Evaluating Resilient and Sustainable Buildings

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BUILDING INNOVATION 2018
National Institute of BUILDING SCIENCES
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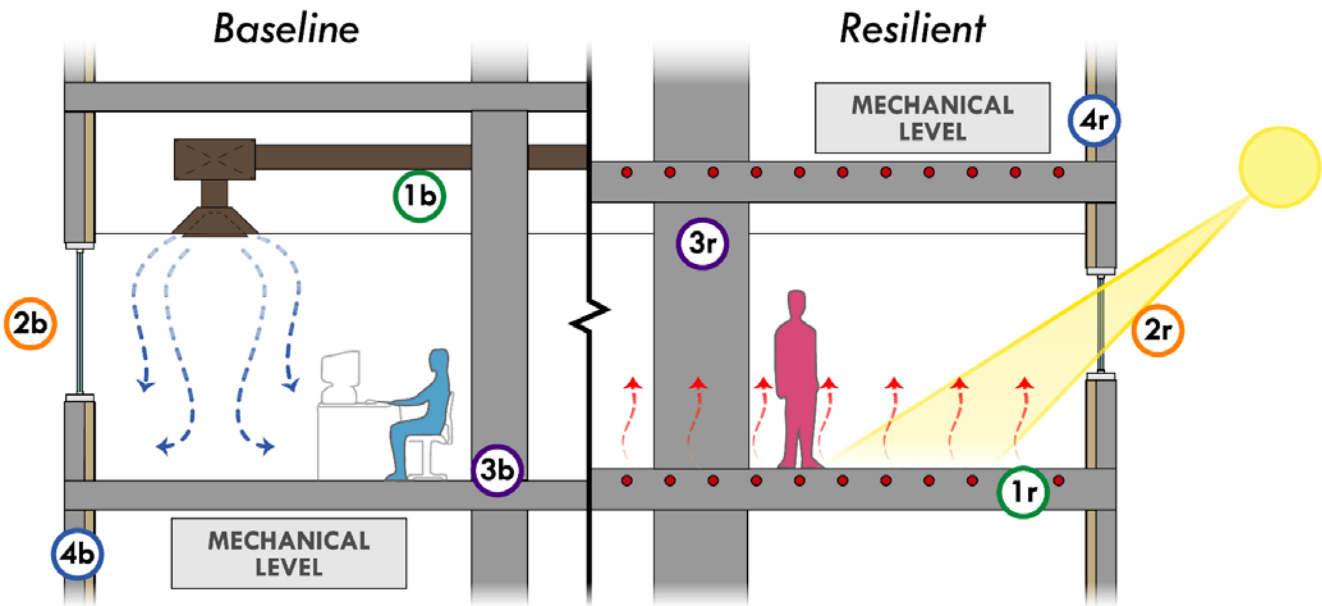


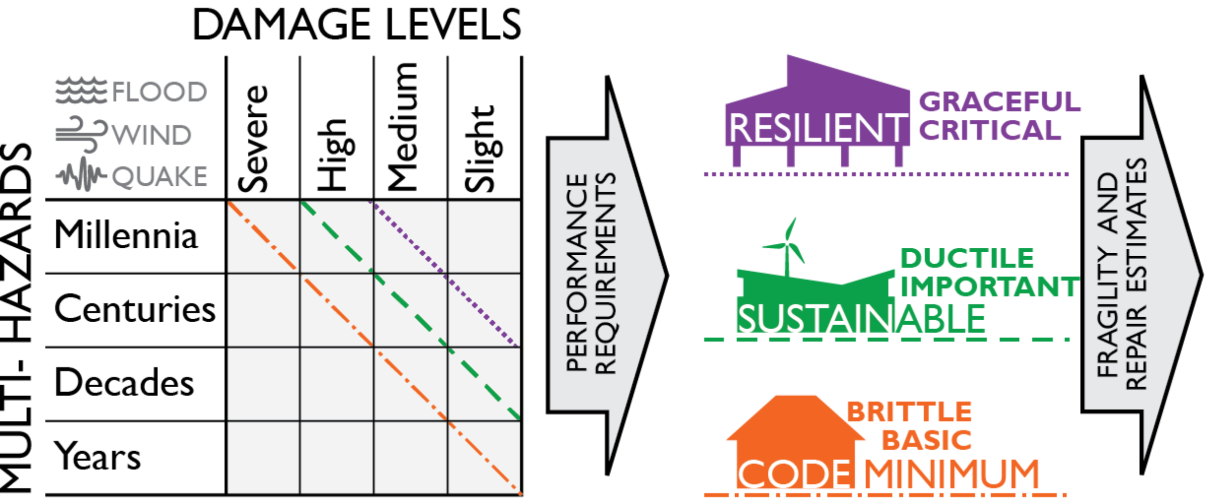
Resilience vs Sustainability?

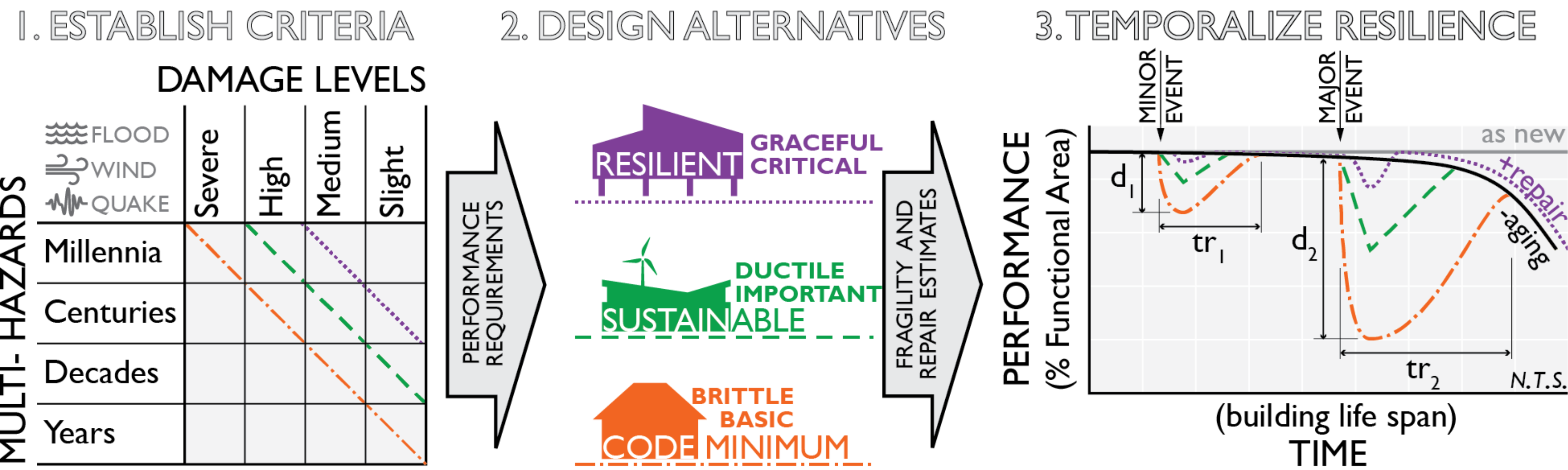
Phillips, R., Troup, L., Fannon, D., Eckelman, M.J. (2017). Do Resilient and Sustainable Design Strategies Conflict in Commercial Buildings? A Critical Analysis of Existing Resilient Building Frameworks and Their Sustainability Implications. *Energy and Buildings*.

A Decision and Design Framework for
Multi-Hazard Resilient and Sustainable Buildings

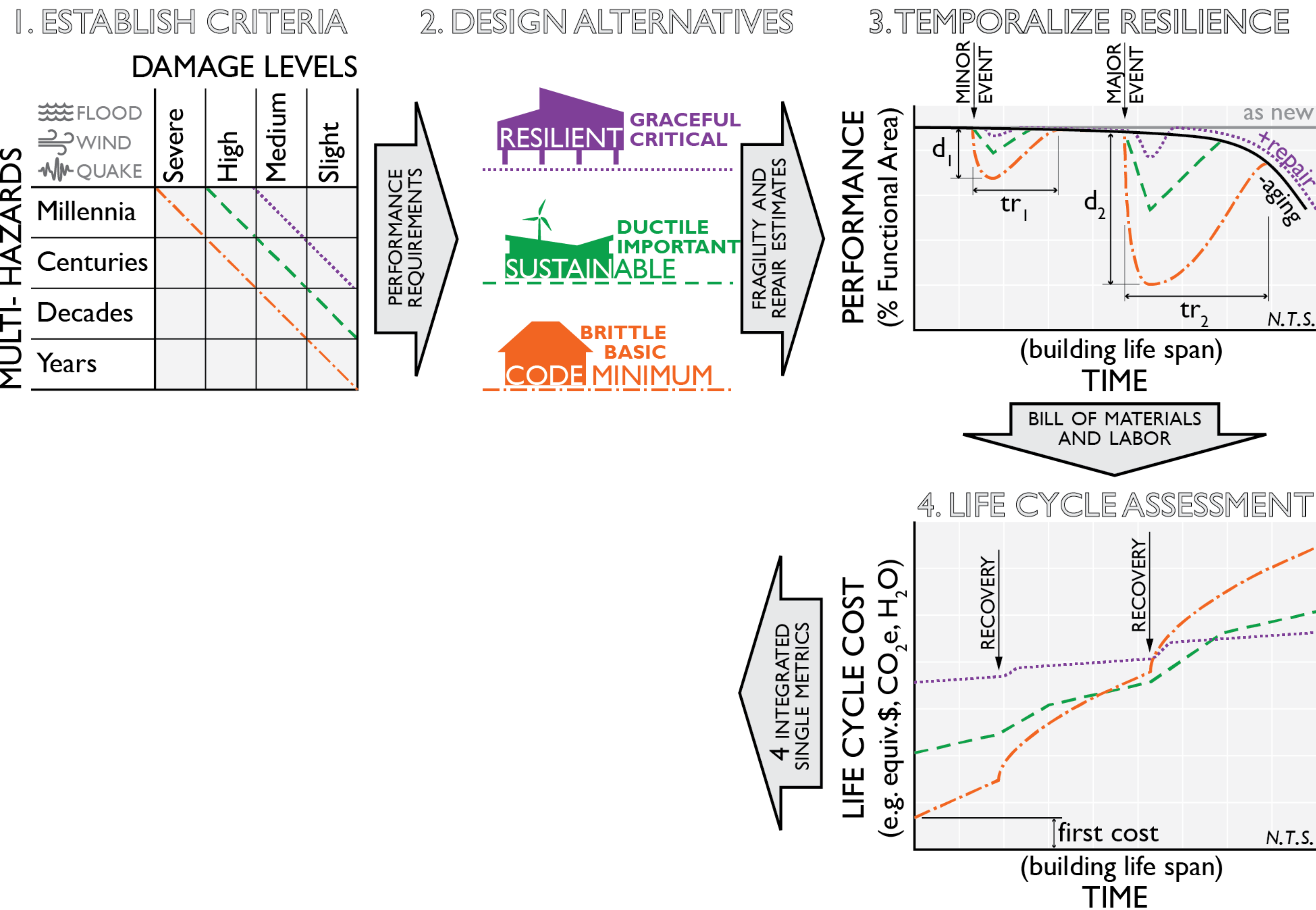
PROJECT OVERVIEW

1. ESTABLISH CRITERIA 2. DESIGN ALTERNATIVES





1. ESTABLISH CRITERIA
2. DESIGN ALTERNATIVES
3. TEMPORALIZE RESILIENCE
DAMAGE LEVELS
FLOOD
WIND
QUAKE
Severe
High
Medium
Slight
MULTI- HAZARDS
Millennia
Centuries
Decades
Years
PERFORMANCE REQUIREMENTS
RESILIENT
GRACEFUL
CRITICAL
SUSTAINABLE
DUCTILE
IMPORTANT
CODE MINIMUM
BRITTLE
BASIC
FRAGILITY AND REPAIR ESTIMATES
MINOR EVENT
MAJOR EVENT
as new
+repair
-aging
PERFORMANCE
(% Functional Area)
d1
tr1
d2
tr2
N.T.S.
(building life span)
TIME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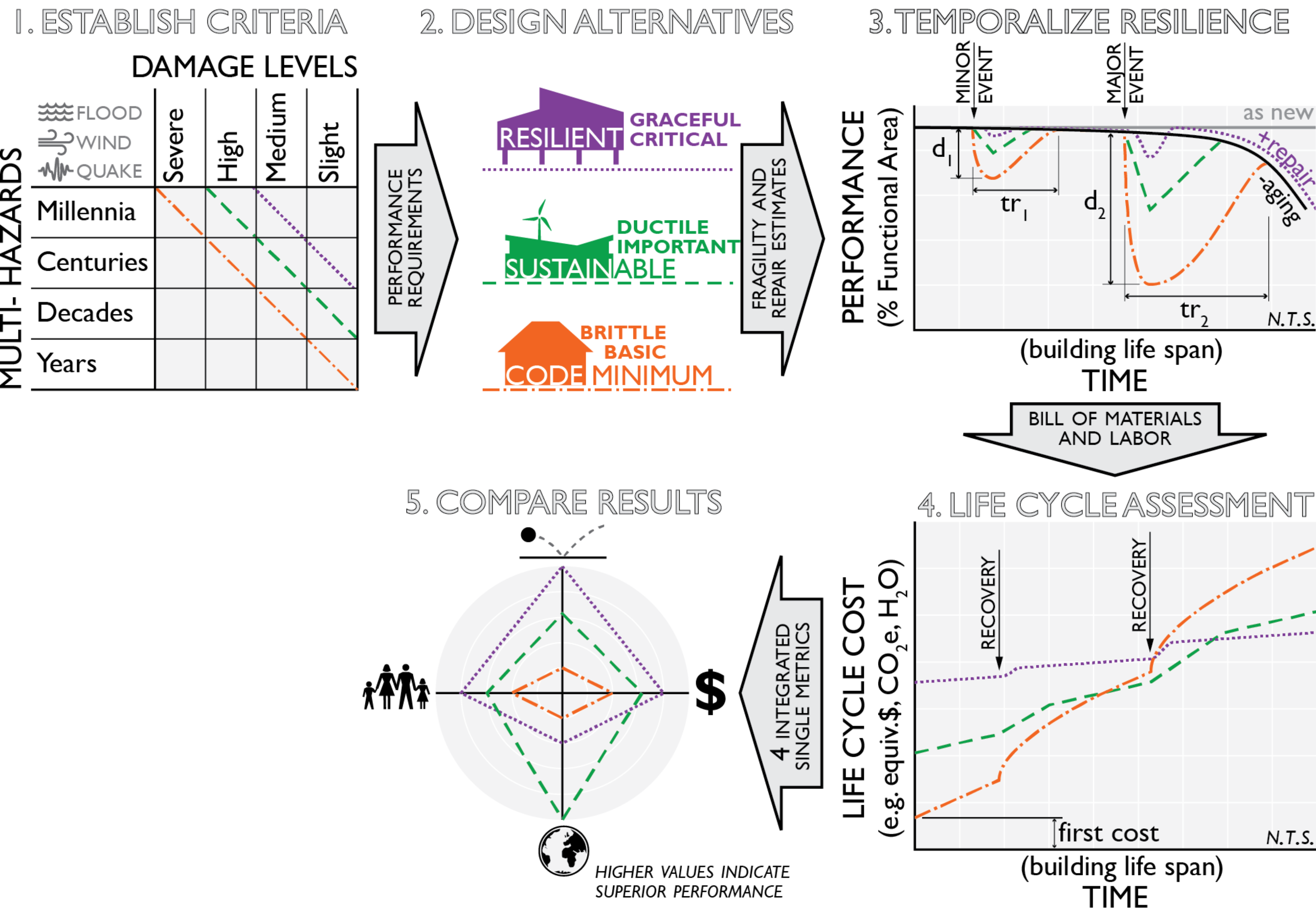
tr_2
N.T.S.
PERFORMANCE
(% Functional Area)
(building life span)
TIME
BILL OF MATERIALS AND LABOR
4. LIFE CYCLE ASSESSMENT
RECOVERY
RECOVERY
LIFE CYCLE COST
(e.g. equiv.$, CO_2e, H_2O)
first cost
N.T.S.
(building life span)
TIME
4 INTEGRATED SINGLE METRICS



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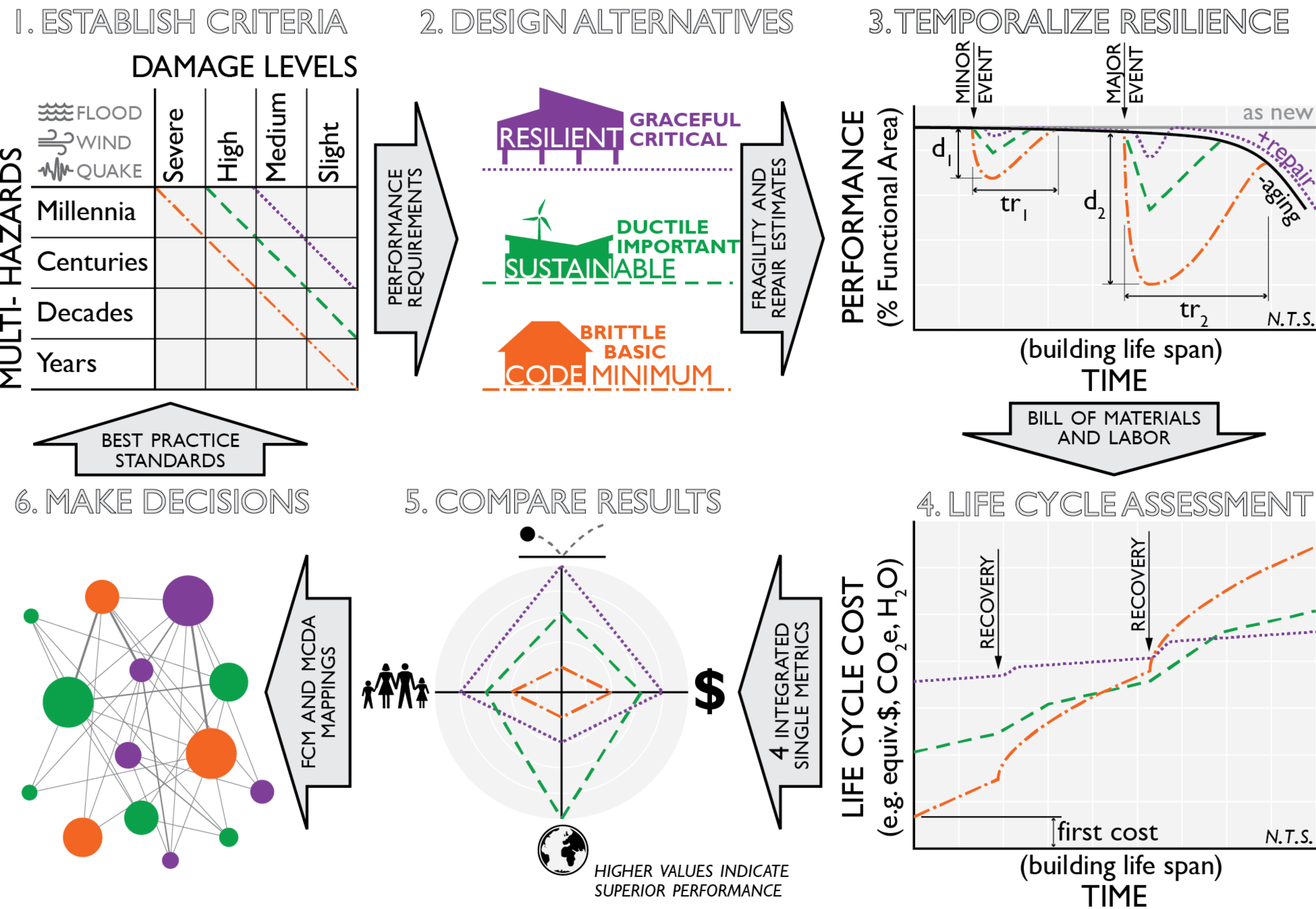
4 INTEGRATED SINGLE METRICS
5. COMPARE RESULTS
$
HIGHER VALUES INDICATE SUPERIOR PERFORMANCE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BEST PRACTICE STANDARDS
2. DESIGN ALTERNATIVES
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4 INTEGRATED SINGLE METRICS
5. COMPARE RESULTS
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HIGHER VALUES INDICATE SUPERIOR PERFORMANCE
FCM AND MCDA MAPPINGS
6. MAKE DECISIONS

A Decision and Design Framework for
Multi-Hazard Resilient and Sustainable Buildings

PROJECT TEAM

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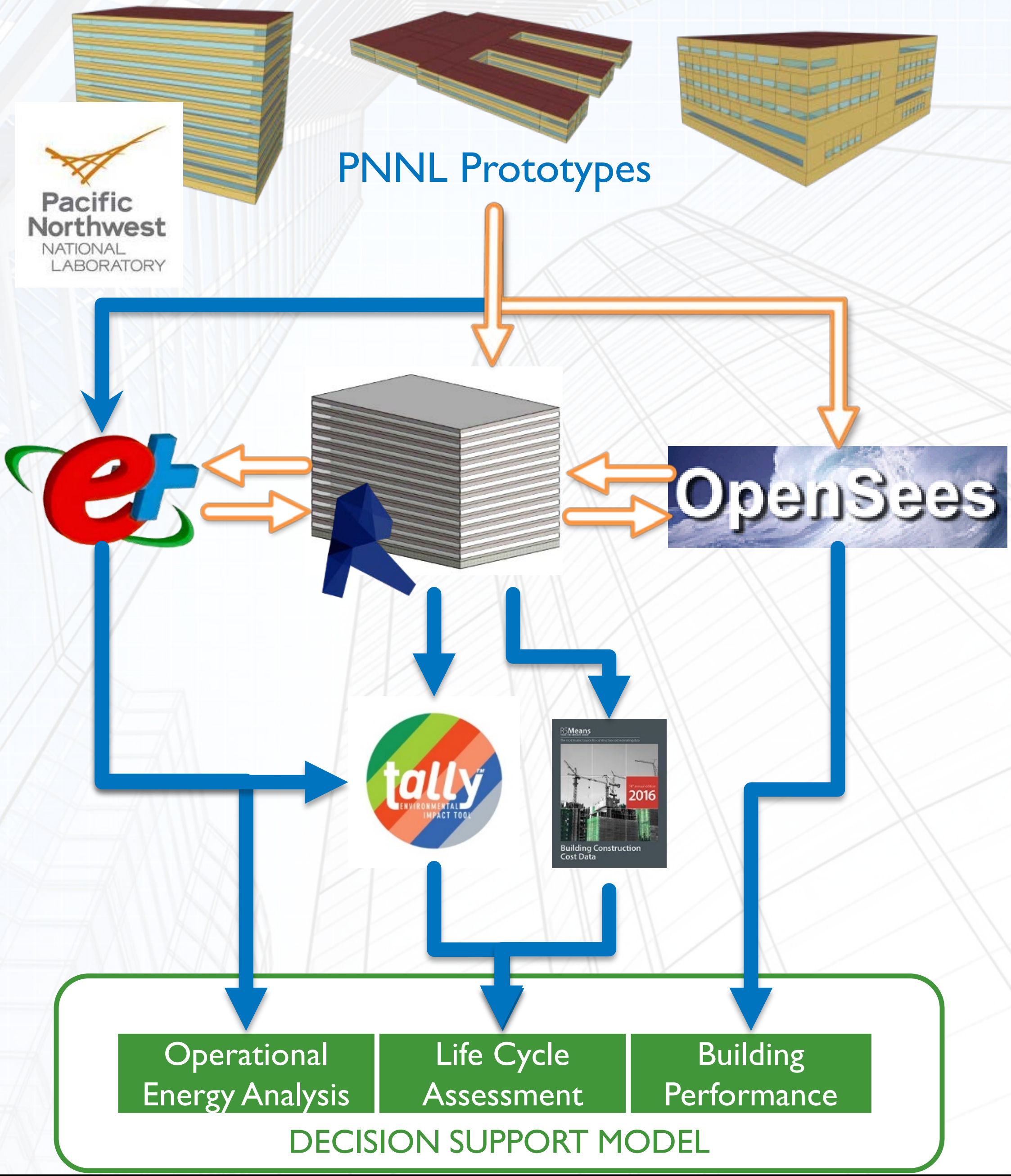
Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

A Decision and Design Framework for
Multi-Hazard Resilient and Sustainable Buildings

PROJECT METHODOLOGY


Pacific Northwest NATIONAL LABORATORY
PNNL Prototypes
OpenSees
tally ENVIRONMENTAL IMPACT TOOL
RSMeans
2016
Building Construction Cost Data
Operational Energy Analysis
Life Cycle Assessment
Building Performance
DECISION SUPPORT MODEL

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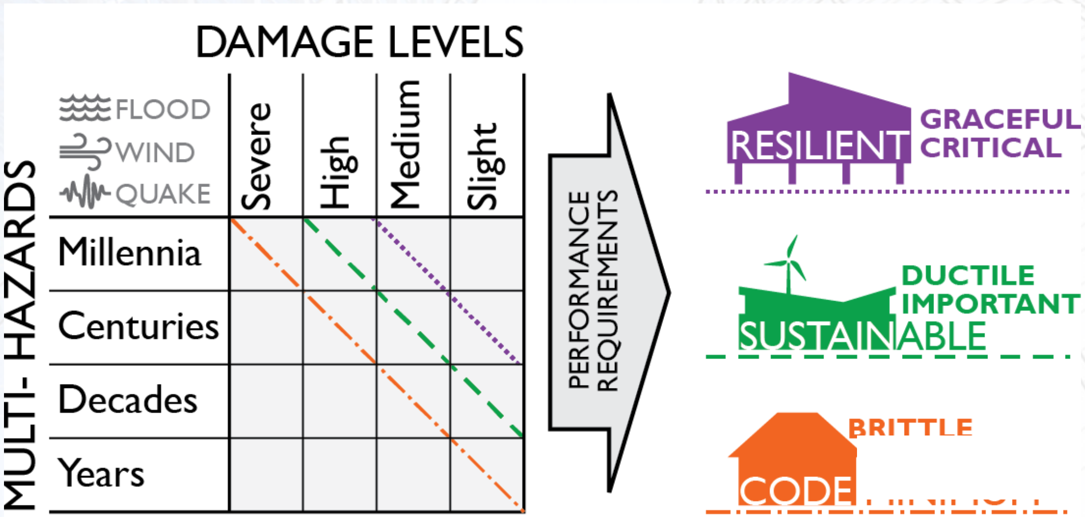

Establish Criteria and Alternatives

Performance-Based Design

Multiple attributes of performance

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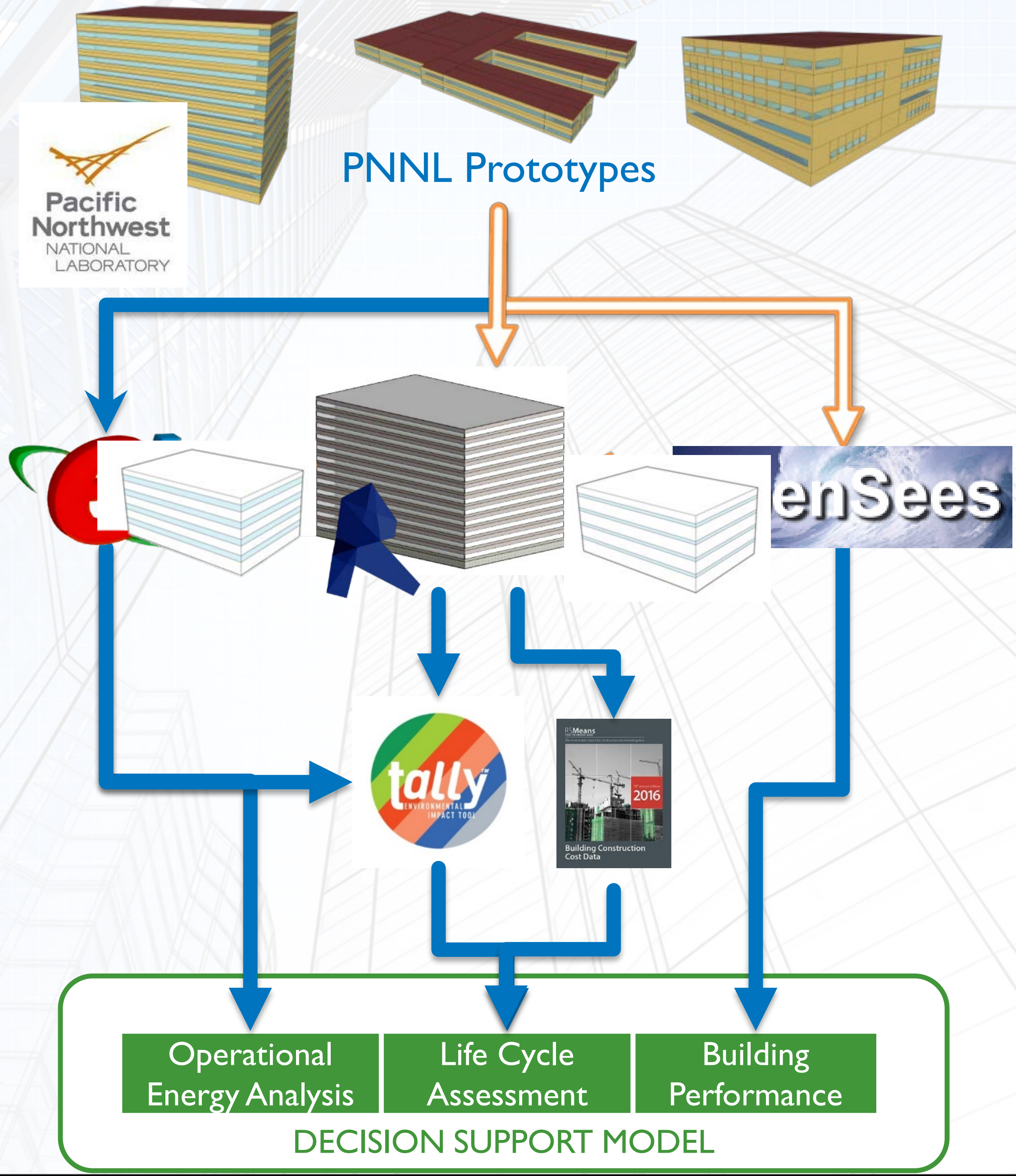
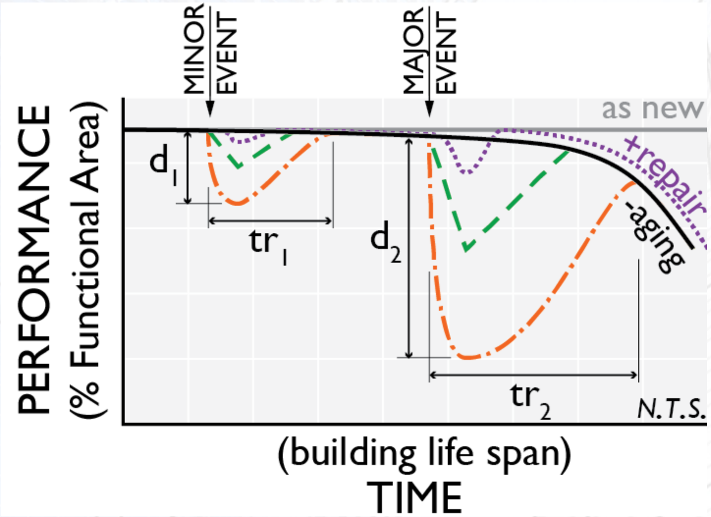


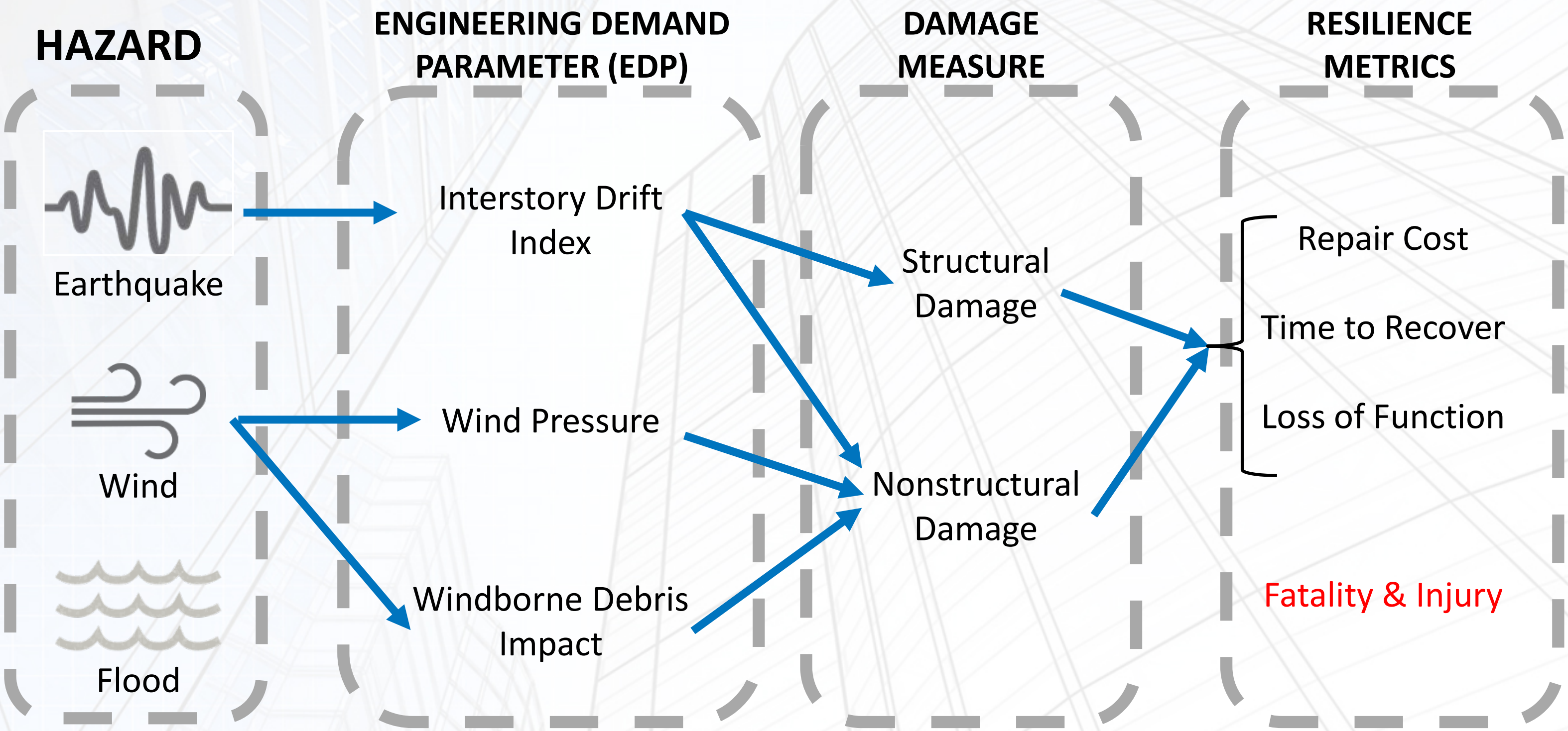


Response to Non-stationary Hazards

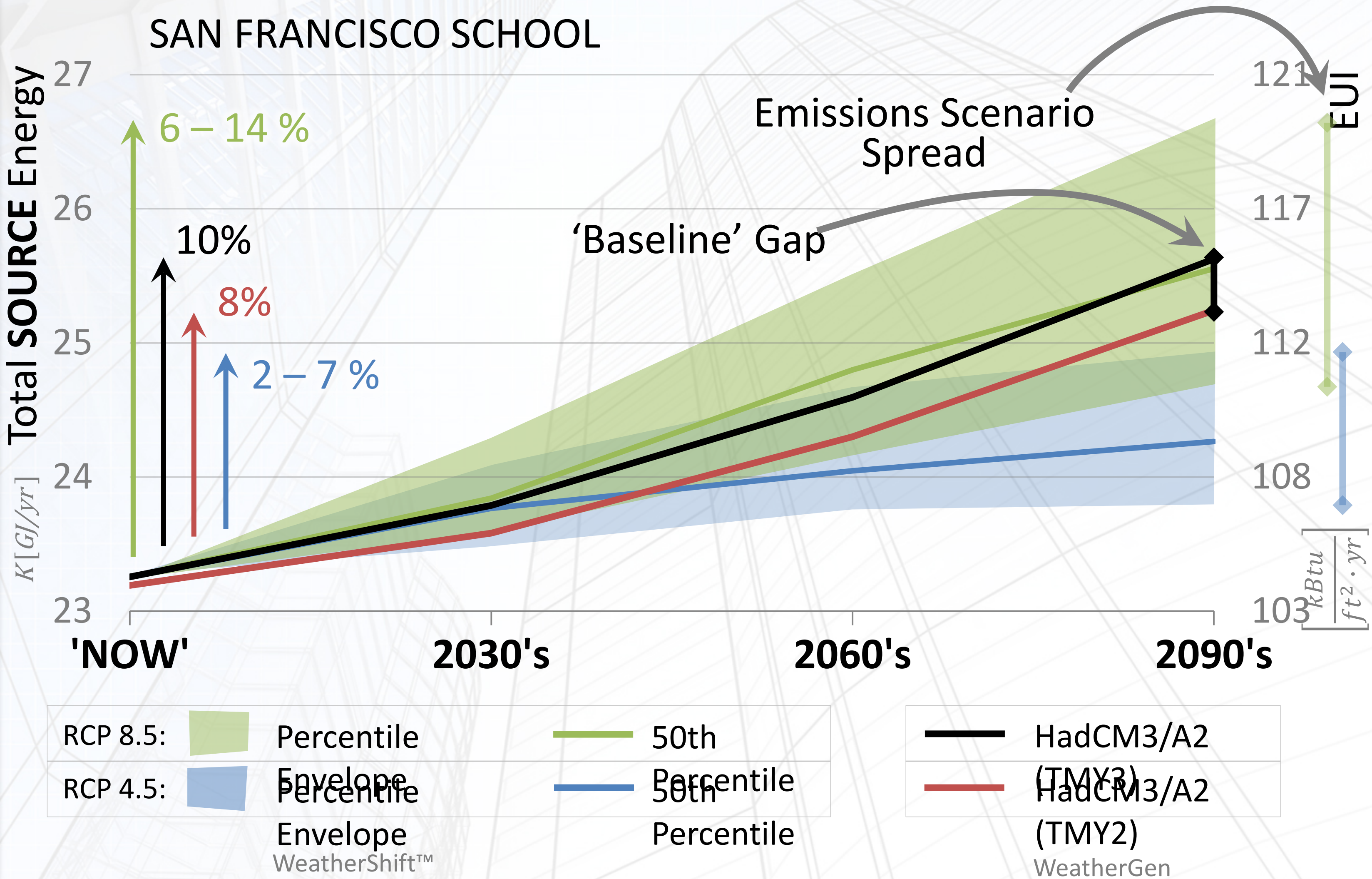
Likelihood of occurrence

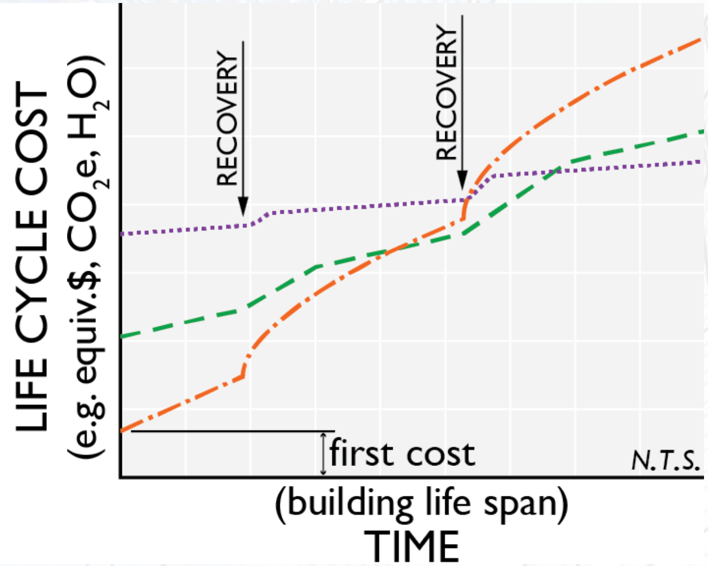
Damage Measure and subsequent resilience

Resilience to multiple hazards



‘Morphing’ Weather Files



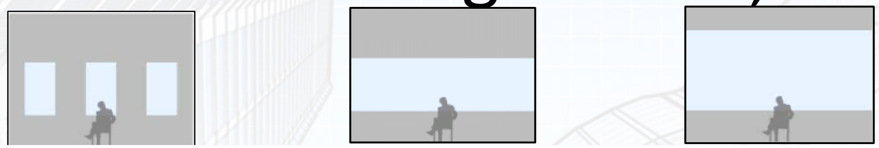


Assessing Life Cycle Impacts of Resilience

Life-cycle approach to resilience

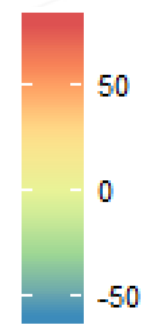
Risk-weighted considerations of sustainability

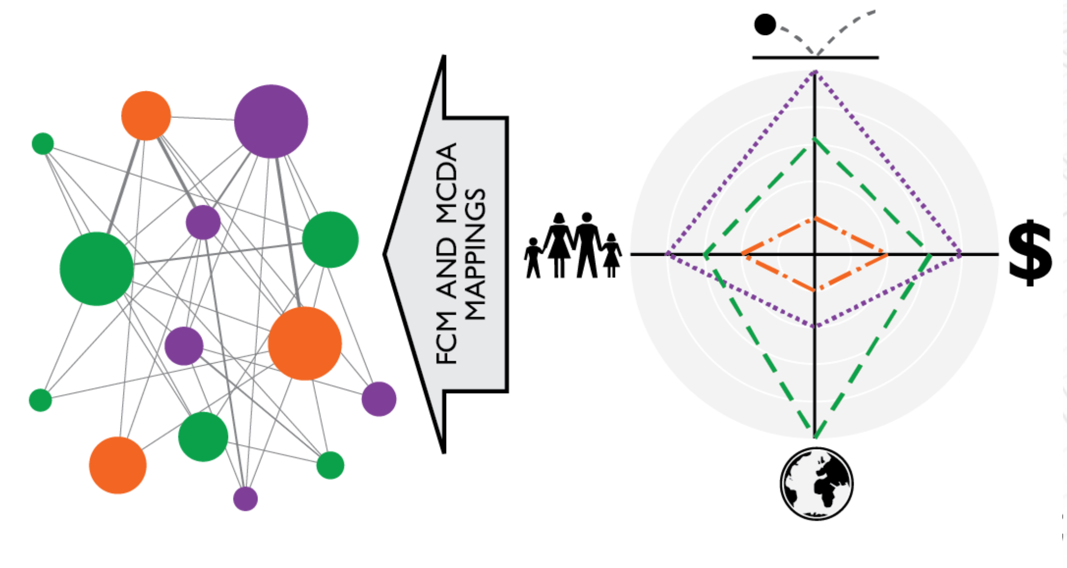
WWR TBL Large Office, Boston



ACP (E+5 kgSO2eq)	13.5	13.6	13.7
EUP (E+3 kgNeq)	65.7	66.2	66.8
GWP (E+7 kgCO2eq)	39	39.3	39.6
ODP (E-2 CFC-11eq)	39.2	39.2	39.3
SFP (E+6 kgO3eq)	10.6	10.7	10.8
PED (E+8 MJ)	60.8	61.2	61.8
NPV.0 (M USD)	83	87.6	92.3
NPV.2 (M USD)	58	67.7	74.1
NPV.5 (M USD)	42.4	49.6	54.4
NPV.10 (M USD)	33.6	39.7	43.6
DD (E+3 SF PPD)	11.7	14.9	18.9
NF.DI (E+1 FC)	1.1	2.4	3.8
NF.GI	5.5	6.9	6.8
NF.TC (PPD)	16.2	18	19.5
SF.DI (E+1 FC)	4.2	9.5	17.7
SF.GI	6.7	8.2	8.2
SF.TC (PPD)	12.7	12	12.6
EF.DI (E+1 FC)	3.6	6.9	11.6
EF.GI	6.8	8.4	8.4
EF.TC (PPD)	14.4	15	15.7
WF.DI (E+1 FC)	2.6	6.7	11.2
WF.GI	5.8	7.3	7.2
WF.TC (PPD)	14.2	14.7	15.4

Δ% from WWR 40





Design & Decision Framework

Decision Making in multi-criteria multi-actor environments.

Seeking Pareto-Optimal solutions

AHP Outranking Survey

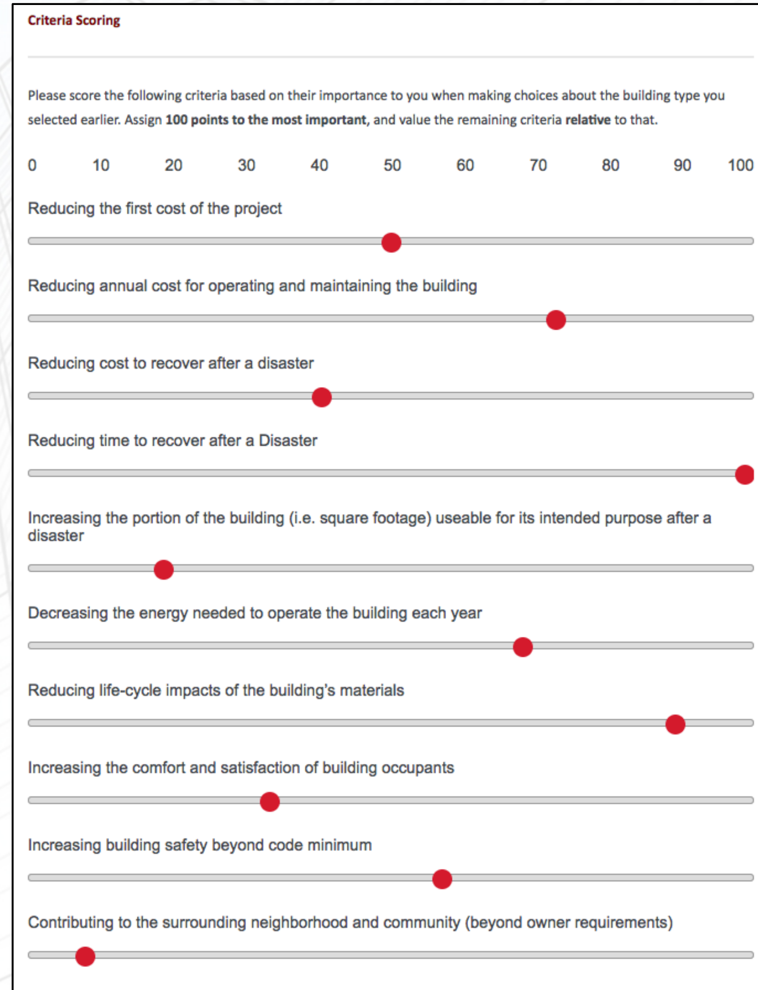
Decision makers assign criteria points based on importance.

Most important = 100 points, the rest relative to that

Widely-used, widely-critiqued

Challenges:

- High cognitive load
- Inconsistency of answers
- Uncertainty in responses



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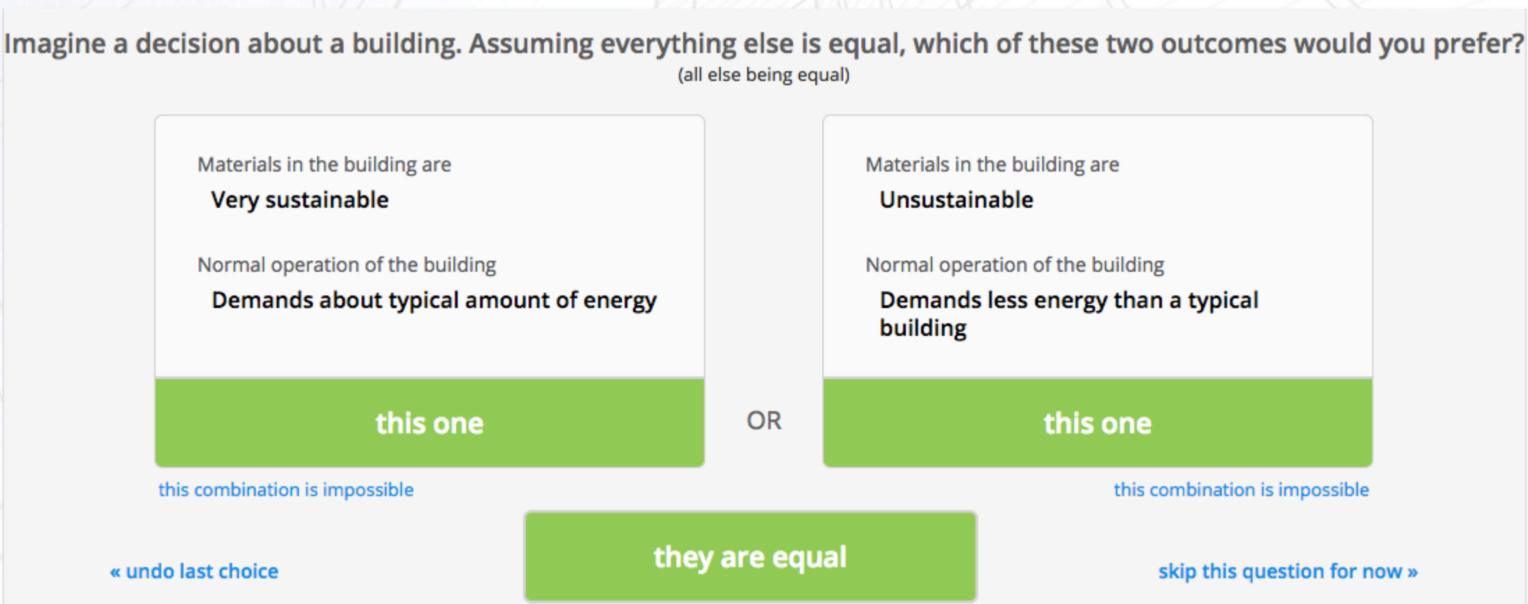
Scenario Comparison Method

Decision makers choose between to scenarios assuming everything else is equal.

Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) method (Conjoint analysis)

Lots of questions



Dynamic Modeling

Thank you!

QUESTIONS?