected damage due to tsunami in many other areas (e.g. Adriano et al., 2014 for in Callao, Peru)

So, which fragility should we use?

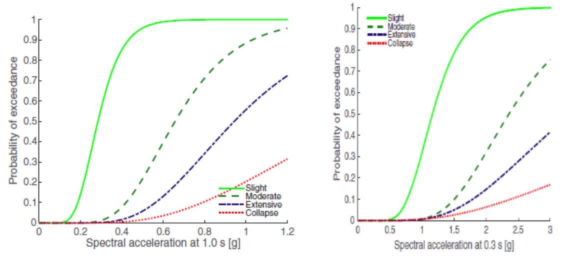




Masonry and wood. Six damage states have been proposed. Figures are reprinted from Suppasri et al., 2013.



C2L, and S'2L, for the case of moderate seismic design level. Four damage states. (FEMA 2012)



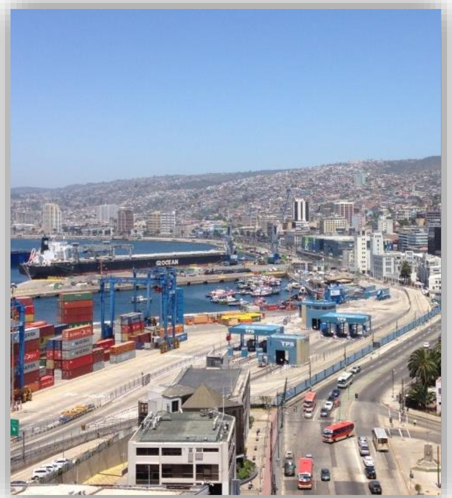
LFM/DUC/H:4 and (b) W+ WLI⁄H:2. Four damage states. Figures are reprinted from Villar-Vega and Silva, 2017.

- Even after narrow down the building classes per site- specific localities (e.g. material and construction practices), the different compatibility levels and compositions allow to visualize the building exposure as a non-fixed model with static proportions, but as **a dynamic one with a statistic signature** (e.g. Pittore et al, 2020)

Careful hazard- driven spacial sampling *(footprint, intensity...?)*

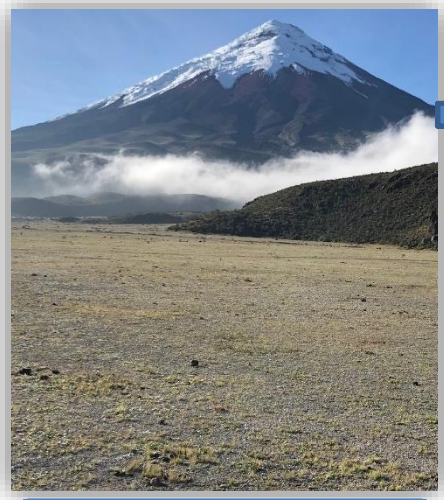
PERU – Metropolitan Lima and Callao

Earthquake



CHILE – Valparaíso province

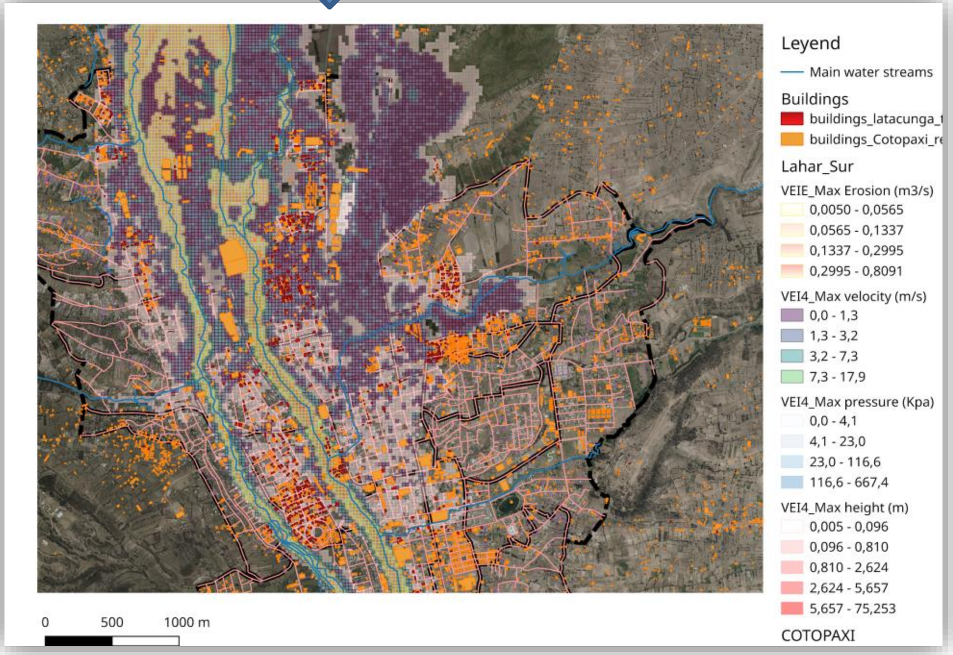
Tsunami



ECUADOR – Quito / Cotopaxi region

Ash-Fall

Lahar



Hazard information has been used to drive the spatial sampling and data collection of building attributes in the field (e.g., Latacunga, Ecuador, with lahar hazard intensities superimposed

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The probabilistic building class assignment

Once we have had:

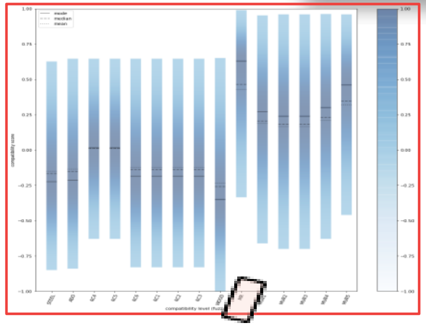
1. The faceted multi-hazard building taxonomy within the RRVS system
2. The fuzzy compatibility scores within every building schema and LOCALLITY

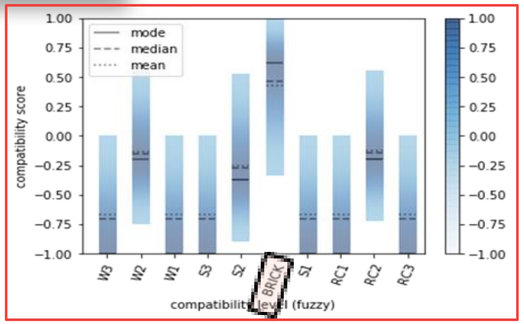
We can then:

3. Create a building sample and let's inspect them!
4. The assignment of a class is carried out *in a post-processing stage and within a fully probabilistic framework by evaluating the level of compatibility between the observed building attributes and the classes available within the considered schema.*

After Pittore et al (2018)

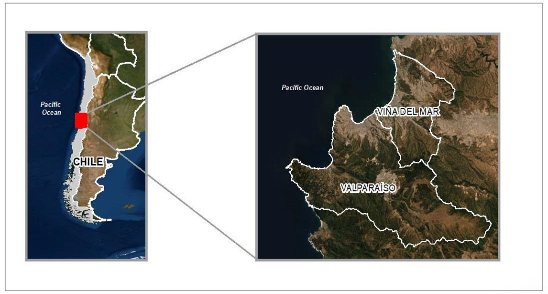
Per- inspected building



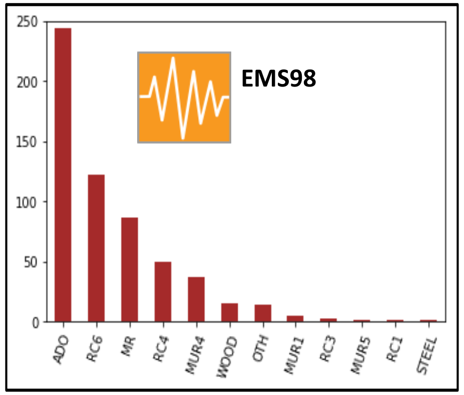


There is certain impact on the weights selection (per attribute value)

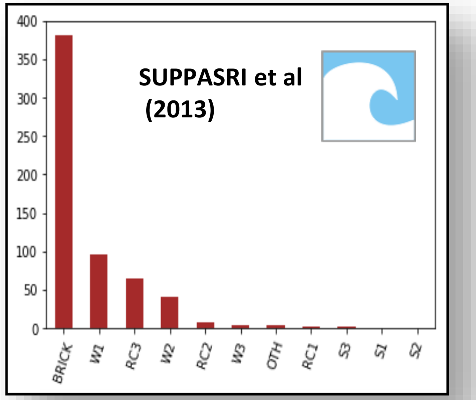
Multi-hazard taxonomies and fuzzy mapping allow to create dynamic exposure models

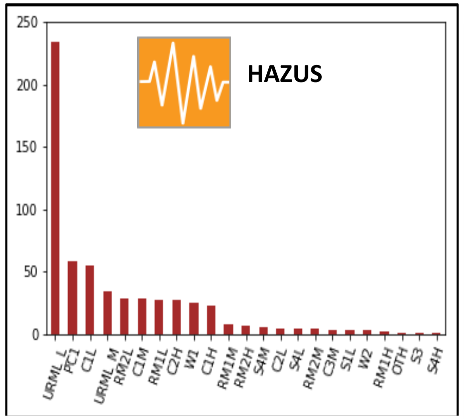


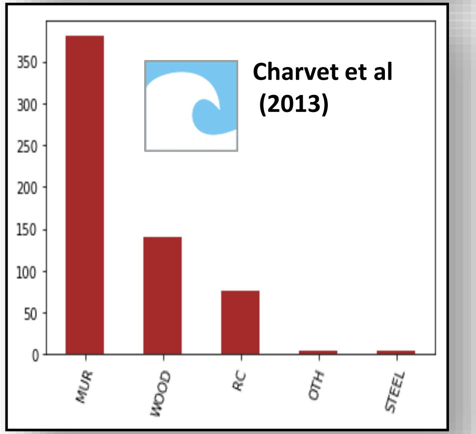
Example: for 602 inspected buildings in Valparaiso, Chile. Let's see their exposure composition under 4 different schemas.



(b)







Some Remarks

- The definition of mutually exclusive, collectively exhaustive (MECE) building classes per reference hazard with associated fragility functions should be constrained at the local study area. and using a multi- hazard building faceted taxonomy in order to define the building exposure models (per every considered hazard) has shown their advantages in a multi-risk- framework.
- A comprenhensive faceted multi-hazard- building taxonomy Faceted provide flexible and (largely) hazard independent support to describe built environment.
- Faceted – Exposure- taxonomies should be able to address most of the building attributes driving the vulnerability with respect to different hazards, and also the pre- existing damage over certain individual building elements.
- The implementation of a multi- hazard- faceted taxonomy to collect local observations over a selected building sample has high relevance in order to constrain the innitial assumptions and as actual inputs in a statistical exposure model.
- The general assumption of “intact” buildings for which the conventional single- hazard fragility functions are made is questioned and overcoming this aspect should be a general issue to be addressed by the Multi- hazard- community.
- Individual, quality observations ensure consistency and long-term sustainability to (multi-hazard) exposure models
- Careful, smart spatial, with hazard- dependency sampling of the exposed assets is a key issue in the building exposure definition.
- Individual, quality observations ensure consistency and long-term sustainability to (multi-hazard) exposure models
- The actual implementation of the explored schemas should be constrained at the local study area.
- Only in the case of the exposure definition, the epistemic uncertainty in the exposure modelling (building class assignment) could be very different depending on the chosen initial schema.

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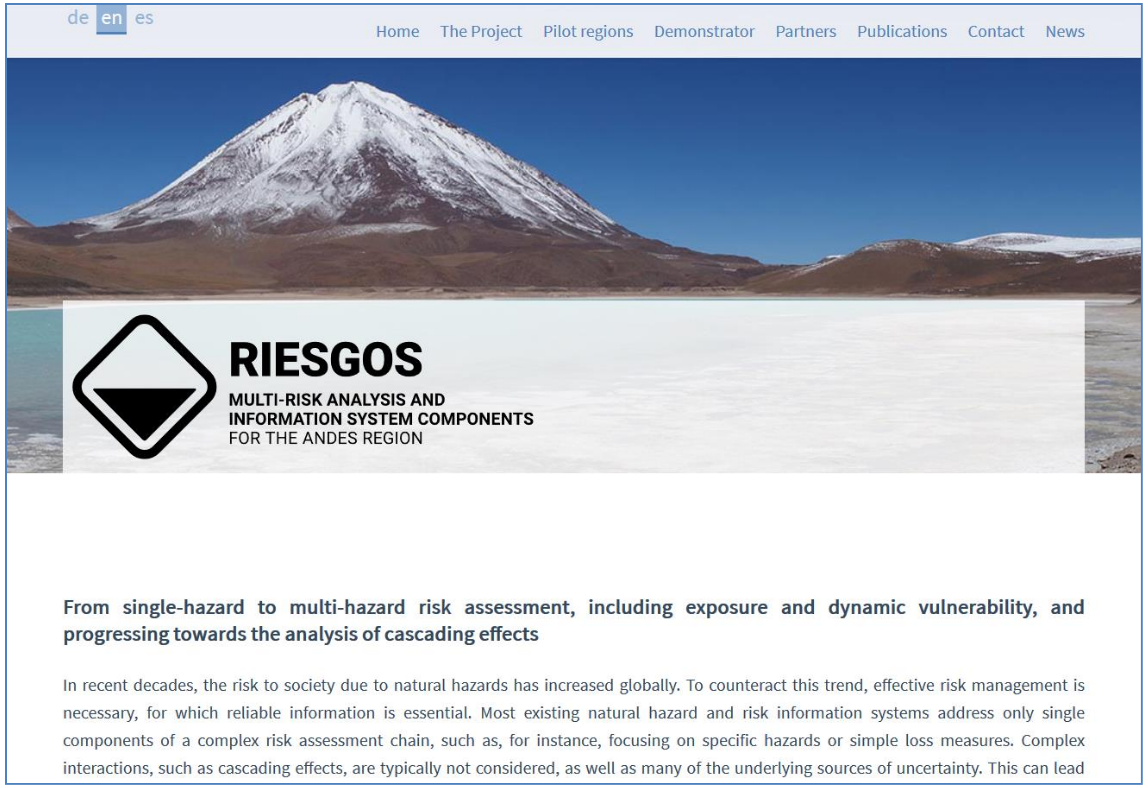

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