REPRESENTING PEOPLE IN BUILDING PERFORMANCE SIMULATION

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ABSTRACT

The presence and actions of building occupants have a significant impact on the performance of buildings (energy efficiency, indoor climate, etc.). Current practices in modeling the presence and actions of people in buildings do not display the necessary level of sophistication to reflect the complexity of people's passive and active impact on building performance. To significantly improve the state of art in representation of people's presence and control actions in buildings, solid empirically-based simulation input models are necessary. In a recent study, we observed, over a period of a year, people's interactions with the buildings' environmental systems (lighting, shading, ventilation) in a number of office buildings in Austria. The results imply the possibility of identifying certain patterns of user control behavior as a function of indoor and outdoor environmental parameters such as illuminance and irradiance.

INTRODUCTION

It is common knowledge that the presence and actions of building occupants have a significant impact on the performance of buildings (energy efficiency, indoor climate, etc.). Current practices in modeling the presence and actions of people in buildings do not display the necessary level of sophistication to reflect the complexity of people's passive and active impact on building performance: general information about building type (residential, commercial) and environmental systems (free-running, air-conditioned) as well as organizational information (working hours) can only provide rough directions regarding the far-reaching implications of user presence and actions in buildings. More reliable people action models require extensive observational data based on empirical studies of control-oriented user behavior (as related to buildings' environmental systems) in a representative number of buildings. Thereby, possible relationships between control actions and environmental conditions inside and outside buildings can provide the underlying basis for predictive functions of user behavior for incorporation in building simulation applications.

In a recent study (Mahdavi et al. 2008), we observed, over a period of a year, people's interactions with the buildings' environmental systems (lighting, shading, ventilation) in a number of office buildings in Austria. The results of this study suggest that such interactions are difficult to predict at the level of an individual person. However, general control-related behavioral trends and patterns for groups of building occupants can be extracted from long-term observational data. Moreover, such trends and patterns show in many instances significant relationships to measureable indoor and outdoor environmental parameters. Thus, our observations underscore the need for typologically differentiated occupancy models for different buildings. Patterns obtained from one building cannot be transposed to other buildings without extensive calibration measures considering differences in buildings' use (function), size, context (physical, climatic, cultural), orientation, envelope, systems, etc. Nonetheless, efforts are justified to apply the collected data to date toward the generation of preliminary models of user presence and behavior. As these data are the outcome of actual long-term observations and high-resolution measurements in typical office buildings, they are more reliable (representative) than most currently applied simulation input assumptions.

APPROACH

A large number of studies have been conducted in the past decades to understand how building occupants interact with buildings' environmental control systems such as windows, blinds, and luminaires. (Boyce 1980, Fritsch et al. 1990, Herkel et al. 2005, Hunt 1979, Inoue et al. 1988, Lindelöf and Morel 2006, Love 1998, Page et al. 2007, Rea 1984, Reinhart 2001). However, there is still a need for systematic collection of a large and consistent set of observational data regarding building occupants' presence and control action patterns. Toward this end, we conducted a long-term monitoring effort (Mahdavi 2008) involving five office buildings in Austria (code: VC, FH, ET, UT and HB). In some cases the data analyses for VC included a differentiation between office groups facing North and South-West (code: VN and VS). Data collection was conducted on a long-term basis (9 to 14 months).

The intention was to observe user control actions pertaining to lighting and shading systems while considering the indoor and outdoor environmental conditions under which those actions occurred. Occupancy and the change in the status of ambient light fixtures were captured using a dedicated sensor. Shading was monitored via time-lapse digital photography: the degree of shade deployment for each office was derived based on regularly taken digital photographs of the façade. The external weather conditions were monitored using a weather station, mounted either directly on the top of the building or the rooftop of a close-by building. Monitored outdoor environmental parameters included air temperature, relative humidity, wind speed and wind direction, as well as global horizontal illuminance and global horizontal irradiance. Internal climate conditions were measured with loggers distributed across the workstations. To obtain information regarding user presence and absence intervals, occupancy sensors were applied, which simultaneously monitored the state of the luminaries in the offices.

RESULTS

Figure 1 shows the mean occupancy level (i.e., presence in users' offices or at workstations) in VC, FH, ET, UT and HB over the course of a reference day (averaged over the entire observation period). Note that occupancy patterns can vary considerably from office to office. Figure 2 shows the probability that an occupant would switch the lights on upon arrival in his/her office as a function of the prevailing task illuminance level immediately before arrival (for FH, VC, and HB). Figure 3 shows the probability that an occupant (in FH, VC, and HB) would switch off the lights upon leaving his/her office as a function of the time that passes before he/she returns to the office. Figure 4 shows the mean shade deployment degree (percentage of the shaded window area) for FH, VN, and VS as a function of global irradiance.

DISCUSSION

The mean fraction of office hours actually occupied by the users is rather low (Figure 1). In general, the differences between the extent and patterns of occupancy in offices buildings are quite considerable. Occupancy models of office buildings must thus take into consideration the specific use types, functions, and required working hours of the respective occupants. Given sufficient observations, statistical methods can be used to generate individual occupancy patterns that, while unique – and realistic in their fluctuations – could represent, in toto, the mean occupancy level associated with a building. The relationship between occupancy and the operation of electrical lighting can be highly complex (due to differences in buildings' location and orientation, floor, window area and glazing type, shading system, available view and daylight, etc.). Nonetheless, there is a certain relationship between occupancy level and electrical light usage in the majority of the monitored offices. In the most monitored offices, only rather low workstation illuminance levels (well below 200 lx) appear to trigger a non-random increase in probability of switching the lights on upon occupants' arrival in their offices/workstations (Figure 2). A possible explanation for this circumstance may be the increasing portion of office time spent in front of computer displays. Our data (Figure 3) confirms the results of a number of previous studies concerning the dependency of switching off probability of lights by occupants who leave their workstations on the duration of the time they stay away. The mean shade deployment levels differ from building to building and façade to façade (Figure 4). In case of FH, where we studied the east-facing façade, a relationship between shade deployment and the magnitude of solar radiation is observable. In case of VS and VN, the shade deployment level does not vary much, but there is a significant difference in the overall shade deployment level between these two façades (approximately 75% in the case of south-west-facing façade, 10% in the case of the north-facing façade). Overall, our data suggests that the shade deployment level in buildings cannot be predicted reliably on the basis of incident irradiance alone.

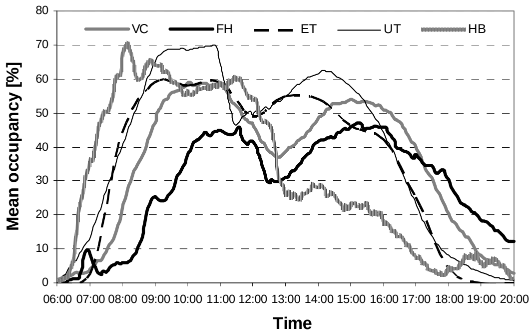

Figure 1. Mean occupancy level for a reference day in VC, FH, ET, UT and HB

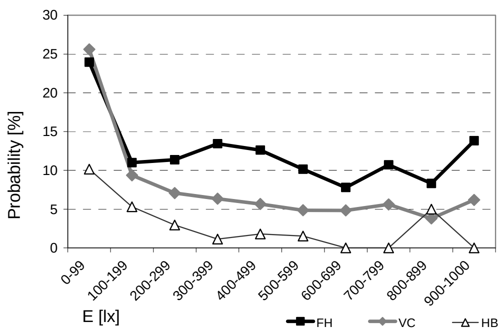

Figure 2. Probability of switching the lights on upon arrival in the office in FH, VC, and HB as a function

of the prevailing task illuminance level prior to the action's occurrence

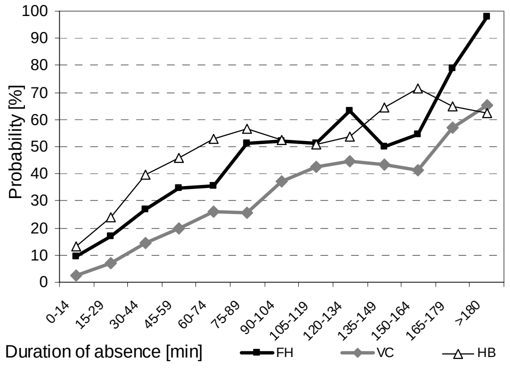

Figure 3. Probability of switching the lights off as a function of the duration of absence (in minutes) from the offices in FH, VC, and HB

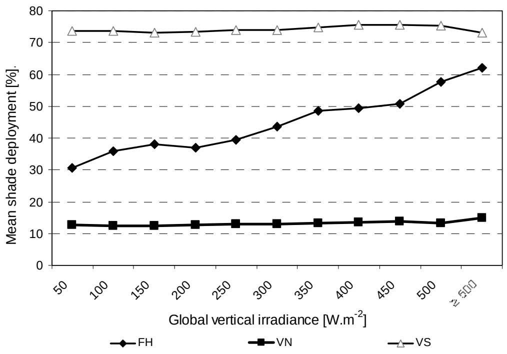

Figure 4. Mean shade deployment degree (FH, VC-N, and VC-S) as a function of global vertical irradiance

CONCLUSION

The results of a study was presented concerning user presence and control actions in a number of office buildings in Austria. The results imply the possibility of identifying certain patterns of user control behavior as a function of indoor and outdoor environmental parameters such as illuminance and irradiance. However, our observations also underscore the need for typologically differentiated occupancy and control action models for different buildings. Patterns obtained from one building cannot be transposed to other buildings without extensive calibration measures considering differences in buildings' use, size, context, orientation, envelope, systems, etc. Nonetheless, efforts are justified to apply the collected data to date toward the generation of preliminary models of user presence and behavior. As these data are the outcome of actual long-term high-resolution observations, they are more representative than most currently applied simplified user models. In future, more reliable people presence and actions models are expected to improve the accuracy of simulation studies (for example, to explore the impact of thermal improvement measures on the building's energy use) and to enrich the control logic in building automation systems.

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