IEA EBC Annex 79

Occupant-Centric Building Design and Operation

Energy in Buildings and Communities Programme

Operating Agents

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Annex 79 Overview

Following the success and critical mass of researchers of IEA EBC Annex 66 Definition and Simulation of Occupant Behaviour in Buildings (2013-2017), Annex 79 was formed. Now nearing completion, Annex 79 is similarly focused on building occupants, but with additional emphasis on multi-domain comfort, interfaces, big data and data-driven modelling, and design and control applications of occupant models.

The purpose of Annex 79 is to provide new insight into comfort-related occupant behaviour and interactions in buildings and its impact on building energy performance. An open collaboration platform for data and software will support the use of data-mining methods and advanced occupant behaviour models. It will further promote the usage of this knowledge in building design and operation processes by giving policy support, preparing proposals for standards and providing guidelines for practitioners. Results of the Annex will be widely disseminated through conference and journal publications, journal special issues, panel discussions and conference workshops, presentations, books, technical reports, and guidelines.

Despite the pandemic, Annex 79 has hosted three successful in-person and seven online/hybrid meetings and symposia – each attended ~~online~~ by approximately 100-150 participants. The past two meetings were hosted by the National University of Singapore and RTWH Aachen (Germany). The Annex 79 meetings normally are two days long and include a combination of plenary sessions and break-out sessions, whereby the researchers work in smaller teams to plan and discuss ongoing research activities (see full details later in newsletter).

The official list of participating countries has grown to 18: Australia, Austria, Belgium, Brazil, Canada, China, Denmark, France, Germany, Italy, Netherlands, Norway, Singapore, Sweden, Switzerland, Turkey, UK, and USA. Furthermore, there are three approved observer countries: Hungary, Poland, and the UAE. In all, there are about 110 active researchers in Annex 79, making it one of the largest of the projects of the Energy in Buildings and Communities (EBC) programme.

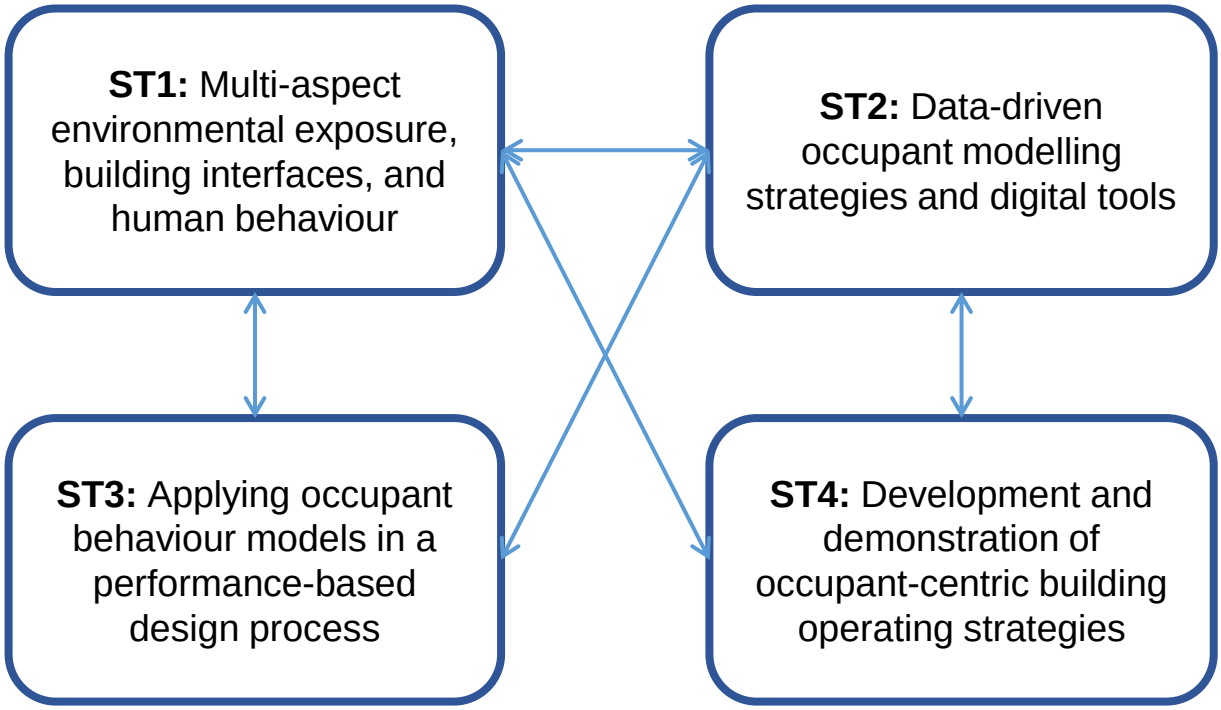
This newsletter is the final of its series, as Annex 79 is formally ending in 2023.

Annex 79 Overview

With the overall goal to integrate and implement knowledge and models of occupancy and occupant behaviour into the design process and building operation to improve both energy performance and occupant comfort, Annex 79 focuses on:

- Developing new scientific knowledge about interdependences between thermal, visual, aural and olfactory influences on perception and occupant behaviour in indoor environments,
- Understanding interactions between occupants and building systems by using interfaces, e.g. how interfaces en/discourage occupants taking advantage of adaptive opportunities for improving their comfort situation, as well as the impact on building energy use,
- Deploying 'big data' (e.g., data mining and machine learning) for the building sector based on various sources of building and occupant data as well as sensing technologies,
- Developing methods and guidelines and preparing standards for integrating occupant models in building design and operation, and
- Performing focused case studies to test the new methods and models in different building design and operation phases in order to obtain valuable feedback for the researchers and practitioners.

Annex 79 is structured into four subtasks, as outlined in the figure below; they are described in greater detail in the remainder of this newsletter.



Annex 79 Overview

To date, Annex 79 has undertaken a series of literature review papers that was published in a special issue of Building and Environment and is in this midst of planning and performing research. The reviews range from comfort-related behaviour, over building interfaces, to building codes and occupant-centric controls. Following these reviews, each subtask has embarked on a wide variety of research and development tasks to advance the state of the art in occupant-centric building design and operation. These are described in detail in each subtask session. Another special issue on OCC has been published in the Journal of Building Performance Simulation. Finally, another special issue in the journal Energy and Buildings is focused on occupant-centric control strategies for building systems.

Ultimately, Annex 79 will yield a series of reports aimed at a variety of audiences, as outlined below. Moreover, a new open-source book on occupant-centric design which has been published with contributions by over 30 Annex 79 members, will be part of the deliverables. In the meantime, Annex 79 participants have been actively disseminating research through online seminars, tutorials, and keynote talks.

Planned Annex Deliverables:

1. Comprehensive final Annex Report, summarizing most essential activities:

- The core of the report will consist of a set of four main chapters which will give an overview of the most significant contributions of each subtask.
- Cross-subtask activities will be filed in thematically closest subtask.
- Corresponding chapters and sections will be tagged for the different audiences addressed in the previous deliverables plan.
- In addition, a comprehensive summary with conclusions and recommendations for future work, as well as all further relevant information about Annex 79 (participants, events, etc.) will be part of the final report.

2. Open-access book: Occupant-centric building design

A comprehensive book that includes fundamentals on occupant comfort, consideration of occupants and occupant behavior in design processes, occupant modelling and simulation, and case studies focused on occupant centric design.

3. Guideline on data collection and modeling of occupant behaviour for building controls

A guideline for technologies and best practices to collect occupant-related data for applications in occupant modelling for simulation and for occupant-centric controls.

4. ASHRAE Global OB Database

A centrally-coordinated database of occupancy and occupant behavior data. Currently available: www.ashraeobdatabase.com.

5. Platform for sharing and evaluating OB models

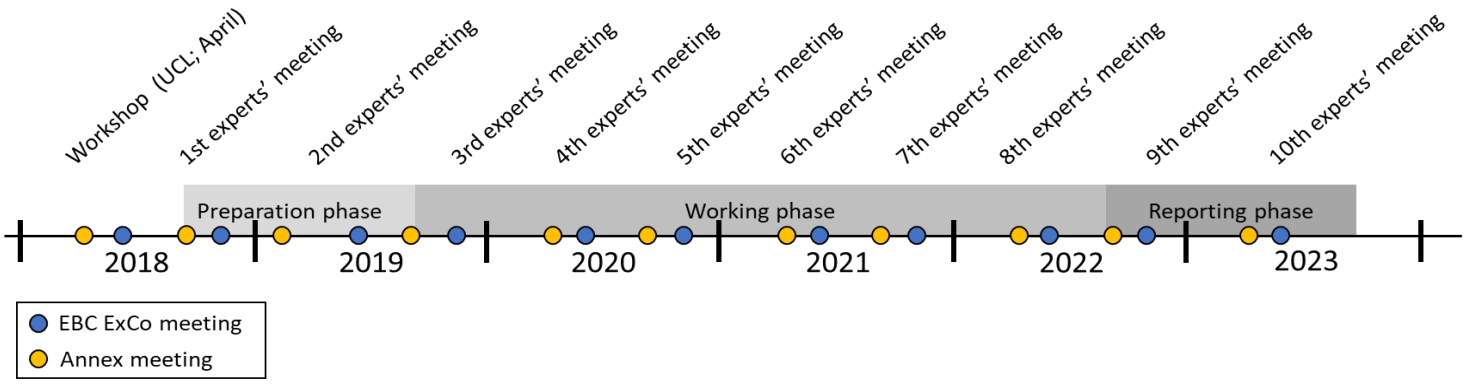
A database with occupant behaviour models that is based partially on the ASHRAE Global OB Database.

6. Online library of case studies on OCC projects

A large international collection of documented case studies of buildings or spaces that demonstrate occupant-centric controls.

Expert Meetings

As we conclude Annex 79, we look back on 10 productive meetings over the past five years. Up-to-date information is posted on the website: http://annex79.iea-ebc.org. Individuals interested in participating in Annex 79's follow-up should contact Professor Liam O'Brien.

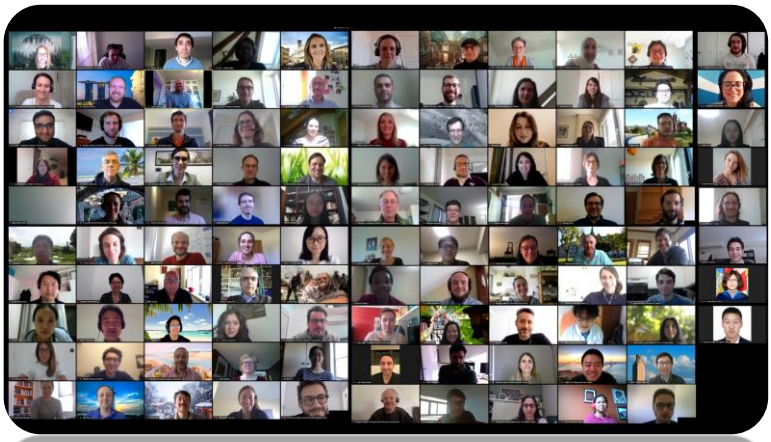


Ottawa 10/2018

San Antonio 03/2019

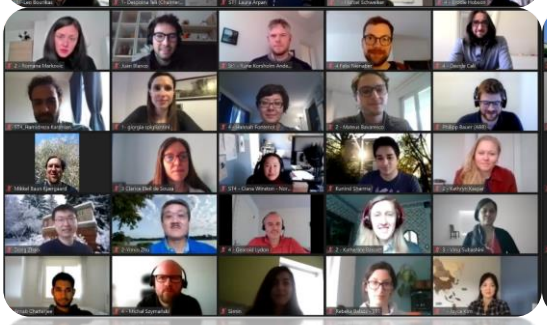
Perugia 09/2019

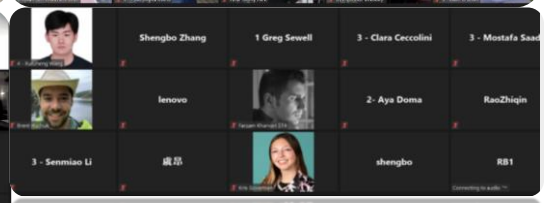
Expert Meetings



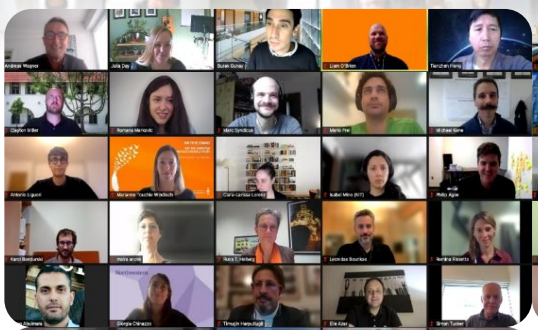
Southampton 04/2020

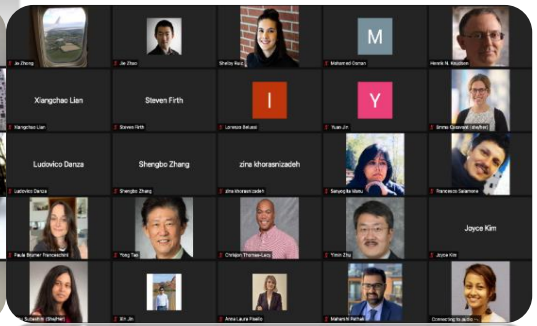
Odense 09/2020





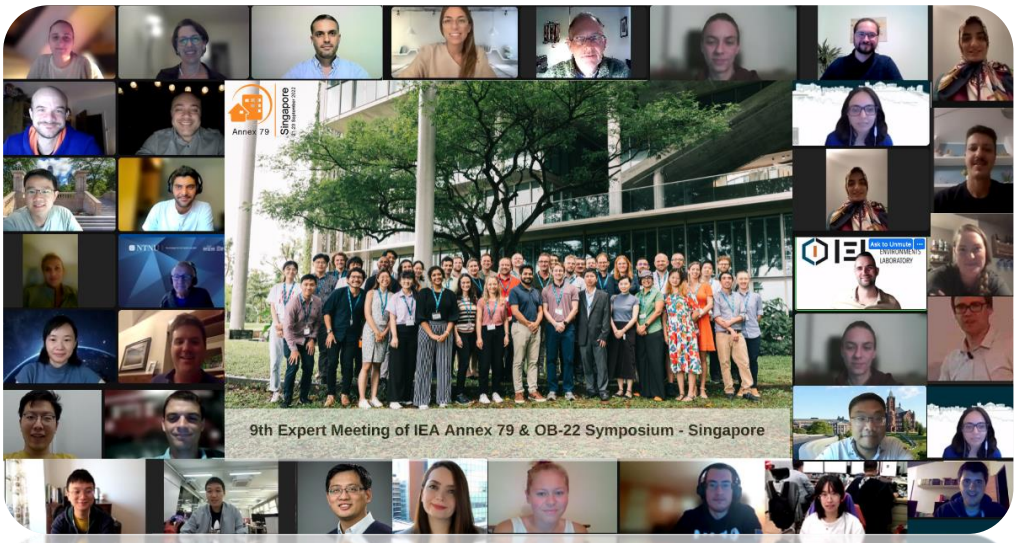
Trondheim 04/2021





Pullman 09/2021

London, 03/2022



Singapore, 09/2022

Aachen, 06/2023

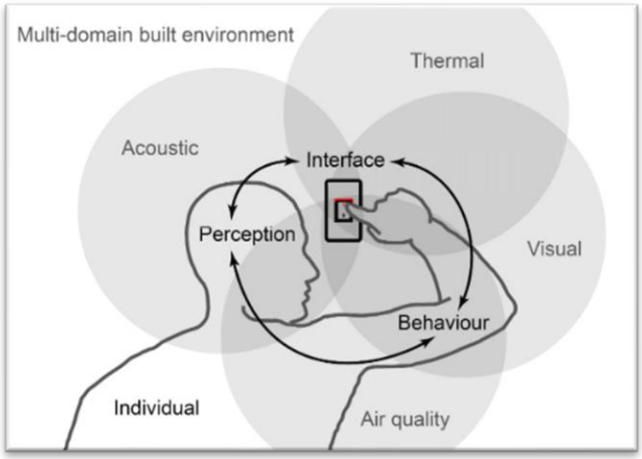
Subtask 1

Multi-aspect environmental exposure, building interfaces, and human behaviour

Leaders: **Ardeshir Mahdavi, Technische Universität Wien, Austria**
Marcel Schweiker, University Hospital RWTH Aachen University, Germany
Julia Day, Washington State University, USA

INTRODUCTION

Existing models of human comfort, perception, and behaviour are commonly formulated for single-domain environmental exposure circumstances (e.g., thermal, visual, aural), while multi-domain exposures are the reality. The main objective of this Subtask I is the investigation and development of the next generation of multi-domain perceptual and behavioural models, based on an interdisciplinary approach between technical/engineering disciplines and human sciences (e.g., psychology, sociology).



To encourage user behaviour patterns that are desirable for comfortable indoor environmental conditions while meeting the operational efficiency criteria, a better understanding of interfaces to control-relevant building features and systems (and corresponding occupant behaviours) is critical. There are many building interfaces which are poorly understood in terms of occupant interactions and resulting energy impacts or comfort. Therefore, a second focus of Subtask 1 is to better understand and develop research techniques to study energy-related occupant interactions in the context of multiple aspects of indoor environmental exposure.

PROGRESS/ACHIEVEMENT

There are multiple activities that have been completed in Subtask 1:

- Three comprehensive initial reviews: (1) An overview of existing theoretical work relevant to multi-domain behaviour; (2) A structured overview of past multi-domain efforts toward the state of the art of scientific knowledge and the formulation of human comfort and behaviour models; and (3) A review on research related to interfaces and their effect on occupant behaviour and energy use.
- Quality criteria for multi-domain studies in the indoor environment: This study critically reviewed the literature on multi-domain studies and proposed research guidelines and recommendations for future multi-domain investigations. One of the main strengths of this contribution was stressing the importance of adopting a consistent terminology and result reporting style in future studies.

Subtask 1

Multi-aspect environmental exposure, building interfaces, and human behaviour

PROGRESS / ACHIEVEMENT (CONT.)

- Exploring IEQ standards' evidentiary basis: This activity examined IEQ standards in view of the robustness of their underlying reasoning and evidentiary basis. The activity entailed five parallel streams, addressing multiple IEQ domains: thermal, visual, acoustic, indoor air quality, and user control aspects in indoor environments. It was explored if and to which extend the standard-based requirements are supported by direct or indirect references to relevant technical literature.

Further completed activities include:

- Review study on the role of building occupants in the energy performance gap
- Necessary conditions for a new generation of multi-domain IEQ standards
- Survey on the influence of pro-environmental values on thermal expectations in energy-saving buildings
- Review studies on world-wide test room-like wellbeing experimental facilities and living-labs for wellbeing analysis

Ongoing activities:

- Ways forward for collecting information in multi-domain studies: Multi-domain studies of human-building interaction are key to understand occupant needs and requirements in an indoor environment for suitable building design and operation. Therefore, a review of multi-domain studies of human-building interaction is done to analyze their methodological approach and data collection strategies. Key findings of this activity are, firstly, that the most popular methods are not able to fully explain complex processes of human-building interaction. Secondly, a significant lack of a framework of methodological approach in multi-domain studies was recognized. The activity findings are important feedback for the scientific community about the state-of-the-art in data collection methods and tools, and gaps in current approaches.
- Acceptability of occupants sharing information: Human perception and occupant behavior are driven by a multitude of factors and the amount of information/data has increased manifold in recent times, including very personal data. To find out which personal information are occupants willing to share and under which conditions, researchers of this activity developed a questionnaire assessing these questions and revealing insides into occupant's willingness to share information, depending on their “cultural” background, and in relation to (perceived) benefits.
- Generational building resilience - learning about buildings and interface use: The goal of this pilot project was to meet with seniors to learn from their generational knowledge and their stories surrounding their experiences with and in the built environment. This pilot study implemented qualitative and narrative methods to interview and observe older adults in buildings to better understand how the passing of time has changed their relationship with and their interactions within the built environment. Qualitative data about well-being, health, socialization, building interfaces, lifestyles across lifetimes, adaptive comfort strategies etc. have been collected in the United States.

Subtask 1

Multi-aspect environmental exposure, building interfaces, and human behaviour

PROGRESS / ACHIEVEMENT (CONT.)

- Round robin large scale experiments: A large-scale experiment in "similar" test rooms for multi-domain comfort investigations is performed among Annex participants. Particular interest lies in investigating physiological responses of occupants exposed to multi-domain environmental stimuli. After the protocol had been finalized and the first series of experiments were performed in summer 2022 and winter 2022/23, intermediate results are analyzed, and the goal is to continue another experimental series in 2023.
- Educational study on the influence of availability of IAQ information on user behavior: This activity includes a multi-national and multi-disciplinary CO2 monitoring campaign with students. The main goal is to monitor the IAQ in student dwellings (temperature, RH, CO2) and evaluate whether having access to data characterizing IAQ from the meter interface can be an effective way to alter occupant behavior and improve IAQ. The data collection efforts were significantly affected in 2020 and 2021 due to the COVID-19 pandemic, but nevertheless three researchers managed to carry on the data collection.
- Examining the impact of working from home (during a pandemic) on occupant health, well-being and productivity: One goal of this activity was to gather information about how individuals perceive their home workplace and whether they feel the environmental quality and the design of their workplace affects their productivity, health and well-being. A questionnaire has been deployed via Qualtrics, in English and ten additional languages. Answers were collected during the Fall of 2022. This activity continues in 2023. Related to this, another objective was to assess evaluations that have been done around Work-from-Home (WfH) settings, best-practice methods for evaluating the dependent variables in WfH field studies and the kind of instrumentation used for such studies. A literature review was done based on papers that range from non-IEQ studies related to WfH context to multi-domain IEQ studies in WfH and residential settings. Literature search for this review has been completed and results on IEQ research in WfH settings will be finalized for inclusion.

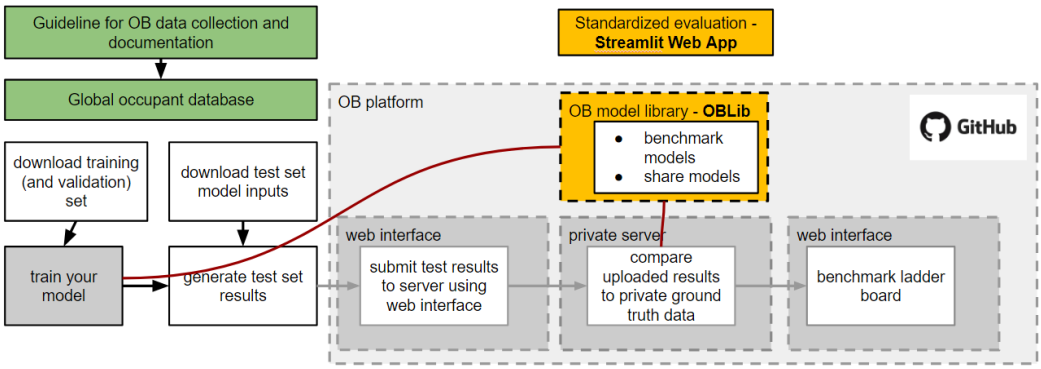
Subtask 2

Data-driven occupant modelling strategies and digital tools

Leaders: **Bing Dong, Syracuse University, USA**
Salvatore Carlucci, Cyprus Institute, Cyprus
Romana Markovic, Karlsruhe Institute of Technology, Germany (until May 2022)

INTRODUCTION

The overall goal of Subtask 2 is to advance methodologies and tools for data-driven modeling and occupant behavior in buildings (i) by deploying "big data" for the building sector based on various sources of building and occupant data as well as fostering the penetration of newer sensing technologies, (ii) by developing and sharing methods and guidelines for integrating occupant models in building design and operation, and (iii) by developing digital tools and platforms for enabling occupant behavior research. These objectives have been pursued by carrying out three main activities consisting of (i) developing a novel occupant data collection approach for occupant data, (ii) investigating different methods for occupant behavior, and (iii) promoting the creation of a research community interested in sharing occupant data and data-driven methods.



OB Framework – A framework for evaluating and sharing OB models

PROGRESS / ACHIEVEMENT

To date, the members of Subtask 2 have completed the following activities:

- Review existing big data source for occupant behavior: In this activity, a comprehensive review of different sources of occupant-centric urban data was conducted that are useful for data-driven modelling and the range of applications and recent data-driven modelling techniques for urban behavior and energy modelling was categorized, along with the traditional stochastic and simulation-based approaches. Finally, a set of recommendations for future directions in data-driven modelling of occupant behavior and energy in buildings at the urban scale was presented.

Subtask 2

Data-driven occupant modelling strategies and digital tools

- Develop and study collection and curation methods with big data: In this activity, a review was conducted for occupant behavior modeling within and beyond building science. The goal was to bridge the data sources and methodology gap between building science and beyond. In order to achieve this goal, different research questions were addressed like modeling requirements of occupant behavior at a community level, data sources which have been used in other domains, current modeling methods of occupant behavior, modeling methods that have been used in other domains and could potentially enhance the modeling capabilities for building domain applications, as well as potential future research directions.
- Developing a data sharing platform for occupant behavior: In this activity, the efforts from ASHRAE global database were leveraged and a data sharing platform was developed. This data sharing platform includes data sets from 32 data contributors from 15 countries. It covers a wide range of occupant behavior including presence and number of occupants in a room or whole building, appliance usages, window opening, shading behavior, lighting operation, etc. The website is open to the public now at www.ashraeobdatabase.com.
- Towards a standardized evaluation protocol and benchmark for OB modeling: The aim of this activity was to propose a guideline for a thorough and standardized occupant-behavior model documentation. A literature screening for existing occupant behavior models in building control was conducted, and occupant behavior modeling processes were studied to extract practices and gaps. The literature screening pointed out that the current state-of-the-art on model documentation shows little unification, which poses a particular burden for the model application and replication in field studies. In addition to this, a model-evaluation schema was presented that enabled benchmarking of different models in field settings as well as the recommendations on how OB models are integrated with the building system.
- Investigation of metadata schemas for OPA data: The objective of this activity was to explore and develop possible metadata schemas in order to properly describe occupant presence and action datasets in a way that the research community can understand and use them. The activity contributed with a section on these matters to the literature of two other activities. The existing metadata schemas were reviewed and the Subtask 2 deliverables are currently being aligned with the state of the research, namely extended BRICKS schema extended by the occupant-related information.
- Review of open data principles, open data availability, usage of open data and software support for sharing: A literature review was completed and a paper has been published in Building and Environment as part of the special issue of the Annex.
- Approaches for data-driven occupant-centric modeling based on big data: This activity collected different approaches of machine learning techniques to OPA databases to identify potentialities, limitations, new opportunities. In the last term, a paper on occupant-oriented model predictive control for demand response in buildings was published.

Subtask 2

Data-driven occupant modelling strategies and digital tools

- Community building for data-driven methods on Occupant-centric data: The creation of a community was fostered by organizing and conducting the 1st ACM International Workshop on Big Data and Machine Learning for Smart Buildings and Cities (ACM BALANCES) at the BuildSys international conference in Coimbra Portugal on 17-18/11/2021. The workshop included 2 keynote speakers, 8 paper presentations with 46 participants and more than 400 views on YouTube. Furthermore, a PhD forum was organized on 12/11/2021 with 2 speakers and 18 participants. A second ACM BALANCES workshop was held in conjunction with ACM BuildSys 2022 on 9 November 2022 with 12 submissions and 8 accepted papers.
- Anonymization methods for handling privacy of occupant data : This activity was investigating cases of privacy risks and possible anonymization methods to protect different typologies of datasets. The screening for the case study data sets was initiated in April 2021. Additionally, this activity contributed with a section on these matters to the literature review of another activity. As the part of this activity, a framework of "privacy by design" versus "privacy preprocessing layer" was included in the planned platform of OB sharing. The current version of the tool is available under http://privacyrisktoolchain.tek.sdu.dk.
- Open source ObLib project: This activity created an open-source occupant behavior library and benchmark model performance based on the same data sources, which are from our Global Occupant Behavior Database. The goal of this ObLib project was to have ready to use occupant behavior models for presence, occupant numbering, window opening, lighting operation and thermostat behaviors. The current version of the tool is available under: https://github.com/yapanliu/OBlib.

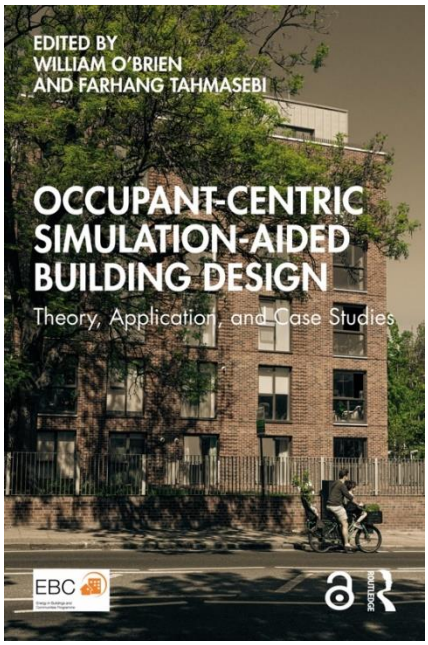
Subtask 3

Applying occupant behaviour models in performance-based designs

Leaders: **Farhang Tahmasebi, University College London, UK**
Tianzhen Hong, Lawrence Berkeley National Laboratory, USA
Da Yan, Tsinghua University, China

INTRODUCTION

Subtask 3 aims to develop systematic methods to apply occupant models for achieving high-performance building designs with regards to comfort, usability, and energy performance. To this end, Subtask 3 benefits from focused literature reviews and the results of Subtasks 1 and 2, develops and refines occupant-centric simulation-aided design procedures, and investigates a number of case study buildings to evaluate and disseminate these progressive design processes in practice.



Cover of the book Occupant-Centric Simulation-aided Building Design

PROGRESS/ACHIEVEMENT

To date, the members of Subtask 3 have completed the following activities:

- Most notably, Subtask 3 team coordinated a wide spectrum of research streams (ranging from indoor environmental quality and design theory to occupant modelling and simulation), to enable the publication of an open-access book by Routledge titled "Occupant-centric Simulation-aided Building Design and Operation" (O'Brien and Tahmasebi, 2023). This book is the first, to our knowledge, to connect occupant needs to the building design process via simulation-based design methods and workflows.

Subtask 3

Applying occupant behaviour models in performance-based designs

- Review of codes and standards involving performance-based design: Concluding the international review of occupant representation in building energy codes (covering 22 countries' building energy codes), a peer-reviewed paper reporting on this research activity was published in Building and Environment special issue.

- Develop, test, and document simulation-based occupant-centric design procedures: This activity successfully concluded an exploration of computational design support methods (such as robust design, parametric design and optimization) with a focus on occupant-centric design metrics and modeling/simulation approaches.

- Develop methods and guidelines to choose fit-for-purpose occupant modelling approaches: Subtask 3 researchers prepared a chapter in the aforementioned subtask-led book titled 'Occupant-centric simulation-aided building design'. In addition to the contribution to the book, the fit-for-purpose strategy was applied to several existing buildings (Arup offices in different locations). The Impact Indices method was further developed to i) allow for different spatial and temporal resolutions; ii) account for real-life scenarios whereby heating and cooling seasons are not clearly distinct; iii) increase its validity by means of rigorous validation; iv) extend its scope and utility; v) increase automation capability (script was provided); and vi) allow for easier and more intuitive visualization. The outcome of this work was drafted as a peer-reviewed paper and presented internally at Arup to the Sustainability Team and Smart Buildings Team.

- Make recommendations for occupant-related prescriptive and performance paths of building codes: Given the successful completion of Activity 3.1, which – amongst other things – resulted in a set of recommendations for representation of occupants in building codes, Subtask 3 participants decided to withdraw this activity. However, one of Annex 79 Operating Agents who has co-led Activity 3.1, informed IEA EBC Working Group on Building Energy Codes about Annex 79 efforts and findings in this area.

- Develop standard ways for communicating occupant-related assumptions between stakeholders: Finalizing a literature review of challenges, barriers and needs to develop effective communication mechanism of the occupant-related assumptions among the building design stakeholder, a conference paper was published in Building Simulation conference in Belgium (BS2021), which documented the common practice and challenges in communicating occupant-related assumptions during design thorough practitioners' interviews. The activity concluded by providing recommendations for best practices in communicating occupant-related assumptions among design stakeholders.

Subtask 3

Applying occupant behaviour models in performance-based designs

- Development of synthetic occupant models: A literature review was conducted on synthetic population models for other disciplines (e.g., transportation), as well as methods to develop synthetic population models. Potential use cases of the synthetic population model across the building life cycle were identified. The existing DNAS ontology and obXML schema were extended and existing datasets have been identified to be used for the model development and verification, including the occupant survey conducted by Annex 66, the ASHRAE Global Thermal Comfort Database, the Annex 66 special issue for Nature Scientific Data, and the ASHRAE Global Occupant Database. A paper on the review and extension of DNAS ontology was published at Automation in Construction. Another paper on methods to generate synthetic occupants from existing datasets is published in the Journal of Building Performance Simulation.

- Big data analytics for occupant behavior research: This activity has concluded a dataset of occupancy at building scale and three articles concerning typical occupancy patterns and occupancy forecasting research in Energy and Buildings journal, including typical clustering patterns, modelling and forecasting methods through big data analytics, and evaluation results. The activity also finished two joint review articles (in collaboration with Subtask 2) which have been published in Building and Environment and Applied Energy journal. The papers were structured to address the modelling requirements and data sources, occupant modelling methodologies at urban scale and opportunities for future resilient building design, operation, and policy at community level. The activity also analyzed the role of occupant behavior research in energy policy concluded in one article in Building and Environment journal.

- Case studies: This activity collected detailed case study buildings to demonstrate the applications of the research on occupant-centric design methods and show the strengths and shortcomings of current occupant modelling and building design approaches. Case studies were selected based on: (1) accessibility to information about the case study, (2) breadth of design/construction phases among the case studies, and (3) usability of analysis outcomes in advancing occupant modelling approaches. The case studies were diverse in project phase, location, climate zone, building type and size, and analysis approach. The analysis of the selected case studies covered the entire life cycle of a building including schematic design, design development, construction detailing and construction, and operation. All case studies were included in the aforementioned book.

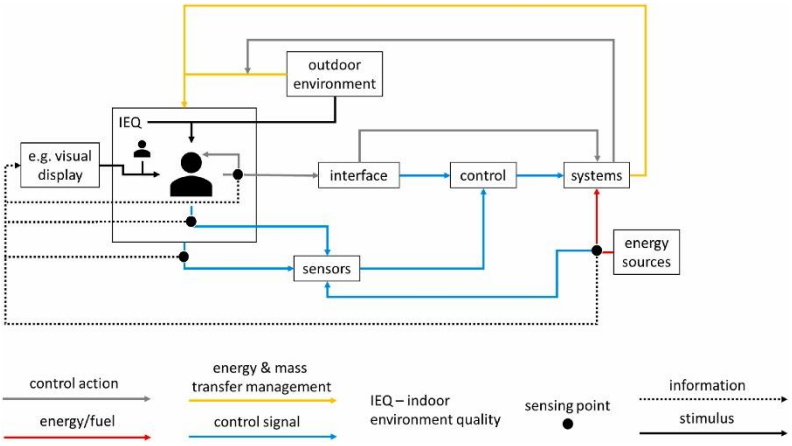
Subtask 4

Development and demonstration of occupant-centric building controls

Leaders: **Burak Gunay, Carleton University, Canada**
Zoltan Nagy, University of Texas Austin, USA
Clayton Miller, National University of Singapore, Singapore

INTRODUCTION

The focus of Subtask 4 is to develop and demonstrate occupant-centric controls (OCC). The activities within Subtask 4 reveal practical challenges regarding the implementation of OCC in existing buildings. The results from focused case studies highlight and quantify potential improvement in occupant comfort and energy savings reductions through OCC. These case studies identify future research and development needs in OCC and they guide practitioners in implementing occupant-centric indoor climate control strategies.



Taken from Nagy et al. (2023)

Further, they help identify appropriate building automation system sensor/actuator configurations. The case study buildings are selected starting with office buildings. However, the focus may extend to other building types such as academic, retail, and health care buildings.

PROGRESS/ACHIEVEMENT

- State-of-the art in real-world implementations of occupant-centric controls: The objective of this activity was to review the real-world implementations of occupant-centric control algorithms in the scientific literature. Two journal papers were published. Of them, one focused on commercial and institutional buildings, and the second one focused on residential buildings.
- Operator Interviews for OCC: This activity focused on interviewing operations professionals from real-world case studies to collect information regarding standards, common practices, needs. The interviews were led by 33 researchers from 16 different institutions. This activity completed and parsed 72 interviews from seven countries and four climate zones. All of them were imported into nVivo on a virtual machine for analysis. The researchers involved have "coded", i.e., pulled out quotes on themes relating to the original research questions. A paper that describes the methods and overall results and another paper on international differences in building operation were published.

Subtask 4

Development and demonstration of occupant-centric building controls

- Case Study Descriptors: The objective of this activity was re-targeted as a method of creating a set of descriptors and a framework for collecting data about case study buildings. A sub-team developed a survey using the Qualtrics platform that included over 120 questions capturing the various attributes of an occupant-centric operations case study. There were several categories of questions related to building meta data, data about occupants, operators and operations policies, building HVAC and lighting information, occupant interaction and motivation, and interventions related to occupant or operator behavior change. Data collection was completed, and survey results were analyzed and compiled for publication.
- Simulation-based Investigation of Occupant-Centric Controls: The objective of this activity was to develop a simulation environment for the development and assessment of occupant-centric control algorithms. This simulation environment was implemented in the building performance simulation tool EnergyPlus. The capabilities of this environment were demonstrated through simulations with archetypical building energy models. Three journal articles were published addressing barriers regarding the simulation of occupant-centric controls. Progress of several case studies was discussed including an in-depth implementation of fine-tuning OCC using optimization. A journal special issue at Journal of Building Performance Simulation including seven original research contributions and an editorial was published in early 2022. Research in this topic was complete with new publications introducing OCC algorithms presenting novel machine learning techniques such as reinforcement learning and providing recommendations for ideal sensor configurations for OCC deployments by using building performance simulation.
- Occupant-Centric Operations for Demand-Response: This activity focused on the analysis of occupant-centric building operations in the context of residential and non-residential demand-response. The objective of this activity was to improve the acceptability of demand-responsive sequences of operation that involves short-term curtailment of various building services. This involved sending personalized demand response signals and prioritizing the curtailment of services to unoccupied spaces. Large scale field implementation involving 30 residential buildings with forced-air heating and cooling systems in three climates in the United States is currently underway.
- Occupant-Centric Longitudinal Intensive Methodologies: This activity focused on the implementation of longitudinally intensive methodologies to collect data from occupants in buildings. Several new projects using smart-watches and smart-phones formed the foundation for this activity. Publications were produced that represent best-practice use cases of longitudinal occupant feedback data collection mechanisms.
- Implementation of occupant-centric control strategies case study buildings: This activity entailed the integration of occupant-centric control algorithms to the building automation systems of the case study buildings. Technical and non-technical obstacles emerging at this phase were be carefully documented for future reference.
- Testing of the case studies: This activity involved measurement and verification of the case study results by individual research groups. On top of this, Subtask 4 set and reported standards to measure and verify energy and comfort performance benefits of occupant-centric controls.

Subtask 4

Development and demonstration of occupant-centric building controls

Ongoing Activity:

- Synthesis of the case study findings: The objective is to summarize the results of the entire Subtask, make the "lessons learned" available for others and highlight promising types of algorithms. The summary will be documented in a report, and a guideline document for the implementation of occupant centric controls will be developed. This activity was discussed in detail regarding the methods of compilation of case studies. We are currently working on a journal paper synthesizing the main findings. While early findings from this activity are included in the final report, the paper publication may go beyond the current Annex.

Cross-subtask Activities

Recognizing the importance of multidisciplinary research, the final years of Annex 79 saw particularly active "cross-subtask activities" that involve expertise from multiple subtasks.

Accounting for occupants in building design and operation practice: The aim of this activity was to gather information on how occupants are considered in building design in the early design stage and get insights on practitioner's perspective and OB consideration in practice. The method used was conducting an online survey among the practitioners in different countries. A questionnaire was translated into 11 languages and 440 valid responses were received which are currently analyzed and evaluated.

Agent-based modelling**:** This activity aimed to advance agent-based modeling for integration with building performance simulation to evaluate impact of occupants on building design and operation and vice versa. Sub-activity A focused on identifying and integrating behavioral theories into ABM to improve modeling of occupant decision making in terms of their activities, comfort preferences, and human-building interactions. Sub-activity B focused on understanding, defining, and demonstrating various levels of detail of ABM to support their use across the building life cycle. Sub-activity A completed with the exploration of behavioral models as the potential knowledge base for the definition of ontologically streamlined behavioral patterns suitable for inclusion in ABM. The activity also involved a literature review to summarize use cases and their modeling details for ABM, leading to the development of a ten-question paper to provide an overview and in-depth discussion on ABM focusing on level of details and applications. The activity also included the development of a framework to define ABM LoDs and five simulation-based case studies using the ABM LoD framework.

Framework for Occupant Behavior Models Documentation: This activity provided a framework to document occupant behavior models that are developed for building performance simulation. The framework should help modelers, practitioners and stakeholders to better comprehend the utility of OB models, as well as to select and adopt the most suitable model for their design application. An overview of the state-of-the-art of occupant behavior model documentation is also provided by systematically reviewing to which degree existing academic papers on occupant models meet the framework. Most of the papers provide occupant models without specifying their purpose and without providing any information about their implementation. The two aspects appear to be related and indicate that occupant models have been so far developed without any specific BPS application in mind. This further indicates the need for such a framework.

ASHRAE Database: This activity focused on developing a database of well-documented occupant behavior data containing 34 field-measured occupant behavior datasets. These datasets are sourced from 39 institutions spanning 15 countries and 10 climatic zones, encompassing a variety of building types in both the commercial and residential sectors. For public accessibility, a website was launched, https://ashraeobdatabase.com, allowing users to interactively browse, query, and download specific datasets or the entire database.

Cross-subtask Activities (continued)

Human Factors and Ergonomics (HF/E) for the Built Environment: This activity focused on characterizing and employing HF/E methods that are well established in other interactive system domains to design buildings that meet the physical, physiological, and psychological needs of human operators (e.g., occupants and facility managers). This activity had a particular focus on HF/E subdomains of human-computer interaction (HCI), systems engineering, and human-centered design (HCD). The first activity, an editorial that framed the problem space, was finished. Another activity is underway, aimed at mapping building interfaces using an artifact analysis approach. It will yield best practices for interface design and evaluation criteria for building interfaces.

Dynamic glossary of IEA EBC Annex 79: The Annex 79 members stem from a quite diverse collection of disciplines. Oftentimes, the connotation and denomination of terms was encountered to be slightly different, depending on which scientific disciplines persons came from. Therefore, the idea for a dynamic glossary hovered around for a longer time. First templates of how this glossary (including key term definitions from various disciplines and the accompanying discussions of terms) have been created and posted on the Open Science Framework: https://osf.io/suhdj/. Due to the effort this voluntary action would have taken, it was not possible to gain enough momentum and augment the collection substantially. The Dynamic Glossary was intended to collect and discuss discipline-specific definitions and connotations in order to facilitate interdisciplinary exchange and to avoid misunderstandings by using key terms that are interpreted differently. No finalized or published deliverable is related to this project.

Activity C.7: Human-System Interfaces for OCC

This activity focused on providing guidance on occupant-centric controls (OCC) by learning from field observations to close the gap between predicted and measured performance and user satisfaction. Among the main investigated success factors were occupants' acceptance of automated systems, the usability of interfaces, and the communication and training of occupants and operators. A pilot story collection study and analysis were carried out based on the field studies of Annex 79 members, and an article presenting this proof of concept was accepted at the ASHRAE-AIVC IAQ joint conference in Athens. Currently, a survey is being piloted to understand how people perceive different features (e.g., colors, symbols, layouts) of thermostats.

National Participation (without Observers)


Australia


Austria

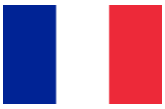

Belgium


Brazil


Canada


China


Denmark


France


Germany


Italy


Netherlands


Norway


Singapore


Sweden


Switzerland


Turkey


UK


USA

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