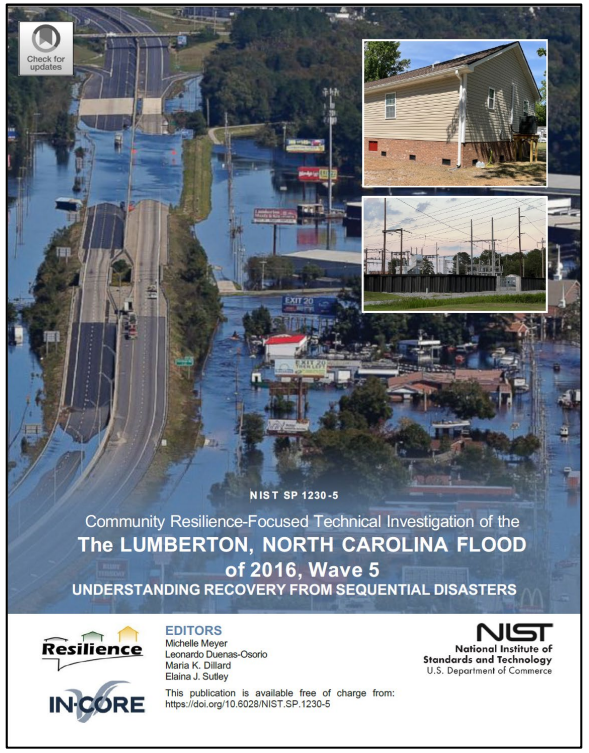
A Software Architecture for a Simplified Systems Model for Resilience Planning

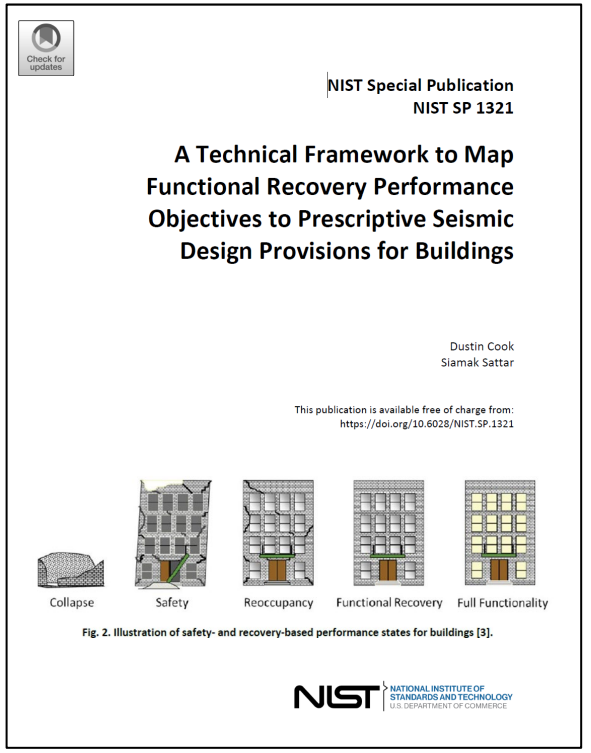
Ken Harrison

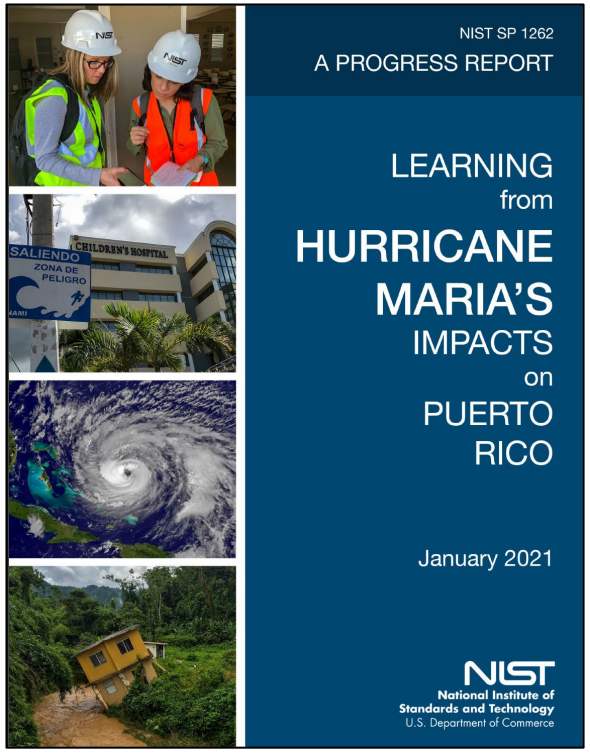
NIST

Friday, Dec. 4, 2017, NIST

Modeling is informed by field studies







Created by Georgiana Ionescu
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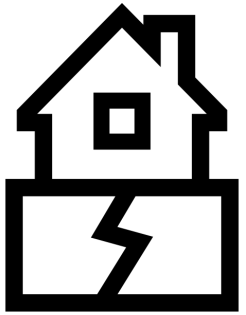

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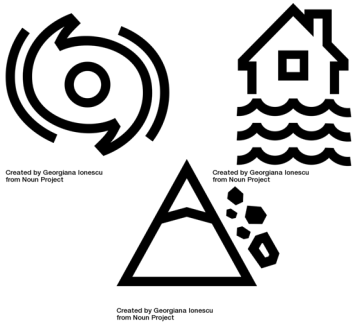

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NIST Alternatives for Resilient Communities (NIST ARC)

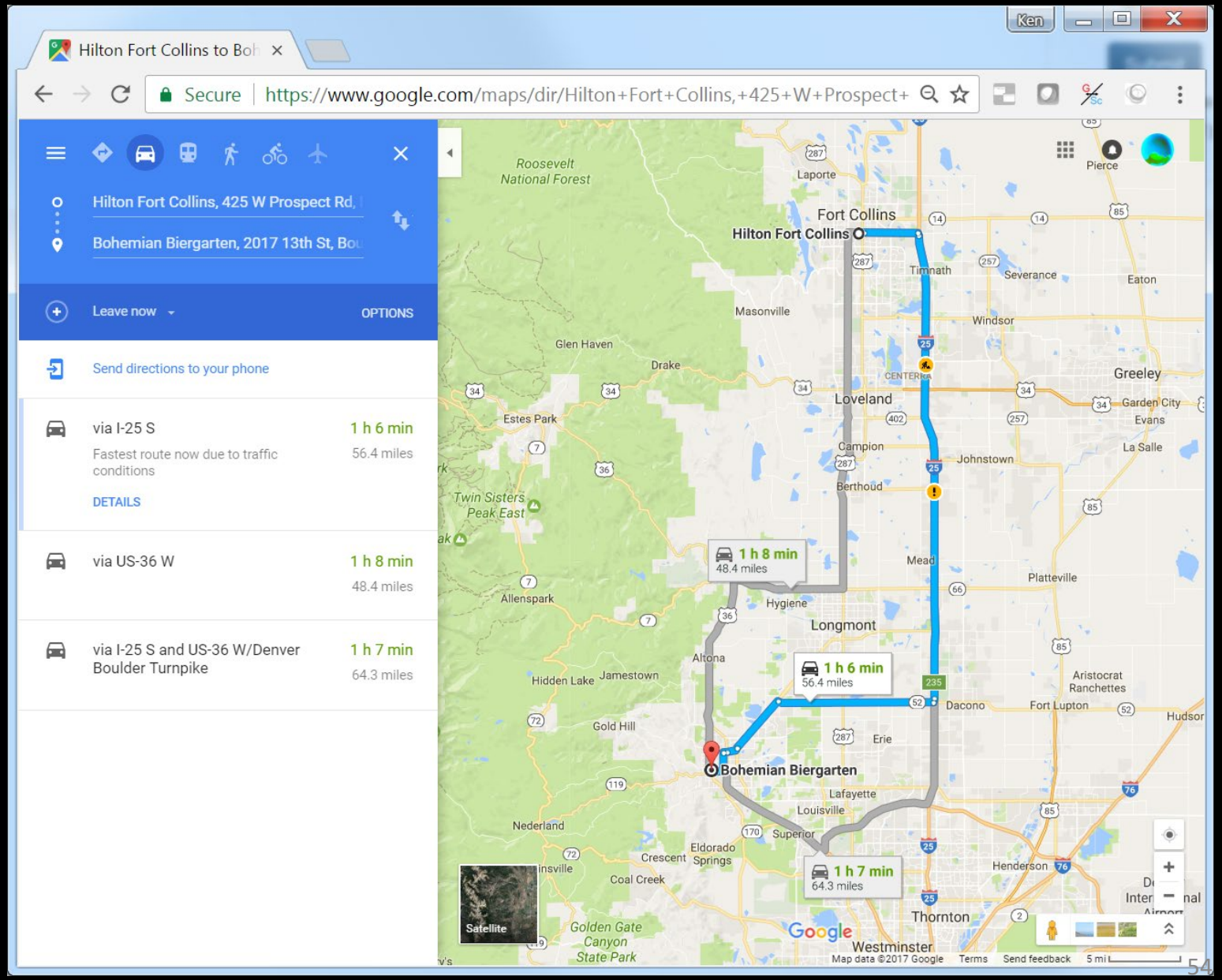
An interactive tool for developing alternative sets of actions that meet community resilience and cost goals, given hazard and interdependency information, and socio-economic data.

Harrison, K, TI Faiz, Z Farahmandfar, S Crawford, and J. Loerzel. 2023. "NIST Alternatives for Resilient Communities (NIST ARC) Software Tool: Mathematical Programming Model." Technical Note (NIST TN) NIST TN 2239pt1. National Institute of Standards and Technology.

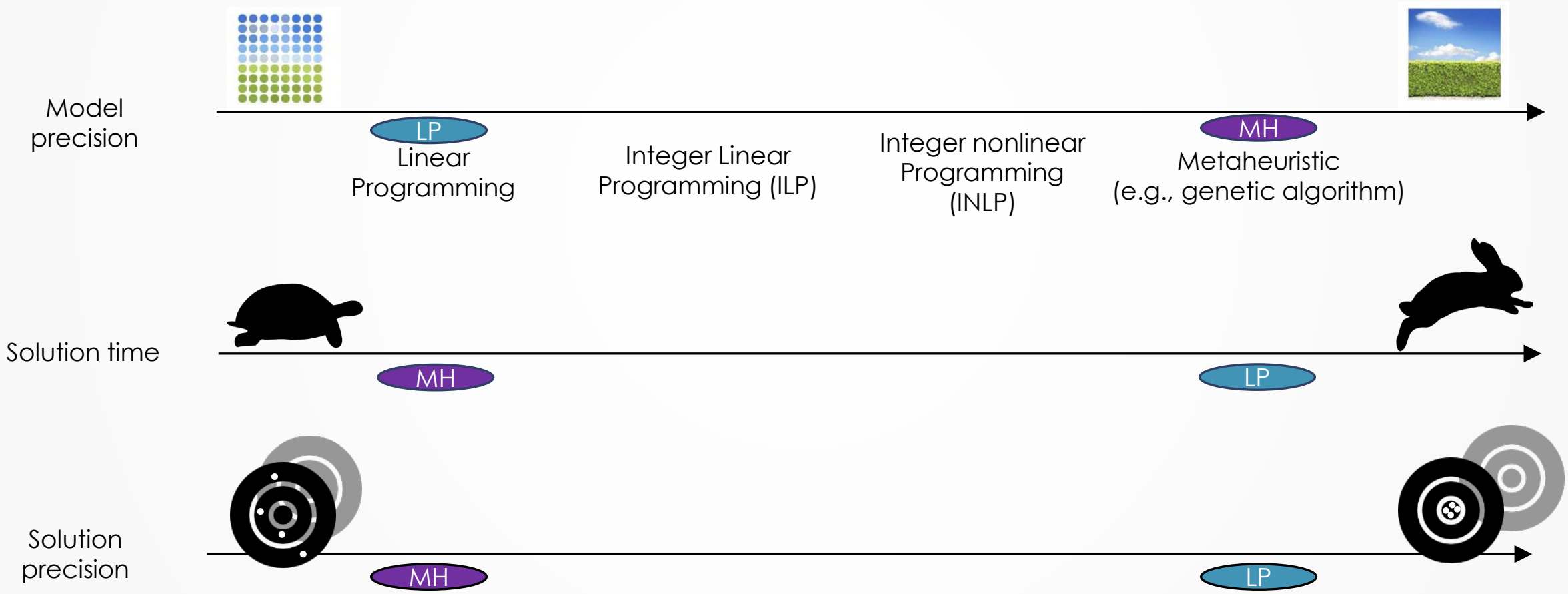
engineering laboratory

Need alternatives !!

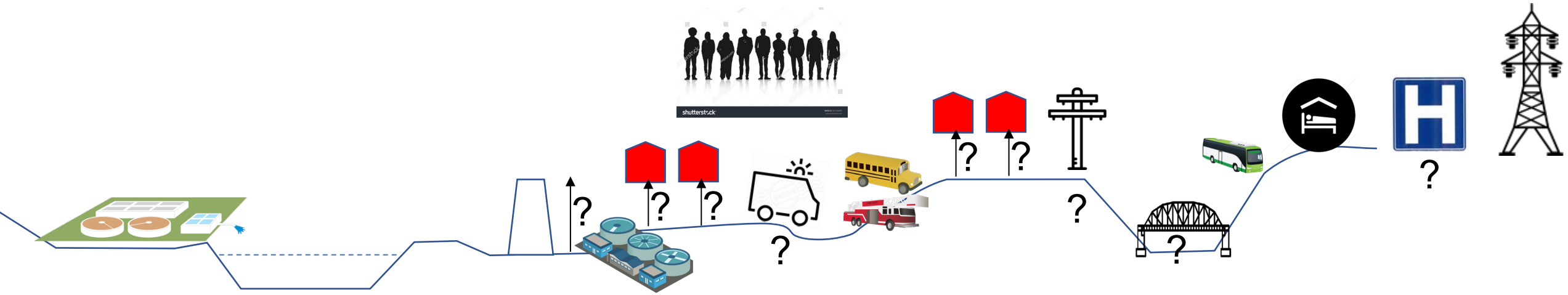
- Many reasons for looking at near-optimal:
  - Valued stops along the way
  - Avoid tolls!
  - Can’t make it Over the Hill
  - Scenery
  - Safety



Which flavor of math programming? Tradeoffs



The resilience system

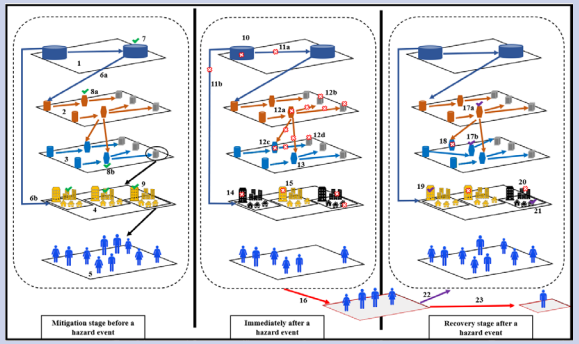


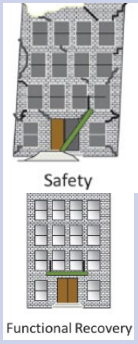
- How to…
  - measure a community's resilience?
  - simulate recovery?
  - model a change in a community's resilience?
  - **find a set of actions that meets resilience (and other) goals?**

Focus here: Immense scale of the decision problem: near infinite combinations of potential actions

Timeline

MP:





Long range planning

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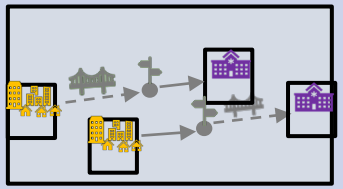
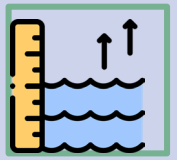
Dynamics
- Building stock

Hazard risk
- Climate



Critical Building services



Incorporate CR research:
- Social Sci.
- Econ
- Policy
- SVI
- Risk pref's

Broader system (e.g.,bus., schools)

Unc/ Risk: Unc Prop. | Param ranking | Fragilities | Efficient sampling | Scenario reduction | Risk obj (collab) | VOI | Climate Adaptation

Haz/ Study: Riverine flooding/Lumberton | Seismic/Shelby | Joplin | Camp Fire | SLR (Fairfield, CT) | Hurr Maria | User-defined

ARC/ User Jupyter notebook | Free/Open opt tools | Commun. Engagement | Usability changes | Tool Integration | Solution schemes

Products ARC | MP | Uncertainty | ARC documentation (TN) | Lumb Wave 6 (TN chapter) | ABM

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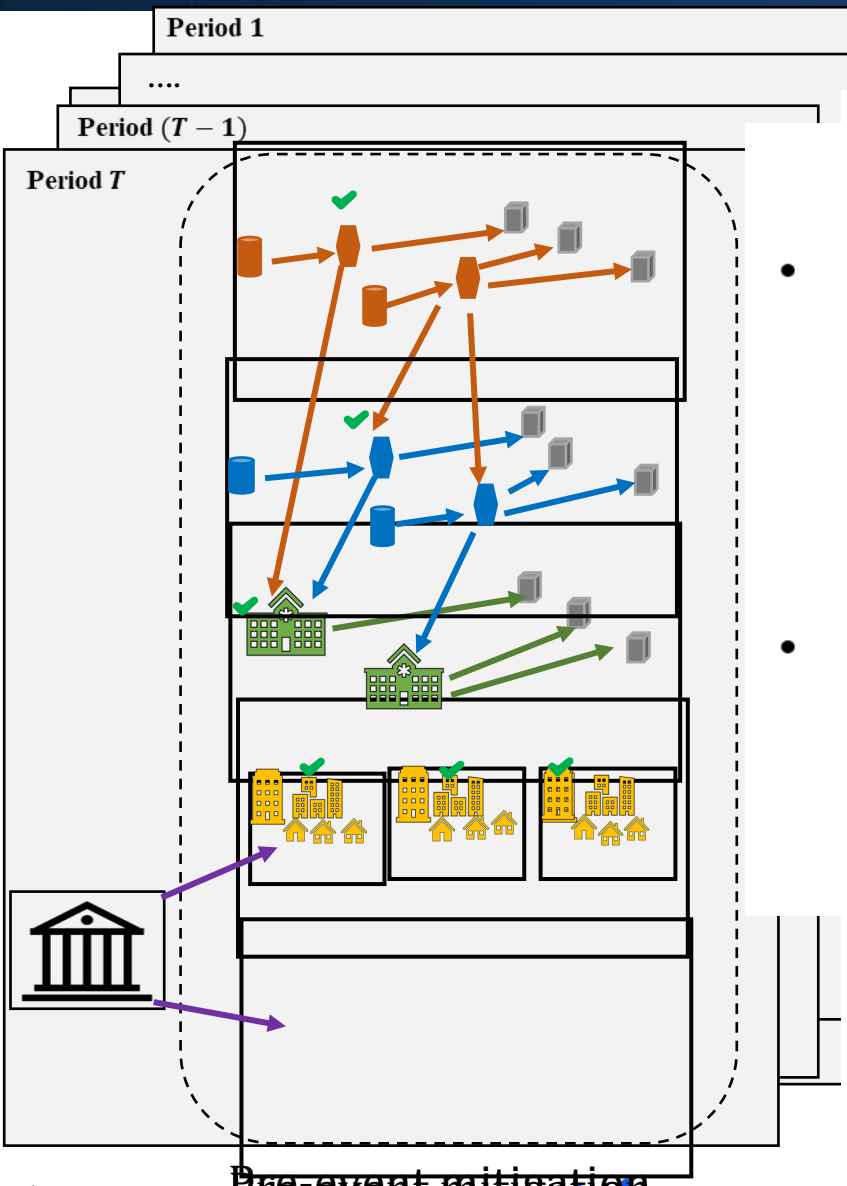
Community Resilience Planning Problem



Mitigation

- Interdependent networks
  - Anchoring components
  - Elevating components
  - Add storage
  - Retrofit critical links
  - Vegetation/ Maintenance management
- Buildings (Critical, Residential, Commercial)
  - Structural elevation
  - Bolt + Brace
  - Roof straps
  - Roofing, Landscaping
- Lines of defense
  - Building ≻ Room
  - Levee ≻ Berm ≻ Floodwall
  - WUI Buffers ≻ Neighborhood
- Incentivize to increase voluntary action:
  - Retrofit, insurance

Pre-event mitigation

Post-event functionality loss

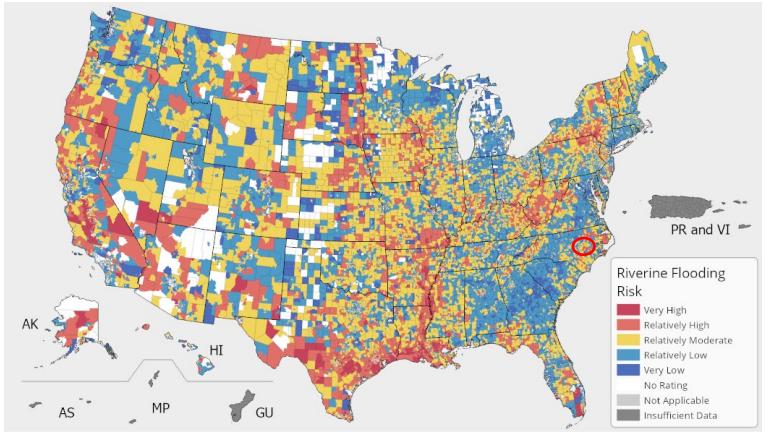
Post-event functional recovery

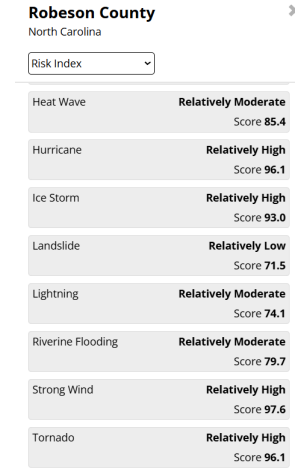
Riverine Flooding Case Study (Lumberton)

Goals :

Community resilience planning considering**:**

- Retrofit of buildings and critical infrastructure
- Population dislocation and reoccupation
- Recovery delays

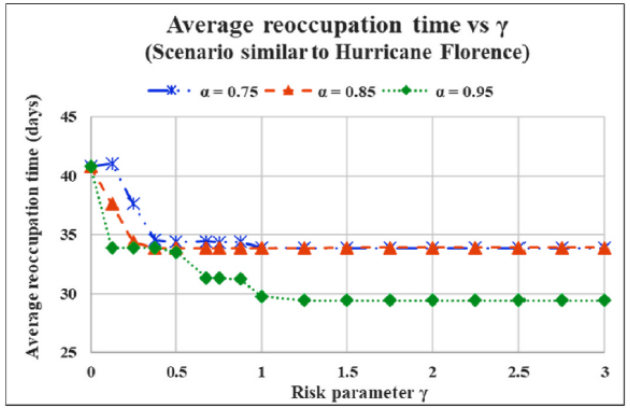




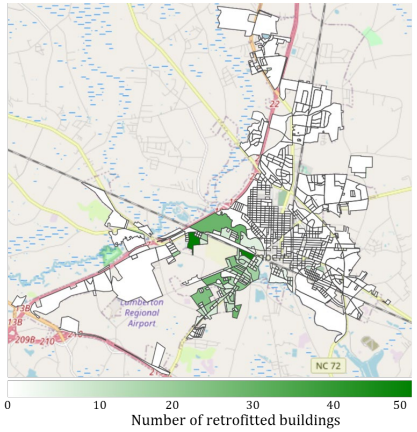
Riverine flooding risk map

Sensitivity Analysis:

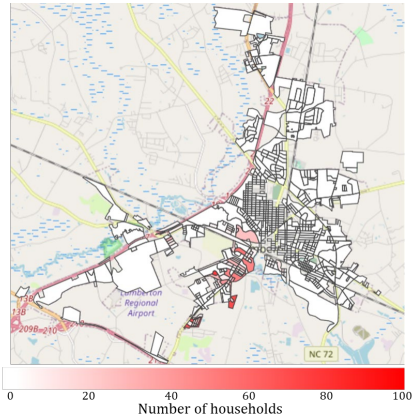
Higher risk aversion lower recovery delays in extreme scenarios



Sample solution



Retrofit of residential buildings



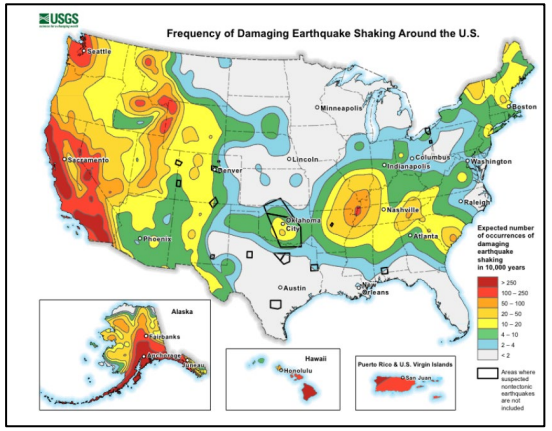
Household dislocation

Faiz, Tasnim Ibn, and Kenneth W. Harrison. 2024. "A Risk-Averse Stochastic Optimization Model for Community Resilience Planning." *Socio-Economic Planning Sciences* 92 (April):101835. https://doi.org/10.1016/j.seps.2024.101835.

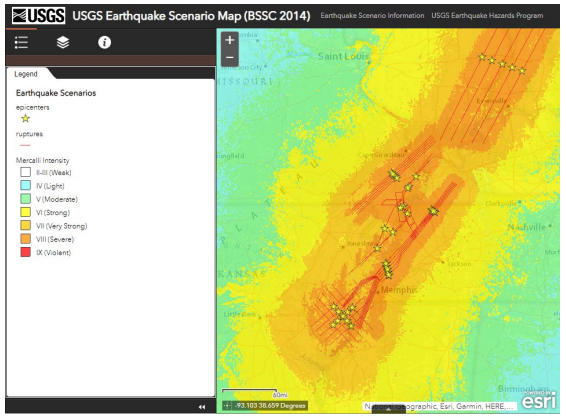
Seismic Case Study (Shelby County)

Community resilience planning:

- Retrofit of buildings and critical infrastructure
- Allocation of incentives for retrofit and insurance
- Population dislocation
- Injuries and fatalities
- Healthcare accessibility



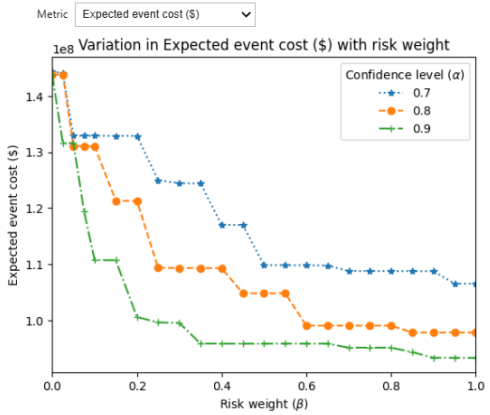
USGS earthquake frequency maps



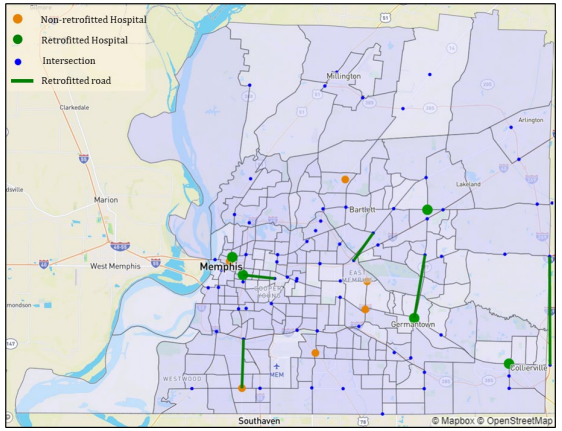
New Madrid Seismic Zone

Sensitivity of risk measure to risk weights

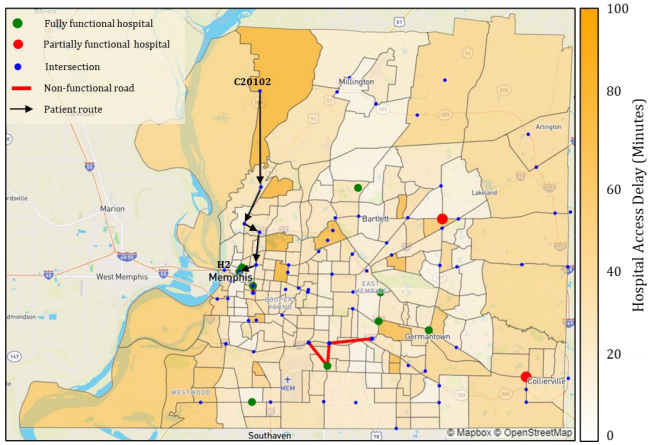
Higher risk aversion ⍰ lower expected scenario costs



Sample solution



Retrofit of bridge and roads

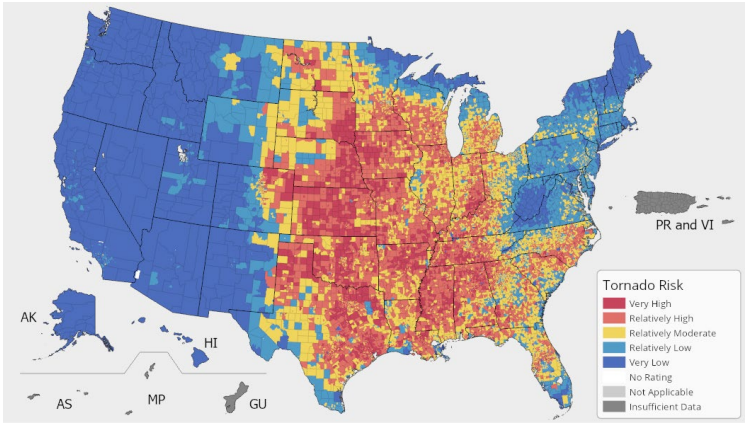


Damaged network and healthcare access delay

Faiz, T, KW Harrison, Z Farahmandfar. "Risk-Averse Community Resilience Planning Considering Retrofit and Insurance Incentives," *Structure and Infrastructure Engineering (Under review)*

Tornado Case Study (Joplin, MO)

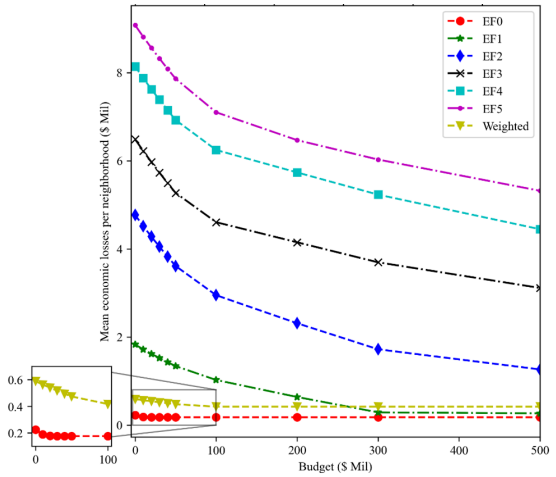
Goal: Explore effective strategies for reducing tornado risk, comparing effectiveness of building retrofits, tornado shelters, etc.

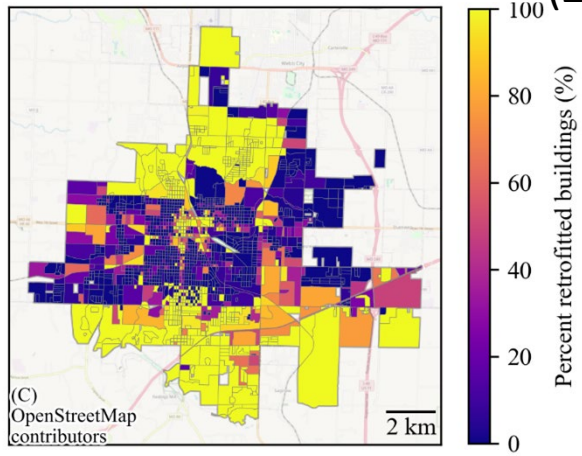


Tornado risk map

Joplin, MO tornado (2011)

Sensitivity to EF scenario and budgets



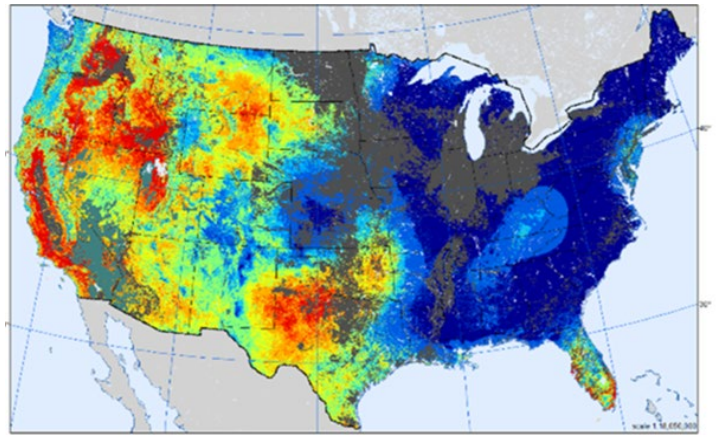


Sample solution

Hughes, W., Faiz, T., Harrison, K. “An Optimization Model to Inform Alternatives for Resilient Communities for Tornado Retrofits” (In NIST review)

Wildfire Case Study (Paradise, CA)

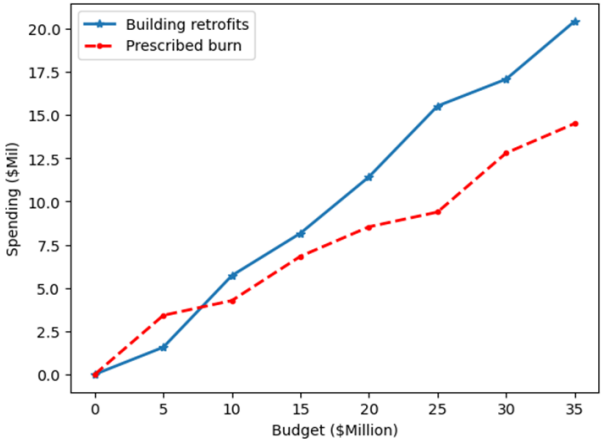
Goal: Improve community planning for wildland-urban interface (WUI) fires through combinations of building-level retrofits and landscape management (e.g., prescribed burns)



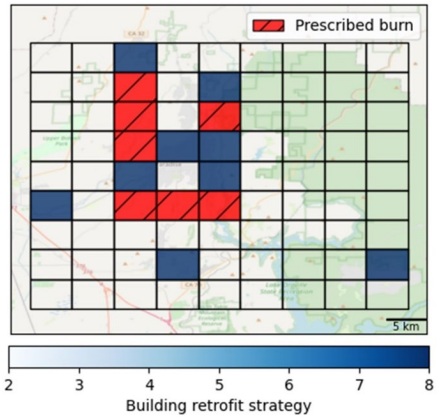
USGS wildfire risk map

Camp Fire (2018)

Trade-offs between landscape management and home retrofits



Comparison of strategy adoption for different budgets

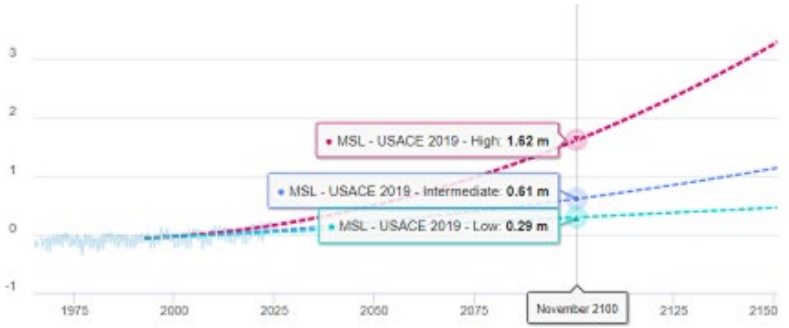


Example optimal solution

Hughes, W., Faiz, T., Hadjisophocleous, G. "An Optimization Model Combining Landscape Management and Building Retrofits to Improve Wildfire Resilience of Wildland-Urban Interface Communities" (In NIST review)

Sea Level Rise Case Study (Fairfield, CT)

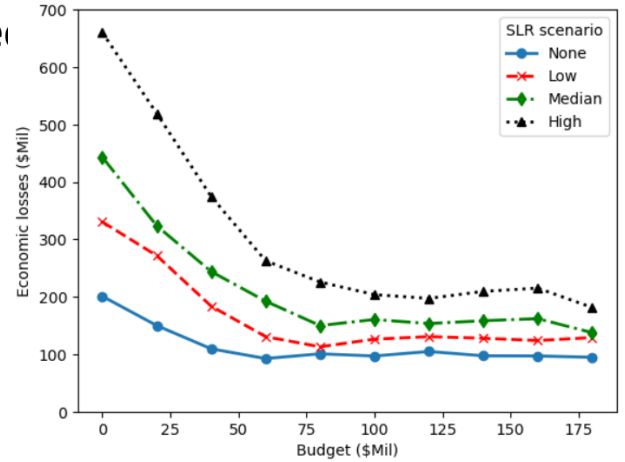
Goal: Inform effective strategies for coastal community climate change adaptation through combinations of building retrofits, grey infrastructure (e.g., seawalls), and nature-based solutions.



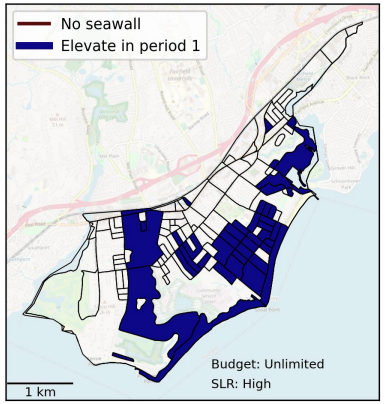
Projected sea level rise scenarios

Flooding from Hurricane Sandy (2012)

Effects of varying budget and sea level proje



2025-2050



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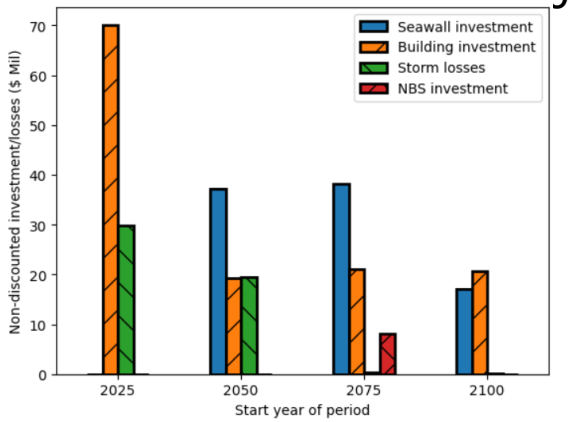
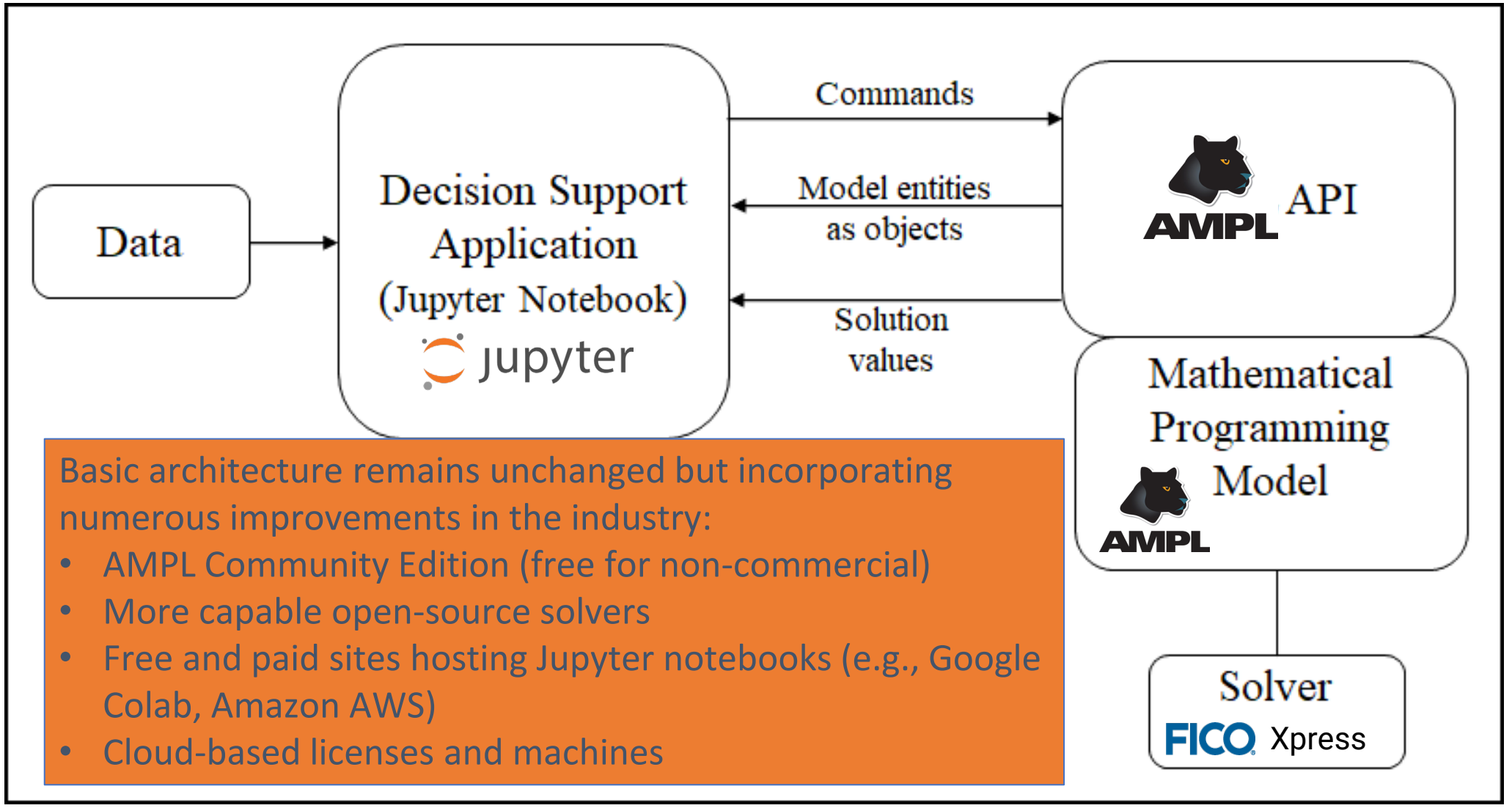


Example investments

Hughes, W., Sanderson, D., Faiz, T., Harrison, K. “Optimizing Coastal Community Resilience to Sea Level Rise through Combinations of Gray and Green Infrastructure and Building Retrofit Options” (In NIST review)

Simple schematic shown previously



Basic architecture remains unchanged but incorporating numerous improvements in the industry:

- AMPL Community Edition (free for non-commercial)
- More capable open-source solvers
- Free and paid sites hosting Jupyter notebooks (e.g., Google Colab, Amazon AWS)
- Cloud-based licenses and machines

Timeline

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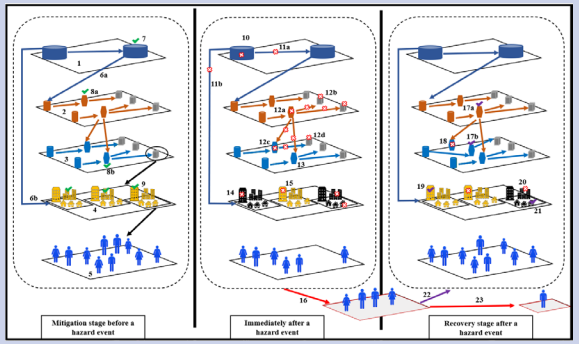

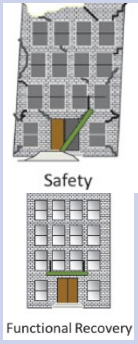

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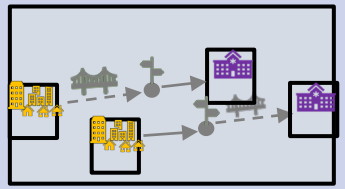
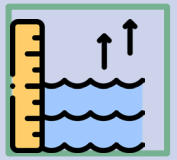
Hazard risk
- Climate



Critical Building services



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Broader system (e.g.,bus., schools)

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Haz/ Study: Riverine flooding/Lumberton | Seismic/Shelby | Joplin | Camp Fire | SLR (Fairfield, CT) | Hurr Maria | Continued collaboration with CoE researchers !

ARC/ User Jupyter notebook | Free/Open opt tools | Commun. Engagement | Usability changes | Tool Integration | Solution schemes

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