

OpenSRA: Open-Source Seismic Risk Assessment Tool

Barry Zheng, PhD

Slate Geotechnical Consultants, Inc.

06/28/2022



Infrastructure

Visualization

General Information

GIS Data

Infrastructure

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

Input Variables

Results

Infrastructure (Limited to a maximum of 1,000 sites)

Pipelines

Wells and Caprocks

Above Ground Gas Infrastructure

Future Infrastructure

Load information from CSV File (headers in CSV file must match those shown in the table below)
Path to file:
Enter the IDs of one or more gas pipelines to analyze.
Define a range of gas pipelines with a dash and separate multiple gas pipelines with a comma.
Component Locations
Startpoint - Latitude: Endpoint - Latitude: Midpoint - Latitude:
Component Length (km): Startpoint - Longitude: Endpoint - Longitude: Midpoint - Longitude:

ID	LON_BEGIN	LAT_BEGIN	LON_END	LAT_END
1	-119.30749	34.36393	-119.308	34.36393
2	-119.308	34.36332	-119.30852	34.36332
3	-119.30852	34.36271	-119.30904	34.36271
4	-119.30904	34.3621	-119.30956	34.3621
5	-119.30956	34.3615	-119.30966	34.3615
6	-119.30966	34.36123	-119.3097	34.36123
7	-119.3097	34.36067	-119.30969	34.36067
8	-119.30969	34.36036	-119.30969	34.36036
9	-119.30969	34.36019	-119.30952	34.36019
10	-119.30952	34.35943	-119.30934	34.35943
11	-119.30934	34.35866	-119.30916	34.35866
12	-119.30916	34.3579	-119.30898	34.3579
13	-119.30898	34.35714	-119.30881	34.35714
14	-119.30881	34.35638	-119.30863	34.35638
15	-119.30863	34.35561	-119.30789	34.35561
16	-119.30789	34.35498	-119.30716	34.35498
17	-119.30716	34.35435	-119.30642	34.35435
18	-119.30642	34.35371	-119.30576	34.35371
19	-119.30576	34.35302	-119.30509	34.35302
20	-119.30509	34.35233	-119.30432	34.35233

OpenSRA: Open-Source Seismic Risk Assessment

Infrastructure (Limited to a maximum of 1,000 sites)

Pipelines

Wells and Caprocks

Above Ground Gas Infrastructure

Future Infrastructure

Load information from CSV File (headers in CSV file must match those shown in the table below)
Path to file:
Enter the IDs of one or more gas pipelines to analyze.
Define a range of gas pipelines with a dash and separate multiple gas pipelines with a comma.
Component Locations
Startpoint - Latitude: Endpoint - Latitude: Midpoint - Latitude:
Component Length (km): Startpoint - Longitude: Endpoint - Longitude: Midpoint - Longitude:

ID	LON_BEGIN	LAT_BEGIN	LON_END	LAT_END
1	-119.30749	34.36393	-119.308	34.36393
2	-119.308	34.36332	-119.30852	34.36332
3	-119.30852	34.36271	-119.30904	34.36271
4	-119.30904	34.3621	-119.30956	34.3621
5	-119.30956	34.3615	-119.30966	34.3615
6	-119.30966	34.36123	-119.3097	34.36123
7	-119.3097	34.36067	-119.30969	34.36067
8	-119.30969	34.36036	-119.30969	34.36036
9	-119.30969	34.36019	-119.30952	34.36019
10	-119.30952	34.35943	-119.30934	34.35943
11	-119.30934	34.35866	-119.30916	34.35866
12	-119.30916	34.3579	-119.30898	34.3579
13	-119.30898	34.35714	-119.30881	34.35714
14	-119.30881	34.35638	-119.30863	34.35638
15	-119.30863	34.35561	-119.30789	34.35561
16	-119.30789	34.35498	-119.30716	34.35498
17	-119.30716	34.35435	-119.30642	34.35435
18	-119.30642	34.35371	-119.30576	34.35371
19	-119.30576	34.35302	-119.30509	34.35302
20	-119.30509	34.35233	-119.30432	34.35233

OWNER	MAP_OWNER	LENGTH_MI	LENGTH_FT	INTERSTATE	LEGEND	DOE_MSID	SUBSYS_NM	PIPE_ID	COMMENTS
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				
calgas	SoCal Gas				Unknown Diameter SoCalGas				

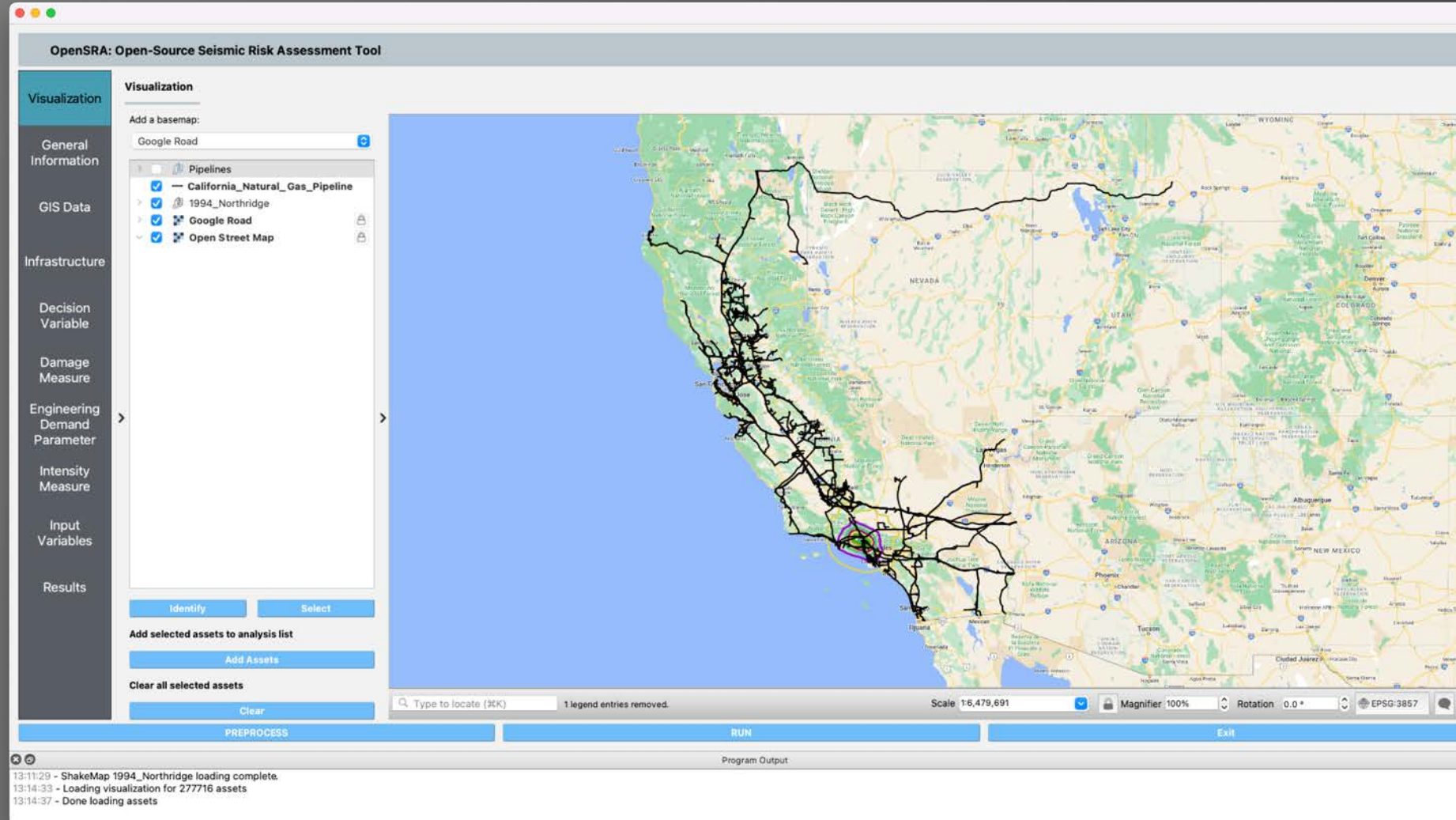
PREPROCESS

RUN

Exit



Infrastructure



Methodology

Visualization

General Information

GIS Data

Infrastructure

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

Input Variables

Results

Decision Variable (DV)

Pipe Rupture

Pipe Rupture

Available Method(s)

Bain et al.(2022)

Returns:

This method returns "probability of pipe rupture [prob_rupture]".

Upstream Dependencies:

This method requires "pipe strain [pipe_strain]" from the "Damage Measure - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. d_pipe:

[mm] pipe outside diameter

2. t_pipe:

[mm] pipe wall thickness

3. sigma_y:

[kPa] pipe yield stress

4. op_press:

[kPa] pipe internal operating pressure

5. welding:

flag for welding - "True" for welded,"False" for seamless or SMLS

6. steel_grade:

"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

List of Cases to Run

BainEtal2022 - weight=1

Model Weight: 1.0

Aleatory Variability: Preferred

Epistemic Uncertainty: Preferred

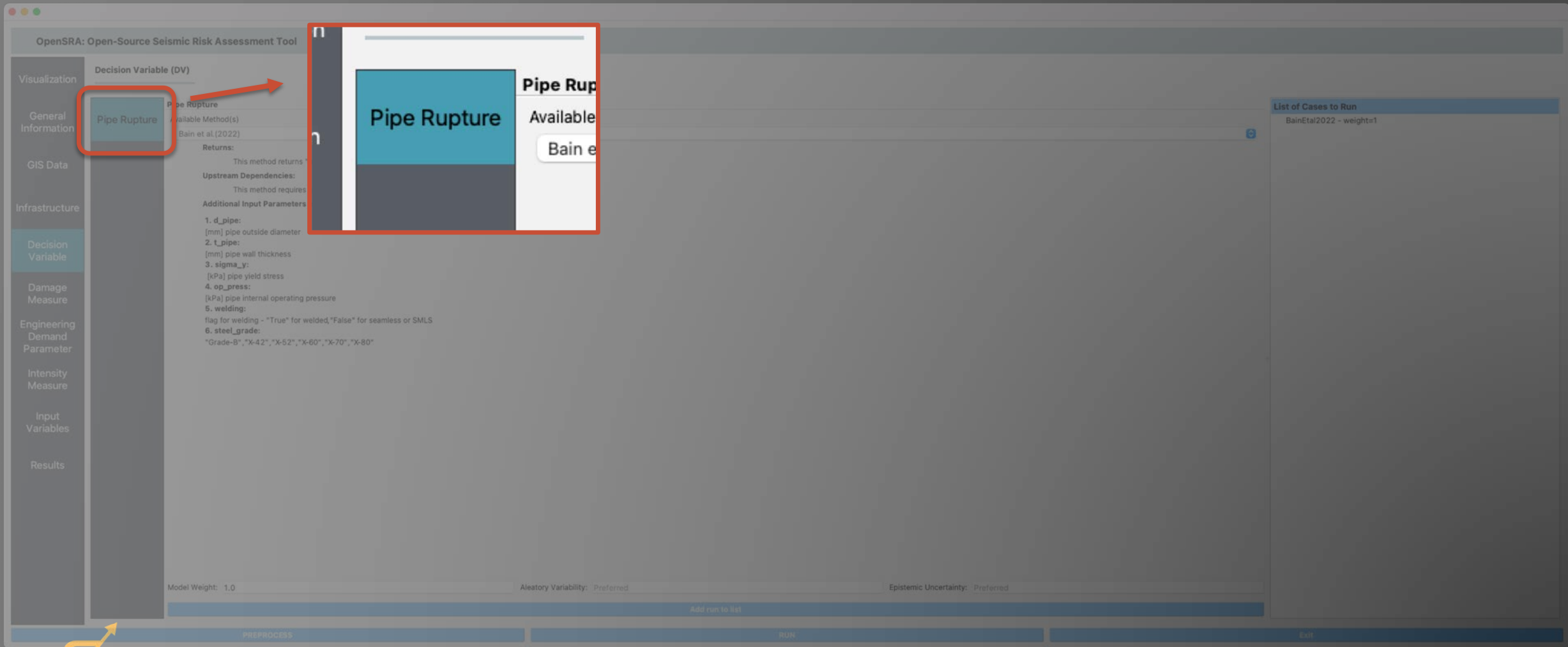
Add run to list

PREPROCESS

RUN

Exit

Methodology



Methodology

The screenshot displays the OpenSRA (Open-Source Seismic Risk Assessment Tool) interface. On the left is a vertical sidebar with navigation options: Visualization, General Information, GIS Data, Infrastructure, Decision Variable, Damage Measure, Engineering Demand Parameter, Intensity Measure, Input Variables, and Results. The 'Decision Variable' option is currently selected. The main window is titled 'OpenSRA: Open-Source Seismic Risk Assessment Tool' and features a 'Decision Variable (DV)' section. Within this section, 'Pipe Rupture' is selected. A red box highlights the 'Available Method(s)' dropdown menu, which currently shows 'Bain et al.(2022)'. A red arrow points from this dropdown to a larger, detailed view of the 'Pipe Rupture' methodology. This detailed view, also outlined in red, lists the available method(s) as 'Bain et al.(2022)', specifies the return as 'This method returns the probability of pipe rupture (prob_rupture)', and lists upstream dependencies including pipe strain (pipe_strain) from the 'Damage Measure' section. It also lists additional input parameters: d_pipe (pipe outside diameter), t_pipe (pipe wall thickness), sigma_y (pipe yield stress), op_press (pipe internal operating pressure), welding (flag for welding), and steel_grade (pipe steel grade). The bottom of the interface includes a status bar with 'Model Weight: 1.0', 'Aleatory Variability: Preferred', and 'Epistemic Uncertainty: Preferred'. A 'PREPROCESS' button is visible at the bottom left, and a 'RUN' button is at the bottom center. A 'List of Cases to Run' panel on the right shows 'BainEtal2022 - weight=1'.

OpenSRA: Open-Source Seismic Risk Assessment Tool

Decision Variable (DV)

Pipe Rupture

Available Method(s)

Bain et al.(2022)

Returns:

This method returns the probability of pipe rupture (prob_rupture).

Upstream Dependencies:

This method requires "pipe strain (pipe_strain)" from the "Damage Measure" section.

Additional Input Parameters (see the "Input Variables" tab):

1. d_pipe: [mm] pipe outside diameter
2. t_pipe: [mm] pipe wall thickness
3. sigma_y: [kPa] pipe yield stress
4. op_press: [kPa] pipe internal operating pressure
5. welding: flag for welding - "True" for welded, "False" for seamless or SMLS
6. steel_grade: "Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

Model Weight: 1.0

Aleatory Variability: Preferred

Epistemic Uncertainty: Preferred

PREPROCESS

RUN

EXIT

List of Cases to Run

BainEtal2022 - weight=1



Methodology

The screenshot displays the OpenSRA (Open-Source Seismic Risk Assessment Tool) interface. On the left is a vertical sidebar with navigation options: Visualization, General Information, GIS Data, Infrastructure, Decision Variable (highlighted), Damage Measure, Engineering Demand Parameter, Intensity Measure, Input Variables, and Results. The main panel is titled 'Decision Variable (DV)' and shows 'Pipe Rupture' as the selected method. A red box highlights the method's details, with an arrow pointing to a larger callout box on the right. The details include the return value, upstream dependencies, and a list of input parameters. At the bottom, there are controls for model weight, variability, and uncertainty, along with buttons for 'PREPROCESS', 'RUN', and 'EXIT'.

OpenSRA: Open-Source Seismic Risk Assessment Tool

Decision Variable (DV)

Pipe Rupture

Available Method(s)

Method Description:

Returns:
This method returns "probability of pipe rupture [prob_rupture]".

Upstream Dependencies:
This method requires "pipe strain [pipe_strain]" from the "Damage Measure - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. **d_pipe:**
[mm] pipe outside diameter
2. **t_pipe:**
[mm] pipe wall thickness
3. **sigma_y:**
[kPa] pipe yield stress
4. **op_press:**
[kPa] pipe internal operating pressure
5. **welding:**
flag for welding - "True" for welded, "False" for seamless or SMLS
6. **steel_grade:**
"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

List of Cases to Run

BainEtal2022 - weight=1

Model Weight: 1.0 Aleatory Variability: Preferred Epistemic Uncertainty: Preferred

PREPROCESS RUN EXIT

et al.(2022)

Returns:
This method returns "probability of pipe rupture [prob_rupture]".

Upstream Dependencies:
This method requires "pipe strain [pipe_strain]" from the "Damage Measure - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. **d_pipe:**

Methodology

OpenSRA: Open-Source Seismic Risk Assessment Tool

Decision Variable (DV)

Pipe Rupture

Available Method(s)

Bain et al.(2022)

Returns:

This method returns "probability of pipe rupture (prob_rupture)".

Upstream Dependencies:

This method requires "pipe strain [pipe_strain]" from the "Damage Measure" - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. **d_pipe:**
[mm] pipe outside diameter
2. **t_pipe:**
[mm] pipe wall thickness
3. **sigma_y:**
[kPa] pipe yield stress
4. **op_press:**
[kPa] pipe internal operating pressure
5. **welding:**
flag for welding - "True" for welded,"False" for seamless or SMLS
6. **steel_grade:**
"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

This method requires "pipe strain [pipe_strain]" from the "Damage Measure" - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. **d_pipe:**
[mm] pipe outside diameter
2. **t_pipe:**
[mm] pipe wall thickness
3. **sigma_y:**
[kPa] pipe yield stress
4. **op_press:**
[kPa] pipe internal operating pressure
5. **welding:**
flag for welding - "True" for welded,"False" for seamless or SMLS
6. **steel_grade:**
"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

Model Weight: 1.0

Alteatory Variability: Preferred

Epistemic Uncertainty: Preferred

Add run to list

PREPROCESS

RUN

EXIT

List of Cases to Run

BainEtal2022 - weight=1



Methodology

OpenSRA: Open-Source Seismic Risk Assessment Tool

Decision Variable (DV)

Pipe Rupture

Available Method(s)

Bain et al.(2022)

Returns:

This method returns "probability of pipe rupture (prob_rupture)".

Upstream Dependencies:

This method requires "pipe strain [pipe_strain]" from the "Damage Measure" - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. **d_pipe:**
[mm] pipe outside diameter
2. **t_pipe:**
[mm] pipe wall thickness
3. **sigma_y:**
[kPa] pipe yield stress
4. **op_press:**
[kPa] pipe internal operating pressure
5. **welding:**
flag for welding - "True" for welded,"False" for seamless or SMLS
6. **steel_grade:**
"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

This method requires "pipe strain [pipe_strain]" from the "Damage Measure" - Pipe Strain" tab.

Additional Input Parameters (see the "Input Variables" tab):

1. **d_pipe:**
[mm] pipe outside diameter
2. **t_pipe:**
[mm] pipe wall thickness
3. **sigma_y:**
[kPa] pipe yield stress
4. **op_press:**
[kPa] pipe internal operating pressure
5. **welding:**
flag for welding - "True" for welded,"False" for seamless or SMLS
6. **steel_grade:**
"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

Model Weight: 1.0

Alteatory Variability: Preferred

Epistemic Uncertainty: Preferred

Add run to list

PREPROCESS

RUN

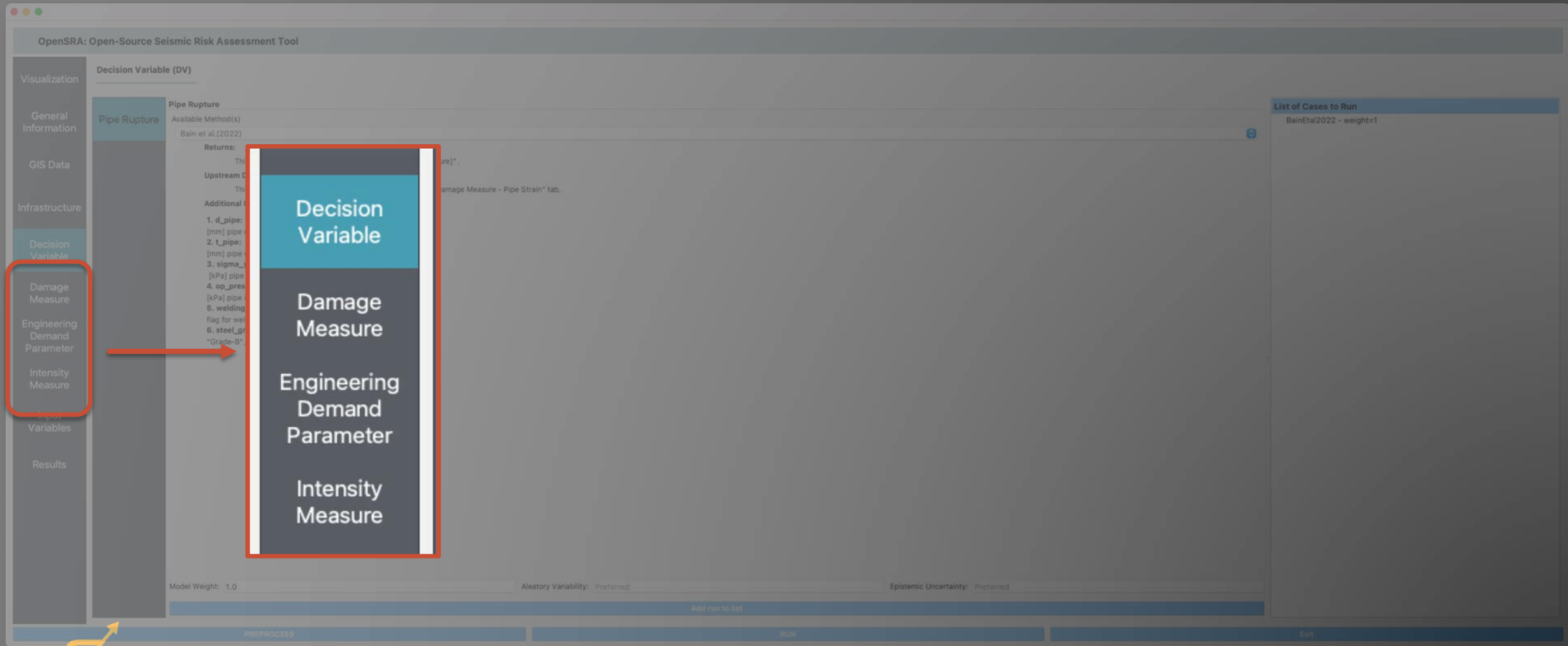
EXIT

List of Cases to Run

BainEtal2022 - weight=1

Input Variables

Methodology



Uncertainty in Inputs Parameters

Visualization

General Information

GIS Data

Infrastructure

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

Input Variables

Results

OpenSRA: Open-Source Seismic Risk Assessment Tool

Input Variables

Random Variables									
Name	Description	From Model	Source	Distribution Type	Mean or Median	Sigma	CoV	Distribution Min	Distribution Max
d_pipe	[mm] pipe outside diameter	Pipe Rupture-BainEtal2022	From Infrastructure Table	Normal	DIAMETER	1		1	50
op_press	[kPa] pipe internal operating pressure	Pipe Rupture-BainEtal2022	Preferred						
sigma_y	[kPa] pipe yield stress	Pipe Rupture-BainEtal2022	Preferred						
t_pipe	[mm] pipe wall thickness	Pipe Rupture-BainEtal2022	Preferred						
dist_water	[km] distance to nearest water body	Ground Settlement-Hazus2014	From user-provided GIS maps	Lognormal	DistWater.shp	0.5			

Constant or Fixed Variables

Name	Description	From Model	Source	Value
steel_grade	"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"	Pipe Rupture-BainEtal2022		
welding	flag for welding - "True" for welded, "False" for seamless or SMLS	Pipe Rupture-BainEtal2022		
liq_susc	liquefaction susceptibility category (none,very low,low,moderate,high,very high)	Ground Settlement-Hazus2014		

Instructions for using this tab

PREPROCESS

RUN

Exit



Uncertainty in Inputs Parameters

OpenSRA: Open-Source Seismic Risk Assessment Tool

Visualization

General Information

GIS Data

Infrastructure

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

Input Variables

Results

Random Variables									
Name	Description	From Model	Source	Distribution Type	Mean or Median	Sigma	CoV	Distribution Min	Distribution Max
d_pipe	[mm] pipe outside diameter	Pipe Rupture-BainEtal2022	From Infrastructure Table	Normal	DIAMETER	1		1	50
op_press	[kPa] pipe internal operating pressure	Pipe Rupture-BainEtal2022	Preferred						
sigma_y	[kPa] pipe yield stress	Pipe Rupture-BainEtal2022	Preferred						
t_pipe	[mm] pipe wall thickness	Pipe Rupture-BainEtal2022	Preferred						
dist_water	[km] distance to nearest water body	Ground Settlement-Hazus2014	From user-provided GIS maps	Lognormal	DistWater.shp	0.5			

Constant or Fixed Variables			
Name	Description	From Model	Source
steel_grade	"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"	Pipe Rupture-BainEtal2022	Preferred
welding	Flag for welding - "True" for welded, "False" for seamless or SMLS	Pipe Rupture-BainEtal2022	Preferred
liq_susc	liquefaction susceptibility category (none, very low, low, moderate, high, very high)	Ground Settlement-Hazus2014	Preferred

Instructions for using this tab

Input variables

Name	Description	From Model
d_pipe	[mm] pipe outside diameter	Pipe Rupture-BainEtal2022
op_press	[kPa] pipe internal operating pressure	Pipe Rupture-BainEtal2022
sigma_y	[kPa] pipe yield stress	Pipe Rupture-BainEtal2022
t_pipe	[mm] pipe wall thickness	Pipe Rupture-BainEtal2022
dist_water	[km] distance to nearest water body	Ground Settlement-Hazus2014

Name	Description
steel_grade	"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"

PREPROCESS RUN EXIT



Uncertainty in Inputs Parameters

Visualization

General Information

GIS Data

Infrastructure

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

Input Variables

Results

OpenSRA: Open-Source Seismic Risk Assessment Tool

Input Variables

Name	Description	From Model	Source	Distribution Type	Mean or Median	Sigma	CoV	Distribution Min	Distribution Max
d_pipe	[mm] pipe outside diameter	Pipe Rupture-BainEtal2022	From Infrastructure Table	Normal	DIAMETER	1		1	50
op_press	[kPa] pipe internal operating pressure	Pipe Rupture-BainEtal2022	Preferred						
sigma_y	[kPa] pipe yield stress	Pipe Rupture-BainEtal2022	Preferred						
t_pipe	[mm] pipe wall thickness	Pipe Rupture-BainEtal2022	Preferred						
dist_water	[km] distance to nearest water body	Ground Settlement-Hazus2014	From user-provided GIS maps	Lognormal	DistWater.shp	0.5			

Constant or Fixed Variables

Name	Description	From Model	Source	Value
steel_grade	"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"	Pipe Rupture-BainEtal2022	Preferred	
welding	flag for welding - "True" for welded, "False" for seamless or SMLS	Pipe Rupture-BainEtal2022	Preferred	
liq_susc	liquefaction susceptibility category (none,very low,low,moderate,high,very high)	Ground Settlement-Hazus2014	Preferred	

Instructions for using this tab

Random Variables

Source	Distribution Type	Mean or Median	Sigma
From Infrastructure Table	Normal	DIAMETER	1
Preferred			
Preferred			
Preferred			
14 From user-provided GIS maps	Lognormal	DistWater.shp	0.5

Constant or Fixed Variables

Description	From Model	Source
X-60", "X-70", "X-80"	Pipe Rupture-BainEtal2022	Preferred

PREPROCESS

RUN

EXIT



Uncertainty in Inputs Parameters

Visualization

General Information

GIS Data

Infrastructure

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

Input Variables

Results

OpensRA: Open-Source Seismic Risk Assessment Tool

Input Variables

Random Variables									
Name	Description	From Model	Source	Distribution Type	Mean or Median	Sigma	CoV	Distribution Min	Distribution Max
d_pipe	[mm] pipe outside diameter	Pipe Rupture-BainEtal2022	From Infrastructure Table	Normal	DIAMETER	1		1	50
op_press	[kPa] pipe internal operating pressure	Pipe Rupture-BainEtal2022	Preferred						
sigma_y	[kPa] pipe yield stress	Pipe Rupture-BainEtal2022	Preferred						
t_pipe	[mm] pipe wall thickness	Pipe Rupture-BainEtal2022	Preferred						
dist_water	[km] distance to nearest water body	Ground Settlement-Hazus2014	From user-provided GIS maps	Lognormal	DistWater.shp	0.5			

Constant or Fixed Variables

Name	Description	From Model	Source	Value
steel_grade	"Grade-B", "X-42", "X-52", "X-60", "X-70", "X-80"	Pipe Rupture-BainEtal2022		
welding	flag for welding - "True" for welded, "False" for seamless or SMLS	Pipe Rupture-BainEtal2022		
liq_susc	liquefaction susceptibility category (none,very low,low,moderate,high,very high)	Ground Settlement-Hazus2014		

Instructions for using this tab

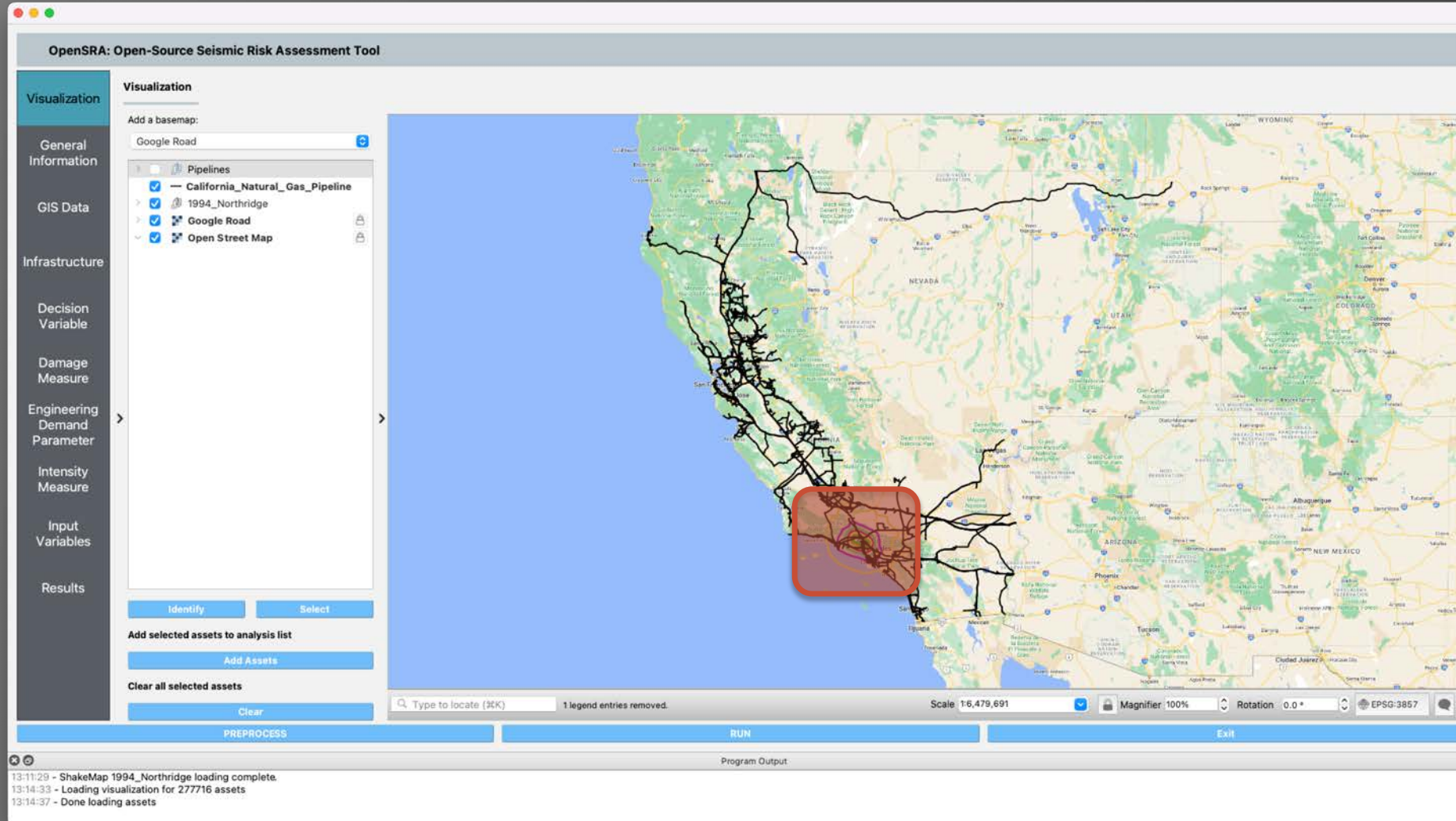
PREPROCESS

RUN

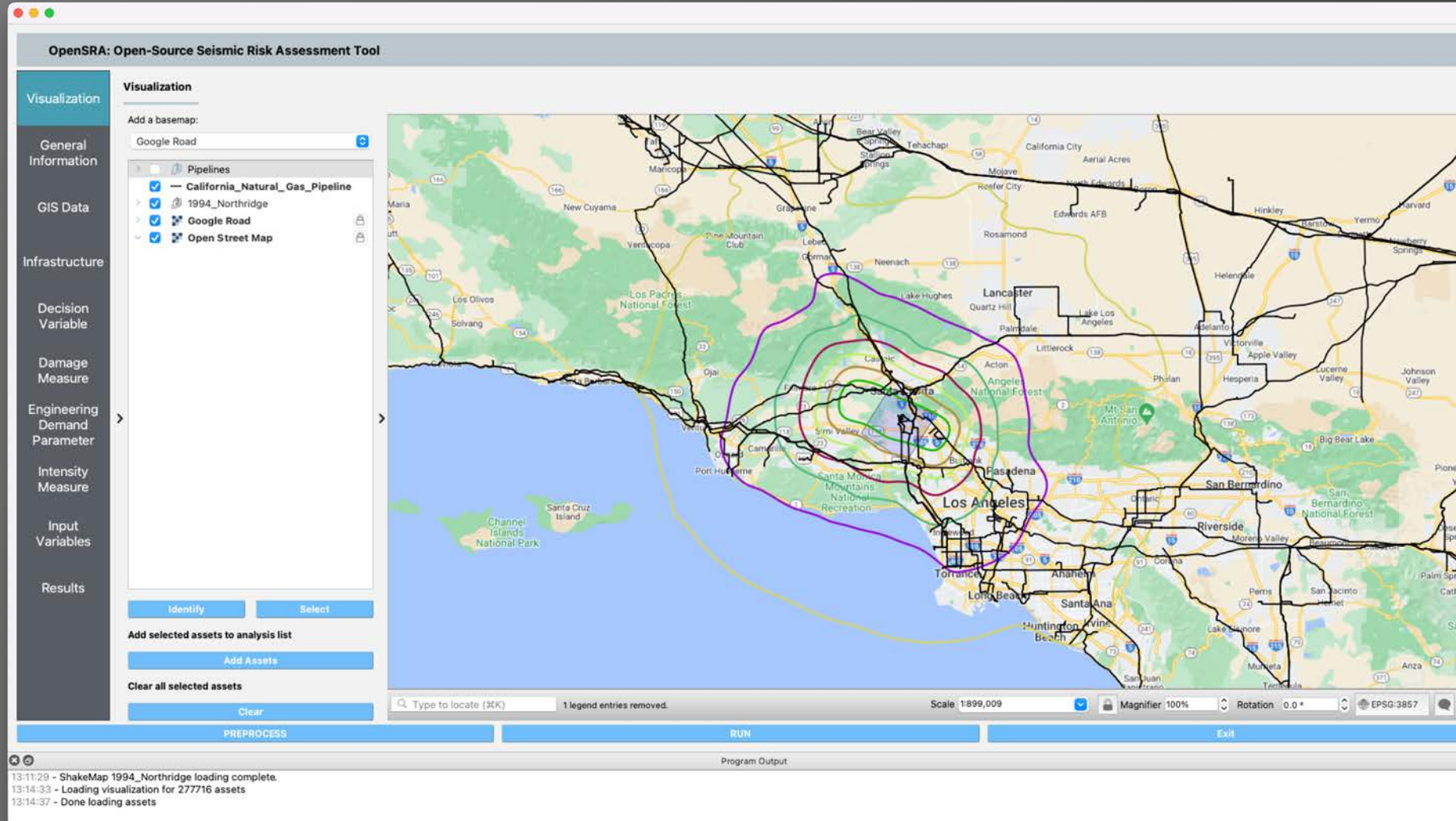
Exit



Ground Motion Characterization



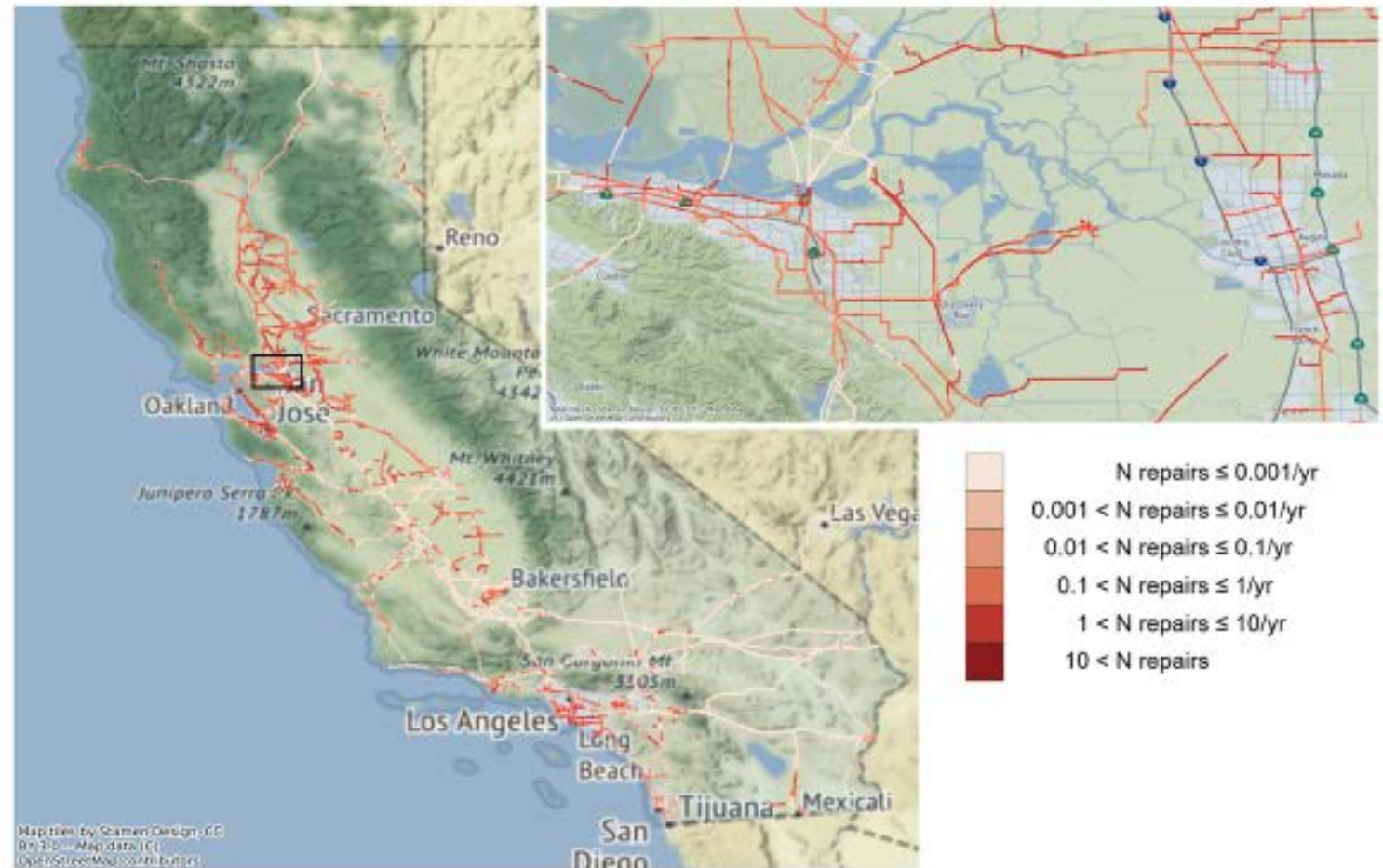
Ground Motion Characterization



Example Results – Statewide

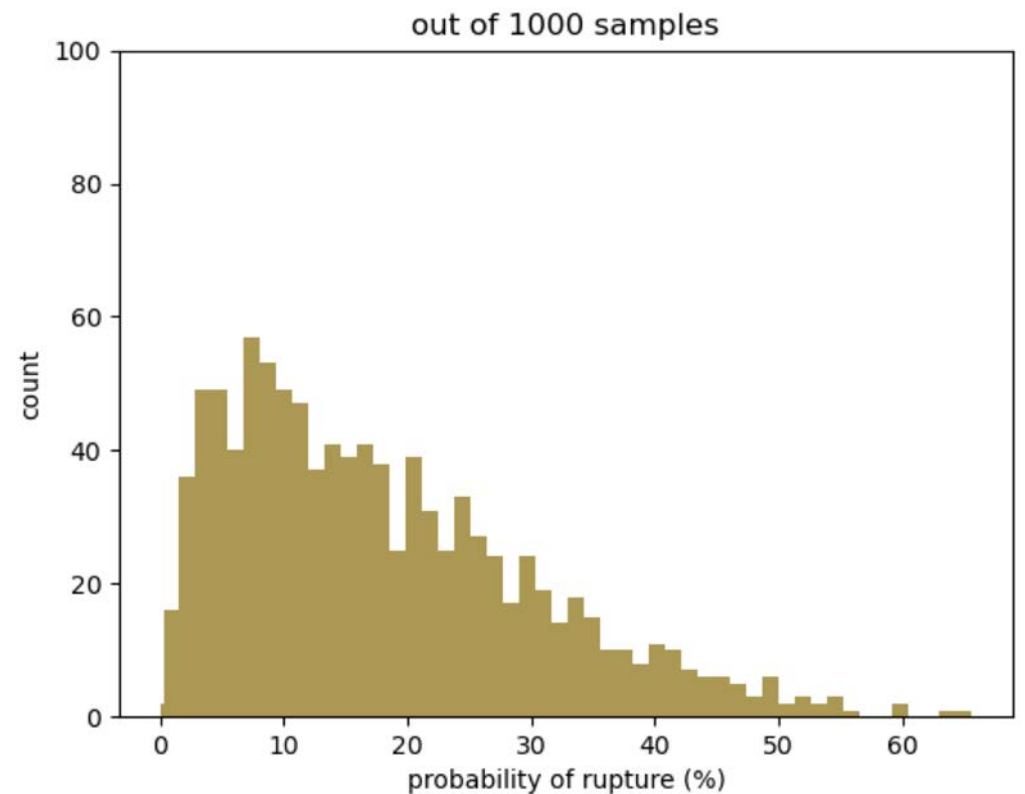
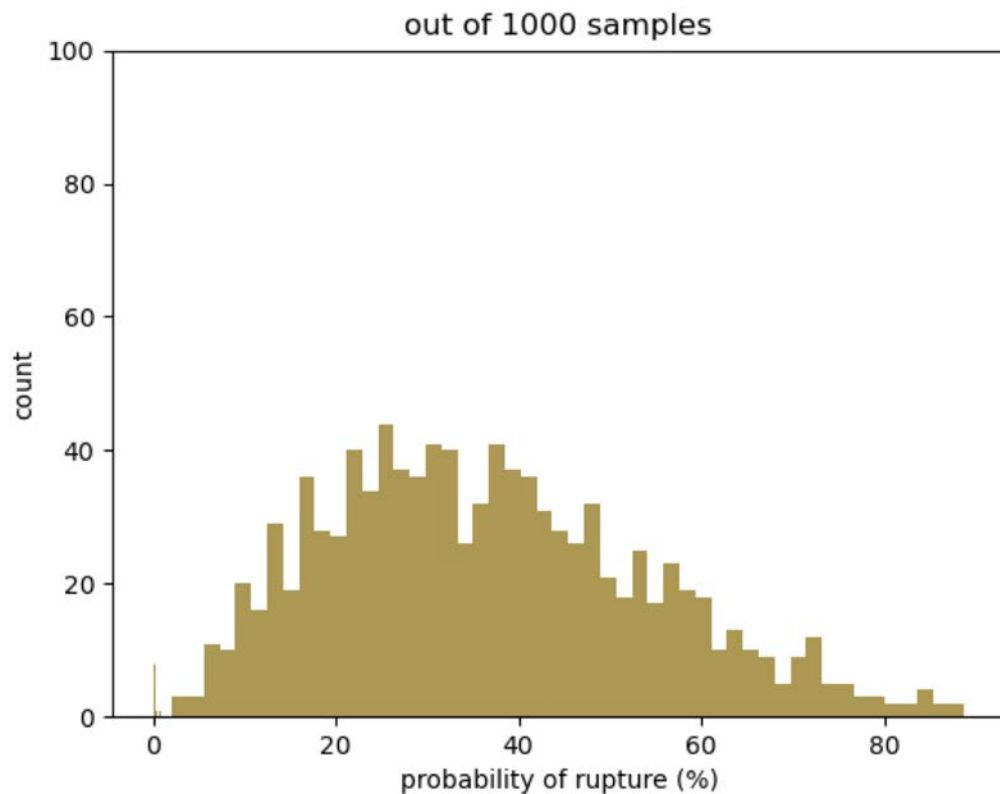
Statewide performance from previous exercise using UCERF3 as seismic source (being updated with new research models)

Figure C.9 – Annual rate of repairs per kilometer due to liquefaction induced ground settlement
Fragility used: updated American Lifelines Alliance
 $SF_{LS} = 4$



Example Results – Component level

Distributions for annual probability of rupture for a specific component given landslide and liquefaction-induced deformations.



Example Results – Component level

Distributions for annual probability of rupture for a specific component given landslide and liquefaction-induced lateral spread.

	A	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW
1	fractiles	site_64	site_65	site_66	site_67	site_68	site_69	site_70	site_71	site_72	site_73	site_74
2	5	10.96	10.96	10.96	10.96	10.96	10.96	0	0	0	0	0
3	16	18.41	18.41	18.41	18.41	18.41	18.41	0	0	0	0	0
4	50	35	35	35	35	35	35	0	0	0	0	0
5	84	55.76	55.76	55.76	55.76	55.76	55.76	0	0	0	0	0
6	95	68.74	68.74	68.74	68.74	68.74	68.74	0	0	0	0	0
7	mean	36.67	36.67	36.67	36.67	36.67	36.67	0	0	0	0	0
8												
9												
10												
11												
12												

prob_rupture_lateral_spread

Acknowledgements

Project website:
<https://peer.berkeley.edu/opensra>



Jennie Watson-Lamprey (Slate)



Stevan Gavrilovic (SimCenter)



Maxime Lacour (UC Berkeley)



Micaela Largent (Slate)



Simon Kwong (USGS)

