Kansas-based Research on Equity-Driven Infrastructure Resilience

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Research by Kansans for Kansans!

arise | KANSAS NSF EPSCoR

NSF

Trivia:

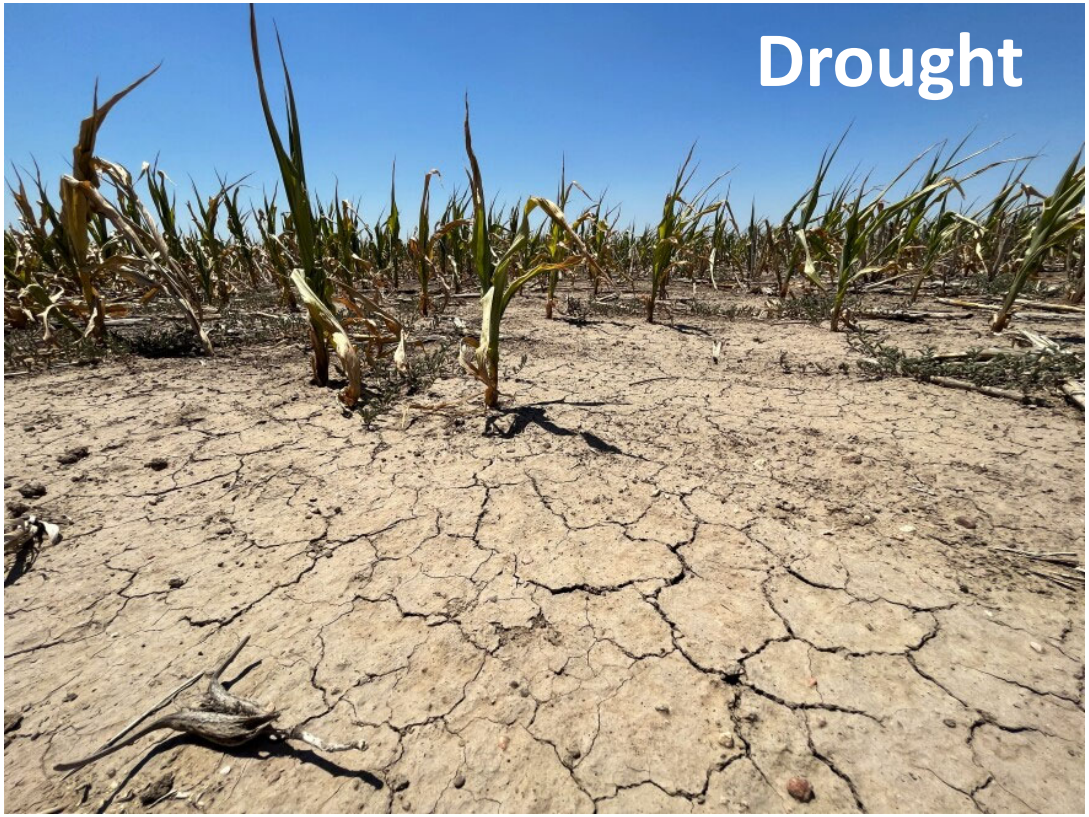
Kansas ranks 8th in Federal Disaster Declarations per Capita relative to the other states

Trivia:

What is the most frequent natural disaster in Kansas?

Trivia:

What is the most costly natural disaster in Kansas?



ARISE: Adaptive and Resilient Infrastructures Driven by Social Equity

National Science Foundation (NSF)
Established Program to Stimulate Competitive Research (EPSCoR)

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Vision

ARISE will **build research capacity in Kansas** by creating a new social equity-driven paradigm for resilience analysis that will transform how communities invest in, and manage, human and physical infrastructure, through a pipeline of community leaders and decision-makers.

0

ARISE Project Leaders

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Slide 7

0 Add affiliations?
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What is resilience?

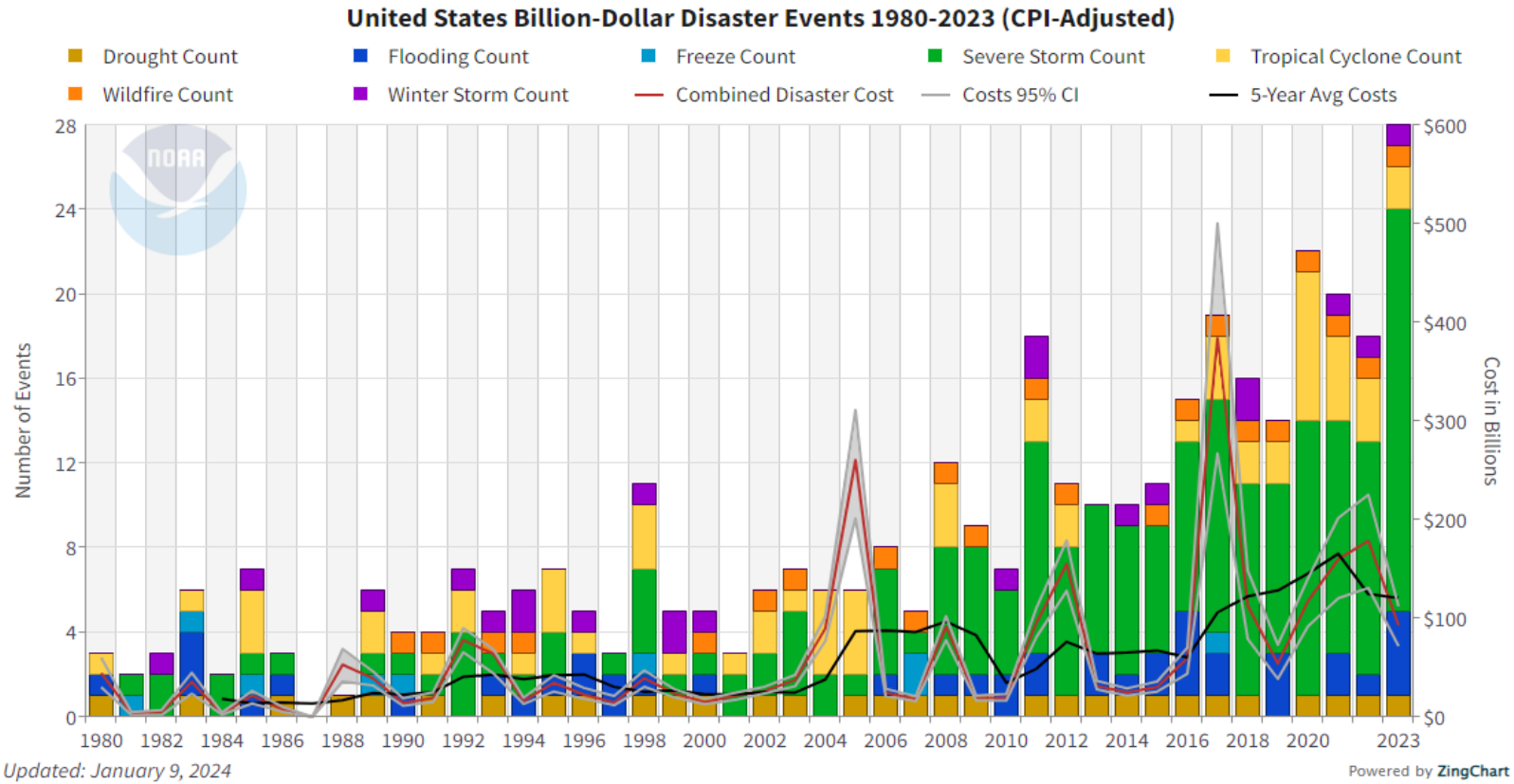
Ability to prepare and plan for, absorb, recovery from, and more successfully adapt to adverse events and changing conditions.

What do we mean by infrastructures?

ARISE is investigating transportation, water, wastewater, and energy systems.

All Disasters | Drought | Flooding | Freeze | Severe Storm | Tropical Cyclone | Wildfire | Winter Storm

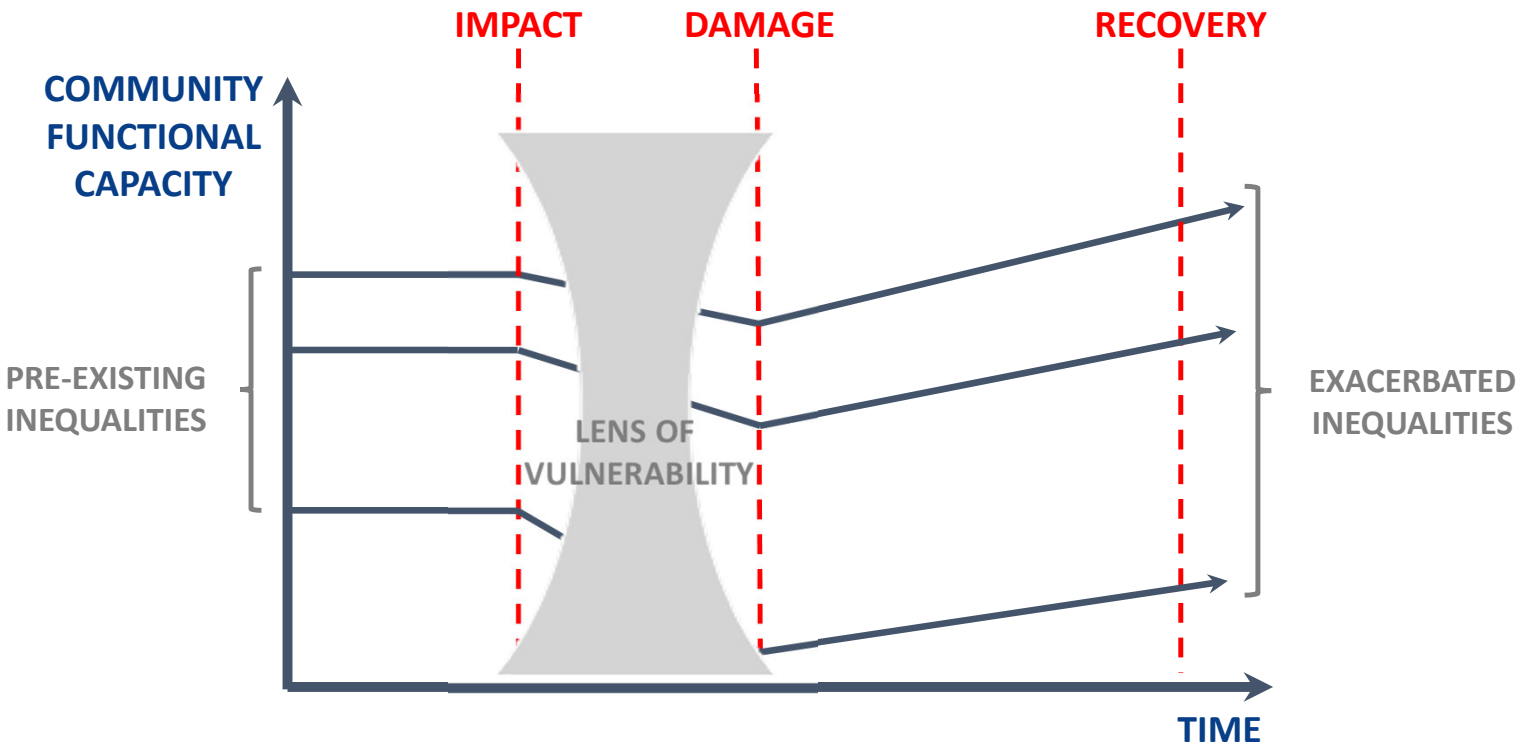
United States | Cost | Update | CPI-Adjusted | Unadjusted



Updated: January 9, 2024

Powered by **ZingChart**

Conceptual Model for Community Disaster Resilience



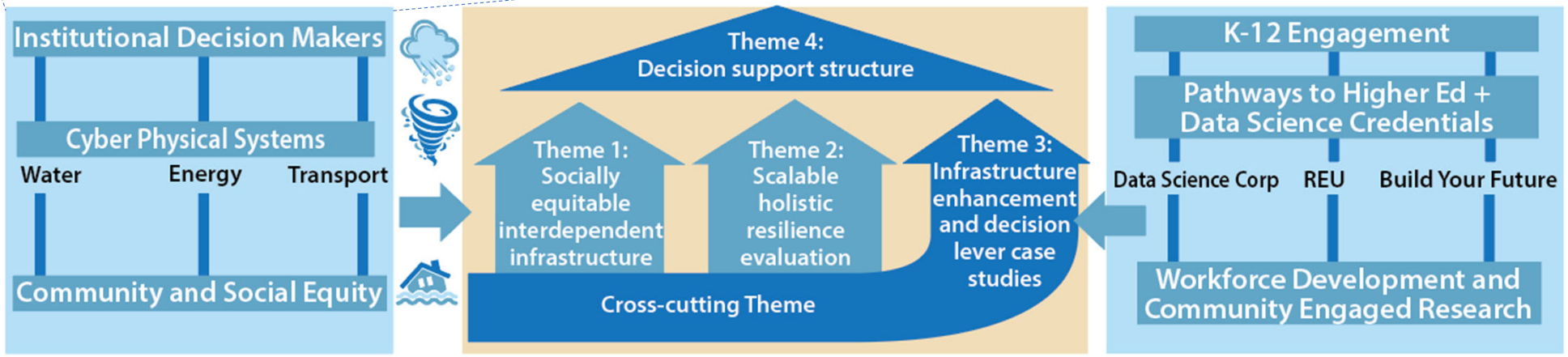
How does this integrate into ARISE research?

Mission

To determine how infrastructure resilience intersects with social equity and how human capacity, physical infrastructure, and policy levers can be designed to achieve socially equitable outcomes that collectively improve policy decisions and community resilience.

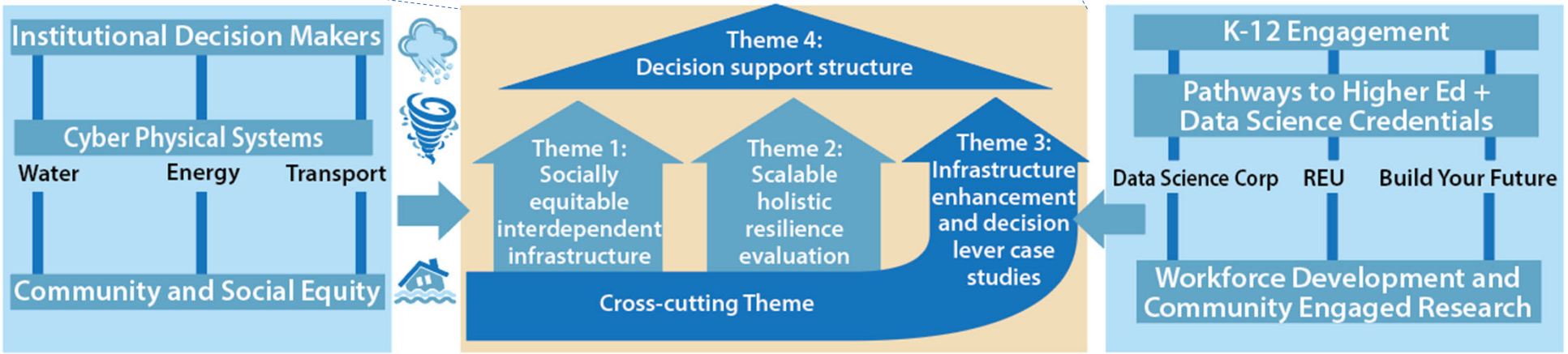
Infrastructure and Community Resilience

- Water, Energy and Transport Infrastructures
- Infrastructure and Community Resilience Planning for Natural Hazards and Disasters
- Social Equity and Vulnerable Populations
- Place-Based Collaboratory

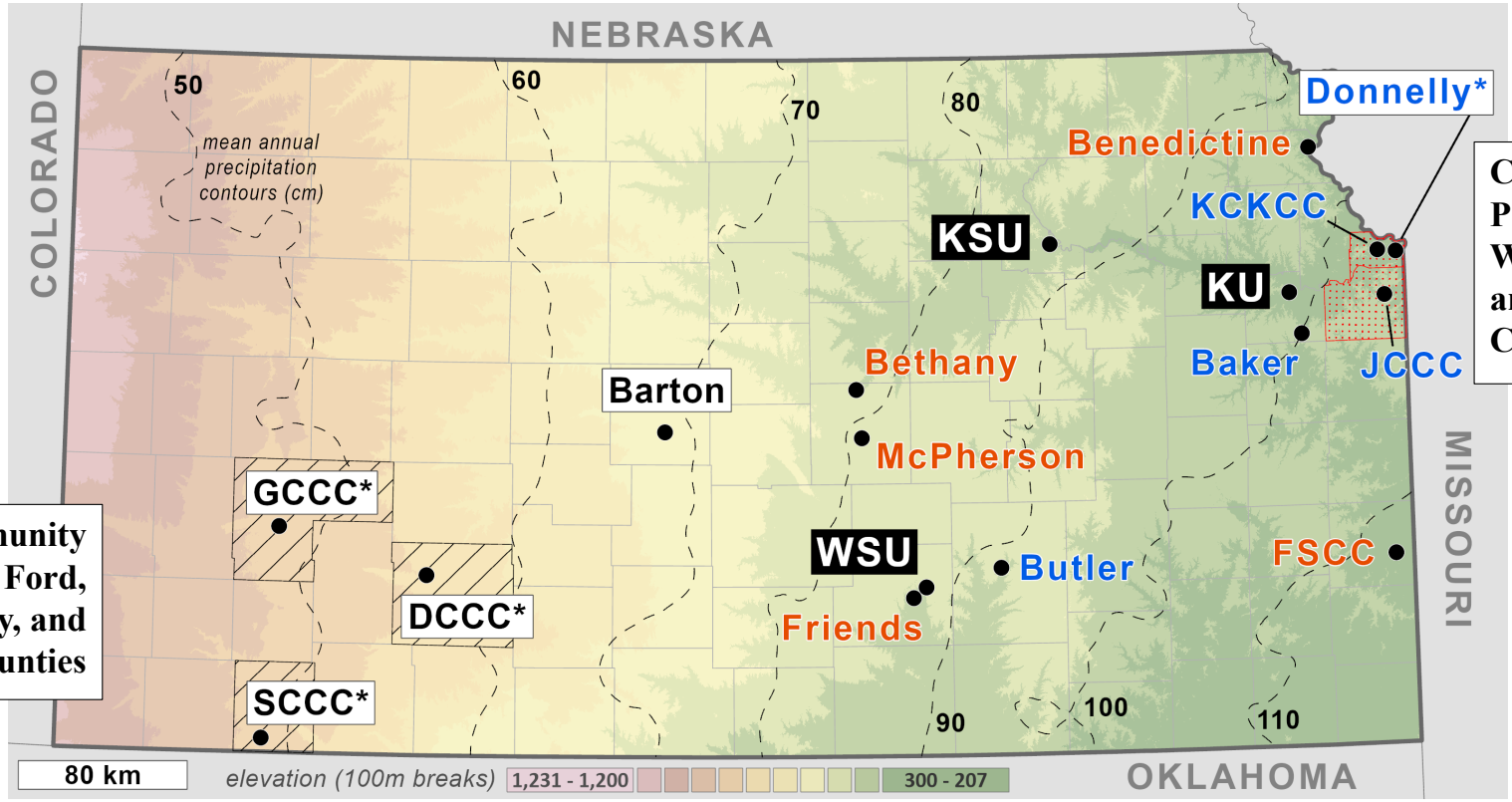


Community Engaged Research

- Because people who live and/or work in communities are experts on local realities.
- Local knowledge is critical for advancing resilience.
- Help develop relevant and actionable research questions and tools.



Partners span population and climate gradients



Community Partners: Wyandotte and Johnson Counties

Rural Community Partners: Ford, Finney, and Seward Counties

Partner Community 1
Partner Community 2
Research Site
Additional Collaborator
LSAMP
Education and Outreach
** Minority Serving Institution*

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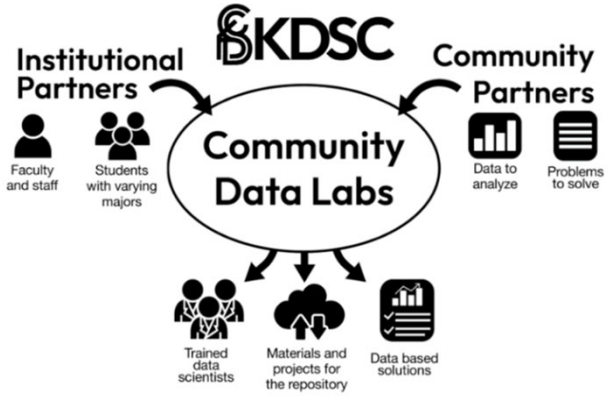
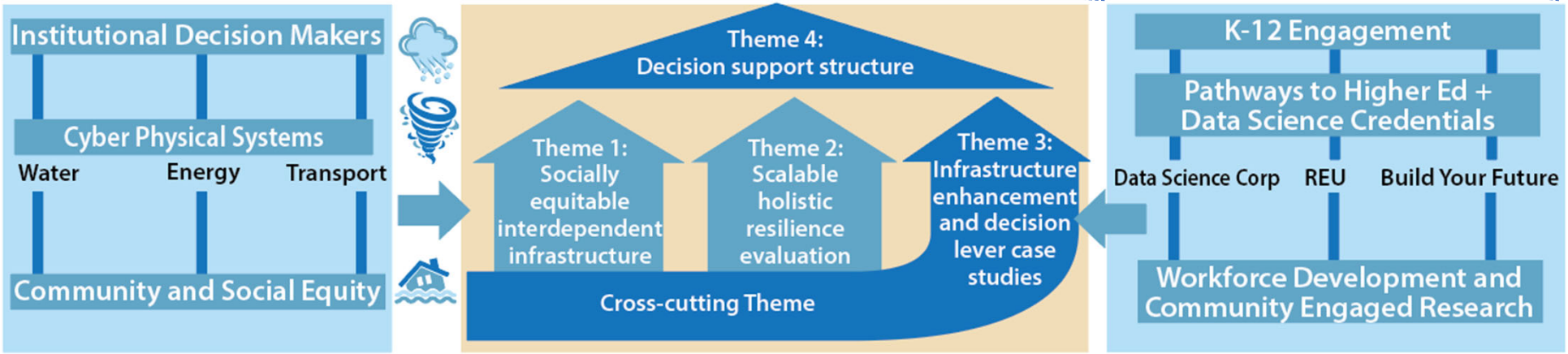
Education and Workforce Development

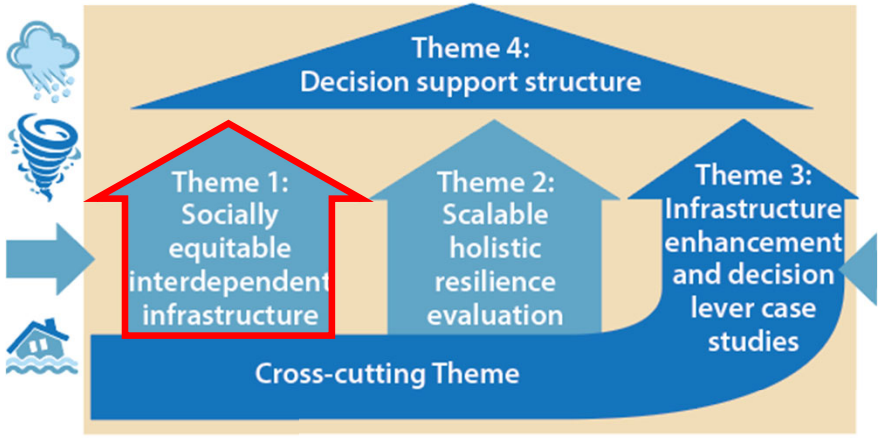
- Our goal is to **enhance education & workforce development**.
- We offer **learning opportunities** for youth, students, families, and adults, helping to grow the State's workforce.
- We **connect students with partners in the community**, giving Kansans data-based solutions free of charge as part of a new Kansas Data Science Consortium.

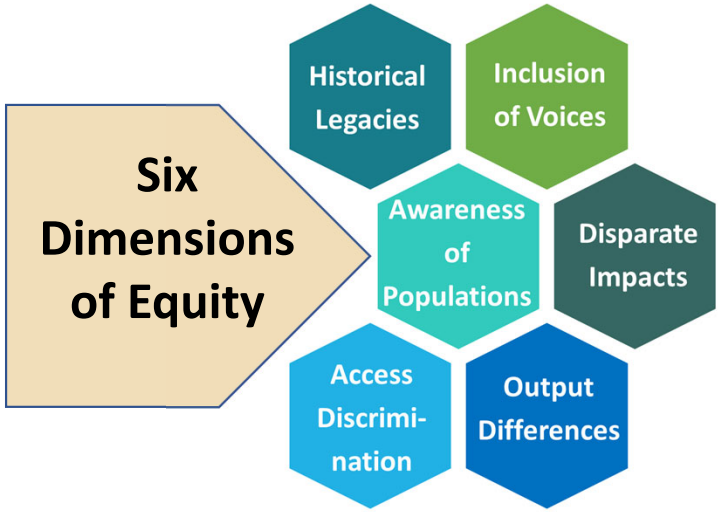




Research Theme 1

- How human systems & physical infrastructures depend on each other **to help communities better plan and communicate across partners**.
- How to guide resilience analysis and planning with an eye on equity and vulnerable populations.
- Local insights and guidance bolster design efforts, ensuring we meet the needs of the most vulnerable Kansans.





What is Equity?

Executive Order On Advancing Racial Equity and Support for Underserved Communities Through the Federal Government from January 20, 2021:

> *The term "equity" means the consistent and systematic fair, just, and impartial treatment of all individuals.*

Six Dimensions of Equity

1. Historical legacies
2. Awareness of populations
3. Inclusion of other voices
4. Access discrimination
5. Output differences
6. Disparate impacts

WHITE PAPER

The State of Equity Measurement

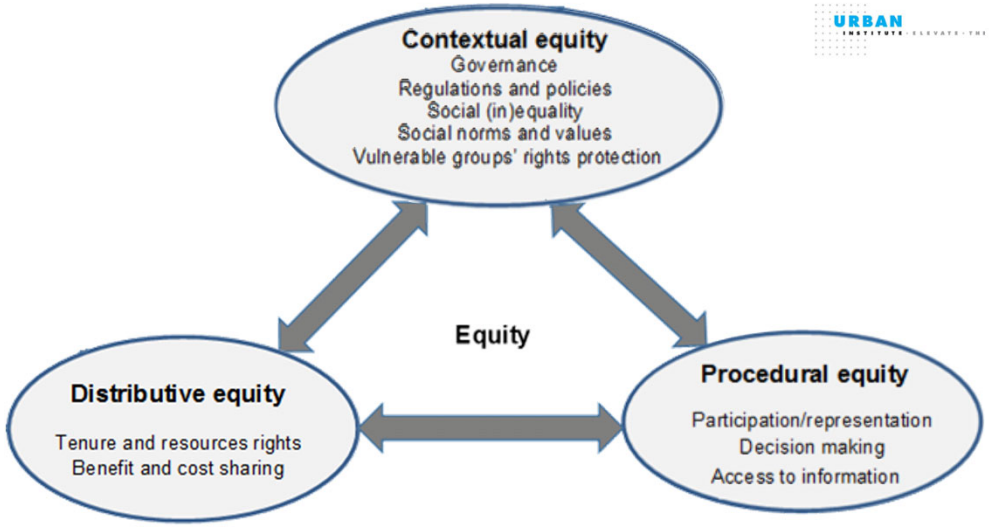
A Review for Energy-Efficiency Programs

Carlos Martin
URBAN INSTITUTE

Jamal Lewis
GREEN & HEALTHY HOMES INITIATIVE

September 2019

URBAN INSTITUTE · ELEVATE · THE · DEBATE



Equity is both a process and an outcome.

"Equity is practiced when those most impacted by structural inequities are meaningfully involved in creation and the implementation of practices and policies that affects their lives."

-Andrews et al., 2019

A guide to incorporating a racial and ethnic equity perspective throughout the research process

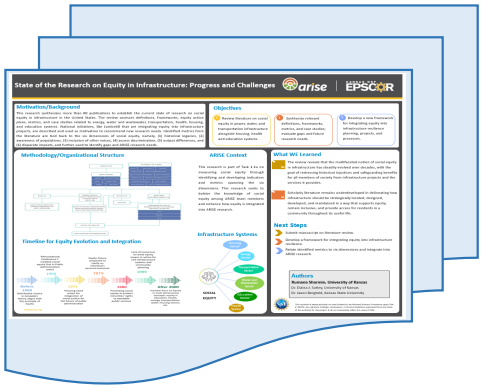
"Equity is achieved when outcomes are not predicted based on someone's identities or characteristics (e.g., race, gender identity, sexual orientation, ability status, etc.)"

-Creative Reaction Lab

Equity Centered Design Field Guide

1.1 Measuring Social Equity

- Literature Review on social equity in infrastructure



Before 1968
Distributive Justice in Aristotle's theory aligns with the principle of equity

1968
'Minnowbrook Conference I' credited social equity first in Public Administration arena

1971
Pressing need arisen for integration of social justice for the future of public administration

1975
Equity theory proposed to clarify an individual's personal outcomes

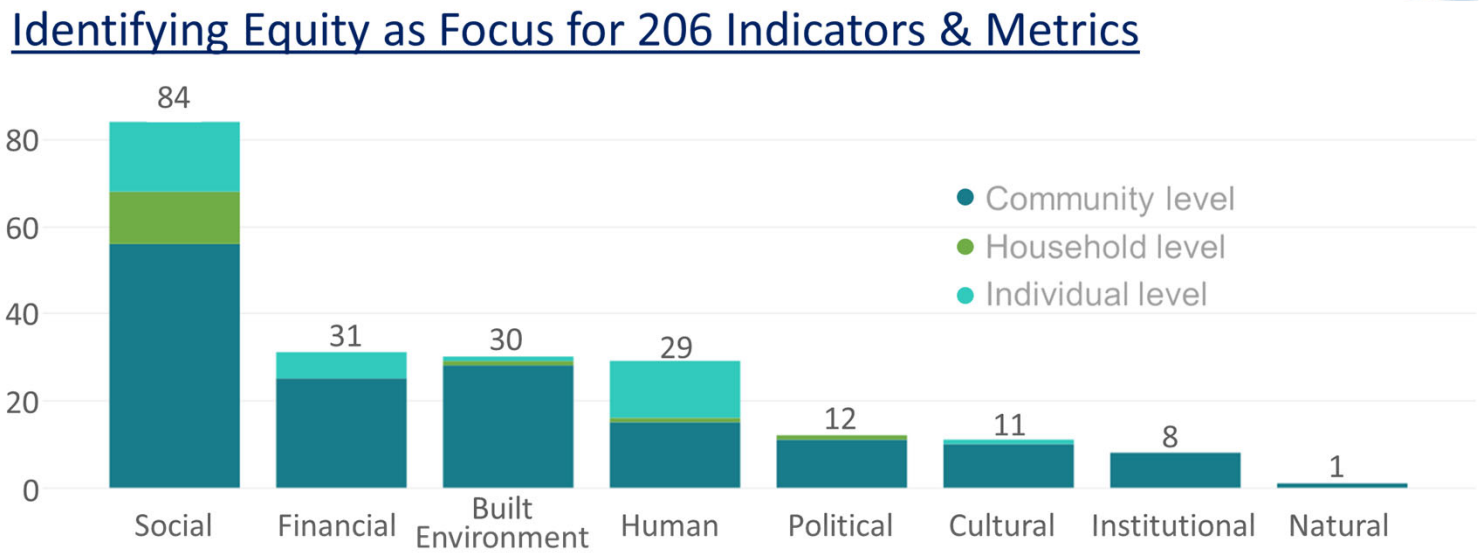
1980
Promoting social equity to protect minorities' rights to equitable public services

1999
Lack of consensus on what equity means in action for civil infrastructure systems and community planning

After 2000
Increase focus on Equity in multi-dimensional concepts: equity in education, health, energy, transportation, water, housing sectors, etc.

1.1 Measuring Social Equity

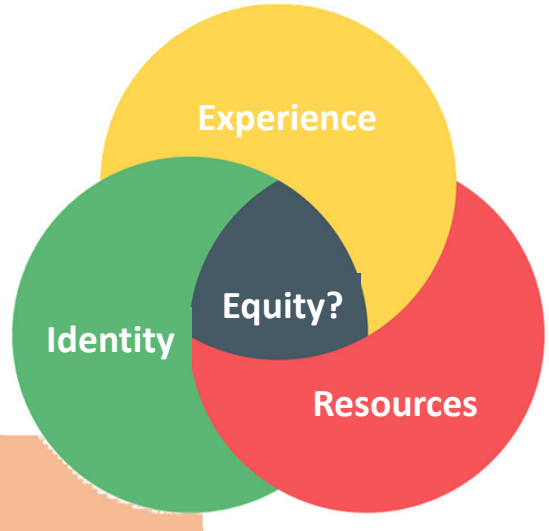
- Compiled, categorized, refined social equity metrics



1.1 Measuring Social Equity

- Community Studios

1.1 Measuring Social Equity



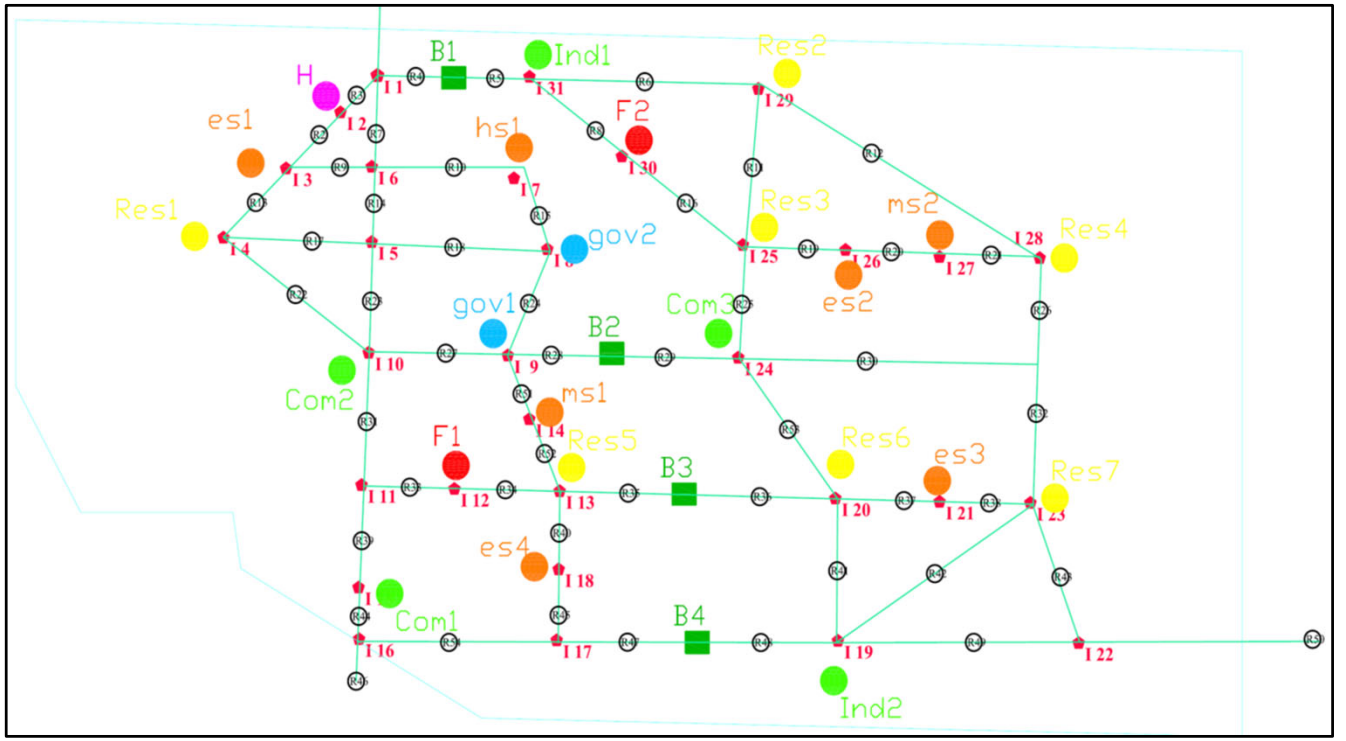
- Wave 1 Survey to Households

Impact
Risk Perception
Preparedness
Infrastructure Service
Reliability
Experience
Access

Zip Code
Urban Density
Household composition
Race and ethnicity
Income
Education
Tenancy

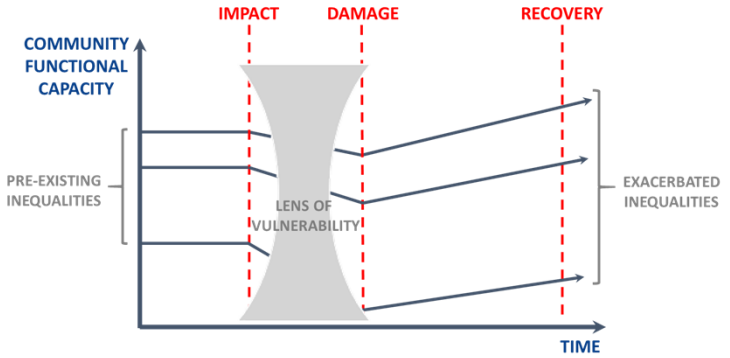
1.2 Stochastic Hetero-functional Graph Framework

- Community Model Functions
  - Provide power
  - Provide water
  - Provide wastewater
  - Provide connectivity
  - Provide housing
  - Provide employment
  - Provide education
  - Provide healthcare
  - Generate human capital



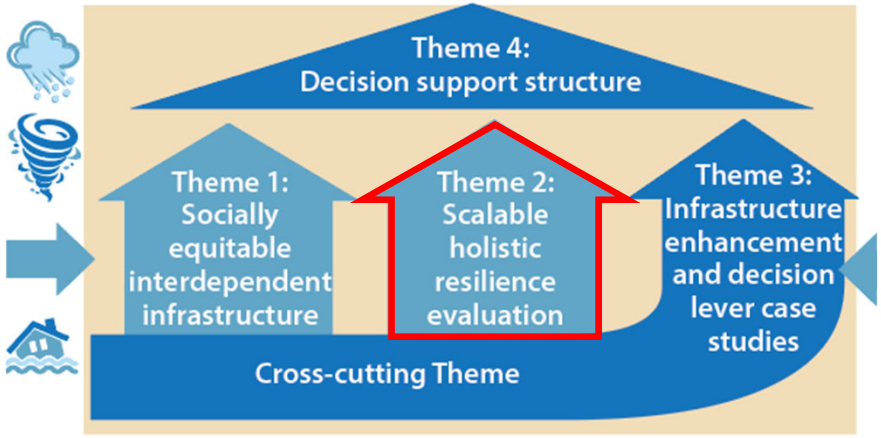
Integrating Equity into Resilience Analysis

- Prioritization scheme for
  - Maintenance projects
  - Restoration after disruptions
  - Targets: maintaining/restoring to enhanced levels
- Siting of new projects
  - Who is involved in finding the location
  - Where is eminent domain happening
  - Who is experiencing benefits/burdens across project lifecycle
  - Who has access
- Thinking beyond the project boundary



Research Theme 2

- Developing **new resilience metrics** for infrastructure and communities that take account of equity and community welfare/quality of life more holistically **that communities can use**.
- Examine relevant resilience metrics and approaches from multiple perspectives with direct community input, evaluation, and guidance.
- Quantify and model changing risk to multiple possible hazards and disasters – tornadoes, flooding, ice storms, among others.

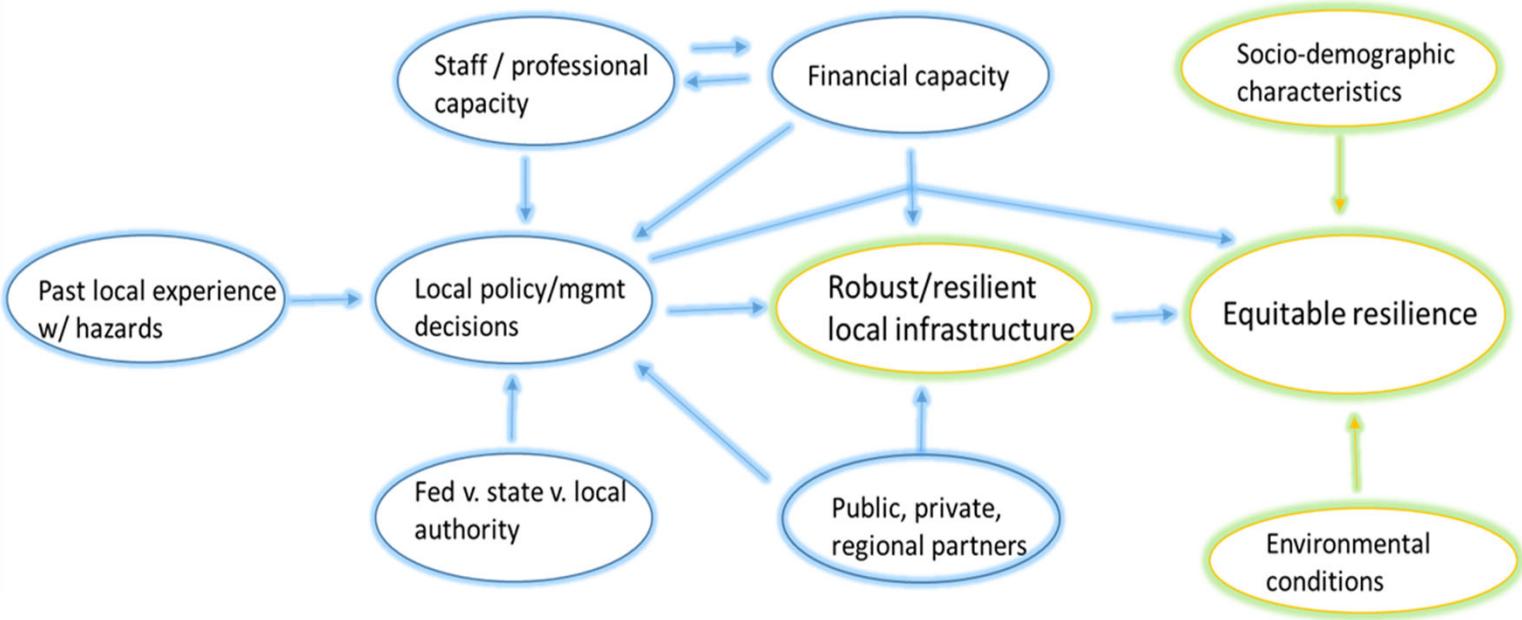


2.2 Institutional Decision-Making

Identify the "institutional factors" shaping equitable community resilience. Develop linkages between institutional decisions and asset importance for holistic resilience measurement.

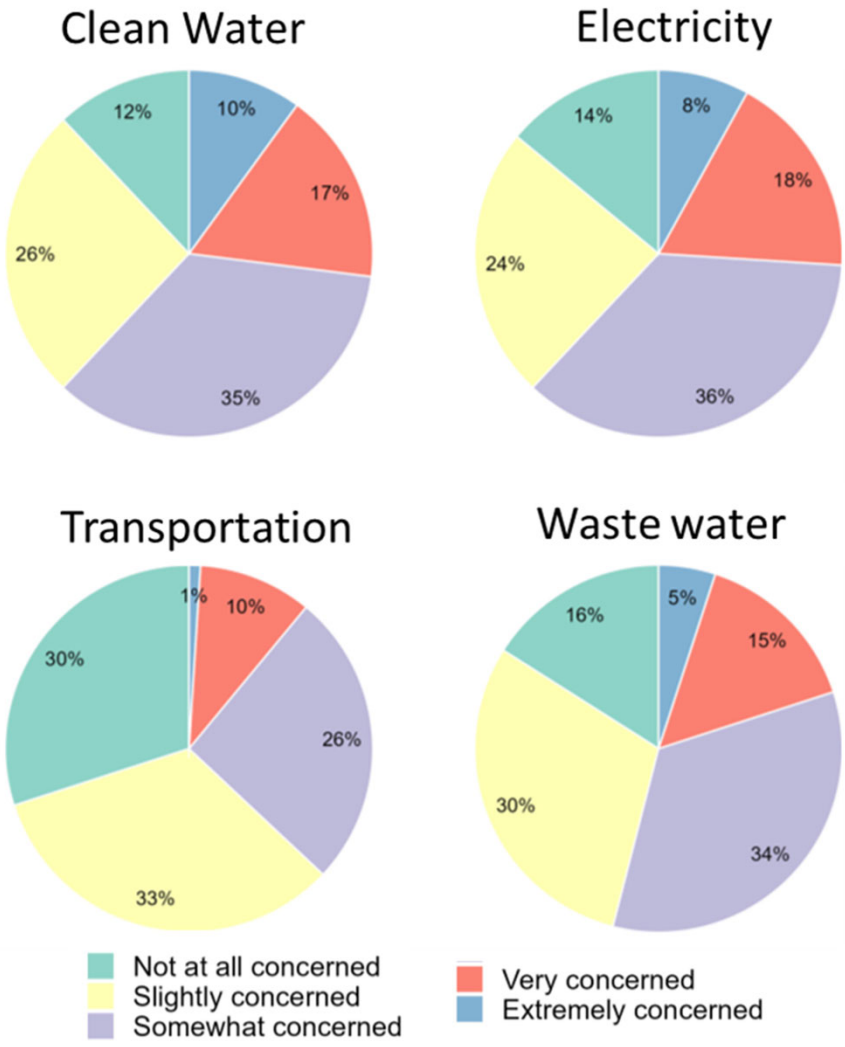
Data Collection

- Interviews with emergency managers, city managers and KDEM officials;
- State-wide local government survey;
- Kansas Response Plans;
- Municipal budgetary data.



2.2 Institutional Decision-Making

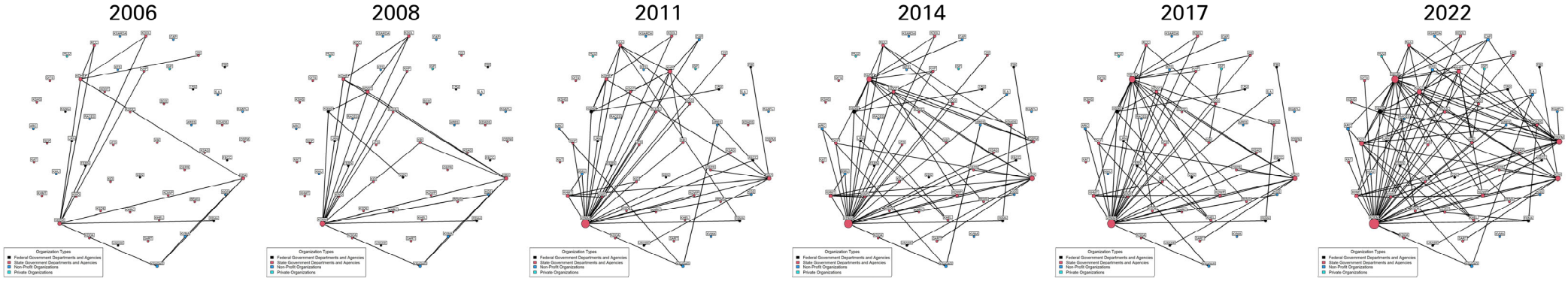
- 33 interviews to understand the decision-making landscape for local government leaders.
- State-wide survey effort completed in Jan 2024 to quantify trends (313 completed surveys 31.6% response rate).
- Survey summary report shared with all ~900 local officials invited to participate.



Level of concern around local infrastructure failure

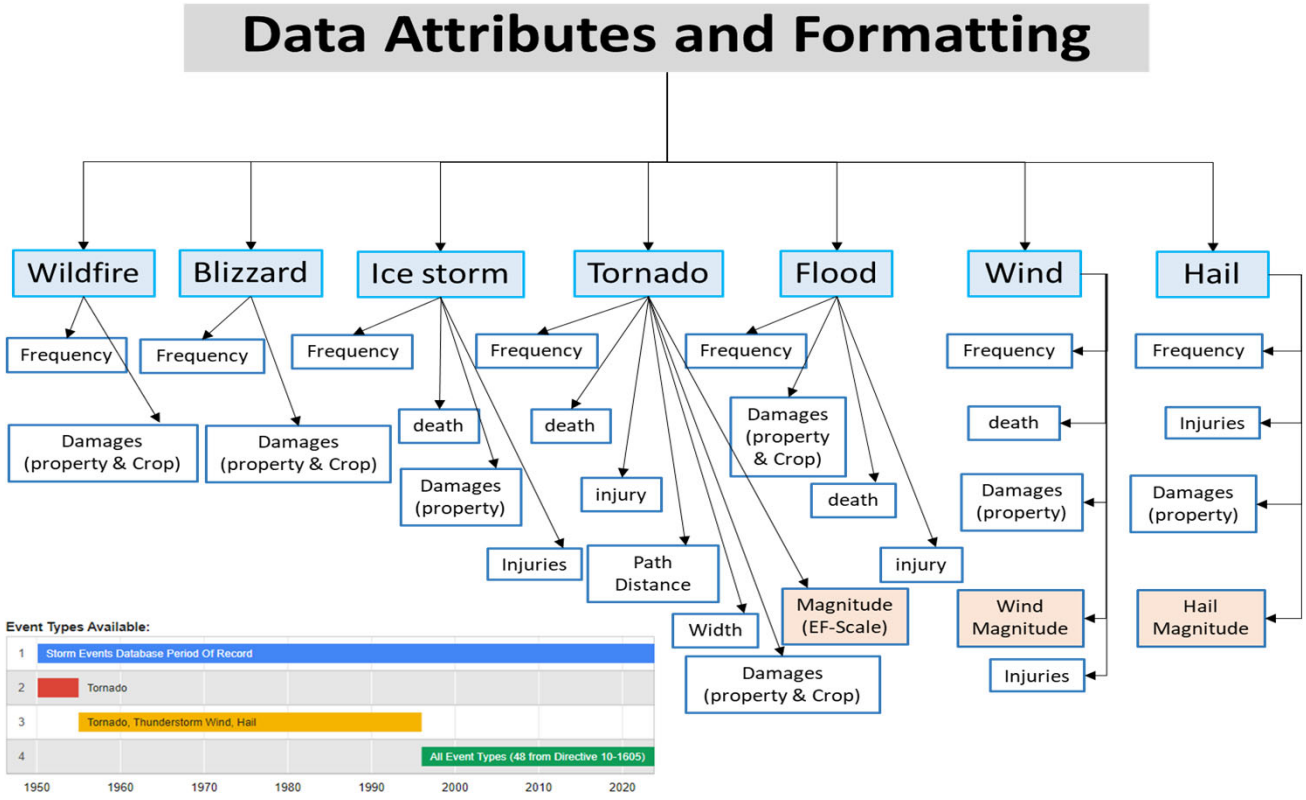
2.2 Institutional Decision-Making

- Examined **Kansas Response Plans,** spanning from 2006 to 2022, using natural language processing and social network analysis to assess the evolution in patterns of formally specified relationships between actors for hazard response.



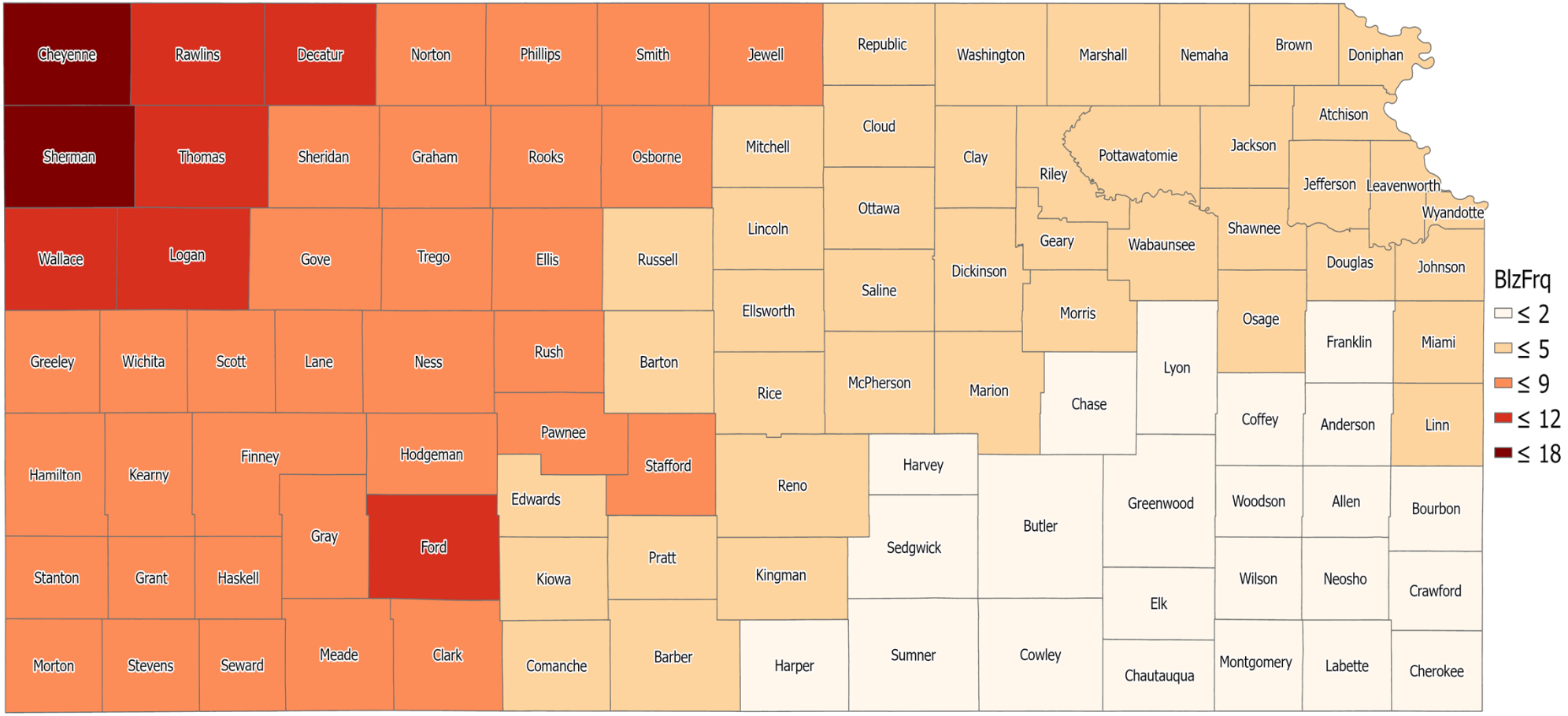
2.3 Probabilistic Resilience Characterization

Kansas Storm Events Data – a summary of historical storm event occurrence, characteristics & impacts



https://kars.geoplatform.ku.edu/pages/arise-kansas

Example: Blizzard Frequency Map (1966 – 2022)



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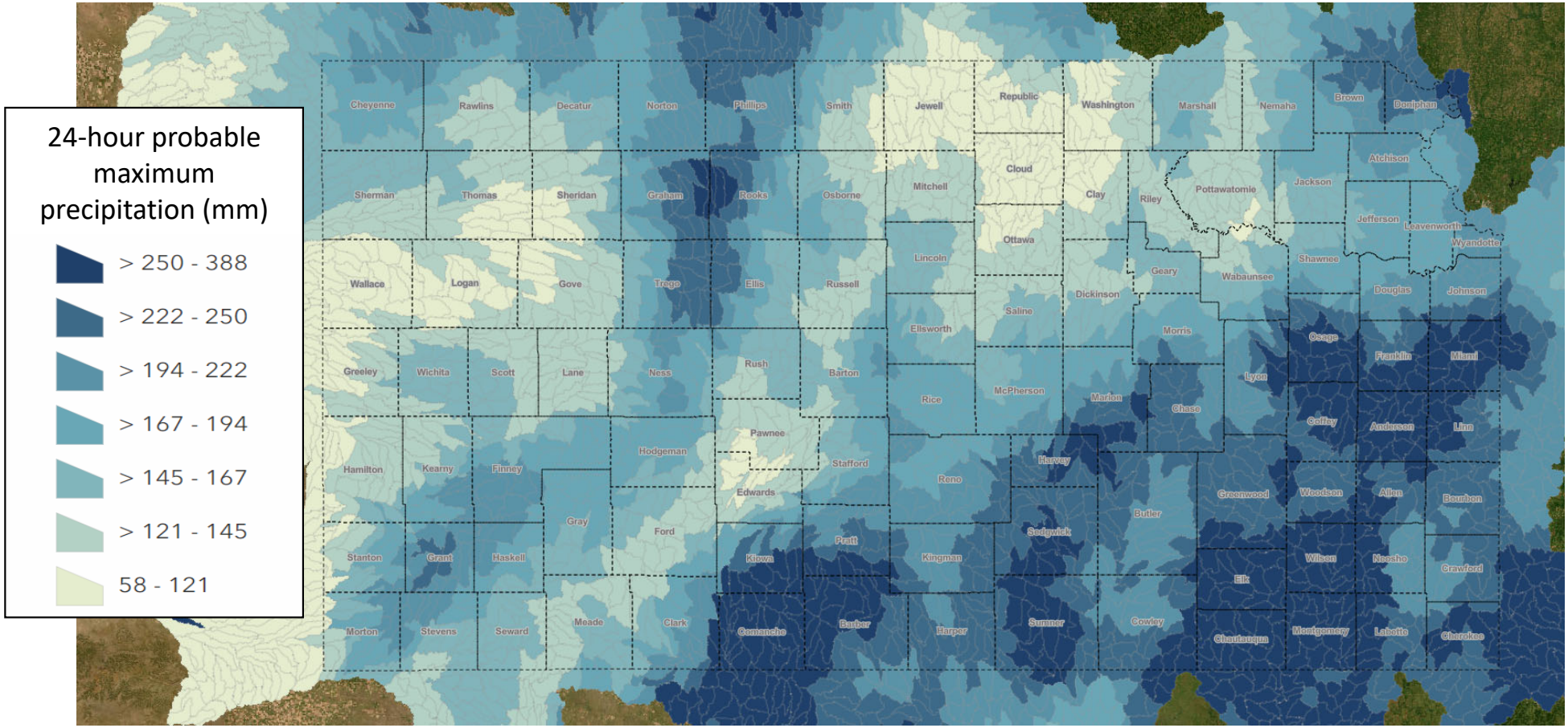
ARISE Reconnaissance Map Showing Extreme Rainfall Tendencies Across Kansas



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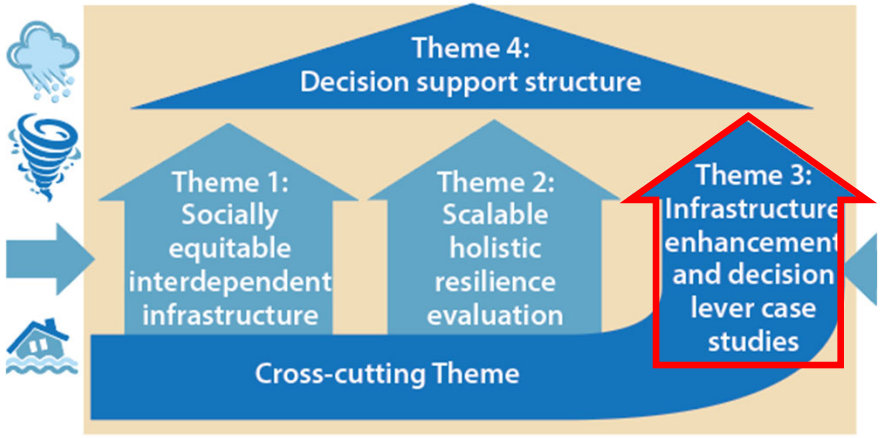
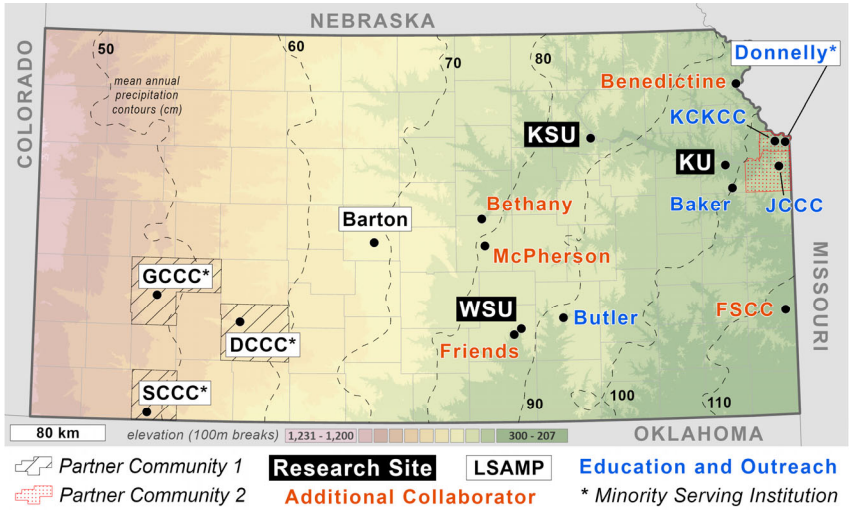
Research Theme 3

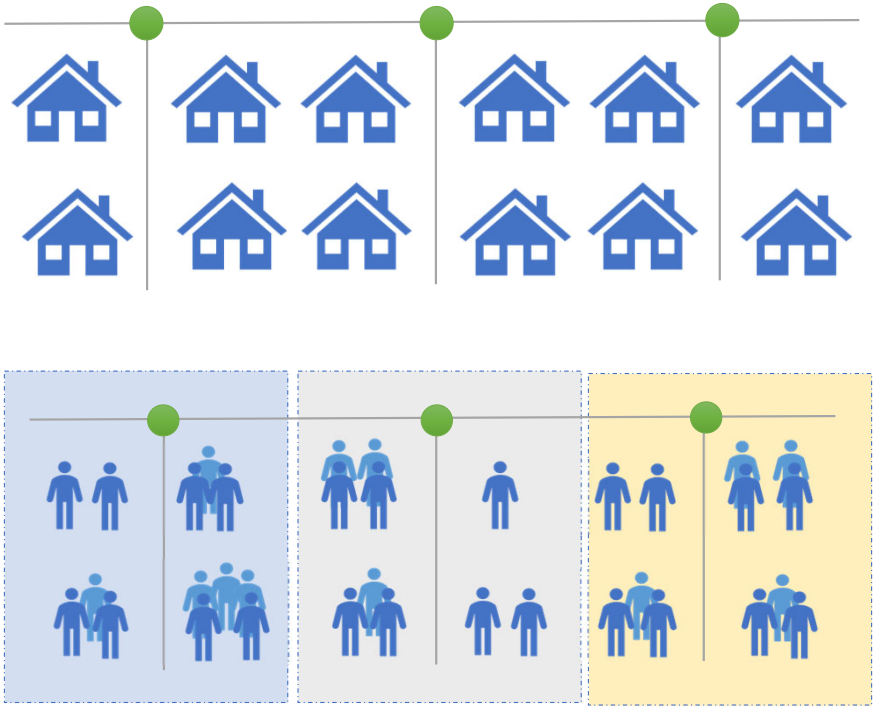
- **Case studies for water, energy, and transportation systems** to help improve resilience across and between infrastructure systems.
- **Identify key levers in communities** to improve disaster risk reduction and recovery after a disaster that provides for and helps all in the community.
- **Improving our infrastructure and community resilience** increases quality of life, helps to minimize impacts from disasters, and helps better protect vulnerable populations.





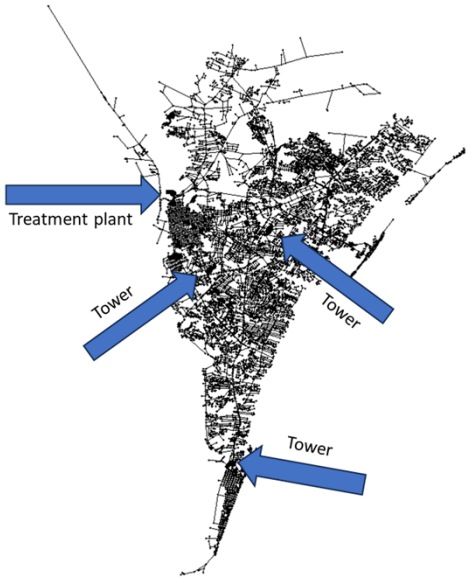
3.2 Safe Drinking Water

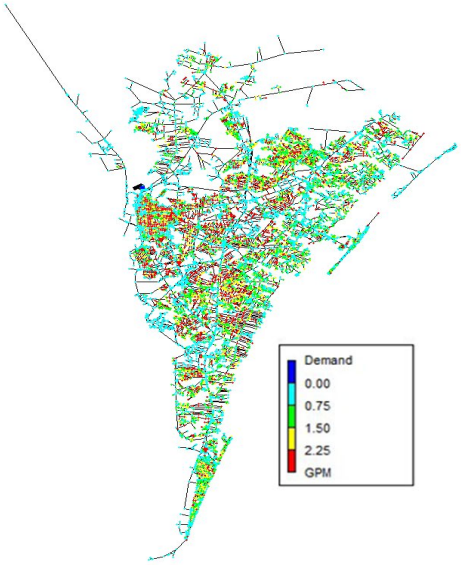
- Primary assumption is that water networks follow road networks. Road networks were obtained from OpenStreetMap.
- Demand was estimated using census data.
- System sizing and optimization was performed based on engineering principles.
- Using census population data from the countries that surround the selected cities, a population inventory was performed.
- Population was assigned to nodes using proximity.
- A demand of 150 gal/per capita/per day was assigned to each node.



3.2 Safe Drinking Water

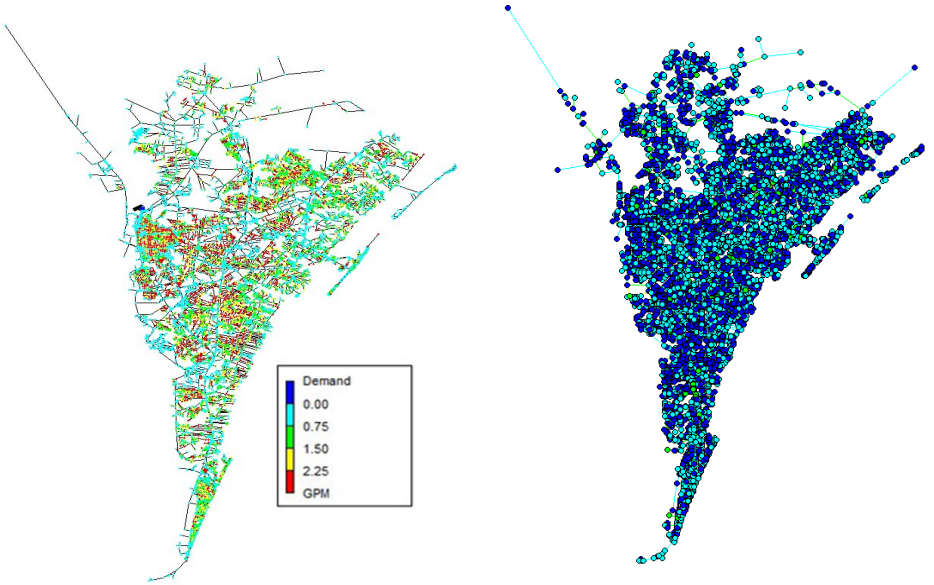
- Node and link information was transferred to EPANET. Links represent pipes and nodes represent junctions between pipes.
- Simulations were performed to estimate water velocity and system pressures.
- Optimization of pipe sizing and system configuration performed based on realistic limits of system water velocity and pressure.





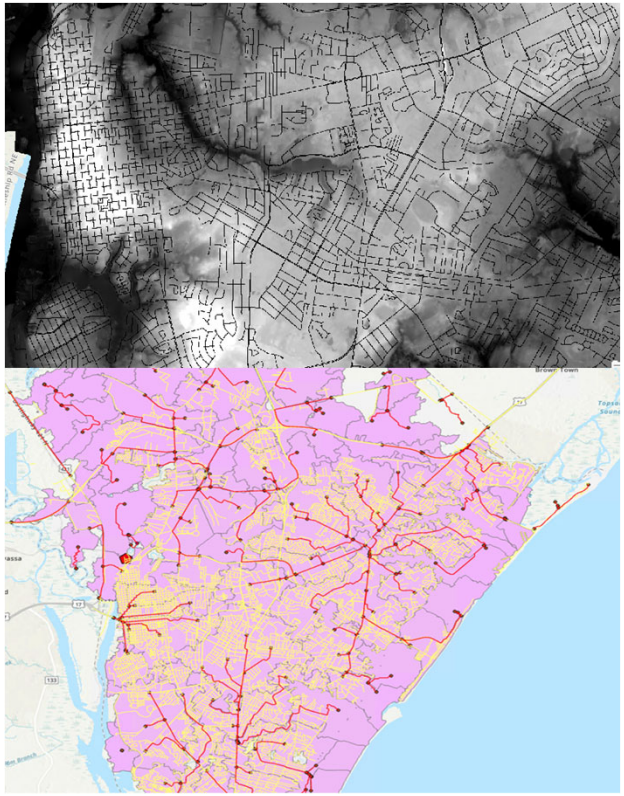
3.3 Resilient Wastewater and Stormwater Collection

- Primary assumption was wastewater collection network mirrors drinking water distribution network.
- Methodology was developed in an artificial system (CLARC).
- Wastewater generation was based on water consumption.
- System sizing and optimization was performed based on engineering principles in Storm Water Management Model (SWMM).



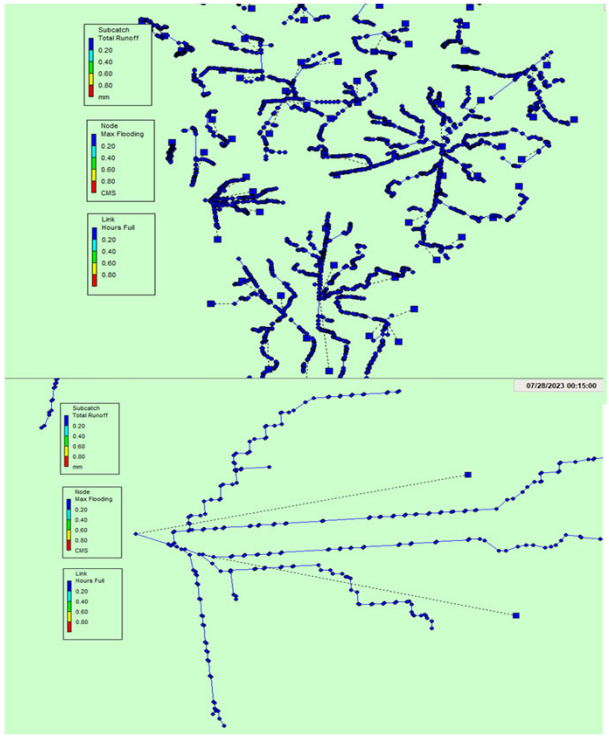
3.3 Resilient Wastewater and Stormwater Collection

- Pipeline network was integrated with Digital Elevation Model (DEM) to divert flows to pipeline infrastructure.
- Using the resulting DEM and different hydrological tools of Arc GIS Pro, the combined sewer pipeline network was computed (represented by red lines).
- Additional storage units and water treatment plants integrated based on satellite imagery.



3.3 Resilient Wastewater and Stormwater Collection

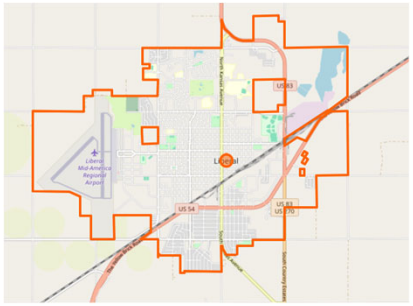
- The disposal network and characteristics of sub catchments data extracted from ArcGIS Pro and then added as inputs in SWMM as .inp file.
- Run the model using a historic rainfalls with households wastewater loads (population based) taken into account.



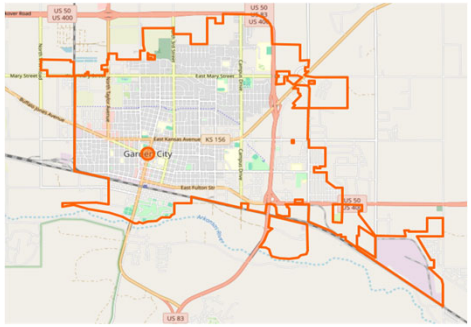
3.2 and 3.3 Outcomes and Future Directions

- CLARC system map for both infrastructure systems to facilitate ***co-simulator*** and ***SHFGT*** development in ***Theme 1*****.**
- Three cities were selected to validate this methodology, **Liberal, Dodge City**, and **Garden City**.
- Using their road networks and census populations, EPANET models were made for each of the three cities. SWMM models are in progress.
- Validation for these models will be completed once data use agreements are in place.
- Platform to model water quantity and quality threats to rural water systems integrated with social equity (***Theme 1***) and resilience metrics (***Theme 2***).

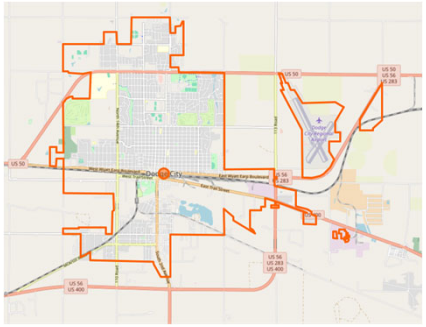
Liberal



Garden City

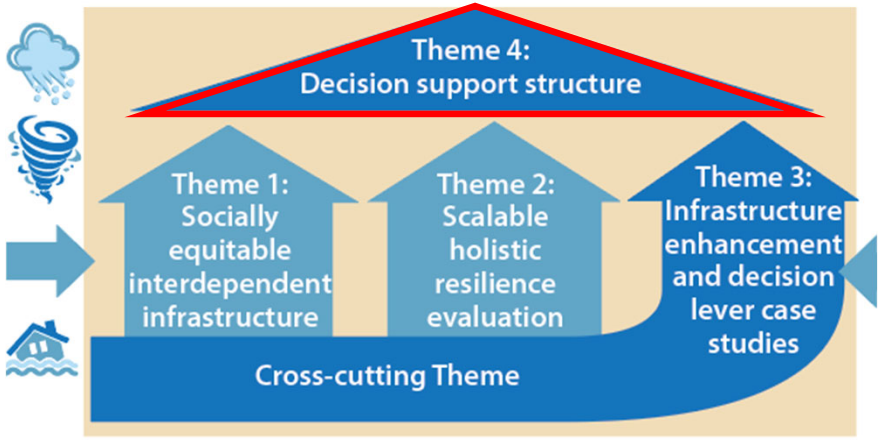


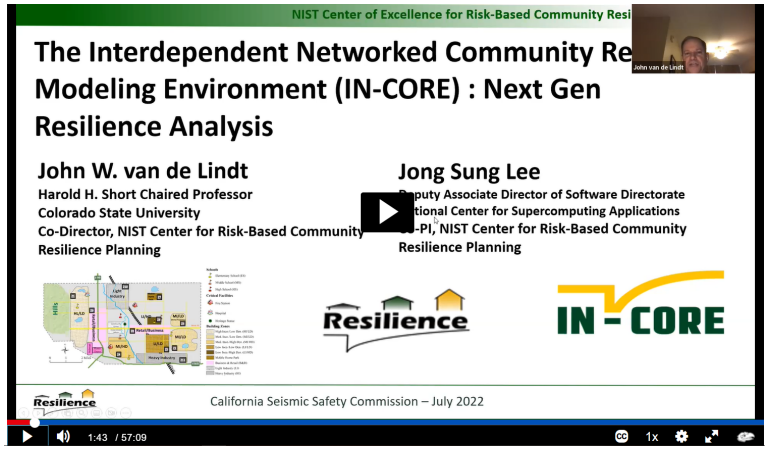
Dodge City



Research Theme 4

- Our research will culminate in a **one-of-a-kind decision-support tool** for **resilience analysis and planning and communities** that transforms how communities manage their infrastructure.
- Rather than focusing solely on efficiency like conventional tools, ARISE factors in principles of social equity.
- ARISE uses a vast web of knowledge to **build tools, resources, grant writing support for improving health, safety, and prosperity in Kansas**. Tool development is driven by community input and guidance.





4.2 Choice Architecture Arrangements

Evaluate how choice architecture arrangements shape the public's expressed risk tolerance and demand for services in order to better inform the design of decision-support tools.

Stated Choice Experiments and Serious Games

- Develop stated choice experiments to examine disaster mitigation behaviors, support for infrastructure policy, estimate WTP for policies and infrastructure services, and valuation of disaster impacts.
- Develop serious games to assess policymaking decision response to natural disasters and other hazards with the SHFGT model as a base.

Power Outages: Please consider the three different situations where your power goes out during a severe weather or a disaster event.

	Situation 1	Situation 2	Situation 3
Duration of the power outage (hours)	4 hours	1 day (24 hours)	8 hours
Part of the week the outage occurs	Weekday	Weekday	Weekend
Starting time of the outage	Morning at 6 a.m.	Evening at 4 p.m.	Night at 10 p.m.
Season when the outage occurs	Summer	Winter	Winter
User fee charged	$5	$150	$25
Would you be willing to pay for this service?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No

WTP to Avoid Water Outage Choice Experiment

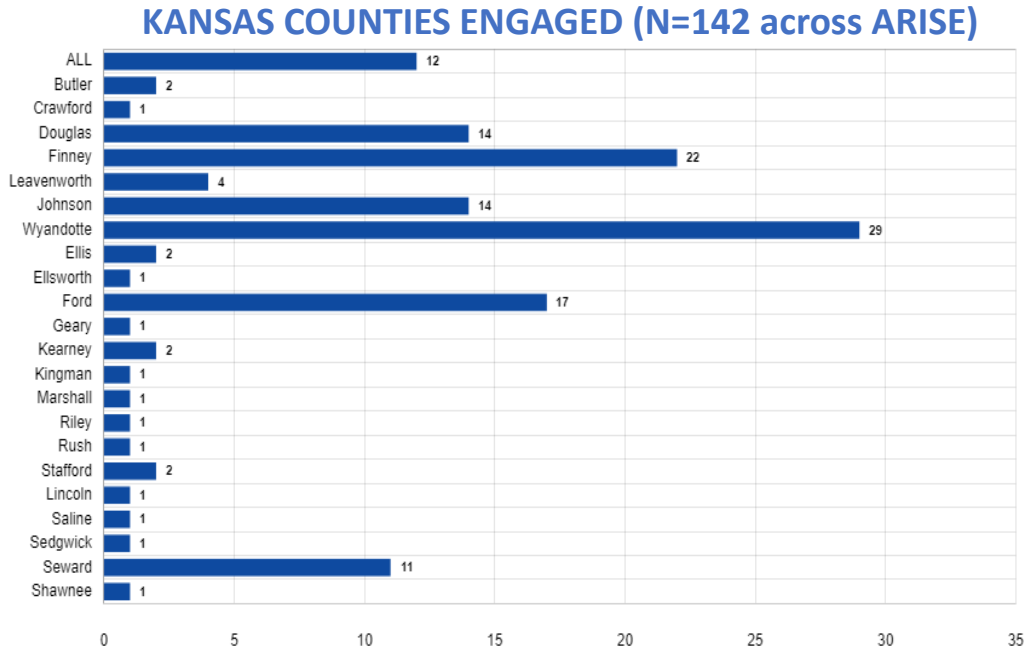
- Being Administered in Wave 1 Survey (Theme 1)
- Can be used to estimate respondent's WTP to avoid an outage, which can represent an indirect estimate of the impact of the water outage on household or business.
- Similar experiment being conducted for power outages.

4.3 Strategic Capacity of Communities

Identify users of decision-making tool in partner communities. Identify community constraints and feasible. solutions.

Tasks:

- **Equip research team with tools for engaging with community members.**
- **Team completion of the community engagement CITI training module.**
  - **45 (out of 54; 83%) research team members have completed CITI CEnR training modules to-date**
- **Make and retain connections with testbed community contacts.**
  - **(14) Johnson County**
  - **(29) Wyandotte County**
  - **(22) Finney County**
  - **(17) Ford County**
  - **(11) Seward County**
- **Train research team on using the community checkbox.**

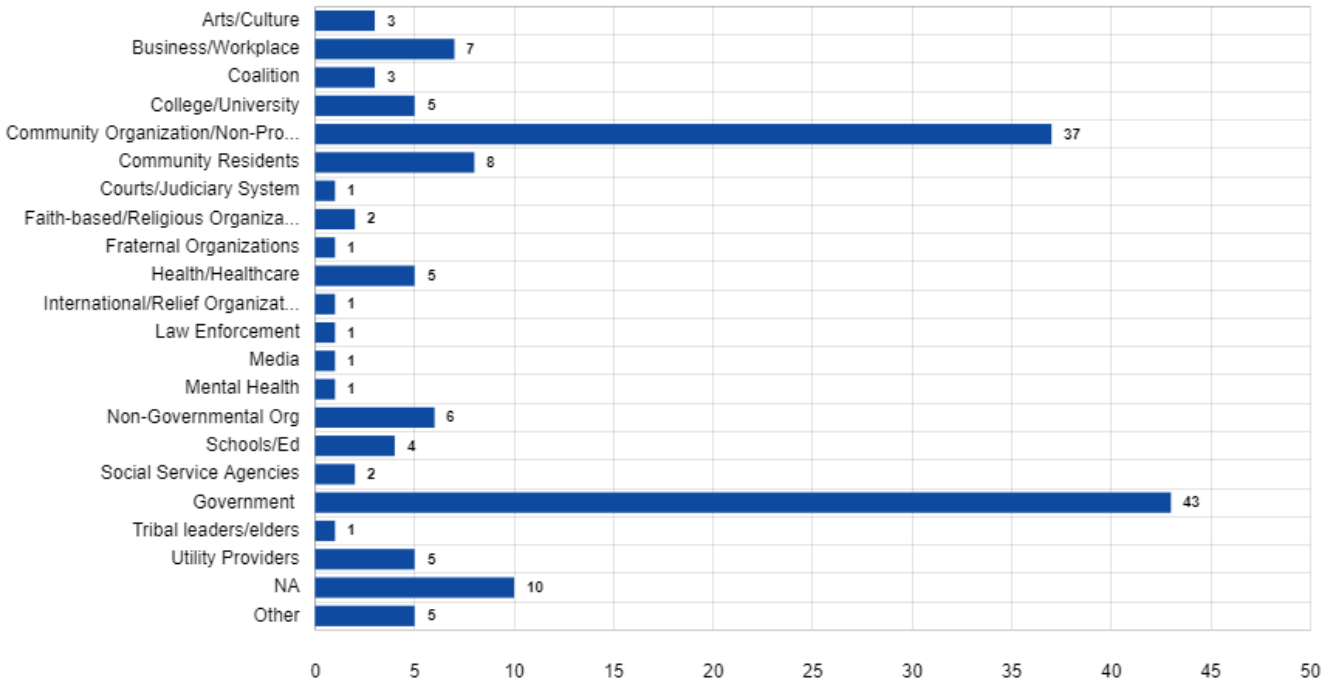


4.3 Strategic Capacity of Communities

Community Engagement Activities

- **105 Research-related Community Engagement Activities to-date**
  - **(27) involving Theme 1**
  - **(58) involving Theme 2**
  - **(4) involving Theme 3**
  - **(16) involving Theme 4**
- **Community Roundtables**
- **Community Studios**
- **Surveys and Interviews**

SECTORS ENGAGED (N= 142 across ARISE)

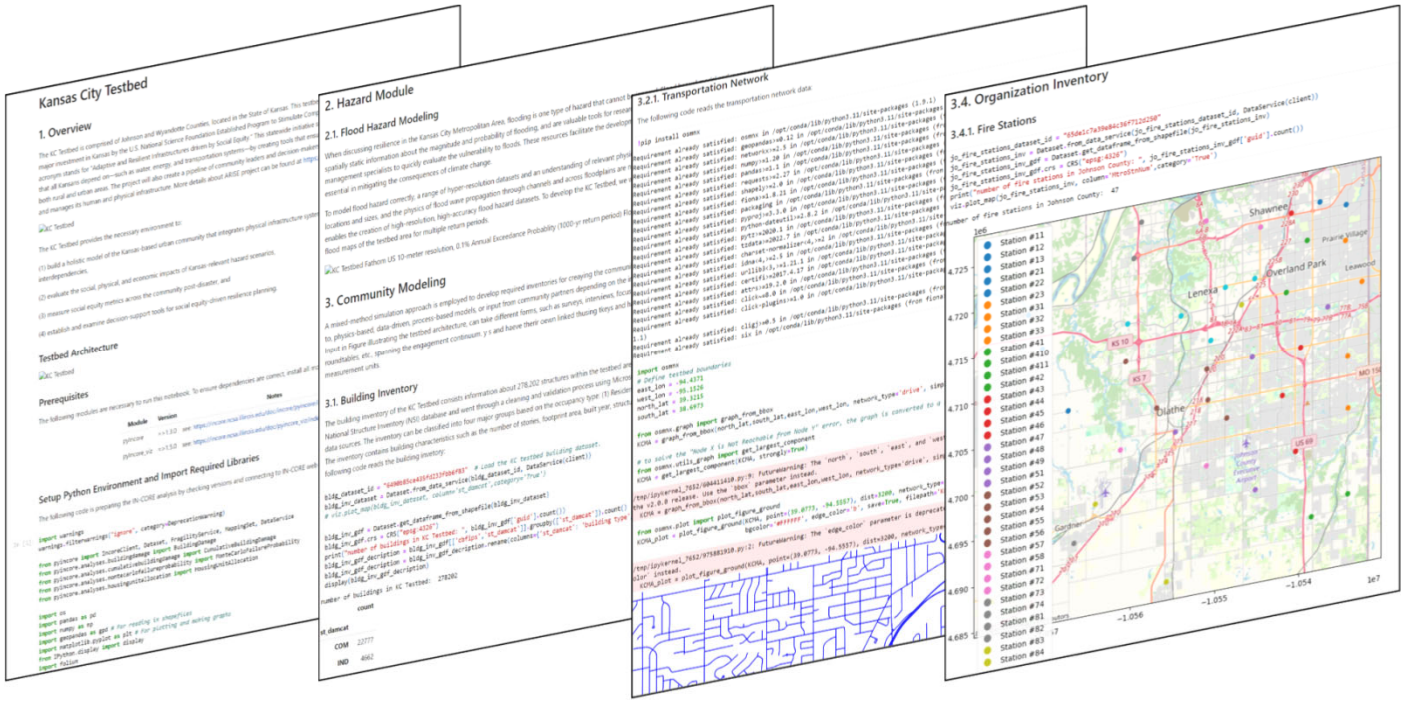


4.4 Decision Support Tool Implementation

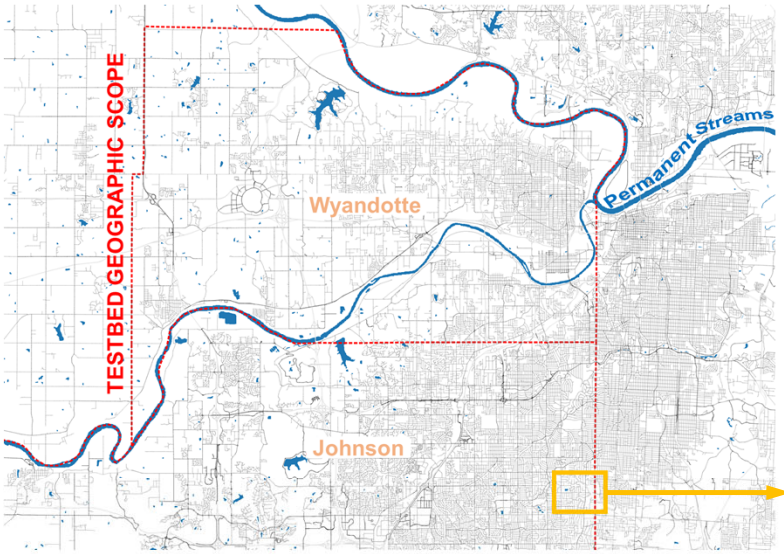
Integrate ARISE Research into IN-CORE

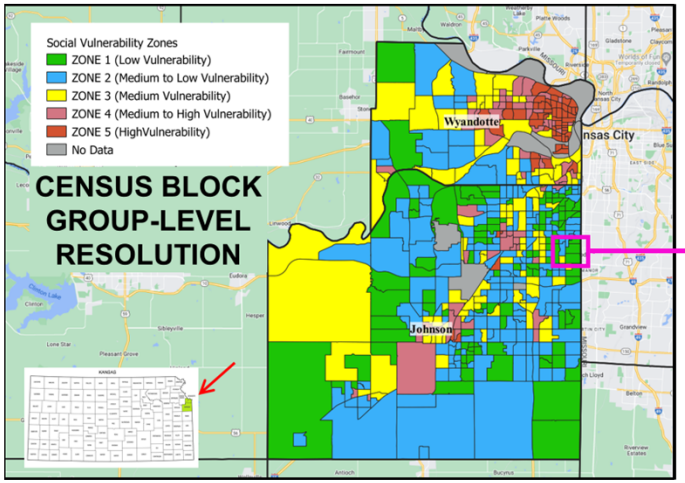
Jupyter Notebooks under development for Urban Testbed and Rural Testbed

1. **Overview**
2. **Hazard module**
    1. **Flood hazards**
3. **Community module**
    1. **Building inventory**
    2. **Infrastructure inventory**
        1. **Transportation network**
    3. **Population inventory**
        1. **Households, SVS**
    4. **Organization inventory**
        1. **Critical facilities**
        2. **Social institutions**

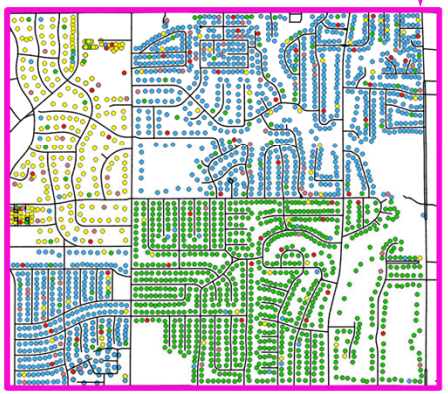


4.4 Decision Support Tool Implementation



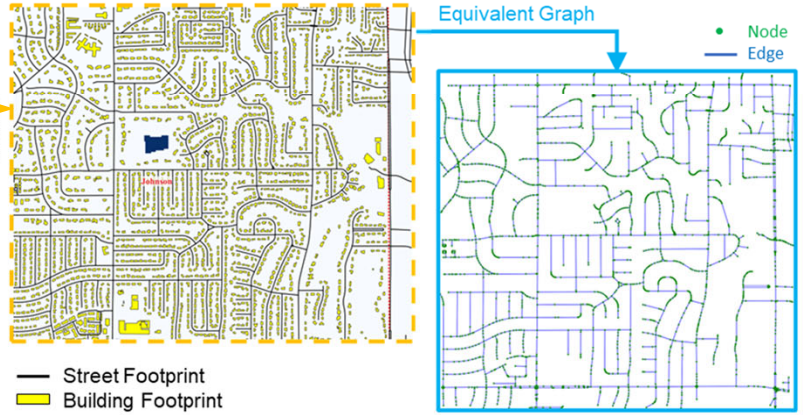


HOUSEHOLD-LEVEL RESOLUTION



Stochastic Algorithm

BUILDING-LEVEL RESOLUTION



Thank you!

ARISE: Adaptive and Resilience Infrastructures Driven by Social Equity

Learn more or get in touch with us!

Dr. Elaina J. Sutley, Ph.D., P.E., LEED AP Homes

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