Exploring the tools and methods to evaluate influence of social groups on individual occupant behavior with impact on energy use

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Abstract. One of the key elements in driving the energy performance of buildings has been recognized as occupant behavior (OB). However, available tools for assessing and simulating occupant behavior are based on fixed schedules and aggregated profiles, which fail to capture the diversity of OB. A significant aspect of OB is its relation to social groups and their influence and interdependence on each other. The data regarding the influence of social groups is important to achieve an effective model of OB as it accentuates the individual OB profile based on the influences it can have from the social groups they belong to. This added module is not present in traditional building simulation tools. This study aims to explore the tools and methods to evaluate the factors that are responsible for the influence of social groups on individuals’ energy-related behavior. The paper investigates the kind of data sets needed for understanding this interdependence, including the occupant’s social group, their standing in the group, and the intent behind different actions and its comparison to the actions the individual would take without any external influence. The results will be used to construct questionnaires, which can prove beneficial in developing social group profiles in OB models.

1. Introduction

Current statistics on worldwide energy consumption indicate that more than one-third of the expenditure comes from residential and commercial buildings [1]. Reportedly, this consumption would have been 40% higher if not for the implementation of energy-efficient technologies, but despite the technological advancement, the challenges in energy reduction are enormous, and these are compounded with the increasing global pressure and concerns to meet the worldwide goals for this reduction [1]. In addition, the disparity between the expected and the actual energy performance [2] [3] of buildings is another cause for concern, and it leads to a need of having a more innovative and holistic approach to bridge this gap and adapt to the energy demands in an efficient manner.
However, occupants are an integral part of the building systems, and due to the dynamic nature of occupant interactions with these systems, building sectors become much more complex in terms of their energy performance. While there can be several other factors involved in the contribution of the performance gap, most notably, faults in the mechanical and electrical systems, malfunctioning of equipment etc. [4], occupant behavior (OB) has been identified as one of the major drivers of this gap [5]. This trend has also been reflected in the fact that, over the last 30 years, the research community has shifted a lot of its focus towards OB [6]. This behavior, then becomes a deciding factor when it comes to the variability in the comfort settings and the implications it has on the energy usage.

In that context, there is a marked dissonance when it comes to the building design and performance simulations as well. Low-energy, or zero-energy buildings, are designed to comply with high-efficiency standards, which are vital for reducing carbon emissions, and these designs are dependent on an active occupant interaction with the building systems. However, the predictions of the energy performances result in an even larger error for these low-energy buildings [7]. This can be attributed to the actuality that the potential for achieving that high level of efficiency in these buildings is reliant on the building being operated in a specific way according to the design. Another side of this problem is also the rigidity in the building performance simulation (BPS) process, wherein OB is most often considered as a fixed or schedule-based model [8]. Earlier BPS tools utilized deterministic inputs to represent OB over the life cycle of the building, which took the form of daily, weekly, and monthly schedules. The main advantage of these inputs was the ease of use and simplicity of the models. However, more and more BPS tools have started incorporating stochastic models to capture the diversity and include the uncertainties which arise in OB [9].

The need to incorporate an interdisciplinary approach is based on this human-building dynamic, and this approach can be viewed at three different levels: the individual occupant, the group behaviors (building level), and the collective behaviors (district scale) [10]. In these terms, a multi-scalar approach, one that deals with different zones and interdisciplinary considerations of occupants’ activities (habits, movement, presence, etc.) will be necessary for both the data collection and the simulation processes, and this will involve an amalgamation of engineers, architects, social scientists etc. Along these lines, Dziedzic et al. proposed a Building Occupant Transient – Agent-Based Model, which would contain several different modules for the different aspects of OB [11]. This would include distinct, individual modules in the simulations to account for the movement, habits, surroundings, and social structure.

This added modules for the social structure and influences is often neglected, since a lot of focus tends to be towards measuring the physical occupant interactions, but not the socio-psychological drivers of that behavior. Researchers have often been sensitive to the cost and technological availability, and largely ignored accompanying factors such as social equity, group status, peer influence etc. Sovacool et al. identified three main negative patterns from the energy research literature over the last 15 years and the first of them was that the social dimensions are under-examined, especially those pertaining to perceptions about energy use, and decision-making process among individuals, organizations, and communities [12].

2. Social group influences on individual occupant behavior

2.1 Occupant social groups and networks

Measurement of social influences is often conducted through the evaluation of social groups. These social networks, or groups, comprise of the group of people that occupants have to interact or share the space with. This is applicable to both residential and commercial buildings. It is an umbrella term which includes distinct nodes, where the nodes would represent the number of people in a particular group
(size), the strength of the relationship between the members (connection), and in some cases, they represent events and ideas that affect the group as well [13]. These networks have been documented having a significant effect on the energy-us behaviors of occupants [14] [15] [16]. While the framework of this paper has its focus on commercial buildings and workplaces, the intended scope is to recognize the kind of behaviors needed to be studied to collect the datasets, and that data collection can be adapted to residential buildings as well, by modifying the kinds of questions asked within the data collection surveys.

2.2 Theory of planned behavior

In order to quantify these influences and behaviors, literature in energy research and social science relies heavily on the theory of planned behavior [13] [18]. The theory states that there exist three factors behind the behavioral intentions and behaviors; attitudes and beliefs towards the action, beliefs about how significant others may respond to the action (subjective norms), and the perceived behavioral control (i.e. beliefs about the ease of performing the action). These three factors have been taken as the foundation in this study, to build the framework for the social structure module in OB modeling.

Abrahamse and Steg used the theory of planned behavior to explain subjective norms in residential households, that is, behaviors that would rely on the extent of importance other members of the household, and the social pressure to carry out the actions [19]. For instance, changing the thermostat settings as an energy saving measure might not be carried out if the family members disapproved of those settings. In addition, when it comes to workplaces, or commercial buildings, the utilization of energy is integrated with the group behaviors, since the equipment and facilities are often shared between co-workers. Chen and Knight used the same theory to examine the influence of colleagues among more than 500 employees in electric power companies in China, and the results indicated that the approval or disapproval from the colleagues was the major factor influencing the individual’s energy saving actions [18].

Streamlining the study of these influences can also take the form of studying the social networks in relation to energy use. Anderson et al. used an agent-based model to investigate different types of social networks in buildings and the extent of their significance on administrative actions designed to reduce energy use [14]. The results indicated that accurate representations of the social networks, in relation to the historical data of the administrative actions, are vital in predicting energy use. Chen et al. also made use of agent-based modeling to build a network level computational model that simulates the decision-making process of individuals under different type of network configurations [15].

3. Framework for incorporating social influences in OB modeling

While quite a few studies have highlighted the impact of this social influence, not much research has been done on integrating this aspect in the OB simulation process. Anderson et al. did manage to conduct simulations based on occupant’s susceptibility to social influences depending on their position in the social network, and the model also took into account the corresponding peer influence on their energy-use behavior [16]. However, this topic warrants a lot more study, especially in the wider context of how it fits into the overall OB profile.

3.1 General Principles

This framework takes into account all the above-mentioned factors that have been determined to be the drivers of the social influences in OB, combined with the principles of the theory of planned behavior, and dictates the datasets required from the framework’s perspective. Since a major part of the topic has its focus on the social networks, this framework will involve the creation of a database that details the
occupant’s involvement and interaction with their respective networks. This would be a representation of the subjective norms, and will include a mapping of the network grid around the workplace, the number of people in the network that count as significant enough to influence the behavior, and the rank of the occupant in their networks. Considering the sharing of facilities in workplaces, the database also has to involve these interactions in designated areas, such as the common areas, lunchrooms/breakrooms, shared office spaces etc.

Regarding the perceived behavioral control (PBC) and the attitude/beliefs of the occupant towards different actions, gathered data has to include their perceptions about the energy-use, concerns for reducing that usage, and awareness of facilities or obstacles that accommodate a specific action. The collection of these datasets can then be utilized by connecting them to different energy-use behaviors such as thermal control, lighting control, ventilation etc.

3.2 Required Datasets to construct the module

As seen in figure 1, the datasets can be divided according to the principles, and the combined effect be correlated to the energy-related behavior using weighed factors that are derived on the basis of the extent of each parameter’s perceived influence. For subjective norms, this influence would be the variability in the action, with and without the external influence. A general description of these is summarized as follows:

- Perceived behavioral control (PBC): Occupants perceptions about their own ability to conduct the action, awareness of the kinds of facilities that are available to ease the performance of the action, or obstacles that may hinder it. This could come in the form of technological aids present at the workplace, administrative actions that incentivize certain behaviors etc.
- Subjective norms: These factors will be tied in with each of the spaces that involve the interaction within the social network, and the factors are as mentioned in 3.1
- Beliefs/Attitudes: These would investigate the occupant’s personal beliefs and perceptions about the action.

![Figure 1. Schematic of datasets required.](image)

3.3 Survey Methodology

There is a growing trend in adapting survey methodology to explore the nuances in OB. The reason behind this is that surveys still remain the most effective method for measuring variables that cannot be monitored or observed directly such as the intentions behind the energy-related behaviors, concerns, and
perceived norms (latent variables) [20] [21]. However, surveys carry their own share of risks, and doubts regarding the validity, since discrepancies are often present between the reported and actual behaviors. To minimize these risks, several factors have to be taken into consideration during the design process of the survey/questionnaire. In addition, in order to incorporate the beliefs and motivations of the occupants’ behind their actions, quantitative survey methods may not be sufficient [22], and qualitative interviews with the occupants might have to be combined with them to give a better understanding of the behaviour. Since the focus and scope of this work is towards OB modelling, the qualitative step will be taken into consideration after the initial results of the quantitative survey, in order to identify the factors that were insufficiently covered, and achieve better design of the process.

When measuring social and psychological parameters, it is necessary to avoid using absolute responses or brief scales, and instead adopt combined items and contextually large scales based on established theories. Vague quantifiers need to be avoided and equal number of choices should be provided on both the positive and negative sides. Apart from these, other general guidelines for designing questionnaires should be implemented as well, such as the use of simplified words over specialized ones, general aesthetic, and response that are mutually exclusive.

4. Discussions and conclusions

Energy research literature gives us definitive insights about the impact of social influences on occupant behavior, and the theory of planned behavior is an effective tool to quantify these influences. This paper brings out the necessity of considering these factors in conjunction with the energy-use behaviors to obtain a better approach to OB modeling. The guidelines and types of datasets outlined in this paper will be used to construct questionnaires and gather the required data. Results from the data collection will be vital for constructing the social modules in OB modeling, in addition to providing insights about general behavioral intentions and norms. However, most limitations here are due to the discrepancies in the reported behaviour. Special care has to be taken to avoid any kind of sampling errors, response bias, or reliance on occupant’s estimations based on long-term memory.

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