# THE LEARNING BUILDINGS FRAMEWORK (LBF) FOR QUANTIFYING BUILDING ADAPTABILITY

Architectural Engineering Institute Conference
April 2017
Oklahoma City, OK

Brandon E. Ross, PE, PhD
Assistant Professor
Glenn Department of Civil Engineering
Clemson University

# Acknowledgements

Zoraya Rockow
Anna Kate Black
Diana Chen
Luay Abo Alarab
Riley Marshall

CLEMSON®
GLENN DEPARTMENT OF
CIVIL ENGINEERING

# Outline

- Introduction
  - Definitions
  - Theory
  - Motivation
- Learning Building Framework (LBF)
- Example calculation
- What's next?

$$DBA = \sum_{i,j} DBA_{ij} = \sum_{i,j} \left( E_i S_j D_{ij} \right)$$

# One of the most common but least understood "hazards"

*Obsolescence* is the state of being antiquated, old-fashioned, or out-of-date (Lemer, 1996).
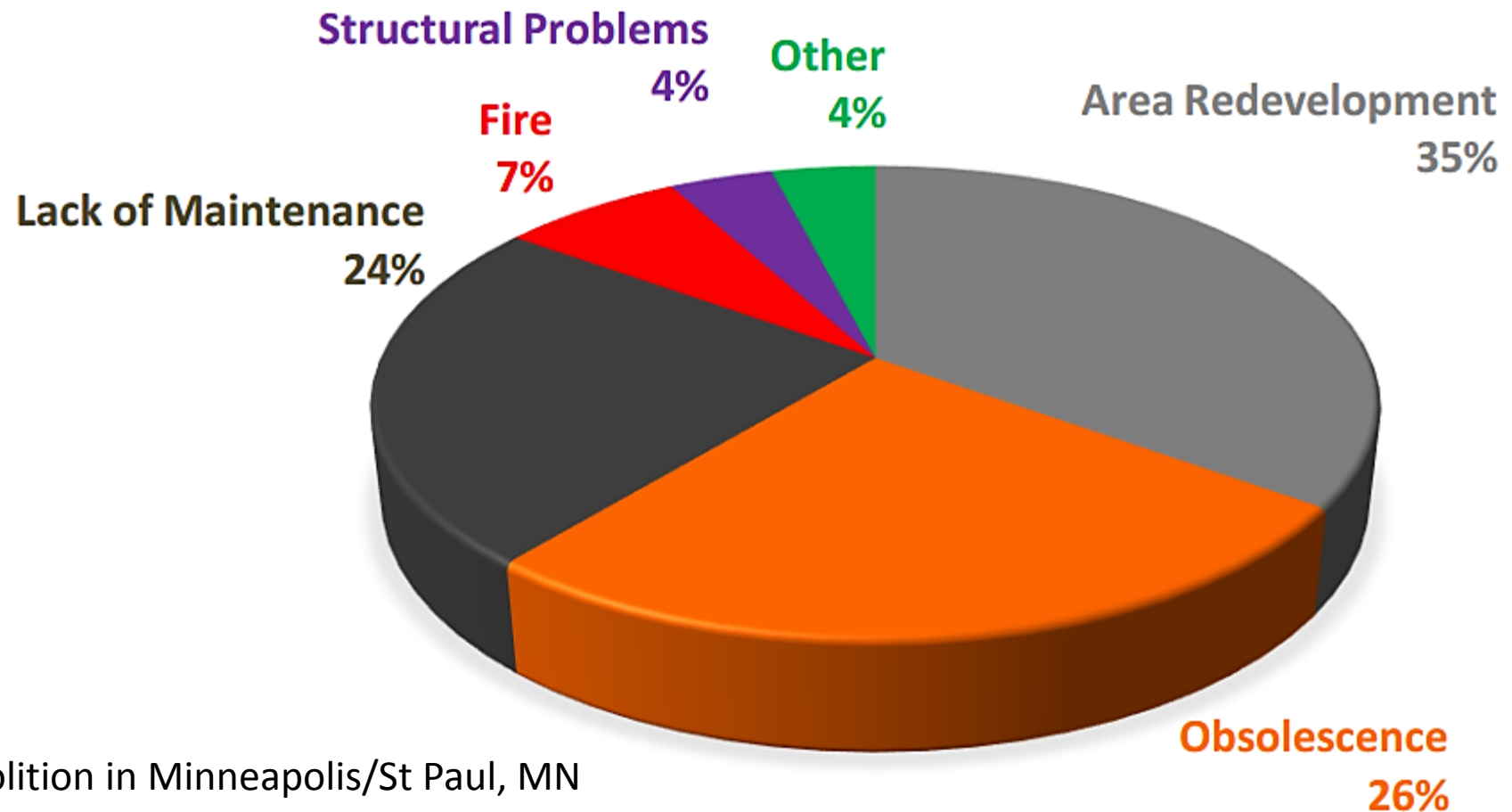
Causes of obsolete buildings (Langston, 2008):
- Physical
- Economic
- Functional
- Technological
- Social
- Legal
- Political

# What happens to obsolete buildings?
*(They get demolished)*



Structural Problems 4%

Other 4%

Fire 7%

Area Redevelopment 35%

Lack of Maintenance 24%

Obsolescence 26%

Demolition in Minneapolis/St Paul, MN
(O'Connor 2004)

# Adaptability can mitigate obsolescence



Wikipedia.org



Wikimedia Commons

# Adaptability can mitigate obsolescence

**Relevant Building**



Time

Changing demands & conditions

**Obsolete Building**



*A building's context and physical features both affect obsolescence and adaptability*



**Yes**



Modify, deconstruct, refurbish, reconfigure, expand and/or repurpose

**Adaptability**

**No**

Demolition and waste
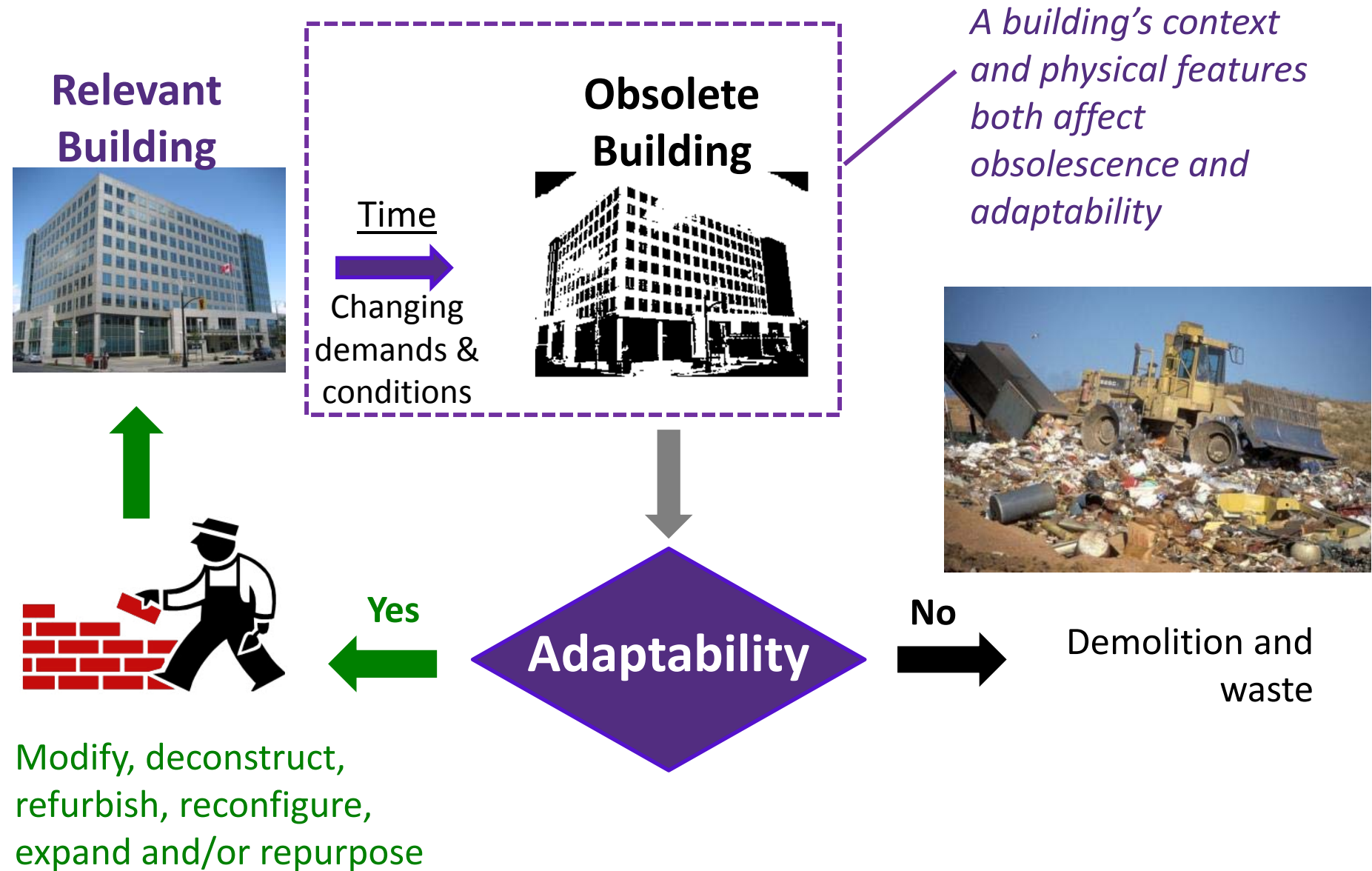
# Why Adaptability?

*Adaptability,* in the context of buildings, is defined as the ease with which buildings can be physically modified, deconstructed, refurbished, reconfigured, and/or repurposed. (Ross et al. 2015)
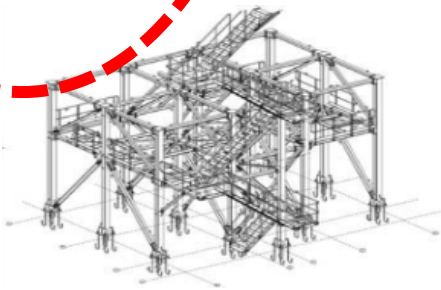
Ease?
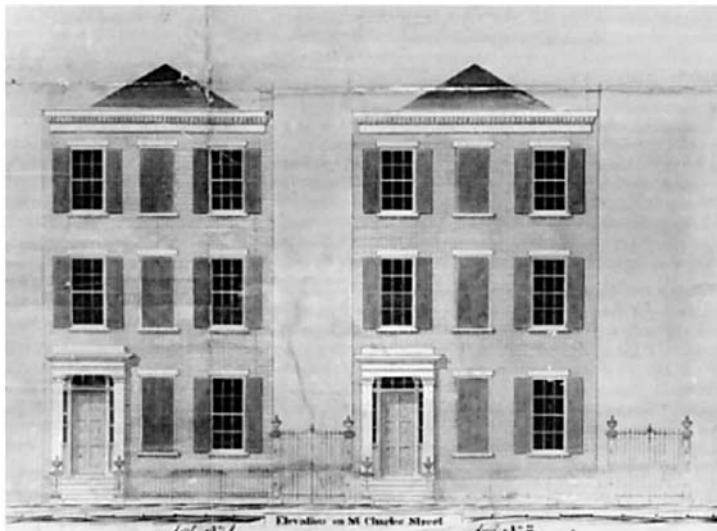


Brand 1993

# What is Adaptability?

**Adaptability**

**Physical**

**Contextual**

**Design Based**

Foundation
Structure
Envelope
Services
Space Plan
..

**Time Based /
Naturally Occurring**

Age
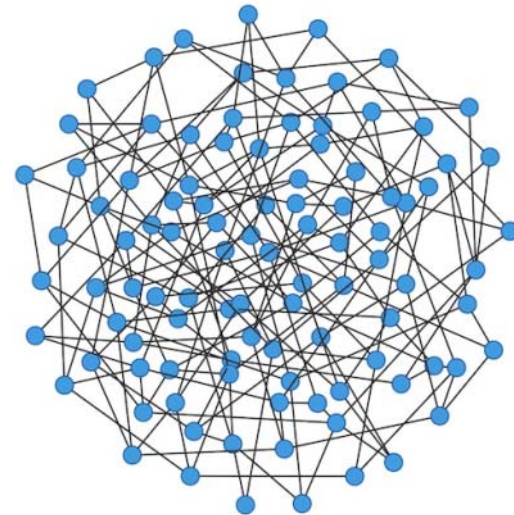Maintenance
Condition
Character
..

Surroundings
Location
Zoning
Economy
Social
Legal
Political
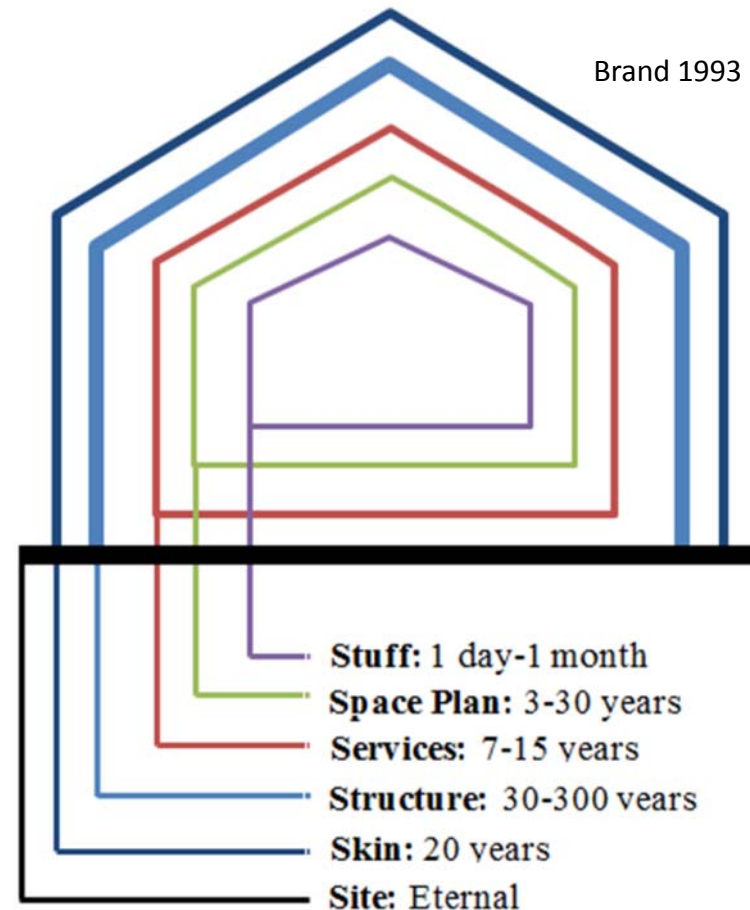...

# Enabling Adaptability

*Design-based enablers* are manipulations to the design that increase the potential for adaptability.

*Process-based enablers* are characteristics of supply, construction, and operational systems that increase the system's ability to adapt and accommodate change.

# Design-based enablers

- **Layering**
- Accurate information
- Reserve capacity
- Open floor plan
- Simple layout
- Modular components
- Connections
- Commonality
- Material
- Access for assessment
- Design for deconstruction

Brand 1993

**Stuff:** 1 day-1 month
**Space Plan:** 3-30 years
**Services:** 7-15 years
**Structure:** 30-300 years
**Skin:** 20 years
**Site:** Eternal

# Design-based enablers

- Layering
- **Accurate information**
- Reserve capacity
- Open floor plan
- Simple layout
- Modular components
- Connections
- Commonality
- Material
- Access for assessment
- Design for deconstruction



http://www.steelconstruction.info

# Design-based enablers

- Layering
- Accurate information
- **Reserve capacity**
- Open floor plan
- Simple layout
- Modular components
- Connections
- Commonality
- Material
- Access for assessment
- Design for deconstruction

ASCE STANDARD [ASCE/SEI 7–10]

| Load combination | Equation | Primary load |
|---|---|---|
| $U = 1.4D$ | (5.3.1a) | $D$ |
| $U = 1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$ | (5.3.1b) | $L$ |
| $U = 1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.5W)$ | (5.3.1c) | $L_r \text{ or } S \text{ or } R$ |
| $U = 1.2D + 1.0W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$ | (5.3.1d) | $W$ |
| $U = 1.2D + 1.0E + 1.0L + 0.2S$ | (5.3.1e) | $E$ |
| $U = 0.9D + 1.0W$ | (5.3.1f) | $W$ |
| $U = 0.9D + 1.0E$ | (5.3.1g) | $E$ |

# Design-based enablers

- Layering
- Accurate information
- Reserve capacity
- **Open floor plan**
- Simple layout
- Modular components
- Connections
- Commonality
- Material
- Access for assessment
- Design for deconstruction



http://www.transsolar.com/projects/lee-hall-complex-expansion

# Design-based enablers and dimensions

| Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
|---|---|---|---|
| • Reserve<br>• Materials | • Open<br>• Simple | • Layer<br>• Access<br>• Modular components<br>• Connections<br>• DfD | • Plans<br>• Common<br>• Simple<br>• Materials<br>• Access |

# As others have quantified sustainability...



...our objective is to quantitatively measure adaptability.

# The Learning Buildings Framework (LBF)

How "friendly" is a design to future adaptation?

Sum DBA across building systems and enabler dimensions

$$DBA = \sum_{i,j} DBA_{ij} = \sum_{i,j} \left( E_i S_j D_{ij} \right)$$

Where: $DBA$ = Design-based adaptability

$i$ = Index for enabler dimensions

$j$ = Index for building systems

$E$ = Enabler weighting factor; values sum to 10

$S$ = System weighting factor; values sum to 10

$D$ = Degree of presence factor for each enabler/system

# The Learning Buildings Framework (LBF)

What is the relative effect of each enabler dimension?

What is the relative criticality of each system?

$$DBA = \sum_{i,j} DBA_{ij} = \sum_{i,j} \left( E_i S_j D_{ij} \right)$$

Where: $DBA$ = Design-based adaptability

$i$ = Index for enabler dimensions

$j$ = Index for building systems

What is the "risk" that an enabler will become effective?

$E$ = Enabler weighting factor; values sum to 10

$S$ = System weighting factor; values sum to 10

$D$ = Degree of presence factor for each enabler/system

# The Learning Buildings Framework (LBF)

| | Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
|---|---|---|---|---|
| Space plan | 1.86 | 1.86 | 3.10 | 3.10 |
| Envelope | 2.29 | 2.29 | 1.38 | 2.29 |
| Services | 1.72 | 1.72 | 2.87 | 2.87 |
| Structure | 1.22 | 0.87 | 0.52 | 0.87 |
| Foundation | 0.87 | 0.87 | 1.74 | 0.52 |
| $DBA = \Sigma\Sigma\ DBA_{ij} = \mathbf{35}$ | | | | |

$i$

$j$

$E_2 S_3 D_{2,3}$

# The Learning Buildings Framework (LBF)
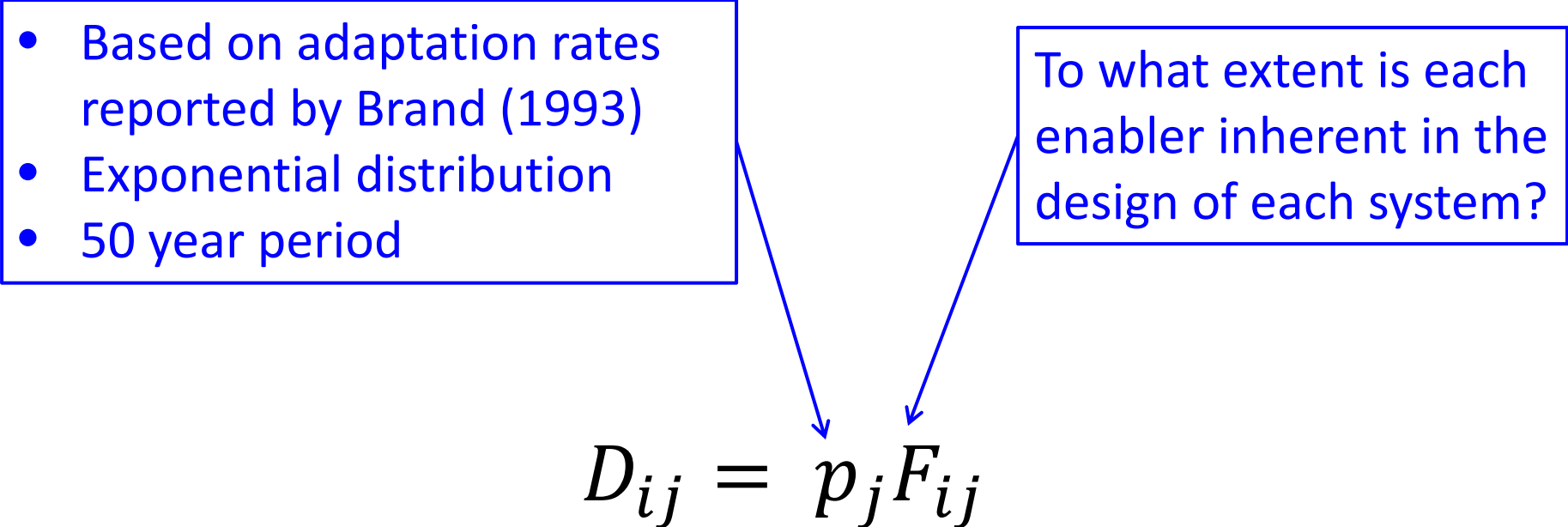
| | Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
|---|---|---|---|---|
| Enabler weighting factors ($E_i$) | 2.5 | 2.5 | 2.5 | 2.5 |

| | System weighting factors ($S_i$) |
|---|---|
| Space plan | 2.5 |
| Envelope | 2.0 |
| Services | 2.5 |
| Structure | 1.5 |
| Foundation | 1.5 |

# The Learning Buildings Framework (LBF)

- Based on adaptation rates reported by Brand (1993)
- Exponential distribution
- 50 year period

To what extent is each enabler inherent in the design of each system?

$$D_{ij} = p_j F_{ij}$$

Where:
$p$ = Probability that a system will require adaptation

$F$ = Facilitation factor; value between 0 and 1

# The Learning Buildings Framework (LBF)



|  | Adaptation recurrence interval | Probability of adaptation in 50 years ($p_j$) |
|---|---|---|
| **Space plan** | 10 | 0.99 |
| **Envelope** | 20 | 0.92 |
| **Services** | 20 | 0.92 |
| **Structure** | 80 | 0.46 |
| **Foundation** | 80 | 0.46 |

# The Learning Buildings Framework (LBF)

| | Facilitation factors ($F_{ij}$) | | | |
|---|---|---|---|---|
| | Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
| **Space plan** | 0.3 | 0.3 | 0.5 | 0.5 |
| **Envelope** | 0.5 | 0.5 | 0.3 | 0.5 |
| **Services** | 0.3 | 0.3 | 0.5 | 0.5 |
| **Structure** | 0.7 | 0.5 | 0.3 | 0.5 |
| **Foundation** | 0.5 | 0.5 | 1.0 | 0.3 |

Is the services layer designed with loose fit? (value between 0 and 1)

# LBF example calculation

## Clemson House

Clemson, SC
Opened 1950
Demolition ~2018

# LBF example calculation



*Is the enable present in the system's design?*

| | Facilitation factors ($F_{ij}$) | | | |
|---|---|---|---|---|
| | Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
| **Space plan** | 0.3 | 0.3 | 0.5 | 0.5 |
| **Envelope** | 0.5 | 0.5 | 0.3 | 0.5 |
| **Services** | 0.3 | 0.3 | 0.5 | 0.5 |
| **Structure** | 0.7 | 0.5 | 0.3 | 0.5 |
| **Foundation** | 0.5 | 0.5 | 1.0 | 0.3 |

# LBF example calculation

$$D_{ij} = p_j F_{ij}$$

*"Risk" that an enabler will be effective in a given system*

| | Degree of presence factors ($D_{ij}$) | | | |
|---|---|---|---|---|
| | Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
| **Space plan** | 0.30 | 0.30 | 0.50 | 0.50 |
| **Envelope** | 0.46 | 0.46 | 0.28 | 0.46 |
| **Services** | 0.28 | 0.28 | 0.46 | 0.46 |
| **Structure** | 0.33 | 0.23 | 0.14 | 0.23 |
| **Foundation** | 0.23 | 0.23 | 0.46 | 0.14 |

# LBF example calculation

$$DBA = \sum_{i,j} \left( E_i S_j D_{ij} \right)$$

*Weight the degree of presence factors by enabler and system factors*



| | Design Based Adaptability | | | |
|---|---|---|---|---|
| | Long Life | Loose Fit | Layer Separation | Reduce Uncertainty |
| **Space plan** | 1.86 | 1.86 | 3.10 | 3.10 |
| **Envelope** | 2.29 | 2.29 | 1.38 | 2.29 |
| **Services** | 1.72 | 1.72 | 2.87 | 2.87 |
| **Structure** | 1.22 | 0.87 | 0.52 | 0.87 |
| **Foundation** | 0.87 | 0.87 | 1.74 | 0.52 |

$DBA = \Sigma \Sigma \, DBA_{ij} = \mathbf{35}$

# LBF example calculation

$$DBA = \sum_{i,j} \left( E_i S_j D_{ij} \right) = 35$$

*Is DBA = 35 good?*
*What does it mean?*

# What's next?

- **LBF validation**
  - Field data
  - Expert elicitation
- **LBF calibration**
  - System factors
  - Enabler factors
- **Rules for facilitation factors**
  - How open is open?
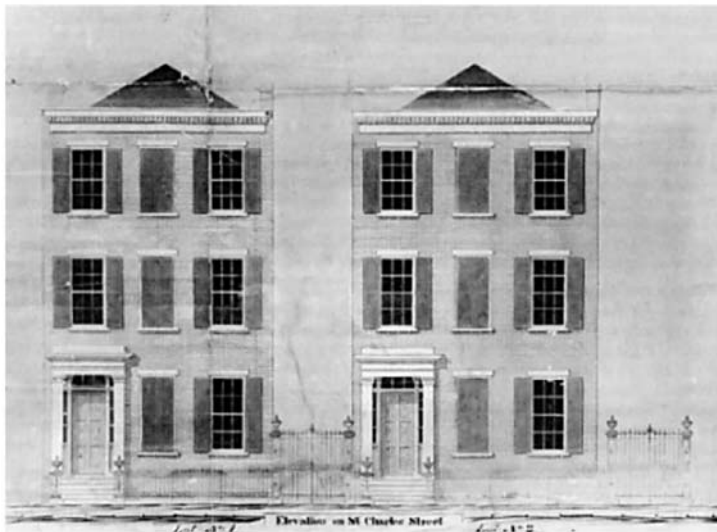  - Do all enablers apply to all systems?



http://www.transsolar.com/projects/lee-hall-complex-expansion

# Parting thoughts…

"All buildings are predictions. All predictions are wrong."

"A building is not something you finish. A building is something you start."

-Steward Brand
How Buildings Learn, 1993

# THE INTERNATIONAL DEMOLITION AND ADAPTATION DATABASE (DaAD)

Architectural Engineering Institute Conference
April 2017
Oklahoma City, OK

Zoraya Rockow, PMP
Anna Kate Black
Brandon E. Ross, PE, PhD

Glenn Department of Civil Engineering

# Acknowledgement

# DaAD

## Demolition and Adaptation Database
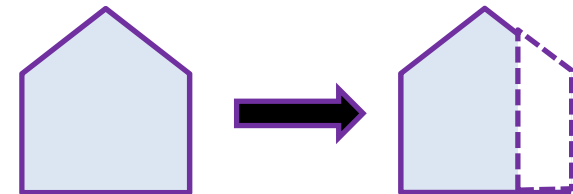
# Types of Projects

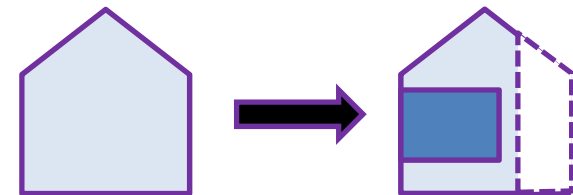**Demolition Project**
*complete* demolition
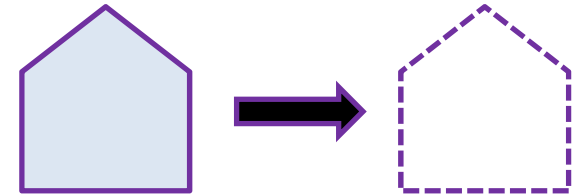
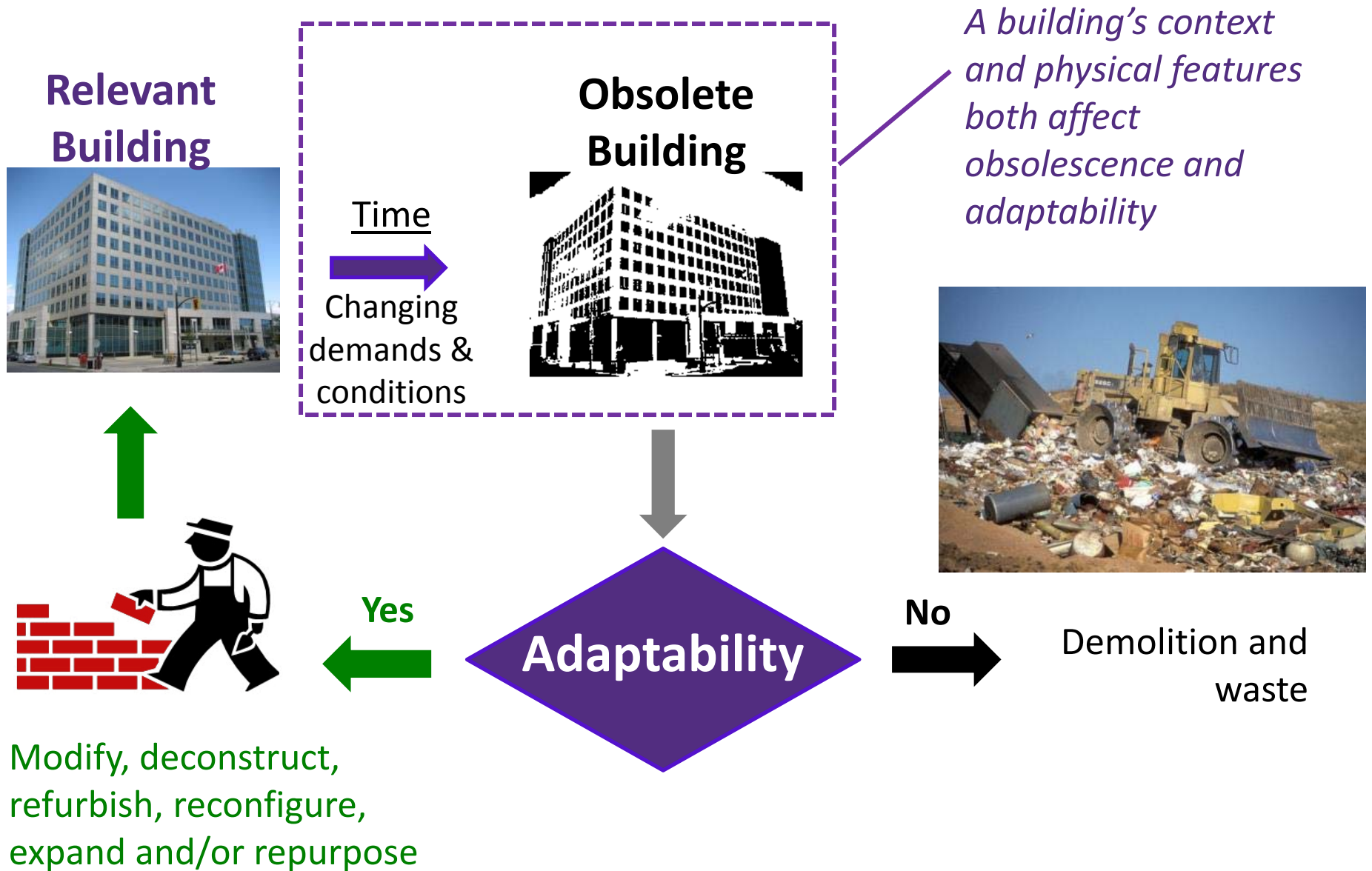**Adaptation Project**
adaptation and/or expansion
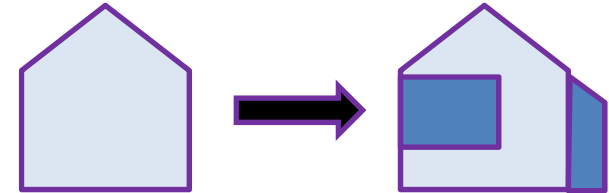
**Partial Demolition Project**
complete demolition of a building wing, section and/or portion

**Mixed Adaptation/Demolition Project**
complete demolition of a building portion and adaption/expansion of the remaining portion(s)

# Why demolish or adapt?

**Relevant Building**

Time → Changing demands & conditions

**Obsolete Building**

*A building's context and physical features both affect obsolescence and adaptability*

**Adaptability**

**Yes** →

Modify, deconstruct, refurbish, reconfigure, expand and/or repurpose

**No** → Demolition and waste

# Types of data

- Context
  - Urban, suburban, rural?
  - Building codes
  - Neighborhood trends
  - …
- Physical
  - Size
  - Occupancy
  - …
- Why demolish or adapt?

# Data framework design

- **Adaptive Reuse Potential**

    *(Langston 2008)*

- **AdaptSTAR**

    *(Conejos 2011)*

- **Melbourne Survey**

    *(Wilkinson 2014)*

- **Minnesota Survey**

    *(O'Conner 2004)*

- **Learning Buildings Framework**

    *(Ross 2017)*

# Data Collection



Project data,
feedback on implementation

Web tool

DaAD

CLEMSON
GLENN DEPARTMENT OF
CIVIL ENGINEERING

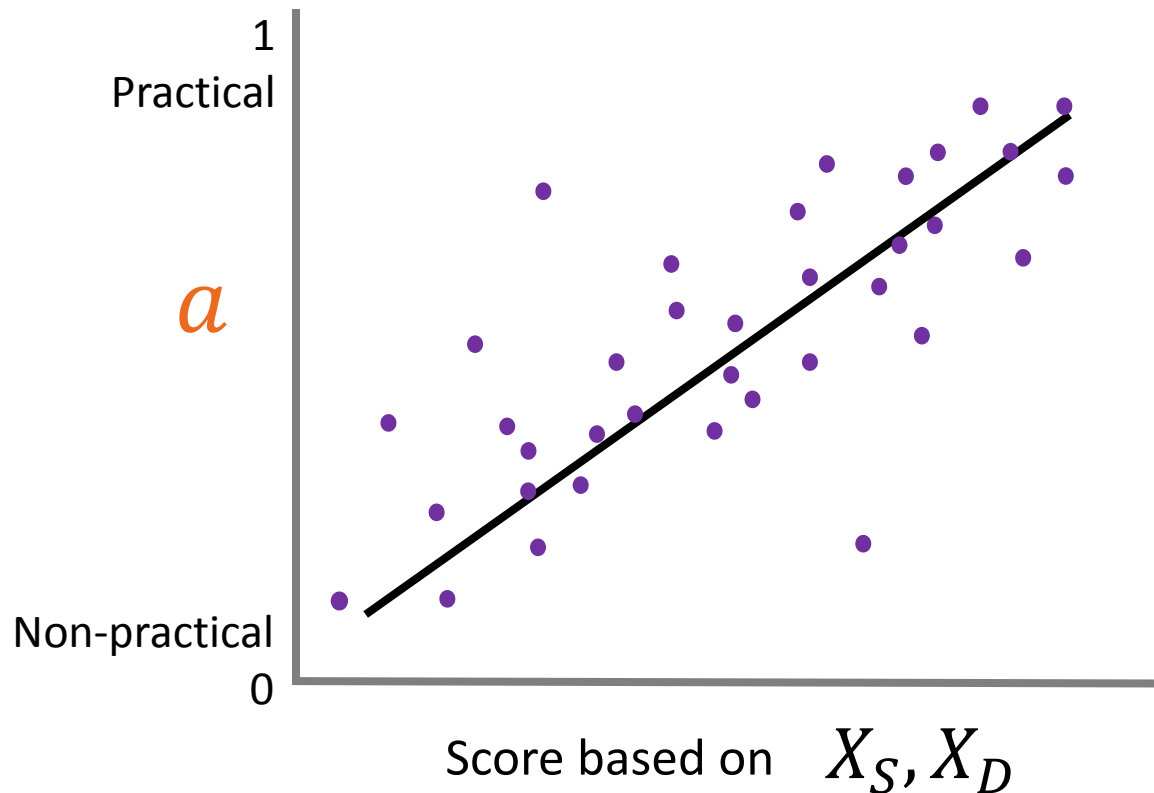Training, PDHs, employees

# Quantifying Practicality of Adaptability

$$a = \underbrace{S_1 X_{S1} + S_2 X_{S2} \ldots}_{\text{Context}} + \underbrace{D_1 X_{D1} + D_2 X_{D2}}_{\text{Design}} + \ldots$$

$S_1, D_1$ : Weight of variables

$X_S, X_D$ : Variables



$a$

1 — Practical

0 — Non-practical

Score based on $X_S, X_D$

# How to get involved?

- Summer 2017
  - Beta test the web tool
  - Peer review data entry questions
- Starting Fall 2017
  - Enter project data
  - Host a workshop