A Vision for Regional PBSA of Transportation Networks

by

Ertugrul Taciroglu, Professor
Civil & Environmental Engineering Department
University of California, Los Angeles

Faculty Affiliate, *UCLA B. John Garrick Institute for the Risk Sciences*

A Vision for Regional PBSA of Transportation Networks

+ work in progress

by

Ertugrul Taciroglu, Professor
Civil & Environmental Engineering Department
University of California, Los Angeles

Faculty Affiliate, *UCLA B. John Garrick Institute for the Risk Sciences*

A Vision for Regional PBSA of Transportation Networks

+ work in progress

A Vision for Regional PBSA of Transportation Networks

+ work in progress

A Vision for Regional PBSA of Transportation Networks

+ work in progress

Outline

Outline

- Motivation and objectives

Outline

- Motivation and objectives
- Vision and scope

Outline

- Motivation and objectives
- Vision and scope
- Details of envisioned components

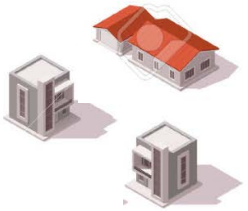
Outline

- Motivation and objectives
- Vision and scope
- Details of envisioned components
- Some preliminary results and outlook

Motivation and Objectives

Why regional assessment?

Why regional assessment?



Why regional assessment?

Why regional assessment?

- Hazards affect regions. The big picture is needed for
  - Actuarial plans (insurance companies)
  - Urban planning & public policy (government)
  - Emergency service planning (1st responders)

Why regional assessment?

- Hazards affect regions. The big picture is needed for
  - Actuarial plans (insurance companies)
  - Urban planning & public policy (government)
  - Emergency service planning (1st responders)
- Built environment is highly interconnected
  - Residential neighborhoods, business centers
  - Transportation networks
  - Lifelines (water, power, communications)

Why regional assessment?

- Hazards affect regions. The big picture is needed for
  - Actuarial plans (insurance companies)
  - Urban planning & public policy (government)
  - Emergency service planning (1st responders)
- Built environment is highly interconnected
  - Residential neighborhoods, business centers
  - Transportation networks
  - Lifelines (water, power, communications)

Why regional assessment?

- Hazards affect regions. The big picture is needed for
  - Actuarial plans (insurance companies)
  - Urban planning & public policy (government)
  - Emergency service planning (1st responders)
- Built environment is highly interconnected
  - Residential neighborhoods, business centers
  - Transportation networks
  - Lifelines (water, power, communications)

Challenges

Challenges

- Data ☞ metadata ☞ models

Challenges

- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)

Challenges

- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)
  - Access to detailed data may be not be possible (requires estimation missing data, machine learning)

Challenges

- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)
  - Access to detailed data may be not be possible (requires estimation missing data, machine learning)
  - Processing requires *large* computational resources (would break records for civil engineers)

Challenges

- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)
  - Access to detailed data may be not be possible (requires estimation missing data, machine learning)
  - Processing requires *large* computational resources (would break records for civil engineers)
- Models ☞ decision variables

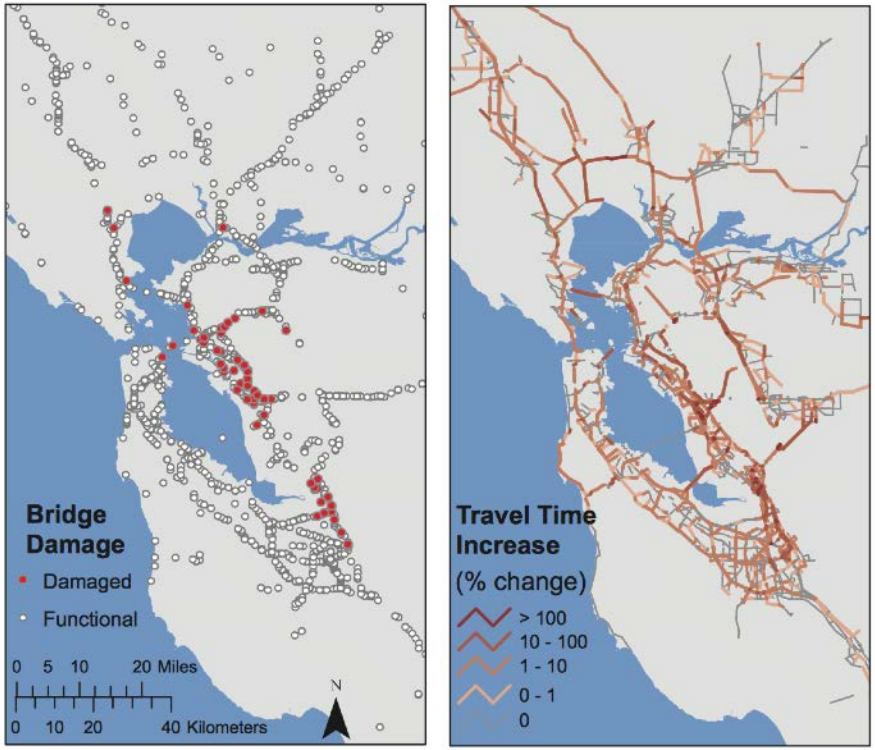
Challenges

- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)
  - Access to detailed data may be not be possible (requires estimation missing data, machine learning)
  - Processing requires *large* computational resources (would break records for civil engineers)
- Models ☞ decision variables
  - Heterogeneous analysis tools (OpenSees, OpenSHA, PACT)

Challenges

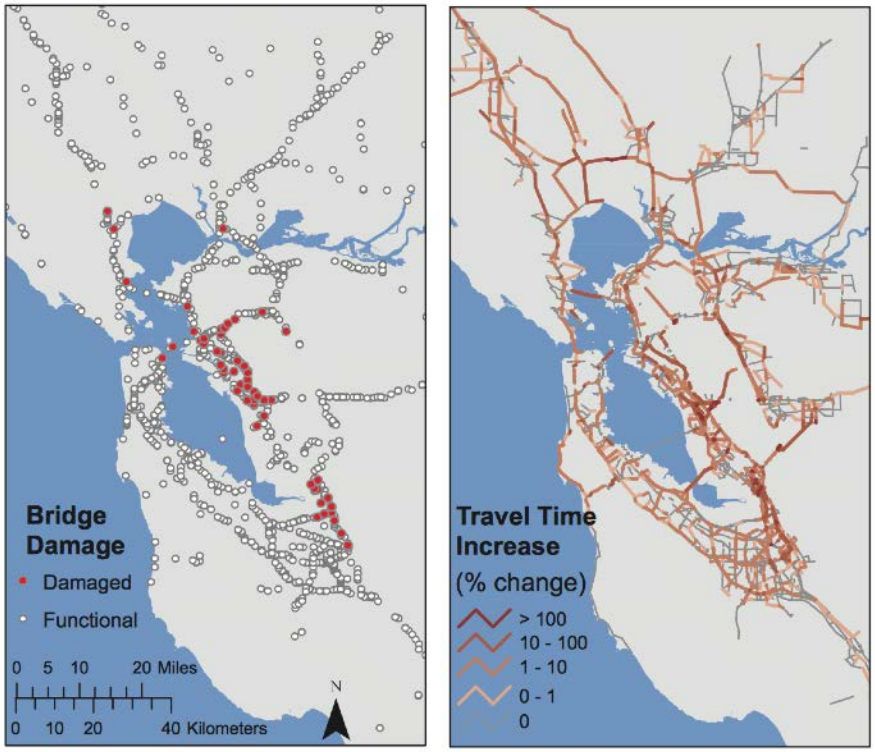
- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)
  - Access to detailed data may be not be possible (requires estimation missing data, machine learning)
  - Processing requires *large* computational resources (would break records for civil engineers)
- Models ☞ decision variables
  - Heterogeneous analysis tools (OpenSees, OpenSHA, PACT)
  - New tech needs to be brought in (data analytics, Bayesian inference, etc.)

Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

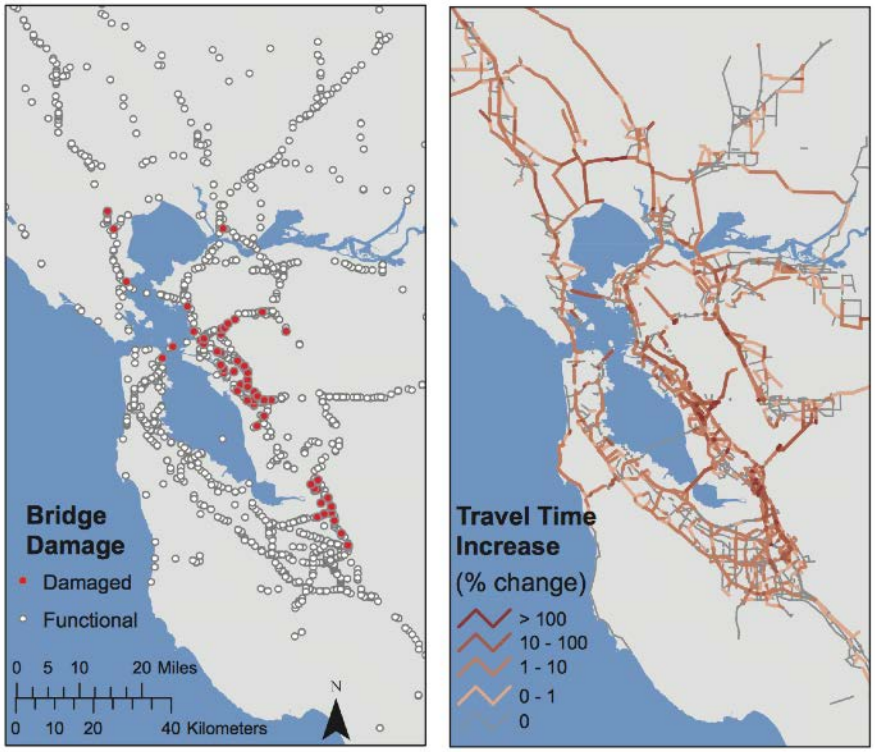
Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

Develop a (semi-) automated interactive platform that can evaluate seismic vulnerability of complex transportation networks:

Objectives

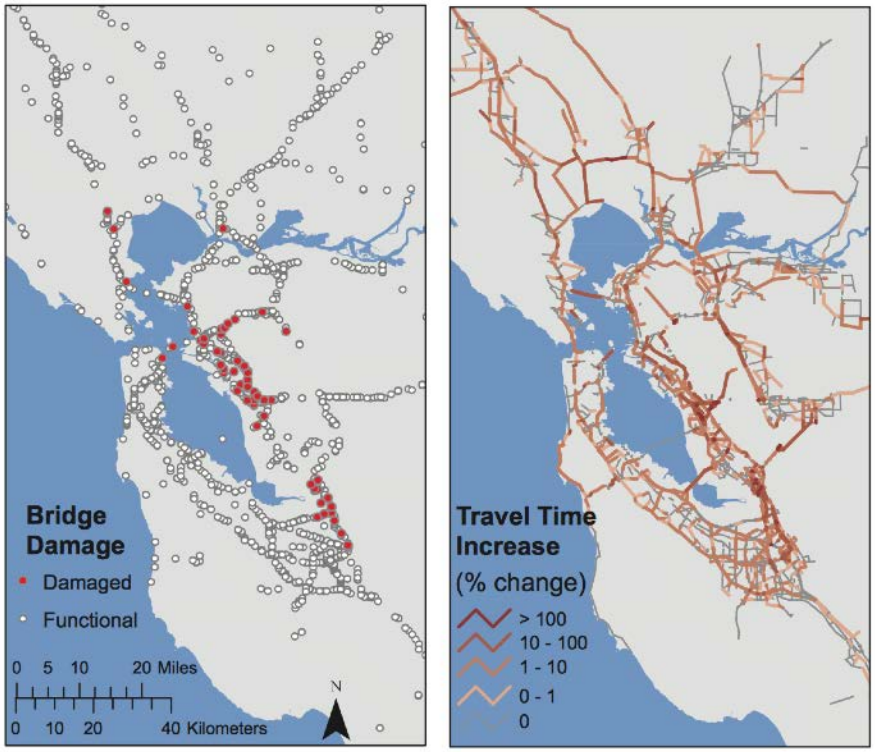


Risk framework for a highway network
(Miller & Baker, 2015)

Develop a (semi-) automated interactive platform that can evaluate seismic vulnerability of complex transportation networks:

1. Generate structural models using data harvested from various sources

Objectives

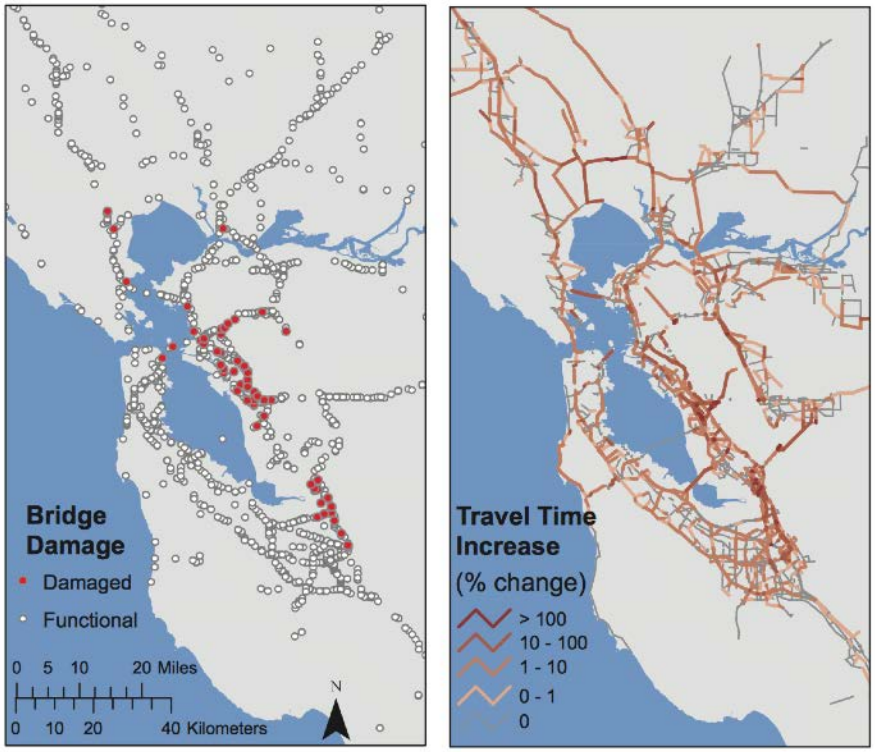


Risk framework for a highway network
(Miller & Baker, 2015)

Develop a (semi-) automated interactive platform that can evaluate seismic vulnerability of complex transportation networks:

1. Generate structural models using data harvested from various sources
2. Carry out site- and structure-specific seismic analyses

Objectives

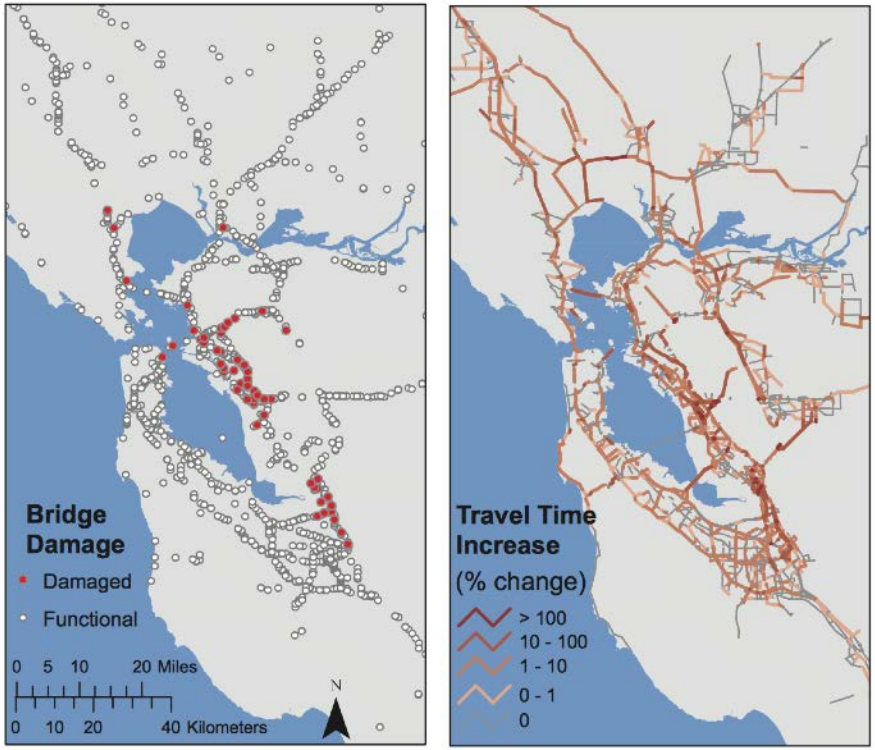


Risk framework for a highway network (Miller & Baker, 2015)

Develop a (semi-) automated interactive platform that can evaluate seismic vulnerability of complex transportation networks:

1. Generate structural models using data harvested from various sources
2. Carry out site- and structure-specific seismic analyses
3. Evaluate the consequent economic losses at the network-level

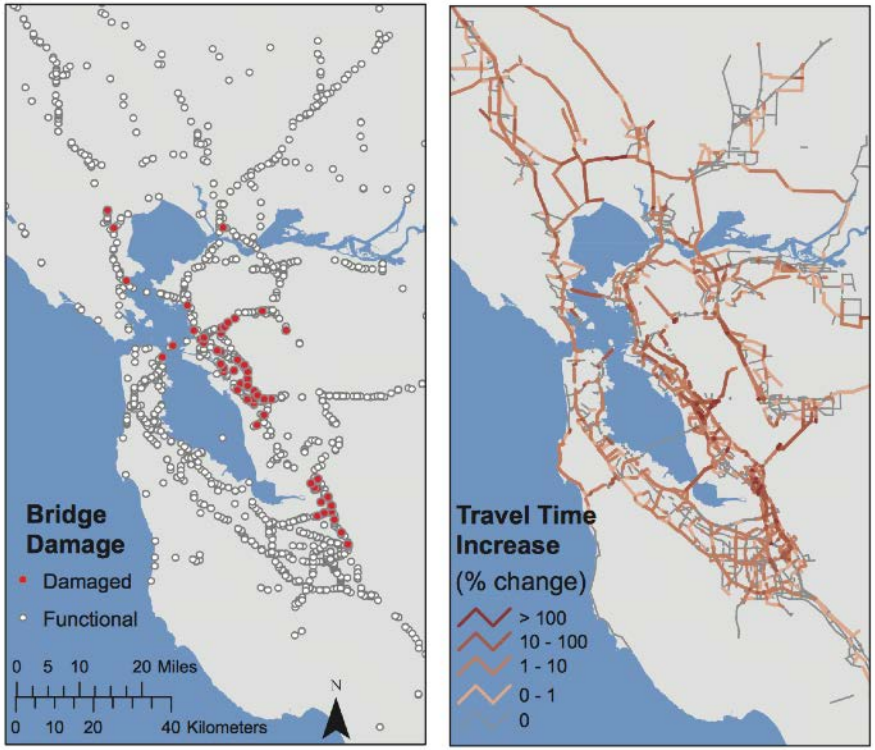
Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

Existing predictive computational tools and IT capabilities allow *unprecedented granularity* for such seismic risk and loss assessment studies

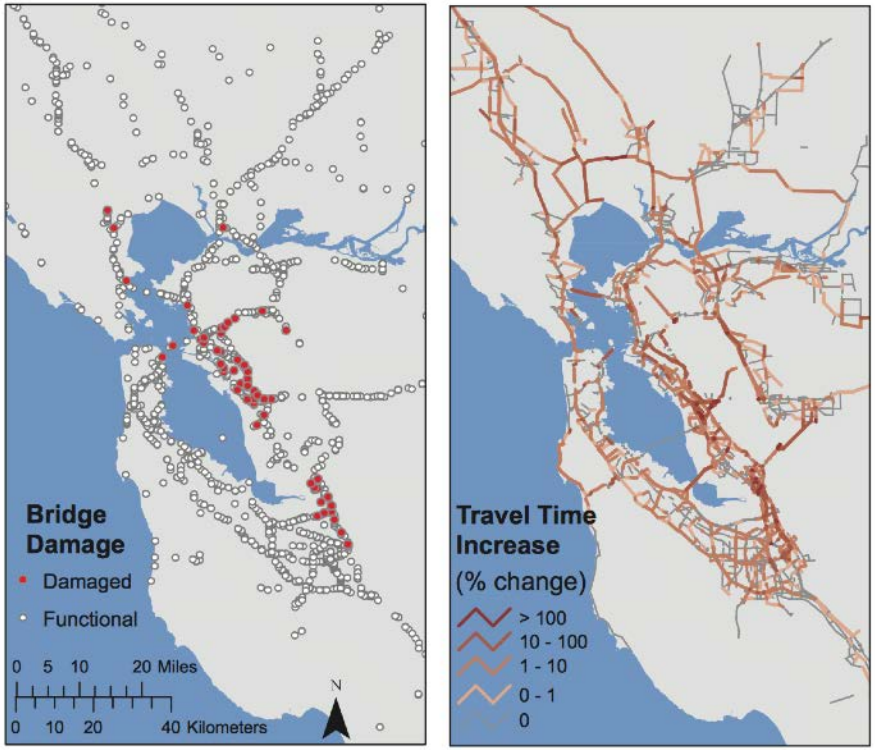
Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

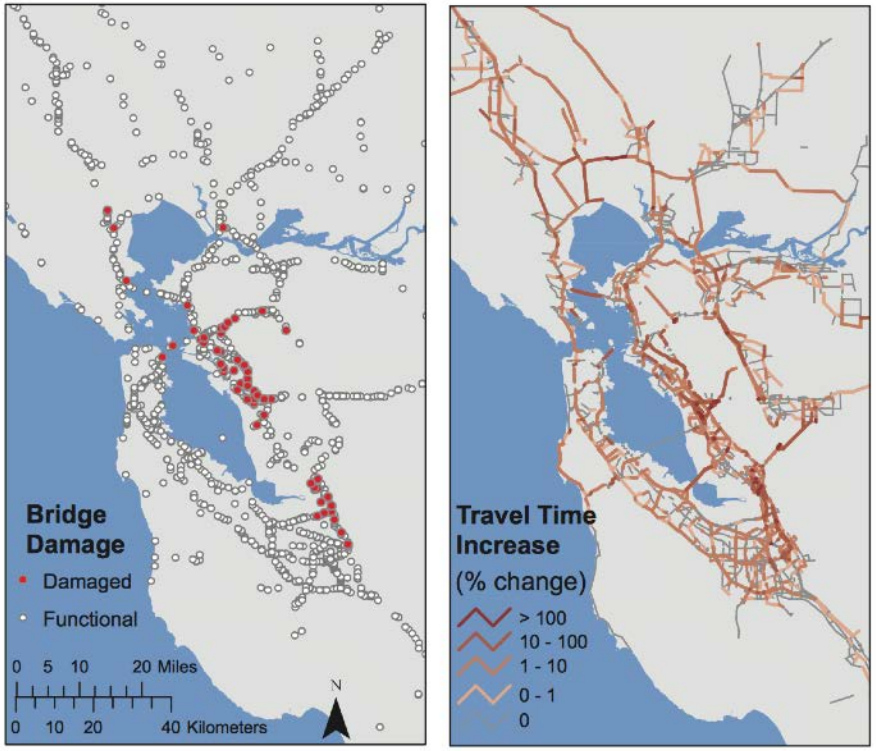
Existing predictive computational tools and IT capabilities allow *unprecedented granularity* for such seismic risk and loss assessment studies

Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

Hasn't been done before [at site-, structure-, and scenario-specific granularity]

M 5.7, 6.7 km (4.2 mi) NW of American Canyon, CA

Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)

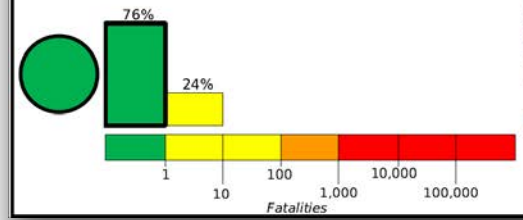
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 1

Created: 12 minutes, 54 seconds after earthquake

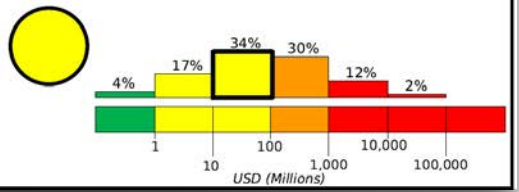
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



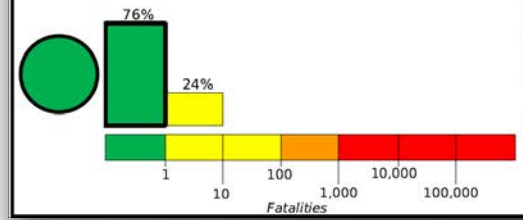
M 5.7, 6.7 km (4.2 mi) NW of American Canyon, CA

Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 1
Created: 12 minutes, 54 seconds after earthquake

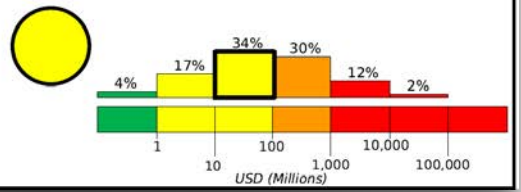
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



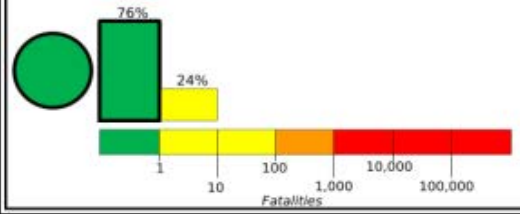
M 6.0, 6.7 km (4.2 mi) NW of American Canyon, CA

Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 5
Created: 47 minutes, 53 seconds after earthquake

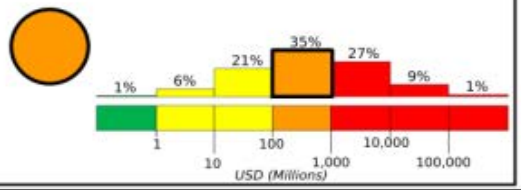
Estimated Fatalities



Orange alert level for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a regional or national level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses

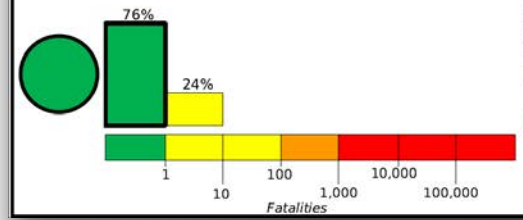


M 5.7, 6.7 km (4.2 mi) NW of American Canyon, CA
Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 1
Created: 12 minutes, 54 seconds after earthquake

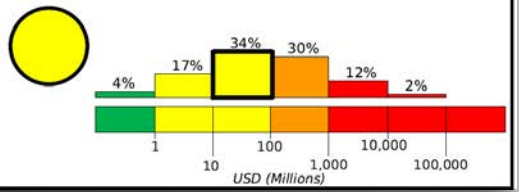
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses

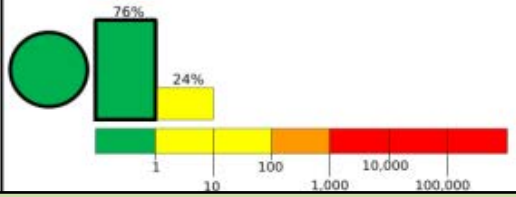


M 6.0, 6.7 km (4.2 mi) NW of American Canyon, CA
Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 5
Created: 47 minutes, 53 seconds after earthquake

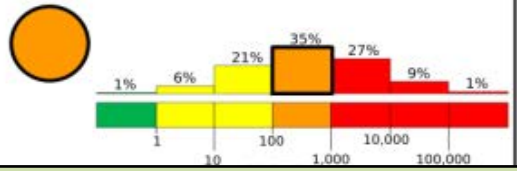
Estimated Fatalities



Orange alert level for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a regional or national level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Early media reports estimated losses around $4B (based on a insurance agency report)

M 5.7, 6.7 km (4.2 mi) NW of American Canyon, CA

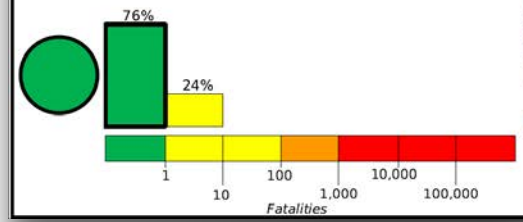
Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER Version 1

Created: 12 minutes, 54 seconds after earthquake

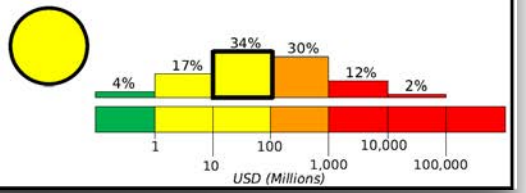
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



M 6.0, 6.7 km (4.2 mi) NW of American Canyon, CA

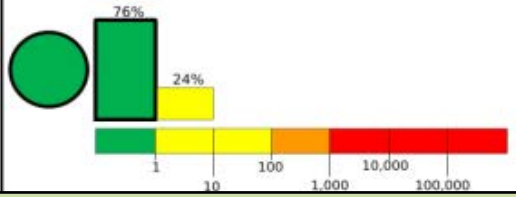
Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER Version 5

Created: 47 minutes, 53 seconds after earthquake

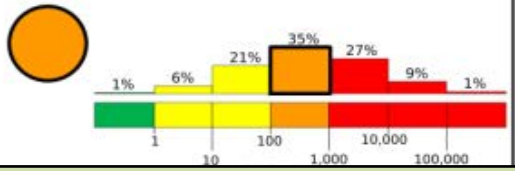
Estimated Fatalities



Orange alert level for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a regional or national level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Early media reports estimated losses around $4B (based on a insurance agency report)

M 6.0, 6.8 km (4.2 mi) NW of American Canyon, CA

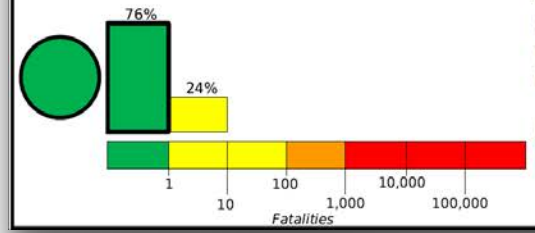
Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.22°N 122.31°W Depth: 11 km

ANSS

PAGER Version 17

Created: 12 hours, 2 minutes after earthquake

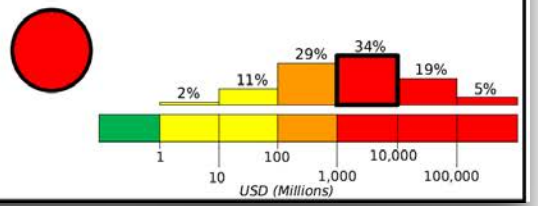
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a national or international level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



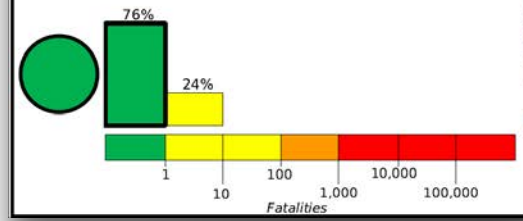
M 5.7, 6.7 km (4.2 mi) NW of American Canyon, CA

Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 1
Created: 12 minutes, 54 seconds after earthquake

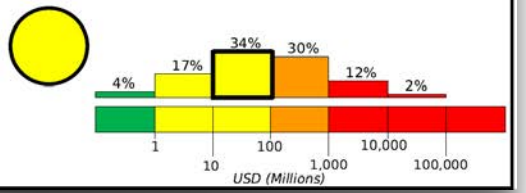
Estimated Fatalities



Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



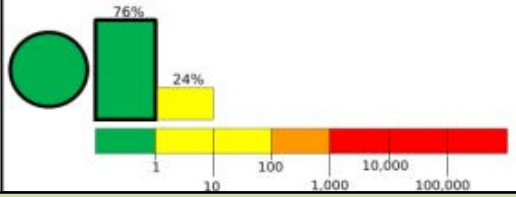
M 6.0, 6.7 km (4.2 mi) NW of American Canyon, CA

Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)
Location: 38.21°N 122.32°W Depth: 10 km

ANSS

PAGER
Version 5
Created: 47 minutes, 53 seconds after earthquake

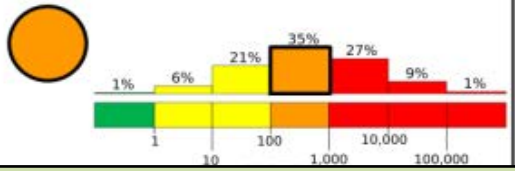
Estimated Fatalities



Orange alert level for economic losses. Significant damage is likely and the disaster is potentially widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a regional or national level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Early media reports estimated losses around $4B (based on a insurance agency report)

M 6.0, 6.8 km (4.2 mi) NW of American Canyon, CA

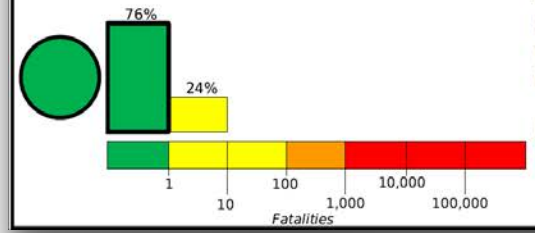
Origin Time: Sun 2014-08-24 10:20:44 UTC (03:20:44 local)

ANSS

PAGER
Version 17

One month after the event, the total losses were reported to be ~$400M (Kale, 2014)

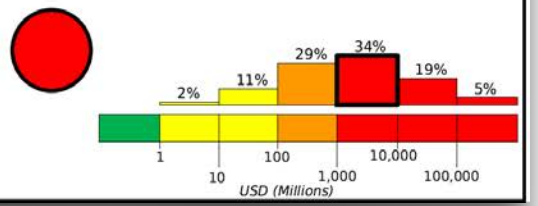
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a national or international level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

Estimated Economic Losses



Vision and Scope

Image to Model

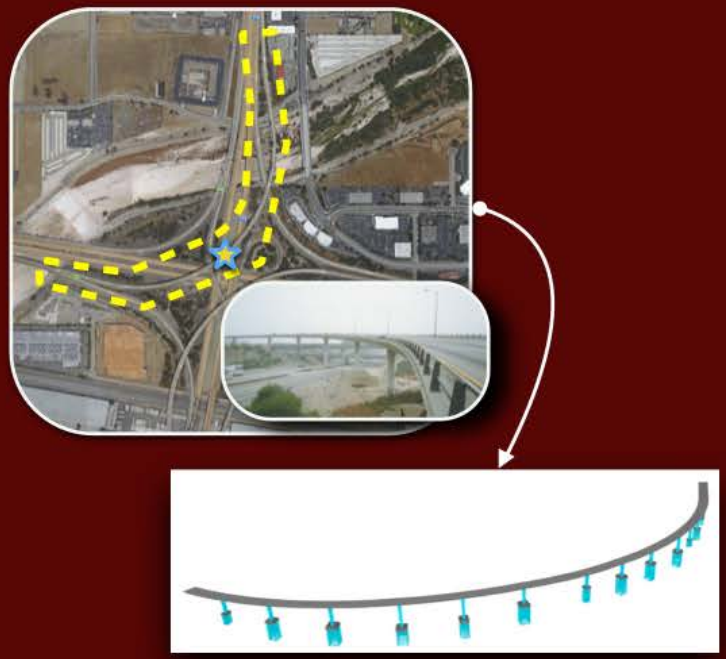
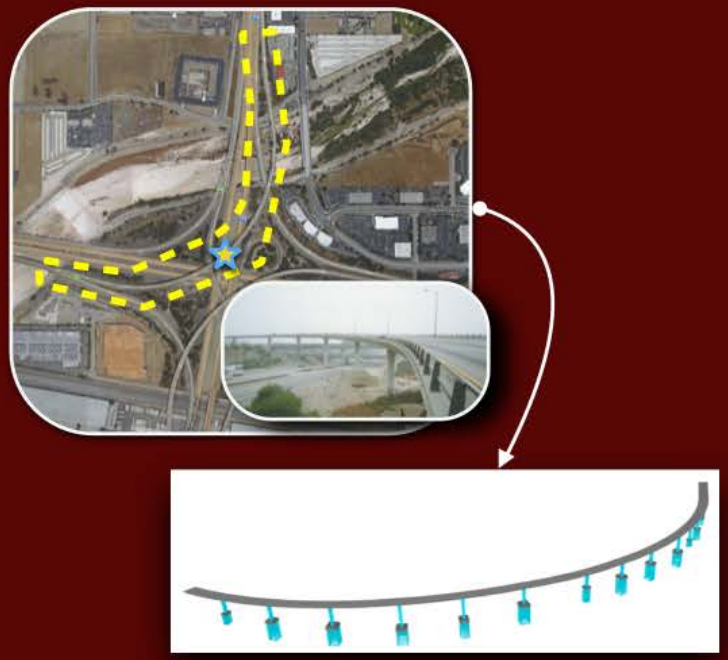


Image to Model



Location to Hazard

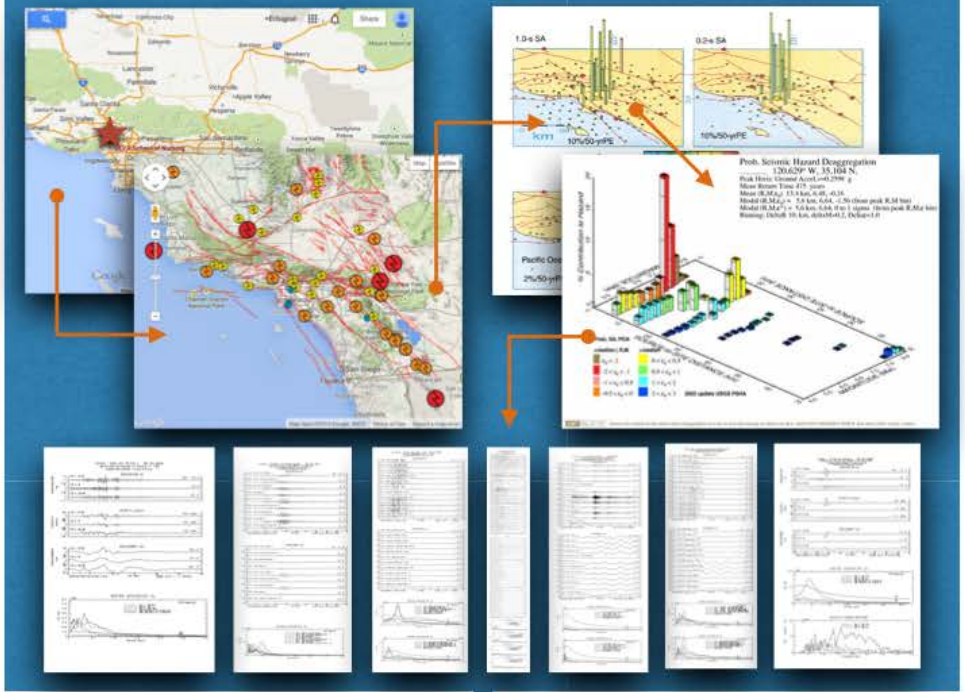
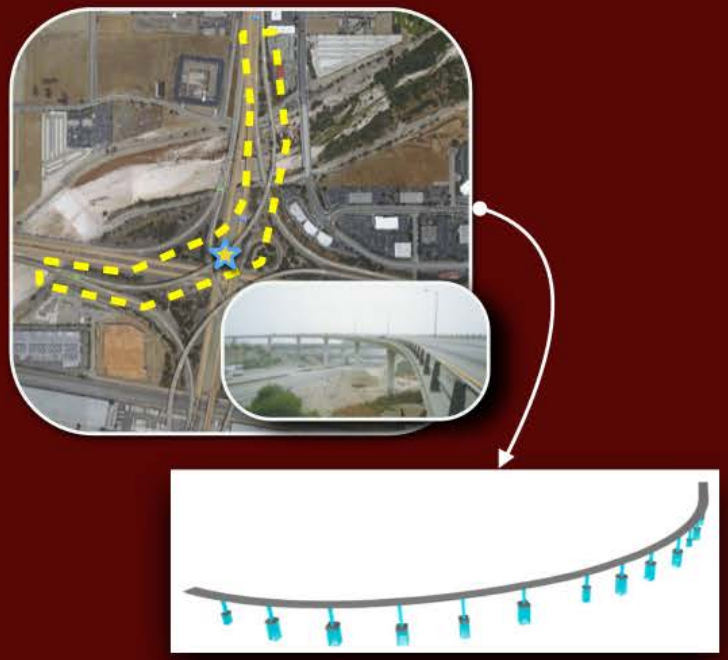
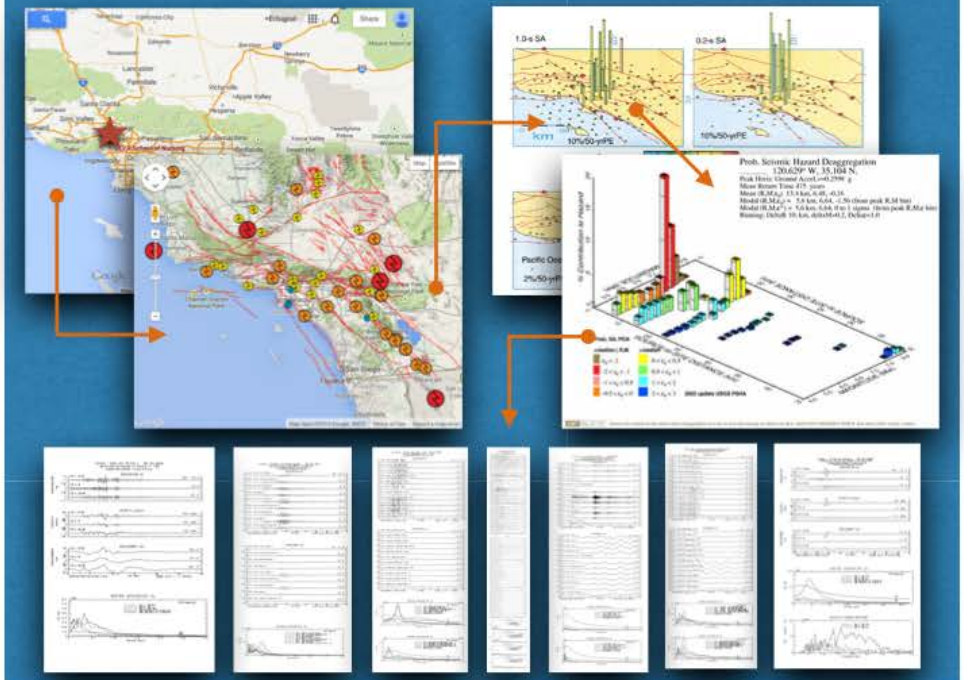


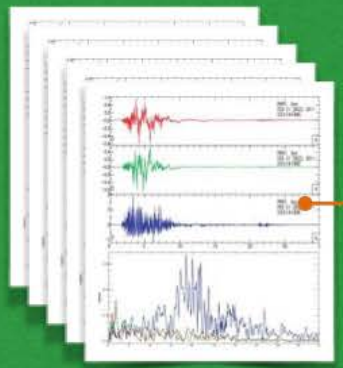
Image to Model



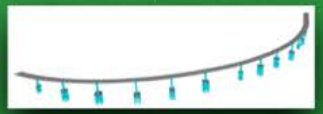
Location to Hazard



Analysis to Decision



seismic loads



analysis model

fragility curves

Decision Variables

- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.

UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module

meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

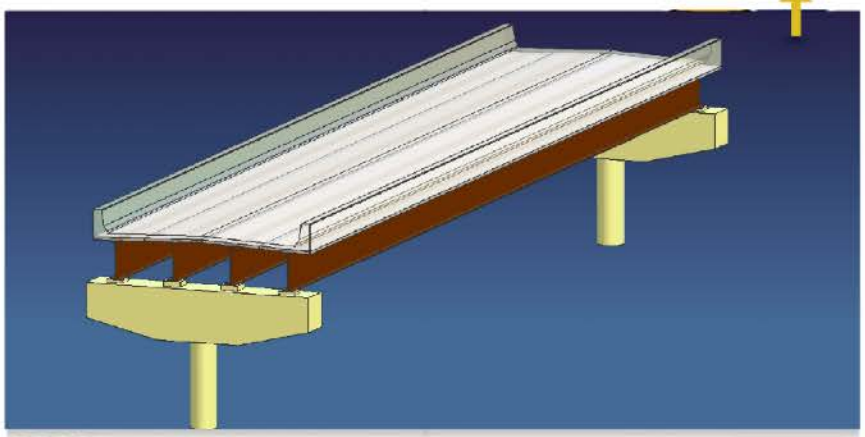
NGA W2

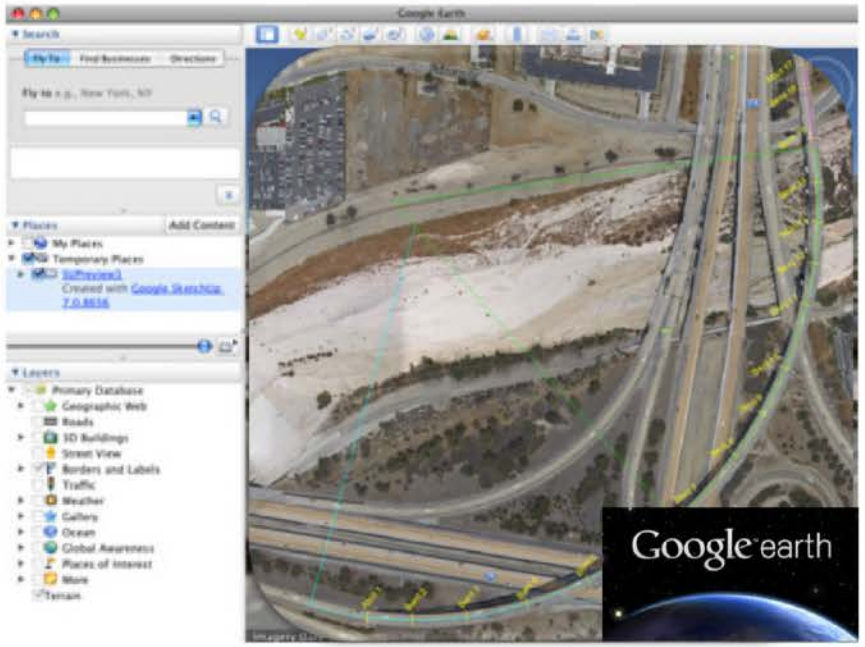
OpenSees

FEMA PACT

visualize

Google Sketch-up

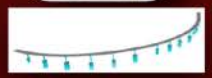




UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module



meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

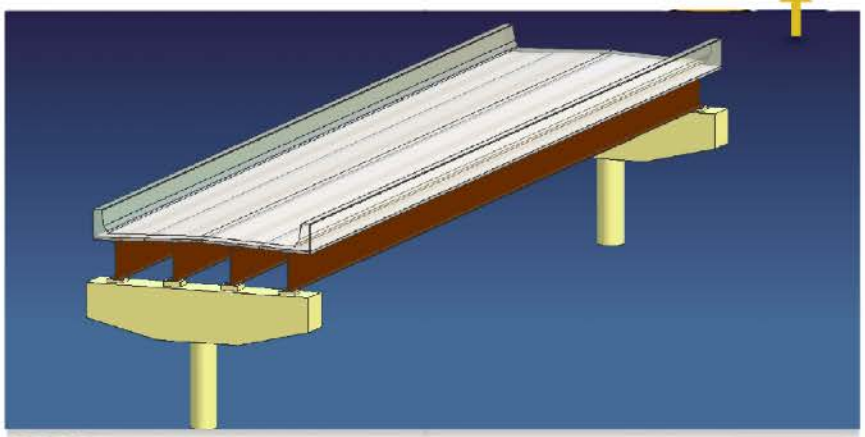
NGA W2

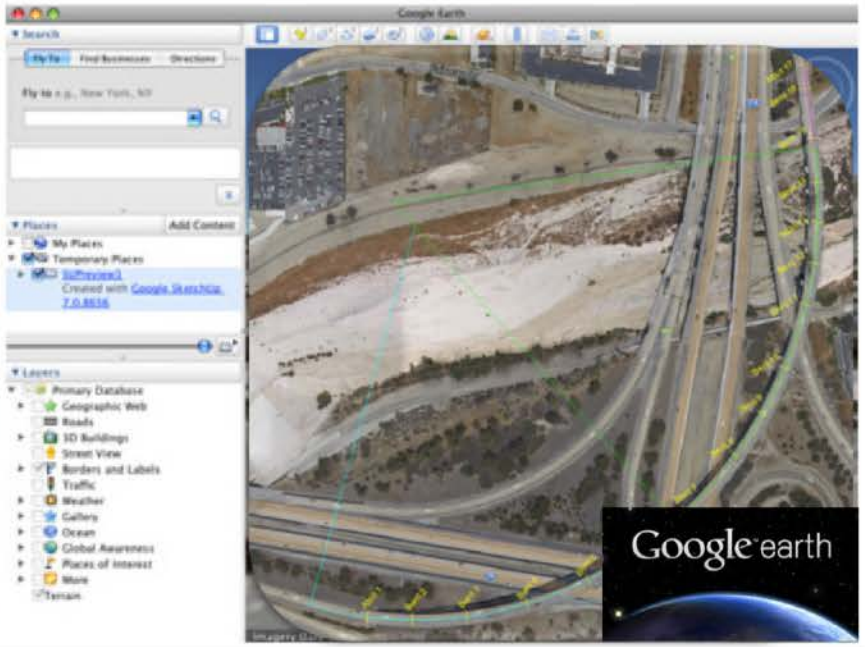
OpenSees

FEMA PACT

visualize

Google Sketch-up





UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module

meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

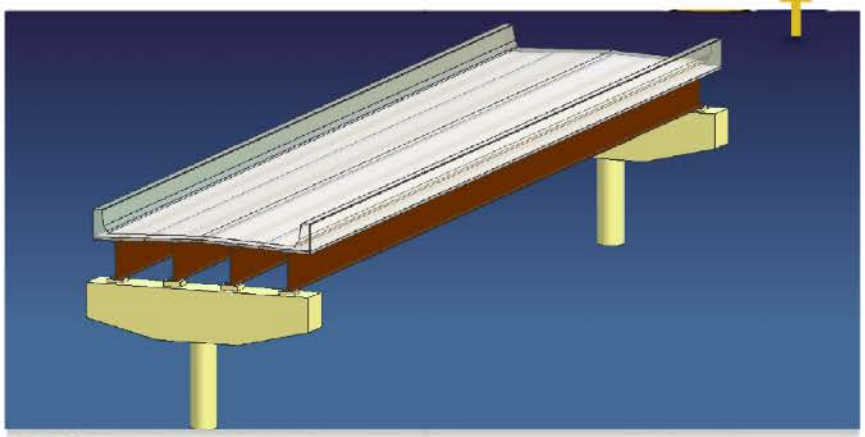
NGA W2

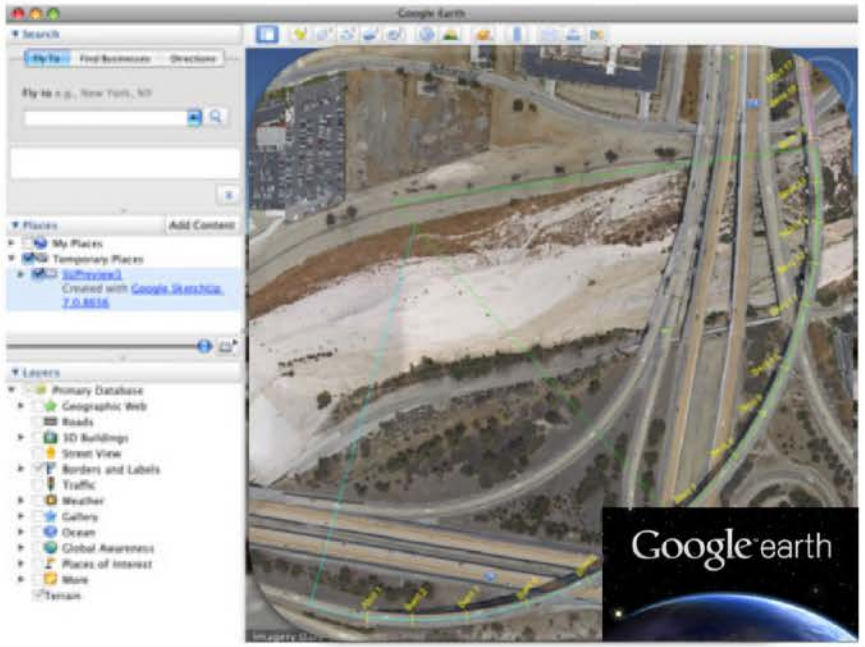
OpenSees

FEMA PACT

visualize

Google Sketch-up





UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module

meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

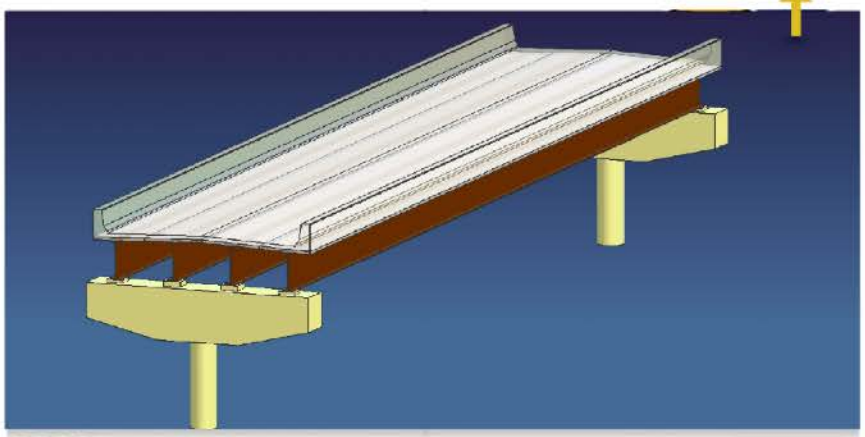
NGA W2

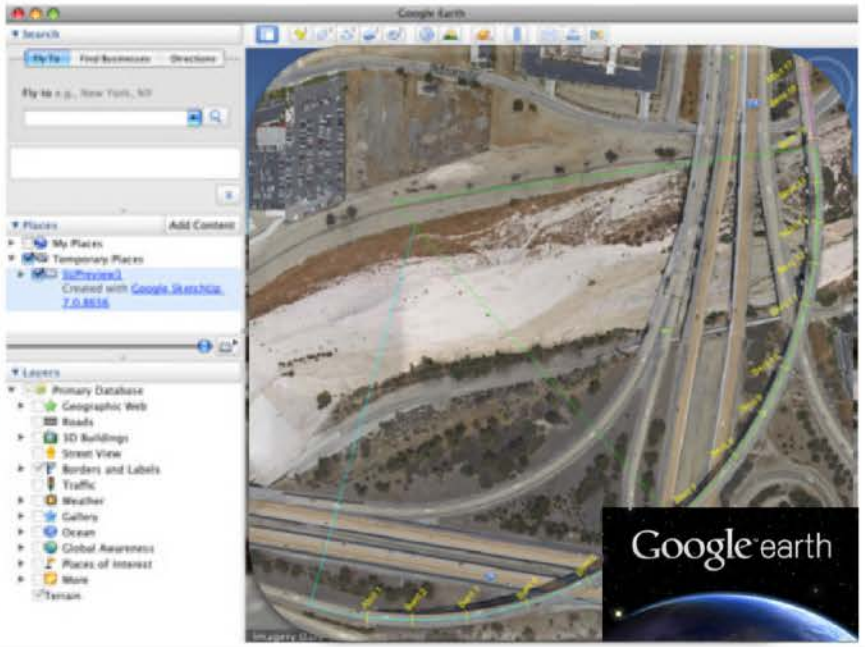
OpenSees

FEMA PACT

visualize

Google Sketch-up

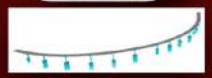




UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module



meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

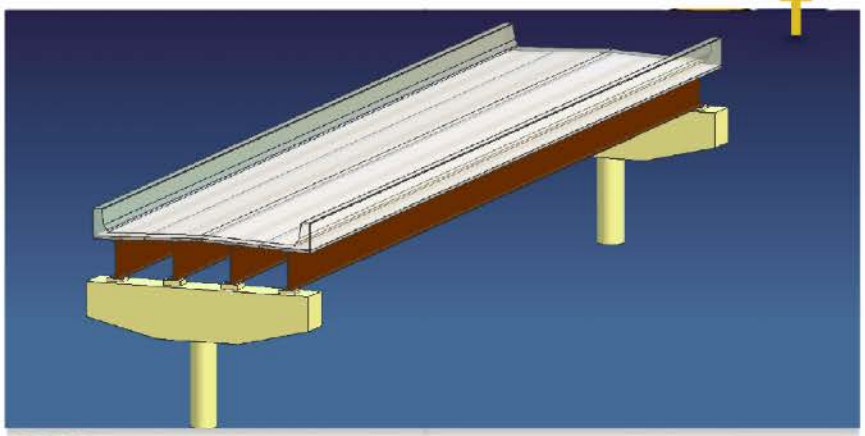
NGA W2

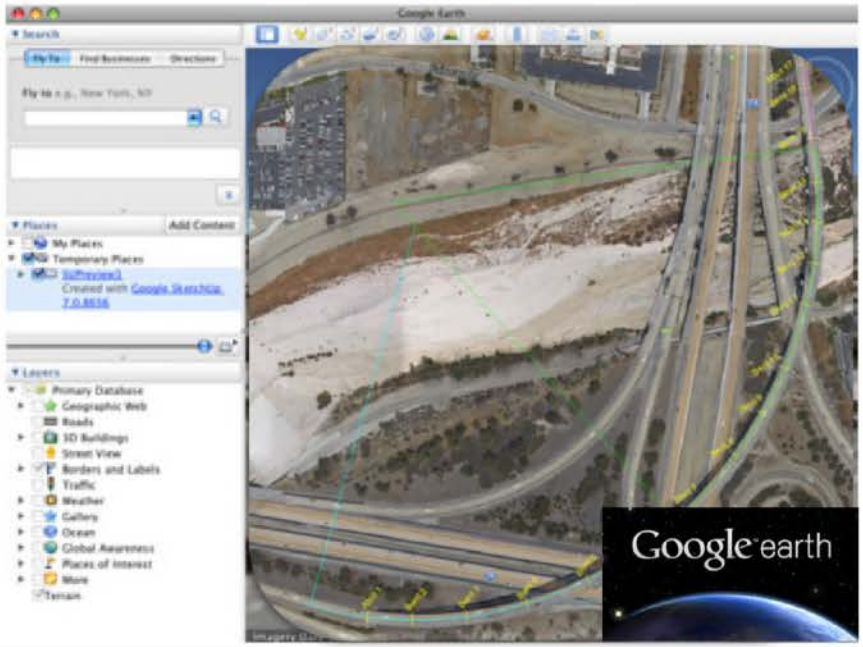
OpenSees

FEMA PACT

visualize

Google Sketch-up





UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module

meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

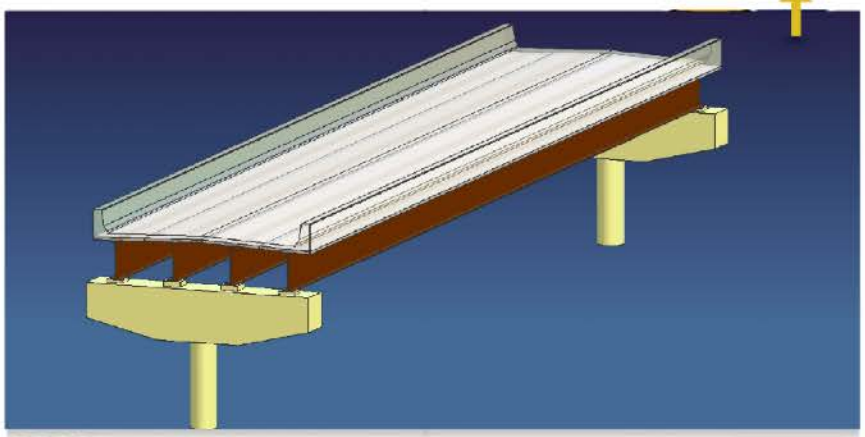
NGA W2

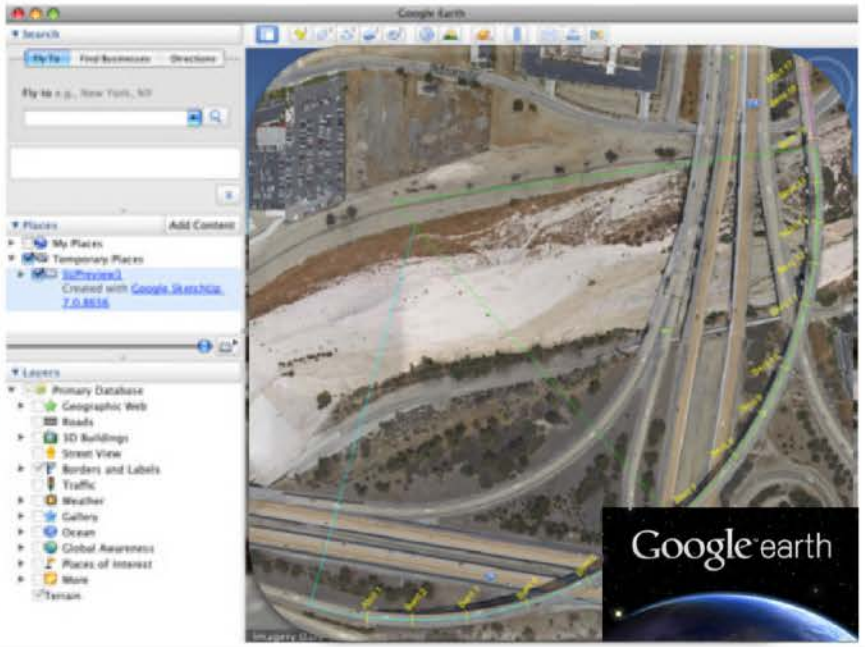
OpenSees

FEMA PACT

visualize

Google Sketch-up





UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module

meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

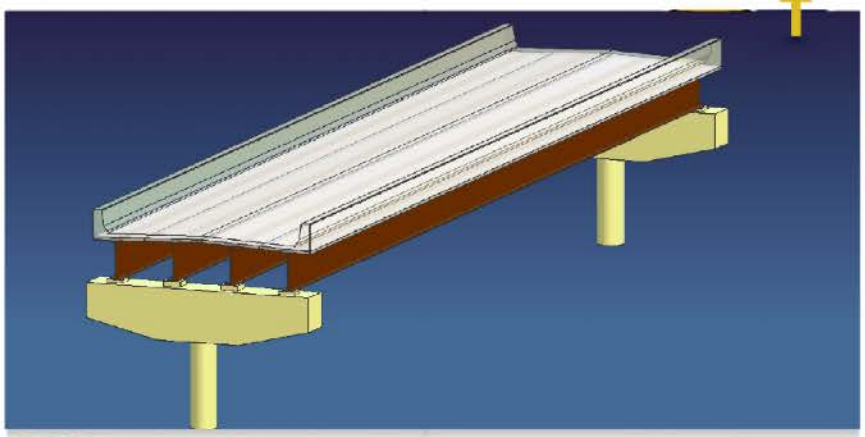
NGA W2

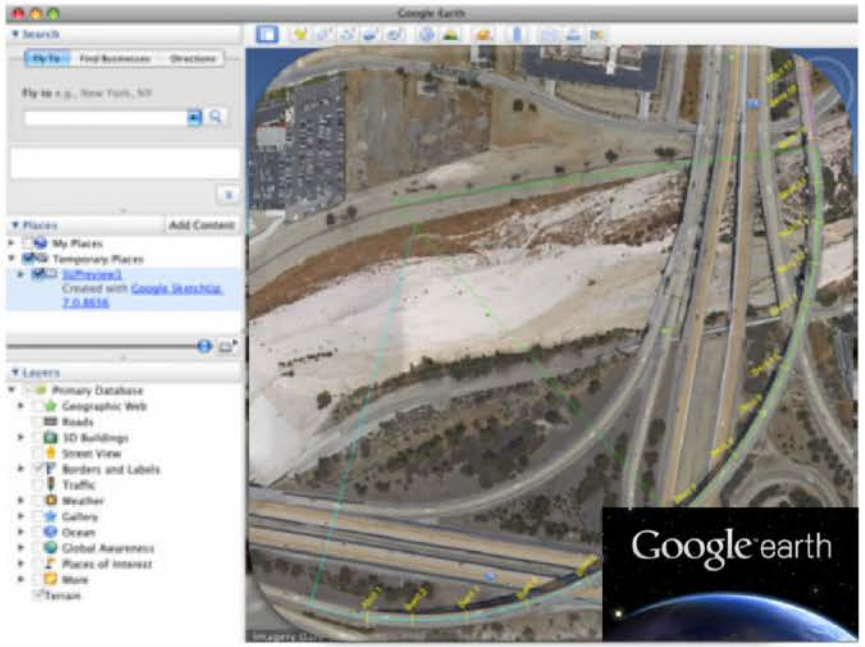
OpenSees

FEMA PACT

visualize

Google Sketch-up

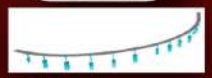




UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module



meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

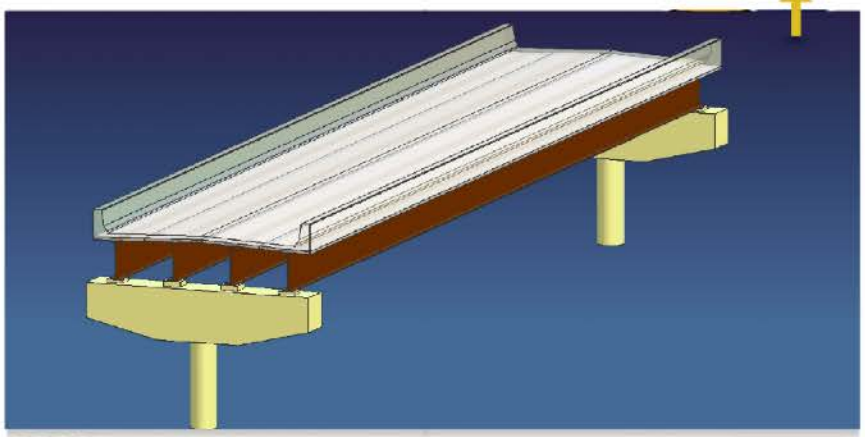
NGA W2

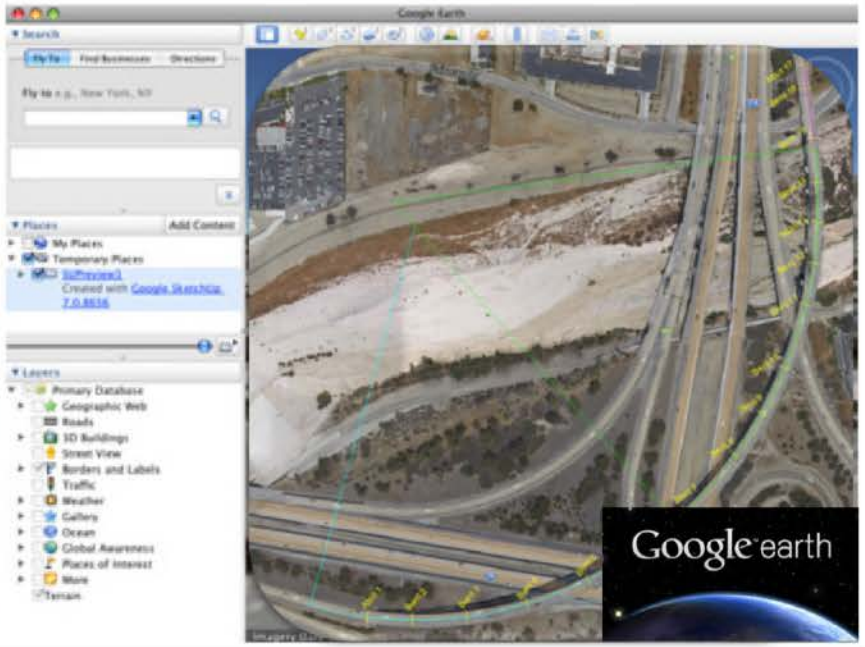
OpenSees

FEMA PACT

visualize

Google Sketch-up

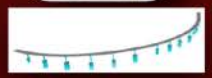




UCLA Regional PBSA Tool

Image and direct metadata from users and public databases

Image-to-Model Module



meta-data-bases for structural system and nonstructural components, loss estimates

compute

commit

amazon web services™

OPENSHA

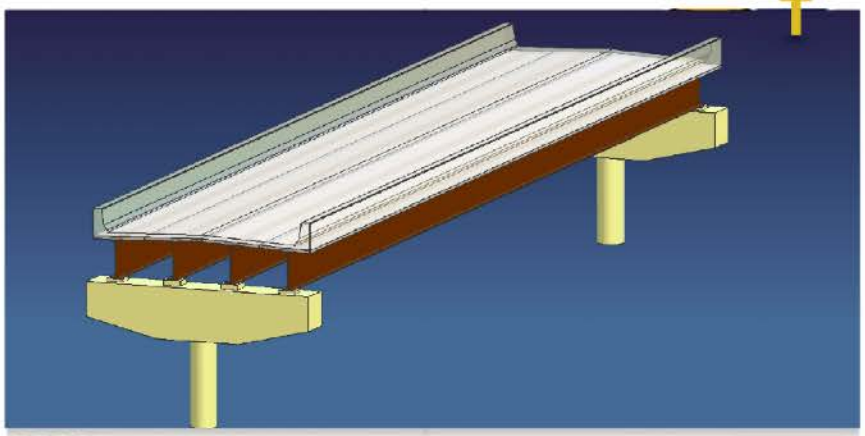
NGA W2

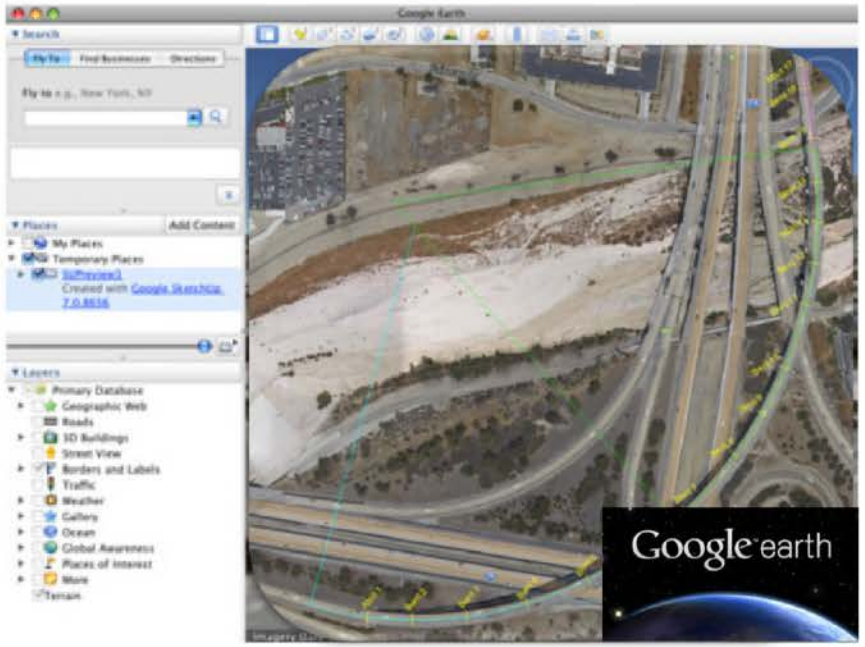
OpenSees

FEMA PACT

visualize

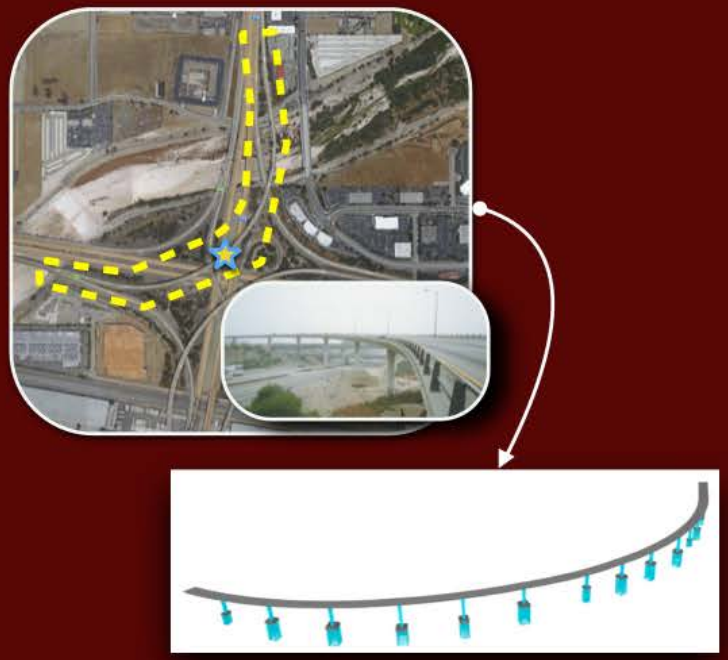
Google Sketch-up



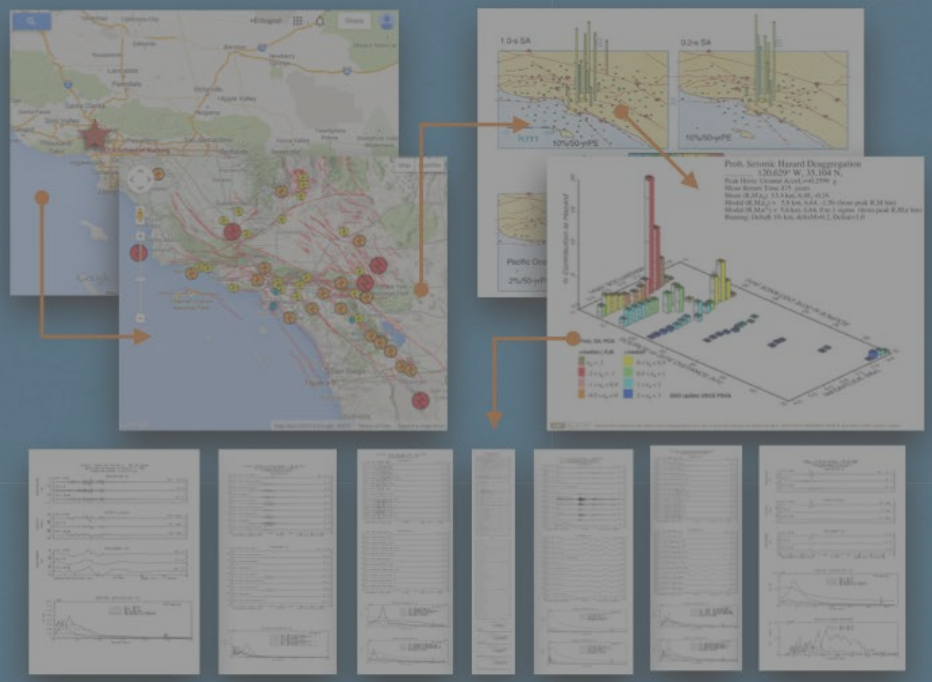


Details of the Envisioned Components

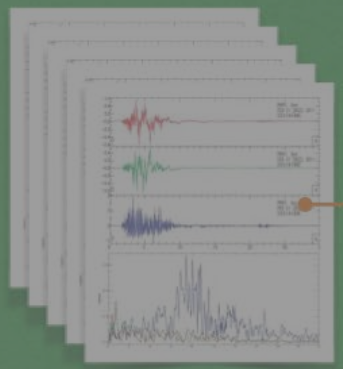
Image to Model



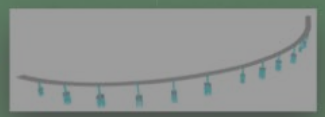
Location to Hazard



Analysis to Decision



seismic loads



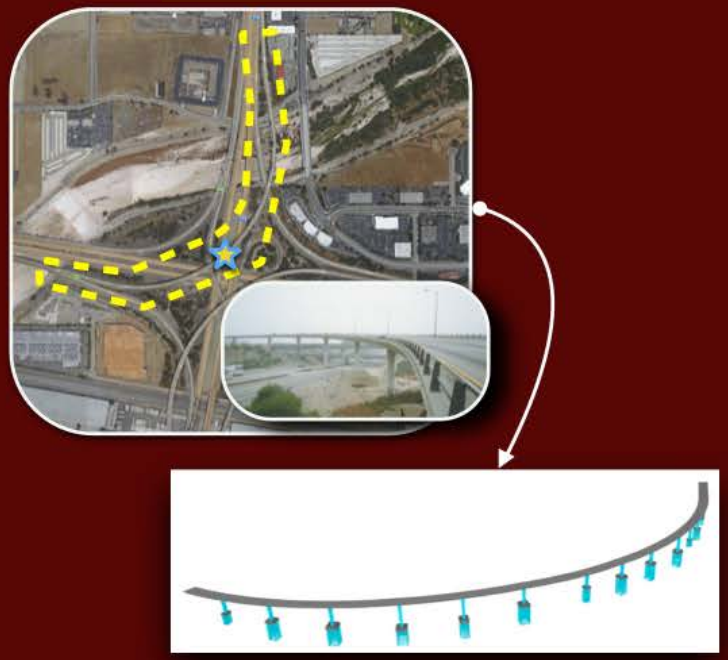
analysis model

fragility curves

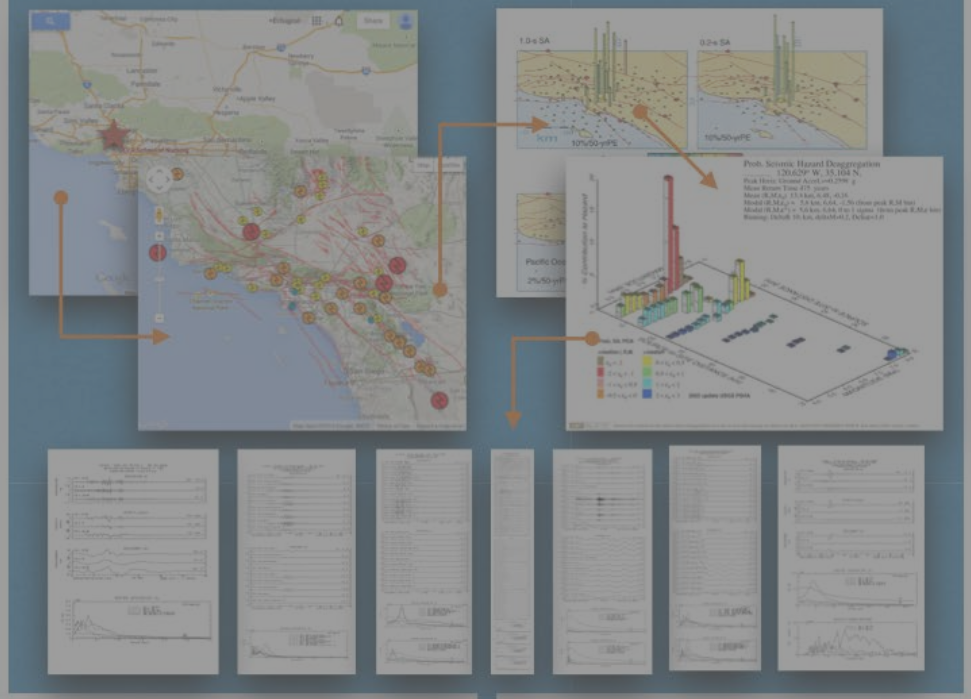
Decision Variables

- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.

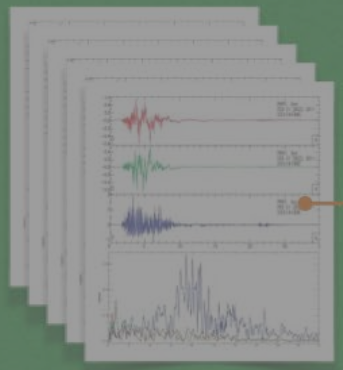
Data to Model



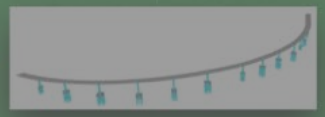
Location to Hazard



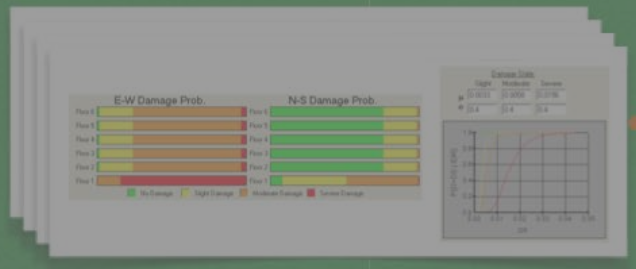
Analysis to Decision



seismic loads



analysis model



fragility curves

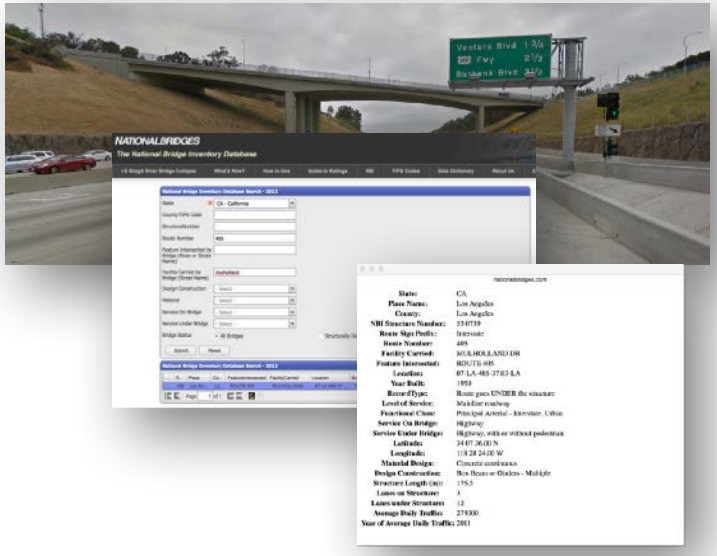
Decision Variables

- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.

Where will the data come from?

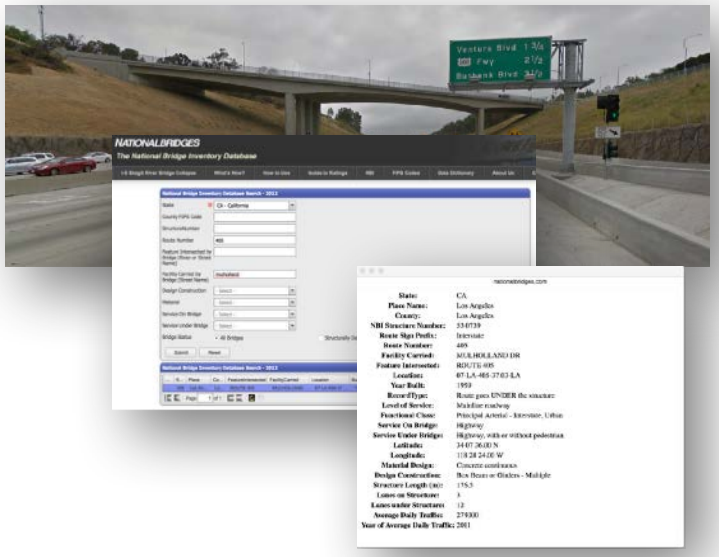
Where will the data come from?

- National Bridge Inventory (NBI) by FHWA



Where will the data come from?

- National Bridge Inventory (NBI) by FHWA
- *Caltrans Bridge Database*

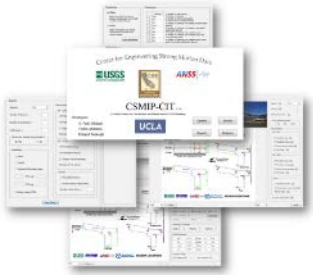


Number of Spans	20
Plan Shape	Straight
Total Length	2507' (764.1m)
Width of Deck	34' (10.4m)
Construction Year	1971
Instrumentation Year	1996
Seismic Retrofit	2006

Where will the data come from?

- National Bridge Inventory (NBI) by FHWA
- *Caltrans Bridge Database*
- California Strong Motion Instrumentation Program (CSMIP) Database

Number of Spans	20
Plan Shape	Straight
Total Length	2507' (764.1m)
Width of Deck	34' (10.4m)
Construction Year	1971
Instrumentation Year	1996
Seismic Retrofit	2006



Where will the data come from?

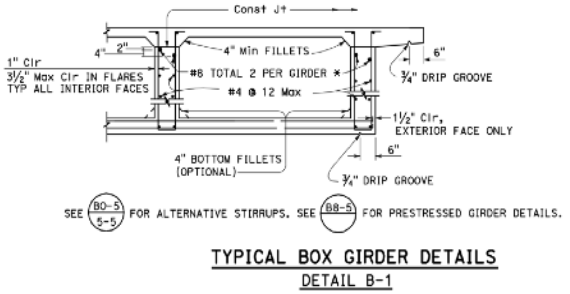
Guideline Documents

Where will the data come from?

Guideline Documents

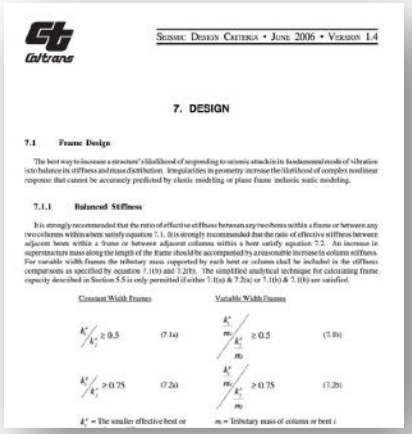
- Caltrans Standard Plans

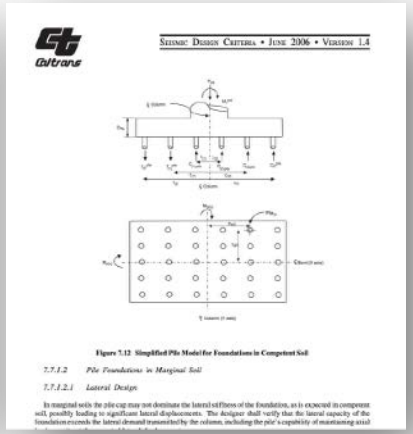
  allow determination of many metadata elements (e.g., abutment seat length, shear-key reinforcement, foundation configuration, etc.)



- Caltrans Seismic Design Criteria Manual (Caltrans SDC)

  provides era-specific information on component and system design





Where will the data come from?

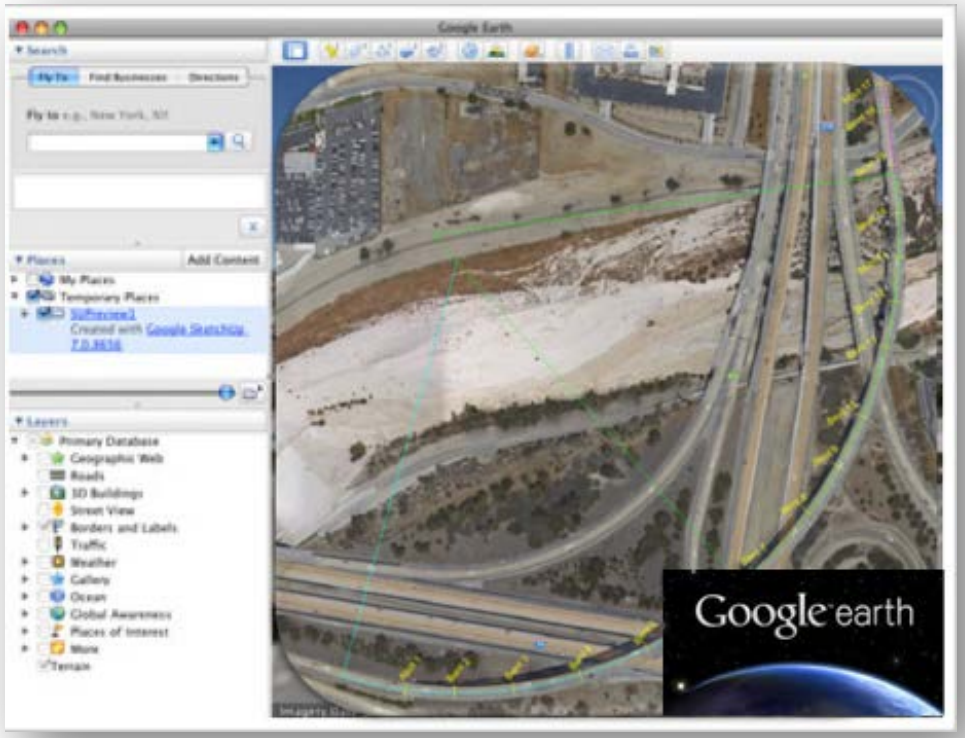
Internet Harvesting

Where will the data come from?

Internet Harvesting

- Google Maps/Earth, MapQuest, etc.

  can be interrogated online
  more on this later …



Where will the data come from?

Internet Harvesting

Where will the data come from?

Internet Harvesting

- Crowd Sourcing

  - uses human intelligence when algorithms are too difficult to devise
  - wikipedia-type consensus models can be built (contributors v. referees)

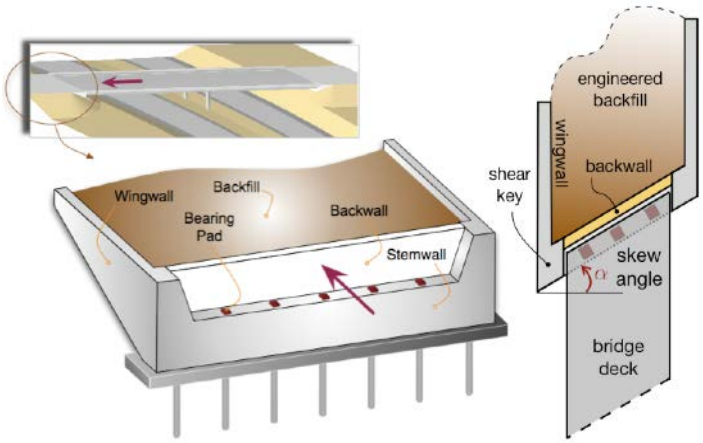
Where will the data come from?

Internet Harvesting

- Crowd Sourcing

  - uses human intelligence when algorithms are too difficult to devise
  - wikipedia-type consensus models can be built (contributors v. referees)

Typical Seat Abutment



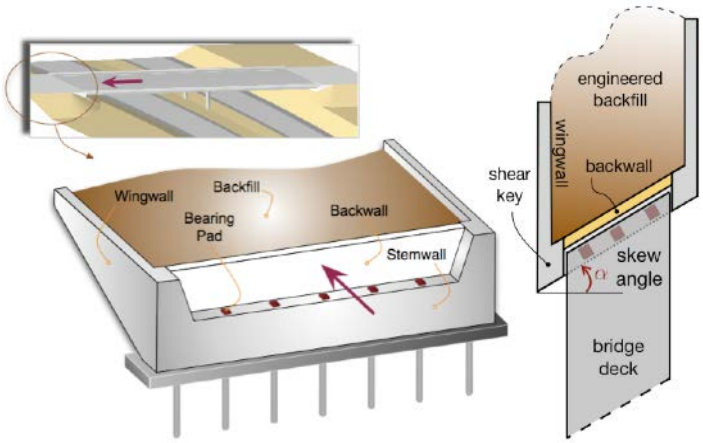
Where will the data come from?

Internet Harvesting

- Crowd Sourcing

  - uses human intelligence when algorithms are too difficult to devise
  - wikipedia-type consensus models can be built (contributors v. referees)

Typical Seat Abutment



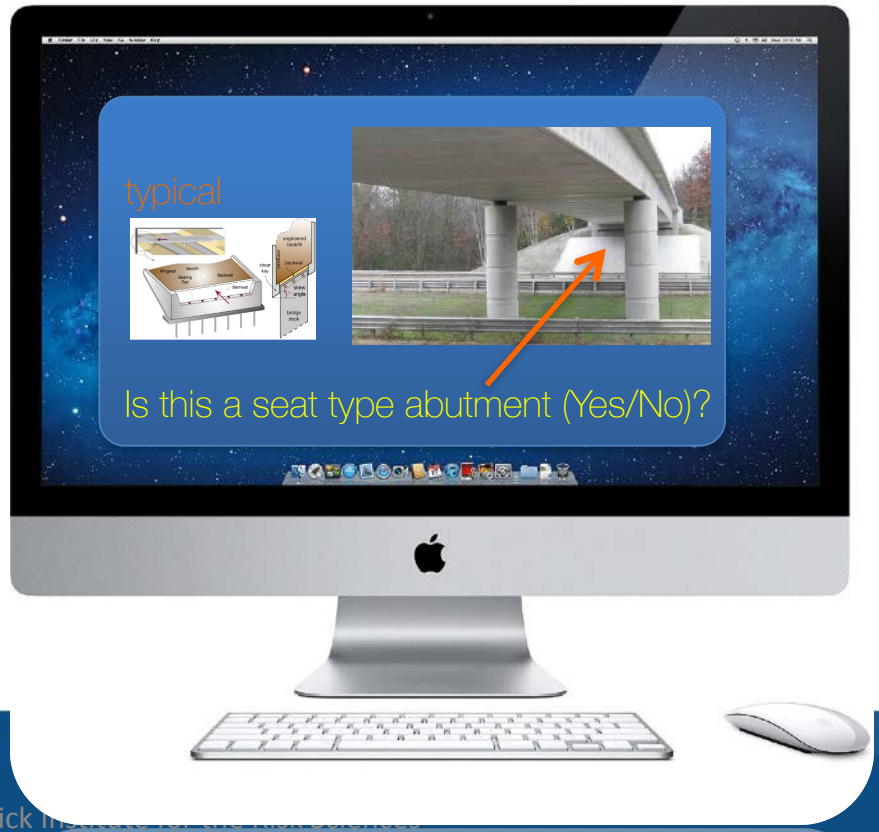


Image to Model

Detection of Bridge Locations

Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

Extract a satellite image of the location corresponding to approximate bridge coordinate

Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

Extract a satellite image of the location corresponding to approximate bridge coordinate

Run a road extraction algorithm to detect roads on the selected image

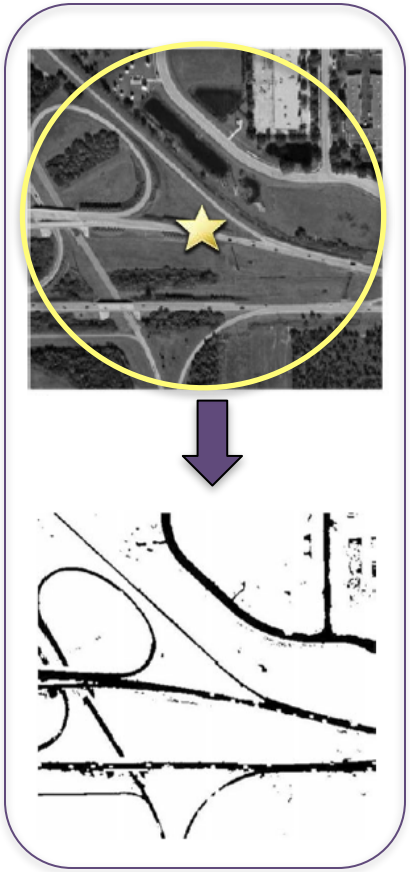


Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

Extract a satellite image of the location corresponding to approximate bridge coordinate

Run a road extraction algorithm to detect roads on the selected image

Generate random points on detected continuous road lines and pass coordinates to Google Roads API

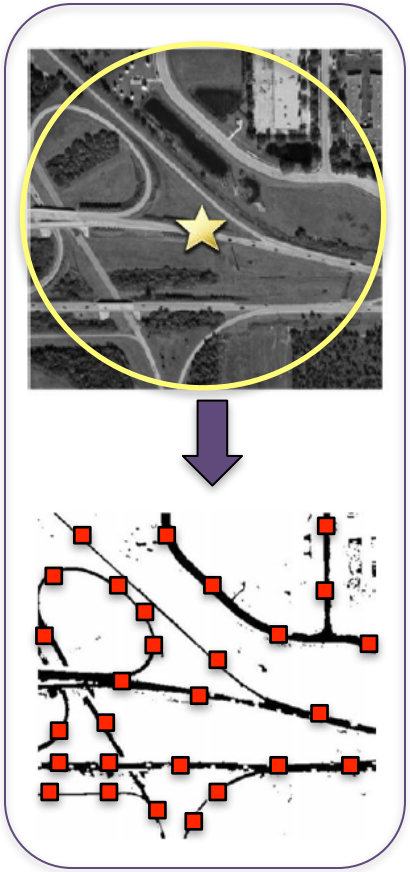


Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

Extract a satellite image of the location corresponding to approximate bridge coordinate

Run a road extraction algorithm to detect roads on the selected image

Generate random points on detected continuous road lines and pass coordinates to Google Roads API

Cross-check route inventory with NBI, then highlight the relevant road line

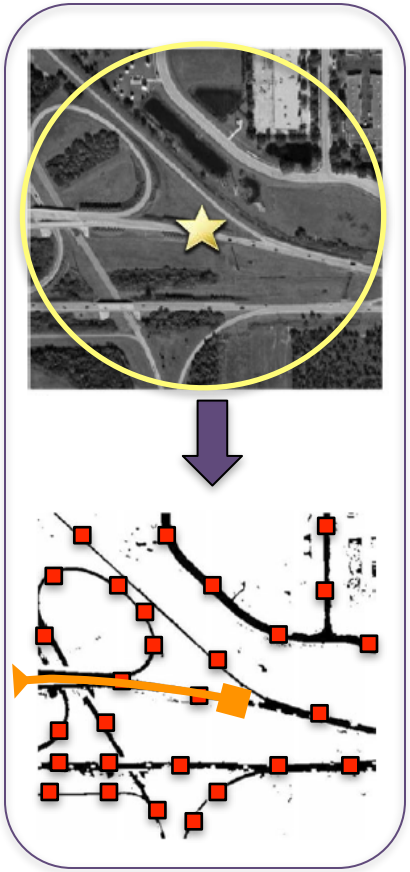


Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

Extract a satellite image of the location corresponding to approximate bridge coordinate

Run a road extraction algorithm to detect roads on the selected image

Generate random points on detected continuous road lines and pass coordinates to Google Roads API

Cross-check route inventory with NBI, then highlight the relevant road line

Prompt user to mark beginning and end points

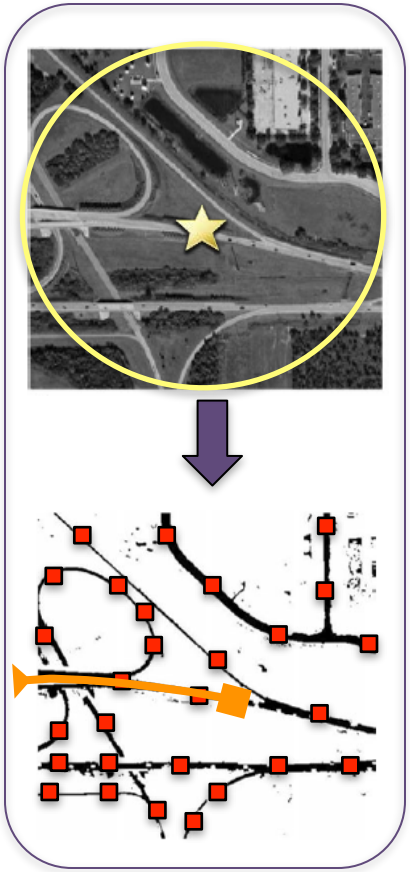


Image to Model

Developing the Wireframe Bridge Models

Create up to 1000 sampling points between user-defined coords.

Snap points to road centerline curve using Google Maps

Determine ground elevations using Google Maps

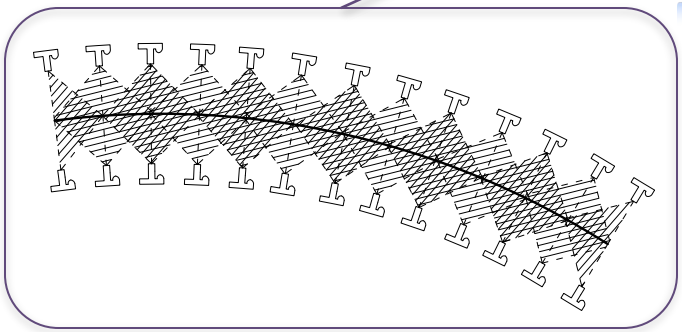
Determine road elevations using MapQuest

Establish wireframe bridge model

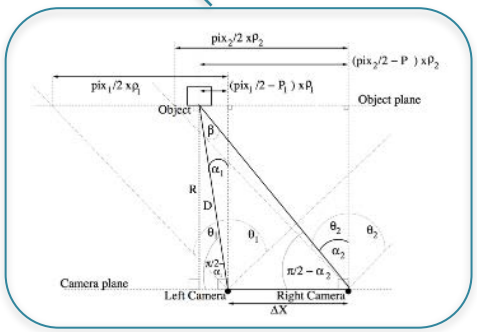
Create virtual cameras from bridge centerline curve

Harvest Street View images at each virtual camera location from Google Street View

Identify bent locations using stereo pair images



A typical virtual camera configuration for a curved bridge



Distance estimation for an object using a stereo pair image

Image to Model

Determination of Deck Properties

Determine deck type, top width of deck and year the structure was built from NBI

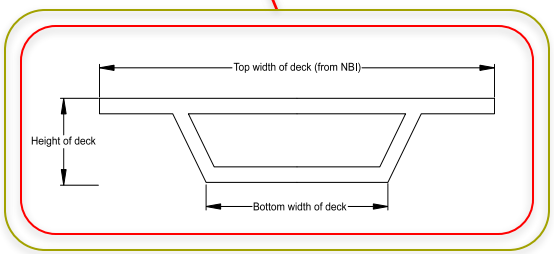
Determine desk superelevation profile by combining geometry info. and speed limit data

Estimate bottom width and height by utilizing fuzzy logic edge detection on harvested Street View images

Estimate reinforcement detailing and corresponding structural properties

Standard Specifications for Highway Bridges

Google Maps



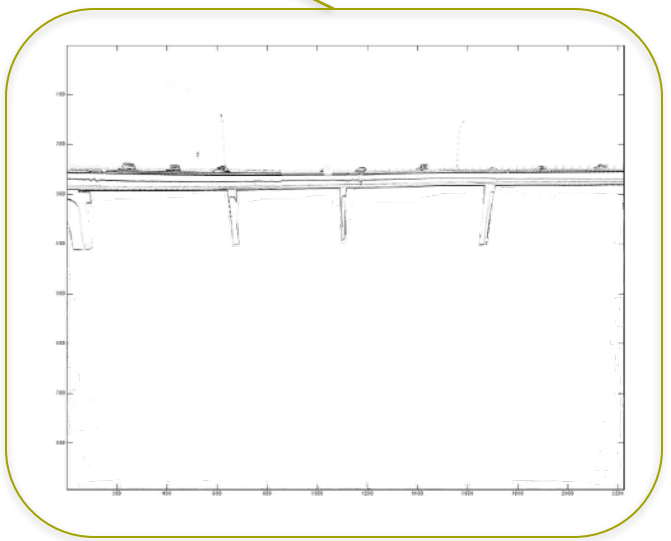


Image to Model

Determination of Column Properties

Determine the column type based on the number of detected column edges

Sample column height and width at a number of levels

Estimate rebar detailing and corresponding structural properties by interrogating a database of similar columns (and by utilizing Caltrans SDC)

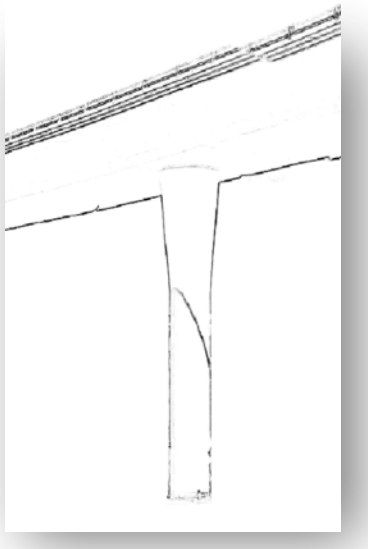


Image to Model

Determination of Column Properties

21.2.1.2 Column Reinforcement Requirements

(1) Longitudinal Reinforcement

Maximum Longitudinal Reinforcement Area, $A_{st,max} = 0.04 \times A_g$ (*SDC* 3.7.1-1)

Minimum Longitudinal Reinforcement Area:

$A_{st,min} = 0.01(A_g)$ for columns (*SDC* 3.7.2-1)

$A_{st,min} = 0.005(A_g)$ for Pier walls (*SDC* 3.7.2-2)

where:

A_g = the gross cross sectional area (in.^{2})

Normally, choosing column $A_{st} = 0.015(A_g)$ is a good starting point.

(2) Transverse Reinforcement

Either spirals or hoops can be used as transverse reinforcement in the column. However, hoops are preferred (see *MTD* 20-9) because of their discrete nature in the case of local failure.

Determine the column type based on the number of detected column edges

Sample column height and width at a number of levels

Estimate rebar detailing and corresponding structural properties by interrogating a database of similar columns (and by utilizing Caltrans SDC)

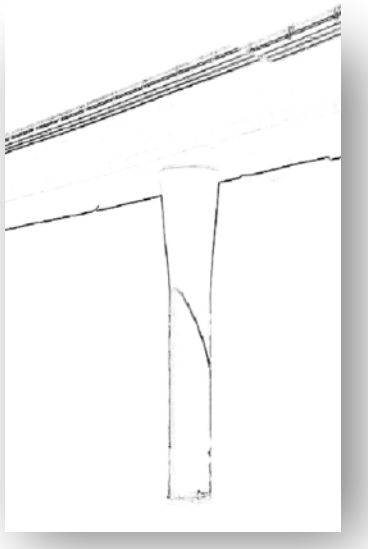


Image to Model

Completion of model using crowdsourced data, metadata harvested from the databases

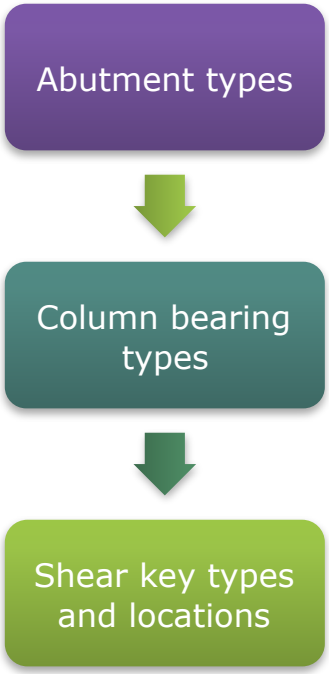
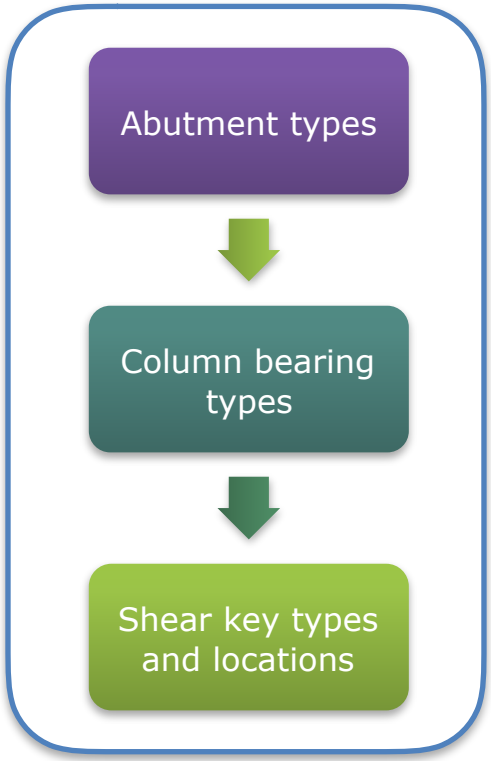


Image to Model

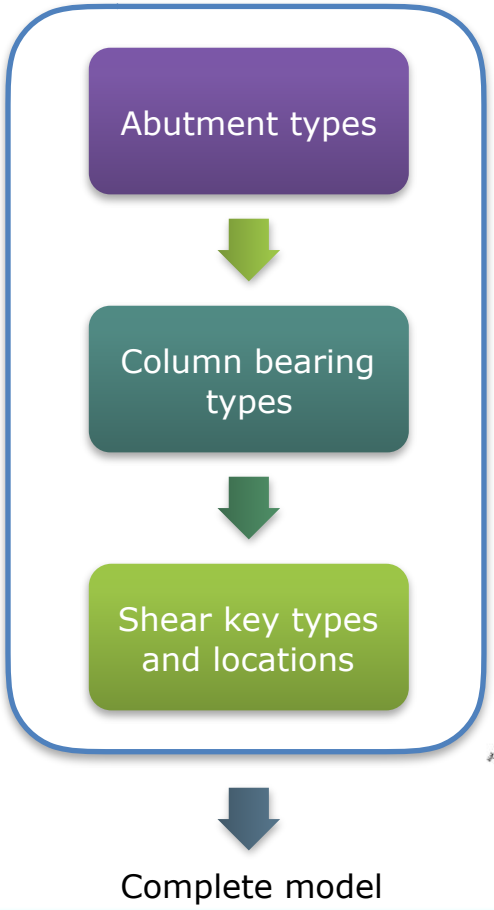
Completion of model using crowdsourced data, metadata harvested from the databases



Data to be refined by utilizing meta-data rules *learned* from Caltrans Standard Plans, Caltrans SDC via Deep Learning

Image to Model

Completion of model using crowdsourced data, metadata harvested from the databases



Data to be refined by utilizing meta-data rules *learned* from Caltrans Standard Plans, Caltrans SDC via Deep Learning

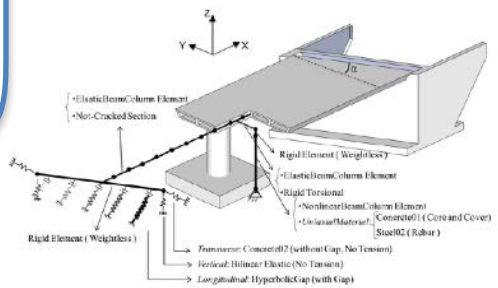
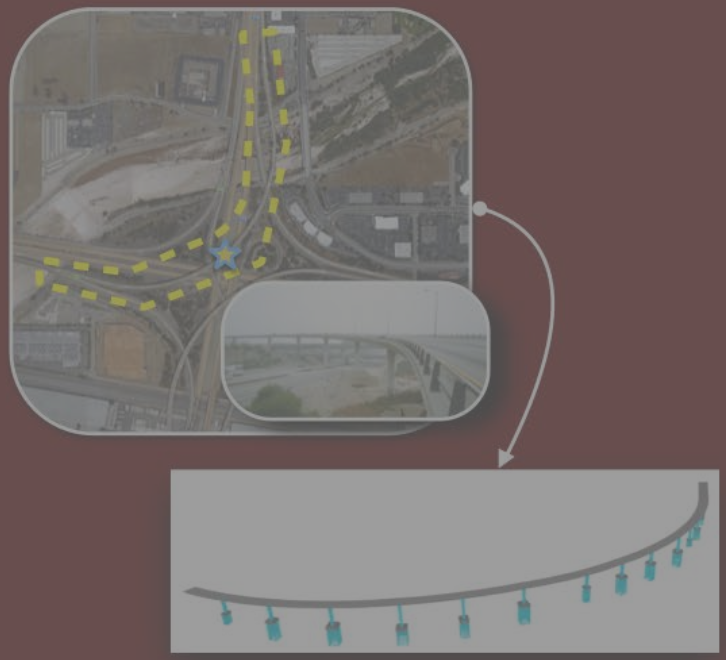
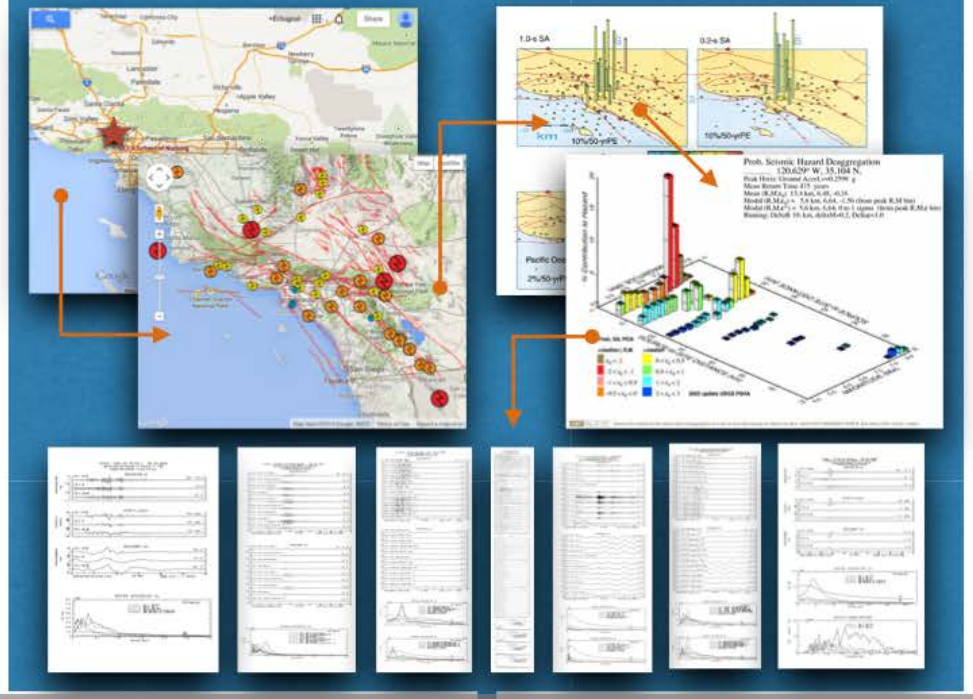


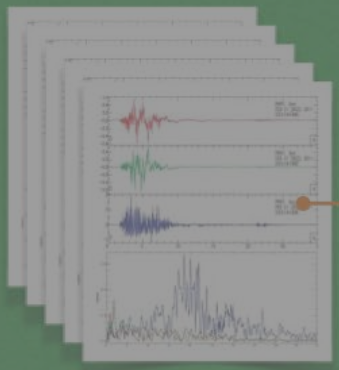
Image to Model



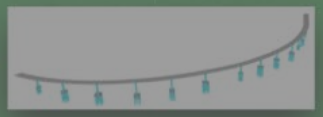
Location to Hazard



Analysis to Decision



seismic loads



analysis model

fragility curves

Decision Variables

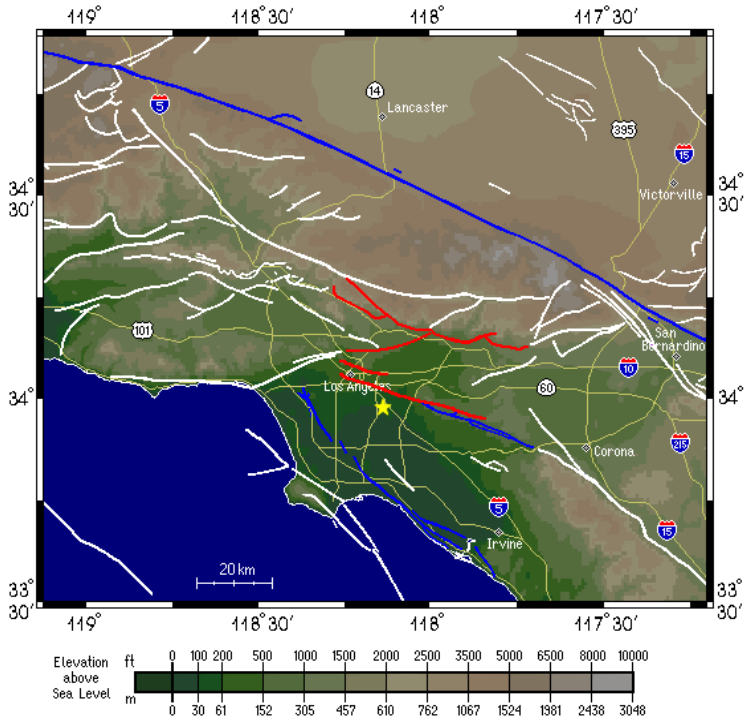
- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.

Location to Hazard

Probabilistic Seismic Hazard Assessment (PSHA)

Location to Hazard

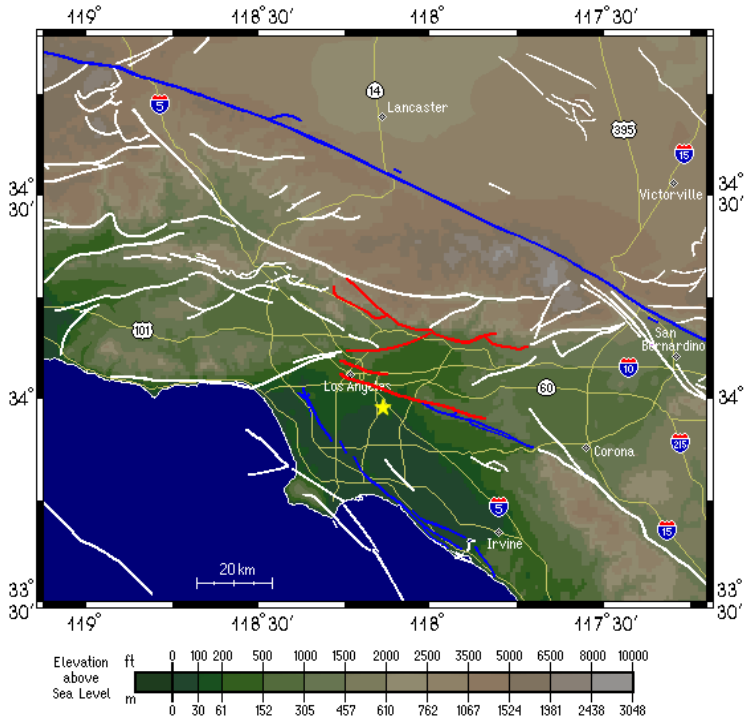
Probabilistic Seismic Hazard Assessment (PSHA)



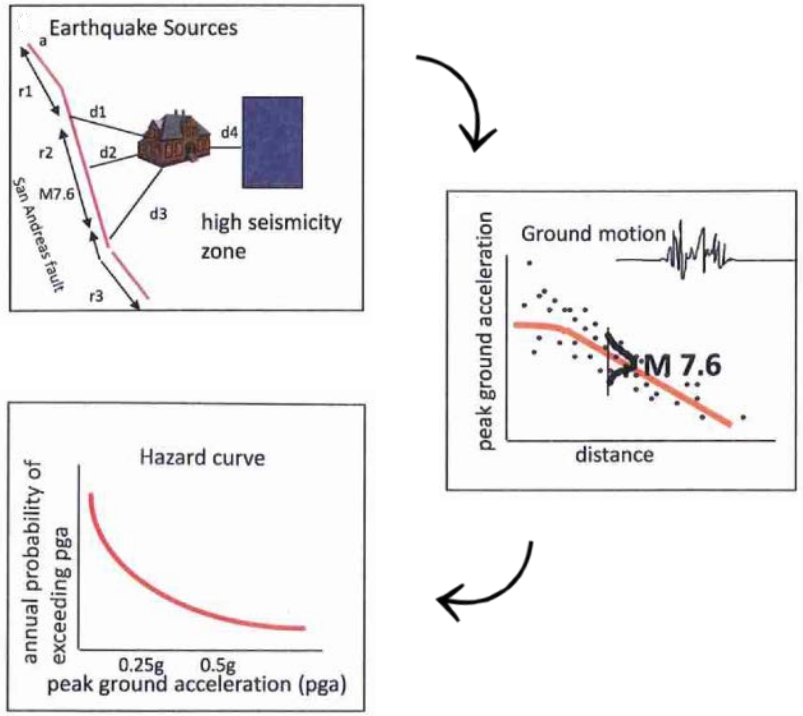
A map of active faults around a Los Angeles site (Stewart, 2014)

Location to Hazard

Probabilistic Seismic Hazard Assessment (PSHA)



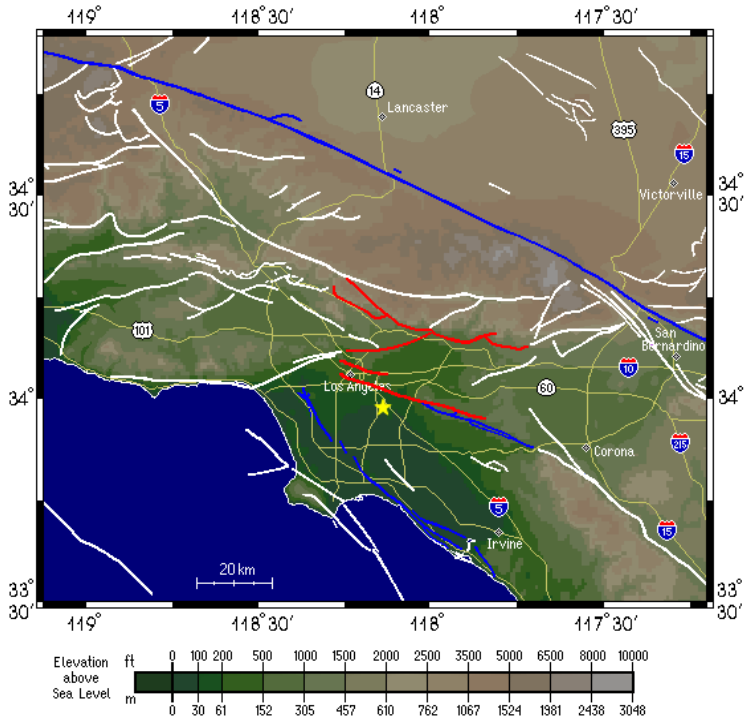
A map of active faults around a Los Angeles site (Stewart, 2014)



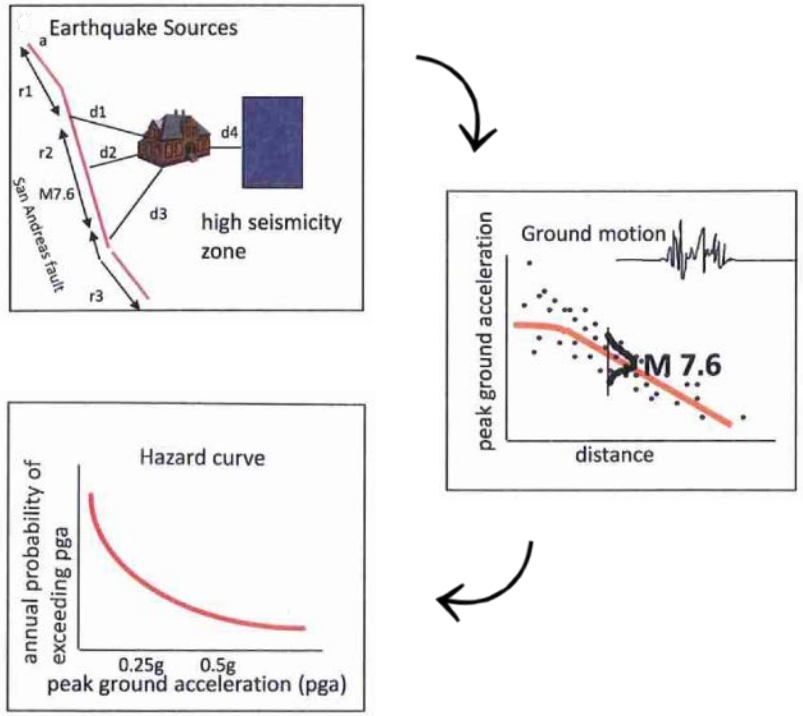
Basic seismic hazard methodology (from Boore et al.)

Location to Hazard

Probabilistic Seismic Hazard Assessment (PSHA)



A map of active faults around a Los Angeles site (Stewart, 2014)

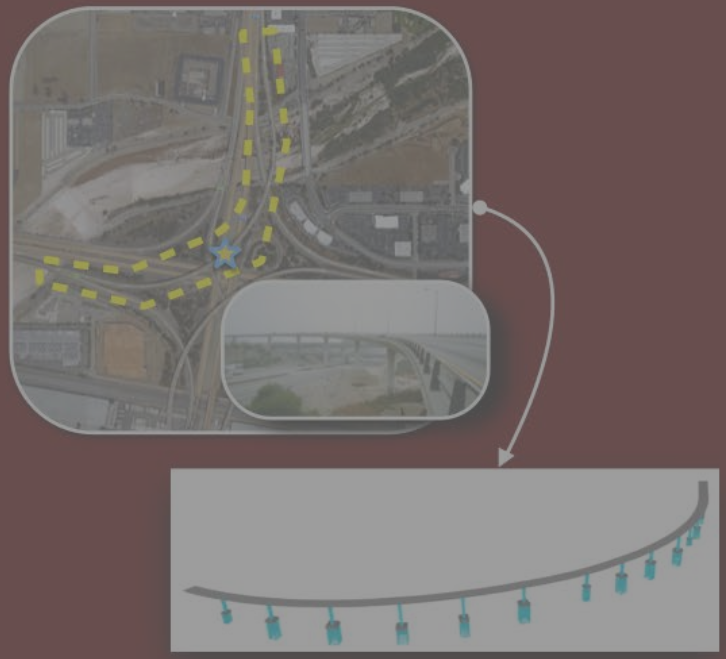


Basic seismic hazard methodology (from Boore et al.)

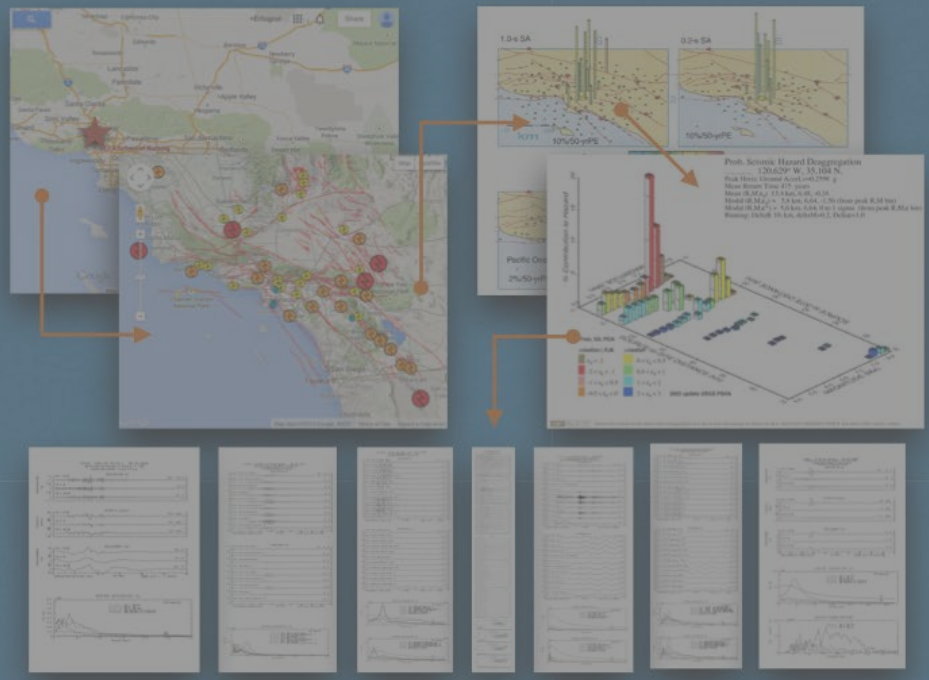
PEER
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

SCEC
AN NSF+USGS CENTER

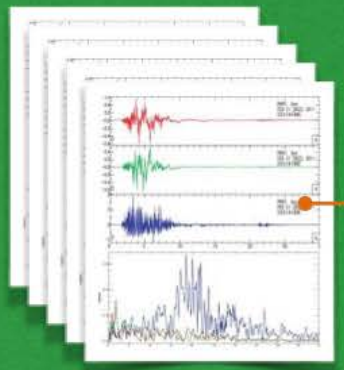
Image to Model



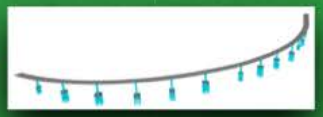
Location to Hazard



Analysis to Decision



seismic loads



analysis model

fragility curves

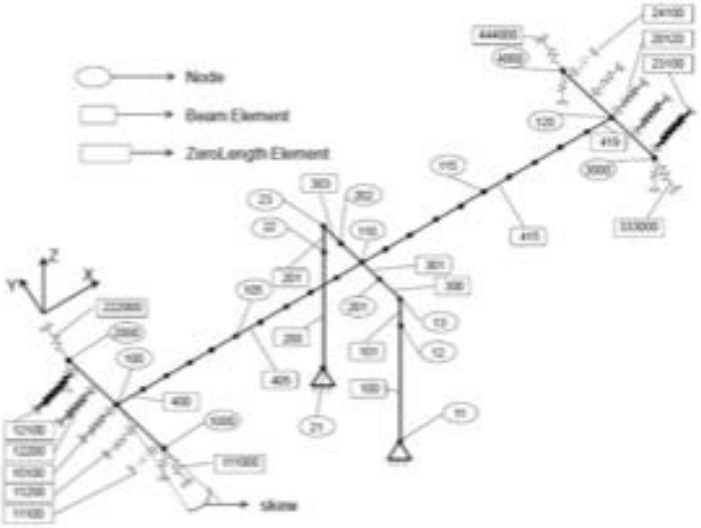
Decision Variables

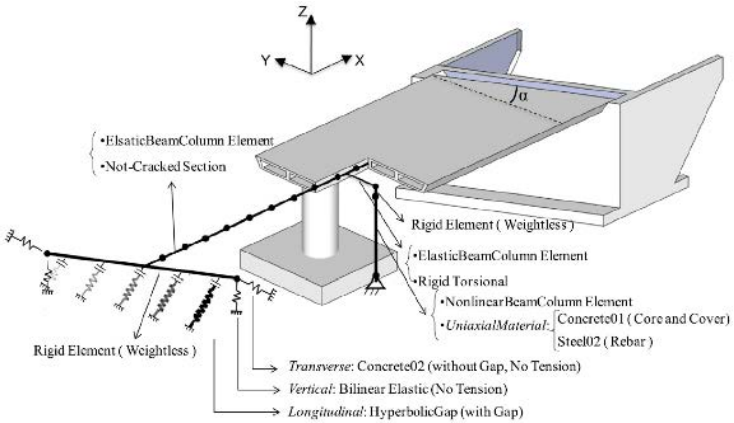
- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.

Analysis Models

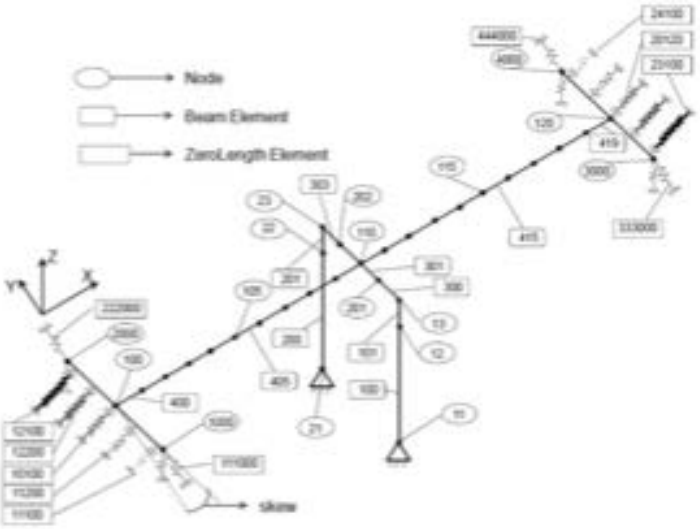
a brief overview

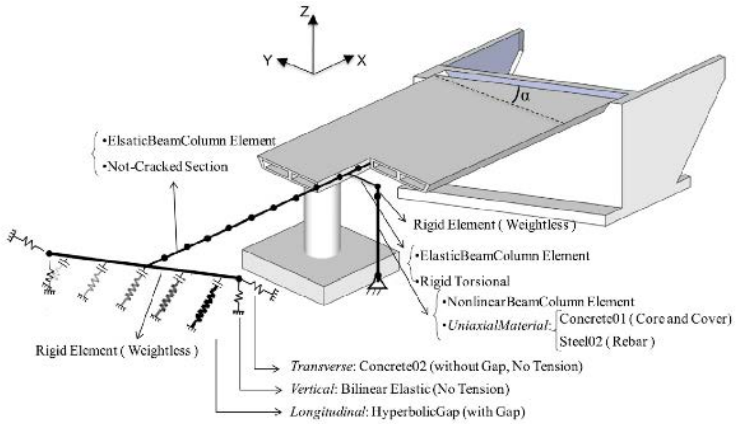
Building blocks of a bridge model





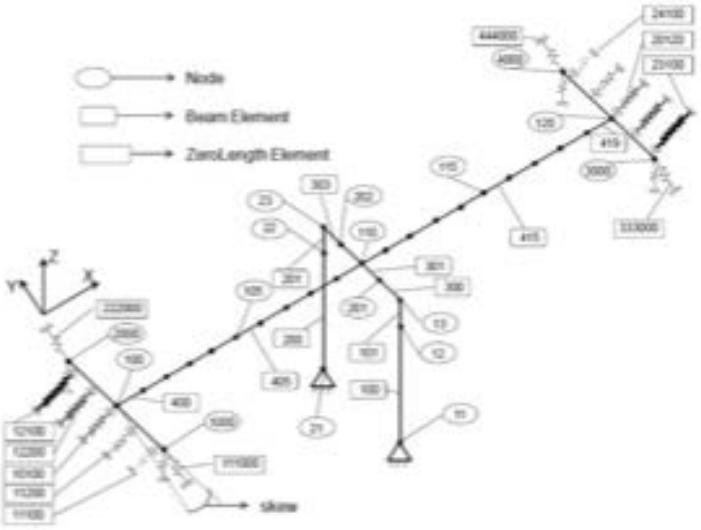
Building blocks of a bridge model

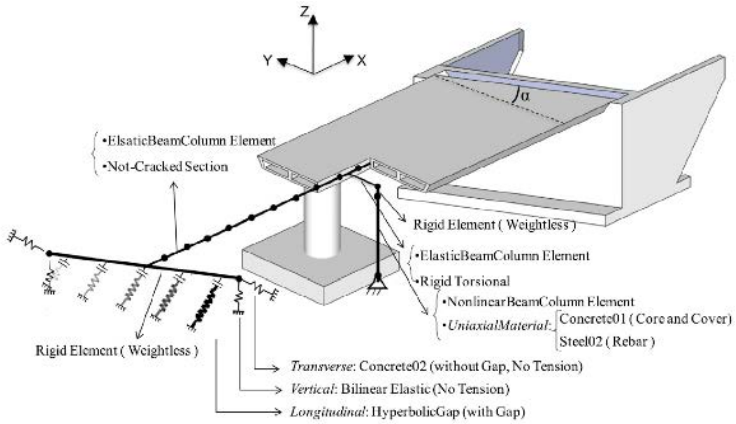




- Piles [Boulanger et al., 1999; Taciroglu et al., 2006; Khalili-Tehrani et al., 2014]
- Abutments [Stewart et al. 2007; Shamsabadi et al., 2010; Nojoumi et al., 2015]
- Shear keys [Mobasher et al., 2015; Omrani et al., 2015]
- In-span hinges [Trochalakis et al., 1997; Hube and Mosalam, 2008]
- Columns [Barry and Eberhard, 2008]
- Girders, deck (elastic)

Building blocks of a bridge model



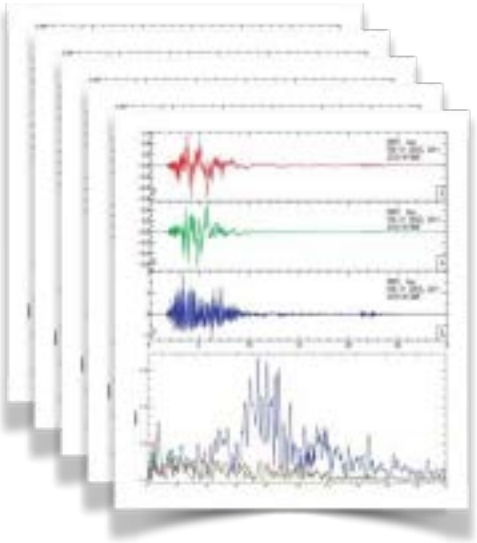


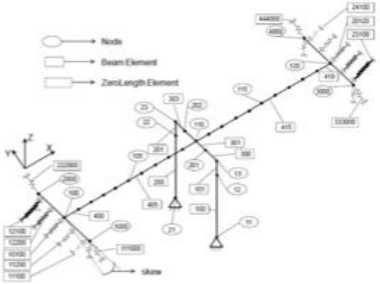
- Piles [Boulanger et al., 1999; Taciroglu et al., 2006; Khalili-Tehrani et al., 2014]
- Abutments [Stewart et al. 2007; Shamsabadi et al., 2010; Nojoumi et al., 2015]
- Shear keys [Mobasher et al., 2015; Omrani et al., 2015]
- In-span hinges [Trochalakis et al., 1997; Hube and Mosalam, 2008]
- Columns [Barry and Eberhard, 2008]
- Girders, deck (elastic)

Detailed descriptions of component and system modeling are provided in

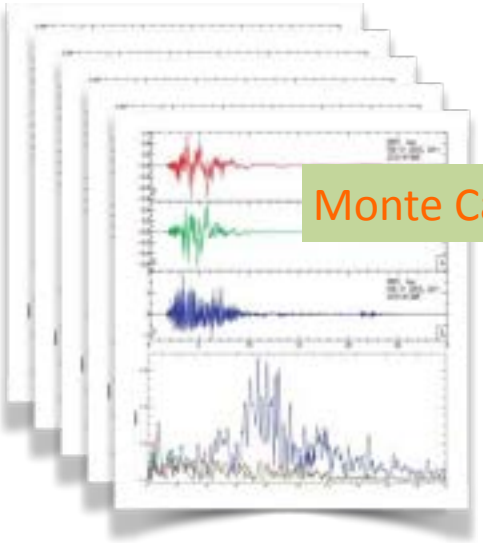
Omrani R, Mobasher B, Liang X, Gunay S, Mosalam K, Zareian F, Taciroglu E (2015). *Guidelines for Nonlinear Seismic Analysis of Ordinary Bridges: Version 2.0*, Caltrans Report No. 15-65A0454, Sacramento CA.

Analysis

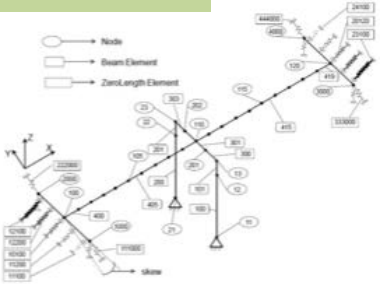




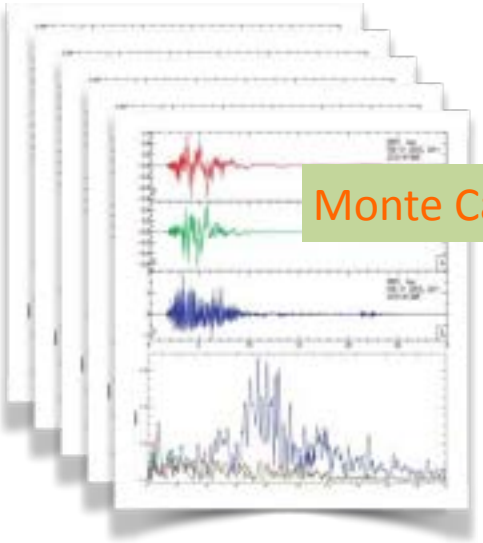
Analysis



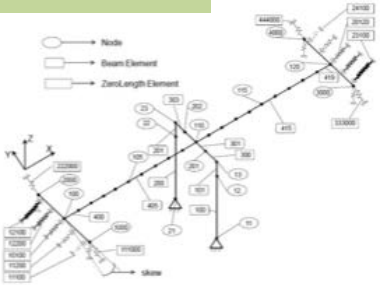
Monte Carlo (on cloud)

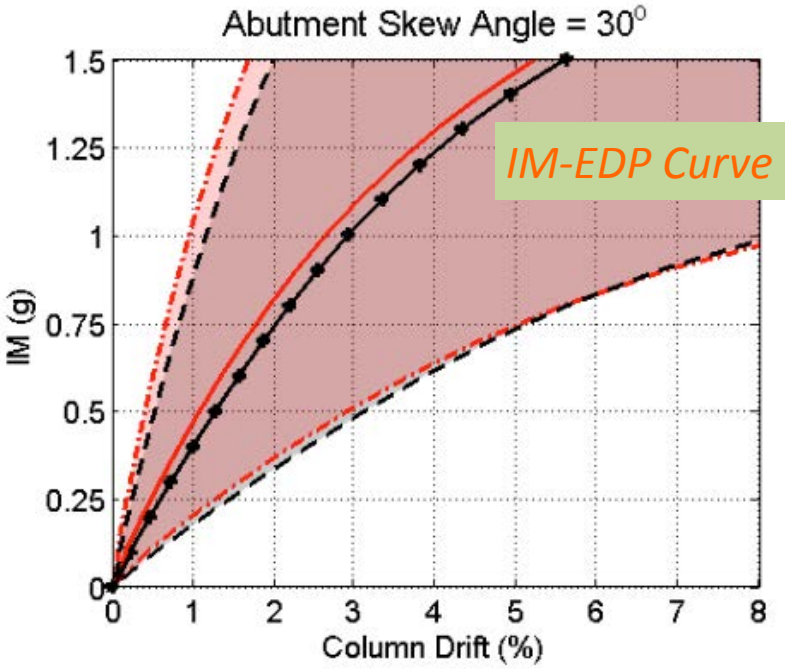


Analysis yields …

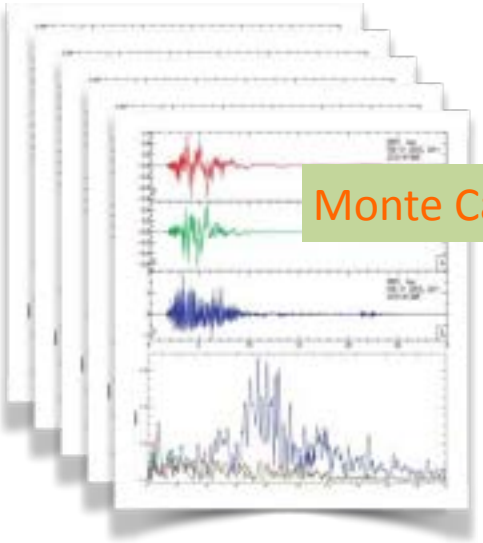


Monte Carlo (on cloud)

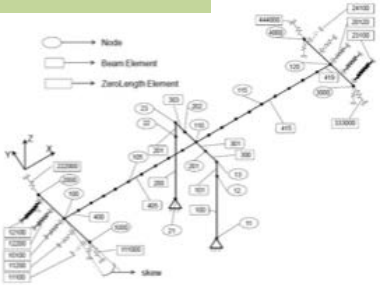


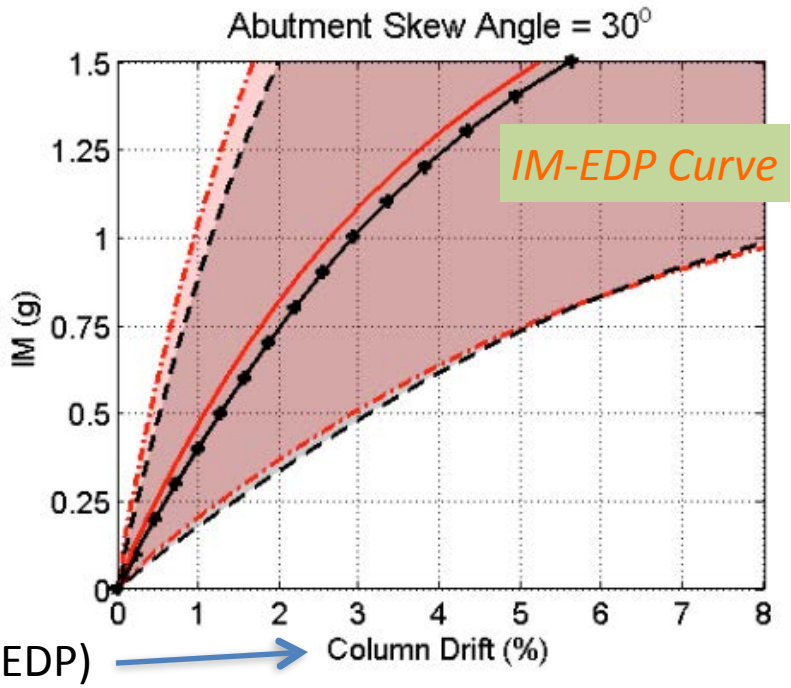


Analysis yields …



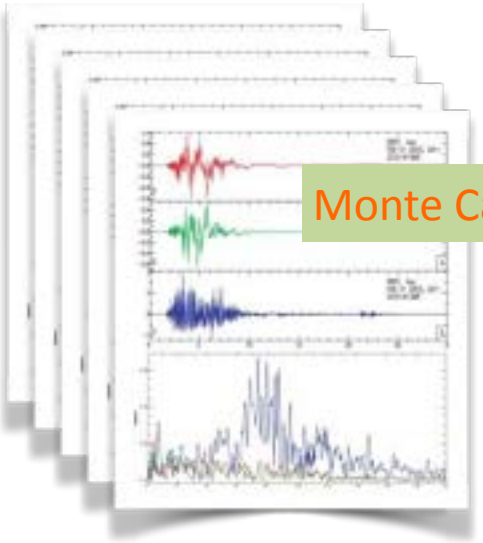
Monte Carlo (on cloud)



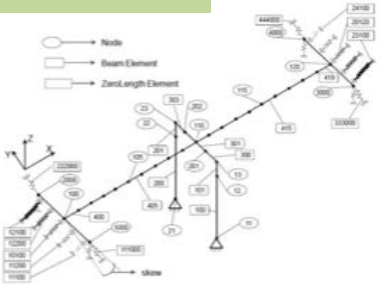


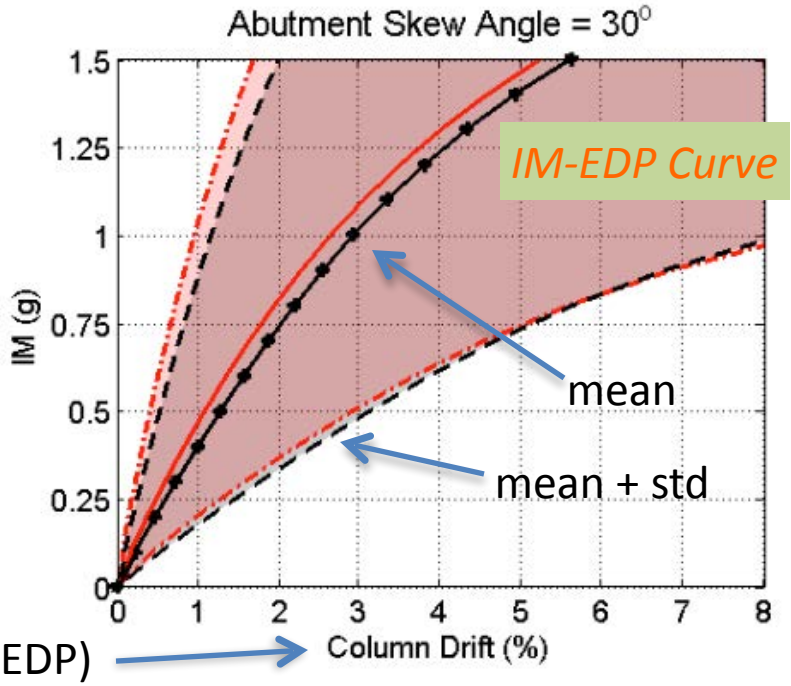
Engineering Demand Parameter (EDP)

Analysis yields …



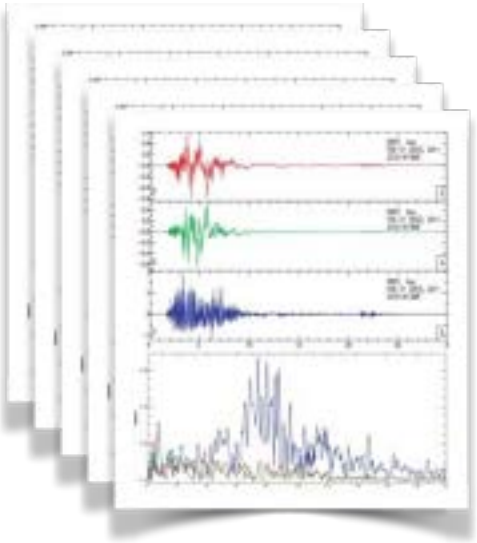
Monte Carlo (on cloud)

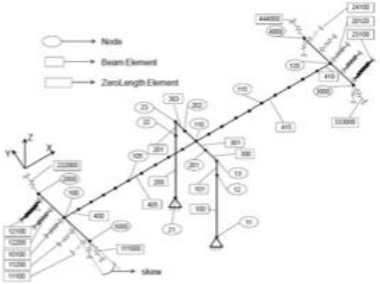




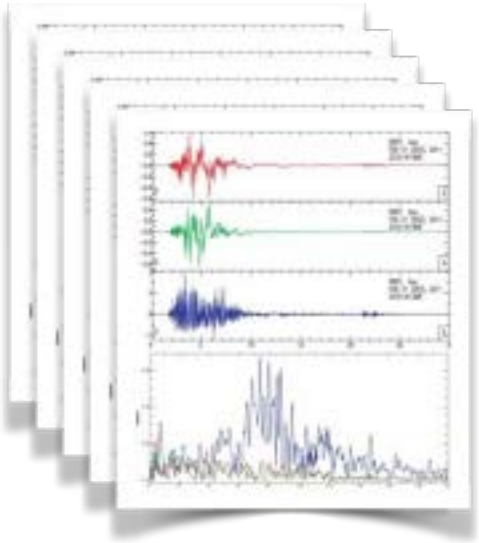
Engineering Demand Parameter (EDP)

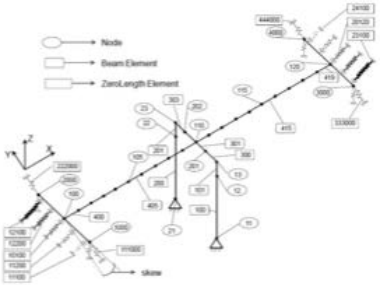
Analysis yields …

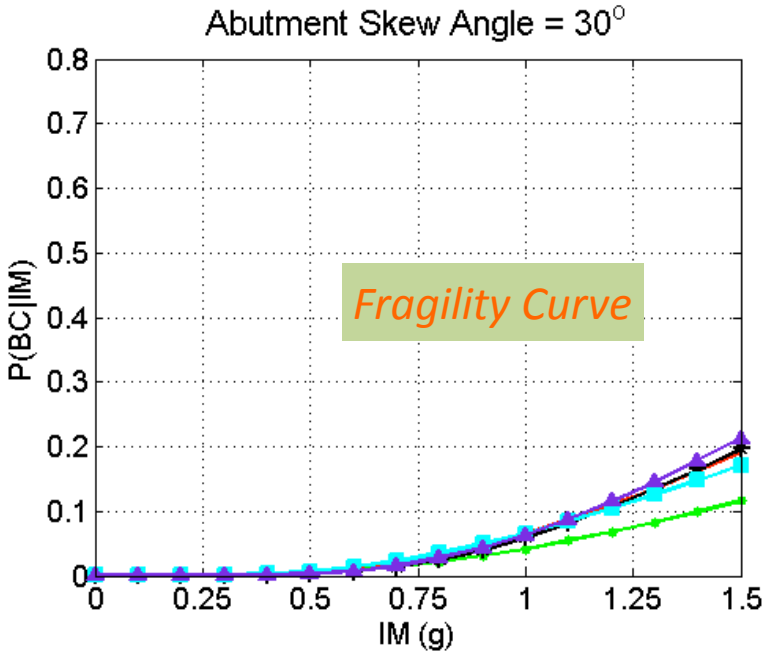




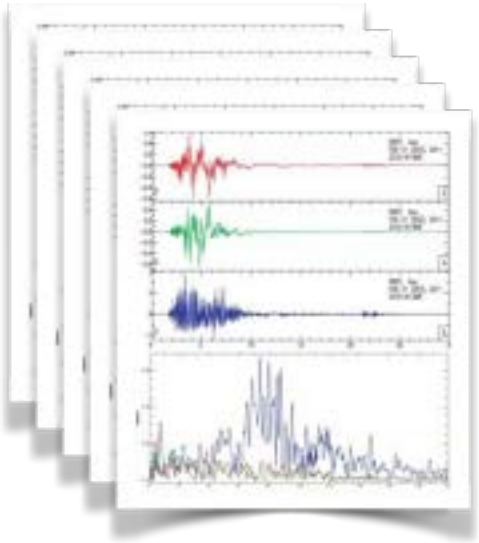
Analysis yields …

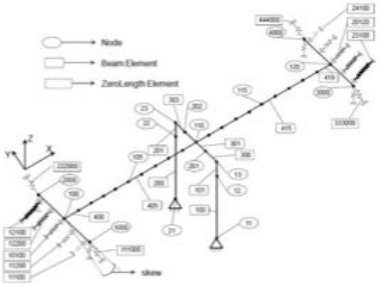






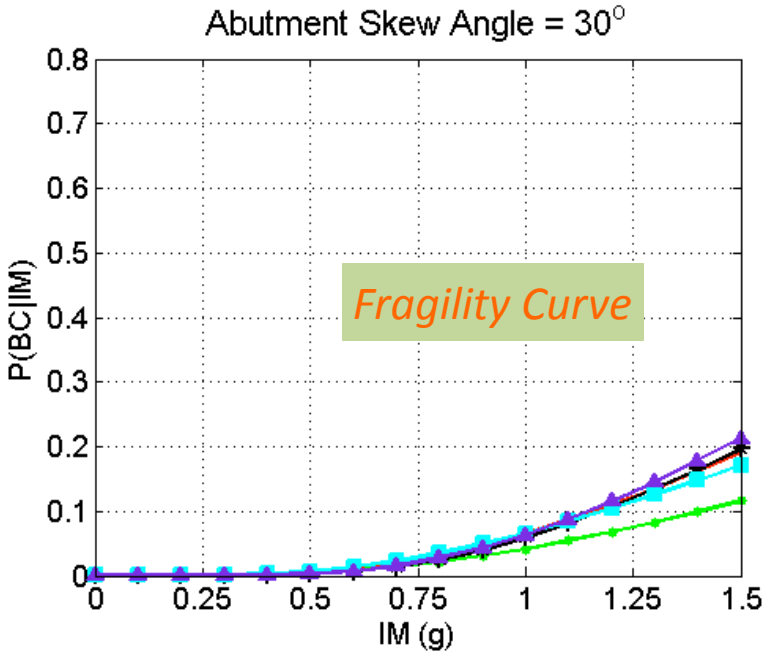
Analysis yields …



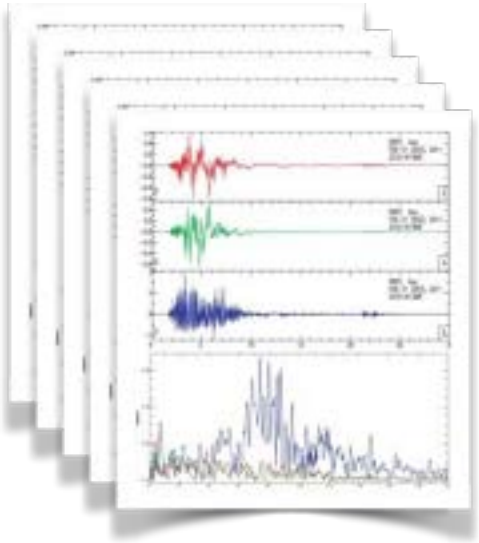


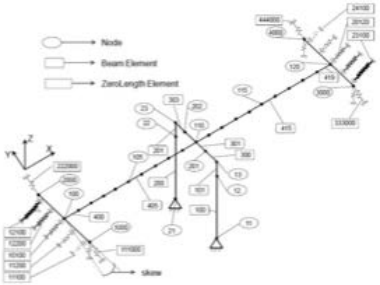
Probability of Collapse

[or *Probably of Exceedance of a pre-defined damage state for a particular component such as a shear key*]



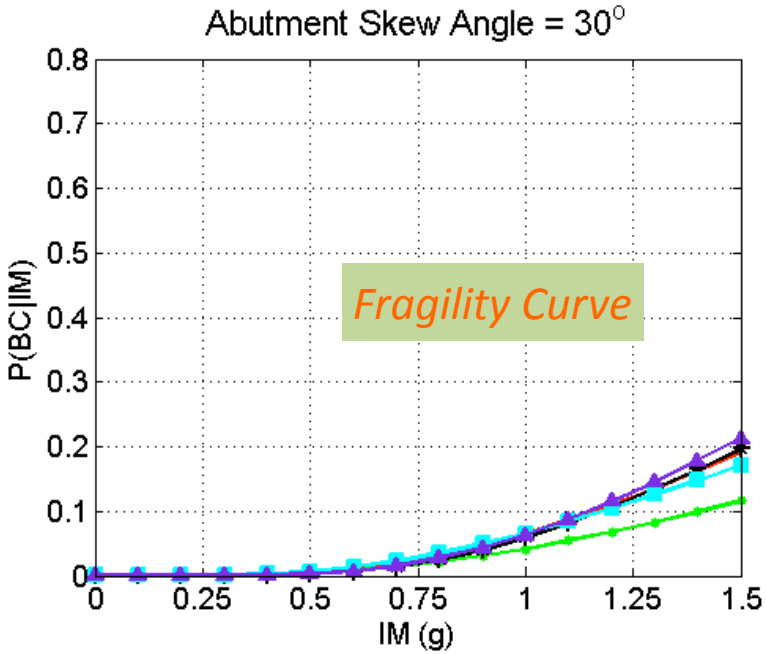
Analysis yields …





Probability of Collapse

[or *Probably of Exceedance of a pre-defined damage state for a particular component such as a shear key*]



Loss Estimation

an open problem for bridges

EDP or Performance State to Loss & Downtime

EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings

EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
  - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*

EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
  - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*
  - *Packaged into FEMA Performance Assessment Calculation Tool (PACT)*

EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
  - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*
  - *Packaged into FEMA Performance Assessment Calculation Tool (PACT)*
  - *Provides fragilities/performance-functions for structural and non-structural components, and systems*

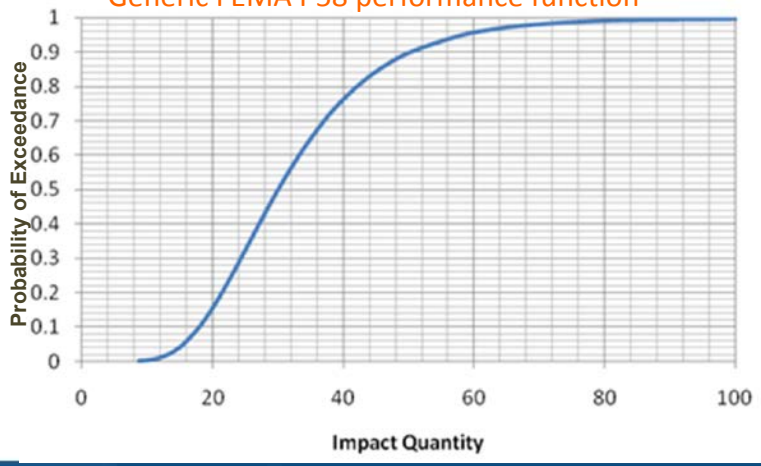
EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
  - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*
  - *Packaged into FEMA Performance Assessment Calculation Tool (PACT)*
  - *Provides fragilities/performance-functions for structural and non-structural components, and systems*

Generic FEMA P58 performance function



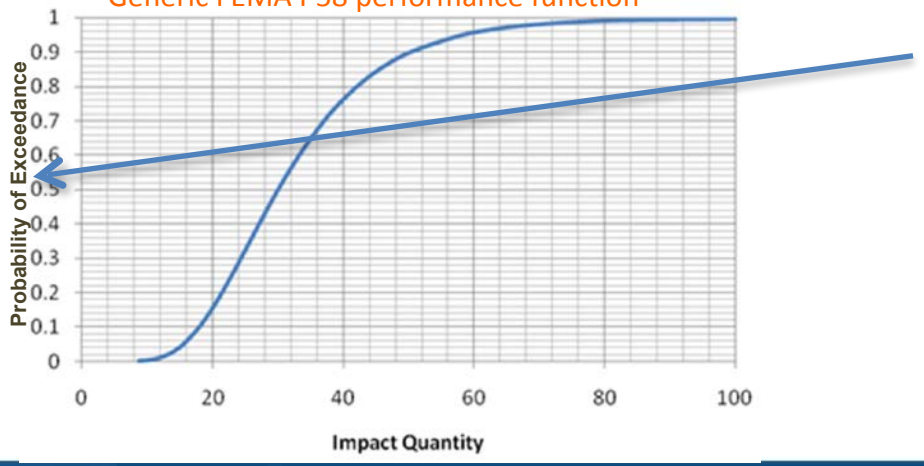
EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
  - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*
  - *Packaged into FEMA Performance Assessment Calculation Tool (PACT)*
  - *Provides fragilities/performance-functions for structural and non-structural components, and systems*

Generic FEMA P58 performance function



e.g., PoE of 2nd floor acceleration value of 0.4*g*

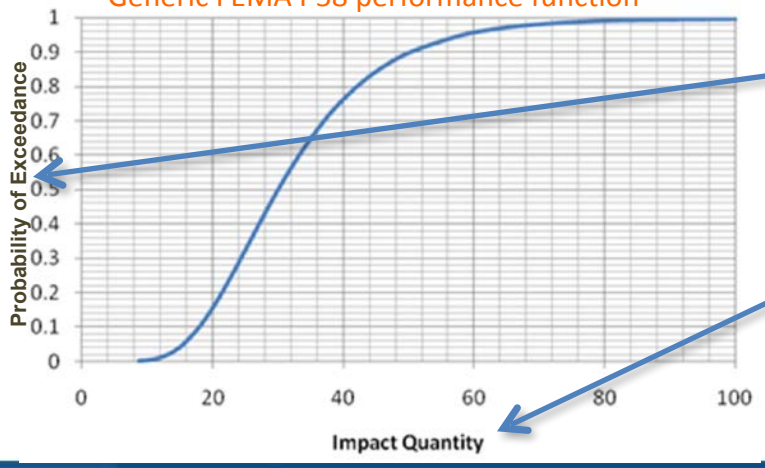
EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

  Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
  - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*
  - *Packaged into FEMA Performance Assessment Calculation Tool (PACT)*
  - *Provides fragilities/performance-functions for structural and non-structural components, and systems*

Generic FEMA P58 performance function



e.g., PoE of 2nd floor acceleration value of 0.4*g*

e.g., repair costs to MRI machine on floor 2
[other IQ examples are repair time, injuries requiring hospitalization, deaths, hours to operability, etc.

EDP or Performance State to Loss & Downtime

EDP or Performance State to Loss & Downtime

- Similar capabilities in loss estimation for bridges are lacking

EDP or Performance State to Loss & Downtime

- Similar capabilities in loss estimation for bridges are lacking

- Our long-term plans
  - Try to replicate the FEMA-P58 methodology for bridges
    - ➢ Develop *apps (tools)* for computing component fragilities (to enable rapid post-event assessment)
    - ➢ Compile repair/downtime data and statistics (Caltrans)
  - Devise methodologies for network impact and recovery analysis (UCLA Luskin Center)

A Validation Study

San Bernardino – I-10/I-215 Interchange Bridge

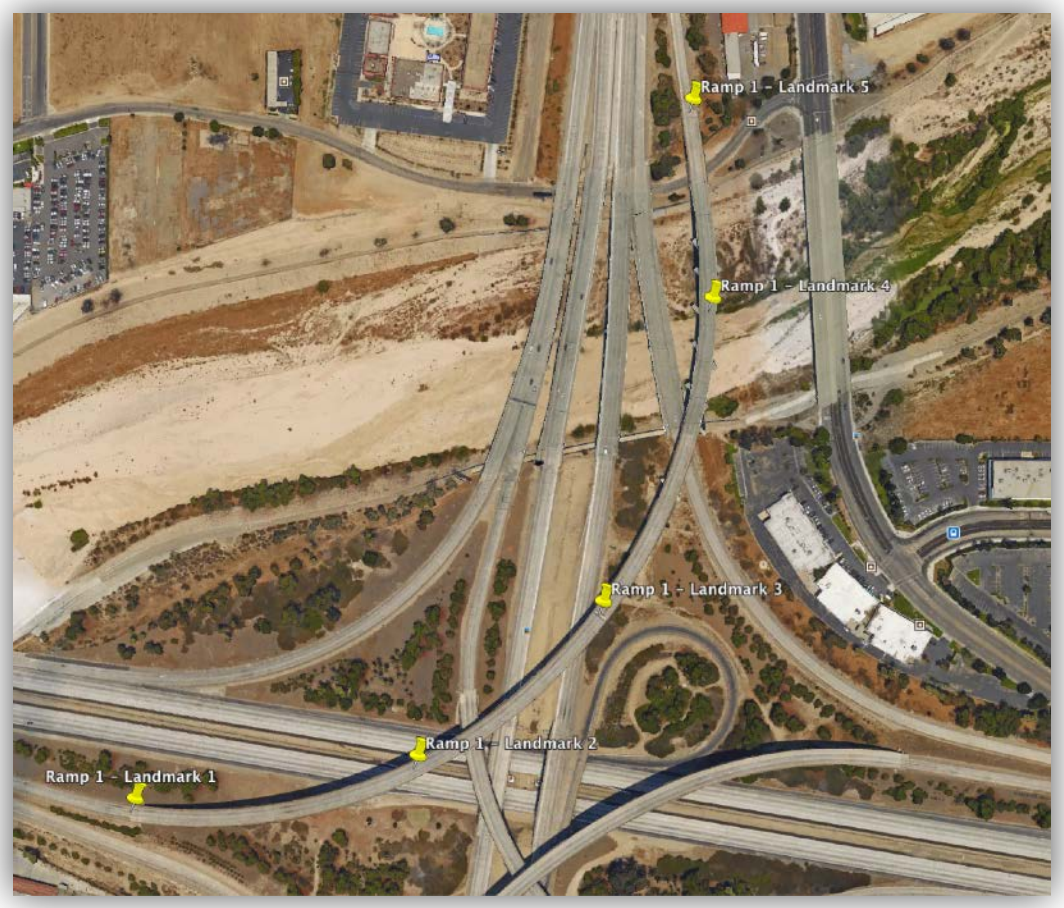
Coronado Bridge, San Diego CA

Validation study

San Bernardino – I-10/I-215 Interchange Bridge

Validation study

Selection of random points on the bridge by the user



Validation study

Initial processing of selected points by program

Validation study

Initial processing of selected points by program

Calculation of bridge centerline curve

*Using ***UCLA*** automated image-based structural model development program through utilization of

Google Maps Roads API

Validation study

Initial processing of selected points by program

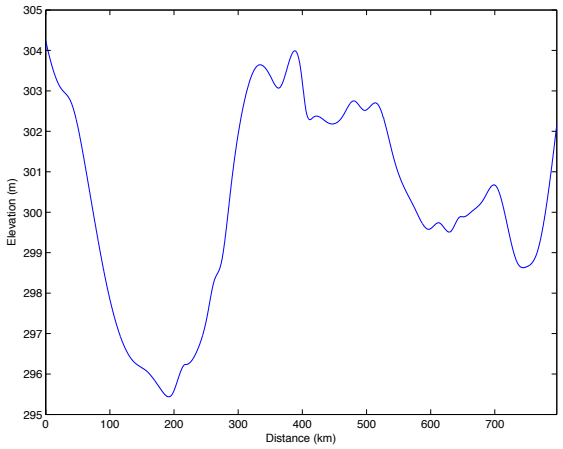
Calculation of bridge centerline curve

*Using ***UCLA*** automated image-based structural model development program through utilization of

Google Maps Roads API

*Using ***UCLA*** automated image-based structural model development program through utilization of

Google Maps Elevation API



Determination of ground elevations

Validation study

Initial processing of selected points by program

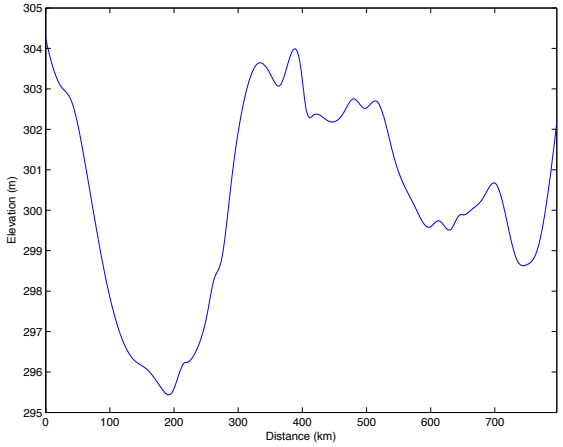
Calculation of bridge centerline curve

*Using ***UCLA*** automated image-based structural model development program through utilization of

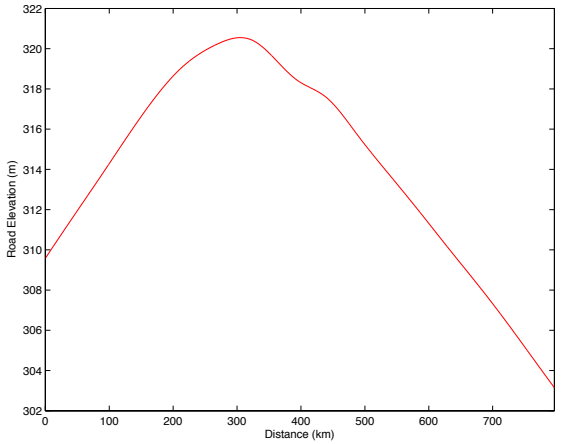
Google Maps Roads API

*Using ***UCLA*** automated image-based structural model development program through utilization of

Google Maps Elevation API



Determination of ground elevations



Determination of road elevations

*Using ***UCLA*** automated image-based structural model development program through utilization of

MapQuest Directions API

Validation study

Image processing to identify bent locations and developing the wireframe model

Validation study

Image processing to identify bent locations and developing the wireframe model

Identification of bent locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

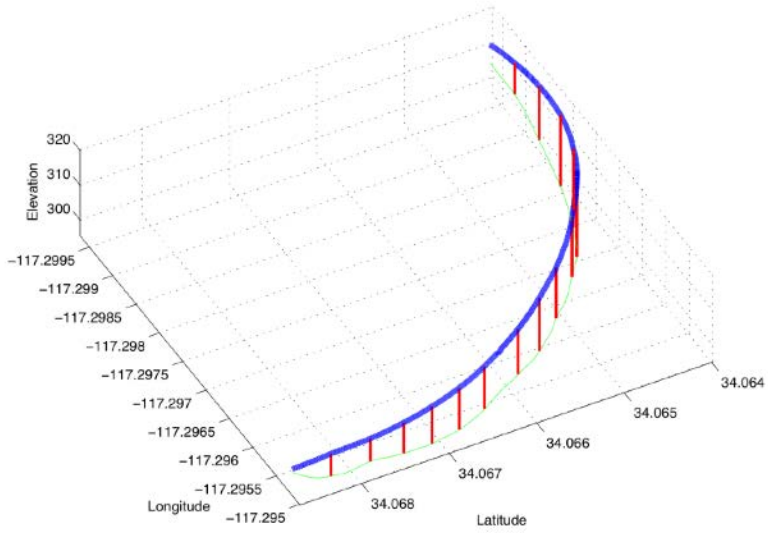
Validation study

Image processing to identify bent locations and developing the wireframe model

Identification of bent locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

*Using ***UCLA*** automated image-based structural model development program via *Wireframe Model Builder Module*



Establishing of wireframe model

Validation study

Image processing to identify in-span hinge locations

Identification of in-span hinge locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

Validation study

Image processing to identify in-span hinge locations

Identification of in-span hinge locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

Validation study

Using of auxiliary data to determine superelevation profile*

Determination of curve superelevation at each sampling point

Using ***UCLA* automated image-based structural model development program via *Image Analyzer Module*

Identify centerline geometry in terms of constituent curves/spirals.

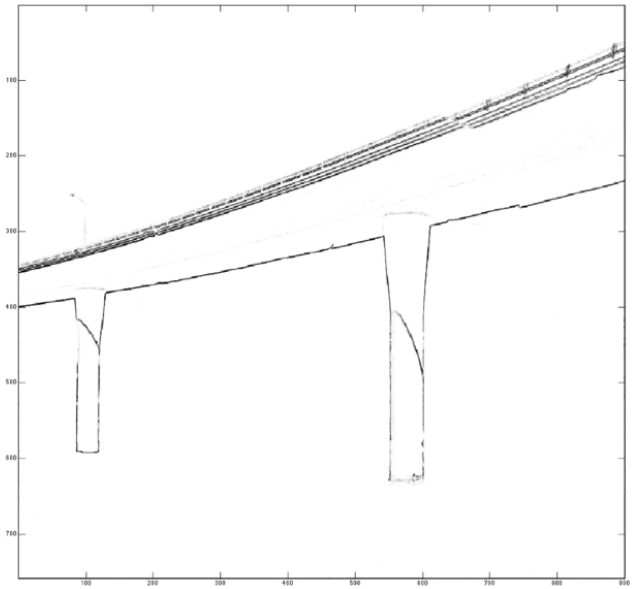
Get bridge speed limit data through Google Roads API.

Estimate curve superelevation at each sampling point.

Basic methodology to determine curve superelevation profile

Validation study

Determination of bridge column dimensions

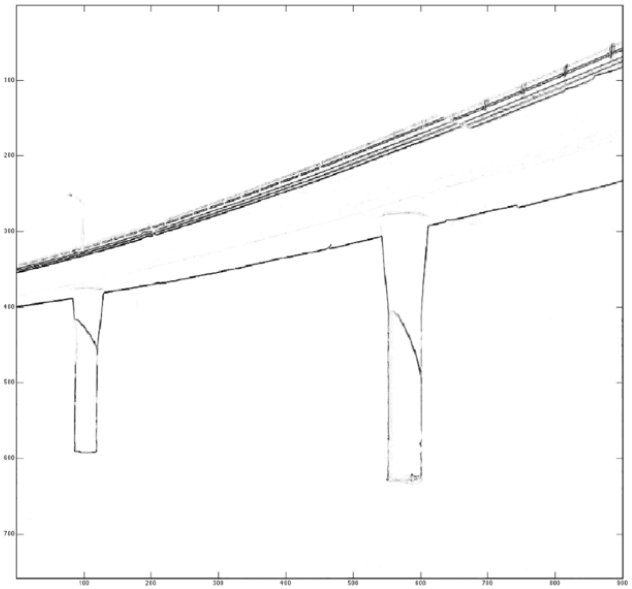


Detection of column edges

*Using ***UCLA*** automated image-based structural model development program via *Fuzzy Logic Edge Detection Module*

Validation study

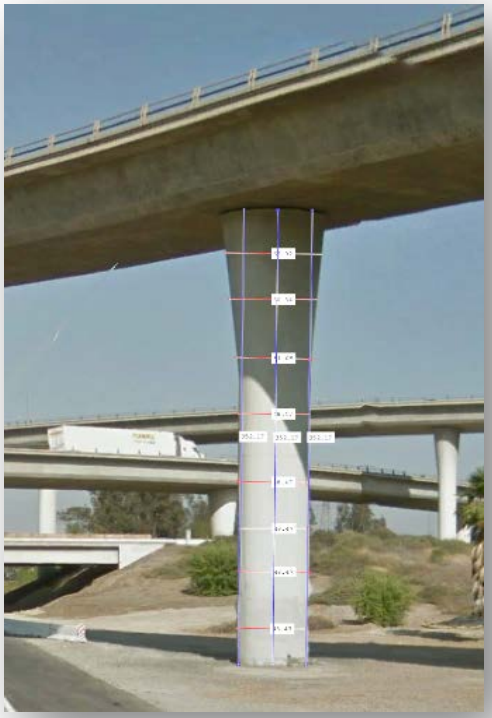
Determination of bridge column dimensions



Detection of column edges

*Using ***UCLA*** automated image-based structural model development program via *Fuzzy Logic Edge Detection Module*

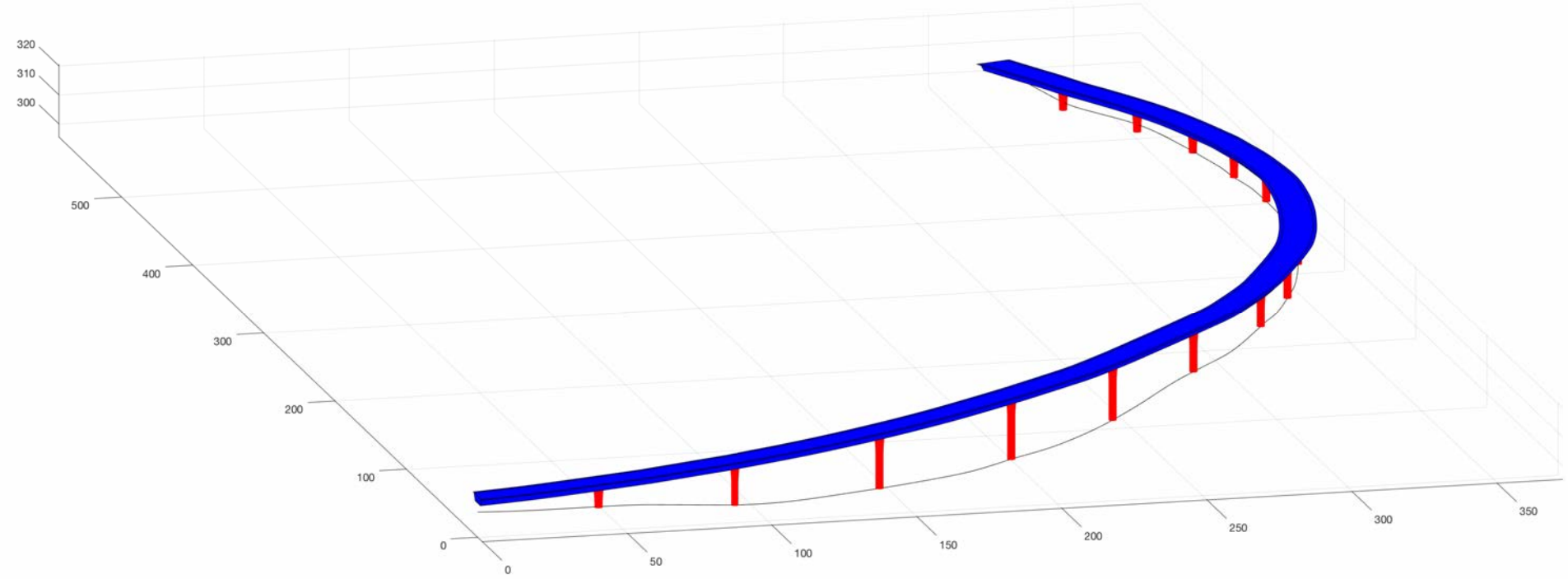
*Using ***UCLA*** automated image-based structural model development program via *Pixel Counter Module*



Determination of column dimensions

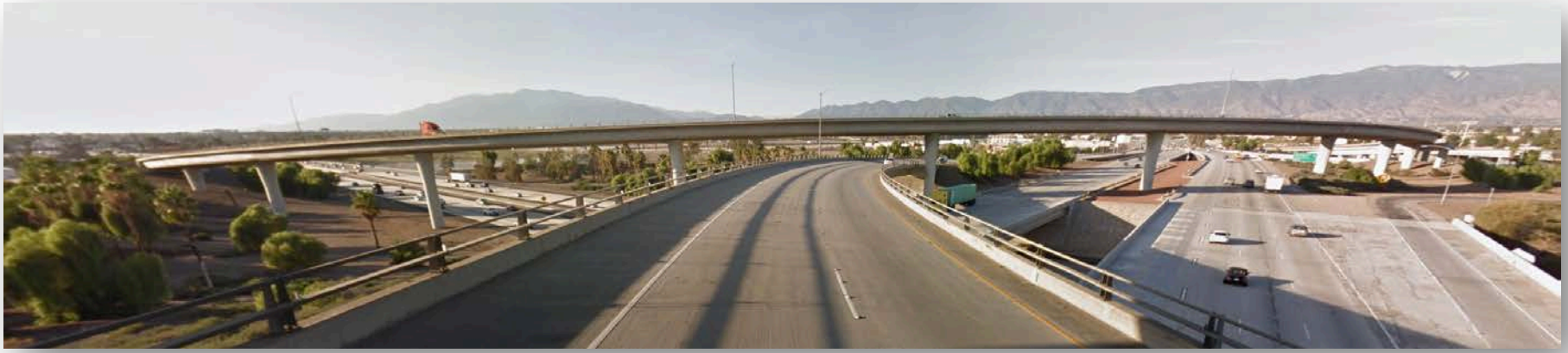
Validation study

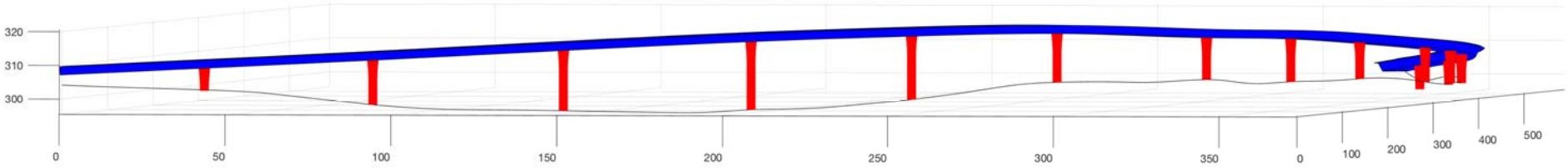
Resulting model



Validation study

Resulting model



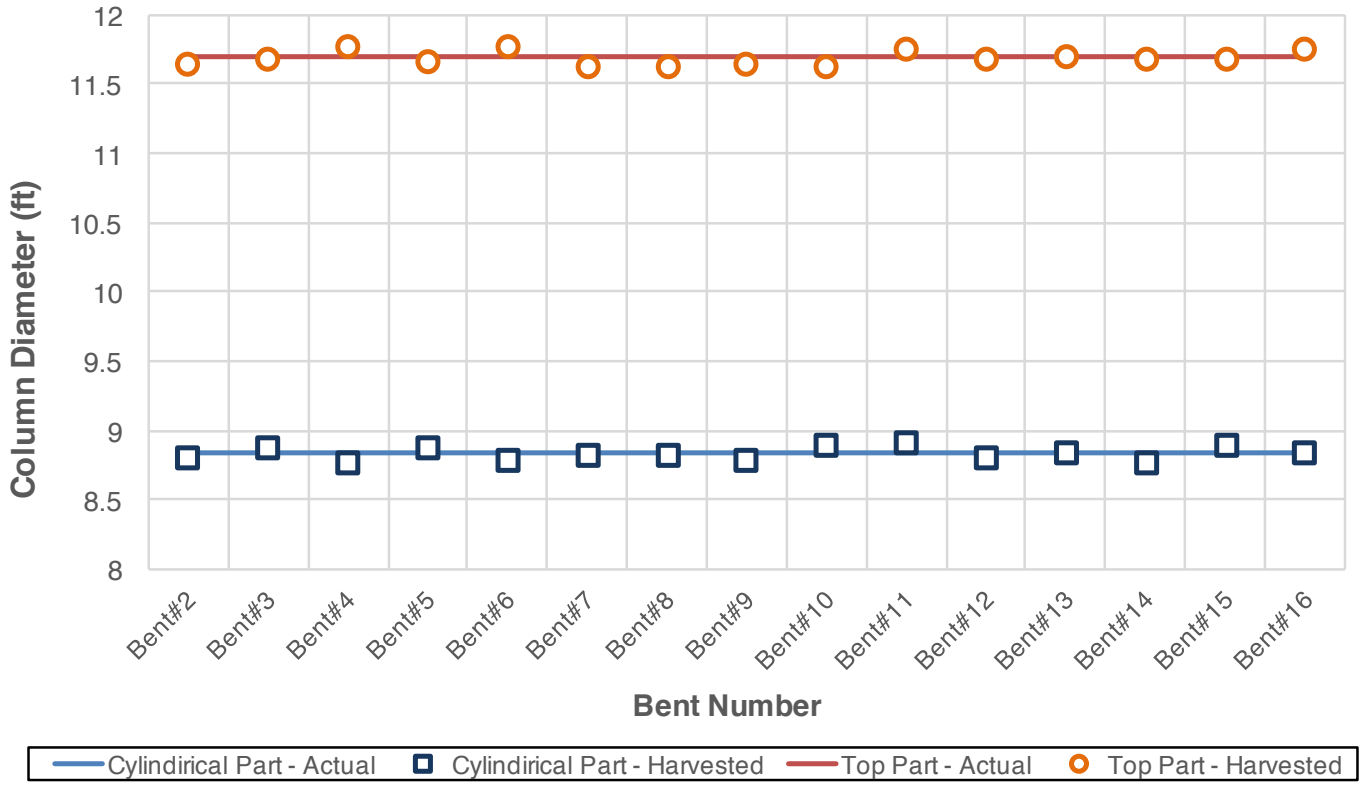


Validation study

harvested data vs. as-built: bridge deck elevation

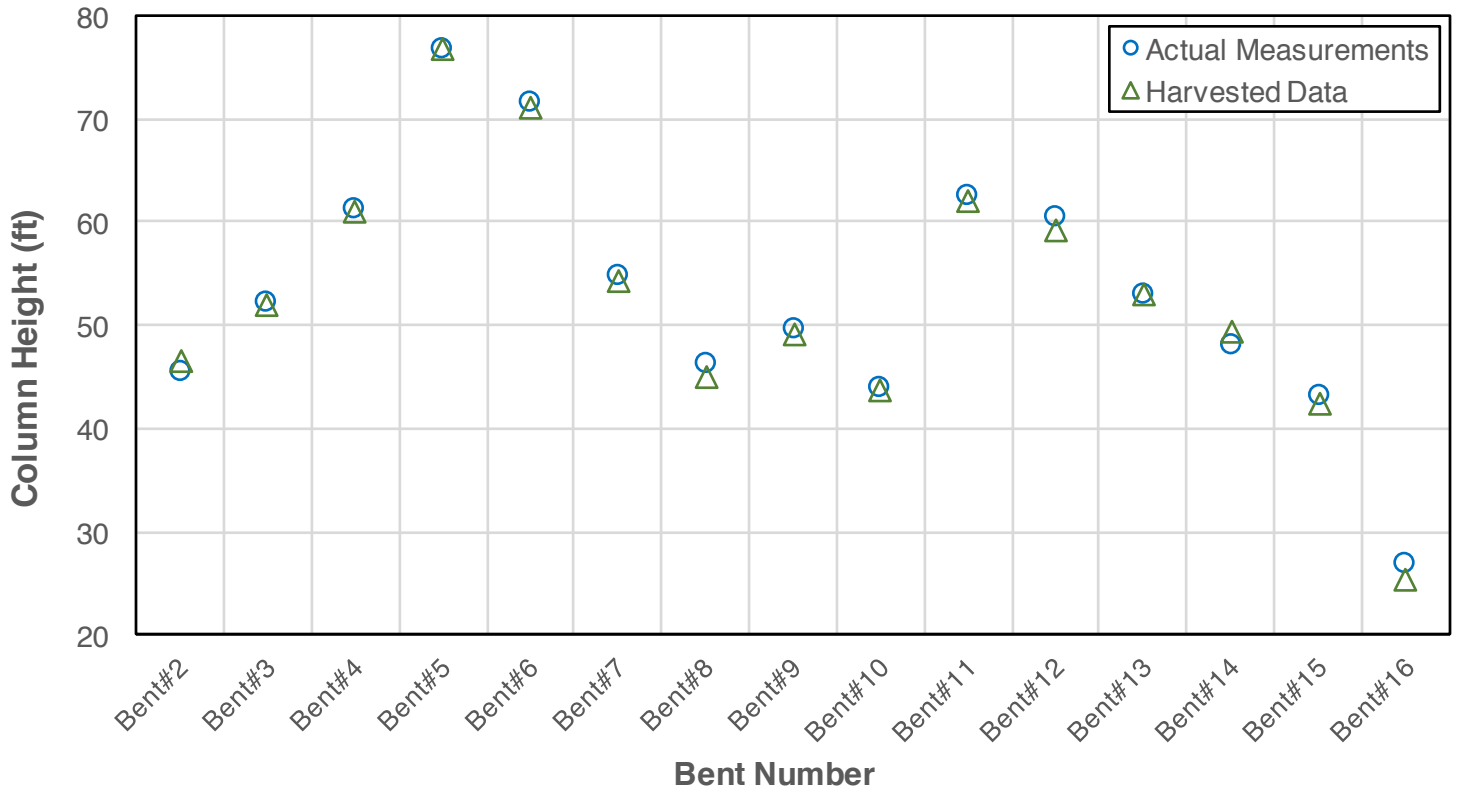
Validation study

harvested data vs. as-built: column diameters



Validation study

harvested data vs. as-built: column heights



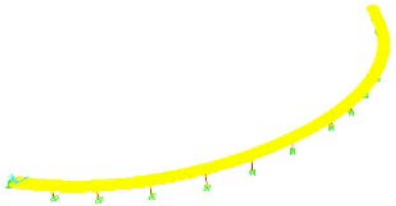
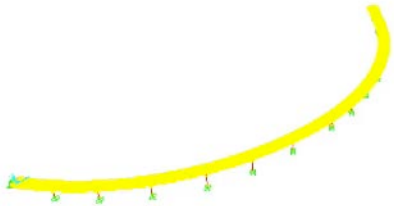
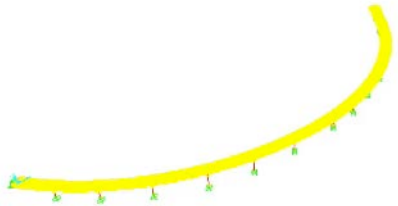
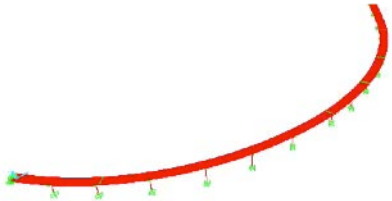
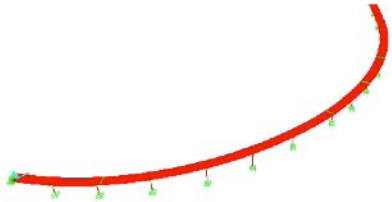
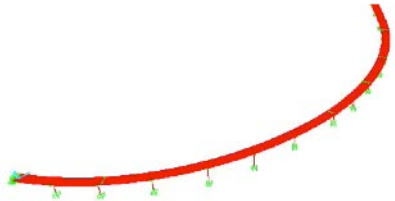
Validation study

harvested data vs. as-built: modal periods

	$T_{Image-Based}$ (sec)	$T_{As-Built}$ (sec)
Mode 1	1.357	1.528
Mode 2	1.182	1.294
Mode 3	1.028	1.091
Mode 4	0.947	1.019
Mode 5	0.892	0.942
Mode 6	0.836	0.881
Mode 7	0.784	0.807
Mode 8	0.746	0.788

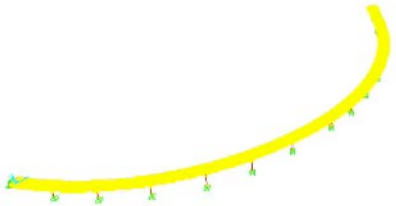
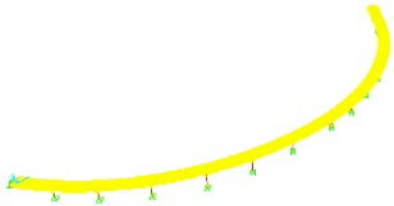
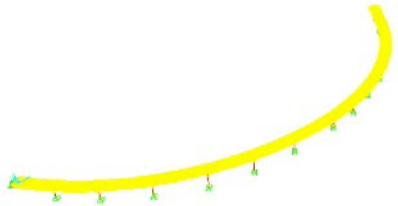
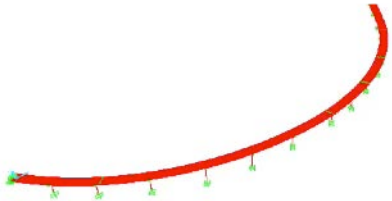
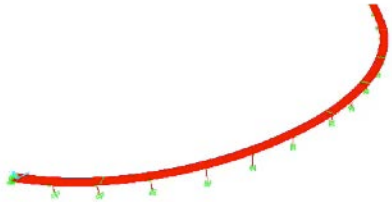
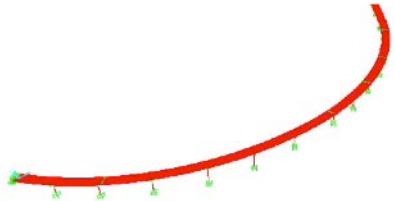
Validation study

harvested data vs. as-built: mode shapes

	Mode 1	Mode 2	Mode 3
Image-Based			
As-Built			

Validation study

harvested data vs. as-built: mode shapes

	Mode 1	Mode 2	Mode 3
Image-Based			
As-Built			

Sample Applications

Coronado Bridge, San Diego CA

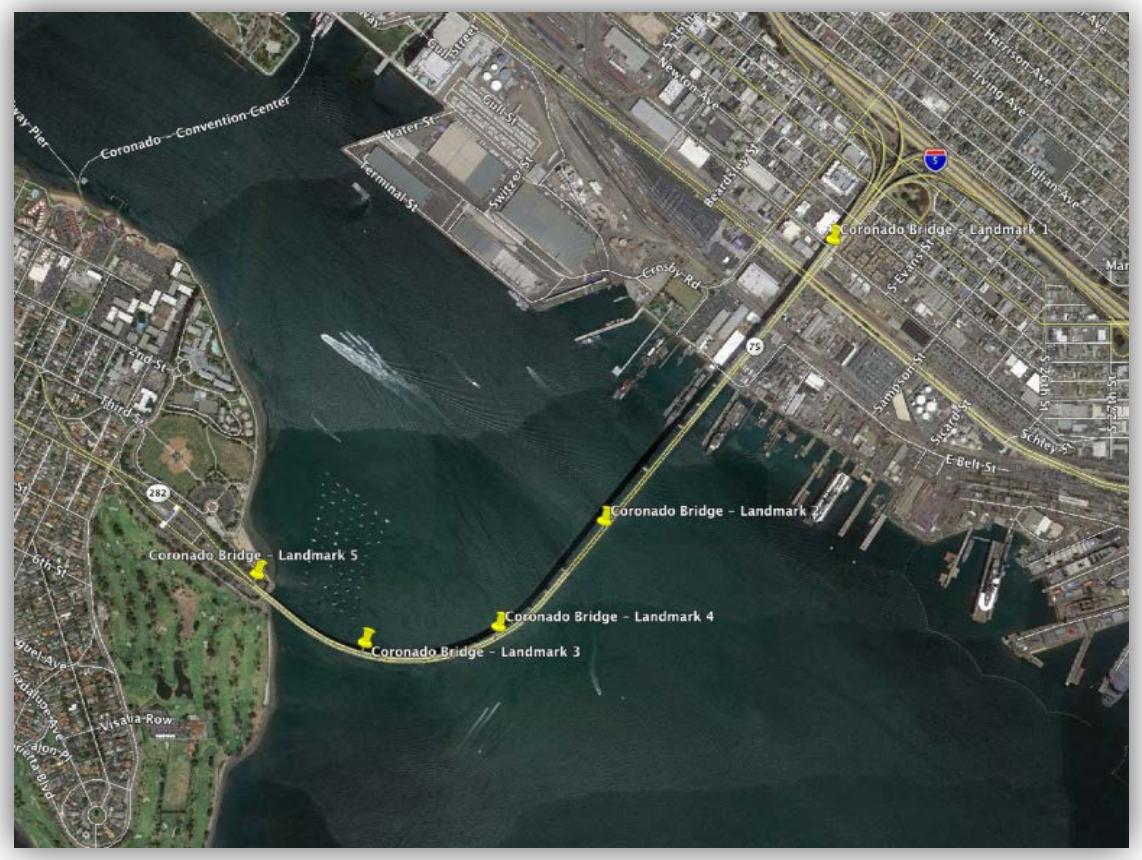
Wilshire Blvd/I-405N On-Ramp, Los Angeles, CA

Sample Application: San Diego – Coronado Bridge

UCLA

Sample Application: San Diego – Coronado Bridge

Selection of points along the bridge by the user



UCLA

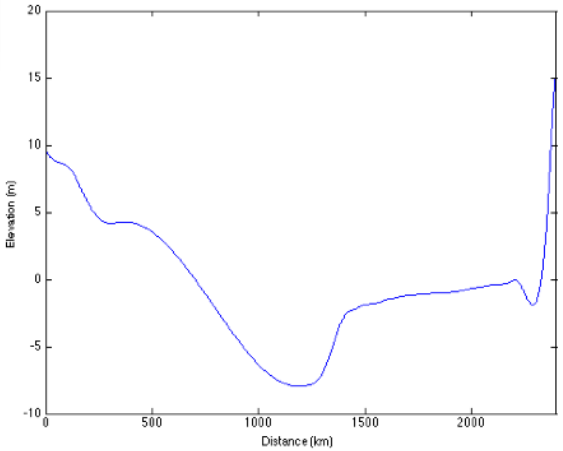
Sample Application: San Diego – Coronado Bridge

Initial processing of selected points by program

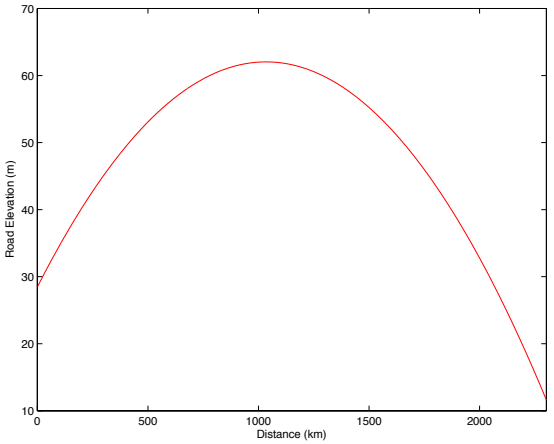
Calculation of bridge centerline curve

*Using ***UCLA*** automated image-based structural model development code

*Using ***UCLA*** automated image-based structural model development code



Determination of ground elevations



Determination of road elevations

*Using ***UCLA*** automated image-based structural model development code

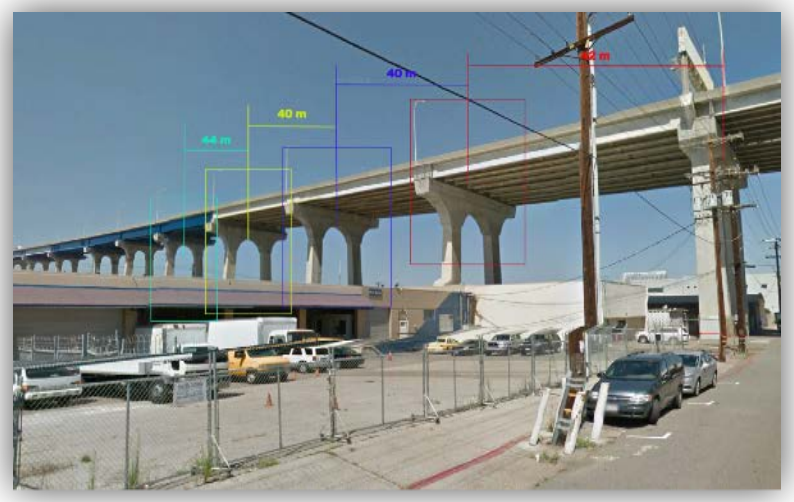
UCLA

Sample Application: San Diego – Coronado Bridge

Using image processing to identify bent locations and developing the wireframe model

Sample Application: San Diego – Coronado Bridge

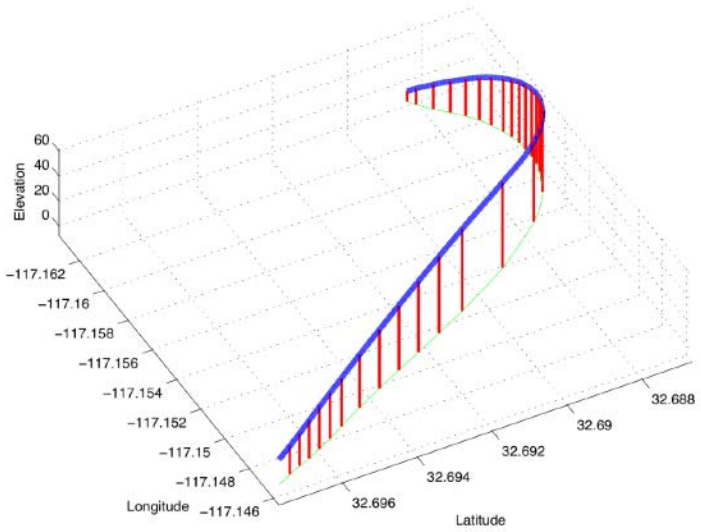
Using image processing to identify bent locations and developing the wireframe model



Identification of bent locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

*Using ***UCLA*** automated image-based structural model development program via *Wireframe Model Builder Module*



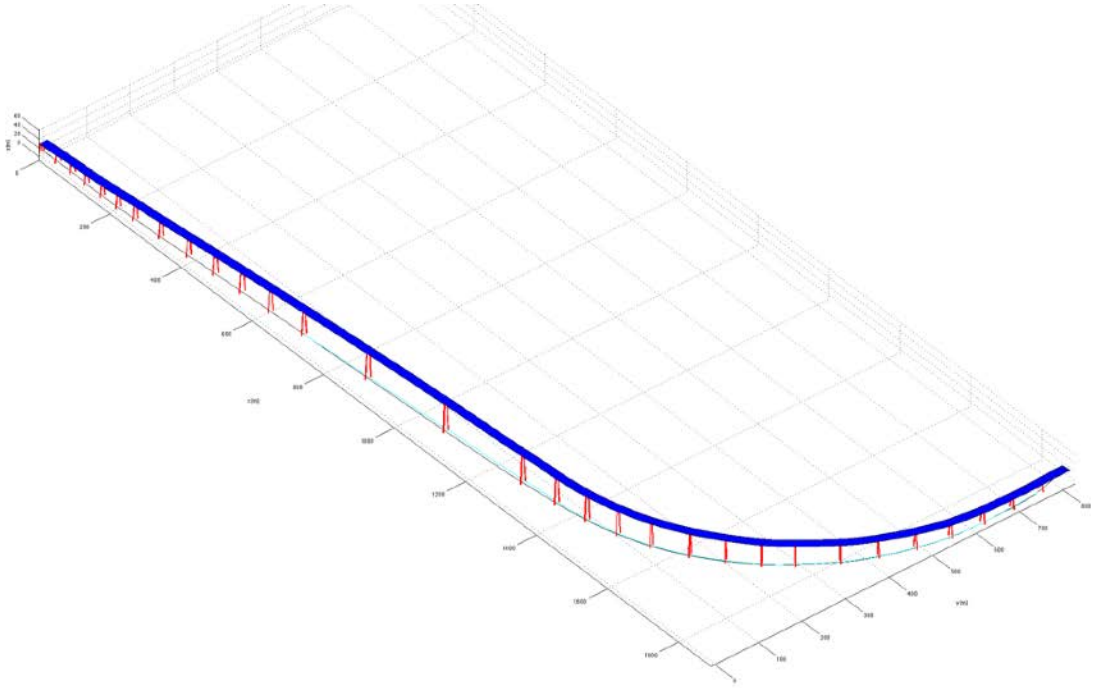
Establishing the preliminary wireframe model

Sample Application: San Diego – Coronado Bridge

Using image processing to identify bent locations and developing the wireframe model

Sample Application: San Diego – Coronado Bridge

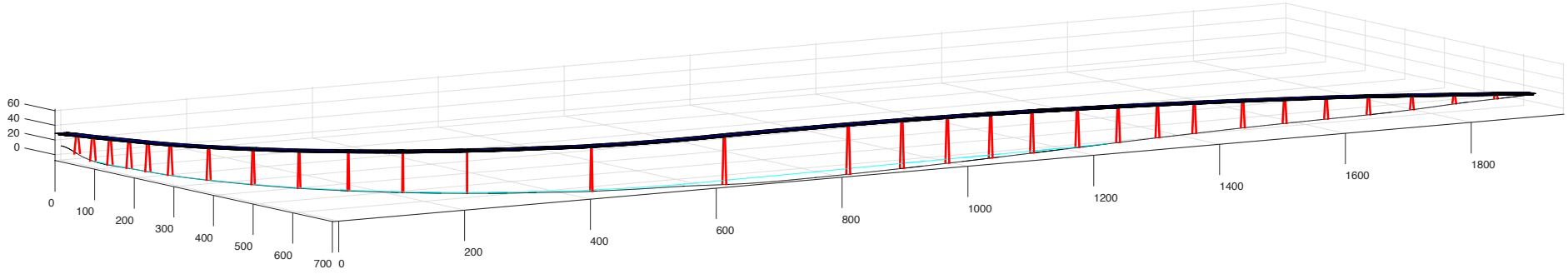
Using image processing to identify bent locations and developing the wireframe model



Final wireframe model

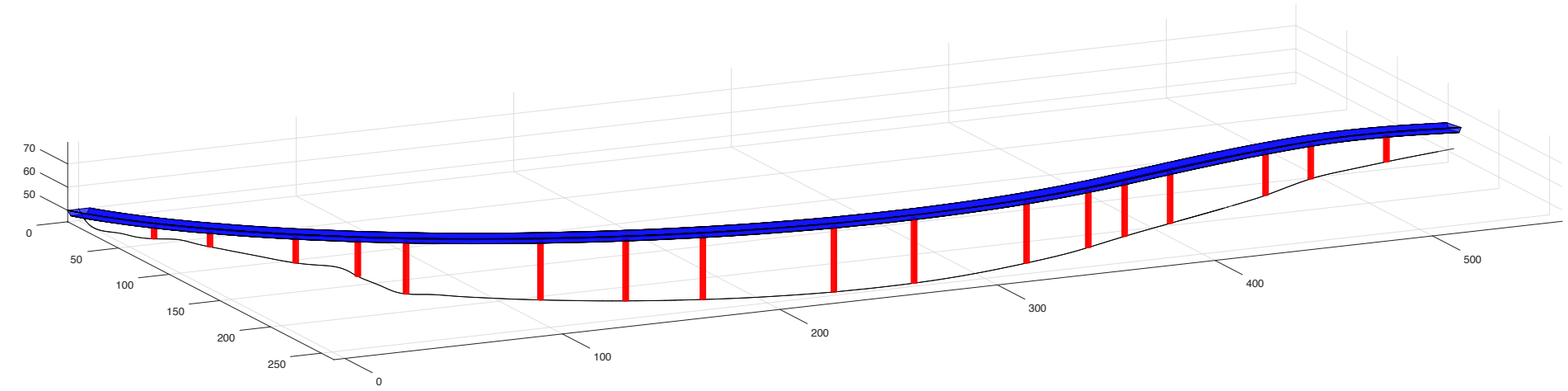
UCLA

Sample Application: Coronado Bridge, San Diego



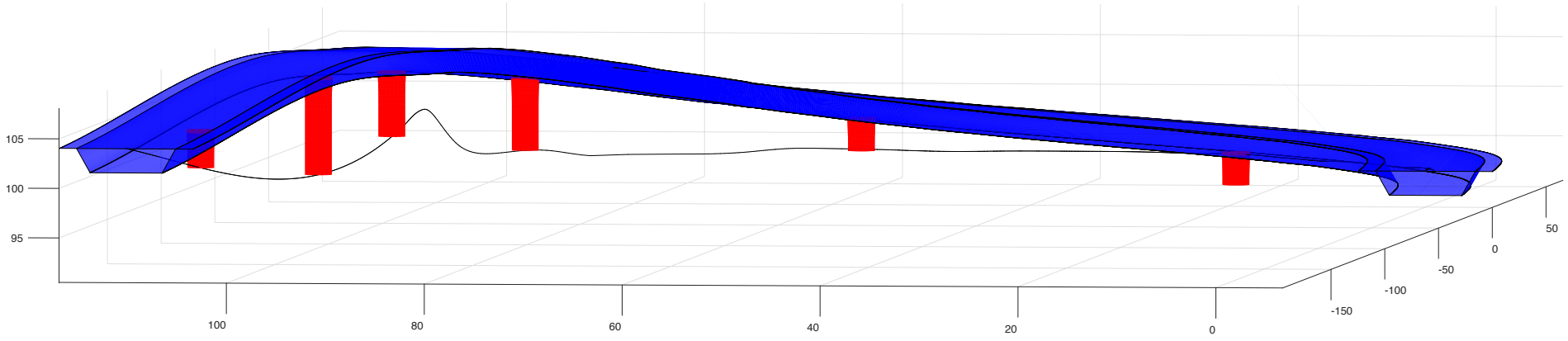
UCLA

Sample Application: LA I10/I405N Interchange



UCLA

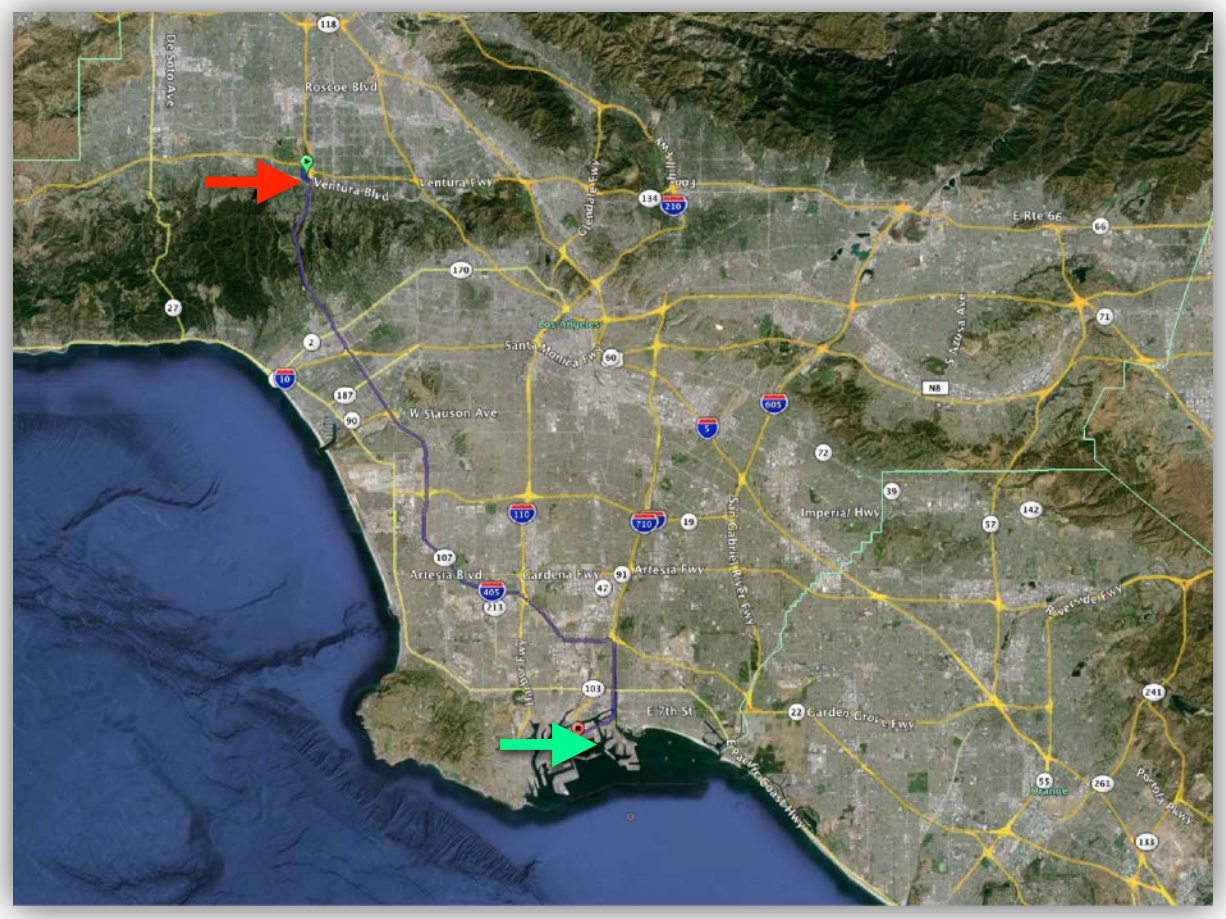
Sample Application: LA Wilshire/I-405N On-Ramp



Testbed Route

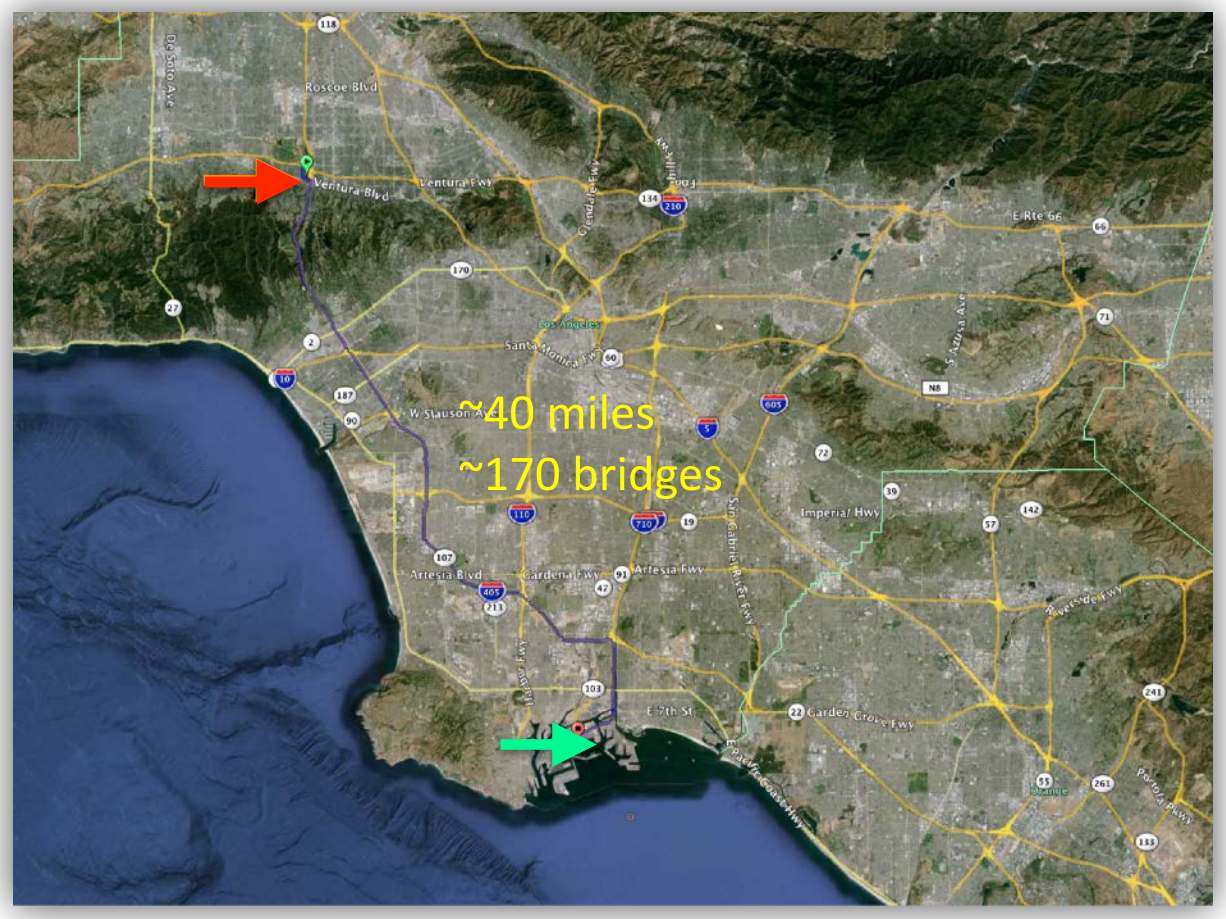
US-101/I-405 Interchange to Port of Los Angeles

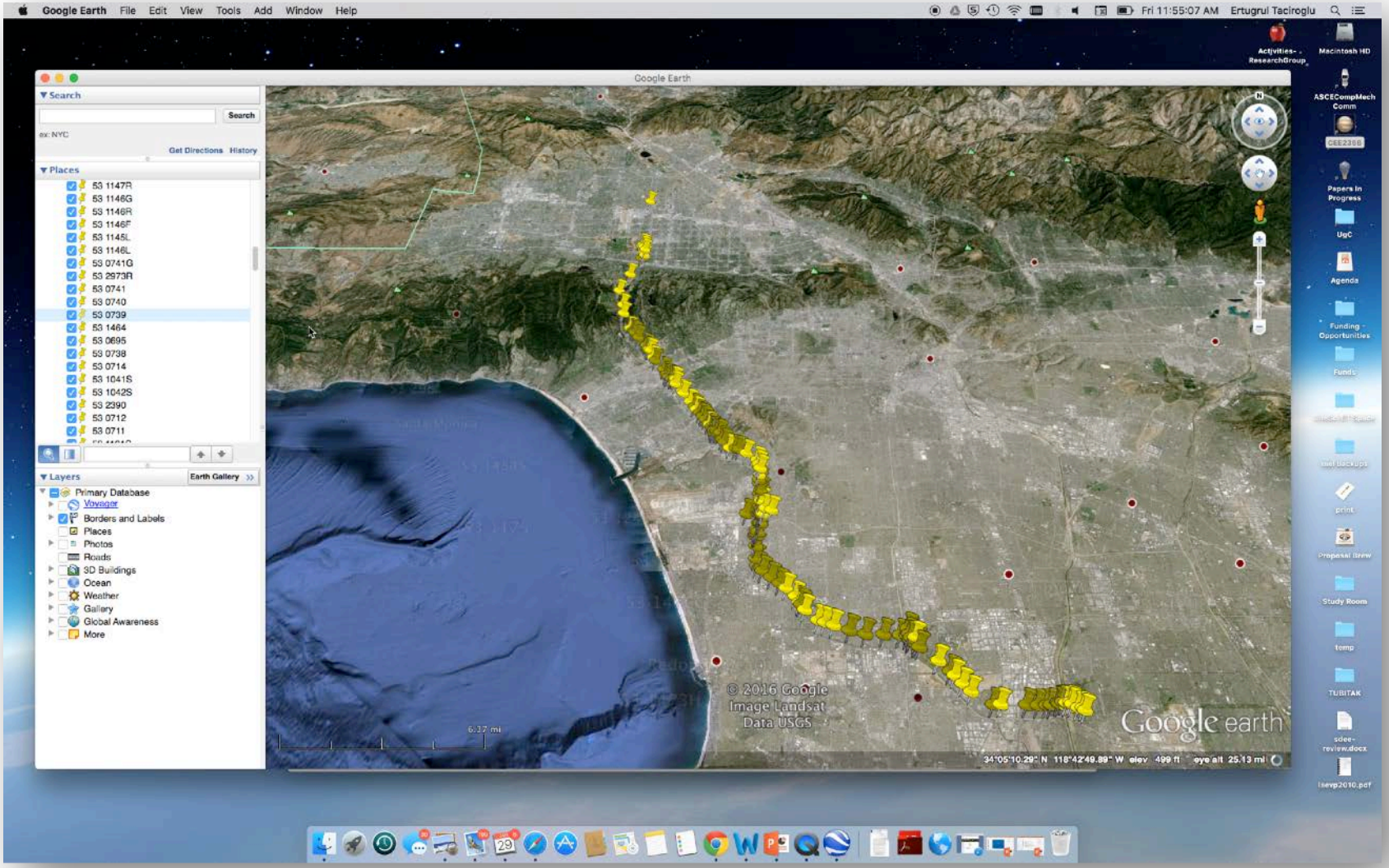
Regional assessment

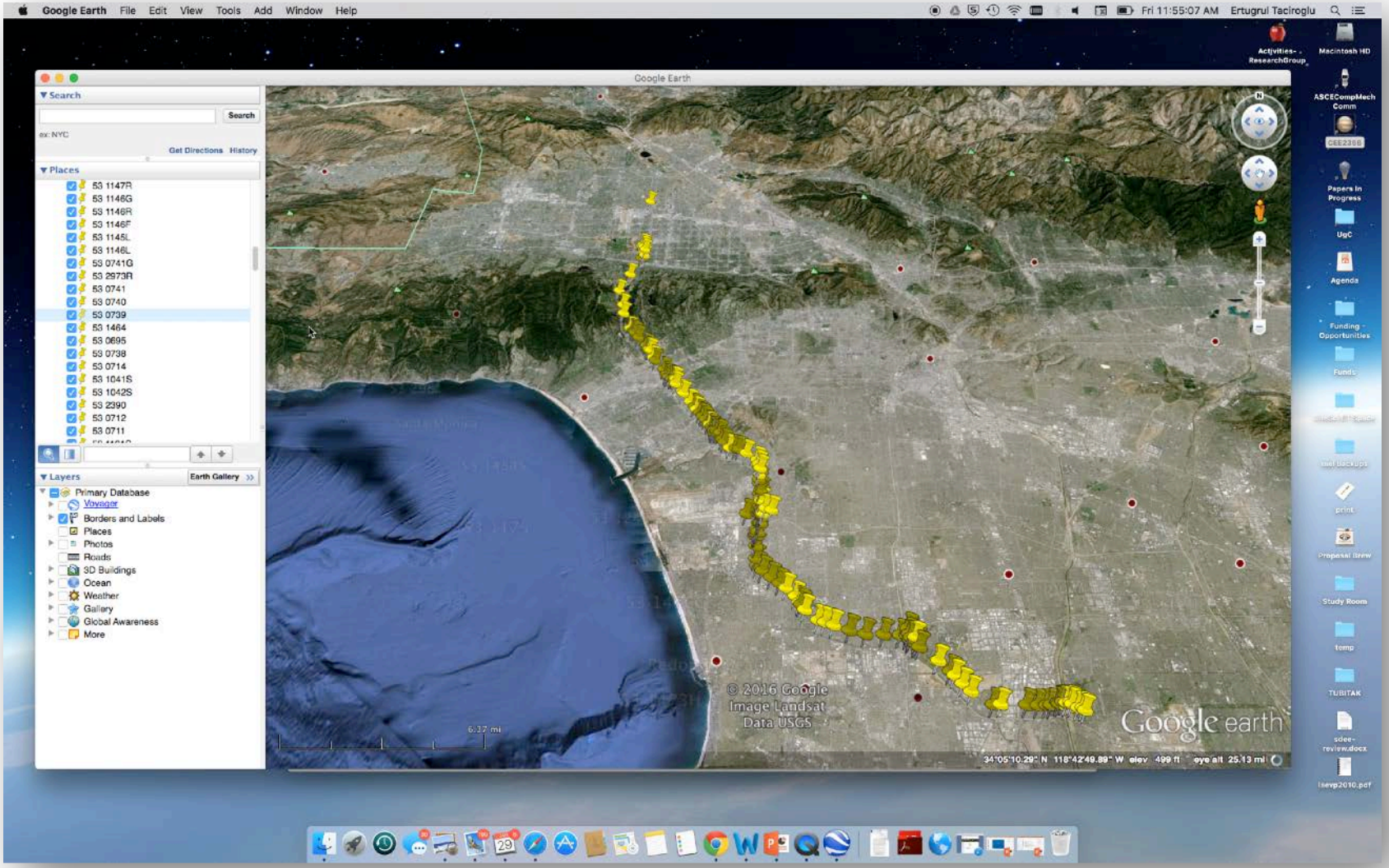


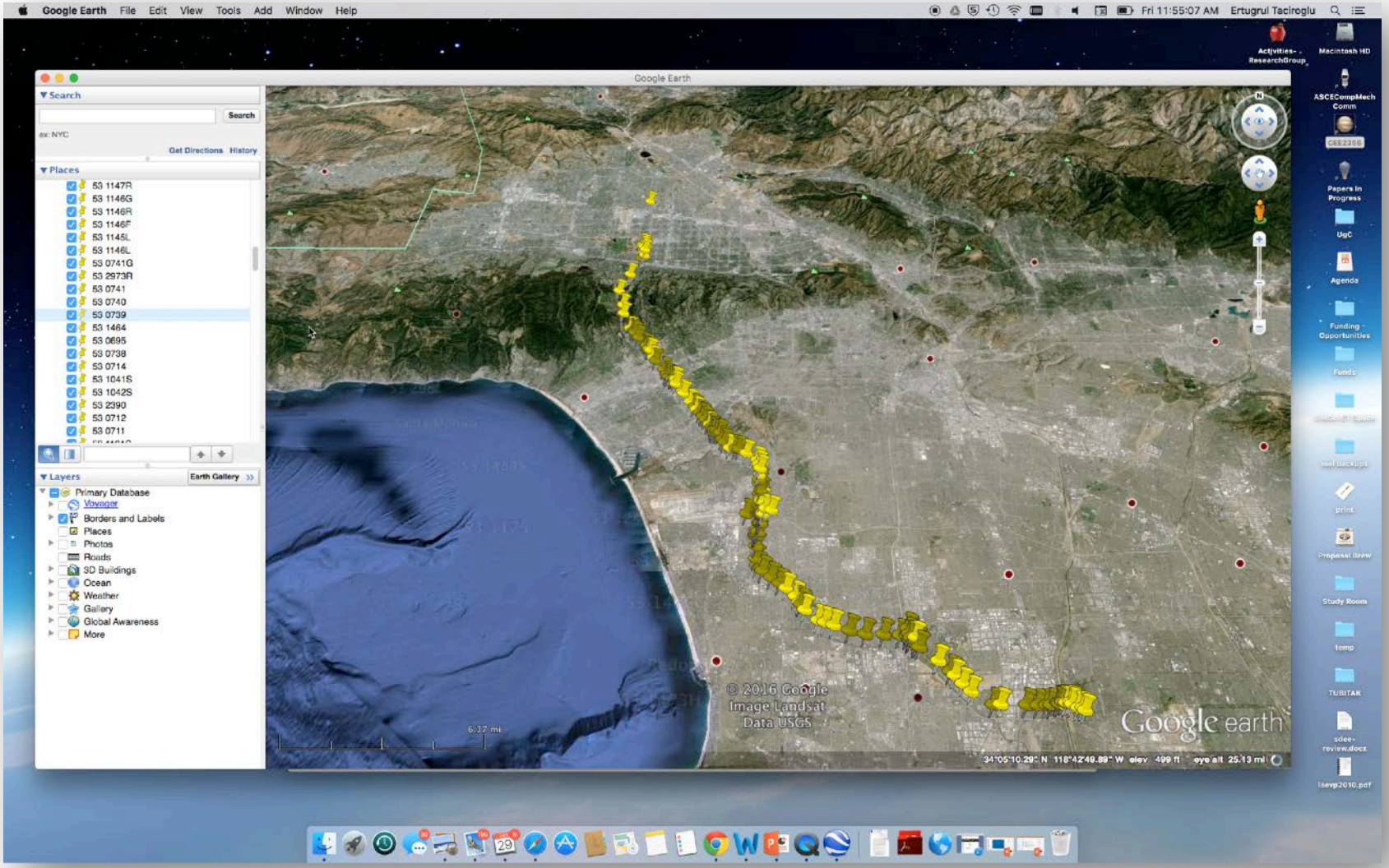
Regional assessment

US-101/I-405 Interchange to Port of Los Angeles



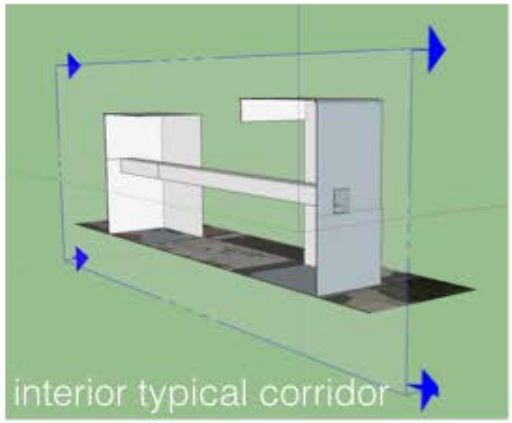

Google Earth File Edit View Tools Add Window Help
Fri 11:55:07 AM Ertugrul Taciroglu
Google Earth
Search
Get Directions History
Places
Layers
Earth Gallery
Primary Database
Voyager
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
© 2016 Google
Image Landsat
Data USGS
Google earth

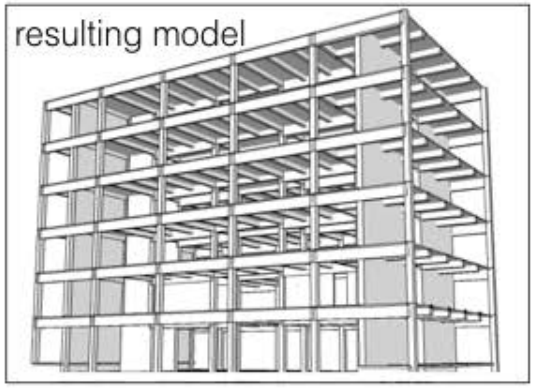

Google Earth File Edit View Tools Add Window Help
Fri 11:55:07 AM Ertugrul Taciroglu
Google Earth
Search
Get Directions History
Places
Layers
Earth Gallery
Primary Database
Voyager
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
© 2016 Google
Image Landsat
Data USGS
Google earth


Google Earth File Edit View Tools Add Window Help
Fri 11:55:07 AM Ertugrul Taciroglu
Google Earth
Search
Get Directions History
Places
Layers
Earth Gallery
Primary Database
Voyager
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
© 2016 Google
Image Landsat
Data USGS
Google earth

What about Buildings?

Building models from image data

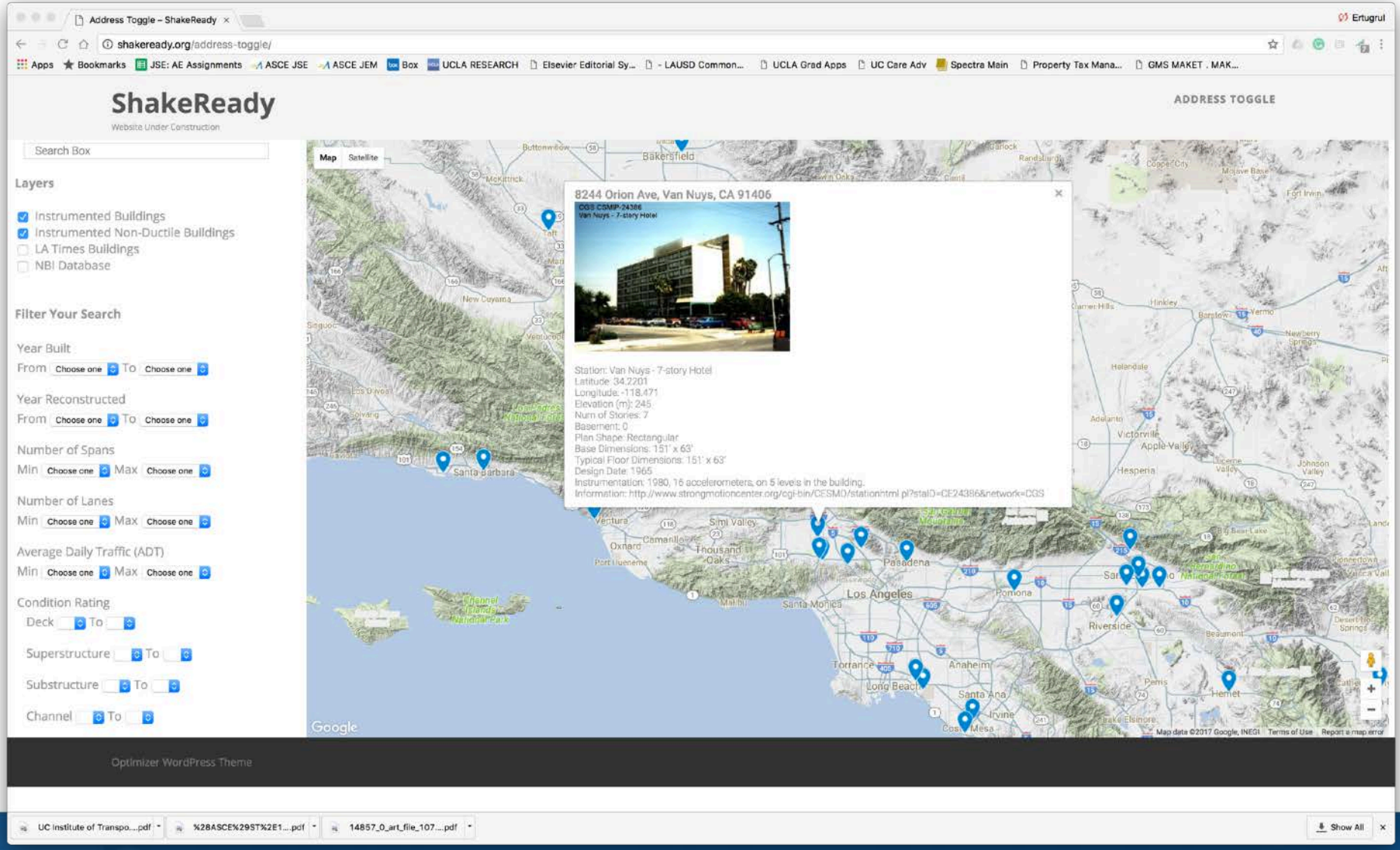




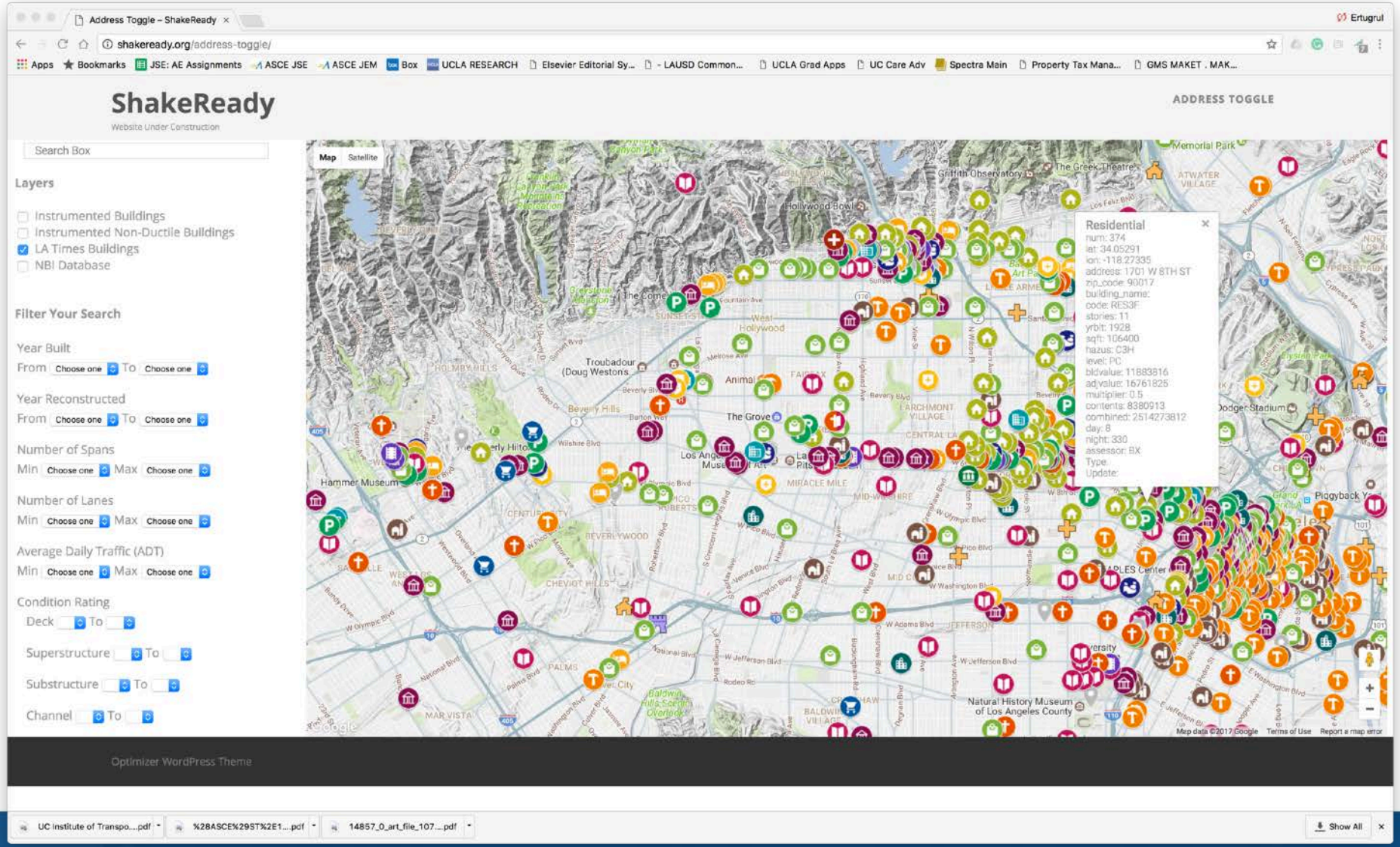
ShakeReady

a user interface under development

Building inventories



Building inventories



Thank you!

etacir@ucla.edu