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Indoor Environmental Quality Effect Analysis in Green and Non-green Office Building to Staff's Performance and Satisfaction in Surabaya

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Abstract. The energy efficiency in an office building can decrease the company's operational cost. Even so, the operational cost for staff is still larger than the cost for energy. It is important to reassure that the impact given by the building's indoor environmental quality (IEQ) is positive to staff. This research focusses on two office building in Surabaya, one of them is designed using the green principles and calculations, and the other is not. The building's IEQ aspects being inspected includes indoor air quality, thermal, lighting, acoustics and layout. A questionnaire survey was held to obtain the reaction from the full time staff regarding the building's IEQ performance, their satisfaction to it and their self-assessed performance. There are IEQ aspects that affects staff's performance and satisfaction significantly. The IEQ mean score differs significantly in green and non-green building, but the mean difference in satisfaction and performance were found not significant.

Keywords: indoor environmental quality, staff, performance, satisfaction, indoor air quality, thermal, lighting, acoustics, layout

1. Introduction

Staff are exposed to building's indoor environmental quality (IEQ) for about eight hours at working days. The relation between office condition and staff's health and wellbeing has been clearly stated on the previous research, where IEQ condition, such as indoor air quality (IAQ) can affect staff's respiratory health, such as the decline of absentism with the cause of ashtma or allergy [1]. Even so, the relation between existing IEQ and performance are still found abstract [2]. Some of the researcher adds variable to relate IEQ and performance, such as comfort. Most of the

findings stated that comfort is subjective to each person, so that measuring comfort using one standard may not be applicable to everyone. Thus, the conclusion found, that the relation between IEQ, comfort and performance are still unclear [2],[3].

Previous research's conclusion regarding the relation between building's IEQ and staff's performance differs one another too. Some of them claim that the indoor environmental quality affects the performance of staff, even more than supervision from management [4],[5]. Other research found that the relation between working environment and staff's performance has not been clearly modeled [3]. Older reference research even claim, that staff's comfort to their working environment has no significant impact to their performance and motivation, not even the cleanliness of the working area [6].

Moreover, the green movement has made energy consumption and building impact, not only to its surroundings, but also the user inside the building, as an important consideration, from the early design phase. This movement evokes general mindset, that green buildings must have a better working environment, as they were designed carefully and efficiently. Better working environment means better satisfaction, and in the end, better performance. This belief has not been proved and still considered as an assumption in researches that focusses on green and conventional building comparation, as they found that the difference between green and conventional building were not significant, or the green building may beat conventional building in a few IEQ aspect, but loss to conventional building in other aspect [7],[8],[9]. On the other hand, there are some findings that supports the mindset, that green building is better at affecting its staff's performance [4],[10],[11].

Eventhough the previous research has various conclusion, there some aspects from IEQ that are highlighted in most of the research, and often mentioned to be significant in the result. Similar recent research in Hong Kong regarding the IEQ and productivity use these five aspects in IEQ [12]. Those five aspects, namely indoor air quality (IAQ), thermal, lighting, acoustic and layout, are chosen for the focus of IEQ inspection in this research.

Satisfaction survey is a common way to asses the successfullness of a product [13]. Building, as a real space where some activity take place, is a product of a design as well. This research attempts to use satisfaction as a variable to connect IEQ and performance, as it is easier to be measured and more objective than comfort. Similar recent research about the relation between satisfaction and productivity stated that the user in green building shows greater satisfaction than the user in conventional building [21].

The contradiction in the previous researches serves as a gap to this research, to observe the impact of the IEQ in green and non-green working area to staff's satisfaction and performance in Surabaya, where this growing city has different climate, population and working culture to the sub tropic areas, where the previous researches mostly took place.

1.1. Research purpose

Salary and fee for staff take 90% of a company's operational cost [3]. Knowing the contribution of staff's fees to operational cost, it is important to reassure that the working environment do have relation to staff's performance at office building in Surabaya. When the relation proved to be exist, companies will have a firm data as a consideration when making decisions, such as investing in technology to maximize the potential of the IEQ, so that the staff's performance may be increase, and in return, may give the greater income to the company.

This research devides IEQ to five main aspects to find out, how much each aspect affects staff's performance and satisfaction; and moreover, which of the aspects affects performance and satisfaction the most. The result of this research may also review the reception of the office building, from the staff's point of view.

1.2. Hypothesis

The hypothesis of this research are :

Hypothesis 1 : There is (or are) IEQ aspect(s) that affects staff's performance

Hypothesis 2 : There is (or are) IEQ aspect(s) that affects staff's satisfaction

Hypothesis 3 : There are IEQ, staff's performance and satisfaction difference in green and non-green building

2. Research Methods

The research focuses on two office buildings, both located in Surabaya. The first building (will be called as building A in this research) is an office for a company that provides medical check up service. Building A has 9 stories. The longest sides of the building are oriented to South East and North West. The first to fourth story of the building serve as lobby and medical check up laboratory. The rest of the building is an office operated from 08.00 to 17.00 on Monday to Friday, or Saturday, when needed. This building was design and calculated using the green principle, using green materials, such as low-e glass, aluminium sheet and eco labelled paint. Therefore, building A represents green building in this paper.

The other building (will be called as building B in this research) is a 3 stories building, used as an office for construction company. This South facing building has been operated as an office since 2013. The staff working hour is from 08.00 to 17.00 on Monday to Friday, and 08.00 to 14.00 on Saturday. This building was renovated from a luxurious residential building, therefore, building B represents non green building in this paper.

In this research, both building's IEQ performance will be assesed. The compared buildings should experience the same condition, to make sure that the comparation is valid and in order to produce an accurate conclusion. The distance between the two buildings is approximately 6,3 kilometers, when measured using google earth. Therefore, the two buildings share quite the same global horizontal irradiaton through the whole year (1939 kwh/m^2 per year for Building A, and 1931 kwh/m2 per year for Building B)[14].

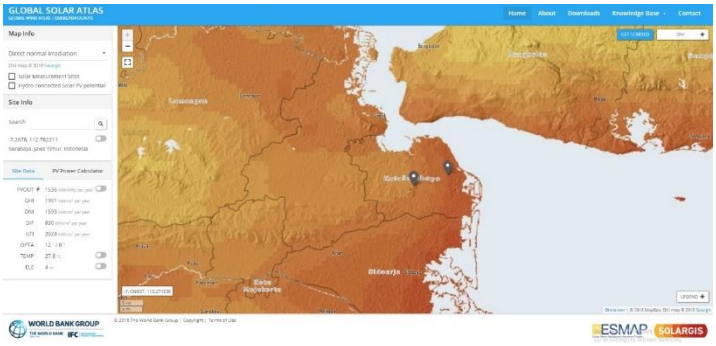

Figure 1. The Global horizontal irradiation score in building A and building B[14].

Field measurements were done at April to May 2018. The difference in time measurement may cause the difference in sun position. Different sun position may cause different intensity of sun radiation. Nevertheless, sun intensity radiation has bigger impact to energy use. The condition of the sky has more significant impact to IEQ, especially in lighting aspect [15].

2.1. Field measurement

Due to time limitation of the research, not all the working area in both building can be observed. Two room from each building were chosen to represent the building. The main criteria for room selection is the type of work done in the room, and the occupancy rate of the room, as different density in occupancy of the room affects occupant's response to their surroundings [13].

The result of the assessment will be compared to the general comfort standards, such as pschycrometric chart, rules and Indonesian national standards per aspect assesed. The result will also be compared to staff's satisfaction in each IEQ aspect, to review the building design acceptance, from the staff's side, using questionnaire. The standards for measurement and comfort can be found in Table 1.

Table 1. Inspected IEQ aspects

IEQ		Standards	Measurement method
Indoor air quality	Ventilation rate	0,3 litre/second per room area + 2,5 litre/second per person [16]	Observation and calculation [16]
	Air change rate	6 – 8 times per hour [17]	
	Cigarrete control	no smoking signages, no smoking area, provide smoking room [16]	Observation
	Operable window area	4% from room area [16]	Observation and calculation [16]
Thermal	Operative temperature	18 – 26^{0}C [18]	HOBO data logger placed in the observed room at 150 cm from floor, to record data hourly for 3 days [19]
	Relative humidity	40% - 60% [18]	
	Cloth insulation	Depends on type of outfit worn [20]	Staff observation
	Metabolic rate	Depends on the activity done [20]	Staff observation
Lighting	Indoor illumination	300 – 500 lux [22]	Observation, measurement and calculation refers to Indonesian Standard of lighting measurement manual [22]
	Outdoor illumination	Depends on the sky condition [22]	
	Daylight factor	75% of the observed area should have DF score in the range of 2-5% [22]	
	Uniformity ratio	0,7 for working area [22]	
Acoustics	Loudness equivalent	30 – 50 dBA for office working area [23]	Observation, measurement and calculation refers to the law of Indonesian minister for the environment [23]
Layout	Work area configuration	Division between working – public and service area, to maintain the working climate [24]	Observation of room condition, documentation and calculation of room density
	Workstation density	4,5m^2 per person for staff that spends 60% working hour at the workstation [24]	
	Furniture - Ergonomic	Using ergonimic furniture for the wellbeing of the staff [25]	

2.2. Questionnaire survey

A questionnaire survey was held to obtain the staff's response. Print out questionnaires were given to the staff by the time the field measurement was held. This method was preffered to online questionnaire, in order to make sure that the respondents were really staff that are exposed to building IEQ most of their working hour, to get more accurate response.

The questionnaire consist of three main part. The first part is to picture the respondent's profile, such as gender, age and smoking habit. The question on this part also includes staff's main activity at work and type of desk.

The second part is to record respondent's response to IEQ aspects inspected. Each aspect has four statement, to which, the respondent must show their degree of agreement. The third statement in each aspect is a statement to measure satisfaction. The third part of the questionnaire is a self assessed performance, consist of twelve statements regarding staff's performance. Self assessed performance were frequently used in the previous research [2],[9],[11],[12]. In this part, the respondents must, again, show their degree of agreement to the statement. The second and third part of the questionnaire are using Lickert Scale. Number 1 on the Lickert Scale represents strongly disagree response, while number 5 represents strongly agree.

The data from the questionnaire are then processed using SPSS 19 software. The data's validity and reability are being checked. Data are reliable when the Cronbach's Alpha score is between 0.5 to 0.7 or more than 0.7. In the descriptive table, when Cronbach's Alpha if item is deleted in each indicator is not larger than the existing Cronbach's Alpha, then the data are valid.

After their validity and reability are confirmed, the correlation between the three variables are analyzed, using Pearson correlation. Regression analysis will model connection between IEQ aspects to satisfaction, and IEQ aspects to performance. Finally, the difference between green and non green building will be assesed using the t-test, comparing the mean of the three variables in green and non green building.

3. Results and Discussions

3.1. Field measurement

In both observed building, most of the working area is a small to medium open office, where 4 to 24 staff share the same working area. Even differ in dimension, the room has quite the same room density. All of the observed room also have window in one side of their wall only as the source of natural light. The activity in the observed room is typical office activity with the range of metabolic rate from 1 to 1,7 met, and all the staff working in both building wear uniform, with the range of garment insulation from 0,57 to 0.67 clo. The detailed description of the room can be found in Table 2.

Table 2. Observed room description

		Building A	**Building B**
Location		Diponegoro Street	Raya Kertajaya Indah Street
Area	1	60 m^2	45,019 m^2
	2	18,24 m^2	51,28 m^2
Picture	1		
	2		
Finishing		• Outdoor Wall : Aluminium sheet + insulation material + kalsiboard • Indoor Partition : Kalsiboard + glass • Openings : Double layered low E glass + argon insulation + aluminium frame • Floor : Light toned granite tile	• Outdoor Wall : dark – light toned textured paint finish brick • Indoor Partition : light toned paint finish brick • Openings : Clear glas + wooden frame • Floor : Grey - green toned marble
User	1	10 person in a 14 full capacity room	7 staff in 11 full capacity room
	2	3 person in a 4 full capacity room	8 person in a 15 full capacity room
Actual Room Density	1	*Medium open office*; 6 m^2 per person	*Medium open office*; 6,43 m2 per person
	2	*Small open office* ; 6,08 m^2 per person	*Medium open office*; 6,4 m^2 per person
Window Orientation	1	South East	North
	2	South West	North
Measurement		April 2018	May 2018
Sky Condition		Clear to partly cloudy sky	Clear to partly cloudy sky
Acoustics		8 measurement point for 2 rooms	6 measurement point for 2 rooms

Indoor air quality

The findings in IAQ aspect in both building can be summarized in Table 2.

Table 2. IAQ aspect comparison

	Building A		Building B	
Room	1	2	1	2
System	VRV		Split	
Air change / hour	7,14	11,74	6,89	3,02
Ventilation rate [m^3/s]	0,043	0,012972	0,033506	0,035384
Ventilation rate from field calculation [m^3/s]	0,3334	0,1667	0,2933	0,1466
Fresh air intake	Exhaust fan + installation pipe connected to each indoor unit		Operable openings	
Cigarrete control	v		v	
Operable window area	2,177m^2 for 60m^2 room	2,177m^2 for 18,6m^2 room	4,42m^2 for 45m^2 room	non-operable

The air change rate standard for an office room is 6 to 8 times per hour. Therefore, both of the observed room in building A has meet the criteria. The second observed room in building B has not meet the standard. All the observed room has meet the minimum ventilation rate standard, except for this room too. Moreover, room A-1 and B-2 has not meet the minimum area of operable window area to accomodate natural ventilation.

Thermal

Using the CBE thermal comfort tool [26], the thermal performance in both building were assessed. We input the operative temperature and relative humidity, that were recorded per hour within the office operational hour in each observed room. We input also the air velocity, garmet insulation and metabolic rate from office activity. The tool will plot the thermal condition in each observed room.

The result is that, the second observed room in green building has achieved the comfort zone for the user (marked with v sign in the Table 3), between 10.00 to 17.00. Other observed room has not meet this criteria. The CBE thermal comfort tool classify them as ‘slightly warm’ room (marked with x sign in Table 3).

Table 3. Thermal condition at each observed room

Time	**Room**	**OT (^{0}C)**	**RH (%)**	**AV (m/s)**	**GI (clo)**	**MR (met)**		**Room**	**OT (^{0}C)**	**RH (%)**	**AV (m/s)**	**GI (clo)**	**MR (met)**	
08.00	A1	28,69	54,08	0,1	0,54	1,2	x	A2	29,79	53,28	0,1	0,54	1,2	x
	B1	29,74	52,60	0,1	0,54	1,2	x	B2	29,61	56,46	0,1	0,54	1,2	x
09.00	A1	27,94	50,31	0,1	0,54	1,2	x	A2	26,32	47,72	0,1	0,54	1,2	x
	B1	28,71	48,15	0,1	0,54	1,2	x	B2	28,79	52,31	0,1	0,54	1,2	x
10.00	A1	27,21	45,95	0,1	0,54	1,2	x	A2	25,98	49,41	0,1	0,54	1,2	v
	B1	28,44	46,91	0,1	0,54	1,2	x	B2	28,69	50,85	0,1	0,54	1,2	x
11.00	A1	26,62	45,33	0,1	0,54	1,2	x	A2	25,38	49,81	0,1	0,54	1,2	v
	B1	28,29	46,70	0,1	0,54	1,2	x	B2	28,29	46,70	0,1	0,54	1,2	x
12.00	A1	27,21	51,33	0,1	0,54	1,2	x	A2	25,18	50,13	0,1	0,54	1,2	v
	B1	28,22	46,85	0,1	0,54	1,2	x	B2	28,89	50,62	0,1	0,54	1,2	x

Table 3. Thermal condition at each observed room (contd.)

Time	Room	OT (^{0}c)	RH (%)	AV (m/s)	GI (clo)	MR (met)		Room	OT (^{0}c)	RH (%)	AV (m/s)	GI (clo)	MR (met)	
13.00	A1	27,01	48,51	0,1	0,54	1,2	x	A2	25,62	47,18	0,1	0,54	1,2	v
	B1	28,02	46,77	0,1	0,54	1,2	x	B2	28,81	50,55	0,1	0,54	1,2	x
14.00	A1	26,96	49,41	0,1	0,54	1,2	x	A2	25,08	49,58	0,1	0,54	1,2	v
	B1	28,04	47,81	0,1	0,54	1,2	x	B2	28,91	50,56	0,1	0,54	1,2	x
15.00	A1	27,01	53,91	0,1	0,54	1,2	x	A2	25,40	51,82	0,1	0,54	1,2	v
	B1	28,19	47,56	0,1	0,54	1,2	x	B2	28,96	50,60	0,1	0,54	1,2	x
16.00	A1	26,84	51,06	0,1	0,54	1,2	x	A2	24,91	53,05	0,1	0,54	1,2	v
	B1	28,19	46,66	0,1	0,54	1,2	x	B2	28,79	50,03	0,1	0,54	1,2	x
17.00	A1	26,79	51,56	0,1	0,54	1,2	x	A2	25,13	55,65	0,1	0,54	1,2	v
	B1	27,92	45,68	0,1	0,54	1,2	x	B2	28,19	49,63	0,1	0,54	1,2	x

Lighting

The lighting measurement were done three times during office operational hour, at 9 AM, 12 PM and 3 PM. These measurement may model the impact of sun movement in working area with different opening orientation.

The observed room's lighting performance in building A has meet the illumination standard for office room. There is indication that the staff in room A-2 are exposed to glare, as the illumination score at some measurement points triple the comfort standard, thus cause great contrast. Unfortunately, due to time limitation, this issue can not be explored further in this research.

Only around 30% of the score in room B-1 has meet the needed illumination. In room B-2, the percentage even decreased to maximum 13,3%. Therefore, most of the measurement point in those room has not meet the standard. The uniformity ratio in both building are also has not meet the comfort standard. The scores in building A are higher and closer to the standards than in the building B.

Table 4. Lighting comparison

Lighting Indicator	Building	Room 1			Room 2		
		09.00	12.00	15.00	09.00	12.00	15.00
Illumination (lux)	A	82,8%	91,4%	22,8%	100%	100%	64,2%
	B	37,2%	34,8%	20%	13,3%	8,8%	4,4%
Daylight Factor (%)	A	60%	71,4%	48,5%	14,2%	71,4%	7,1%
	B	13,9%	11,6%	4,6%	13,3%	0%	2,2%
Uniformity Ratio	A	0,49	0,51	0,65	0,52	0,49	0,53
	B	0,19	0,17	0,16	0,41	0,39	0,57

Noise and Acoustic

Building A is located in the corner of a junction, as the building B, by the roundabout. Both building experience noise from the street, especially in the morning and evening. The result of the measurement, summarized in Table 5, shows that both building has not meet the required standard for acoustic comfort. The Leq score ranged betweed 61,63 to 71,43 dBA, and still exceed the maximum tolerance for office working area in operational hours.

Table 5. Acoustic comparison

Building - Room	Empty			Operational		
	Min	Max	Leq	Min	Max	Leq
A-1	53,3	61,2	58,89	57,7	82,3	62,14 – 71,43

Table 5. Acoustic comparison (contd)

Building - Room	Empty			Operational		
	Min	Max	Leq	Min	Max	Leq
B-1	50,5	56,7	53,44	53,1	77,2	63,79 – 66,32
A-2	43,0	53,1	55,15	56,1	78,1	61,80 – 66,34
B-2	48,5	56,9	49,16	52,2	74,3	61,63 – 64,38

Layout

Both observed building have different zoned with different activity. The working areas are separated from public areas, such as lobby and waiting room. The service area, including place for photocopy machine and other office amenities is well partitioned from the working areas, to isolate the potential air pollution from the machines. Staff rest area is also designed with enough distance to the working area, so that the noise caused by the activity will not disturb other rooms.

Both building also use office chair with adjustable seat and curve to supprot the spine. The chairs in building A has armrest, while in building B has no armrest. The dimension of the working desk and the monitor size has meet the comfort standards.

The density of the designed working area is close to the standard, that makes the staff feel comfortable with their space. One thing that can be improved from the observation, is the quantity of storage. In building A, we found documents flooding an unused desk in both observation room. In building B, we also found that the documents are flooding the workstation, but the storage –that happened to be open racks- is empty.

3.2. Questionaires

A questionaire survey was held to obtain the staff's response regarding the IEQ performance, their performance and satisfaction. 110 questionnaires were given to the staff, 50 for the staff in green building and 60 for the non-green. There were 90 valid filled questionnaires, 37 from the green building and 53 from the non-green.

Respondent's Profile

Staff profile in both building were found similar : most of them are female (A:83,8%; B:75,5%), aged between 20 to 40 (A:81%; B:78%), with administrative job (A:70,2%; B:67,9%) and not smoking (A:97,3%; B:90,6%). Most of the workstation type is open plan with personal desk (A:48,6%; B:67,9%)This profile makes the comparation between the two building more balanced, because not only the building, but also the user have similarities.

Validity and Reability

The crownbach's alpha score for the three variables are larger than 0.7 (0,751 for IEQ, 0,903 for performance and 0,706 for satisfaction). The score means that these variables are reliable. The crownbach's alpha if item is deleted in each indicator shows score that are lower or slightly higher than the existing crownbach's alpha. Therefore, the data is valid and able to be processed futher.

Correlation

Using the pearson correlation, we can conclude that the three variables have a significant correlation. This means that each variable affects one another, like the IEQ affects staff's performance, and staff's satisfaction, and vice versas. The result of the correlation can be found in Table 6.

Table 6. Pearson correlation between IEQ, Satisfaction and Performance

		IEQ	Satisfaction	Performance
IEQ	Pearson Correlation	1	,719**	,360**
	Sig. (2-tailed)		,000	,000
	N	90	90	90
Satisfaction	Pearson Correlation	,719**	1	,315**
	Sig. (2-tailed)	,000		,003
	N	90	90	90
Performance	Pearson Correlation	,360**	,315**	1
	Sig. (2-tailed)	,000	,003	
	N	90	90	90

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

Regression

Using the regression analysis, we can model how each aspect of IEQ affects staff's performance, and also satisfaction. From the analysis, we can conclude that performance is affected by IEQ aspects altogehter (sig.0,001). Then, it is found that thermal has a significant impact to performance (sig.0,011). The relation formula between performance and Thermal can be seen in Eq. 1

$$\text{Performance} = 29{,}637 + 0{,}849\ \text{Thermal} + \varepsilon \quad (1)$$

As for satisfaction, it is affected by IEQ aspects altogehter as well (sig. 0,00) Then, it is found that thermal, lighting and layout has a significant impact to performance (sig.0,009 thermal; sig.0,012 lighting; sig.0,00 layout). The relation formula between satisfaction and those three IEQ aspects can be seen in Eq. 2

$$\text{Satisfaction} = 0{,}372\ \text{Thermal} + 0{,}347\ \text{Lighting} + 0{,}529\ \text{Layout} + \varepsilon \quad (2)$$

T-test

Using t-test, we can compare the mean in each building category. Mean in IEQ, satisfaction and performance in green building (representated by building A) is higher than the means in non green building (representated by building B),to be precise 57,30 to 54,25 in IEQ, 18,43 to 17,72 in satisfaction, and 47,89 to 47,25 in performance. Even so, not all the difference in mean score were found significant. IEQ mean difference was found to be significant (sig. 0.025). The difference in satisfaction and performance are not significant, (sig. 0.247 for satisfaction and 0.554 for performance)

3.3. Comparation and Discussion

From the field measurements in IEQ aspects, we found that the observed room in the building A has meet the comfort standard requirements in most of the aspect inspected, while building B still lack in some aspects. But the satisfaction level in each aspect in building A and B is very close. In thermal aspect, eventhough building A has reach the comfort standard, its satisfaction mean in this aspect is still lower than the building B.

Acoustic in both building are still have not meet the standard requirement for office. This statement is reflected by the lowest point of aspect satisfaction.

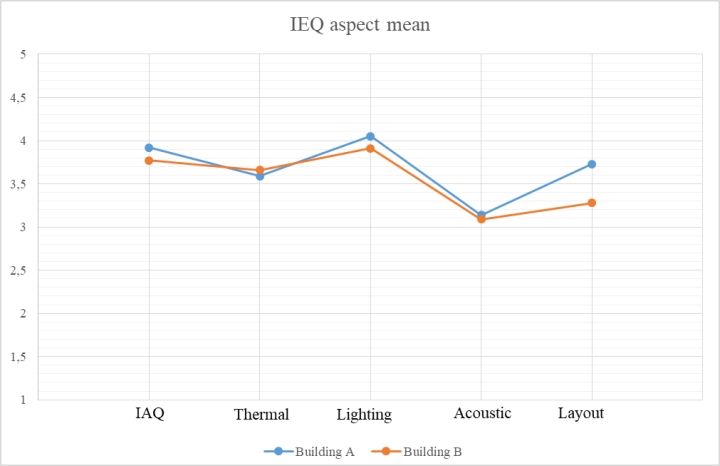

Figure 2. IEQ aspects mean comparation between building A and B

4. Conclusion

From the research, we can conclude that :

- There is significant correlation between IEQ, staff's performance, and staff's satisfaction
- Among other IEQ aspect, thermal condition in a working area affects staff's performance the most
- Thermal, lighting and layout affects staff's satisfaction. Layout has the largest impact to staff's satisfaction.
- The mean difference between green and non green building in IEQ was found significant, but in performance and satisfaction were not significant.

Comparing the result of the questionaires and field measurement, we can conclude that not all the comfort standards in IEQ aspects represents the staff's comfort standard. The performance and satisfaftion mean score was found neutral to high (3,09 to 3,91) in building which has not meet the comfort standard requirements.

This findings can serve as a topic in future research, regarding more aspect, other than IEQ alone, that affect staff's satisfacton and performance. The limited size of observed building can be improved too in the future research, so that the conclusion made can represent the model of office building in Surabaya.

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