



RICE

George R. Brown
School of Engineering

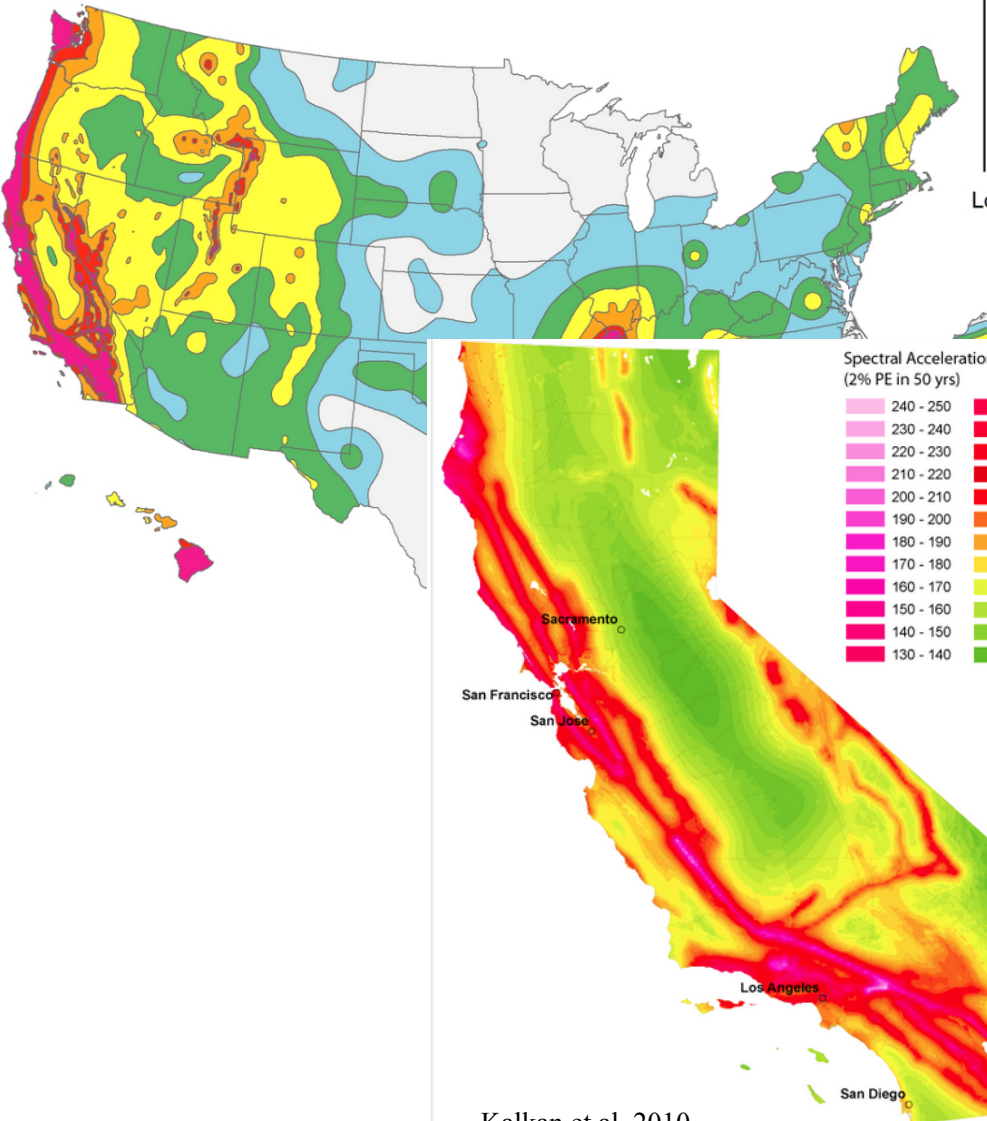
DEVELOPMENT OF A RAPID POST- EARTHQUAKE SITUATIONAL AWARENESS TOOL FOR CALIFORNIA BRIDGES

Reginald DesRoches, Ph.D., F. ASCE, F. SEI
William and Stephanie Sick Dean of Engineering
Rice University



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Motivation



Highest hazard



Kalkan et al. 2010



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Motivation

I5 / I10 Interchange



- 10

1995 Prieta



1994 Ridge

- 2
- 2



loss



I10 at



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Motivation

Post earthquake emergency response

- Where do we expect the most extensive damage?
- Where should we send emergency responders?
- Can we better guide the bridge inspection process?

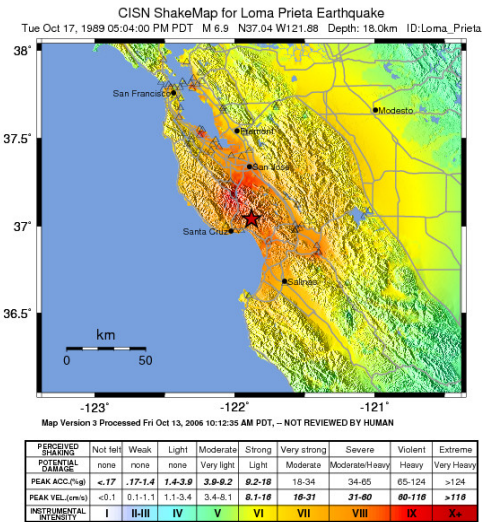
Resilience of transportation networks

- Improve the recovery effort
- Prioritize the retrofiting strategies



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Post EQ Response :



ShakeCast

Shake Map

Strong motion data

Faults

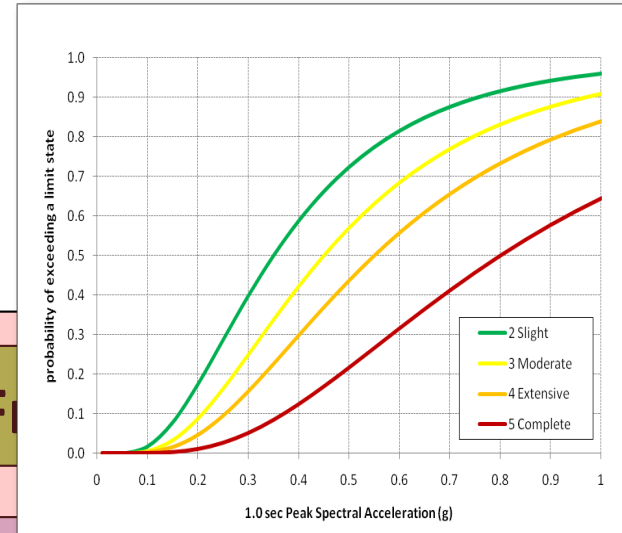
Geology

Bridge Fragility

Caltrans bridge data

Vulnerability modeling

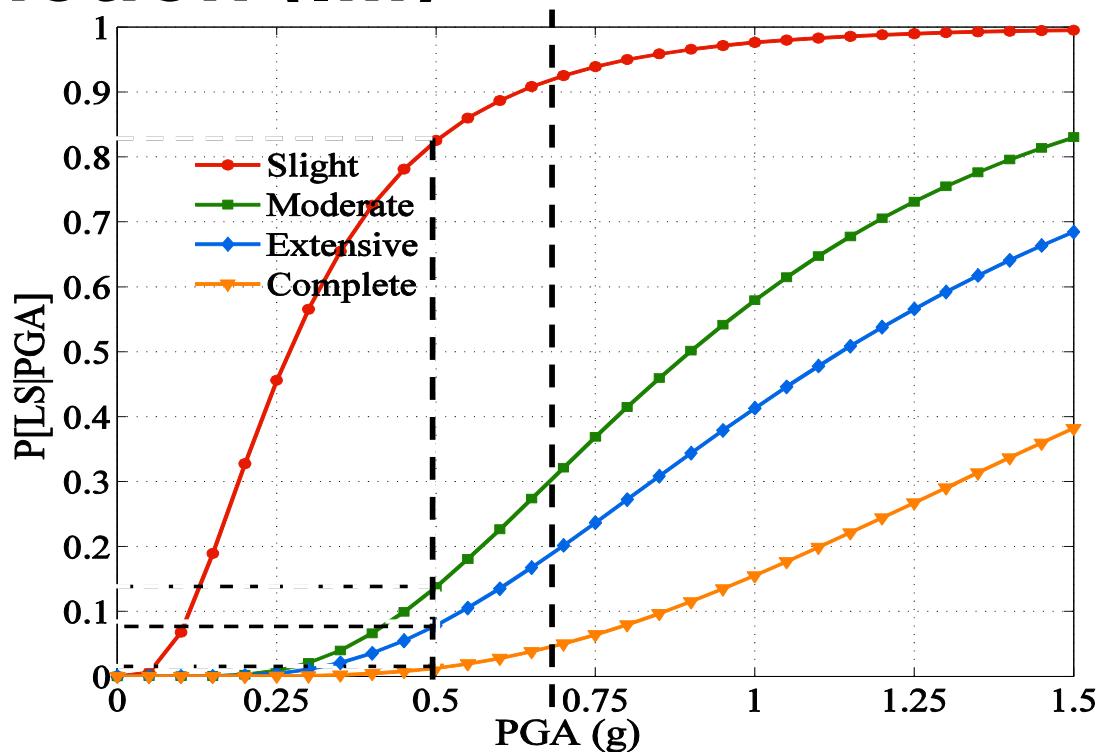
Engineering judgment



ShakeCast analyzes measured ground motions from Shake maps against bridge fragilities stored in the system



Conditional probability of a structure meeting or exceeding certain level of damage (LS) given a particular level of ground motion (IM)





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Challenges



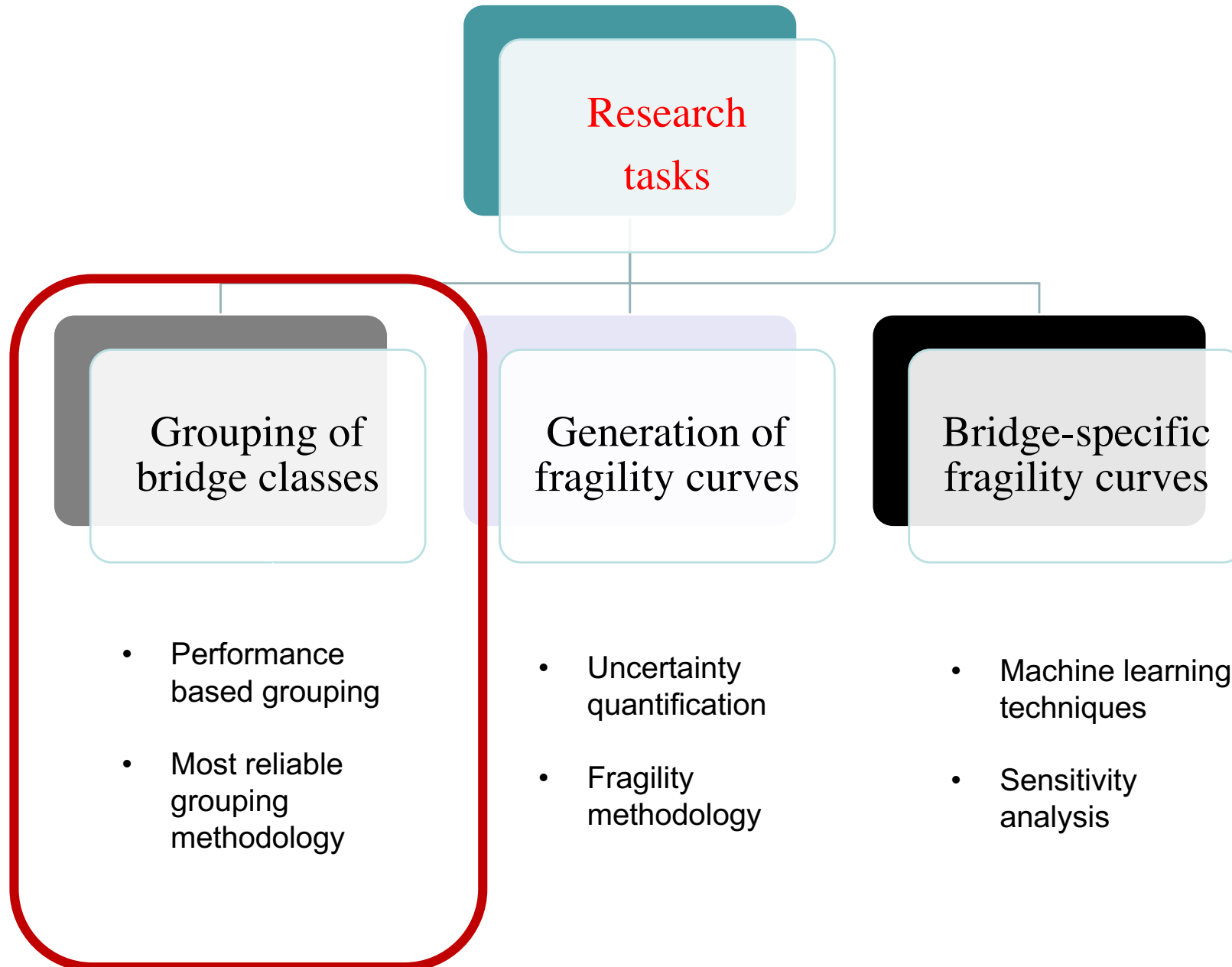
Caltrans 2017

- More than 24,000 bridges
- Vary in age, location, number of spans, frame system, number of columns & column cross-section
- Significant uncertainty



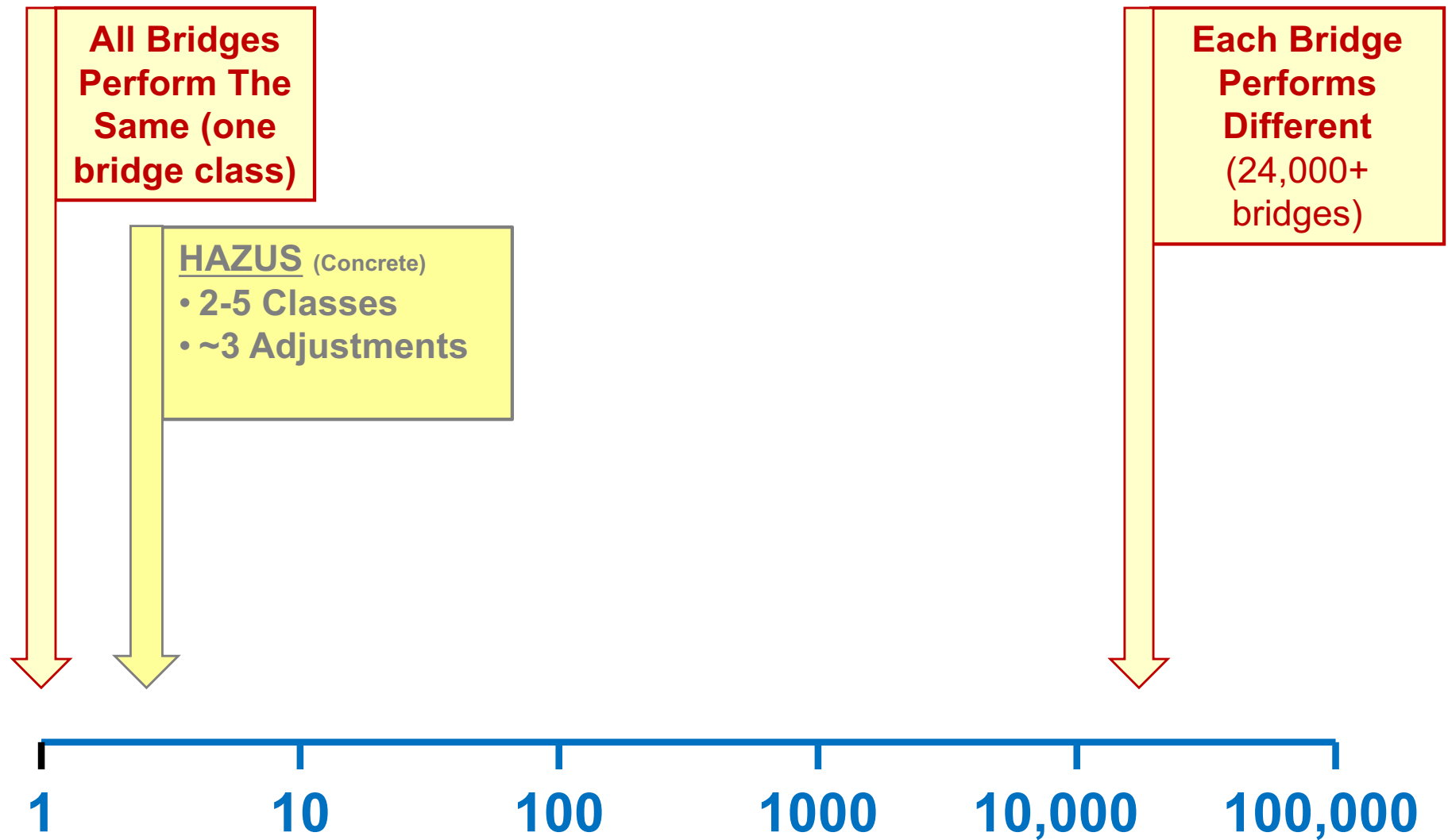
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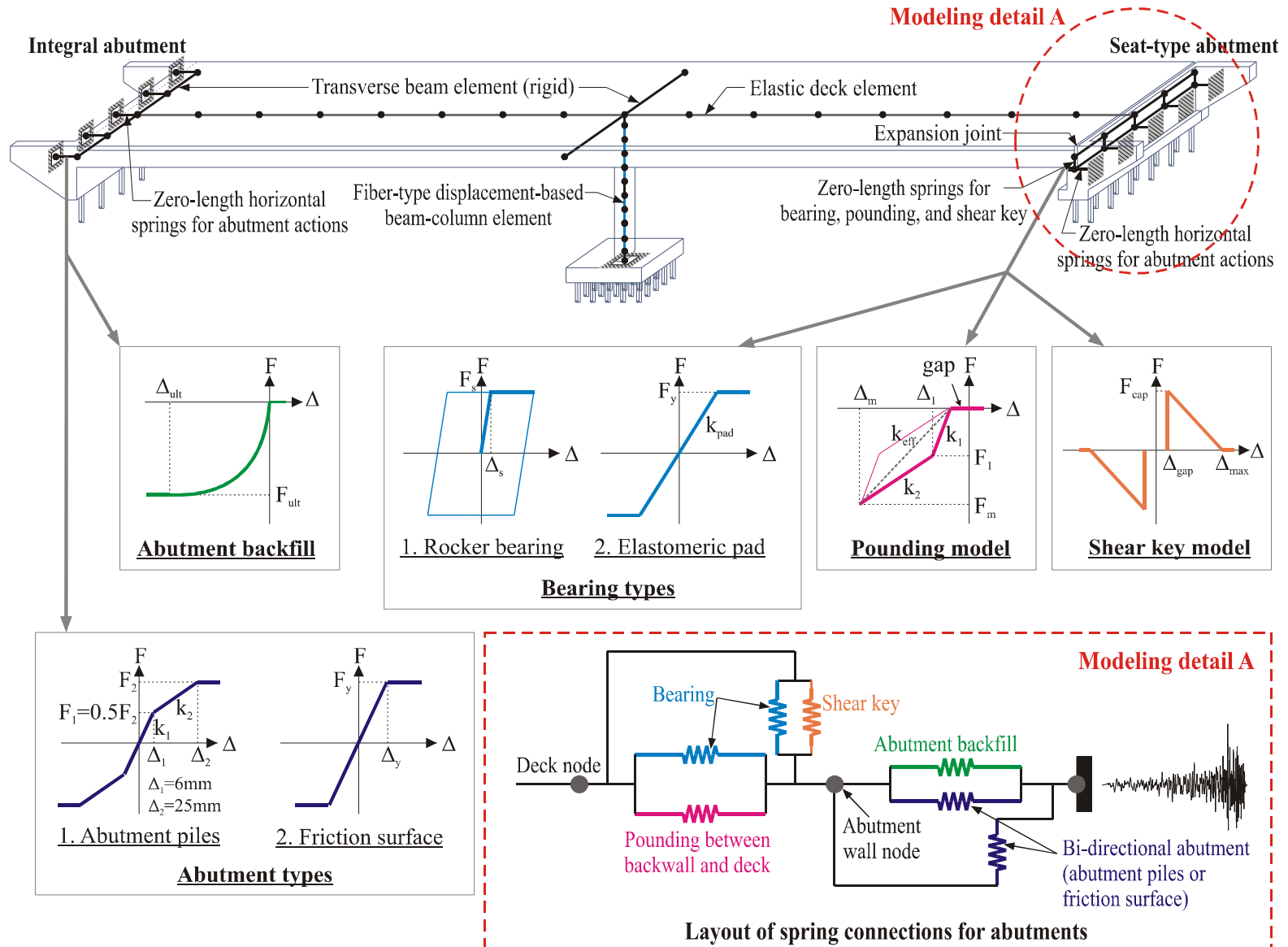
Research tasks





RICE Bridge Classes for Fragility Analysis



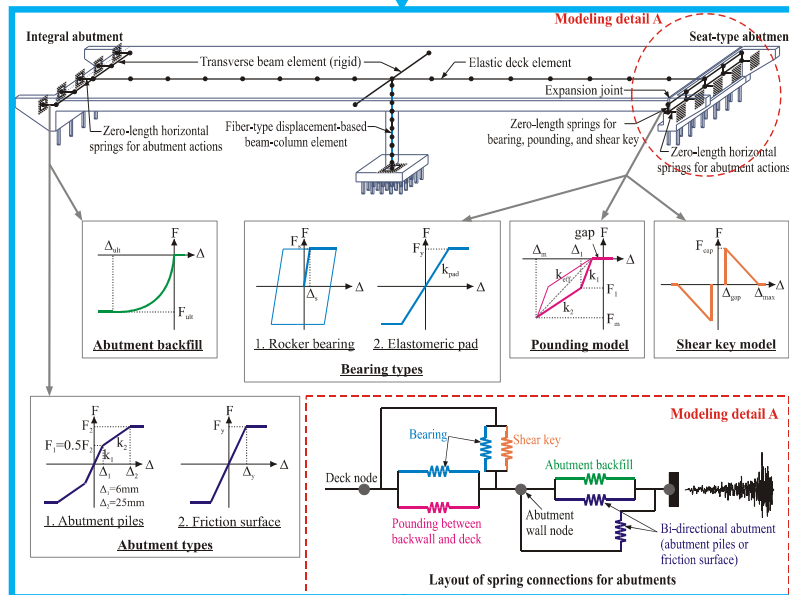




Suppose each possible combination of bridges

Using Latin Hypercube method, select **30** ground motions

Analyze each bridge configuration in *OpenSees* for the selected **30** ground motions



Collect output of interest including **curvature ductility**, **seat displacement**, **abutment active/passive/transverse displacement** etc.

Conduct a separate analysis of variance (**ANOVA**) to evaluate the sensitivity of each component to the variation in bridge configurations.

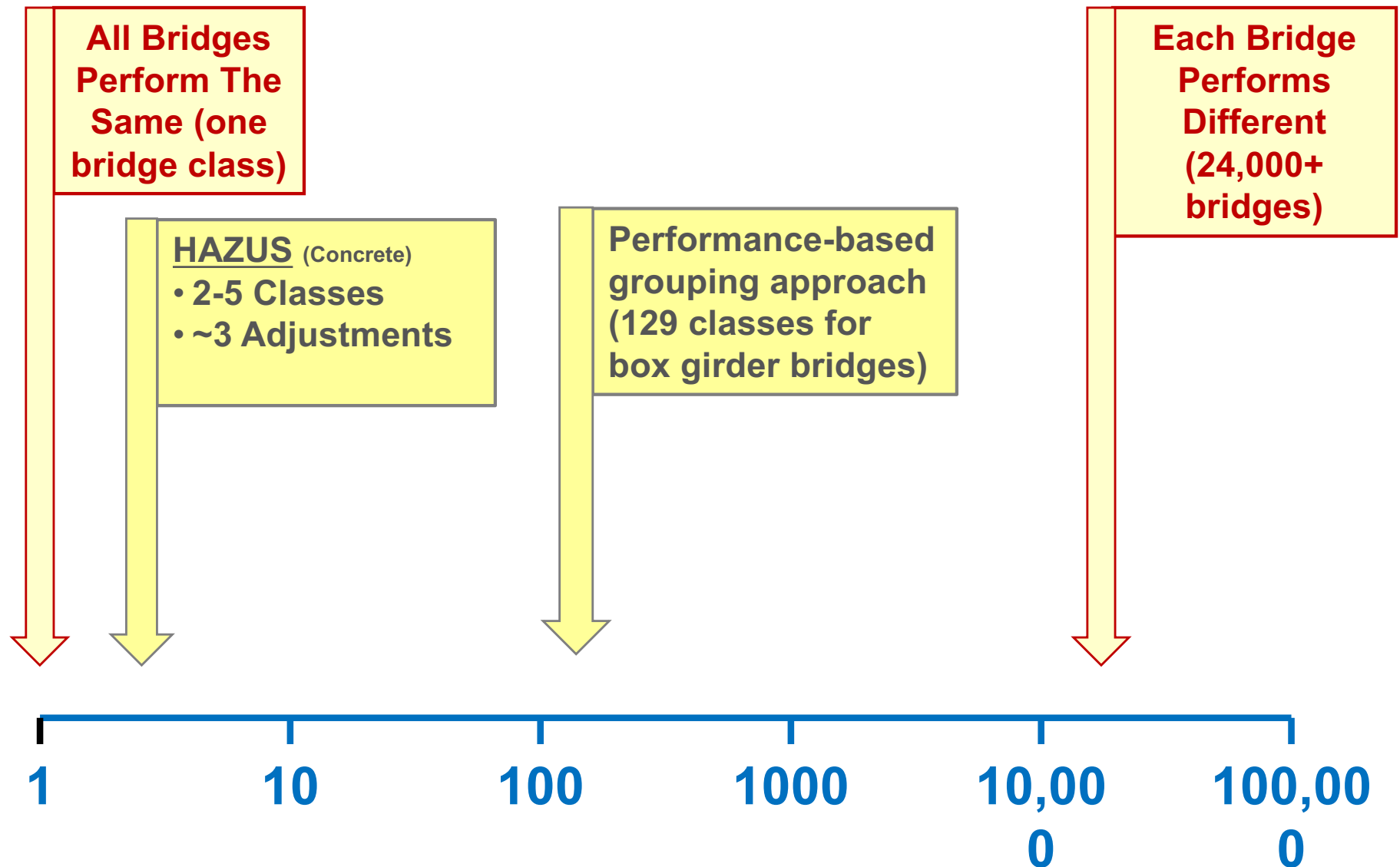
Performed **Fischer Method** on **ANOVA** output to group the bridge configuration which have similar effects on the response (e.g. column ductility).



<http://en.wikipedia.org/wiki/M%26M%27s>



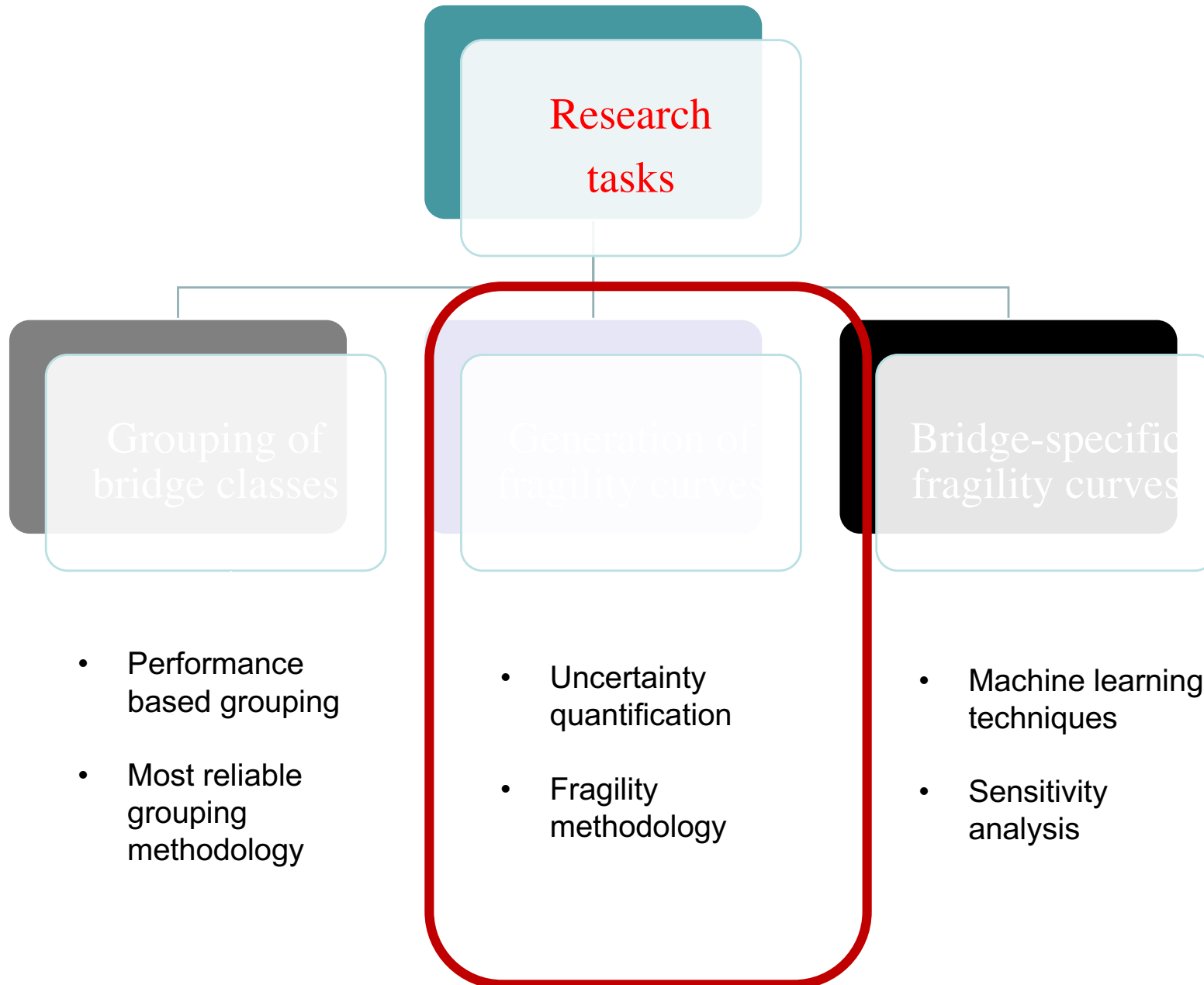
RICE Proposed Grouping





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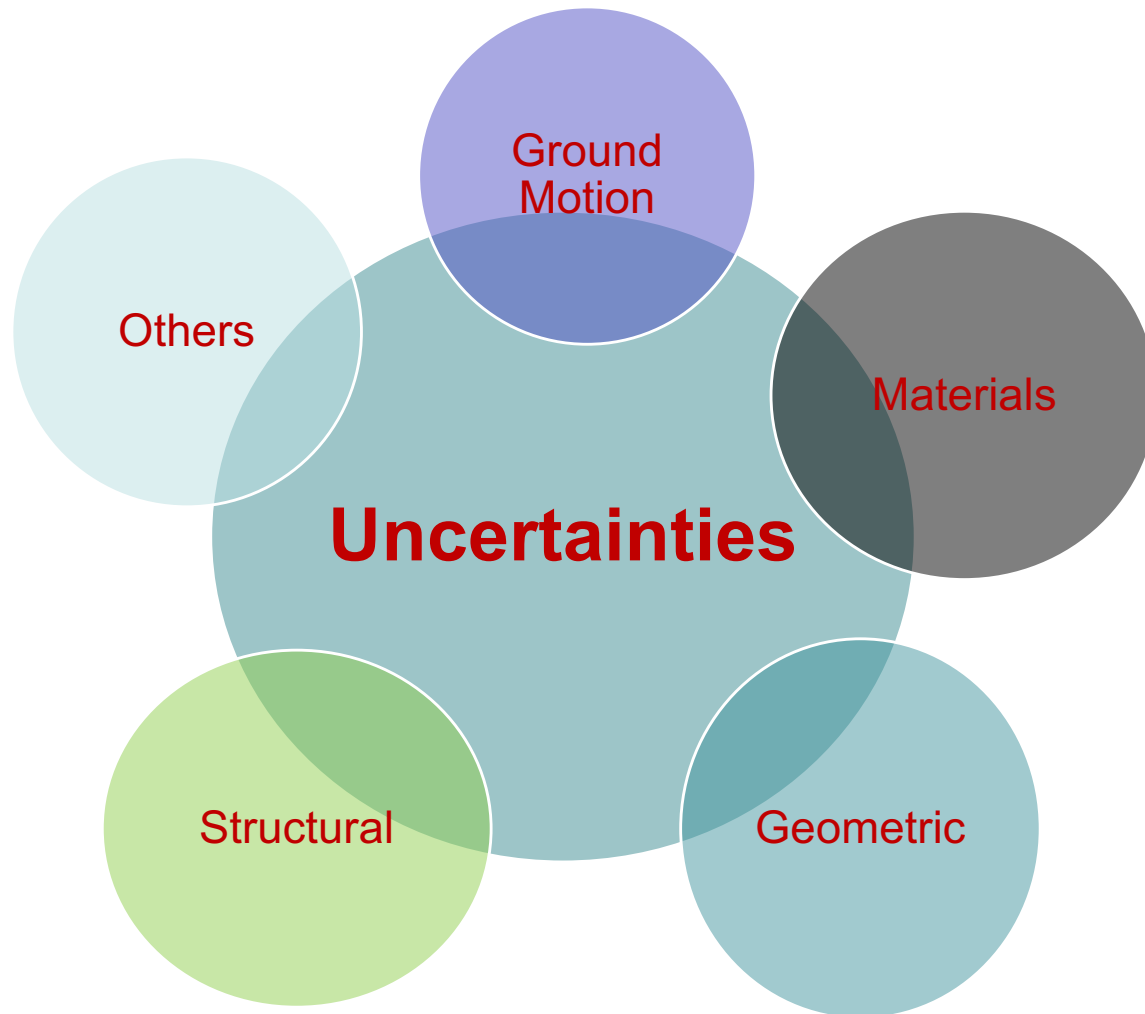
Research tasks

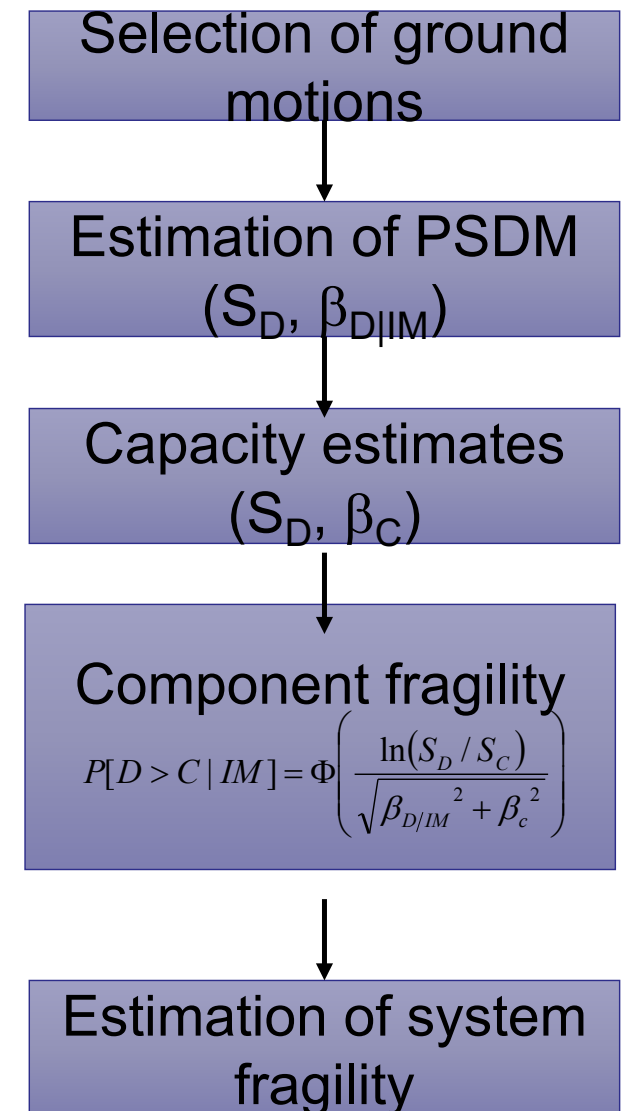
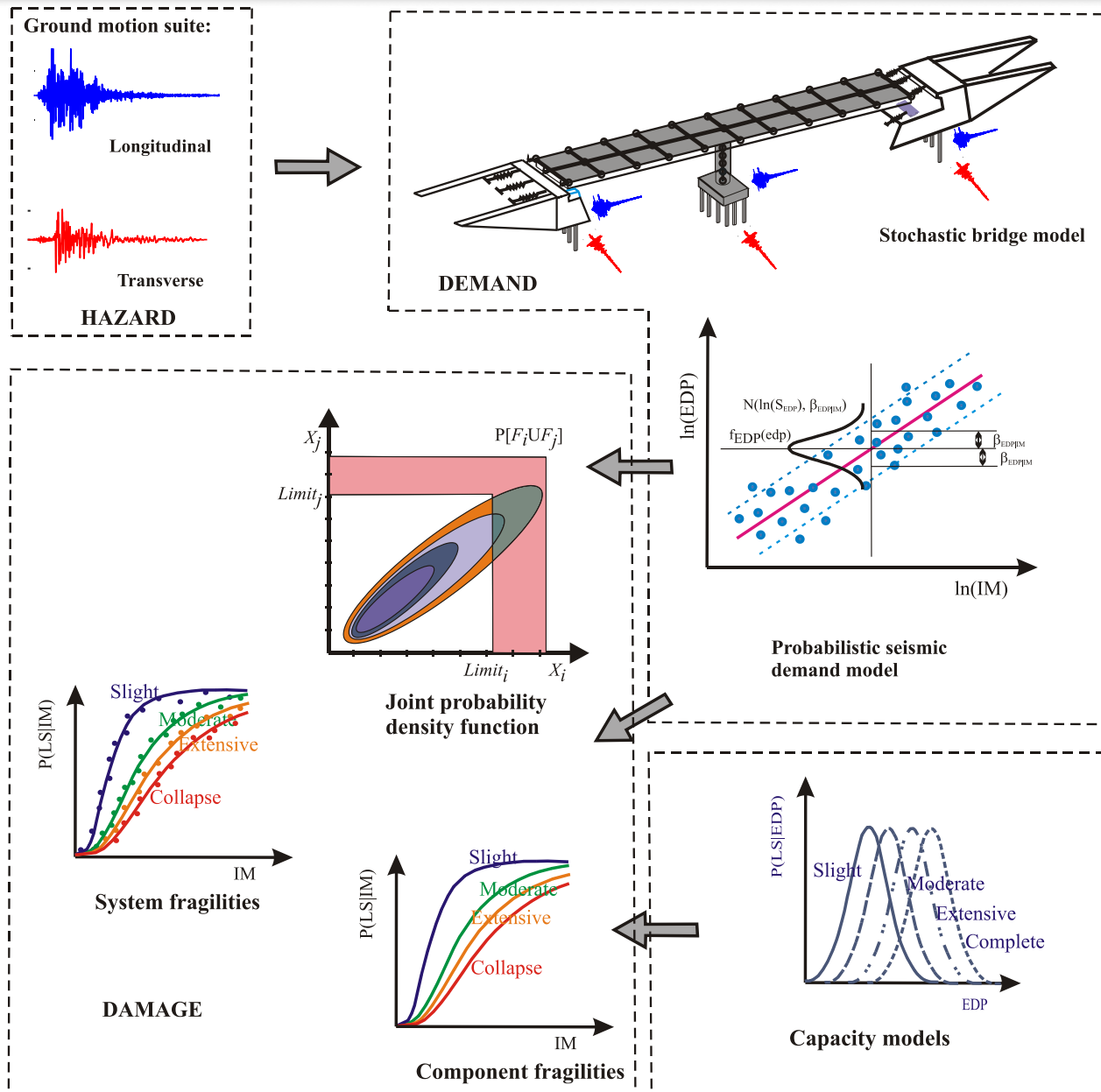




RICE Uncertainty quantification

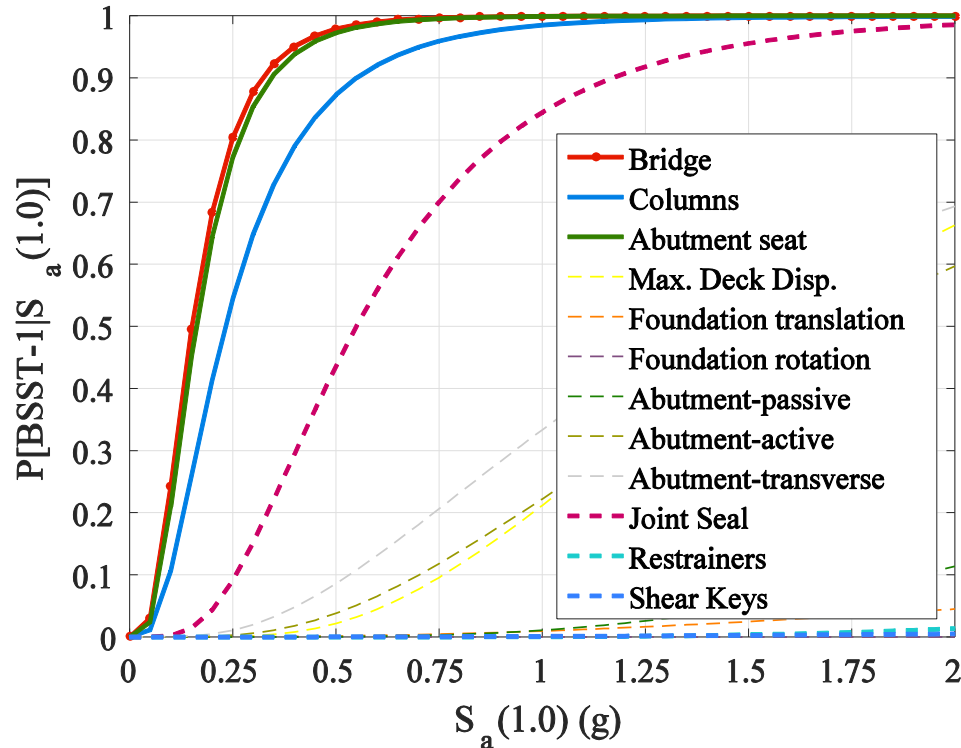
- **Uncertain input variables**



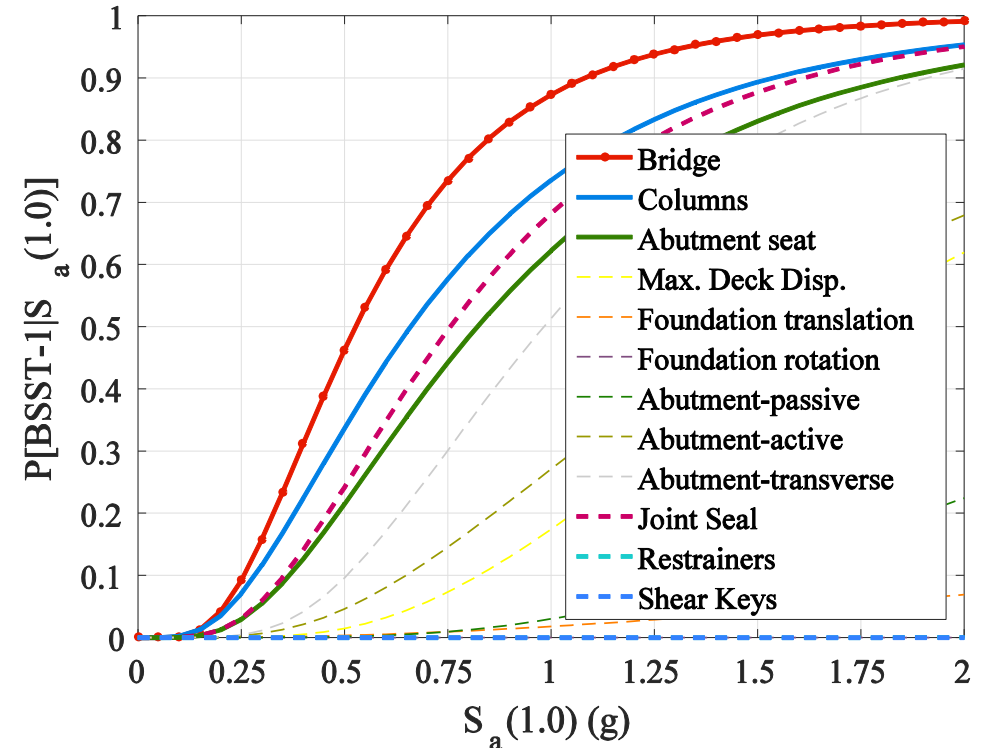




Fragility Curves



2-span Single column pre 1970
bridge with circular column



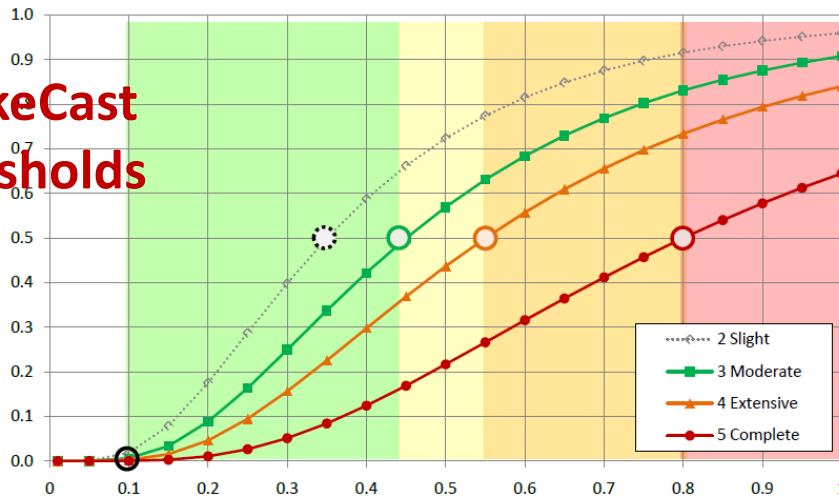
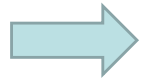
2-span Single column post 1990
bridge with circular column



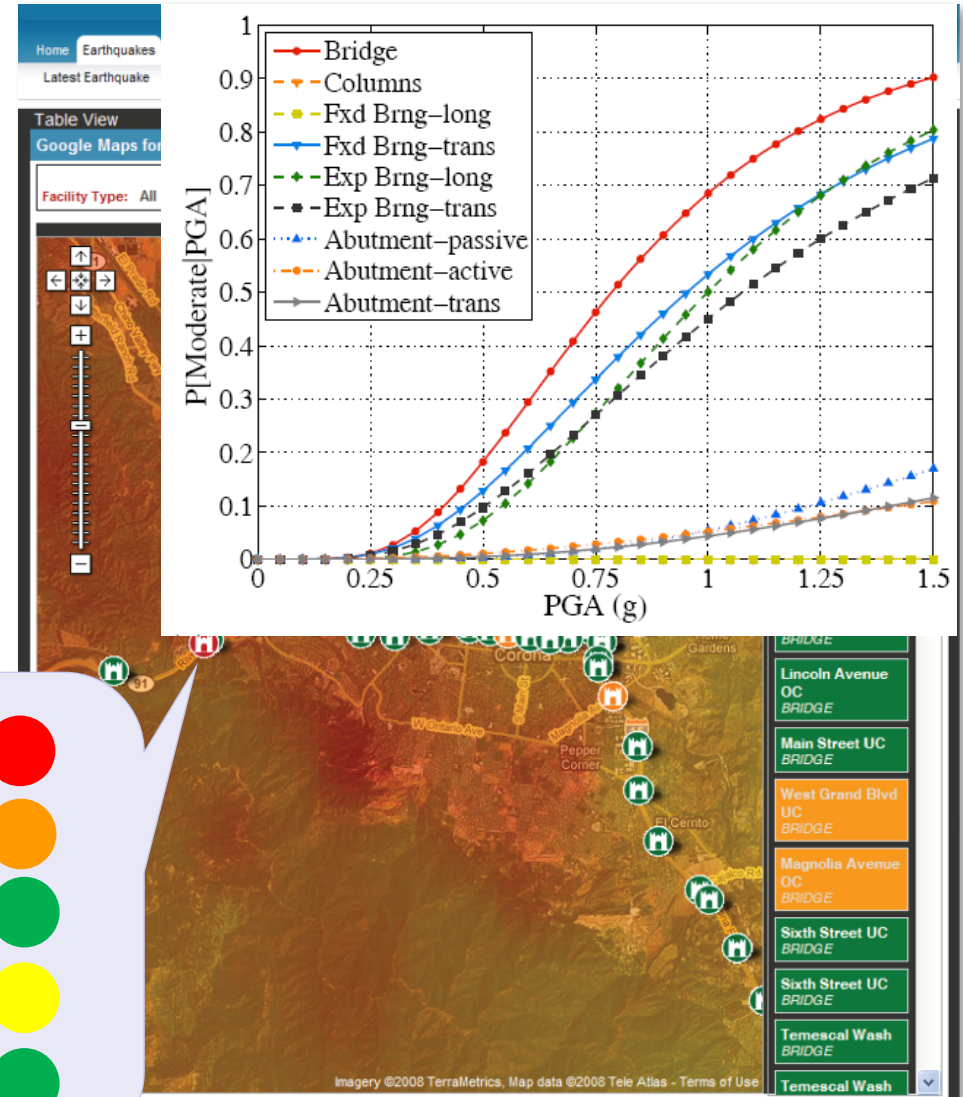
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Situational Awareness

ShakeCast
Thresholds



Trigger for bridge
inclusion on list



Color code	Inspection Priority	Priority engineering
RED	High	
ORANGE	Medium	Med
YELLOW	High	
	Medium	M
GREEN	Low	

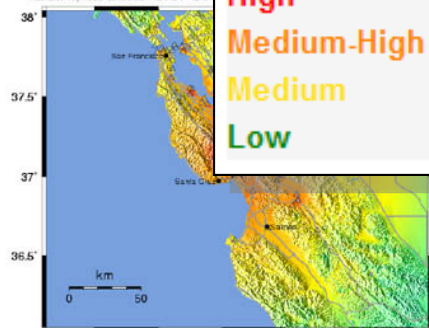
Columns
Bearings
Shear keys
Seat
Abutment



05/09/2008 11:18 AM

Caltrans ShakeCast Preliminary

This report supersedes any earlier reports about
reviewed by an Engineer or Seismologist. Info:
California Integrated Seismic Network (CISN).
ShakeMap (unverified) and estimated fragility
& Mander (1999). This report is intended to be
impacted by the event.

CISN ShakeMap
Tue Oct 17, 1999 05:04:00 PM PDT M 6.9

Map Version 3 Processed Fri Oct 16, 2008 10:30:30 AM PDT. - NOT REVIEWED BY HOMAN

PERCENT SHAKING	not felt	Weak	Light	Underlain	Strong	Very strong	Severe	Violent	Extreme
US SHAKE SCALE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACCEL (g)	<0.17	0.17-0.4	0.4-0.8	0.8-1.2	1.2-1.6	1.6-2.0	2.0-3.0	3.0-4.0	>4.0
PEAK VEL (cm/s)	<0.1	0.1-1.1	1.1-2.4	2.4-4.1	4.1-6.1	6.1-10	10-16	16-25	>25
PEAK ACC (mm/s²)	1	II-III	IV	V	VI	VII	VIII	IX	X

Event Summary

Name: (Unnamed Event) - Version 1

Magnitude: 6.9
ID: Loma Prieta, sctc-1
Location: 7 km NNE of Aptos, CA
Latitude: 37.04
Longitude: -121.88
Time: 1989-10-18 00:04:00 GMT

Downloads & Resources

Caltrans Intranet Links:

[Caltrans ShakeCast Intranet](#)
[Caltrans ShakeMap Products](#)
[ShakeCast Bridge Assessment](#)
[Statewide Bridge Inventory](#)
[Caltrans Real-time Traffic](#)
[USGS Real-time Earthquakes](#)

GoogleEarth KML files:
(save to your computer as a KML file
and open with GoogleEarth)

Bridge Assessment Summary

Maximum Peak 1.0 sec Spectral Acceleration: 105.3003%g

Maximum Acceleration: (not measured)

Total number of bridges assessed: 2030

Summary by inspection priority:

High	22	High Priority for full engineering assessment
Medium-High	107	Medium-High Priority for full engineering assessment
Medium	106	Medium Priority for full engineering assessment
Low	1795	Low Priority for full engineering assessment; quick visual inspection likely sufficient.

Bridge Assessment Details

Bridges presented in the table below are sorted in order of severity of impact to bridges.

Bridge Name	Bridge Number	Dist-Cty-Rte-PM	Inspection Priority	1sec Peak Spectral Acceleration (%g)	Exceedance Ratio
Ralston Avenue OC	35 0114	04-SM-101-9.55-BMT	High	105.3003	2.934
Via Del Oro OH	37 0477L	04-SCL-085-1.22-SJS	High	49.2711	2.472
San Mateo-Hayward Bridge	35 0054	04-SM-092-R14.44-FSTC	High	49.6514	2.167
Constitution Way OC	33 0513K	04-ALA-260-R.86-ALA	High	68.2755	1.415
Meridian Road Underpass	37 0258	04-SCL-280-R3.89-SJS	High	59.9229	1.122
Campbell Underpass	37 0135	04-SCL-017-12.22-CMB	High	70.2112	1.087
East Hillsdale Blvd OC	35 0138	04-SM-101-11.15-SM	High	68.3762	1.071
Redwood Creek	35 0145	04-SM-101-6.2-RDWC	High	61.0924	1.064
Sfobb-Approach Lower Deck	34 0118R	04-SF-080-4.95-SF	High	33.2578	1.057
Holly Street OC	35 0037	04-SM-101-8.4	High	65.904	1.048
Route 13/80 Separation (North)	33 0191G	04-ALA-013-13.92-BER	High	66.6766	1.046
Race Street Overcrossing	37 0260	04-SCL-280-R3.76-SJS	High	59.9229	1.045
Presidio Viaduct	34 0019	04-SF-101-9.14-SF	High	68.3123	1.035
South Delaware Street UC	35 0158L	04-SM-092-R11.61-SM	High	35.1822	1.030
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Powell Street UC	33 0020	04-ALA-080-3.79-EMV	High	66.6766	1.020
Redwood Harbor Overhead	35 0065	04-SM-101-5.5-RDWC	High	56.8606	1.018
Macarthur Avenue OC	37 0100	04-SCL-280-L5.18-SJS	High	54.4613	1.012
N101-S84 Connector OC	35 0081G	04-SM-101-5.39-RDWC	High	56.8606	1.009
N17-N85 Connector Separation	37 0515G	04-SCL-017-9.24-LGTS	High	86.2137	1.008
San Francisco Creek	35 0013	04-SM-101-.01	High	55.3678	1.007
N&S87-S280 Connector Separation	37 0396H	04-SCL-087-5.1-SJS	High	50.5564	1.001
Blossom Hill Road OC	37 0345	04-SCL-082-R.35-SJS	Medium-High	49.4998	0.951
Harkins Slough Road OC	36 0089	05-SCR-001-R2.27-WAT	Medium-High	56.0768	0.938
Sunol Street Rr UC	37 0263L	04-SCL-280-R3.41-SJS	Medium-High	52.8878	0.909
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Bridge Assessment Summary

Maximum Peak 1.0 sec Spectral Acceleration: 188.76%g

Maximum Acceleration: (not measured)

Total number of bridges assessed: 3133

Summary by inspection priority:

High	119	High Priority for full engineering assessment
Medium-High	156	Medium-High Priority for full engineering assessment
Medium	152	Medium Priority for full engineering assessment
Low	2706	Low Priority for full engineering assessment; quick visual inspection likely sufficient.

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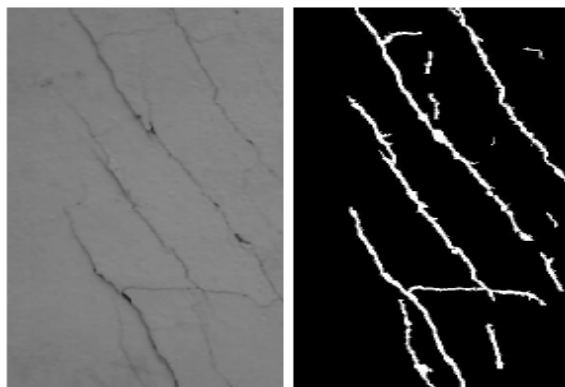
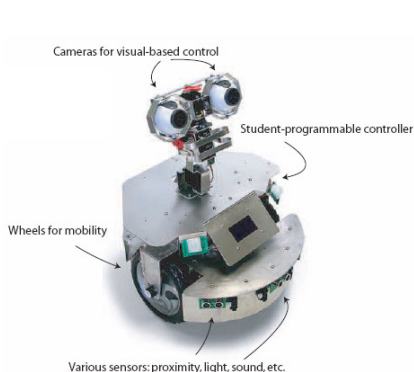
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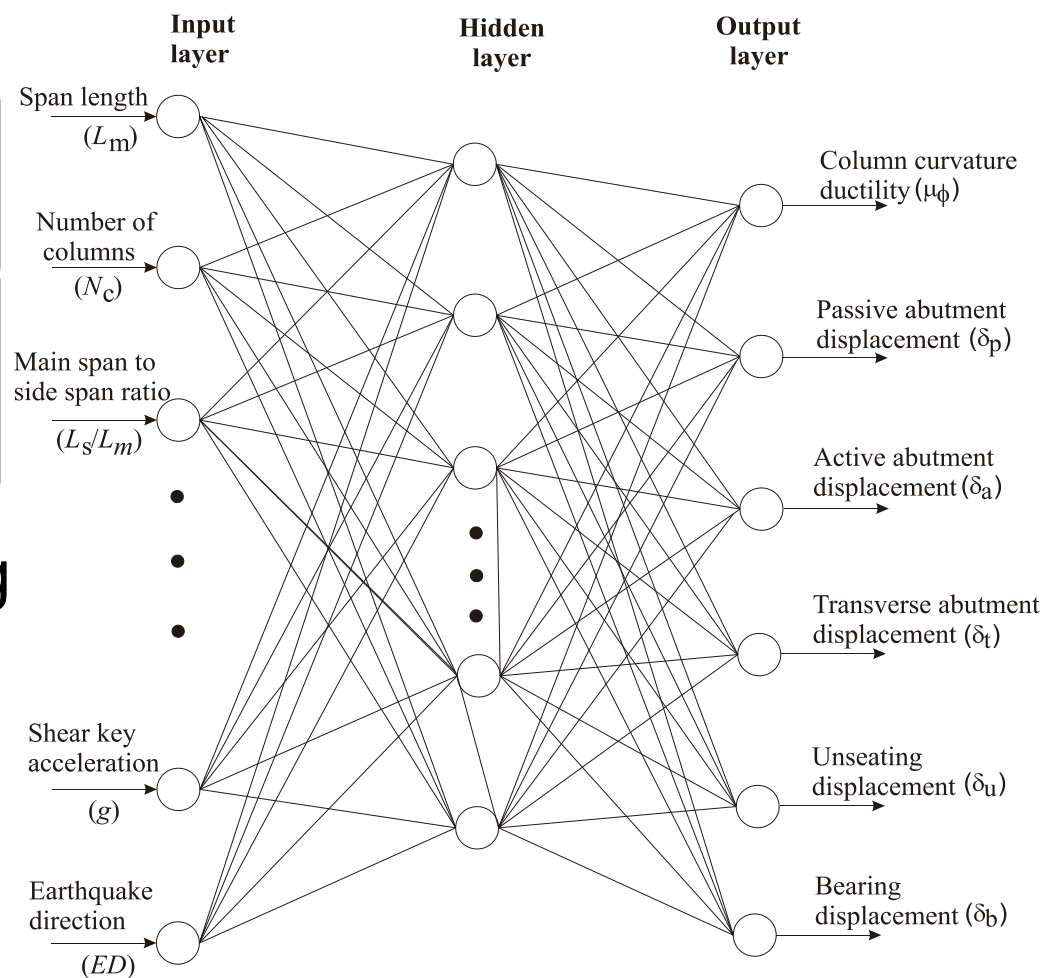
RICE

Future Enhancements

UTC – INSPIRE Project



Citizen Sensor & Crowdsourcing



Artificial Neural Network

Mangalathu, S., Jeon J-S., DesRoches, R., "Critical Uncertainty Parameters Influencing Seismic Performance of Bridges ", *Earthquake Engineering and Structural Dynamics* (under



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Acknowledgements



Dr. Jamie Padgett, Associate Professor – Rice University

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