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Task-Based Approach to Define Occupant Behaviour in Agent-Based Modelling

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Abstract
This paper presents a development approach and design of a task-centered agent-based model (ABM) to represent the interactions of occupants with a commercial office building. The model is built with the understanding that occupant behaviour is driven by tasks the occupant performs. A contextual task analysis questionnaire explored occupant perspectives on the interactions between their tasks, their individual behaviour and comfort, and the physical characteristics of their workspace. This task-based information defines five ABM elements that represent occupants, task and workspace environment, task list, occupant actions, and the impact of the occupant-workspace interaction on tasks. An example of an occupant, performing a task, and conducting an action in response to an environmental mismatch demonstrates the ABM design. The example discusses the generation of possible actions as well as the result from those actions in terms of task performance and occupant satisfaction. As the ABM design evolves, it will aid in the understanding of occupant behaviour in buildings, and ultimately standardize the approach to occupant behaviours affecting building energy demand.

Keywords: Agent-based modelling, Occupant-building interaction, task performance, occupant satisfaction

1 Introduction

Building occupants play a critical role in affecting building operation. Occupant behaviour is multi-disciplinary, complex, and stochastic. Occupant behaviour affects building energy demand and indoor environmental quality (Ole Fanger, 2001; Hoes et al., 2009). The resulting environment may affect future occupant decisions and behaviour (An, 2012). For example, occupants who open a window shade for daylight also allow solar radiation to penetrate the building, adding to the building's cooling load. The increased solar radiation may cause the occupant to feel warmer, causing the occupant to turn down the temperature, further increasing the building's cooling load.

In traditional building simulations, schedules represent occupant-environment interactions. Schedules define building occupancy and occupant actions as a set of static events that occur regardless of environmental influences (Klein et al., 2012). For example, an office building's equipment schedule dictates equipment is "on" 6 am to 6 pm and "off" 6 pm to 6 am Monday through Friday, and is "off" Saturday, Sunday, and holidays. Schedules ignore individual-occupant level actions (e.g. occupant leaving mid-day), do not account for complexities in their actions (e.g. occupant opening a window shade might also turn off lights) , and fail to integrate cross-discipline data (e.g. equipment usage is not integrated with an occupant schedule)(An et al., 2005). For example, the "on" equipment from 6 am to 6 pm is actually turned on and off throughout. This affects internal heat gains, leading to improper calculation of occupant thermal comfort and space cooling demands. Additionally, failing to include periods of “off” misrepresents the equipment’s actual energy demand.

Agent-based modelling (ABM) has been particularly useful to understand and manage multi-disciplinary systems with many interacting elements (Axelrod, 1997; Bonabeau, 2002). ABM is a computer simulation technique that replicates the behaviour of individuals (agents), and their interactions with the environment and other agents (Axtell et al., 2002). In commercial office buildings, individual agents are building occupants, and the occupant’s environment is their workspace. ABM simulates the unique decision-making behaviour of individual occupants and then shows how the overall, complex building behaviour emerges as a result of those behaviours (Klein et al., 2012). The decision-making process of individual occupants explains behaviour intentions and actions in response to environmental stimuli (Gaudiano, 2013). Behavioural intentions are the occupants’ goals of eliminating undesired environmental conditions. Occupant actions initiate changes in the environment.

Behaviour intentions define an ABM structure to evaluate impact of various occupant actions in response to a number of different physical environment stimuli factors. Coupled with building energy simulation, a majority of ABM efforts thus far focus on evaluating building energy demand in a variety of different building types (Azar and Menassa, 2012; Chen et al., 2013) and building occupancy (Azar and Menassa, 2015) in response to occupant thermal comfort behaviours (Langevin et al., 2014; Lee and Malkawi, 2014) and, less commonly, visual comfort behaviours (Andrews et al., 2011). For example, using thermal comfort, an occupant takes action with the intention to eliminate discomfort. The behaviour, or action, of the occupant is evaluated for its impact on building energy demand and the resulting occupant satisfaction or dissatisfaction with their thermal environment (Langevin et al., 2015).

While ABM has been successful in representing occupants in building simulation, using comfort as the behaviour intention has caused several issues. First, this limits the model to only what the occupant would and could interact with, and leaves out components that potentially could affect simulation results. For example, evaluating thermal comfort leaves out actions related to visual comfort, such as turning lights on/off, that would affect space heat gains and overall building energy use. Second, the lack of consistency between models makes it difficult to compare models and incorporate multiple behaviour intentions for evaluation. To address these issues, the key is to select the proper intention.

To select a proper intention, one must understand the overall purpose of the building. In a commercial office building, the building’s purpose is to support business goals. The goal of the business is to make a profit (Von Paumgartten, 2003). While profit is related to building energy performance, employee salaries account for 80% of operating costs (Von Paumgartten, 2003) signifying the major determinant of business profit is employee task performance. If task performance is the basis of success in an office building, an ABM structured on occupant tasks to define behaviour intentions should provide the link between task performance and building energy demand.

In order to develop an ABM using behaviour intentions as the structure, one must understand the need behind the intention. When an occupant is uncomfortable, they seek comfort, but what is the original need for the occupant to seek comfort? Because discomfort is the result of a mismatch between the environment and task requirements, tasks, in which the occupant is engaged, drives the need and type of comfort. The need, therefore, is to remove discomfort to improve task performance.

This paper proposes a novel ABM structure to represent occupant behaviours that affect building operation. The realization that tasks are integral drivers of occupant behaviour in a commercial office building provides the basis for the ABM approach. Based on occupancy task data collected in the fall of 2015, this paper builds towards two main objectives: 1) define an ABM structure that uses tasks to define behaviour intentions, and 2) integrate task performance with occupant satisfaction to evaluate occupant behaviour. While this ABM is in early stages of development, the goal is to couple the ABM with a building simulation, such as EnergyPlus, to evaluate the impact of the task-based occupant behaviour on building energy usage.

While there is research available relating occupant behaviour to their environment and the environment to task performance, there are significant gaps in current research regarding the link between occupant behavior and task performance. Further, research tends to define these connections in generic terms such as “the occupant is working”, which lacks the specificity to distinguish between different types of work that have different environmental requirements. Thus, further task-specific data are needed to define the ABM model. The next section of this paper describes the data collection and the modelling approach to collect task-specific data. A contextual task analysis (CTA) questionnaire was designed to collect the basic data required to establish the ABM: occupants, the environment, and their relations to tasks. The task-based information defines the five ABM elements. Two elements are initialization definitions that represent occupants and task and workspace environment. Two elements are inputs representing task list and occupant actions. The fifth element is a process model that evaluates the impact of the occupant-workspace interaction on tasks in terms of task performance, occupant satisfaction, and building energy. The subsequent section describes an example that demonstrates the ABM design: an occupant, performing a task, and acting in response to an environmental mismatch. Finally, the paper concludes with a discussion, future work, and recommendations.

2 Methods

2.1 Data Collection

The contextual task analysis (CTA) questionnaire explored occupant perspectives on the interactions between their tasks, their individual behaviour, comfort, and the physical characteristics of their workspace. 35-questions, derived from a variety of survey instruments for building performance and post-occupancy evaluation (Ornstein et al., 2005; Vos and Dewulf, 1999; IBPE Consortium, 1995), were grouped into five parts in the questionnaire. The first part asked basic demographic questions along with individual characteristics, such as mode of transportation and length of time with company and current job. The second part asked participants to identify their daily work schedule. From this schedule, participants were to select five tasks that are critical, performed most frequently, and most important for their job. The third part, participants listed and sketched furniture and equipment within their workspace. Participants associated each item in their workspace to the selected tasks as well as identified any equipment required for their job that is located outside their workspace, such as a copier located in the copy room. The fourth part asked how aspects of the participant’s workspace affected their task performance. The fifth part asked about participant values and overall perception of their workspace. These include identifying objects the participant is allowed to change, current clothing level, and overall satisfaction with their workspace. While the participant took the survey, physical measurements of the occupant's workspace were documented. The measurements included the interior air temperature, relative humidity, air speed, work surface light levels, and dimensions. Additionally, the workspace location within the overall building, office type, building systems, and any available controls with the workspace were recorded. Exterior conditions were taken prior to administering the questionnaire at the business, which included air temperature, relative humidity, air speed, and other conditions, such as cloud cover and rain.

Participants were included in the survey if the occupant worked in a typical commercial office setting and performed at least 50% of their tasks in their workspace. A typical office setting is defined as business group B, per the International Building Code, where the use of a building is for professional or office-type services (IBC, 2011). The questionnaire took no longer than 30 minutes to complete, and was conducted in the participant's workspace during the fall of 2015. Follow-up interviews were used to clarify any of the questionnaire responses, and to allow the occupant to demonstrate and expand on any comments.

CTA responses were recorded from 37 participants (22 male and 15 female) with a mean age of 34 years (range: 22-56). Participants were from three different businesses located in five buildings. Follow-up interviews were conducted with nine participants.

CTA analysis was conducted by part. Therefore, if a participant did not complete a part of the questionnaire, the responses from the other parts were still included. The detailed analyses and results for each CTA part are not included in this paper. Rather, the information from each part of the CTA is discussed on how it is used to develop the ABM elements in next section.

2.2 ABM Elements

The CTA and sources from literature develop and refine the structure, dynamics, and data for five ABM elements. Table 1 outlines the CTA part(s) and source(s) from literature associated with each ABM element. The ABM includes five elements: occupant, task and workspace environment, task list, occupant actions, and workspace environment impact. Occupant and task and workspace environment are initialization definitions that representing building occupants and the space in which they perform their tasks. Task list and occupant actions are ABM inputs. Task list represents a daily list of the tasks the occupants perform, the order performed, and for how long. Actions are the events an occupant may take to change their environment. The workspace environment impact is a process that evaluates the occupant-workspace interaction on tasks in terms of task performance and occupant satisfaction.

Table 1. Data sources referencing the part of the Contextual Task Analysis (CTA) and the research literature used to develop each ABM element.

ABM Element	CTA Part	Sources from Literature
Occupant	1,5	Disability (BLS, 2015) Workspace type (IFMA, 2010)
Task and Workspace Environment	2,3,4	Comfort Standards and Environment Ranges (see section for references)
Task List	1	
Occupant Actions	5	Decision order (An, 2012)
Workspace Environment Impact	4	Environment impacts on productivity (see section for references)

2.2.1 Occupant

Occupant agents are an element generated during the initialization of the ABM. Occupant attributes define occupant characteristics and influence their actions and perception of the environment. Characteristics, values, and attributes define each individual occupant, which allows for individual evaluation and preferences. For instance, if an occupant has a disability, the environment might need to be changed to enable the occupant to complete his or her tasks. Static variables define occupants' attributes and values, and do not change. Static variables include the occupant's gender, employee type, workspace, preferences (e.g. tendency to be hot or cold, preference of brighter/darker illumination levels, preference of daylight to electric light, and tolerance of louder/quieter sound levels), and disability (e.g. vision impairment). Dynamic variables are those that may change per model time step as influenced by other environmental or occupant static attributes. For example, an occupant may modify their clothing throughout the day in response to their environment. Dynamic variables include clothing and activity levels.

2.2.2 Task and Workspace Environment

The task and workspace environment is an element generated in ABM initialization. Occupants perform tasks in the workspace environment. Tasks were identified and defined (Kalvelage et al., 2016b) by outlining the physical and mental processes, furniture and equipment, and physical movement required to perform the task. Tasks were grouped in five categories: 1) create and analyse information, 2) search for information, 3) process information, 4) communicate information, and 5) manage information. Communicate information was divided into three sub-categories representing phone call, small meeting, and large meeting.

The workspace and task requirements generated a specific task definition for each task category. Workspace requirements define the physical workspace, and building operating schedules link the requirements to the building model. Workspace requirements include the furniture, equipment, and number of occupants required. Schedules represent when equipment is on/off, when an occupant is present/absent, and the furniture internal mass.

The task requirements define the processing resources and environment parameters. Processing resources are the capabilities and resources an occupant has to bear on a task (Wickens and Hollands, 1999; Clements-Croome and Baizhan, 2000). Four components typically describe processing resources: visual, auditory, cognitive, and psychomotor (commonly referred to as VACP). Visual (V) and auditory (A) refer to the external stimuli that must be attended to; cognitive (C) refers to the level of information processing required; and psychomotor (P) refers to physical actions. Rating scales developed by McCracken and Aldrich (1984) for each VACP component provide a relative rating of the use each resource component in tasks. The rating interval scales range from 0.0 or no activity, to 7.0 or a high degree of activity.

Each task places a specific workload demand on an occupant (Keller, 2002). For example, resources required for a large meeting (communicating information) include the visual component of looking at the speaker, the auditory component of hearing the speaker, the cognitive component of processing speech, and the psychomotor component of taking notes. The base VACP for values for a task are determined when the environment is at optimal task performing conditions. The environment parameters define the task's optimal environment. Parameters for thermal, visual, acoustical, and air quality were developed by using design reference standards to define a reference range. References include: ASHRAE standards 90.1

(2013b), 62.1 (2013a), 189.1 (2014), EN standard 15251 (2007), and ISO standards 9241 (2006) and 7730 (2005). Next, these ranges were fine-tuned using other research: temperature (Wong et al., 2008), (Jakubiec and Reinhart, 2012) glare, (Boyce, 2014) illumination levels (Ayr et al., 2002; Kjellberg et al., 1996), sound levels, and air quality (Niemela et al., 2006). Information from the CTA questionnaire correlated parameter ranges to specific tasks.

2.2.3 Task List

The task list is the first ABM input, and dictates time on task and the order of tasks. Figure 1 outlines the process to generate an occupant's daily task list. First, task list constraints define the workday start and end times as well as any lunch or break times (Kalvelage et al., 2016a). Next, occupant characteristics modify the task list; for example, assign a time-slot for a 15-minute smoke break. The occupant's employee type selects the task list type. Previous work (Kalvelage et al., 2016a) identified four task list types: active meeting, semi-active meeting, inactive meeting, and stationary. The task list types represent the time spent performing the five different tasks as a percentage of the available work time. Using these percentages, the tasks are distributed throughout the remaining time-slots in the workday to create the occupant's specific task list. Task lists are automatically generated, daily, during the simulation for an entire reference year, which includes holidays and weekends.

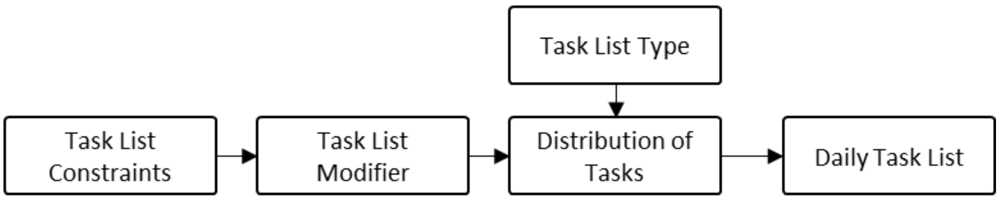

Figure 1. Task list definition combines task list constraints with occupant-defined task list type and task list modifiers to generate a daily task list.

2.2.4 Occupant Actions

The occupant action is an input element in the ABM, and defines the available actions for an occupant and organizes them into the appropriate order for the occupant to choose. Occupant actions are those in response to an environment mismatch, such as distractors, interruptions, or stressors that negatively affect task performance. For example, a workspace may be too dark to read text in a book. The actions available to the occupants are gathered from object actions (e.g. adjustable furniture and occupant clothing layers) and workspace actions (e.g. turn on/off lights) (Kalvelage et al., 2016b).

When an individual has to choose from among two or more mutually exclusive actions, the action that generates the "best" environment for task performance determines the decision order. These actions would be determined based on balancing minimal task workload impact, energy efficiency, and effectiveness at producing the desired conditions. For instance, an occupant could open the window shade to increase illumination, but this adds additional workload by requiring the occupant to stop working, walk over to the window, raise the blind, walk back to their chair, refocus on task, and resume working. Further, while it is the most energy efficient, there is no guarantee adequate illumination levels and introduces the potential for glare. Alternatively, turning on a task lamp guarantees adequate illumination and adds minimal workload by only requiring the occupant to reach up and turn on the lamp – only stopping work for a fraction of the time it would take to open the blinds.

2.2.5 Workspace Environment Impact

The workspace environment impact is the runtime ABM process, and consists of three submodels to evaluate the impact of the workspace environment on task performance and occupant satisfaction. The three submodels compare environment parameters, evaluate comfort, and evaluate processing resources (Figure 2).

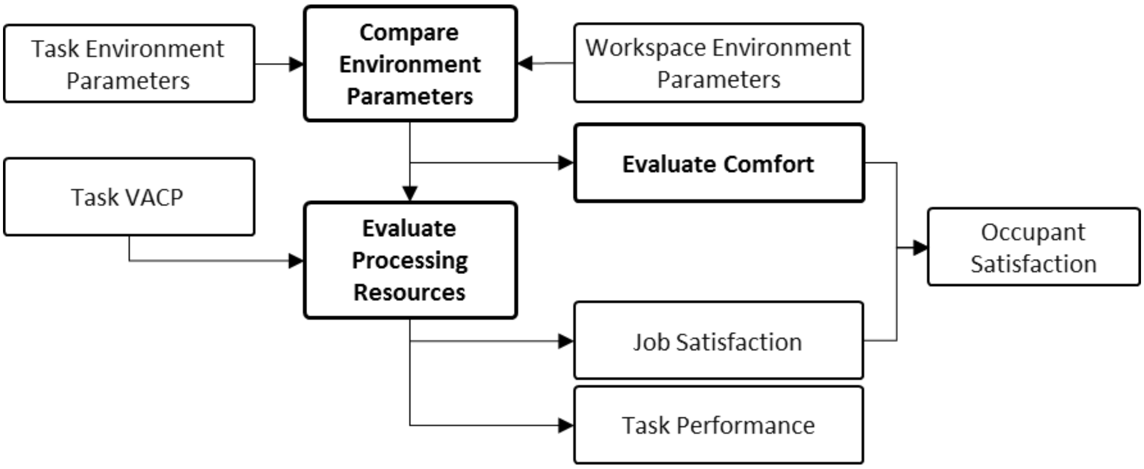

Figure 2. Environment impact process, consisting of three submodels (bold boxes), evaluates task performance and occupant satisfaction as a result of the occupant-workspace interaction.

Compare environmental parameters retrieves the workspace environment parameters (as a result of previous action and component interaction) from the building model and compares to the task environment parameter ranges. The ABM compares effective temperature (thermal), illumination level (visual), decibel level (acoustic), and CO_2 concentrations (air quality). Any environmental mismatch affects both occupant comfort and processing resources.

Evaluate comfort submodel corresponds an environment mismatch to a comfort category (i.e. thermal, visual, acoustical, air quality). Evaluating each comfort category individually then combining, generates a single comfort rating. For this reason, one comfort rating cannot determine the occupant's overall comfort. For example, a beeping printer generates noise. The noise would negatively affect the occupant's acoustical comfort. However, if thermal, visual, and air quality comforts are deemed acceptable, the occupant could report they are comfortable.

Evaluate processing resources examines the additional workload on the occupant caused by the environment mismatch. For instance, if the beeping printer causes an acoustical annoyance to an occupant creating and analysing information, the increased noise adds to the cognitive component by causing concentration difficulties for the occupant (Kjellberg and Skoldstrom, 1991). Further, prolonged exposure may reduce the occupant's motivation to work (Evans and Johnson, 2000), and cause negative long term effects on occupant health, such as sleep disturbance and physiological stress (Job, 1996). Numerous studies have examined the effect of various environmental factors on occupant processing resources; for example: thermal factors (e.g. temperature) (Kosonen and Tan, 2004a; Wyon, 2013; Lan et al., 2010; Niemelä et al., 2002; Seppanen et al., 2006), visual factors (e.g. type of light system) (Fostervold and Nersveen, 2008), acoustical factors (e.g. sound levels)(Maxwell, 2000; Smith-Jackson and Klein, 2009), and air quality factors (e.g. CO2 levels) (Kosonen and Tan, 2004b; Singh, 1996; Apte et al., 2000; Wargocki et al., 2000; Niemela et al., 2006).

The environment's impact on processing resources is added to the task's processing resources to generate task performance and job satisfaction. Task performance can be viewed as both quantitatively (e.g. amount of work completed and accuracy) and qualitatively (e.g. quality of work). Job satisfaction is the perceived satisfaction the occupant has with their task performance. Job satisfaction is influenced by comfort (Clements-Croome and Baizhan, 2000), and therefore, is combined with comfort to produce the overall occupant satisfaction. Occupant satisfaction is used to determine the occupant's health. Low satisfaction for an extended period of time could result in the occupant being sick or quitting.

2.3 ABM Structure

Figure 3 outlines the interactions and relationships between the ABM elements in the overall ABM structure. While not included in this paper, the external building model simulation (grey box) was included in the diagram to suggest its relationship in the ABM. (The building model simulation will be used to evaluate overall building energy usage as a result of the ABM element interactions.) The ABM starts by generating the occupant and the task and workspace environment. These elements remain unchanged throughout simulation run. These two elements are used to generate the occupant's daily task list. The task list is generated automatically accounting for monthly and yearly activities variations, and contains the information regarding the optimal task and workspace environment and occupant characteristics required to evaluate the actual workspace environment. The workspace environment impact compares the environment parameters required for the task and the actual environment parameters from the building model simulation. Using the comparison, comfort and processing resources are evaluated and output task performance and occupant satisfaction. Should the two workspace environment parameters not align, the occupant has the option of taking action to change the environment. Any change made in the environment is sent to the external building model simulation for recalculation of environment parameters then re-evaluated.

The ABM is conducted for each occupant in the building, performing their specific task(s), in their specific workspace(s). Because of this, individual satisfaction and task performance can be examined in addition to calculating building-wide occupant satisfaction and task performance.

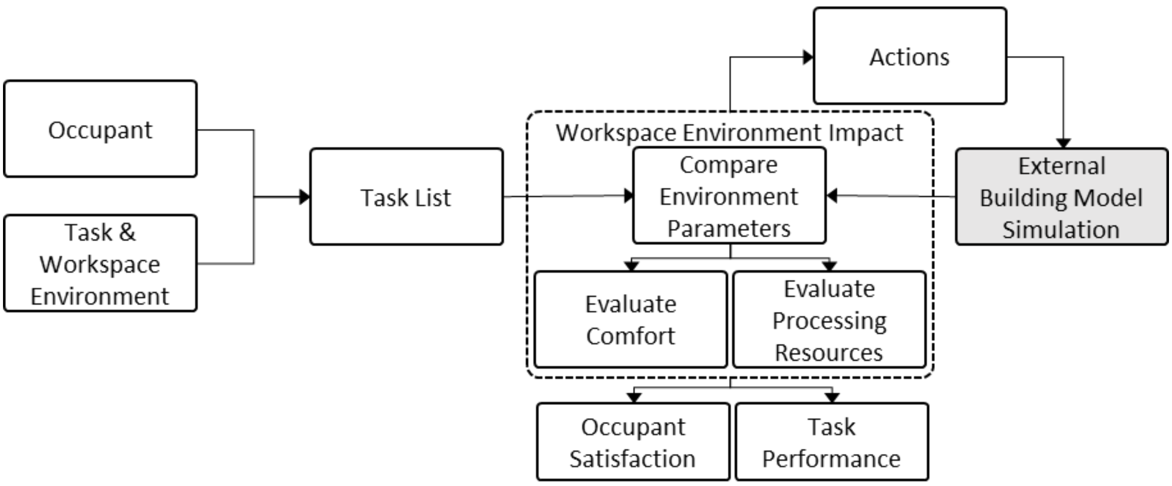

Figure 3. ABM used to evaluate the occupant-workspace interaction impact on tasks. The external building model (grey box) was included in the diagram to suggest its relationship in the ABM.

3 Demonstrative Example and Discussion

Discussion of the ABM uses a demonstrative example. Figure 4 outlines the parameters generated for one day, for a single occupant performing a process information task, and turning on a task light in response to illumination levels too low to perform the task. The output results are task performance and occupant satisfaction.

The ABM first generates the occupant profile shown in box 1 of Figure 4. The occupant profile includes the following variables: non-smoking male (no smoking break needed in the task list), non-management employee (determines task list type), works in a private office (determines available actions), has no disabilities (no additional workload on processing resources), and prefers the standard environment parameters as defined by the task (no modification to the environment parameter comparison to account for occupant comfort preferences). Additionally, occupant clothing (box 3) is generated daily. Today the occupant is wearing the base level of clothing for a male: socks, shoes, briefs, light trousers, a t-shirt under a long-sleeved shirt. The combined clothing insulation value is 0.70 clo. A common range in an office environment is 0.5 to 1.2 clo. The building simulation uses this value to calculate the effective temperature.

The non-management employee type is assigned the inactive meeting task list type for today (box 2), which has 30%-40% meetings (most of which take place in his workspace), 40%-50% create/analyse, < 10% search, < 10% process, 5%-10% manage, <10% email, and <5% break distributed into a schedule. The occupant begins his day at 8:00 am and ends at 4:30 pm with a 30-minute lunch and a 15-minute break in the afternoon. After defining the occupant and task list, the ABM operates at a 15-minute time step, and uses the occupant's task list to determine which task the occupant is performing during that time step. The time step for this example is 8:30 am, and the occupant is performing the process information task (box 2).

The processing information task is performed in the occupant's workspace (box 5), and defines the equipment (box 8), furniture (box 9), and affordances (box 10). These items introduce possible environment factors as well as define the possible actions the occupant can take to change his environment. The activity level for this task is low at 1.2 because the occupant is seated with low physical exertion (only typing is required) (box 4). The building simulation uses the activity level to calculate the effective temperature. The task also defines the two set of parameters used for evaluation. The environment parameters (box 6) and task processing resources (box 7) as shown in Figure 4 and Table 2, which indicate the processing information task is a visual- and motor-related intensive task.

The *Compare environmental parameters* ABM submodel compares the task environment parameters (box 6) to the workspace environment parameters (box 15) retrieved from a building simulation. The reported values indicate the illumination levels are 300 lux below the task requirements (box 11). During the *evaluate comfort* submodel, the occupant's visual comfort drops (box 16), and in the *evaluate processing resources* submodel, the lack of illumination increases the processing resources of the task (box 12). The environment and task processing resources are combined (box 13). The resulting VACP values determine task performance (box 19) and job satisfaction (box 17). High values correspond to low task performance and low job satisfaction, and vice versa for low values. In the example, both task performance and job satisfaction decrease due to the high visual demand of the task. Combining Job satisfaction with comfort produces the overall occupant satisfaction of eight (box 18).

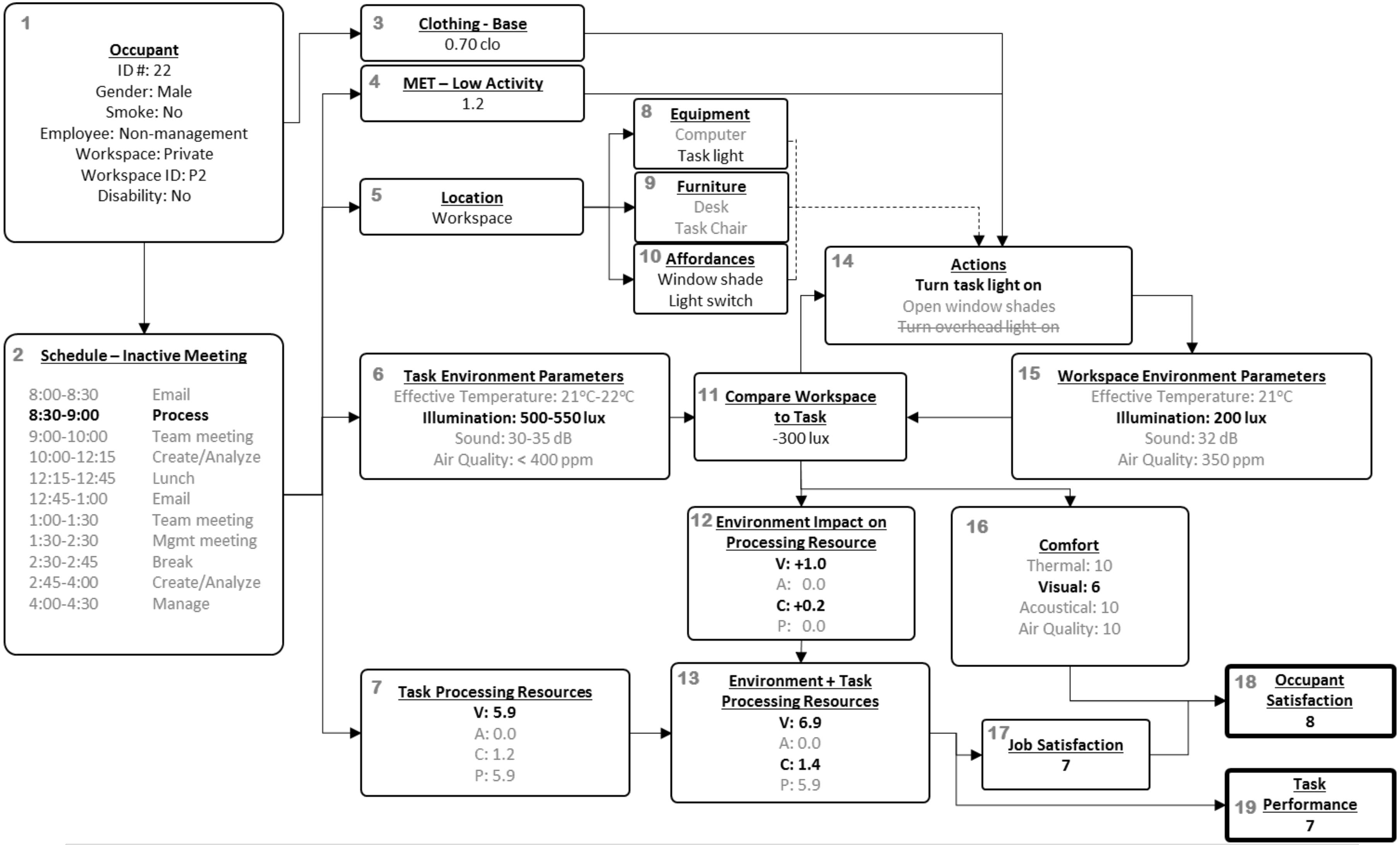

Figure 4. Example ABM. Each box lists the title and corresponding ABM variables. Grey text represent the information in the model that does not apply to the example, and the crossed out text represents an item removed from the available actions. The bold boxes are ABM output results.

Table 2. Processing information task variable values for processing resources and environment parameters.

Task Processing Resource	Value	Environment Parameter	Value
Visual	5.9	Effective Temperature	21^oC-22^oC
Acoustical	0.0	Illumination Level	500-550 lux
Cognitive	1.2	Sound level	30-35 decibels
Psychomotor	5.9	CO2 level	< 400 parts per million

The occupant could continue working without modifying the environment. The effects would compound, eventually causing significant occupant dissatisfaction and very low task performance until the occupant left or took action to change his environment. In this case, the occupant has several options available to improve his workspace environment. The actions available to the occupant are those that provide additional illumination. Actions presented to the occupant are in order as to the "best" option for the task rather than by allowing the occupant to choose based on their own experience – what they think is the "best" option. The available actions are turn on task light, open window shades, or turn on overhead lights (box 14). The overhead lights have already been turned on, and therefore, are removed from the available actions (crossed out). Turning on the task light is the first action because it results in less energy than the overhead lights, and it is convenient for the task (less workload and time away from task). While the occupant could open the window shades, glare on the computer screen is a potential source of discomfort. The model completes the time step by sending the selected action of turning on the task light to the building simulation to recalculate the environment parameters. The new environment parameters are compared to the task environment parameters to output an updated satisfaction and task performance rating.

4 Conclusion

This paper presents an approach to representing occupant behaviours using the understanding that occupant tasks are the driver of behaviour intentions. Defining occupant behaviour as an intention to satisfy tasks defines a clear boundary to work within to identify model input parameters. Using a contextual task analysis questionnaire, the model input parameters are represented as five ABM elements in the task-based ABM structure. By using tasks to define the ABM structure, behaviour actions consider task performance when determining occupant actions. While the ABM is still in its early stages, the data collection enabled the development of the overall ABM structure on which we will continue to build. As this ABM evolves, further ABM development should build a strong understanding of how task-related occupant behaviours affect office buildings.

This ABM approach goes farther than previous approaches in that it includes task performance and occupant satisfaction metrics that can translate to cost-savings. An additional benefit is the ability to expand on the elements enabling the integration of new building systems and occupant behaviours. The next steps in this research include expanding on data collection and model development. Continued data collection using the CTA questionnaire as well as additional studies to collect task-specific data relating to the optimal task environment, specific environment factors that affect task performance, and occupant preferred actions. In addition to informing the current identified inputs, future work includes expanding evaluation criteria to include additional comforts such as ergonomics, and incorporating transient occupants, such as stakeholders and guests, into building operation.

Finally, validation of the model will require sensitivity analyses to ensure a reasonable simulation of office occupant behaviour as well as comparisons to conventional, standalone building simulations. Comparisons can be made related to building energy demand and overall thermal comfort, but comparisons of occupant satisfaction and task performance will require alternate means, such as a cost-benefit analysis, because these metrics are not available in the conventional building simulations.

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