SEISMIC RISK ASSESSMENT OF TRANSPORTATION NETWORKS

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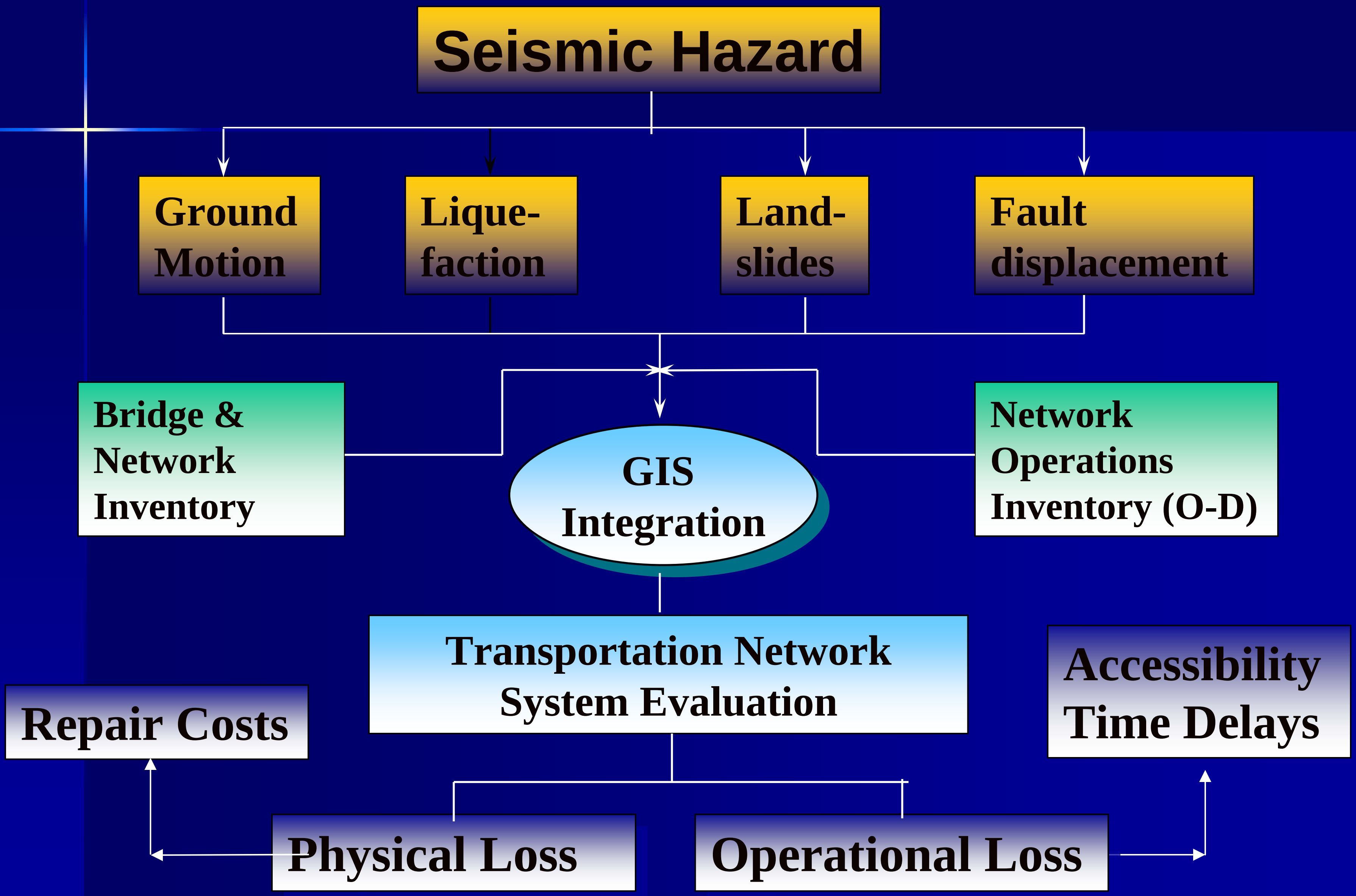
Objectives

- Summarize results from previous PEER supported research
- Present some issues that need to be addressed

Main Research Efforts

- Developed a framework for transportation network risk assessment for
  - From a scenario earthquake event
  - From all possible earthquake events
- Loss contributors considered
  - Direct damage to transportation infrastructure
  - Traffic delay time
- Developed methods for ground motion and damage correlation and evaluated their effect on direct loss estimates

Methodology Overview



Direct Loss – Application ot the San Francisco Bay Are Bridges

Hayward 7.5 Scenario

$$v(DV)=\iiint G\langle DV\,|\,DM\rangle\,|\,dG\langle DM\,|\,EDP\rangle\,|\,dG\langle EDP\,|\,IM\rangle\,|\,d\lambda(IM)$$

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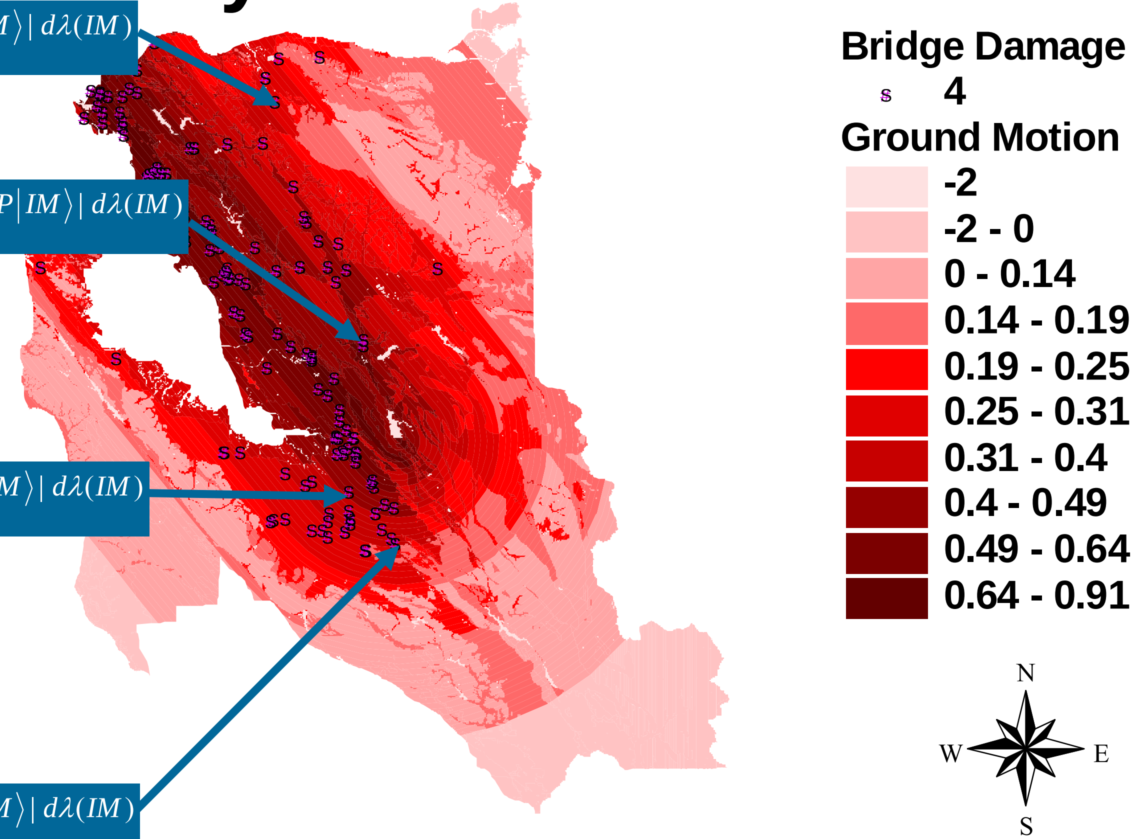
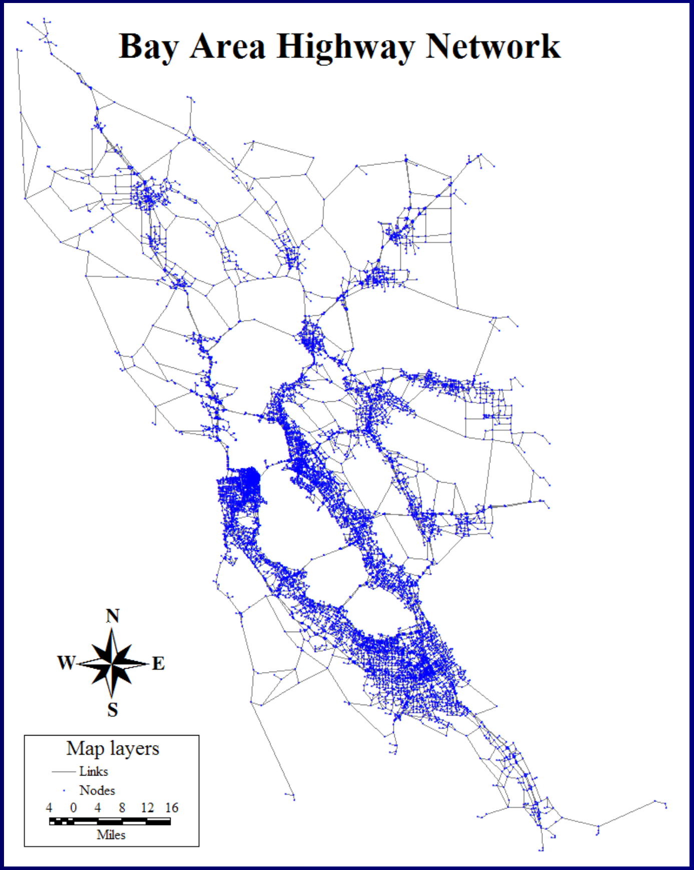


Expected total repair costs by hazard case and by retrofit category for the scenario event *SA8.0* (values x10^6)

	Retrofit Cases	Shaking Only (1)	Shaking + Liquefaction (2)	Shaking + Landslide (3)	Shaking + Liquefaction + Landslide (4)	Liquefaction Only (5)	Landslide Only (6)
Minimum	No-Retrofit	$349	$979	$434	$981	$951	$263
	γ=5%	$324	$968	$408	$971	$942	$251
	γ=10%	$300	$957	$384	$960	$933	$239
	γ=20%	$259	$934	$342	$938	$914	$217
Maximum	No-Retrofit	$1,248	$3,295	$1,526	$3,302	$3,194	$917
	γ=5%	$1,159	$3,257	$1,439	$3,265	$3,164	$876
	γ=10%	$1,077	$3,220	$1,358	$3,228	$3,133	$835
	γ=20%	$934	$3,147	$1,216	$3,157	$3,071	$761

Traffic Flow Analysis – Application to San Francisco Bay Area



- 1,125 bridges
- Five counties
- 29804 links
- 10647 nodes

1990 Base & San Andreas 7.5 Scenario Comparison

(Fixed Demand Trip Assignment Model)

Total Assigned Trips:

1990 Base: **681605**
San Andreas 7.5 Scenario: **681605**

Fixed Demand

Link Type	Number of Links		Link Length (mi)		Lane Length		Vehicle Hours	
	1990 Base	SA 7.5	1990 Base	SA 7.5	1990 Base	SA 7.5	1990 Base	SA 7.5
Fwy to Fyw Ramp	178	92	87	42	141	65	2,420	1,490
Freeway	2,013	1,495	1,327	1,025	3,593	2,772	116,589	119,347
Expressway	829	709	432	392	862	786	11,951	19,820
Collector	6,931	6,857	4,426	4,385	5,304	5,251	17,156	59,094
On&Off Ramp	1,852	1,489	528	416	567	443	8,632	11,353
Centroid Connector	4,892	4,892	1,922	1,922	5,765	5,765	5,385	5,385
Major Road	9,741	9,595	4,680	4,614	8,114	7,984	59,894	147,671
Meter Ramp	78	47	30	18	31	19	485	419
Special	8	8	4	4	12	12	3,389	9,195
Total	26,522	25,184	13,437	12,818	24,389	23,096	225,901	373,774

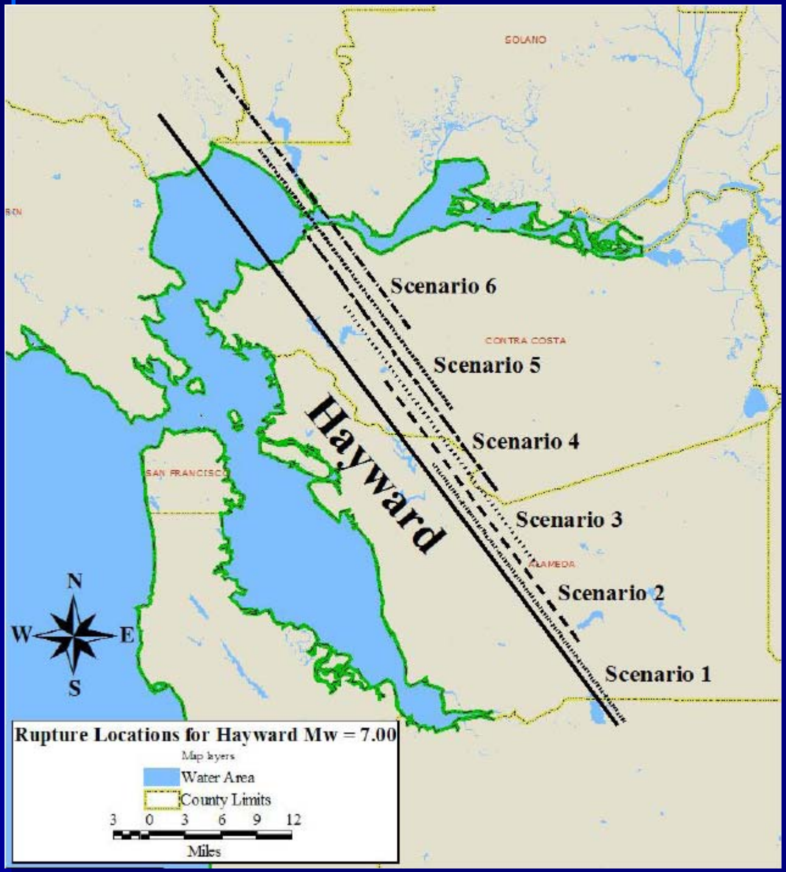
Annual Risk Curve Estimation

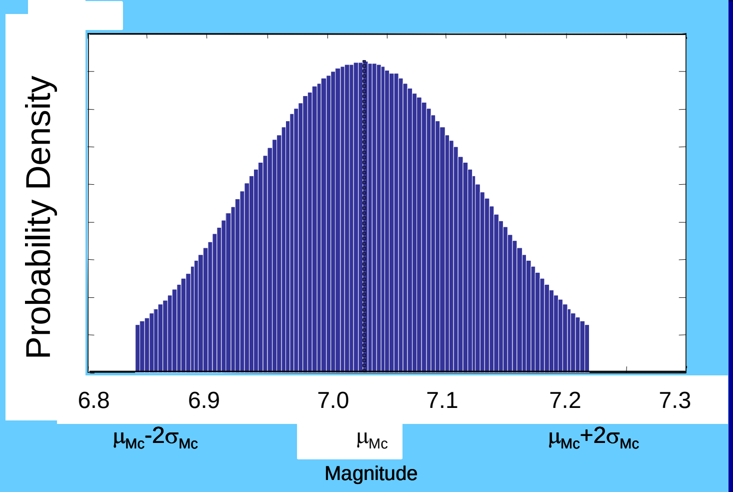
- Consider all possible earthquake events
- Evaluate direct loss from damage to bridges
- Evaluate loss from reduced network functionality

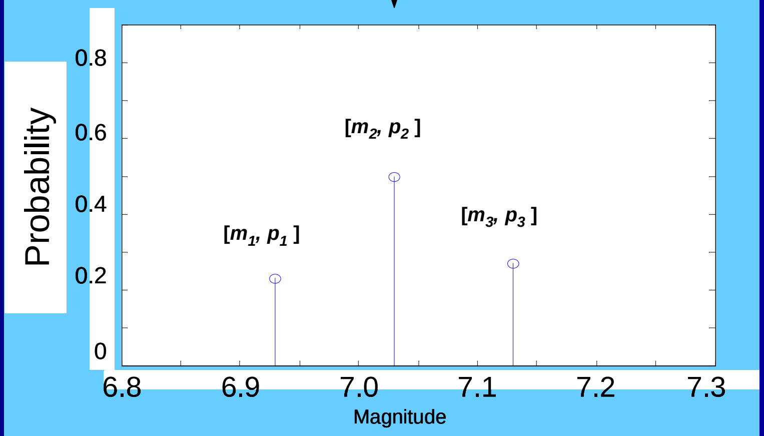
Event Modeling – use probability concentrations to reduce number of scenarios

Characteristic event modeling

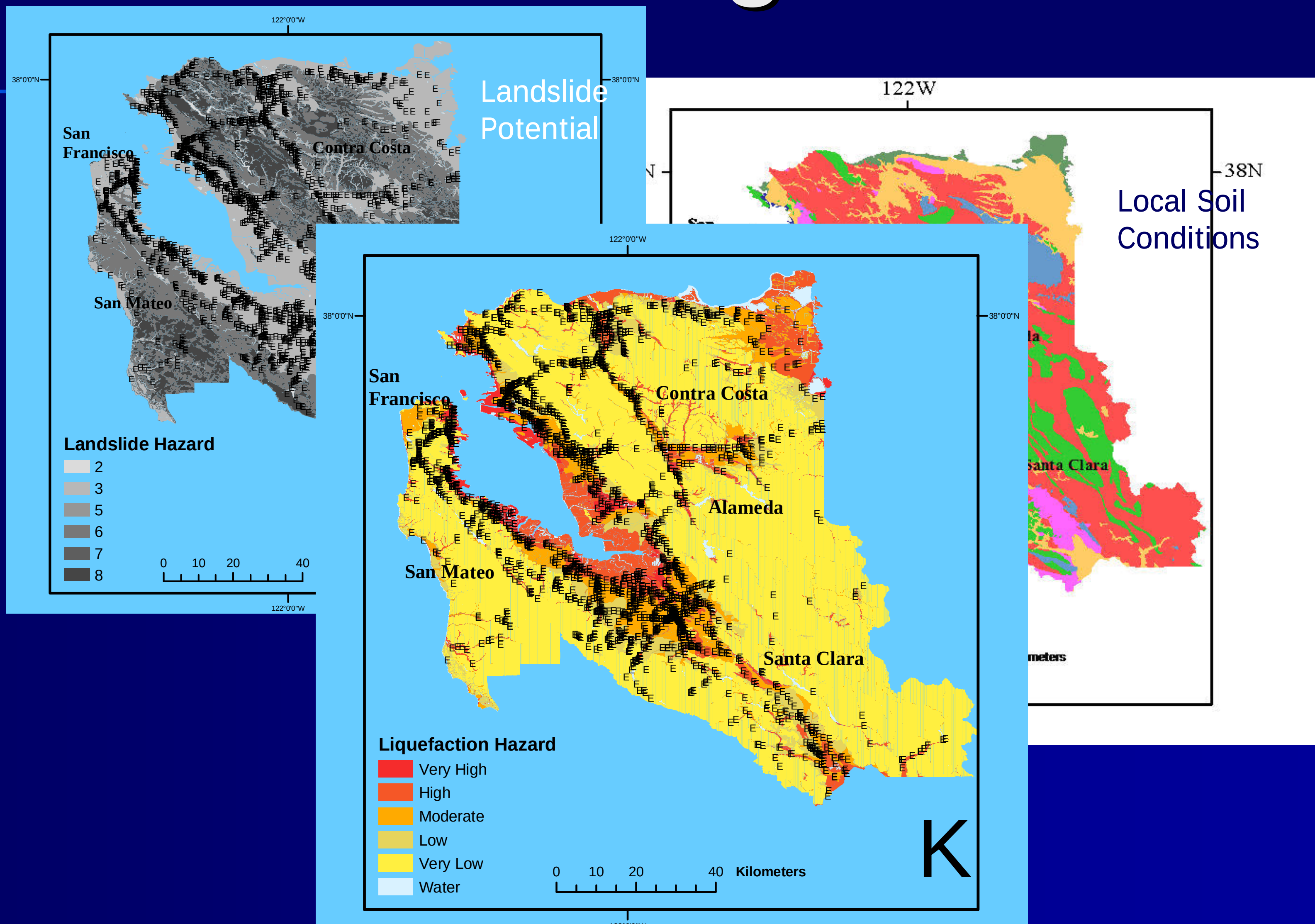
Sliding scenario event modeling



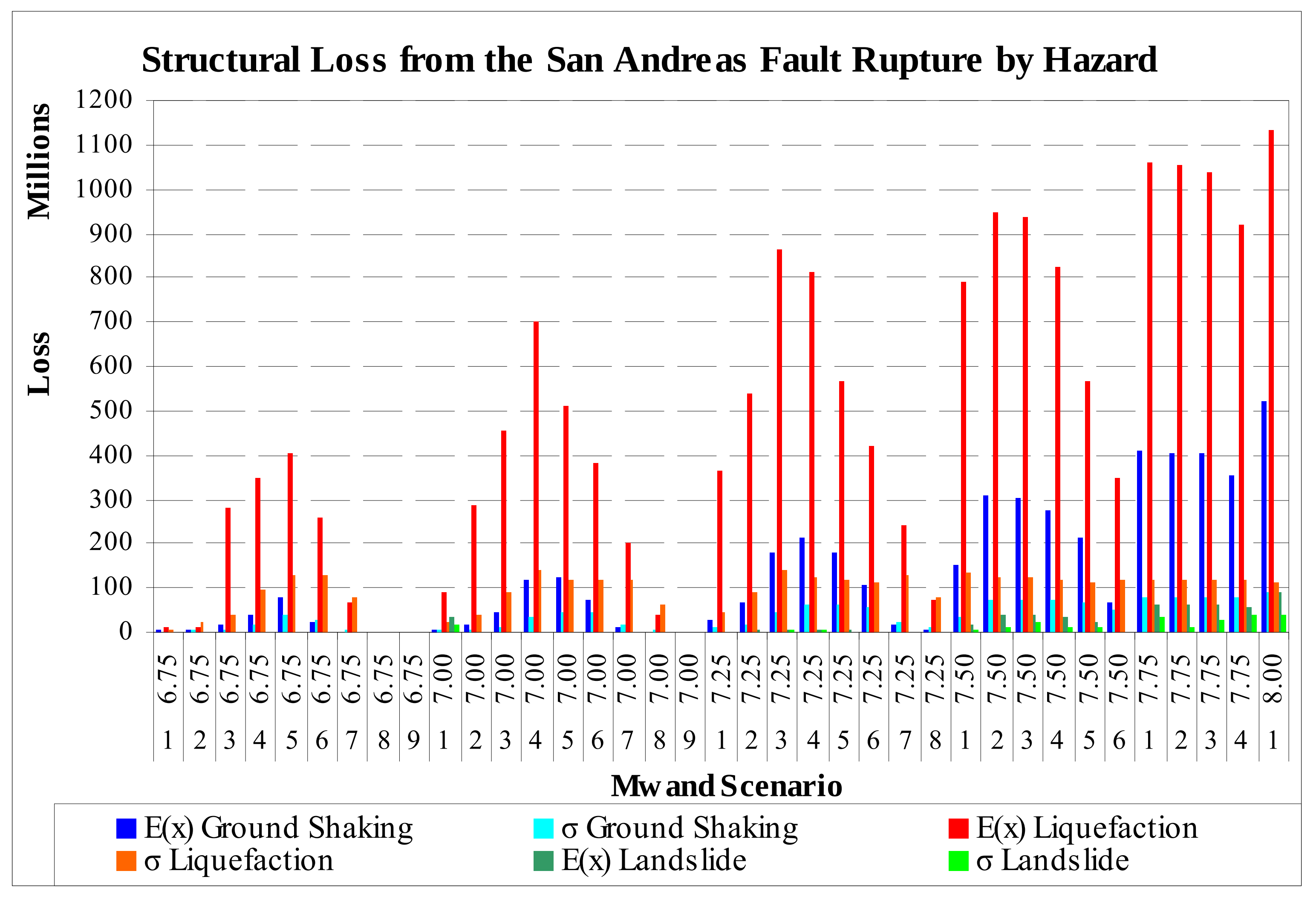




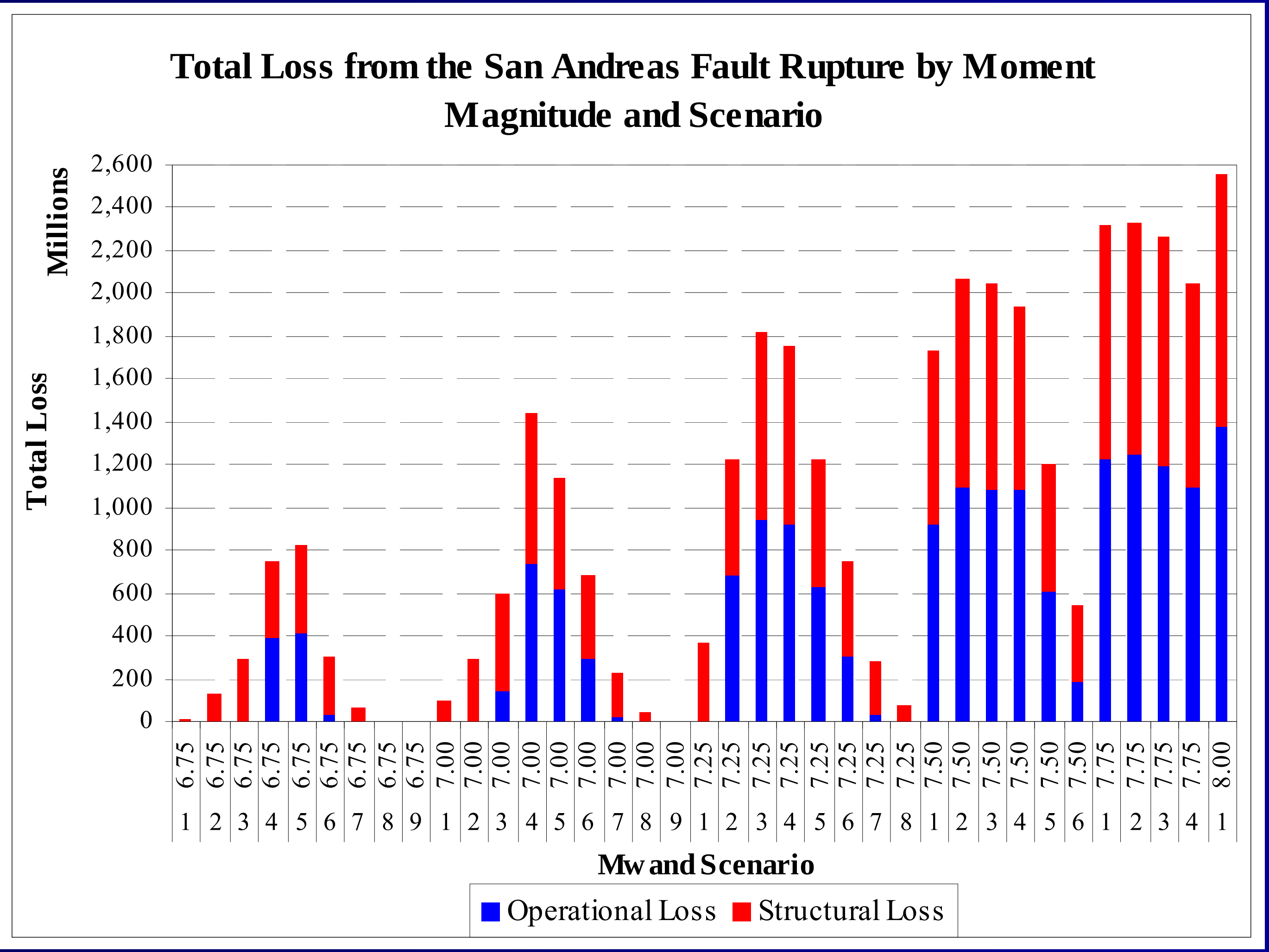
Hazard Modeling



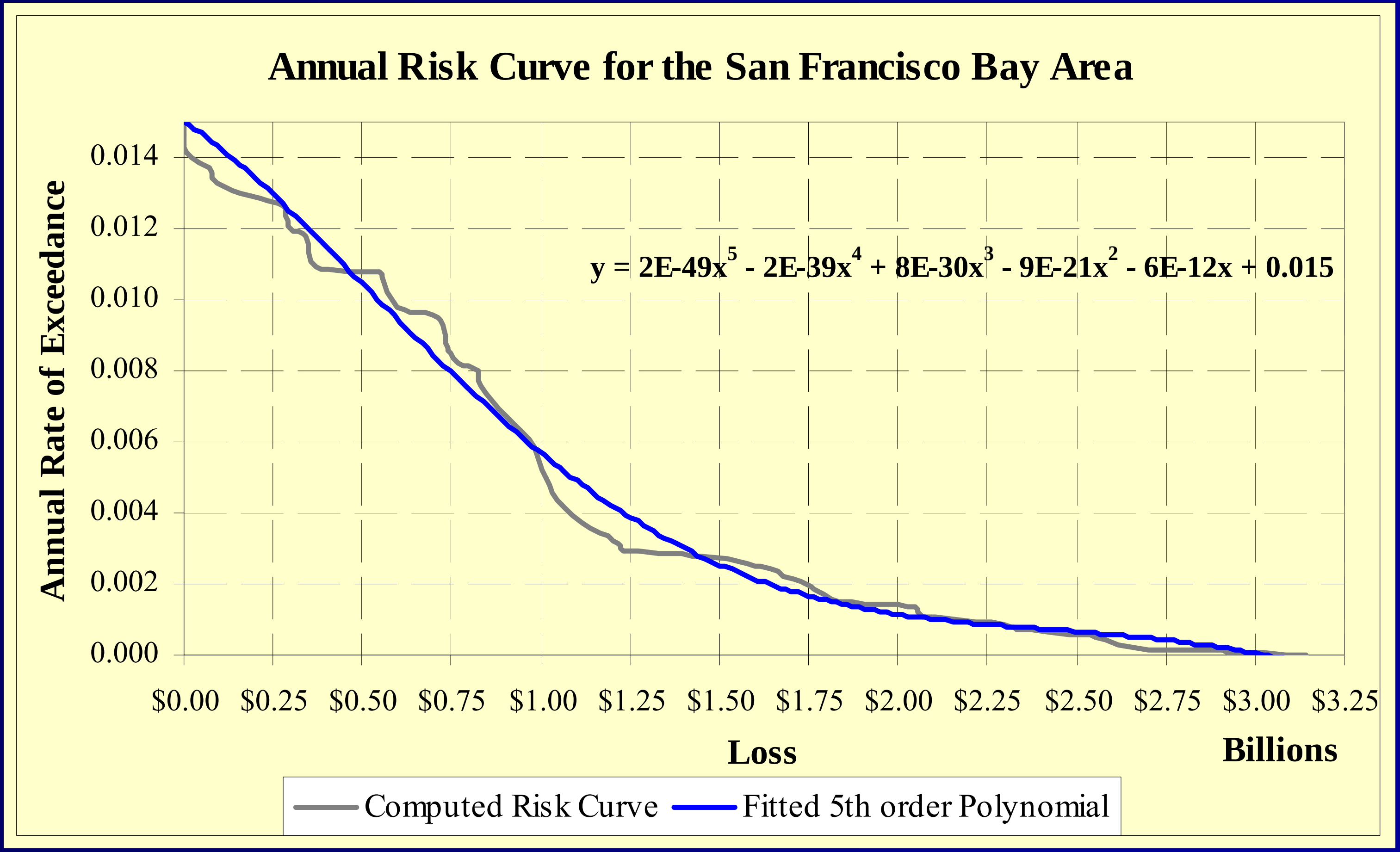
Direct Loss Estimates



Aggregated Direct and Functionality Loss



Annual Risk Curve



Ground Motion Correlation Model

- Variance of Loss
  - Uncorrelated components

$$\sigma^2_{L_{total}} = \left[\sum_{i=1}^{N} \sigma^2_{L_i} \right]$$

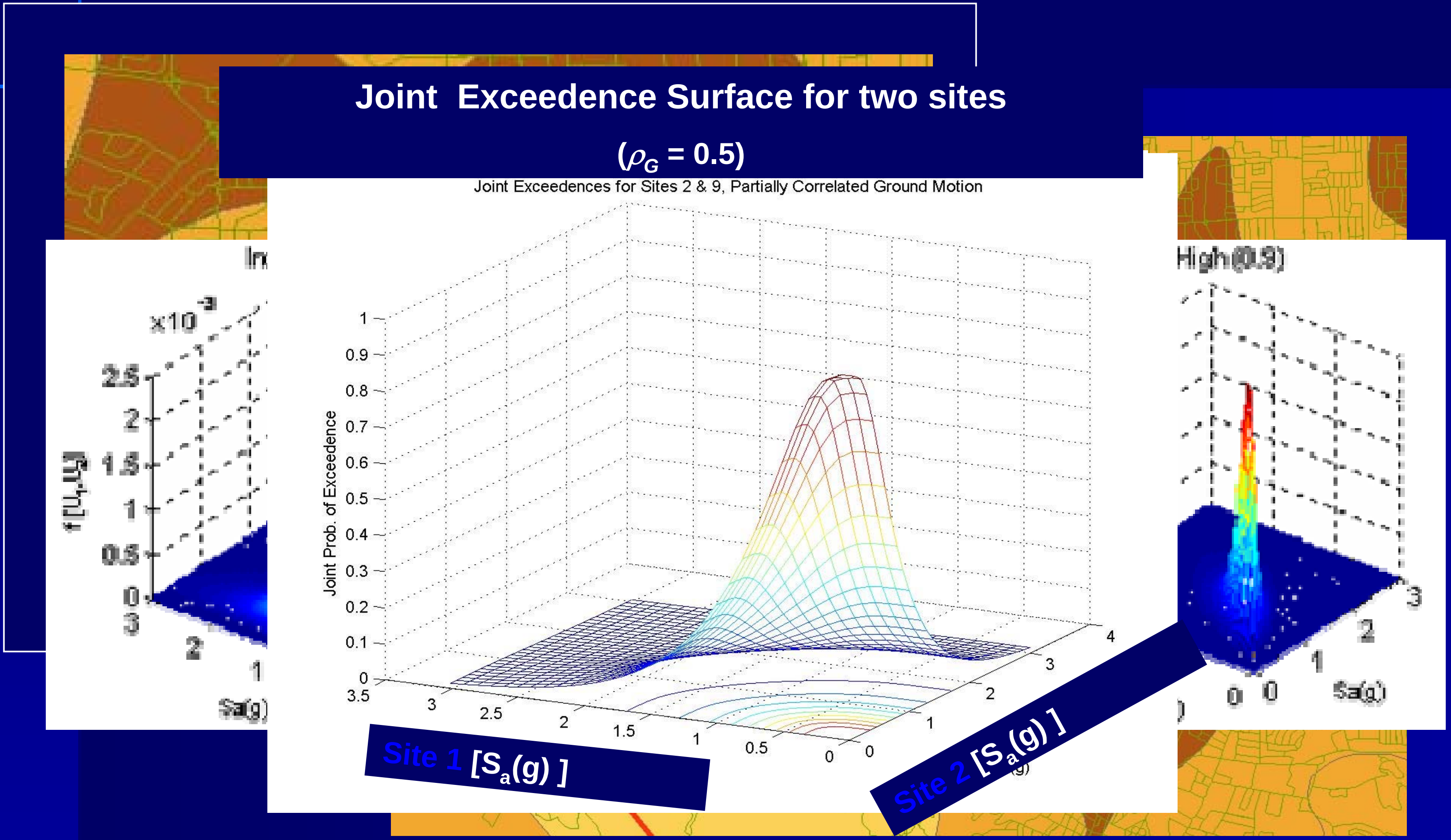
  - Correlated components

$$\sigma^2_{L_{total}} = \left[\sum_{i=1}^{N} \sigma^2_{L_i} + \sum_{i=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} \rho_{L_i L_j} \sigma_{L_i} \sigma_{L_j} \right]$$

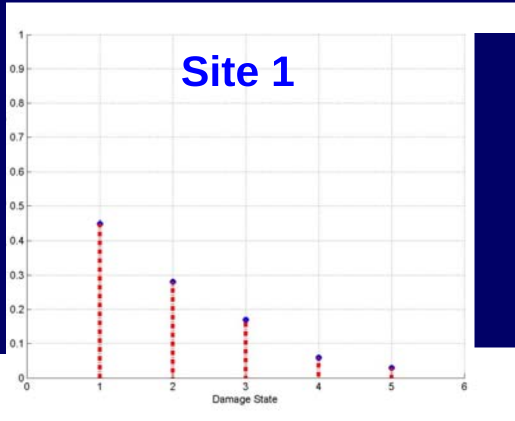
    - Ground motion correlation
    - Analyzed data from the San Francisco Bay Area to obtain correlation

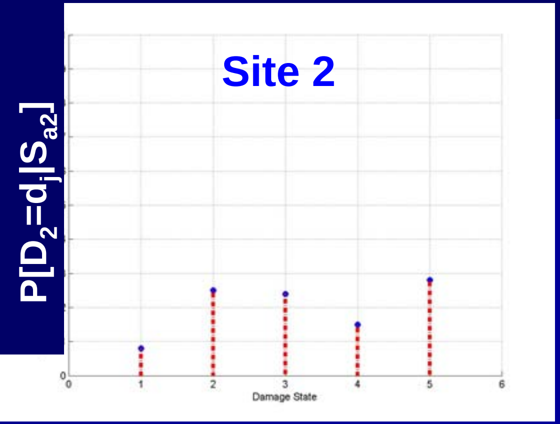
Ground Motion Correlation

see Lee and Kiremidjian, 2007 – Earthquake Spectra

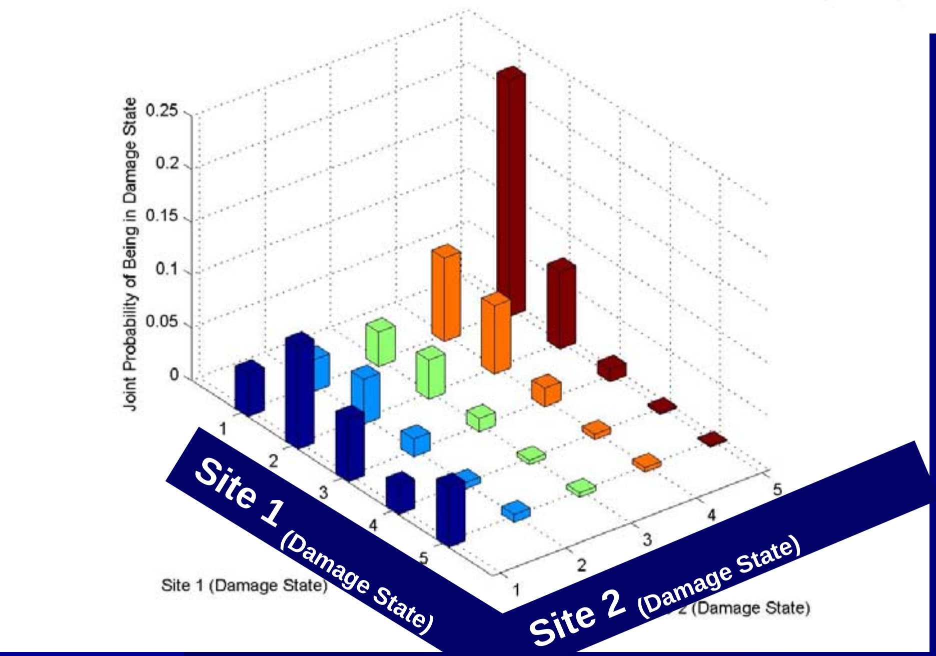


Damage Correlation



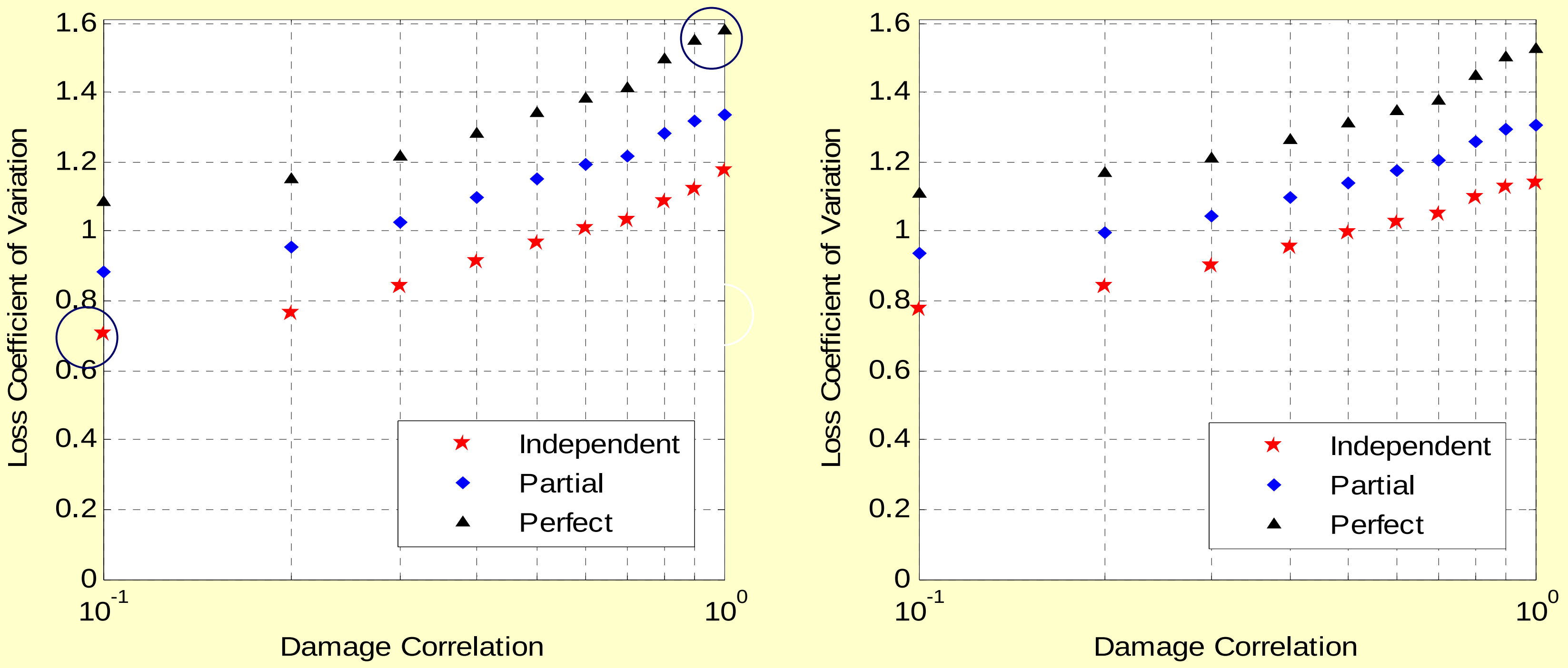


$P[D_1 = d_i, D_2 = d_j | S_{a1}, S_{a2}]$



Input Damage Correlation

CoV of Aggregate Loss



Results:

Network Size	CoV (No Correlation)	Range of CoV
Large (16)	0.6	[0.7 , 1.6]
Small (9)	0.7	[0.8 , 1.5]

Conclusions

- A framework for direct and functionality loss is developed for spatially distributed systems that includes
  - Ground motion, liquefaction and ground deformation hazards
  - Ground and damage correlation
  - Considers the risk to the network from all possible events
- Liquefaction appears to contribute the most to damage and loss
- Functionality loss is found to be a major contributor to the overall loss
- Neglecting correlation may underestimate CoV_L by as much as a ***factor of two***

Some Observations

- How do we model post-event traffic demand?
- How do we increase the computational efficiency
- We need significantly improved bridge vulnerability functions – based on current PBEE methods
- We need to consider recently developed liquefaction/landslide models
- Can we develop decision support tools that utilize the loss estimates obtained from such analyses