

# Seismic Risk Model for a Designated Highway System

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July 21-25, 2002

7NCEE, Boston, MA



# Objective

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- ◆ To develop a method for evaluating the performance of a highway network system
- ◆ To apply the method to the San Francisco Bay Region incorporating research within PEER

# The PEER Performance Based Equation

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# Approach

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## ◆ Scenario – based

- Define scenario (s)
- Obtain bridge inventory database
- Evaluate hazard (s)
- Estimate damage to bridges
- Obtain transportation systems inventory
- Integrate bridge and network system databases
- Perform transportation network analysis
  - ◆ Pre-event base case
  - ◆ Post-event case
- Estimate costs
  - ◆ Bridge repair
  - ◆ Network time delays



## ◆ Complete probabilistic analysis

- Repeat scenario for complete set of events

# Estimated Bay Area Bridge Damage

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*Scenario Earthquakes:*

*Hayward 7.0 and 7.5*

*San Andreas 7.5 and 8.0*

# Uses

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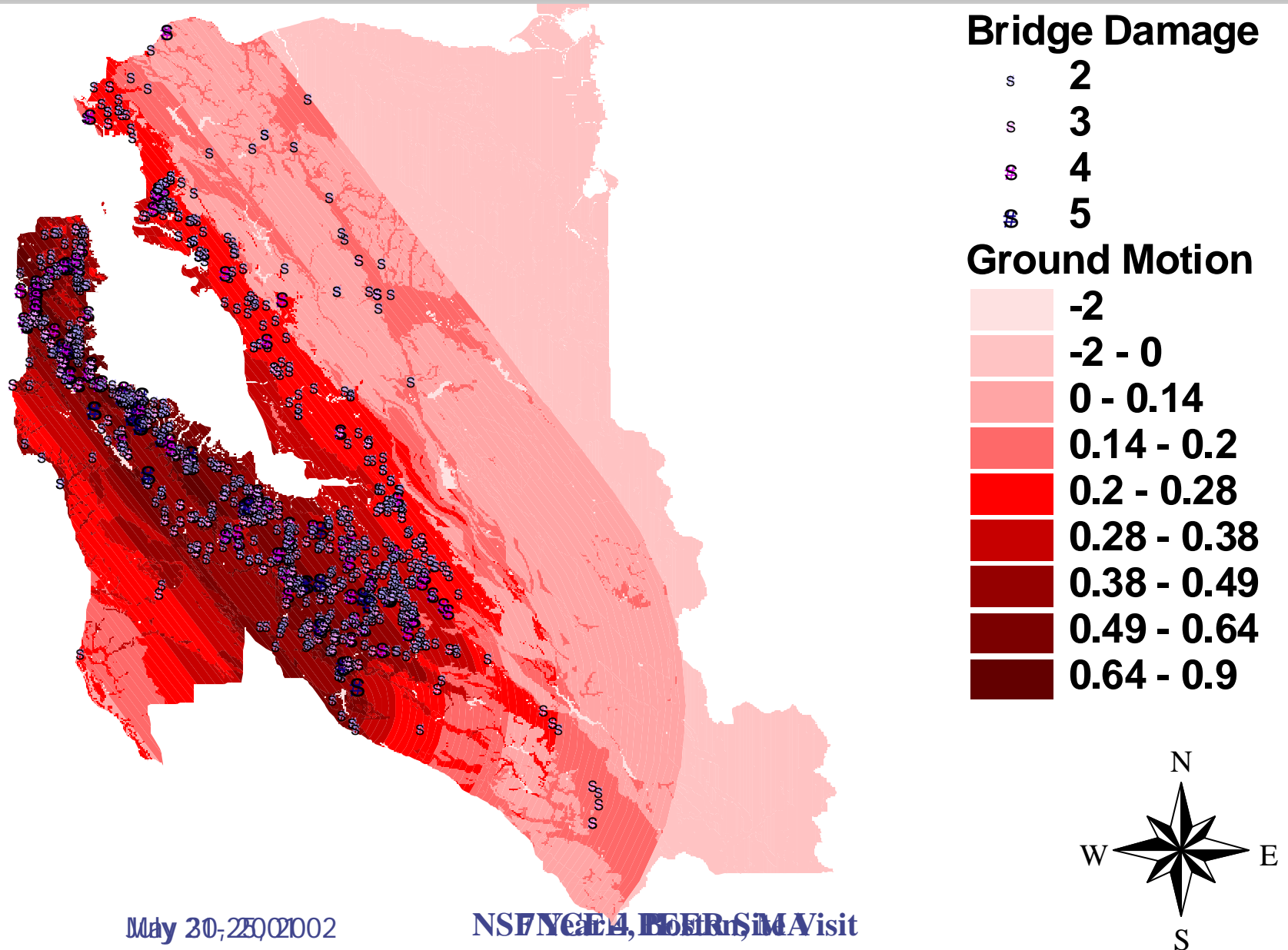
- ◆ Evaluate the economic impact of a transportation system on the economy of a region
- ◆ Identify high risk network links
- ◆ Provide tools for bridge retrofit and post earthquake repair prioritization strategies
- ◆ Provide information on the performance of a bridge in terms of its importance to the network economic loss

# Damage State Definitions

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1. No Damage
2. Slight Damage- cracking, spalling
3. Moderate Damage- bond, abutment backwall collapse
4. Extensive Damage- pier concrete failure
5. Complete Damage- deck unseating, pier collapse

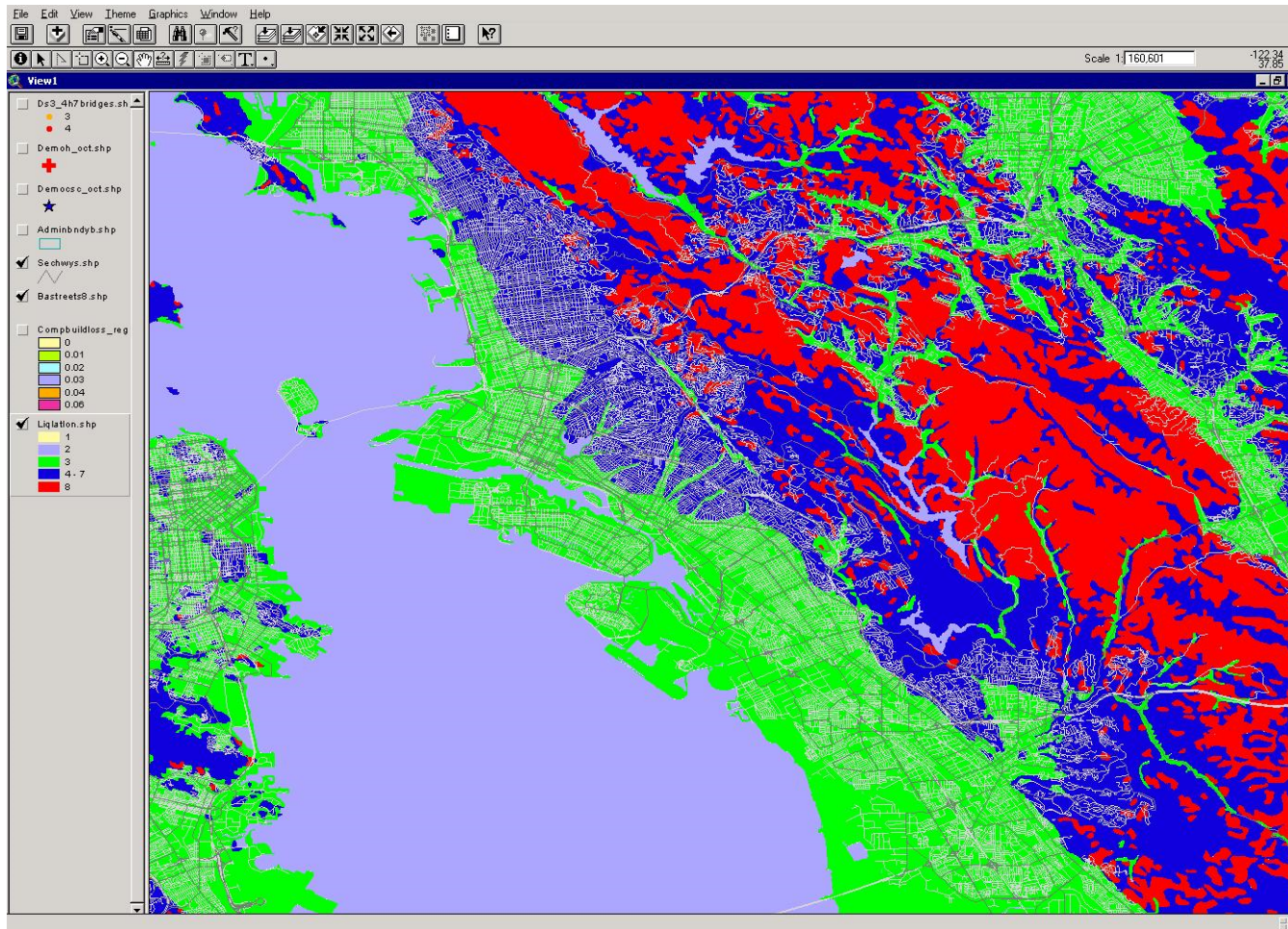
# San Andreas 7.5 Scenario





# Liquefaction susceptibility

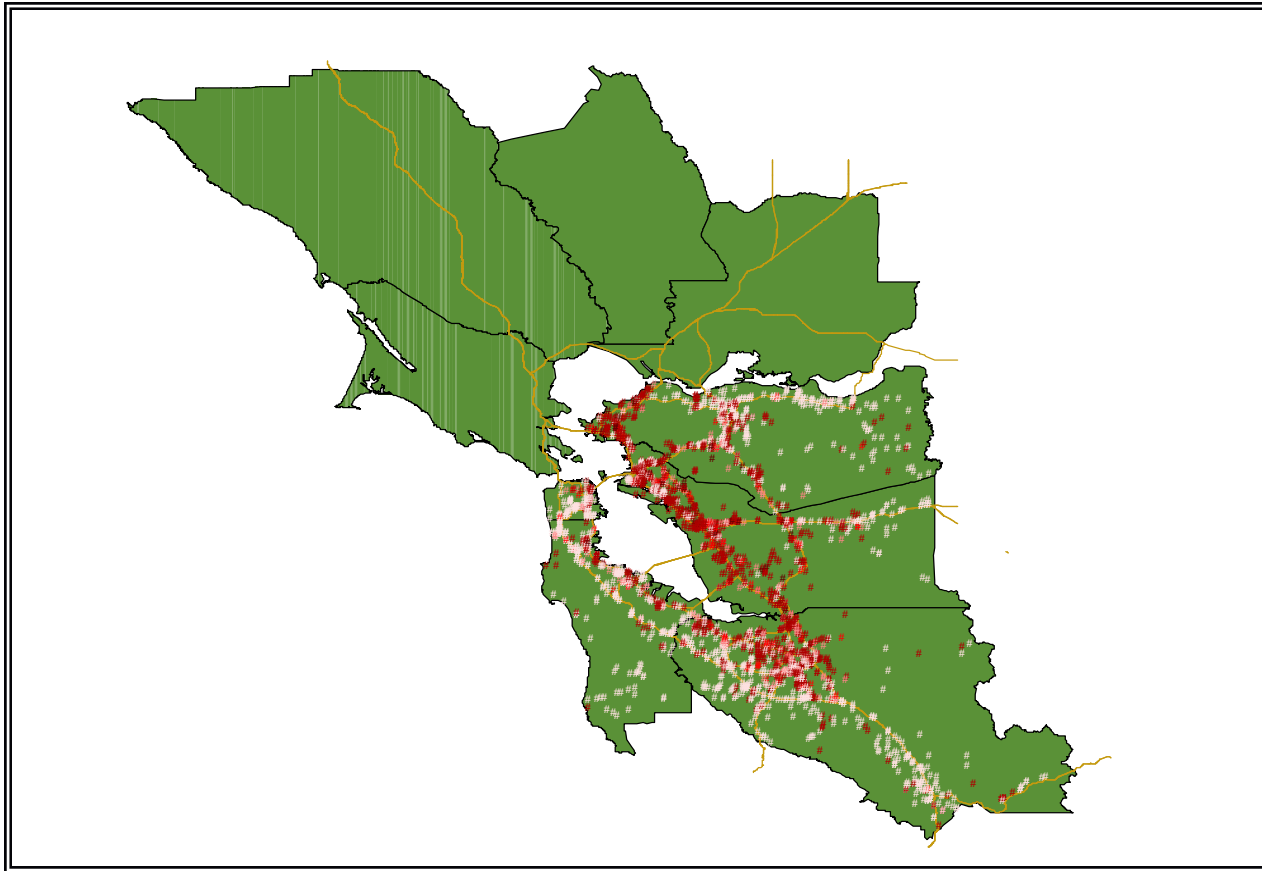
Liquefaction susceptibility with secondary highways and streets



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# Damage Caused by Liquefaction (Hayward 7.0)

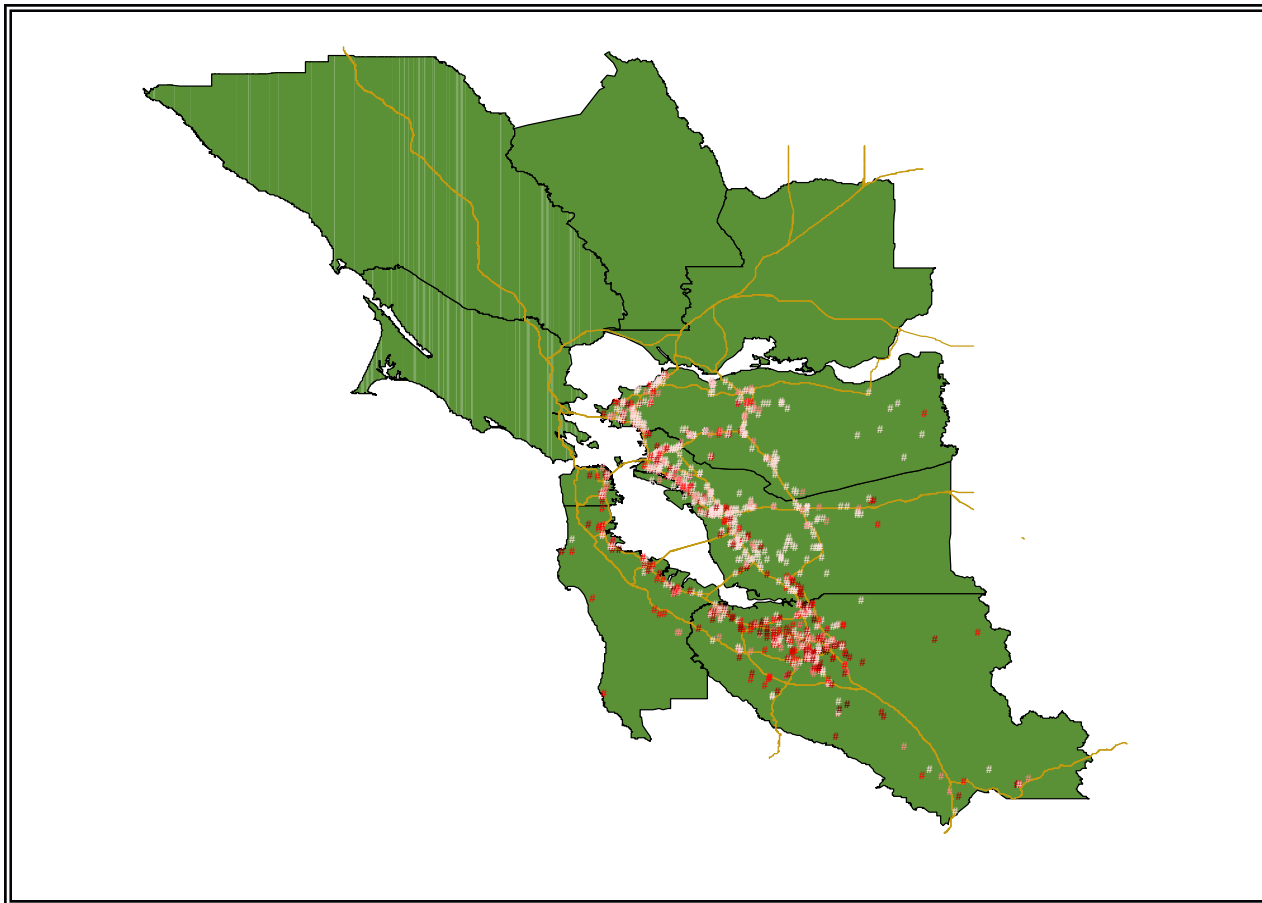


Pre-Retrofitted Bridges

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# Damage caused by Landslide (Hayward 7.0)

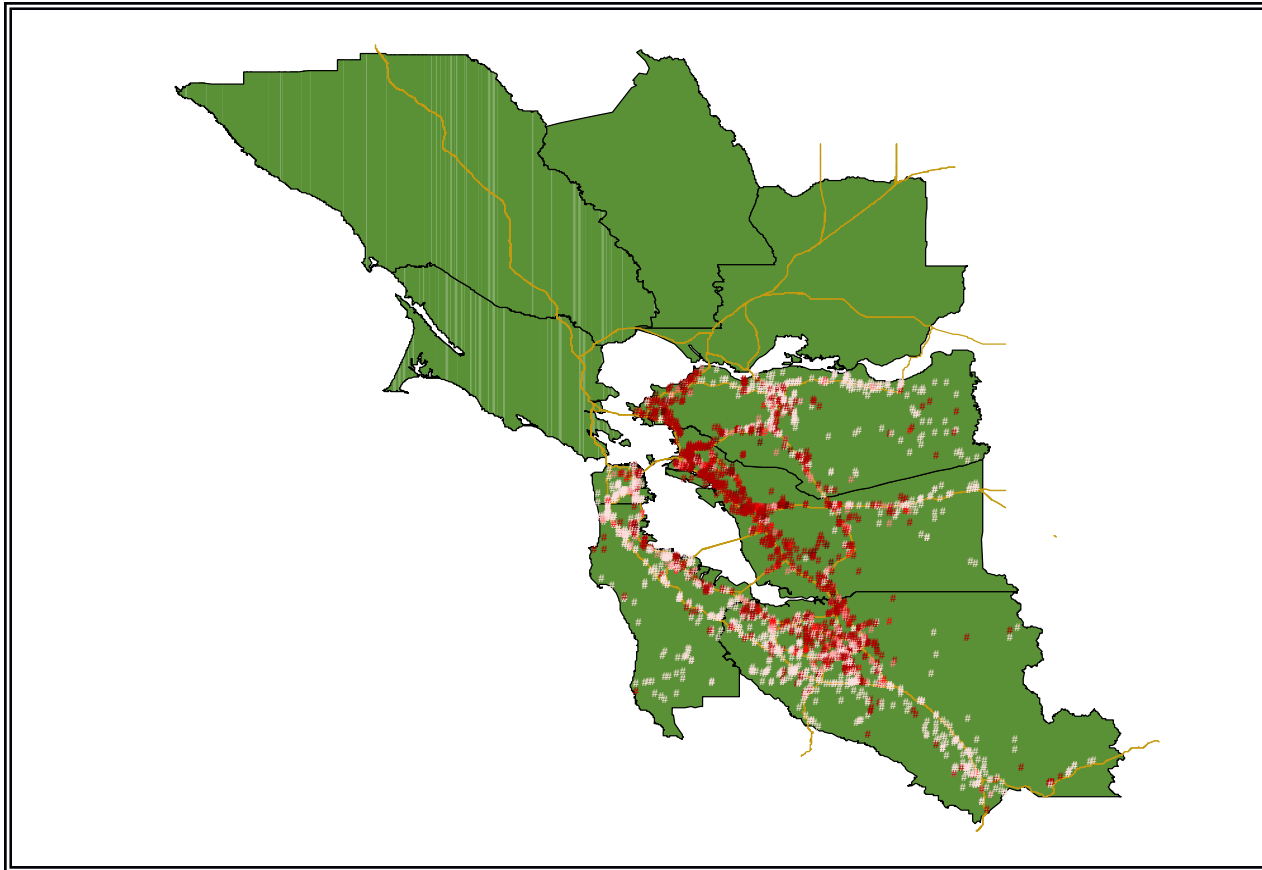


Pre-Retrofitted Bridges

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# Damage caused by Liquefaction and Landslide (Hayward 7.0)

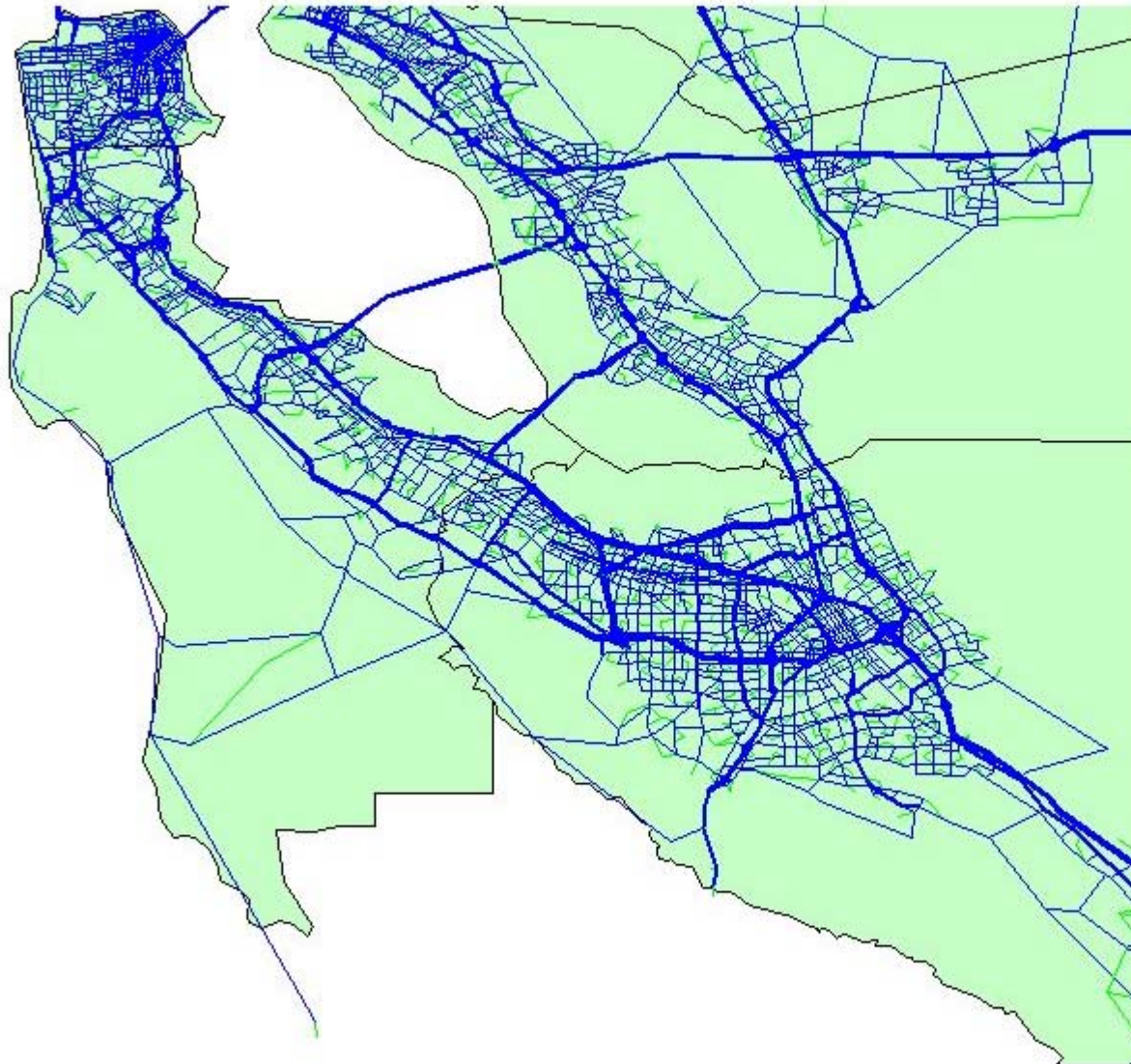


Pre-Retrofitted Bridges

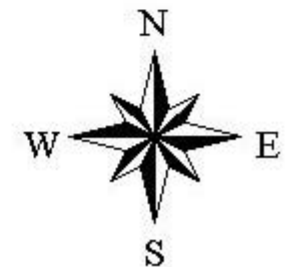
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# MTC Highway Network



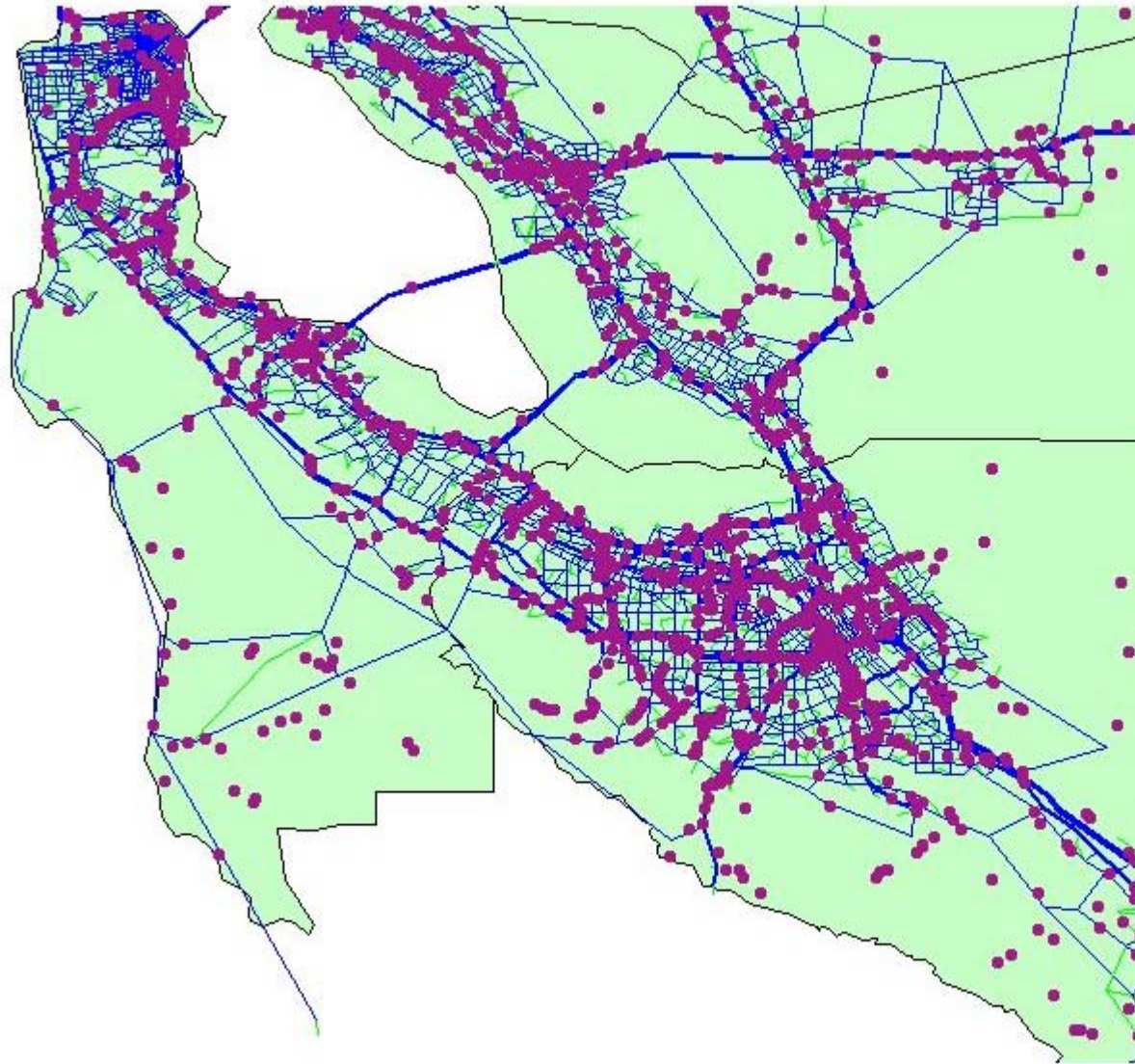
- MTC Links**
- Centroid Connectors
  - Major Roads
  - Frwy&Expwy
  - Bay Area



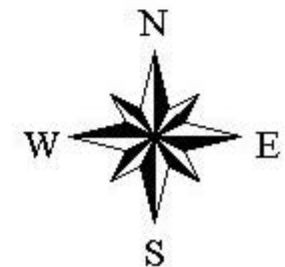
May 30, 2001

NSF Year 4 PEER Site Visit

# Caltrans District 4 Bridges



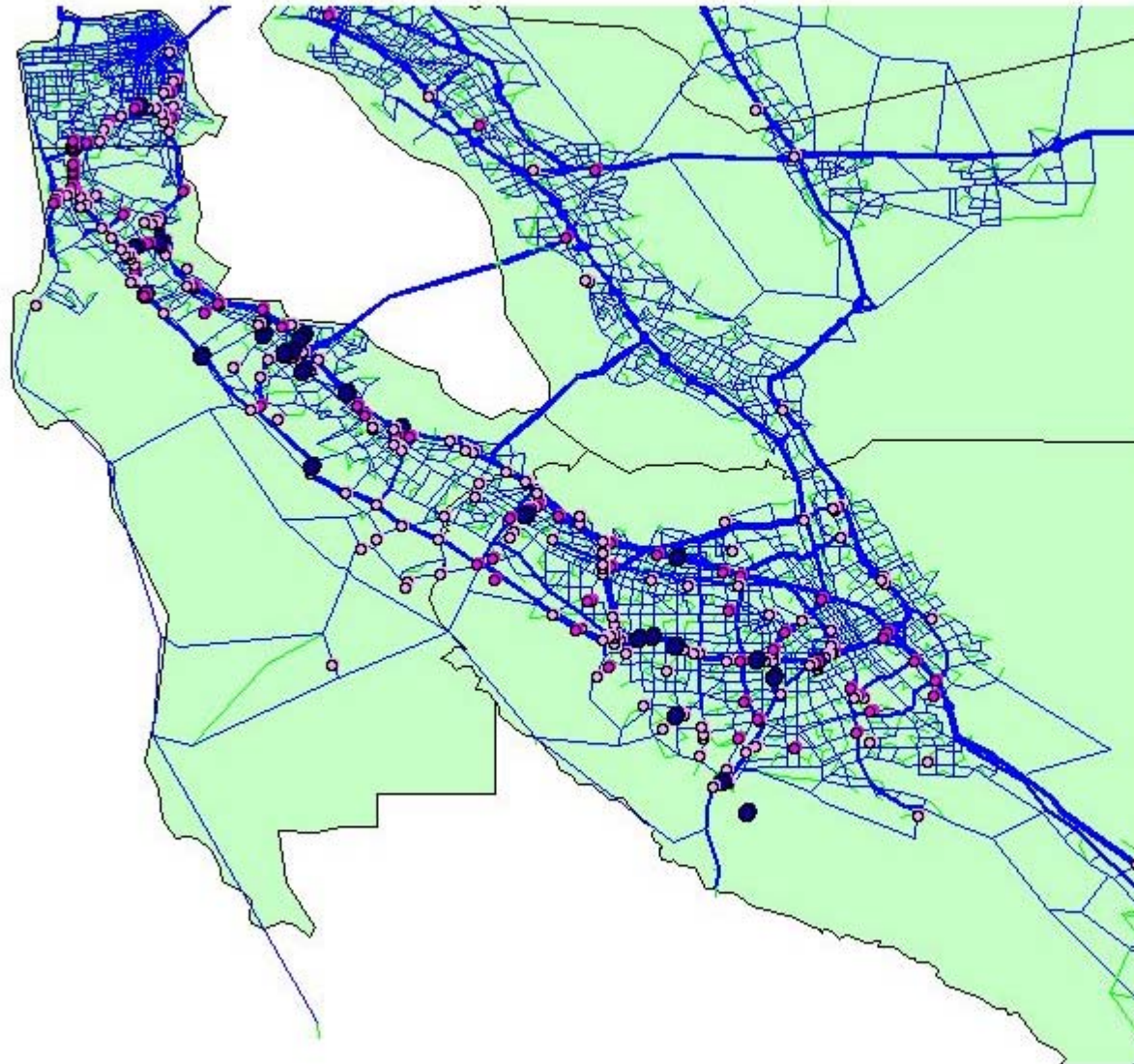
- Caltrans District 4 Bridge
- MTC Links
- Centroid Connectors
- Major Roads
- Frwy&Expwy
- Bay Area



May 30, 2001

NSF Year 4 PEER Site Visit

# San Andreas 7.5 Scenario

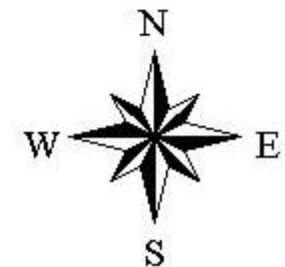


## Damaged Bridges

- 3
- 4
- 5

## MTC Links

- Centroid Connectors
- Major Roads
- Frwy&Expwy
- Bay Area



May 30, 2001

NSF Year 4 PEER Site Visit

# Ground Motion Damage Summary

(pre-retrofitted bridges)

<u>Damage State</u>	<u>Hayward 7.0</u> <u># of bridges</u>	<u>Hayward 7.5</u> <u># of bridges</u>	<u>San Andreas 7.5</u> <u># of bridges</u>	<u>San Andreas 8.0</u> <u># of bridges</u>
<u>1</u>	1732	1350	1589	1334
<u>2</u>	585	778	658	634
<u>3</u> <u>closed</u>	221	280	249	413
<u>4</u> <u>closed</u>	91	182	110	201
<u>5</u> <u>closed</u>	21	50	35	59

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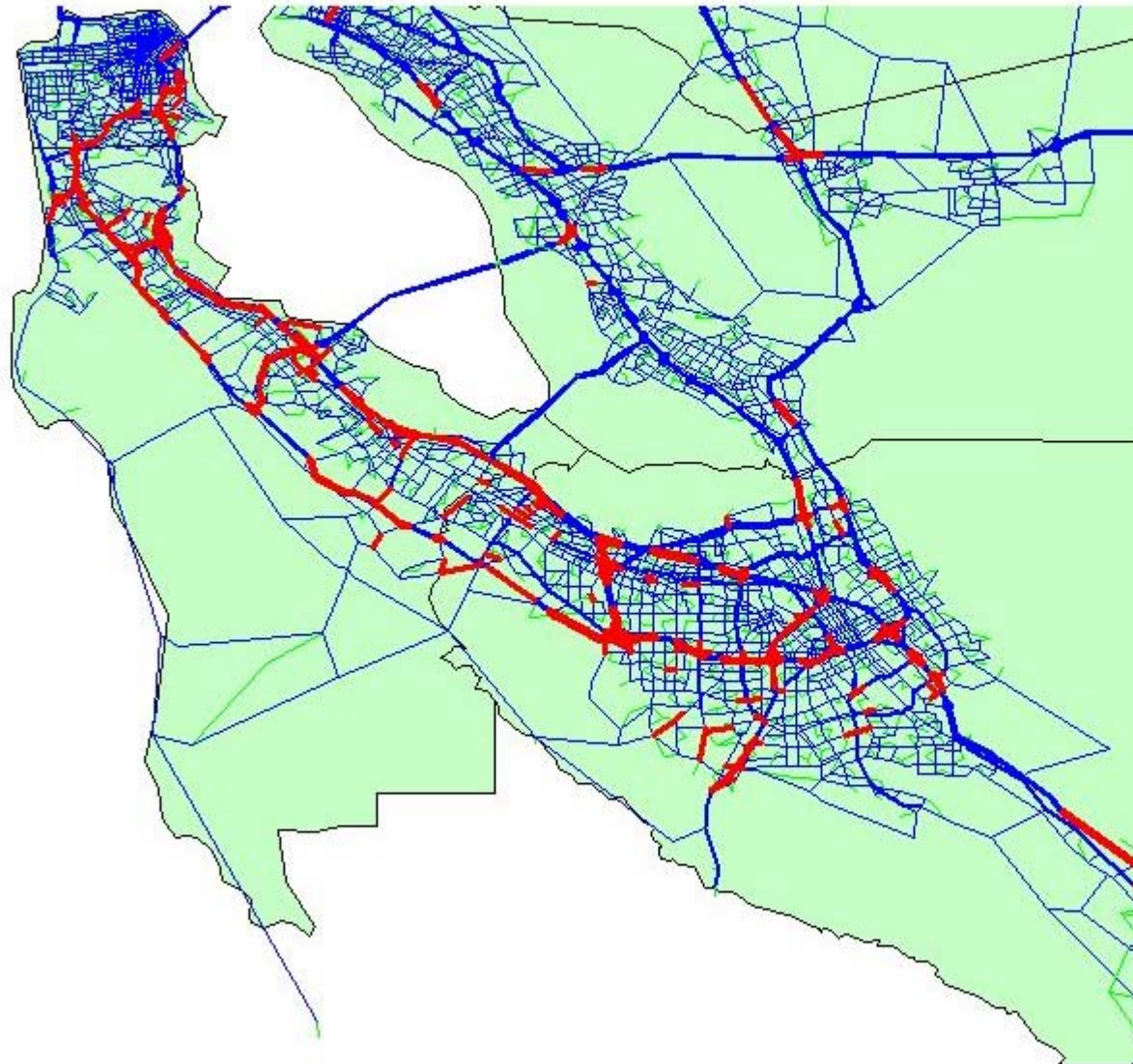




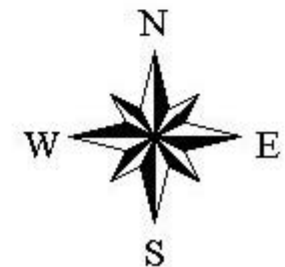
# Expected Damage States for Pre-retrofitted Bridges San Andreas 7.5 Scenario Event

	DS1	DS2	DS3	DS4	DS5
SA75GS	1849	465	170	99	57
SA75GS+Liq	1073	151	244	1065	107
SA75GS+Land	1834	346	123	255	82
SA75GS+Liq+Land	1063	149	228	1092	108

# San Andreas 7.5 Scenario



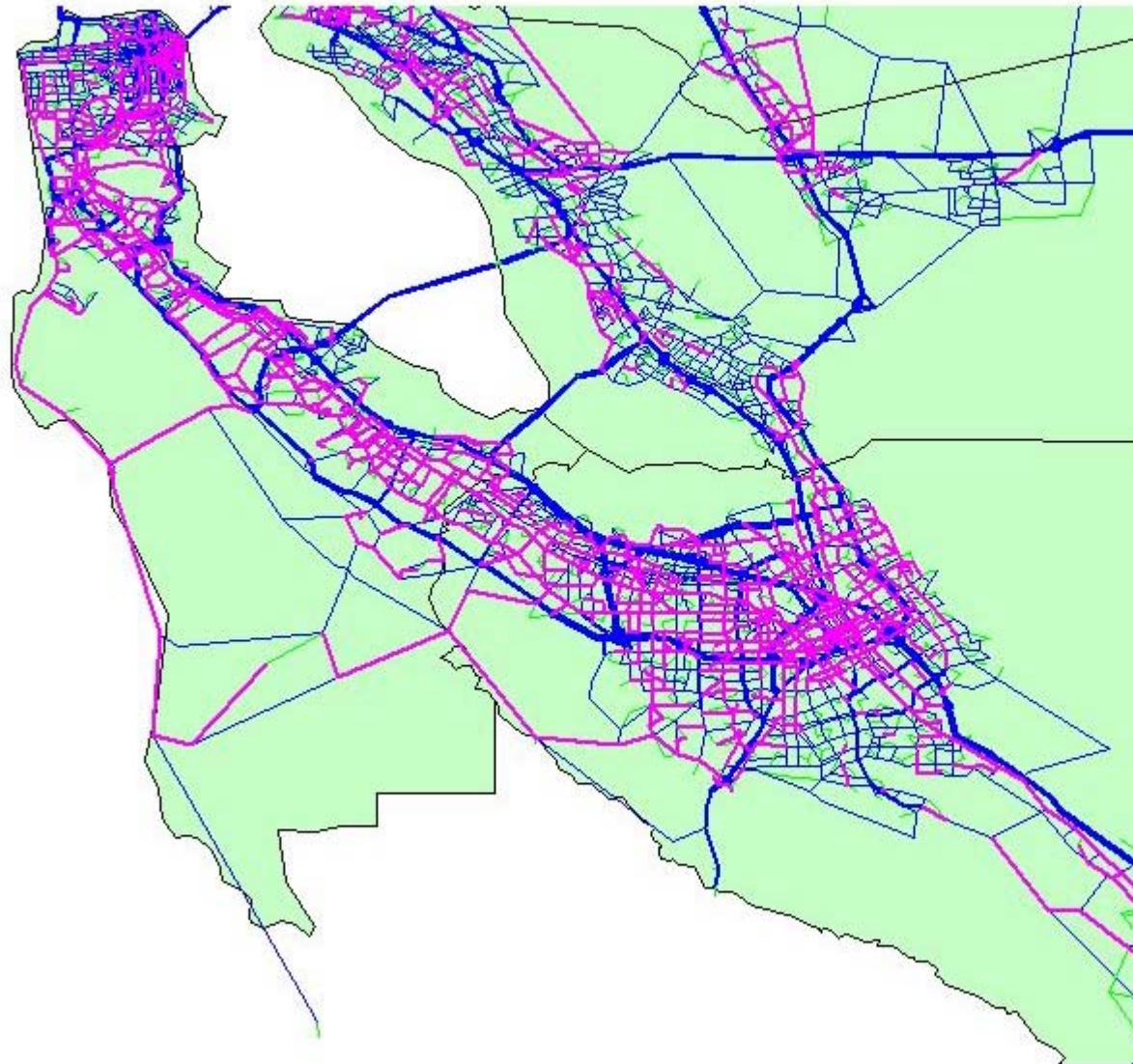
-  Closed Links
-  MTC Links
-  Centroid Connectors
-  Major Roads
-  Frwy&Expwy
-  Bay Area



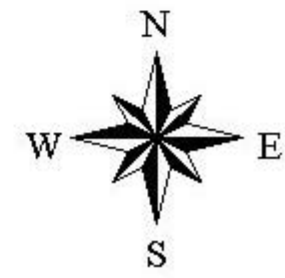
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# San Andreas 7.5 Scenario



- Significant Increase in Vol. MTC Links
- Centroid Connectors
- Major Roads
- Frwy&Expwy
- Bay Area



May 30, 2001

NSF Year 4 PEER Site Visit

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

# 1990 Base & San Andreas 7.5 Scenario Comparison

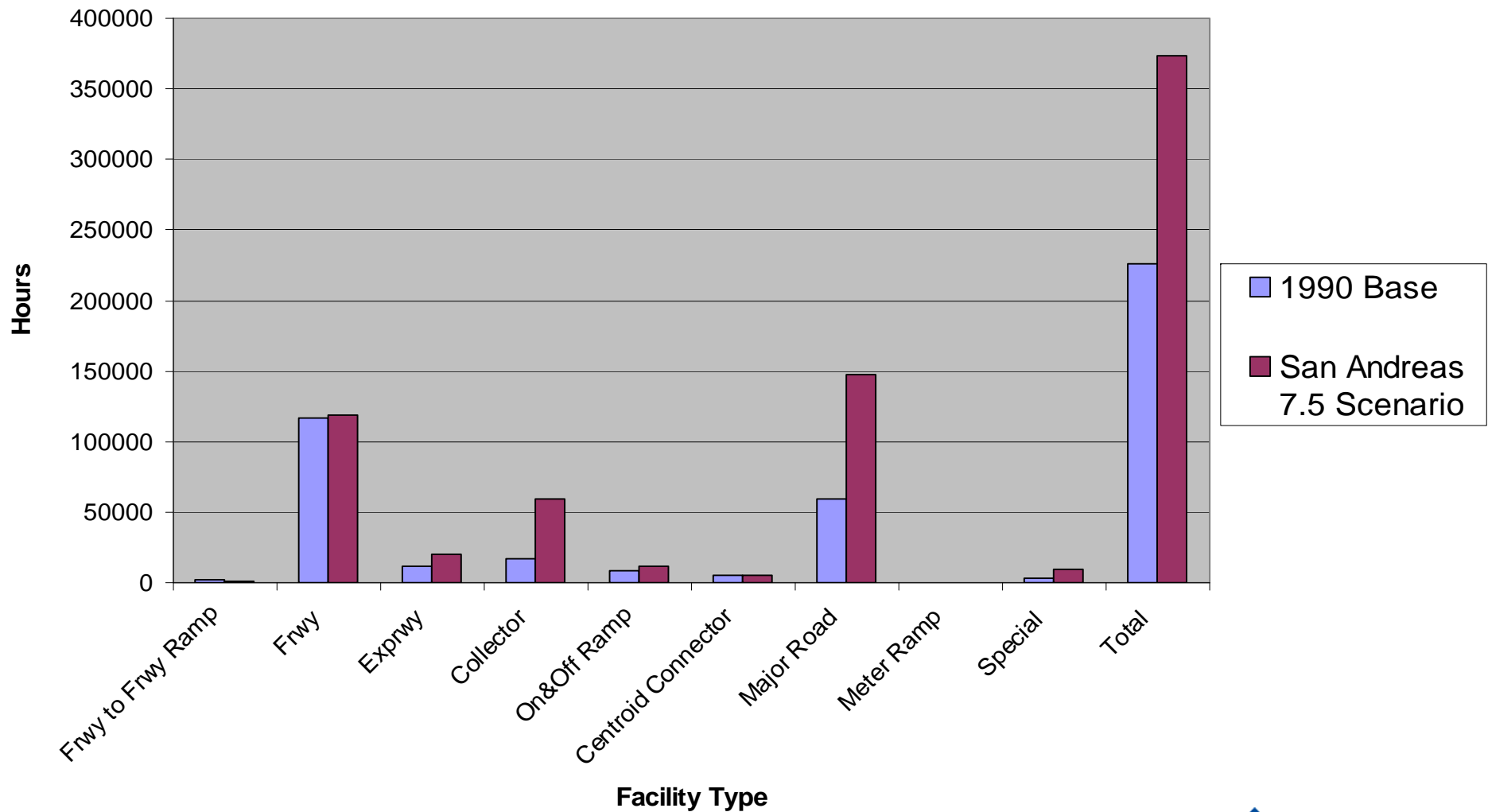
(Continued)

Link Type	Vehicle Miles		Average Speed		Average Auto Vol.	
	1990 Base	SA 7.5	1990 Base	SA 7.5	1990 Base	SA 7.5
<b>Fwy to Fyw Ramp</b>	103,774	56,683	43	38	1,192	1,336
<b>Freeway</b>	4,740,782	3,043,641	41	26	3,572	2,968
<b>Expressway</b>	538,111	722,303	45	36	1,245	1,844
<b>Collector</b>	458,204	1,032,831	27	17	104	236
<b>On&amp;Off Ramp</b>	234,930	201,356	27	18	445	484
<b>Centroid Connector</b>	537,591	537,163	100	100	280	280
<b>Major Road</b>	1,779,913	3,229,454	30	22	380	700
<b>Meter Ramp</b>	11,718	6,758	24	16	392	370
<b>Special</b>	44,576	56,282	13	6	11,172	14,106
<b>Total</b>	8,449,598	8,886,470	37	24	629	693

**Endogenous 5%  
increase in VMT**

# Vehicle Hours Comparison

(Fixed Demand Model)



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# 1990 Base & San Andreas 7.5 Scenario Comparison

(Variable Demand Trip Assignment Model)

Total Assigned Trips:

1990 Base: **737482**  
 San Andreas 7.5 Scenario: **628250**

**Endogenous  
15% decrease**

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	2,686	1,212
Freeway	2,013	1,495	1,327	1,025	3,593	2,772	122,782	63,440
Expressway	829	709	432	392	862	786	16,151	14,782
Collector	6,931	6,857	4,426	4,385	5,304	5,251	21,863	26,841
On&Off Ramp	1,852	1,489	528	416	567	443	8,256	7,184
Centroid Connector	4,892	4,892	1,922	1,922	5,765	5,765	6,167	5,264
Major Road	9,741	9,595	4,680	4,614	8,114	7,984	70,789	88,067
Meter Ramp	78	47	30	18	31	19	575	299
Special	8	8	4	4	12	12	1,347	1,268
<b>Total</b>	<b>26,522</b>	<b>25,184</b>	<b>13,437</b>	<b>12,818</b>	<b>24,389</b>	<b>23,096</b>	<b>250,615</b>	<b>208,358</b>

# 1990 Base & San Andreas 7.5 Scenario Comparison

(Continued)

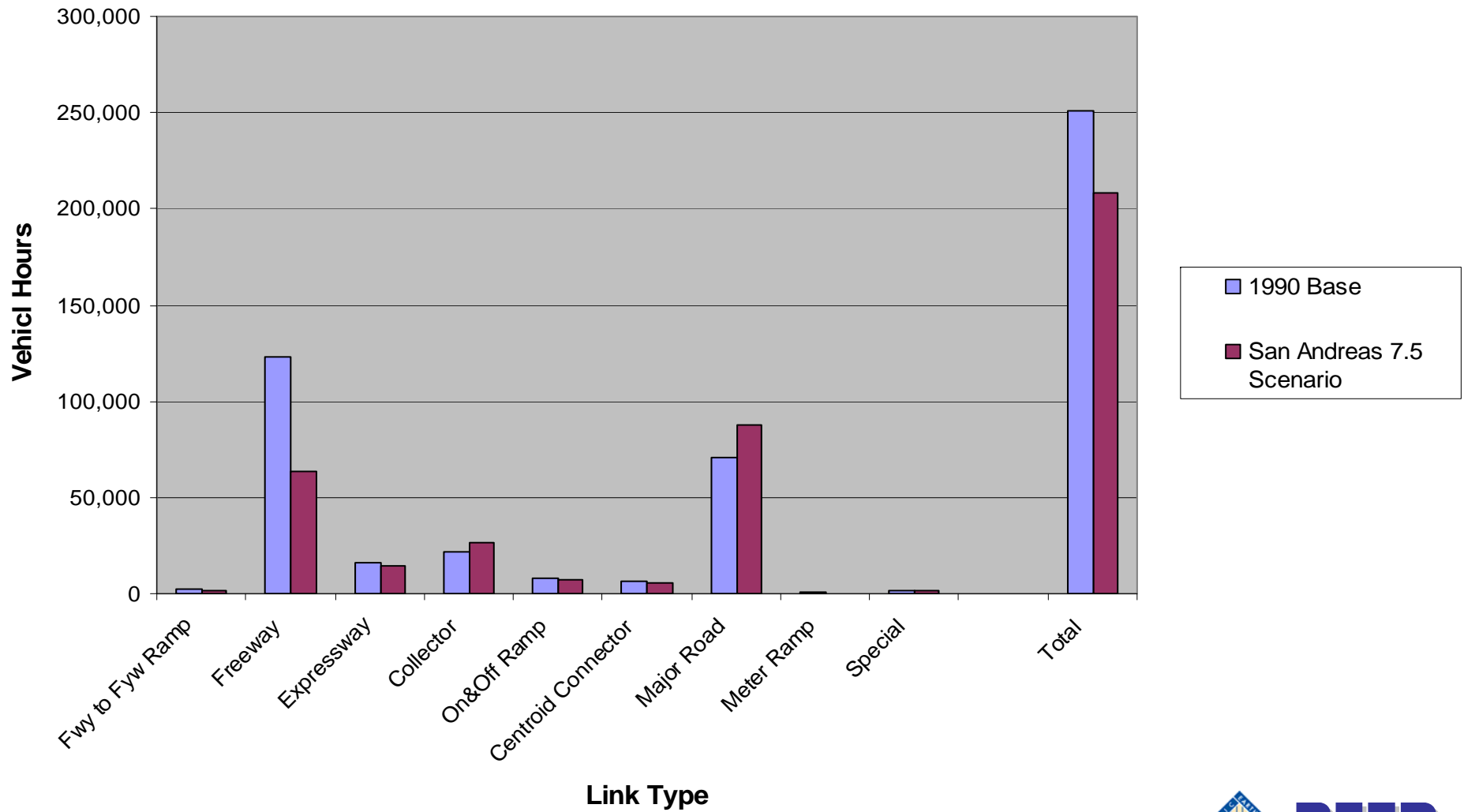
Link Type	Vehicle Miles		Average Speed		Average Auto Vol.	
	1990 Base	SA 7.5	1990 Base	SA 7.5	1990 Base	SA 7.5
<b>Fwy to Fyw Ramp</b>	112,628	51,226	42	42	1,293	1,207
<b>Freeway</b>	5,552,406	2,919,935	45	46	4,183	2,848
<b>Expressway</b>	686,064	617,213	42	42	1,588	1,576
<b>Collector</b>	599,881	686,337	27	26	136	157
<b>On&amp;Off Ramp</b>	258,276	186,242	31	26	489	448
<b>Centroid Connector</b>	615,618	525,842	100	100	320	274
<b>Major Road</b>	2,129,951	2,528,585	30	29	455	548
<b>Meter Ramp</b>	13,319	5,767	23	19	446	316
<b>Special</b>	34,248	33,557	25	26	8,583	8,410
<b>Total</b>	10,002,391	7,554,705	40	36	744	589

**Endogenous 25% decrease in VMT**



# Vehicle Hours Comparison

(Variable Demand Model)



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# Loss Estimates for Pre-Retrofitted Bridges (x10<sup>6</sup>)

	GS only	GS+ Liq	GS+ Land	GS + Liq + Land
HW 7.0	\$494	\$1,392	\$ 571	\$ 1,416
HW7.5	\$595	\$1,855	\$ 811	\$ 1,861
SA 7.5	\$517	\$1,686	\$ 677	\$ 1,704
SA8.0	\$779	\$2,188	\$1,060	\$ 2,233

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# Conclusions

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1. Components of overall methodology well understood and fit well within the PEER performance based framework.
2. State of the art transportation network models need significant modifications for applications to seismic risk assessment.
3. In order to obtain reliable loss estimates significant improvements are needed in the following:
  - Bridge inventory information
  - Fragility functions for bridges
  - Special studies for major bridges
  - Post-retrofit fragility functions
  - Repair cost estimates
  - Repair time estimates
  - Post-demand and its variation with repair times