USER INTERACTIONS WITH ENVIRONMENTAL CONTROL SYSTEMS IN BUILDINGS

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ABSTRACT

The design and operation of energy-efficient systems for indoor environment control (heating, cooling, ventilation, lighting) can benefit from reliable (empirically grounded) information on occupants' actions to bring about changes in the status of building control systems. Specifically, the computational modeling of occupants' control-oriented control actions in building performance simulation applications can be significantly improved based on such empirical information on user behavior. The present paper concerns the type and number of user control actions as related to building systems in two office buildings in Vienna.

INTRODUCTION

Buildings are generally equipped with components and systems that can act as control devices. Windows, shades, luminaries, radiators, fans, and other similar devices can be operated by building occupants with the intention of bringing about desirable indoor conditions. The design and operation of systems for indoor environment control (heating, cooling, ventilation, and lighting) can benefit from reliable (empirically grounded) information on building occupants' needs and motives to change the status of building control systems. Likewise, performance simulation applications can provide more accurate predictions of buildings' indoor climate conditions and energy consumption if the patterns of user presence and control actions are modeled on a more realistic basis.

While there have been a number of past research efforts in this area (see for example, Bourgeiois et al. 2005, Hunt 1979, Newsham 1994, Reinhart 2002), there is still a need for further detailed data in different types of buildings and in different climatic and cultural settings. Thus, multiple studies are being conducted internationally, to collect data on building users' interactions with building control systems and devices.

The present contribution is part of an effort to observe control-oriented occupant behavior in a number of office buildings in Austria. In each building we study in average 20 workstations. These workstations are typically equipped with desktop or laptop computers. In some cases task lights are used. In the course of the study, we register the type and number of user control actions as related to one or more of the following building systems: ambient lighting, shading, window ventilation, and heating. Simultaneously, indoor and outdoor environmental conditions (e.g. temperature, relative humidity, illuminance, solar radiation) are measured. The present paper involves the study of the control-oriented actions of a number of occupants in two office buildings in Vienna over a period of a year. The collected data is analyzed to explore hypothesized relationships between the nature and frequency of the control actions on one side and the magnitude and dynamism of indoor and outdoor environmental changes on the other side. These relationships provide the empirical basis for user behavior models that can be integrated in building performance simulation applications. Moreover, the collected data allows for the exploration of the implications of user behavior for buildings’ energy consumption.

METHODOLOGY

The change in the status of ambient light fixtures is captured using a dedicated sensor. Shading and window ventilation are monitored via time-lapse digital photography. The status of heating devices is either captured via user logbooks. The external weather conditions are monitored using a weather station, mounted on the top of each building. Internal climate conditions (temperature, relative humidity, illuminance) are measured with autarkic loggers distributed across the workstations. To obtain information regarding user presence and absence intervals, occupancy sensors are applied. All of the above parameters are logged regularly every 5 minutes.

The present contribution addresses data collection and analysis in two office buildings in Vienna, Austria. In the first object (code: "FH_TU") we selected 10 single-occupancy staff offices facing east. In the second object we selected 15 offices facing north (code: "VC_NO") and 15 offices facing south-west (code: "VC_SW").

Monitored indoor parameter included room air temperature (in ^{o}C), room air relative humidity (in %), ambient illuminance level at the workstation (in lx), luminaire status (on/off), and occupancy (present/absent). Monitored outdoor environmental parameter included air temperature, relative humidity, wind speed (in $m.s^{-1}$) and wind direction, horizontal global illuminance and horizontal global irradiance (in $W.m^{-2}$). Vertical global irradiance incident on the façade was computationally derived based on measured horizontal global irradiance. The the degree of shade deployment for each office was derived based on regularly taken digital photographs of the façade. Shade deployment degree was expressed in percentage terms (0% no shades deployed, 100% full shading).

ILLUSTRATIVE RESULTS

Figure 3 shows the occupancy patterns (mean worker presence level as a function of the time of the day) for FH_TU as well as for VC_SW+NO. Figures 4 and 5 show (for FH_TU and for VC_SW+NO respectively) the probability (in %) that an occupant switches on lights upon arrival in the office as a function of the prevailing illuminance level (in lx) in the offices. Figures 6 and 7 illustrate (for FH_TU and VC_SW+NO respectively) the probability that an occupant switches off the lights upon leaving his/her workstation as a function of the time (in minutes) that passes before he/she returns to his/her workstation. Figures 8 and 9 illustrate the mean monthly shades deployment level over one year for FH_TU and VC_SW+NO respectively. Thereby, the degree of shade deployment is expressed as the percentage of window occlusion due to shades operation averaged over all windows of the observed offices. Thus, for example, 0% denotes no shades deployed, whereas 100% denotes full shades deployment.

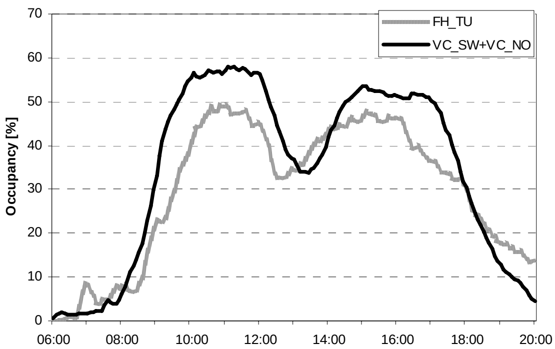

Figure 3 Mean presence level (in %) as a function of the time of the day for FH_TU and for VC_SW+NO

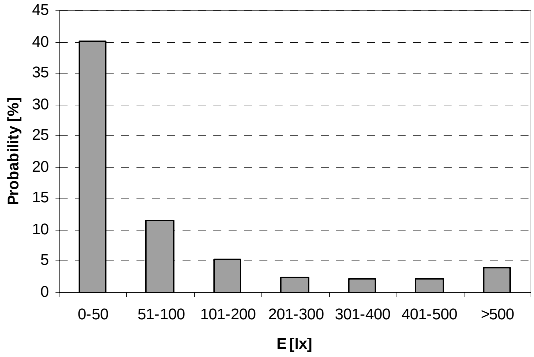

Figure 4 Switching on probability of electrical lights as a function of the prevailing illuminance level in the offices at occupant's arrival time in FH_TU.

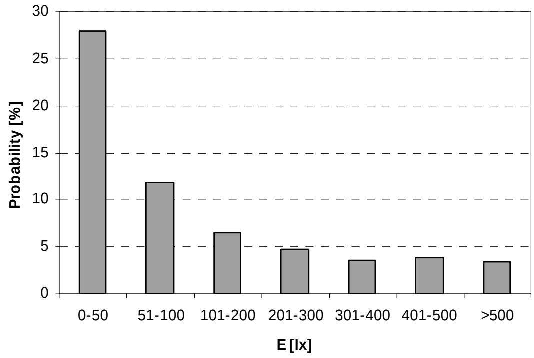

Figure 5 Switching on probability of electrical lights as a function of the prevailing illuminance level in the offices at occupant's arrival time in VC_SW+NO.

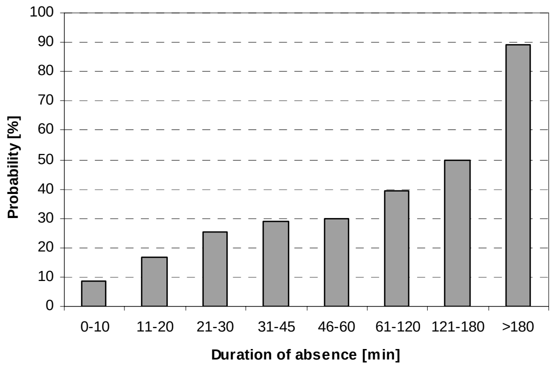

Figure 6 Switching off probability of electrical lights upon leaving the office as a function of the time that elapses (in minutes) before the occupant returns to his/her office in FH_TU.

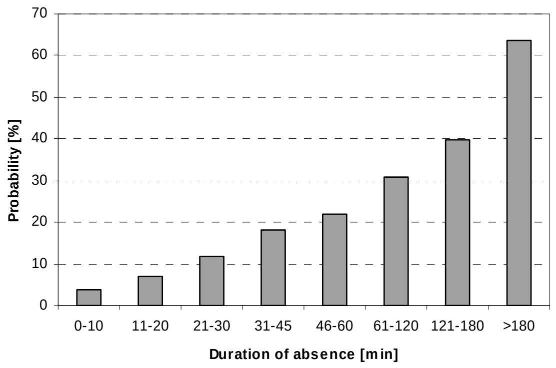

Figure 7 Switching off probability of electrical lights upon leaving the office as a function of the time that elapses (in minutes) before the occupant returns to his/her office in VC_SW+NO.

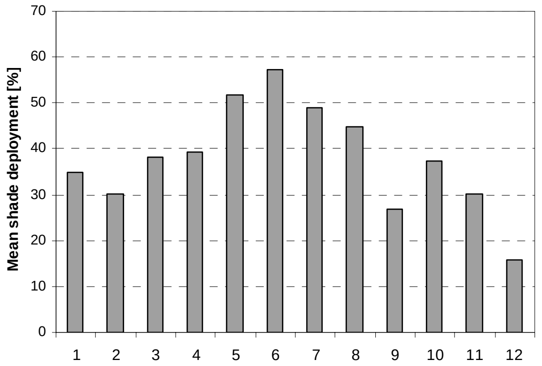

Figure 8 Mean shades deployment degree in FH_TU (in %) over a period of one year (1: January; 12: December).

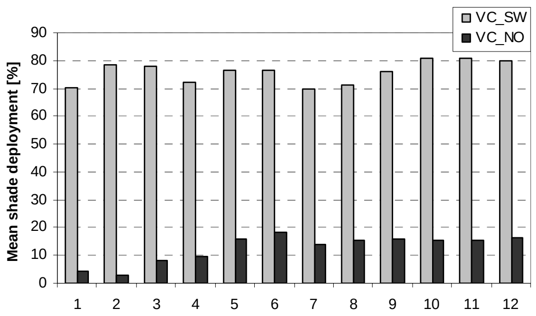

Figure 9 Mean shades deployment degree in VC_SW and VC_NO (in %) over a period of one year (1: January; 12: December).

DISCUSSION

Data collected to date seems to warrant certain initial observations: *i)* Office users are more likely to switch on the light upon entering their offices only if the prevailing ambient illuminance is less than 100 lx (cp. Figures 4 and 5); *ii)* Office users are less likely to switch off the lights upon leaving their offices unless they remain absent for one hour or more (see figures 6 and 7). This circumstance points to a significant electrical energy saving potential (for lighting) using occupancy sensing technologies; *iii)* The position of shades does seem to be affected by incident solar radiation. The relationship is, however, rather complex and different from building to building and façade to façade. In FH_TU, where we studied the east-facing façade, a significant difference in the level of shades deployment can be seen between the high-radiation summer months and the low-radiation winter months (Figure 8). In case of VC_SW and VC_NO the shades deployment level does not vary much in the course of the year (Figure 9), but there is a significant difference in the overall shades deployment level between these two facades (approximately 75% in the case of south-west-facing façade, 10% in the case of the north-facing façade).

CONCLUSION

We presented case studies from an ongoing project concerning user control actions in office buildings in Austria. The results imply the possibility of identifying general patterns of user control behavior as a function of indoor and outdoor environmental parameters such as illuminance and irradiance. The compound results of the ongoing case studies are expected to lead to the development of robust occupant behavior models that can improve the reliability of computational building performance simulation applications.

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