AN EXPERT SYSTEM FOR EVALUATING ENVIRONMENTAL QUALITY OF OFFICE BUILDINGS IN SAUDI ARABIA

Ali A. Shash* and Rabee M. Reffat*

* King Fahd University of Petroleum and Minerals
Saudi Arabia

ABSTRACT The environmental quality of office buildings is evaluated as an integrated system consisting of lighting, acoustic, thermal and indoor air quality. The performance criteria of office buildings were extracted from the literature and experts of office building in Saudi Arabia. A computerized expert system program was developed for evaluating the environmental quality of buildings. Simulating the methods that the domain experts follow for evaluating the environmental quality of office building revealed the developed expert system is sound and representative.

1. Introduction

A major function of an office building is providing a comfortable environment for its users. Environment is defined conventionally in terms of lighting comfort, acoustic comfort, thermal comfort and indoor air quality [1]. Building professionals such as service specialists, architects and engineers incorporate such elements into the designs of office buildings for the purpose of achieving quality environment for the tenants.

The environmental quality is a combination of environmental elements interacting with the building users to make the building environment the best possible one for the activities that goes on in it. These elements have to meet a number of specific requirements to achieve comfort conditions for the users. In this research environment quality factors were extracted from experts for evaluating the environmental quality of office buildings in the tropical region of Saudi Arabia.

2. Environmental Quality Factors in Office Buildings

Environmental quality in an office building means the ability of the building to provide lighting comfort, acoustic comfort, thermal comfort and indoor air quality for its occupants as well as to provide building integrity versus debilitation [2].

The evaluation of the environmental quality in office buildings is broken down into relevant factors such as performance requirements, lighting comfort, acoustic comfort, thermal comfort and indoor air quality.

2.1 Lighting Comfort

Traditionally, lighting plays an important part in building design implicitly if not explicitly. Architects have always recognized the visual environmental as a top priority, in the context of space, form and color, with natural light. Until the post war period, prediction of daylight in the interior was mostly associated with law rather than with comfort and convenience [3]. Many factors may be relevant to the design of a particular lighting system. Light quantity, directional quality, natural light, color quality, glare comfort are the main factors that need to be considered for lighting comfort. The priority association with each factor depends upon the type of situation [4].

2.2 Acoustic Comfort

The objectives of good acoustic design are to enhance wanted and control unwanted sounds (noise). People prefer to work in an environment that is quiet but not totally free form sounds [1]. The acoustical environment in an occupied space is the resultant of the sound arriving at the space from the engineering services, adjacent areas, external environment, and form sound generation within the space.

In order to have a comfortable office space from the acoustic point of view, acoustical principles such as general noise level, speech privacy, noise form equipment, air handling and from outside sources should be considered.

2.3 Thermal Comfort

Thermal comfort is a state of mind that expresses satisfaction with thermal environment [5]. It is achieved through the gain and loss of heat from the human body to and from the environment. This heat exchange is called thermal balancing.

Six major factors affect thermal comfort. These factors are divided into two main categories. The first category consists of environmental factors such as, air temperature, mean radiant temperature, relative humidity and air movement. The second category involves personal factors such as activity level and nature of clothing. In addition to these factors, secondary factors such as the rate of change of any of the above mentioned factors could result in the change of the thermal comfort. If any one of the above-mentioned determinants changed, the others must be adjusted to maintain the thermal equilibrium between heat gain and heat loss in the body [6].

2.4 Indoor Air Quality

Indoor air quality is defined as an air in which there are no contaminants at harmful concentrations and with which a substantial majority of the people exposed do not express dissatisfaction. Indoor air quality depends on many factors such as ventilation comfort, air exchange rate and indoor air pollutants [7].

3. Environmental Quality Evaluation of Office Buildings

Environmental quality of office buildings aims at providing a comfortable place for the users to perform their activities. But, each user has his own needs and tastes so that it might be what was good for one is obsolete for another. So, comfort is subjective sensation. There is no such think as a perfect combination of conditions of comfort since it is not possible to satisfy every one at the same time. Even when the optimum thermal conditions are achieved, only 50% to 70% of the population may feel comfortable, with the reminder feeling either slightly warm or slightly cool. A small proportion of the population may feel comfortable in condition which most will feel either too warm or too cool [8]. Despite the subjective nature of comfort, and the variability of individual response to the thermal environment as an example, the evaluation of comfort conditions is an essential input in the design stage [9].

The evaluation of environmental quality factors have been treated as independent of each other, although the designer typically tries to solve the individual problems by an integrated approach. Indeed, this approach is necessary since decisions about daylight may have severe consequences for thermal comfort. Decisions about how to deal with noise problems may lead to seal buildings that would have consequences on air conditions [10].

This research treated environmental quality factors as an integrated system. The integration was through the determination of weights of environmental quality factors and scales of the attributes of each factor. The weights and seals were obtained from 50 experts. A structured questionnaire was developed to analyze and elaborate these factors with (21) academicians and (29) practitioners who are considered experts in these areas. These questionnaires were discussed and field out through interviews conducted with those experts. The end result of this field study as well as an extensive literature review is sixty five factors in the environmental quality evaluation as well as the associated attributes for each factor. The formula of the total environmental quality evaluation was extracted from the analysis of the collected knowledge from fifty interviewed experts.

Total environmental quality evaluation =

$$[1.89 * [\sum A_1W_1 + A2W_2 ..A15W_{15}] + 2.29* [\sum B_1X_1 + B_2X_21..B15X_{15}] + 2.39 * [C1Y_1 + C_2Y_2 + ...C_{14}Y_{14}] + 3.44* [\sum D_1Z_1 + D_2Z_2..D_{21} Z_{21}].$$

Where;

A_1 The weight of each acoustic factor
W_1 The scale of each acoustic factor attribute
B_1 The weight of each thermal factor
X_1 The scale of each thermal factor attribute
C_1 The weight of each indoor air quality factor
Y_1 The scale of each indoor air quality attribute
D_1 The weight of each lighting factor
Z_1 The scale of each lighting factor attribute

A unified computerized model was developed for EQE using the expert systems. Using a computerized model to handle EQE makes the evaluation of the environmental quality of office buildings more easily, accurate, faster and more efficient.

4. Development of an Expert System for EQE

In recent years, the growing use of computer aided systems permits and calls for the application of computer in the design and evaluation of our buildings Expert Systems (ES) which have been defined as an intelligent computer programs, have proven to be effective in solving a wide variety of real world problems [11]

4.1 Structure of An Expert System (ES)

Expert systems are composed of two major parts: the development environment and the consultation (run time) environment. The development environment is used by the builder of Expert Systems to build the components and to introduce knowledge into the knowledge-base. The consultation environment is used by none experts to obtain expert knowledge and advice [12].

4.2 Development of An ES for EQE

The procedures, which were followed in the development of an Expert System for environmental quality evaluation, include the knowledge base development, weights determination decision trees, productions rules, computer program development, validation of the EQE model and the instructions to run the model [13]. The EQE model simulating the evaluation supported by the extensive experts and the their thoughts review used to build the knowledge base the computerized model that correlated 100% with a hand worked solution. The following are samples of the production rules of the knowledge-base and program screens.

Table 1. Examples of EQE Production Rules of Office Buildings

Rule Number: 23	
If	Impact Sound Insulation [ISI] of walls, partitions, floor and ceiling is {greater than or equal 35 dB to less than 45 dB}.
Then	
	Impact Sound Insulation [ISI] - confidence = 7/10
and	[ISI] is given the value ((0.068) * 7)

Rule Number: 49	

If	The illuminance (E) for Electrical Light in General Clerical Area [EELGC] is {greater than or equal 400 lux to less}

Then	
	The illiminance of Electrical Light in General Clerical Area [EELGC] - confidence = 7/10

and	[EELGC] is given the value ((0.06) * 7)

Table 2. An example of an EQE program screen

EXSYS Pro You may select only one value: The floor temperature (degree centigrade) of the office work place is: 1. Greater than or equal 25 to less than 27 2. Greater than or equal 27 to less than 29 3. Greater than or equal 29

Enter the value number (s) or select with arrow keys and press <enter> m <why>-rule used (quit)-save <H> help, <Ctrl > undo.

5. Conclusion

An integrated evaluation approach for the environmental quality of office buildings in the tropical regions such as the Kingdom of Saudi Arabia was developed. Also, a computerized unified program using expert system for EQE was developed. The computerized model was tested and correlated 100% with a hand worked solution simulating the methods that the domain experts used for the EQE of office buildings.

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