EDRA 50 - Brooklyn
Sustainable Urban Environments

Session 2330: Humanizing Building Technology and Experience: a Collaborative Forum for Re-envisioning Sustainable, Healthy Buildings and Occupants

Wednesday, May 22, 2019

Jennifer Senick [1] Clinton Andrews [1] Nora Wang [2], Patrick Phelan [3], Adina Dumitru [4], Rich Wener [5]

1. Rutgers University; 2. Pacific Northwest National Laboratory; 3. Arizona State University; 4. University of A Coruña, Spain; 5. New York University

Learning Objectives

1. Describe methods for utilizing knowledge and experience in human studies to inform and shape engineering research of buildings and building occupants.
2. Share best practice on harvesting behavioral data via building management systems, building sensors, and personal device data streams and how to pool these data.
3. Evaluate and advance the case for evaluating occupant health and well-being in buildings, including measurement of avoided health costs.
4. Describe the role of persuasive visualization technology in building occupant behavior based on case study data.
5. Model multidisciplinary activity to foster collaboration on funding and other scholarships opportunities

Short Takes (45 min)

Short Takes to inspire:

Brainstorming about proposed ideas, research questions, proposals, collaborations, needs

Presentations:

Routes to Evidence-Based Design
Clinton J. Andrews, Rutgers University

An Economic Framework for Monetizing Healthy Buildings
Nora Wang, Pacific Northwest National Laboratory

Thermal Engineering, Occupant Health and Productivity
Patrick Phelan, Arizona State University

The Role of Persuasive Visualization Technology in Building Occupant Behavior
Jennifer Senick, Rutgers University

Buildings as Biodiversity Connectors
Adina Dumitru, University of A Coruña, Spain

Routes to Evidence-Based Design

Clinton J. Andrews

The routes that evidence follows into the design process are often tortuous, and their relative merits are not well understood. Most common is the establishment of a heuristic, a rule of thumb that gets passed from master to apprentice. Field studies using post-occupancy evaluation and building performance evaluation techniques have taught lessons one building at a time, but those lessons mostly accrue to the individual designer and the limited number of structures designed and built during that person's working life. Formal scientific studies increasingly inform standards development and establish a performance floor for broader design practice. The advent of building information modeling and building performance simulation tools has opened up the possibility of learning and designing *in silico*, if data are available for calibrating the models. For physics questions that influence structural, mechanical, and electrical engineering design, there are plenty of data to support simulation modeling. Data on human behavior are much more limited, and it is only recently that researchers have collected enough data to calibrate sophisticated models of human interactions with building systems. Such models typically represent behavior as either a Markov process or an agent-based model. Current efforts attempt to make behavioral data much more widely available by harvesting building management system and personal device data streams, developing large-scale occupant surveys, and pooling building-specific data sets. This paper develops a typology of categories of evidence and of the routes by which evidence influences design. It assesses the strengths, weaknesses, histories, trajectories, and fitness for specific purposes of each, and provides illustrative examples. It makes a first step toward realizing a more ambitious and evidence-based Vitruvian design paradigm.

Routes to evidence-based design

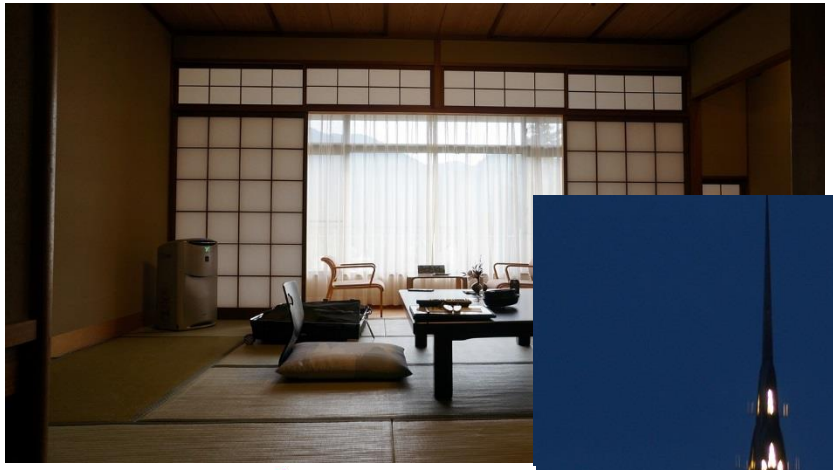
RUTGERS

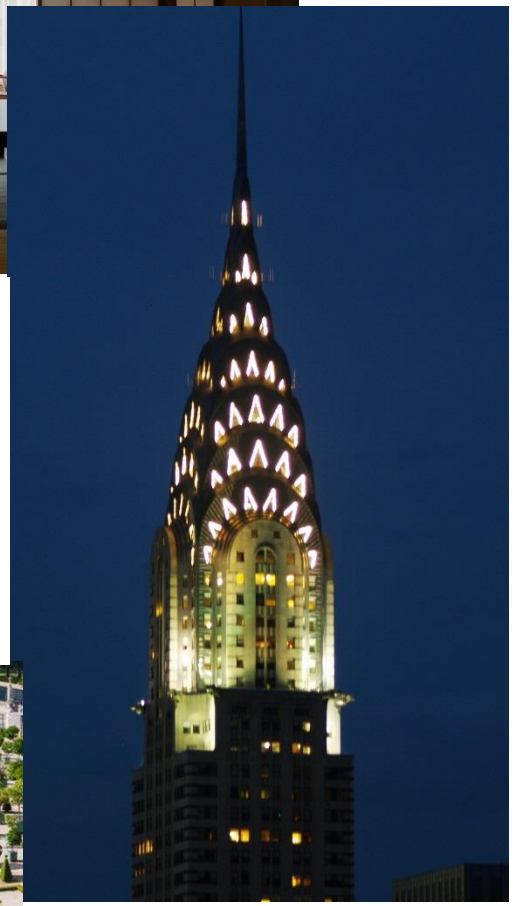
Clinton J Andrews
Edward J Bloustein School of Planning & Public Policy

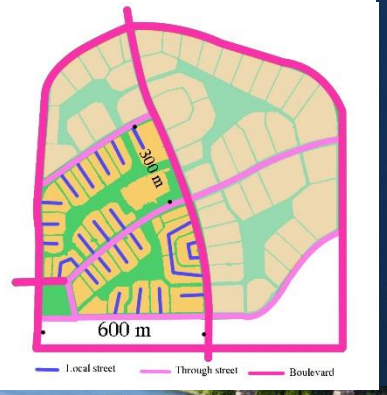
www.pritzkerprize.com

Specialization

- Interior design
- Architecture
- Landscape architecture
- Urban design & planning
- Infrastructure design







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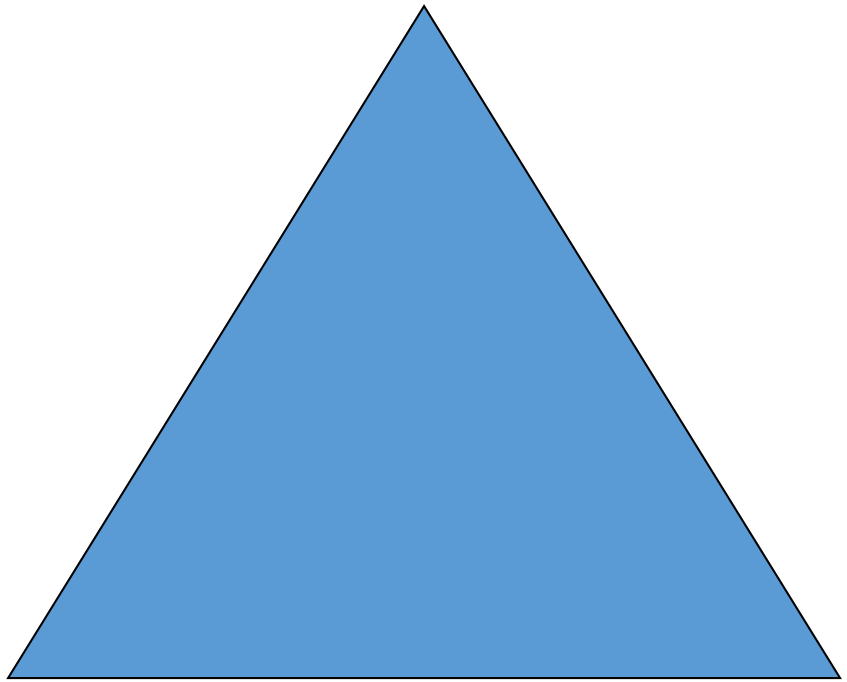
FIRMNESS
COMMODITY
DELIGHT

Vitruvius
25 BC

Utilitas

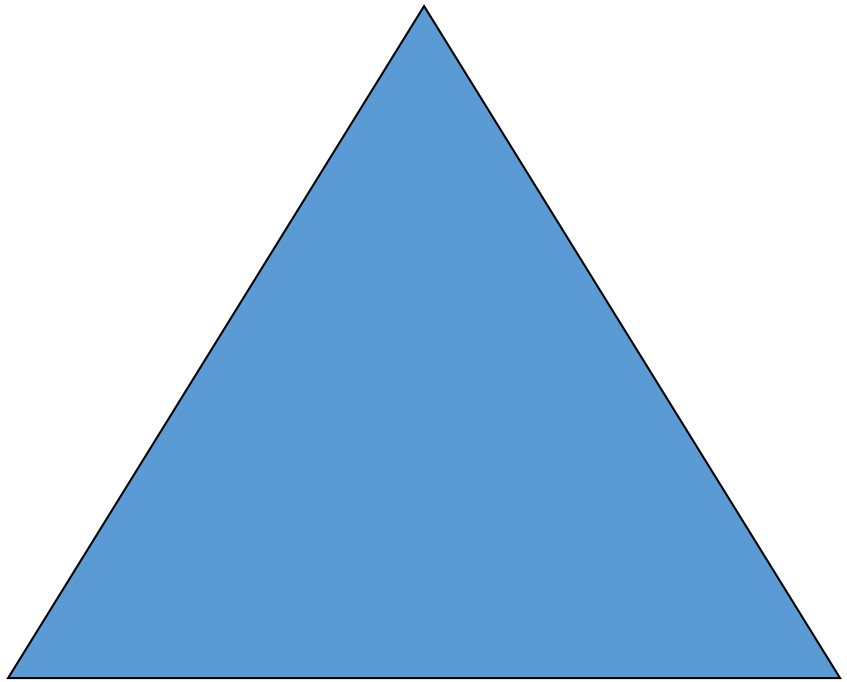


Firmitas

Venustras

Commodity

Wotton
1624

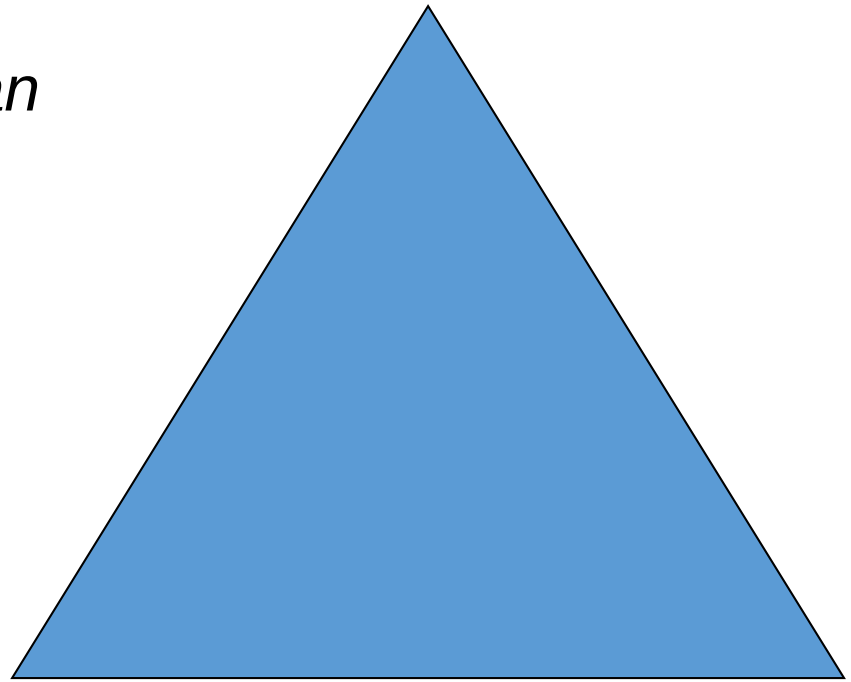


Firmness

Delight

Function

O’Gorman
1998

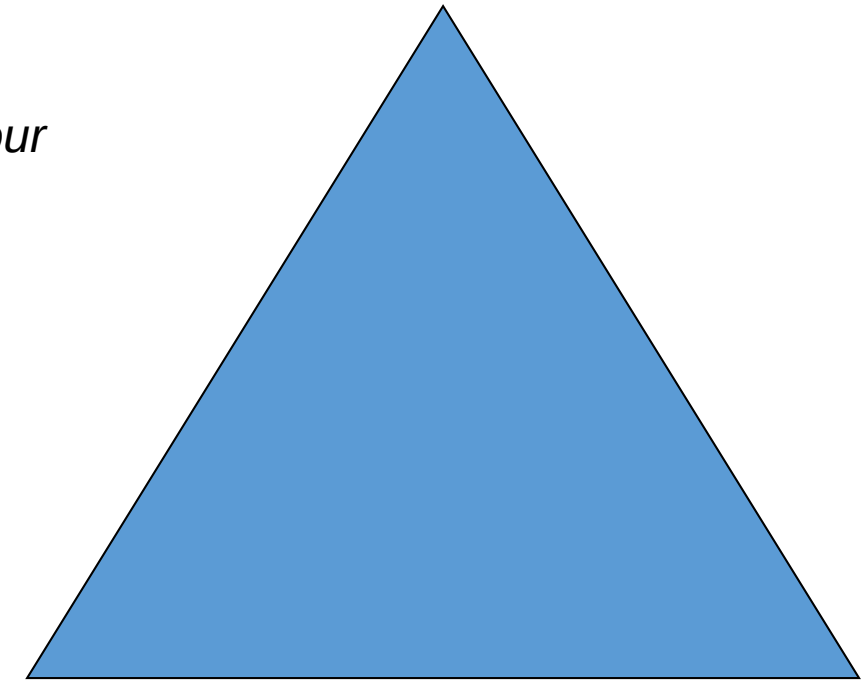


Structure

Beauty

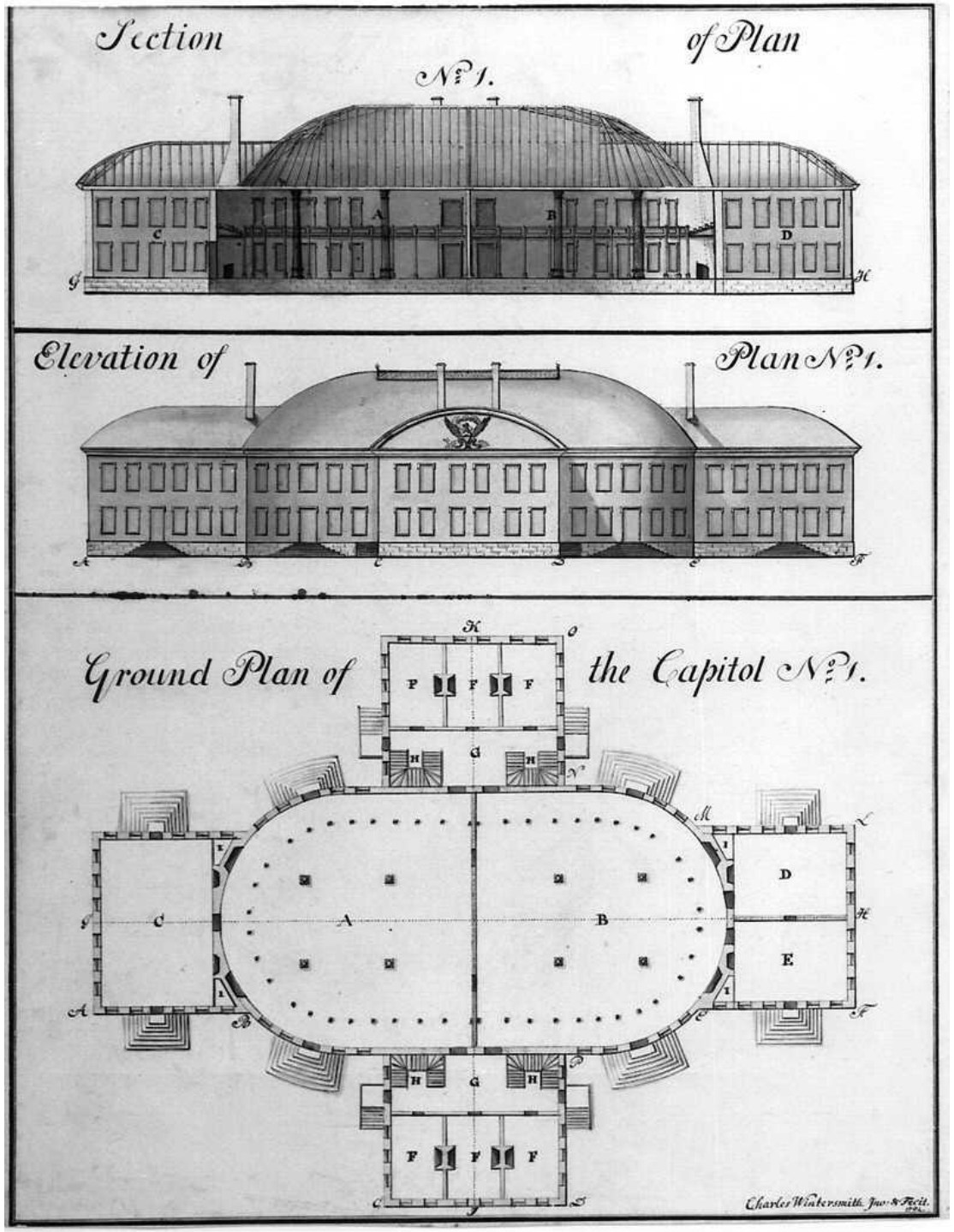
Plan (Function)

How do we communicate our design intent?

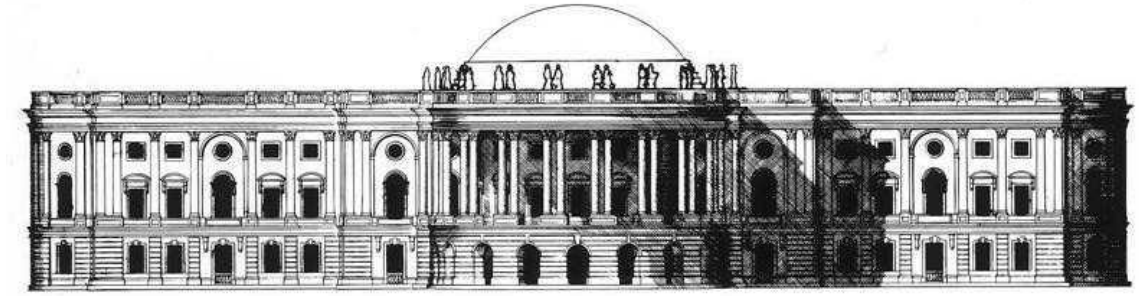


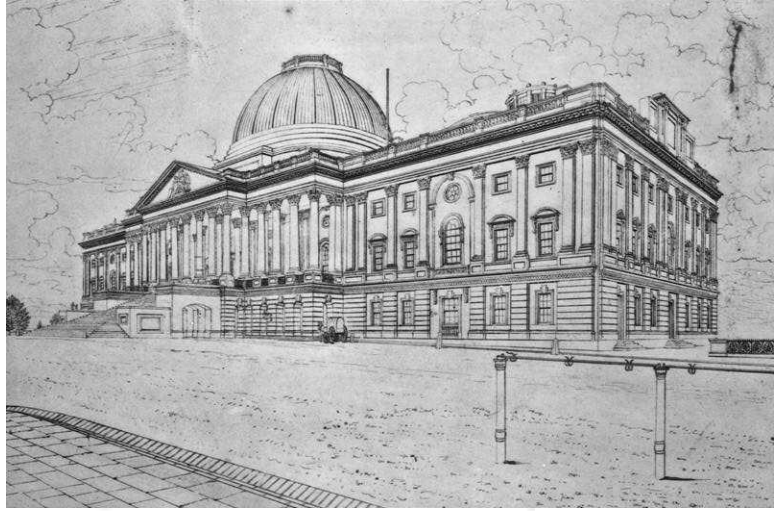
Section (Structure) Elevation (Beauty)

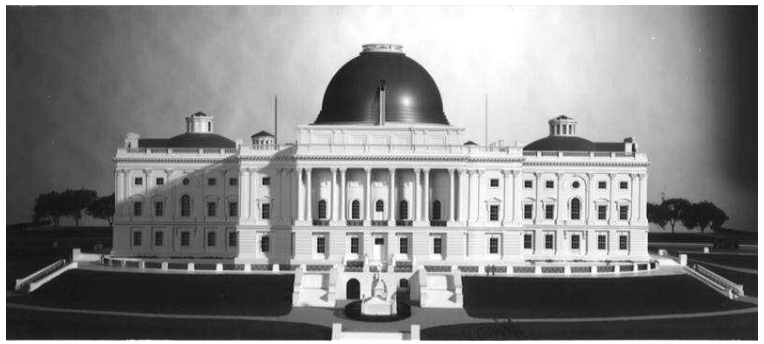
commons.wikimedia.org/wiki/Image:US_capitol_building.jpg

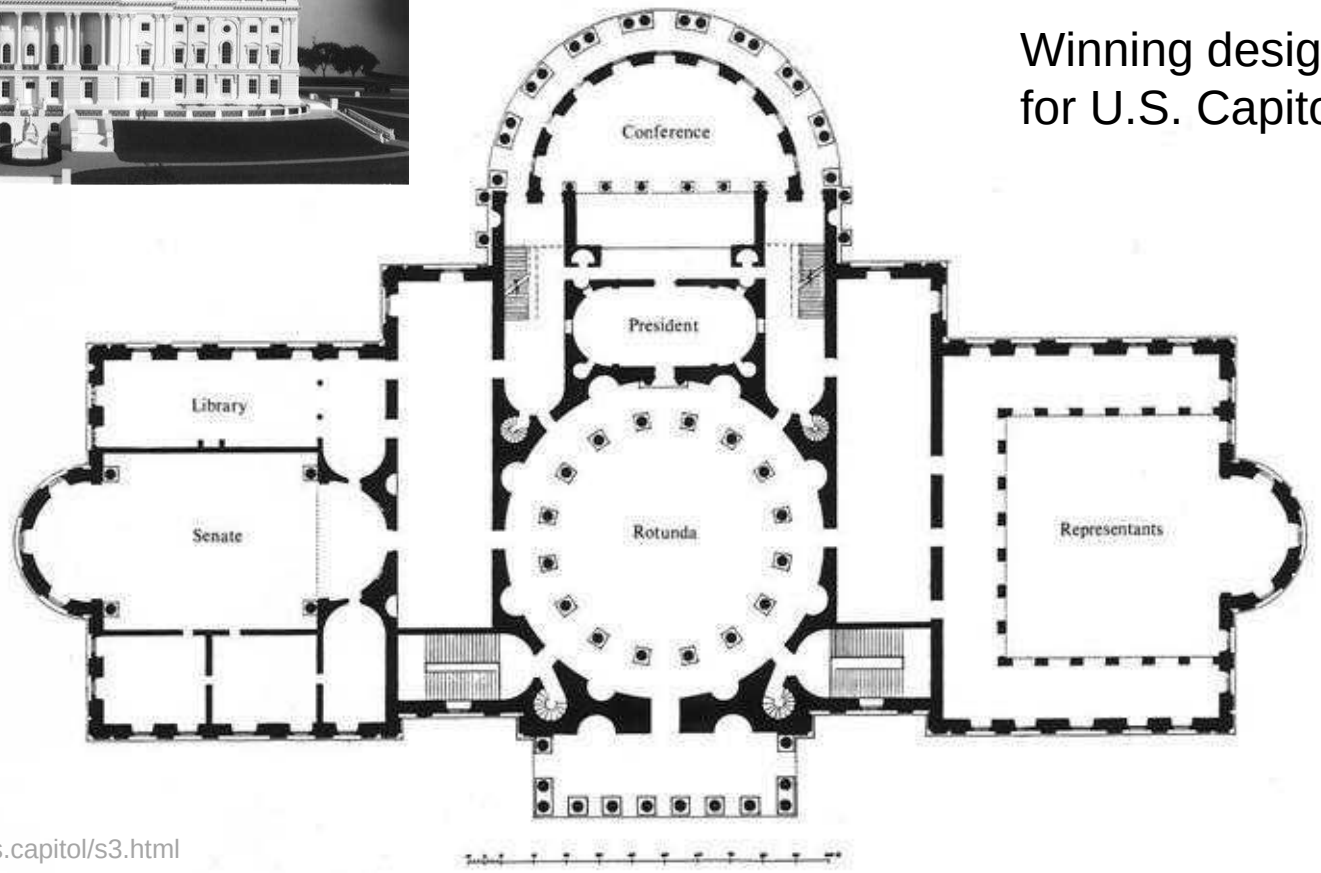


Losing design for U.S. Capitol
1792







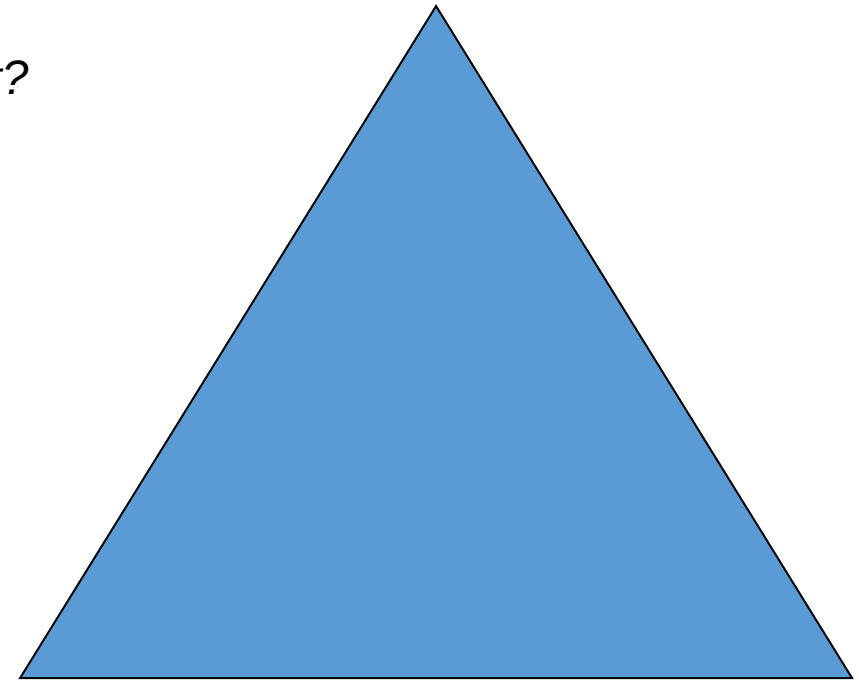


Winning design
for U.S. Capitol

www.loc.gov/exhibits/us.capitol/s3.html

Client (Function)

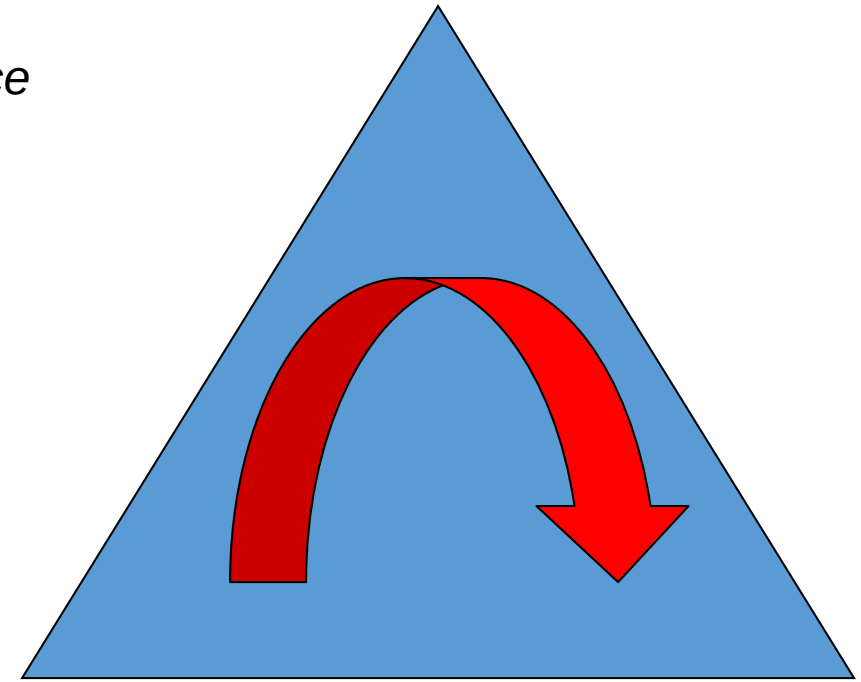
Who does what?



Builder (Structure) Architect (Beauty)

Function

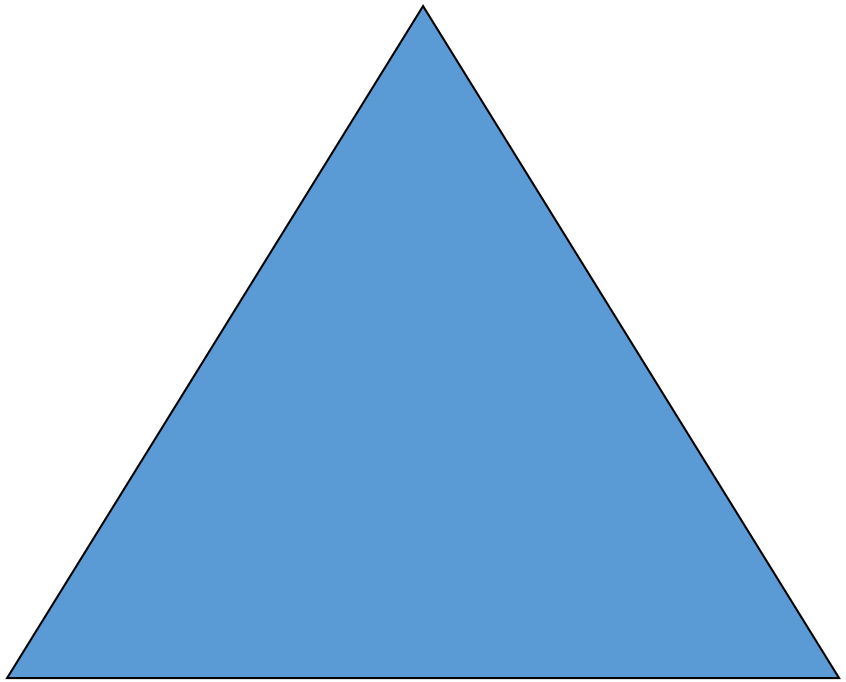
Role of evidence



Structure

Beauty

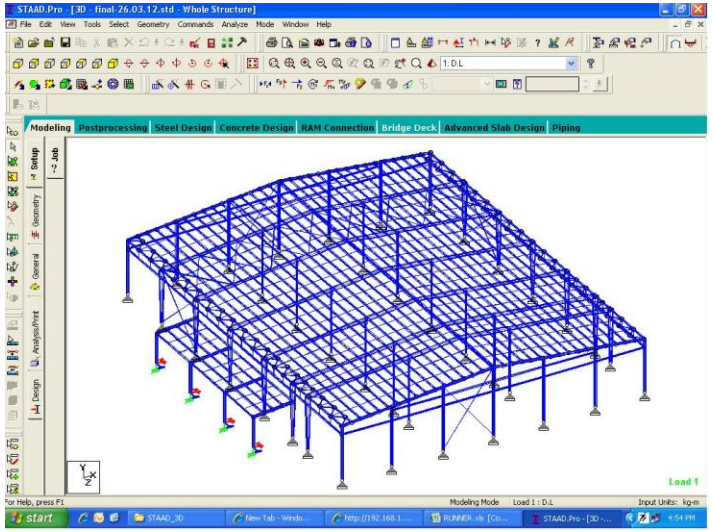
Function

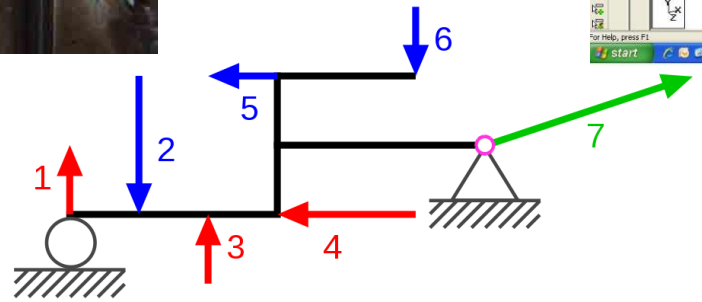


Structure

Beauty

Measure Model Design

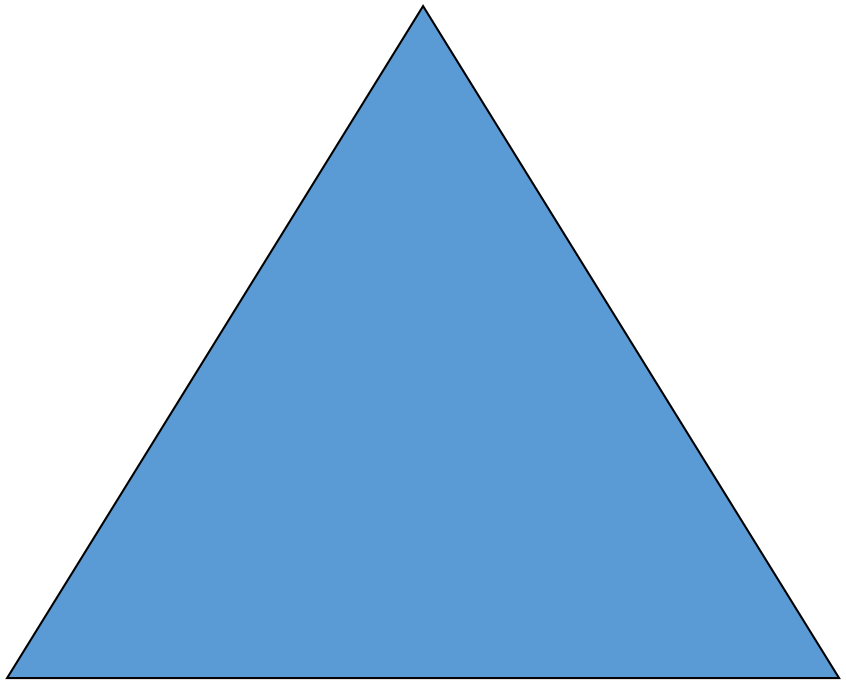




$$\sum_{(i)} \vec{F}_{(i)} = \vec{0} \qquad \sum_{(i)} \vec{M}_{(i)} = \vec{0}$$

http://seasoft022.blogspot.com/2013/05/pre-stressed-concrete-structures-02.html https://commons.wikimedia.org/wiki/File:Beam_in_static_equilibrium2.svg
https://upload.wikimedia.org/wikipedia/commons/b/b9/3d.JPG

Function



Structure

Beauty

Functionality includes:

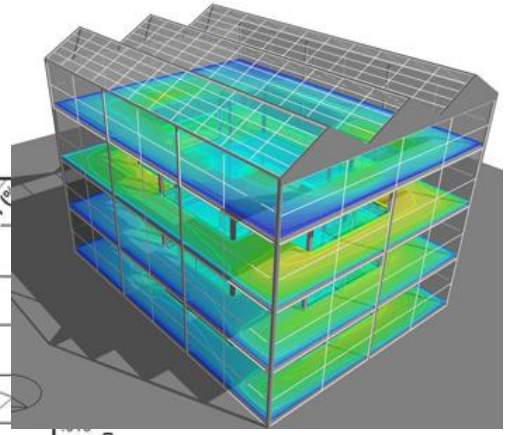
- Layout
- Security
- Wayfinding
- Lighting
- Thermal comfort
- Indoor air quality
- Noise
- and more

Approaches:

- Meet minimum standards
- Maximize usability

Measure Model Design

Meet thermal comfort standard



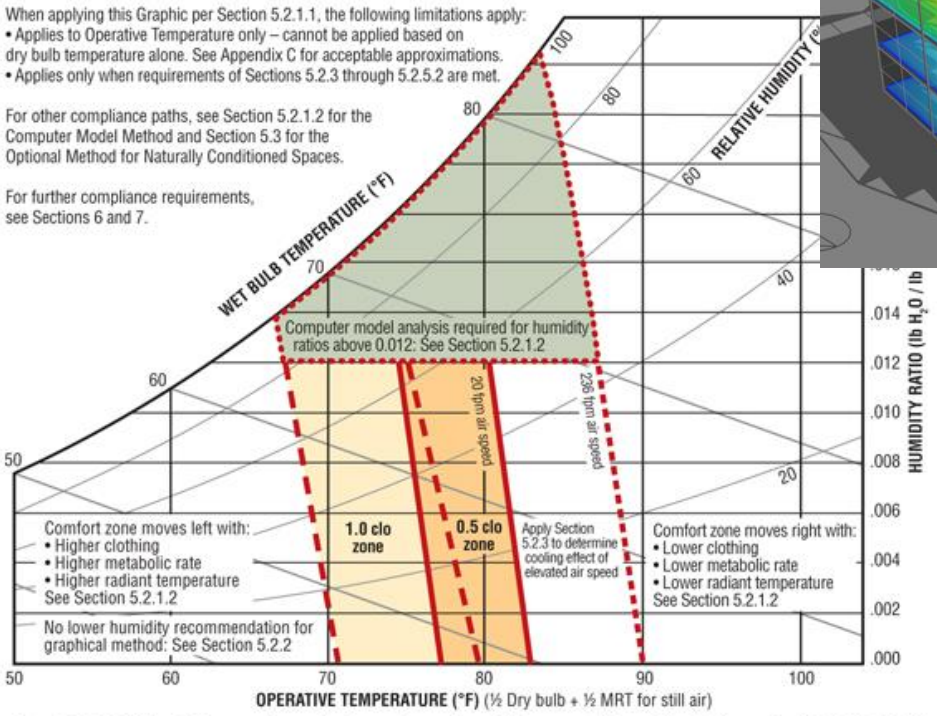
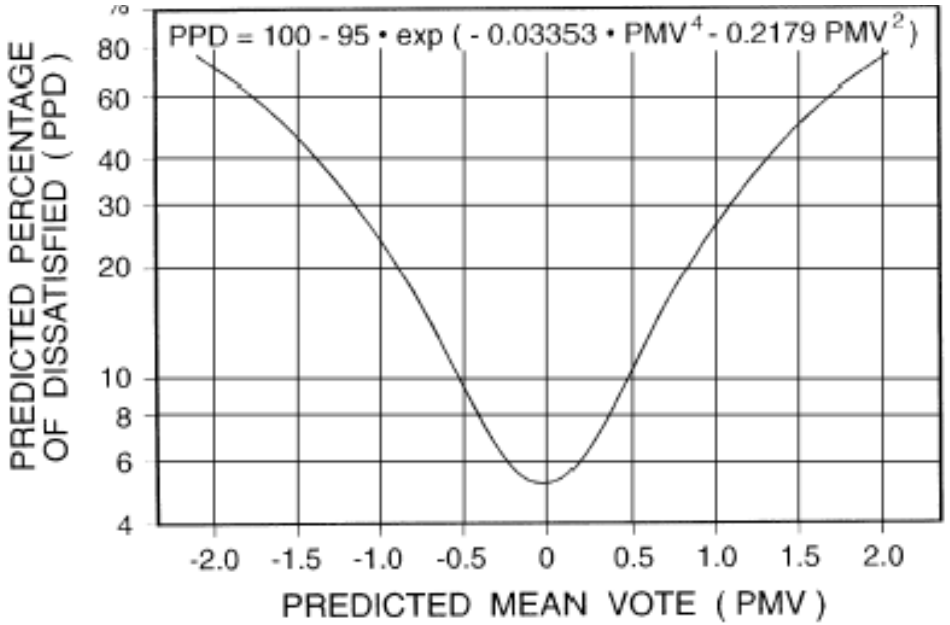


Figure 5.2.1.1 (IP) Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section 5.2.1.1.
1.1 met, 0.5 & 1.0 clo

http://www.exceltest.com.my/index.php https://www.hpac.com/heating/thermal-comfort-more-just-air-temperature https://www.ibpsa.us/designbuilderenergyplus-training-dubai

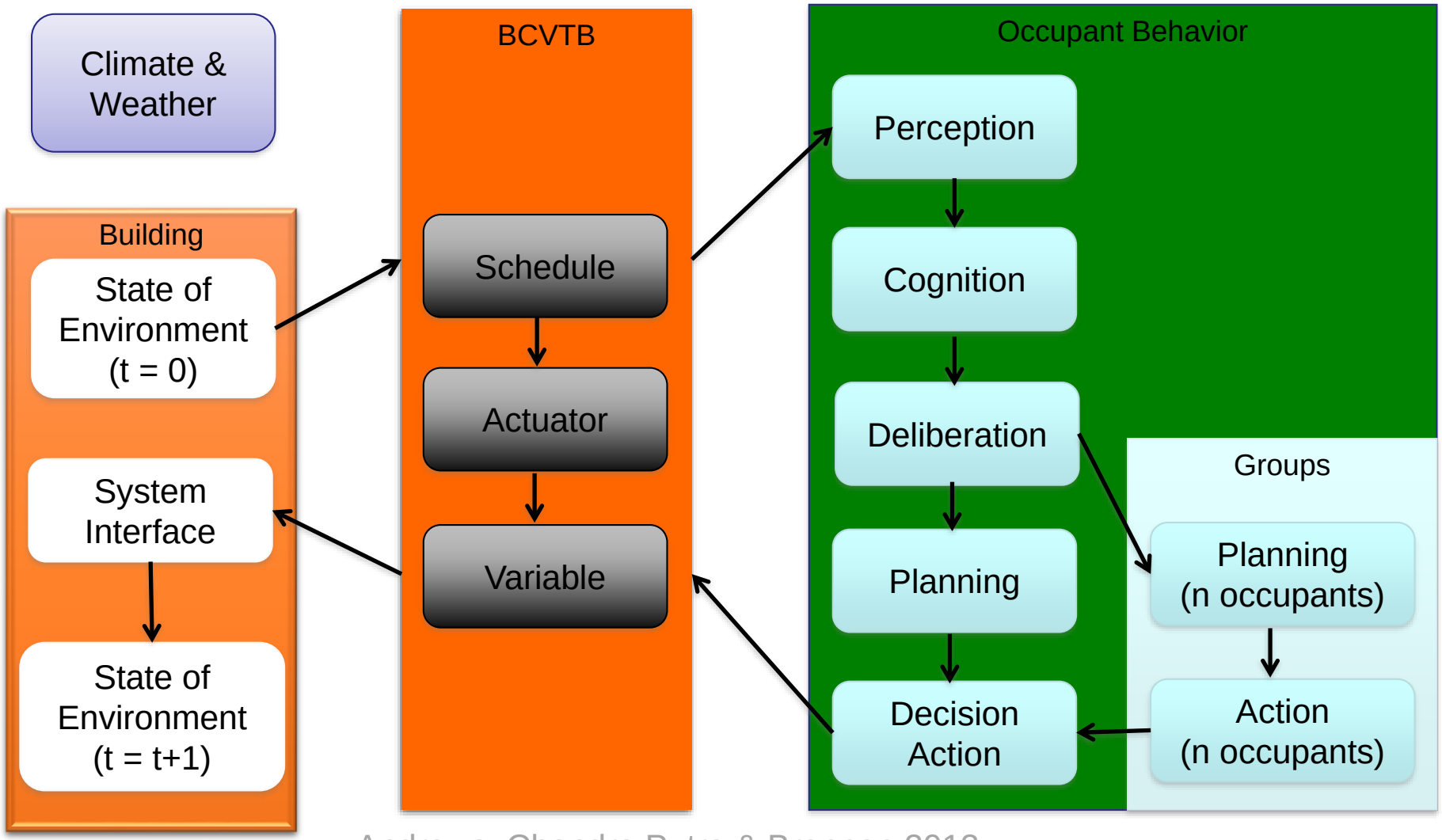
Measure Model Design



But people have diverse thermal preferences

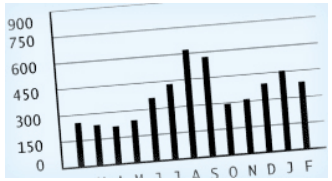
ASHRAE Standard 55-2004
Overby 2013

Co-simulation Framework



Andrews, Chandra Putra & Brennan 2013

Measure Model Design



Building Data (Architectural and Mechanical Drawings)

Building Geometry

Google SketchUp

HVAC Construction Lighting, Etc

Open Studio

Utility Bills

Calibration Analysis

Energy Plus

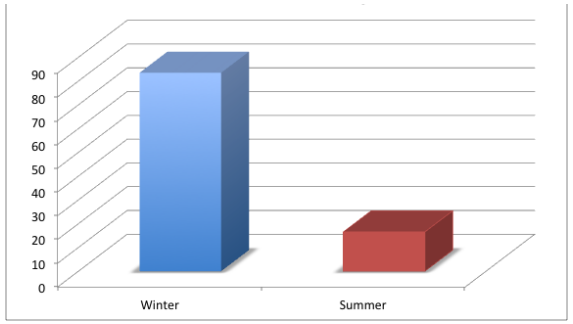
Occupant Behavior Survey Data

NetLogo

Calibrated Building Models

What-if scenarios

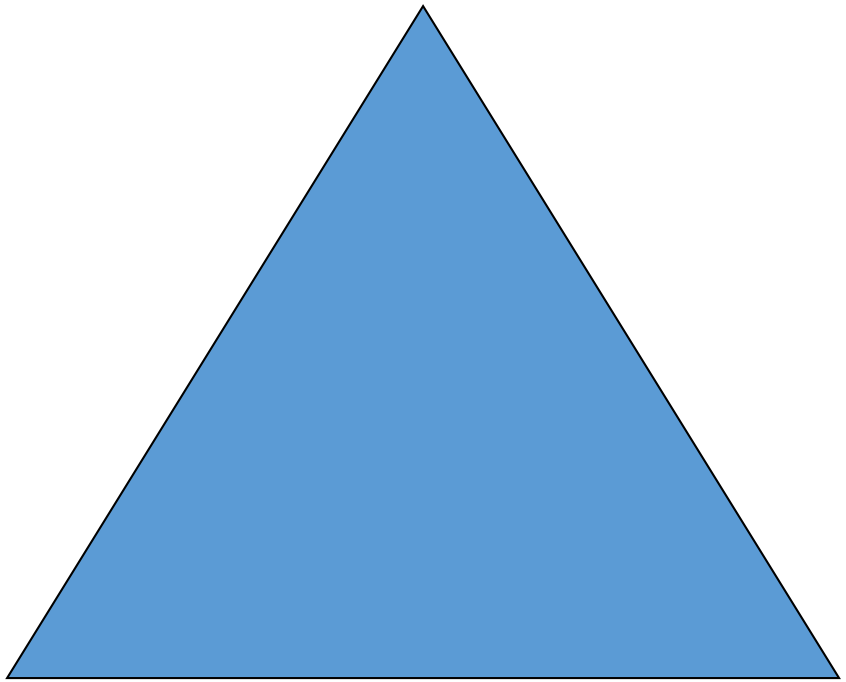
Occupant Behavior Simulation



Andrews, Chandra Putra & Brennan 2013

Peak day discomfort

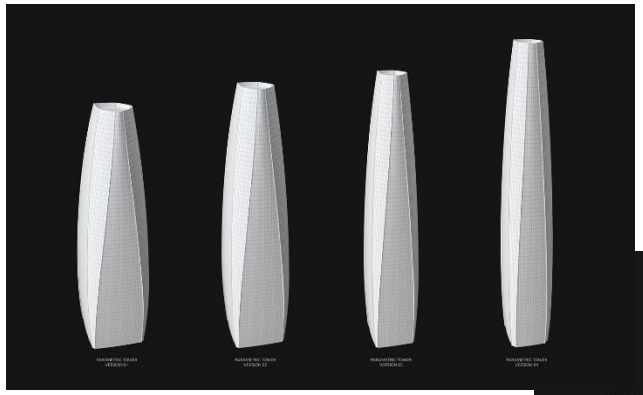
Function

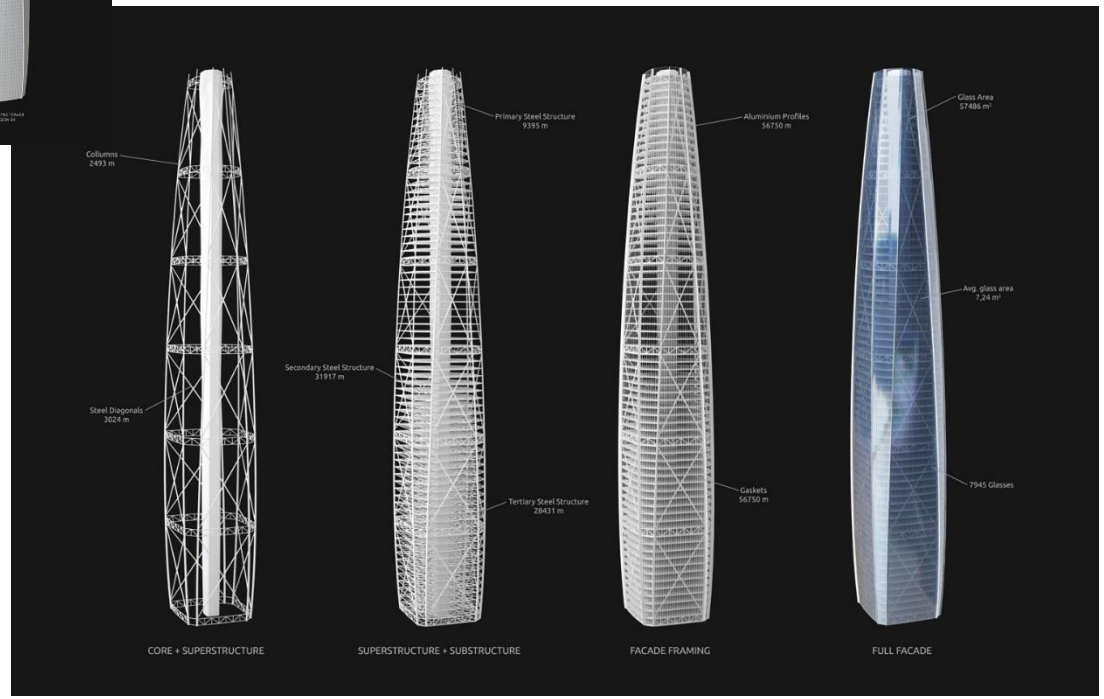


Structure

Beauty

Measure Model Design





? What do we measure?

http://seasoft022.blogspot.com/2013/05/pre-stressed-concrete-structures-02.html https://commons.wikimedia.org/wiki/File:Beam_in_static_equilibrium2.svg
https://upload.wikimedia.org/wikipedia/commons/b/b9/3d.JPG

“Visual Preference Survey Finds Support for Colonial Style”

https://www.tapinto.net/towns/scotch-plains-slash-fanwood/sections/community-life/articles/back-to-the-future-scotch-plains-downtown-visual

Neuroscience of Aesthetics
Eye Tracking

Neurotypical Person

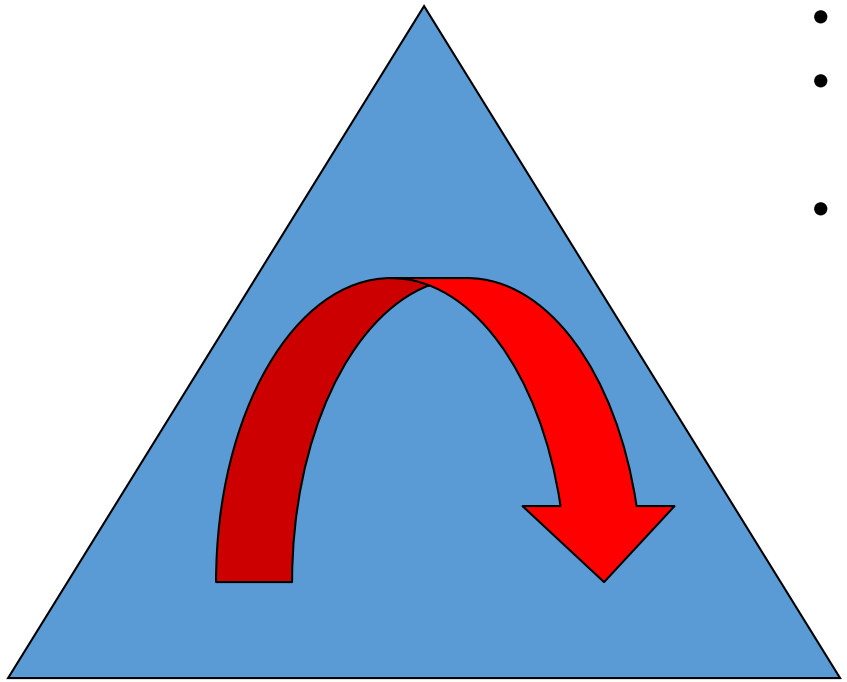
Autistic Person

“Le Corbusier remained blind to others’ views—he literally couldn’t process visual stimuli normally”

Ann Sussman, Katie Chen. 2017. http://commonedge.org/the-mental-disorders-that-gave-us-modern-architecture/

Available evidence varies from objective & universal to subjective & contextual

Function



Ways used to incorporate evidence include

- *standards,*
- *heuristics,*
- *evaluation protocols,*
- *models*

Structure

Beauty

Need to teach not just design rules but also measuring & modeling

http://Bloustein.Rutgers.edu/Andrews

Thermal Engineering, Occupant Health and Productivity

Patrick Phelan

Indoor environmental conditions (e.g., temperature, relative humidity) are currently designed according to prescriptive comfort criteria (e.g., ASHRAE 90.1) and then controlled based largely on occupants' reported comfort conditions (i.e., cold calls), but are those the healthiest conditions for the building occupants? In other words, should buildings be designed according to other criteria (e.g., reported comfort data) and controlled not only to optimize comfort, but also to optimize health? Similarly, can energy-efficient design features such as daylighting, increased thermal mass to minimize temperature fluctuations, and windows with high thermal resistance and minimal glare also enhance occupant health and productivity? This talk seeks to utilize knowledge and experience in human studies to inform and shape engineering research.

An Economic Framework for Monetizing Healthy Buildings

Nora Wang

There has been continuing research leading to a rich literature on how the built environment affects human behavior. The challenge is to understand these studies in context and to convert the research findings to business cases. This presentation will discuss an economic framework to outline the value of balancing and integrating energy and healthy building goals and to quantify the return on investment. Using federal facilities as examples, this framework explores how to translate the potential occupants' health and work productivity gains from improved indoor environments to facility investment and personnel spending. The presentation will also discuss how to integrate healthy building strategies with goals to increase energy efficiency and resilience.

Pacific Northwest
NATIONAL LABORATORY

Framework to Integrate Energy Efficiency and Occupant Health/Wellness

EDRA 50, Brooklyn
May 22, 2019

Nora Wang, Kevin Keene,
Mark Weimar, Julia Rotondo
Pacific Northwest National Laboratory

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

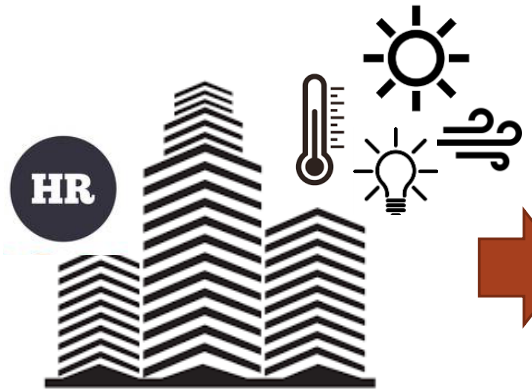
Pacific Northwest
NATIONAL LABORATORY

Objectives

Source: www.gsa.gov

- Quantify and customize the cost-benefit results in terms **of improved productivity**, **reduced absenteeism**, **and reduced employee turnover.**
- Integrate these interventions with building **energy efficiency** planning and investment, to provide a greater, more relevant context for decision makers.

Methodology



Baseline measurements (IAQ, thermal comfort, lighting, daylighting)

ASHRAE
IES
fitwel
WELL BUILDING STANDARD

Potential improvement from baseline to targets

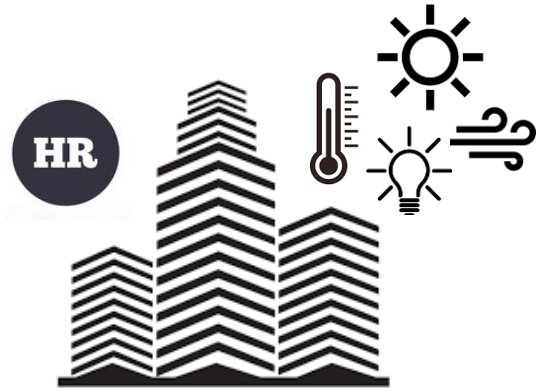
Literature

Correlation between building metrics and occupants (productivity, absenteeism, turnover)

Quantification of financial/personnel savings

Feedback loop to improve correlation

Pacific Northwest NATIONAL LABORATORY



Baseline Measurements

- **Building Metrics**
  - Measured with an energy-style audit
  - Based off WELL, Fitwel, ASHRAE, IES
- **Occupant Metrics**
  - HR and manager info (default assumptions provided)
    - ✓ Absenteeism rate, turnover rate, and recruiting expense
  - Satisfaction survey (optional)
    - ✓ Supplementary to building metrics

Category	Building Metrics
Lighting Quality (visual comfort, circadian rhythms, customization)	Lighting Controls
	Light Zones
	Supplemental Lighting
	Equivalent Melanopic Lux
	Circadian Stimulus
	Illuminance
	Color Rendering Index
Daylight (access, quality)	Spatial Daylight Autonomy
	Window Proximity
	Visible Light Transmittance
	Light Shelves
	Control for Solar Glare
Indoor Air Quality (pollution, ventilation, control)	Ventilation Rate
	Individual Air Diffusers
	Demand Controlled Ventilation
	Variable Air Volume
	Air Quality Devices
	Air-side Economizers
	Particulate Matter – PM2.5, PM10
	Inorganic Gases – CO_2, CO, O_3
	Organic Gases – TVOC, Formaldehyde
Thermal Comfort (customization, comfort)	Thermal Zones
	Individual Thermal Control Devices
	Radiant Systems
	Dedicated Outdoor Air System
	Clothing Level
	Metabolic Level
	Temperature
	Humidity

Potential Building Improvement

- The metrics have corresponding “target” values based on ASHRAE 189.1/55/62.1, IES Lighting Handbook, WELL v2 and Fitwel
- Metrics for each category (IAQ, lighting quality, daylight, thermal comfort) will be averaged into a single “potential improvement” value for each

Hypothetical Example:

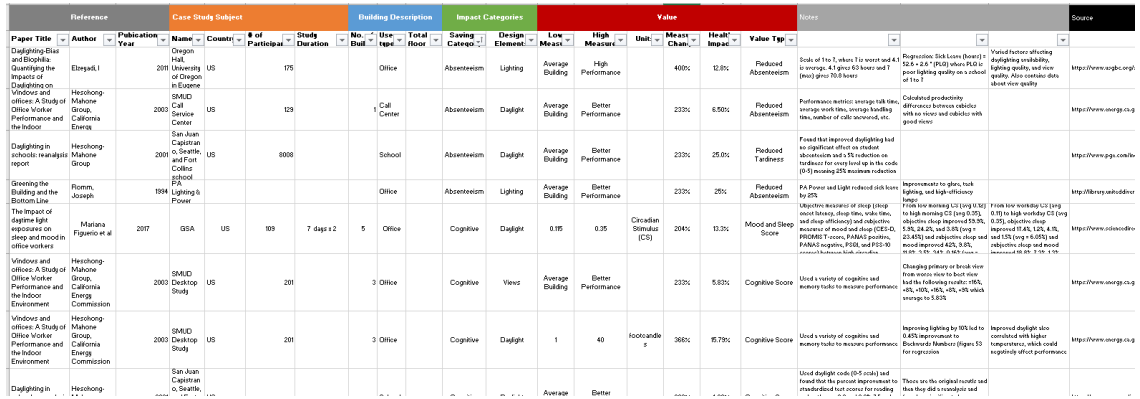
Metric Category	Metric	Notes	Min	Baseline	Target	% Potential	Weight*
Lighting Quality	Illuminance (Horizontal Footcandles)	Average value by activity type, e.g. open office space	15	27	40	50%	1
	Circadian Stimulus (calculated)	Typical value between 9AM and 1PM	0.1	0.22	0.3	40%	3
	Supplemental Lighting (%)	Percent of office spaces that have task lighting available	0	20%	100%	80%	2

*Weights are being developed, these are samples values

- After data normalization and applying weights, the lighting quality for this example building has a potential improvement of 55% (see next slide for continuing analysis)

Literature Correlation From Building Systems to Occupant Health

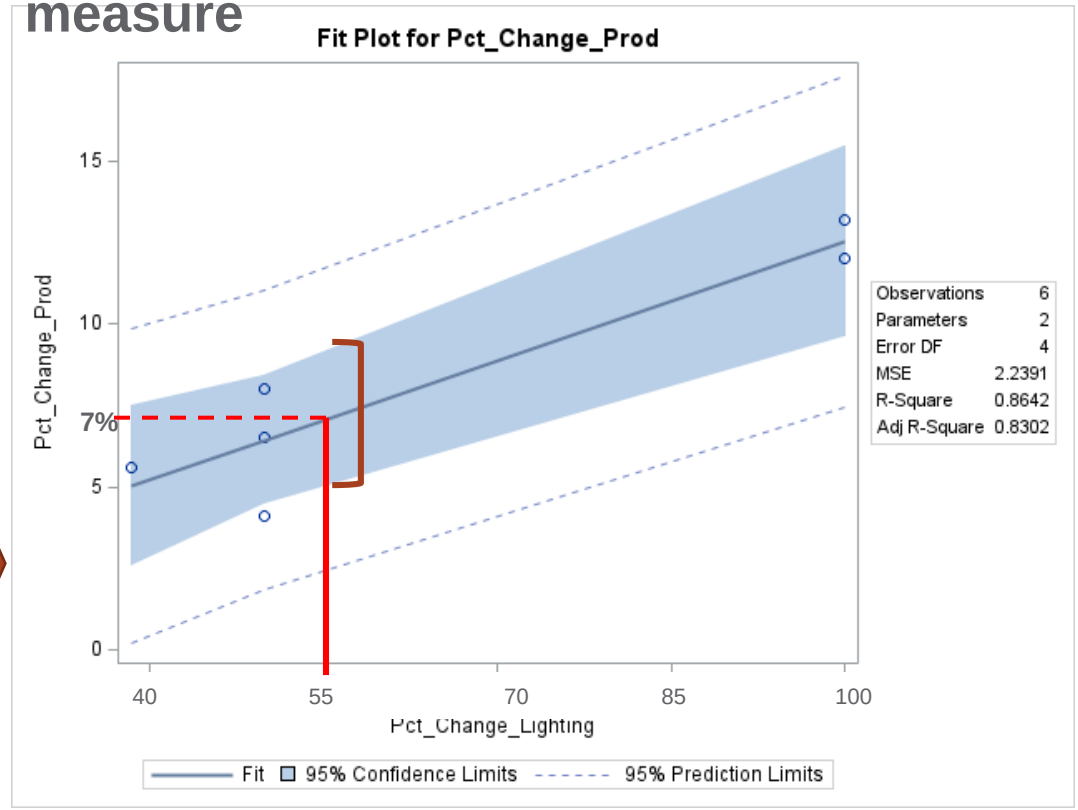
Collection of publications relating lighting quality to productivity



Reference			Case Study Subject				Building Description			Impact Categories		Value						Notes			Source
Paper Title	Author	Publication Year	Name	Country	# of Participants	Study Duration	No. of Buildings	Use type	Total floor	Saving Category	Design Element	Low Measure	High Measure	Unit	Measure Change	Health Impact	Value Type				
Daylighting-Bias and Biophilia: Quantifying the Impacts of Daylighting on	Elzeyadi, I	2011	Oregon Hall, University of Oregon in Eugene	US	175			Office		Absenteeism	Lighting	Average Building	High Performance		400%	12.8%	Reduced Absenteeism	Scale of 1 to 7, where 7 is worst and 4 is average. 4.1 gives 43 hours and 7 (max) gives 70.8 hours	Regression: Sick Leave (hours) = 52.6 + 2.6 * (PLG) where PLG is poor lighting quality on a scale of 1 to 7	Varied factors affecting daylighting availability, lighting quality, and view quality. Also contains data about view quality	
Windows and offices: A Study of Office Worker Performance and the Indoor	Heschong-Mahone Group, California Energy	2003	SMUD Call Service Center	US	129		1	Call Center		Absenteeism	Daylight	Average Building	Better Performance		233%	6.50%	Reduced Absenteeism	Performance metrics: average talk time, average work time, average handling time, number of calls answered, etc.	Calculated productivity differences between cubicles with no views and cubicles with good views		
Daylighting in schools: reanalysis report	Heschong-Mahone Group	2001	San Juan Capistrano, Seattle, and Fort Collins school	US	8008			School		Absenteeism	Daylight	Average Building	Better Performance		233%	25.0%	Reduced Tardiness	Found that improved daylighting had no significant effect on student absenteeism and a 5% reduction on tardiness for every level up in the code (0-5) meaning 25% maximum reduction			
Greening the Building and the Bottom Line	Romm, Joseph	1994	PA Lighting & Power					Office		Absenteeism	Lighting	Average Building	Better Performance		233%	25%	Reduced Absenteeism	PA Power and Light reduced sick leave by 25%	Improvements to glare, task lighting, and high-efficiency lamps		http://library.wbdg.org/
The Impact of daytime light exposures on sleep and mood in office workers	Mariana Figueiro et al	2017	GSA	US	109	7 days ± 2	5	Office		Cognitive	Daylight	0.115	0.35	Circadian Stimulus (CS)	204%	13.3%	Mood and Sleep Score	Objective measures of sleep (sleep onset latency, sleep time, wake time, sad sleep efficiency) and subjective measures of mood and sleep (CES-D, PROMIS T-score, PANAS positive, PANAS negative, PSQI, and PSS-10	From low morning CS (avg 0.15) to high morning CS (avg 0.35), objective sleep improved 53.5%, 5.3%, 24.2%, and 5.8% (avg = 23.45%) and subjective sleep and mood improved 42%, 3.5%,	From low workday CS (avg 0.11) to high workday CS (avg 0.35), objective sleep improved 17.4%, 1.2%, 4.1%, and 1.5% (avg = 6.05%) and subjective sleep and mood	http://www.sciencedirect
Windows and offices: A Study of Office Worker Performance and the Indoor Environment	Heschong-Mahone Group, California Energy Commission	2003	SMUD Desktop Study	US	201		3	Office		Cognitive	Views	Average Building	Better Performance		233%	5.83%	Cognitive Score	Used a variety of cognitive and memory tasks to measure performance	Changing primary or break view from worse view to best view had the following results: +16%, +8%, +10%, +16%, +6%, +9% which average to 5.83%		http://www.usergy.co.g
Windows and offices: A Study of Office Worker Performance and the Indoor Environment	Heschong-Mahone Group, California Energy Commission	2003	SMUD Desktop Study	US	201		3	Office		Cognitive	Daylight	1	40	footcandles	368%	15.79%	Cognitive Score	Used a variety of cognitive and memory tasks to measure performance	Improving lighting by 10% led to 0.45% improvement to Backwards Numbers (figure 5) for regression	Improved daylight also correlated with higher temperature, which could negatively affect performance	http://www.usergy.co.g
Daylighting in	Heschong-		San Juan Capistrano, Seattle,							Average	Better							Used daylight code (0-5 scale) and found that the percent improvement to standardized test scores for reading	There are the original results and then they did a reanalysis and			

- 80 publications in database – continuing to expand and quality check

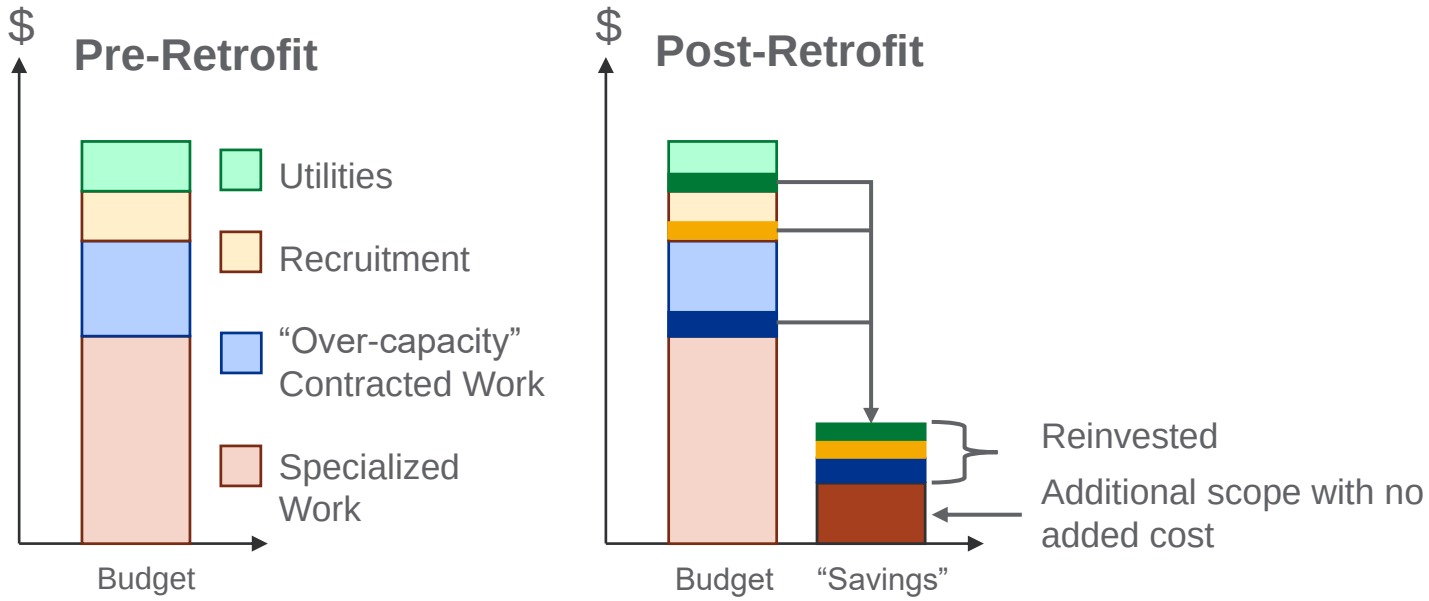
Plot of studies with percent improvement to productivity vs percent improvement to lighting quality measure



- Percent Potential Improvement: **55%**
- Corresponding Productivity Improvement: **7%**
- Uncertainty: **+/- 3%**

→ Find improvements to absenteeism and turnover as well, and then repeat for daylight, thermal comfort, and IAQ

Quantification of Financial Savings



Savings Source	Savings Category	Explanation	Action
Utilities	**Energy**	Building retrofits will likely reduce energy consumption	Utilities savings can be reinvested in building retrofits or agency programs
Recruitment	**Turnover**	Reduced turnover saves overhead expenses on recruitment	Recruitment savings can be reinvested in agency programs
"Over-capacity" Contracted Work	**Productivity/ Absenteeism**	Federal employees and flexible contractors in building are more efficient and decrease need for contracted work	Contractor savings can be reinvested in agency programs
Specialized Work	**Productivity/ Absenteeism**	Federal employees and essential contractors are more efficient and complete specialized work sooner [and/or improved quality of service and mission achieved]	Programs can request additional scope with the same budget

Decision Matrix, NPV, and Uncertainty

- Decision matrix can compare personnel savings to:
  - Energy savings/costs
  - Cost of construction
  - External/non-monetary benefits
    - Aesthetics, employee satisfaction, office culture, GHG emissions
- Uncertainty from the confidence intervals in literature data and number of metrics completed
- NPV to compare discounted benefits and payback period to upfront cost of improvements

Retrofit	Monetary					Non-Monetary	
	NPV (personnel savings)	Uncertainty	NPV (energy savings)	Estimated Retrofit Cost	Benefit / Cost Ratio	Occupant Satisfaction	Office Culture
Option 1 - Combined	$10,164K	+/- 15%	$1,994K	$2,010K	6.05 +/- 0.76	66%	High
Option 2 - IAQ	$7,988K	+/- 10%	$798K	$1,546K	5.68 +/- 0.52	25%	Low
Option 3 - Lighting	$6,196K	+/- 9%	$1,196K	$464K	15.9 +/- 1.23	35%	Medium

Pacific Northwest
NATIONAL LABORATORY

Thank you!

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Art as Input to Air Quality Management: Persuasive Technology

Jennifer Senick

This presentation will share results of recent participatory-based research into how children in low-income housing settings perceive and assess indoor air quality. As an example of an HCI approach based on theories of environmental and behavioral psychology, this work offers insights into how socio-technical systems may help to combat the detrimental health impacts of poor IAQ, especially in lower resource communities. The topic of how persuasive systems may condition behavior towards, and impacts on, environmental factors is an important one in HCI. Lessons drawn from this work have broader applicability to the design of persuasive systems in various building settings.

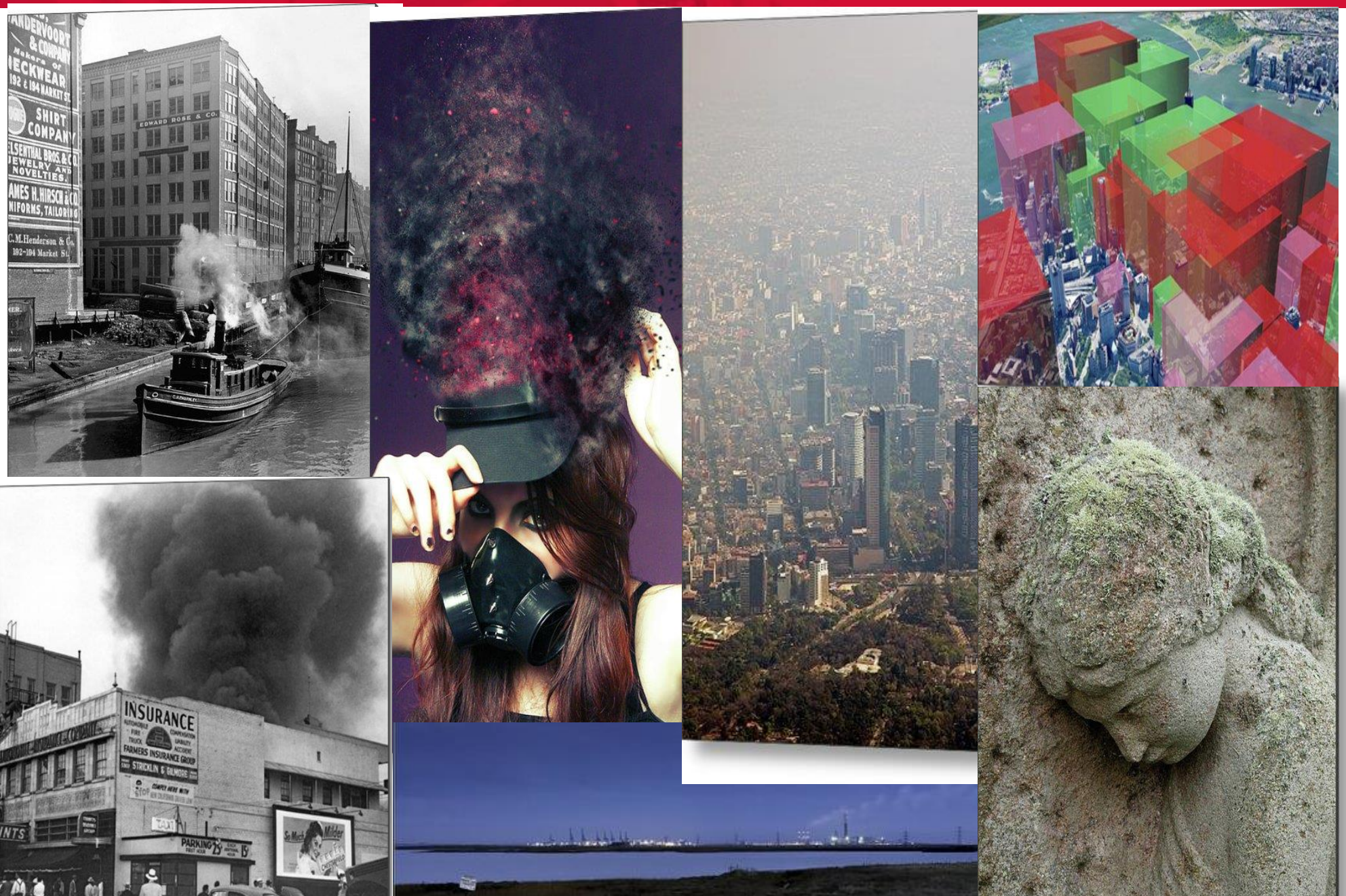
RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Art as Input to Air Quality Management: Persuasive Technology

Jennifer Senick, Rutgers Center for Green Building
Sunyoung Kim, School of Communication & Information
Gediminas Mainelis, Department of Environmental Sciences

EDRA 50, Brooklyn - Sustainable Urban Environments
Humanizing Building Technology and Experience: a Collaborative Forum for Re-envisioning Sustainable, Healthy Buildings and Occupants
Wednesday May 22, 2019

https://fineartamerica.com/art/air+pollution



Rutgers Professor Alan Robock with an image of The Scream, an 1895 painting by Norwegian artist Edvard Munch. From top to bottom on the right are: a nacreous cloud over McMurdo Station in Antarctica in 2004; an 1883 drawing by William Ascroft showing the sky in London after the Krakatau eruption; and a 1982 volcanic sunset over Lake Mendota in Madison, Wisconsin, after the El Chichón eruption in Mexico. Photo: Nick Romanenko/Rutgers University

ART IN AIR QUALITY MANAGEMENT: INTRODUCTION

The US Environmental Protection Agency defines Indoor Air Quality as, "*the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants*." [1]

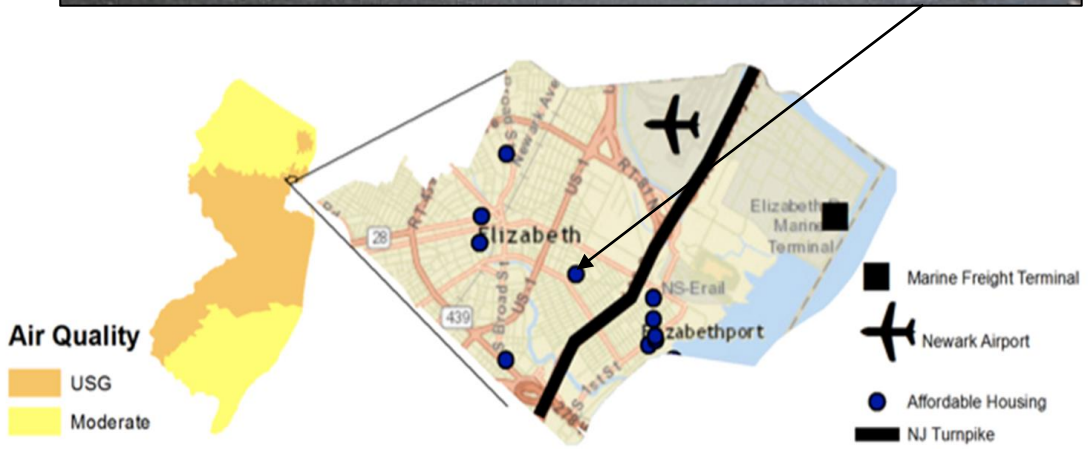
- IAQ is an important determinant of health; people spend the majority of time indoors (in their homes)[1].
- Air pollution is higher in non-white and low-income neighborhoods, causing health risk disparities [2,3].
- The objectives of this pilot study were to: 1) understand how children in low income households perceive and assess IAQ; 2) provide education about IAQ; 3) develop insights for future IAQ interventions.

METHODS

- Motivated by participatory design research
- Community-based research approach

Study Site:

- City: Elizabeth, NJ which has some of the worst air pollution in New Jersey [4] and high rates of chronic respiratory disease[5]
- Housing complex: Built in 1938, the complex houses approximately 750 residents whose annual household income is below 30% of the area's median income level



The Workshops (August 2017)

Researchers partnered with the housing authority to conduct 4 participatory design workshops to explore how low-income families, especially children, currently perceive and assess IAQ.

Workshops had 4 modules:

- Icebreaker
- Educational session
- IAQ monitoring exercise
- Hands-on design activity session

AirVisual, an IAQ monitoring station: it uses colors, graphs, numbers, and icons to visualize IAQ.

The Participants

Nineteen children and sixteen caregivers participated in the study.

Session	Children	Caregiver
1	3 girls, 1 boy	3 mothers, 1 grandmother
2	2 girls, 5 boys	5 mothers
3	2 girls, 3 boys	3 mothers, 1 father
4	3 girls	2 mothers, 1 father
Total	10 girls, 9 boys	14 females, 2 males

Children's ages: all but two between 7 and 9 years old
Caregiver's ages: all but two between 24 and 51 years old
Fifteen African-American families, one Latino family

FINDINGS: Perceiving Indoor Air Quality Through Sensory Cues

Participants rely heavily on sensory cues – e.g., sense of smell, sense of air temperature (thermal comfort), and visual cues (cleanliness of a space) to perceive and assess IAQ.

Sense of Smell

"There are different smells outside than inside." (Participant P5)

"Bad air quality is like something that stinks that comes from your pants." (Participant C8)

"When you are in a dirty room… like dirty clothes and like really smelly and it stinks." (Participant C12)

"It (school) smells musty." (Participant C3)

Thermal Comfort

"In the summer outside it's very hot so the air is heavy." (Participant C3)

"The sunrise during the day heats up the ground. That's why in summer the air pollution becomes worse because of the Sun." (Participant C1)

"Air is nice and cool in here because of an air conditioner." (Participant C2)

"It was really hot. We were outside so the air was really heavy and it smelled contaminated." (Participant C2)

Visual Cues

"Air is nice and clean when the plants and grass are greener." (Participant C13)

"It's very bright and air is clean outside because of the Sun. It's colorful outside" (Participant C9)

"My hypothesis is that when there's - when the air is like dirty, it's not as bright." (Participant C8)

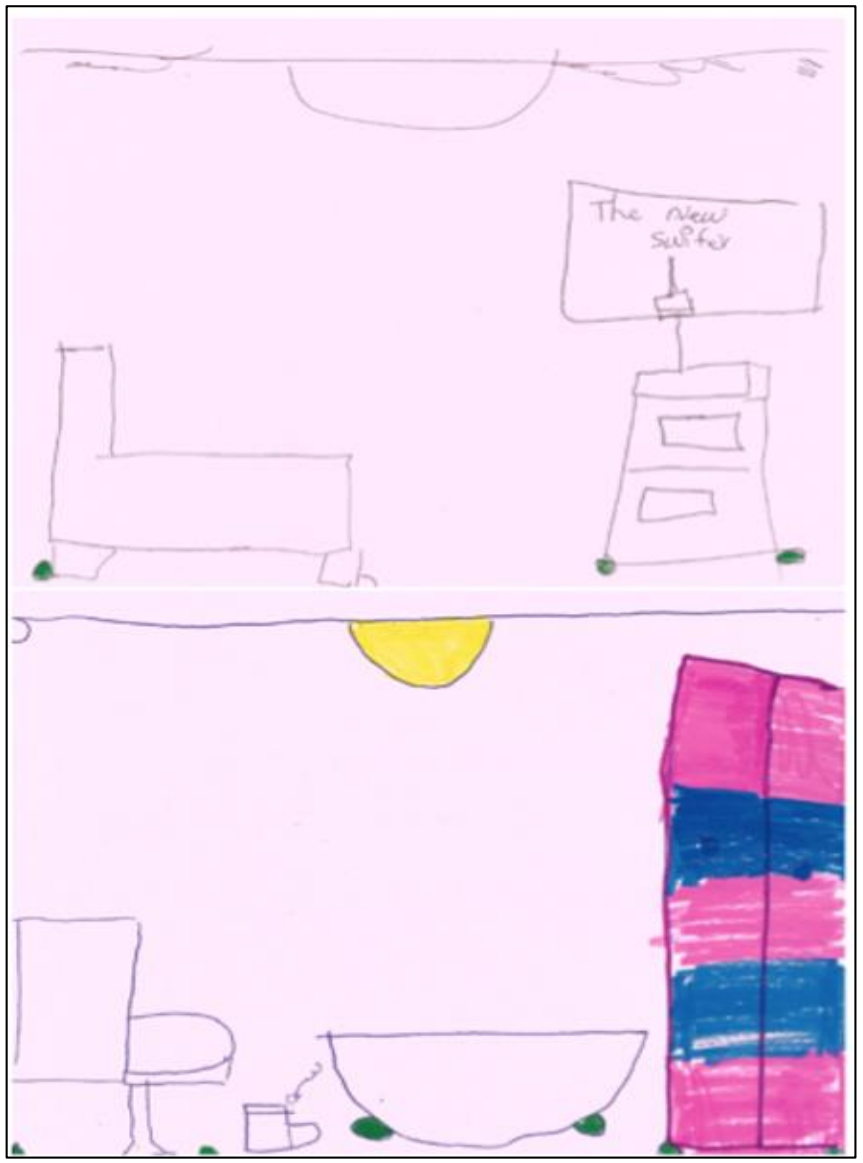
FINDINGS (cont.)

- *"Air in my house is good because there's less germs and dirt inside than outside." (Participant C9)*
- *"Sometimes I can smell that somebody is smoking in the backyard." (Participant C10)*
- *"That's like nasty air on the outside and like good air inside and you open your window and nasty air outside, some of that air may come in to your house." (Participant P3)*

A sketch of a house with bad IAQ: "*Dirt is coming into a house through these windows. This is a dog and it's also making indoor air bad… and a mop to clean the air*" *(Participant C8)*

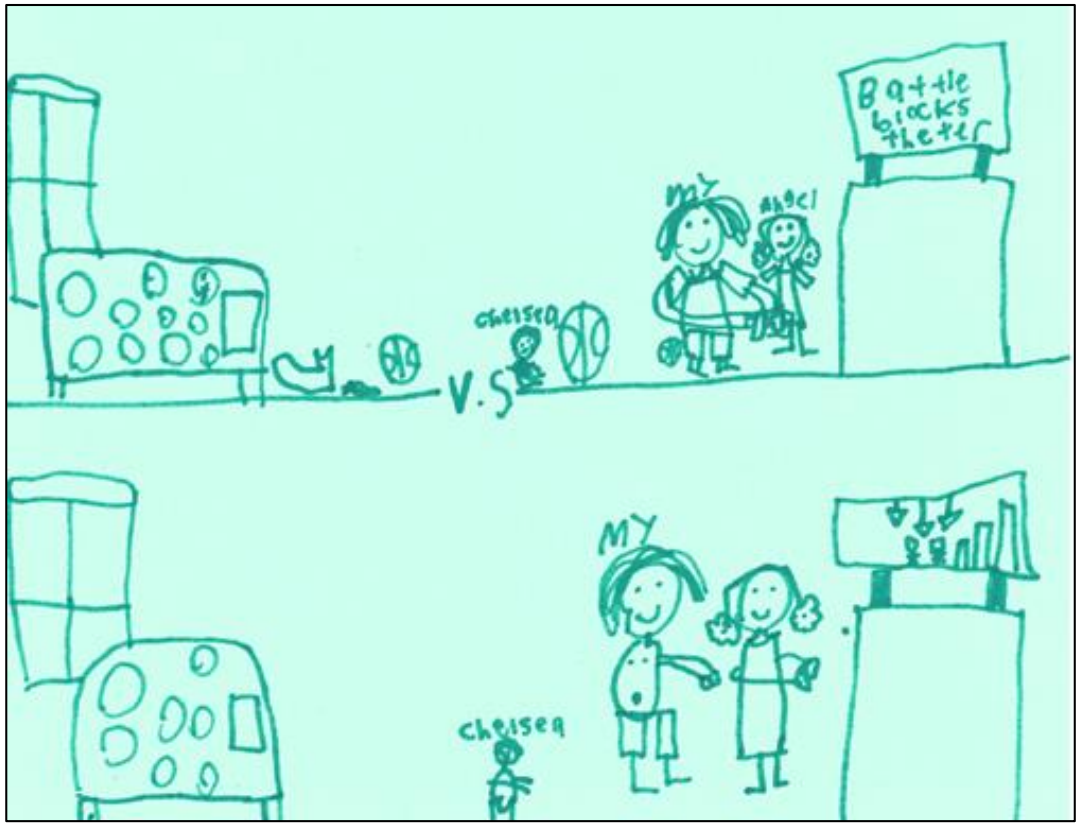
FINDINGS (cont.)

- *"Pets are outgoing so they like to run around a lot. And all the dirt from outside, it'll come inside and then it runs around and it (the dirt) can fly off from it (pets) and go in the air." (Participant C14)*
- *"When you open one window, don't you have pollutants come in it?" (Participant P5)*
- *"You should keep your space closed so that not everything can transfer from outside to inside." (Participant C8)*



Sketches of a bedroom (top) and a bathroom (bottom) where perceived air pollutants are marked with green color

FINDINGS: Practices to Improve Indoor Air Quality



Sketches of a bedroom with bad IAQ (top) and good IAQ (bottom): *"Air quality in my room gets bad when it is messy"* (Participant C12)

"If there's some stuff on the floor, you can pick it up and put it in the garbage." (Participant C3)

"If you don't wash the dishes it starts to have a smell to it." (Participant C1)

"If you don't wash your hands after you use the bathroom, you're going to get germs." (Participant C13)

"I use candles and air fresheners all the time, all day." (Participant P2)

CONCLUSIONS AND NEXT STEPS

- IAQ remains a critical health threat to low-income households and existing knowledge and interventions are insufficient for members of these households to take appropriate protective actions.
- Many existing solutions are top-down approaches – e.g., building codes and other forms of regulation, voluntary guidelines.
- Behavioral interventions would complement existing public policy solutions, but researchers and the design community, in particular, lack information for producing situationally appropriate interventions.
- The research team is writing an NSF grant and will look for other funding sources to develop a socio-technical system to help combat the detrimental health impacts of IAQ in low-income communities. This system will comprise an IAQ measurement device with intuitive output and instruction for remedial action with the reinforcing capabilities of a community-level organization, as informed by sensory perceptions and drawing inputs.

ENDNOTES

1. EPA, An Introduction to Indoor Air Quality, available from https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality, 2016
2. Dadvand, Payam, Mark J. Nieuwenhuijsen, Mikel Esnaola, Joan Forns, Xavier Basagaña, Mar Alvarez-Pedrerol, Ioar Rivas et al. "Green spaces and cognitive development in primary schoolchildren." Proceedings of the National Academy of Sciences 112, no. 26 (2015): 7937-7942.
3. Lin, Lian-Yu, Hsiao-Chi Chuang, I-Jung Liu, Hua-Wei Chen, and Kai-Jen Chuang. "Reducing indoor air pollution by air conditioning is associated with improvements in cardiovascular health among the general population." Science of the total environment 463 (2013): 176-181.
4. New Jersey Department of Environmental Protection, Air Quality Index Summary (2015), http://njaqinow.net/App_Files/2015/AQI%202015.pdf
5. New Jersey Department of Health, Asthma in New Jersey: Union County Asthma Profile (2014), http://www.nj.gov/health/fhs/chronic/documents/asthma_profiles/union.pdf

Integrating nature-based solutions with building design and evaluation

Adina Dumitru

Transforming cities into vibrant, sustainable and resilient living places has become a key global priority, reflected in numerous policy documents, city-to-city agreements (like the 100 Resilient Cities Rockefeller program), and the global sustainable development goals (www.undp.org), that calls for design and implementation of innovative solutions to tackle multiple and intertwined problems. Against this background, the idea of nature-based solutions has been proposed as a sustainable approach to support transitions to vibrant, healthy, resilient and sustainable futures in cities (UN, 2013). Cities are building blocks of various sizes, shapes and assets. In today's intensive, we will discuss how to integrate nature-based solutions interventions with healthy and resilient building design.

Nature-based solutions have been defined as "actions which are inspired by, supported by or copied from nature" (EC, 2015) and have recently emerged as one of the main policy drivers for transitioning cities for their potential to fulfil multiple, simultaneous objectives (Faivre et al 2017). Existing research has supported the view that nature-based solutions have the potential to simultaneously provide social, environmental and economic benefits (Haase et al., 2014), such as improved quality of life, physical and mental health (Kabisch et al 2017), social cohesion and well-being (Brink et al 2016), social interaction and supportive relationships among neighbors and a sense of belonging and place (Hartig et al., 2014; Sullivan, Kuo & de Pooter, 2004; Keniger et al., 2013; Gulsrud et al 2018).

However, research on their specific benefits is scarce and the evidence of the delivery of such multiple benefits by nature-based solutions is still rather fragmented (Brink et al 2016). Connecting Nature, a €12m five year project funded by the European Commission's Horizon 2020 Innovation Action Programme, aims to develop a reference framework for the design, implementation, and evaluation of nature-based solutions across Europe, through implementations across 11 European cities and comparative evaluation of their environmental, economic and social impacts. We wish to discuss further the challenges posed and describe the efforts to build a robust impact monitoring and evaluation framework for NBS in applications to buildings.

Nature-based solutions and building design for healthy and sustainable cities

Adina Dumitru
Director of the Sustainability Specialization Campus
University of A Coruña

Preconference Intensive: Humanizing Building Technology and Experience:
EDRA 50, Brooklyn, NYC

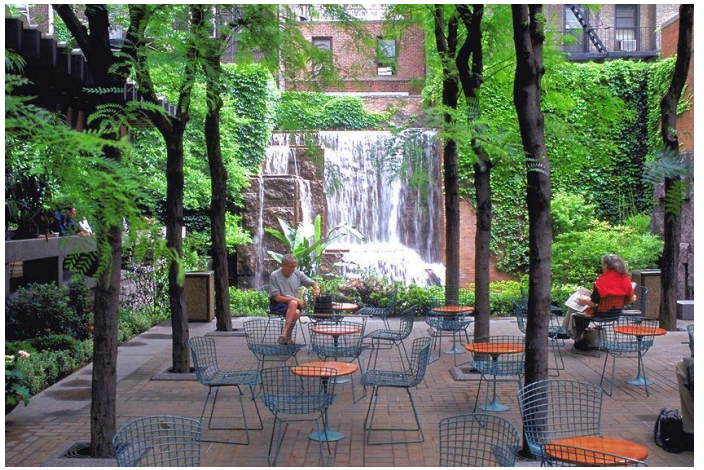
Bringing cities to life, **Bringing life into cities.**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730222

The concept of nature-based solutions

- “solutions that are inspired and supported by nature, which are cost-effective, simultaneously providing environmental, social and economic benefits and help build resilience”
- “…bring more diverse natural features and processes into cities, through locally adapted, resource efficient and systematic interventions”

European Commission, 2016



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Challenges we need to address

Climate change
Losses in biodiversity and key natural resources

Declining physical and mental health
Social polarization and inequality
Economic instability

How do we reinvent:

- Lifestyles and communities
- Infrastructures and technologies
- Governance of urban design
- Systems of consumption and production
- Economic models

¿to make transition to sustainable cities a reality?

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The Connecting Nature Project

- **32 partners:**

- 11+2 city councils: Genk, Glasgow, Poznan, A Coruña**,** Bologna, Burgas, Ioannina, Málaga, Nicosia, Pavlos Melas, Sarajevo, Yerevan, Tbilisi etc).
- 9 universities (University of A Coruña**,** University of East London, Erasmus University Rotterdam, Trinity College Dublin, Humboldt University etc).
- 9 SMEs

www.connectingnature.eu

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The Connecting Nature Project

- To demonstrate and implement nature-based solutions for a variety of urban problems
- To design, implement and manage these nature-based solutions through co-production and an open innovation ecosystem
- To provide the reference framework for urban regeneration through thorough monitoring and evaluation of their impacts
- To promote inter-city sharing and learning

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Monitoring and evaluation of NBS

- Develop and test a global Impact Monitoring and Assessment Reference Framework for the evaluation of NBS in global cities – that accounts for both outcome and process

- Innovative procedures for continuous data gathering and sharing among cities – develop a solid evidence base for NBS and stimulate inter-city learning

- Develop an online platform as a decision support tool, with robust, context-sensitive guidelines and examples of best practice – a structured way of thinking about and planning NBS

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Categories of impacts

1. Climate change adaptation and resilience (sustainable use of resources)
2. Health and wellbeing (physical and psychological)
3. Social Cohesion
4. Economic development potential
5. Green business opportunities

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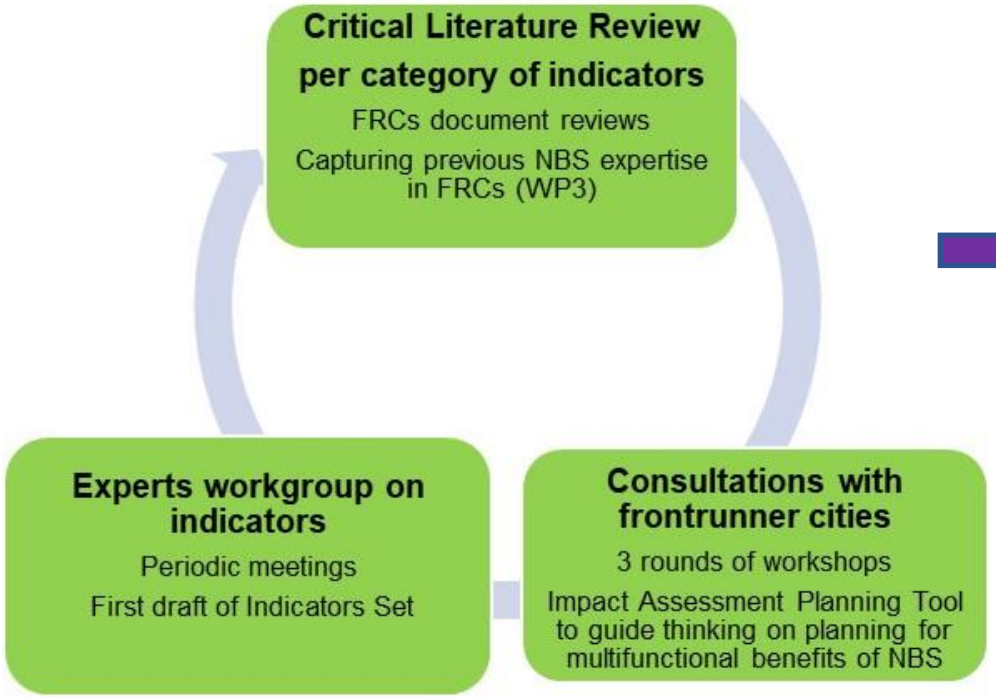
Co-producing evidence-based and city-relevant indicators



INDICATOR SET

Analyzing indicators in terms of: scalability; appropriateness to the case studies; alignment with FRC strategic planning documents; alignment with SDGs; prioritize those that capture multiple benefits where posible

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Health and wellbeing indicators

- Sustainable nutrition (adoption)
- Sustainable food production
- General Wellbeing and Happiness
- Life expectancy and Healthy life years expectancy
- Prevalence and incidence of chronic autoimmune diseases (AIDs)
- Prevalence, incidence, morbidity and mortality of cardiovascular diseases (CVDs)
- Prevalence, incidence, morbidity and mortality of respiratory illnesses and diseases (RIsDs)
- Incidence of obesity/obesity risks (adults and children)

- Heat reduced mortality
- Prevalence, incidence, morbidity of chronic stress
- Mental Health Wellbeing: Depression and Anxiety
- Restoration-Recreation: Enhanced physical activity and meaningful leisure
- Levels of aggresiveness and violence
- Improvement in behavioural development and symptoms of attention deficit/hyperactivity disorder (ADHD)
- Exploratory behavior in children

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Nature-based solutions, buildings and health

- Buildings as connectors of green spaces
- Indoor nature-based solutions: green roofs, green or edible walls, green living rooms
- The human experience indoors and outdoors: providing opportunities for physical activity, stress reduction and psychological restoration
- Building design as part of an urban regeneration, sustainability and human health agenda
- Blue-green spaces in and around buildings as multifunctional

- Understanding the influence of urban design on human behavior, and impacts on health and wellbeing – badly needed

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Developing I-APT

Impact Assessment Planning Tool for cities – to guide planning of NBS to meet city objectives; to embed monitoring and evaluation from the beginning; to guide knowledge transfer to fast-follower cities

European Dialogue on Nature-Based solutions in A Coruña

EU projects: CONNECTING NATURE, THINK NATURE, Urban GreenUP, GROWGREEN, UNALAB, PHUSICOS, ISOCARP y NAIAD

Organizations: United Nations Environment Program, the European Environment Agency, the European Platform of Construction Technology (ECTP), the Swedish Environmental Protection Agency, WWF.

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Connecting Nature

Thank you for your attention!

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4 Break Out Sessions

(1) How to measure human outcomes (health, including avoided health issues, productivity, etc.) in buildings non-intrusively;

(2) How to represent building information (environmental conditions, workplace functionality) to building occupants and create an effective feedback loop;

(3) How to design technologies, including Nature-based Solutions, that can impact human behavior to achieve collective objectives (e.g., energy savings, better indoor air quality, optimal lighting or thermal comfort), leveraging what we have learned via evidence-based design;

(4) How emerging technologies --low-cost sensors, wearable devices, and machine learning can enable healthy, sustainable, and inspiring buildings?

Breakout Groups to Address – Gaps in Knowledge

What don’t we know?

How can we know it?

Breakout Groups to Address – Other Resource Needs

e.g., Gaps in Collaboration? How to address this?

Gaps in Resource Needs? How to address?

Pitch Sessions (45 min)

Conclude your brainstorming session with a presentation of your findings and wish list as a proposal to a panel of judges! Winner gets treats from Spain!

Next Steps – Collective Summary