

# A conceptual process model for the sustainability of a healthy building

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## Abstract

Healthy buildings may lose their healthy characteristics over time and due to changing circumstances during their usage phase, which may lead to biological and psychological health problems for their users. Thus a process model is required for buildings which ensures that the initial healthy environment is retained. This study therefore introduces a conceptual Process Model for the Sustainability of a Healthy Building. In the study, the sustainability of the healthy building and its criteria were determined by the help of the definition of sustainability and associated criteria. Then, the changes which prevent the building from sustaining its healthy status were introduced. Based on the events that lead to the loss of healthy building performance, the actions and functioning of the process model were created. Action steps were then composed and the relationship between these steps were established. As a result, the principal components of this model are determined as Achievement of a Healthy Building, Sustainability Assessment of a Healthy Building, and Sustainability Management of a Healthy Building. Application of the procedures in the proposed model can help maintain the healthy characteristics of buildings throughout their operational lifespan, thereby preserving the basic requirement for a healthy environment.

## Keywords

Healthy building, Building biology, Performance evaluation, Sustainability assessment, Sustainability management.



## 1. Introduction

Healthy buildings meet biological, psychological and social needs of users by their quality indicators (Balanlı et al., 2006). People may spend up to 90% of their life within buildings; when those buildings fail to fulfil the users' needs, they may cause health problems or even contribute to death. To establish a healthy building, and to prevent health problems related to the use of buildings, architects should make the maximum use of building biology which "... is a scientific study, the objectives of which are to prevent the negative effects that influence people's lives, by establishing the relationships between the building, its environment and people; to produce and control the decisions which lead to the design, construction and use of buildings in terms of people's health..." (Balanlı and Öztürk, 2004). However, buildings which are designed, constructed and presented to use under healthy conditions may change in character over time, and may cause biological and psychological health problems for their users.

Discontinuity of a building's healthy characteristic during its usage phase results from the fact that quality indicators of the building degrade in time due to the changes and new circumstances which the building is exposed to. Since a healthy lifestyle is a basic human need, buildings which are designed and constructed to meet these health needs should not be negatively affected from the changes which lead to health problems for users. It is therefore important that the initial health performance of the building should be sustained throughout its lifespan.

A review of the literature indicated that the majority of studies on sustainability focus on an object, project or system in terms of sustainable development. Analogously, studies which assess the sustainability of a building show whether or not the building is ecologically, economically or sociologically sustainable. However it is thought that sustainability is not a concept that is limited to sustainable development, but that it encompasses the sustainability of any positive situation or characteristic. Based on this approach, it should be possible to de-

termine the health-performance of a building with regard to the needs of users, and to evaluate the sustainability of this healthy building status over time.

A building can be thought to follow a specific process, since the following situations may occur while ensuring that the building continues to provide a healthy environment during its lifespan:

- being presented to users in a condition which meets healthy building indicators,
- losing healthy building status during the usage phase, and
- regaining healthy building status.

In this context, a process model is needed to ensure that the building initially meets healthy building performance indicators and sustains this condition. Literature review revealed no such model for healthy buildings. Therefore it was considered necessary to establish a conceptual process model intended for the sustainability of a healthy building.

In the framework of this sustainability process model, the satisfactory ongoing performance of a building in terms of providing a healthy environment for users is important for the following reasons:

- contributing to the sustainability of human health by facilitating the well-being of users,
- increasing the quality of life and efficiency of users,
- contributing to sustainable development in the following fields:
  - ecological sustainability, by minimizing natural resource consumption arising from the recurring maintenance and rehabilitation of buildings,
  - economic sustainability, through the efficient use of resources (land, labour, capital),
  - social and cultural sustainability, through the protection of a healthy social environment.

In addition to healthy buildings such a model may be applicable to other studies on the sustainability of a positive situation or the characteristics of any object, project or system.

The present study was based on the following assumptions:

- The sustainability model of a

healthy building comprises three main activities as:

- Achievement of the healthy building; a precondition for sustainability.
- Sustainability assessment of the healthy building; determining whether the building has lost its healthy status during the usage phase.
- Sustainability management of the healthy building; determining and applying any necessary procedures in accordance with the results of the sustainability assessment.
- By the application of those activities, the building's healthy status can be sustained as long as it exists.

In this study, healthy buildings were defined at first. The sustainability of the healthy building and its criteria were determined by the help of the definition of sustainability and associated criteria. Then, the changes which prevent the building from sustaining its

healthy status were introduced. Based on the events that lead to the loss of healthy building performance, the actions of the process model were created. Action steps were then composed and the relationship between these steps were established. The result of the sustainability process is a series of procedures which will ensure that the building retains its initial performance level, in terms of providing a healthy environment, throughout the usage phase.

## 2. Healthy buildings

Buildings which fulfil the users' biological, psychological and sociological needs by their quality indicators related to physical and social outdoor/indoor environmental characteristics can be defined as healthy buildings. Table 1 and 2 show the quality indicators of a healthy building.

**Table 1.** Healthy building quality indicators related to physical and social outdoor environmental characteristics.

CHARACTERISTICS			QUALITY INDICATORS	
PHYSICAL OUTDOOR ENVIRONMENT	Natural	Non-living	Air	Prevention of polluted air access Resistance to wind ...
			Water	Prevention of polluted water access Resistance to flood ...
			Earth	Prevention of the access of soil pollutants Resistance to earthquake Resistance to landslides ...
		Living	Plants	Prevention of the access of plant remains, pollens, etc. ...
			Animals	Prevention of harmful animal (insect, mosquito, snake, rat, bee, etc.) access ...
			Micro-organisms	Prevention of virus, bacteria, fungi formation and access ...
	Built	Buildings	Protection from visual pollution Not being affected from the negative conditions (fire, noise, etc.) from surrounding buildings Benefit from the surrounding buildings against the factors like sunlight, prevalent wind, etc. Not being negatively affected from surrounding buildings while benefiting from the daylight Having a sufficient infrastructure system (clean water-waste water, gas, etc.) Appropriate solid waste management Protection from electro-climate pollution (ion concentrations, electro-magnetic fields) ...	
		Roads	Having an acceptable outdoor noise level Having roads with the qualification that fulfils the user needs (roadway, pedestrian way, disabled path, etc.) ...	
		Parks	Physical and visual benefit from gardens, landscape, etc. ...	
		....	...	
SOCIAL OUTDOOR ENVIRONMENT	Groups	Gathering the compatible groups together Providing the relationships between the groups ...		
	Norms (religion, moral, custom, trend, law)	Conformity to the norms related to outdoor social structure		
	Socialization process	Affecting socialization process positively (development of personality, attitude, belief, etc.) Suitability to outdoor social structure (education, occupation, income level, intellectuality level, status, etc.) Conformity to cultural structure ...		

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**Table 2.** Healthy building quality indicators related to physical and social indoor environmental characteristics.

CHARACTERISTICS		QUALITY INDICATORS	
PHYSICAL INDOOR ENVIRONMENT	Dimensional-formal	Dimension	Width, length, height, area, volume, proportion which fulfil the user needs ...
		Form	Appropriate form for user needs Appropriate furnishing layout for user needs ...
	Visual	Light (daylight, artificial light)	Having required lighting quantity (illuminance) Having required lighting quality (directionality of light, colour properties of light, shadow properties, illuminance distribution) Having required surface specifications (light reflectance, transmittance, luminance of the surfaces, surface reflection types) ...
		Colour	Appropriate colour compositions for user needs (surface hue, value, chroma; contrast colour schemes) Light with colour properties (colour appearance, colour temperature, colour rendering index) that doesn't affect the desired colour composition Surfaces with textural properties that don't impair the desired colour effect ...
		Aesthetics	Appropriate proportion, balance, symmetry, rhythm, harmony for the creation of the desired effect Forming from products which fulfil the user needs with their sight, pattern, texture Well-cared appearance ...
	Auditory	Acoustics	Appropriate sound reflectance for user needs Appropriate sound absorption for user needs ...
		Noise	Not creating noise Appropriate sound transmission loss for user needs Having acceptable noise levels ...
	Tactile	Safety	Surface hardness-softness that doesn't create negative effects on users Surface roughness- slipperiness that doesn't create negative effects on users Not being sharp Appropriate surface temperatures Not being toxic ...
		Cleanliness	Not depositing dust Not depositing dirt, rust, stain Not hosting microorganisms Not producing pollution ...
	Atmospheric	Air quality	Appropriate air compound for user needs (O <sub>2</sub> ratio, etc.) Not containing air pollutants (gases and vapours /carbon monoxide, carbon dioxide, nitrogen oxide, sulphur dioxide, formaldehyde, benzene, toluene, ozone, radon, etc./ and suspended particulates, fibres, organisms /dust, lead, asbestos, plant and animal fibres, bacteria, viruses, etc./) Not containing radiation (UV, X-ray, etc.) Not producing unwanted odours ...
		Climate	Supplying comfort temperatures Having required relative humidity (water permeability, water absorption, moisture equalization) Having required air pressure Airflow not affecting users negatively ...
		Electro-climate	Having acceptable natural electric and magnetic field strengths Ion concentration balance Artificial alternative electric, magnetic and electromagnetic field protection ...
SOCIAL INDOOR ENVIRONMENT	Groups	Contribution to indoor group formation Being able to integrate the groups Gathering the compatible groups together Preventing the negative interaction of the groups with different structures ...	
	Norms (religion, moral, custom, trend, law)	Conformity to norms ...	
	Socialization process	Contributing to having a positive socialization process Suitability to beliefs, interests, attitudes, requests Suitability to education, occupation, income-intellectuality levels, status, etc. Conformity to cultural structure ...	

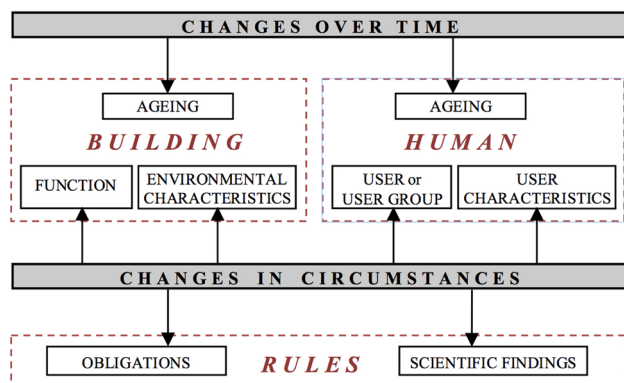
### 3. Sustainability of a healthy building

Sustainability can be defined as ensuring that an existing, intended or achieved positive situation or characteristic of any object, project or system is maintained at the same quality over a specific period of time. In this context, sustainability criteria can be determined as follows (Sarp, 2007):

- The object, project or system should achieve a specified performance.

- The object, project or system should resist to the changes by performing the functions expected from it.
- The continuity (permanence) of the object, project or system's specified performance should be protected over a specific period of time.

Based on this definition of sustainability, the sustainability of a healthy building can be defined as the continuation of the capacity of a building



**Figure 1.** The changes which cause to the loss of healthy building status during the usage phase.

to meet the state of being healthy required from it, without interruption, as long as it exists. The relevant criteria regarding the sustainability of a building's healthy status can be determined as follows:

- The building should be designed and constructed in a way that does not negatively affect its users' health.
- The continuity of the building's state of being healthy should be ensured over its lifespan.

From the sustainability definitions and sustainability criteria above, it can be inferred that the loss of a building's initial healthy status during the using phase arise from exposure to new conditions and therefore potentially negative effects over time. According to this concept, the following points play a role in the loss of sustainability of a healthy building:

- Changes over time.
- Changing circumstances.

These changes which may occur during the lifespan of the building can relate to the building itself, the users or the rules followed during design and construction.

Ageing causes a gradual decrease in a building's performance. As a result, the building may fail to meet the levels of performance required of it. Due to the changes in building (change of function, changes in environmental characteristics) or in users (ageing of the existing user, replacement by a new user, changes in biological, psychological or social characteristics of the existing user), user needs may change. Changes in rules (laws, regulations, directives, codes, guidelines, specifications, scientific findings, etc.) may result in the building's existing perfor-

mance being insufficient to meet new guidelines (Figure 1).

It can be concluded that two basic problems arise from changes which affect a building:

- Deficiency in the building's quality indicators, depending on the changes over time and changes in rules.
- Inability of the building to continue to meet user needs, which change over time or instantly.

The impairment of the healthy building status during the usage phase occurs as follows:

- From the date of completion, a building is exposed to changes over time or variations in circumstances.
- Being affected negatively by those changes, the quality indicators fail to meet the functions required from them or remain insufficient for the new circumstances or needs.
- The building is not able to sustain the healthy status required from it.

#### 4. A model for the sustainability process of a healthy building

The term process is defined as "... a series of events or actions which have a union between each other or which repeat, progress, or develop in an order" (Turkish Language Institution, 2005). Ensuring the sustainability of a healthy building can be characterized a process, as it contains the following components:

- Design phase,
- Construction phase,
- Usage phase,
- Temporal or circumstantial changes,
- Actions to re-establish the healthy building status.

Sustainability of the healthy status throughout the lifespan of the building is thought to be possible with the help of a sustainability model which contains the actions of this process.

##### 4.1. Actions of "the process model for the sustainability of a healthy building"

According to the sustainability criteria, in order to provide sustainability, firstly, there needs to be a positive condition which is worth sustaining. In this context, designing, construc-



tion and presenting the building for use such that it meets the requirements for health performance and does not negatively affect the health of users is a prerequisite for the sustainability of the healthy building. Accordingly, the first action of the model can be determined as achievement of a healthy building.

Each building which is in a healthy status at the beginning of the usage phase by performing the first action of the model, undergoes time or circumstance changes during the operational phase. Those changes may cause loss of healthy status. Therefore it is necessary to determine whether the building still meets health performance criteria following these changes. This can be achieved by a sustainability assessment study.

Sustainability assessment is defined by the IUCN [International Union for Conservation of Nature and Natural Resources (1956)-The World Conservation Union (1990)] as a structured analytical process for measuring circumstance changes and assessing the progress of a system toward sustainability (Guijt and Moiseev, 2001). Based on the sustainability definition and criteria explained in Chapter 3, sustainability assessment can be defined as determining whether or not any object, project or system could protect the positive situation or characteristic desired from it against an existing constant change over a desired period of time. Briefly, sustainability assessment determines whether or not there is sustainability. Therefore the second action of the model can be determined as sustainability assessment of the building's health. Sustainability assessment of the healthy building can be defined as determining whether the building could retain the health performance expected from it against changes associated with time and circumstances during the usage phase.

If the result of the sustainability assessment is negative, one should proceed with the management study to restore the previous healthy conditions. Sustainability management can be defined as a series of actions for determining and achieving the required targets of any object, project or system in order to ensure re-running

of the concerned object, project or system properly, effectively and efficiently. Following the negative judgement of the sustainability assessment, the management study seeks responses to the questions of "What can be done about the issue?", "What is the appropriate response to the existing negative situation?", "Which precautions can be taken?". Briefly, sustainability management includes regulatory precautions that should be taken following the loss of sustainability. In this context, when it is found that the building has failed to meet health performance criteria, the third action of the model (sustainability management of the building's health) should be performed. Sustainability management of the healthy building can be defined as a series of actions performed in the framework of the process of applying the activities required for the building to possess the targeted health performance and to regain its sustainability.

Following these definitions, the actions within the sustainability model for a healthy building can be summarised as follows (Figure 2):

- Achievement of a Healthy Building
- Sustainability Assessment of a Healthy Building
- Sustainability Management of a Healthy Building

A building which appears to sustain its healthy status by means of sustainability assessment, or which regains it by means of sustainability management intervention may be repeatedly exposed to further ageing or changes of circumstance during the usage phase. Sustainability assessment and (if necessary) management intervention is therefore a cyclical process, as seen in Figure 2.

## **4.2. Action steps of "the process model for the sustainability of a healthy building"**

### **4.2.1. Steps of the "achievement of a healthy building" action**

The first stages in the delivery of a healthy building are the design and construction phases. The building should be designed and constructed in such a way that it does not contribute to biological or psychological health problems for its users. In order

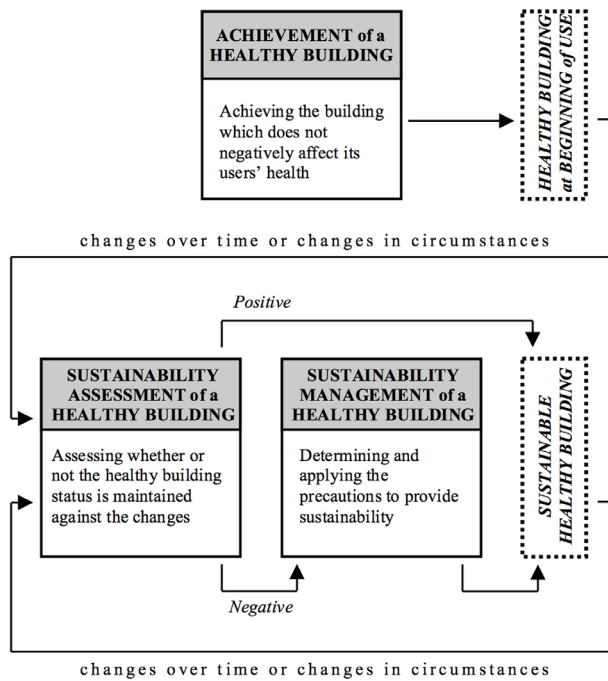


Figure 2. The running of the process model for the sustainability of a healthy building.

to achieve this, it is necessary to determine data which will feed into the performance targets. Determination can be achieved by;

- defining the building,
  - identity of the building (name, location, size, number of storeys, designers, contractors, operation year, useful lifespan, etc.),
  - function/s of the building,
  - environmental factors related to physical/social outdoor/indoor characteristics of the building
- ♦ physical – outdoor factors related to natural and built environment,
- ♦ social – outdoor factors related to groups and individuals forming those groups,
- ♦ physical – indoor factors related to dimensional-formal, visual, auditory, tactile, and atmospheric characteristics of the building,

- ♦ social – indoor factors related to groups and their members.
- defining its users,
  - identity of the users (age, duty at the building, usage period / daytime-night-full time/, temporary-permanent usage, etc.),
  - biological, psychological, sociological characteristics of the users (physiological disorders, sicknesses, disabilities, sensitive groups /infants, children, elders, pregnant women/; psychomotor, emotional, cognitive behaviours; their groups, norms, etc.),
- defining the rules (laws, regulations, directives, codes, guidelines, specifications, scientific findings, etc.) that should be followed during the design and construction.

Thereby, it can be clearly defined what type of environment is to be created for which type of users and by obeying which rules. These data help determine the performance targets which will guide the design. Table 3 samples the determination of a target health performance. This determination should be performed within all of the quality indicators shown in Table 1 & 2. While measurable values can be expressed by numbers, subjective values can be scaled as more/less, easy/difficult, etc.

Following the design and construction phases, the building should be checked to establish whether it actually meets the agreed health performance targets, against potential negative situations such as design and construction errors. In this context, the initial health performance of the building should be evaluated to confirm that it meets the target performance (Table 4). While values able to be expressed by numbers are measured by the relevant devices, subjective indicator values (aesthetics,

Table 3. Determination of target performance.

USER			BUILDING				
CHARACTERISTIC		NEED	QUALITY INDICATOR & VALUE		ENVIRONMENTAL CHARACTERISTIC		
BIOLOGICAL	Nervous system	Being able to sleep and rest	Having acceptable indoor noise level that meets requirements of sleeping and resting	35 dBA*	Noise	Auditory	Physical Indoor Environment

\* Assessment and Management of Environmental Noise Regulation; WHO, 2009.

**Table 4.** An example of performance evaluation at the beginning of the use.

QUALITY INDICATOR	TARGET INDICATOR VALUE	EXISTING INDICATOR VALUE	COMPARISON	RESULT
Acceptable indoor noise level that meets requirements of sleeping and resting	35 dBA*	25 dBA**	$35 \text{ dBA} - 25 \text{ dBA} = F$ $10 \text{ dBA} > 0$ $F > 0$	POSITIVE

\* Assessment and Management of Environmental Noise Regulation; WHO, 2009.

\*\* Measured data at the beginning of use.

etc.) can be determined by observations, interviews or surveys. Thereby, the building which is healthy can be identified as an object and environment in this stage. During the identification, the building materials/pieces of components and elements can be clarified as well as the environmental quality indicators and their values on a “health status document”.

In terms of achieving the required performance, the steps of the “Achievement of a Healthy Building” Action can therefore be determined as follows:

- Pre-design identification
- Determination of target performance
- Design
- Construction
- Performance evaluation at the beginning of use
- Healthy building identification at the beginning of use

#### 4.2.2. Steps of the “sustainability assessment of a healthy building” action

Undergoing changes related to time or circumstances, failure of the current health performance to meet the conditions of the post-change period, and loss of healthy building status may occur. According to this sequence, time-related or circumstantial changes which can negatively affect the sustainability should be determined first. While changes of;

- function,
- user or user group,
- ageing of users

can be easily determined by observation or interview;

- ageing of the building,
- environmental factor changes,
- biological, psychological, or sociological characteristic changes in users,
- changes of rules

determinations are more complicated as these topics involve many components and there is a possibility of developing many changes in each of all. To determine latter changes, control lists may be used.

Identifying the building, users or rules which have changed is necessary in order to determine the new operating conditions. Post-change identification can be made as;

- the identity, object (building products), environment, function definitions of the building,
- the identity, biological, psychological, sociological characteristic definitions of the users,
- the obligation and/or scientific finding definitions.

Identification should be made not for all of the characteristics, but only for the changed ones, unlike the pre-design identification. Any revised performance targets arising from new identification should also be determined. This determination should only be performed within the quality indicators that may be affected from the changes. Table 5 samples the determination of the new target health performance for supposed occasions as a user change (new user with psychological disorder and ischemic heart disease) and an outdoor environmental factor change (construction of a highway nearby the building).

A performance evaluation can then be conducted to determine whether the building’s existing health performance is appropriate for the new situation. Meanwhile, the ways in which the performance has been affected by time-related and circumstantial changes should be determined and a decision should be made regarding the adequacy of the building’s quality indicators (Table 6). At the end of the assessment, the following decisions may be made about the situation of the building:



**Table 5.** Determination of post-change target performance.

USER			BUILDING				
CHARACTERISTIC		NEED	QUALITY INDICATOR & VALUE		ENVIRONMENTAL CHARACTERISTIC		
BIOLOGICAL	Nervous system	Being able to sleep and rest without being affected from environmental noise	Having acceptable indoor noise level that meets requirements of sleeping and resting	35 dBA*	Noise	Auditory	Physical Indoor Environment
	Circulatory system	Not having a myocardial infarction due to stress reaction	Having acceptable outdoor noise level that meets requirements of the user with circulatory disorders	50 dBA**	Roads	Built Environment	Physical Outdoor Environment
	Endocrine system	Not secreting stress hormones (catecholamines, corticosteroids)	Having acceptable indoor noise level that not creates a psychophysiological effect on user	30 dBA***	Noise	Auditory	Physical Indoor Environment
PSYCHOLOGICAL	Emotional behaviour	Not getting stressed	Having acceptable indoor noise level that meets requirements of the sensitive user (individuals with physical - psychological disorders or chronic insomnia; elders)	30 dBA****			

\* Assessment and Management of Environmental Noise Regulation; WHO, 2009.

\*\* WHO, 2009.

\*\*\* Ising and Braun, 2000.

\*\*\*\* WHO, 1999; 2009.

Note.  $L_{night}$  = 50 dBA is the outdoor threshold noise level. For indoor level, a 21 dB insulation level is accepted by WHO.

- The status of the building remains healthy, or
- The healthy building status is no longer sustained due to the effects of time and/or changing circumstances on the quality indicators.

From these explanations, it is considered that the “Sustainability Assessment of a Healthy Building” Action should contain the following steps:

- Determination of changes
- Post-change identification
- Determination of post-change target performance
- Post-change performance evaluation
- Decision

#### 4.2.3. Steps of the “sustainability management of a healthy building” action

If a result of an assessment study determines a negative condition, a management plan should be conducted, to develop, analyse, and compare potential actions to achieve the required situation and to select the appropriate response among them. Then, the ap-

plication of the decision is carried out (NRC, 1983).

The sustainability management plan of a healthy building identifies the potential actions to regain the health performance, to select the most appropriate solutions, and to carry out the necessary actions to achieve the required level of performance. Based on the example above, precautions should be taken for the 35 dBA noise difference seen in Table 6 to regain the sustainability. Options as;

- precautions at the environmental factors by creating artificial ridges, noise barriers, landscaping, etc.
- precautions at the building itself by designing a double wall construction, using sound absorption products, etc.

should be determined at first. After the prediction of the noise insulation value of each option by calculations and/or comparisons, the decision upon the most appropriate option should be made. After the application of the selected option, the building with the new environmental factors will be

**Table 6.** An example of post-change performance evaluation.

QUALITY INDICATOR	TARGET INDICATOR VALUE	EXISTING INDICATOR VALUE	COMPARISON	RESULT
Acceptable indoor noise level that meets requirements of a sensitive user	30 dBA*	65 dBA**	30 dBA – 65 dBA = F – 35 dBA < 0 F < 0	NEGATIVE

\* The minimum target level is selected from the “Table 5 Determination of post-change target performance” as the required min. level will fulfil the whole needs.

\*\* Measured data after the occurrence of changes.

healthy again for its new user.

Based on these functions, the steps of the action of the “Sustainability Management of a Healthy Building” can be determined as follows:

- Determination of appropriate options
- Decision
- Application
- Result

#### 4.3. Application of “the process model for the sustainability of a healthy building”

The major actions and minor steps of the model for the sustainability of a healthy building, and their relationships is shown in Figure 3. By applying the first action of the model, buildings achieve the required level of health performance at the beginning of the usage phase. In the event of a negative result produced by the performance evaluation made during this process, feedback should be provided to ensure the healthy status of the building at the beginning of use.

Once the building is operational, the first sustainability assessment should be performed when a circumstantial change is thought or reported to have occurred. For example, the building should be assessed when it is thought or predicted that an environmental change has occurred, or when a change of function or user is reported. If a regulatory change occurs, the assessment should be conducted when the relevant specialist who attends the study is acquainted with the change. However, in terms of the ageing of the building, the assessment should be performed within the first three years at the earliest and six years at the latest. Because it can be concluded that the earliest ageing at the building occurs within this duration as the acceptable minimum service life of building products (easy to replace or repair) is determined as three or six years by standards (EC, 1999; ISO, 2000). In terms of the ageing of the user, the first sustainability assessment should be made when the user passes to the next chronological age group.<sup>1</sup>

Determination of changes, which is the first step of the sustainability assessment action, can be made by com-

paring pre-design and healthy building identification data (acquired by observation, interview, survey, etc.) with the conditions prevailing during the assessment. If the result of the comparison does not reveal any change, it means that the building sustains its healthy status. In this case, the building can be continued to be used without taking any precaution. But existence of a change would require the application of other assessment steps. If the performance evaluation shows that the health performance of the building is still convenient for the new situation after the change, the healthy building status is sustained. But, if the health performance is not sufficient for new conditions, the first sustainability management action should be applied to restore the initial health status.

In case of a new change during the usage, the second sustainability assessment should be performed. During the determination of changes, comparisons should be made with the help of information gained from the earlier identification steps (the initial achievement of the healthy building and the first sustainability assessment actions) and the new condition should be determined. After the application of the other steps of the action, the appropriate sustainability decisions should be made and, if required, the second sustainability management should be carried out.

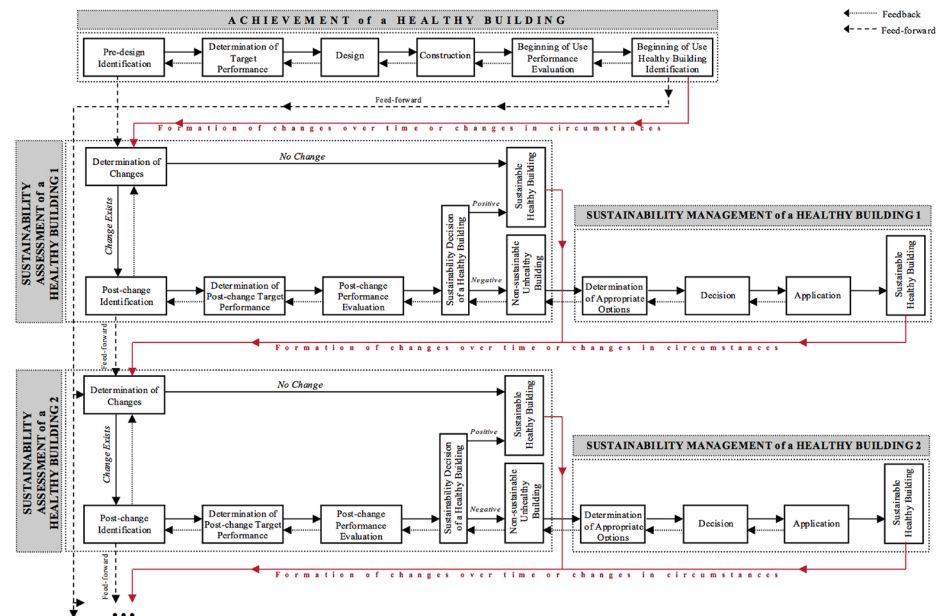
The frequency of sustainability assessment varies with the type of time-related or circumstantial changes. Changes in circumstance do not follow a specific time interval. Sustainability assessment should therefore be applied whenever a change occurs. For the ageing of the building, healthy building sustainability should be checked every three – six years. In terms of the ageing of the user, the assessment should be repeated when the user passes to the next chronological age group.

#### 5. Conclusion

During the service life of a healthy building, changes related to time or circumstances may occur. The protection of the healthy status against these changes is aimed within the sustainability of a healthy building. This re-

<sup>1</sup>The human life which starts with birth and ends with death chronologically consists of following steps (Erickson, 1984; Piaget and Inhelder, 200; WHO, 2004):

- infancy (0-2 years)
- childhood (2-12 years)
- adolescence (12-18 years)
- adulthood (18-60 years)
- old age
- young old (60-75 years)
- old old (75-85 years)
- oldest old (85 years and over)



**Figure 3.** The process model for the sustainability of a healthy building.

quires the creation of a process model. The proposed conceptual model, Process Model for the Sustainability of a Healthy Building, consists of the following actions and action steps:

- Achievement of a Healthy Building
  - Pre-design Identification
  - Determination of Target Performance
  - Design
  - Construction
  - Performance Evaluation at the Beginning of Use

Healthy Building Identification at the Beginning of Use

- Sustainability Assessment of a Healthy Building
  - Determination of Changes
  - Post-change Identification
  - Determination of Post-change Target Performance
  - Post-change Performance Evaluation
  - Decision
- Sustainability Management of a Healthy Building
  - Determination of Appropriate Precaution Options
  - Decision
  - Application
  - Result

Application of this model can help maintain the healthy status of a building throughout its lifespan. By this way, the occurrence of health problems caused by buildings is prevented and humans' basic need to live a healthy

life is met.

This model should be applied by specialists across the fields of construction, environment and health [designers (architects, interior architects, landscape architects, ...), building physics specialists (lighting, colour, thermal comfort, acoustic, ... specialists), engineers (civil, mechanical, environmental, chemical, physics, electrical, ... engineers), environmental health doctors, psychologists, sociologists, etc.] under the coordinatorship of building biologists.

The following actions are recommended to ensure successful implementation of the model, and to benefit further studies in this field:

- making users aware of the healthy building and its sustainability,
- basing the achievement and sustainability of the healthy building on legal obligations,
- establishing groups of secondary health specialists, who are trained in sustainability assessment and management, in the relevant disciplines,
- forming and institutionalizing a working team established from the specialisms mentioned above, to apply the model,
- taking the model into consideration during every stage of the building lifecycle, to fully realise the potential benefits to human health.

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