Introducing PRIISM:
Probabilistic Resilient Interdependent Infrastructure System Modeling

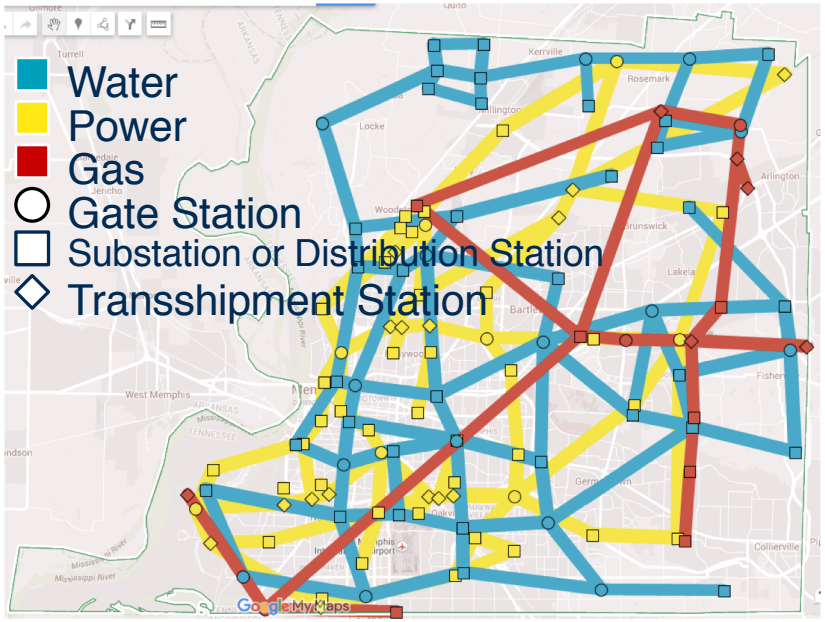
Iris Tien, Ph.D.

Williams Family Associate Professor
School of Civil and Environmental Engineering
Georgia Institute of Technology

Critical Infrastructure Resilience Institute (CIRI) Webinar
November 12, 2020

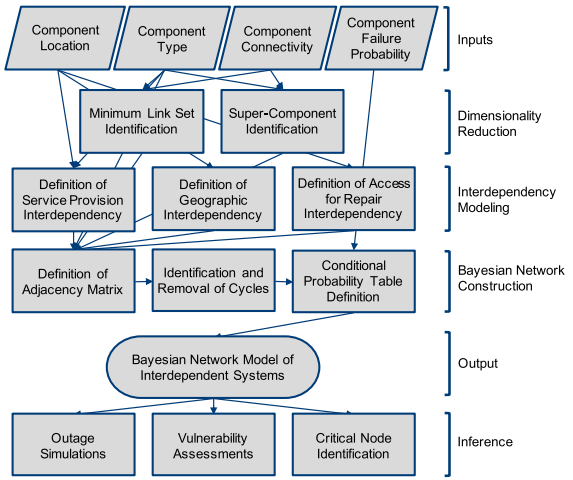
Motivation

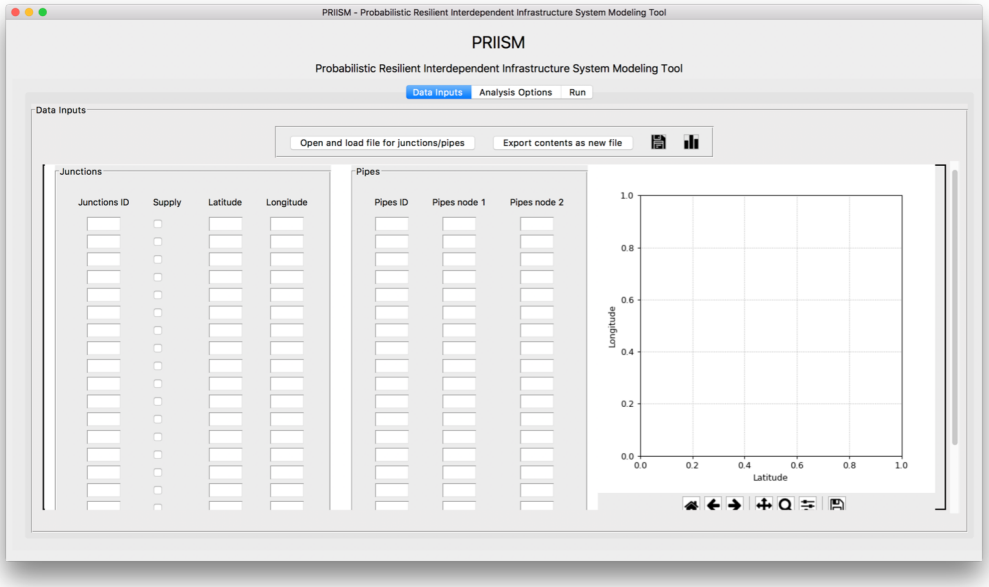
- Increasing connectivity of critical infrastructure systems and dependencies across national critical functions
- Single → multiple infrastructure systems
- Capture interdependencies between systems
  - Threat of cascading failures
  - Geographical hazards
  - Dependence for recovery



Outline

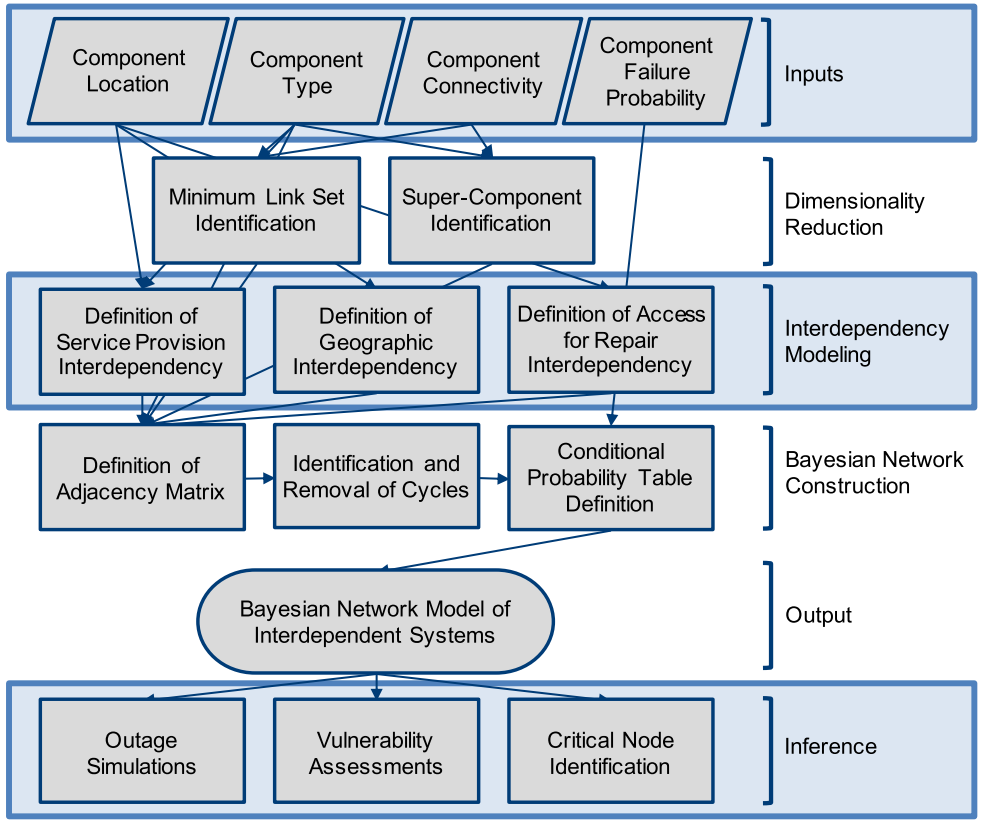
- Methodology for interdependent infrastructure system analysis → Software tool PRIISM





- Example analyses (2)

Methodology



Multi-step process and algorithm

- Individual component characteristics
- **Define interdependencies across system (3)**
- Analyses across range of threat and outage scenarios

✧ **Applegate** and **Tien**, "Framework for Probabilistic Vulnerability Analysis of Interdependent Infrastructure Systems," *JCCE*, 2019

Define infrastructure system interdependencies

- Comprehensive, generalized interdependencies (3)

Service Provision Interdependency

- One component depends on service outputs of another to function

Geographic Interdependency

- Two or more components in same geographical area may fail together

Access for Repair Interdependency

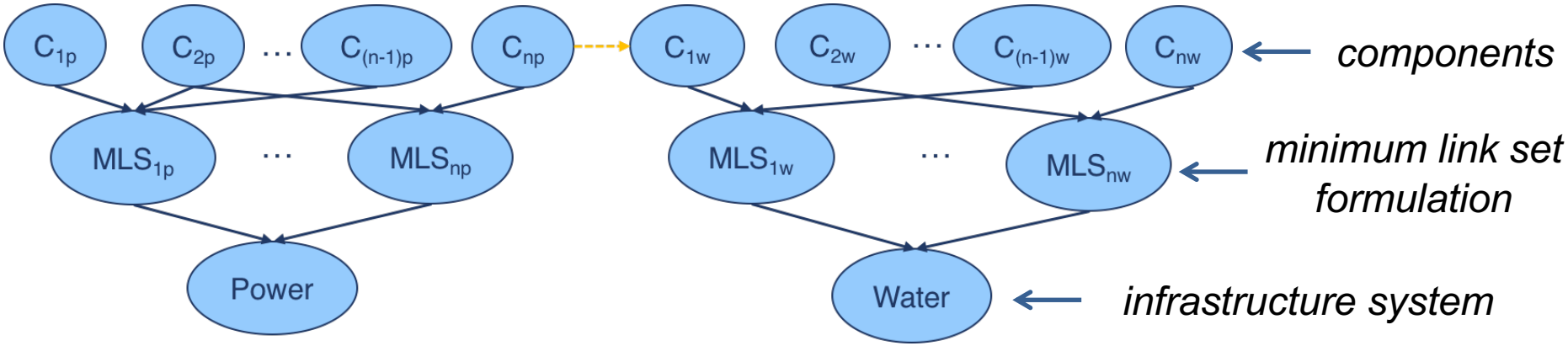
- Infrastructure components must be functional for cyber or physical access to failed components

- Methods for *quantitative probabilistic* modeling of each interdependency type

✧ **Johansen** and **Tien**, "Probabilistic Multi-Scale Modeling of Interdependencies between Critical Infrastructure Systems for Resilience," *SRI*, 2018

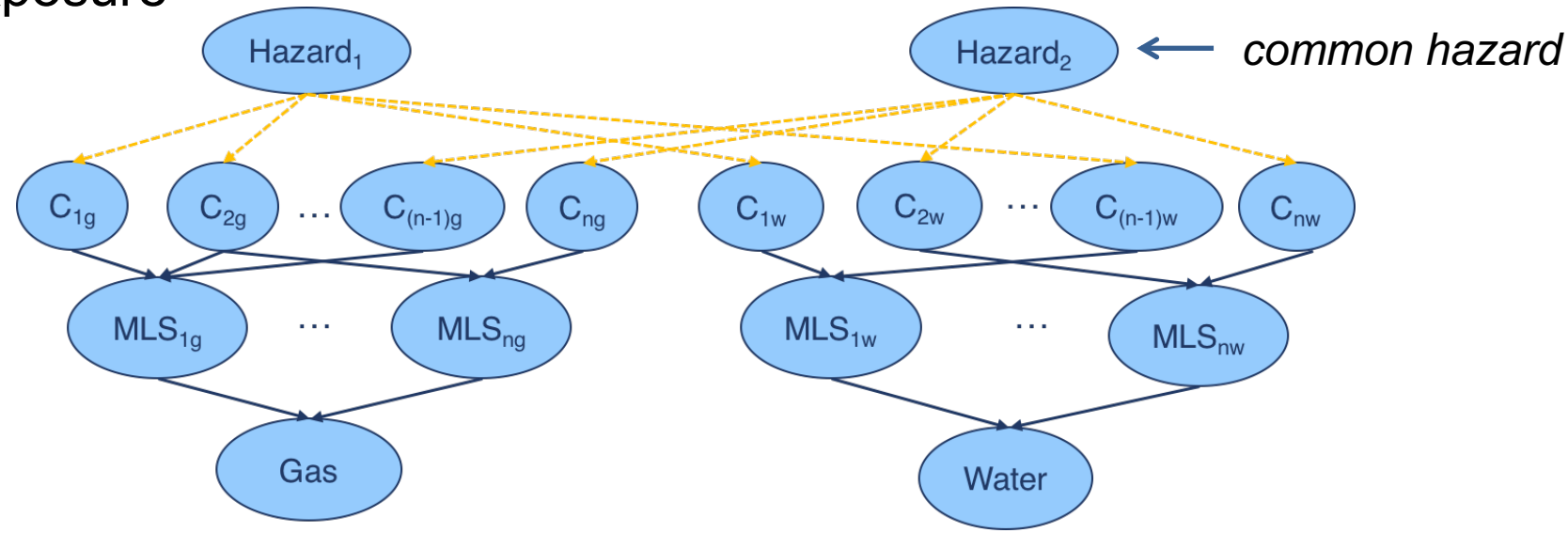
Service provision interdependency

- Functioning of one infrastructure depends on service outputs of another
- e.g., fuel supply for power generation, electricity for water pumps



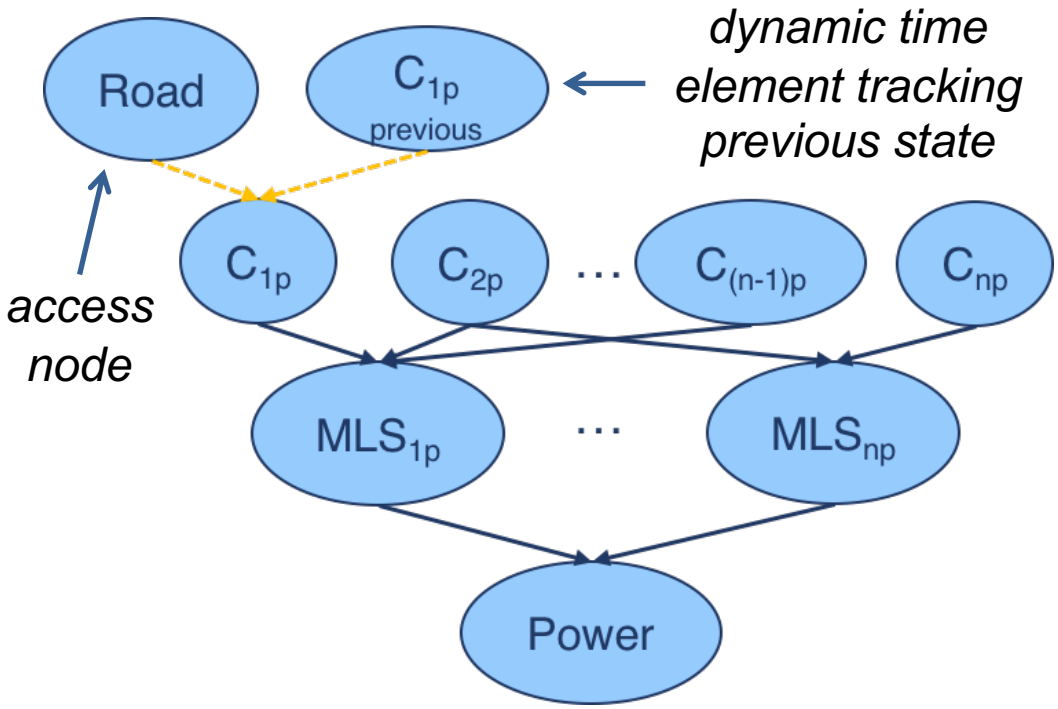
Geographic interdependency

- Functioning of one infrastructure connected to functioning of another due to physical similarity, geographic proximity
- e.g., collocated gas lines and water mains, common hazard exposure

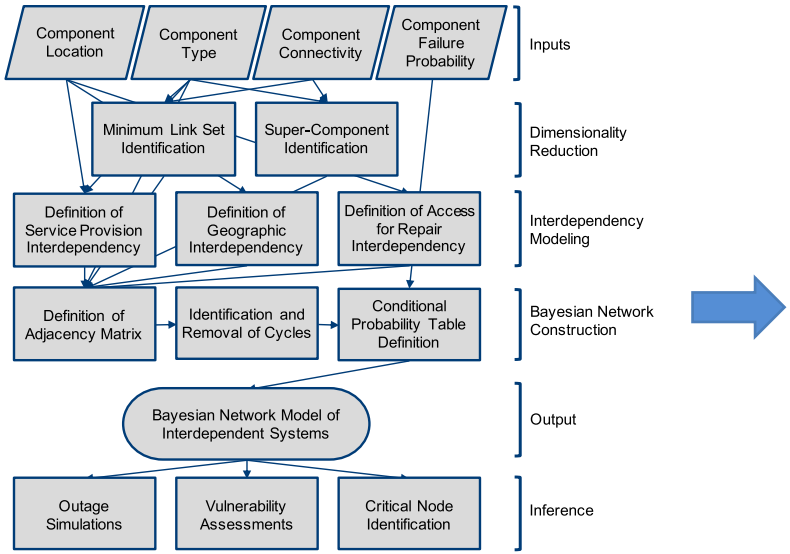


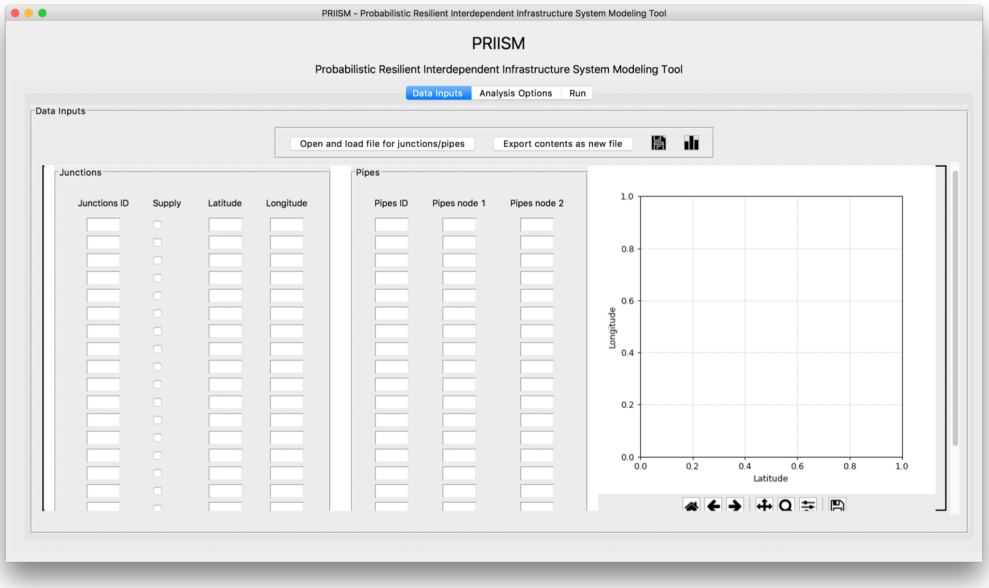
Access for repair interdependency

- Ability to repair one infrastructure affected by access (physical, remote/cyber) provided by another infrastructure
- Addresses post-disaster recovery for resilience
- e.g., communications for controls, transportation systems for repair



Methodology → Software tool





- PRIISM: Probabilistic Resilient Interdependent Infrastructure System Modeling

PRI

- In

Compo
charact
of conn
infrastru
system

- *Junc*
  (poir
  netw
- *Pipe*
- *Conn*
- *Coor*
  locat

PRIISM - Probabilistic Resilient Interdependent Infrastructure System Modeling Tool

PRIISM - Probabilistic Resilient Interdependent Infrastructure System Modeling Tool

PRIISM

Probabilistic Resilient Interdependent Infrastructure System Modeling Tool

Data Inputs | Analysis Options | Run

Data Inputs

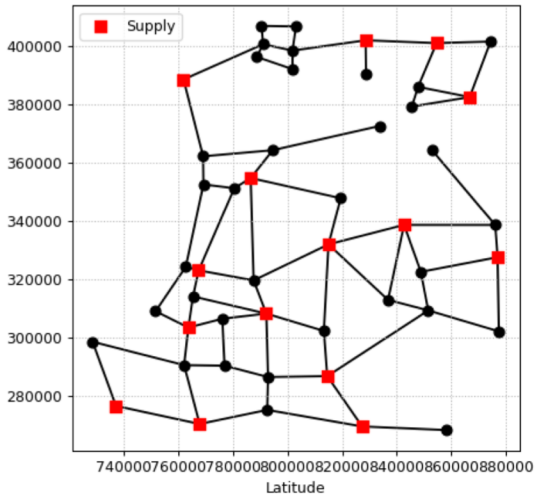
Open and load file for junctions/pipes | Export contents as new file

Junctions

Junctions ID	Supply	Latitude	Longitude
16		79263(	27508!
17		85798:	26816'
18		79293:	28636!
19		77704!	29027(
20		76226.	29046'
21		72876!	29847.
22		75184!	30895(
23		77624'	30638(
24		87731:	30203(
25		81333(	30219(
26		85151:	30924:
27		76551'	31404!
28		83678!	31285.
29		76287'	32420'
30		84878.	32247(
31		78767.	31954!

Pipes

Pipes ID	Pipes node 1	Pipes node 2
1	1	17
2	16	1
3	4	1
4	3	2
5	2	16
6	21	3
7	20	21
8	16	18
9	19	18
10	18	4
11	26	4
12	20	19
13	23	19
14	2	20
15	4	25
16	20	5

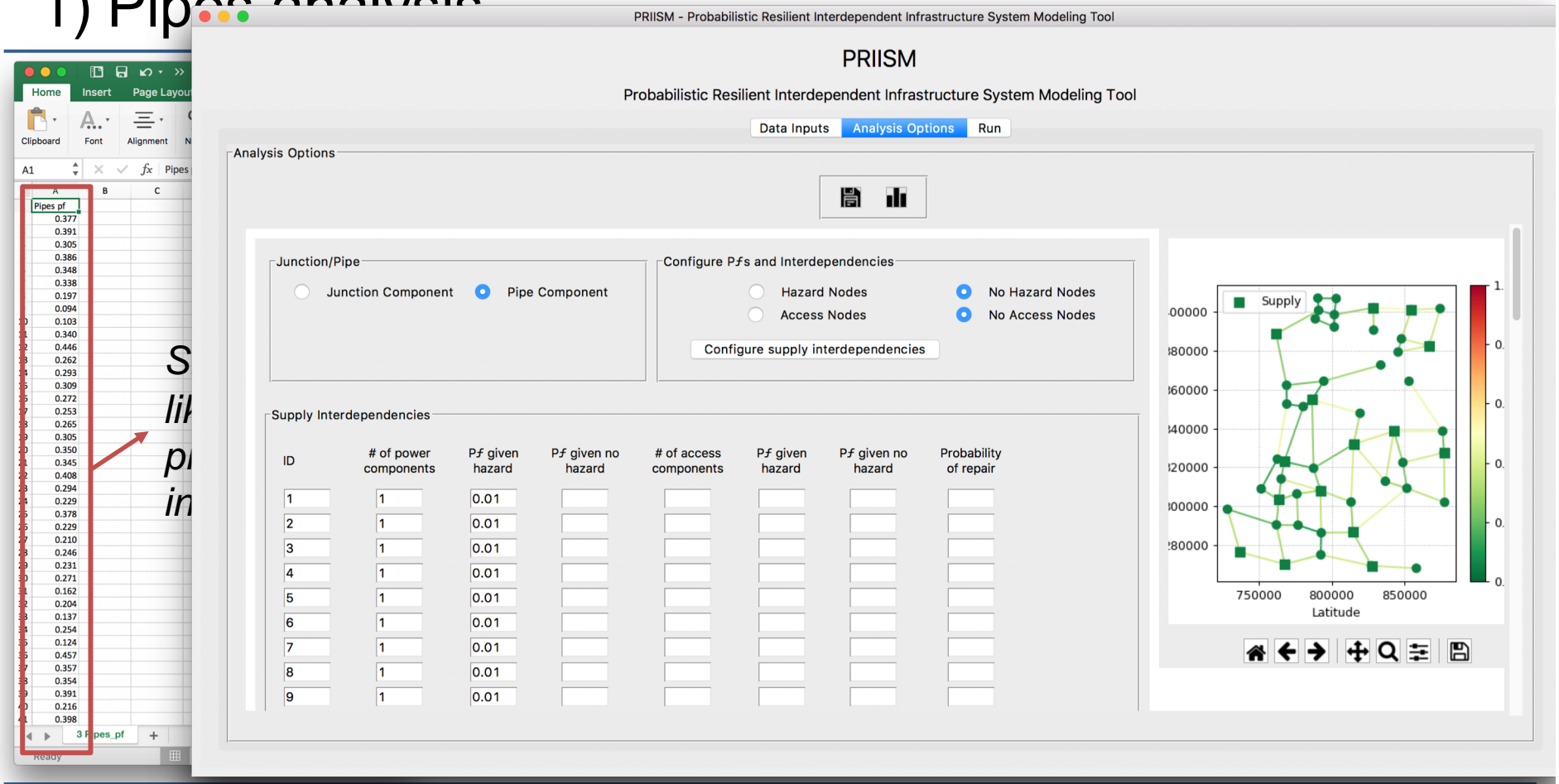


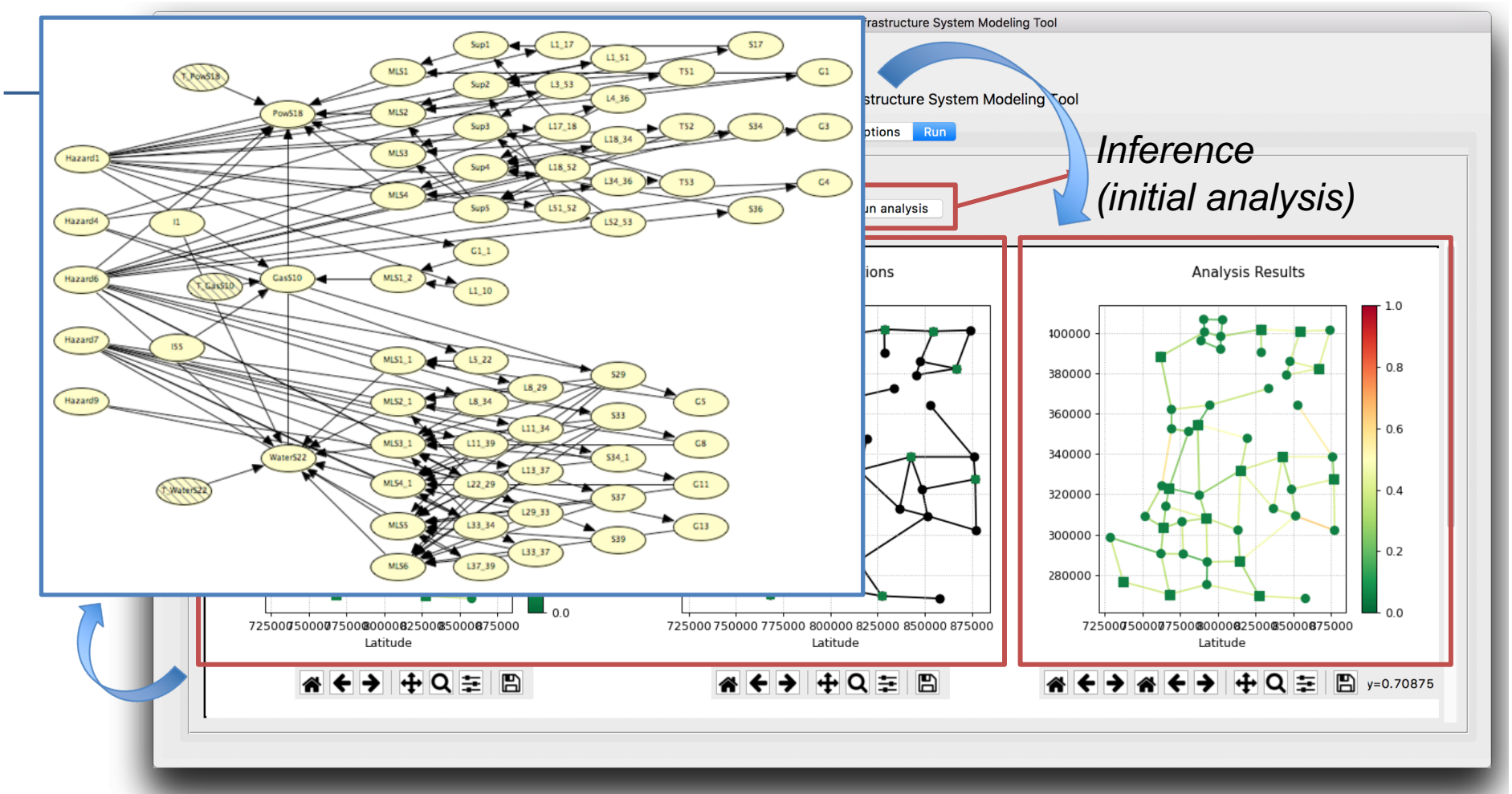
Two example analysis scenarios

1) Pipes analysis, upstream simulation of pipe breaks in a hazard, include service provision interdependencies, vulnerability assessment to cascading failures

2) Junctions analysis, include service provision interdependencies, and hazard nodes and access nodes (for geographic and access for repair interdependencies), interdependent system risk assessment

1) Pipes analysis



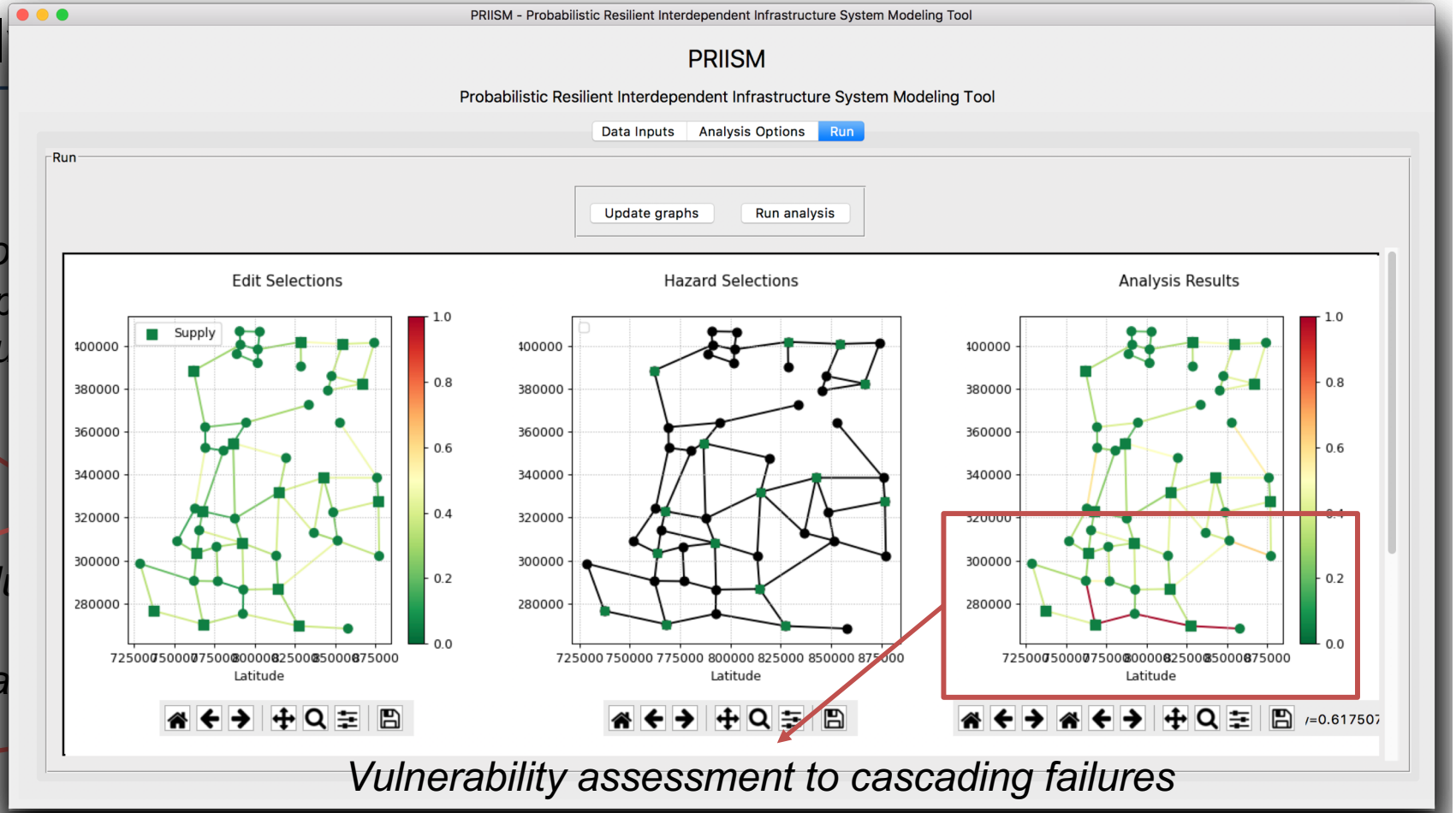

Inference
(initial analysis)
Analysis Results
Latitude
y=0.70875

Anal

Select no
from grap
input failu
scenario

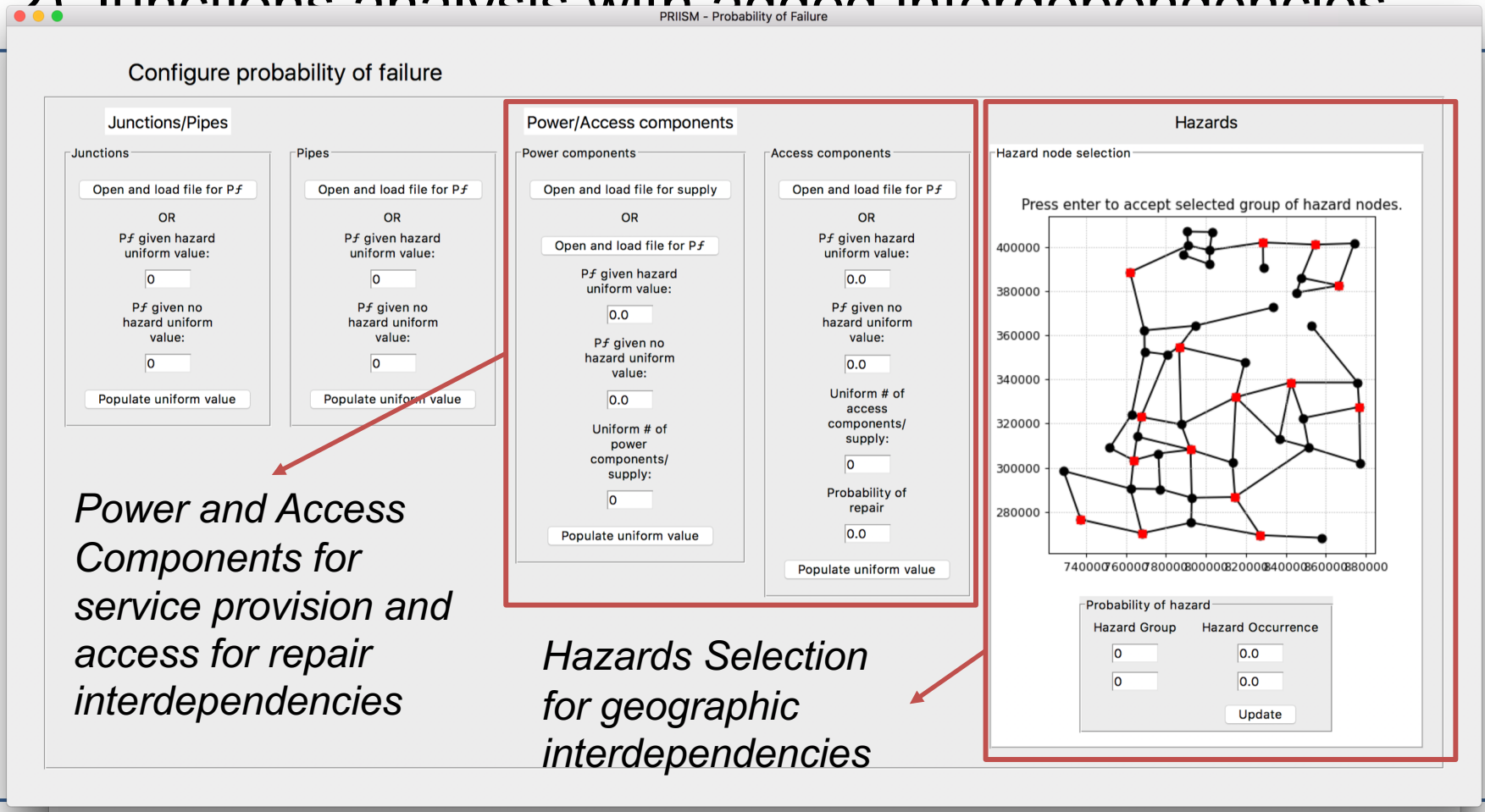
Node failu
scenario
and upda

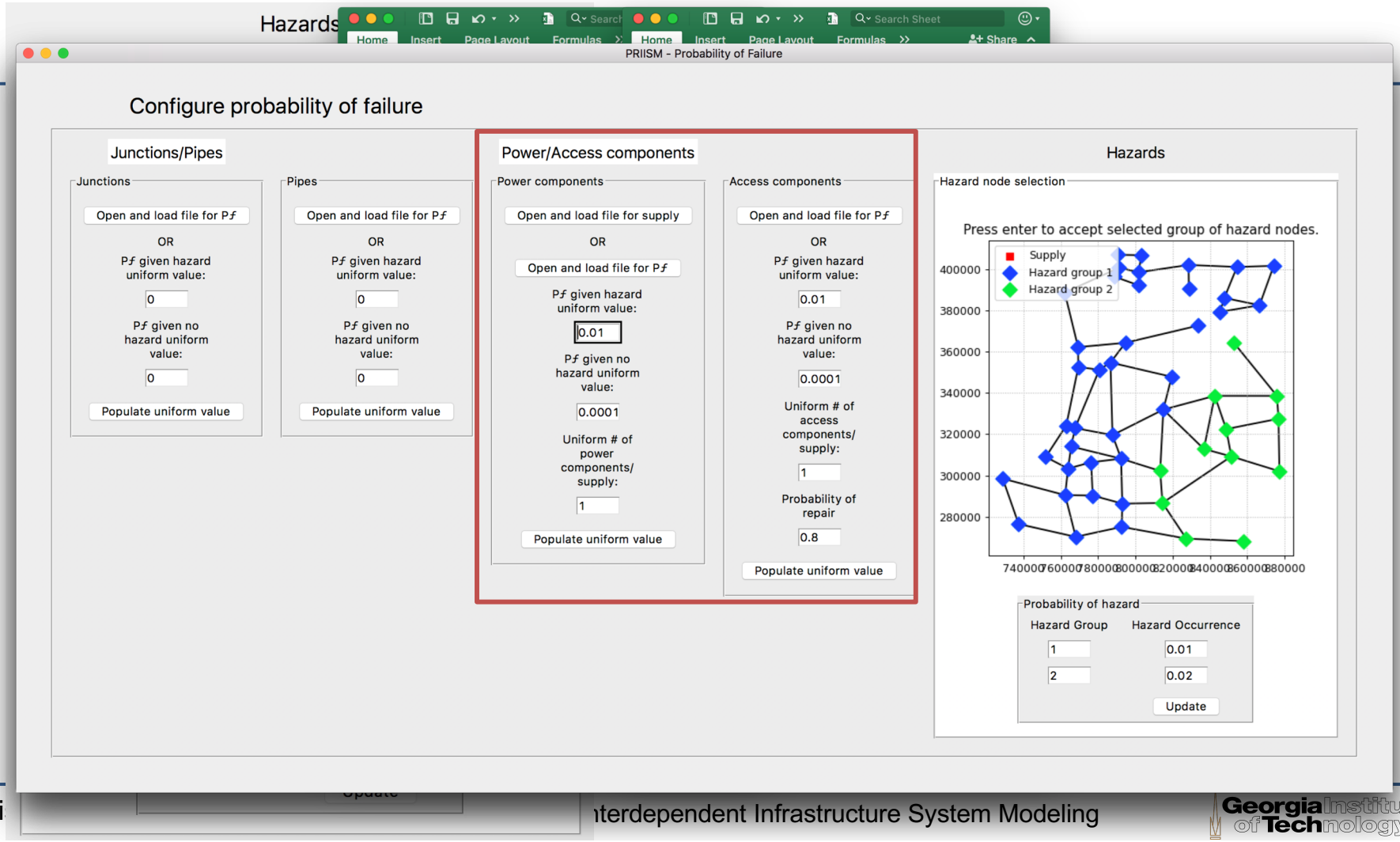
Update



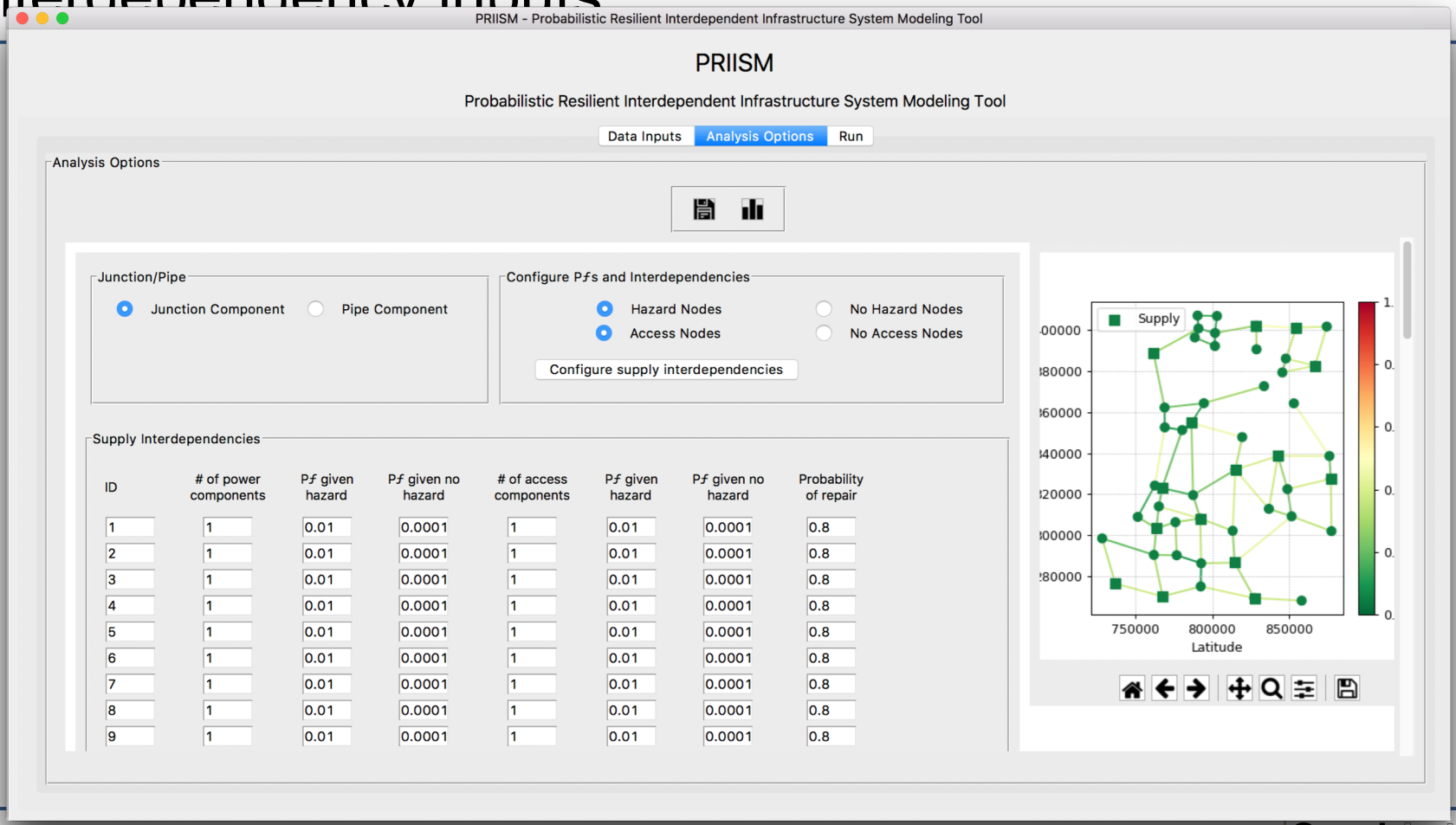
Vulnerability assessment to cascading failures

2) Junctions analysis with added interdependencies

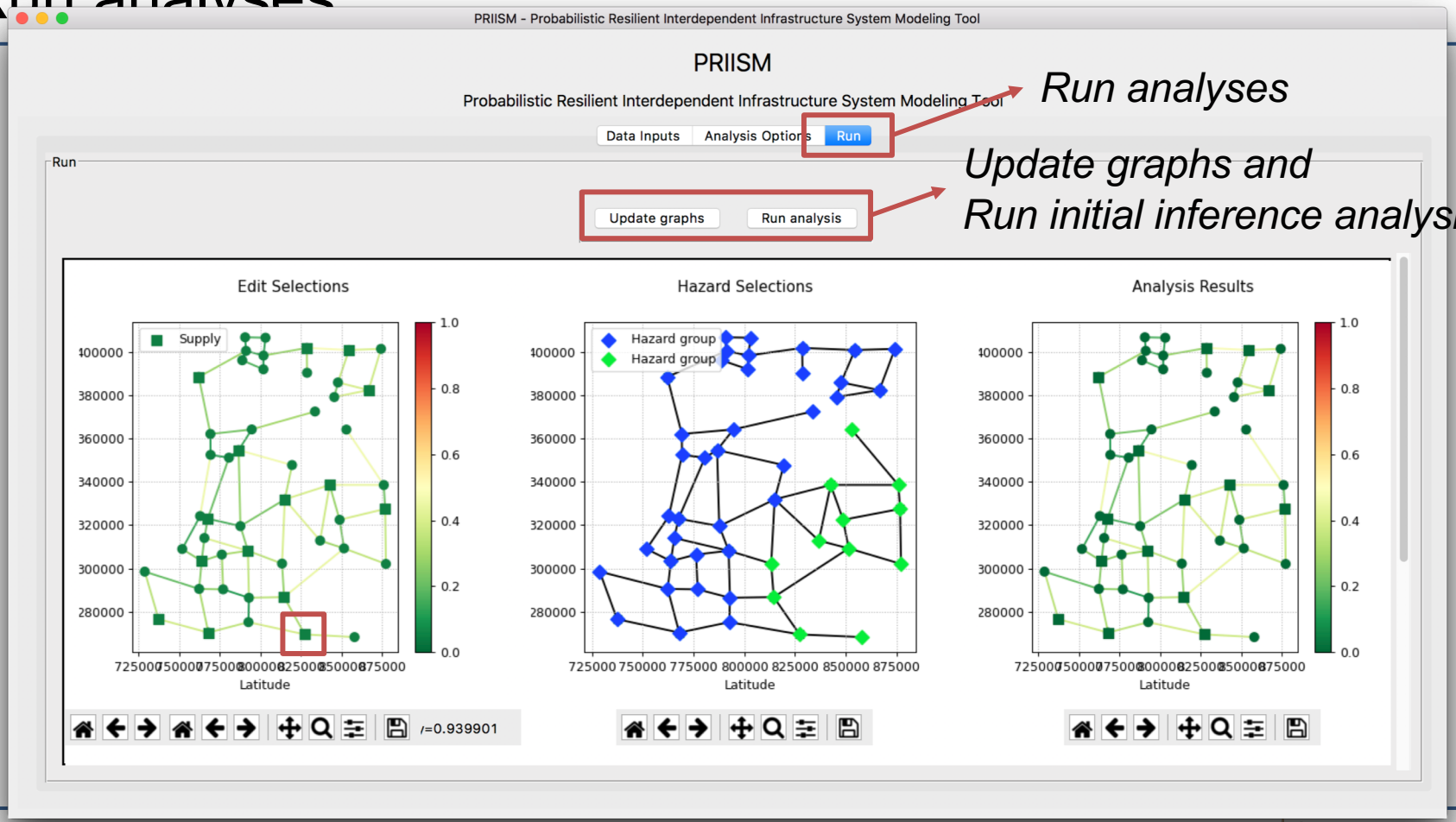


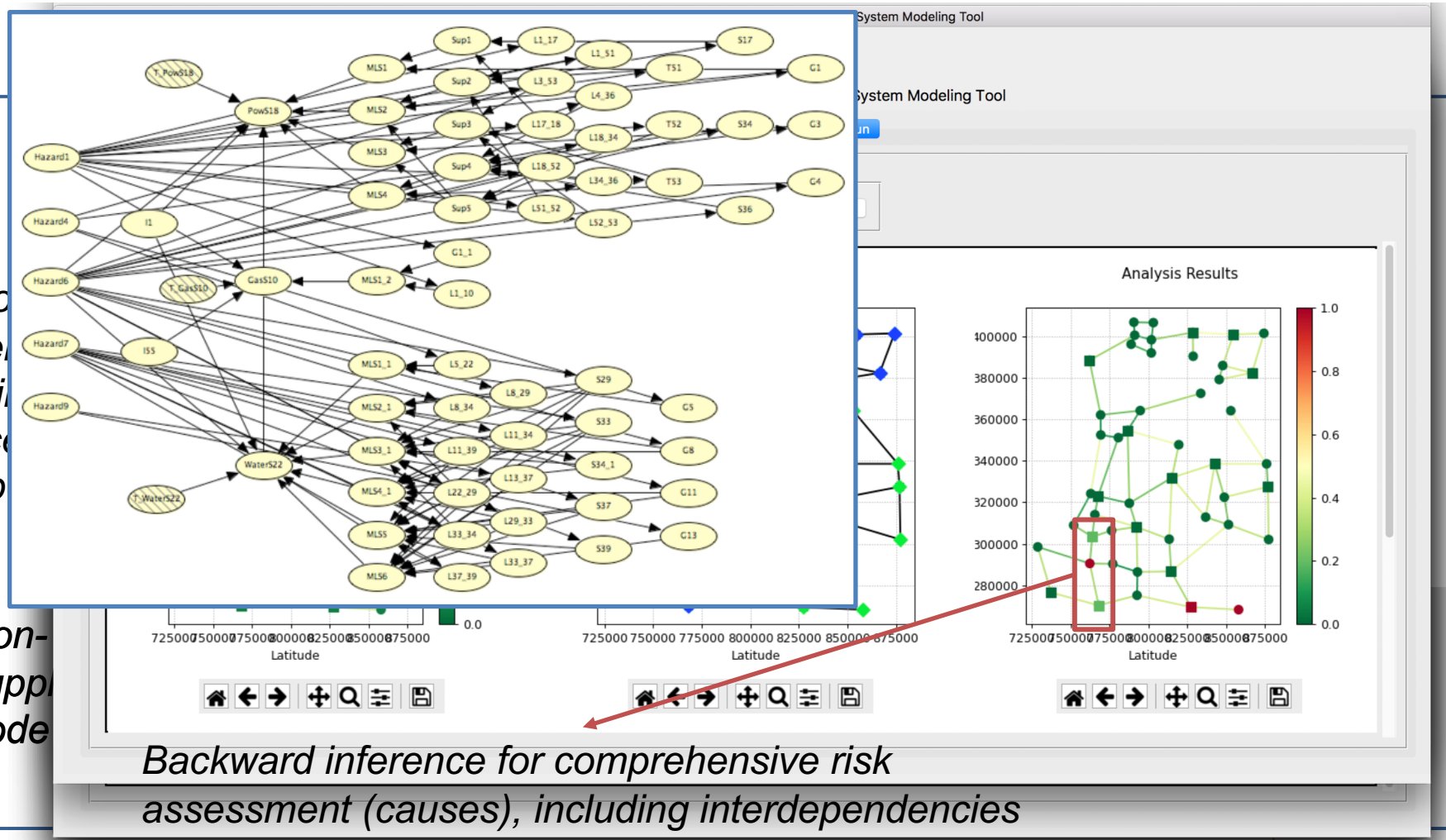

Hazards
Home
Insert
Page Layout
Formulas
Search Sheet
Share
PRIISM - Probability of Failure
Configure probability of failure
Junctions/Pipes
Junctions
Open and load file for Pf
OR
Pf given hazard uniform value:
0
Pf given no hazard uniform value:
0
Populate uniform value
Pipes
Open and load file for Pf
OR
Pf given hazard uniform value:
0
Pf given no hazard uniform value:
0
Populate uniform value
Power/Access components
Power components
Open and load file for supply
OR
Open and load file for Pf
Pf given hazard uniform value:
0.01
Pf given no hazard uniform value:
0.0001
Uniform # of power components/ supply:
1
Populate uniform value
Access components
Open and load file for Pf
OR
Pf given hazard uniform value:
0.01
Pf given no hazard uniform value:
0.0001
Uniform # of access components/ supply:
1
Probability of repair
0.8
Populate uniform value
Hazards
Hazard node selection
Press enter to accept selected group of hazard nodes.
Supply
Hazard group 1
Hazard group 2
400000
380000
360000
340000
320000
300000
280000
740000
760000
780000
800000
820000
840000
860000
880000
Probability of hazard
Hazard Group
Hazard Occurrence
1
0.01
2
0.02
Update

Interdependency inputs



Run analyses





Backward inference for comprehensive risk assessment (causes), including interdependencies

PRIISM

- Simple inputs
  - Component characteristics (location, function, vulnerability, connectivity)
- Outputs
  - System vulnerability assessments
  - Cascading failure impacts
  - Including service provision, geographic (hazard areas), and access for repair interdependencies
- Component-level information → system-level outcomes for comprehensive critical infrastructure risk assessments
- Quantitative probabilistic analysis capabilities accounting for interdependencies across systems and functions, uncertainties in component outcomes and threat scenarios

Acknowledgements:

- Chole Applegate, Ph.D.
- Cynthia Lee, Ph.D.
- Shirling Xu

Department of Homeland Security Award #2015-ST-061-CIRC01

Contact: **itien@ce.gatech.edu**