BUILD UP

The European portal for energy efficiency and renewable energy in buildings

WEBINAR


Book Launch
OCCUPANT-CENTRIC
SIMULATION-AIDED
BUILDING DESIGN
Speakers: William O'Brien, Philip Agee, Clinton Andrews,
Christiane Berger, Clarice Bleil De Souza, Isabella Gaetani,
Burak Gunay and Farhang Tahmasebi
20 June 2023
14:00 - 16:00 CET
BUILD UP
The European portal for energy efficiency
and renewable energy in buildings
Energy in Buildings and
Communities Programme
EBC
ROUTLEDGE

14:00 - 14:05 Introduction to webinar from *BUILD UP Team*
14:05 - 15:30 Presentations

Introduction	*Liam O'Brien*
Fundamentals of IEQ and occupant needs	*Christiane Berger*
Occupants in building design decision-making process	*Clarice Bleil De Souza*
Methods to obtain the occupant perspective	*Clinton Andrews*
Occupant-centric performance metrics and targets	*Liam O'Brien*
Questions and answers	
Introduction to occupant modelling	*Liam O'Brien*
Fit-for-purpose occupant modelling	*Isabella Gaetani*
Simulation methods for occupant-centric building design	*Farhang Tahmasebi*
Building interfaces: Design & considerations for simulation	*Philip Agee*
Design of sequences of operation for occupant-centric controls	*Burak Gunay*
Detailed case studies	*Liam O'Brien*

15:30 - 15:55 Questions and discussion
Moderated by Clarice, Liam, Farhang

15:55 - 16:00 Thank you from *BUILD UP Team*

Introduction

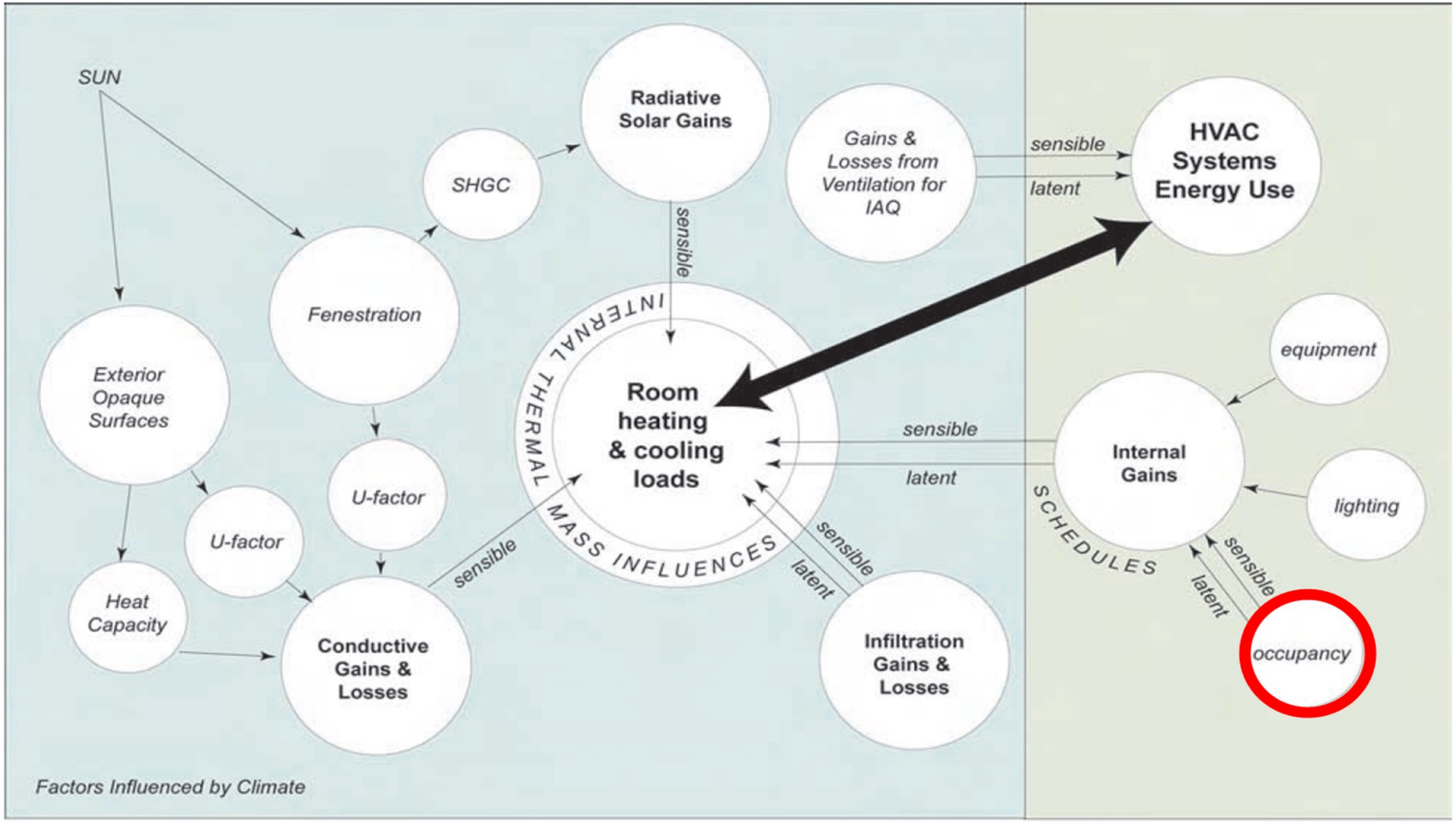
William O’Brien

Carleton University

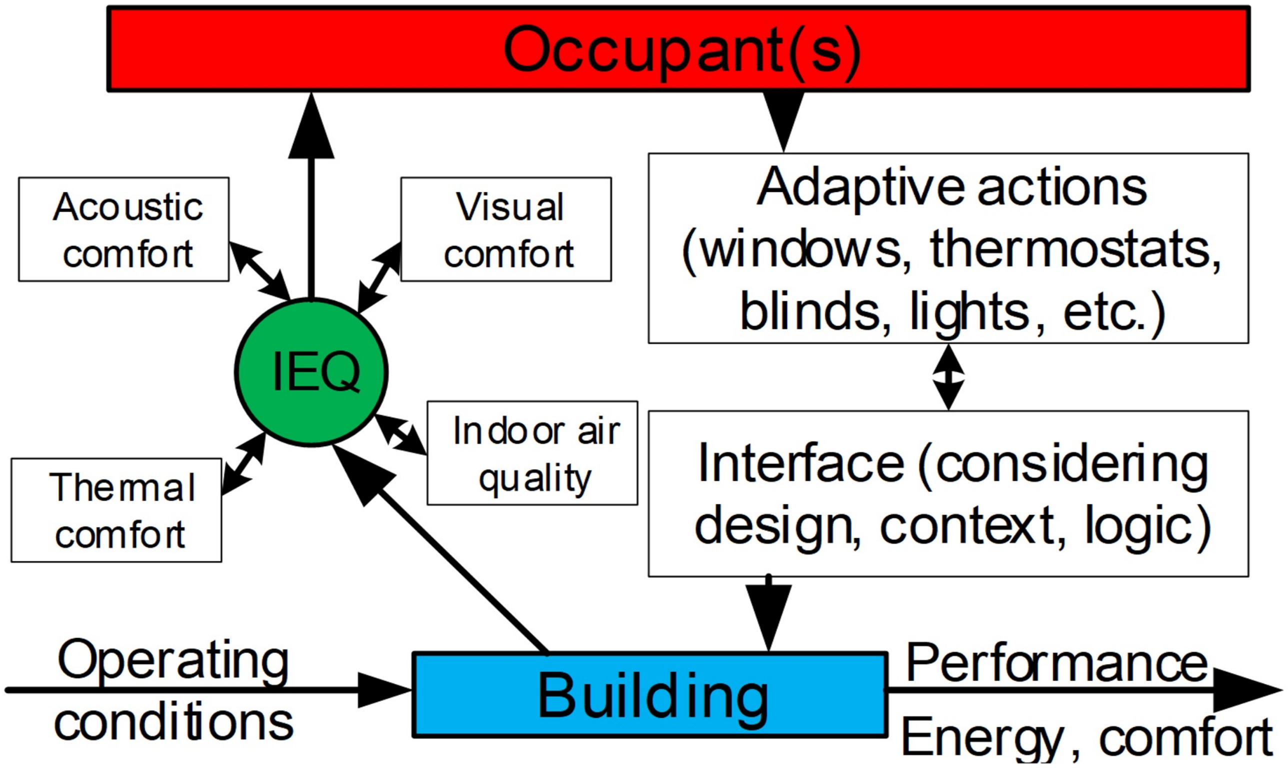
Motivation

- Current design approaches are remarkably void of occupants
- Tremendous uncertainty about occupants ⇨ “performance gap”
- Common solution: take adaptive opportunities/affordances away from occupants

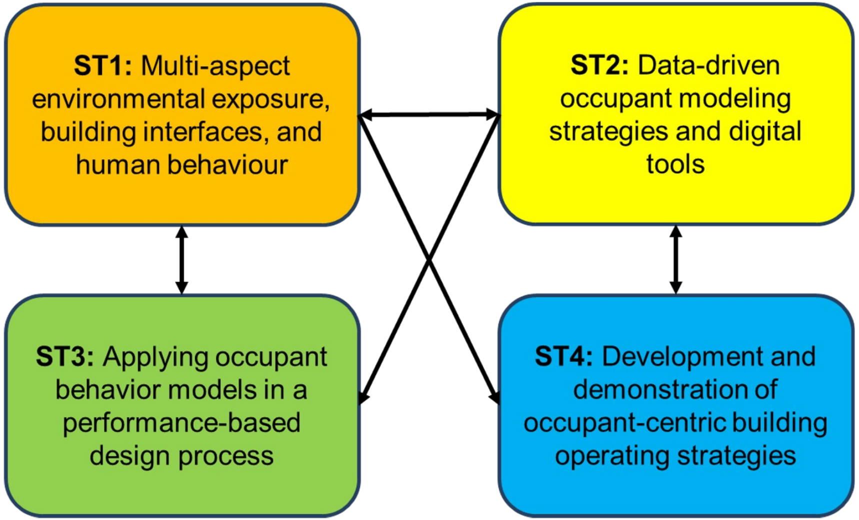
Motivation


SUN
SHGC
Radiative Solar Gains
Gains & Losses from Ventilation for IAQ
sensible
latent
HVAC Systems Energy Use
Fenestration
Exterior Opaque Surfaces
sensible
INTERNAL THERMAL MASS INFLUENCES
Room heating & cooling loads
equipment
sensible
latent
Internal Gains
U-factor
U-factor
lighting
SCHEDULES
Heat Capacity
sensible
sensible
latent
sensible
latent
Conductive Gains & Losses
Infiltration Gains & Losses
occupancy
Factors Influenced by Climate

Motivation

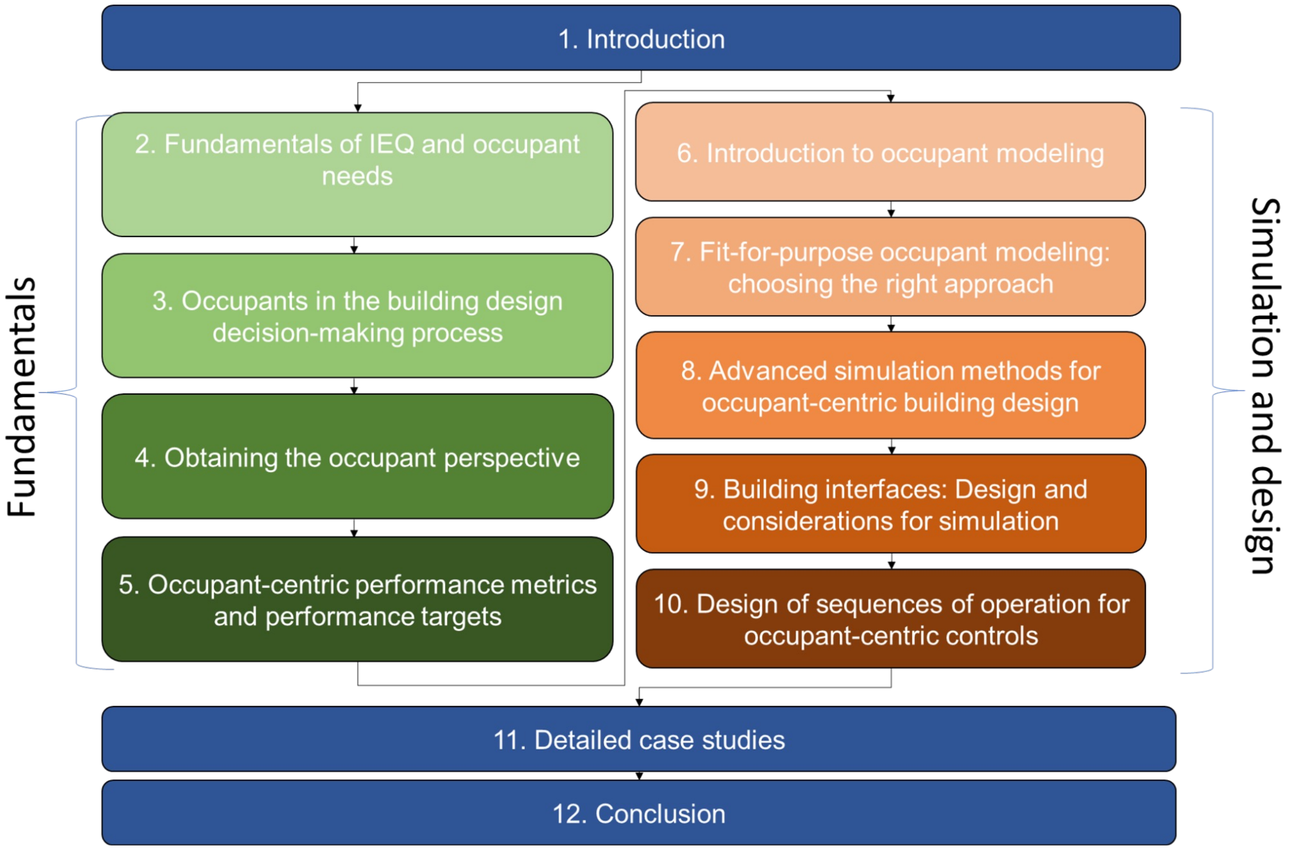

Occupant(s)
Acoustic comfort
Visual comfort
Adaptive actions (windows, thermostats, blinds, lights, etc.)
IEQ
Indoor air quality
Thermal comfort
Interface (considering design, context, logic)
Operating conditions
Building
Performance
Energy, comfort

IEA EBC Annex 79: Occupant-centric design and operation (2018-23)



Aachen, Germany
June 9-10, 2023

Structure



1. Introduction
2. Fundamentals of IEQ and occupant needs
3. Occupants in the building design decision-making process
4. Obtaining the occupant perspective
5. Occupant-centric performance metrics and performance targets
Fundamentals
6. Introduction to occupant modeling
7. Fit-for-purpose occupant modeling: choosing the right approach
8. Advanced simulation methods for occupant-centric building design
9. Building interfaces: Design and considerations for simulation
10. Design of sequences of operation for occupant-centric controls
Simulation and design
11. Detailed case studies
12. Conclusion

Fundamentals of Indoor Environmental Quality and Occupant Needs

Christiane Berger

Aalborg University

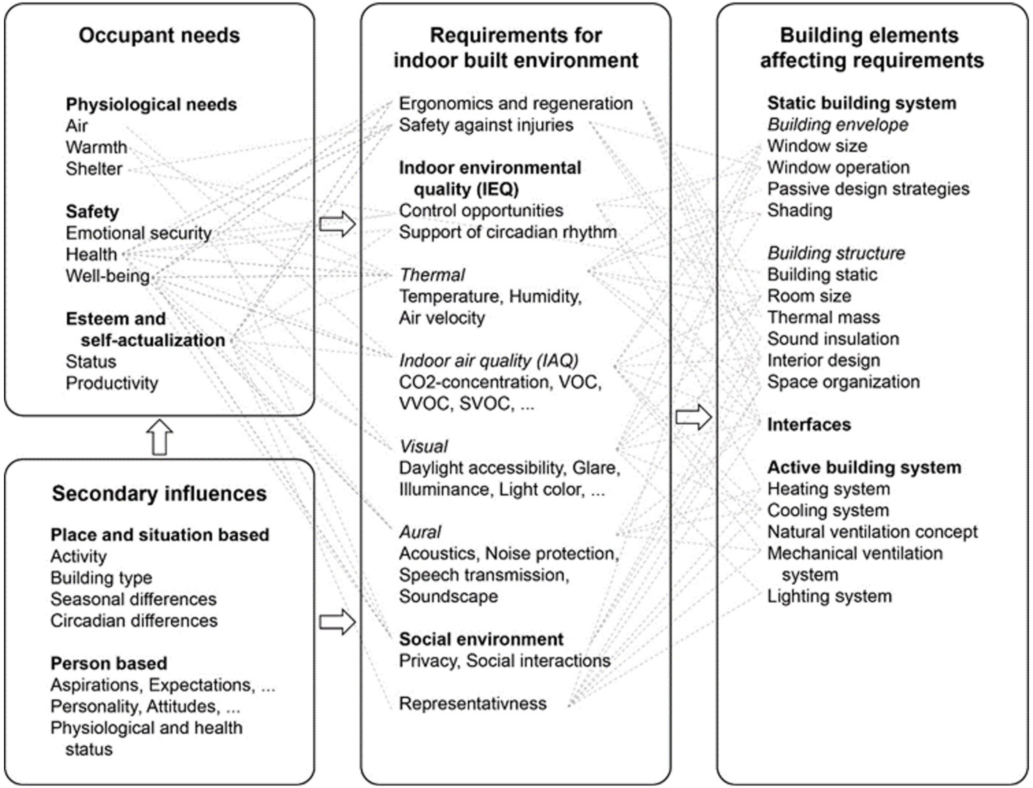
Fundamentals of IEQ and Occupant Needs

… fundamental understanding of the relationship between the built environment and occupants' needs for health, well-being, and productivity

- Introduction
- The human being in a built environment: Fundamentals and theories
- Common practices regarding specification of IEQ
- Ongoing work and open questions
- Conclusions and outlook

Fundamentals of IEQ and Occupant Needs

The human being in a built environment: Fundamentals and theories

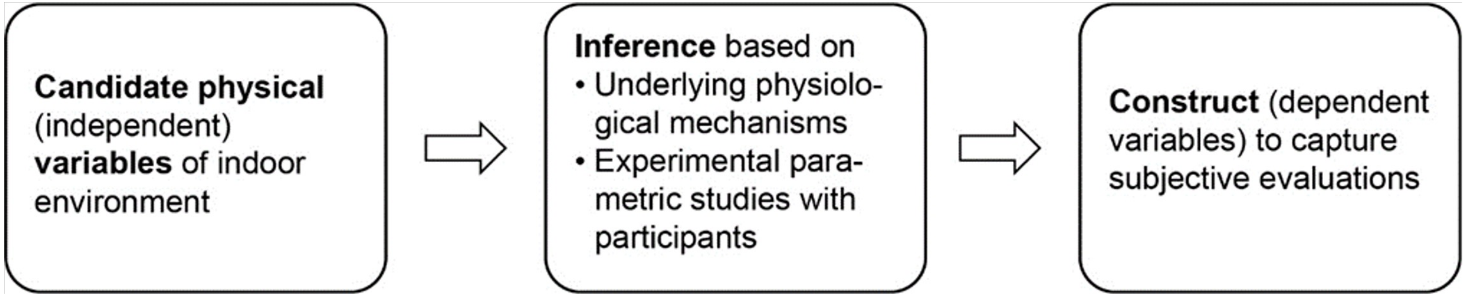


Fundamentals of IEQ and Occupant Needs

Common practices regarding specification of IEQ

- IEQ codes, standards, and guidelines represent the main reference source for professionals and stakeholders

- Comfort equations:



Fundamentals of IEQ and Occupant Needs

Ongoing work and open questions

- Adaptive Thermal Comfort, Perceived Control, and Personalized Control
- Energy, IEQ, and the Human-Building Interactions
- Interaction among IEQ domains and other factors

Occupants in Building Design Decision-making Process

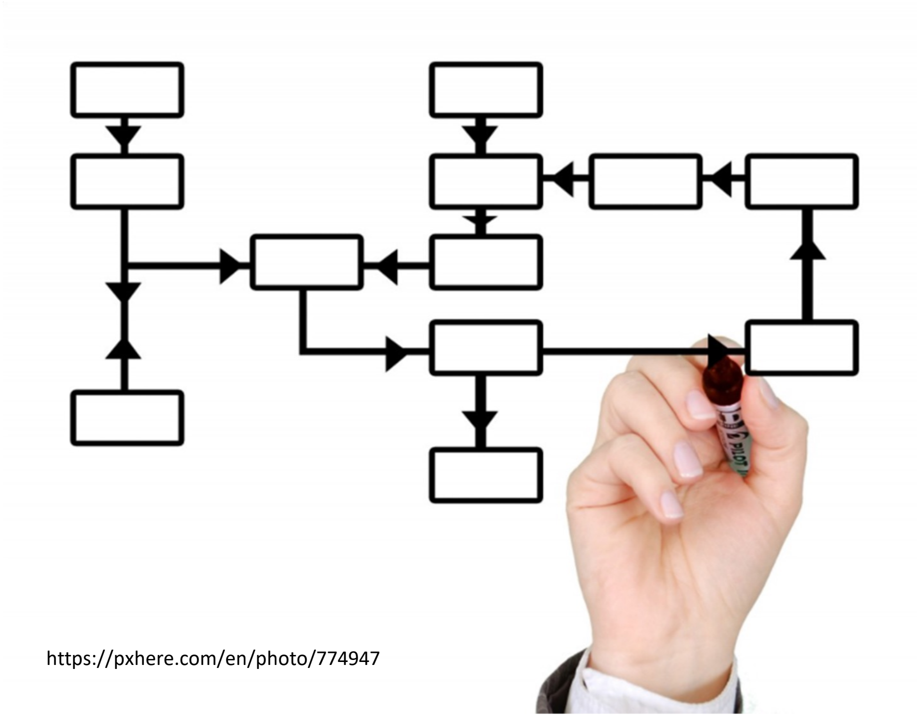
Clarice Bleil De Souza
Cardiff University

Occupants in the Building Design Decision-making Process

Overarching Principle

Occupant considerations must be formally integrated into building information management systems !

Practice is a complex process of exchanging information *timely* between different team members and disciplines



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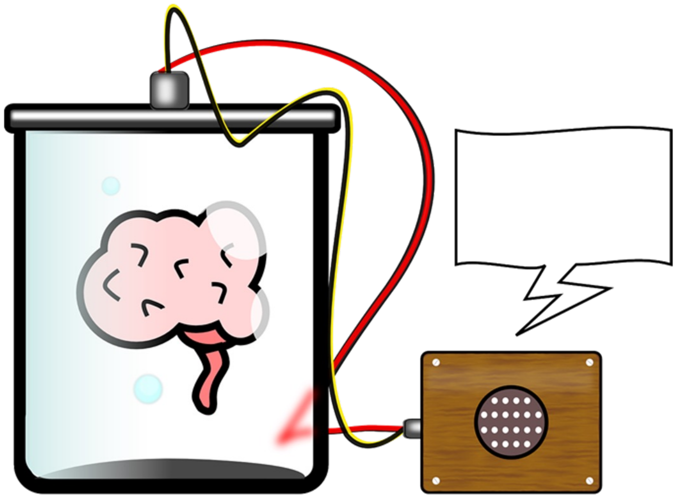
Occupants in the Building Design Decision-making Process

Design decisions on occupants within built spaces

- Constraints
- Persuasive strategies
- Affordances
- Adaptive opportunities

https://pixabay.com/illustrations/house-home-lock-residence-chains-5560582/



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Occupants in the Building Design Decision-making Process

Decisions affecting or affected by occupants

Decisions undertaken in relation to 'Construction entities' and 'Built spaces'	Examples of design aims/requirements/considerations/decisions		
	Effects / effects of occupant *within* the building	Effects / effects of occupants *with* the building	Effects / effects of occupants *with environment*
Building form and volume	Convey a sense of place; Display the status of the building owner;	Create exhilarating spaces; Ensure the feeling of 'coziness'; Minimize heating/cooling costs of the building;	Help shaping the street; Configure outdoor courtyards; Integrated with landscape;
Building footprint on site & orientation	Provide places for children to play in the sun; Shape secluded spaces for people to interact outdoors and with each other;	Provide clarity of access; Create useful outdoor spaces integrated with the street;	Minimize environmental impact on the site; Protect from solar overheating; Low impact on neighbors' right of light and sun; Take advantage of cooling breezes;
Program distribution & orientation	Allow for flexibility in separating or joining rooms; Consider public / private interactions;	Relationship of noisy/ quiet, day / night spaces (isolate the bedrooms from the living area); Orientate spaces with regards to heating and cooling needs;	Provide daylight, natural ventilation, and view to the outside for main living spaces; Enable patients to see the day go by; Enable visual contact with nature;
Form and area of building spaces	Provide office workers appropriate visual / aural contact with each other (open plan cellular / offices); Mix of functions (e.g., bar, dance space and seating);	Efficient and clear circulation inside the building (functionality, escape and evacuation routes etc.); Spaces support functions;	Provide sense of connection to outside (shallow office spaces); Admit sun in the bedrooms in the mornings;
Fire & evacuation routes	Safe evacuation of building occupants	Provide safe route to the outside; Clarity on emergency access;	Provide required access to external services (e.g., emergency vehicles, hydrants)
Floor to ceiling heights	Convey status; Provide views from the top (mezzanine);	Improving sound dispersion; Manage overheating (stratification);	Improve daylighting and sky view (large glazing); Facilitate segregated natural ventilation (e.g., above the occupant);
Heating & cooling system choice	Consider running costs for the client; Charge energy bills at room level (e.g., care homes);	Position systems to minimize furniture disruption; Reduce response time on conditioning the building; Consider passive heating and cooling strategies; Shift peak demand in relation to energy tariff;	Minimize Greenhouse Gas emissions; Consider low energy technologies (e.g., heat pumps); Consider heat release and noise affecting pedestrians or outdoor recreation areas;
Heating & cooling system demand	Ensure thermal comfort for occupants, either working or not in the building (e.g., doctors and patients in hospital)	Ensure temperatures / humidity suitable for building contents; Provision of 'thermal delight'	Minimize demands by taking advantage of the climate;
Cooking system choice	Appropriate to occupant's lifestyle (food type)	Appropriate ventilation system and cooking facility	Consider environmental impact of fuel
Hot water system choice	Appropriate to occupant's lifestyle (e.g., run a bath and do the dishes at the same time);	Correct system sizing;	Consider low energy technologies (e.g., solar hot water);
Ventilation system choice & demand	Consider the different types of activities; Consider number of occupants & type of occupancy;	Consider occupant preferences (e.g., opening windows, HVAC, ceiling fans)	Consider natural/hybrid ventilation; Avoid outdoor noise; Filter outdoor air pollutants;
Heating, Cooling and Ventilation control type	Consider shared or individual control; Consider providing individual control;	Consider 'intelligent' controls; Controls appropriate to occupants (e.g., elderly, children); Appropriate to system type; Control customized to activity;	Provide climate responsive/efficient controls (temperature sensors Daylight responsive control;

Occupants in the Building Design Decision-making Process

Occupant-centric decisions in context

Index	Index or code to store the proposed pattern in a database for retrieval into a BIM environment. Index could refer to building type, design actions, analytical methods, climate, type of human / building / environment relationship etc.
Occupant-centric design pattern **name**	Name should clearly reflect the abstract problem-solution pair and can refer to building typology, specific design actions, design goals to be addressed, analytical methods, outputs required, type of human / building / environment relationship etc.
Introduction	Situates the pattern in its design context and describes how it related to occupants.
Problem	A brief outline of the problem addressed by the pattern, including the aims of the design decision(s) to be undertaken.
Context and examples	Situates the use of the pattern in relation to occupancy, simulation, and design practice, explaining the context of the decision(s) to be undertaken by designers and providing examples. Information (e.g., on theory or practice) is provided that justify the advice given by the pattern.
Solution	A description of the occupancy models and simulation methods that will produce the information required by the designers with an indication of what BIM objects can affect or be affected by it
Pattern elements	Describes the simulation details (aim of simulation, model settings: simulation and occupancy, processing and analysis methods, simulation outputs, required user interaction with outputs)
Further modelling details	Further notes on modelling.
Interpretation and Quality Assurance	Instructs the designers on how to interpret results, what to expect from results and why, and which quality assurance patterns to use.
Further patterns	Information on other patterns that may potentially be relevant
Comments and further development	Further comments and observations for pattern development

Occupants in the Building Design Decision-making Process

Occupant-centric design patterns

Introduction	Low energy co-housing can provide a sustainable solution for affordable housing for low-income occupants. The requirements of this building type are low running costs and some shared rooms and facilities. A participatory design process is used to inform details of occupancy schedules for the project at hand as well as obtaining feedback on the design from its future occupants. This pattern is used to reduce energy demand and energy costs to occupants. It is a sub-pattern of the class 'Effect on thermal performance of occupants' and is used to test the effects on thermal performance of a range of building occupation schedules that can result from the variety of employment conditions that typical inhabitants may expect to encounter. It provides simulation output information that should more accurately reflect actual heating, cooling and ancillary energy use and therefore help address the 'performance gap' between simulation results and buildings in-use, which in turn can support decision making on heating, cooling and renewable energy system sizing. The pattern also affords custom inputs to schedules based on the availability of survey data. Such data can also be used to inform design decisions on shared building facilities. The pattern is intended to be used at a detailed design stage when the construction and form of the building are known. Earlier patterns are mainly from classes including 'low energy housing' in their titles (list of related patterns *here*). If used at an early stage, building defaults are selected.
Problem	The problem here is to provide a range of occupancy schedules that describe the effect on thermal loads of differing occupancy patterns and to allow data input of survey results where available. There will be a measure of uncertainty concerning occupant behavior and it is part of the aim to inform the designer of this in the presentation of results.
Context and examples	Example 1: Apartment building in Budapest, Hungary. This research examined the effect of different occupancy profiles on heating and cooling loads (details *here*) 

Index	***# (#Building occupants, #low energy buildings, #heat load, #cooling load, #plug loads)***	
Occupant-centric design pattern **name**	***Effect on building energy use of occupants in low energy co-housing apartment building***	
Introduction	Low energy co-housing can provide a sustainable solution for affordable housing for low-income occupants. The requirements of this building type are low running costs and some shared rooms and facilities. A participatory design process is used to inform details of occupancy schedules for the project at hand as well as obtaining feedback on the design from its future occupants. This pattern is used to reduce energy demand and energy costs to occupants. It is a sub-pattern of the class 'Effect on thermal performance of occupants' and is used to test the effects on thermal performance of a range of building occupation schedules that can result from the variety of employment conditions that typical inhabitants may expect to encounter. It provides simulation output information that should more accurately reflect actual heating, cooling and ancillary energy use and therefore help address the 'performance gap' between simulation results and buildings in-use, which in turn can support decision making on heating, cooling and renewable energy system sizing. The pattern also affords custom inputs to schedules based on the availability of survey data. Such data can also be used to inform design decisions on shared building facilities. The pattern is intended to be used at a detailed design stage when the construction and form of the building are known. Earlier patterns are mainly from classes including 'low energy housing' in their titles (list of related patterns *here*). If used at an early stage, building defaults are selected.	
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Context and examples	Example 1: Apartment building in Budapest, Hungary. This research examined the effect of different occupancy profiles on heating and cooling loads (details *here*) 	
Solution	ASHRAE, UK NMC and French Th-BCE 2012 schedules plus co-design informed ('active', 'passive' and weighted average) schedules are used in the simulations to provide information on magnitude and variance of heating, cooling, and plug loads in each apartment or zone. Model variants are simulated using a full hourly weather file (TMY and climate change scenarios).	
Pattern elements	Aims	- To inform the designer of effect on performance metrics of uncertainty in occupancy schedules. This information contributes to a robust design. - To be able to compare performance metrics for heating and cooling energy use for different occupancy schedules that are automatically run and/or defined by the designer
	Model settings	- 'Construction entity' = Whole building - 'Construction elements' and 'Construction properties' (discrete) = combination of designer defined and defaults for built spaces & their respective services (e.g., plant ideal load in early stages with detailed plant in later stages) - Climate file: full year (hourly) - Operation parameters = designer defined + defaults - Occupancy schedules: ASHRAE, UK NMC and French Th-BCE 2012, custom co-design
	Processing & analysis	- Full year simulation - Comparative assessment of each metric across models - Metric 1: heating load (kW) - Metric 2: cooling load (kW) - Metric 3: heating energy (kWh) - Metric 4: cooling energy (kWh)
	Outputs	*Overview:* - Time series: occupant heat loads all profiles (W/person) - Bar chart: annual heat energy all profiles (kWh) - Bar chart: annual cooling energy all profiles (kWh) - Time series: typical summer day occupant heat loads - all profiles, cooling load - all profiles
	Interaction with model & outputs	*Interaction afforded:* Zoom in location and time. *Designer can select:* individual space, occupant profile. *Outputs afforded:* as for Overview (see above)
Further Modelling Details	- Surrounding buildings should be modelled	
Interpretation and Quality Assurance	- Advice on heating and cooling load interpretation - Record of operational model settings (ventilation rates, internal gains, occupancy profiles)	
Further patterns	Follow-up patterns include detailed design patterns for HVAC design and/or specific gbXML model of occupant interaction with the building or its systems (e.g., # Opening windows to avoid overheating)	
Comments and further development	An 'early design stage' version of this pattern could use a massing model and small range of default building constructions and parameters to give indicative figures on heating and cooling load variance	

Occupants in the Building Design Decision-making Process

Occupant-centric design patterns

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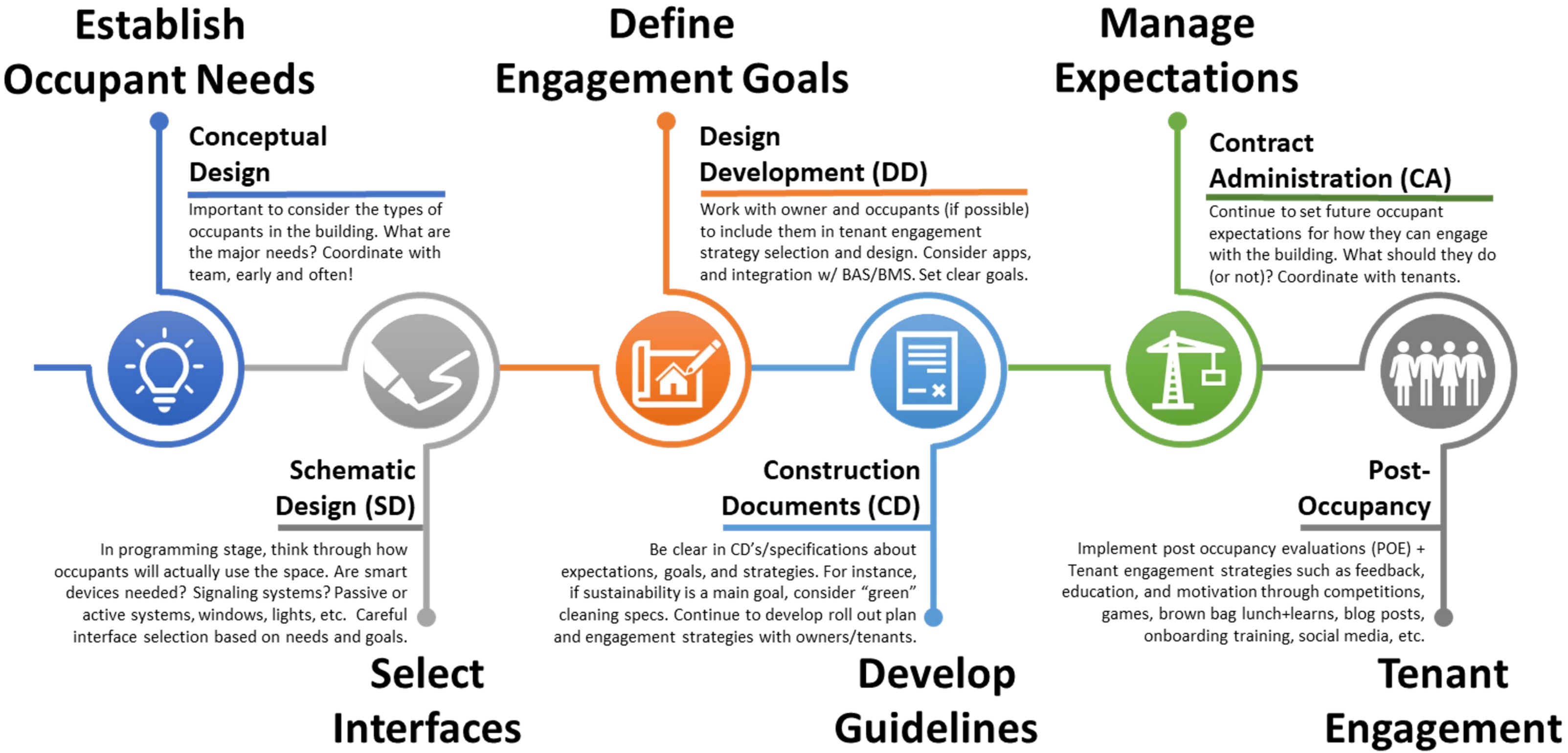
Methods to Obtain the Occupant Perspective

Clinton Andrews

Rutgers University

Methods to Obtain the Occupant Perspective: Life Cycle Needs



Methods to Obtain the Occupant Perspective: Nature of Occupant data

- Objective evidence: occupancy patterns, measuring indoor conditions, tracking occupants' adaptive responses, measuring physiological effects
- Subjective evidence: occupant perceptions of comfort, control & satisfaction; expressed preferences, mental models of systems

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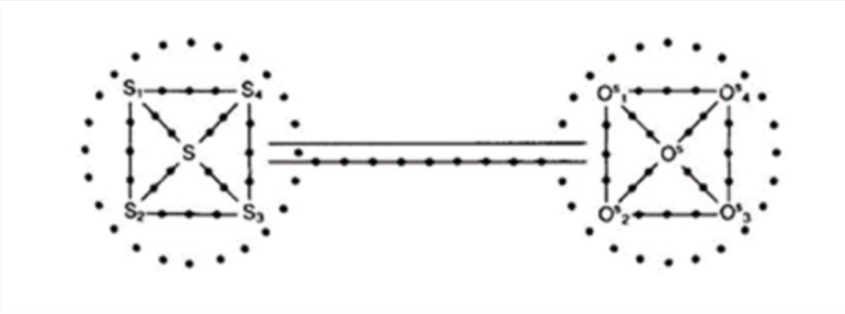
Methods to Obtain the Occupant Perspective: Challenges

Problem: Both subject (researcher) & object of study (occupant) are people subject to social forces

Solutions:

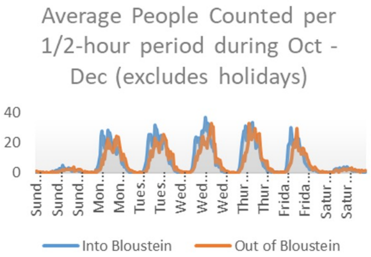
- Be humble regarding what experts assume they know about people
- Acknowledge objective agreement on material facts of the physical world
- Let people speak for themselves
- Study people in their physical context

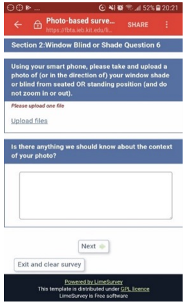


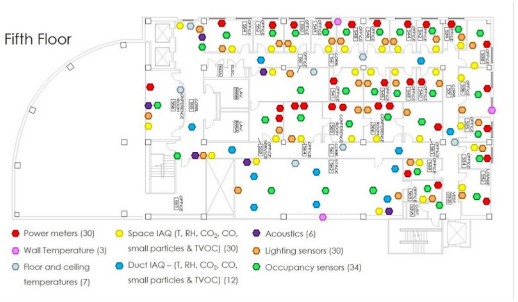
Sayer, A., 2010. *Method in Social Science: A Realist Approach*. Revised second edition. London: Routledge.
https://en.wikipedia.org/?title=Stereotype#/media/File:18th_century_ethnography.jpg

Methods to Obtain the Occupant Perspective: Uses, Strengths, Weaknesses

Self-reported & self-engaged methods	Observational & simulation methods
Interviews	Direct
Focus groups	Photography: still & time lapse, video
Charrettes	Occupancy & flow counters
Virtual reality (visualization, auralization, etc.)	CO2 and IAQ (building) sensors
Questionnaires	BMS logs
Diaries (traditional)	Occupant Behavior Models
Ecological Momentary Assessments	Digital Twins
Social Media Posts, Individual Sensing (posts)	Affinity Diagram



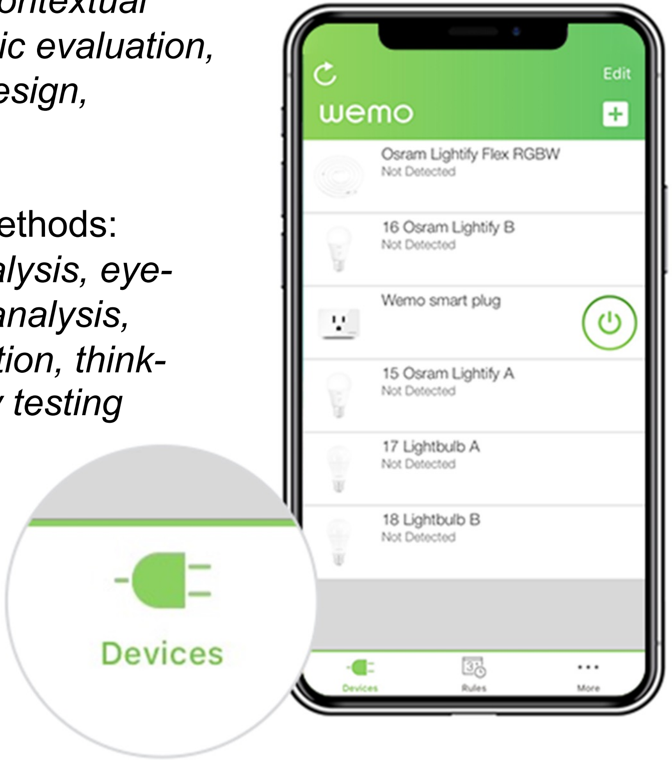




Methods to Obtain the Occupant Perspective: Interface Design

Qualitative methods: *Affinity diagramming, cognitive walkthrough, contextual inquiry, heuristic evaluation, participatory design, personas*

Quantitative methods: *Ergonomic analysis, eye-tracking, task analysis, function allocation, think-aloud, usability testing*



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https://www.belkin.com/us/support-article?articleNum=229104

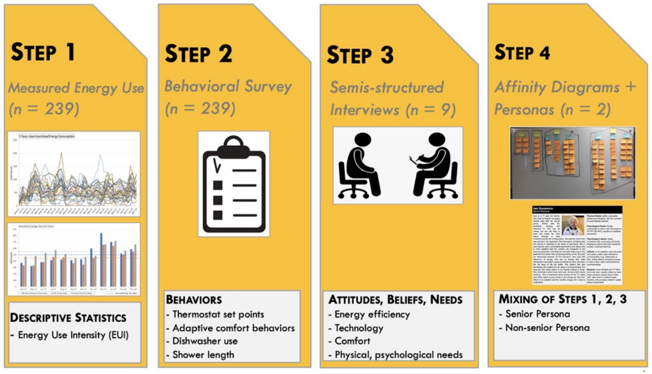
Methods to Obtain the Occupant Perspective: Final Thoughts

Managing the occupant-professional relationship

- **Philosophy of control** (local vs centralized)
- **Usability** (comprehensible, efficient, effective?)
- **Which occupants?** (from other buildings vs based on standards or client perceptions)
- **Whose data?** (building owner/operator vs citizen science)

Data Reduction Strategies

- **Statistical data reduction**
  - Central tendency, Dispersion
- **Personas**
  - Ideological types
  - Behavioral clusters
  - Preference profiles



Conclusions:

- Valuable
- Feasible

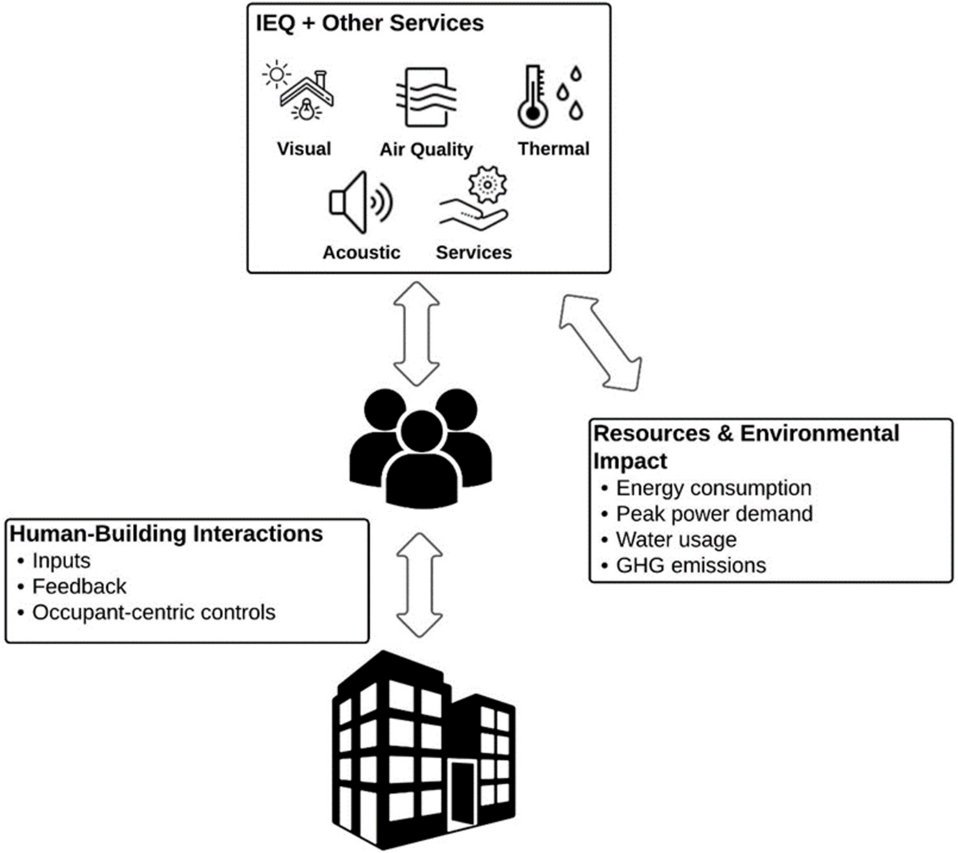
Occupant-centric Performance Metrics and Performance Targets

William O'Brien

Carleton University

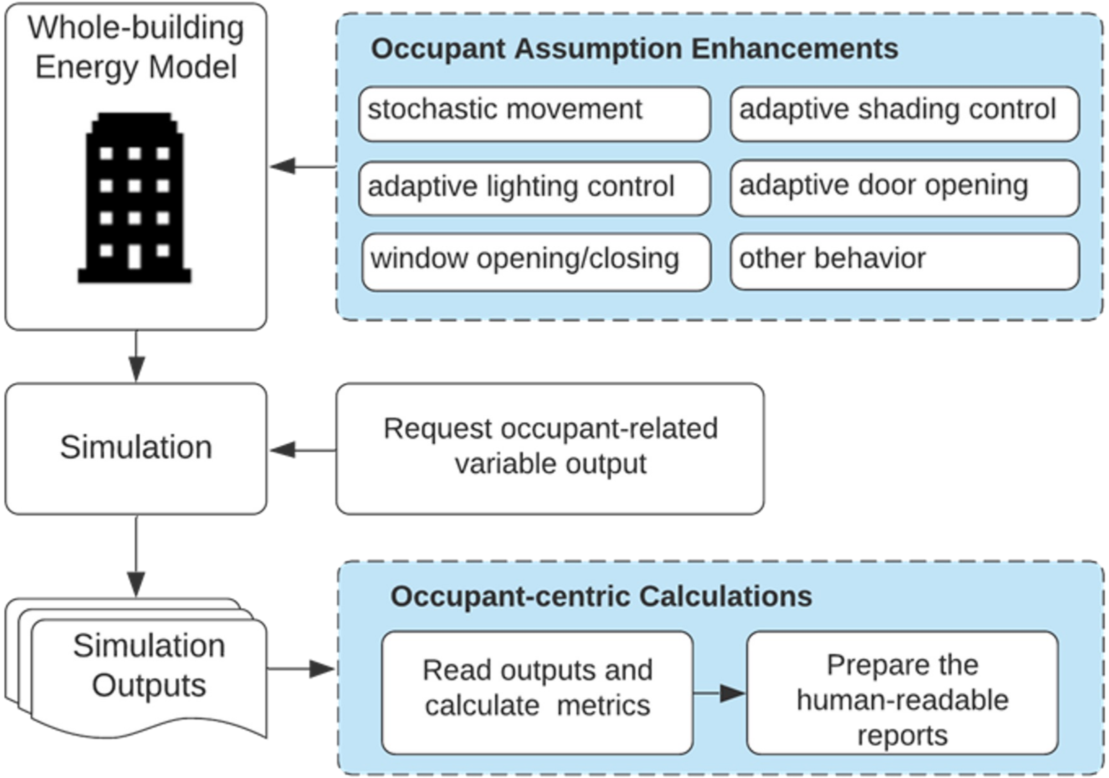
Occupant-centric Performance Metrics and Performance Targets

Occupant-centric metrics reframe building performance to be all about occupants (e.g., normalization of energy use by occupants)

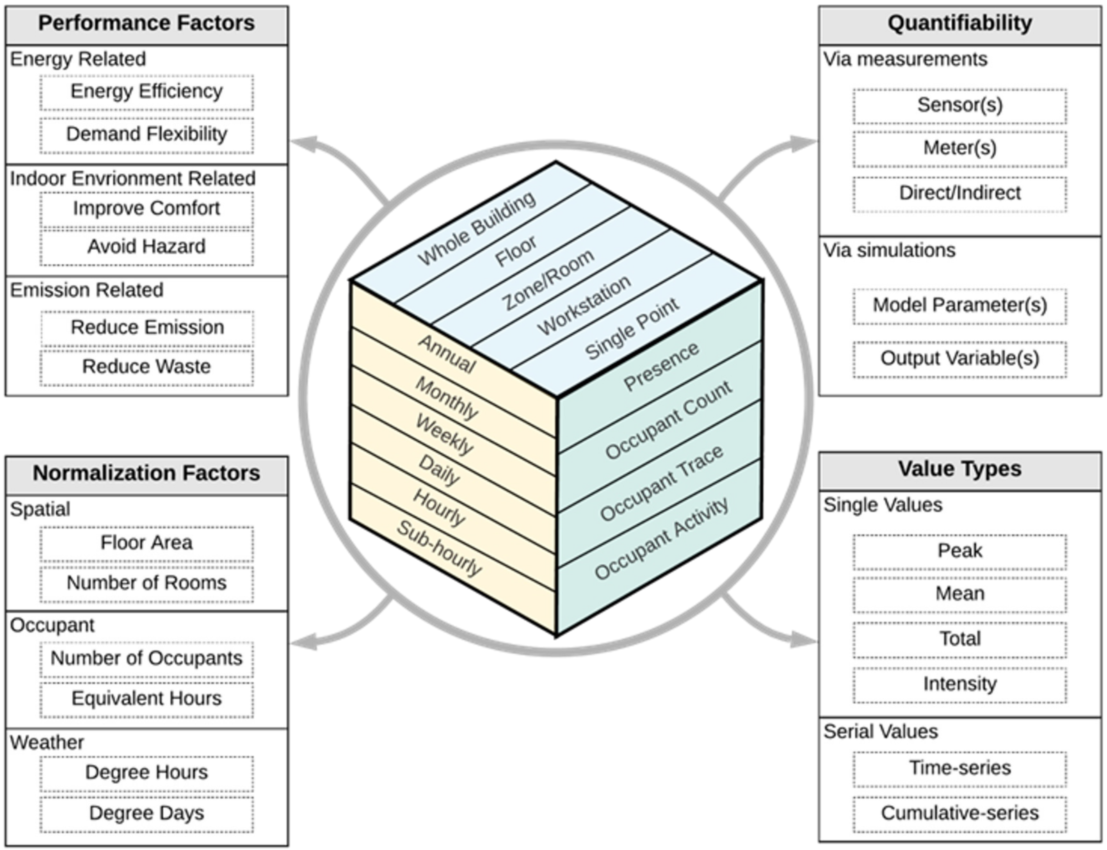


Occupant-centric Performance Metrics and Performance Targets

Occupant-centric metrics have never been easier to model or measure

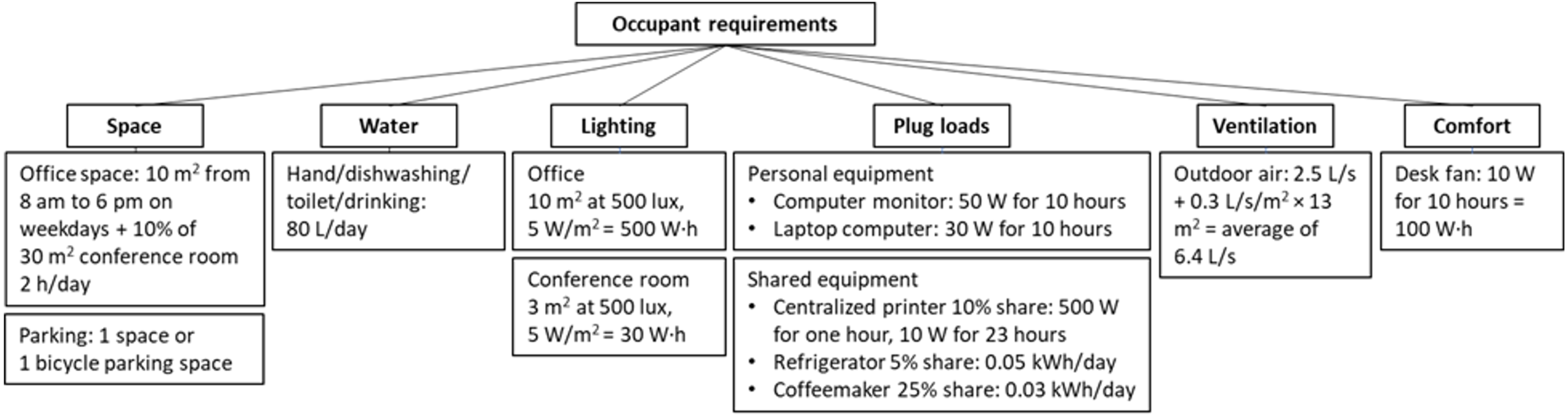


Occupant-centric Performance Metrics and Performance Targets



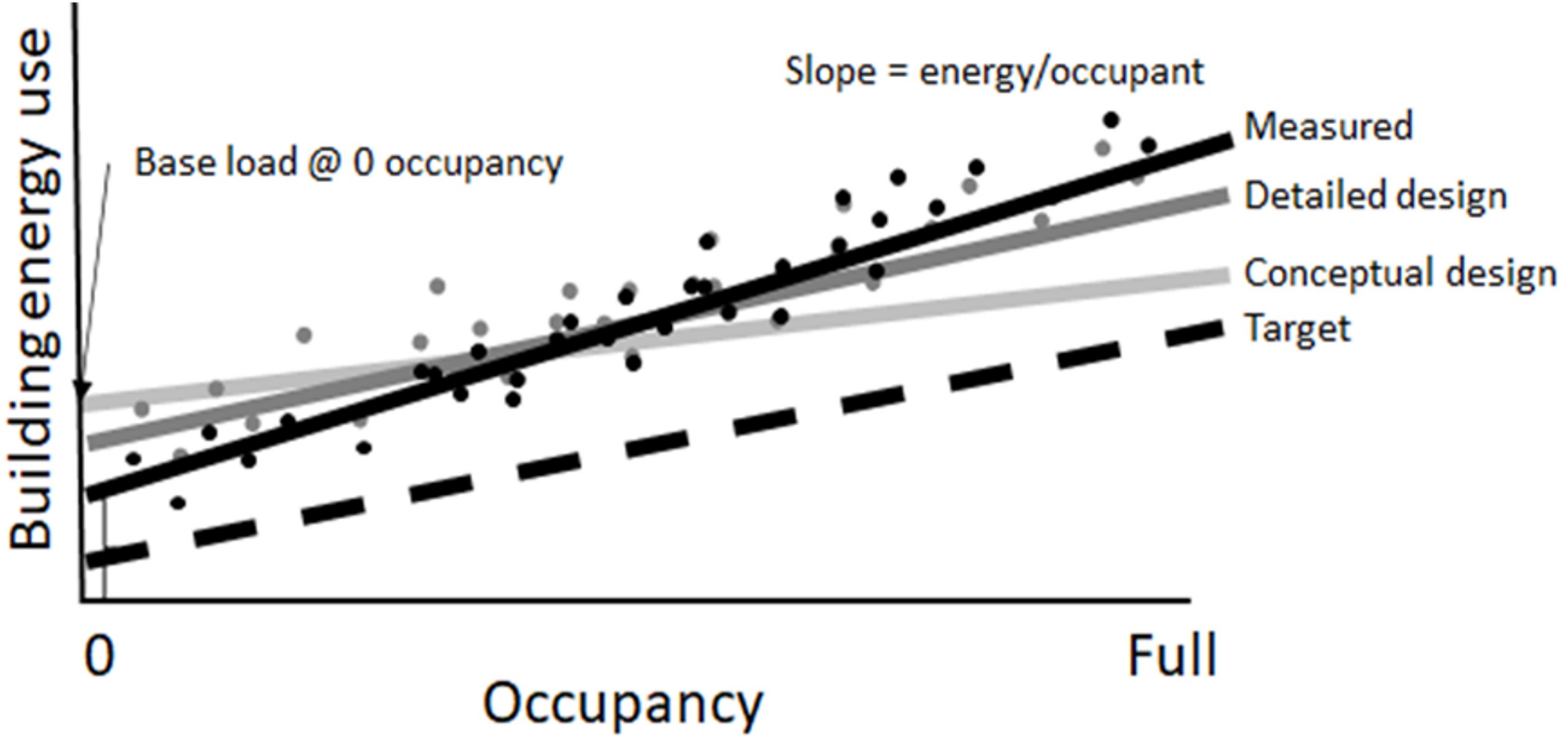
Occupant-centric Performance Metrics and Performance Targets

Bottom-up approach



Occupant-centric Performance Metrics and Performance Targets

Top-down approach



Questions and Answers

Introduction to Occupant Modelling

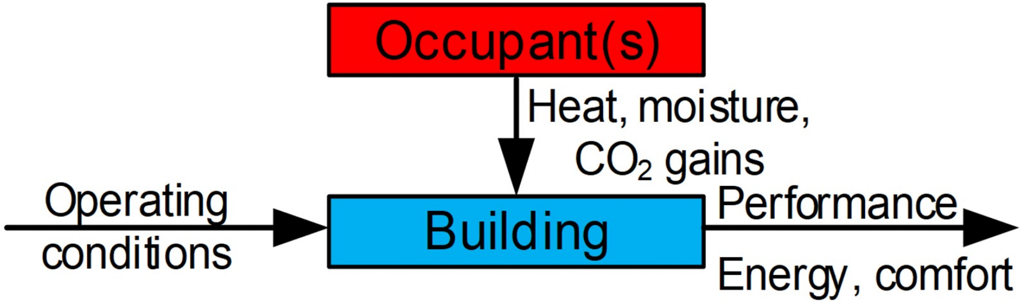
William O'Brien

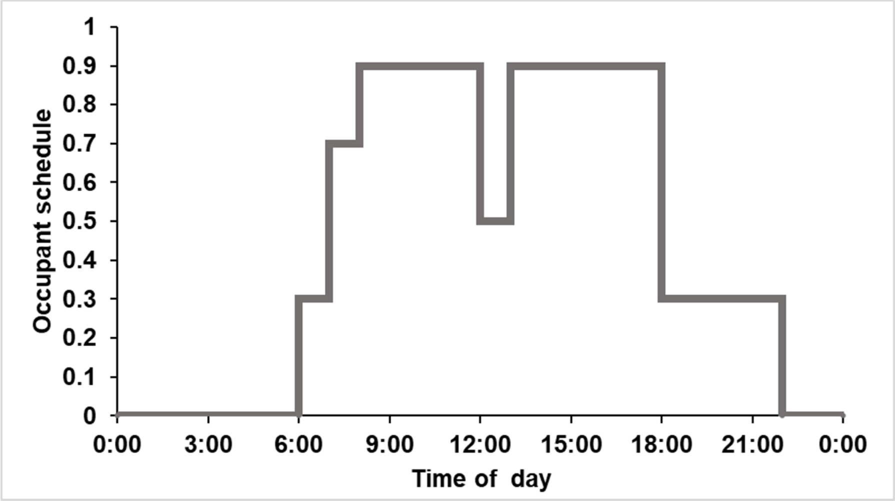
Carleton University

Introduction to Occupant Modelling

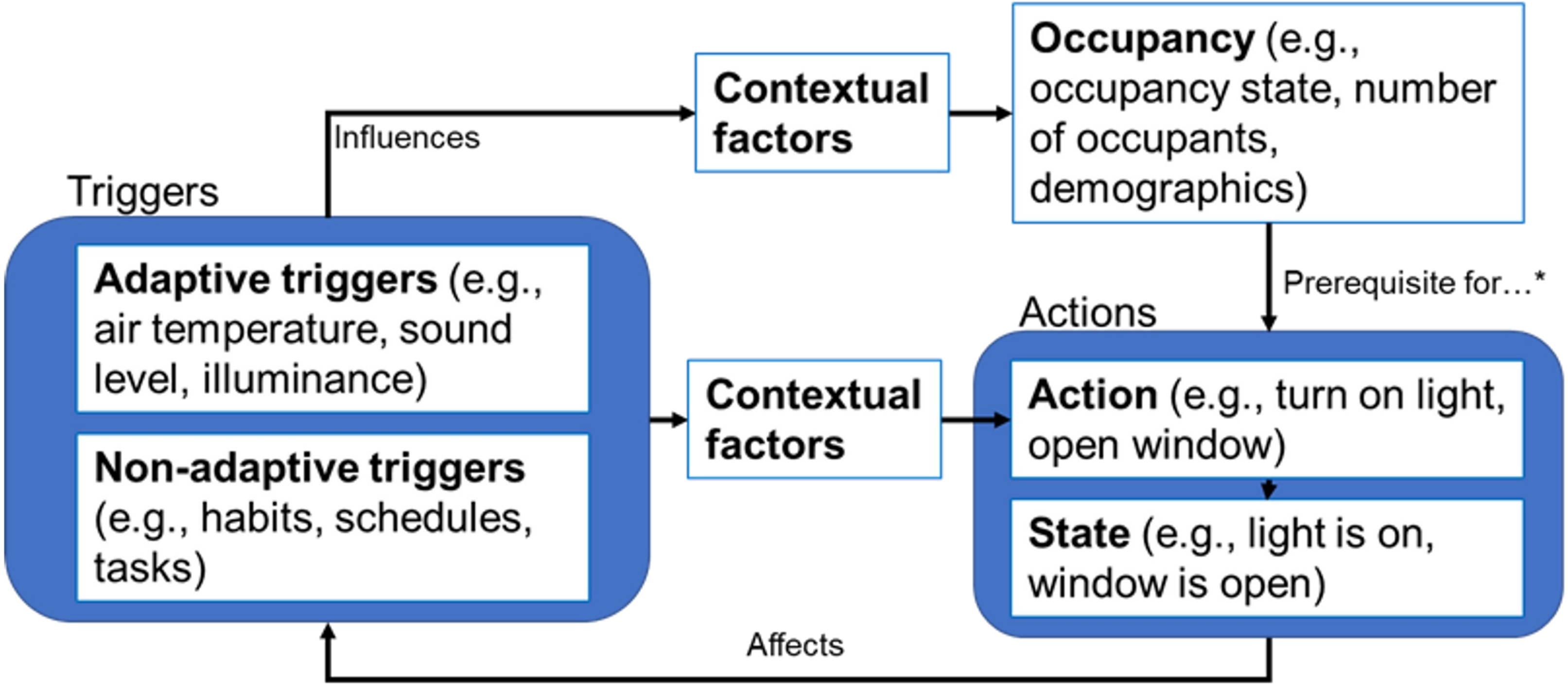
Why model occupants?

- Improve predictions (mean and variance) of building performance during design
- Improve building performance and design
- Account for how building design influences behaviour
- Understand behavior, comfort, human factors, etc.
- Elevate discussion about occupants during design process





Introduction to Occupant Modelling



*Occupancy is a necessary condition for actions unless a building system is controlled remotely

Introduction to Occupant Modelling

Desirable occupant model traits

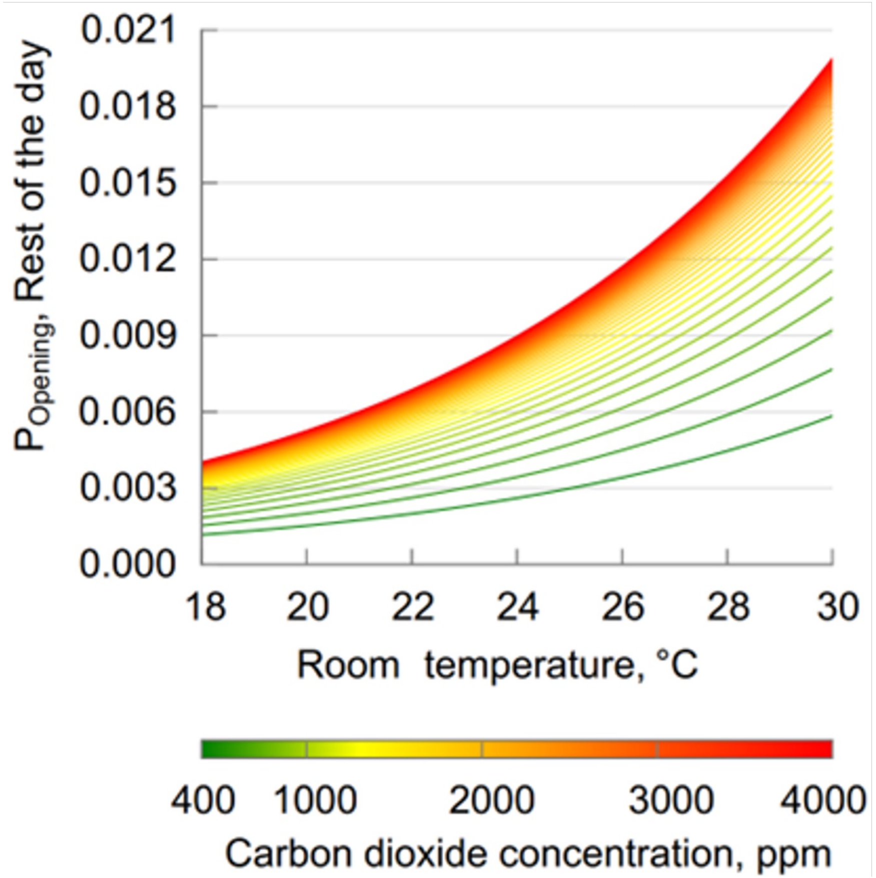
- Stochastic: random
- Dynamic: two-way
- Data-driven: evidence-based

Key domains

- Presence/mobility
- Use of appliances/equipment/lighting
- Use of doors, windows, blinds
- Thermostat adjustment

Introduction to Occupant Modelling

Markov model



Introduction to Occupant Modelling

Personas

Sadie

Senior Persona

Sadie is a 78-year-old retiree and widow. She lives by alone, but keeps a full schedule of commitments (e.g., with her church group, visiting with her grandkids, reading, and watching TV). She enjoys learning and keeping an active mind with a daily crossword puzzle and reading her Bible. She spends most of her day at home in her apartment. She lives alone, so feeling safe is important to her sense of well-being. She is cold-natured, and a cozy housing unit is one reason she is more satisfied with her current unit compared to her previous unit. She likes the heat pump in her apartment but is sensitive to direct air blowing on her. She sets her thermostat between 72-75°F (22-24°C). She uses 88 kWh/m^2/yr of energy. She has an Energy Star rated dishwasher, but cleans her daily dishes by hand. Inez feels the old ways of life are better. She doesn't like new technology and prefers the old ways of communicating.

Physical Needs: *safety, easy to access and understand spaces and interfaces, level floor surfaces and transitions to avoid tripping hazards*

Physiological Needs: *her comfort is critical, she keeps thermostat between* 72-75°F (22-24°C), she is keenly aware of drafts/air movement

Psychological Needs: *safety, connection with community and family, continuing to stay active and involved in her family and community*

Attitude*: uses only what she needs, prefers traditional communication (e.g., talking face to face, writing letters), conserves energy to avoid wasting money, feels agnostic toward technology*

Behavior: *turns off lights and plug loads when not in the room, cleans dishes by hand, takes short to medium length showers, uses space heater to adapt indoor environment*

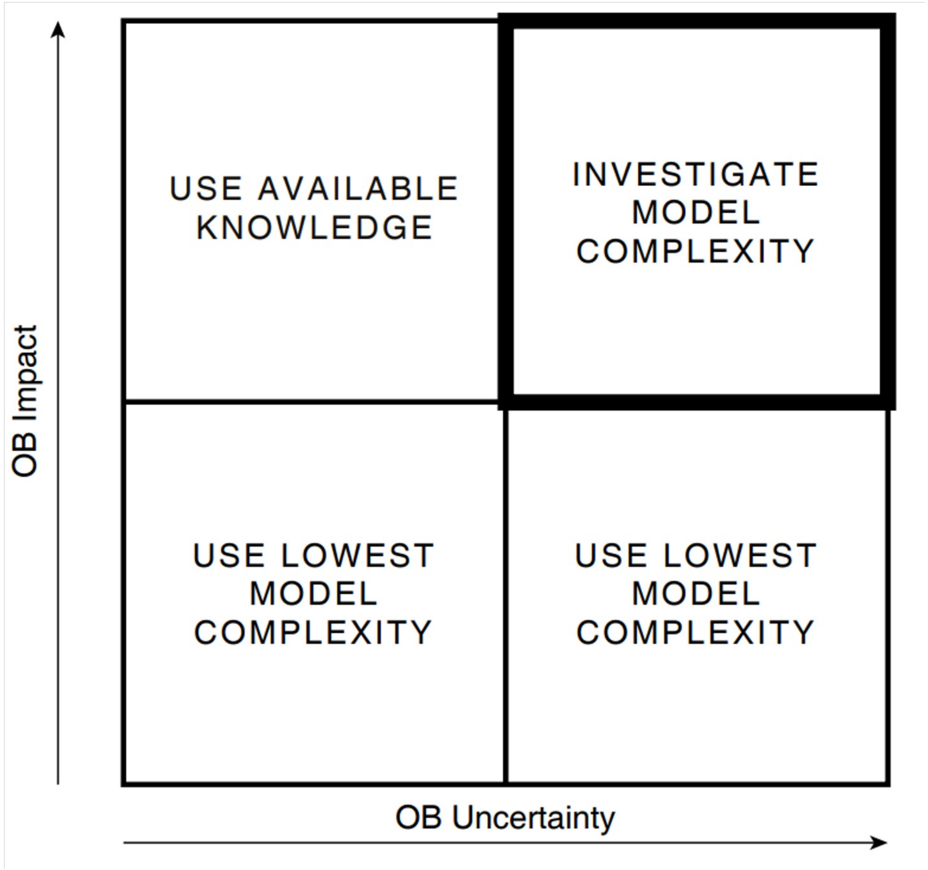
Fit-for-purpose Occupant Modelling

Isabella Gaetani, PhD

Arup Smart Buildings

Fit-for-purpose Occupant Modelling

OB modeling should ***depend on the purpose of the simulation, the building, the granularity of the KPI, …***



Fit-for-purpose Occupant Modelling

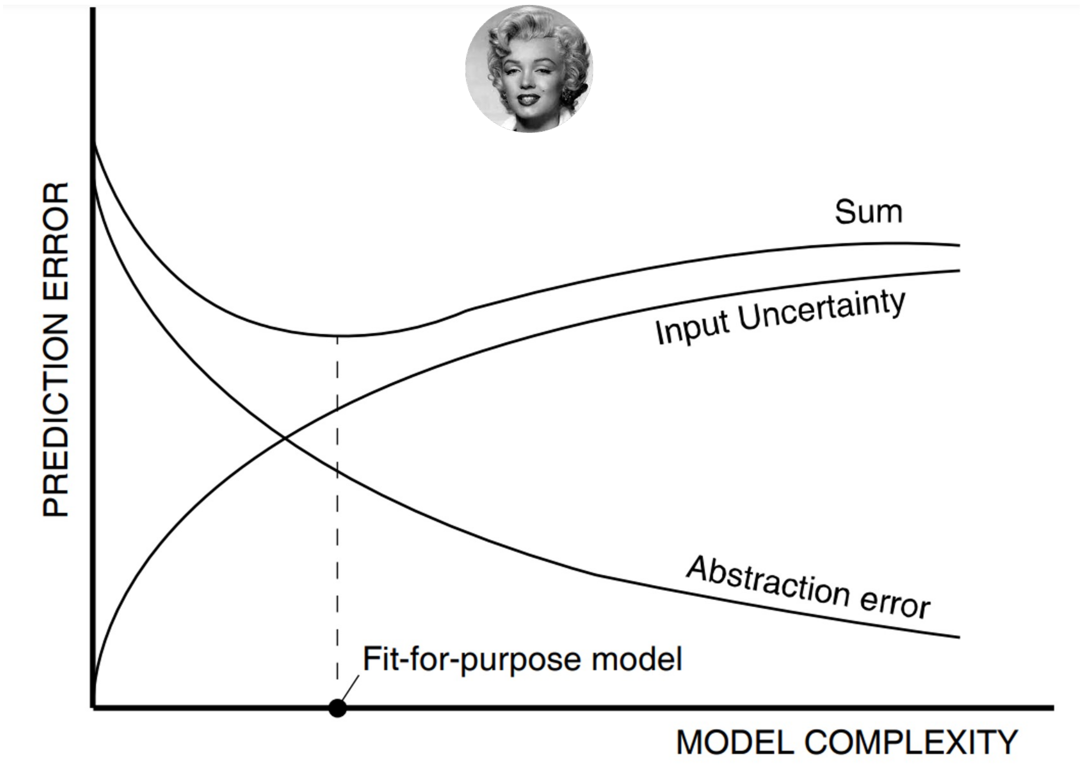
Numquam ponenda est pluralitas sine necessitate.

Plurality must never be posited without necessity.

William of Ockham

- Model simple, think complicated
- Be parsimonious, start small and add
- Divide and conquer; avoid megamodels

Pidd 1999



Fit-for-purpose Occupant Modelling

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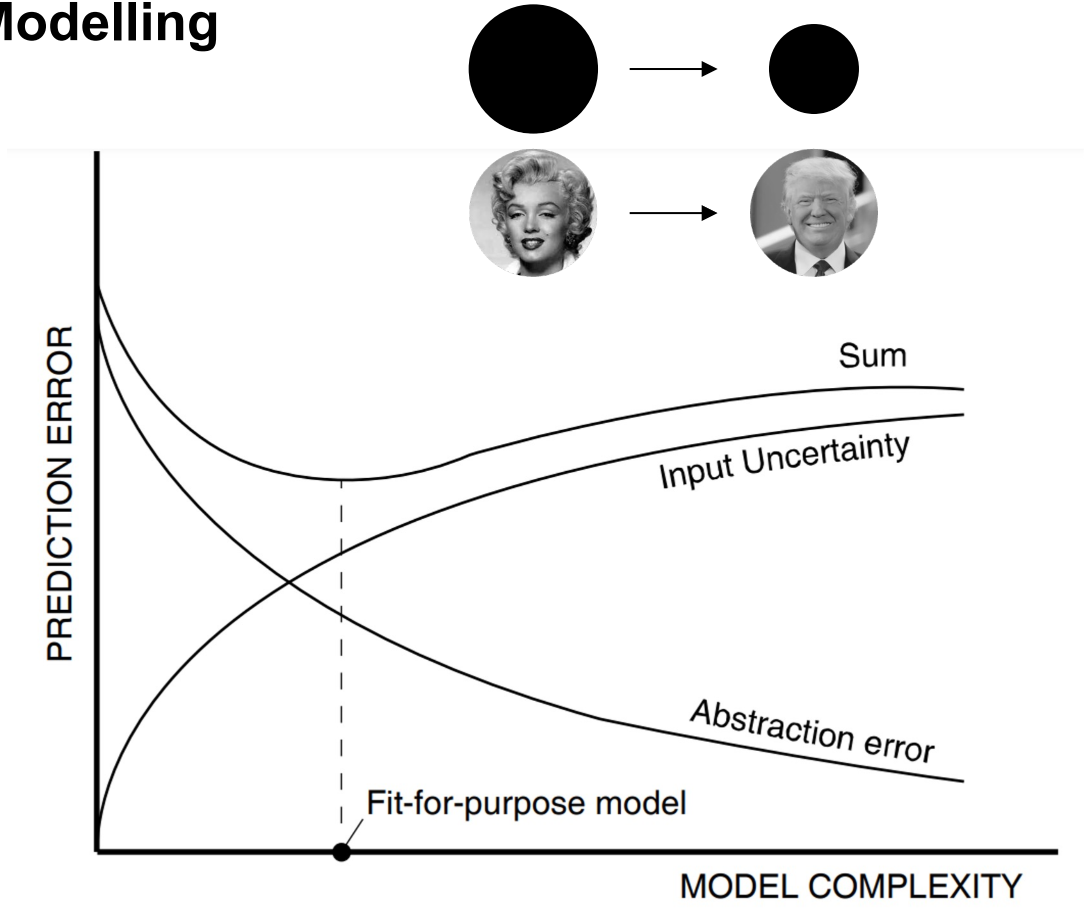
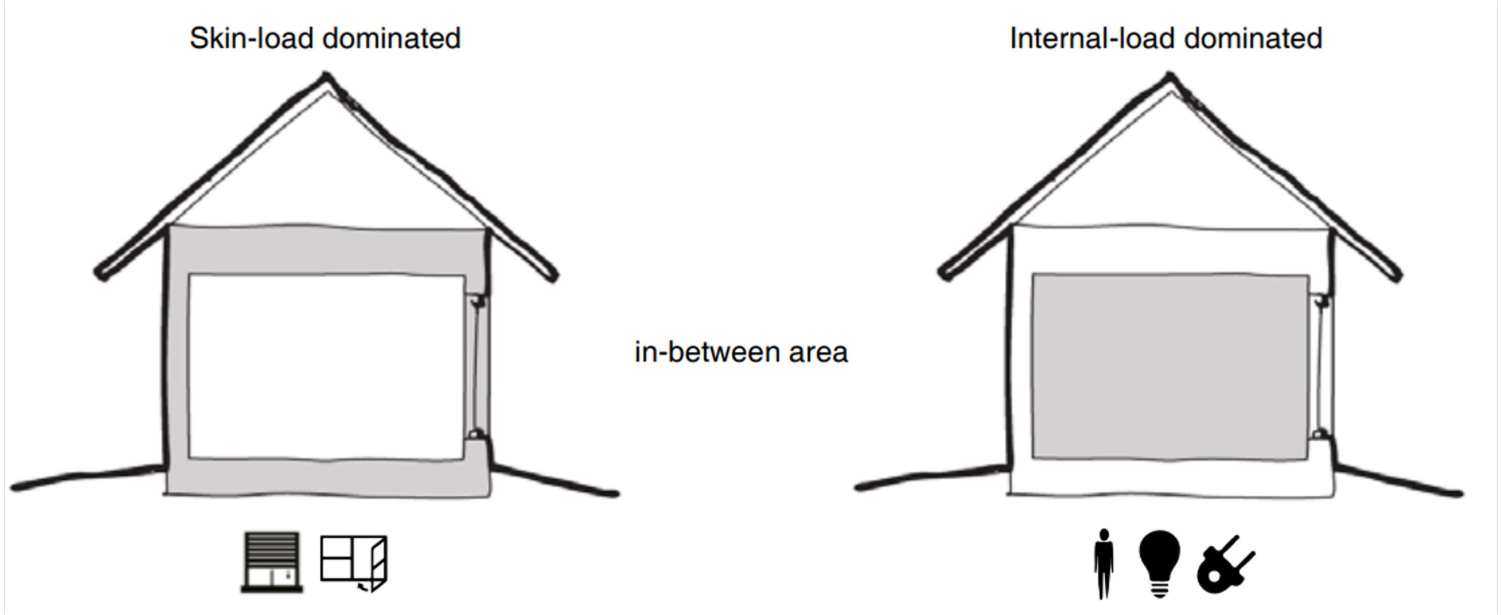


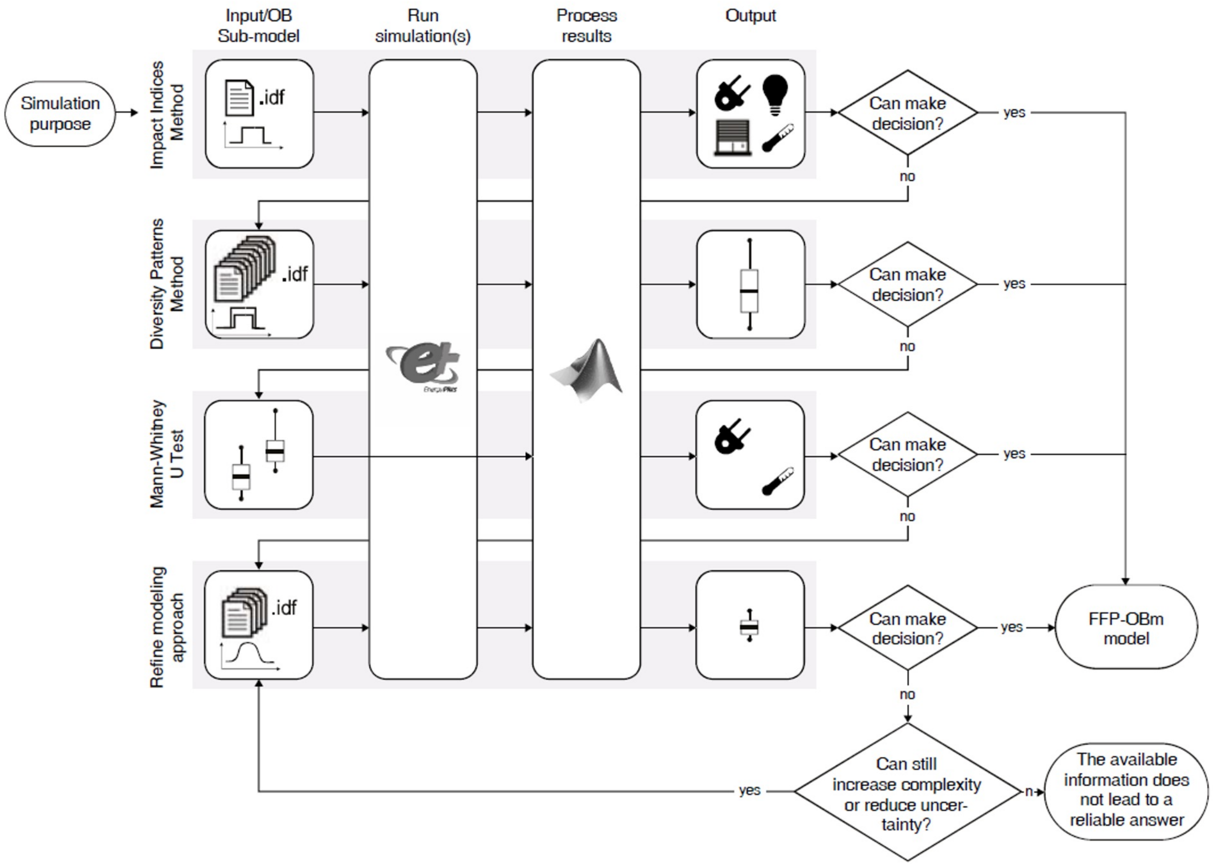
Fit-for-purpose Occupant Modelling

But assessing the impact of occupant behavior is not as easy as it sounds …



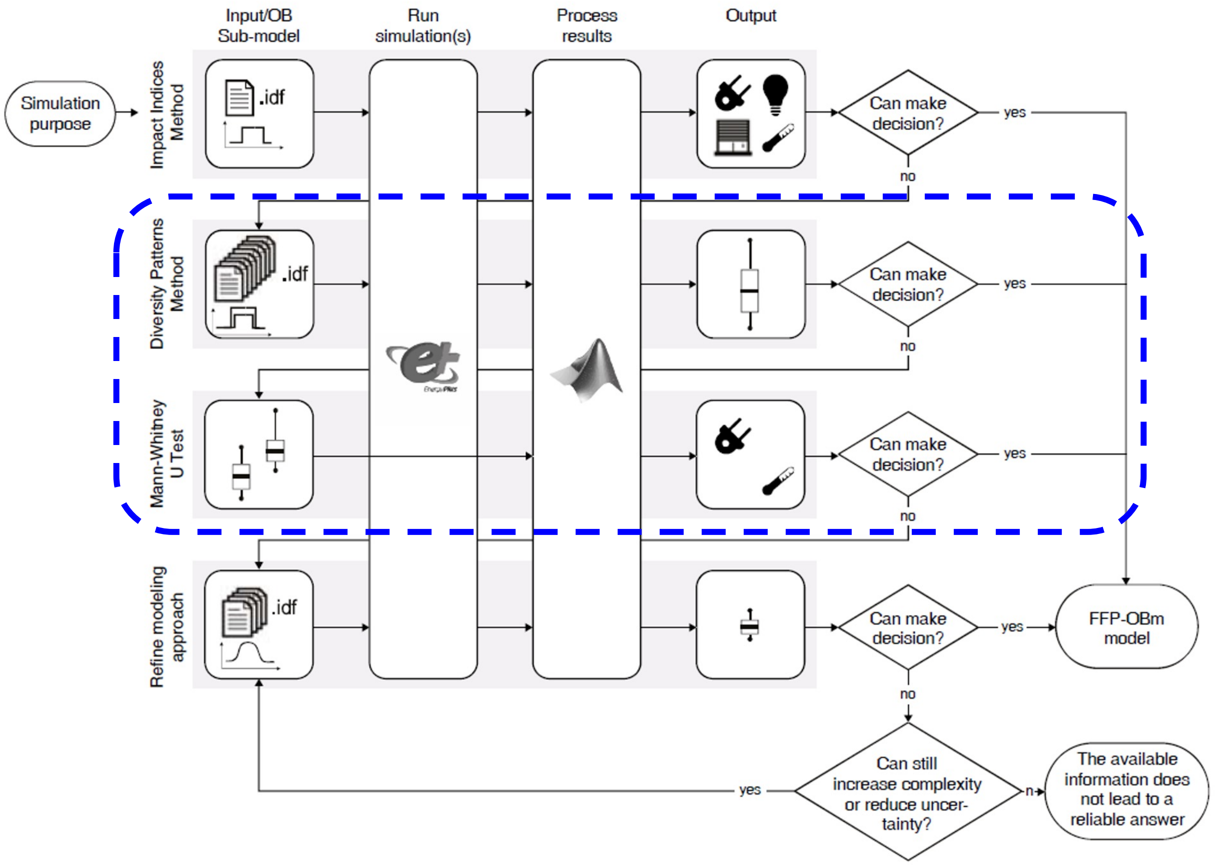
Fit-for-purpose Occupant Modelling

… a simulation approach is needed!

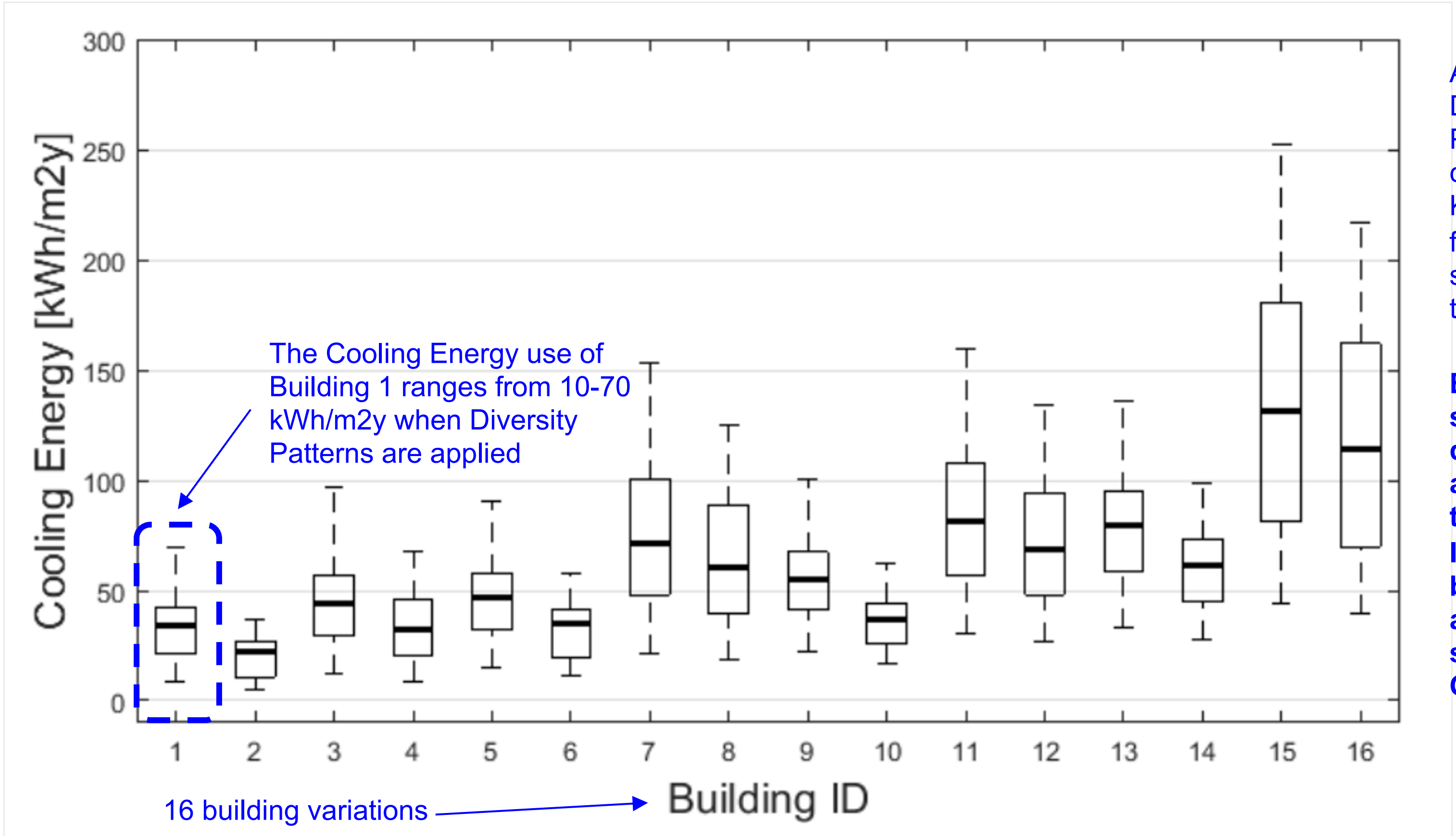


Fit-for-purpose Occupant Modelling

Diversity Patterns are all possible combinations of high/low variations of uncertain OB aspects



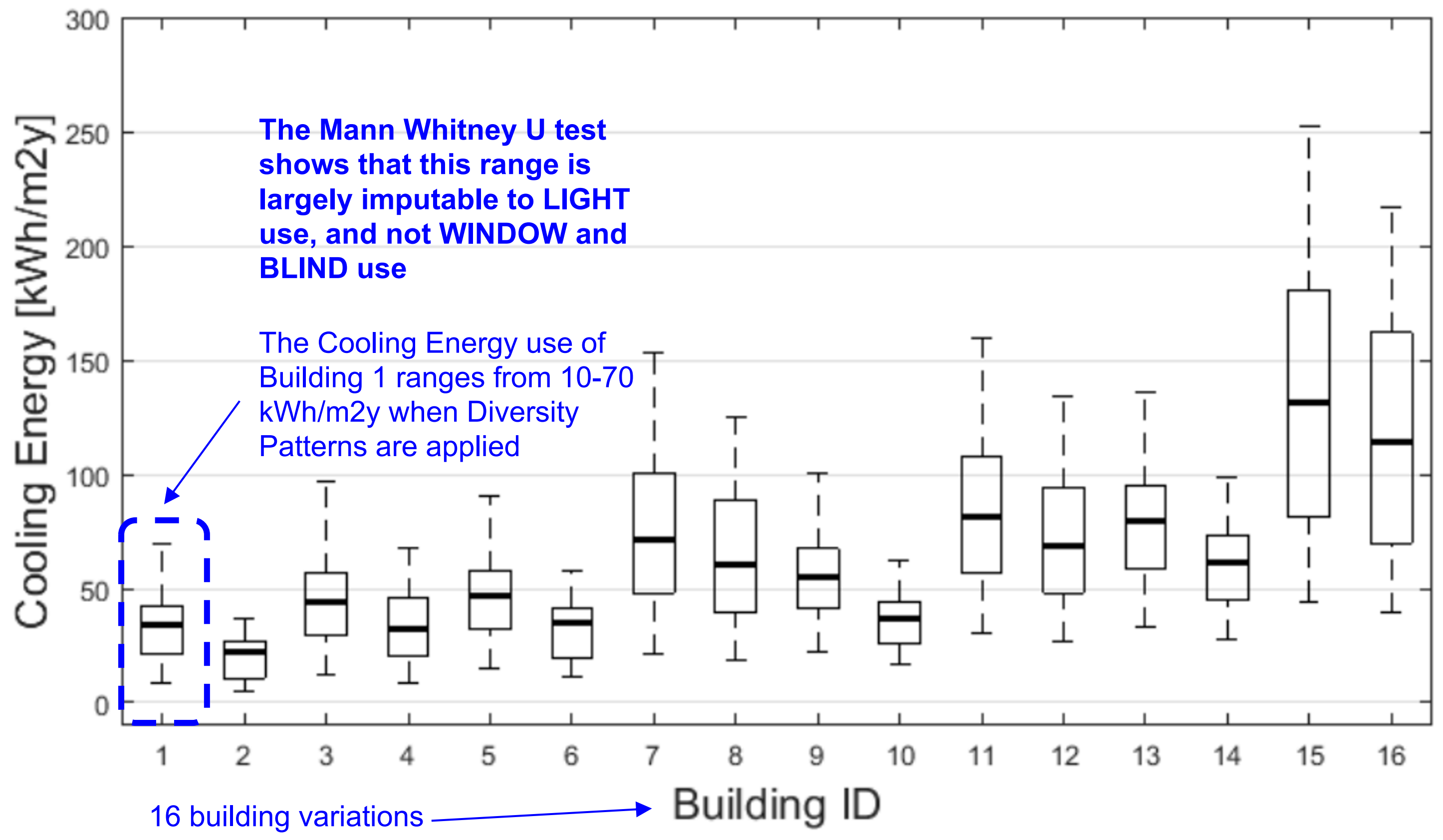
Fit-for-purpose Occupant Modelling



Applying Diversity Patterns causes the KPI to move from a single value to a spread

But the spread is different according to Building ID - some buildings are more sensitive to OB

Fit-for-purpose Occupant Modelling

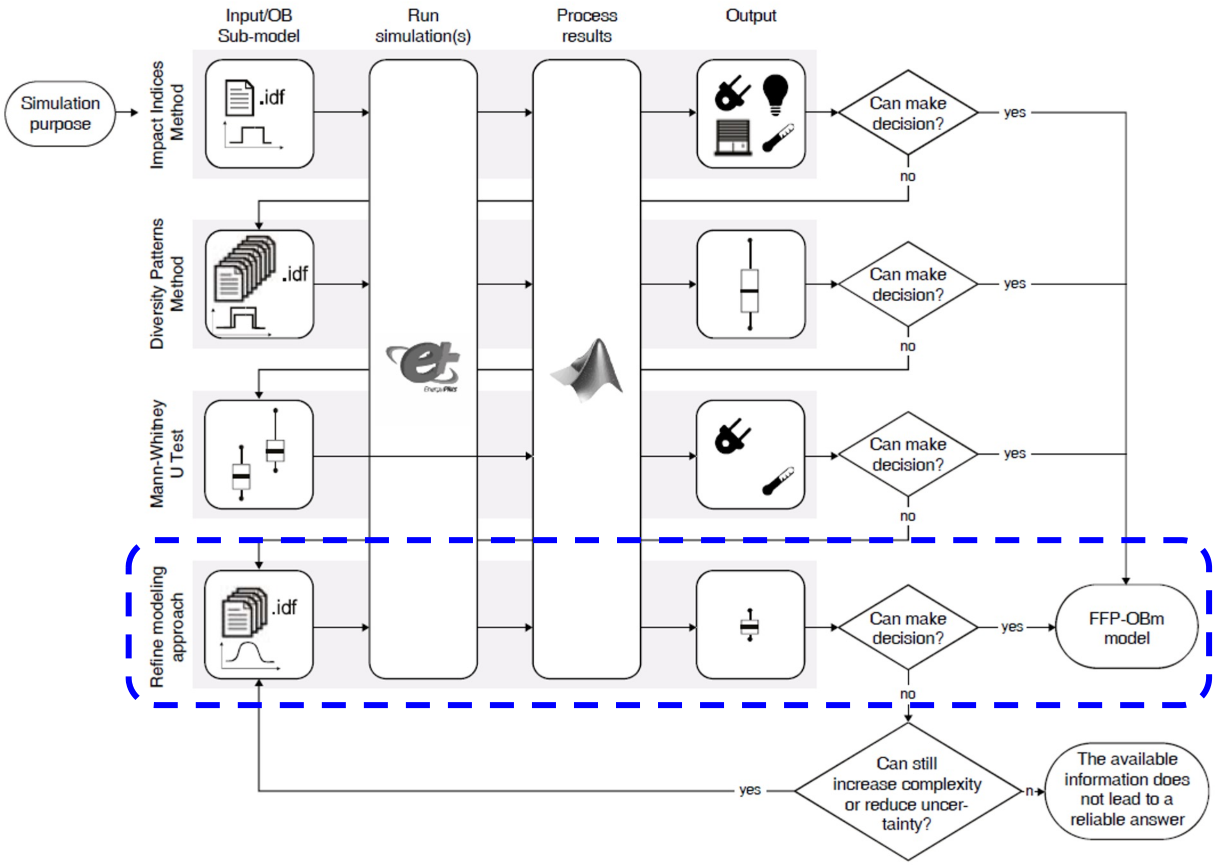


Applying Diversity Patterns causes the KPI to move from a single value to a spread

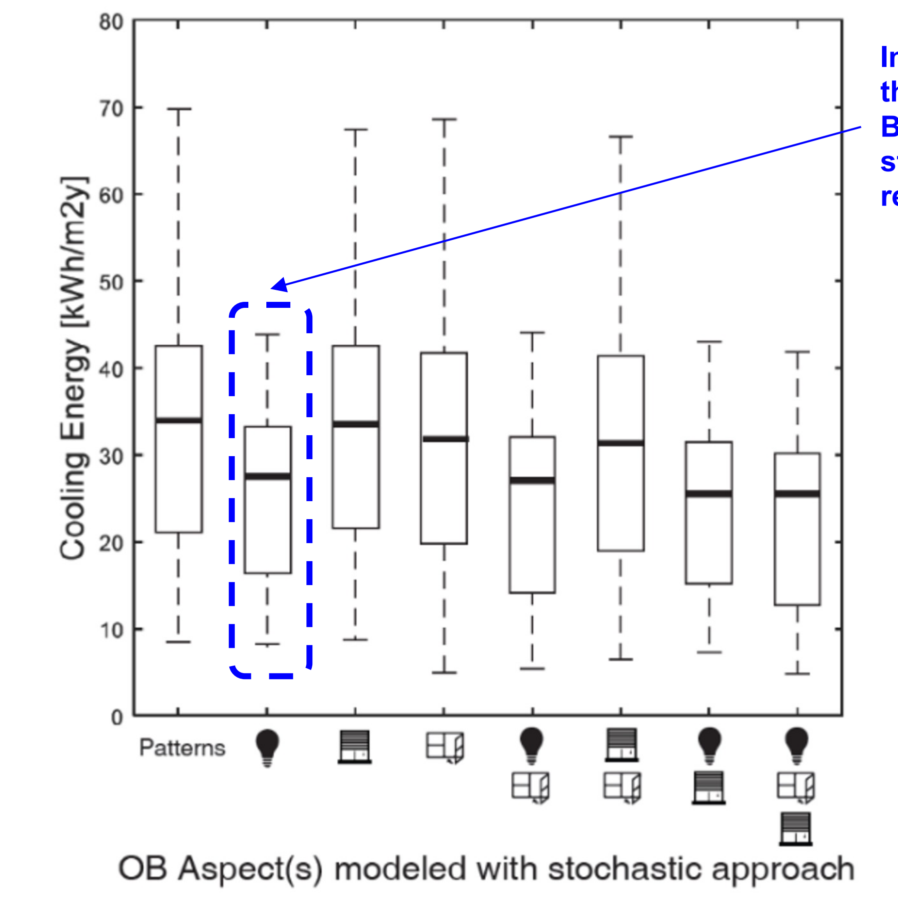
But the spread is different according to Building ID - some buildings are more sensitive to OB

Fit-for-purpose Occupant Modelling

Refining the OB modelling approach has a different effect on the results ***depending on the impact of a given OB aspect*** *(previous step)*



Fit-for-purpose Occupant Modelling



Increasing the complexity of the Light use Occupant Behavior model has the strongest impact on the results

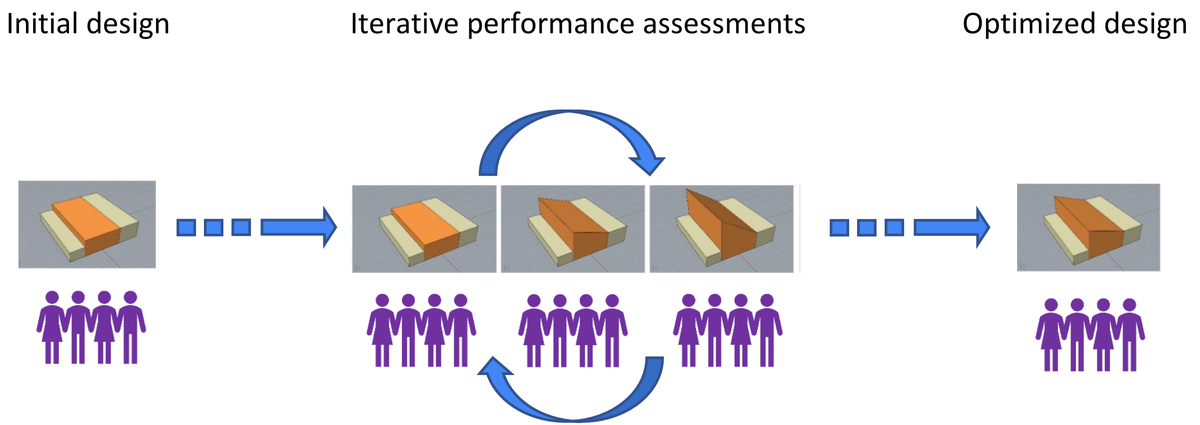
Simulation Methods for Occupant-Centric Design

Farhang Tahmasebi

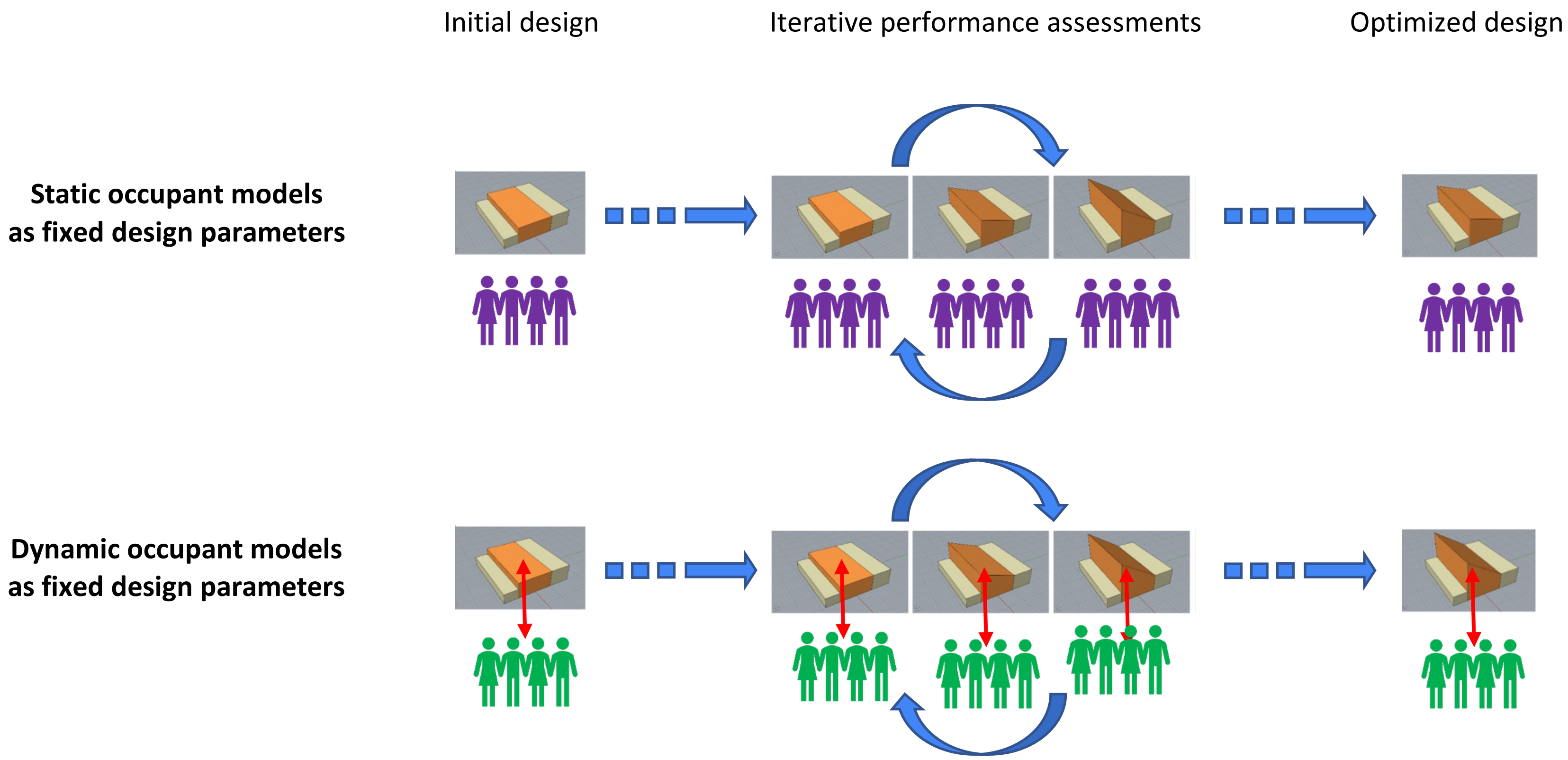
University College London

Occupants in simulation-aided design

Static occupant models as fixed design parameters

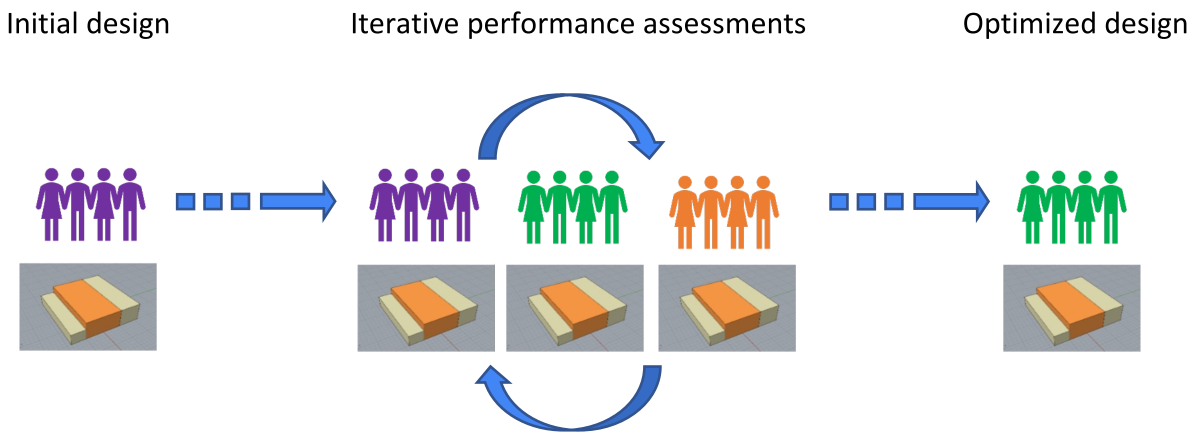


Occupants in simulation-aided design

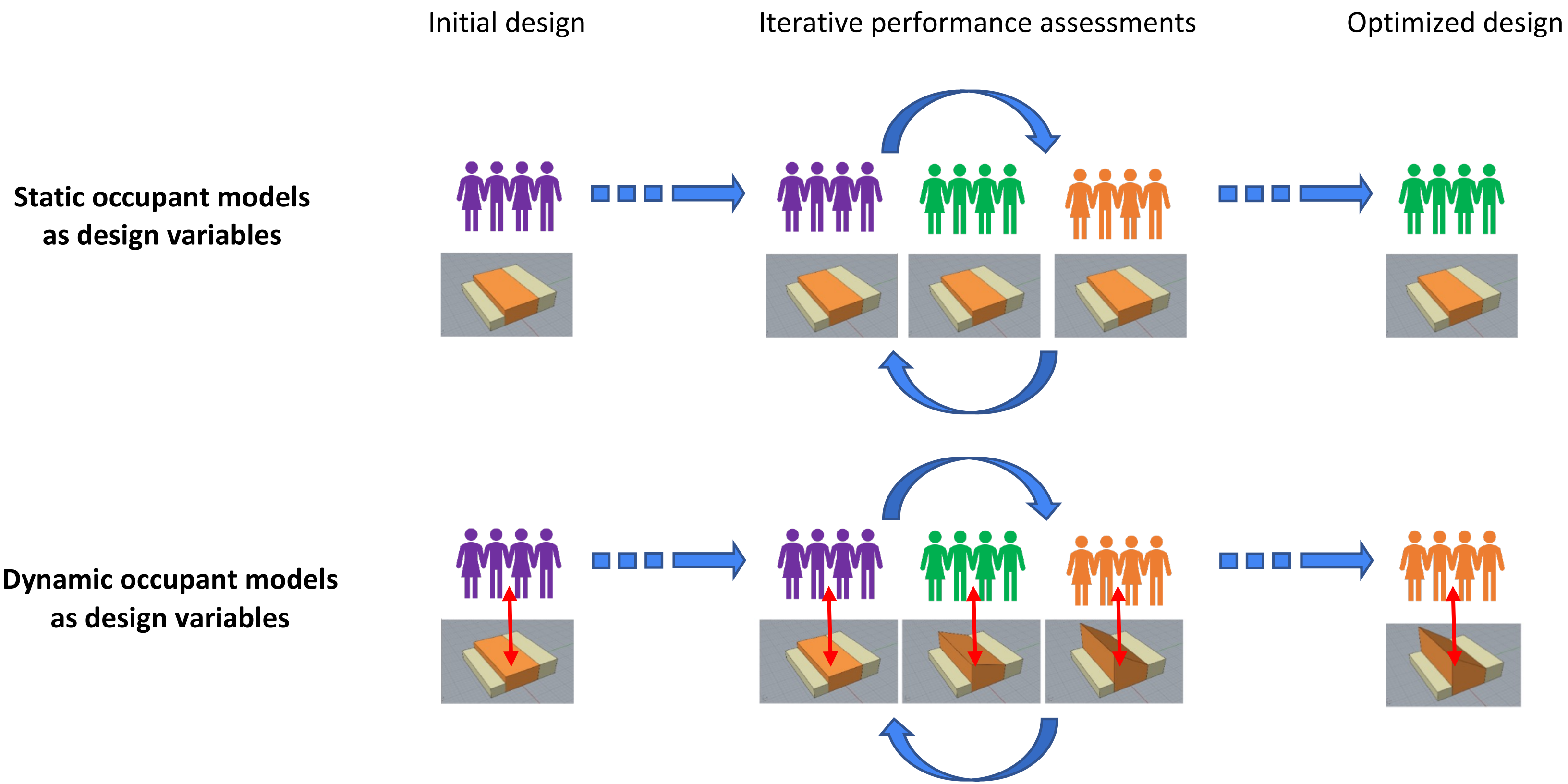


Occupants in simulation-aided design

Static occupant models as design variables

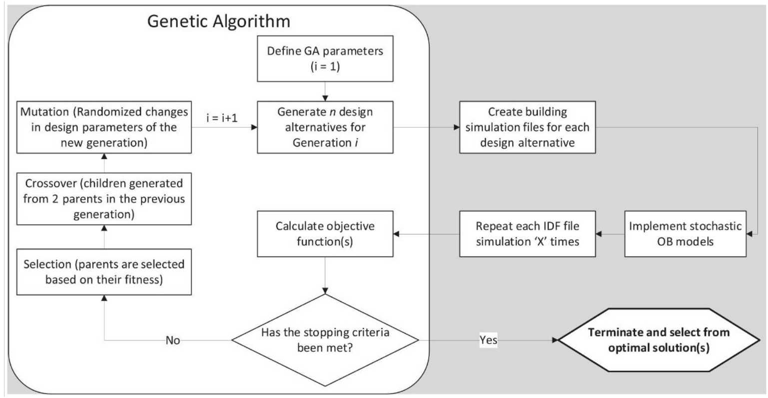


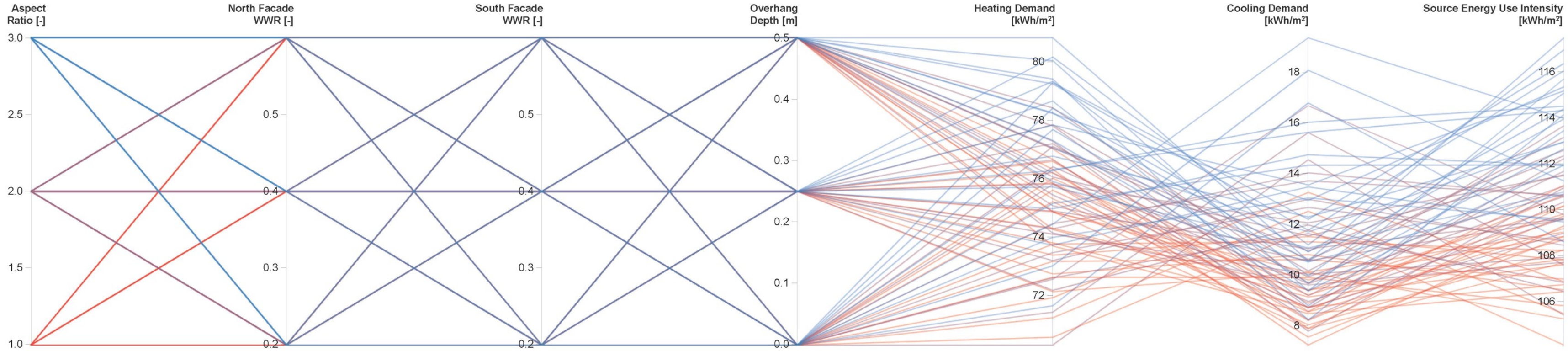
Occupants in simulation-aided design



Simulation-aided design methods

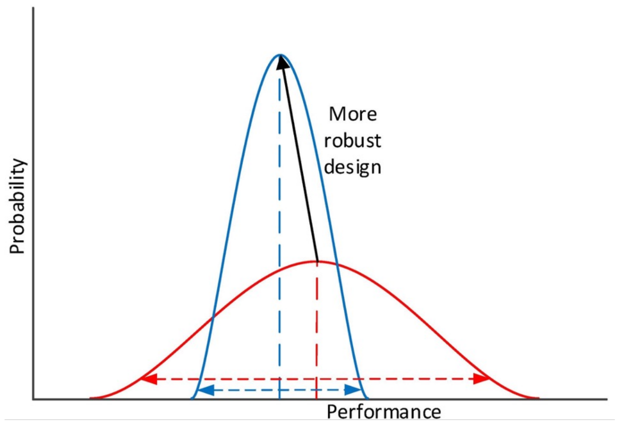
- Uncertainty assessment
- Sensitivity analysis
- Parametric design
- Optimization

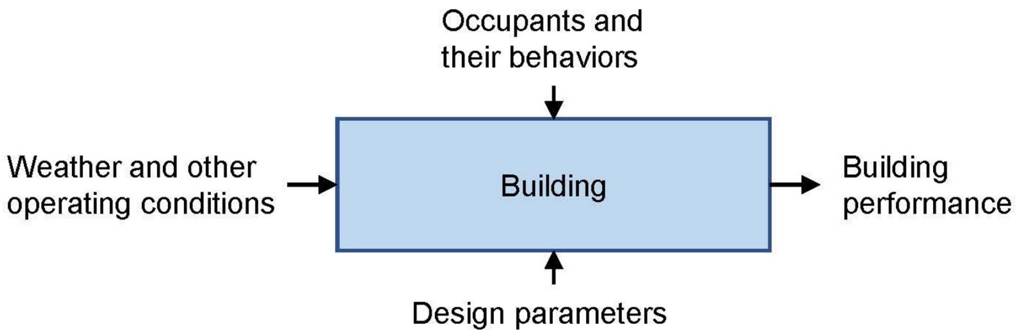


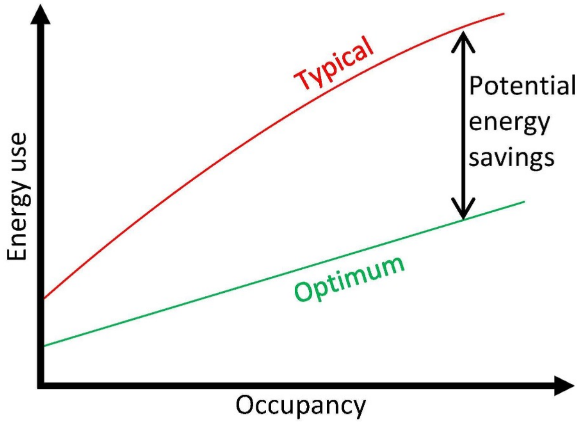


Simulation-aided design objectives

- Performance compliant design
- Robust design
- Occupant adaptive design
- Resilient design



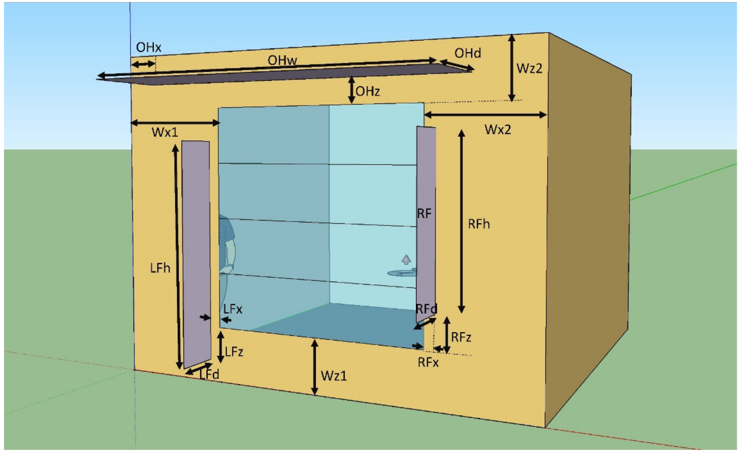


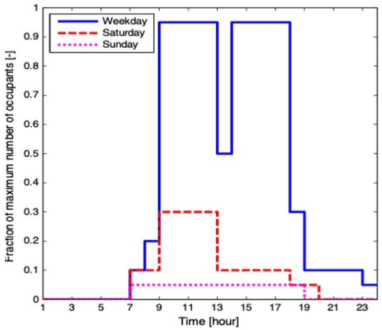


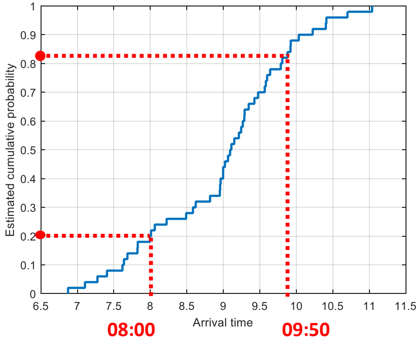
A prototypical testbed for simulation-aided design

- Parametric shoe-box model
- With standard and advanced occupancy assumptions

Domain	*First version: ASHRAE Standard 90.1 schedules*	*Second version: occupant behavior models*
Occupancy	Standard schedule for occupancy (Appendix G-I)	Randomly sample five arrival and departure times each day from pre-defined normal distributions (Wang *et al.*, 2005)
Lighting	• Standard schedule for lighting (Appendix G-I) • Daylighting controls using continuous dimming	Predict light switch behavior based on occupancy state and work plane illuminance (Reinhart, 2004)
Blinds	No blinds modeled	Predict blinds use behavior based on occupancy state, work plane illuminance, and outdoor illuminance (Haldi and Robinson, 2011)
Output	One simulation	50 simulations

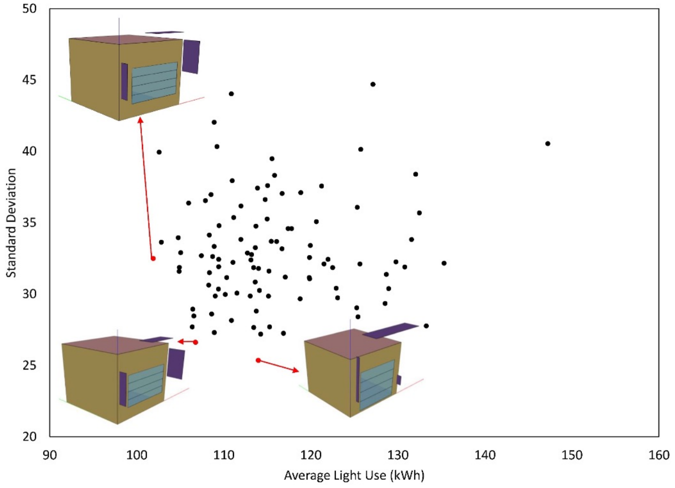


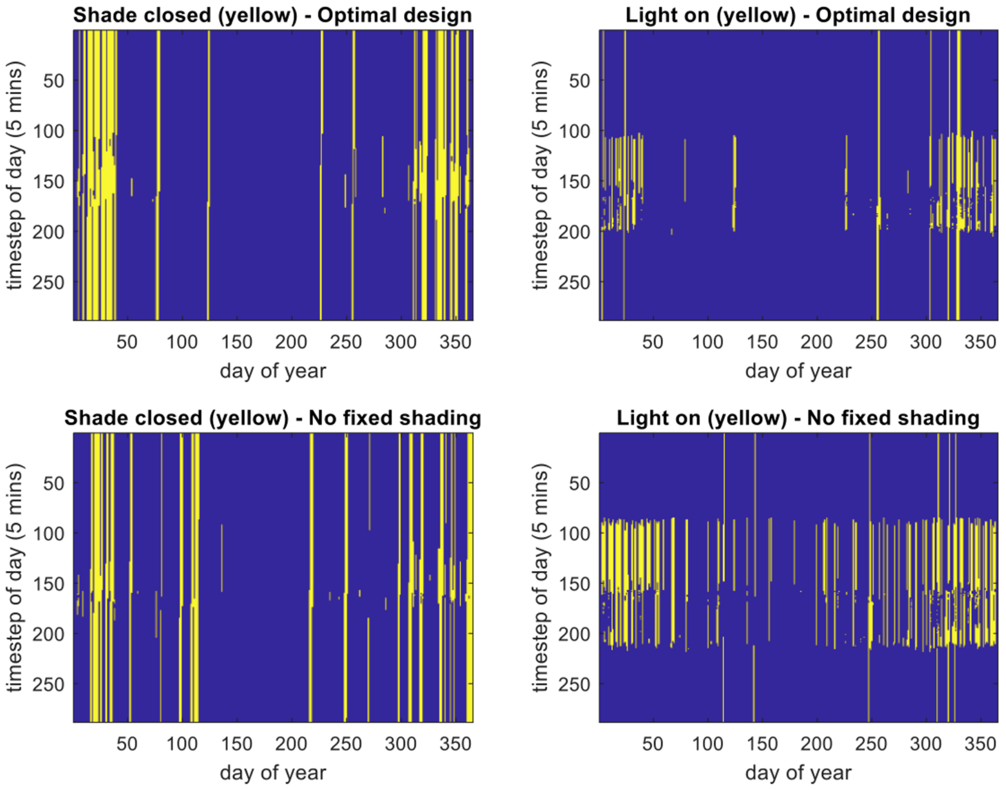


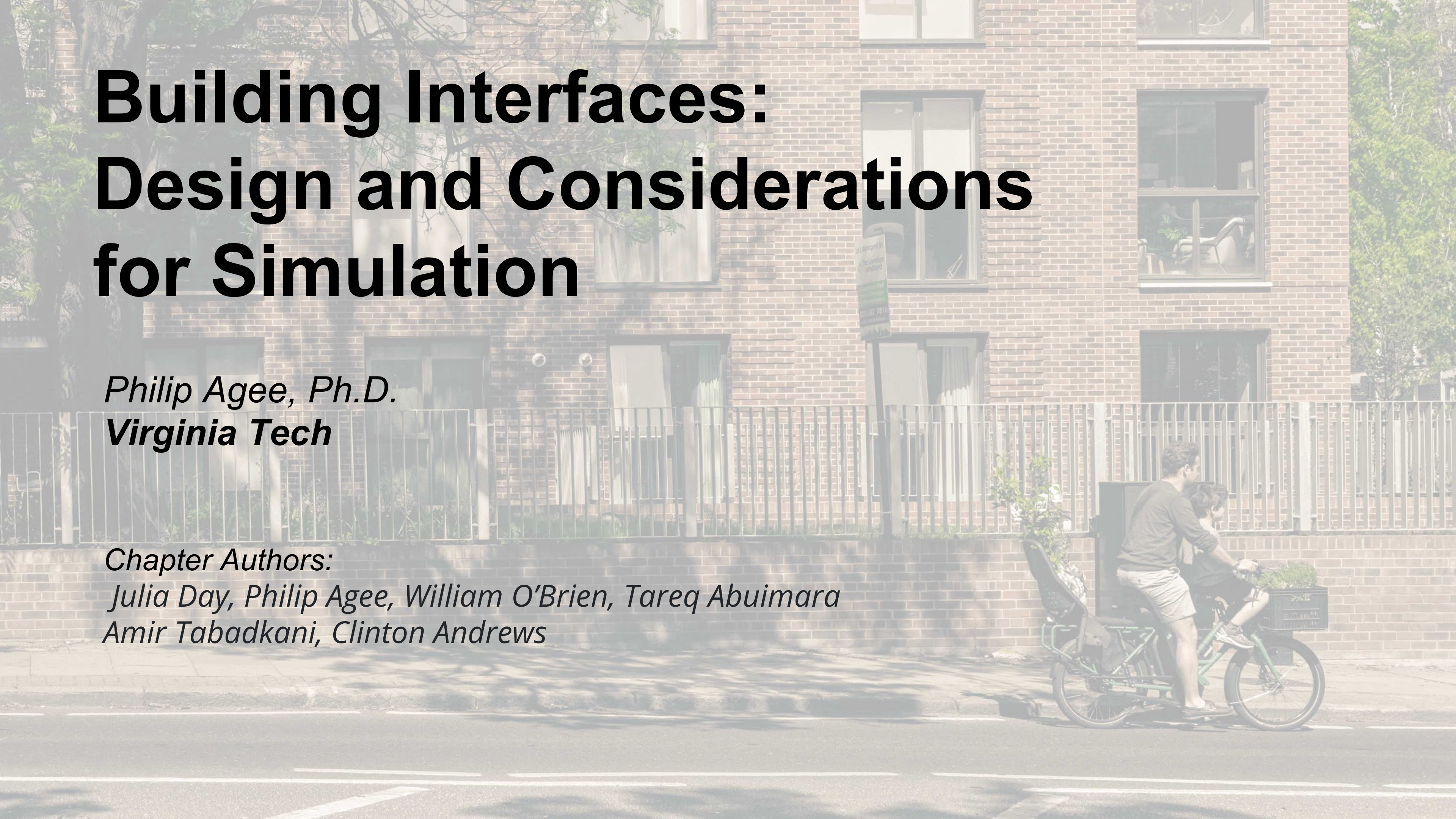


A prototypical testbed for simulation-aided design

Robust design optimization







Building Interfaces: Design and Considerations for Simulation

Philip Agee, Ph.D.
Virginia Tech

Chapter Authors:
Julia Day, Philip Agee, William O'Brien, Tareq Abuimara
Amir Tabadkani, Clinton Andrews

Building Interfaces: Design and Considerations for Simulation

Building Interfaces: What and why

building interface: *is a system component(s) where intentional or unintentional interaction occurs between a human, a building, and its subsystems (e.g., plumbing, electrical devices/controls, mechanical systems or thermostats, windows, blinds).*

Why building interfaces matter? *occupants have interactions with interfaces, the frequency and variety of interactions impact human and performance outcomes in buildings*

Context matters*: residential versus commercial re: design for control*

Human factors: *most building interfaces are designed for the visual sensory system*
combining visual/haptic is common interaction approach (e.g., identify target, press icon)

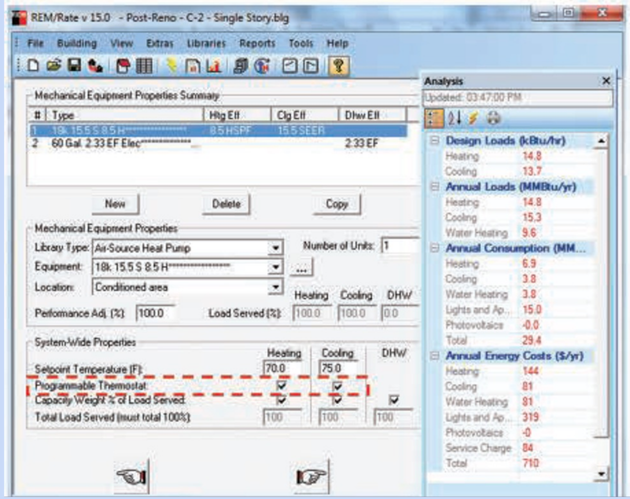
Building Interfaces: Design and Considerations for Simulation

Building Performance Simulations (BPS)

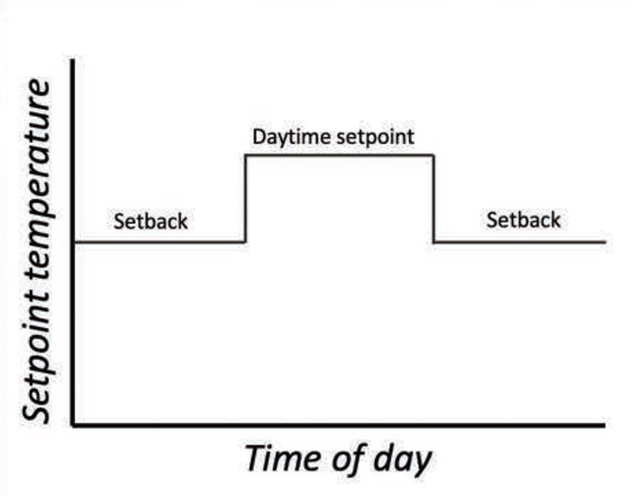
- Human-building [interface] interactions are a gap in BPS
- For examples: setpoint schedule approach does not account for complexity of user interaction(s)

- additional modalities (e.g., app-based, voice controlled) adds complexity/uncertainty

Simulator view: thermostat interface



Simulator output: thermostat interface



User view: thermostat interface

Building Interfaces: Design and Considerations for Simulation

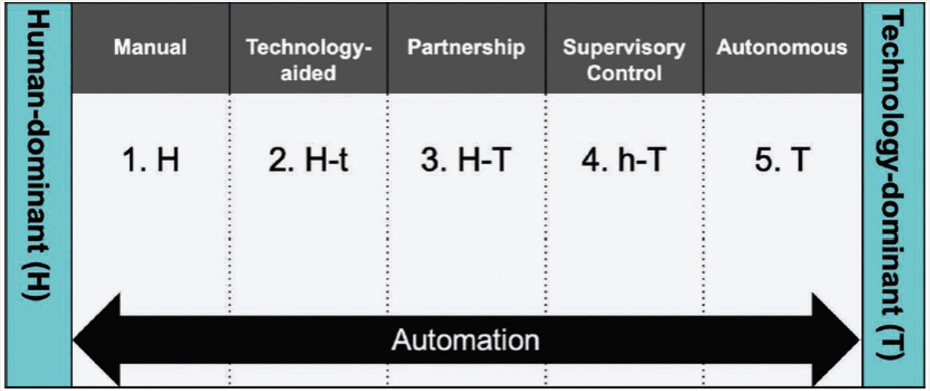
Automation

Current view of building automation is technology-centered, over-simplified: *automated/not-automated*

Automation in other complex systems (e.g., aerospace, transportation) aims to support human performance

Current approach is a “leftover approach” to function allocation (e.g., we give the occupant what’s leftover)

Function allocation model

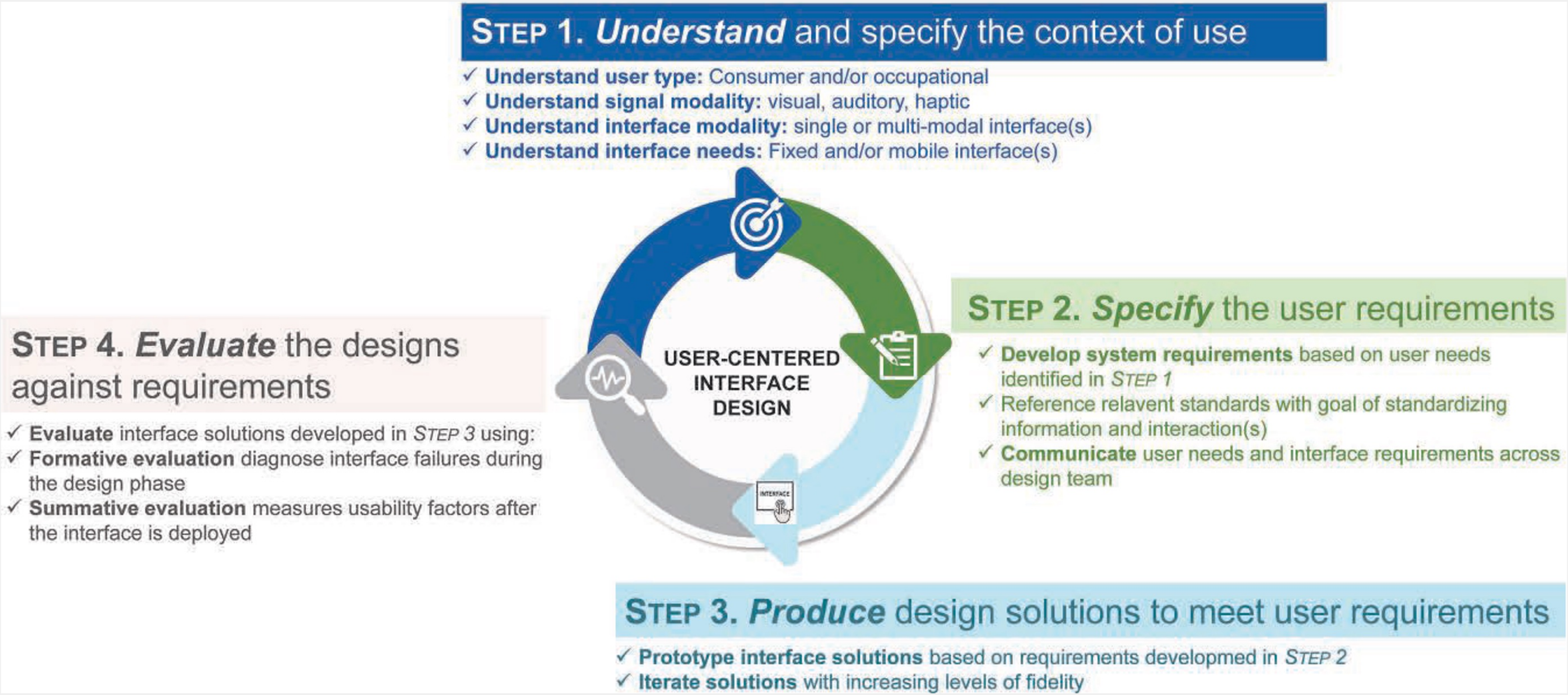


Function allocation: thermostats

	Manual	Simple Programmable	Complex Programmable	Programmable and Communicating	Programmable, Sensing, Learning
THERMAL COMFORT INTERFACE EXAMPLE					
FUNCTION ALLOCATION	|< HUMAN DOMINANT		TECHNOLOGY DOMINANT >|		
LEVELS OF AUTOMATION	H-t	H-t	H-T	h-T	h-T

Building Interfaces: Design and Considerations for Simulation

Interface design and evaluation approach

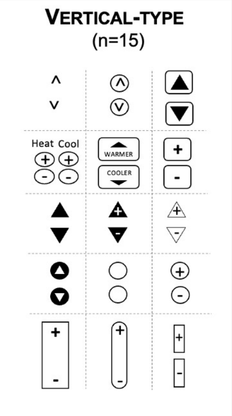


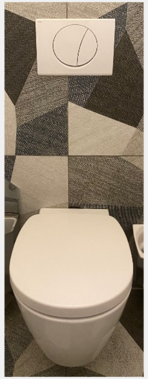
Adapted from ISO 9241- 210, Ergonomics of human system interaction.

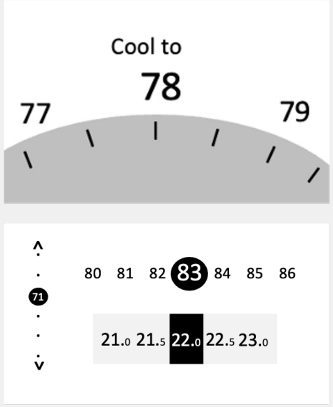
Building Interfaces: Design and Considerations for Simulation

Summary

1. Humans interact with buildings and their subsystems
2. These interactions occur at the building interface, predominantly as visual/haptic interactions
3. Lack of standards for building interfaces (icons, task-interaction relationships)
4. Current BPS approaches do not accurately represent the complexity of these interactions; adding additional modalities adds complexity and uncertainty to BPS





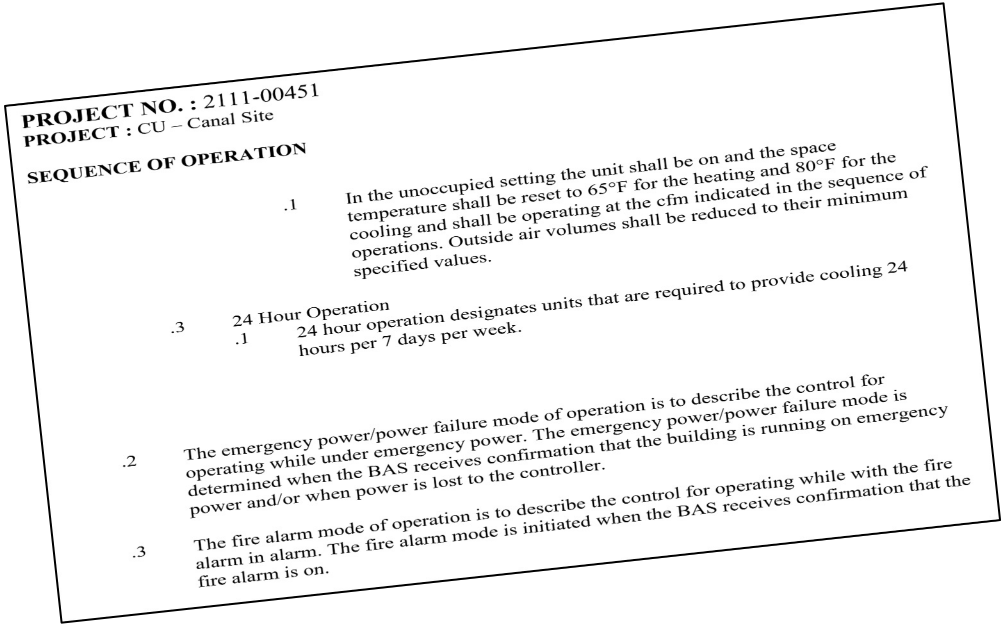


Design of Sequences of Operation for Occupant-centric Controls

Burak Gunay
Carleton University

Design of sequences of operation

- Details the operating conditions for a building's energy systems
- One of the most influential design phases
- Often overlooked, rushed, and improperly implemented into the building automation system
- Occupant sensing technologies can be inappropriately selected, and occupant data is typically not optimally used.



PROJECT NO. : 2111-00451
PROJECT : CU – Canal Site

SEQUENCE OF OPERATION

.1 In the unoccupied setting the unit shall be on and the space temperature shall be reset to 65°F for the heating and 80°F for the cooling and shall be operating at the cfm indicated in the sequence of operations. Outside air volumes shall be reduced to their minimum specified values.

.3 24 Hour Operation

.1 24 hour operation designates units that are required to provide cooling 24 hours per 7 days per week.

.2 The emergency power/power failure mode of operation is to describe the control for operating while under emergency power. The emergency power/power failure mode is determined when the BAS receives confirmation that the building is running on emergency power and/or when power is lost to the controller.

.3 The fire alarm mode of operation is to describe the control for operating while with the fire alarm in alarm. The fire alarm mode is initiated when the BAS receives confirmation that the fire alarm is on.

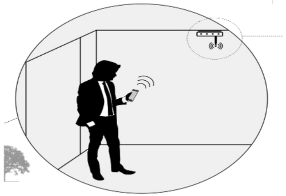
Chapter Structure

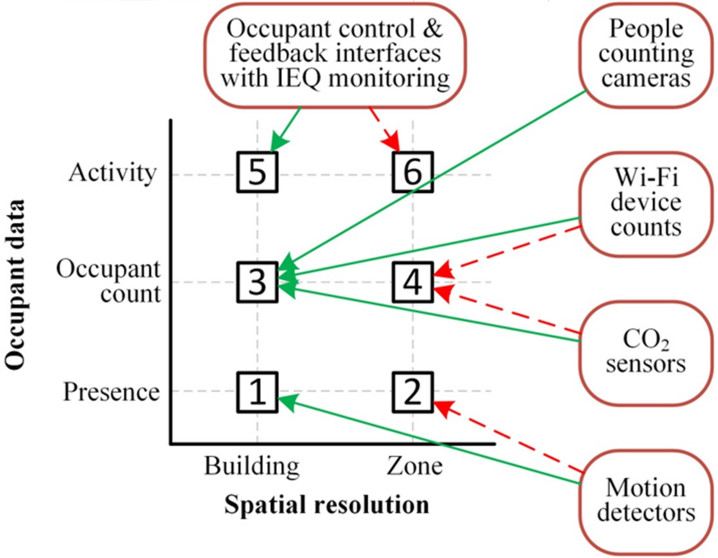
1. Introduces **occupant-centric controls (OCC)** as part of the development of **sequences of operation phase** in design
2. Controls-oriented **occupant data**
   - Different grades of occupant data
   - Most promising current sensing technologies
3. **Occupant-centric control (OCC) variables**
4. **Sequences of operation** using OCC variables
5. Illustrative **examples** for OCC variables and sequences
6. Integration of **OCC in the BPS-based design process**
7. **Energy savings potential** of OCCs

Controls-oriented occupant data

BACnet thermostat

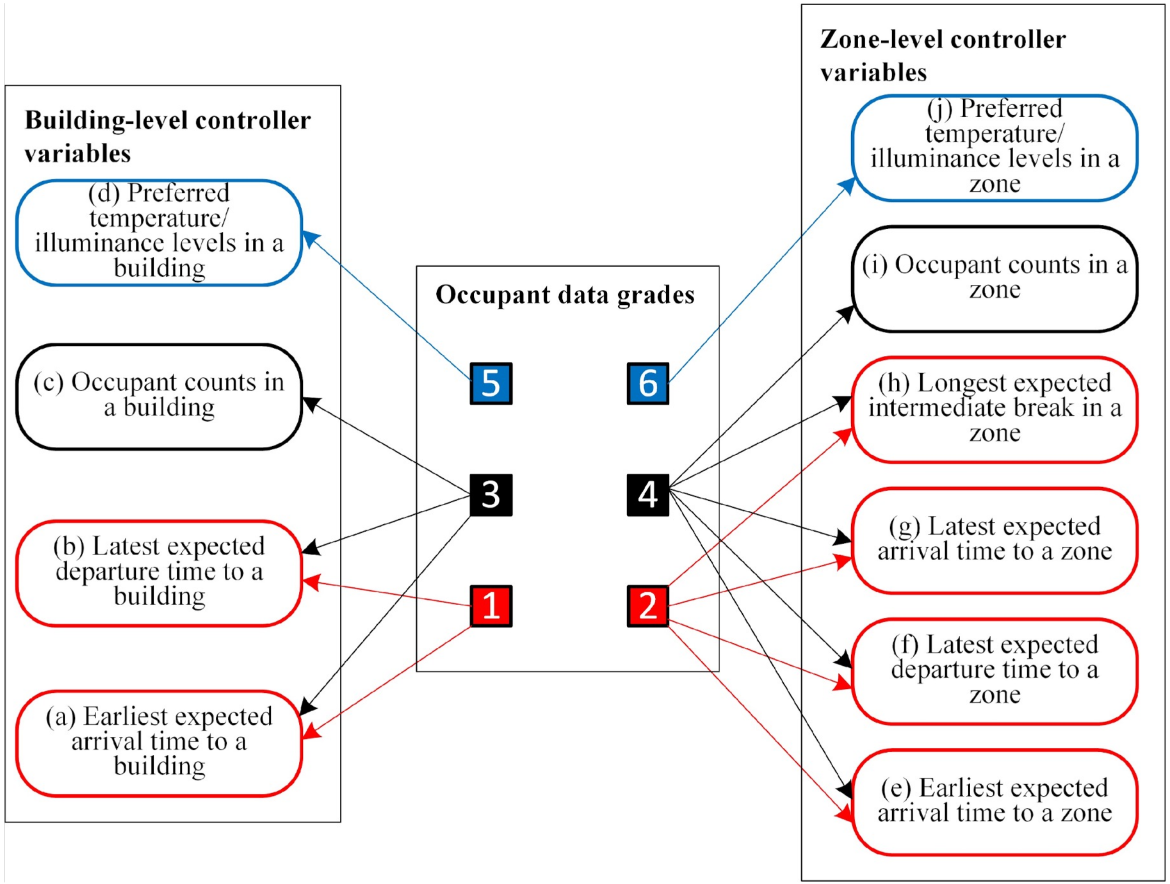
Window contact sensors



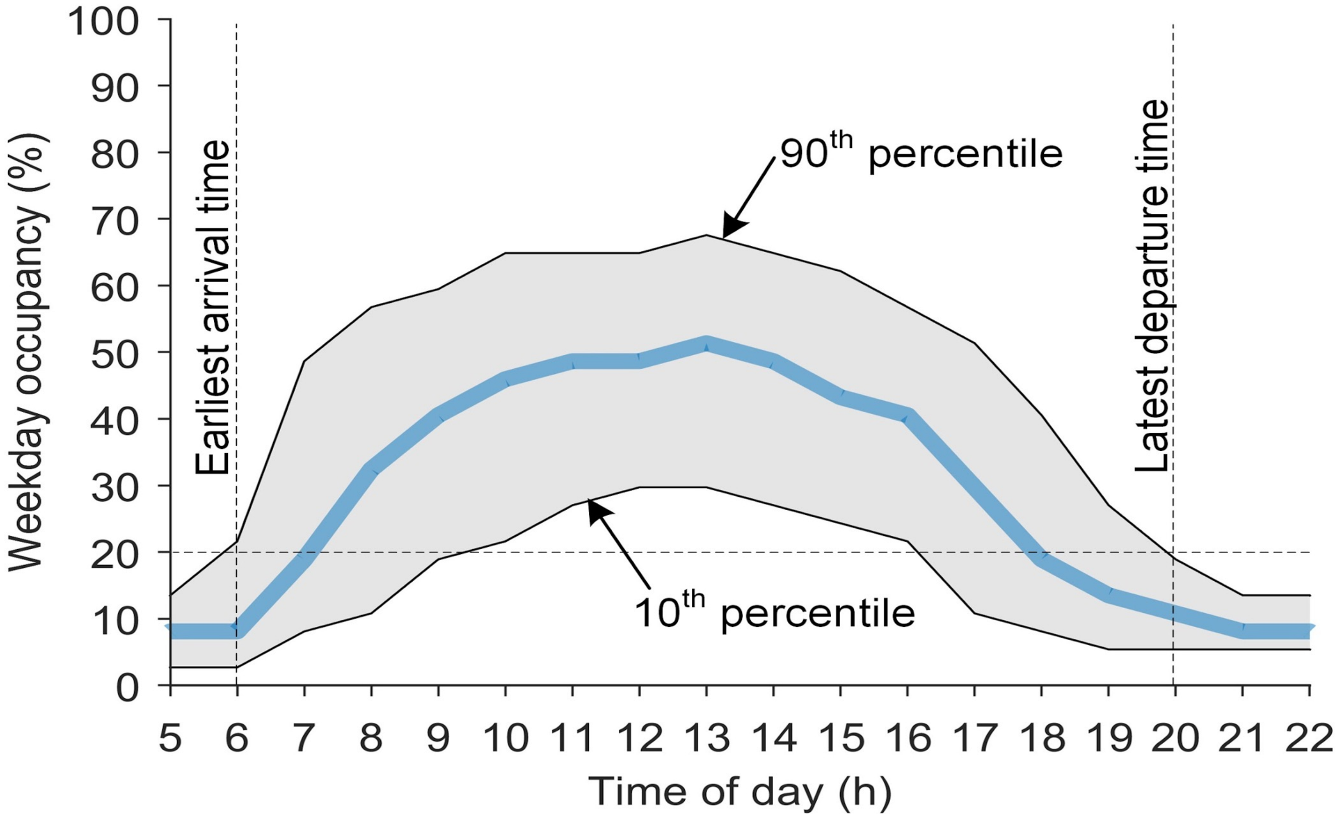


- Red dashed lines require sensor deployment to accommodate zone-level coverage.
- Green solid lines require sensor deployment only at a few locations in a building such as entry points.

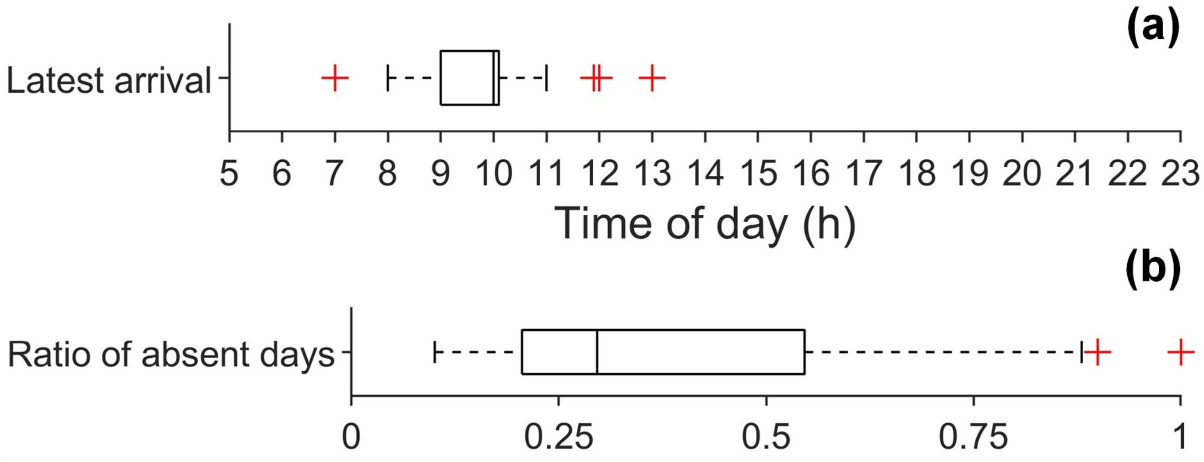
OCC Variables



Examples for OCC variables and sequences

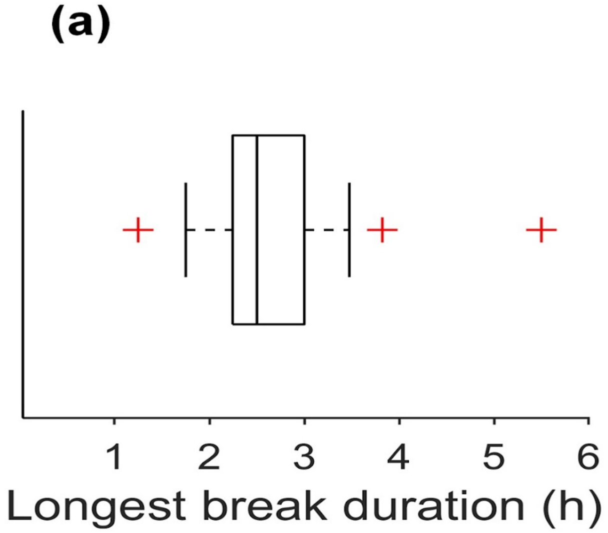


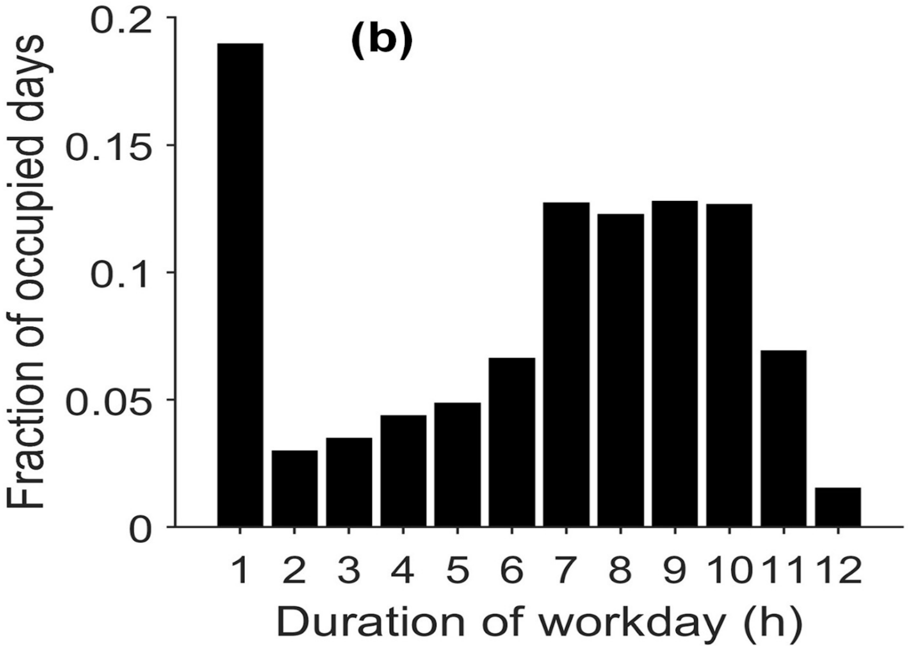
- Some zones in a building can be frequently empty.



- A simple, yet very effective sequence can exploit this:
  - If a **motion detector** has not been triggered until noon, the space will likely remain empty for the rest of the day.
  - Revert to zone to unoccupied mode & apply a 2-3°C temperature setback

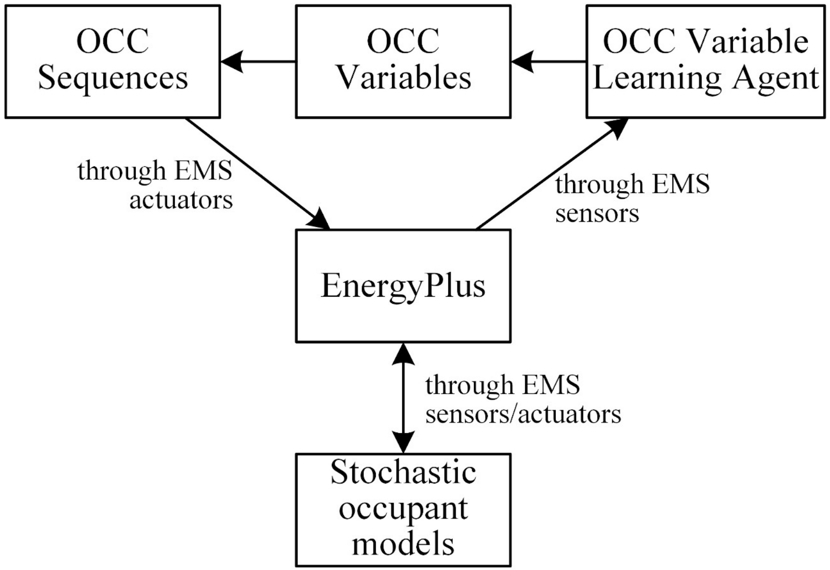
- On many days, occupants drop in for brief periods – just for meetings, pick up a delivery, etc.
- If the motion detector in a room hasn't been triggered for longer than the four hours, apply a 2-3°C temperature setback.





OCC in the BPS-based design process

(b)



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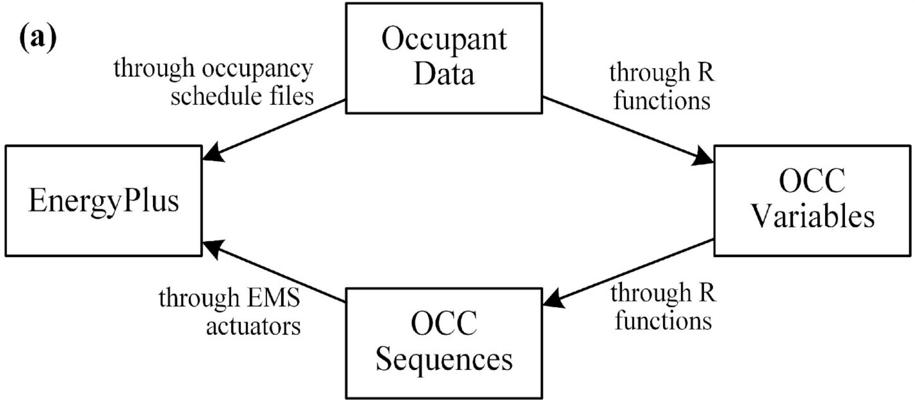
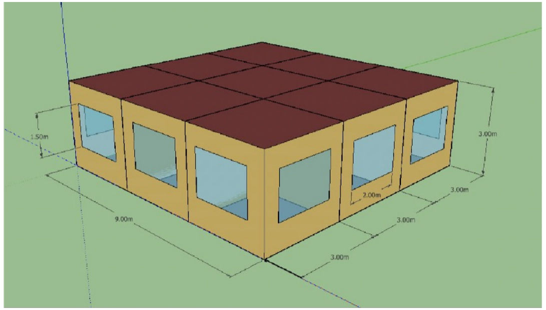


Energy savings potential of OCCs



OCC combination	Spatial resolution	OCC intervention	Average EUI reduction (%)
1	Building	Occupancy-based AHU start/stop	-4%
2	Building	Occupancy-based AHU minimum outdoor air fraction	10%
3	Zone	Occupancy-based VAV start/stop and setback	24%
4	Zone	3 + individual occupants’ preferred temperature setpoint	31% (+7%)
5	Zone	4 + individual occupants’ preferred illuminance setpoint	35% (+4%)

Detailed Case Studies

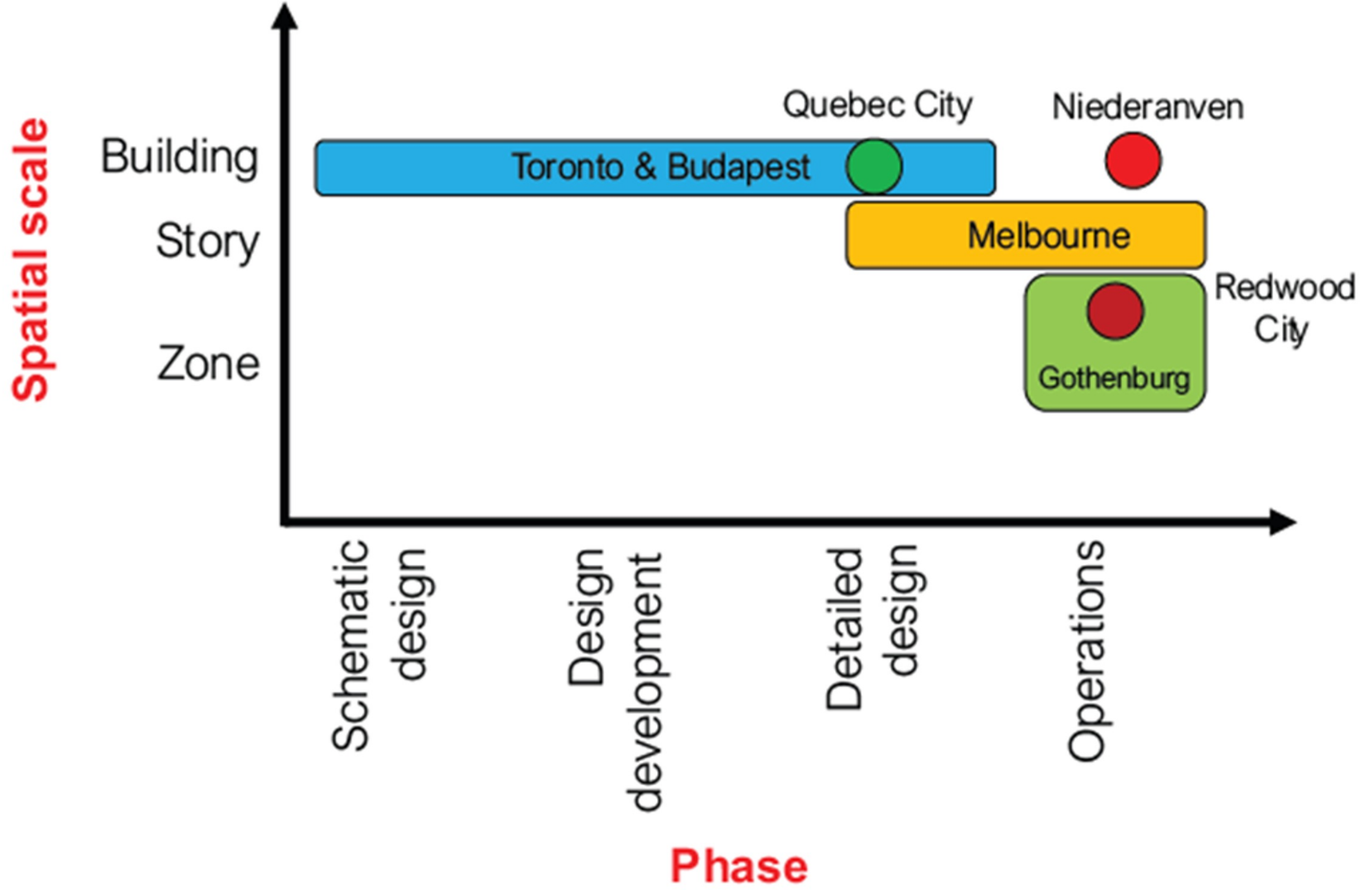
Tareq Abuimara
United Arab Emirates University

Detailed case studies

- Case studies demonstrate the real-world application of the occupant-centric design methods
- We provide analysis of seven unique case study buildings
- We demonstrate how occupant-centric design can assist in developing better designs
- We demonstrate alternative approaches for considering OB and occupant-related assumptions throughout the building design process
- Analysis involves simulation, field studies, surveys, and interviews with design stakeholders and occupants

Geographical distribution

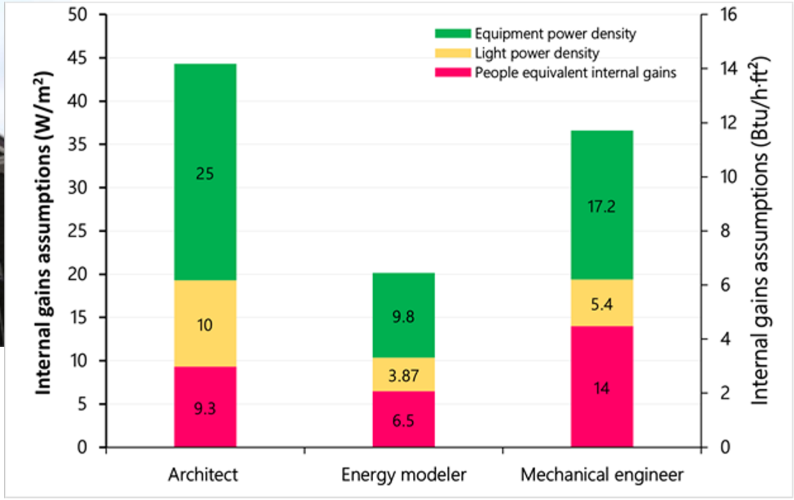
Spatial and phase distribution



Case study 1: Toronto, Canada [Design phase]

By: Tareq Abuimara, William O'Brien, Burak Gunay, & Juan Sebastian Carrizo

- Mid-rise office building
- Document the current practices of occupant modeling
- Alternative methods for occupant considerations



Case study 2: Budapest, Hungary [Design phase]

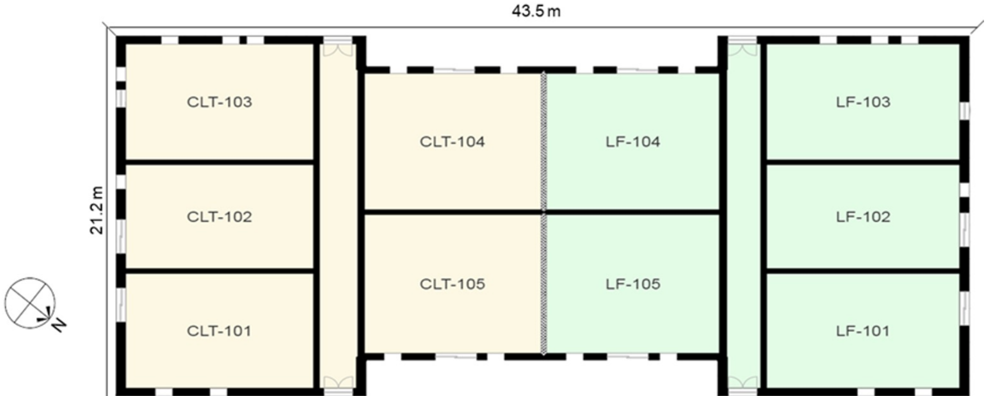
By: Attila Kopányi, Viktor Bukovszki, & András Reith

- A 27-unit apartment building
- Method to create occupancy schedules based on participatory design

Case study 3: Quebec City, Canada [Operation phase]

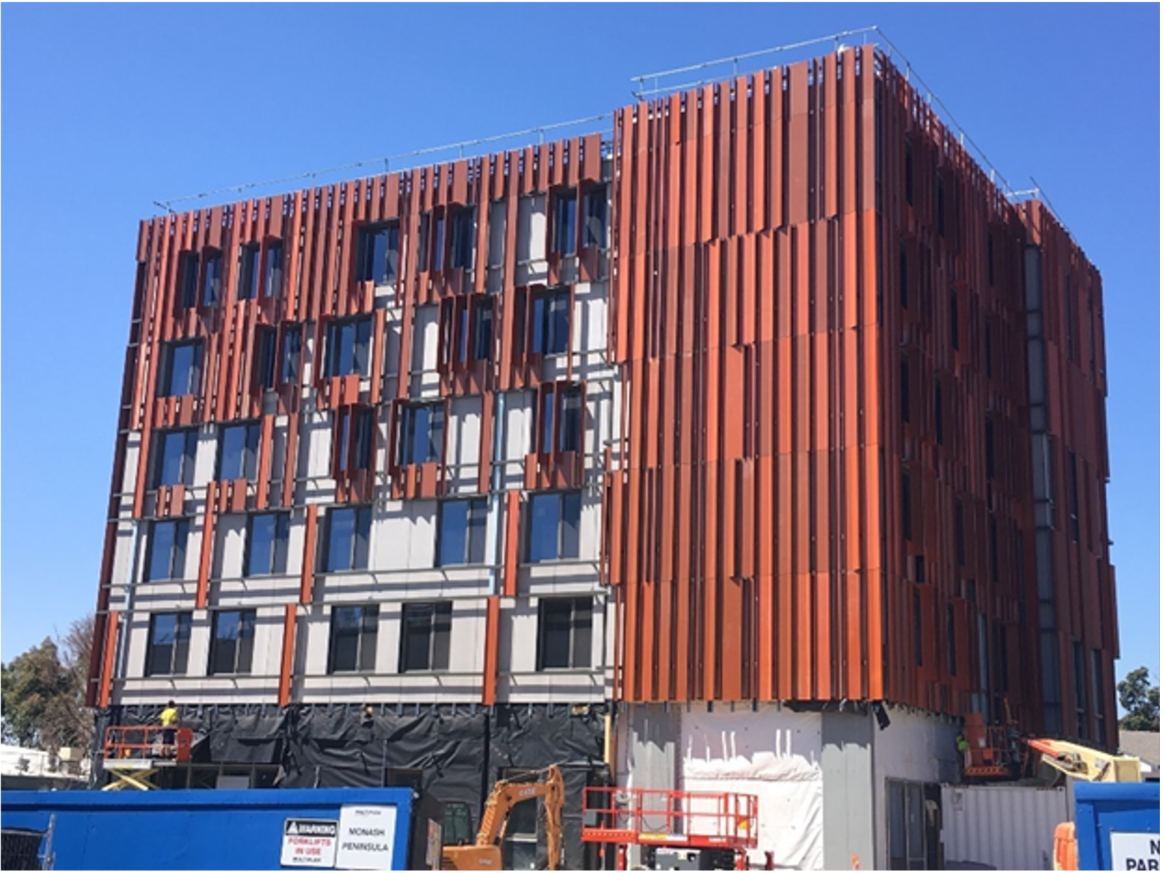
By: Jean Rouleau, & Louis Gosselin

- A forty-unit, four-story social housing building
- Explore the causes of performance gap
- Develop occupant-centric performance evaluation methods



Case study 4: Melbourne, Australia [Operation phase]

By: Ye Kang ,& Jenny Zhou



- Multi-story student accommodation
- Timber structure built to Passivhaus standard
- Occupants’ presence and Interactions with equipments and lighting were evaluated
- Thermal comfort was assessed

Case study 5: Redwood City, USA [Operation phase]

By: Andrew Sonta, Thomas Dougherty, & Rishee Jain

- A three-story commercial office building
- leveraging OB datal to optimize a commercial building's layout to save energy.

Case study 6: Niederanven, Luxembourg [Operation phase]

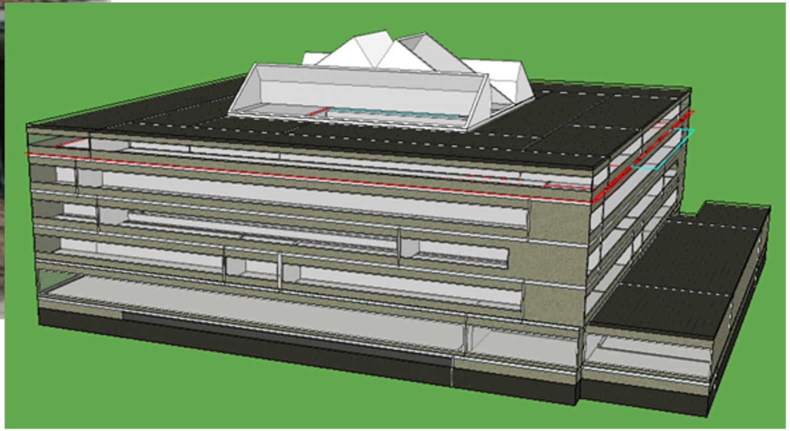
By: Ghadeer Derbas, Karsten Voss, & Tugcin Kirant Mitic

- Mid-rise office building
- Occupants' interaction with automated exterior shading system
- Identify occupant-centric rules for optimal shading design

Case study 7: Gothenburg, Sweden [Operation phase]

By: Quan Jin,& Holger Wallbaum

- Newly renovated office building
- Compare the predicted and actual indoor environmental performance



Questions and Discussions

William O’Brien, Farhang Tahmasebi
And Clarice Bleil De Souza

Thank you!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