Georgia Institute of Technology

July 25, 2018

Economics of Built Environment Resilience

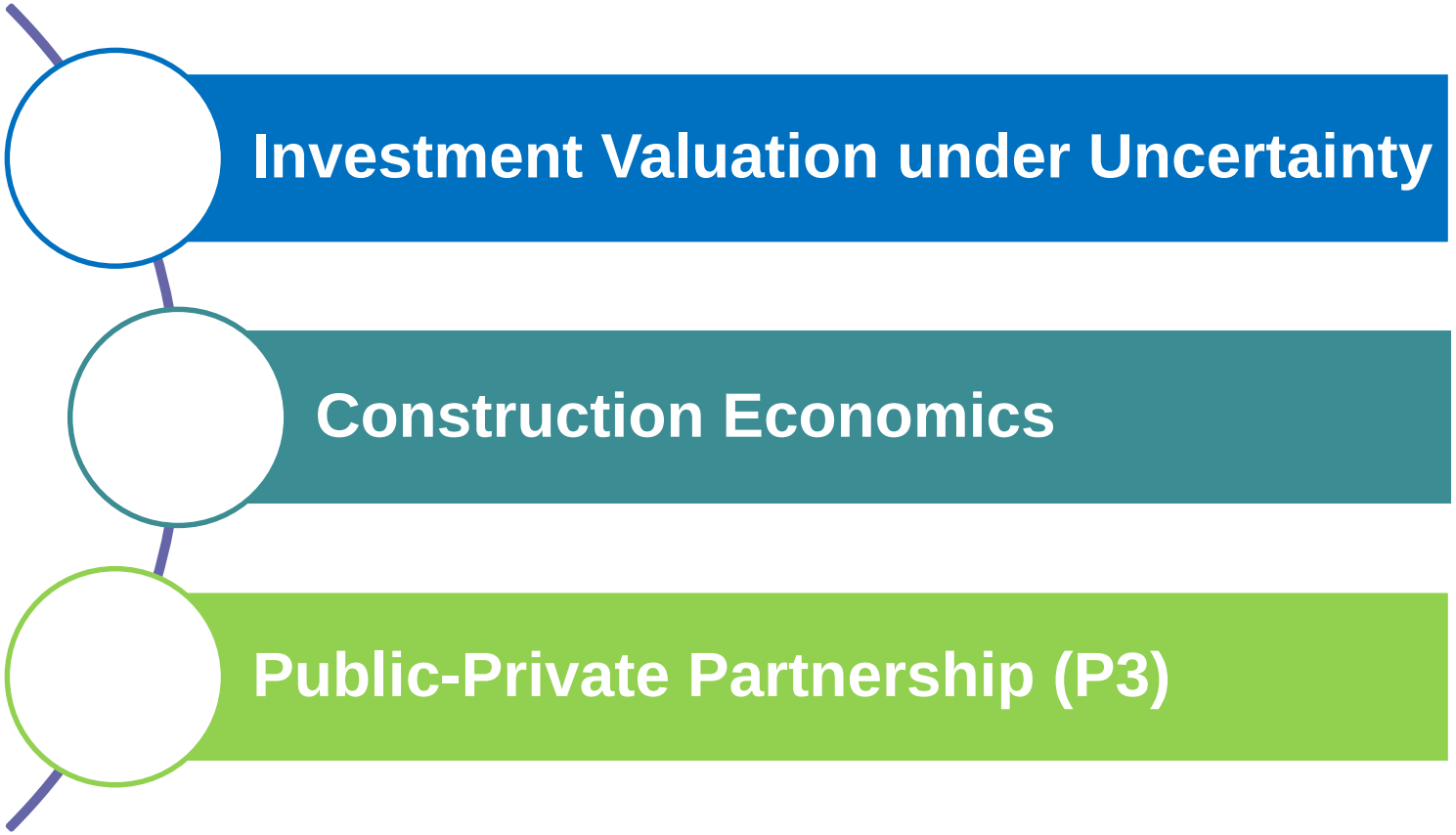
Baabak Ashuri

Associate Professor & Chair, Integrated Project Delivery Systems
Fellow, Brook Byers Institute for Sustainable Systems (BBISS)
School of Building Construction | Civil & Environmental Engineering
Georgia Institute of Technology

Hurricane Disaster Infrastructure Resilience and Planning Workshop II
Organized by AIChE, Madison, WI

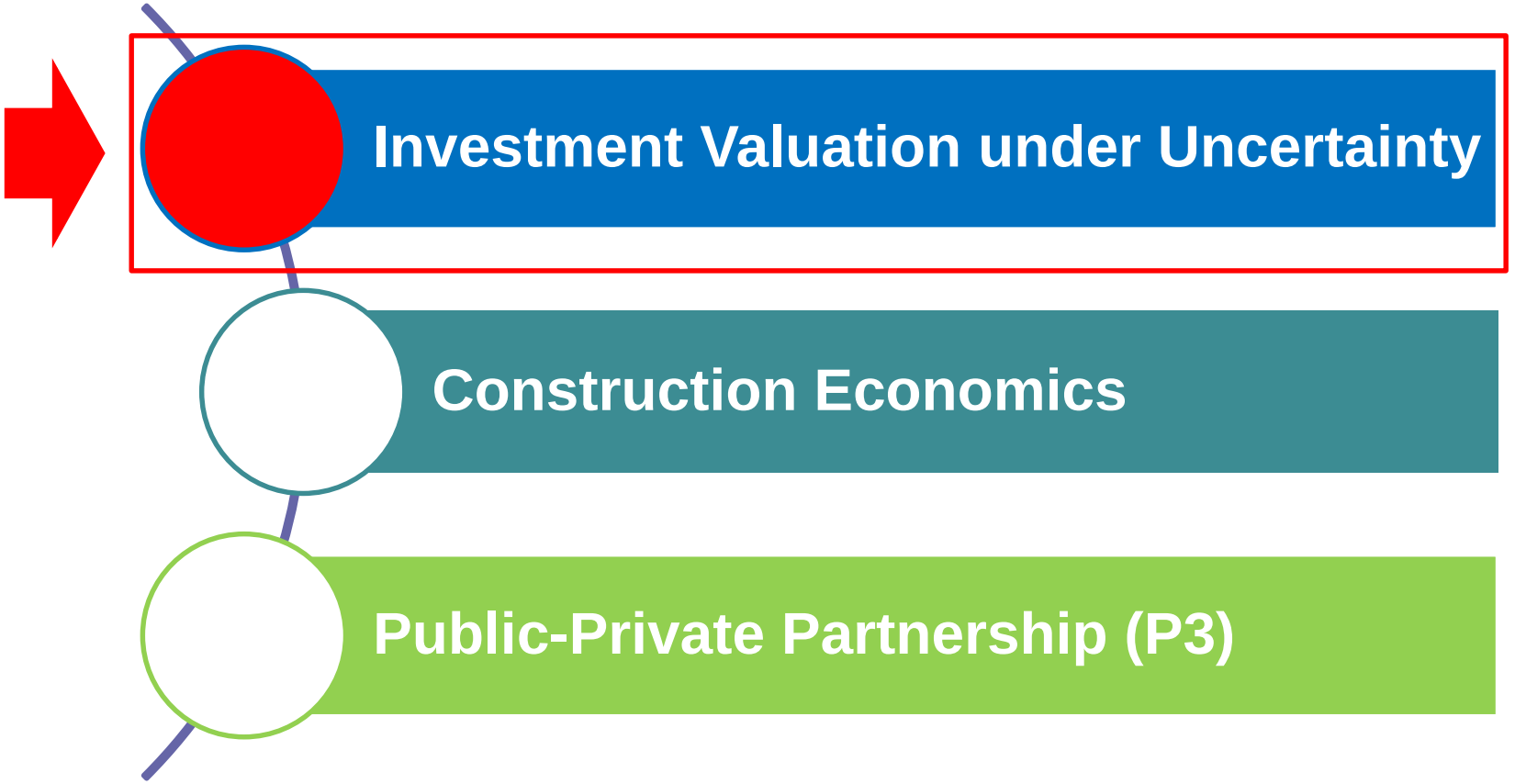
Overview

Economics of Built Environment Resilience



Overview

Economics of Built Environment Resilience

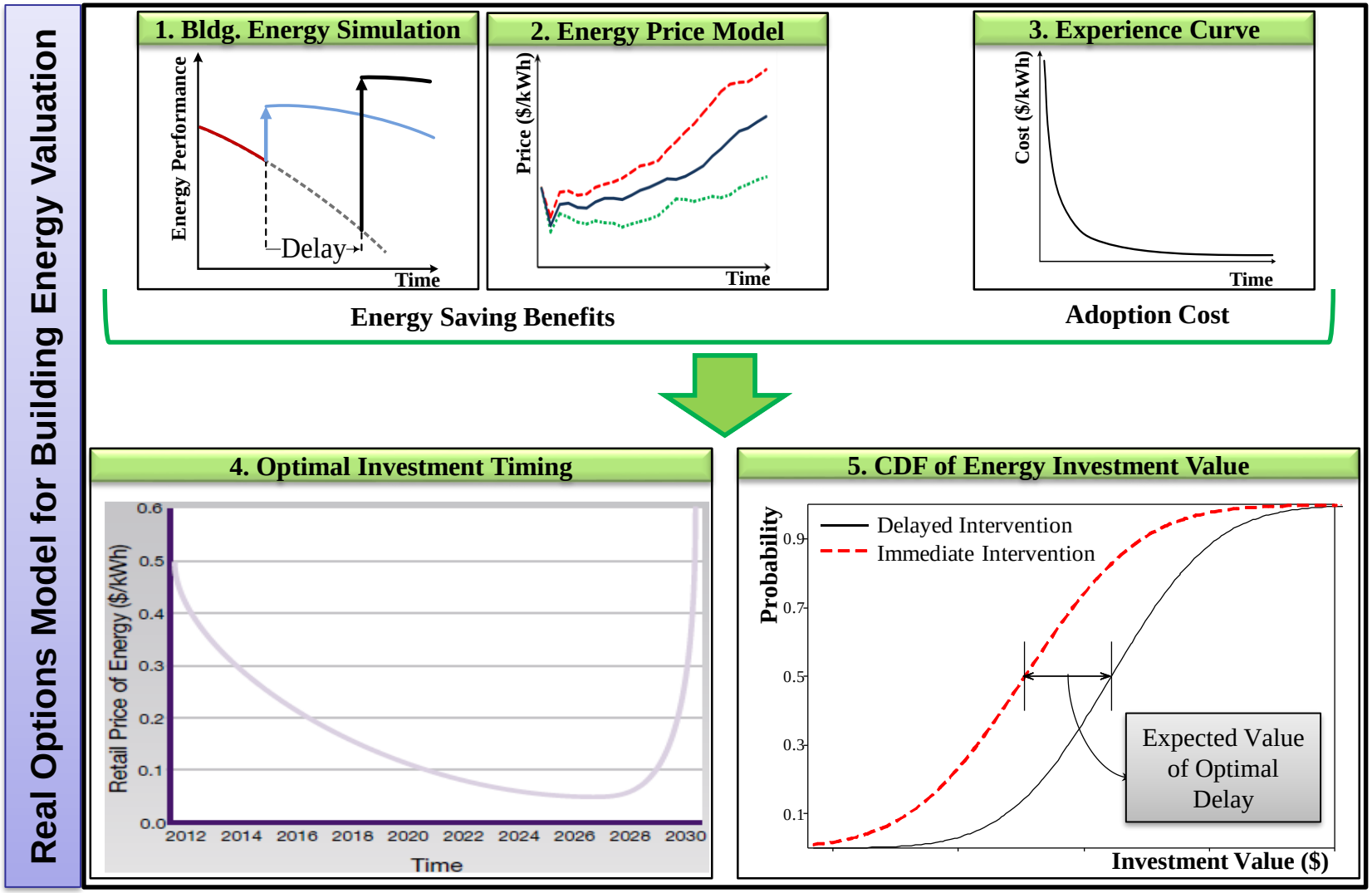


Investment Valuation of Building Energy

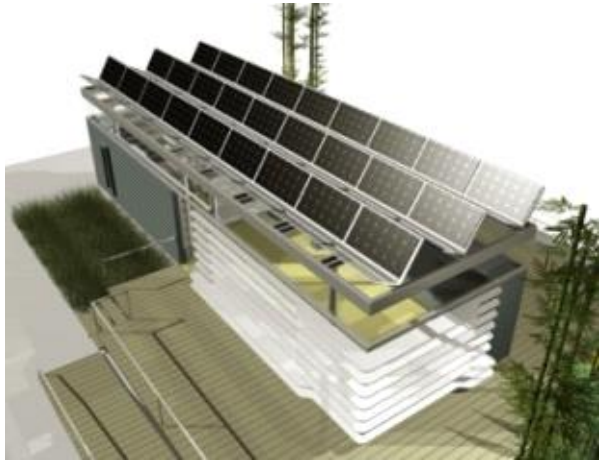
- Major issues:
  - Many promising energy solutions are still in the infancy stage
    - Significant implementation cost
    - Uncertainties about performance, deterioration and service life
    - Uncertainty about building energy demand
    - Uncertainties about energy price and environmental regulations
- New perspective:
  - Think of energy conservation measures and renewable energy sources as investment options
    - Example: Solar ready buildings

National Science Foundation
WHERE DISCOVERIES BEGIN

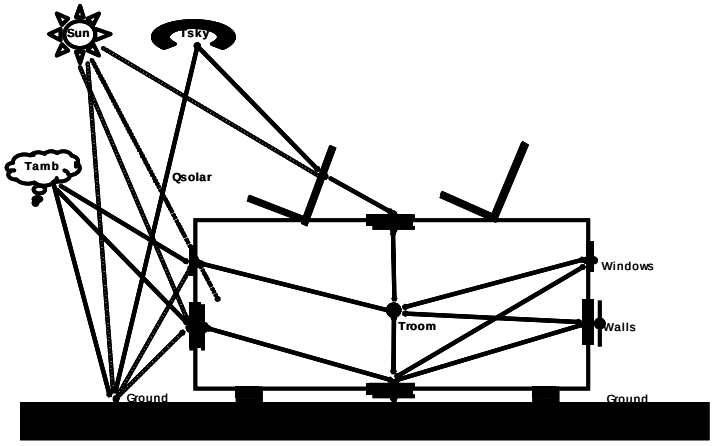
Overview of the Real Options Model



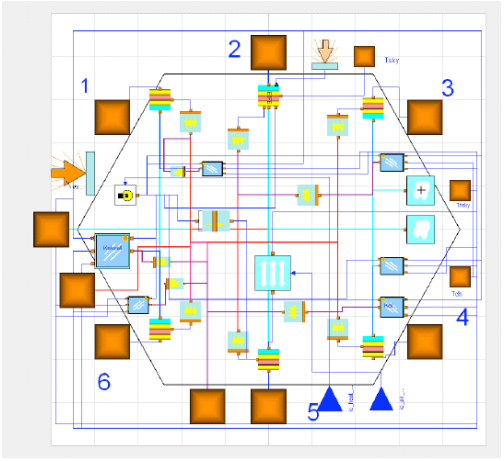
Uncertainty Quantification for Building Energy



Design Representation



Idealization (Physical Model)

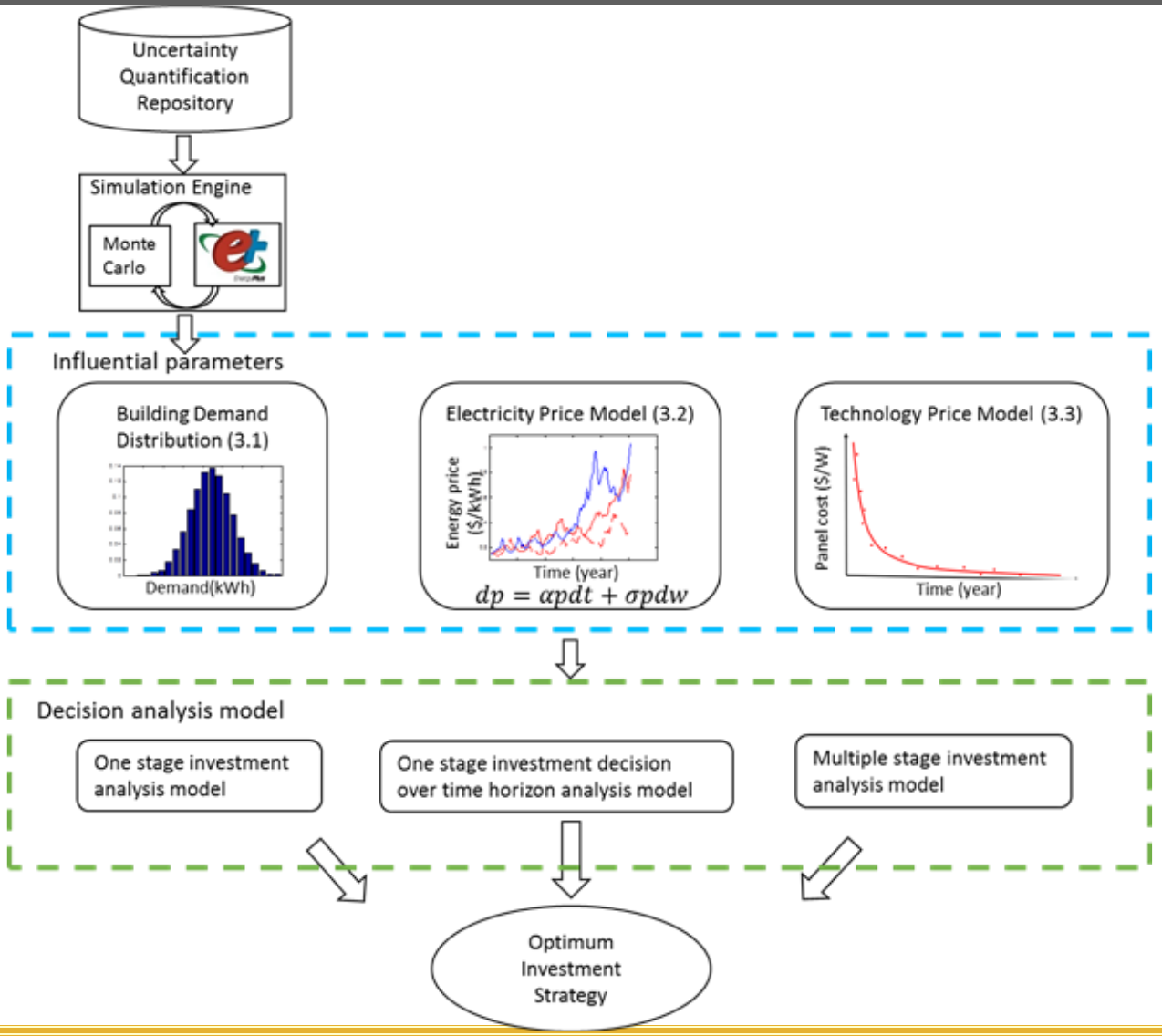


Computational Model

Uncertainty Quantification

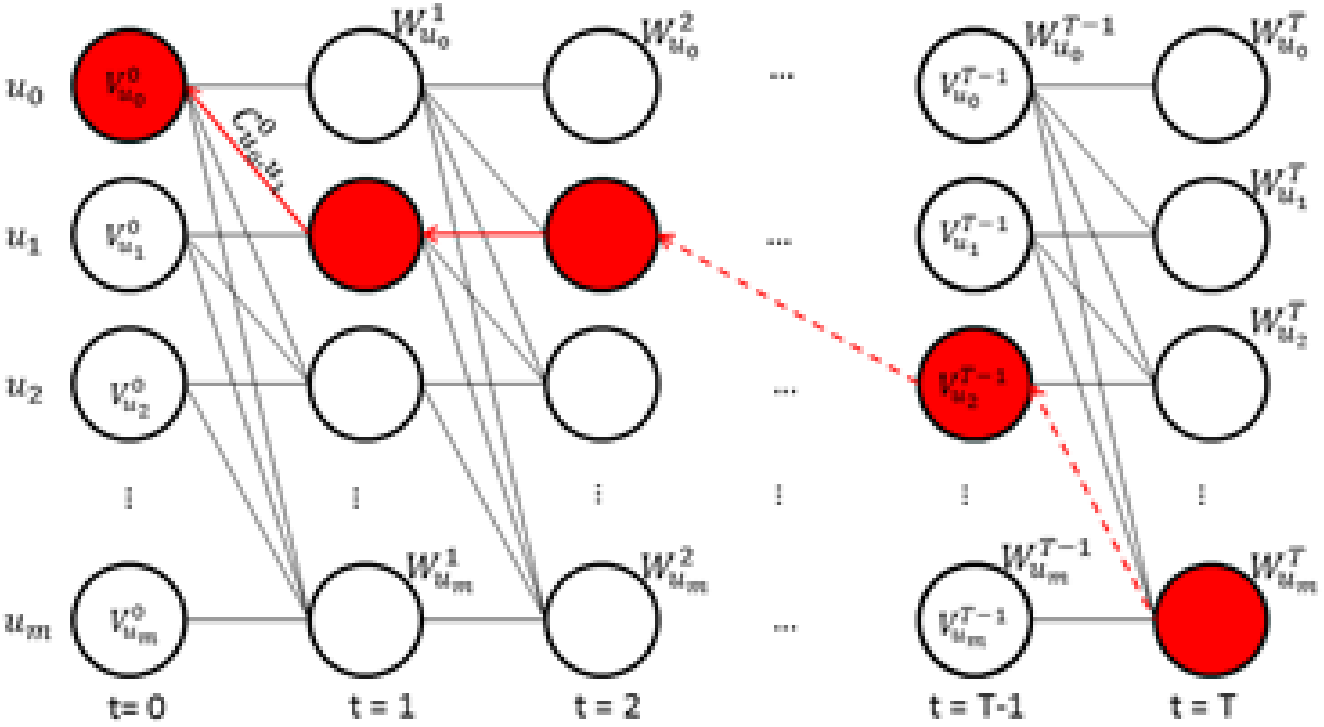
Overview of Building Energy Simulation
Copyright of Augenbroe 2010

Staged Energy Investment Decision Analysis Platform (SEIDAP)



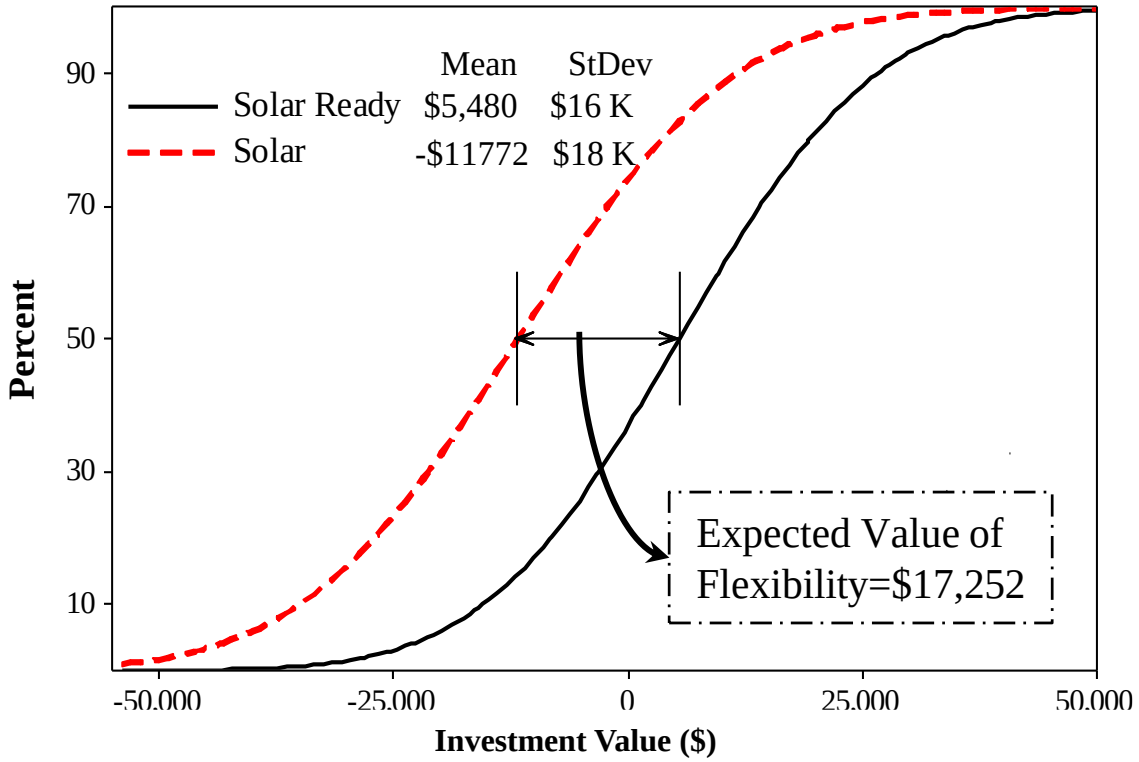
Dynamic Programming

- The dynamic programing algorithm to find the optimal path of investment in solar panels
  - Each circle represents a panel size at a given time.



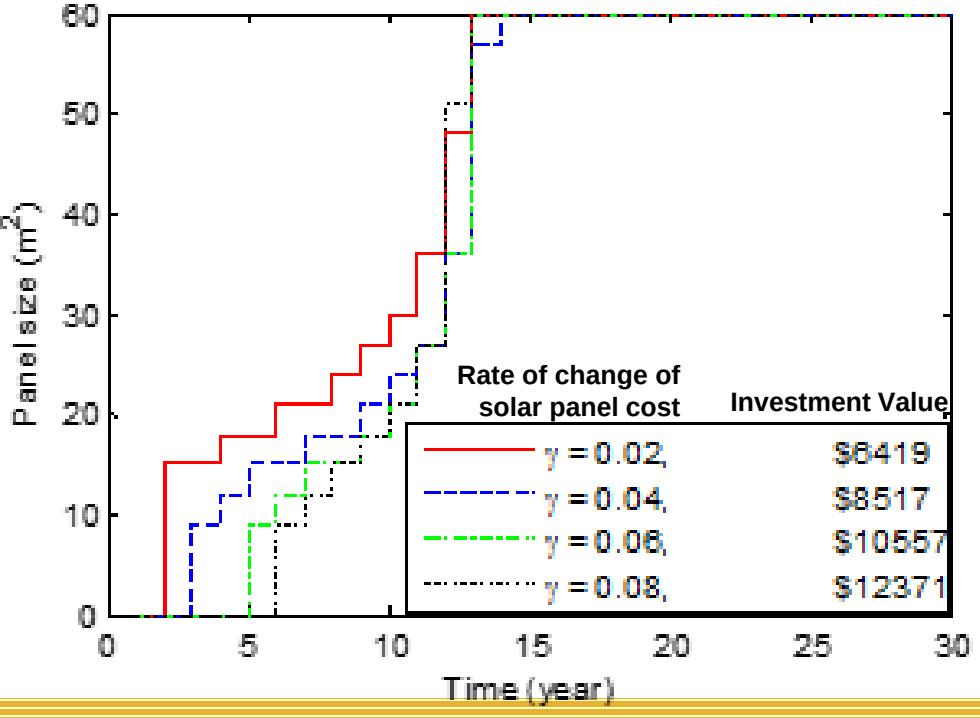
Optimal Timing & Value of the Delayed Intervention

- Main findings:
  - Showed how optimal timing enhances the investment risk profile
  - Quantified the value of the deferred intervention



Value of the Staged Investment in Solar

- Main findings:
  - Showed how the investor benefits from simultaneous optimal sizing and timing
  - Showed how the optimal decision depends on the rate of changes in the electricity price and the solar installation cost



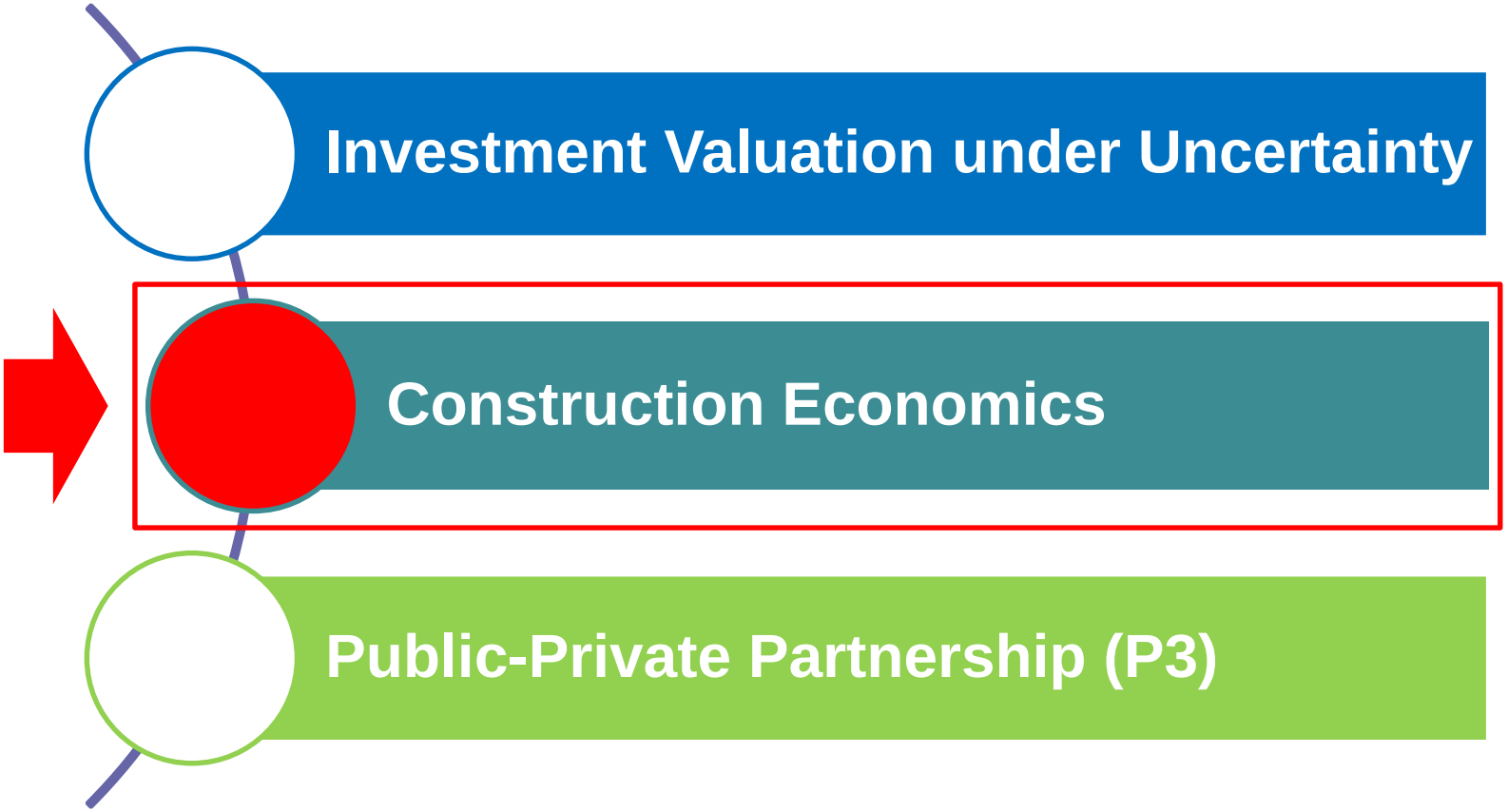
Resilience Valuation under Deep Uncertainty

- Current work: Valuation of resilient systems
  - Adaptable and modular system design that can grow over time

- Pressing issues:
  - Adaptation options:
    - Emerging high-risk high-reward resilient solutions
      - How to quantify underlying uncertainties surrounding the evolving systems?
        - » Limited (or even no) performance data
  - Investment risk analysis:
    - Why is there a long way to adopt?
    - How to quantify the role of perception and bias?

Overview

Economics of Built Environment Resilience



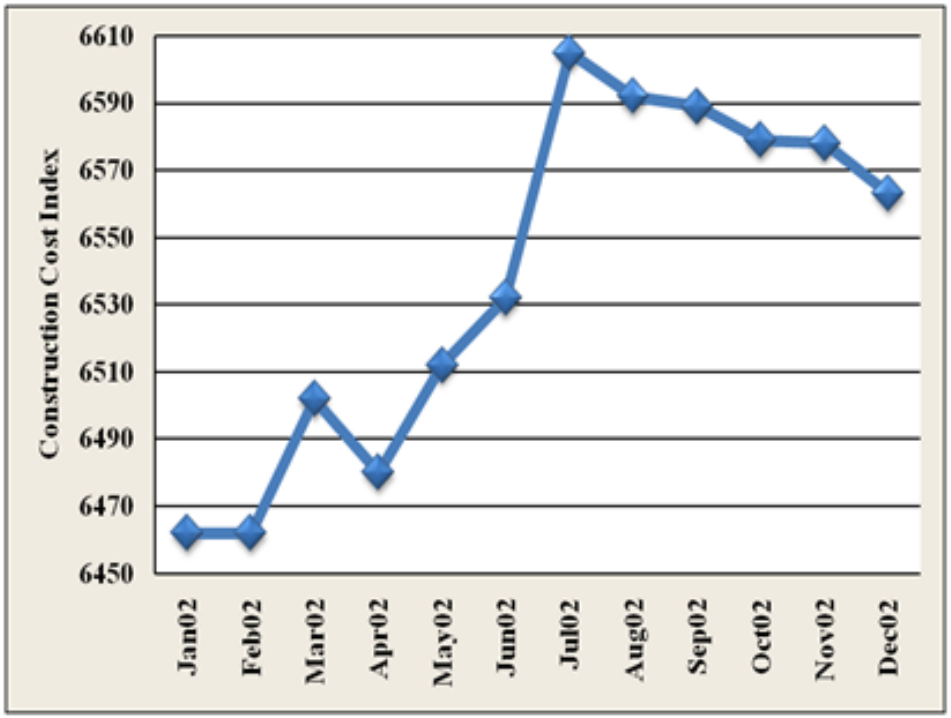
Construction Cost Analysis

- Major issues:
  - Significant variations for construction costs from a project to project, a region to region, and over time
    - Cost overrun, financial problem, and project delay or cancellation
    - Failure in budgeting and making right investment decisions
    - Credibility issues with the public

- Ultimate goal:
  - Identify leading indicators of construction cost
  - Create predictive models that explain the variability in construction cost trend (spatially and temporarily)

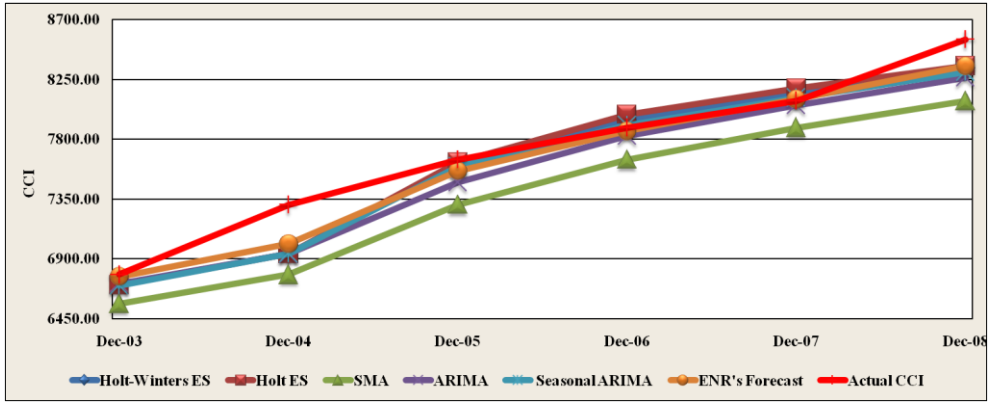
Engineering News-Record Construction Cost Index

- High-level question:
  - How can the variations in the ENR's CCI be forecasted?



Univariate Time Series Forecasting

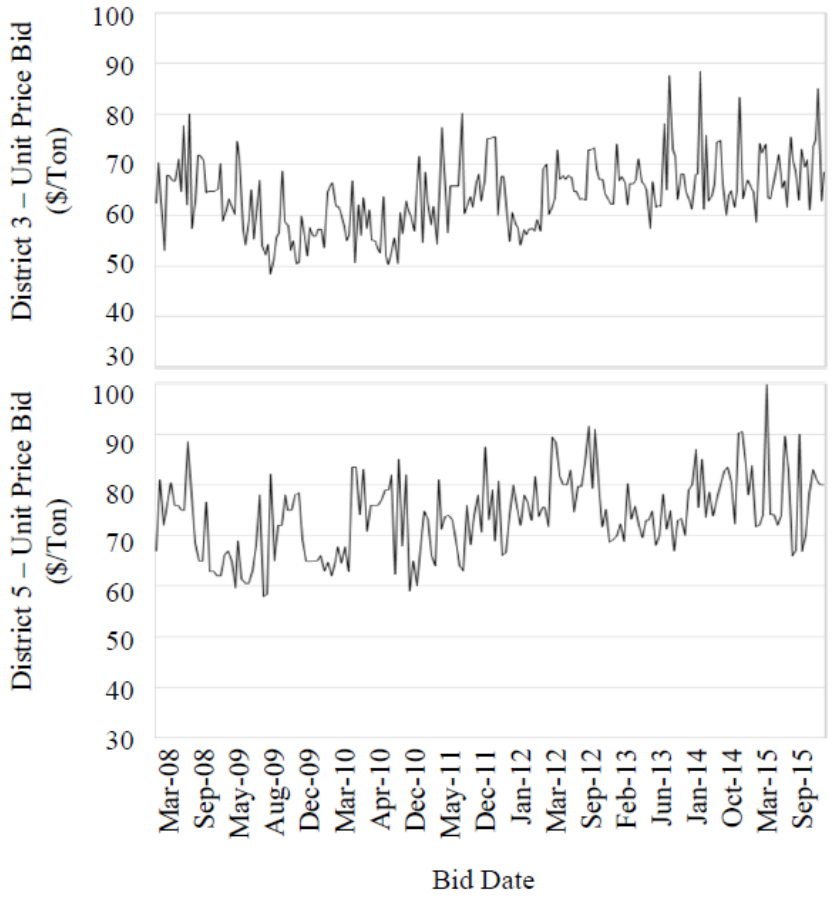
- Major finding:
  - Significantly improved subject matter experts' forecasts

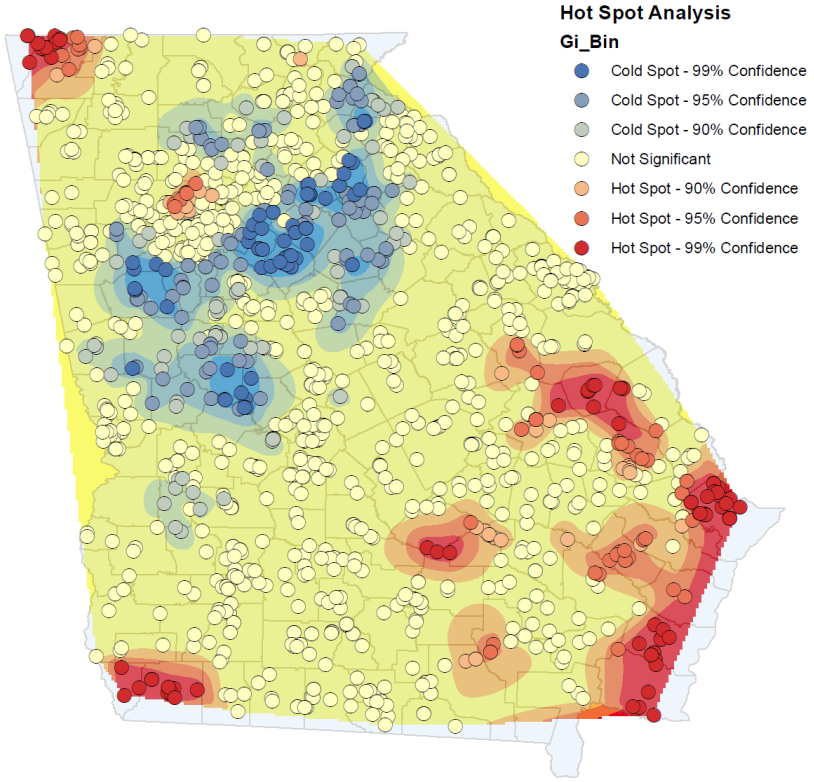


	ENR Forecasts	SMA	Holt ES	Holt-Winters ES	ARIMA	Seasonal ARIMA
Error Measures						
MAPE	1.22%	3.02%†	1.03%†	1.00%†‡	1.29%†	1.06%†
MSE	12910.00	49521.45	10990.77	10745.36‡	14134.73	11624.04
MAE	73.33	190.91	67.68	65.36‡	82.04	67.93
Robustness*	N.A.	Extremely Robust	Not Robust	Not Robust	Moderately Robust	Moderately Robust
Implementation	N.A.	Easy	Moderately Difficult	Moderately Difficult	Difficult	Difficult

Explaining the Variability of Submitted Bid Prices

- Spatial and temporal variability of construction cost





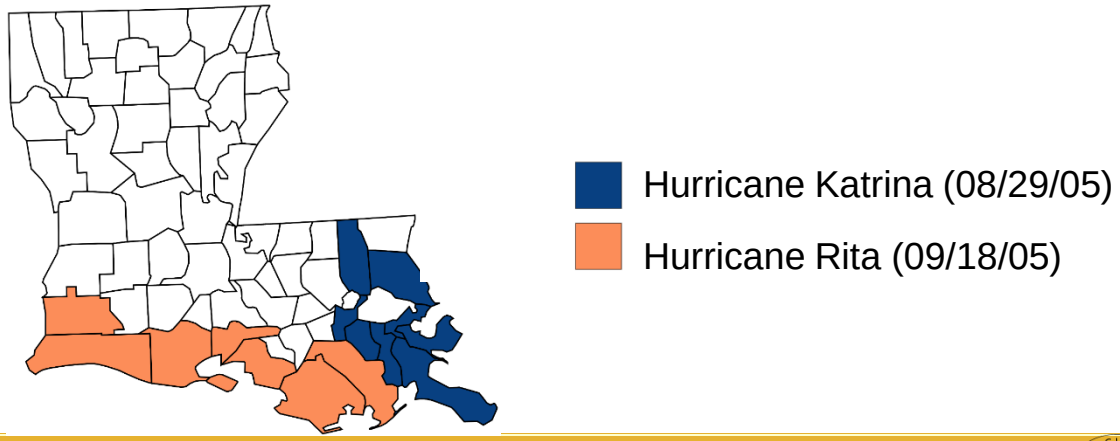
Results of Stepwise Regression

- A notable finding:
  - No statistically significant effect was found for the price adjustment clause.

Model	Unstandardized Coefficients	Standardized Coefficients (Beta)	t statistic	P-Value	VIF
(Constant)	44.764		10.274	0.000	-
Coastal	7.018	0.180	8.613	0.000	1.173
Flat	2.957	0.142	6.352	0.000	1.353
District 3	-3.480	-0.155	-7.394	0.000	1.181
Quantity of the Bid Item (in transformed natural logarithmic form)	-3.107	-0.493	-15.999	0.000	2.556
Total Contract Price	4.286×10^{-7}	0.319	12.914	0.000	1.640
Percentage of Asphalt Intensive	0.084	0.249	8.912	0.000	2.099
Georgia Asphalt Cement Price Index	0.023	0.230	8.017	0.000	2.219
Number of Nearby Asphalt Plants	-0.123	-0.178	-5.873	0.000	2.477
Georgia Fuel Price Index	2.266	0.154	6.201	0.000	1.657
Average weekly wage	0.007	0.141	5.220	0.000	1.972
Equipment Operator Wages (Paving)	1.757	0.132	5.249	0.000	1.718
Number of Bidders	-0.680	-0.128	-5.659	0.000	1.388
Total Asphalt Volume of Resurfacing and Widening Projects	5.937×10^{-7}	0.060	2.432	0.015	1.629
R-Squared		0.489			
Adjusted R-Squared		0.485 (48.5%)			

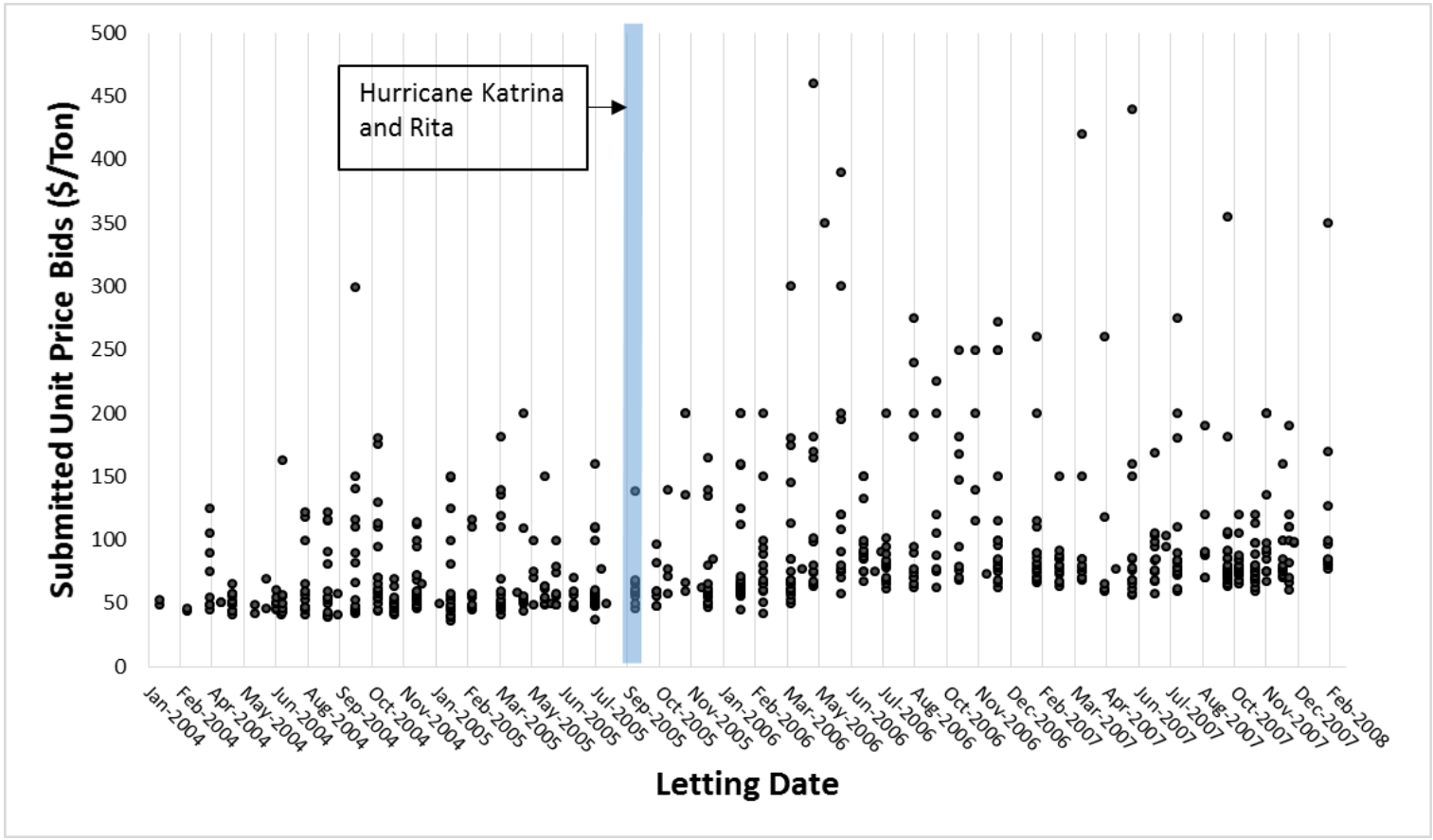
Resilience of Construction Economy

- The major gap in existing cost forecasting methods:
  - Inherent incapability to detect and treat shocks
  - Limited knowledge about the effects of large-scale disasters on construction market
- Examine the variability of construction cost after large-scale disasters
  - Profile monitoring for the variation in the submitted unit price bids after hurricanes



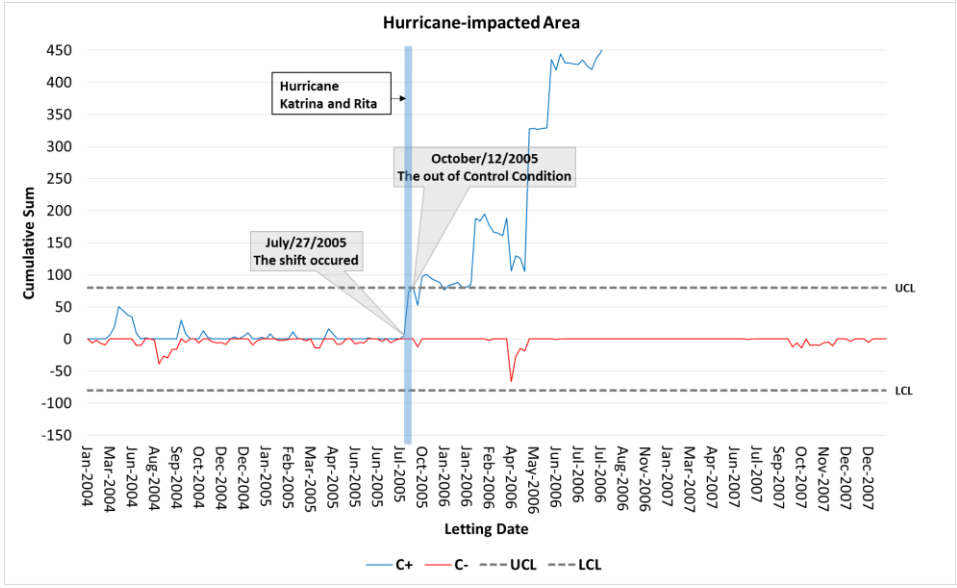
Panel Data on Construction Cost

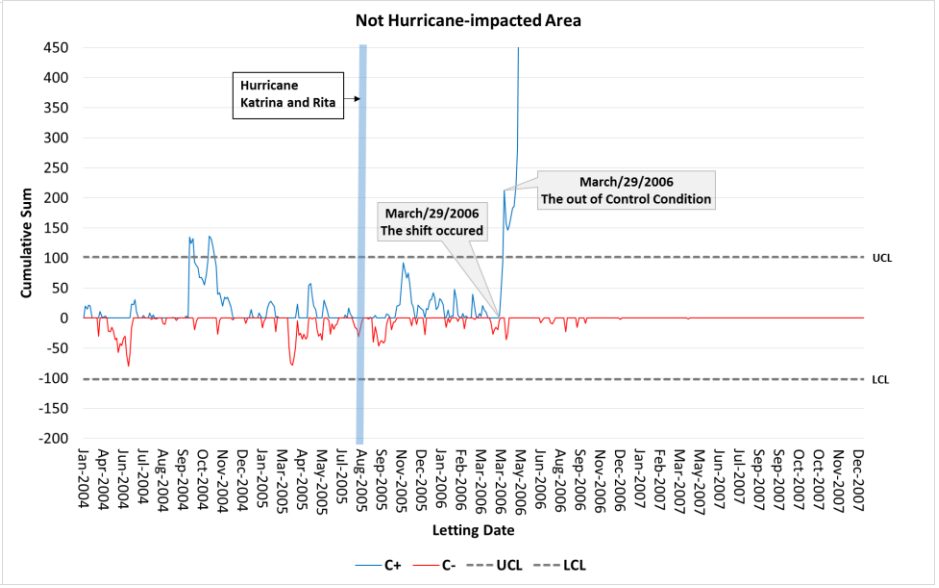
- Submitted unit price bids for asphalt line items in LADOTD highway projects



Preliminary Findings

- Results of CUSUM control chart for unit price bids
  - Significant increase immediately after the hurricanes in the hurricane-impacted area
  - Significant increase six months after the hurricane in the non-hurricane-impacted area





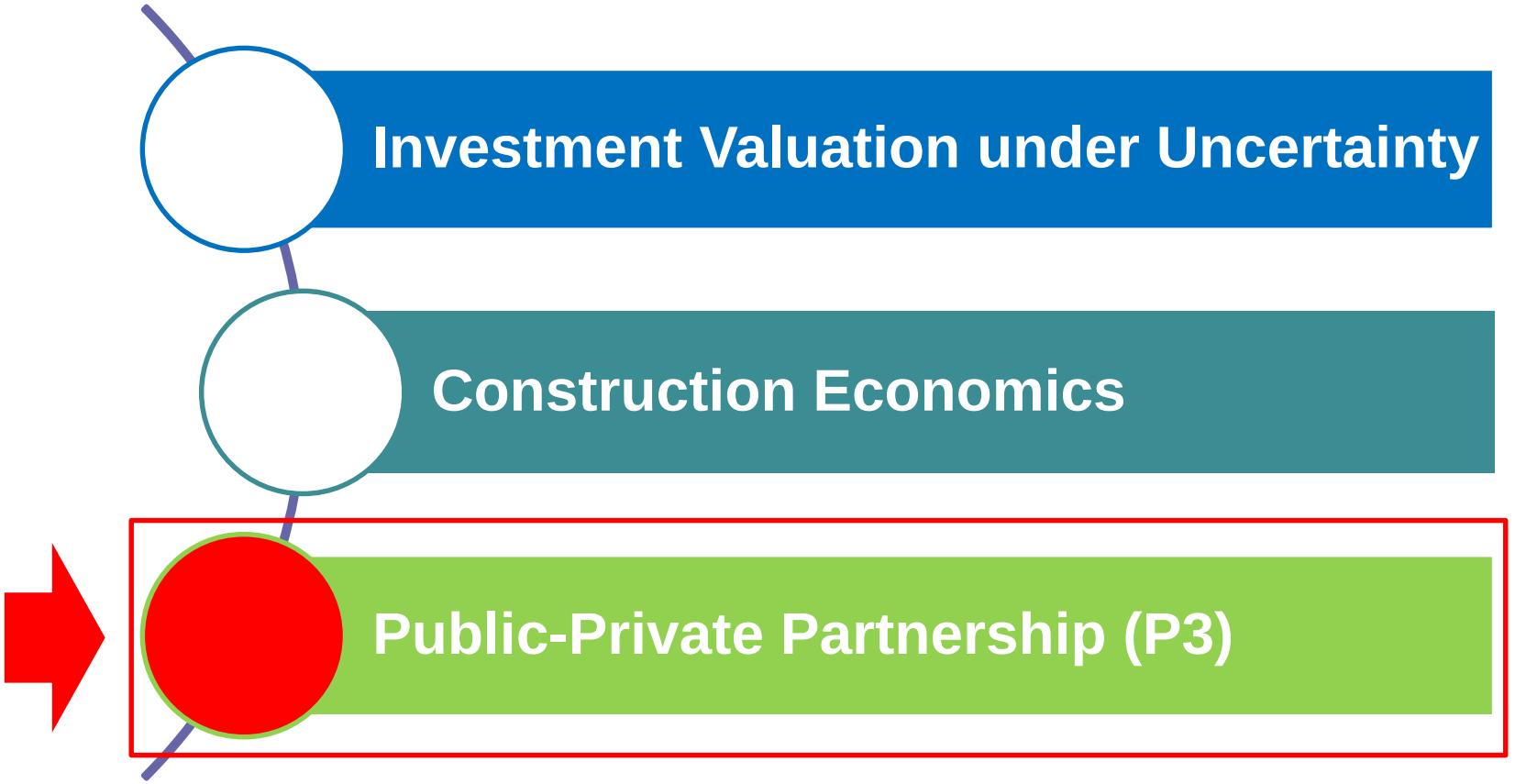
Diagnostics and Prognostics for Resilience Assessment

- Current work: Monitoring, diagnostics and prognostics in large-scale disasters
  - Modeling the effects of catastrophic events on different construction sectors

- Pressing issues:
  - Vulnerability assessment:
    - How severe and long are the true effects of large-scale disasters on the construction market?
  - Risk mitigation actions:
    - How to measure the effectiveness of rebuilding incentives and reconstruction polices?

Overview

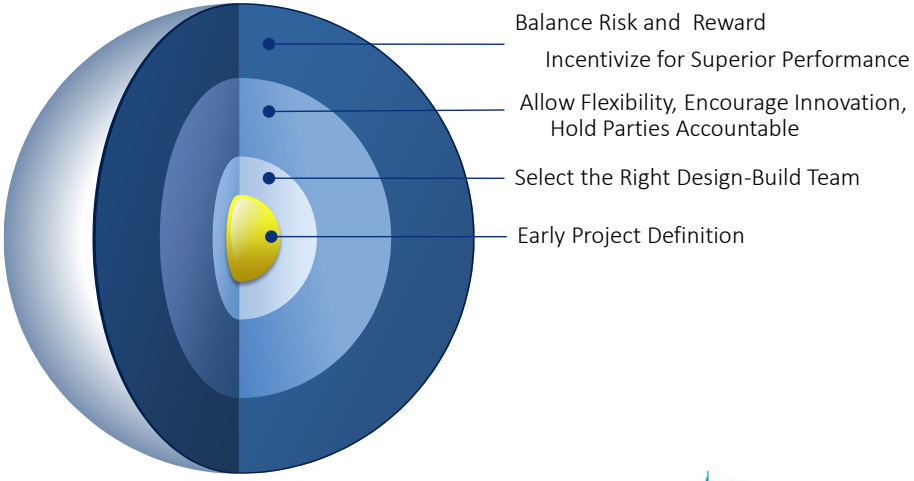
Economics of Built Environment Resilience



Innovative Project Delivery Systems

- Major issue:
  - Ineffective and inefficient acquisition strategy
- Ultimate goal:
  - Define high-performance contracting

Copyright of DBIA



Georgia Department of Transportation

STC

NCTSPM
NATIONAL CENTER FOR TRANSPORTATION SYSTEMS PRODUCTIVITY AND MANAGEMENT

Infrastructure Project Finance

- Major issues:
  - Unprecedented funding shortfalls across all infrastructure types
  - Limited consideration of infrastructure systems interactions

ASCE Failure to Act Economic Studies

"*The cumulative impact of failing to invest over time and the interaction between modes ensures that deficiencies in one sector will have an impact on other sectors*."

- Paying for resilient infrastructure:
  - Develop innovative methods for financing resilient systems
  - Investigate how flexible developments (e.g., multi-sector, multi-scale, and multi-stage) enhance project economic value and mitigate risks
    - Examples: Green infrastructure, energy performance contracting (EPC) and microgrid

Public-Private Partnership for Resilience

- Current work: P3 for resilience
  - ASCE Grand Challenge:
    - Significantly enhance the performance and value of infrastructure projects over their life cycles by 2025
    - Foster the optimization of infrastructure investments for society

- Pressing issues:
  - Adoption barriers:
    - How to mitigate the perceived loss of public control?
    - How to set long-term service performance indicators under uncertainty?
  - Contract and risk allocation:
    - How to enhance demand and revenue estimation?
    - How to design and evaluate risk-sharing mechanisms?

Sponsors

RICS the mark of property professionalism worldwide

NCTSPM NATIONAL CENTER FOR TRANSPORTATION SYSTEMS PRODUCTIVITY AND MANAGEMENT

CII The Knowledge Leader for Project Success Owners • Contractors • Academics

Powered by SunShot U.S. Department of Energy

NSF National Science Foundation WHERE DISCOVERIES BEGIN

aum the power of one

GDOT Georgia Department of Transportation

ELECTRI INTERNATIONAL THE FOUNDATION FOR ELECTRICAL CONSTRUCTION INC.

Thanks!

- Questions & Comments

- Contact Info

Baabak Ashuri, Ph.D., DBIA, CCP, DRMP
Associate Professor
School of Building Construction | School of Civil & Environmental Engineering
Director, Economics of the Sustainable Built Environment (ESBE) Lab
Chair, Integrated Project Delivery Systems Masters Track
Georgia Institute of Technology
280 Ferst Drive Atlanta, GA 30332-0680
Phone: (404) 385-7608
E-mail: baabak@gatech.edu
Web: http://www.esbe.gatech.edu