Title

Analyzing occupancy profiles from a lighting controls field study

Authors

Rubinstein, Francis
Colak, Nesrin
Jennings, Judith
et al.

Publication Date

2003-04-30

Title: Analyzing Occupancy Profiles from a Lighting Controls Field Study

Authors: Francis Rubinstein, Nesrin Colak, Judith Jennings, and Danielle Neils
Lawrence Berkeley National Laboratory

Introduction

Despite a number of published studies on the effectiveness of lighting controls in buildings [1-4], only one US study [5] examines the occupancy patterns of building occupants. Occupancy profiles allow one to determine, for example, the probability that an office is occupied for each hour of the workday. Occupancy profiles are useful for many purposes including: 1) predicting the effectiveness of occupancy sensors for reducing peak demand, 2) evaluating the impact of human activity on building lighting and other electric loads and 3) providing lighting equipment manufacturers with detailed lighting operation data to help evaluate the impact of advanced lighting controls on equipment life. In this paper, we examine the occupancy profiles for 35 single person offices at a large office building in San Francisco and analyze the data to obtain average occupancy as a function of time of day. In addition, we analyzed the data to identify how the use of occupancy sensors may affect switching cycles and lamp life.

Methods

For the entire year of 1999, we logged the exact occupancy times for each office using occupancy sensors coupled to a data acquisition system. Details on the building site, experimental protocols and control strategies tested are presented in [1,2]. Each time that the occupant turned his/her light switch on or off, the time, date, and switch state (ON or OFF) were recorded. Similarly, each time that the occupancy sensor detected a change in occupancy, the time, date, and occupancy state (occupied or vacant) were also recorded. In this way, we were able to track the operation times of both the occupancy sensor and the wall switch in each office to a resolution of 1 minute. The occupancy sensors recorded the occupancy state of each office regardless of whether the light switch was on or off, but would not operate the lights automatically unless the wall switch was on. Occupancy sensors in this installation were commissioned to turn off the lights in each office when no occupancy had been detected for approximately 15 minutes. The lighting energy usage in each zone was recorded automatically every 15 minutes. Using this data, we were able to determine how long the lighting controls in each office were in one of four states as defined below in Table 1:

Table 1. Lighting Use State Definitions

State	Definition	Switch	Occupancy Sensor	Overhead Light
0	Office vacant with light switch OFF	OFF	OFF	OFF
1	Office occupied with light switch OFF	OFF	ON	OFF
2	Office vacant with light switch ON	ON	OFF	OFF
3	Office occupied with light switch ON	ON	ON	ON

The lighting use state of most importance to this study is State 2, which reflects the potential of the occupancy sensor to reduce lighting energy usage.

In selecting data for analysis, we chose to examine only “regular” weekdays, that is, days when the office was occupied for at least 4.5 hours and the overhead lights were on for at least 1 hour. This allowed us to develop a more accurate picture of the effectiveness of occupancy sensors to reduce demand in a typical office during regular working hours. The total number of days analyzed varied for each individual office.

Results
We compiled the accumulated data from all offices in order to look at the trends in occupancy and lighting usage for these zones. Table 2 below gives general lighting operation statistics for both the 3rd and 5th floor offices.

Table 2. Lighting operation statistics for 3rd and 5th floor offices

Category	3rd floor (21 offices)		5th floor (14 offices)	
	Average	**STD**	**Average**	**STD**
Total analyzed weekdays/year	167.0	29	170.3	34.7
Average wall switch ON time (hr/day)	8.7	2.6	8.9	2.8
Average occupancy sensor ON time (hr/day)	7.8	1.6	7.7	1.7
Average energy savings (%)	20.5	14.7	21.6	17.9
Average delay time (minutes)	13.0	2.8	14.8	2.8
Average actual occupied time (hr/day)	6.3	1.7	6.0	1.5
Average wasted ON time	1.5	0.4	1.7	0.6
Average number of OS offs/weekday	6.9	1.3	6.9	2.4
Average ON time per switch cycle (hr/cycle)	1.2	0.3	1.4	0.5

These results show that the occupancy sensors frequently switched off the lights in both 3rd and 5th floor offices (7 times per average weekday for both floors), which implies that these offices are frequently vacated during working hours. Additionally, the results indicate that lighting systems operated by occupant sensors will have significantly shorter average ON times per switching cycle (1.2 hours/cycle for 3rd floor offices and 1.4 hours/cycle for 5th floor offices) than systems without occupancy sensors.

The occupancy data per hour were examined both on a room-by-room basis and averaged across rooms in the 3rd and 5th floors. Examples of occupancy per hour for three typical rooms are given below in Figure 1. These graphs plot the likelihood of each office being occupied during each hour of the day, for the year 1999.

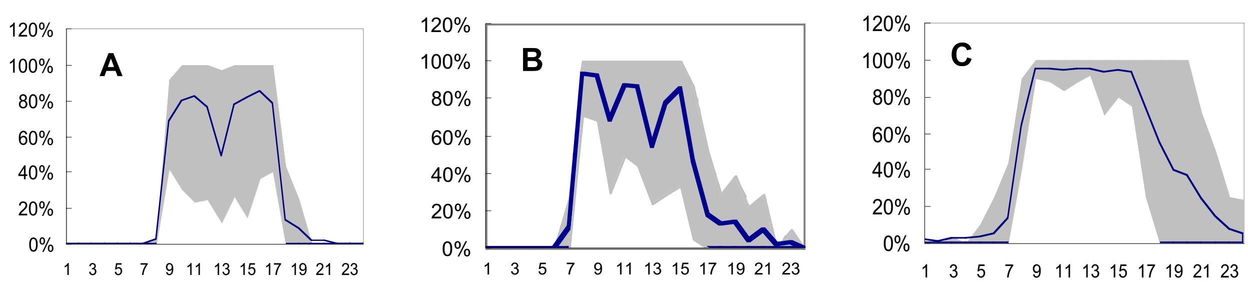

Figure 1. Average occupancy data per hour for two typical rooms (A and B) on the 3rd and one room (C) on the 5th floor. The blue line is the hourly occupancy averaged over 156 and 196 regular days for rooms A and B, respectively and over 194 regular days for room C. The gray areas in each graph give the bounds containing 80% of the measured data.

In Figure 1, room A is an example of an occupant who typically leaves his/her office during the middle of the day. Figure 1B shows an occupant who leaves twice during the day, once in the morning around 10 am and once in the afternoon around 2 pm. In Figure 1C, the occupant tends to stay in his/her office for the entire day.

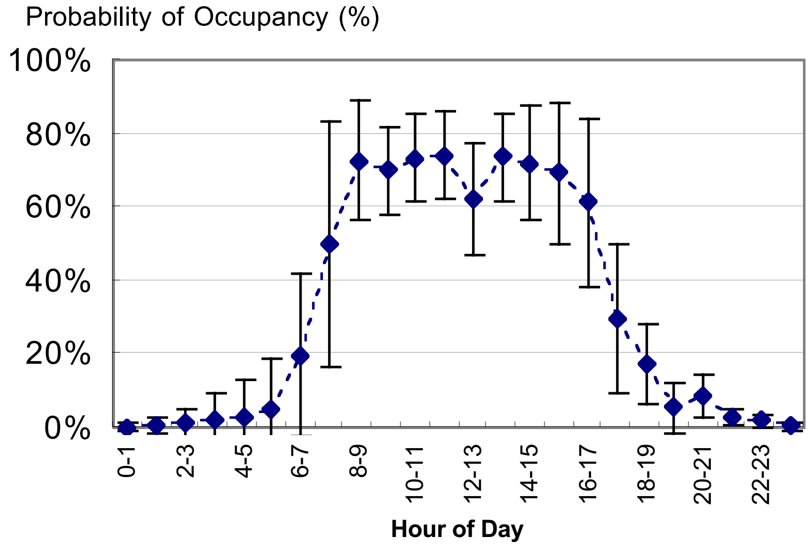

Figure 2. Probability of occupancy by hour for all regular weekdays averaged across all 21 offices on the 3rd floor. Blue dots indicate the average values and error bars indicate the corresponding standard deviations.

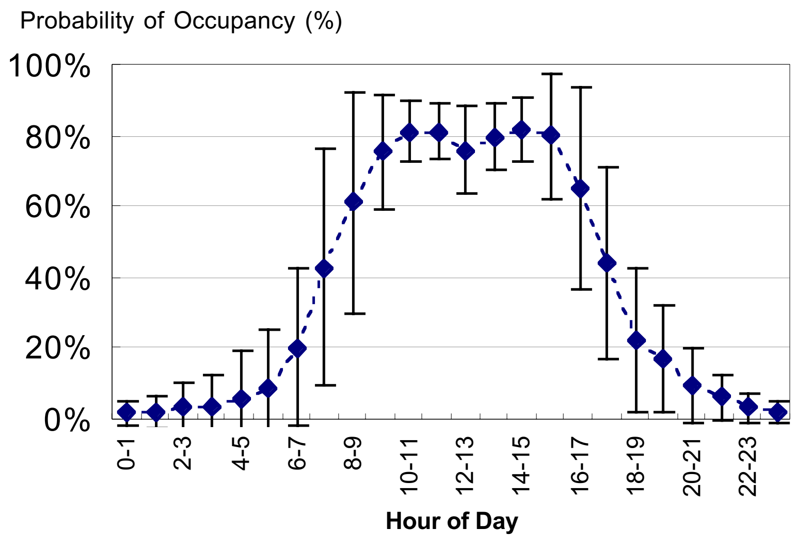

Figure 3. Probability of occupancy by hour for all regular weekdays averaged across all 21 offices on the 5th floor. Blue dots indicate the average values and error bars indicate the corresponding standard deviations.

In terms of average occupancy behavior across all rooms, Figures 2 and 3 give the average probability of occupancy for all offices on the 3rd and 5th floors at hourly intervals during the day. The graphs show similar results, with peak occupancy periods between the hours of 8am and 5pm, and a reduced occupancy during the lunch hour (12-1pm).

Discussion

Our results show that in this installation, occupancy sensors were an effective means for reducing lighting hours during primary working hours. This new result is significant as earlier research has focused primarily on the role of occupancy sensors for curtailing lighting outside normal working hours. The occupancy data we accumulated in our study showed that there are several occasions throughout a typical workday when lighting ON hours can be reduced through the use of occupancy sensors. Because the general trend in these offices was to leave during the middle of the day, the lunch hour represents a prime opportunity to save lighting energy. Additionally, shortening the delay time on the sensors could lead to even larger energy savings and less wasted ON time.

Another important insight to be gained from looking at these occupancy profiles is the short average ON time per switching cycle, which results from occupants vacating their offices frequently throughout the day. This information has ramifications for producers of lighting equipment since most manufacturers rate lamp life based on a 3-hour switching cycle.

Acknowledgements
This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, Building Technologies Program, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

References

1. Jennings, J.D., et al., Comparison of control options in private offices in an advanced lighting controls testbed. *Journal of the Illuminating Engineering Society*, 2000. 29(2): p. 39-60.
2. Rubinstein, F., et al., Preliminary results from an advanced lighting controls testbed. *Journal of the Illuminating Engineering Society*, 1999. 28(1): p. 130-141.
3. Rubinstein, F., M. Siminovitch, and R. Venderber, Fifty percent energy savings with automatic lighting controls. *IEEE Transactions on Industry Applications*, 1993. 29(4): p. 768-773.
4. Von Neida, B., D. Maniccia, and A. Tweed, An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems. *Journal of the Illuminating Engineering Society, 2001*. 30(2): p. 111-125.
5. Keith, D.M. and M. Krarti, Simplified prediction tool for peak occupancy rate in office buildings. *Journal of the Illuminating Engineering Society*, 1999. 28(1): p. 43-56.