Towards a New Methodology for Integrating User Aspirations into Passive Building Design

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Abstract

Integrating user needs into passive building design is emerging as an important issue in designing responsive buildings. Integration can promote the performance of buildings and satisfy users' psychological and physical needs. Traditional passive design methods are mainly aimed at addressing the ecological aspects of a design rather than integrating end-user needs into the operational aspects of the building. Thus there is an urgent need for a new design approach that integrates end-user needs with passive design strategies. This paper aims to introduce a methodology that has been used to propose a conceptual user-centred passive building design (UCPBD) model. This methodology can be distinguished from other methodologies in the sense that it comprises passive design strategies, user-centred design processes and user-centred design attributes in a way that helps the designer to fulfil user needs at the design stage.

Keywords: Methodology Process, Passive Design, User Centered Design and User Centered Passive Building Design new approach.

Introduction

Recent developments in the field of climate change and sustainability have led to an intensive interest in environmental design. Passive design (PD) is one of these environmental design approaches. PD is defined as "*an approach to building design that uses the building architecture to minimize energy consumption and improve thermal comfort. The ultimate vision of passive design is to fully eliminate requirements for active mechanical systems*" (Vancouver, 2008, p. 3). However, PD is distinguished from other design systems by its relying on the use of natural sources such as solar and wind patterns without the need for mechanical systems. The issue of the users and occupants of buildings is still emerging as an important factor in the design of resilient building assets, even though there have been various attempts that have addressed user needs during the last decades. These include post-occupancy evolution and ergonomics theories. These theories consider user needs based on one perspective only, such as comfort. A major problem with these kinds of theories is that none of them has a systematic approach that can help the designer capture users' aspirations through various design constructs at the design stages. This research is, therefore, aimed at contributing to the endeavour of understanding how end-user needs are fully integrated into PD processes. Our approach is based on ISO 13407, which deals with user-centred design (UCD) in the software industry. We are developing a similar process for architects to capture user needs during the design process in a systematic way. This paper will introduce the argument for the need for this type of research. Then, it will review some of the existing theories regarding users. The third phase

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will introduce UCD theory and its application followed by a description of the proposed methodology, which could help designers in the building industry to meet ever-changing user needs.

The need for integrating users needs into passive design processes

The research into architecture design to date has tended to focus on environmental issues rather than the building users. The existing passive building design (PBD) processes are limited in meeting users' aspirations. The current trend in design processes relies mainly on the benefits from natural sources to operate buildings. However, there is still a mismatch between end-user needs and the existing PBD theories. This issue has been pointed out by several authors. For example, MFE (2008, p. 8) claims that "*The design team should involve future users and facilities management staff in the design process, and develop a building user's guide to inform occupants of the building's design intent*". User participation during the design process has become of paramount importance, as this statement puts forward. This will help user needs to be incorporated into a design before the actual construction and operation of the building assets. This statement reflects the emergent need for an approach that can help designers to capture users' needs. It also indicates that there is a capacity gap in this research field that needs to be addressed. This need is reinforced by the fact that "*The area that is still not covered is the research on human factors, especially the post occupancy evaluation and the reuse or recycling of building products*" (Ismail and Hokoe, 2009, p. 3). In this statement, the authors support the need for further research into human factors. Other authors have also indicated that considering human factors throughout the design process will lead to the provision of comfort for the end user. The correlation between human factors and ergonomics has also been referred to by Karwowski (2007b, p. 25), who has stated that "*The greatest challenge for HF/E today is to develop a new mission of sustainable human-centred*". The importance of human factors should be taken into account by the various stakeholders in the different disciplines. This is confirmed by TSB (2009, p. 4): "*More expertise in human factors research and user-centred design is needed in engineering consultancies, product manufacturers, building designers, facilities management companies and others*". The building designers are one group of responsible stakeholders who need to be aware of both UCD processes and human factors. Designing without considering user needs in a systematic way may lead to various complaints at the post-design stages. This view is supported by Goins and Moezzi (2012, p. 1): *"When there is a mismatch between assumed and actual user needs or assumed and actual operators' practices, complaints can arise. These complaints might be viewed as part of the information gap between the incorrect or incomplete assumptions made during design and actual end-users needs and requirements"*. If there is any dissatisfaction from the users, then there must be a dysfunctional integration of user aspiration into the design. This issue can be solved through creating a system that can help designers elicit the users' needs and integrate them into design solutions. For example, Levin (2003, p. 26) has claimed that "*By integrating the analysis of the interactions between building, occupants, and the larger environment, researchers and designers will model successfully the fundamental relationships that should drive our design*". Clearly these statements support the need to integrate the user's needs into PBD. Before starting to explain the proposed approach to solving this issue, a brief review of the architecture design theories and approaches is provided with the purpose of checking their relevance to UCD theories. Only some of the existing approaches are reviewed in the following section, however, due to the space limitation in this paper.

The existing approaches and theories

There are various approaches in the building industry that have addressed to some extent the question of a building's occupants. For example, post-occupancy evaluation, ergonomics, usability measurements for building, building use in design management perspective, building accessibility, and design for all. Some of these are briefly reviewed below.

Post occupancy evaluation

Post-occupancy evaluation (POE) as a theory considers user needs through including the physical, technical and psychosocial aspects in the evaluation process. POE is "*the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time*" (Preiser et al., 1988 as cited in Blakstad, 2010). This definition is directly related to the importance of users' perceptions at the post-design stages. The theory presents an assessment tool for capturing the views of the users after they have occupied a building. The constructs used in the assessment are substantially different from those used in the process of user centred design.

Ergonomic design and building sustainability

The comfort of the user is the main driver behind these theories. Ergonomics theory is a good example of this. Hedge (2008) refers to ergonomic design as part of the environment that should accommodate the end-user's comfort, health and productivity. LEED also refers to the importance of having a comprehensive ergonomic strategy that promotes user health and comfort. Hussain and Hussain (1984, p. 624 as cited in Carey, 1988) have defined ergonomics as "*the science of human engineering which combines the study of human body mechanics and physical limitations with industrial psychology*". In this definition the psychological and physical aspects of users are considered the axis on which to achieve users' comfort. Other design attributes are not cited in this theory. USGBC (2008) provides guidance for current or expected ergonomic design. It has identified four steps, as cited by Hedge (2008), which will now be explained and summarized. The first stage is aimed at identifying the functions and activities of the building in a way that enhances ergonomics. User preferences should also be considered. There is also the possibility of users participating in the design processes. The second stage deals with the characterization of a group of expectations and performance goals to enhance health, productivity and comfort for ergonomic strategies. Then, a group of constructs is used to drive the design process. The third stage refers to design features such as equipment, tools, work aids, furnishings and accessories to reduce risk and be accepted by the end users. The last stage is to provide ergonomic education for the users. The designer should provide an opportunity for the end users to understand and take advantage of the ergonomic features of their environment. Meeting user needs in the early stages of design is not considered in this theory. Neither does the theory provide a systematic approach for capturing and using users' aspirations in the design processes.

Usability measurements for building

In this theory, the concept of usability is integrated into the design of a building from a human purpose point of view. It has been conducted through the CIB Working Commission on the Usability of Workplaces (CIB W111,2010). Blakstad (2010) refers to usability as a building that supports user activities and its physical surroundings. Usability is measured through efficiency, satisfaction and effectiveness attributes. The USETool has been determined as a tool for evaluating the usability of a workplace (Blakstad, 2010). Usability could be looked on as a social construction process, as argued by Fenker (2008).

It is defined as follows: "*given that they are designed for one or more activities, the artifacts are bearers of a set of possibilities and constraints as well as, most importantly, activity and social practices models*" (Fenker,2008,p. 3). The activities and social practices of the end user are pivotal, around which usability is conceived in a design. Blakstad (2010) has stated that usability consists of three main points. Firstly, specifying a building to achieve users' needs. Secondly, the building context is to determine the dimensions and relationship between the building and the end users. Finally, efficiency, through which user satisfaction and value creation contribute to the usability agenda. These three points indicate that usability depends largely on the type of users in mind. Usability should capture their age, gender, ability, etc. It is also essential to point out that usability requirements for a school are not similar to those for an office or residential building. In some cases, user needs could be attained without achieving a high level of satisfaction, for example by providing functions which are not suitable for the users' abilities.

The above theories have, to some extent, considered some of the user needs. However, they lack, in their systematic processes, consideration of capturing and translating end users' design constructs into design solutions. For this reason, there is a need to investigate the development of a new approach that can help designers to meet user needs through integrating various attributes of PD into a design. The questions that one may pose here are as follows:

- What is a suitable process for capturing and integrating user needs into PD strategies?
- What is the approach that could enable the designer to meet user needs during the design process?

We will try in this research to answer these questions and show how to establish a conceptual approach to solving the problem.

The Research Method for Integrating User Needs into Passive Building Design

The methodology followed in this research is classified into two parts. The first part follows normal research processes and the second the research methods used in systems development for creating the proposed UCD. Figure 1 illustrates the main steps that were followed in developing the conceptual model.

The first part

The first part of the research methods comprises identifying the research aim, the research problem and making sure there are no other approaches or theories that already exist which have tackled the problem under investigation. This part is also used as a platform for extracting the necessary knowledge for forming end-user design constructs.

The second part

The second part deals with the process used to develop our conceptual model. The process consists of several iterative steps, as shown in Figure 1. The process starts by classifying PD strategies into three dimensions. Then, the PD strategies are reviewed to ensure that their functionality is designed based on end-user needs. The third stage of the process is to search for a design paradigm that satisfies the conditions set in the previous step. A UCD theory which is used in the IT industry was investigated for its suitability for PBD processes. We found that there was great similarity between IT systems and building design processes. Based on this finding, we modified some aspects of the theory to harmonize with PD attributes and contents. Figure 1 shows the process stages.

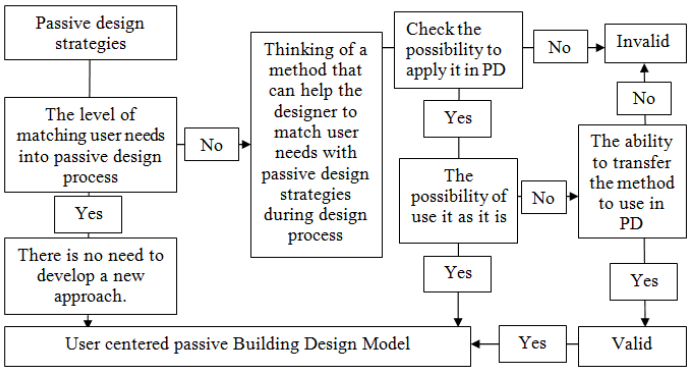

Figure 1: The process of the research methods to develop UCPBD conceptual model

User Centered Passive Building Design Concept

Three main stages were used to develop the concept model. The first stage comprises the determination of the PD dimensions. The second stage encompasses the design processes needed to implement the proposed approach. The third stage of the design involves the attributes that the designer must select and use to meet user needs. All of the stages are grouped to form the user-centred passive building design conceptual model as shown in Figure 2.

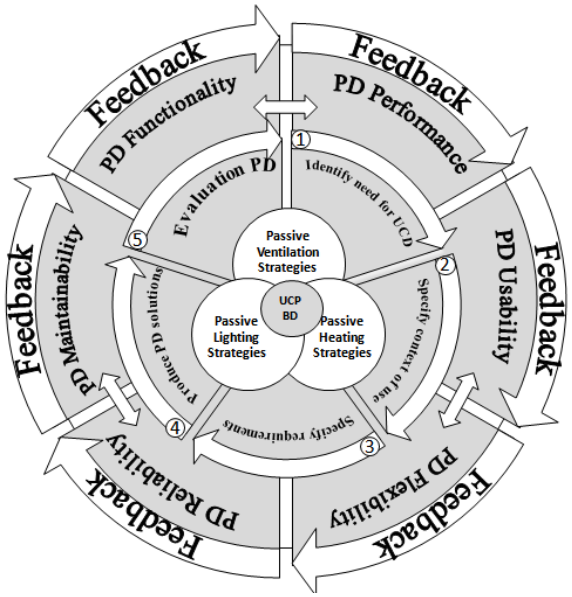

Figure 2: User centered Passive Building Design Model [UCPBDM]

Passive design Dimensions

PD is one of the approaches which have been proposed to reduce negative environmental impacts. It is one of the environmental design features. In our model, we categorized PD strategies into three main dimensions: passive design ventilation, passive design lighting, and passive design heating, as shown in Figure 3. The PD dimensions have been placed at the core of our conceptual model. This is the first task a designer needs to adopt. Based on these core dimensions, a designer will be able to develop design solutions that fulfil user needs as well as the functions of these core design elements.

Figure 3: Passive design strategies

User Centered design

Our thesis in this work is that UCD theory is the most suitable approach for bridging the gap between user needs and PD. UCD theory stems from software design in computer science and information technology. The purpose of establishing this theory is to promote user needs when designing software. The theory has been defined as follows: "*User centered design is a broad term, used to describe a design philosophy and a variety of methods in which the needs, wants, and limitations of end users are placed at the centre of attention at each stage of the design process*" (Uckelmann et al., 2011, p. 68). The ability of end users to manipulate the product to suit their purposes is described thus: "*Users are able to customize and adapt the software systems in use to their particular needs at hand, so that they can perform their work more efficiently and effectively*" (Prähofer et al., 2002, p. 1). This theory has also been applied in various other fields. This was one of the motivations that encouraged us to adopt it in passive building design processes.

Application of User Centered Design Theory

UCD was introduced as a theory for the designing of software. It was introduced as a process which helps users to be involved in the design process or at least to be asked to specify their aspirations. The theory is also used in other fields. Some of the applications are described next.

Applying UCD in Education

Education is one of the fields in which UCD has been used extensively, as stated by Kahraman (2011). It is employed in developing education courses. The process used in this type of application is as follows. Students as users are used as experimental tools in the development of a course by the tutor, in our research the tutor is the designer. Students give feedback about the models when they receive the positive and negative attributes from the tutor. This interactive and dynamic relationship is viewed as one of the best methods for developing online courses.

The UCD theory approach has been used to redesign three modules of interior design at the School of Architecture at Cankaya University in Ankara in Turkey. The three courses were part of Social and Cultural Factors in Design, which concerned the interrelationship between cultural dynamics and physical settings. UCD was also used to elicit user needs and satisfaction with the Interior Architecture course. The last course was Urban Design. The design of this course also followed the same pattern.

Two methods were used for the purpose of assessing the above courses. These were focus groups and a questionnaire, which were used to allow students to identify their needs and expectations. The first method used three questions (Kahraman, 2011):

- What are the factors which increase the learnability of courses?
- What are the factors that might increase your success in the courses?
- If you were the teacher or lecturer for this course, what are the best methods to increase the success of your students?

The questionnaire included the following questions:

- What do you think about the content, teaching method and the tutor of the course?

- What is your satisfaction about the course: please evaluate from 5 to 1 as maximum satisfied to minimum satisfied?

The above method shows that a questionnaire can be used to evaluate products that are designed based on UCD methods. This will be further investigated in our research to examine whether a similar method could be developed to assess our proposed model.

The findings of the data from the previous steps were collected and analysed and the results from this exercise used to redesign the above-mentioned courses. The findings were summarized under five main points: (1) the students asked to practise what they learned in the class; (2) the support of friendship between the lecturer and the students was very important; (3) the communication between both the tutor and the students must be continuous; (4) the feeling of memorizing the whole course must be mitigated; and (5) remembering the course through other methods, such as visual association. A design solution was presented via visual media and focus groups and was evaluated under eight categories: (1) discussion in class; (2) using visual media to present the subject; (3) creating an exchange relationship with students; (4) discussing several subjects and their relationship with the design; (5) changing from memorizing the course by heart; (6) providing examples, such as those from Ankara; (7) motivating the students to express their feelings; and (8) participating in the course, including through group work, which increases learnability.

The result of this assessment was 92% satisfaction. This is a very significant result, which demonstrates the usefulness of the UCD approach when utilized to develop courses. Thus, using UCD in this instance has resulted in users' satisfaction and improved their productivity, i.e., assessment results.

Applying UCD in the Swedish National Union Catalogue

Lindström and Malmsten (2008) have used the UCD approach to rebuild the Swedish National Union Catalogue. They followed some of the ISO 13407 processes. The design process has been iterative and at the same time the group project was formed of individuals from several sectors, such as engineers and designers. The users were part of the process. Various methods were used to encourage users to participate in the process. The methods were survey, usability testing and a focus group. In addition to this, interviews with several categories of user such as researchers and library workers were used.

Survey method

Understanding and specifying the context of use is the first process under ISO 13407. The survey and focus group methods were used to extract the context. The survey technique used was that of multiple choice and open questions. The questionnaire was concerned with the old version of LIBRIS (the Swedish National Union Catalogue of the National Library of Sweden). The open-question method was used to help develop and improve LIBRIS through open questions which gave the users a free area to express their ideas.

Focus group

The main task of the focus group was to gather qualitative data. The approach included two routes: the first was to record user behaviour, the second involved workshop groups to discuss the positive and negative aspects of the design and make suggestions.

These two examples and others have used UCD design theory to ensure that the designer can empower the user to participate in the design processes without conflict. The theory is also used in other sectors, such as telecommunication, health care and dentistry. The wide use of the theory is evidence of its capability to capture and integrate users' aspirations into design processes and, because of these characteristics, it has been chosen for eliciting end users' design constructs in passive building design processes.

A literature review has shown that the theory has been used to develop some of the ISO standards, such as ISO 9126 and ISO 13407. These standards have been designed to

enhance the integration of user needs into software design. These ISOs are reviewed briefly in the following section because of their importance to our work section.

ISO 13407

This standard illustrates the process that helps designers to integrate user needs throughout the design process. The process is divided into several stages, as cited in ISO 13407 (1999) and shown in Figure 4.

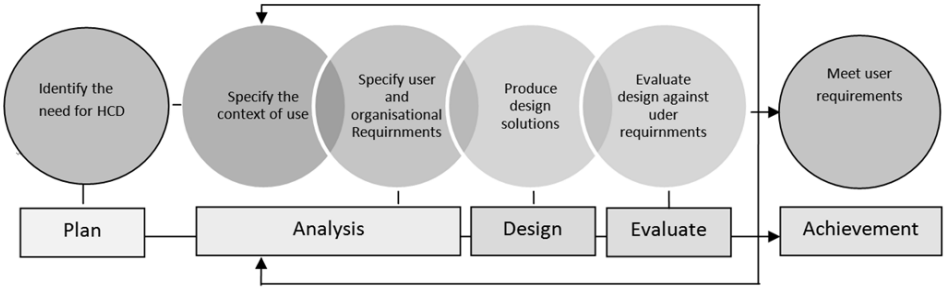

Figure 4: ISO 31407 process (ISO 13407, 1999, p.6)

The process for an ISO has been summarized by Jokela et al. (2003) as follows:

- *Specify the context of use*: this stage consists of three main areas, starting with identifying the user, the usage environment, and the purpose for using the product.
- *Specify user and organizational requirements:* this will be achieved through identifying the factors that can help users to be able to perform a task when they use a product quickly without any barriers. This stage aims at determining the design line requirements.
- *Produce design solutions:* that is to say, create a solution for a product based on factors such as usability attributes.
- *Evaluate designs against requirements*: this answers the question of the extent to which the end product can be measured against user assignments.

The above key processes are the main core of UCD theory. The first stage is to assist the designer in managing, planning the design process and defining the context of building asset use. The second phase is directly related to extracting and organizing user requirements. The subsequent stage is for the designer to derive a possible solution that satisfies all of the user wants and wishes. In the last stage, the designer needs to verify if the proposed solution or product satisfies and meets user requirements. If the requirements are not met, then, ultimately, the designer needs to go back and specify the context of use and go through the design processes until the end-user wishes are fulfilled. Following this design paradigm will ensure that user needs are met before delivering the end product.

Design process of the proposed approach

The second component of the UCPBD conceptual model is the design process steps that are extracted from ISO 13407. The process comprises five main stages, as shown in Figure 5. The first stage aims at identifying the need for UCD. In this stage the designer starts to think of the design concepts. The designer should keep the user requirements in mind when searching for design concept solutions. The stage starts with the designer thinking of the problem context, designing a bubble diagram and creating design solution sketches. The designer should comply with both the user needs and passive design strategy [Lighting, Ventilation and Heating (L.V.T)] functional requirements. The purpose of the second stage is to identify the requirements and contexts of use. The stage includes an assessment of the passive design attributes and their interrelationships. The main outcome is to optimize the passive design functionality, i.e., the three dimensions (L.V.T) of PD. The passive design

functions should operate in a way that satisfies user needs. The third stage is aimed at selecting the best design solution. The user contextual design attributes from the previous stages will enhance and support the designer's role in creating the best design solution strategies that meet both functionality and user needs. The fourth stage is the evaluation and is one of the tricky phases. The designer should be experienced in evaluating his/her work based on the user-needs design constructs. The outcome of this stage is to decide whether the derived design solutions are successful or unsuccessful in capturing both the functionality of PD and the users' design constructs. If the design solutions pass the assessment test, the designer will then proceed to the development of the next design solution. If this is not the case, the designer should go back to the first stage to remedy the dysfunctional aspects of the derived design solution.

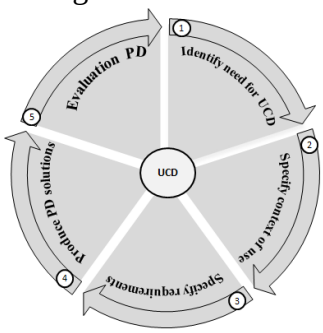

Figure 5 : UCD process

To meet end-user requirements, a raft of attributes are normally considered and evaluated by the designer at various stages of design. ISO 9126 was developed to illustrate how to incorporate human factors into the design of software. The importance of this process to our research is explained in the following section.

ISO 9126:

This standard was conceived to promote the quality of software design. The standard is defined as "*a software product quality model, quality characteristics, and related metrics*" (Zeiss et al., 2007, p. 2). As shown in Figure 6, the standard includes six attributes that are composed from several sub-attributes.The model is mainly based on quality-in-use attributes. Quality in use is defined as "*the quality perceived by an end user who executes a software product in a specific context*" (Zeiss et al., 2007, p. 2). The focus of this definition is on the necessity of considering user needs in the design of a product in a specific context. This model has been developed based on six main attributes and their sub-attributes, as shown in Figure 6. The main attributes are: Functionality, Reliability, Usability, Efficiency, Maintainability and Portability. We have adopted ISO 9126 in developing our user-centred passive building design model and, because of the importance of these model components for our study, they are explained in the following sections.

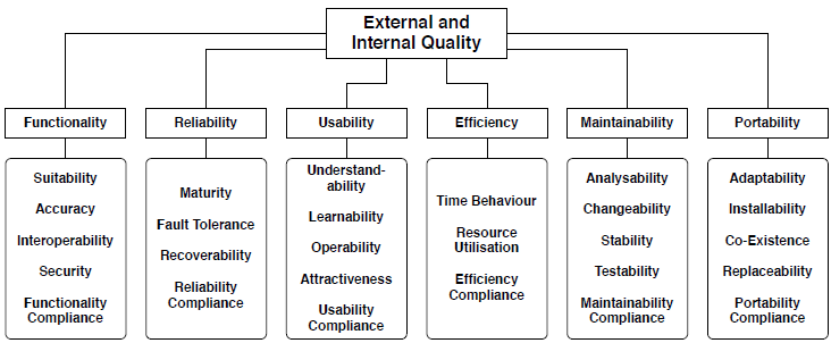

Figure 6: External and Internal Quality ISO 9126 (Padayachee, 2010, P.3**)**

Passive design human attributes

This is the third component of our conceptual model. This research has identified six main attributes. The sub-attributes for each attribute are specified based on ISO 9126, as illustrated in Figure 3. Figure 7 shows the sub-attributes of each of the main attributes of the user-centred passive building design. PD human attributes are defined as [Factors that capture the needs, wants and limitations of end users in relation to functionality, performance, maintainability, reliability, usability and flexibility]. These attributes will be used to aid designers in integrating PD issues and human needs into the design process. In our model we have replaced the efficiency and portability criteria with performance and flexibility, respectively. We selected the "performance" term instead of efficiency to assess passive design effectiveness. Furthermore, the portability terminology is replaced by flexibility because it is in line with architecture practices. The number of sub-attributes for all the main attributes is 22, as illustrated in Figure 7. Each of these attributes is formed from several end-user factors. There are 132 of these factors in total and these have been extracted from the literature review.

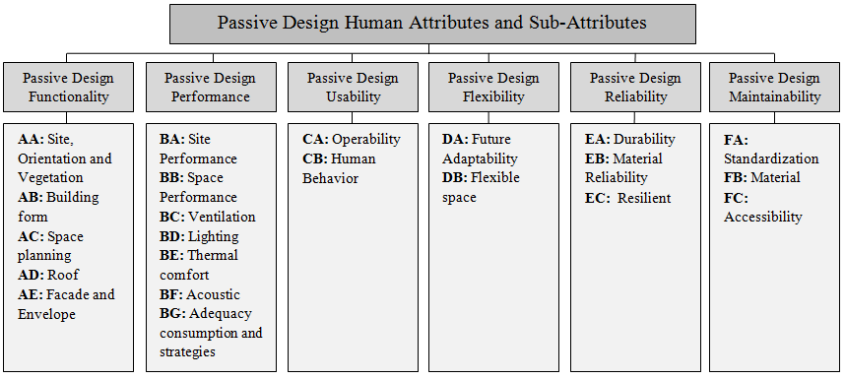

Figure 7 : UCPBD Attributes and sub-attributes

Model testing process

The purpose of this stage is to develop a systematic process for testing the solutions generated from the model. The systematic process consists of four steps. The first step compares the proposed approach with the existing architecture theories as introduced in the previous section. The second step is designing the questionnaire for capturing end users' aspirations. The questionnaire should include the attributes, sub-attributes and end-user factors identified in the previous sections. The third stage is the validation for both the model and the questionnaire. This was carried out by seeking the views of architects who work in academia. Their feedback was used to modify the contents of the model and questionnaire. The next step was to seek the opinion of practising architects on the effectiveness of the end users' design constructs and the usefulness of the main model components.

Discussion:

The proposed user-centred passive building design is an innovative approach and a tool that will assess and integrate user needs during the design processes. Making user needs the benchmark around which design solutions are derived will help to enhance the indoor environment and well-being of the occupants. The proposed approach will help to ensure that the design functions and user attributes are integrated to maximize user comfort and satisfaction. This approach will assist in finding the interaction between user needs and

passive design strategies. Our approach aims to assess if end users' needs are met during the design processes, whereas other existing methods assess user needs at the post- design stages. The existing approaches also use a very limited number of design constructs in the assessment process. Thus, our proposed methodology might go a long way towards responding to some of the research needs identified in the previous sections of this paper.

Conclusion and future research work:

The main thesis of this paper is to demonstrate that there is a lack of research in the area of UCD. The spectrum of researchers in the built environment working on user-centred design is very limited. The paper gave an overview and evaluation of some studies that have been carried out in relation to user-centred design. An approach that links user needs and passive design is proposed in this work. The approach has been developed through various processes and stages. We have shown to some extent that socio-techno-economic drivers ought to be considered in the passive design of buildings in order to meet users' requirements. User-centred design is an important tool that is able to assess the satisfaction and comfort level needs of building end users during the design processes. By using end-user needs as a benchmark for design assessment, the potential for improving the indoor environment and user well-being in buildings is enormous. This study may go a long way to building capacity and knowledge in this vital area of practice and research. It is hoped that design standards and the appropriate tools could be developed for research and practice purposes.

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