Lawrence Berkeley National Laboratory

Occupancy Simulator

- TUTORIAL -

Version 1.3.2

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Getting started with Occupancy Simulator App

This tutorial provides a step-by-step guide for users to quickly learn the Occupancy Simulator App.

Introduction

The International Energy Agency (IEA) Energy in the Buildings and Communities Program (EBC) Annex 53 (Total Energy Use in Buildings: Analysis & Evaluation Methods) pointed out that occupants' activities and behavior is one of the six key factors directly influencing building energy use. Occupant behavior is now widely recognized as a major contributing factor to uncertainty of building performance [1]. The occupant behaviors can be organized into two categories: occupancy and occupants' interaction with building systems [2]. The occupancy determines the location of each occupant in each time period. When occupants are located in a space, they may be able to control the building systems (such as lights, HVAC, and windows), and thus impact the energy consumption of the space. Traditionally, in building energy modeling (BEM) programs, occupancy inputs are static and less indicative of real world scenarios, contributing to discrepancies between simulated and actual energy use in buildings.

The occupancy simulation is the foundation of occupant behavior research. Wang et al. introduced a novel approach [2] for building occupancy simulation based on the Homogeneous Markov chain model to simulate occupants' stochastic movement process. The model can generate the location (which space) for each occupant and the occupancy of each space of the building at a particular time.

This App is an agent-based occupancy simulator for building performance simulation. It is a web application running on a server and simulates occupant movement in a building using the Markov-chain model [2, 3]. The App takes high level input of occupants, spaces and events, then simulates occupant movement and generates occupant schedules for each space. The generated schedules capture diversity and stochastic nature of occupant activities. These schedules can be downloaded and used for building simulation.

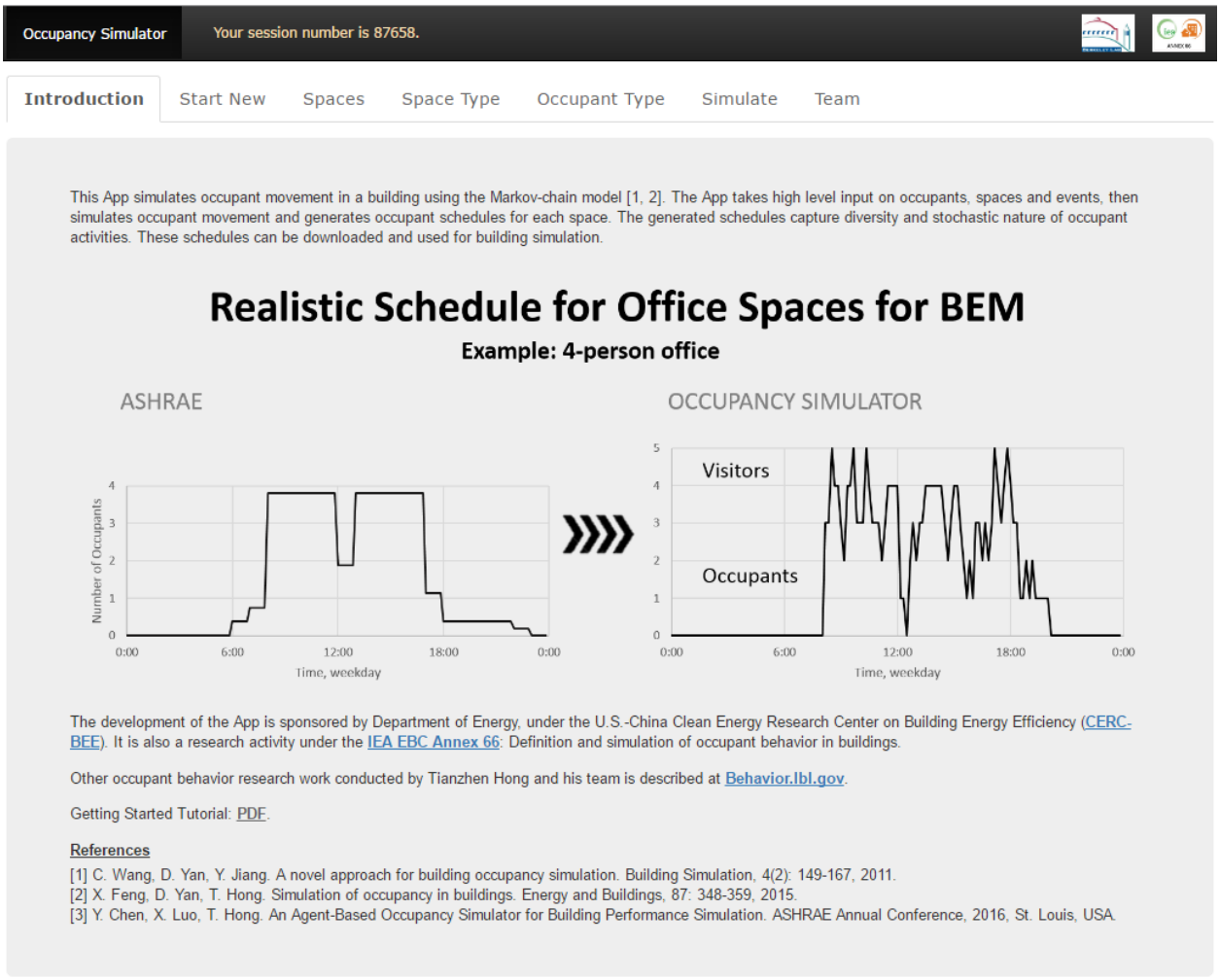

Figure 1 - Opening page of Occupancy Simulator

Figure 1 shows the Introduction page of the occupancy simulator. The simulator includes a top bar, a tab bar, and a main content area. The top bar provides links to several related projects, and shows the unique session number for each simulation case. The session number can be used to retrieve all the information related to the simulation case, including inputs and results. The tab bar organizes data into multiple pages including Introduction, Start New, Spaces, Space Type, Occupant Type, Simulation, and Team.

Figure 2 presents the software architecture of the occupancy simulator. The agent-based web application was built upon Ruby on Rails (rubyonrails.org), an open-source web framework with model-view-controller (MVC) software architecture. The (1) viewer generates html pages for users to see in web browsers. The (2) controller handles the commands from users, performs necessary calculations, updates the data model, and refresh the (1) viewer. The (3) data model defines the data structure and the methods to update/extract data to/from the (4) database. The (4) database stores the users' inputs as well as the results. One control command named "Simulate" triggers the movement simulation. For this command, the (2) controller generates an (7) occupant model in XML format based on the occupant behavior (OB) obXML Schema [4], which is developed on top of the OB DNAS (drives, needs, actions and systems) framework [5]. The (7) occupant model is used as input by the (8) movement solver to generate the (9) occupancy results in CSV and EnergyPlus IDF formats. The results are imported back to the (3) data model,

stored in the (4) database, and displayed in the (1) viewer. Moreover, it can also be used by other BEM programs (e.g. EnergyPlus) to better predict the energy performance of buildings.

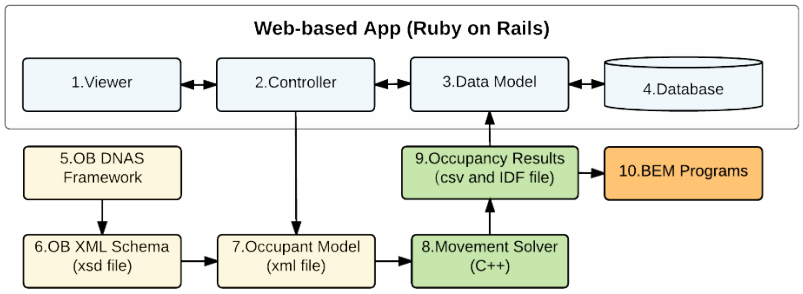

Figure 2 - Software architecture of the occupancy simulator

Tutorial Example for Running the Occupancy Simulator

Overview

A 44 m (L) × 20 m (W) × 3.5 m (H) one-story office building located in Miami, USA, is used for the case study. Figure 3 shows the plan view of the office building, including the number of occupants in each space as designed. The case study is presented to demonstrate the usage of the occupancy simulator step by step. This tutorial introduces the required data inputs and the available results from the occupancy simulator.

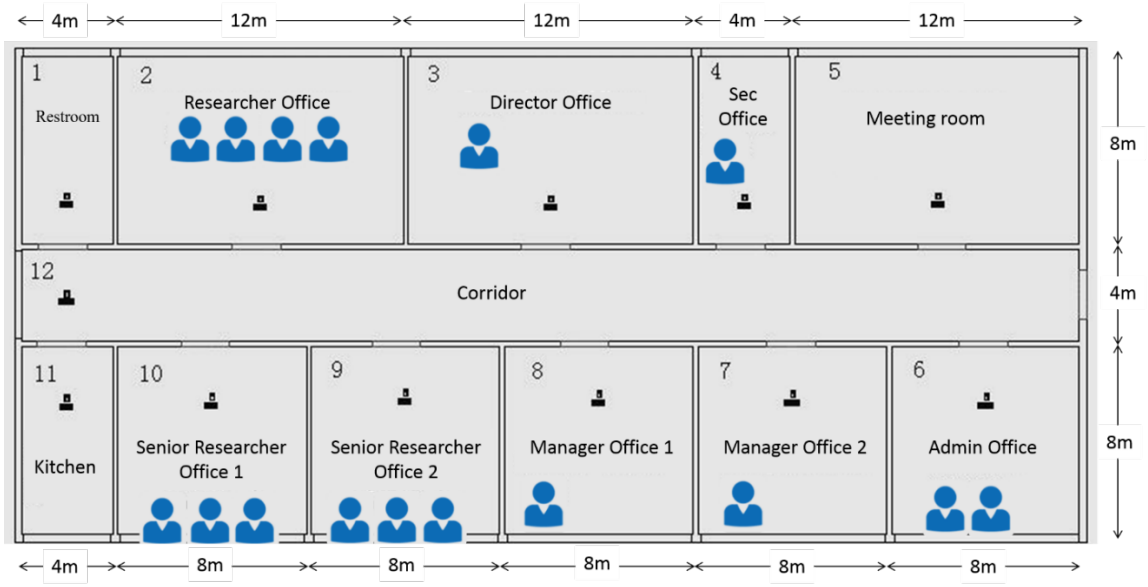

Figure 3 - Schematic of the case office building

The Start New Page

Figure 4Figure 4 shows the Start New page. To start a new analysis, we need to provide the building type and area, which are "Office – Small" with 880 m^2 in this case. The other building types available are "Office – Large" for office buildings with a floor area of more than 3000 m^2 and "Other" for all other types of buildings. After the building type selection and giving the floor area of the building, we should click on the "New Analysis" button. In case, we wish to continue to work on a previously set up session, the session can be reopened by referring to the session number and clicking on the "Continue button" (Figure 5).

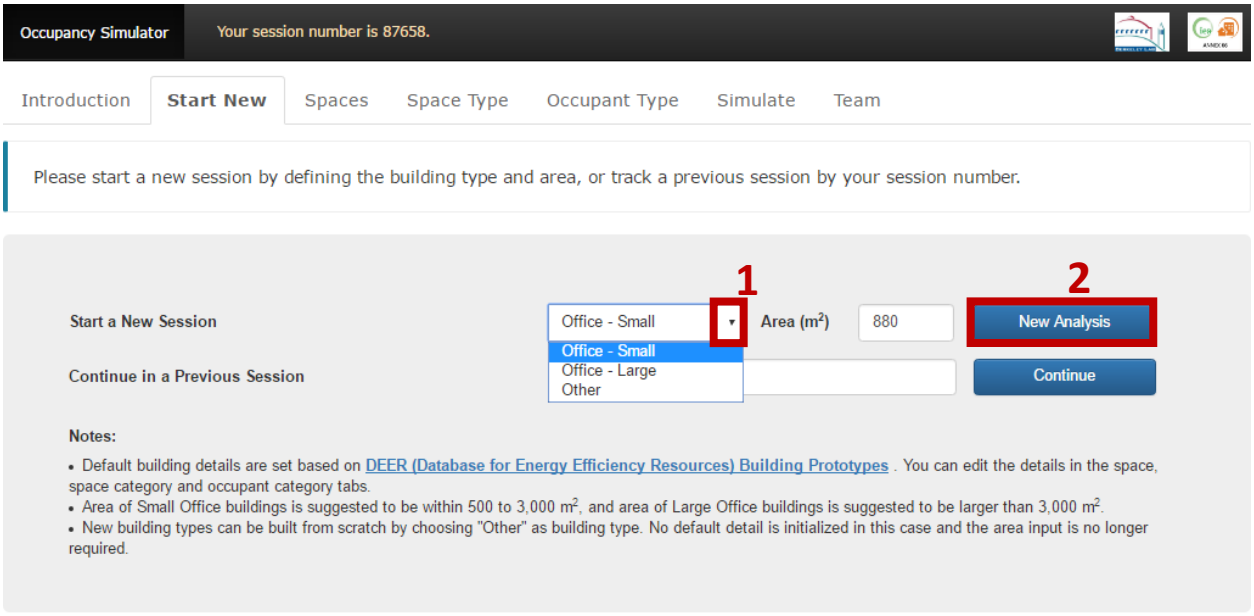

Figure 4 - Start New page

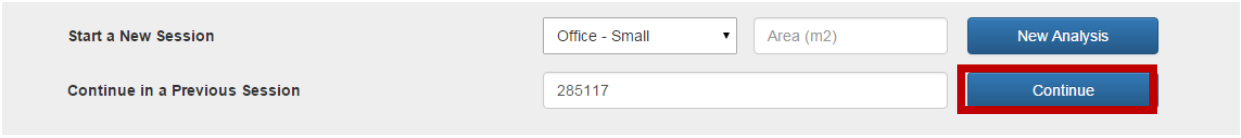

Figure 5 - Continue on a previous session at the Start New page

The Spaces Page

Figure 66 shows a snapshot of the Spaces page, where the Basic info section provides an overview of the floor area, number of rooms and number of occupants in our building. The Space list shows all spaces with each space having a floor area, a multiplier, and a Space Type. The multiplier represents the number of similar spaces in the building. The number of rooms is calculated automatically from the number of spaces specified in the Space List multiplied by the given space Multipliers. The number of occupants is calculated by multiplying the floor area and the specified Occupant Density of each space type set under the Space Type page. (See also section on the Space Type page.)

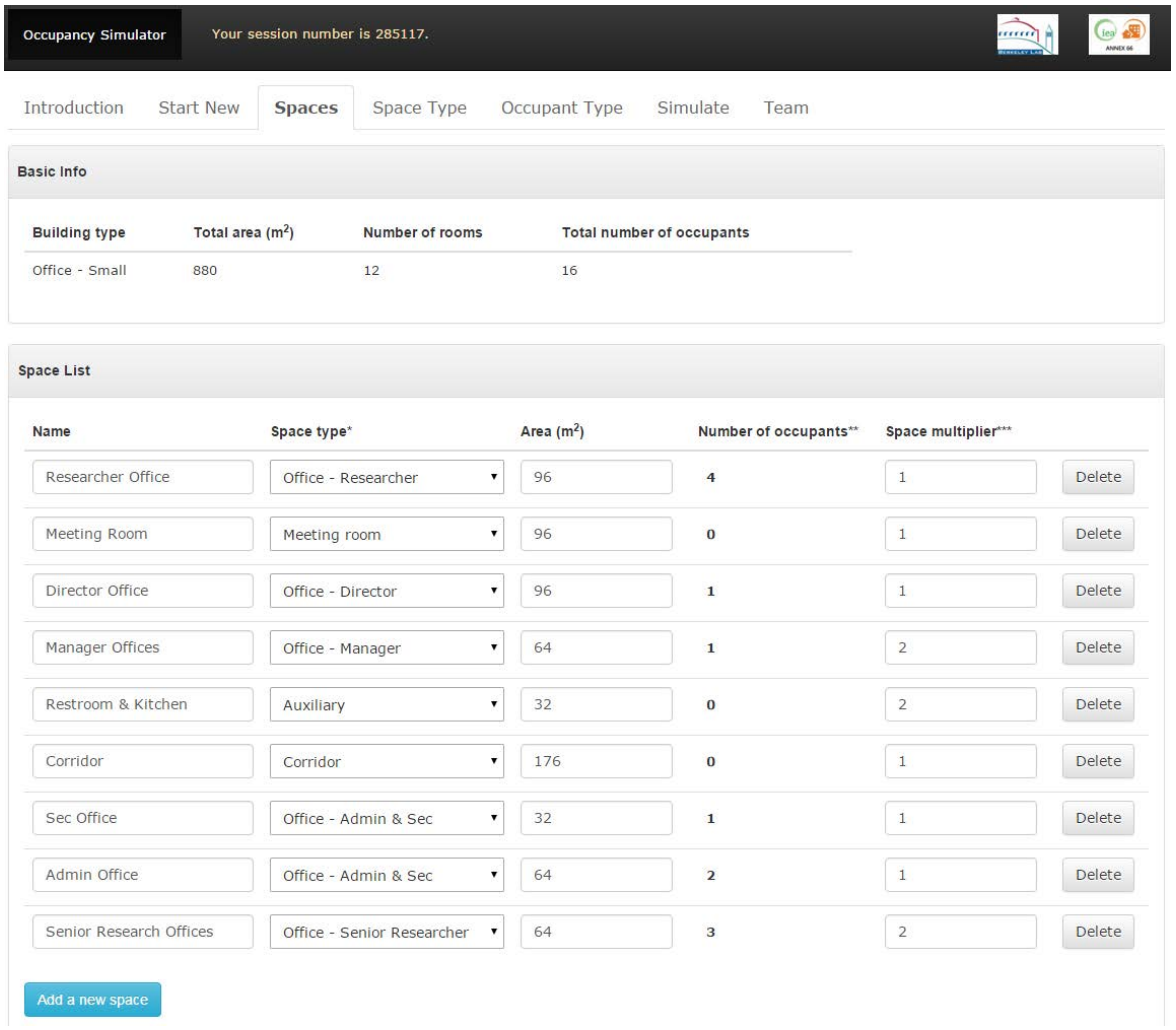

Figure 6 - Spaces page

To define a new space, we need to click on the "Add a new space" button, give a name, specify floor area and multiplier, and select the Space Type from a drop-down list where those options are from what we specified on the Space Type page (Figure 7).

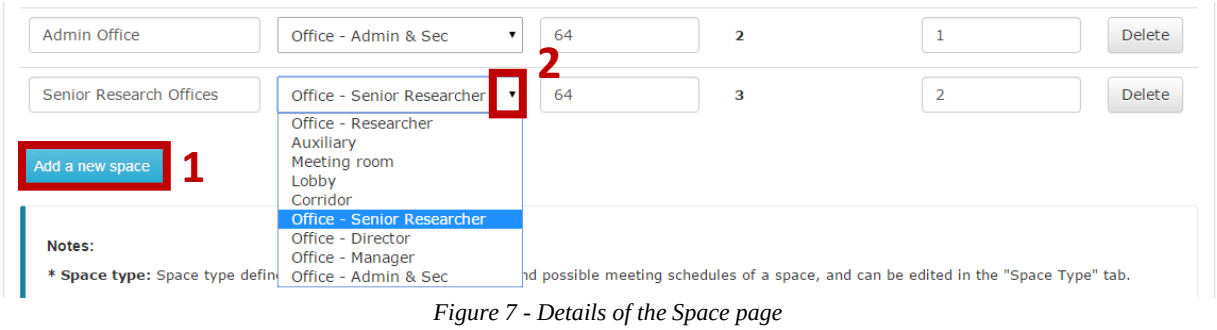

Figure 7 - Details of the Space page

The Space Type Page

Figure 8 shows the Space Type page. On top of the page a new space type can be created by giving a name, choosing the usage type from a dropdown list and by clicking the Create button.

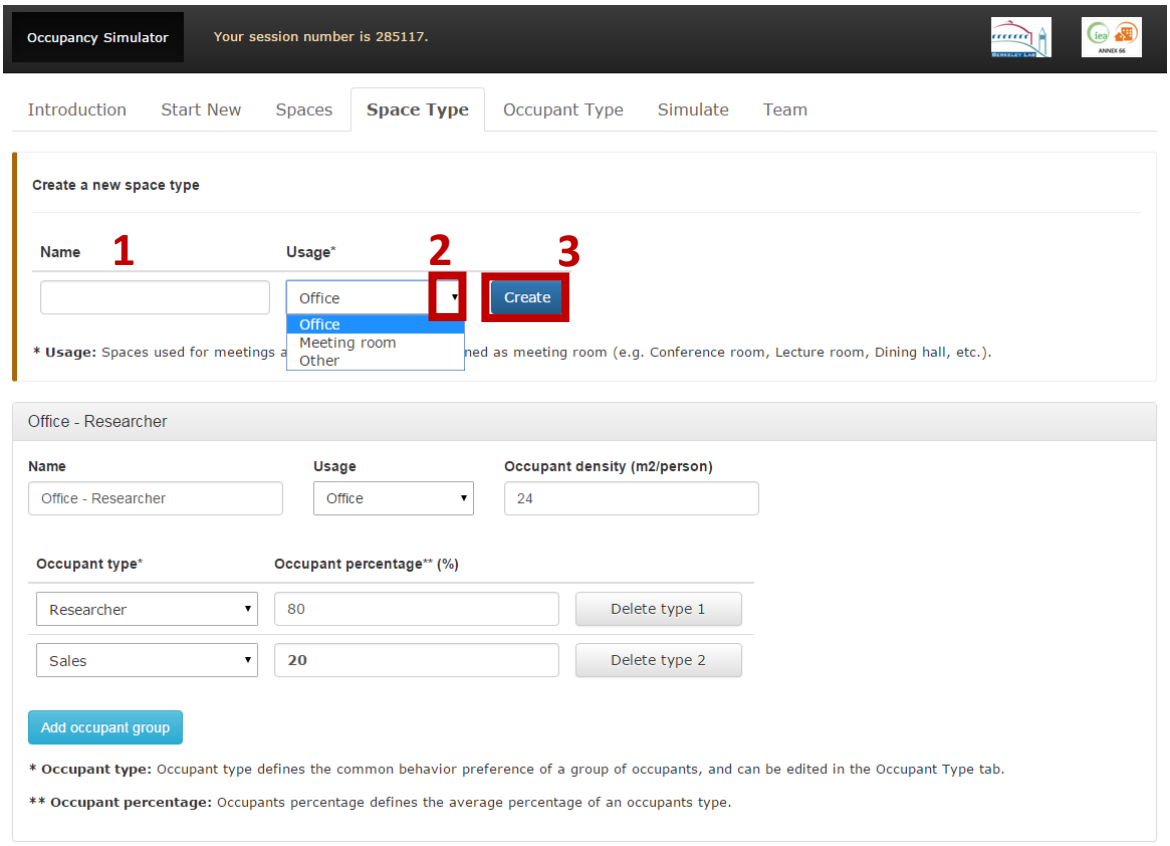

Figure 8 – The Space Type page

In case of a Space Type with "Office" usage, users need to provide the occupant density (m^2/person) and the Occupant Types using that Space Type (Figure 9). (See Occupant Type definition in section Occupant Type Page). Users also specify the percentage of Occupant Types in the given Space Type.

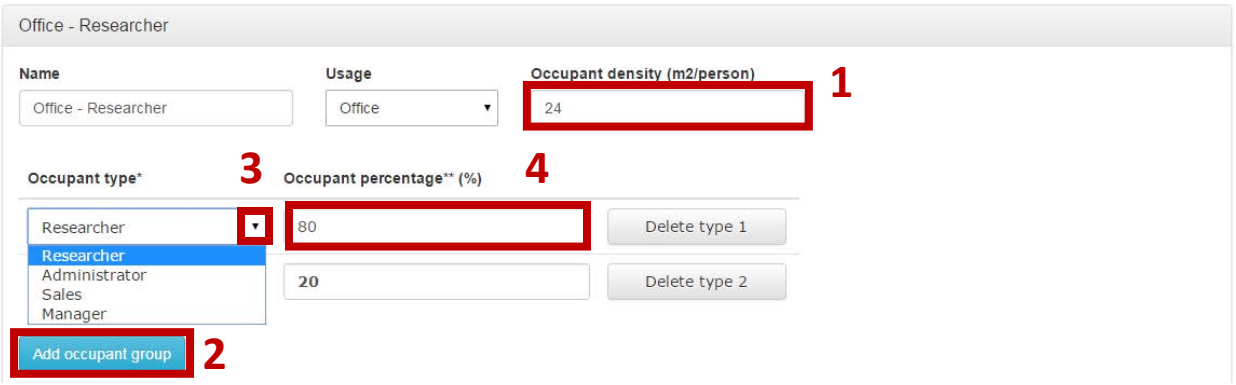

Figure 9 - Space Type definition with the Office usage

For the "Meeting room" space type, users can define the meeting events for selected day of week, as shown in Figure 10. Users can click the "Add meeting event" to add another meeting event for different day of week. For each meeting event, the minimum and maximum values of the number of occupants per meeting and the meetings per day are required. Further, users need to provide the probabilities of meeting duration from 30 mins to 2 hours.

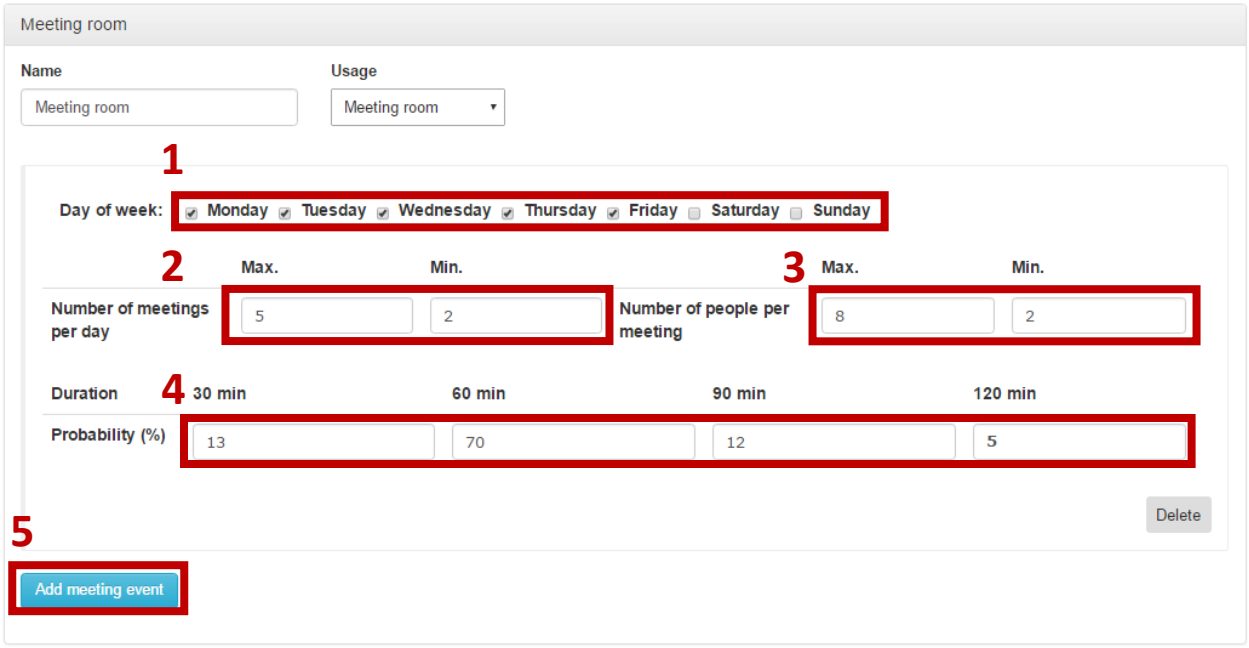

Figure 10 - Space Type definition with the Meeting room usage

If we want to define a Space Type with Other usage, the only thing we have to set is the space category name. (See Figure 11)

Figure 11 - Space Type definition with Other usage

The Occupant Type Page

On the Occupant Type page, the user can define the events and space occupancy for each Occupant Type (Figure 12). After giving a name to the new Occupant Type, the new Occupant Type can be initialized by clicking on the Create button. Similar to meeting event, users can define different patterns for different day of week by checking or unchecking the boxes of the days of a week. It should be noted that if no movement behavior is checked on a specific day of week, the occupant is assumed to be vacant.

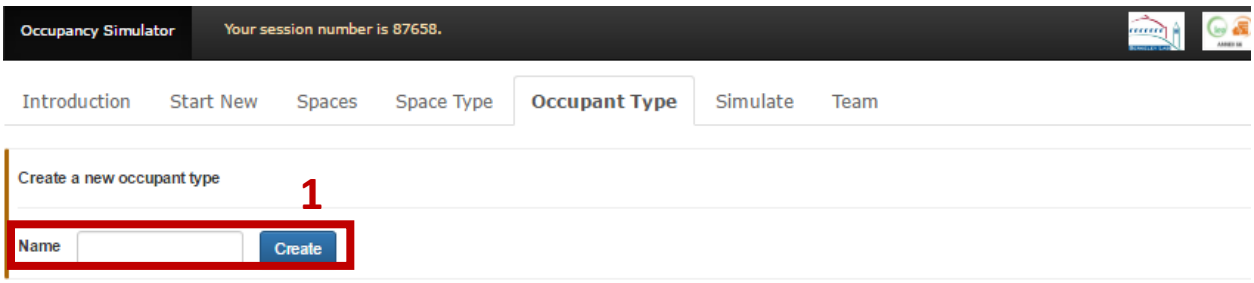

Figure 12 – The Occupant Type Page

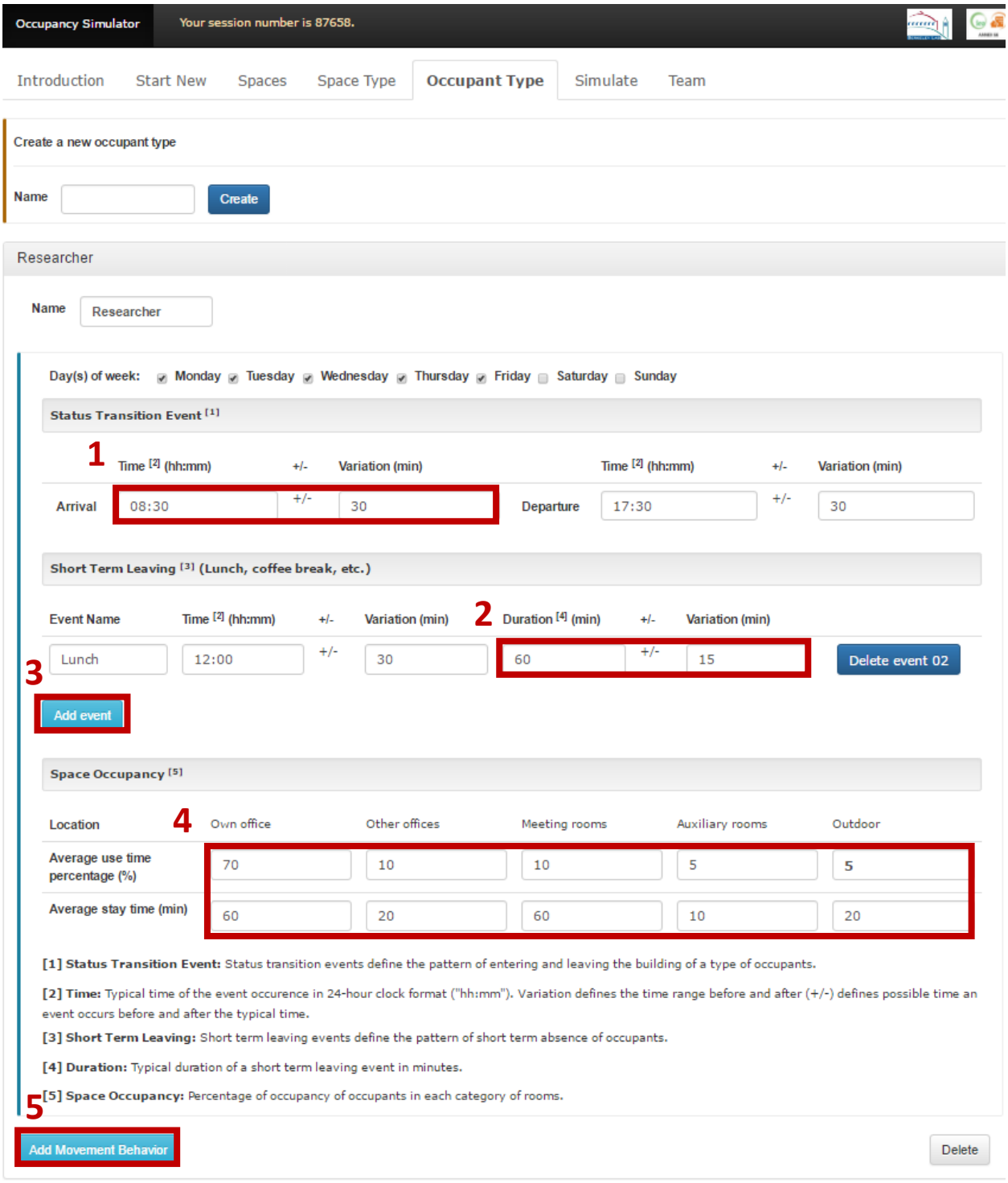

Figure 13 – The Occupant Type Page

To define a movement behavior of an Occupant Type, at first, the occurrence times and their variations of "Arrival" and "Departure" events are required to describe the pattern of entering and leaving the building. Variation defines the possible time an event occurs before and after the typical time. Specifically, the

"Time" field should be entered in 24-hour clock format ("hh:mm") and latest possible time of the arrival events should be earlier than the earliest departure time. Further, if the user wants to add other events describing short-term leaving the building, such as lunch and coffee break, such events can be added by clicking the "Add event" button. In this case, apart from occurrence time and its variation, the user should also enter the duration and its variation of the shorting term leaving. As the example shown in Figure 13, the "lunch" event in this case normally starts from 11:30am to 12:30pm, and would last 45 to 75 minutes.

For the last step, the space occupancy can be adjusted. At each possible location of the given Occupant Type (e.g.: Own office/Other offices/Meeting rooms/Auxiliary rooms/Outdoors), we can specify the percentage of their time they stay there and for how long (average stay in mins). Based on these inputs, the occupant simulator determines the location of each occupant at each time step.

The Simulate Page

After all the input information are collected, users can specify the simulation period and time step then either the U.S. or Customized holidays can be selected on the Simulate page (Figure 14). By clicking on the Simulate button, the simulation starts and it takes about one minute to run an annual simulation for this example.

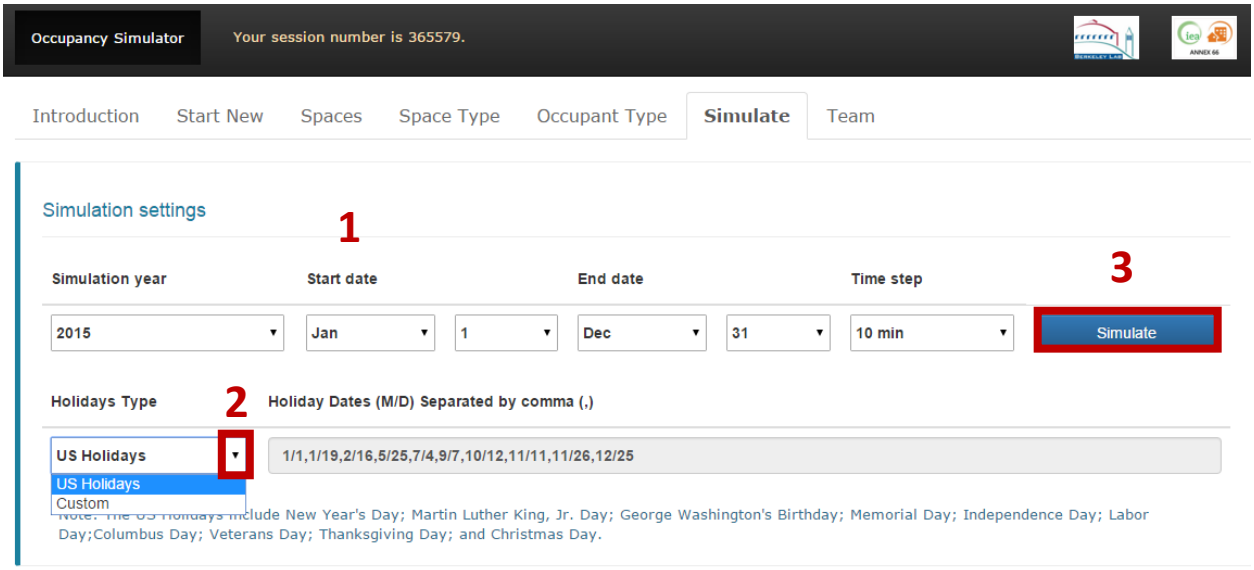

Figure 14 – The Simulate Page

The results can be viewed on the Simulate page, with the customization of results period and the choices of spaces / whole building (Figure 15). Users can also download the occupancy results in CSV and EnergyPlus IDF formats, and further use them in building performance simulation.

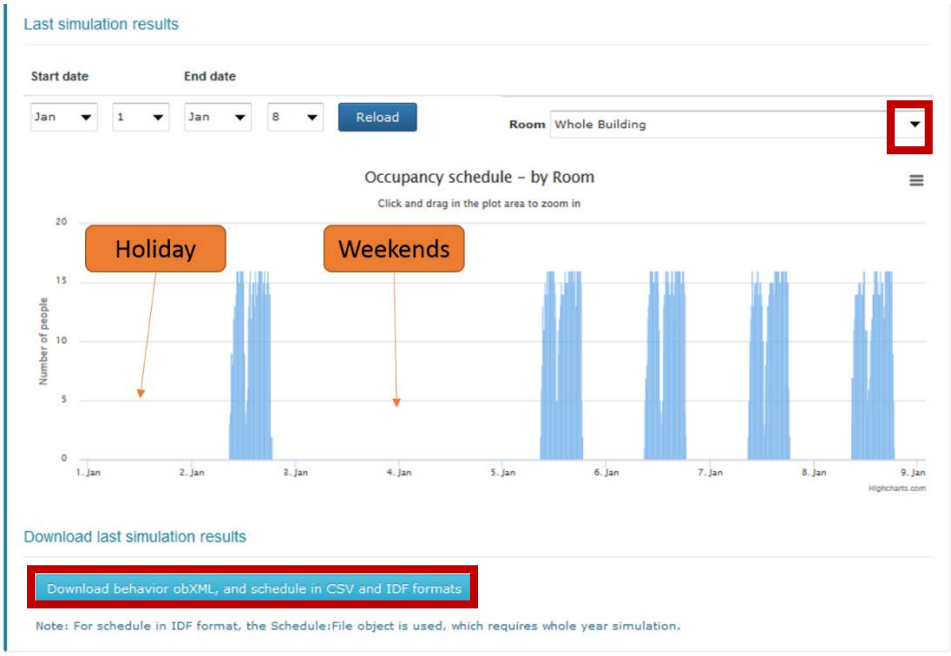

Figure 15 View of occupancy simulation results on the Simulate page

Limitations of the Occupancy Simulator

There are several limitations of the current occupancy simulator. It uses the Markov chain model to simulate the occupant movement behavior, but does not consider the walking time from one space to another. The templates of buildings (providing default spaces profiles) currently only cover small and large office buildings. Users have to provide much more data for other building types. The App does not support personal vacations or leaves. Future updates of the App will address these limitations.

References

[1] Yan, D., O'Brien, W., Hong, T., Feng, X., Gunay, H.B., Tahmasebi, F., and Mahdavi, A. 2015. Occupant behavior modeling for building performance simulation: Current state and future challenges. Energy and Buildings 107:264-278.

[2] Wang, C., Yan, D., and Jiang, Y. 2011. A novel approach for building occupancy simulation. Building Simulation 4(2):149-167.

[3] Feng, X., Yan, D., and Hong, T. 2015. Simulation of occupancy in buildings. Energy and Buildings 87:348-359.

[4] Hong, T., D'Oca, S., Taylor-Lange, L., Turner, W., Chen, Y., Corgnati, S. 2015. An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema. Building and Environment 94:196-205.

[5] Hong, T., D'Oca, S., Turner, W., Taylor-Lange, S.C. 2015. An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs Framework. Building and Environment 92:764-777.