DEVELOP AN ENVIRONMENTAL ASSESSMENT TECHNIQUE FOR HUMAN COMFORT REQUIREMENTS IN BUILDINGS

ABSTRACT

Environmental assessment methods have emerged to assess the environmental performance of buildings across the world. Accurate results obtained using these methods are considered highly important, especially when taking into account the global trend of being obligatory and the use of their results to compare the environmental performance of buildings creating a fair competition among them. They are used for assessing green buildings regarding issues such as energy, water …etc. The indoor quality is one of these issues and human comfort is evaluated in those methods using a set of items to assess achieving the identified comfortable ranges by evaluating a number of factors influencing them. These items are using quantitative measurements, so the current assessing way is considered complex besides the consumption of time and effort without reaching significantly accurate results. Therefore the research problem appears in the lack of an appropriate mean in the current assessment methods to evaluate items linked with sensation and emotions. The research paper aims to propose a more credible and an accurate assessment approach to assess those items, and also helps evaluating another set of items which are linked to the psychological comfort. The previous type of comfort rarely appears in current assessment methods despite of being one of the green architecture principles. The 'Kano Model' is the proposed way used for the application of questionnaires that are put through the information network and linked to assessment methods to get more accurate and creditable results when assessing human comfort items.

Key words: Human comfort; environmental assessment methods; LEED; BREEAM; Kano Model

1. INTRODUCTION

Green Architecture is known as a highly efficient system that is compatible with its surroundings through self-control in the inputs and outputs of the system, [1] with minimal negative impacts on the environment and minimal energy and resource consumption over the building's life cycle. [2] Green Architecture puts a set of principles to treat the imbalance in the relationship between the building and the environment. [1] Creating a healthy society, providing comfort and enjoyment, reducing stress from buildings on their users, increasing satisfaction and achieving integration with the surrounding environment are some of the Green Architecture principles along with many others. [3] There are several forms to meet the human requirements associated with Green Architecture starting from nature accommodating to continuous responding to the environmental changes. [4] Assessing human comfort requirements is currently done by using quantitative techniques although their subjective characteristics, which raises a question about the efficiency of such techniques and the validity of having another more efficient technique to express achieving those requirements.

2. ENVIRONMENTAL ASSESSMENT OF BUILDINGS

Environmental assessment methods of buildings appeared to lay the principles and standards that are meant to be reached with the environment, posed by the principles of the Green Architecture. Assessment certificates were issued and granted for buildings to confirm their commitment to the environment according to a specific classification that places buildings in competition with one another environmentally.

2.1. Importance of the environmental assessment of buildings

Environmental assessment concept appeared in line with the increasing of environmental awareness and the need for global systems to measure its application in various sectors. In the buildings sector, significant and accelerated development appeared in the field of issuing certificates to assess the environmental dimension in new and existing buildings.[5] Environmental assessment methods of buildings are voluntary in many places and mandatory in others, like most American cities, where it is necessary to obtain an environmental approval prior to the construction of any buildings. [6] Environmental assessment methods are also considered as a solution to the commitment of energy codes, helping to reduce carbon dioxide emissions and increase energy utilization efficiency. They can also help creating a comparison system between buildings, and making a specific scale for the classification of buildings in terms of preference in dealing with the environment. [2]

2.2. Environmental assessment methods of buildings

A number of environmental assessment methods of buildings appeared all over the world. Building Research Establishment Environmental Assessment Method (BREEAM) in England is considered the first, [5] which emerged in 1990 to assess the environmental performance of offices. Many different other methods appeared later in other places in the world,[7][8] such as Leadership in Energy and Environment Design(LEED) in the United States, which first appeared in 1998 and began to be applied in 2000,[6] Green Star in Australia which appeared in 2003,[9] and Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan in 2004.[5] In Egypt Green Pyramid Rating System (GPRS) was put to use in 2011 to assess the residential buildings, and it is issued by the Egyptian Green Building Council (EGBC),[10] Those methods were developed for assessing green buildings regarding many issues such as energy, water,...etc. The indoor quality is one of these issues.

3. HUMAN COMFORT

Man feels comfortable when equilibrium is achieved between the inside and the outside of the human body. There are a set of requirements associated with achieving human comfort, and which its achievement is considered one of the important principles in Green Architecture.

3.1. Human comfort requirements

The human being is the main element affected by the building, and he is the key element in selecting the appropriate design of healthy buildings. Achieving human requirements is a major objective for the success of any building. Physical and psychological human comforts are the clearest amongst these requirements. [1] Physical human comfort is achieved when the person stays in a balanced state (thermal, visual, acoustical) to be able to do tasks with the maximum energy possible and without any stress. There are limits of physical balance, which are common

for most people, thus when exceeding these limits the rate of person's work will be affected leading to exhaustion and additional wasted energy. [3] The building helps in influencing human physical requirements by affecting those limits, for example, it helps achieving thermal comfort by providing climatic suitable conditions in terms of temperature, humidity, and ventilation. [4] It can also help achieving acoustical comfort by providing appropriate voice level, and helps achieving visual comfort by taking into account the acceptable level of brightness. [2]

A human being has a psychological energy expressed in his response actions and behavior, and this energy helps him in interacting subconsciously with the surroundings besides other patterns of interaction which expresses the status of the human psychological balance. Psychological equilibrium limits vary from one person to another; however, there is a range of psychological satisfaction determined by psychologists. As the human psychological energy is involuntary, it is difficult to determine the influence on it, so it may be determined by experience. Human psychological requirements include security, privacy, need of forming relationships, the ability to control the surrounding environment and to share in its formation, sense of beauty and its perception, need of meeting with others and interacting with them, and so on. These requirements may vary amongst individuals and groups, and the absence of any of the human psychological needs leads to mental balance losses and prevents human interaction and responsiveness with the environment. [3]

3.2. Characteristics of human comfort requirements

It could be easily noticed from the information stated above that there is a direct relationship between achieving human comfort requirements and the surrounding environment, therefore the human comfort requirements properties are linked to the environment properties which can't be defined in a static state, so a problem appears when determining the human comfort requirements and the effect of environment on them. Mathematical equations can't define the various environmental relations with buildings due to its complexity and great number of inputs, and it is impossible to write equations that describe what nature does, even if there are some components which could be calculated digitally such as temperature.[1] Therefore human comfort requirements are difficult to be measured, and there is no accurate mathematical system to do so without being relatively inaccurate.[11] However, the human comfort requirements can be described as well as the performance of buildings to ensure achieving them. Therefore when determining a number of quantitative standards to assess the achievement of human comfort requirements they can be a result of trial and error to reach the acceptable limits of comfort requirements. [12] Thermal comfort, for example, can be identified by a set of quantitative standards to set its limits range depending on the relationship between temperature and moisture content in the air. This relationship can appear in the 'Psychometric Chart', or can be determined using the traditional 'Victor Olgyay Chart' that shows the various relationships between temperature, moisture content, air speed and the need for shade to reach the thermal comfort zone, [2] but those ways to determine thermal comfort don't deny dealing with a changing environment and various human characteristics which cause ineffectiveness and unreliability in evaluating its achievement.

4. CRITIQUE OF THE CURRENT ASSESSMENT WAY OF HUMAN COMFORT REQUIREMENTS

Human comfort requirements are assessed in the environmental assessment methods of buildings using a set of items, but the technique used to determine its achievements is accompanied by several cons which can be shown below.

4.1. Critique of assessing human comfort requirements using quantitative measurements

Current environmental assessment methods of buildings are using quantitative standards to assess the achievement of human comfort, assuming that the achievement of those measurements will lead to the desired comfort. For example, to assess the achievement of thermal comfort, a number of figures and ratios can be used, [9] which are associated with measuring air temperature, moisture content, rate of ventilation, thermal insulation properties used and other quantitative measurements. [12] Likewise assessing visual comfort depends on some measurements associated with required lighting levels, the percentage of glare, and other features. Assessing acoustical comfort can also depend on the sound level, and the used sound insulation characteristics. [10] Different assessment methods share in common the dependence on quantitative evaluation, while the assessment items differ between them. [5] As previously mentioned, the characteristics of human comfort requirements are subjective and not qualitative, so reliance on quantitative measurements reduces the credibility and accuracy when assessing them.

4.2. Critique dealing with the diversity of human comfort requirements

Human comfort requirements vary between countries as a result of its association with different natural factors and climatic properties, for example, they vary from one country to another and may vary between different zones in the same country, while the diversity of these properties are not usually reflected on the current assessment items. For example, laws used in evaluating energy consumption in Europe don't reflect the differences in its distribution according to different climatic conditions, as the various national regulations all over the European Union were unified for energy performance of buildings, which is illogical, as there is a wide geographical range represented in about 35 latitudes degrees with a wide range of climatic conditions, thereby when the average heat transfer coefficient of separate buildings in Italy 1W/ m^2Kelvin is enough, in Finland 0.4 W/ m^2Kelvin is enough.[13] At the country level there are also some problems in unifying the evaluation figures. For example, 'Green Star' which is used for assessment in Australia covers different climatic zones, and this makes the task of setting unified standards applicable to all those areas more challenging than 'BREEAM' for example, and for this reason, some items in 'Green Star' are not always due to application. For example, the item assessing the lack of use cooling towers is very easy to be achieved in South Australia. [9] In Egypt 'GPRS' is used all over Egyptian cities regardless of their climatic characteristics, where Aswan for example is generally dry and hot, while Matrouh is of a moderate climate, and has high rates of rainfall in winter with a relatively high humidity, and low evaporation rate.

4.3. Additional problems with the current assessment of human comfort requirements

Additional problems in the way of evaluating human comfort requirements in the current assessment methods of buildings can be shown in the following:

First: Separation of the items assessing the achievement of human comfort requirements; which means that even in the absence of the individuals' feeling of the desired comfort, some items can grant grades which the building is not worth, [10] for example, assessing visual comfort is depending on a series of separate items including assessment of natural light, controlling of glare, indoor and outdoor light levels, controlling light zones and others. [6] Each previously mentioned item gets a separate score. So in the case of not achieving any of these items the rest will still present their scores regardless of achieving the main goal of their existence.
Second: Condone assessing the achievement of psychological comfort requirements; although Green Architecture is considered the most considerate environmental architectural approach focusing on the human feelings and senses. [7] Current environmental methods of buildings condone assessing them as a result of the difficulty of measuring those needs using quantitative criteria, besides their relation with several variables influencing its achievement. [9] Only limited items were raised to assess them, like the item of the linkage with nature by using appropriate openings, [5] but this item helps achieving a limited interaction with nature leading to a sensation of boredom although applied as a result of dealing with the nature in a constant vision. Changing in buildings is a goal of psychological comfort requirements, and it is a main aspect of nature, so achieving excitement and interaction with the surroundings by connecting with the environmental variables to achieve internal changes is considered one of the requirements to achieve psychological comfort, besides influencing on the senses to cease the boredom and monotony in the internal spaces. [3]
Third: Reduced interest in achieving human comfort requirements. As environmental assessment methods of buildings are issued from different countries, they reflect the different interest of environmental issues involved in these methods. Each country has its characteristics leading to the increase or decrease of the rate of interest for some issues more than others. Assessing water consumption efficiency for example in rainy countries has a different interest than in dry ones.[14] Likewise, current environmental assessment methods of buildings contain various interest levels to assess the achievement of human comfort, which can be noticed in different versions of some methods as shown in the following table for residential building at the same time period. [12] (Table1) It is also noticed in general that the items weights associated with these requirements are low in comparison to other items, [6] especially in developing countries where the items of conserving energy and global warming issues have got the higher weights in spite that they are the least causing them. [10] So it is preferable to unify the attention to human comfort in all countries, and to put a unified minimal level in all countries to achieve the environmental issues in buildings which include human comfort issues.

Table1: Diversity of weights associated with human comfort requirements for some environmental assessment methods of buildings. [Researcher using Ref. [7-9-10-11-12]]

BREEAM (England)	**LEED** (United states)	**Green Star** (Australia)	**GPRS** (Egypt)
Health and Wellbeing (14.6%)	Indoor Environmental Quality (16.8%)	Indoor Environmental Quality (13.3%)	Indoor Quality (10%)

5. PROPOSED APPROACH TO ASSESS HUMAN COMFORT REQUIREMENTS

A set of questions appear from the previous discussion about the adequacy of the existing items in the environmental assessing methods of buildings to assess human comfort requirements, and the efficiency of the used approaches to assess those requirements. The majority of the problems can be summarized in the use of quantitative standards to measure the achievement of the human

comfort requirements despite their descriptive and subjective characteristics. [15] Questionnaires are the most feasible approach in dealing with those characteristics than the traditional quantitative ones. The research suggests using 'Kano Model' to assess the level of human comfort and individual's satisfaction. It first appeared to assess the quality of management and marketing technology to measure the user's joy, this model can be used also to assess buildings and measure the personal satisfaction related to them according to the achievement of their requirements, as the assessed product in this case is the building. [16]

5.1. Feasibility of questionnaires to assess human comfort requirements

Questionnaires are an effective way to identify human demands. They are considered the most famous and widespread data collecting technique. Questionnaires depend on providing a series of questions that can evaluate the assessed goals. Questionnaires are done through a series of steps, which begin by setting the required goals, determining the required data, transforming the objectives into a set of questions and inquiries, then sending the questionnaires to the involved people and entities. [17] It is preferable to collect 75% or more of the needed answers to be sufficient to analyze the information. It has been found from the field investigations that 20-30% of users in homogeneous sectors are enough to identify 90-95% of any product's requirements. [15]

5.2. Kano Model used to assess the individual's satisfaction

The Kano model is a theory of product development and customer satisfaction developed in the 1980s by Professor Noriaki Kano. The Kano Model's main objective is to help teams uncover, classify, and integrate three categories of Customer Needs and Attributes into the Products or Services they are developing. [16] The three types of needs are classified depending on their ability to create customer satisfaction or cause dissatisfaction. Missing any of these needs will jeopardize the success of the offering. The Kano model offers some insight into the product attributes which are perceived to be important to customers. The purpose of the tool is to support product specification and discussion through better development of team understanding. Kano's model focuses on differentiating product features, as opposed to focusing initially on customer needs. [18] (Figure 1)

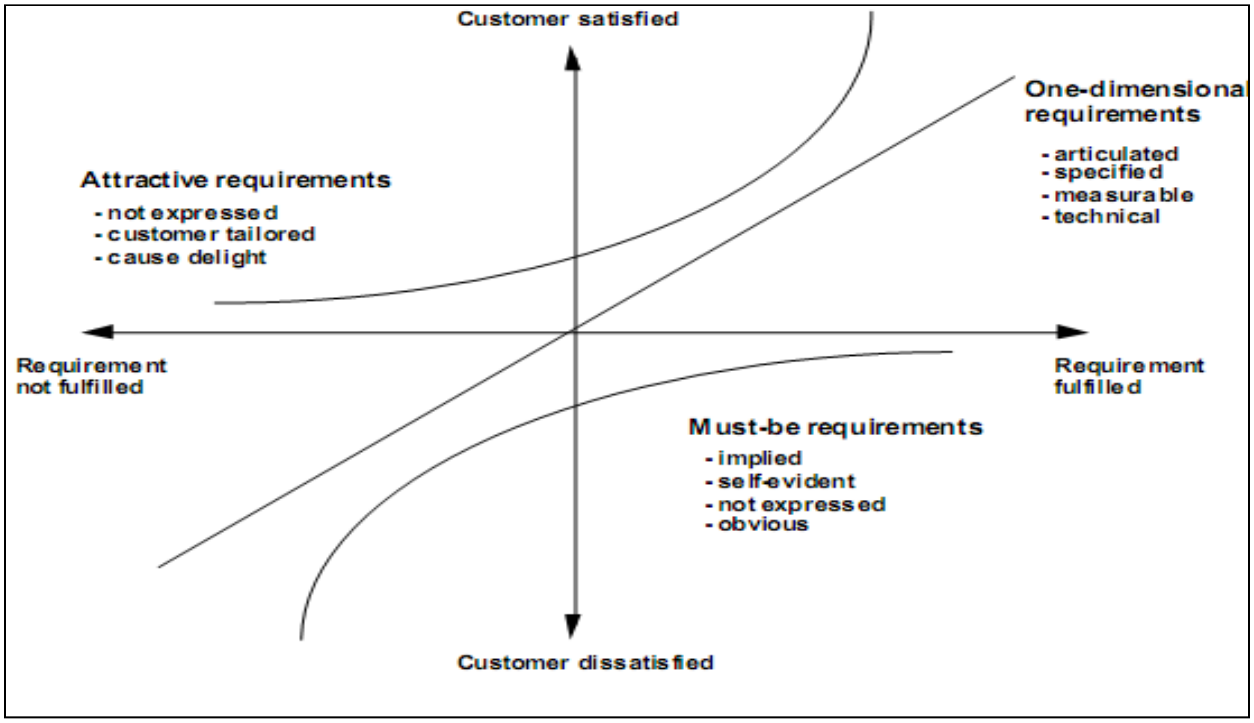

Fig. 1: Kano's model of customer satisfaction. [17]

Kano produced a methodology for mapping consumer responses to questionnaires onto his model, it is a development of the traditional questionnaire used to measure user satisfaction, as the user satisfaction in that model can be expressed in one of these categories: attractive, must-be, reverse, one-dimensional, questionable, indifferent. [15] Kano had added three kinds of categories were not presented before, including the feeling of the user of the indifference of a property presence (indifferent), the lack of clarity to expect this property (questionable), and the user expect of the reflection of a property on the product (reverse). The other three categories are taken from the traditional product evaluation, the first category is linked to the essential characteristics that must be found in any product which is linked to the minimum requirements that cause resentment if not complete and doesn't cause satisfaction if not accomplished (must-be), such as the presence of service spaces beside their functional spaces in buildings, the second category is related to the attractive and exciting characteristics which lead to a higher user satisfaction, but doesn't cause dissatisfaction if not obtained (attractive), such as the use of wind energy in achieving ventilation or power generation, the third category is linked to the characteristics that are one-dimensional, which means that the more the products performance increase the more the user satisfaction increase and vice versa (one-dimensional), such as the efficient use of electric appliances in buildings. Kano also developed axes of user satisfaction's change and the relationship of that change with what the user want from the product and what he expect and don't expect. [16]

Questions in traditional questionnaires focus on the product's properties that don't cause the user to feel comfortable, that cause problems, defects and complaints associated with the product use, standards that user doesn't take into account when getting the product and features that are better than the user expectations. [17] Kano Questionnaire summarizes the user satisfaction of the product characteristics in two questions, the first one is about the user's reaction when receiving

a feature in the product, and the second is about his reaction when there is a lack of this feature in the product. The answer to the previous questions may be one of the following options: like - must be - neutral – live with – dislike. [18] (Table 2) Depending on the first answer which is placed on the vertical direction in the Kano table questionnaire and the second answer which is placed on the horizontal direction in the table the final result is obtained at the intersection of the two answers, which represents one of the six user satisfaction categories which were previously represented: A (attractive) – M (must-be) – R(reverse) – O(one-dimensional), Q(questionable) – I(indifferent). [16] (Table 3)

Table 2: Some differences between traditional questionnaires and questionnaires based on Kano Model. [Researcher using Ref. [15-16-17-18]]

Differences	Traditional Questionnaires	Questionnaires based on Kano Model
Questions	Generally discuss the characteristics, problems, defects, complaints, and advantages of a product to get specific results.	Briefly use two questions (positive and negative questions) for each product aspect to express many results.
Answers	Answers are expressing either customer satisfaction or customer dissatisfaction.	Answers contain different expressions that may refer to aspects that are neither good nor bad, and they do not result in either customer satisfaction or customer dissatisfaction, thus preventing vague answers or answers that may have more than one meaning, they also take into consideration the fact that not all customers are alike.
Relationship with time	Not clear.	Attributes drift over time from Exciting to performance and then to essential. The drift is driven by customer expectations and by the level of performance from competing products.

Table 3: Kano Table used to assess user satisfaction for the product's characteristics depending on the answer of two questions. [15]

Customer requirements		Dysfunctional (negative) question: reaction without the feature				
		Like	**Must be**	**Neutral**	**Live with**	**Dislike**
Functional (positive) question: reaction with the feature	**like**	Q	A	A	A	O
	Must be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

Similar results expressing users' satisfaction (A-M-R-O-Q-I) are gathered in a result table, then percentages of each are calculated. These percentages can help in identifying the order of importance of the products' characteristics. [17] To complete the assessment of the products' characteristics, the customer satisfaction coefficient (CS) should be calculated in two forms. The first form with a positive signal and could be calculated by the formula: (A+O) / (A+O+M+I), while the second form with a negative signal and could be calculated using the formula: (O+M) /

(A+O+M+I)×(-1).(Table 4) Finally, the two positive and negative results are collected in one result which can be used to assess the product's characteristics. The closer the value to (+1), the better the product is, while it is ineffective when the value is (0), and it leads to individual's dissatisfaction the closer it comes to (-1). [18]

Table 4: Illustrative table to calculate the positive and negative user satisfaction coefficient (CS) for a product's characteristics. [15]

Product requirements	A%	O%	M %	I%	Total	Category (helps in ordering priorities)	$\frac{A+O}{A+O+M+I}$	$\frac{O+M}{(A+O+M+I) \times (-1)}$
1st aspect	٧	٣٣	٥٠	١٠	100%	M	٠,٠٤	-٠,٨٣
2nd aspect	١١	٤٦	٣١	١٢	100%	O	٠,٥٧	-٠,٧٨
3rd aspect	٦٦	٢٢	٣	٩	100%	A	٠,٨٩	-٠,٢٥

5.3. Proposed method to use Kano Model in assessing human comfort requirements

Questionnaires based on Kano Model can be used to assess the items associated with a group of individuals. These groups should be homogenous and connected to the assessed building, such as the users of the building, visitors, passers-by, owners, so as the building constructors, operators, preservers and eliminators. Some item scores may depend on a combination of individual views results beside other calculations. Questionnaires results may be provided with the documents provided by the designer, and some may also be provided through some life stages of the building, as they require the passage of some time that may exceed the evaluation period, like the items linked to the users' comfort during the operational phase of the building. So buildings can be assessed before getting a final result of these requirements, then the assessment is completed after that by collecting opinions of a certain percentage of the groups of people related to the assessed requirements during a specified time period - such as determining the first year of the occupation to finalize the building assessment - to make sure that the required levels of comfort are achieved, which requires providing initial environmental permits to run the building according to preliminary results, then they are updated and developed based ongoing specialists reviews, for example every quarter of a year.

Items used to assess physical human comfort have got a second option -which is using quantitative measurements- to be assessed if there is a problem in the possibility of using questionnaires in the assessment. So assessing these items begins by choosing the way of evaluation, and if using quantitative way is chosen, then the items that depend on questionnaires are neglected automatically, and vice versa. Many items assessing psychological human comfort have no alternatives for the use of questionnaires to evaluate them, so the lack of technological development in a country may affect the possibility of assessing those items due to the effect on using questionnaires in it. In case of selecting the questionnaires evaluation items, the scores of these items are accompanied by determining the minimum number of people required to answer those questionnaires, and then the questionnaire is put through a website linked to the assessing method, so the people requested to express their opinion may be easily linked to the site to give their answers. As previously mentioned the Kano questionnaire includes only two questions and by answering them the opinion of a person is obtained. By collecting opinions, the positive and negative CS are calculated, then they are gathered to get a final result for the comfort item from (-1) to (+1), putting into consideration that the numbers from (-1) to zero are considered zero. Finally, the scores obtained for each item are multiplied by certain weight expressing its importance which is previously determined by experts.

After that, intervals are determined to repeat those questionnaires to get more than one score for the same item at different time periods. These intervals are determined depending on the type variations associated with achieving the assessed items, as the item's requirements may be changed periodically as during the day and night or seasonally during different seasons of the year, or may be changed sequentially such as dust accumulation, growth of cities, increase of family sizes and so on, or may be changed suddenly with the occurrence of some sudden events such as earthquakes or floods or sudden emissions and so on. It may be noted, for example, that achieving thermal comfort is affected by all of the previously stated types of variables, as it differs daily, seasonally, sequentially and suddenly due to different variables. So experts specify time periods required to repeat questionnaires associated with thermal comfort to get results that ensure the continuity of achieving comfort in the maximum possible periods of time which was not expressed in the previous evaluation methods. Grades obtained from repetition are added to the previously obtained grades, by taking into account the importance weight of each type of variation depending on its influence on the item's requirements.

5.4. Illustrative example for using Kano Model in the building assessment methods

Benefits of using questionnaires based on Kano Model in the environmental assessment of buildings can be shown through the following example; this example shows the difference between achieving points for an item according to traditional requirements and the possibility of achieving them according to the proposed methodology, the example is for assessing thermal comfort. This type of comfort is usually assessed upon set of various requirements which may include:

- Provide thermal comfort control systems for a certain percentage of the building occupants either individual occupants within a specific range, or groups in multi-occupant spaces. Control strategies can be developed to expand on the comfort criteria to allow adjustments to suit occupant's needs and preferences. Comfort system control is provided to include at least one of the primary factors of air temperature, radiant temperature, air speed and humidity. Control strategies may involve system designs incorporating operable windows, hybrid systems integrating operable windows and mechanical systems, or mechanical systems alone. Individual adjustments may involve individual thermostat controls, local diffusers at floor, desk or overhead levels, or control of individual radiant panels, or other means integrated into the overall building. [10]
- Ensure that operable windows meet the requirements of specific standards (e.g. ASHRAE) to achieve natural ventilation. [6]
- Design heating, ventilation and cooling (HVAC) systems and the building envelope to meet the requirements of specific standard (e.g. ASHRAE) to meet thermal comfort conditions for human occupancy under expected environmental and use conditions. [6]
- Provide appropriate distribution of space heating and cooling. Room-by-Room Load Calculations are required for Forced-Air Systems according to specific standards (e.g. ASHRAE), beside installing ducts accordingly, ensuring that certain rooms have adequate return air flow through the use of multiple returns, transfer grilles, or jump ducts, and ensuring that the total supply air flow rates in each room tested using a flow hood with doors closed, or one of the other acceptable methods. [19]

- Provide a permanent monitoring system to ensure building performance, by the implement of thermal comfort survey of building occupants within a period of time (e.g. six to 18 months) after occupancy. This survey should collect anonymous responses about thermal comfort in the building including an assessment of overall satisfaction with thermal performance and identification of thermal comfort-related problems. Agree to develop a plan for corrective action if the survey results indicate that more than a certain percentage of occupants are dissatisfied with thermal comfort in the building. This plan should include measurement of relevant environmental variables in problem areas in accordance with specific standards (e.g. ASHRAE). [6]

From the previous requirements it is notable that:

- There can't be a final conclusion that ensures if the desired comfort achieved or not, as every requirement is evaluated separately and the grades are given for each of them when achieved alone regardless of achieving the overall thermal comfort or not.
- All or some of the requirements can be achieved and given points without ensuring that the occupants will feel the desired comfort.
- Some of the requirements may drive designers to use mechanical systems to achieve the thermal comfort points as they are easy to prove achieving these requirements, regardless of the preference of using natural systems to provide that type of comfort or not.
- The final score of this type of comfort depends on a survey within a period of time after occupancy to ensure occupant's thermal comfort over time, while the requirements of this item which were given the initial points did not include such a survey.

It is proposed to design the environmental assessment method of buildings so that the use of Kano Model questioner is one of the available selections to assess some of the assessed items including thermal comfort items, and it is proposed then to change the traditional requirements as previously mentioned from a requirements with a given grades into requirements without any grades, and use them only to allow the building operation. The thermal comfort initial grade will be given after the building operation using a Kano Model questionnaire for a certain occupant's percentage, then repeated several times for different climatic conditions over a specified period of time (e.g. for a year) to get the final score for these items depending on the compilation of results as previously mentioned. Kano Model questionnaire to assess the thermal comfort in the building may include:
What is your reaction towards the thermal comfort means designed in the building?
What is your reaction without the thermal comfort means designed in the building?

5.5. Benefits of using Kano Model in the environmental assessment of buildings

Questionnaires based on Kano Model are noted to be feasible in the environmental assessment of buildings as they:

- Are easy to be used in the evaluation of some items that cannot be described or calculated mathematically.
- Deal with the subjective properties associated with the satisfaction of a group of people, and can obtain more accurate and creditable results than the quantitative evaluation measurements.
- Deal with human differences from one person to another and takes them into account.

- Don't need time or effort to answer them, as the participant answers two questions with existing choices.
- Can be used for all zones and countries without the liability of changing the item's requirements used to assess the human comfort, as they are consistent with the characteristics of each zone, which are diverse and need time and effort to study their impact when transferring these methods across different places, and thereby they help spreading environmental assessment methods worldwide.
- Deal with time variables, affecting the level of satisfaction, as other options may appear by time, changing the individual view about the level of satisfaction for the same product.
- Possibility of assessing the overall performance of building requirements rather than separate assessment items, from which the building can obtain undeserved grades without achieving the main objective of their presence and evaluating it.
- Help in the recognizing of conflicts in the achievement of some human comfort functions with one another when using the same building elements to achieve them.
- Possibility of verifying the continuity of achieving items for the maximum possible periods of time, by linking the outcome of the assessment with the frequency of questionnaires during different periods, commensurate with the different types of variables affecting those items.
- Possibility of obtaining a specific grade to evaluate items by having a result from 0 to 1, which are later multiplied by the item importance weight to estimate the item's final score.
- Take into account the change of needs and restrictions, as the excitement features today may be essential requirements tomorrow, and may become things that the user doesn't asks about, but rather expect.
- Possibility of assessing psychological comfort, which rarely appears in the current environmental assessment methods of buildings due to the difficulty of being measured mathematically.
- Help in assessing the impact of changes in the building on the human satisfaction, which was not expressed in the previous evaluation methods such as assessing visual works that alerts users and prevent the feeling of boredom and monotony, with noticing the repetitions and similarities in the building preventing the person from thinking and preventing him from changes which the scientists have agreed to be required for the maintenance of his intelligence level.
- Help in assessing the impact on the human senses which did not appear in the previous assessment methods, however, it appears in some buildings.

Items linked with sensation, emotions & psychology may include:

- Safety: by assessing the appropriately of the overall design of fences and entries to achieve security depending on individual's choices, and the distribution of lighting units in different spaces to feel secure. [20]
- Privacy: by assessing overall privacy requirements in different spaces in the building according to their function and the individual's culture and needs. [20]
- Movement orientation: by assessing the spaces formation to create movement guidance according to their function, the use of appropriate elements to identify spaces to commensurate with the movement, the use of lighting to divide spaces when needed. [20]
- Excitement: by assessing the variation in lighting units and their characteristics to create a pleasant visual environment, the lighting shifts to help focusing on senses, and the manipulation of the surface characteristics when needed. [21]

- Connecting the external nature: by assessing the occupant's connection to the external nature directly through windows, or indirectly by using the nature characteristics effects into the internal spaces. [21]
- Information exchange through the building: by assessing the ability and ease of using an appropriate information network, or compacted digital plates separated or integrated to the building to exchange the information through internal spaces. [21]
- Compatibility with social life: by assessing the overall form of the building to maintain the prevailing social relations in society, and to help the presence of traditions. [20]

5.6. Disadvantages of using Kano model in the environmental assessment of buildings

Some defects associated with the use of questionnaires in the environmental assessment of buildings can be displayed with some proposed solutions to treat them as follows:

- Using questionnaires in general needs an electronic link between the assessment methods and individuals whose views are required in the assessment, whereas the technological delay in some countries or its high fees may limit the ease of handling the electronic linkage required. The previous problem can be treated by depending on the paper questionnaires until being able to deal with electronic questionnaires and developing an infrastructure in the assessed region.
- Minimum number of individuals whose views are required in the questionnaire should be achieved, whereas there is no guarantee on that except the individual interest to fill those questionnaires. Failure to achieve the minimum number of individuals may return the assessment to the quantitative measurements of comfort. The previous problem can be treated by raising the environmental awareness among different communities and the need to deploy sustainable buildings for their benefit as well as the environmental goals, especially when governments start the obligation of providing a proof of environmental classification of the buildings before giving building or completion permits, as it is already applied in many places all around the world.
- Some difficulties may appear when using the environmental assessment method outside the boundaries of the producer country of the assessment method due to the possibility of a failure in the technological connection between the assessing organization and the individuals concerned. Therefore, although using questionnaires can treat the problem of dealing with spatial and temporal variations affecting the environmental assessment methods internationally when assessing the items associated with human comfort, it may face other difficulties. The previous problem can be treated by providing paper questionnaires when needed.

6. RESULTS

- Assessing human comfort requirements in the current environmental assessment methods of buildings contain some deficits as a result of measuring them quantitatively although they are descriptive and subjective. There is also a difficulty in considering spatial and temporal variables that influence the assessment of those items, besides the absence of the evaluation of human psychological comfort due to its characteristics that prevent assessing it quantitatively.
- Questionnaires help to get a set of goals, to solve a set of problems that appear in the current environmental assessment methods of buildings that are used to achieve the human comfort requirements, as they are considered more effective in dealing with the descriptive and

subjective characteristics, and to deal with different variables associated with the human comfort requirements. Therefore, they lead to more accurate and creditable results.

- Questionnaires help the transmission of the assessment methods over place and time, without exerting time and effort to change the method versions to be compatible with the spatial and temporal variations. They also lead to evaluation results quickly and easily, and thereby help to express the overall performance of the building when achieving different comfort types rather than relying on unrelated items, which may lead to undeserved scores.
- Questionnaires help to recognize the presence of the conflict of some human comfort functions that may affect each other when using the same building elements to achieve them. Along with the foregoing, the grade obtained from the questionnaires commensurate with the results of the assessment items in the current methods, which encourages their use.
- Questionnaires based on 'Kano Model' are considered a quick and easy technique used in the environmental assessment methods of buildings.
- A set of important items linked to the human psychological comfort associated with buildings can be evaluated in the environmental assessment methods of buildings, which does not appear in the current assessment methods, as evaluating the human interaction with the building and the impact of building changes on human senses, which can be included when using appropriate questionnaires.
- Questionnaires repetition according to the different types of variations that affect the achievement of the comfort items helps in assessing the continuity of achieving those items for the maximum possible periods of time.
- A set of defects are accompanied with the usage of questionnaires in the environmental assessment of buildings which can be treated by increasing the environmental awareness amongst people, and using paper questionnaires when needed until developing the electronic connectivity around the world.

7. RECOMMENDATIONS

- Institutions, organizations and councils involved with the environmental assessment methods of buildings around the world are recommended to depend on questionnaires to assess the achievement of human comfort requirements, especially those based on 'Kano Model', rather than quantitative measurements, which are not commensurate with the characteristics of the previous requirements.
- Institutions, organizations, and councils involved with the environmental assessment methods of buildings around the world are recommended to develop the assessment methods and to put them electronically to help providing the connection constituents required for contacting individuals whose opinions are used in determining the scores of some items.
- Research organizations are recommended to develop questionnaires based on 'Kano Model to assess the human comfort requirements used in the environmental assessment of buildings with the utmost available effectiveness.
- Different media are recommended to spread environmental awareness and the importance of the environmental assessment of buildings around the world, and to provide the constituents of public feedback, to develop the assessment methods and to raise the global environmental concern.

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