

The Effect of Smart Buildings on the Work Efficiency among Office Employees

Reyhaneh Nehchiri^{1*}, Shima Vahedparast², Hossein Hafezolghorani Esfahani³

¹MA, Faculty of Architecture and Urban Planning, Shahid Beheshti University, Tehran, Iran; ²MA, Faculty of Architecture and Urban Planning, Isfahan University of Art, Tehran, Iran; ³MA, Faculty of Architecture and Urban Planning, Isfahan Azad University, Isfahan, Iran

*E-mail: nehchiri.sbu.ac@gmail.com

Abstract

According to researches conducted in the field of industrial psychology, the physical conditions of a work environment highly affect the mental health of employees. Therefore, the appropriate physical conditions in the work environment will lead to improved productivity and enhanced quality in employees' work. Since providing appropriate physical conditions need to spend a lot of energy and fuel, thus the use of technology in order to save energy consumption is of great importance. Among the applications of modern technologies in the field of energy consumption management, smartization of buildings can be mentioned. Smartization of buildings or use of building management systems (BMS), by commanding different components of a building to do their functions in optimum conditions, reduces unwanted consumptions while providing a pleasant and safe environment. To answer this question that how smart office buildings affect the performance and efficiency of its staff, this article deals with investigating and introducing the physical features and indicators of a suitable work environment. Then, the performance of each component of smart buildings in creating the physical comfort of the environment is introduced.

Keywords: Smart buildings, Building management system (BMS), Office buildings, Improved productivity of employees

Introduction

Nowadays, the use of technology is increasing in the improvement of living conditions and creation of physical and mental comfort. Humans have always considered nature as a model in designing, production and manufacturing, and by looking at the way of its adaptation to the ecosystem, have achieved modern technologies to improve living conditions. By taking advantage of new technologies, architects are trying to turn architecture into peaceful coexistence in their ecosystem, and in other words, they are trying to provide conditions for buildings to adapt to the environment. This adaptation, in two approaches; consistency with the external environment, and empathy with the internal needs and functions of the space, is seeking to optimize material and energy consumption, and optimize the space and performance of users, respectively. In order to realize these two approaches, architects and designers have created smart buildings by using modern technologies, and by applying a set of programmable electronic equipment, micro-conductors, sensors, motors, so on (Khabbazi, 2014). In order to control and manage the components to meet some requirements, including efficiency, profitability, energy saving, entertainment, comfort, return on investment, and reducing the cost of living, in buildings with smart systems, coherent information exchange is carried out by computer among all the components involved in the control of building (Mahdavejad & Molayee, 2012). Given the efficiency of building smartization in energy consumption management and provision of comfort conditions, the importance of its usage in buildings such as office buildings is doubled.

Work force is considered as the main source in organizations and departments, and as a factor for their survival and development, prior to elements such as equipment, capital and technology. Obviously, the efficiency of work force is associated with several factors, and the result of the same work in two different conditions and situations can be quite different. According to researches carried out in the field of industrial psychology, the work environment is one of the main parameters affecting the efficiency of employees, so that the provision of an appropriate and efficient work environment can dramatically affect the enhancement in the working power and productivity of work force, either in terms of physical aspect or in mental aspect. Therefore, by organizing the work environment, and creating a desirable environment, some results can be expected, such as reduced costs, dramatic progress in work, provision of higher quality services, reduced occupational errors, and, in more complete words, the improved performance of organizational staff (Golabchi, Yusefi, & Foruzanfar, 2012).

According to what was said, the use of modern tools and technologies in office buildings, in order to provide appropriate physical conditions in the work environment to achieve the above-mentioned results, is of great importance. By continuously controlling different parts of a building and issuing commands in a way that the performance of different components of the building are balanced and in optimum conditions, the management systems in smart buildings, provide appropriate physical conditions and comfort conditions for staff, in addition to the management of energy consumption (Janbozorgi & Ghannad, 2009).

Smart buildings: The term "smart" is used in introducing the buildings that, by taking advantage of modern technology, provide the possibility of automated control of different components and devices. By assessing the events inside and outside the building and using a central control system, a smart building is able to make decision in order to create a suitable environment for its users. A central control system or a building management system (BMS) is a system that, when necessary, by monitoring the issues related to buildings, automatically takes necessary actions according to changes in environmental conditions (Ahmadi, Nateghi, & Ahmadi, 2013). This means that, the environment information enters the control system through communications equipment and receiving tools, and after processing and analyzing the communication data, the control system makes necessary decisions and sends them to components and outputs to be implemented, by taking considerations of time. By taking into account the needs in accordance with the building use (residential, office, commercial, hospitals, etc.), this system can monitor all activities, including: opening and closing the doors, people's entry and exit, lighting systems, air conditioning systems, the windows and shutters of rooms, audio-visual systems, etc. (Ahmadi, Nateghi, & Ahmadi, 2013). Among the objectives of using BMS and smart buildings, the following items can be indicated:

- Restricting unwanted consumptions of energy
- Optimization and economization on energy consumption
- Creating a desirable environment and increasing the comfort and convenience for users
- Continuous processing of all the building components
- Decision-making and building management, in case of events and/or changes in environmental conditions
- Reducing the costs related to the maintenance and repair of buildings
- Optimal use of equipment thus increasing its useful life (Janbozorgi & Ghannad, 2009)

The physical features of a desirable work environment: As mentioned earlier, one of the factors affecting the performance and work efficiency of human resources in organizations and departments is the physical conditions and architectural features of a work environment. Thus, in order to optimize the work environment, the first step is to recognize these features. In general, the

factors affecting the work environment, can be divided into two categories; internal and external factors. Here the external factors mean the existence of urban facilities such as transport stations, green spaces, parking lot, usages related to and required for employees at office hours, etc., whose effect on the performance of employees, is beyond the scope of this topic. In addition to the external effective factors, there are parameters in the internal space such as lighting, the type of windows, size and color of space, equipment and spatial arrangement, as internal factors that affect the quality of space. Moreover, since employees spend most of their working time in the internal space, these factors will be of greater importance in determining the quality of an environment, compared with external factors (Mahmood Golabchi & Foruzanfar, 2012). These internal factors being in a desirable condition, is considered among the prerequisites of enhancement in users' efficiency. In addition to having basic facilities, such as: appropriate tools and equipment, a desirable work environment should also have desirable lighting and ventilation, be away from the noise of the environment, etc. Generally, among the physical indicators of a suitable work environment, the following items can be indicated:

Appropriate lighting: One of the most important physical factors affecting the manpower performance, is lighting. As eyesight decreases due to the increase in age, people's need for light also increases. In addition, with continuous changes in the intensity of light, eyes will try to adopt themselves to the new light intensity, which causes eyestrain, and which reduces one's performance by disrupting the visual perception (Korman, 1992).

Low level of light pollution: Light pollution is the incorrect and non-standard use of lighting equipment; in other words, the overuse of light causes light pollution. Long-term exposure of humans under artificial light, due to infrared and ultraviolet radiation, causes eye injuries, stress, loss of concentration of thoughts, and in the long term, reduces the performance of immune system (Emani, Ramezani, & Arjang, 2009).

The ambient temperature being in the comfort range: According to Peters and Schmidt (2009), when the air temperature is mild and within the comfort range, the work efficiency of employees dramatically increases. This is while, the high temperature of an environment, adversely affects individuals' cognitive, physical and perceptual performance. Moreover, the willingness for work decreases in hot and humid air. The adverse effect of high temperature on the occupational performance of employees increases with an increase in the amount of work (Salehifard & Alizadeh, 2008).

Low level of air pollution: A decrease in air quality, due to the existence of a variety of pollutants, which cause respiratory problems, is called air pollution. According to researches carried out, air pollution, like noise pollutions, causes job stress in employees, in addition to physical problems such as headaches. The incidence of headache and stress in employees, is among the factors influencing the way of performing the work, and thus reduces the work efficiency of these people (Taleshi, Saleh, Imami, & Hamidian, 2012).

Low level of noise pollution: Any unwanted sound in the environment, which disturbs individuals' peace or concentration while working, can be called noise or noise pollution. Noise pollution causes physical problems such as chronic headaches, stomach discomforts, and extreme fatigue, so that these factors reduce the work efficiency of office employees (Mahmood Golabchi & Foruzanfar, 2012).

Music: One of the methods used to enhance employees' work efficiency and to improve their job performance, is playing music, which has become common in recent years. Music reduces fatigue, and has a significant effect on employees' consciousness level. The music, which is played for this purpose in the work environments, is called elevator music or Muzak (Peters & Schmidt, 2009).

The existence of green spaces inside and outside the building: Spending a lot of working hours in a stable environment, is boring and stressful for employees. The use of green spaces is a solution to reduce fatigue, which can lead to a positive result in employees' efficiency and improving their performance (Baharvand, Alizadeh, & Karimifard, 2014). Such that, according to researches conducted, the existence of suitable green spaces inside and outside the building, in addition to providing physical health, reduces stress, nervousness and tension, and increases concentration and work efficiency, and overall, causes mental comfort and enhances the quality of life (Ebrahimzadeh and Ebadi Jokandal, 2008). Among the other factors affecting the physical quality of a work environment, the type of design and arrangement of a workspace, can also be mentioned.

The facilities of the building's smart system and its application in the adjustment of the work environmental conditions

In most fields, modern technologies have developed to achieve progress and enhancement in the quality of life. Smart buildings are not an exception to this issue either. One of the advantages of smart systems is creating a desirable environment and enhancing the users' comfort (Moosavi Tarshizi & Ebrahimi, 2012). This desirable environment is created with the aid of different systems, in smart buildings. Smart lighting systems, the ability to create the desired temperature and humidity by taking into account the climatic conditions of the environment outside the building, controlling the doors, windows and awnings, audio and video systems, and telecommunication systems, are among the efficient systems for this purpose (Janbozorgi & Ghannad, 2009). Continuing, the performance of each of the above mentioned systems and how they affect the provision of a desirable work environment and thus enhancing the employees' efficiency in smart office buildings, will be introduced separately.

Lighting control system

The main function of this system, is controlling the electrical energy, and providing the appropriate lighting. The logic of this control, changes in accordance with the required light intensity, and proportionately to any space. A smart lighting system has the ability to change and adapt the lighting, with changes in the situation and use of space. In this way, with changes in the conditions resulting in a change in the logic of control, the system implements the new logic by applying the new programming. Therefore, it is possible to define different logics for different situations. For example, in office buildings, it is possible to define different lighting modes in situations such as holding meetings, lectures, playing films, study, and using computers. Moreover, by using this system, it is also possible to apply changes in the level of environment brightness with regard to lighting changes outside the building (based on the time and intensity of natural light). This capability is very important for office employees who are busy doing their tasks for a long period just in one space; because this system prevents the environment brightness level from changing continuously, and prevents eyestrain. In addition, time-based programming and controlling the switches with a remote control are considered among the other benefits of lighting control systems (Janbozorgi & Ghannad, 2009).

Temperature control system (air conditioning)

The task of this system is to measure the ambient temperature continuously and to adjust it according to the desired temperature defined for the system. The adjustment of heating and cooling degree is performed in accordance with temperature control logic, and in case of opening the windows, the system can switch off in order to avoid energy waste (Janbozorgi & Ghannad, 2009). It is also responsible for intelligently controlling the space ventilation based on time, the ambient air temperature outside the building, and the presence or absence of staff. By stabilizing the ambient

temperature and humidity within the comfort range (the desired temperature defined for the system or the control logic) in office spaces, the temperature control system has a considerable impact on the improvement of employees' performance.

Awnings and shutters system

In smart buildings, awnings and windows can be opened and/or closed automatically by remote control and/or manually, in accordance with the environmental conditions of the space outside the building and in order to adjust the internal space lighting (Janbozorgi & Ghannad, 2009). The control logic of the awnings can be defined based on the time of sunrise and sunset and/or beyond that, it can be programmed for different times of a year, in order to benefit from sunlight in winter, and stay safe from the hot summer sun. The smart awnings system provides the opportunity for the users of the space to use natural light appropriately and optimally. On the other hand, the lack of sunlight and constant use of fluorescent lamps can cause fatigue, depression and restlessness. This is while, studies show that, in terms of psychological and physiological properties, the light of day can improve one's performance, and in the work environments where natural light is used, a significant increase can be seen in the work efficiency of employees.

Audio system

By having a smart audio system, it would be possible to play music in different parts of a building, and it is also possible to announce general messages while playing music. Therefore, by employing this system in public buildings that have numerous spaces, there will no longer be a need to embed audio players separately in each of the spaces. Although there are different uses in office buildings, by programming the smart audio systems, it will be possible to play or mute the sound and music in a specific and defined space and based on the entry and exit of people into/from some spaces.

The green space irrigation system

By using this system, it is possible to irrigate the green spaces inside and outside a building automatically. This is while, manual irrigation of green spaces requires a lot of water and spending a lot of time, and despite their significant effect on relieving fatigue and creating mental comfort in users, green spaces are used on a limited basis inside buildings. Therefore, the use of automatic irrigation system in a building, saves both water consumption and time, and provides the possibility of using green spaces both inside and outside the building. In office buildings, due to the presence of work stress and employees' fatigue, a need for green spaces and thus a smart irrigation system, is felt more.

In addition to the previously mentioned items, there are also other smart systems, such as smart equipment control systems, that will be a great help for users by providing the possibility of simple control. Smart switch systems in offices, that usually have different systems such as lighting and shutter control, and that cover various uses and functions such as meetings, reading, working with computers, and resting, save time by accelerating the performance of tasks.

Conclusion

In smart buildings, many of the actions that the occupants do habitually and involuntarily are performed by intelligent systems that save time and work force costs, resulting in a reduction in system fallibility in addition to reducing energy consumption and costs. The building management system (BMS) in smart buildings, leads the environment to achieving a comfort space and ideal conditions, by controlling all the components using different types of sensors both inside and outside the building. Since intelligent systems are flexible and programmable in order to be used in different scenarios and applications, thus they are usable and efficient for creating users' comfort conditions in office buildings.

Table 1: The performance and impact of intelligent systems on creating desirable conditions in work environments, and its impact on the staff

The physical conditions of a desirable work environment:	Intelligent systems:	The system performance	The impact of the system performance on the staff
Lighting:	Lighting control system:	- Adjusting the light intensity proportionately to the space use	The prevention of eyestrain and dysfunction of visual perception
		- Adjusting the light intensity proportionately to the natural light intensity	
		- Adjusting the light intensity based on time	
		- Preventing the environment brightness level from changing continuously	
	Awnings and shutters system:	- Controlling the awnings based on the time of sunrise and sunset	The prevention of fatigue, depression and restlessness with optimal use of natural light
- Controlling the awnings based on different times of a year			
Temperature	Air conditioning system	- Adjusting the heating and cooling degree according to the desired temperature	The prevention of dysfunction in employees' cognitive, physical and perceptual performance
		- Adjusting the ambient temperature by opening and closing the windows	
		- Adjusting the ambient temperature based on the air temperature outside the building	
		- Adjusting the ambient temperature based on the presence or absence of staff	
		- Adjusting the ambient humidity	
Air pollution	Air conditioning system	- The space ventilation based on time	
Green space	Irrigation system	- The irrigation of green spaces inside and outside the building	A reduction in work stress, fatigue and nervousness, the increase in employees' concentration and efficiency, and the enhancement in the quality of life
Music	Audio system	- Playing or muting the sound and music in a specific space	A reduction in fatigue and the increase in the consciousness level
		- Playing or muting the sound and music based on the entry and exit of people	

Because spending many working hours in a stable environment, is boring for employees and reduces their efficiency. Hence, taking advantage of strategies to reduce the fatigue can be effective in improving employees' performance and enhancing their work efficiency. In this regard, providing desirable physical conditions and work environment for employees, is of great importance.

A desirable work environment in terms of physical aspect, has defined features in terms of brightness, environmental and human pollutions, etc., and the intelligent systems of a building make it possible to provide them by spending a minimum of time and energy. The following table shows different types of intelligent systems, their performance for creating desirable conditions in work environments, and its impact on the staff of office environments (Table 1).

References

- Ahmadi, E., Nateghi, A., & Ahmadi, H. (2013). Intelligent optimization of energy consumption in central heating systems. The Second National Conference on Climate, Building, and Optimizing Energy Consumption.
- Baharvand, R., Alizadeh, H., & Karimifard, L. (2014). The effect of green spaces in creating a sense of belonging to the work environment. The First National Conference on Urban Planning, Urban Management and Sustainable Development, 2014.
- Ebrahimzadeh, I., Ebadi Jokandal, E. (2008). An analysis on the space-place distribution of the green space land use, in Municipal District 3, Zahedan, Quarterly Journal of Geography and Development.
- Emani, H., Ramezani, A., & Arjang, A. (2009). Light pollution, its definitions and investigating its adverse effects on human health, and providing solutions, The Conference on Light Pollution, Electricity Distribution Company.
- Janbozorgi, A., & Ghannad, Z. (2009). Intelligent Systems of Buildings. Kayson Quarterly, 43.
- Khabbazi, Z. (2014). Digital designing processes. Kasra Publication.
- Korman, A. (1992). Industrial and Organizational Psychology (Trans: H. Shokrkon). Tehran, Roshd Publication.
- Mahallati, S. (2011). Human, Society, and Environment, Shahid Beheshti University Press, Tehran.
- Mahdavinejad, M.J., & Molayee, M.M. (2012). Smart technology and its application in architecture and design. Road publication, Housing and Urban Development Research Center, First edition.
- Mahmood Golabchi, S. Y., & Foruzanfar, M. (2012). Prioritizing the role of physical and architectural factors of the work environment in enhancing the performance of staff in project-based organizations. Third International Conference on Construction Industry, Tehran, Research & Development Institute of Construction Industry.
- Moosavi Tarshizi, S.E., & Ebrahimi, M. (2012). A review of the methods of replacing artificial light by sunlight in buildings, Iranian Journal of Energy.
- Peters, J., & Schmidt (2009). Music Therapy (Trans: A. Mohammadi), Tehran, Shabahang Publication.
- Salehifard, M., & Alizadeh, D. (2008). An Investigation on Social and Psychological Dimensions of Urban Green Spaces - with an Urban Management Approach, Journal of Urban Management, 21.
- Taleshi, A., Saleh, M., Imami, A., & Hamidian, A.H. (2012). An Investigation on the Effects of Air and Noise Pollution on the Efficiency of High School Staff in Districts 1, 2, 10 and 11 of Tehran. The First Conference on Air and Noise Pollution Management, Tehran, Sharif University of Technology.