CIVE 709: Infrastructure Systems and Resilience

This course introduces the principles, methods, and real-world applications involved in building resilient physical infrastructure systems. Students will examine emerging climate-related infrastructure challenges and learn to address them using data-driven, equity-centered, and management-informed approaches. The course integrates technical methods, including damage modeling, network analysis, geospatial analytics, and AI/ML, with socio-economic perspectives, including community vulnerability and stakeholder decision-making. Through case studies and hands-on projects, students will examine how infrastructure systems interact, respond, and recover under disruption and uncertainty. Emphasis is placed on resilience-based planning and design as a foundation for long-term sustainability, equity, and risk reduction.

By the end of this course, students should be able to:

1. Explain the concepts of resilience and vulnerability within the context of infrastructure systems.
2. Analyze the effects of climate-induced hazards on urban infrastructure performance, restoration, and recovery.
3. Apply quantitative and computational methods to identify infrastructure damage and evaluate system resilience.
4. Design economic and equitable infrastructure adaption and mitigation strategies for resilient infrastructure development.

Week 1 – Toward Sustainable and Resilient Physical Systems: Current State and Future Directions

- Introduction to sustainability and resilience concepts in infrastructure systems.
- Evolution from traditional risk-based approaches to resilience-based frameworks.
- Global megatrends: urbanization, resource constraints, and climate change.

Week 2 – The Role and Impact of Climate Change

- Climate change and extreme weather impacts on infrastructure reliability.
- Post-disaster infrastructure recovery cycles: mitigation, response, recovery, reconstruction.
- Emergency evacuation and rescue as critical resilience functions.
- Examples: floods, wildfires, and hurricanes impact infrastructure systems.

Week 3 – Resilience of Different Infrastructure Systems

- Buildings: structural resilience, damage modeling at building, community, and regional scales.
- Transportation: disruptions, rerouting, and accessibility challenges during hazards.
- Power and water systems: cascading failures, interdependency with water, telecom, and health systems.

Week 4 – Infrastructure Damage Identification Methods I

- Data collection methods: lidar, photogrammetry, satellite imagery, point cloud data, drones.
- Challenges in large-scale data collection and integration (quality, cost, real-time availability).
- Damage detection using AI/ML
- Case Study 1: Automated first-floor extraction of buildings using point cloud data.

Week 5 – Infrastructure Damage Identification Methods II

- Sources of uncertainty in post-disaster damage identification.
- Uncertainty modeling and quantification.
- Damage detection using spatio-temporal data analytics.
- Case Study 2: Flood inundation detection on highways through geospatial analytics.

Week 6 – Project Idea Presentation and Feedback

- Students present preliminary project concepts.
- Peer and instructor feedback on feasibility, scope, and innovation.
- Refinement of project goals, methods, and expected outcomes.

Week 7 – Infrastructure Resilience Assessment I

- Understanding infrastructure dependencies and interdependencies.
- Network modeling fundamentals: nodes, links, flows, and criticality measures.
- Graph-theoretic resilience indicators and their interpretations.
- Applications in transport, energy, water, and building infrastructure networks.

Week 8 – Infrastructure Resilience Assessment II

- Advanced network modeling: dynamic processes, cascading impacts, and recovery curves.
- Probabilistic and simulation-based approaches.
- Case Study 3: Hurricane Harvey impacts on transportation infrastructure.

Week 9 – Infrastructure Response

- Short-term emergency evacuation planning and real-time rescue operations.
- Resource allocation and restoration optimization under uncertainty.
- Importance measures: prioritizing recovery of critical nodes and links.
- Case Study 4: Hurricane Ida’s impacts on evacuation and emergency response

Week 10 – Infrastructure Planning and Recovery

- Long-term strategies for climate-resilient infrastructure design.
- Measuring and addressing community social vulnerability.
- Adaptation and mitigation measures: building elevation, buyout, relocation.

- Economic evaluation of resilience: benefit–cost analysis.

Week 11 – Urban Planning and Public Policies

- Role of urban planning in shaping resilient and sustainable cities.
- Stakeholder collaboration and decision-making.
- Economic considerations: financing mechanisms, insurance, and equity in resilience planning.
- Case Study 5: Stakeholder collaboration during transportation infrastructure restoration following Hurricane Harvey

Week 12 – Final Project Presentations

- Students deliver their final projects.
- Integration of technical, policy, and social perspectives into resilience strategies.
- Discussion of lessons learned and future research opportunities.