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Investigating the Effects of Environmental Factors on Office Buildings' Indoor Environment Quality in Iran's Cold Climate
(Case study: Kermanshah)

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ABSTRACT: The inappropriate indoor environmental quality of a building causes different problems such as headache and breathing difficulties which are called the syndrome of building sickness. These diseases reduce the efficiency of people and deteriorate the quality of their life. Studies carried out in hundreds of big office buildings across the world show that the indoor environment qualities of these buildings are about the average and a lot of employees are dissatisfied with their work place. Besides, the studies show that many of employees suffer from diseases associated with buildings. These diseases greatly affect the efficiency and working hours of employees and have grave economic consequences for the countries. If a space, including an office space, enjoys a qualitative interior, the employees` health and as a result their efficiency will improve. Therefore, attending to the indoor environment quality is a must in designing modern office buildings. The present field study was conducted on 10 office building in Kermanshah in winter 1390—a city which is located in a cold climate—and investigated the effect of environmental factors on the office indoor environment quality. The analysis of data by Statistical Package for Social Science Software[1] revealed that the variables of suitable view and landscape, and ventilation have had the greatest effect and the sun light variable has had the smallest effect on the indoor environment quality.

Keywords: *Office buildings, Health, Indoor environmental quality, Enviromental factors.*

INTRODUCTION

Building construction has important role in sustainable development it is not only due to participation in national economy, but it is due to the fact that built environment has great influence on life quality, comfort, security and health (Zabihi, Habib & Mirsaeedie, 2013,49). Since more than 90% of people's life is spent in closed- space environments such as home, work place or public transportation, pretending about indoor environmental quality is a necessity for designing modern buildings. Qualified indoor environment prepares health for its residents (Olesen, 2005, 1-2).

The phrases "indoor environmental quality" and "indoor air quality" are often mistakenly assumed as same. Nevertheless indoor environmental quality is a general concept which includes indoor air quality as one of the principal elements. Most rating systems for green buildings use indoor environmental quality as an evaluation criterion. LEED[2] as one of the most popular rating systems considers the criteria below for evaluation of indoor environmental quality:

Indoor air quality;
Thermal comfort;
Acoustics and noise;
Lighting levels.
Visualperception(American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, 2010 a,181-182).

Likewise LEED in other rating systems for green buildings indoor environmental quality is one of principal criteria such as CASEBEE[3], BCA[4], GRIHA[5], NABERS[6], Three Star, and Green Star (Attmann, 2009) (Table1).

Studies around the relationship between indoor/ outdoor air quality suggest that indoor air quality is a combined function of Concentration of contaminants in the outside air, building permeability, meteorological condition, ventilation system design and indoor pollution makers (Wade III, Cote, & Yocom, 1975, 933).

Since outdoor air should cross building envelope, the density of outdoor air polluters is less in indoor environment. Nevertheless the amount building envelope protection against outdoor air

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Table1: Criteria to evaluate and rate green buildings in different rating systems (Attmann,2009).

Rating systems	Criteria
LEED	Sustainable site development, water efficiency, energy and atmosphere, material and resources, indoor environmental quality ;and innovation and design process
Green Star	Management, indoor environment, energy, transportation, water, materials, land use and ecology, emission; and innovation
CASBEE	Energy, site, indoor environmental quality, resource, material; and water conservation
NABERS	Energy, water, waste management, indoor environment
GRIHA	Site planning, building envelope design, building system design, HVAC[7],lighting and electrical, integration of renewable energy sources to generate energy onsite, water and waste management, selection of ecologically sustainable material ;and indoor environmental quality
BCA	Energy efficiency, water efficiency ,site/project development and management, indoor environmental quality and environmental protection; and innovation
Three Star	Land saving and outdoor environment ,energy saving, water saving, material saving, indoor environmental quality; and operation and management.

polluters is pretty dependent on the way in which the building is ventilated. That is to say the time an individual has passed indoor, exposures him to the indoor pollutions (Freijer & Bloemen, 2000, 292).

New materials and technologies which nowadays are available in building field, mostly effect on indoor environmental pollution. For instance finishes (walls, floors and roofs) have a significant role for the quality of the indoor air (Šeduikyte&, Bliūdžius, 2005,137). Pollution of heating and cooling system components, air conditioning, high temperature, low ventilation rates, humidity and mold are counted as other polluters. Most indoor air pollution resources make symptoms such as influenza, cold or allergy. Complains like respiratory irritation, fatigue, eye and skin irritation and headache have been frequently by offices staff. All these are building- related diseases (building sickness syndrome)(Mendell et al., 2008). Persons who suffer from this syndrome state that symptoms are unfold when they spend time at indoor environment specially office and they are improved when they leave (Apte, Fisk & Daisey, 2000,133). Studies accomplished by Wargocki et al. (2000) suggest that decreasing indoor air pollution is an effective solution for improving air quality and decreasing building sickness syndrome.

In fact inappropriate indoor air quality causes several diseases and therefore decrement of efficiency and their life quality. Studies implemented through hundreds large office buildings around the world represent that indoor environmental quality of these buildings is about moderate, several staff are unpleasant and several are suffering building sicknesses. These sicknesses effect on staff performance and work time, and therefore follow significant economic consequences (Olesen, 2005, 1-2).

Nowadays improving indoor environmental quality and its effective role on staff's health and efficacy is considered more than ever. Hence the study in hand addresses surveying and ranking the effective elements on indoor environmental quality of cold climate office buildings by using field study and questionnaires.

MATERIALS AND METHOD

In the study in hand field method of conducting questionnaire has been applied and Kermanshah city has been chosen as case study. Since this city has not got a dominant type for office buildings and the only common aspect of office buildings through the city is closed office environment, this character is been considered through choosing the samples (Fig.1).

In order to arrange the questionnaires the questionnaires available at ASHRAE Standard 55(2010) standard is been applied, however according to the research type and questions coverage some changes have been made as to adding some related questions. The questions are divided to two principal groups; subjective questions about measurable variables such as age, gender, work type and objective questions containing variables such as indoor air quality, ventilation, acoustics, thermal comfort and performance. Questions about indoor environmental quality are adjusted according to light, sunlight variation, visual comfort, view and ventilation. Voting scale to these questions is based on thermal sensation 7point scale of ASHRAE standard 55 (-3 to +3) in which the three middle scales (-1 to +1) represent satisfaction (Table 2). Some instances of mentioned questions

Fig.1: An example of the building studied

are cited below:

How do you evaluate you work place according to the amount of light?

-Very satisfied -satisfied -a little satisfied -neutral -a little unsatisfied -unsatisfied -very unsatisfied.

If there is sunlight in your work place, how satisfied are you about it?

Very satisfied -satisfied -a little satisfied -neutral -a little unsatisfied -unsatisfied -very unsatisfied.

How satisfied are you about the noises around your work place?

Very satisfied -satisfied -a little satisfied -neutral -a little unsatisfied -unsatisfied -very unsatisfied.

How do you evaluate your workplace according to air quality and air conditioning?

Very satisfied -satisfied -a little satisfied -neutral -a little unsatisfied -unsatisfied -very unsatisfied.

RESULTS AND DISCUSSION

In order to determine the effect of environmental elements on indoor environmental quality of Kermanshah offices, 328 questionnaires were led through 10 office buildings. The summary of these offices staff is available at Table 3. Kermanshah city is located at latitude 34.23° north and longitude 47.03° east in cold climate of Iran. According to Olgyay's bioclimatic chart this region have got cold winters and dry and hot summers. The average of minimum and maximum temperatures and the large cities in this region are shown in the Table 4.

In order to analysis questionnaires data and achieving the result, SPSS software has been used.

Surveying Factors Effective on Indoor Enviromental Quality

Toward finding the relationship between independent variables such as thermal comfort and dependent variables of indoor environmental quality, a multiple regression model has been applied. In Table 5 the correlation coefficient of data is been calculated and the significance level is mentioned between

Table 2: ASHRAE 55Thermal Sensation Scale(Sourse: American Society of Heating, Refrigerating and Air-Conditioning Engineers,Inc, 2010 b)

Very cold	Cold	Slightycold	Neutral	Slightly warm	Warm	Very warm
-3	-2	-1	0	+1	+2	+3

Table 3: Summary of occupants time spent at work, type of work, age, gender and clothing insulation.

Occupants data		
Time spent at workspace(hours)	10 or less	26.2%
	11-30	10.4%
	More than 30	63.4%
Type of work	Managerial	12.8%
	Professional	52.5%
	Clerical/Secretarial	35.7%
Age	30 or under	20.1%
	31-50	74.1%
	Over 50	5.8%
Gender	Male	70.7%
	Female	29.3%
Clothing insulation (clo)(Heidarinejad, 2009, 19)	Male	0.77
	Female (Islamic wear is considered for women)	1.17

Table4: The average of minimum and maximum temperature and the large cities of the cold climate region of Iran (Source: Kasmaei,2009, 99).

Cities	Average of min temperature in winter(C)º	Average of max Temperature in summer(C)º	Climates in winter and summer
Tehran Shiraz Mashhad Kermanshah	(-5) -0	35-40	Cold winter- warm and dry summer

brackets. As it is seen there are correlation between all variables except for sunlight and humidity, the significance level of which is higher than 0.05.

In order to choose the most appropriate model the stepwise regression method is applied. As there are 8 variables there will be 8 models. The analysis of models is available at Table 6.

Model 1- Dependent variable: indoor environmental quality independent variable: visual comfort.

Model 2- Dependent variable: indoor environmental quality independent variable: visual comfort, air Ventilation and Suitable air quality.

Model 3- Dependent variable: indoor environmental quality independent variable: visual comfort, air Ventilation and Suitable air quality, noise.

Model 4- Dependent variable: indoor environmental quality independent variable: visual comfort, air Ventilation and Suitable air quality, noise and light rate.

Model 5- Dependent variable: indoor environmental quality independent variable: visual comfort, Ventilation and Suitable air quality, noise and light rate, suitable view.

Model 6- Dependent variable: indoor environmental quality independent variable: visual comfort, Ventilation and Suitable air quality, noise and light rate, suitable view, sunlight.

Model 7- Dependent variable: indoor environmental quality independent variable: visual comfort, Ventilation and Suitable air quality, noise and light rate, suitable view, sunlight, thermal comfort.

Model 8- Dependent variable: indoor environmental quality independent variable: visual comfort, Ventilation and Suitable air quality, noise and light rate, suitable view, sunlight, thermal comfort, humidity rate.

As it is observed coefficient of variations in models 7 and 8 are so closed. Hence model 8 which owns less independent variable is more appropriate.

For model 7 as to the significance level is 0.00 and less than 0.05, null is rejected in analysis and variance table, in other words the linear regression model of indoor environmental quality is significant to visual comfort, Ventilation and Suitable air quality, noise, light rate, Suitable view, sunlight and thermal comfort. If variables are represented as such: thermal comfort asX1, light rate as X2, sunlight as X3, noise as X4, Ventilation and Suitable air quality as X5, Suitable viewas X6, and dependent variable of indoor environmental quality as Y; according to the regression coefficients, the linear regression model fitted to the data would be as below:

Using this regression model, any considered amount of indoor environmental quality could be predicted using variables thermal comfort, visual comfort, Ventilation and Suitable air quality, noise, light rate, suitable view and sunlight.

Since the determination coefficient for this model is 0.990, it is to be concluded that the chosen regression model will justify 99% of whole variations toward dependent and independent variables.

In order to survey the amount of independent variables effect on dependent variables, standardized coefficients of independent variables is calculated (Table 7). Each variable which has got a higher standard coefficient, affects more on dependent variable. The amount of standard coefficients suggests the amount of effect of each dependent variable. Therefore , each variable which got higher standard coefficient affects more and each getting lower standard coefficient affects independent variable less.

As it is observed in Table 7, according to the defined regression model, variables of suitable view and ventilation and suitable air quality have got the highest effect and the variable of sunlight

Table 5.Calculation of correlation coefficient among variables

Humidity rate	Visual comfort	Suitable view	Ventilation and Suitable air quality	Noise	Sunlight	Light rate	Thermal comfort	
0.214 (0.000)	0.397 (0.000)	0.318 (0.000)	0.564 (0.000)	0.371 (0.000)	0.148 (0.000)	0.395 (0.000)	1	Thermal comfort
0.234 (0.000)	0.563 (0.000)	0.427 (0.000)	0.469 (0.000)	0.241 (0.000)	0.318 (0.000)	1		Light rate
0.068 (0.220)	0.258 (0.000)	0.149 (0.007)	0.212 (0.000)	0.283 (0.000)	1			Sunlight
0.179 (0.001)	0.329 (0.000)	0.270 (0.000)	0.418 (0.000)	1				Noise
0.245 (0.000)	0.514 (0.000)	0.400 (0.000)	1					Ventilation and Suitable air quality
0.192 (0.000)	0.557 (0.000)	1						Suitable view
0.241 (0.000)	1							Visual comfort
1								Humidity rate

Table6: Analysis and variance tables.

R^2	significance level	statisticsF	Mean of squares	Degree of freedom	Sum of squares	Source of changes	Regression model
0.647	0.000	598.309	224.981	1	224.981	regression	1
			0.376	326	122.585	error	
				327	347.566	sum	
0.812	0.000	702.267	141.127	2	282.254	regression	2
			0.201	325	65.312	error	
				327	347.566	sum	
0.869	0.000	719.506	100.735	3	302.204	regression	3
			0.140	324	45.362	error	
				327	347.566	sum	
0.911	0.000	826.036	79.157	4	316.615	regression	4
			0.096	323	30.951	error	
				327	347.566	sum	
0.943	0.000	1063.670	65.545	5	327.724	regression	5
			0.062	322	19.842	error	
				327	347.566	sum	
0.967	0.000	1578.046	560.28	6	336.169	regression	6
			0.036	321	11.397	error	
				327	347.566	sum	
0.990	0.000	4376.342	49.139	7	343.973	regression	7
			0.011	320	3.593	error	
				327	347.566	sum	
0.999	0.000	2006789.632	43.445	8	347.559	regression	8
			0.0001	319	0.007	error	
				327	347.566	sum	

Table7: Calculation of standard coefficient to investigate the effect of independent variables on dependent variable

ranking	standard coefficient	independent variables
6	0.185	thermal comfort
5	0.196	light rate
7	0.172	sun light
3	0.216	noise
2	0.222	ventilation and suitable air quality
1	0.228	suitable view
4	0.215	visual comfort

has got the least effect on indoor environmental quality. Thermal comfort is ranked 6th. As mentioned before indoor environmental bad quality can cause some consequences for residents. According to the questionnaires' data there is correlation between observed consequences and indoor environmental quality. To do this, Spearman correlation coefficient is been calculated through all observed consequences and indoor environmental quality. As it is remarked at table8, significance level for all diseases is less than 0.05 except for runny nose. Therefore all diseases are dependent to indoor environmental quality and runny nose is not related to it.

CONCLUSION

Different rating systems for green buildings which consider indoor environmental quality as an effective element on health and performance of staffs, represent various elements as effective ones on indoor environmental quality. Although surveying separate influence of effective elements on indoor

Table 8: Relationship of observed symptoms with the quality of indoor

Quality of indoor		Observed symptom
Correlation coefficient	Significance level	
0.000	-0.213	headache
0.000	-0.219	Eye dryness
0.000	-0.245	Itchy or watery eyes
0.004	-0.157	adenoid
0.098	-0.092	Runny nose
0.010	-0.141	Lung dryness
0.000	-0.321	fatigue

environmental quality is simple using mathematical methods, but through surveying indoor environmental quality it is the relation between these elements which is important.

In the study in hand to determine the effect of environmental elements on indoor environmental quality of Kermanshah offices, 328 questionnaires were led through 10 office buildings. . In order to analysis questionnaires data and achieving the result, SPSS software has been used. Toward finding the relationship between independent variables such as thermal comfort and dependent variables of indoor environmental quality, a multiple regression model has been applied According to defined regression model, variables of suitable view and ventilation and suitable air quality have got the highest effect and the variable sunlight has the least effect on indoor environmental quality. Also by calculating Spearman correlation coefficient through all consequences, it was observed that all interviewees count all consequences they are exposed to with the indoor environmental quality except runny nose. Thus optimizing the quality of indoor environment will decrease staffs complaint and increase their productivity.

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ENDNOTE

1.SPSS Software.
2.Leadership in energy and environmental design.
3.Comprehensive Assessment System for Building Environmental Efficiency.
4.Building and Construction Authority.
5.Greeb Rating for Integrated Habitat Assessment.
6.National Australian Built Environment Rating System.
7.Heating Ventilation and Air Conditioning.

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