مرکز پژوهشی پایداری و تاب‌آوری زیرساخت‌ها

Probabilistic Framework for Evaluating Urban Resilience under Natural Disasters

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Sharif University of Technology

IIEES

INSF Workshop on Urban Resilience through Applied Systems Analysis

Aban 3, 1401 | Tehran, Iran

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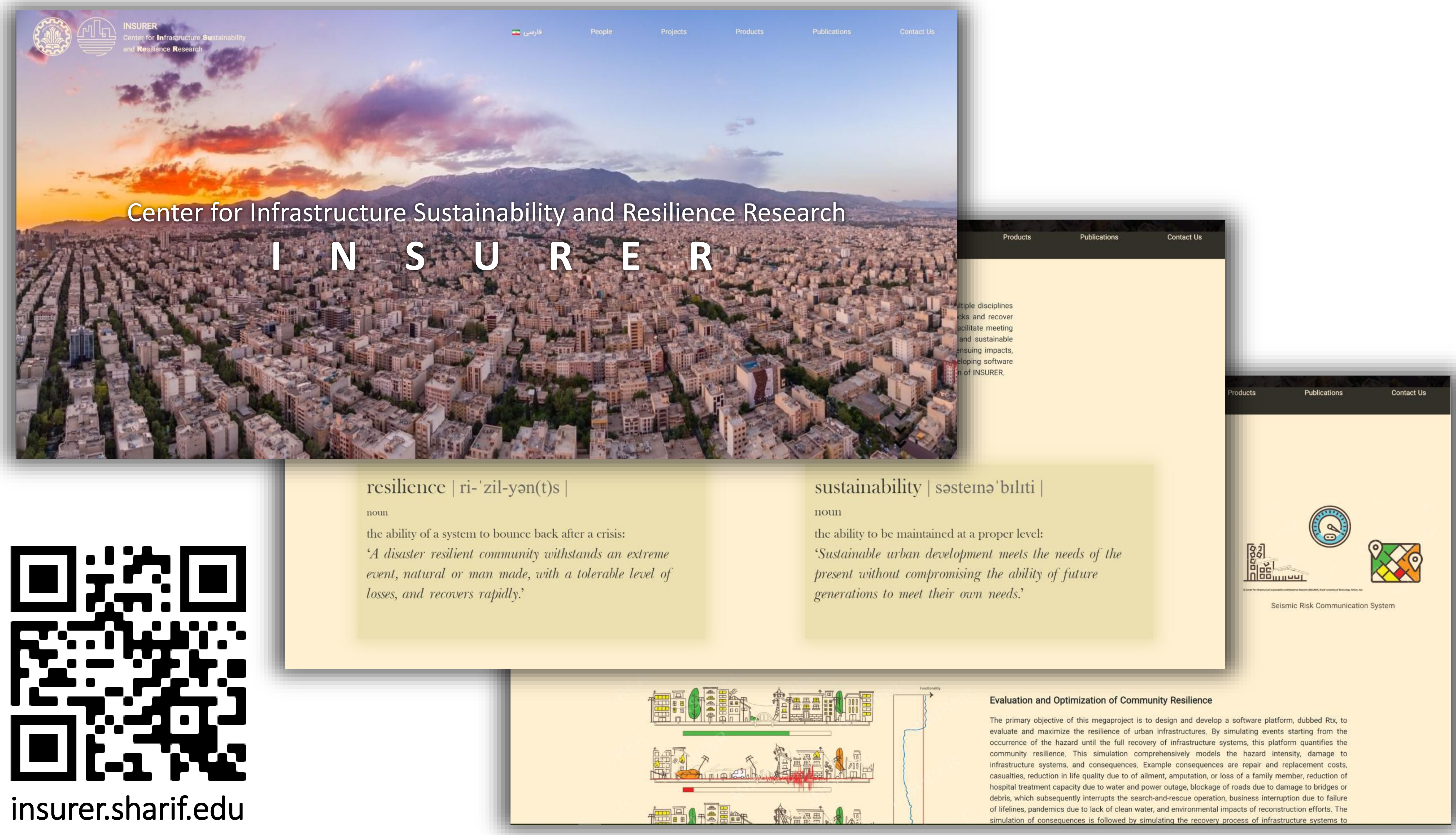
Vice-Presidency for Science and Technology
Iran National Science Foundation



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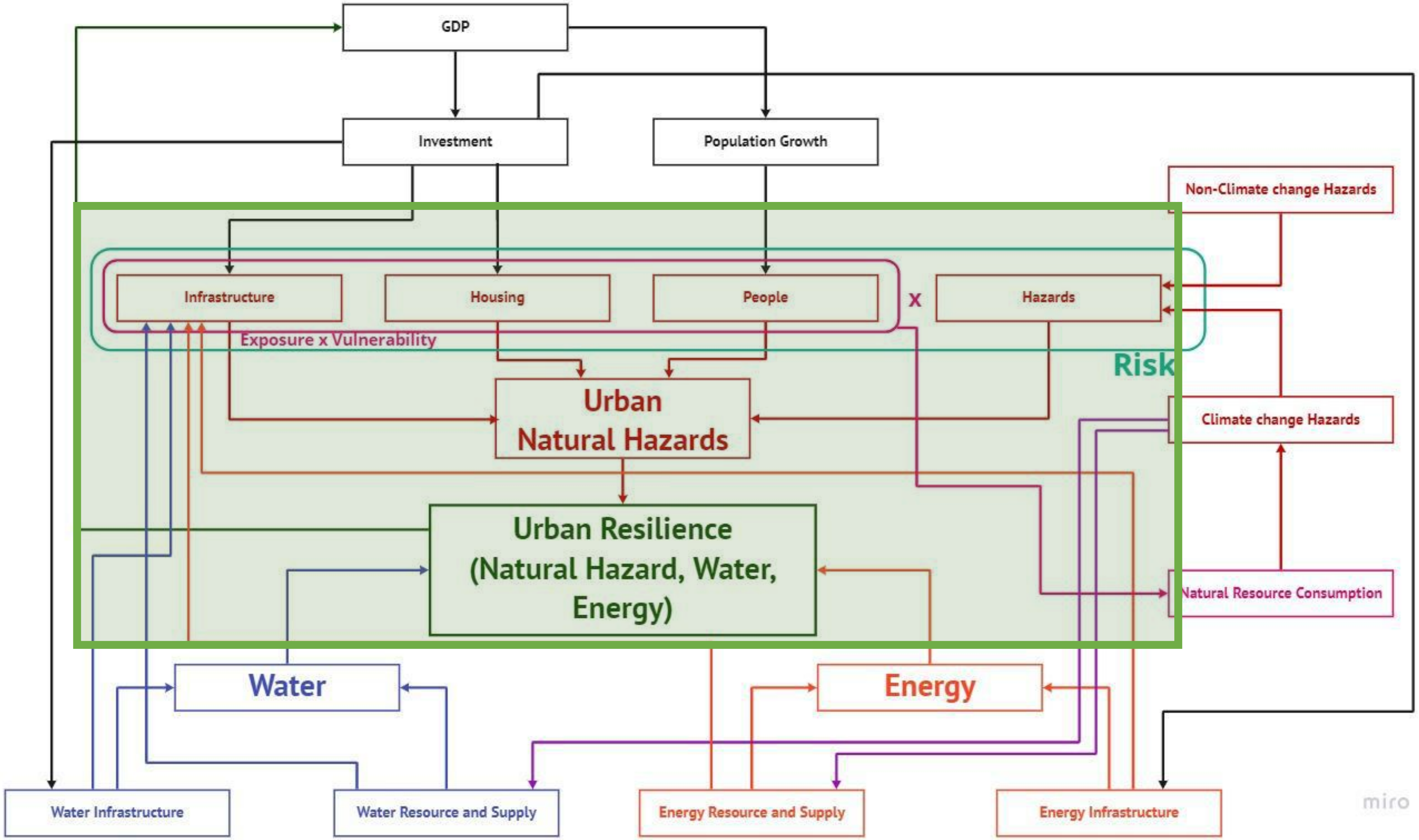
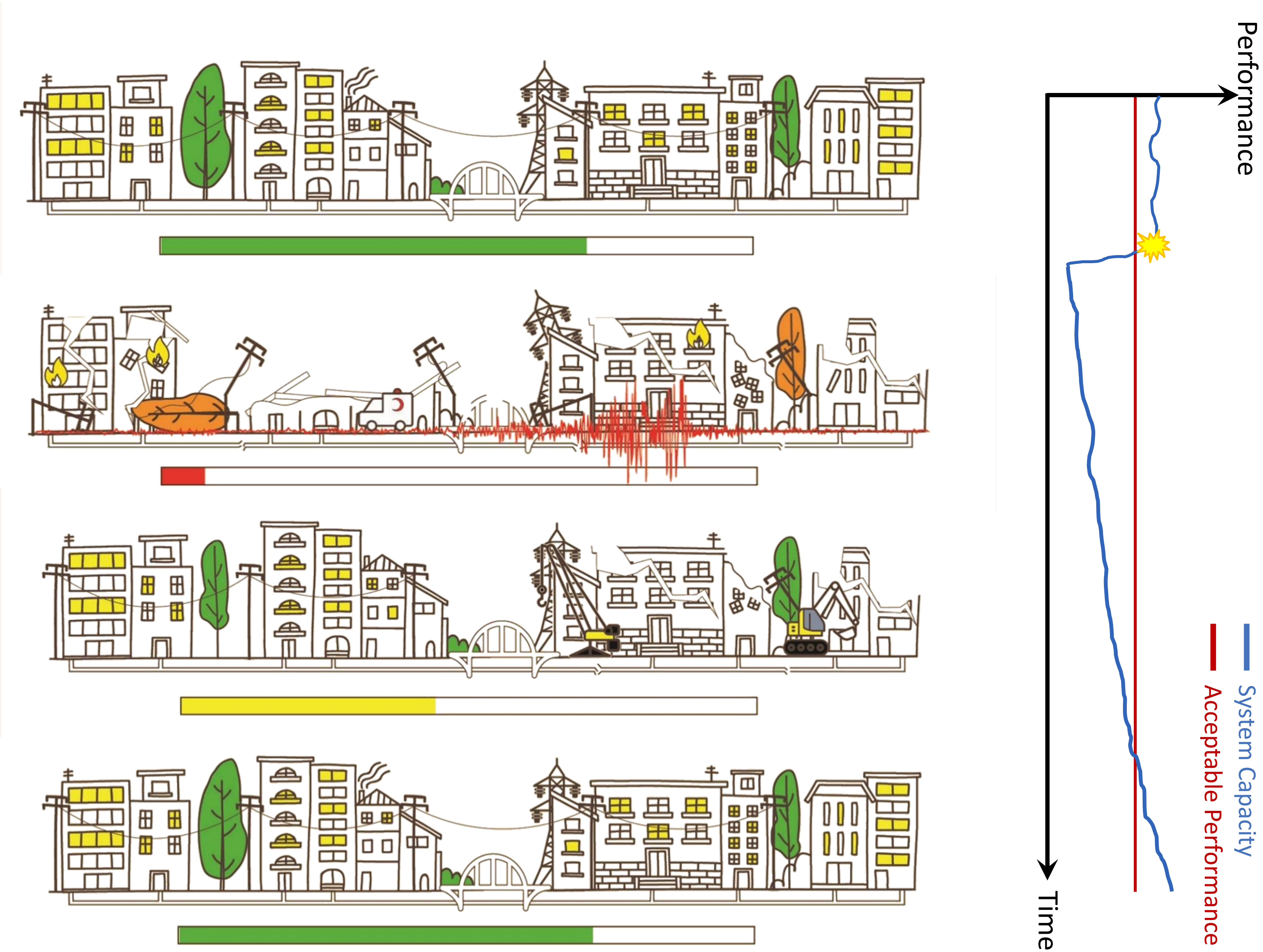
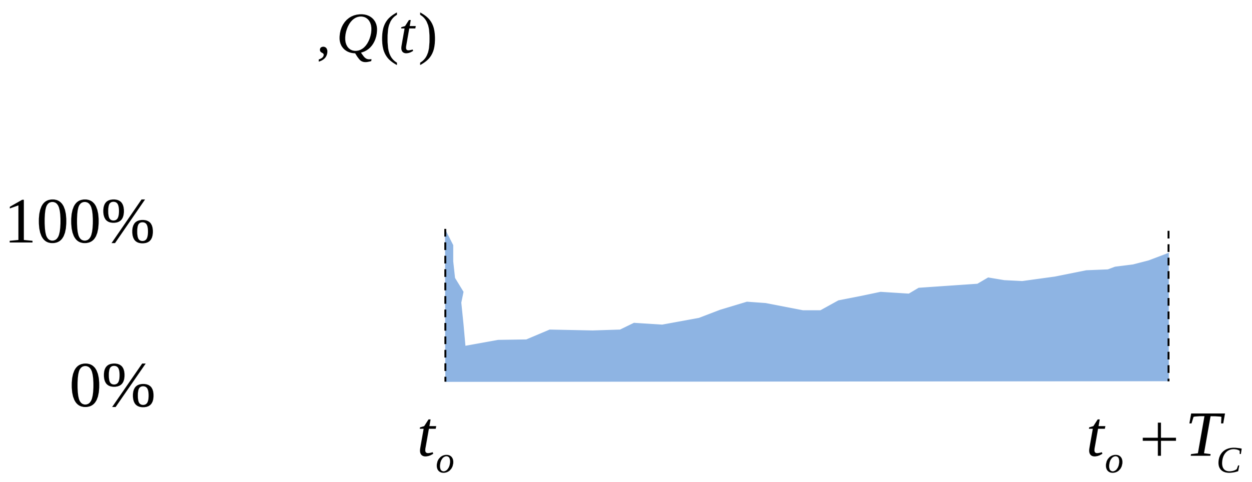
System of Systems

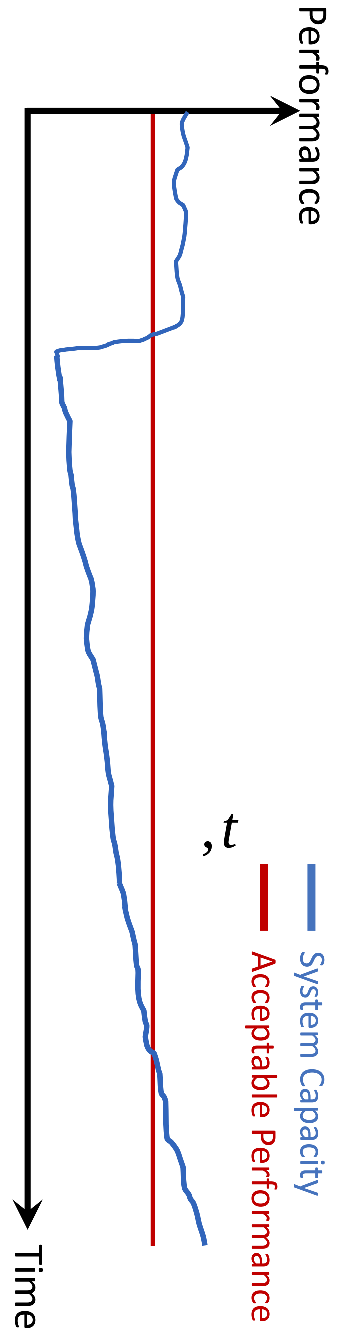



Performance
Time
System Capacity
Acceptable Performance

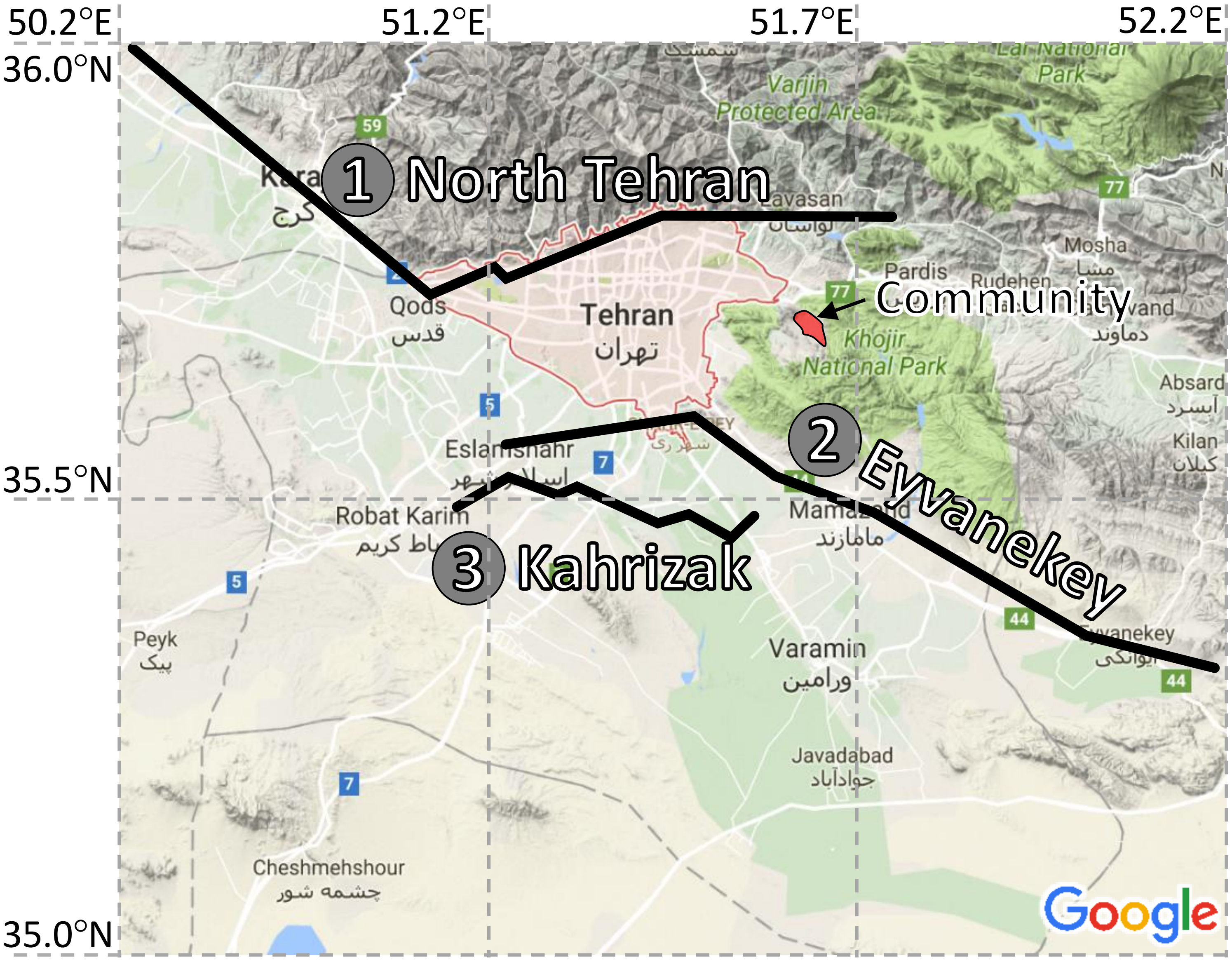
Resilience



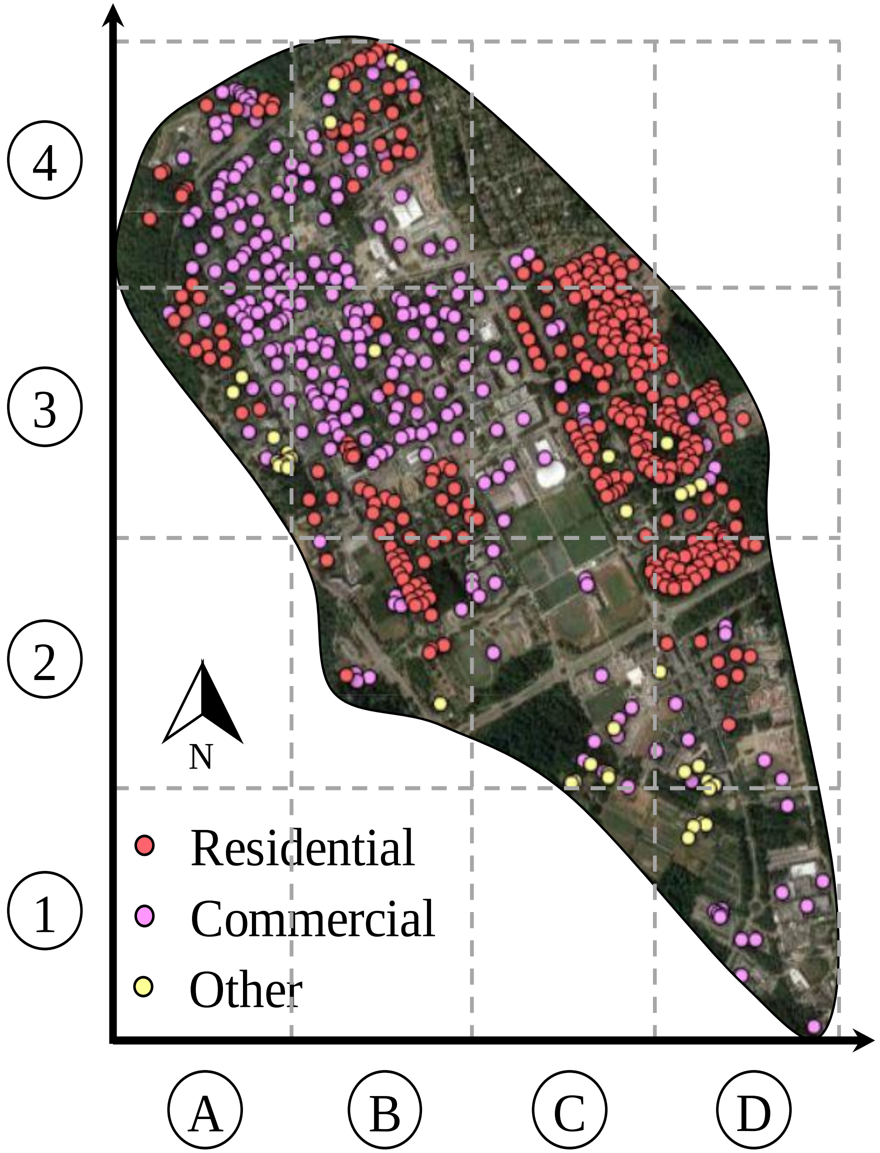
$$\square = \frac{1}{T_C}\int_{t_o}^{t_o+T_C} Q(t)\mathrm{d}t$$

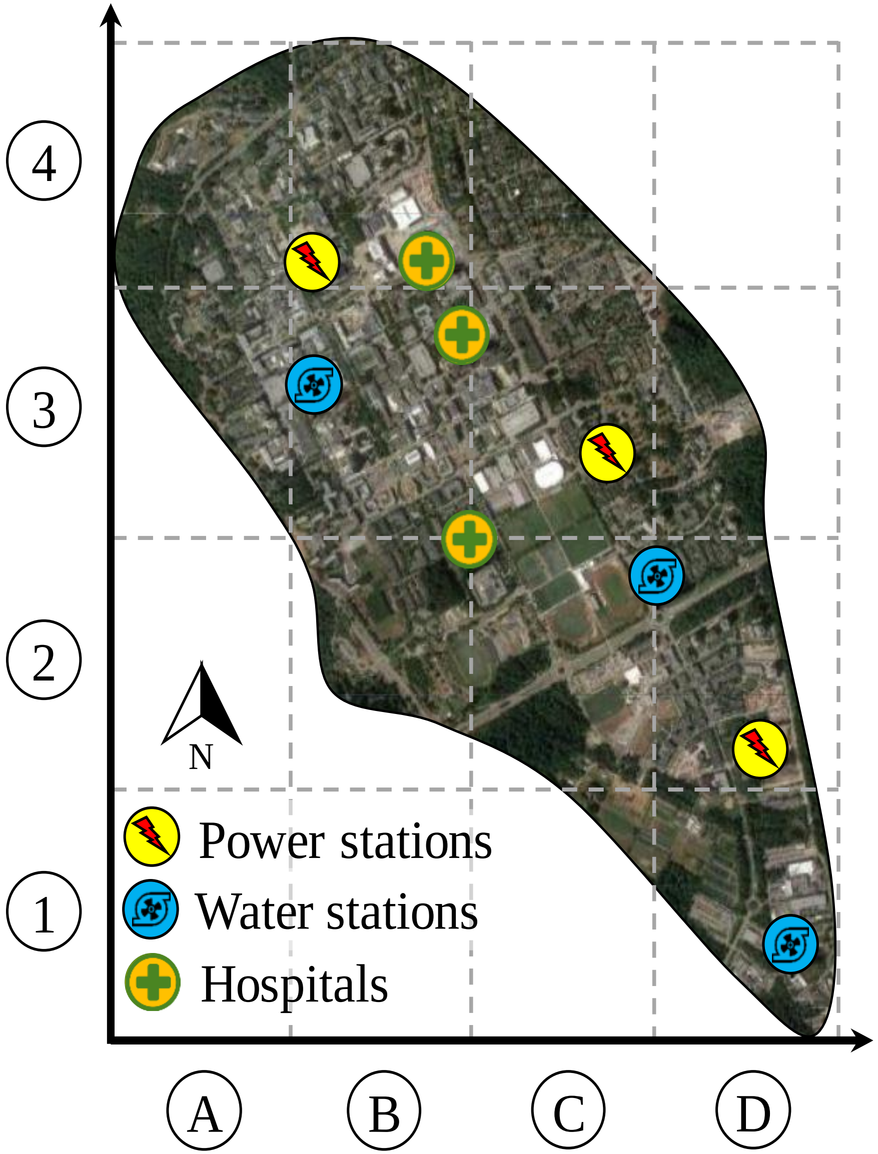


Hazard Sources

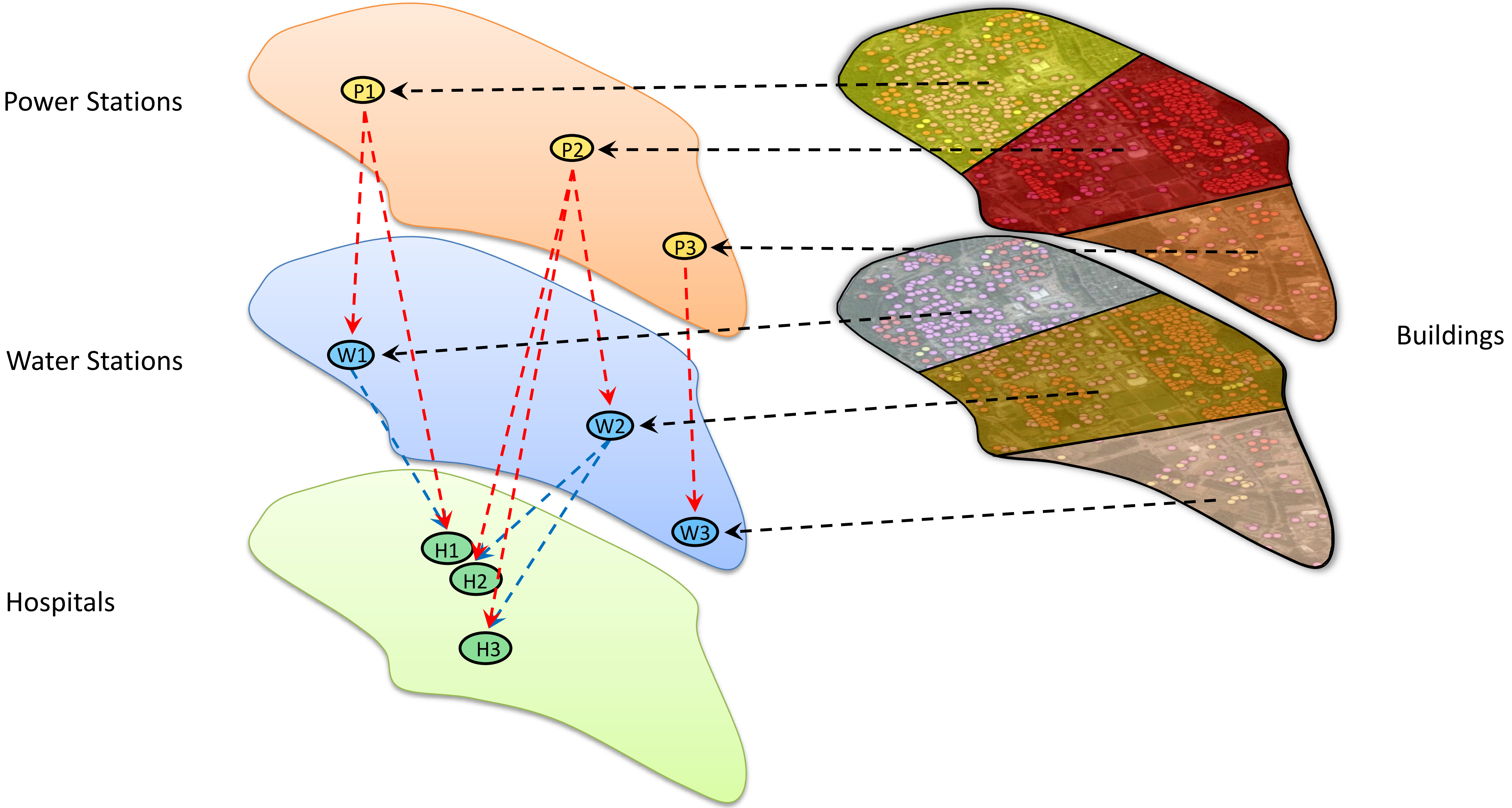


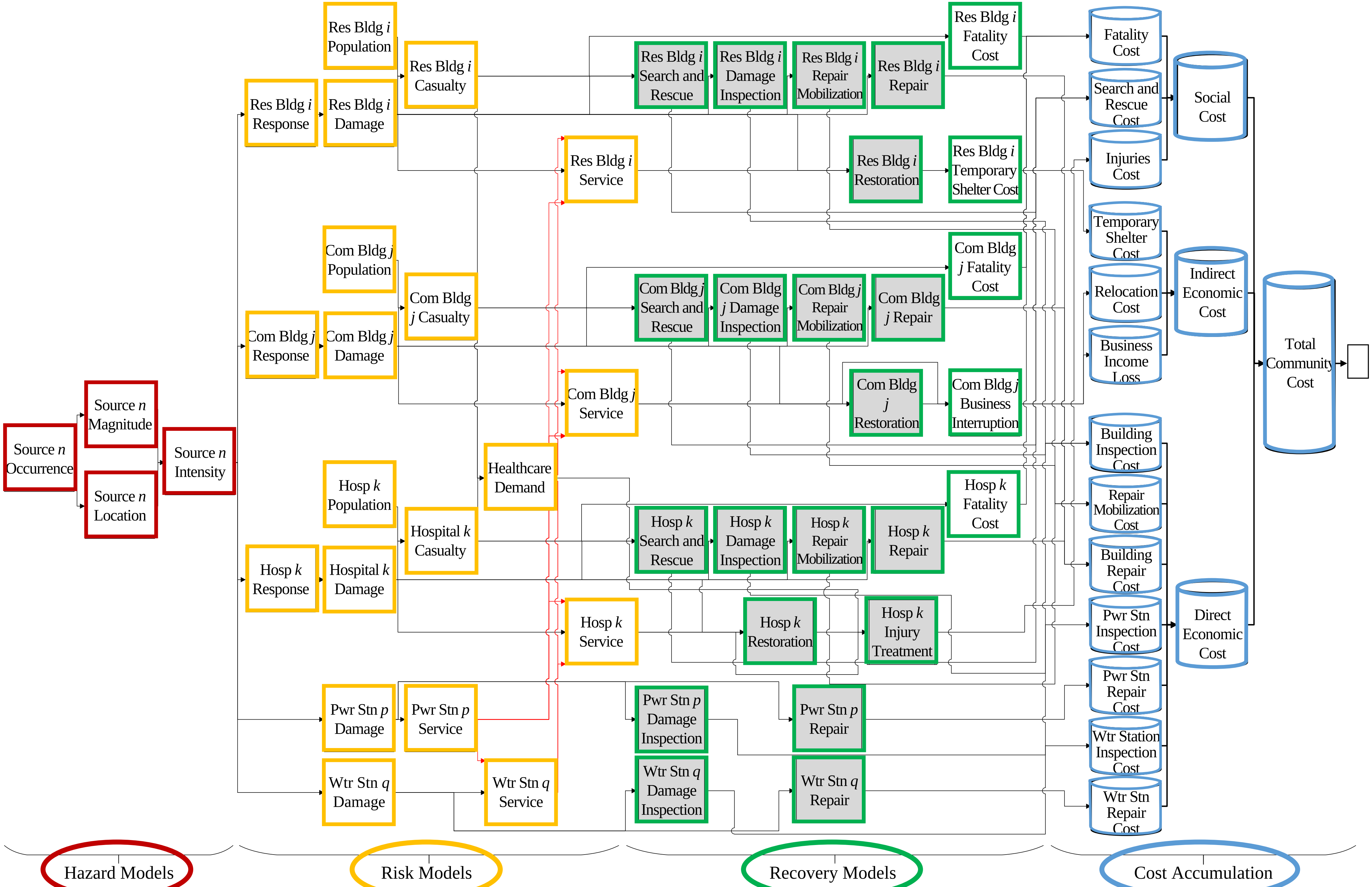
Infrastructure





Dependencies




Source n Occurrence
Source n Magnitude
Source n Location
Source n Intensity
Res Bldg i Population
Res Bldg i Response
Res Bldg i Damage
Res Bldg i Casualty
Com Bldg j Population
Com Bldg j Response
Com Bldg j Damage
Com Bldg j Casualty
Hosp k Population
Hosp k Response
Hospital k Damage
Hospital k Casualty
Healthcare Demand
Pwr Stn p Damage
Pwr Stn p Service
Wtr Stn q Damage
Wtr Stn q Service
Res Bldg i Service
Com Bldg j Service
Hosp k Service
Res Bldg i Search and Rescue
Res Bldg i Damage Inspection
Res Bldg i Repair Mobilization
Res Bldg i Repair
Res Bldg i Fatality Cost
Res Bldg i Restoration
Res Bldg i Temporary Shelter Cost
Com Bldg j Search and Rescue
Com Bldg j Damage Inspection
Com Bldg j Repair Mobilization
Com Bldg j Repair
Com Bldg j Fatality Cost
Com Bldg j Restoration
Com Bldg j Business Interruption
Hosp k Search and Rescue
Hosp k Damage Inspection
Hosp k Repair Mobilization
Hosp k Repair
Hosp k Fatality Cost
Hosp k Restoration
Hosp k Injury Treatment
Pwr Stn p Damage Inspection
Pwr Stn p Repair
Wtr Stn q Damage Inspection
Wtr Stn q Repair
Fatality Cost
Search and Rescue Cost
Injuries Cost
Temporary Shelter Cost
Relocation Cost
Business Income Loss
Building Inspection Cost
Repair Mobilization Cost
Building Repair Cost
Pwr Stn Inspection Cost
Pwr Stn Repair Cost
Wtr Station Inspection Cost
Wtr Stn Repair Cost
Social Cost
Indirect Economic Cost
Direct Economic Cost
Total Community Cost
Hazard Models
Risk Models
Recovery Models
Cost Accumulation

Simulation Example

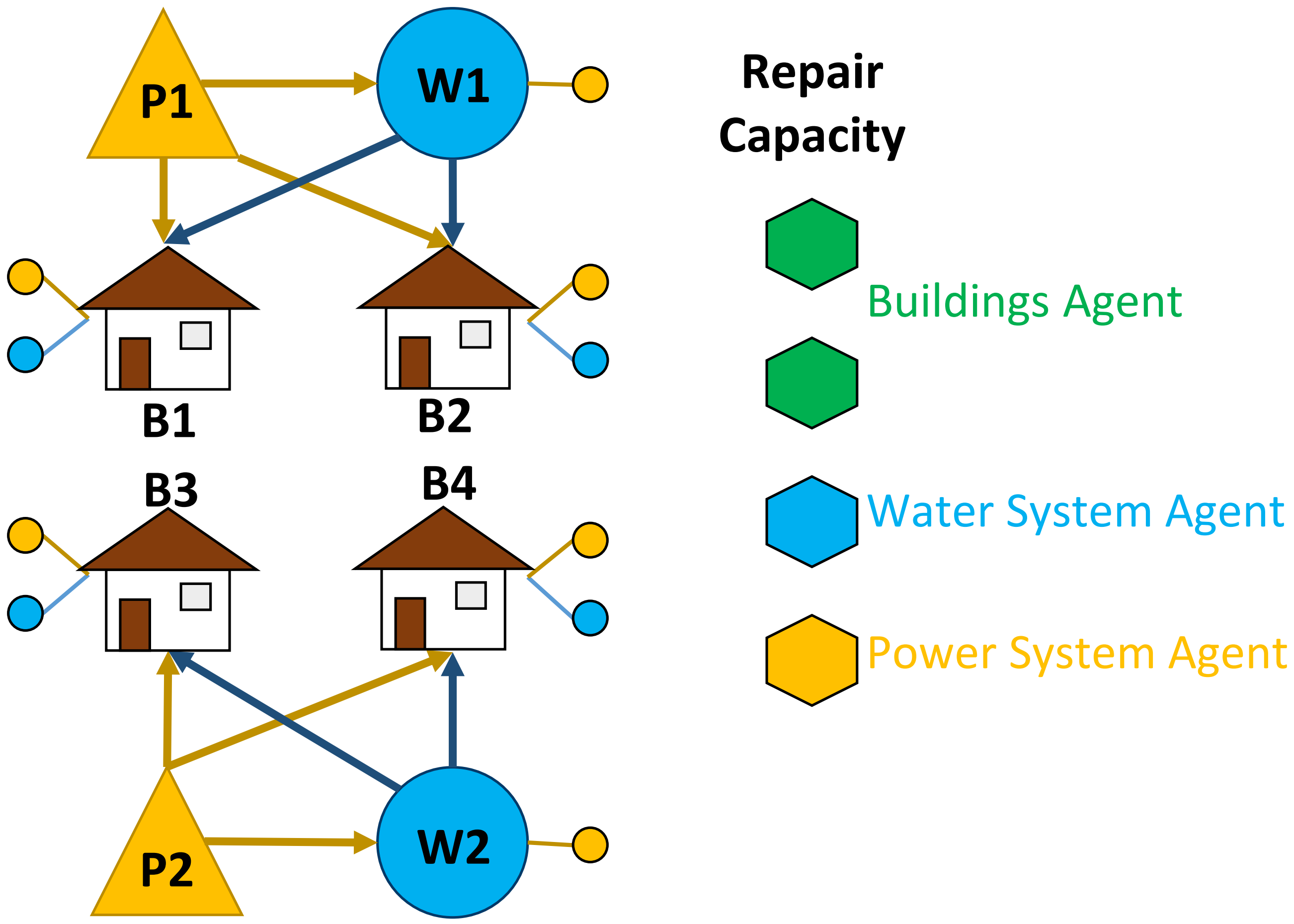
Information

Buildings: B1, B2, B3, B4
Building repair capacity: 2

Water stations: W1, W2
W1 provides service for: B1, B2
W2 provides service for: B3, B4
Water station repair capacity: 1

Power stations: P1, P2
P1 provides service for: B1, B2, W1
P2 provides service for: B3, B4, W2
Power station repair capacity: 1

Community



Risk

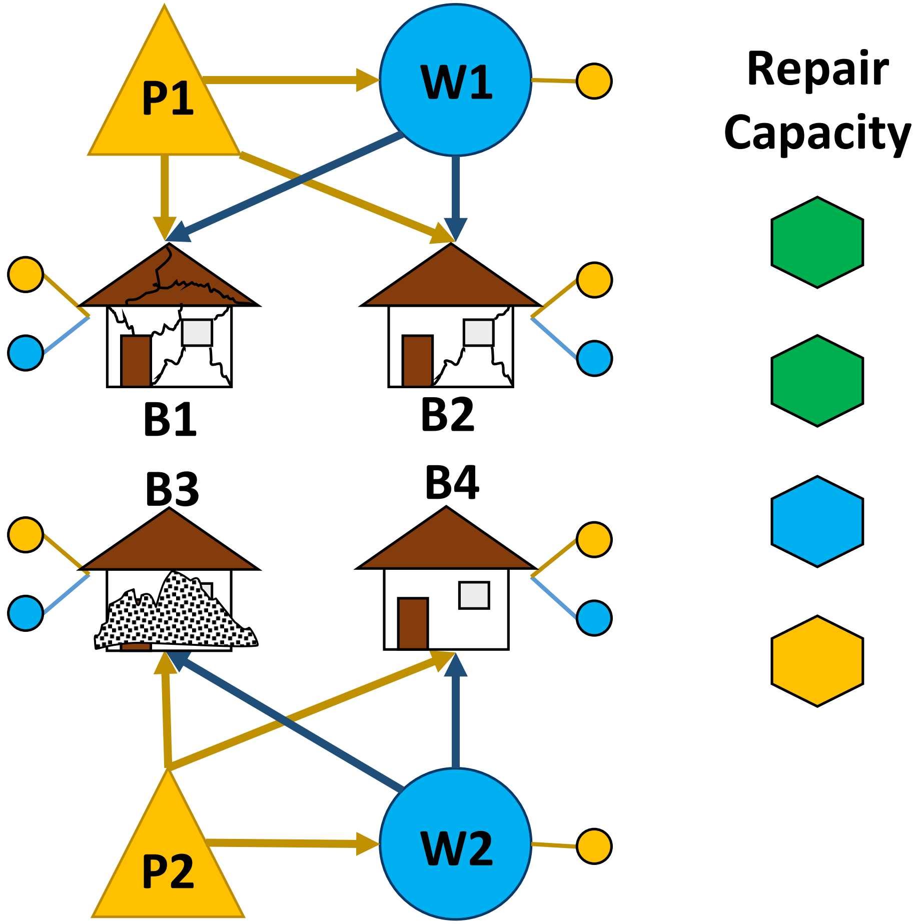
Post-hazard Status

B1: Moderate damage
B2: Slight damage
B3: Complete damage
B4: No damage

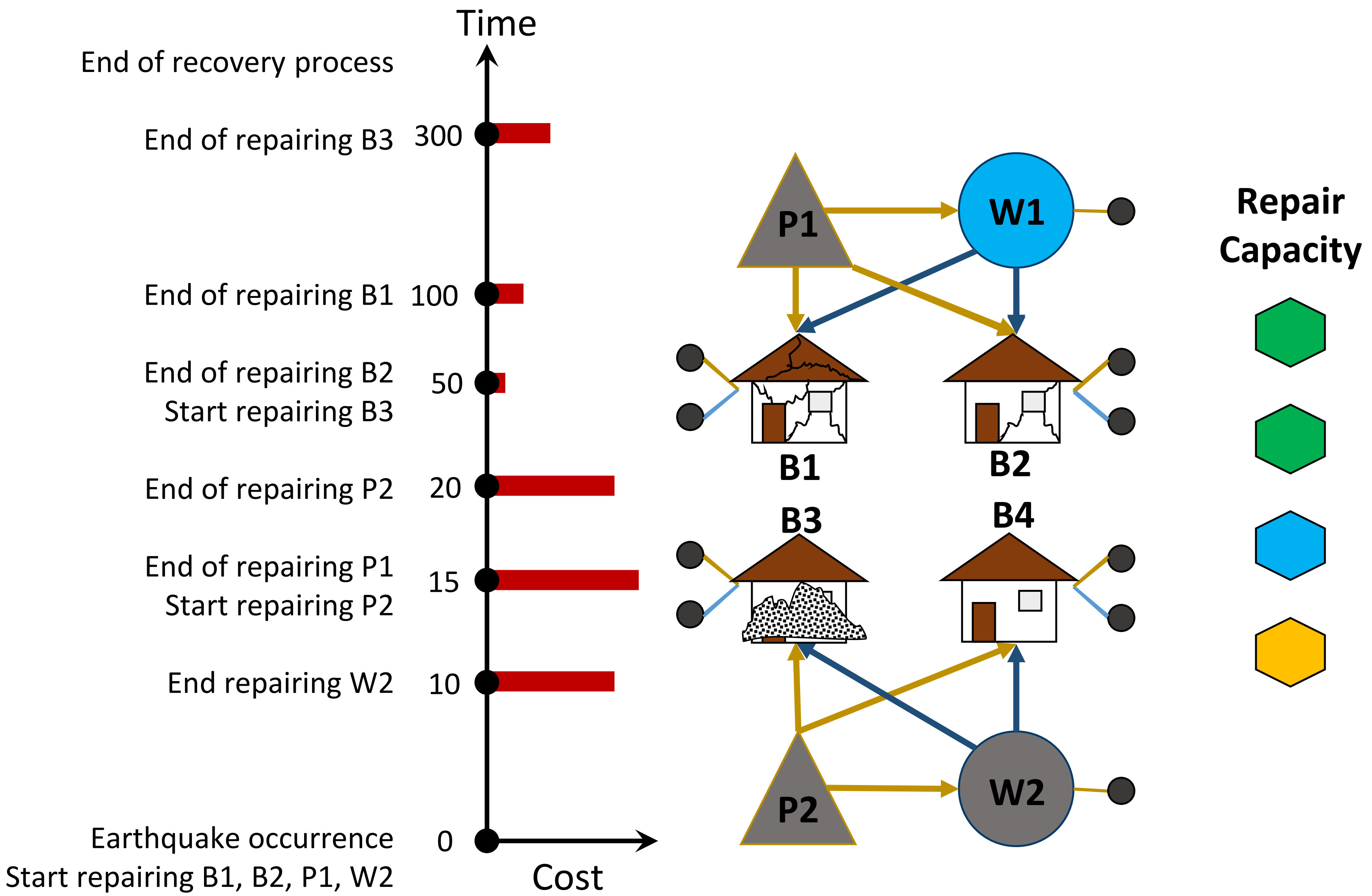
P1: Damaged
P2: Damaged

W1: Undamaged
W2: Damaged

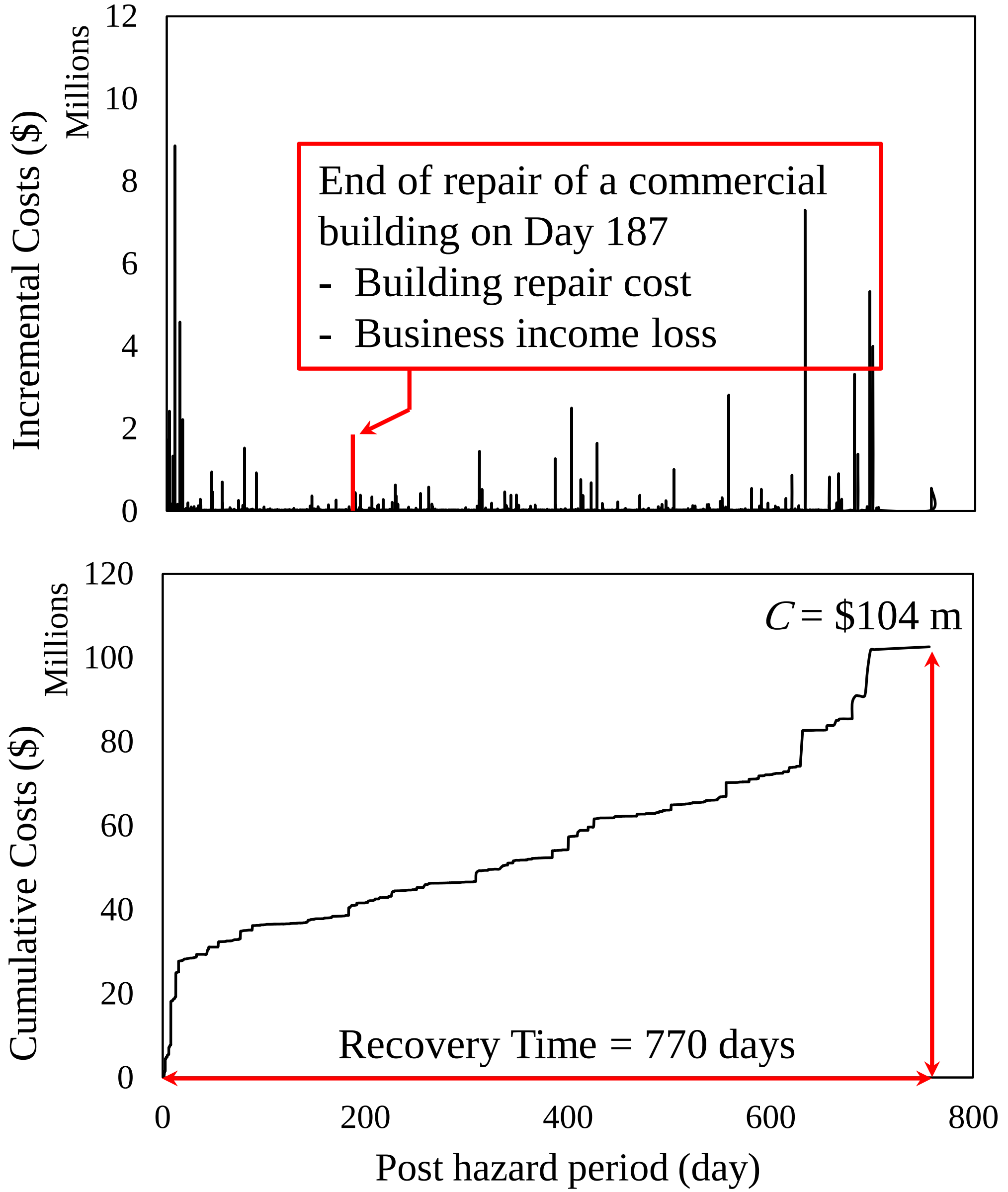
Community



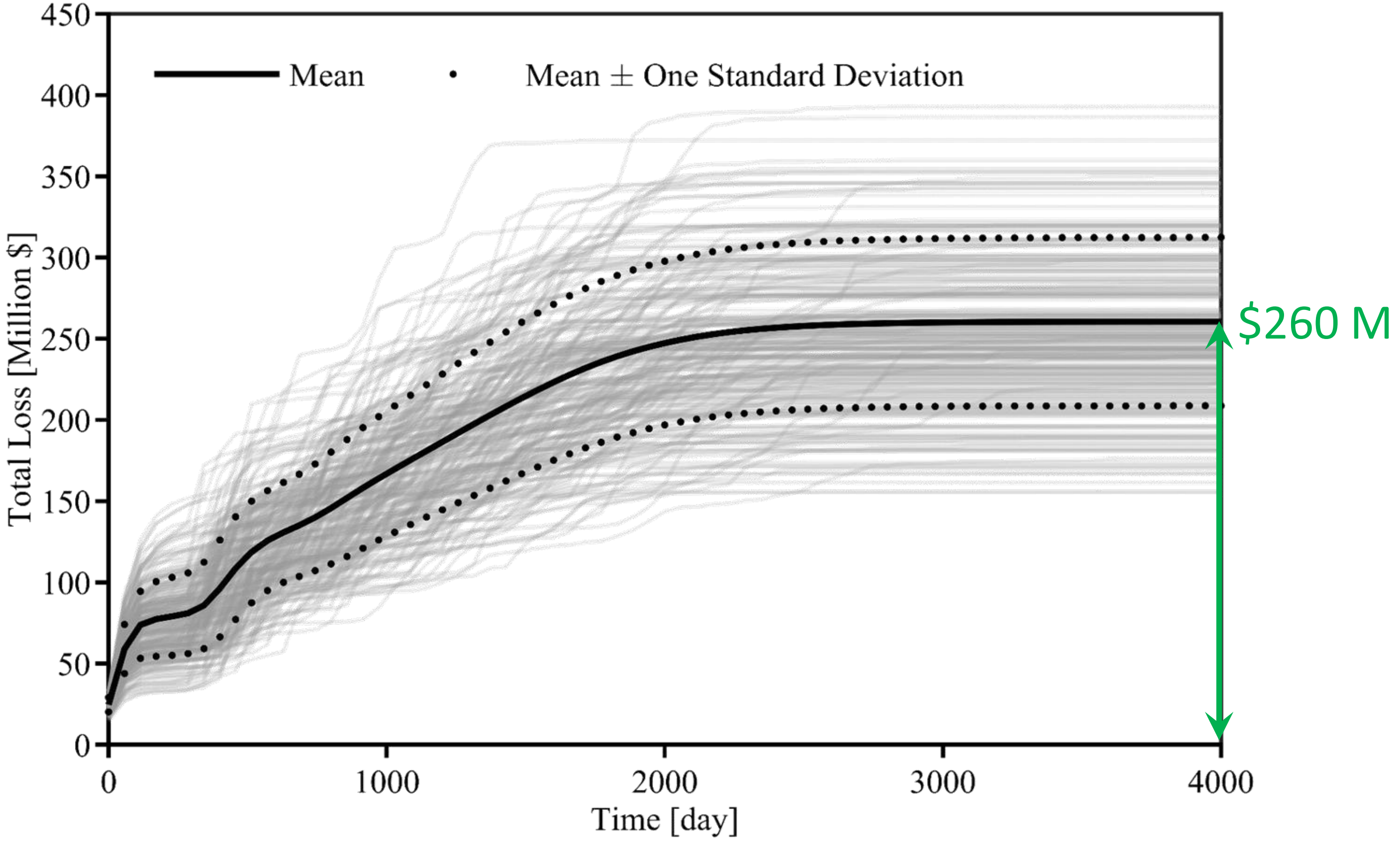
Agent-based Simulation



Simulation Output



Community Resilience Measure



$$\bar{\square} = 1 - \frac{\mu_C}{\text{GRP}} = 15\%$$

Decision Making

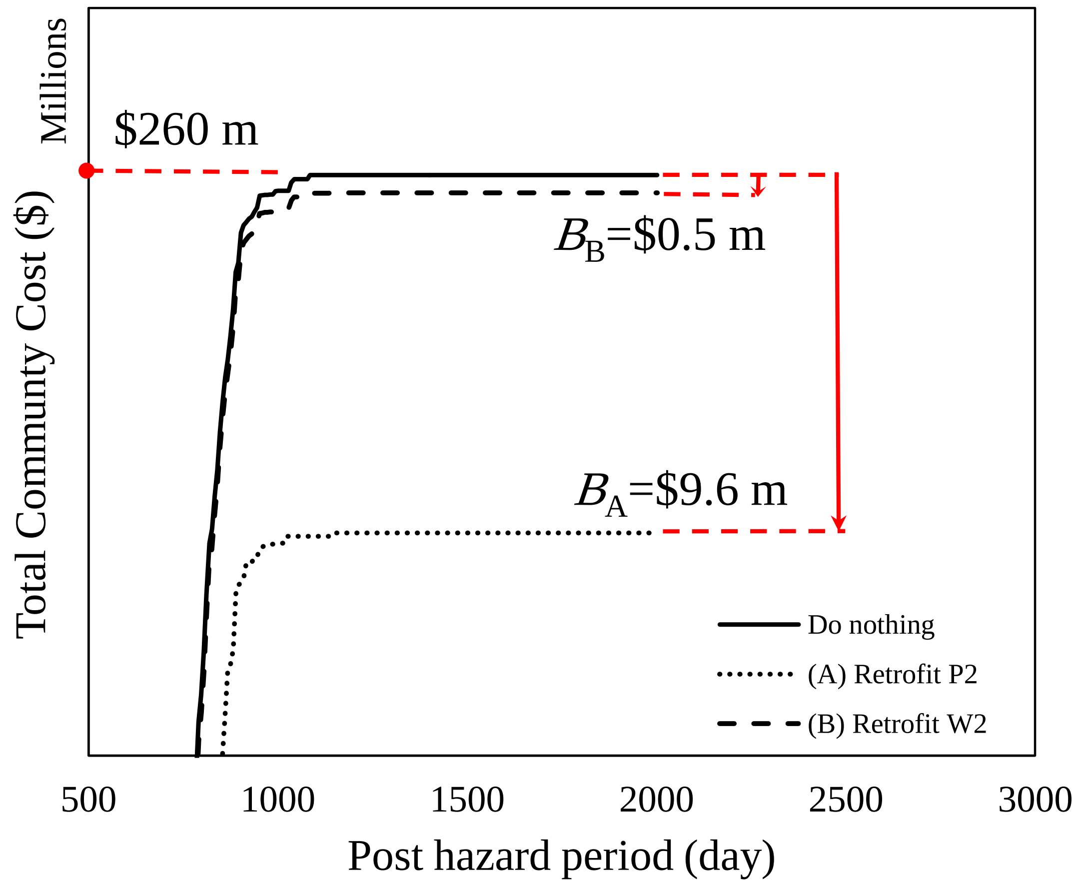
Decisions

Description
Decision A: Retrofit Power Station P2
Decision B: Retrofit Water Station W2

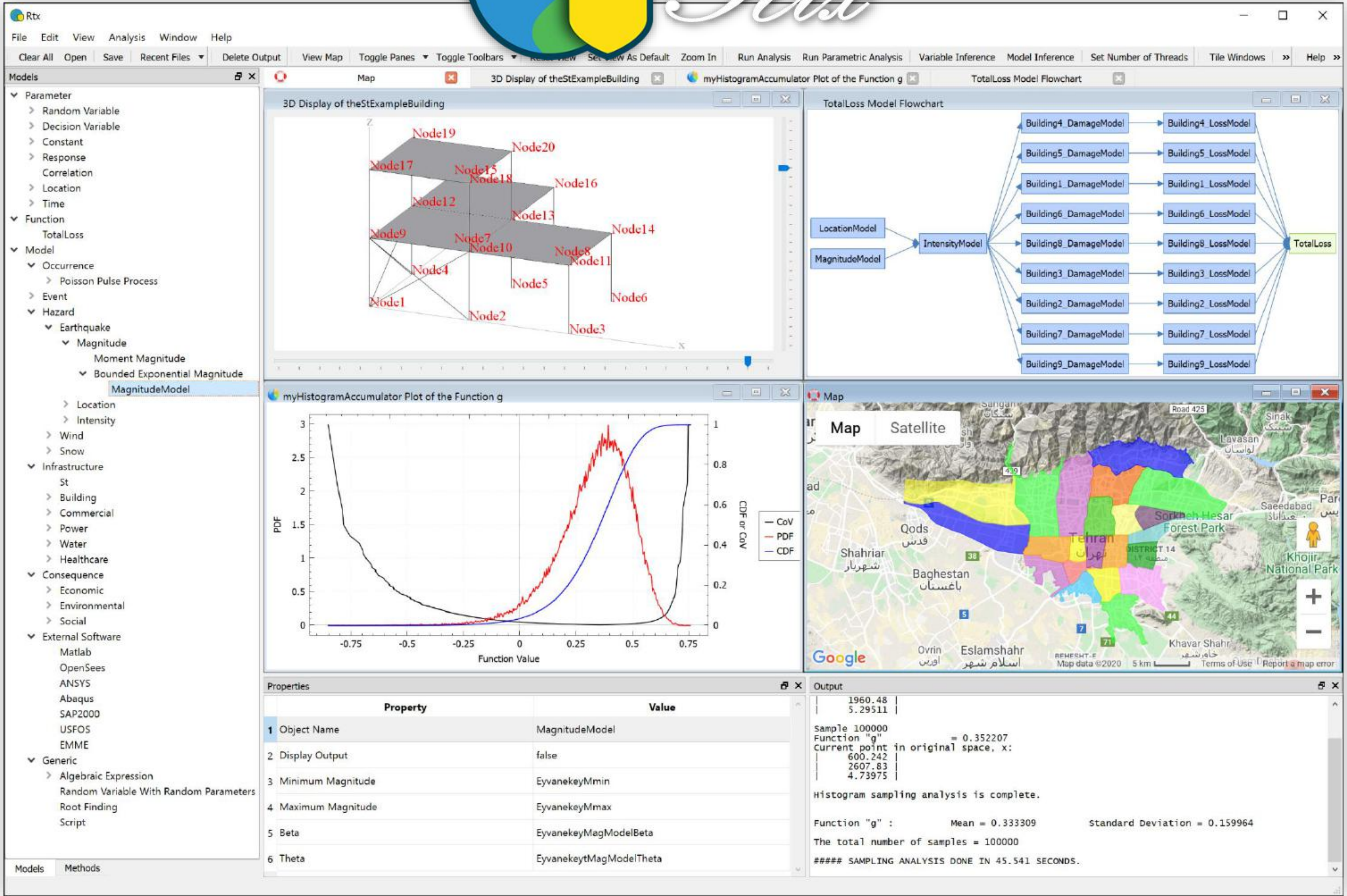
Cost of Implementation
Decision A: C_A= $0.5 m
Decision B: C_B= $0.1 m

Benefit of Implementation
Decision A: B_A= $9.6 m
Decision B: B_B= $0.5 m

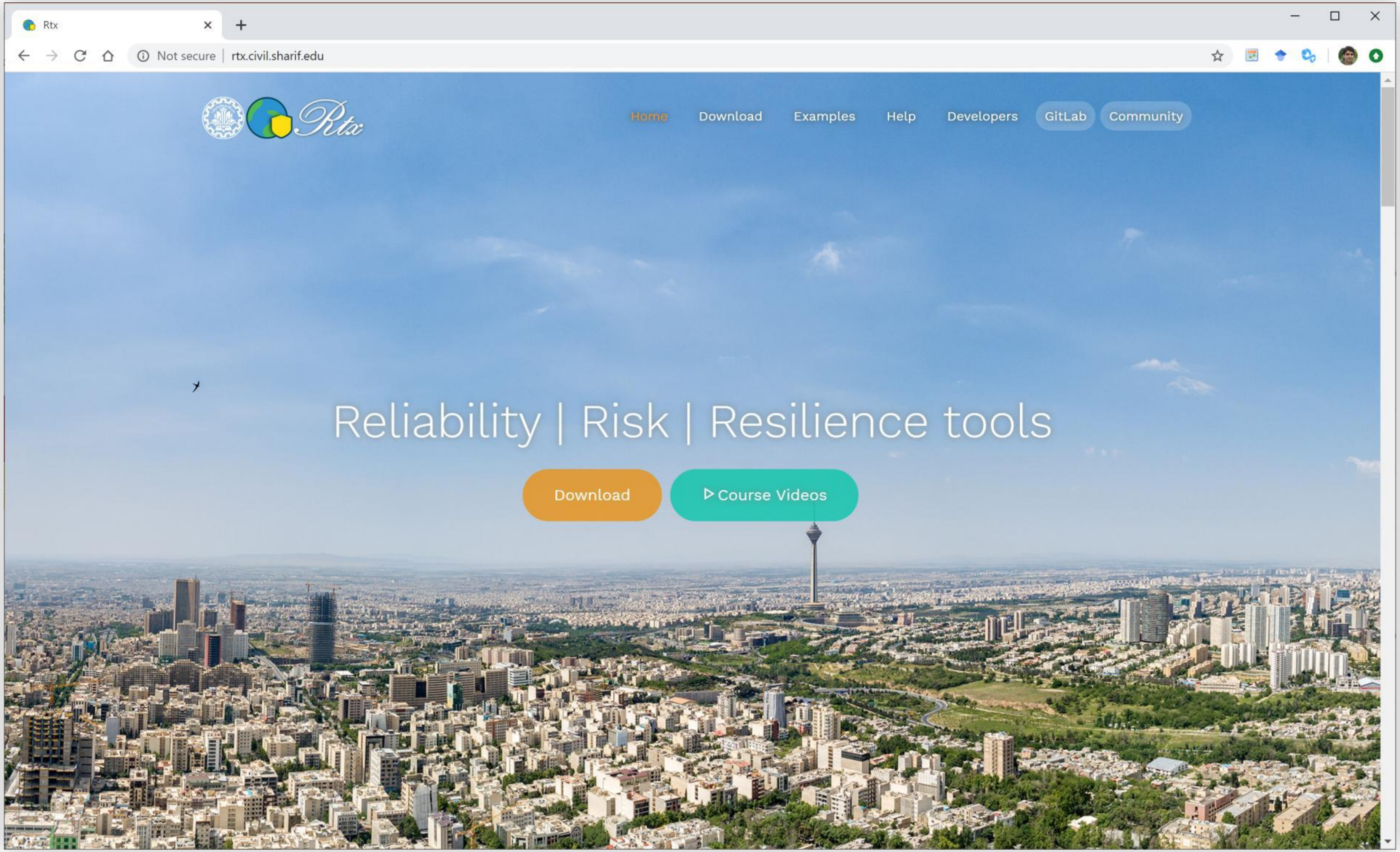
Evaluation Criterion: B/C
Decision A: B_A/C_A= 19.2
Decision B: B_B/C_B= 5.0



Rtx


Rtx
File Edit View Analysis Window Help
Clear All Open Save Recent Files Delete Output View Map Toggle Panes Toggle Toolbars Zoom In Run Analysis Run Parametric Analysis Variable Inference Model Inference Set Number of Threads Tile Windows Help
Models
Parameter
Random Variable
Decision Variable
Constant
Response
Correlation
Location
Time
Function
TotalLoss
Model
Occurrence
Poisson Pulse Process
Event
Hazard
Earthquake
Magnitude
Moment Magnitude
Bounded Exponential Magnitude
MagnitudeModel
Location
Intensity
Wind
Snow
Infrastructure
St
Building
Commercial
Power
Water
Healthcare
Consequence
Economic
Environmental
Social
External Software
Matlab
OpenSees
ANSYS
Abaqus
SAP2000
USFOS
EMME
Generic
Algebraic Expression
Random Variable With Random Parameters
Root Finding
Script
Models Methods
Map
3D Display of theStExampleBuilding
myHistogramAccumulator Plot of the Function g
TotalLoss Model Flowchart
LocationModel
MagnitudeModel
IntensityModel
Building4_DamageModel
Building4_LossModel
Building5_DamageModel
Building5_LossModel
Building1_DamageModel
Building1_LossModel
Building6_DamageModel
Building6_LossModel
Building8_DamageModel
Building8_LossModel
Building3_DamageModel
Building3_LossModel
Building2_DamageModel
Building2_LossModel
Building7_DamageModel
Building7_LossModel
Building9_DamageModel
Building9_LossModel
TotalLoss
PDF
CDF or CoV
Function Value
CoV
PDF
CDF
Map Satellite
Google
Properties
Property Value
1 Object Name MagnitudeModel
2 Display Output false
3 Minimum Magnitude EyvanekeyMmin
4 Maximum Magnitude EyvanekeyMmax
5 Beta EyvanekeyMagModelBeta
6 Theta EyvanekeytMagModelTheta
Output
Sample 100000
Function "g" = 0.352207
Current point in original space, x:
600.242
2607.83
4.73975
Histogram sampling analysis is complete.
Function "g" : Mean = 0.333309 Standard Deviation = 0.159964
The total number of samples = 100000
SAMPLING ANALYSIS DONE IN 45.541 SECONDS.

Rtx Website



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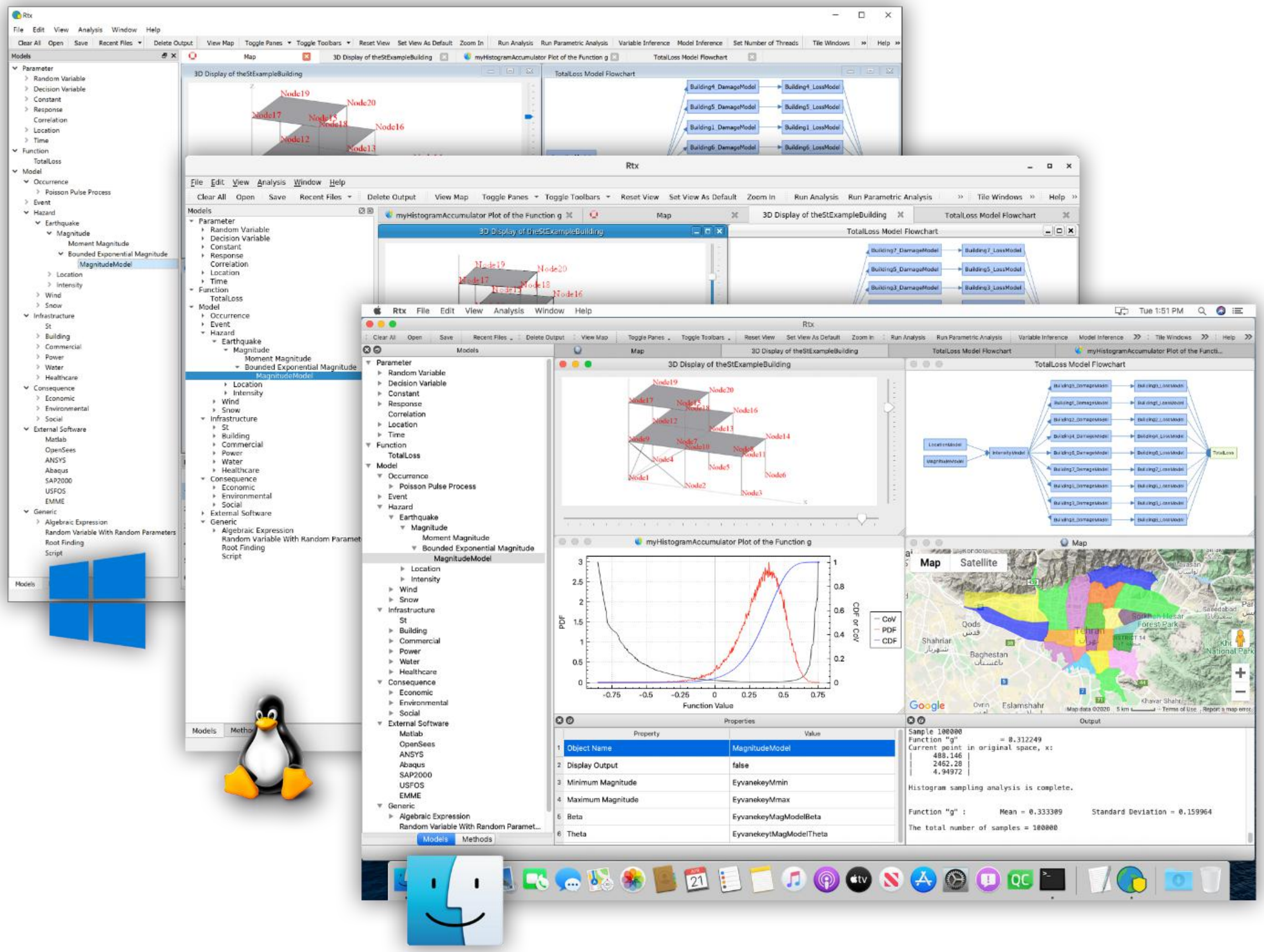
Rtx
File Edit View Analysis Window Help
Clear All Open Save Recent Files Delete Output View Map Toggle Panes Toggle Toolbars Reset View Set View As Default Zoom In Run Analysis Run Parametric Analysis Tile Windows Help
Models
Parameter
Random Variable
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Wind
Snow
Infrastructure
St
Building
Commercial
Power
Water
Healthcare
Consequence
Economic
Environmental
Social
External Software
Matlab
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EMME
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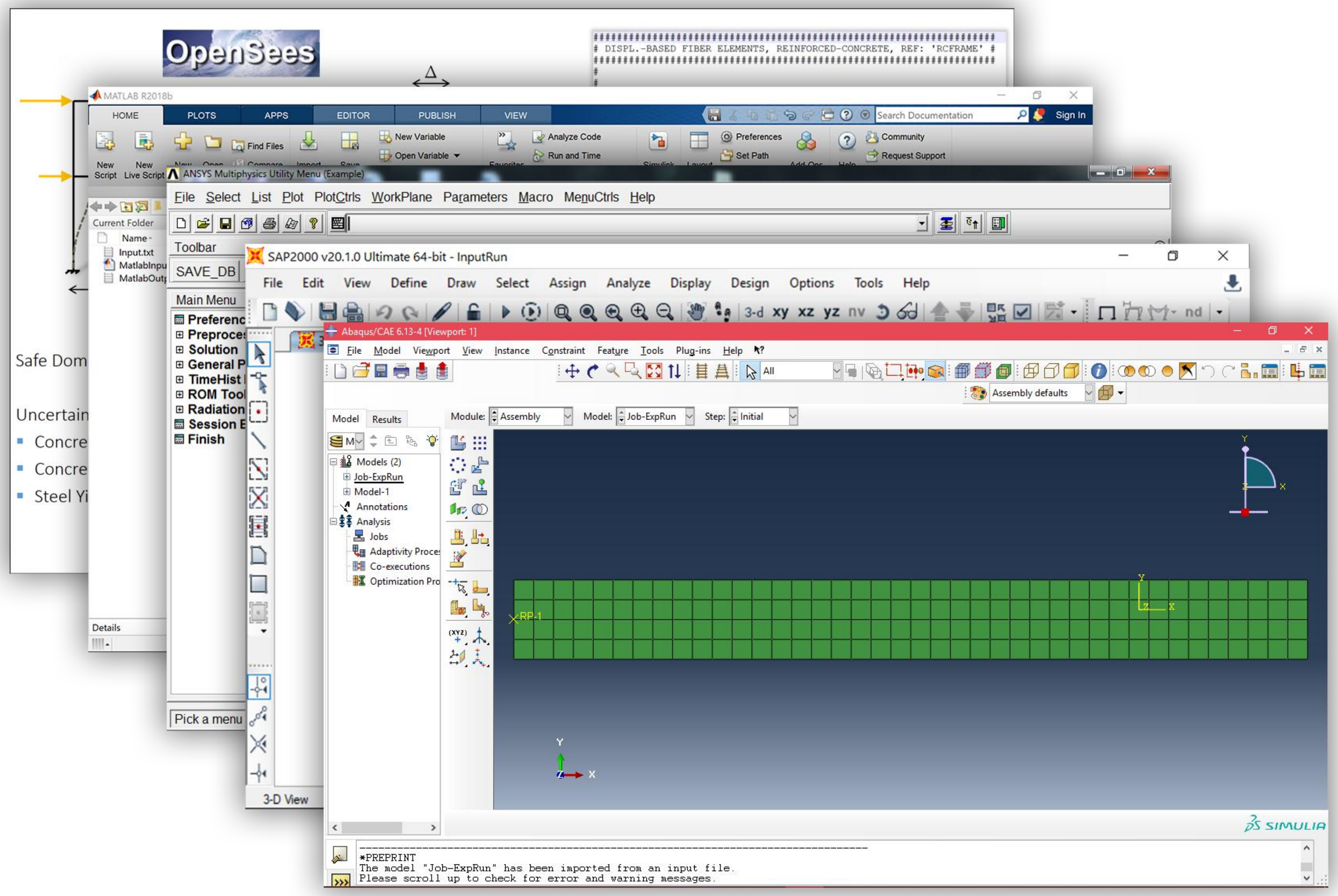
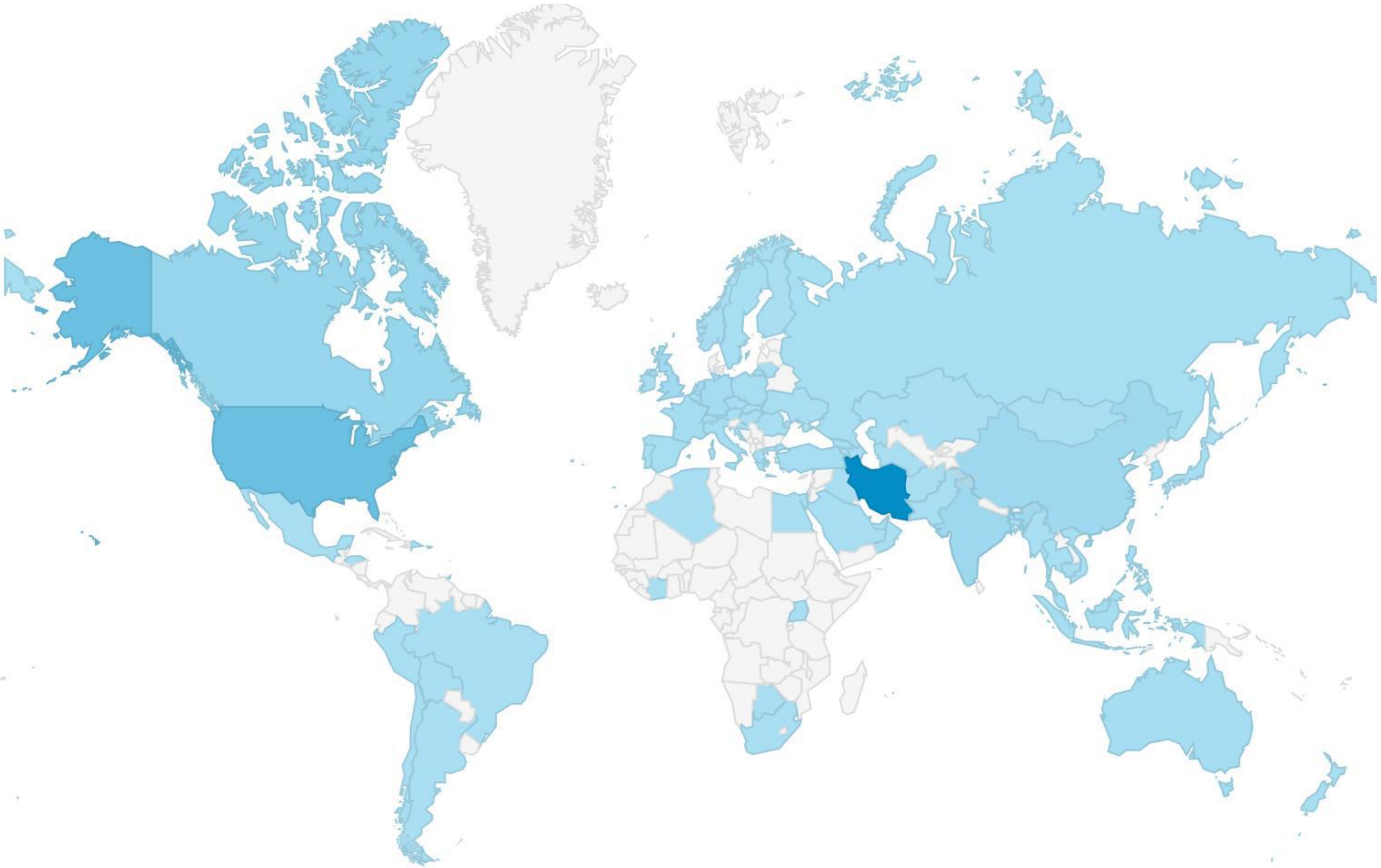
Models Methods
3D Display of theStExampleBuilding
TotalLoss Model Flowchart
myHistogramAccumulator Plot of the Function g
Map
Satellite
PDF
CDF or CoV
Function Value
CoV
PDF
CDF
Properties
Property Value
1 Object Name MagnitudeModel
2 Display Output false
3 Minimum Magnitude EyvanekeyMmin
4 Maximum Magnitude EyvanekeyMmax
5 Beta EyvanekeyMagModelBeta
6 Theta EyvanekeyMagModelTheta
Output
Sample 100000
Histogram sampling analysis is complete.
Function "g" : Mean = 0.333309 Standard Deviation = 0.159964
The total number of samples = 100000

External Software

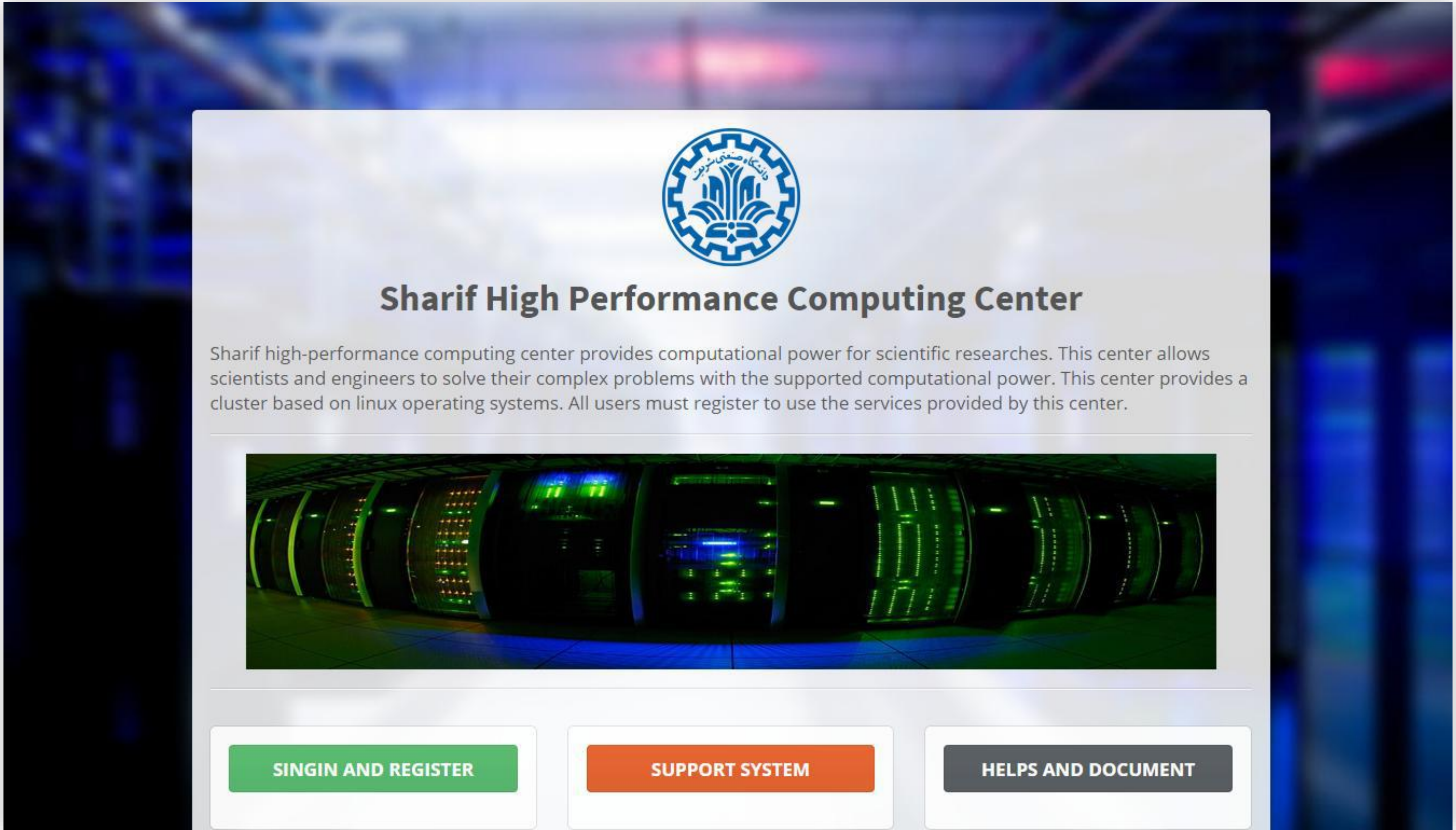


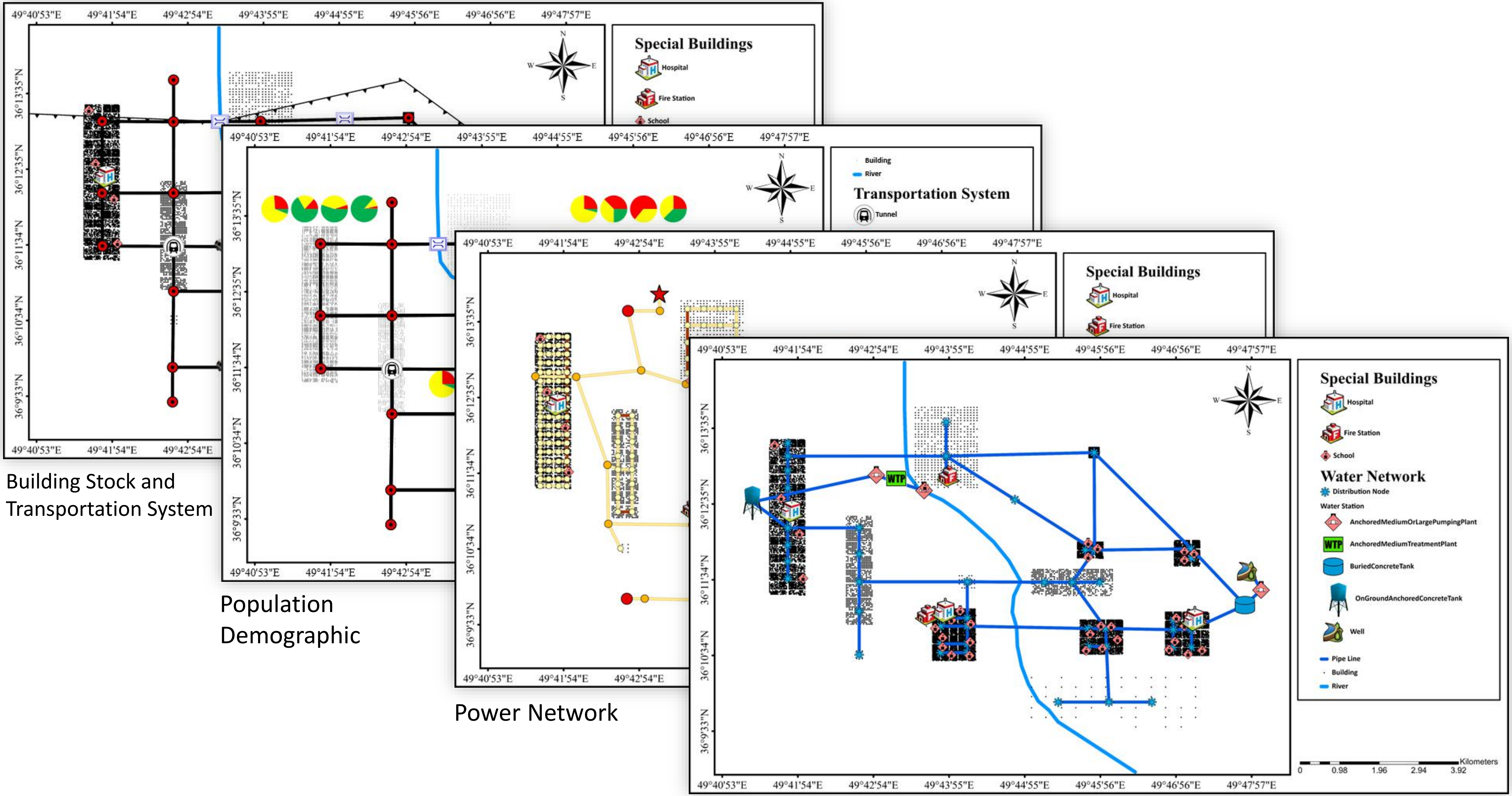
Rtx Users Worldwide

1.		Iran
2.		United States
3.		Canada
4.		India
5.		China
6.		United Kingdom
7.		Germany
8.		Netherlands
9.		Australia
10.		France



Analysis of Large Systems





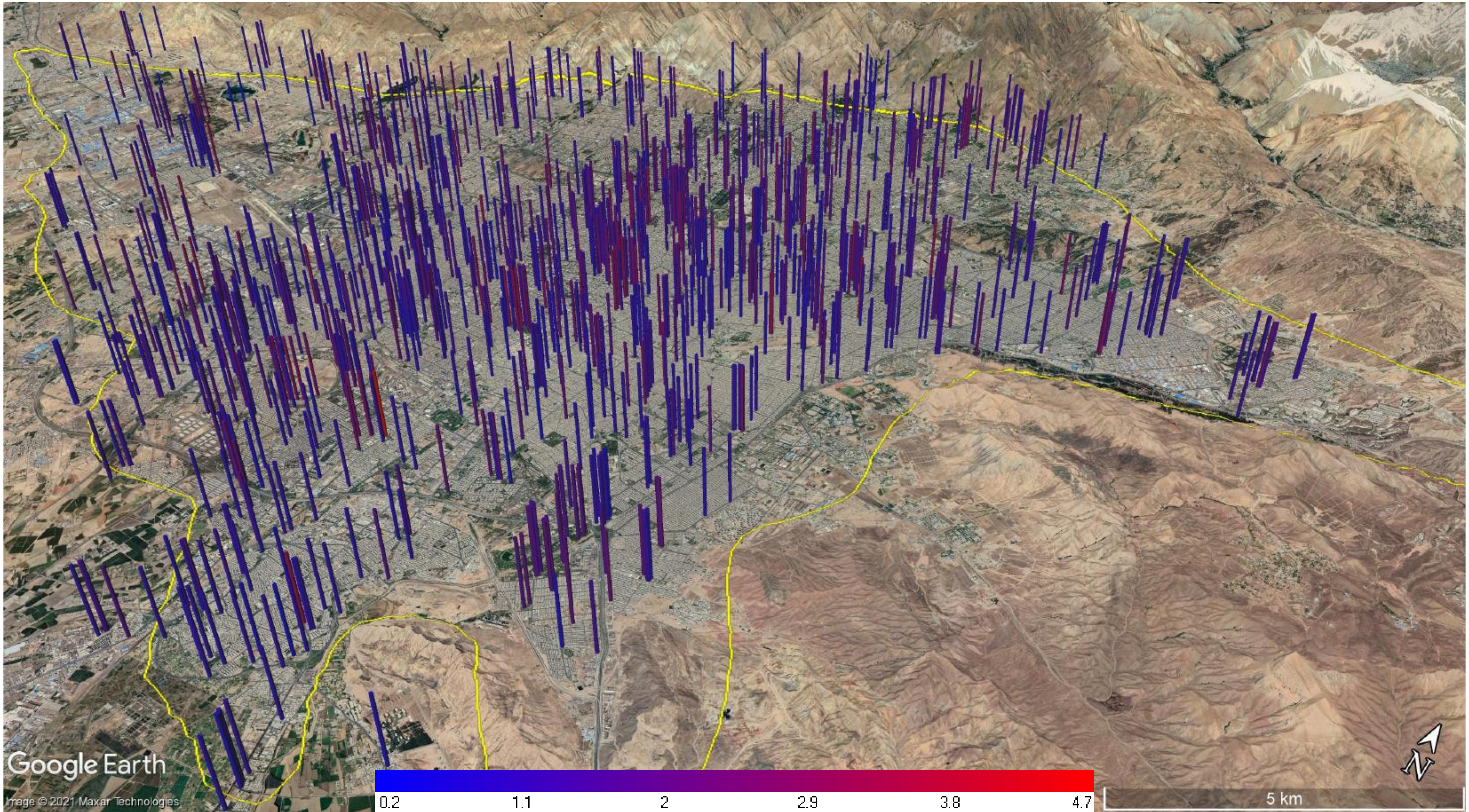
Building Stock and Transportation System

Population Demographic

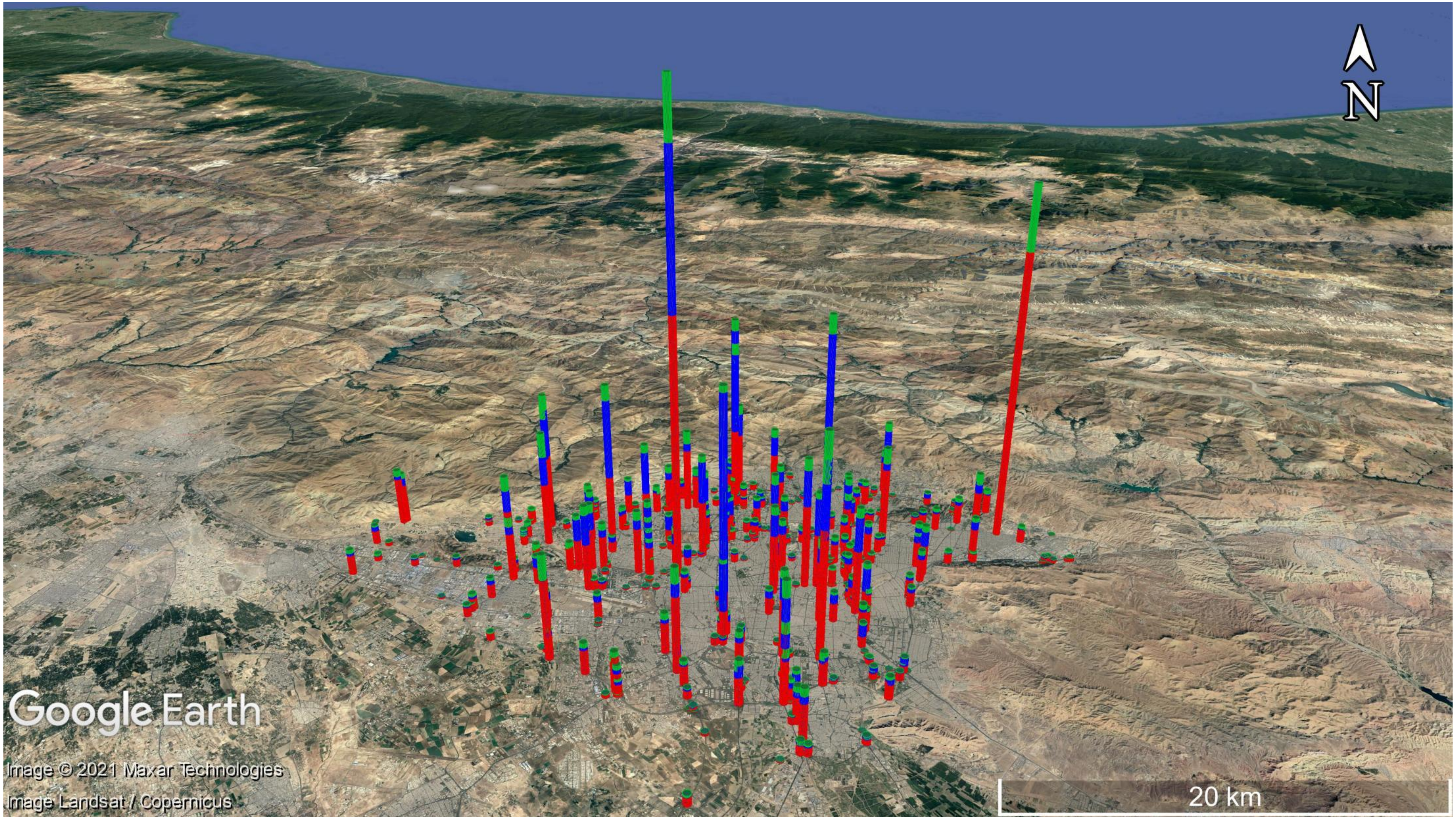
Power Network

Water Network

Tehran Municipality Buildings

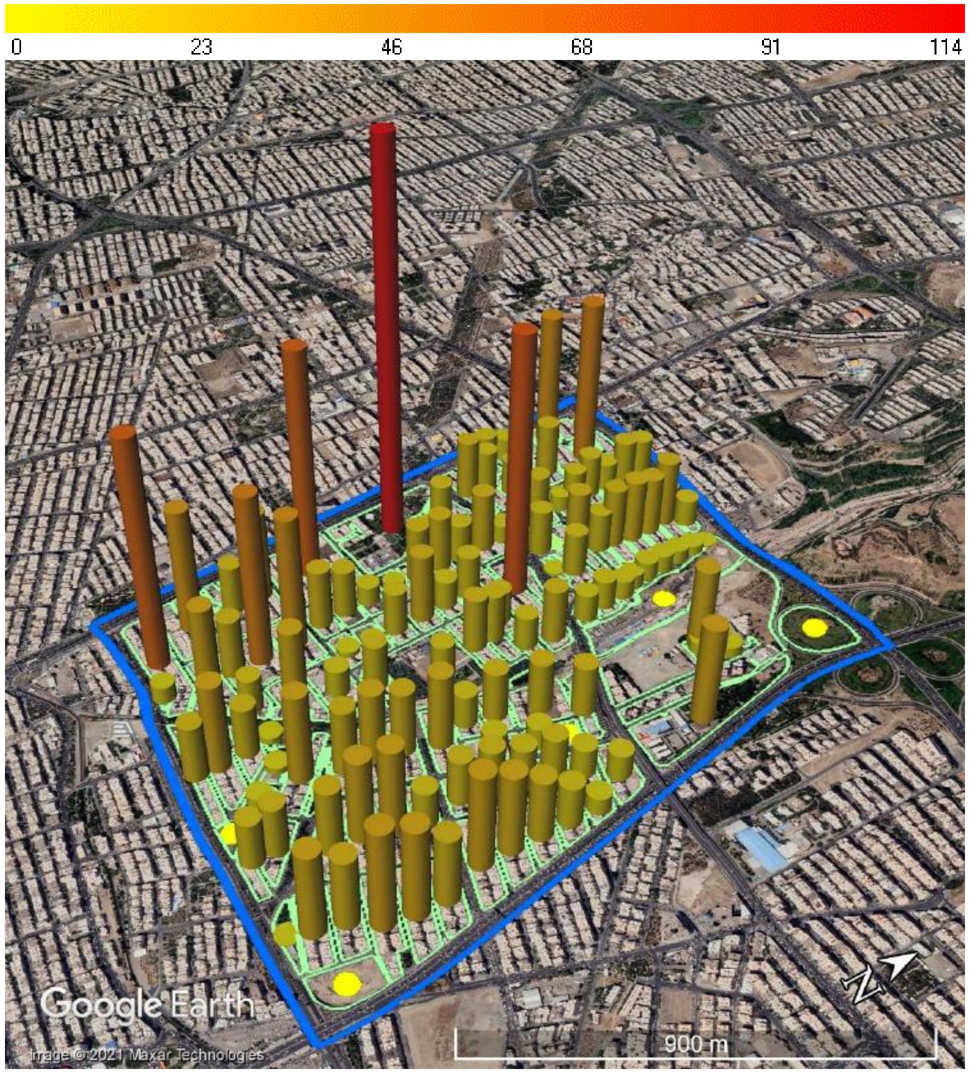


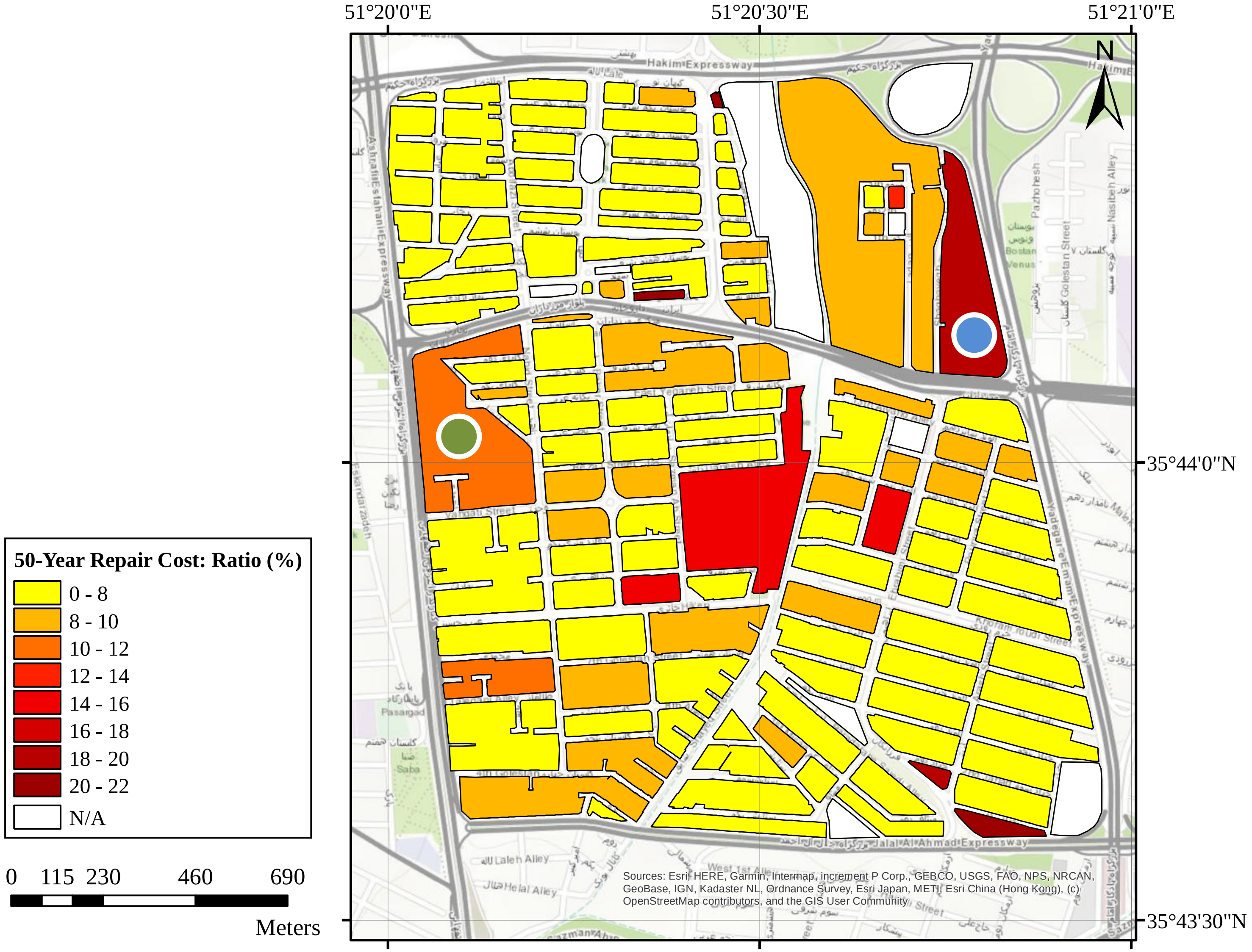
Tehran Bridge Network



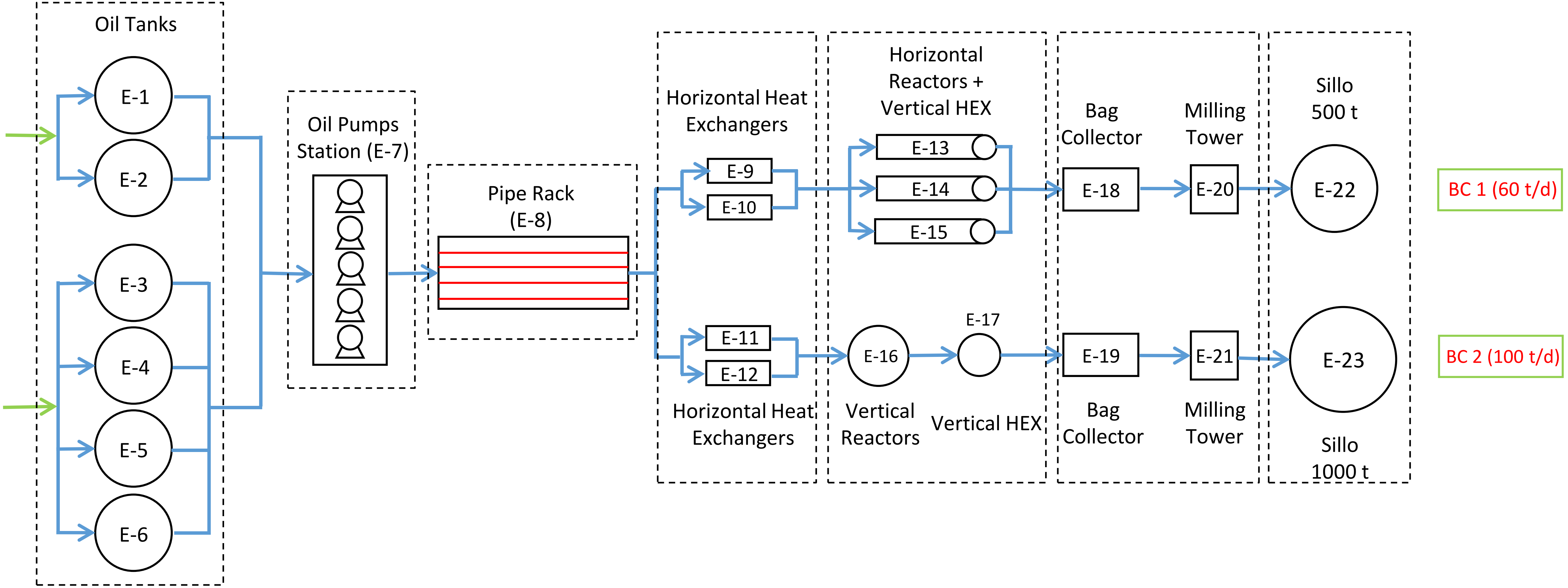
Risk Model of Tehran

50-Year Repair Cost (BT)





Oil Infrastructure



Further Information

Check for updates

ASCE

Probabilistic Framework for Evaluating Community Resilience: Integration of Risk Models and Agent-Based Simulation

Hossein Nasrazadani, S.M.ASCE[1] and Mojtaba Mahsuli, A.M.ASCE[2]

Abstract: This paper proposes a novel probabilistic framework to quantitatively evaluate the resilience of communities comprising buildings and various interdependent infrastructure systems. To this aim, the proposed framework seamlessly integrates risk models and agent-based simulation in a Monte Carlo sampling scheme. The risk module includes models that evaluate the initial posthazard state of the community by probabilistic simulation of the hazard event, the structural response and damage of buildings and infrastructure systems, and cascading consequences that arise from interdependencies. Subsequently, the agent-based module simulates the recovery of the community from those consequences in which decentralized autonomous decision-making entities called "agents" undertake recovery operations. The agents prioritize buildings and infrastructure components for recovery and schedule operations as discrete events with uncertain duration and cost. Consequently, the probability distribution of the total cost incurred by the community and the total recovery time is evaluated. A resilience measure is then proposed as a function of the total community cost, which represents demand, and the gross regional product of the community, which represents the capacity to cope with that demand. The framework is showcased by a comprehensive application to a community comprising a portfolio of residential and commercial buildings, an electric power system, a water system, and a healthcare system subject to seismic hazard. **DOI:** 10.1061/(ASCE)ST.1943-541X.0002810.

Author keywords: Community resilience; Risk analysis; Recovery analysis; Agent-based simulation; Infrastructure systems; Interdependency; Cost.

Nasrazadani, H., Mahsuli, M. (2020) "Probabilistic framework for evaluating community resilience: Integration of risk models and agent-based simulation," ASCE Journal of Structural Engineering, 146 (11): 04020250

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