

CRITICAL FACILITY VULNERABILITIES AND BENEFIT-COST ANALYSIS

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March 12, 2015

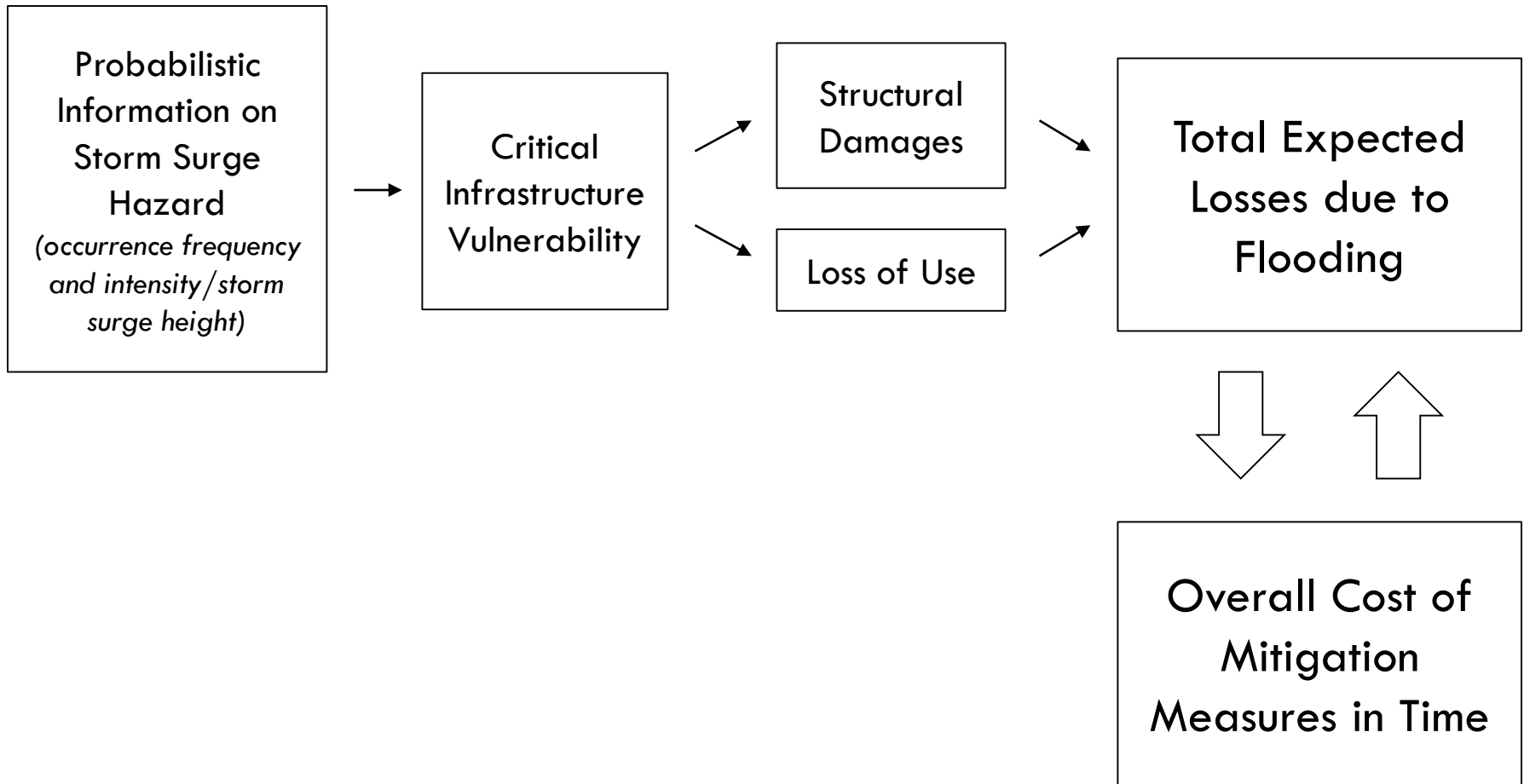


RESILIENCY INSTITUTE FOR
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RESEARCH OBJECTIVE

- Determine optimal mitigation strategies under budget constraints to protect critical infrastructure
- Mitigation strategies may evolve dynamically over time

RESEARCH METHODOLOGY



HOSPITALS – LOSS OF USE METHODOLOGY

Cost Analysis Includes:

- Decreased functionality due to flooding
- Evacuations to other hospitals
- Loss of revenue while hospital is closed

Assumptions:

- Decreased hospital functionality is the cause for increased mortality during floods
- One year of life is worth \$95,000 (this input variable can be modified)
- Deaths in hospitals during hurricanes occur an average of 10 years before expectancy of natural death

HOSPITALS – LOSS OF USE ESTIMATES

| | |
|-------------------------------|-----------------|
| Lower Manhattan Hospital | \$103 million |
| Bellevue Hospital Center | \$533 million |
| Saint John's Episcopal Center | \$406 million |
| Mount Sinai Beth Israel | \$1,300 million |
| NYU Langone Medical Center | \$1,000 million |

TOTAL DAMAGE (COST) IF A HOSPITAL IS CLOSED FOR 30 DAYS

FIRE STATIONS— LOSS OF USE METHODOLOGY

Cost Analysis Includes:

- Loss of firemen's wages drawn from state averages
- Monetary value of structural damages caused by fires not fought by fire department

Assumptions:

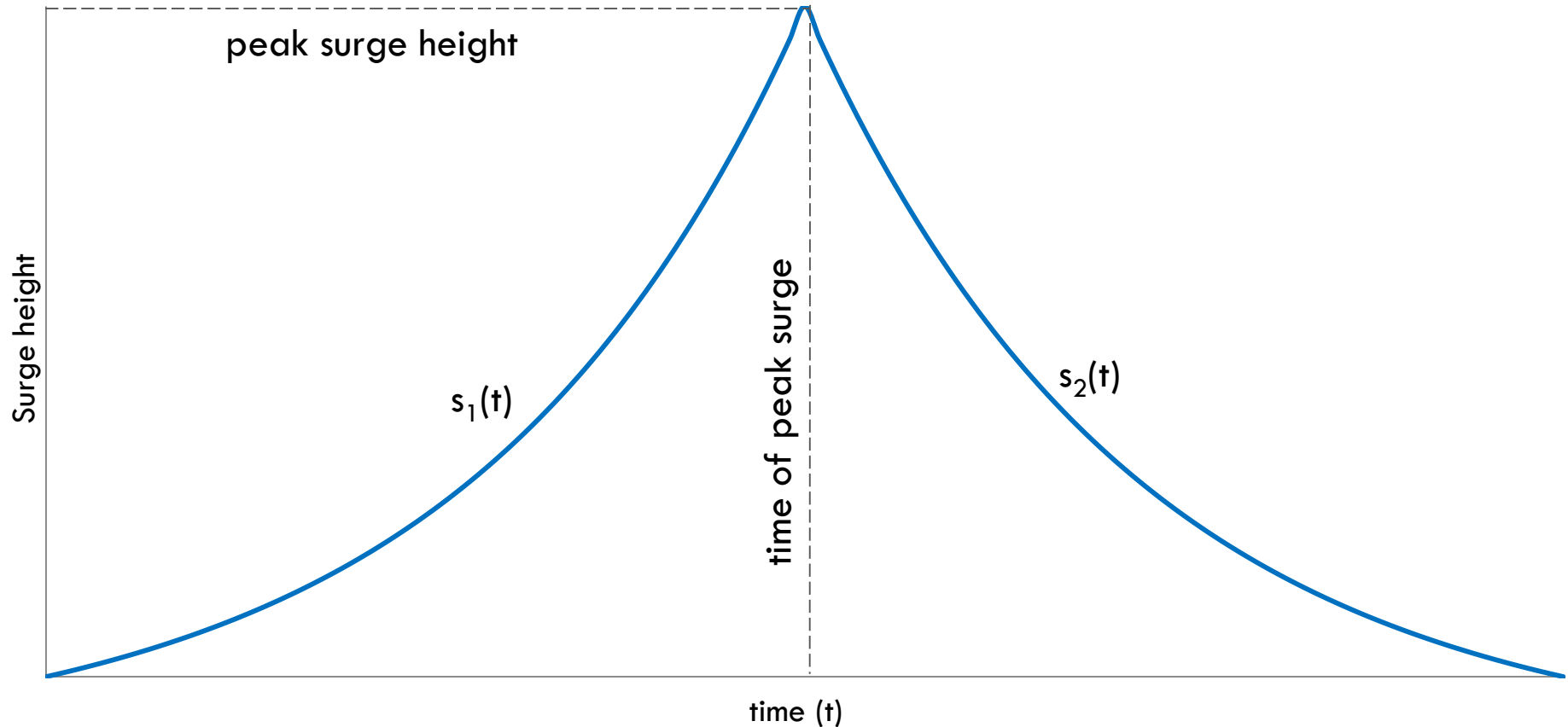
- There is no statistically significant increase in ignition of fires during a hurricane
- The revenue lost from transportation costs (fire trucks) is minimal

FIRE STATIONS – LOSS OF USE ESTIMATES

| | |
|---------------------------|----------------------|
| Structural Cost | \$700,000/day |
| Loss from Potential Wages | \$200,000/day |
| Total Cost | \$900,000/day |

ESTIMATED DAILY COST IF ALL FIRE STATIONS
IN LOWER MANHATTAN WERE TO CLOSE DOWN

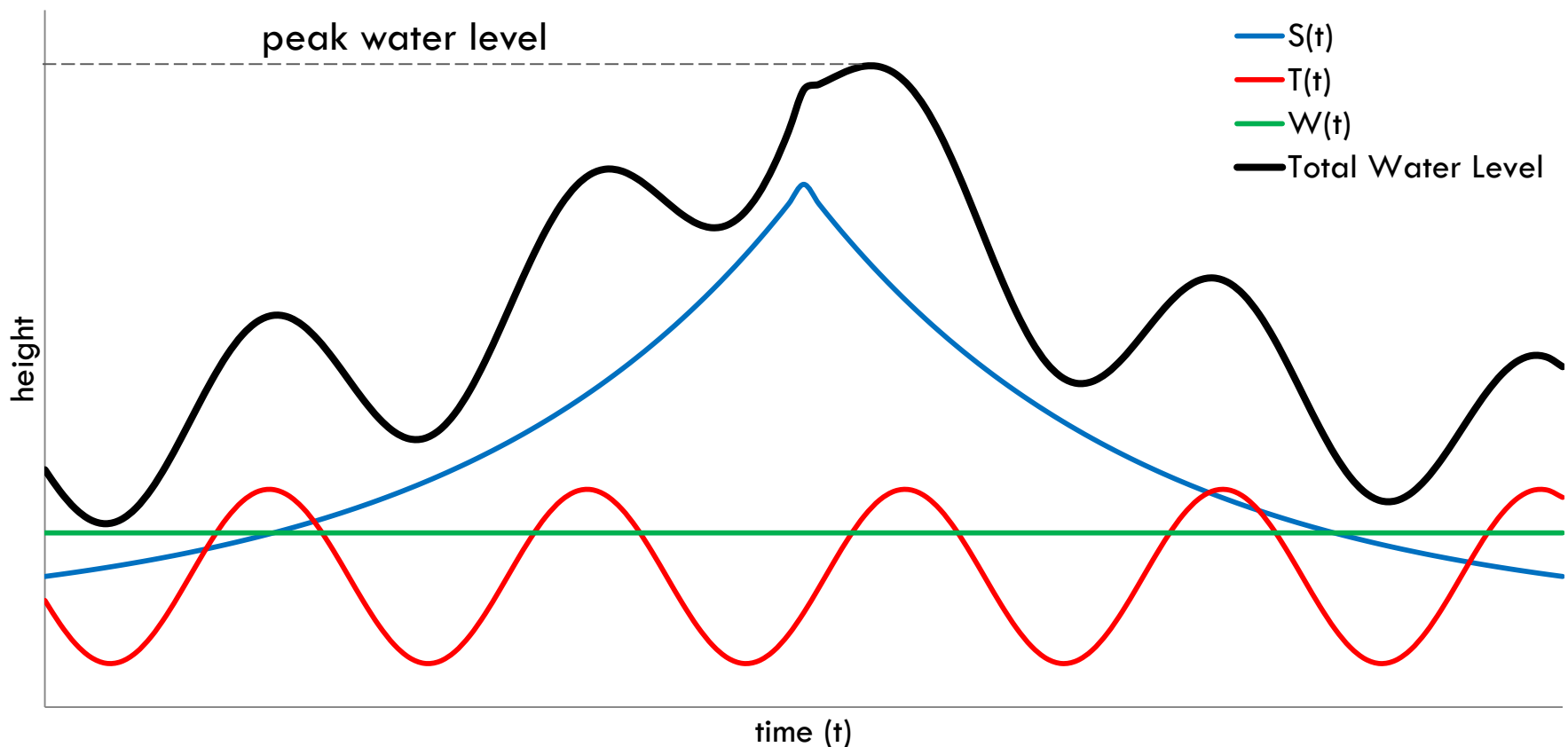
TIME EVOLUTION MODELS (STORM SURGE)



The rise and fall of storm surges are each modeled as a shifted exponential function:

$$s_1(t) = Ae^{\alpha t} \quad \text{and} \quad s_2(t) = Be^{\beta(t-t_p)}$$

TIME EVOLUTION MODELS (TOTAL WATER LEVEL)



Three contributors add together to yield total water level $Y(t)$:

- $S(t)$ Storm surge's exponential rise and fall
- $T(t)$ Tidal height (harmonic analysis)
- $W(t)$ Mean water level (rising due to sea level rise)

$$Y(t) = S(t) + T(t) + W(t)$$

VIABILITY OF MITIGATION MEASURES

Measures Considered:

- Building removal & relocation
- **Individual building retrofit**
- Enhanced flood warning and evacuation plan
- Land use, zoning and flood insurance
- Deployable floodwalls
- **Floodwalls and Levees**
- Shoreline stabilization
- Storm surge barriers
- Barrier island preservation
- **Beach restorations & breakwaters**
- Beach restorations and groins
- Drainage improvements
- Living shorelines



Viable Measures:

- **Individual building retrofit**
- **Floodwalls and levees**
- **Beach restoration & breakwaters**

COST OF MITIGATION MEASURES

| | |
|--|--------------------------------|
| Building Retrofit (Elevation Increase) | \$8,200 total cost annually |
| Building Retrofit (Industrial Ring Wall) | \$206,319 total cost annually |
| Structural Floodwalls | \$237 per linear foot annually |
| Levee Systems | \$77 per linear foot annually |
| Beach Restoration | \$488 per linear foot annually |

PARAMETRIC COSTS OF FLOOD MITIGATION MEASURES

*Figures are obtained from the North Atlantic Coast Comprehensive Study (NACCS) by United States Army Corps of Engineers. Project life is assumed to be 50 years.

ONGOING RESEARCH WORK

- Obtaining exact elevations of critical facilities (through surveys and topographic models of NYC)
- Developing precise Loss of Use estimates by verifying with hospitals and fire departments
- Incorporating models of time evolution of storm surge with Loss of Use estimates
- Finalizing accurate cost estimates for mitigation measures by:
 - Translating NACCS estimates to New York State valuations
 - Analyzing current flood mitigation efforts such as *The Big U* (Rebuild by Design)
 - Coordinating with US Army Corps of Engineers
 - Collaborating with two consulting firms in NYC

ONGOING RESEARCH WORK (CONTINUED)

- Estimating overall cost of various mitigation measures/strategies as a function of time
- Using Monte Carlo Simulation, estimate expected values of overall losses of above mitigation measures/strategies as a function of time by combining:
 - Probabilistic information on storm surge hazard (occurrence frequency, intensity, duration, time evolution, intensification with sea level rise)
 - Structural losses
 - Loss of use
- Comparing cost versus expected losses of various mitigation measures/strategies as a function of time