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Effective Environmental Factors on Efficiency of Office Buildings Staff in a Cold Semi-Arid Climate (Case Study: Kermanshah)

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Abstract
Human beings spend most of their time in indoor environments. A large part of people around the world work and live in urban areas. Economic productivity is an important goal of different buildings, especially office buildings. Various factors play a role in economic productivity including reducing energy consumption, managerial programs, and increasing the personnel's efficacy. Increasing attention to efficiency see day by day. Efficiency is a dependent variable, i.e. it depends on the individual, environmental, and work conditions. In the recent years, most offices pay attention to the indoor environmental quality because the cost of hiring staff is higher than the cost of operating and maintaining a building. Thus spending on improving the workplace is the most effective strategy to improve efficiency. This research work seeks to study the effective factors on the efficiency of the employees through field studies. The environmental measurements of temperature, humidity, and carbon dioxide are measured in office buildings (from February 4, 2012, to March 5, 2012). The physical measurements show that as these parameters increase, the efficiency decrease.
Then the employees fill out the questionnaires (N = 328) in the offices of the Kermanshah city. An indoor environment is effective for public health. Having healthy indoor environments is a definite right of the people. The results of this research work show that satisfaction with the thermal condition, thermal comfort, optimal thermal condition, suitable workplace, and high quality of the workplace are the factors influencing efficiency. Providing the desired thermal conditions and increasing the quality of the workplace have the highest and lowest effects on the efficiency of the employees.

Keywords: *Staff efficiency, Office building, Indoor thermal comfort, Office indoor thermal comfort, Kermanshah city.*

1. Introduction

As the world's seventeenth-largest economy and a significant exporter of fossil fuels, the choice of future energy paths and policies that Iran will pursue over the next three decades will have a considerable impact on the global energy security as a whole, especially the eastern region [1].

The energy supply chain of Iran is deeply reliant upon fossil fuels. Further obstacles such as electricity blackouts in the hot season and future energy security require us to address these issues. For this reason, the growing consensus is to dominate a sustainable energy system on the grounds of energy, especially renewable energies, with low emission and pollution [2].

The energy-efficient buildings reduce energy demand. The building envelope parameters, as an interface between the interior of the building and the outdoor environment, can greatly influence energy consumption.

The studies on the different office buildings have shown that crowded workplaces, individual non-satisfaction, and physical environment are the most important factors affecting efficiency [3].

The terms "indoor environment quality" and "indoor air quality" are sometimes wrongly used interchangeably. The term "indoor environment quality" is a broader term that contains indoor air quality as one of its major factors. Five factors are the keys to provide a high-quality indoor environment:

1- indoor air quality and ventilation, 2- thermal comfort, 3- acoustic and noise, 4- lighting, 5- visual perception [4-5].

The indoor environment quality is an important aspect of office buildings. According to the employees working in these buildings, the best environment is the environment that creates no complaint (illness or injury). According to the evaluation instructions, the workplace should be designed and constructed in a way that poses no threat to its habitants. According to the definition of the World Health Organization (WHO) [6], health is the desired physical, mental, and social condition, not only the lack of physical illness [7]. Based on field and laboratory studies, the quality of the indoor environment affects the efficiency of the employees. The illnesses will influence the efficiency and the work time of the people, which will have serious economic outcomes for the countries. The studies on the hundreds of large office buildings throughout the world have shown that their indoor environment quality is average, and many employees are dissatisfied with the workplace and some of them suffer from the illnesses caused by the office building [8].

Without a doubt, an unhealthy indoor environment leads to a reduction in efficiency and an increase of absence caused by illness [7]. The studies have shown that the salary of the office employees is several times the cost of operating a building in a developed country. Therefore, even a minor progress in the efficiency due to improving the quality of the indoor environment can lead to a sustainable economic interest since the studies have shown that the thermal environment has a direct effect on the mental work. Besides, Fisk and Rosafeld have estimated that the thermal improvement of office buildings in the United States has increased the efficiency up to 0.05% to 0.5%, saving 12 to 125 billion dollars per year [9]. Another study has shown that increasing the efficiency up to 0.1% to 2% can have a significant effect on the interests of the company [3]. Another research work in Norway by Skaret has shown that increasing the efficiency caused by improving the quality of the indoor environment could be 10 to 100 times of the costs related to operating and maintaining the building [10]. It is necessary to mention that in England and the United States, 15 million pounds and 38 million dollars are wasted due to the reduction of employees' efficiency and illnesses caused by lack of fresh air [11].

The complexity of the real environment makes the evaluation of the effect of a parameter on individual efficacy difficult since there are different parameters simultaneously that affect a person. Besides, motivation affects the relationship between the efficiency and the environmental conditions. A motivated individual may have a good efficiency in the undesired condition. Environmental dissatisfaction has the highest effect on the efficiency compared to the job satisfaction or job stress [8]. In sum, we can say that the indoor environment of the office has a considerable effect on the efficiency of the employees. For example, the study of sustainable buildings shows that a green design strategy promotes the indoor environment quality in the offices, and leads to the comfort and better performance of the employees [10]. Therefore, this research work seeks to study the efficiency of the personnel in the office buildings of the Kermanshah city by using field studies and questionnaires.

2. Theopetical foundations and research background

2.1. Indoor environmental quality

The study about the direct effect of indoor environmental quality on the performance of the employees dates back to the 1920s when Maslow, like Vernon and Bedford (1926), published their works about the workplace and its requirements [11]. As stated earlier, efficiency has a direct and close relationship with the indoor environment quality but how to measure the efficiency of the employees is a challenge [12].

By reviewing 300 articles in 67 journals, conferences, and books, we identified 8 factors related to the indoor environmental quality that have a higher effect on the efficiency of the employees. These factors are thermal comfort, indoor air quality, noise and acoustic, light, place, feel vision facilities, Biophilia, and office layout [13].

The increasing concern about the efficiency of the employees has led to paying more attention to the indoor environment of the offices. Different standards consider various factors like thermal comfort, indoor air quality, hearing, and the visual environment separately. These environmental factors have a considerable combined effect on the satisfaction and efficiency of the employees. ASHRAE 10P guideline emphasized the interaction of these factors. This study was conducted by Huang *et al*. in 2011, in which the thermal environment, lighting, and acoustic parameters were measured. The satisfaction of the employees was measured by the questionnaires, and the results obtained showed that satisfaction was more related to the changes in the temperature and noise than the changes in lighting [14].

Comparative studies by the US Environment Protection Agency (EPA) reported that indoor air quality was one of the five environmental risk factors affecting the health of the employees as well as their efficiency. Besides, noises prevent concentration, and unsuitable lighting leads to the fatigue of the eye; all of these factors affect the efficiency [14].

Bluyssen and Cox have studied the problems that lead to dissatisfaction with indoor environmental quality through a questionnaire and examining 12 buildings. The results obtained showed that these problems related to the followings factors: temperature control (78%), ventilation control (79%), light control (44%), thermal comfort (61%), and indoor air quality (dry) (44%) [7]. According to the studies on the 99 young adults in the test room, the following factors have a combined effect on the acceptability of the environment and efficiency of people: thermal comfort, indoor air quality, visual and hearing environment [14].

2.2. Temperature

The thermal environment can cause thermal non-comfort that affects the efficiency. In the office simulated environment, this study provided enough evidence that showed that air temperature could have a significant effect on the efficiency; cold weather activates the brain and stimulates the neural system that is responsible for controlling thermal settings. The activation of sympathetic increases brain awareness, i.e. the state that needs accuracy, tolerance, and endurance [15]. Temperature and humidity are the essential factors in analyzing a building's thermal performance [16].

Therefore, the indoor air quality, like thermal comfort, has an important effect on the efficiency of the employees in office buildings. This factor may reduce the efficiency of the employees, and causes financial damages in the long term. Swings can also affect efficiency. This study aims to analyze the changes in the efficiency of the employees based on the temperature changes. The results showed that when the temperature increased, the efficiency reduced up to 0.1%. When the temperature was reduced, the efficiency improved 0% to 5.2% [17].

Temperature is generally used as the thermal environment index. In a research work about the indoor environmental quality and efficiency, Berglund *et al*. have predicted the reduction of efficiency in different temperature ranges [9].

In an experimental research work, Lan *et al*. have concluded that the efficiency is related to the lack of comfort caused by increasing the temperature. The optimal efficiency occurs when few people feel cold, i.e. when PMV is 0 to 0.5 [9]. Lan *et al*. have studied the effect of temperature (17 ^{o}C, 21 ^{o}C, 28 ^{o}C) on the efficiency of 21 volunteers. During the test, the participants did a neural behavior computer test. Their physiological parameters like heartbeat were also measured. The results obtained showed that the lack of thermal comfort caused by high or low temperatures had negative effects on the efficiency of the employees. The lack of comfort caused by high temperatures also affected the health of the employees [12].

2.3. Ventilation

Increasing ventilation increases the efficiency of the employees, restricts pollution sources, promotes air quality by cleaning it, and increases productivity up to 5-10% [8].

This study is about the effect of indoor air quality on the reduction of efficiency of office buildings equipped with air-conditioning. The results showed that the dissatisfaction caused by the indoor air quality was an important factor in determining the reduction in the efficiency. It is clear that the indoor environment plays an effective role in the public health, and having a healthy indoor environment is an integral right of the habitants. The laboratory studies also showed that increasing the ventilation rate could increase the indoor air quality and the satisfaction of the employees in the office buildings [10]. The studies in 14 cities in the US showed that natural ventilation had a considerable effect on the indoor air quality and energy consumption compared to the mechanical ventilation [18].

2.4. Windowing (windows)

Solar radiation can be considered as the most important meteorological parameter that affects all the climatological and biological processes [19].

The office buildings are exposed to large loads like lighting load, equipment, and individuals. The proper design of the windows and their covers can reduce the use of lighting and mechanical system energy by about 10-40%. The window to wall ratio (WWR) influences the use of building energy and comfort of habitants through convection of heat, increasing solar heat (radiation), air leakage or ventilation, and daylight [20]. Studies in the office buildings suggest that WWR is a significant predictor of energy use for cooling, and to a lesser extent lighting and ventilation [21]. The studies also showed that if daylight was the main source of lighting in indoor space, efficiency and health would significantly increase [22].

2.5. Adaptive behaviors

The case study demonstrates that the human adaptive behavior including clothing insulation changes, window adjustments, and air conditioning use has a fine seasonal sensitivity and is individual-dependent. In addition, the window-opening probability was not driven by temperature changes but rather by relative humidity variations. The window opening behavior is also affected by humidity [23].

A long-term field study on six office buildings in Japan measured the adaptation of the respondents to the indoor environment. The findings showed that the buildings with higher options for personal control tracked natural temperatures more closely [24]. Some field studies carried out in Spain [25], China, and Brazil investigated the thermal sensation in mixed-mode office buildings, and the general conclusion was that there were certain adaptive behaviors required to maintain the thermal comfort.

Particular concentrations have been on occupancy (occupant presence) [26], window-opening [27], light-switching [28], blind-adjusting [29], and clothing level adjustments [30], as a function of one, and sometimes multiple, environmental variables (e.g. indoor air temperature and vertical daylight illuminance).

3. Materials and methods

The field study methods include a questionnaire, and environmental measurement of temperature, humidity, and carbon dioxide has been used to study the effective factors on the efficiency of the employees in the Kermanshah city.

In order to more accurately assess the factors affecting the efficiency of the people in office buildings, while filling out the questionnaire, the environmental measurements were performed using the Fluke air-meter (Figure 1).

In order to determine the extent of the impact of these factors and the efficiency of the individuals using the SPSS software, this data was compared with the answers to the questionnaire.

This city is located at 34.23^0N latitude and 47.03^0E longitude in the cold semi-arid part of Iran. This study was conducted on 10 office buildings of this city (from February 4, 2012 to March 5, 2012) by completing 328 questionnaires. The sample size by using the Cochran formula was 328. As this city has not have a dominant building type for office buildings and the only common feature in all of these buildings is closed office space, this feature was considered in the selection of samples.

Figure 1. Fluke 975 air-meter.

Questions have two general forms: subjective questions (measurable variables) like age, gender, work type, etc., and objective questions like air quality, ventilation rate, acoustic, thermal comfort, efficiency, etc.

In the section on the employees' efficiency, the following items were considered:

-Effect of desired thermal condition on the efficiency

-Effect of workplace quality (lighting, ventilation, vision, etc.) on the efficiency.

-Effect of workspace on the efficiency.

-Current performance.

-Efficiency when the optimal environmental conditions are met.

The complications and illnesses caused by workplace, moisture, vision, and landscape were asked from the respondents. The scale of responding to these questions is ASHRAE 7-point thermal sense scale (-3 to +3), and three middle scales, i.e. -1 to +1, indicate satisfaction.

Some of the key questions about how to measure the efficiency of the employees are presented in the following:

-Is providing the desired thermal condition effective in your workplace?

□Yes □Neutral □No

-Is increasing the quality of the workplace (light, vision, ventilation) effective on your efficiency?

□Yes □Neutral □No

-Does the design of your workplace increase your efficiency?

□Yes □Neutral □No

-How will your efficiency in your work environment be if the optimal thermal conditions are provided?

□0-20% □20-50% □50-70% □70-100%

-What is your current efficiency in your workspace?

□0-20% □20-50% □50-70% □70-100%

-During the past year, which of the following symptoms and complication affects you have been related to your work environment (Table 1)?

Table 2, table 3, and table 4 are the mathematical models for the measurements and the obtained results.

As it could be seen, the Pearson correlation coefficient test was used to investigate the significant relationship between the CO_2 variable and the efficiency variable. The results of table 2 indicate that the correlation coefficient is -0.663 and the level of significance is 0.000, which was less than 0.05. As a result, it indicates the existence of a relation between two variables. Also due to the negative domain, it can be said that it has the opposite effect.

As it could be seen, the Pearson correlation coefficient test was used to investigate the significant relationship between the humidity variable and the efficiency variable. The results of table 3 indicate that the correlation coefficient is -0.446 and the level of significance is 0.000, which was less than 0.05. As a result, it indicates the existence of a relation between two variables.

The results of table 4 indicate that the correlation coefficient is -0.263 and the level of significance is 0.000, which was less than 0.05. As a result, it indicates the existence of a relation between two variables.

Table 1. Symptoms and complications that affect staff.

Observed Symptom	Never	Sometimes	Always
Headache		Yes	
Eye dryness		Yes	
Itching or watery eyes		Yes	
Nose congestion	Yes		
Dry lungs	Yes		
Fatigue		Yes	
Skin dryness, itching or sensitivity	Yes		

Table 2. CO_2 correlations.

		CO_2	Performance
co2	Pearson correlation	1	-0.663**
	Sig. (2-tailed)		0.000
	N	253	253
Performance	Pearson correlation	-0.663**	1
	Sig. (2-tailed)	0.000	
	N	253	253

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Humidity correlations.

		Performance	Humidity
Performance	Pearson correlation	1	-0.446
	Sig. (2-tailed)		0.000
	N	253	253
Humidity	Pearson correlation	-0.446	1
	Sig. (2-tailed)	0.000	
	N	253	253

Table 4. Temperature correlations.

		Temperature	Performance
Temperature	Pearson correlation	1	-0.263**
	Sig. (2-tailed)		0.000
	N	253	253
Performance	Pearson correlation	-0.263**	1
	Sig. (2-tailed)	0.000	
	N	253	253

**. Correlation is significant at the 0.01 level (2-tailed).

4. Results and discussion

4.1. Results of questionnaire

Employees are seen in figure 2 and figure 3. The education of the majority of employees was bachelor degree, and more than 60% of them worked more than 30 hours per week.

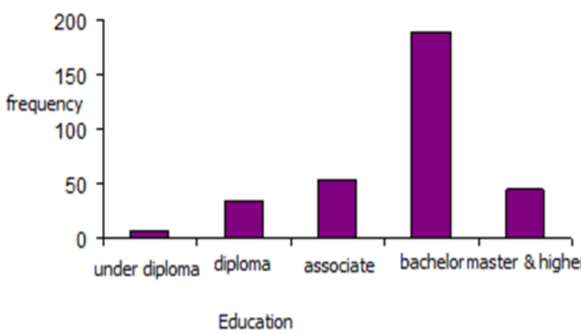

Figure 2. Education of employees

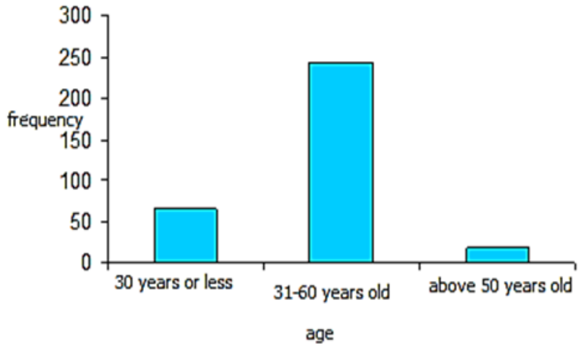

Figure 3. Age range of employees (most interviews were in 31-50 years age range)

4.1.1. Relationship between efficiency and type of workplace

The correlation and relationship between two variables are very important in statistics. There are various factors to measure correlation. In some studies, it is not possible to obtain the interval data or if it is possible, they lack the necessary features. In these cases, the raw number can be replaced by rank. If the data was gathered in rank, the Spearman correlation could be used to analyze it. Data analysis and calculation of the Spearman correlation coefficient showed that there was no significant correlation between the efficiency and type of workplace. As table 5 shows, the correlation coefficient of the two variables is -0.011 and 0.837, which is significant and larger than 0.05. This means that 50.9% of the respondents believe that their efficiency is 50-70%, i.e., the type of workplace does not affect the efficiency.

Table 5. Relationship between efficiency and type of workplace.

Variable	Workplace type	
	Correlation coefficient	-0.011
Efficiency	Significance level	0.837
	Number	328

4.1.2. Relationship between efficiency and satisfaction with thermal condition

According to table 6, there is a positive and significant correlation between efficiency and satisfaction with thermal conditions.

According to table 6, by calculating the Spearman coefficient for efficiency and satisfaction with the thermal condition, since the correlation coefficient between two variables is 0.736 and the significance level is less than 0.000 (less than 0.05), therefore, there is a significant correlation between the two variables.

Table 6. Relationship between efficiency and satisfaction with thermal condition.

Variable	Thermal condition	
	Correlation coefficient	0.736
Efficiency	Significance level	0.000
	Number	328

4.1.3. Relationship between efficiency and thermal comfort

A similar analysis showed that there was a significant correlation between thermal comfort and efficiency (table 7**.** correlation coefficient: 0.133; significance level: 0.016).

Table 7. Relationship between efficiency and thermal comfort.

Variable	Thermal comfort	
	Correlation coefficient	0.133
Efficiency	Significance level	0.016
	Number	328

4.1.4. Relationship between efficiency and providing optimal thermal conditions

Calculating the Spearman correlation coefficient between providing optimal thermal conditions and efficiency of the employees indicates that the correlation coefficient between two variables is 0.273 and the significance level is 0.000 (table 8), and therefore, providing the optimal thermal conditions is effective on the efficiency of the employees.

Table 8. Relationship between efficiency and providing optimal thermal conditions.

Variable	Optimal thermal comfort	
	Correlation coefficient	0.273
Efficiency	Significance level	0.000
	Number	328

4.1.5. Relationship between efficiency and improving quality of workplace

According to table 9, improving the quality of the workplace is effective on the efficiency of the employees: the correlation coefficient is 0.310 and the significance level is 0.000; therefore, improving the quality of the workplace is effective on the efficiency.

Table 9. Relationship between efficiency and providing the quality of workplace.

Variable	Quality of workspace	
	Correlation coefficient	0.310
Efficiency	Significance level	0.000
	Number	328

4.1.6. Relationship between efficiency and workplace design

According to table 10, the workplace has effects on the efficiency because the correlation coefficient is 0.278 and the significance level is 0.000.

Table 10. Relationship between efficiency and workplace design.

Variable	Workspace design	
Efficiency	Correlation coefficient	0.278
	Significance level	0.000
	Number	328

4.1.7. Relationship between independent variables (providing optimal thermal conditions, improving quality of workplace and workplace design) (efficiency variables) with dependent variable (efficiency of employees)

Now the relationship between the independent variables of providing optimal thermal conditions, improving the quality of work environment, and workplace design with the dependent variable of efficiency of employees is studied. A multiple regression model is used for this purpose. Using this regression model, any desired value of the employee efficiency can be predicted using the independent variables of providing optimal thermal conditions, improving the quality of the work environment, and designing the workspace. Since the determining factor of this model is 0.953, we can conclude that the selected regression model explains 95.3% of the changes between the dependent and the independent variables.

By calculating the standard coefficients, it becomes clear which independent variable has the highest effect on the dependent variable. The variable with a higher standard coefficient has the highest effect on the dependent variable (table 11).

Table 11. The comparison of providing optimal thermal conditions, improving workplace quality, and workplace design.

	Ranking	Standard coefficients
Providing optimal thermal conditions	0.445	1
Improving workplace quality	0.397	2
Workplace design	0.418	3

As seen in table 11, providing the optimal thermal conditions and improving the workplace quality have the highest and lowest effects on efficiency, respectively. Therefore, according to this study, the effective factors on the efficiency are satisfaction with the thermal condition, thermal comfort, providing optimal thermal conditions, workplace design, and improving workplace quality but the workplace type does not affect the efficiency of the employees.

4.2. Results of physical measurements

Figure 4. The Humidity-efficiency diagram shows that the relationship between these two variables is inverse, and if the humidity is between 18 to 24, the efficiency is over 80-85%, and with increasing humidity, the efficiency decreases below 75%.

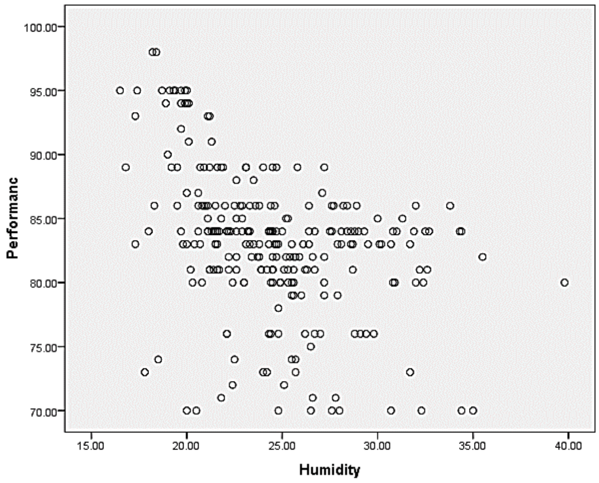

Figure 4. Performance-humidity.

Figure 5**.** The CO_2-efficiency diagram shows that the relationship between these two variables is inverse, and if CO_2 is below 1000, the efficiency is almost above 80%, and with increasing CO_2, the efficiency decreases below 75%.

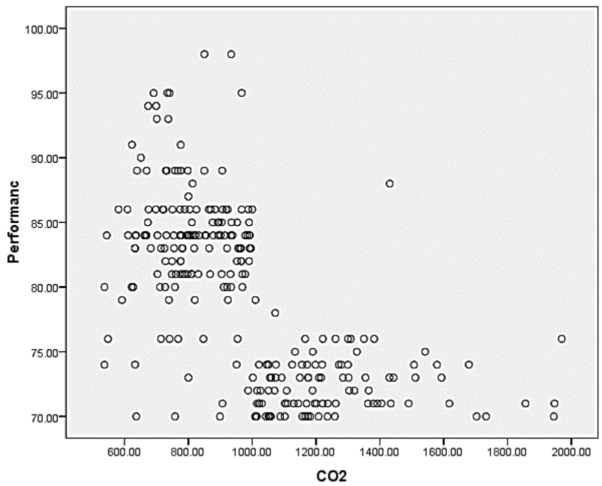

Figure 5. Performance-CO_2.

Figure 6. Temperature-efficiency diagram shows that the relationship between these two variables is inverse, and if the temperature is between 20

degrees to about 26-27 degrees, the efficiency is high, and the efficiency decreases with increasing temperature.

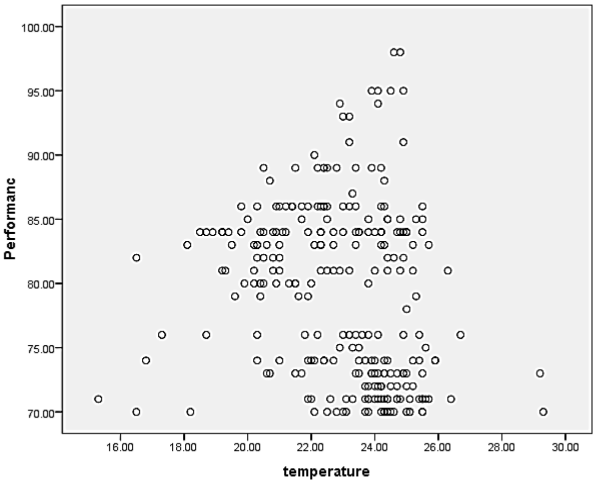

Figure 6. Performance-temperature.

5. Conclusion and results
The studies on hundreds of large office buildings throughout the world have shown that the indoor environmental quality of these buildings is average. Many employees are dissatisfied with their workplace, and many suffer illnesses caused by the buildings. These illnesses affect the efficiency and work time of the employees with significant economic consequences for the countries. In Iran, the lack of necessary standards has led to thermal dissatisfaction and the reduction of productivity of the employees. This research work was conducted about the effective variables on the staff efficiency in offices of the Kermanshah city by using field studies including environmental measurements of temperature, humidity, and carbon dioxide (February 4, 2012 to March 5, 2012) and completing 328 questionnaires (N = 328).

5.1. Questionnaire results
The results of 328 questionnaires (N = 328) indicated that satisfaction with the thermal condition, thermal comfort, providing optimal thermal conditions, workplace design, and improving quality of workplace were 5 effective parameters on the efficiency. The independent variable of providing optimal thermal condition (standard coefficient: 0.445) and independent variable of improving workplace quality (standard coefficient: 0.397) have the highest and lowest effect on the efficiency of the employees, respectively (Figure 7).

Figure 7. Parameters with highest effect on efficiency of employees.

5.2. Physical measurement results
Physical measurements of temperature, humidity, and carbon dioxide, measured using a Fluke air-meter, and placement of these measurements against performance-related responses showed that as these parameters increased, the efficiency decreased (Figure 8). They have a slow and efficient photo ratio.

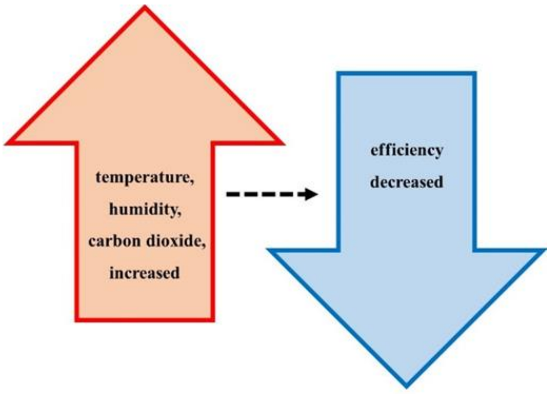

Figure 8. Relation between temperature, humidity, carbon dioxide, and efficiency.

6. References

[1]. Behzadi, A. Forough, N. Fani, M. (2021). More secure Iranian energy system: A markal-based energy security model for Iranian energy demand-side. Iranian Journal of Energy and Environment (Iranica), Vol 12, No. 2, pp. 100-108.

[2]. Poukiaei, S.M. Pourfayaz, F. Shirmohammadia, R. Moosavi, and S. Khalilpoor, N. (2021). Potential, Current Status, and Applications of Renewable Energy in Energy Sector of Iran: A Review. Renewable energy research and applications (RERA), Vol. 2, No. 1, pp. 25-49.

[3]. Clements-Croome, D. and L. Baizhan. (2000). Productivity and indoor environment. in Proceedings of Healthy Buildings.

[4]. Goyal, R., Khare, M., and Kumar, P. (2012). Indoor Air Quality: Current Status, Missing Links and

Future Road Map for India. Journal of Civil and Environmental Engineering, 2:118. https://www.hilarispublisher.com

[5]. Yellamraju, V. (2010). LEED-New Construction Project Management (Green Source). McGraw Hill Professional: New York, NY, USA.

[6]. WHO. (2008). In: Schwab M. (Eds) Encyclopedia of Cancer. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-47648-1_6244.

[7]. Bluyssen, P.M. and C. Cox. (2002). Indoor environment quality and upgrading of European office buildings. Energy and Buildings, 34(2): pp. 155-162.

[8]. Olesen, B.W. (2005). Indoor environment-health-comfort and productivity. Proceedings of Clima.

[9]. Lan, L., P. Wargocki and Z. Lian. (2011). Quantitative measurement of productivity loss due to thermal discomfort. Energy and Buildings, 43(5): pp. 1057-1062.

[10]. Kosonen, R. and F. Tan. (2004). The effect of perceived indoor air quality on productivity loss. Energy and Buildings, 36(10): pp. 981-986.

[11]. Mujan, I. et al. (2019). Influence of indoor environmental quality on human health and productivity-A review. Journal of cleaner production, 217: pp. 646-657.

[12]. Lan, L., Z. Lian, and L. Pan. (2010). The effects of air temperature on office workers' well-being, workload, and productivity-evaluated with subjective ratings. Applied Ergonomics, 42(1): pp. 29-36.

[13]. Al Horr, Y. et al. (2016). Occupant productivity and office indoor environment quality: A review of the literature. Building and Environment, 105: pp. 369-389.

[14]. Huang, L. et al. (2012). A study on the effects of thermal, luminous, and acoustic environments on indoor environmental comfort in offices. Building and Environment, 49: pp. 304-309.

[15]. Tham, K.W. and H.C. Willem. (2010). Room air temperature affects occupants' physiology, perceptions, and mental alertness. Building and Environment, 45(1): pp. 40-44.

[16]. Hermawan, H. and Švajlenka, J. (2022). Building Envelope and the Outdoor Microclimate Variable of Vernacular Houses: Analysis on the Environmental Elements in Tropical Coastal and Mountain Areas of Indonesia. Sustainability, 14,1818.

[17]. Valančius, R. and A. Jurelionis. (2013). Influence of indoor air temperature variation on office work performance. Journal of Environmental Engineering and Landscape Management, 21(1): pp. 19-25.

[18]. Ben-David, T and Waring, M.S. (2016). Impact of natural versus mechanical ventilation on simulated indoor air quality and energy consumption in offices in fourteen U.S. cities, Build. Environ, 104: pp. 320–336.

[19]. Adeniji, N.O., Adeniji, J.O., and Ojeikere, O. (2020). Global Solar Radiation, Sunshine-hour Distribution, and Clearness Index: A Case Study of Sub-Sahara Region in Nigeria. Renewable energy research and applications (RERA), Vol. 1, No. 2, pp. 161-174.

[20]. ASHRAE. (2017). 2017 ASHRAE Handbook - Fundamentals, I-P, ASHRAE, Atlanta, GA.

[21]. Troup, L., Phillips, R., J. Eckelman, M., and Fannona, D. (2019). Effect of window-to-wall ratio on measured energy consumption in US office buildings. Energy and Buildings, 203.

[22]. De Carli, M., V. De Giuli, and R. Zecchin. (2008). Review on visual comfort in office buildings and influence of daylight in productivity. Indoor Air, pp. 17-22.

[23]. Ming, R., Yu, W., Zhao, X., Lin, Y., Li, B., Essah, E., and Yao, R. (2020). Assessing energy saving potentials of office buildings based on adaptive thermal comfort using a tracking-based method, Building, and Environment, 208.

[24]. Goto, T., Mitamura, H., Yoshino, A., Tamura, E. Inomata. (2007). Long-term field survey on thermal adaptation in office buildings in Japan, Building and Environment, 42 (12): pp. 3944-3954.

[25]. Barbadilla-Martín, E., Guadix Martín, J., Salmerón Lissén, J.M., Sánchez Ramos, J., Álvarez Domínguez, S. (2018). Assessment of thermal comfort and energy savings in a field study on adaptive comfort with application for mixed mode offices, Energy and Buildings, 167: pp. 281-289.

[26]. Bourgeois, DJ. (2005). Detailed occupancy prediction, occupancy-sensing control, and advanced behavioural modelling within whole-building energy simulation [PhD Thesis]. Quebec: University of Laval.

[27]. Andersen, R., Fabi, V., Toftum, J., Corgnati, SP., and Olesen, BW. (2013). Window opening behavior modelled from measurements in Danish dwellings. Build Environ, 69: pp.101-13.

[28]. Boyce, P. (1980). Observations of the manual switching of lighting. Light Res Technol, 12: pp.195-205.

[29]. Haldi, F., Robinson, D. (2010). Adaptive actions on shading devices in response to local visual stimuli. J Build Perform Simul, 2010/06/01. 3: pp.135-53.

[30]. Morgan, C., de Dear, R. (2003). Weather, clothing, and thermal adaptation to indoor climate. Clim Res, 24: pp. 267-84.