Analysis of Indoor Environmental Quality Influence toward Occupants' Work Performance in Kompleks Eureka, USM

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***Abstract*—Indoor environment much more important for people health and comfort than the outdoor environment for most people who spend most of their living times in industrialized countries lives in an artificial indoor environment. Along these lines, this research is to upgrade indoor environmental quality conditions for comfort and work performance of occupants in Kompleks Eureka, USM while conserving energy of the building. Detailed field investigations of the indoor environment in large office buildings in many parts of the world have documented that the indoor environmental quality is typically rather mediocre, with many people dissatisfied and many suffering from sick-building syndrome symptoms. Recent studies have shown an important impact of the indoor thermal environment on occupants' work performance. Also studies on occupants medical leave show a very high loss of work time and working performance, which have important economical consequences for companies. The paper will mainly dealing with the indoor environmental qualities, such as thermal comfort level, air quality, lighting, and acoustic quality. The studies before showing that comfortable room temperatures, increased air ventilation above normal recommendation, comfortable acoustic surrounding will increases the work performance of occupants in Kompleks Eureka, USM.**

***Keywords*—** *Indoor Environmental Quality, Work Performance, Thermal Comfort, Acoustic, Indoor Air Quality*

1. Introduction

Outdoor air quality in cities in industrialized countries has enhanced significantly in these ten years. During this same period, indoor air quality has declined because of energy conservation; reduce ventilation and the sources of many new materials and sources of indoor pollution. These developments and the fact that people in industrialized countries spend the vast majority of their lives inside by and large makes the quality of thermal environmental issue with far reaching implications for occupants' work performance. While talking about issues with the indoor environmental quality is often on the requirements for thermal comfort, acoustic quality, air quality, and lighting comfort. Besides that, in office buildings it was shown that occupants' satisfaction was affected not only by indoor environmental parameters but also by workspace and building features, control over the indoor environment, level of privacy, layout, size, personal workspace, and furniture of office. In this paper will present new results with respect to the influence of the indoor environment quality on the work performance of the occupants in Kompleks Eureka, USM.

2. Literature Review

2.2 Definition And Theory Of Thermal Comfort

Thermal comfort can define as 'the condition of mind which expresses satisfaction with the thermal environment'. When thermal comfort level has reached the comfort standard, a building user will wish to feel too hot or too cold. The meaning applies to the thermal comfort of a single person. In structures, on the other hand, an individual share the building environments with other people.

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Standard ISO 7730 gives the lists predicted mean vote (PMV) and predicted percentage dissatisfied (PPD), which make it conceivable to anticipate the mean warm sensation and mean fulfillment with warm states of a gathering of individuals [1]. The standard characterizes the warm environment as a capacity of four physical variables (air temperature, mean brilliant temperature, relative air speed and air moistness) and two variables identified with individuals (action level and apparel). Moreover, prerequisites for warm solace must be met if no neighborhood distress exists, i.e. on the off chance that building clients are not aggravated by draft, too high brilliant temperature asymmetry, too low or too high inside surface temperatures, or too high internal surface air temperature difference [2].

While the above way to deal with the assessment of thermal conditions is in view of the warmth trade between a human body and the surrounding environment, an adaptive methodology has subsequent to been proposed. It expected that individuals have the capacity to adjust to the warm environment by method for behavioral modification. Building users are then ready to feel comfortable in a more extensive scope of conditions than the conditions recommended by applying the PMV index [3]. Studies have proved that human performance bears an important relationship to the indoor environment quality (IEQ). The IEQ included several components, such as warm surrounding, indoor air quality, lighting quality, acoustic quality, and so on. Air temperature is the usually utilized pointer of warm environment as a part of IEQ and execution research. In the present study, the relationship in the middle of execution and air temperature was review [1].

Many field and lab examinations have been led to study the relationship between air temperature and human work performance. A few studies have demonstrated that air temperature impacts execution by implication through its effect on commonness of SBS symptoms or fulfillment with air quality [4]. In the mean time air temperature likewise specifically influence human work performance. Studies demonstrate that a decrement in execution of call focus laborers when the temperature was above 25 C [2]. Analyst studied call focus specialists and discovered no big impact of temperature on execution in the comfort level [3].

Many studies in fact imply that comfort, health and performance are better when occupants are provided with options for control over their indoor climate. Researcher interpreted field study outcomes and concluded that people are more tolerant of their thermal environment if they can control it [5]. Most people are satisfiers not optimizers and want conditions that are ‘good enough’ while tolerating offsets from the ‘ideal’ as long as they have adequate opportunities to make indoor climate interventions [2]. In this context stated that the ability of the individual to control his or her environment is a rather subtle but important aspect and one that affects our satisfaction with the surroundings to a large extent [6].

Laboratory studies that looked at the impact of personal control on comfort, health and performance are scarce. Researcher designed a climate chamber study with one façade connected to the outside. During certain episodes people were exposed to relatively high indoor temperatures (>25 C) while not being allowed to use available thermal controls (operable windows, ceiling fans, sun blinds). At other moments, they were allowed to use these controls at will. Indoor temperatures were slightly lower when subjects were allowed to use the controls (about 1 to 2 C). At the same time comfort scores were much better than when control use was prohibited. And the comfort perception offset was much more than was expected just from the 1 to 2 C lowered temperature and the locally elevated air speeds. There are much better comfort scores in situations where behavioral interventions were allowed. This will cause them to the hypothesis that just the permission to interact with the built environment in itself leads to a higher satisfaction and acceptance of (suboptimal) thermal conditions [7].

Since raised temperatures in summer may have negative outcomes for building occupants, it may be recommended that air temperature in summer should be set within the lower a large portion of the summer comfort range, mostly to improve performance of office work additionally to keep away from the negative wellbeing impacts examined previously. This does not need to cost energy if procedures permitting evading thermal discomfort because of warmth with low vitality utilization are progressed. One of the strategies worth considering can for instance be utilizing the customized ventilation for cooling by increasing the convective heat transfer [2].

2.3 Definition of Acoustic Quality

Acoustic quality can be defined as “a state of satisfaction with acoustic conditions” [8]. However, the term acoustic quality is not widely used and providing a good acoustic surrounding is mainly associated with preventing the event of discomfort (inconvenience). The quality of the sound environment is connected to various physical parameters, which include both the physical properties of sound itself and the physical properties of a room. Sound is characterized by the sound pressure level in a short and long period of time and by sound frequency. The acoustic environment is influenced by such physical room properties as sound insulation, absorption and time [9].

2.4 Lighting Comfort

Lighting comfort is defined as "a subjective condition of visual well-being induced by the visual environment or surrounding". Although the definition demonstrated that there is a psychological dimension of comfort, a number of physical properties of the visual environment are characterized and used to access its quality in a objective manner. Visual conditions are described by such parameters as luminance distribution, luminance and its uniformity, glare, color of light, color rendering, flicker rate and amount of daylight [10].

2.5 Definition of Air Quality

Good air quality can be defined as "air in which there are no referred to contaminants at damaging concentrates as controlled by aware power and with which an impressive predominant part (80% or more) of the people uncovered don't express disappointment". So, the majority of the measures giving the requirements to indoor air quality characterize the conditions by giving the base rate of persons frustrated with air quality. They are for the most part taking into account the inconvenience and irritation brought on for occupants to indoor spaces [11].

2.6 Adaptive Thermal Comfort and Personal Control

As stated recently, our body control warm adjust with environment through a degree of self-governing physiological thermoregulatory exercises. Close to these activities, occupants still have many methods to adjust to indoor and outside thermal conditions. The speculation of thermal condition predicts that apropos parts and past warm history affirm the occupants' thermal desire and inclinations [12]. Occupants in warm area would incline toward higher indoor temperatures than occupants living in cooler area. Adjustment is characterized as the enduring lessening of the human response to repeated surrounding stimulation, and can be both behavior (clothing attire, windows, ventilators), and physiological (acclimatization) [13].

Besides that, differences in the perception of the thermal environment were found among occupants of naturally ventilated (also referred to as free-running), fully air-conditioned and mixed mode (hybrid) buildings [14]. The studies found that for naturally ventilated buildings the indoor temperature regarded as most comfortable increased significantly in warmer climatic contexts, and decreased in colder climate zones. These studies demonstrated that the neutral temperature observed in air-conditioned buildings differs from that observed in naturally ventilated buildings in the same climatic context. Researcher analyzed and broke down analysis that occupants of fully air-conditioned buildings are twice as sensitive to changes in temperature as occupants in natural ventilation buildings. People inside the air-conditioned buildings mostly will adjust less, and this will cause their thermal sensation become more sensitive to changes in temperature [10].

The indoor temperature viewed as most comfortable increases significantly in hotter climatic contexts, and reduced in cool climate zones, because of adjustment. Researcher found that the thermal history influenced indoor comfort experienced in identical climate chamber conditions, which become the initial elements of the PMV-model. Studies also found that people who use air conditioning at home responded with warmer thermal sensations than the subjects who did not use air conditioning. Besides that, researcher brought up the issues if air conditioning at home influences the adaptation process of working in a naturally conditioned office and also proposed two models of adaptive thermal comfort, which indicated cover with the PMV-model, and another one is used for naturally ventilated buildings [15].

2.7 Work Performance Based on Thermal Environment

One of the factors that have come within reach of study by computer is the efficiency of workers from improved performance, for example, through the computerized measuring the yield of call-focuses and office specialists (writing errands). Apart from human interaction and dynamic elements of the work environment [16], profitability on the work floor is additionally influenced by indoor environmental parameters, are the most important. Improved indoor environmental quality has a profound impact on work performance, important effect on execution, and this subject is altogether mulled over and studies again [14]. Losses or gains of up to 15% of turnover in a typical office organization might be contributed to the management and usages of the indoor environment. Besides that, researchers have estimated that the potential financial benefits of improving indoor environmental quality exceed costs by many factors [17]. There are connections between the upgrades to the indoor situations and lessened medicinal consideration expense, decreased medical leave, good performance of work, lower amount turnover of workers, and lower expenses of building support because of less complaint [18].

3. Methodology

A new methodology is proposed for examining the relationship between indoor environments and work performance in Kompleks Eureka USM. The Objectives of this paper research is to analysis the AC systems used in Kompleks Eureka USM. After that, it is important discuss the quantitative relationship between thermal environment and work performance in Kompleks Eureka USM and also can evaluate the energy-saving potential by improving occupants' behavior through energy-saving education. The effects of indoor temperature on human performance are also need to discuss. Data-collection about thermal comfort of occupants in Kompleks Eureka are taken. Besides that, a questionnaire survey was prepared, distributed among occupants in Kompleks Eureka and studied. The randomly selected method is used for sampling method. There are about 173 occupants in Kompleks Eureka building. There are totally 122 questionnaire forms are collected back, which is about 70% of the total amount of occupants in Kompleks Eureka building. The questions included in the questionnaire were selected in accordance with the objectives of the project, which is to analysis the list of indoor environmental factors inside the building, which will ensure comfort to building occupants and at the same time increase the work performance of them. The questionnaire survey collected the following information, like occupants background information, including their age and gender of the respondent, the time they work at their personal workspace, type of work position of the respondent, their office layout, air quality, lighting, acoustic quality, building features and also their thermal comfort level. Besides that, for the purposes of comparison, we used different scale to categorize their satisfaction, which choose from very satisfied to very dissatisfed with 0 as no comment. Besides that, by using the information and data collected in the questionnaire survey form, the relationship between acceptability of each environmental parameter (thermal, visual and acoustic environment and air quality) and occupants work performances was examined and analyzed.

4. Result And Discussion

4.2 Thermal Comfort

TABLE 1. Dataset of temperature satisfaction votes.

		Value	Count	Percent
Standard Attributes	Position	20		
	Label	How satisfied with temperature in your workspace		
	Type	Numeric		
	Format	F8		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	very satisfied	18	14.80%
	2	satisfied	80	65.60%
	3	no comment	17	13.90%
	4	dissatisfied	5	4.10%
	5	very dissatisfied	2	1.60%

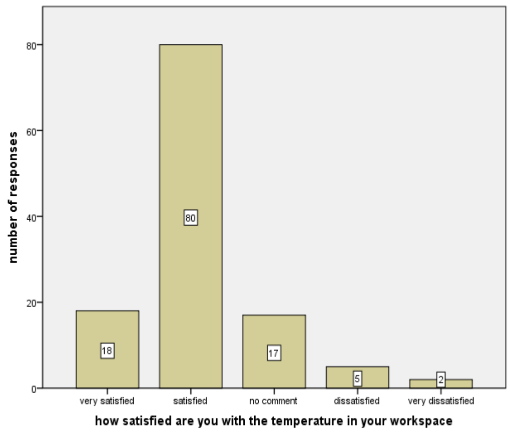

FIGURE 1. Distribution of temperature satisfaction votes across all occupants.

Fig. 1 shows the distribution of thermal comfort satisfaction scores for all occupants. Overall, most of the occupants are satisfied with the temperature in their workspace, which is 80 occupants (65.6%), the following is 18 occupants very satisfied with the temperature of their workspace, which is 14.8%. 17 occupants (13.9%) didn't have any comment about the temperature in their workspace. There are 5 occupants (4.1%) dissatisfied and 2 occupants (1.6%) very dissatisfied with the temperature of the workspace. Some of them complaint that their workspace either slightly cool or slightly warm, and this will affect their ability to focus on their job done. For reference, the dataset of occupants' temperature satisfaction is presented in Table 1.

TABLE 2. Dataset of air conditioning system satisfaction votes.

		Value	Count	Percent
Standard Attributes	Position	21		
	Label	How satisfied with temperature in your workspace		
	Type	Numeric		
	Format	F8		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	very satisfied	17	13.90%
	2	satisfied	87	71.30%
	3	no comment	9	7.40%
	4	dissatisfied	6	4.90%
	5	very dissatisfied	3	2.50%

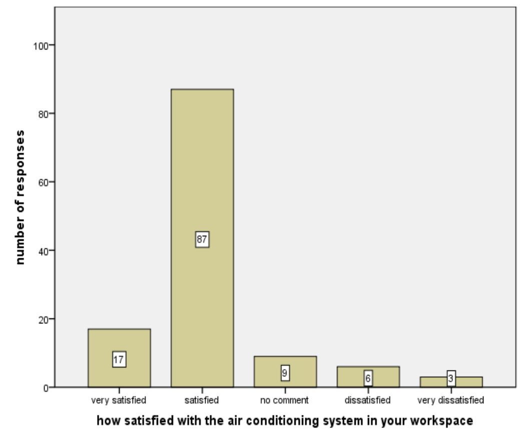

FIGURE 2. Distribution of satisfaction votes towards air conditioning systems across all occupants.

Fig. 2 shows the distribution of satisfaction votes towards air conditioning systems for all occupants. Based on the analysis of bar chart, most of the occupants are satisfied with the air conditioning systems, which is 87 occupants (71.3%), 17 occupants (13.9%) satisfied, 9 occupants (7.4%) no comment, 6 occupants(4.9%) dissatisfied and 3 occupants (2.5%) very dissatisfied with the air conditioning systems. Few of the occupants complaint that some air conditioning unit always have problems and cannot function well. This will cause the surrounding become warm and not comfortable thus affect their work performances. For reference, the dataset of air conditioning systems satisfaction is presented in **Table 2.**

4.3 Air Quality

TABLE 3. Dataset of air quality satisfaction votes in workspaces**.**

		Value	Count	Percent
Standard Attributes	Position	22		
	Label	How satisfied with temperature in your workspace		
	Type	Numeric		
	Format	F8		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	very satisfied	18	14.80%
	2	satisfied	80	65.60%
	3	no comment	17	13.90%

	4	dissatisfied	5	4.10%
	5	very dissatisfied	2	1.60%

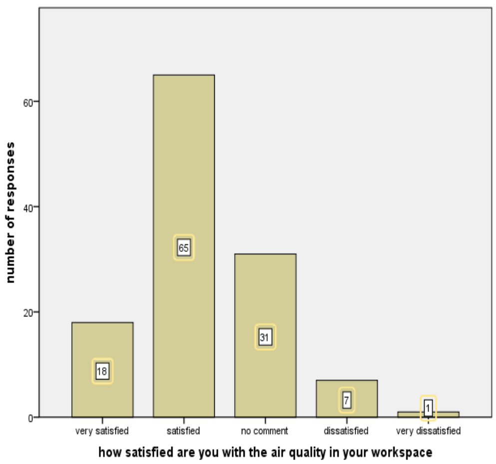

FIGURE 3. Distribution of satisfaction votes toward air quality in workspaces

Air quality satisfaction is somewhat lower than the thermal satisfaction in the buildings we surveyed. **Fig. 3** shows the distribution of air quality satisfaction votes across all occupants. Overall, most of the occupants satisfied with the air quality in their workspace, which is 65 occupants (53.3%). Following are 31 occupants (25.4%) didn't have any comment about the air quality in their workspaces, 18 occupants (14.8%) very satisfied, 7 occupants (5.7%) dissatisfied and only 1 occupant (0.8%) very dissatisfied with the air quality there. One of the occupant complaint that the air quality in their workspace is quite bad and always cause nose itchy and sneeze.

4.4 Acoustic Quality

TABLE 4. Dataset of satisfaction votes towards acoustic quality.

		Value	Count	Percent
Standard Attributes	Position	28		
	Label	How satisfied with temperature in your workspace		
	Type	Numeric		
	Format	F8		
	Measurement	Ordinal		
	Role	Input		
Valid Values	1	very satisfied	7	5.70%
	2	satisfied	71	58.20%
	3	no comment	26	21.30%
	4	dissatisfied	16	13.10%
	5	very dissatisfied	2	1.60%

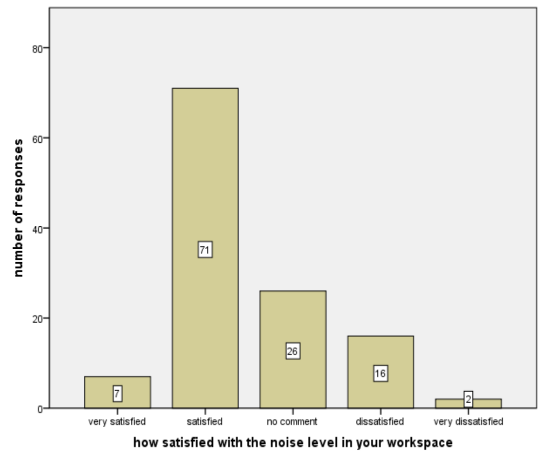

Fig. 4 shows the distribution of satisfaction votes towards the acoustic quality in workspaces for all occupants. Based on the analysis of bar chart, most of the occupants are satisfied with the acoustic quality in their workspaces, which is 71 occupants (58.2%), 26 occupants (21.3%) no comment, 16 occupants (13.1%) dissatisfied, 7 occupants (5.7%) very satisfied and 2 occupants (1.6%) very dissatisfied with the acoustic quality in their workspaces. The occupants that dissatisfied with the acoustic quality of the workspaces, complain that sometimes it is too noisy because of the voice of others occupants, and also the sound of activities that held near their workspaces. These will cause they cannot concentrate on their work and affect their work performances. For reference, the dataset of acoustic quality systems satisfaction is presented in **Table 4**.

4.5 Lighting Quality

TABLE 5. Dataset of satisfaction votes towards lighting comfort.

		Value	Count	Percent
Standard Attributes	Position	26		
	Label	How satisfied with temperature in your workspace		
	Type	Numeric		
	Format	F8		
	Measurement	Ordinal		
	Role	Input		
	1	very satisfied	15	12.3%

Valid Values				
	2	satisfied	85	69.7%
	3	no comment	15	12.3%
	4	dissatisfied	7	5.7%
	5	very dissatisfied	0	0.0%

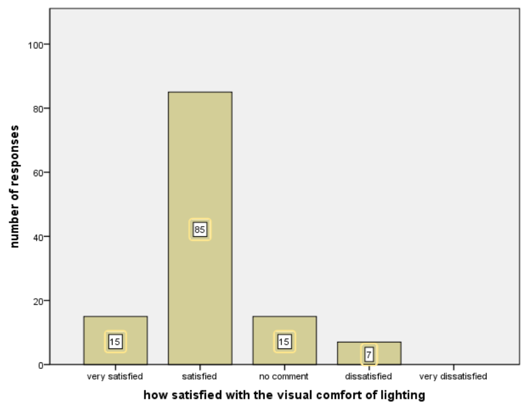

FIGURE 5. Distribution of satisfaction votes towards lighting comfort in workspaces.

Fig. 5 shows the distribution of satisfaction votes towards the lighting comfort in workspaces for all occupants. Overall, most of the occupants are satisfied with the lighting comfort in their workspaces, which is 85 occupants (69.7%), 15 occupants (12.3%) very satisfied, 15 occupants (12.3%) no comment, 7 occupants (5.7%) dissatisfied and no occupants votes for very dissatisfied with the lighting comfort in their workspaces. The occupants that dissatisfied with the lighting quality of their workspace complain that occasionally the sunlight refracted into their workspaces through the windows and cause them difficult to concentrate on their works. Besides that, some occupant complaint their workspaces are slightly far from the lighting zone. This cause them didn't have enough light to do their work and they need prepared desk light for their own. For reference, the dataset of satisfaction votes towards lighting comfort in workspaces is presented in **Table 5**.

5. Conclusion

With the factors of indoor environmental quality goals set out by standards, many buildings appear to be not reached the standard and target. ISO Standard 7730:1994 [19] recommends that the condition that can be accepted is in which at least 90% of people are satisfied with their thermal environment. Our survey results clearly show that much higher rates of satisfaction occur in Kompleks Eureka buildings. Most of the occupants in Kompleks Eureka satisfied with the indoor environmental quality and the air conditioning systems in the building. We show very clearly that personal control over environmental conditions, for example thermostat, room air conditioning unit, operable window and door to exterior or interior spaces has an important positive impact on occupant satisfaction. To achieve higher occupant satisfaction would be to provide such control to more occupants. In the previous year, occupant complaints to facilities staff have been one of the few ways to assess a building's performance. Occupant surveys provide a standardized and systematic method for assessing occupant satisfaction with the indoor environment. They also provide the information for collecting data to help analysis and solve the problems that faced. The results of this research show the state of indoor environmental quality in office buildings influenced towards occupants work performances. This information has important information for the methods of buildings are designed and built to increase occupant work performance and comfort in the building.

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