

Sensor data, AI and drones for enhanced monitoring and seismic risk decision support

Gerard J. O'Reilly

IUSS Pavia, Italy

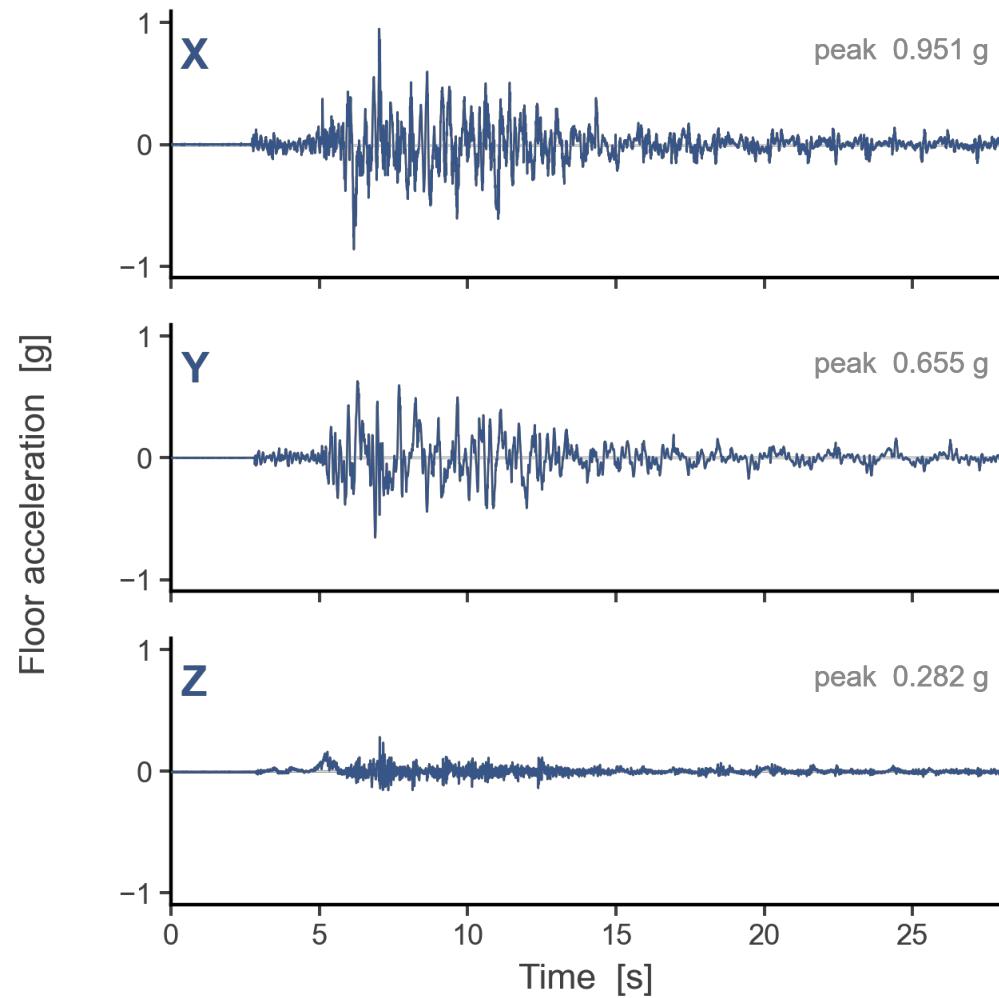
Djura | Risk – Data – Engineering



The structure was safe, but the building stayed closed

2010 Chile

Monitoring shows how a building responded, but not what to do next



How it moved

Measured: floor accelerations, drift, dynamic properties

What to do now

Still open: what is damaged, and can the building be used?

Damage is still assessed manually



San Fernando, 1971

manual assessment



Colombia, 2026

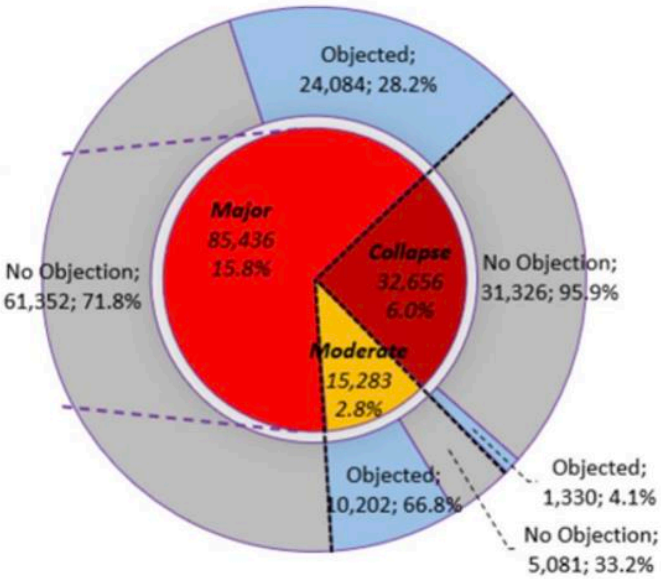
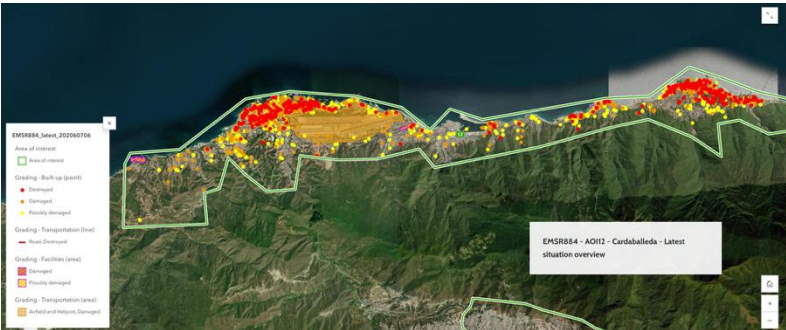
manual assessment

Assessing damage by hand can be problematic

Slow

Dangerous

Subjective



We still record non-structural damage by hand



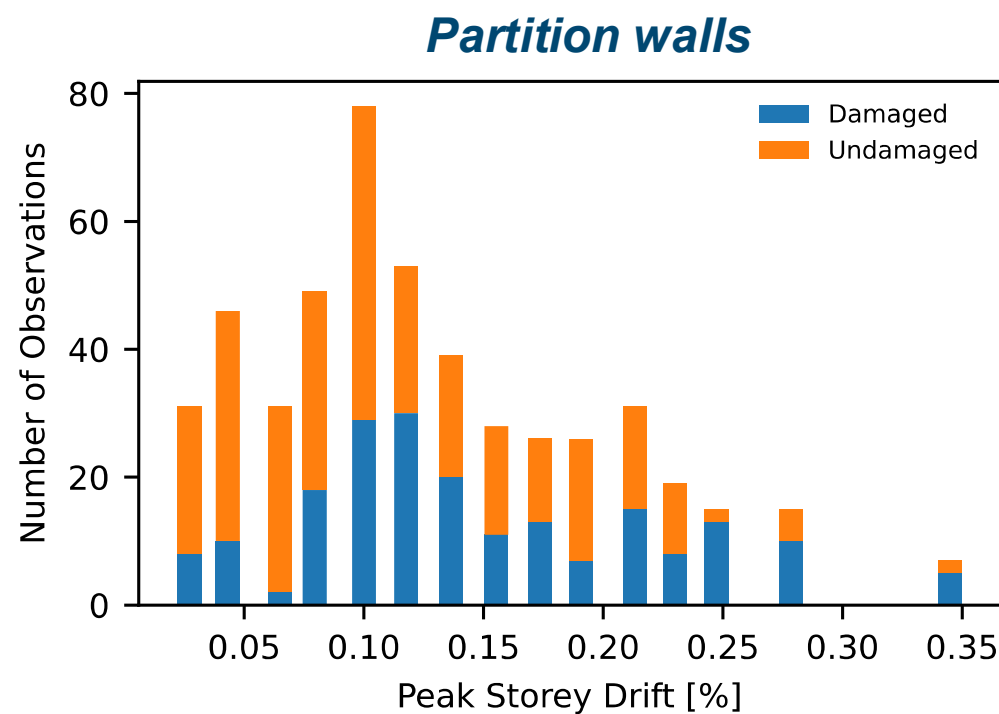
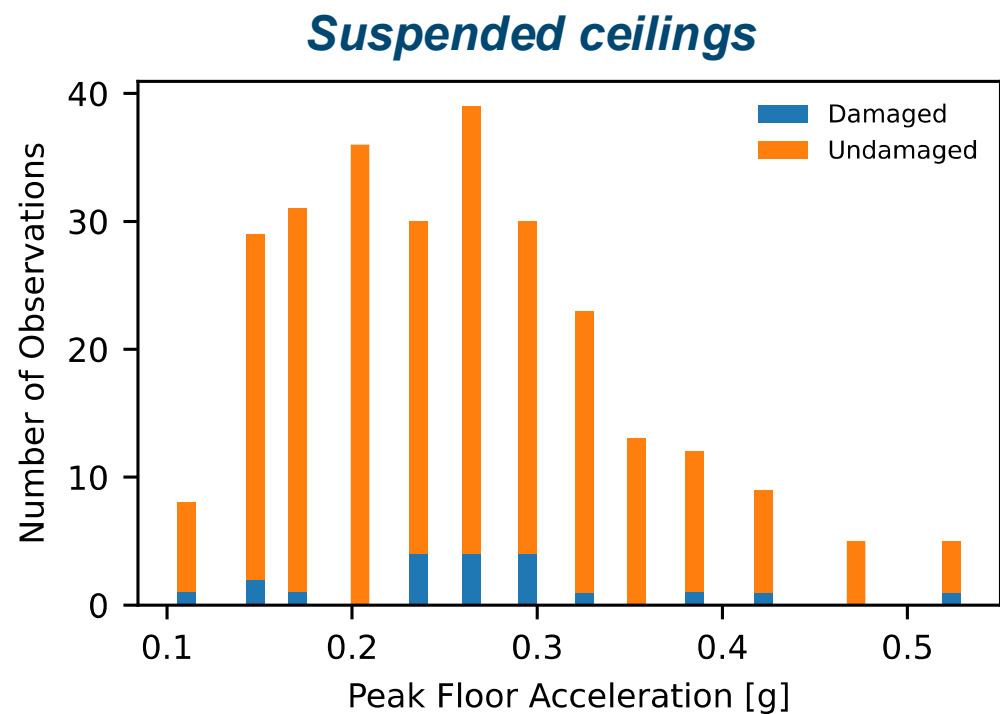
SECTION 5 - DAMAGE TO NON-STRUCTURAL ELEMENTS and emergency countermeasures (E.C.) carried out

Type of damage		Presence of damage	Emergency countermeasures carried out					
			None	Removal	Shoring	Repair	Access prohibition	Barrier & passage prot.
		A	B	C	D	E	F	G
1	Detachment of plaster, claddings, suspended ceilings, ...	☐	☐	☐	☐	☐	☐	☐
2	Falling of tiles, chimney pots, flues, ...	☐	☐	☐	☐	☐	☐	☐
3	Falling of cornices, parapets, ...	☐	☐	☐	☐	☐	☐	☐
4	Falling of other internal or external objects	☐	☐	☐	☐	☐	☐	☐
5	Damage to the water, sewer or heating-plumbing network	☐	☐	☐	☐	☐	☐	☐
6	Damage to the electrical or gas network	☐	☐	☐	☐	☐	☐	☐

Tools available, but require better integration



In Osaka, monitored response was compared to observed damage



26

monitored office buildings

494 + 270

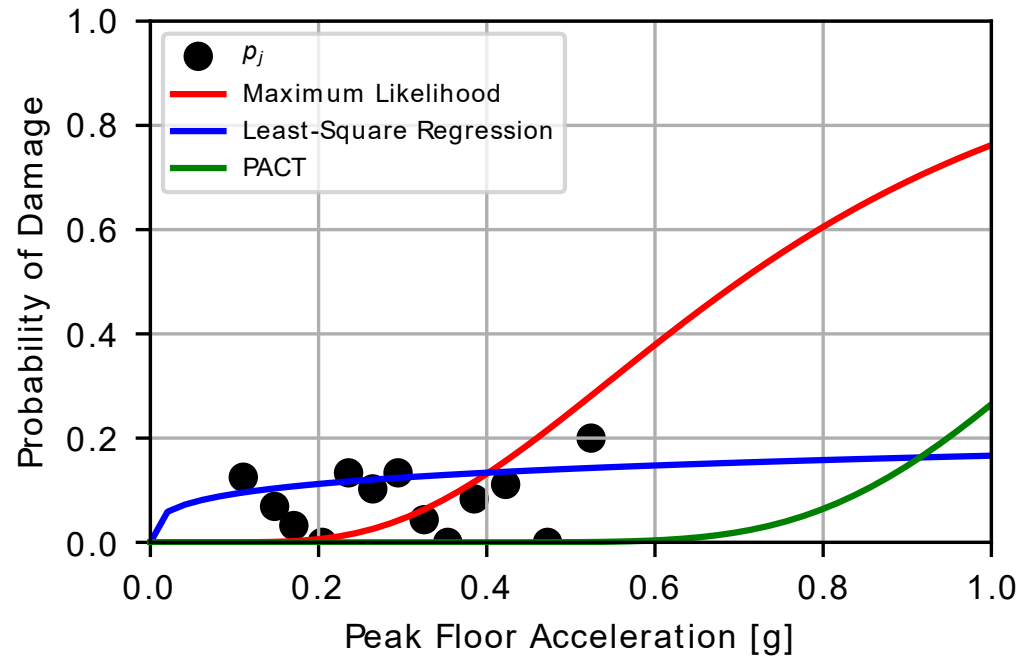
partition and ceiling observations

~2 months

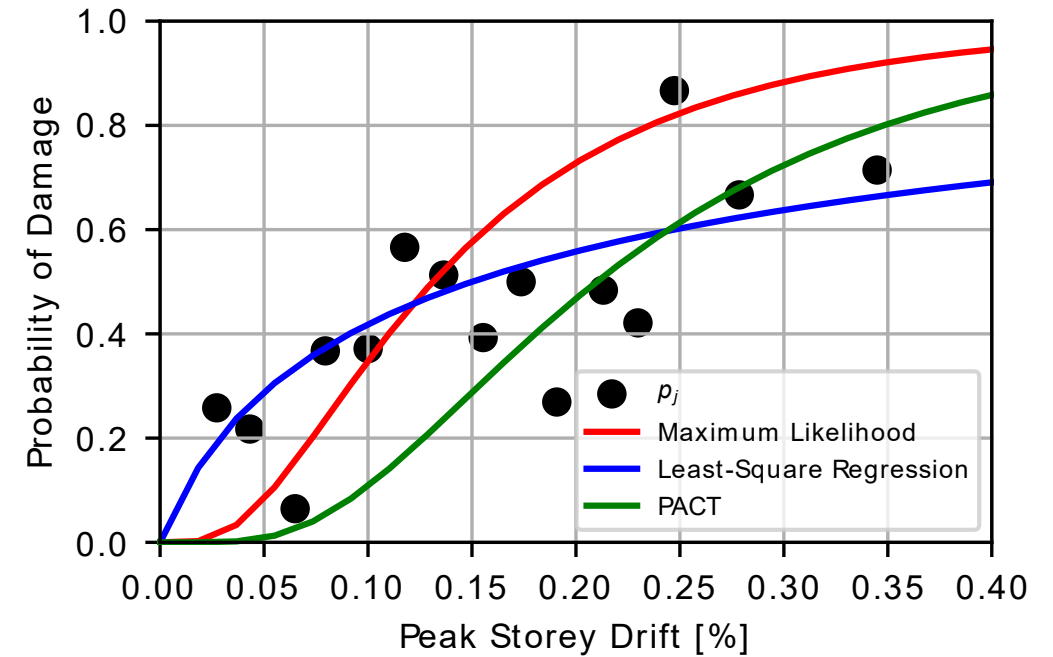
later, damage from interviews

Real buildings were more fragile than the library curves suggest

Partitions: field median 0.13% drift



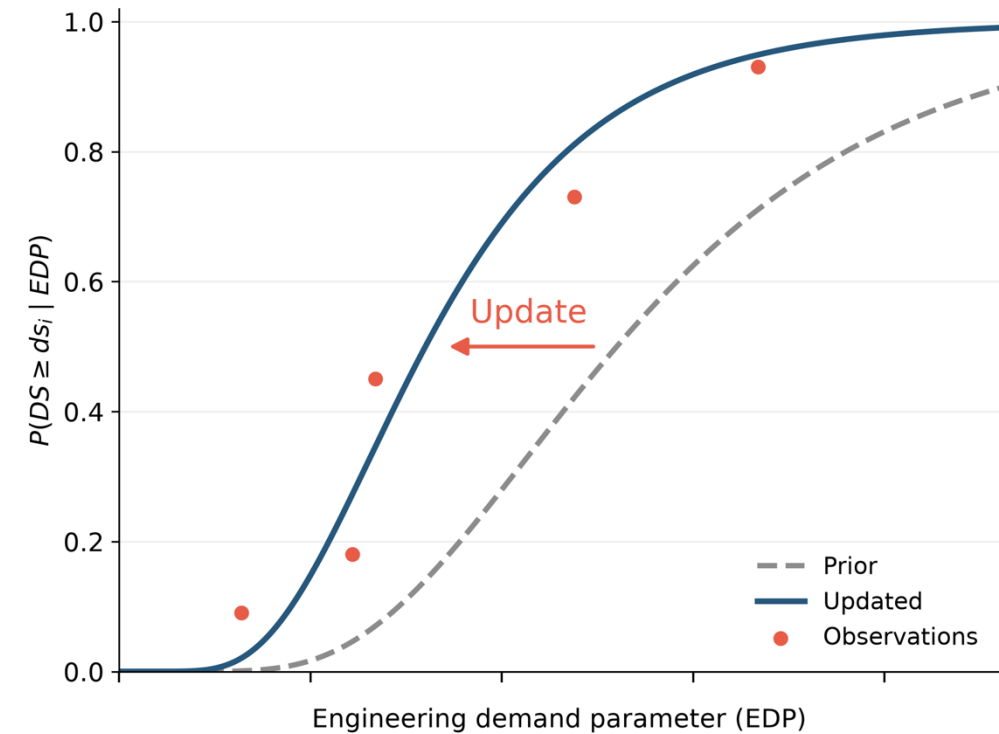
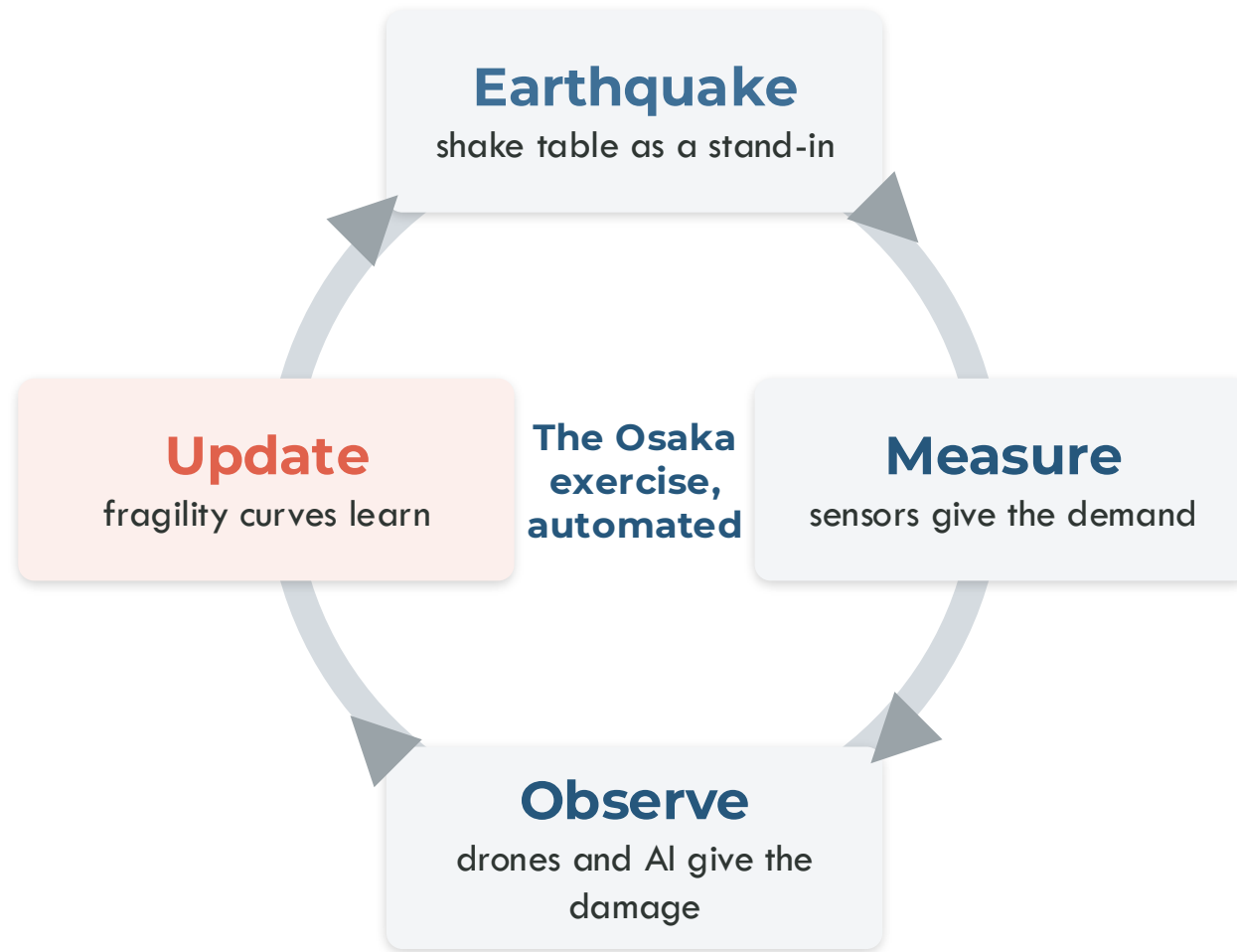
Ceilings: field median 0.71 g



Library (FEMA P-58) medians about 38% higher

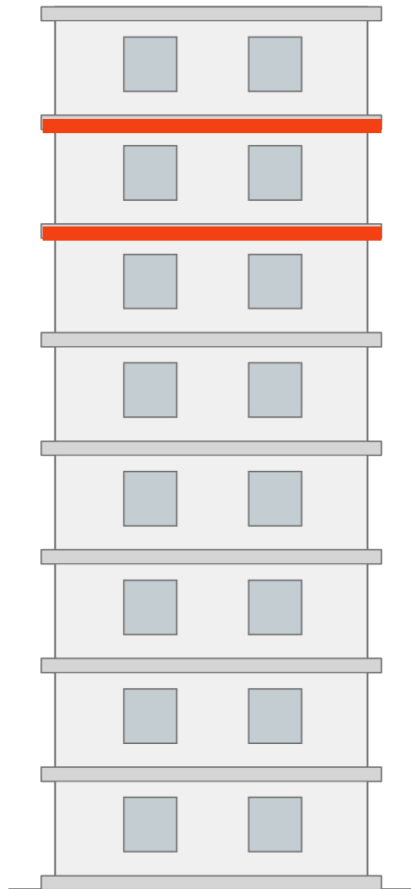
red: fitted to field data green: library

SONATA joins measured demand and observed damage in one loop



Decide
what the owner does next

Two shake tables impose storey drift without building the storey



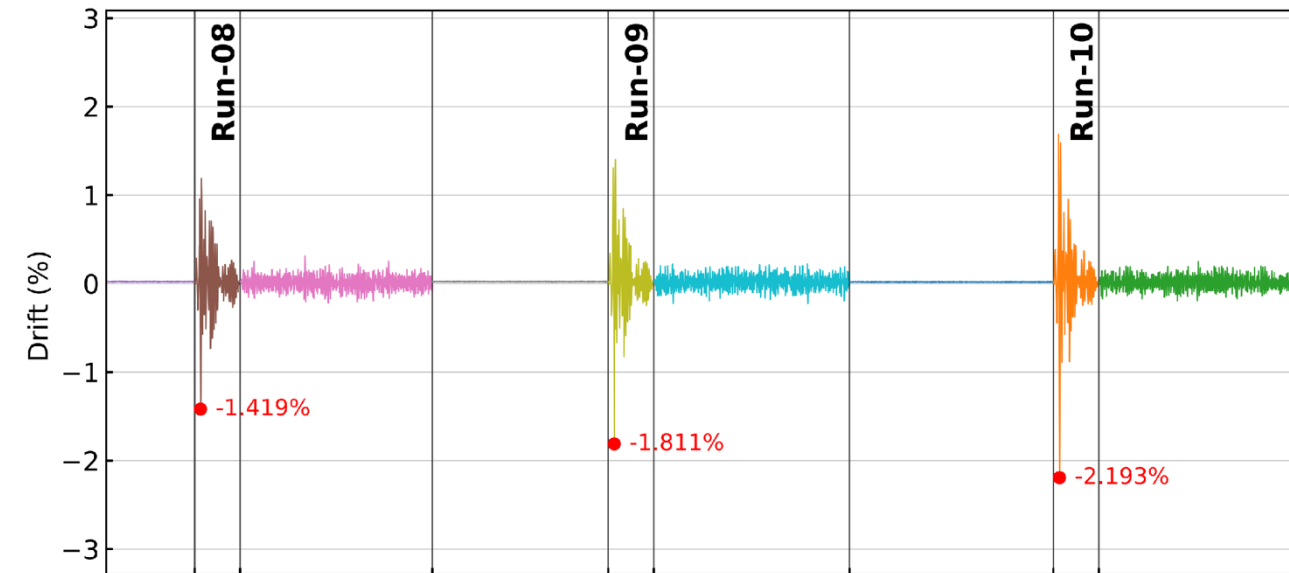
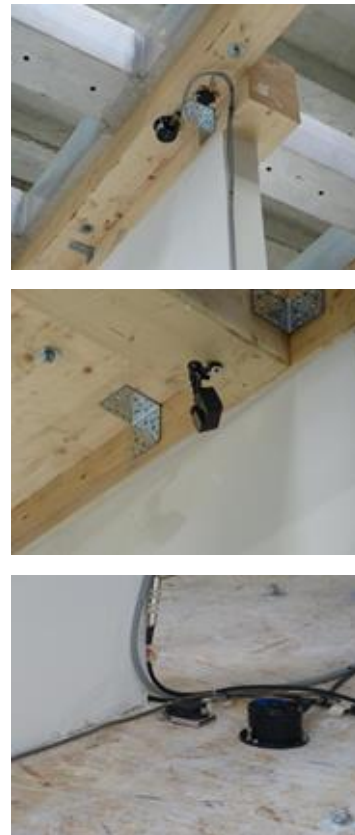
Floor i+1
upper table

Floor i
lower table

8-storey RC office
building, L'Aquila;
2009 record scaled
0.3 to 4



Each run pairs a measured drift with an observed damage state



Three partitions reached the same damage states at similar drifts

P01 single-layer at DS3



Corner crushing

P02 double-layer, T shaped at DS3



Total collapse

P03 double-layer at DS3



Sliding

Drift at first attainment (%)	DS1 minor	DS2 moderate	DS3 major
P01 single-layer	0.56	1.21	1.87
P02 double-layer, T-shaped	0.73	1.21	2.22
P03 double-layer	0.73	1.48	1.87

Drones can inspect a room before anyone needs to enter it

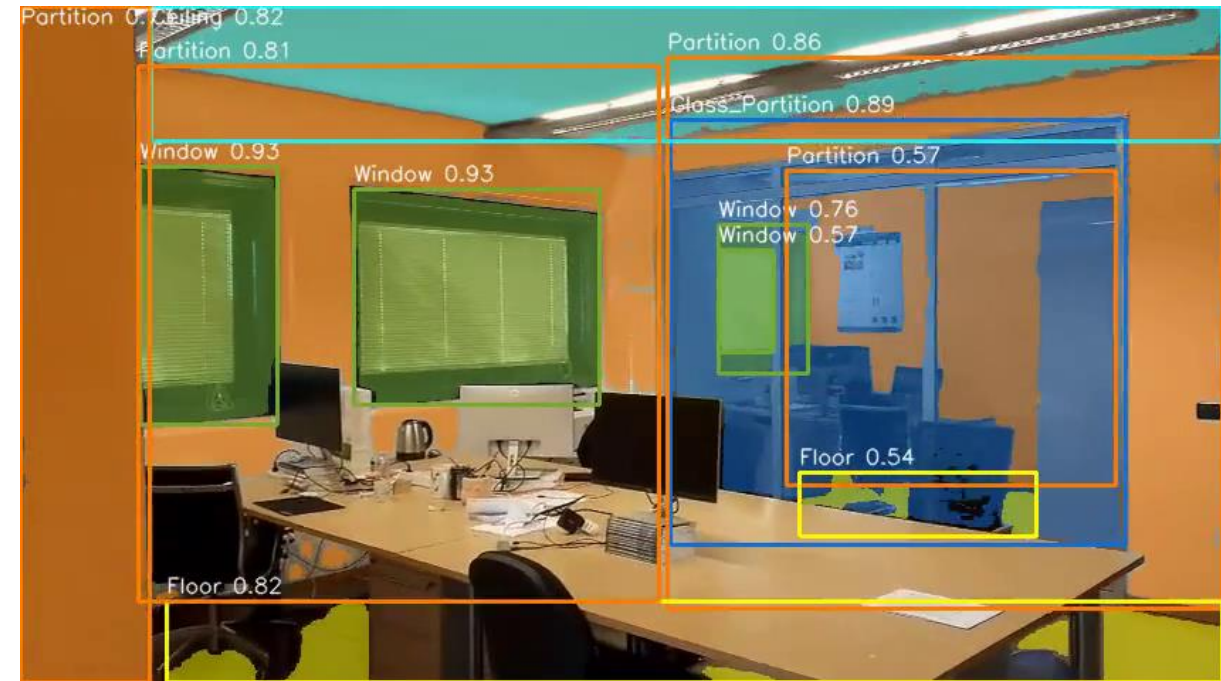


First test flights, 9DLAB, Pavia

LiDAR gives a room's geometry; recognition says what each element is



LiDAR scan, iPhone and Scaniverse. Undamaged office, for illustration



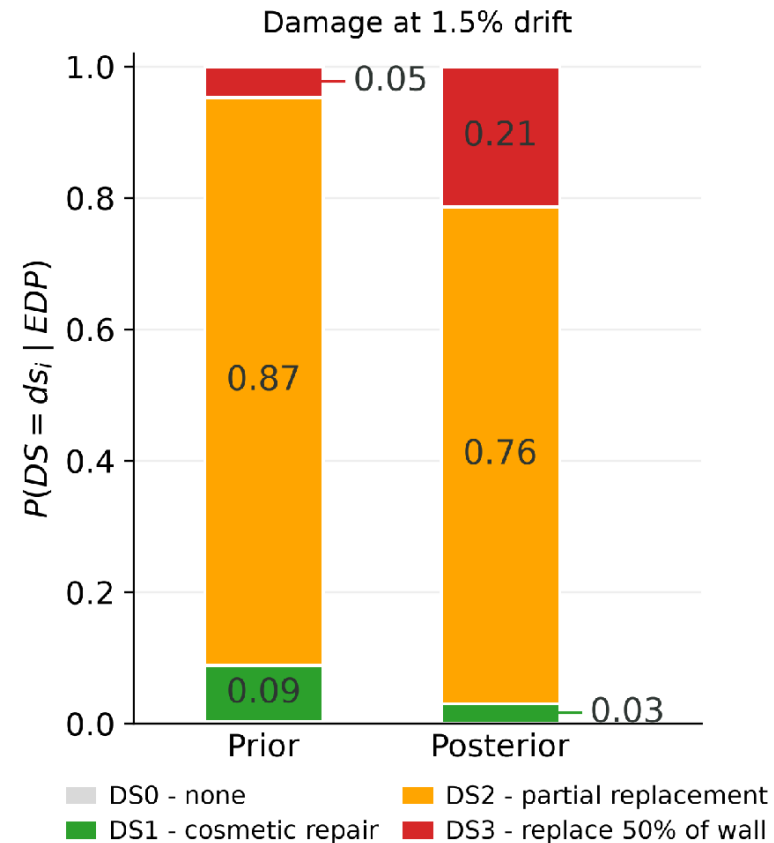
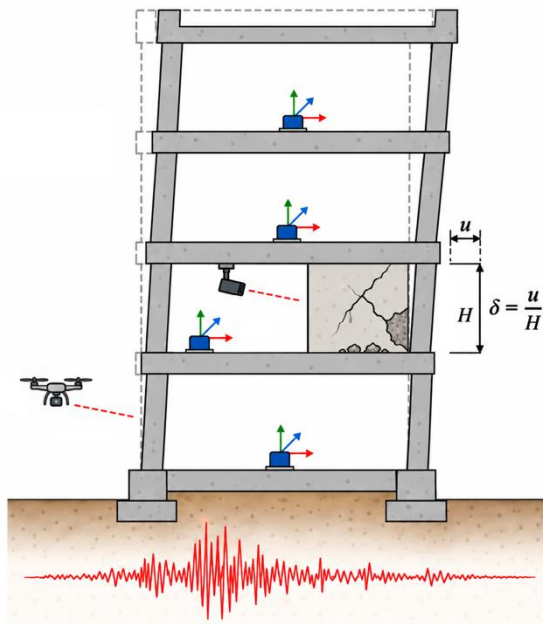
Recognition on the office, Mauricio Guamán

We can have different indicators of damage/problems



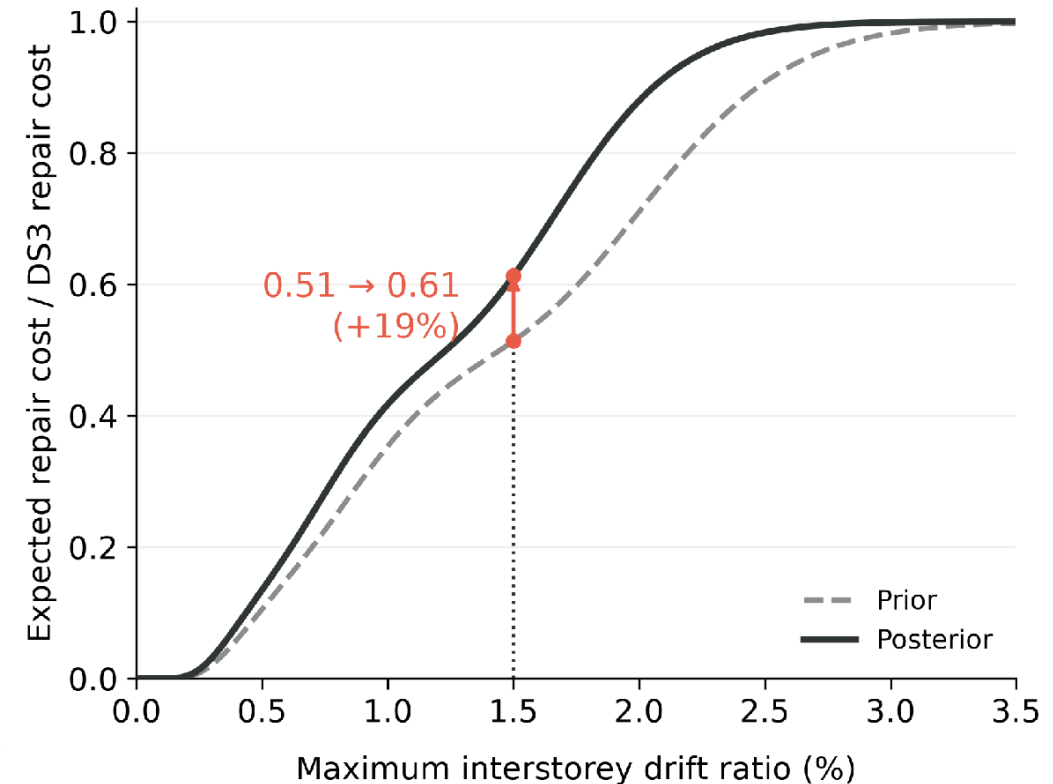
Updating raises the expected repair cost by 19%

EDPs + DSs

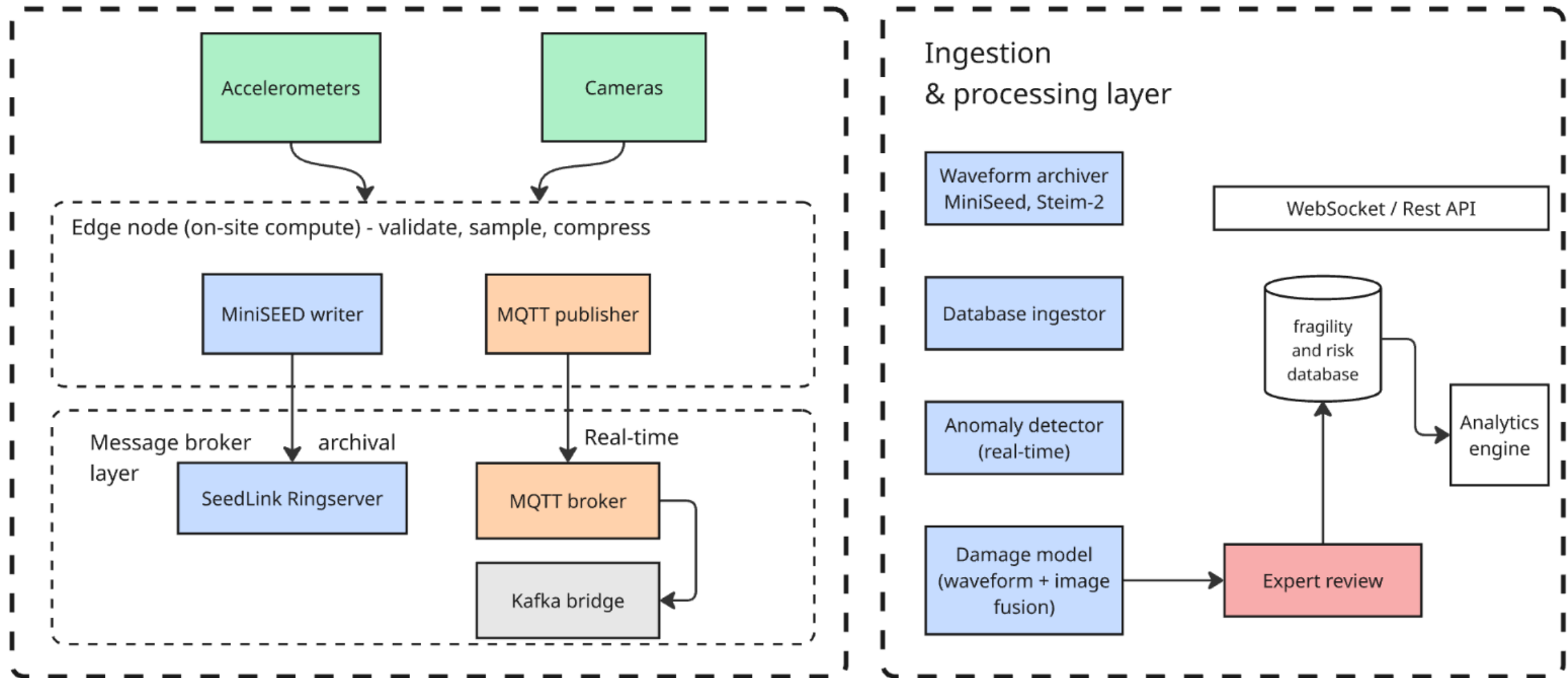


P01 · Single layer

Loss for one partition (FEMA P-58 C1011.001a)



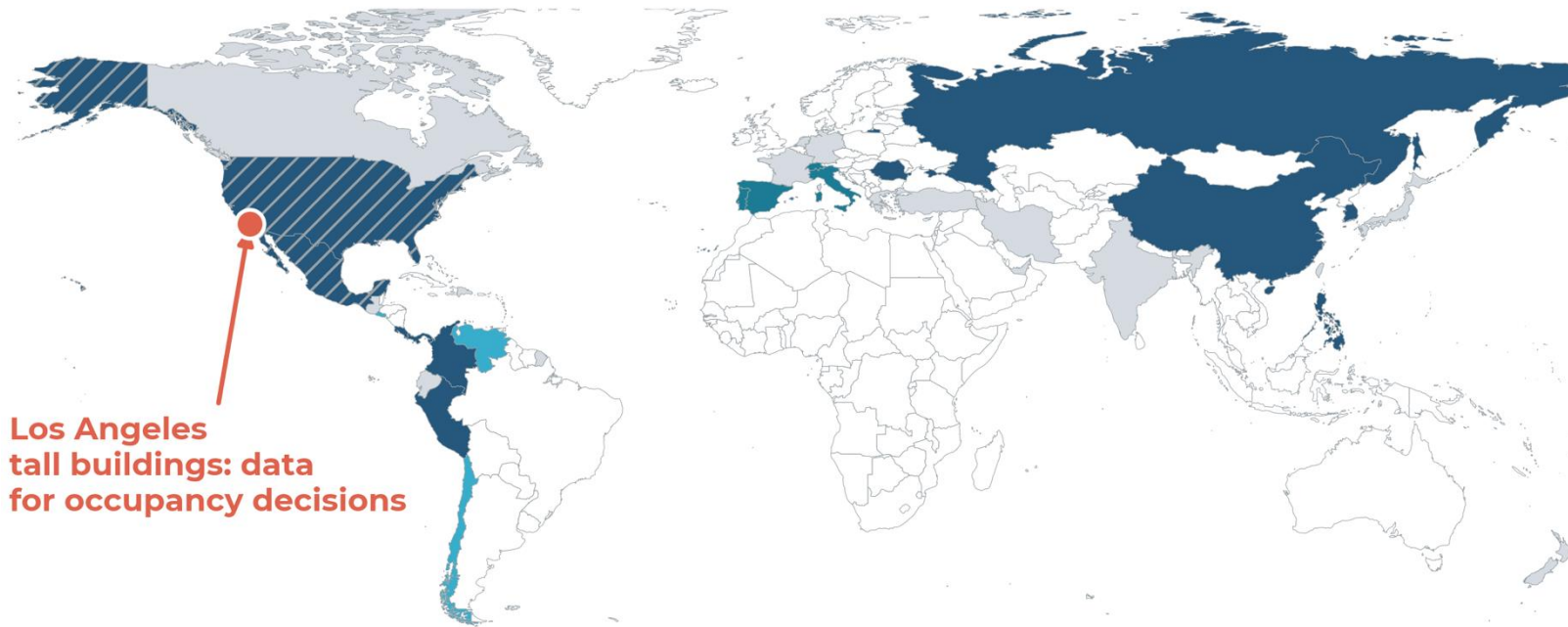
A prototype pipeline carries data from the sensors to updated curves



A dashboard shows shaking, alerts and updated curves together



Coming back to structural health monitoring



Los Angeles
tall buildings: data
for occupancy decisions

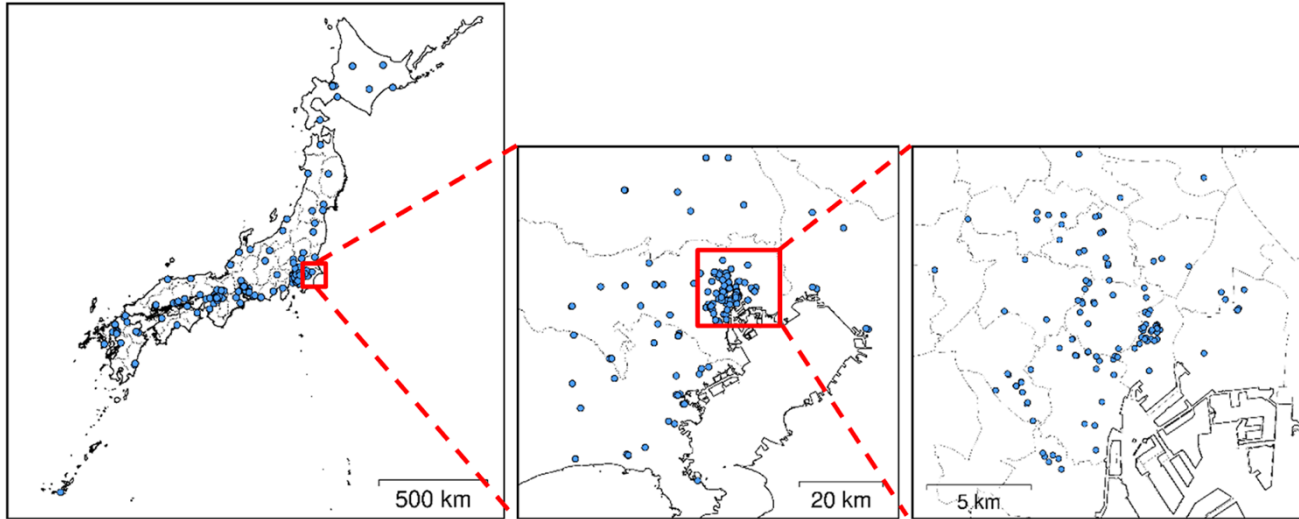
- Some buildings must have recording stations
- Only when the authority asks
- Bridges and dams only
- No duty on building owners found
- Hatched: city or state level only

Monitoring for decisions?

Many codes require recording stations

Few require monitoring for decisions

In Japan, owners paid for monitoring because it gave decisions within minutes



553 buildings, monitored at their owners' expense (2023)

LESSONS LEARNED

Thresholds must learn

- Initially set based on judgement
- Should update with new data and observations

A warning needs a plan

- Without one, yellow only frightens owners and increased uncertainty
- «A red waiting to be confirmed»

2011 Tohoku

Disruption came from uncertainty rather than structural damage:

- Public transport stopped, **people were stranded**
- **Aftershocks left them unsure**
- Companies did **not know the state of their buildings**, held up business continuity

Solution

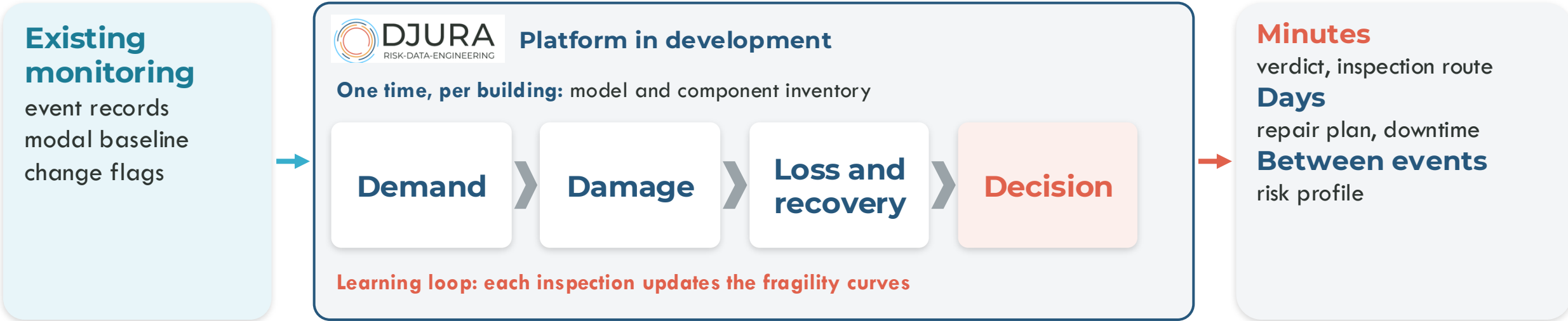
- Owners saw the benefit of a SHM-based decision system for their assets
- Pay for a tag within 1 to 2 minutes
- Market and needs-driven solution

Safe

Caution

Danger

A platform to turn monitoring into decisions



WHO IT IS FOR

Owners and companies

stay, check or leave; reopen fast, as in Japan

Insurers

parametric triggers indexed to the measured shaking

Civil protection

where to start inspecting after an event

Shahnazaryan (2026), concept sketch

Grounded in experiments, learning from each event, and giving owners decision metrics

- 1 Built on experimental data
- 2 Learns from new field data
- 3 Fully exploits existing monitoring
- 4 Drones and AI see the damage
- 5 **Risk metrics**
expected loss, downtime, usability
- 6 Instructions for owners and authorities



**Daniele
Sivori**



**Mauricio
Guamán**



**Marco
Todaro**



**Volkan
Ozsarac**



**Davit
Shahnazaryan**



The work presented here has been developed within the framework of the “Sensor-driven statistical tools to evaluate risks and manage safety in the built environment” (SONATA) project, which is a Starting Grant awarded by the Italian Science Fund (Fondo Italiano per la Scienza) at IUSS Pavia under grant number FIS2023-03215.