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EXAMINING OCCUPANCY AND ARCHITECTURAL ASPECTS AFFECTING MANUAL LIGHTING CONTROL BEHAVIOUR IN OFFICES BASED ON A USER SURVEY

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ABSTRACT

Further understanding the building occupants' needs and behaviors can reduce lighting energy consumption. This research explores how the occupancy and interior architectural aspects become effective in manual lighting control in offices. It involves a multiple sectioned questionnaire focusing on the possible architectural factors such as the desk position, the surface colours, the distance to window, the distance between desk and lighting switch, and inquiring participants' manual lighting control behaviour through the photographs of modified interior layouts, surface colours and time intervals. Statistical methods are used to determine the significant aspects, which may reduce the use of lighting control. Interior layout, distance to window, time of the day, and number of occupants in the offices are the most significant contributions to the manual lighting control behaviour. To pay attention in these contributions, it would be possible to reduce the use of electricity for lighting while user satisfaction increases.

Keywords: lighting energy consumption, manual lighting control, interior layout, user behaviour

1. INTRODUCTION

User behaviour is the action involving the presence of users and the way of performing their activities in the building [1, 2]. One possible action to decrease lighting electricity use has become the users' control over the lighting systems due to its inevitable impact on total energy consumption [3–5]. Manual lighting control, which is a sub-branch of user behaviour, is the switch on/off control by the user without any automatic control systems involvement.

Only a few of user behaviour studies have focused on manual lighting control [6]. Reinhart (2004) reviewed an extensive literature on existing user behaviour models for manual lighting control [7]. He emphasized the Hunt's and Newsham's model, generating switch on/off probabilities, assuming that users control the lights twice a day (upon arrival and on departure) and daylight illuminance has a strong role in switching on behaviour [7, 8]. Both models did not, yet, consider the switch on/off events during occupation period, i.e. for lunch or short breaks [7]. Pigg (1996) figured out that absence time proportionally determines the switching off probability [9]. Bourgeois et al. (2005) mentioned studies about "active" and "passive" users according to their stochastic functionality and dynamic responses to short-term changes in lighting conditions considering occupancy patterns [6, 10]. The active user referred to those who seek for optimal use of daylight, that controls artificial lighting and shading during the day, while the passive user referred to those who undertake no actions towards the lighting system during day [10, 11]. A recent study dealt with occupants' lighting-use patterns as a function of electricity usage of lighting and switch-on times in offices. It defined users as active and their relation to illuminance was significantly strong [5]. Daylight illuminance and absence time are two key variables; and users are categorized as active and passive due to their action type. Arrivals and leaves during the occupation period are other subject matters in this sense.

It is realized that architectural aspects have not yet been analyzed in relation to manual controls. For example, the relation of manual lighting control to occupants' desk position and distance to window (which affects the direction of daylight coming on the desk area) to manual lighting controls are not inquired yet. Similarly, although daylight illuminance has a powerful influence on lighting switch on/off actions, window area, distance to window and interior surface colours (walls, ceiling, floor), which determine the amount of illuminance, are not subjected to any correlation with the manual lighting control. Besides, triggering or inhibiting factors of lighting control (to turn on/off the lights) actions need to be explored since occupants' illuminance preferences vary significantly among each other. If the users' expectations, preferences and underlying reasons are understood in relation to architectural aspects, the manual lighting control could be modified to be more effective.

Utilizing such knowledge, architectural design can have an active role in energy savings revising/ or enhancing the users' manual control action. If complexity of user actions complementing to lighting conditions and control are figured out thoroughly, such information would be integrated in simulations to predict energy consumptions.

The purpose of this study is to examine the influence of the occupancy rate and the architectural aspects of offices on manual lighting control behaviour to generate user behaviour data on manual lighting control. The research process involves a questionnaire, which was applied to the academic staff of the university in İzmir, Turkey. The questionnaire explores the spatial, visual and contextual factors that influence user behaviour. This research design addresses two research questions:

1. Do changes of interior architectural aspects (such as desk position, distance to window, distance to switch, surface colours, and orientation) in an office affect manual lighting control behaviour?

2. How the occupancy rate (absence and occupancy time intervals) influence manual lighting control frequency?

2. SURVEY DESIGN

A multiple-sectioned questionnaire was developed to reveal the participants' current experience of her/his working environment and manual lighting control behaviour within their office. Considering that limited amount of daylight penetration may trigger the manual lighting control behaviour, the questionnaire was conducted during winter, specifically in February 2015. The participants were provided with a finite time, i.e. one month, which they had to keep in mind when answering the questions – *for instance, "how would you describe the daylight availability in your office for the last month? / the amount of light at this work area for the tasks you performed in the last one month: ...".*

Participants are academic staff using offices at the university that is located in Izmir. Academic staffs enter/leave their offices frequently during the day depending on their lectures, seminars and meetings, which would provide a variation of user behaviour to examine. Invitations to this survey were sent /distributed via email to participants. A total of 125 (60.8 % females and 39.2 % males; the age of 85 % < 36) out of 398 participants (approx. 30 %) voluntarily submitted the questionnaire forms through 'Survey' (a questionnaire domain), which runs the statistical evaluations.

The questionnaire includes a variety of question formats such as multiple-choice, Likert-scale and yes-no questions. It is mainly composed of five sections that are described in detail below.

The first section of the questionnaire focuses on the architectural/physical conditions of the participants' current offices, and aimed to relate participants' visual satisfaction and manual lighting control preferences, which were gathered in subsequent sections. It involves a list of 9 multiple-choice questions, such as number of people working on the office, orientation of the room, total area of windows etc. The required information of the existing office environment was asked on the following two questions. Knowing the distance between their desk and the window (less than 1m, 1m-2m, 2m-5m, more than 5m) would be useful to interpret how they benefit from daylight penetration on their workplace. Collecting data about the interior layout (i.e, when sitting on the desk, whether the window is on the left, right, back, front or other) provides an insight into daylight penetration direction. Besides, the daylight illuminance on their desks may have distinct and varying evaluations about their visual environment depending on the direction of occupants' view (whether the occupant is facing window *-front layout-* or facing wall *-back layout-*). Participants were also asked to indicate whether they suffer from glare or not.

The second section of the questionnaire evaluates the satisfaction with daylighting availability and artificial lighting environment separately with a format of five level Likert rating designating as 1=not very satisfied, 2=unsatisfied, 3=medium, 4= satisfied, 5= very satisfied. A subsequent semantic scale is constructed to collect information on how participants assess the amount of light in the room, on the desk and at the computer screen. It ranged from –2, too dim, to +2, too much, with a neutral value of 0 corresponding to the right amount of lighting. Besides that, users were asked to define the tasks (such as working with computer, reading or writing) they accomplish, and their frequencies, using a five scaled rating. The frequency scales are composed of five categories, such as; 1=all the time, 2=most frequent, 3=sometimes, 4=rarely and 5=never.

Questions of the third section concentrate on manual lighting control habits and subjective reasons behind it. To reveal participants' manual lighting control actions, first they were asked to describe the frequency of their manual lighting control through the day. Then, four groups of questions were asked about reasons effecting their manual lighting control or inhibiting their control; aspects influencing them to turn on the lights; and the ones not to turn on (such as visual comfort needs, indicating occupancy, colleagues' request, creating an atmosphere etc.) were measured on a Likert scale from *1(always) to 5(never).* Each listed item in Figs. 1a–1d is subjected to Likert scale. Regression analysis were performed to test which reasons relate most strongly to the frequency of changing the lighting condition. Each group of listed item was significantly tested due frequency of participants' lighting control at a level of 0.05 confidence. Each item also was included separately and some aggregate per group was implemented as well.

The fourth section is composed of questions about the employee's subjective impression of how their current office layout and whether any architectural changes therein may affect their use of manual lighting control. Here, closed ended questions would be a useful and efficient way to get information about what participants have in their mind. The first question, rated on a five- point Likert scale is 'how would you rate the following interior architectural factors in terms of increasing your manual lighting control?': *'position of your desk', distance between your desk and window', 'window area', 'orientation of the window', 'surface/or objects colour in the room', 'distance between switch and your table'.* The second question aimed to learn to what extent they agree with the following statement which starts with 'my manual lighting control increases with' the subsequent factors: 'a change in my desk's position related to window', shortening the area between my desk and window', 'enlarging the window, 'a change of the orientation of the window', 'colour of the objects area'/surfaces/room', 'shortening the distance between the switch and my table'. Responses were obtained on a scale ranging from '1' = agree to '5' = disagree.

To find out participants' response to modifications in surface colour and time of the day, photograph-response yes-no questions were used *in the fifth section.* These questions are based on a 1/5 scale model of a single occupied office (3.6 m × 5.4 m × 2.7 m) [12]. The model (Fig.2) becomes the demonstration for each photograph case. Exposure adjustments of photographs were implemented using Photoshop to avoid possible visual illusions and provide balanced brightness contrasts. Participants used the same screen all through the questionnaire, which prevented the visual perception differences.

The interior surfaces were covered with dark-coloured (surface reflectance (ρ) of walls and floor are 0.50 and 0.20) paper firstly; then with light coloured (ρ: 0.85 and 0.50) paper secondly. The reflectance was calibrated with a calibrated reflection disc with a reflection coefficient of 95.2 %. The scale model was placed in front of a North-facing window at the TU Delft Architecture and Built Environment Faculty (52^0.00' N, 4^0.37' E). The photographs were taken with a digital camera with fish eye lenses, on Dec. 21, 2014. The model faces north to reduce high contrast differences and to avoid visual discomfort caused by direct sunlight. Diffuse daylight penetration provides relatively balanced daylight distribution during the day.

The scale model was photographed three times at the same day: respectively, at entrance in the morning (09:00–09:30), at midday after lunch (13:00–13:30) and in the afternoon after a short

2. Please, rate the following reasons on your manual lighting control over fixtures/systems?

	Never	Rarely	Sometimes	Generally	Always
To obtain visual comfort (increase/decrease illuminance level-avoid glare)	☐	☐	☐	☐	☐
For energy saving	☐	☐	☐	☐	☐
To indicate your occupancy/absence	☐	☐	☐	☐	☐
Colleagues' request	☐	☐	☐	☐	☐
For thermal comfort	☐	☐	☐	☐	☐
For computer work	☐	☐	☐	☐	☐
For reading printed text	☐	☐	☐	☐	☐
To compensate for daylight	☐	☐	☐	☐	☐
To create atmosphere for work	☐	☐	☐	☐	☐

(a) Contribution to manual lighting control

3. Which factors inhibit you from manually controlling lighting fixtures/systems?

	Never	Rarely	Sometimes	Generally	Always
My colleagues' preferences	☐	☐	☐	☐	☐
To stay focused on my work	☐	☐	☐	☐	☐
My distance to switch is far	☐	☐	☐	☐	☐
I don't care the illuminance level inside	☐	☐	☐	☐	☐
I don't notice the changes in illuminance levels	☐	☐	☐	☐	☐

(b) Inhibiting factors

4. How the following factors influence you on turning lights ON manually upon your arrival?

	Never	Rarely	Sometimes	Generally	Always
If the room is dark	☐	☐	☐	☐	☐
To indicate your occupancy	☐	☐	☐	☐	☐
Prefer to work with artificial light	☐	☐	☐	☐	☐
Generally daylight is not sufficient through the day	☐	☐	☐	☐	☐

(c) Influencing factors

5. How the following factors influence you on "NOT turning lights ON manually" upon your arrival during a regular work day?

	Never	Rarely	Sometimes	Generally	Always
To avoid excessive light and glare	☐	☐	☐	☐	☐
To indicate your absence	☐	☐	☐	☐	☐
I don't notice whether it is on or off	☐	☐	☐	☐	☐
Position of the light switch	☐	☐	☐	☐	☐

(d) Reasons for not turning on lights manually

Fig.1. Listed factors effect on manual lighting control

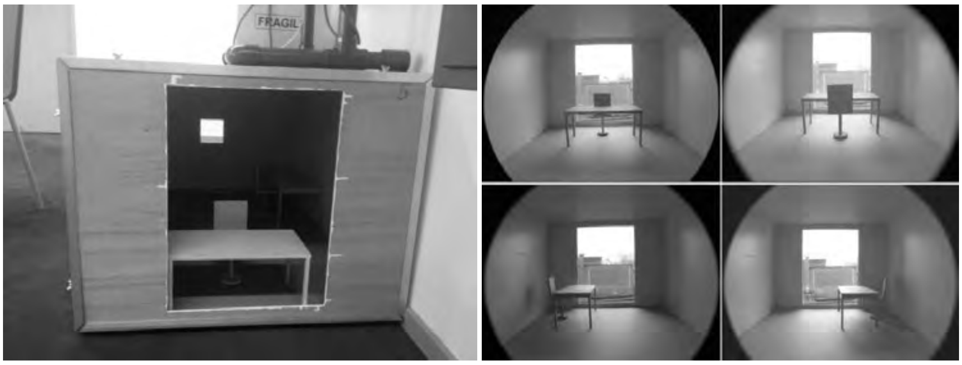

Fig. 2. Scale model and photographs for Back and Front layout (upper), Left and Right layout (lower), with light surfaces

break (15:00–15:30). Participants were asked to indicate their manual lighting control action while looking at the photographs for these three different time intervals. Based on the aspects of visual environment of the photographs, they stated their decisions as either “I would turn on the lights” or “I would not turn on the lights” upon entrance. The dependency of their decisions to control lights, on distance to window, desk position and time of the day, were analyzed through cross tabulations and chi-square tests.

3. SURVEY FINDINGS

Regarding the questions about the existing environment, 26 % of participants work single, while 17 % share the office with 1–2 people, 24 % share with 3–4 people and 32 % share the office with 5 or more people. The rates of the offices with 15m^2–30m^2 window area is 51.2 %, while 16 % of offices have smaller than 15m^2 window area and 32,8 % of offices have more than 30m^2 window area. The major room orientation is North with a 20.8 % rate, while the percentage of other orientations ranged from 1.6 % to 16.8 %. The distance to window varied from 1m to 2m for 40.8 % of respondents while 31.2 % of them declared that the distance is less than 1m. The majority participants do not suffer from glare in their offices (92 %).

When the respondents were asked to rate their satisfaction of the artificial lighting condition in their office, the highest “satisfactory” responses were obtained from participants who work in single and 3–4 people-occupied offices, both with a similar rate of 80 %. The participants who work in the 5–6 people sharing offices gave the highest “unsatisfied” responses. Type of artificial lighting system was not questioned considering the wide variety of lamp and luminaire types, and respondents may not be capable of describing the existing system. In the latter, users are more likely to find the illuminance higher than what they would wish (80 %). This output can be interpreted as, if they would have the chance to control the lights individually, they would prefer lower illuminance, which leads to less energy consumption. This outcome corresponds with Gu’s study (2011) [13] that there will be energy savings with individual lighting control, since there are always some occupants who prefer illuminance lower than the fixed lighting levels. Such a finding can provide feedback to architects, in terms of promoting them to design single occupied or up to 3–4 people occupied working spaces, to contribute in electricity savings. Another possibility, for crowded offices, can be the design of desks with personal visual comfort, with personal lighting.

Almost 50 % of respondents whose offices face North were satisfied with the daylighting condition in their working environment, due to their choice of indicating *“4-very satisfied”* in the questionnaire form. A similar rate of satisfaction was observed among respondents in North-East facing offices. Among the responses about various desk positions, left positioned desks have the highest value of satisfaction (with almost 50 %), while the back position has gathered the lowest (approx.30 %). As the window area was the matter to find out its relation to daylight fulfillment, highest satisfaction responses (approx. 42 %) were given by the respondents with window areas of 2m^2–5m^2. Participants’ responses verified that the ones, who have a distance of more than 5m between their desks and window, consider the daylight penetration as too dim. Participants, whose desks are (1–2) m away from the window, were in majority in declaring the daylight penetration “sufficient”.

To figure out whether daylight satisfaction was independent of orientation, desk position, window area, distance to window or not, chi-square test of independence tests and cross-tabulations

Table 1. Chi-Square Results

	Pearson chi-square (χ^2-crit)	p-value	
Orientation	33.267	0.405	independence
Desk position	10.588	0.834	independence
Window area	18.407	0.018	dependence
Distance to window	24.024	0.020	dependence

were applied at a 5 % level of confidence (α=0.05). Daylight satisfaction was dependent of only two aspects: window area and distance to window. Results, indicated independency of orientation and desk position on participants' daylight satisfaction, are in Table 1.

Respondents were asked to indicate their ideas to the each given statements which proposes a modification increase their manual lighting control. Orientation of the window (81 %) and enlarging the window area (79 %) are the most commonly chosen factors to increase manual lighting control. Shortening the distance between the desk and the window (Always 31 %, Generally 43 %), changing colours of the surfaces (Always 22 %, Generally 29 %), and changing the desk's position (Always 37 %, Generally 32 %) are the other significant modifications on lighting control behaviour; while the distance between the switch and table (Always 11 %, Generally 14 %) has the least effect. However, users' opinions on how the above listed modifications can influence their control behaviour were conflicting with their responses on daylight satisfaction in their actual work environment.

Almost 57 % of the participants control the lighting system manually several times a day depending on either their absences or daylight penetration. They do not operate the lighting system only during entrance and departure; so they can be categorized as active users. 21 % of the participants claim that they control it twice a day (only when they enter in the beginning of the day and when they leave at the end of the day); while 9 % of them state that, they control it before/after lunch and breaks, additional to their control in their morning entrance and evening departure. Yet, 13 % of them indicated that generally they do not control lighting systems manually. So, 34 % of the participants can be grouped as *passive users*. The above data show that the assumption in studies and models, which identifies all users as passive, is not realistic. This study shows the importance of taking the user behaviour realistically.

The majority of the participants (39 % and 40 % respectively) declare that the main reason for manual lighting control is to provide visual comfort and to create atmosphere for work; in other words, to fulfil their tasks. To save energy (by 21 %) has become the second meaningful personal motivation to control the lighting system. Indicating their occupancy/or absence has no or a very slight impact on control decisions of 52 % and 20 % of participants. Response rates for the two factors; 'computer work' and 'reading printed text' are quite similar, meaning that, one type of task does not have a stronger effect on users' control behaviour than the other one has. Almost 27 % of the participants never take into consideration their colleagues' demand of lighting control; 32 % of participants turn on/or off the lights because of colleagues' demands, even they do not prefer it themselves. Thus, individual lighting control for each workstation can be a good solution for obtaining visual comfort.

Regarding associations of each listed reasons to affect manual lighting control (as explained in Section 2.2.3, when aggregate per group was tested, a low value of R^2 is calculated as 0.12 (group in Fig. 1a), 0.04 (group in Fig.1b), 0.04 (group in Fig. 1c) and Significance F and *p* values are greater than 0.05. Results are not reliable so, listed items are decreased, only two individual items, obtaining visual comfort (Significance F=0.002, *p*=0.002) and creating atmosphere for work (Significance=0.002, *p*=0.001), are found to be significantly related to manual control with almost 0.10 R^2. That means, we can explain/predict the 10 % of the variation among data. For example, visual comfort, alone, might affect manual lighting control without a major contribution. This makes sense and is reasonable; since, manual control decision is a human action and many other factors might be influential and some cannot be predictable. Not noticing the changes in illuminance is the only significant factor (Significance F=0.042, p=0.04), which inhibits the users to control light.

Almost 72 % of respondents consider that modifications on interior layout can be effective on their control behaviour. Accordingly, the window area (39 %-Always, 40 %- Generally), its orientation (37 %-Always, 44 %-Generally), position of the desk (37 %-Always, 32 %-Generally) and distance to window (31 %-Always, 43 %-Generally) were defined to have a strong effect while distance between switch and table (18 %-Rarely, 40 %-Never) was found to be the least effective factor. Colour of the surfaces has shown no strong effect among the response rates.

To understand participants' reactions according to the desk layout, distance to window, surface colours of the walls, and time of the day, they were asked to give feedback by looking to photographs of given indoor scenes of the scale model. Those feedbacks could be derived from two choices; "I would turn on the lights" or "I would not turn on the lights". Chi-square test of independence was applied to reach a deep and notable understanding whether manual lighting control was independent of the above mentioned interior factors or not.

First, participants' manual lighting responses to two different distances to window (A and B) were compared significantly. When the desk was in Back position and the surfaces were light, control responses showed very slight or no variation if the desk was moved away from the window. After the 'afternoon break', the control action displayed variation. The rate which corresponds to 32,8 % of respondents turning on the lights was raised up to 40.8 % when the desk moves to away from the window in B position. After lunch arrival, the reverse was happened. The responses of 36 % for turning the lights on decrease to 32,8 % when the desk was in B position. When the desk was in Front position, the approx. 88–96 % of respondents prefers not to turn on the lights during the day. In the morning, a strong drop was observed in rates of responses "I would not turn on the lights" (11 % to 2.41 %) when the desk is moved near the back wall in B position.

Cross-tabulations and chi-square tests are applied to figure out statistically whether there is any significant relation between distance and turn on/off behaviour. The implication for each case of layout and surface colour according to time (morning, lunch and afternoon) was iterated extensively. Results on a total of 24 cross tabulations for each time interval – morning, lunch, afternoon break – separately indicate that the turning on/off behaviour is dependent to distance to window since p-values are below α=0.05 in all cases (p=0.000) except only Left A-B in the afternoon (χ^2= 2.65, df=1, p= 0.104).

When manual lighting control responses of Back are compared to Front, significant differences are achieved in all time intervals (morning, lunch and afternoon break). For example, during morning entrance "turn on the lights" response is 57,6 % for Back B Light, while it falls to 2,41 % in Front B Light under same conditions. Similar results are valid for Back A Dark and Front A Dark during morning entrance. For Back A position, the response of "not turn on the lights" is 8 %, while it increases to 84 % for Front A desk position. However, the response percentages of Right and Left desk positions do not vary significantly with each other compared to Back-Front. For instance, "not turn on the lights" response Left A Dark (after lunch) is 87,2 %, while under same conditions Right A Dark positioned desk responses reduces to 45,6 %. Chi-square tests and cross-tabulations reveal the dependency of manual control behaviour on desk position according to very low p-values (p<0.001) except the positions of Front-Back B in the morning entrance and lunch (χ^2= 2.30, df= 1, p=0.129 and χ^2 = 3.34, df= 1, p= 0.067), Front-Back A(dark) in the morning (χ^2 = 0.29, df= 1, p=0.589).

Such an outcome is noteworthy not only in developing architectural design merits but also in enhancing technical ways to evaluate daylight performance and energy efficiency in working spaces. Users' desk layout can be involved as a certain affecting variable/or constant in performance and energy calculating tools. Additionally, personal issues can be integrated to get a deep understanding and insight. A further study can analyze in detail how a left-hand writer receiving daylight from the left side satisfies differently than a right-hand writer in the same layout; and how the lighting electricity is consumed or saved in both cases.

To understand whether the time of the day reflect to respondents' manual lighting control or not, photographs were taken at three different time moments (morning entrance, lunch and afternoon break). Users most likely attempt to turn on the lights for all desk positions and surface colours during morning entrance. For example, the percentage of "turn on the lights" response for Left A Light condition is 65.85 % during morning entrance, while it reduces to 4,8 % and 4 % for after lunch and break entrances respectively. After Lunch and after Break manual lighting control responses are closer to each other when compared to after morning responses. Chi-square tests of independence applied to 48 cross tabulations supported the significant relation among manual lighting response to time of the day. Significantly low p-values ranged from 0.000 to 0.003. However, a few observations such as relations between morning and lunch in Left A-Light position (χ^2 =3.27, *df*=1, *p*=0.070) and between morning and afternoon in Left A-Light position (χ^2= 0.46, df= 1, *p*=0.496) constitute the independency with higher *p* values.

4. DISCUSSIONS AND CONCLUSIONS

This research aimed to statistically determine the contribution of certain factors (such as architectural and occupancy) to manual lighting control behaviour and user comfort within the university offices. Testing the relation between the physical environment and satisfaction of daylight conditions among the given parameters, window area and distance to window are found to be the two most significant and dependent aspects on users' daylight satisfaction. On the other hand, neither orientation nor position of the desk was found to have a statistically significant effect on daylight satisfaction.

Some factors are found to be remarkable on how they affect manual lighting control. In detail, North/North East orientation, the window area of 2–5 m^2 and distance to window of 1–2 m are specifically identified as sufficient for successful daylight conditions. Such conditions would increase the number of people not turning on the lighting when entering the office. Responses show that most of the participants can be classified as "active" users, since they don't only turn on the lights during their entrance in the morning, and turn off them in their departure at the end of their working period, as defined by Love (1998) [10], but frequently do control during the working period. These results are in contrast with the European Standards, where the value of manual control factor (occupancy dependency factor) is implemented as 1 (which means the lights are switched on during the working hours and users are passive) indicating that users do not control the lighting system during the day [14]. This active user behaviour can contribute to energy savings significantly, yet it is impossible to determine the saving with the data obtained in this study. A further study that analyzes the energy savings according to different user profile can be suggested. Obtaining visual comfort and creating atmosphere have significant impact on switching the lights, while energy saving has not such a strong impact when compared to them. That is interesting to realize that energy consciousness is less of a motivation than the wish for comfort. The reason may be the unawareness of users about the amount of energy they are consuming, so energy use takes place without any conscious considerations as mentioned in Toth et.al. 2013 [15].

Interior layout modification (change of location of desks) has been the strongest deriving force in the manual lighting control as supported significantly through analyses. For instance, locating desk close to window (in A position) and/or positioning desk facing window result as lower rates of switch on behaviour. These two factors were significantly affecting for all time moments. Such findings are similar to Thorndike et al.'s outputs [16], where interior layout affects user behaviour. Lighting control behaviour differs due to changes in daylight penetration. When the daylight penetration is not sufficient (especially in the morning), it triggers users to switch on the lights upon entrance. Thus, daylight illuminance should be taken into consideration when predicting lighting energy consumption.

Users' contribution on improving energy savings should not be underestimated. This study intends to enrich the knowledge on user behaviour in lighting energy consumption by analyzing possible effective factors and interpret how they influence the manual lighting control. The listed findings of manual lighting control frequency, with triggering and inhibiting factors, can be used as inputs during eco-friendly office design without using any automatic lighting control systems, but only the users. Furthermore, this study revealed to give best insight to user preferences, raise awareness on their manual lighting control actions, and point on how users should be realistically included in user behaviour models. To deliver energy efficient buildings, a more sophisticated understanding of user behaviour is needed, and interior design parameters should be taken into consideration for that purpose.

REFERENCES

1. Hoes, P., Hensen, J.L.M., Loomans, M.G.L.C., de Vries, B., Bourgeois, D. User Behaviour in Whole Building Simulation. Energy and Buildings 41(3): 295–302.

2. Mahdavi, A., Pröglhöf C. User Behaviour and Energy Performance in Buildings. In 6. Internationalen Energiewirtschaftstagung IEWT 2009, TU Wien, 2009, pp. 1–13.

3. Tetlow, R.M., Beaman, C.P., Elmualim, A.A., Couling. K. Simple Prompts Reduce Inadvertent Energy Consumption from Lighting in Office Buildings. Building & Environment, 2014. V81, pp. 234–242.

4. Yang, L., Yan, H., Lam. J. Thermal Comfort and Building Energy Consumption Implications – A Review. Applied Energy, 2014. V115, pp. 164–173.

5. Yun, G.Y., Kim, H.,. Kim, J.T, Kong. H. J. 2012. Effects of Occupancy and Lighting Use Patterns on Lighting Energy Consumption. Energy and Buildings, 2012. V46, pp. 58–152.

6. Bourgeois, D., Reinhart, C., Macdonald. I.A. Assessing the Total Energy Impact of Occupant Behavioural Response to Manual and Automated Lighting Systems. In Ninth International IBPSA Conference, Montreal, Canada, 2005, pp. 99–106.

7. Reinhart, C.F. Lightswitch-2002: A Model for Manual and Automated Control of Electric Lighting and Blinds A Versio. Solar Energy, 2004. V77, pp. 15–28.

8. Hunt, D.R.G. The Use of Artificial Lighting in Relation to Daylight Levels and Occupancy. Building and Environment, 1979. V14, pp. 21–33.

9. Pigg, S., Eilers, M., Reed. J. Behavioural Aspects of Lighting and Occupancy Sensors in Privates Offices: A Case Study of a University Office Building. ACEEE1996 Summer Study on Energy Efficiency in Buildings, 1996, pp. 161–70.

10. Love, J.A. Manual Switching Patterns in Private Offices. Lighting Research & Technology, 1998. V30, pp. 45–50.

11. Bourgeois, D., Reinhart, C., Macdonald, I. Adding advanced behavioural models in whole building energy simulation: A study on the total energy impact of manual and automated lighting control, Energy and Buildings, 2006. V38, pp. 814–823.

12. Hellinga, H. Daylight and View; The Influence of Windows on the Visual Quality of Indoor Spaces. Technische Universiteit Delft, 2013.

13. Gu, Y. The Impacts of Real-Time Knowledge Based Personal Lighting Control on Energy Consumption, User Satisfaction and Task Performance in Offices. Carnegie Mellon University, 2011.

14. PrEN15193–1, Energy performance of buildings; Energy requirements for lighting, 2007.

15. Toth, N., Little, L., Read, J.C., Fitton, D., Horton M. Understanding Teen Attitudes towards Energy Consumption. Journal of Environmental Psychology,2013. V34, pp. 36–44.

16. Thorndike, A.N., Sonnenberg, L., Riis, J., Barraclough, S., Levy, D.E. A 2-Phase Labeling and Choice Architecture Intervention to Improve Healthy Food and Beverage Choices. American Journal of Public Health, 2012. V102, pp. 527–33.

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