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Conceptual Framework for Sustainable Design

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Abstract: *In this paper by review and studying definitions and concepts of sustainability in building and architecture sector, as sustainable design and architecture, a comprehensive definition of sustainable design and architecture have been presented. Also, this paper presents a conceptual framework aimed at implementing sustainability principles in the building industry. The proposed framework based on sustainable triple bottom line principle, includes resource conservation, life cycle design, and design for human adaptation. Following a thorough literature review, each principle involves strategies and methods to be applied during the life cycle of the building. The framework will allow designers to have an appropriate balance between economic, social and environmental issues, changing the way construction practitioners think about the information they use when assessing building projects, thereby facilitating the sustainability of building industry.*

Keywords: Sustainability, Sustainable Development, Sustainable Architecture, Sustainable Design, Sustainable Design Method

INTRODUCTION

Sustainability as a concept has been around for centuries. Writings by Vitruvius from many years ago emphasized the need of balance between architecture and nature. Throughout the ancient world – Rome, Egypt, etc – it is possible to find the evidence of human adaptation and environmentally friendly design with nature, environment, and ecosystem. But by the advent of industrial revolution the balance between nature and building environment has been broken. The technology and its achievements are mainly considered, and architecture converts from "part of environment" to "separate from environment". So architecture destroys the nature and could have unprecedented damage on environment without adequate consideration (Mirsaeedi, 2009). In result, new solution should be proposed to benefit from technology in addition to interaction with environment. In this regard, sustainability approach is defined in building and architecture in order to reduce the environmental impact and improve quality of life for human.

Definition and concept of sustainability

sustainability and sustainable development

Several attempts have been made to describe sustainability. The world commission on environment and development has put forth a definition of "sustainability" as: meeting the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987).
Sustainable development is about ensuring a better quality of life for everyone, now and for generation to come. This requires meeting four main goals at the same time in the world as a whole (Bani, 2007):

1. Social progress which recognizes the needs for every one
2. Effective protection of the environment
3. Prudent use of natural source
4. maintenance of high and stable level of economic growth and employment

sustainable design and architecture

In recent years, there has been an increasing amount of literature on sustainable building and architecture. The main idea of sustainability is to concentrate on environmental conditions to achieve a designed product with maximum internal attributes of environment so that it can minimize the undesirable aspects of these constructions. The aims of sustainability in environmental design as follow (Bani, 2007):

1. Maximizing the human comfort
2. Design for change
3. Minimizing waste of spaces
4. Minimizing buildings maintenance expenses.

Sustainable architecture involves a combination of values: aesthetic, environmental, social, political and moral. It's about one's perception and technical knowledge to engage in a central aspect of the practice i.e. to design and build in harmony with the environment. It is the duty of an architect to think rationally about a combination of issues like sustainability, durability, longevity, appropriate materials and sense of place (Sinha, 2002; Datschefski, 2001).

In general, and comprehensive definition, sustainable architecture is: replying and interacting with environmental and local conditions and it is trying to apply contexts ecological abilities to create desirable environmental conditions; consequently, it is ecological equilibrium means it has minimum damages on ecology in addition to its flexibility, adaptability and continuity to changes and needs, and it is distinctive since it has some local attributes (Bani, 2007; Sinha, 2002; Datschefski, 2001; Williams et al., 2007).

Principle, strategies, and method for sustainable design

In this section we have provided a conceptual framework for sustainable design. The three level of the framework (principle, strategies, and method) correspond to the main goal of architectural environmental education: creating environmental awareness, explaining the building ecosystem, and teaching how to design sustainable building. The conceptual diagram for sustainable design is shown in figure1.

In this paper we propose three principles of sustainability in architecture. Resource conservation is concerned with the reduction, reuse, and recycling of natural resources that are put to a building. Life cycle design provides a methodology for analyzing the building process and its impact on the environment. Human design focuses on the interaction between human and natural world. These principles can provide a broad awareness of environmental impact, both local and global, of architectural consumption.

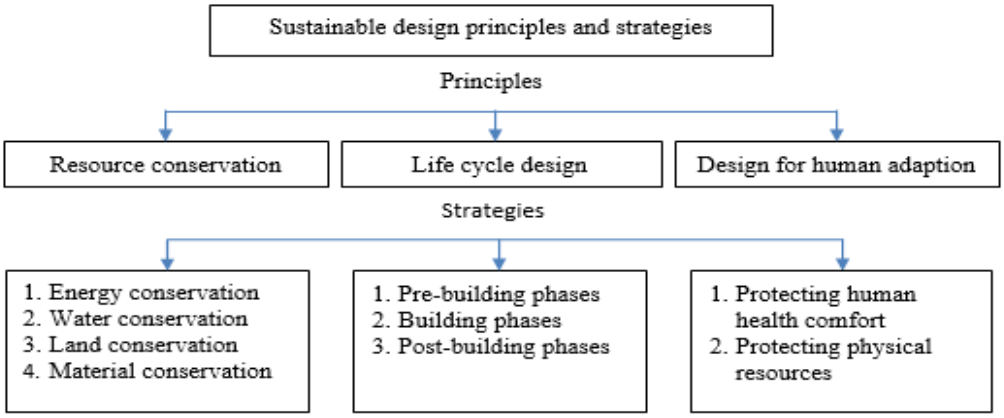

Figure 1: conceptual framework for sustainable desig

resource conservation

Resource conservation is concerned with the reduction, reuse, and recycle of the natural resource that are input to a building.

There is a continuous flow of resources, natural and manufactured, in and out of the building. This flow begins with the production of the building materials and continues throughout the building life span to create an environment for sustaining human well-being and activity. When examining a building, consider two stream of resource flow (see figure 2).

Upstream, resources flow in to the building as input and downstream, resources flow out of the building as output from building ecosystem.

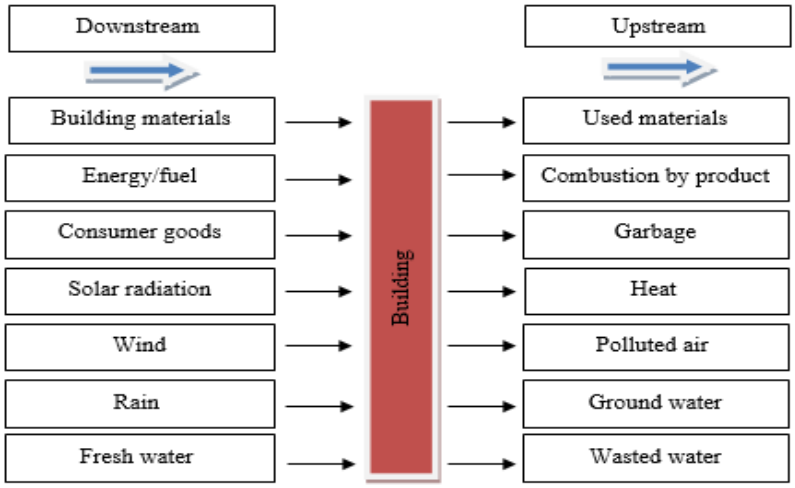

Figure 2: resource and material flow in the building ecosystem

For a given resource, its forms before entry to a building and after exist will be different. This transformation is caused by the many mechanical processes or human interventions that rendered to the resource during their use in building. Resource conservation yields specific design strategies and methods, as defined in Figure 3.

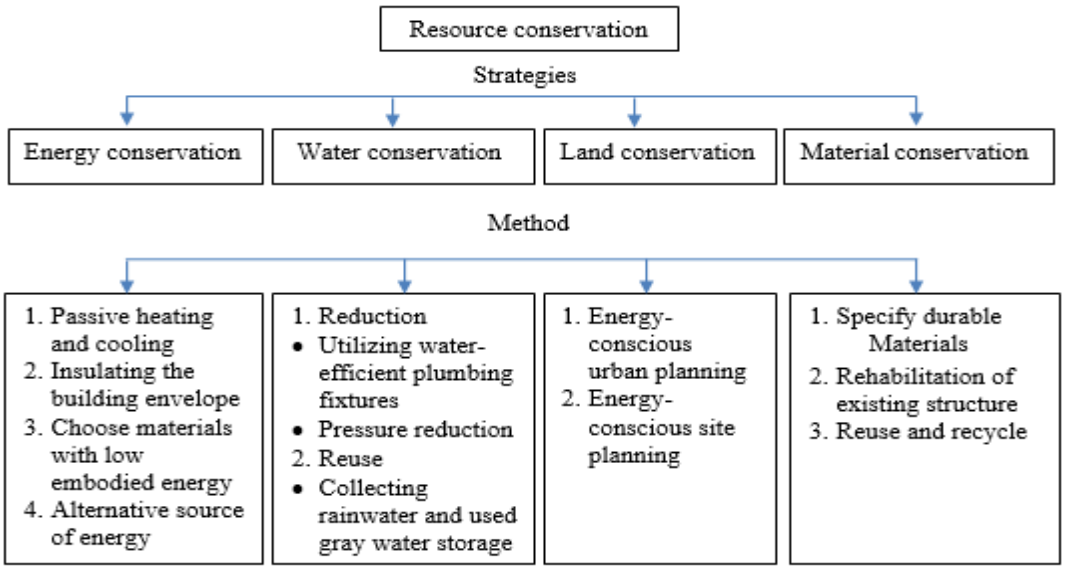

Figure 3: strategies and method to achieve resource conservation

- **Energy conservation**

The environmental impacts of energy consumption by building occur primarily away from the building site, through mining resources and other manufacturing processes. After construction, a building requires a constant flow of energy input during its operation for cooling, lighting, and etc. The energy life of a building can therefore be considered to be made up of from constructional and operational processes. Therefore, the main goal in energy conservation is to reduce the consumption of fossil fuels, as well as increasing the use of renewable energy sources. These purposes could be achieved by the consideration of the following methods.

- ✓ Passive heating and cooling
  Solar radiation incident on building surface is provided heat, light, and ultraviolent radiation necessary for photosynthesis. Historically, architects have advised building forms that provide shading in summer and retain heat in winter. Passive solar architecture offers design scheme to control the flow of solar radiation using building structure, so that it may be utilized at a more desirable time of day. Shading in summer, by plants or overhangs, prevents summer heat gain, and use of desirable flow of air provides cooling benefit in building.
- ✓ Insulation
  High-performance wall and window prevent both heat gain and loss. Reducing such heat transfer reduces the building's heating and cooling loads and thus its energy consumption. Due to the insulation properties of the materials, the surface temperatures of windows and wall will be higher in winter and lower in summer.
- ✓ Choose materials with low embodied energy
  Building materials vary with respect to how much energy is needed to produce them. Choosing materials with low embodied energy will help to reduce energy consumed through mining, processing, manufacturing and transporting the materials. For instance, aluminum has a very high embodied energy because of the large amount of electricity consumed to mine the raw material. True low energy building design will consider this important aspect and take a broader life cycle approach to energy assessment
- ✓ Alternative source of energy
  Solar, wind, and water energy system are all commercially available to reduce or eliminate the need for external energy source. Electrical and heating requirement can meet by these systems in all climates.

- **water conservation**

Methods for water conservation may reduce input, output, or both. This is because, the water that is supplied to a building and the water that leaves the building as sewage is all treated by municipal water treatment plans. Therefore, a reduction in use also produces a reduction in waste.

- ✓ Reduction
- ✓ Water supply system and fixtures can be selected to reduce consumption and waste. Low-flow sink, low-flow showerheads, and water-efficient dishwashers, can minimize both water waste and water consumption.
- ✓ Reuse

  Water consume in building can be classified as two types: gray water and sewage. Gray water is produce by activities such as hand washing. This type of water can be recycle within a building, and use for irrigation of plans or flush toilets. Well-planned plumbing systems facilitate such reuse.

  In most parts of the world, rainwater falling on building has not been considered a useful resource. Building envelopes, particularly roofs, can become rainwater collecting devices, in combination with cisterns to hold collected water. This water can be used for irrigation or toilet-flushing.

- **Land conservation**

Land is an important resource upon which the construction industry depends. Land use through urban expansion has been identified as a growing problem in both developed and developing worlds.

The impact of the construction industry on the environment and the expansion of urban areas show the importance of land as a vital indicator of sustainability with the potential to become an absolute indicator of sustainable construction (San-Jose et al., 2010). In this regard, we propose some method for land conservation along with healthy growth of urban expansion.

- ✓ Energy-conscious urban planning

  Cities and neighborhoods that are energy-conscious are not planned around car, but around public transportation and pedestrian walkways. These cities have zoning laws favorable to mixed-used development, allowing people to live near their workplace. Urban sprawl is avoided by encouraging redevelopment of existing site and adaptive reuse of the building.
- ✓ Energy-conscious site planning

  Such planning allows the designer to maximize the use of natural resources on the site. In temperate climates, open southern exposure will encourage passive solar heating; deciduous trees provide shade in summer and solar heat gain in winter. Evergreens planted on the north of a building will protect it from winter winds and improve its energy efficiency.

- **material conservation**

Large amount of minerals resources are consumed in the built environment and most of these mineral resources are non-renewable. Therefore, it is important to reduce the use of non-renewable materials. The sub-section discusses some of the methods to be considered in achieve material efficiency in construction.

- ✓ Specify durable materials

  Durability is defined as an indicator which informs of the extent to which a material maintains its original requirements over time. The sustainability of a building can be enhanced by increasing the durability of its materials. Materials, may be considered durable when its useful service life is fairly comparable to the time required for related impacts on the environment to be absorbed by the ecosystem
- ✓ Rehabilitation of existing structure

  One of the effective methods for material conservation is to make use of the sources that already exist in the form of building. Most building can be converted to new uses at a lower cost than new construction.
- ✓ Reuse and recycle

  During the process of the designing the building and selecting the building materials, look for ways to use materials that can themselves be recycle.

life cycle design

Life cycle design provides a methodology for analyzing the building process and its impact on the environment. This approach recognizes environmental consequences of the entire life cycle of architectural resources, from procurement to return to nature. LCD is based on the notion that a material transmigrates from one form of useful life to another, with no end to its usefulness. Life cycle of a building can be categorized into three phases: pre-building, building, and post-building, as shown in figure 4.

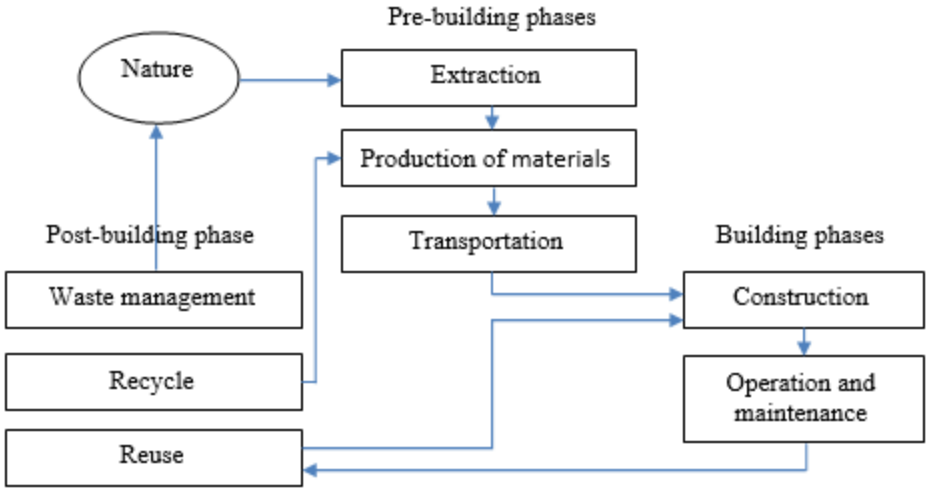

Figure 4: the sustainable building life cycle

As we discussed earlier, the life cycle design principle embodies three strategies: pre-building, building, and post building. These strategies, in turn, can yield specific design method that will improve the sustainability of architecture. Figure 5 shows each method related to the main strategies of life cycle design. These methods focus mainly on reducing input. Consuming fewer materials lessens the environmental impact of the associated manufacturing processes. This then reduces the eventual output of the building ecosystem.

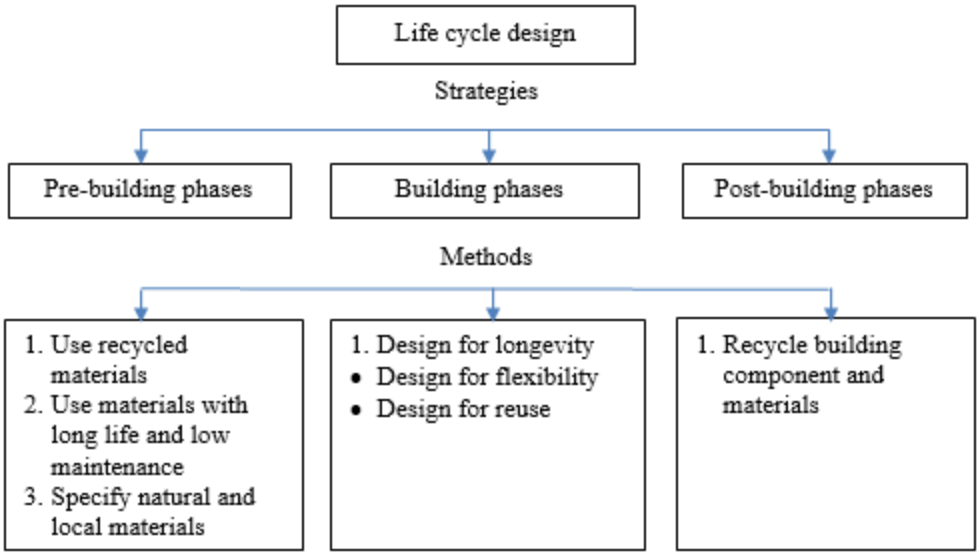

Figure 5: strategies and methods to achieve life cycle design

- **pre-building phases**

During pre-building phase, the design of a building and materials selected for it are examined for their environmental impact. The selection of materials is particularly important at this stage.

- ✓ Use recycled materials
  Using recycle materials reduce waste and saves scarce land fill space. Recycled materials also reduce the consumption of materials made from virgin natural resource. Many building materials, particularly steel, are easily recycled, eliminating the need for more mining and operations.

- ✓ Use materials with long life and low maintenance
  Maintenance of materials requires both energy and materials and is associated with similar impacts as the construction of buildings albeit on a smaller scale. Minimizing requirements for maintenance by designing for durability and longevity helps to reduce the life impacts of materials.
- ✓ Specify natural and local materials
  Natural materials are generally lower in embodied energy and toxicity than man-made materials (Godfaurd et al., 2005). Often, local materials are better suited to climatic conditions, and these purchases support area economies. For instance, the decorative use of marble quarried halfway around the world is not a sustainable choice.

- **building phases**

The methods associated with the building phase strategy are concern with the environmental impact of actual construction and operation processes.

- ✓ Design for longevity
- Design for flexibility
  To ensure a long life for a building it is therefore essential to design in sympathy with the environment, but also to provide a building that can accommodate changes of use. Flexibility has become of prime importance and buildings that can accommodate change are likely to have a long life. The ability to alter the internal layouts of buildings is perhaps the most important issue in terms of providing a flexible building. The ability to change internal layouts relies on internal partitions being non-load bearing and easily dismantled. Designing for flexibility ensures that the main structure of the building has the potential for a long life.
- Design for reuse
  In designing for reuse and recycling, it is important to consider the life span and frequency of replacement of building components and to detail components, liable to be replaced sooner than others, so as to enable their removal without affecting the rest of the building. The use of simple fixings and durable materials helps enhance a building component's ability to be installed and dismantled several times. Designing buildings so that components can be removed and replaced is not only beneficial in terms of sustainability: general maintenance is facilitated and made less costly, as is upgrading building elements or periodic refurbishment.

- **post-building phases**

During this phase, architect examines the environmental consequences of structure that have outlived their usefulness. At this point, the main consideration is given to recycle of the materials.

- ✓ Recycle materials
  Recycling materials from a building can often be difficult due to difficulty in separating different substance from one another. Some materials, like glass and aluminum, must be scavenged from the building by hand. Steel can easily be separated from rubble by magnets and concrete can be crushed and used as aggregate in new pours.

design for human adaptation

One of the main purposes of a sustainable building is to provide healthy and comfortable environments for human activities. A building must accommodate the activities it is built for and provide floor-space, room

volume, shelter, light and amenities for working, living, learning, curing, processing etc. Furthermore, the building must supply a healthy and comfortable indoor climate to the people using it. In meeting these basic requirements, the building should not cause harm to its occupants or the environment. To promote and enhance human adaptation the following two design methods should be considered (Figure 6).

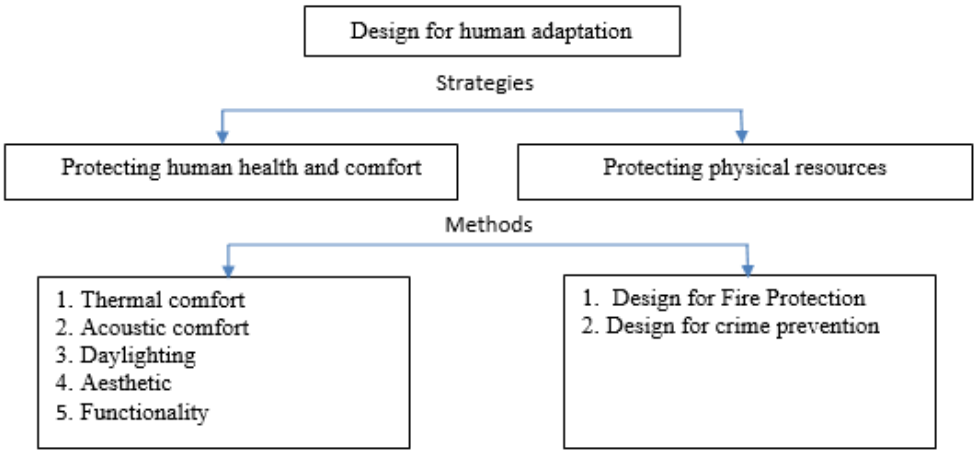

Figure 6: strategies and methods to achieve human adaptation

- **protecting human health and comfort**

Well-being (health and comfort) is an important aspect determining the quality of life of an occupant. In a modern society, where individuals spend more than 90% of their time indoors—and more than 70% of their time indoors at home (Sev, 2009; Adgate et al., 2002), an essential role of architecture is to provide occupants' health, physiological comfort, physiological satisfaction and productivity. The concept of health is significant for identifying the concept of a "sustainable building" in terms of building performances. A review of the literature identified the following (but not limited to) methods as a necessity in enhancing the coexistence between the environment, buildings and their occupants.

- ✓ thermal comfort

  Maintaining thermal comfort for occupants of buildings or other enclosures should be one of the important goals of every building designer. The environmental parameters which constitute the thermal environment are: Temperature (air, radiant, surface), humidity, air velocity and the personal parameters: clothing together with activity level. Building envelope considerations, such as reflective roofing, Low-E windows, window tinting and solar shading are some of the tools that enable designers to optimize thermal comfort as well as improving energy efficiency. Siting the building according to seasonal heat gain and use is another key to thermal comfort, as is landscaping.
- ✓ Acoustic comfort

  Acoustic comfort must be achieved by controlling sources of noise from mechanical and electrical equipment and from sources exterior to the building. Proper selection of windows, wall insulation and wall framing, and materials are essential to reducing noise from outside. Some sound insulating materials, such as acoustic ceiling tiles and straw-bale construction, can offer the advantages of recycling and using natural materials (Sev, 2009, Oral et al., 2004).
- ✓ Daylighting

  Daylighting involves designing buildings for optimum use of natural light and provides numerous benefits over artificial lighting. Maximizing good daylight in housing is therefore an important

consideration. Good daylight means levels of daylight which are sufficient to see properly without glare or excessive contrast. Too much direct sun can actually cause discomfort and ill health, particularly with highly reflective surfaces.

- ✓ Aesthetic
  Building aesthetics is a further value to bear in mind, with a view to contributing to psychological comfort in the work and living environment. This aspect of psychological comfort could mean pleasing architecture, visual interest, art on the walls, or natural elements, such as a fountain, plants, or an aquarium. The effect of beauty may be hard to measure, but it emphasizes the aesthetical requirement as a sustainable aspect.
- ✓ Functionality
  Building functionally should be planned to enable the smooth operation of the activity for which the building is designed. The capacity of a building to absorb future functions should be studied at the outset, in the event of an expansion, and to reduce the additional material and building waste disposal costs.

- **protecting physical resource**

Protecting physical resources is one of the most important principles of sustainable design and construction. Consideration must be given to design that incorporate building resilience against natural and man-made disasters such as fire incident, earthquake, flooding, and crime attack. Hazard mitigation planning is the process of determining how to reduce or eliminate the loss of life and property damage and the methods to achieve these tasks are as follow.

- ✓ Design for fire protection
  Consideration of Passive Fire Protection is vital to the stability and integrity of a building or structure in case of fire (Bagchi et al., 2008). Passive fire protection in building can be achieved by use of insulated fire-resisting partitions, cavity barriers, specialist fire-stopping of gaps in structure with their proven fire performance properties. Beside that architects can design escape routes in some building in order to allowing the occupants escape from fire.
- ✓ Design for crime prevention
  The basic tenet of crime prevention through design in building is that proper design and effective use of the built environment can reduce the fear and incidence of crime and thereby improve the overall quality of life. Crime prevention methods emphasize the following three design approaches: natural access control; natural surveillance; and territorial behavior (Marzbali et al., 2011). Access control uses doors, shrubs, fences, gates, and other physical design elements to discourage access to an area by all but its intended users. Surveillance is achieved by placing windows in locations that allow intended users to see or be seen while ensuring that intruders will be observed as well.
  Surveillance is enhanced by providing adequate lighting and landscaping that allow for unobstructed views. Finally, territory is defined by sidewalks, landscaping, porches, and other elements that establish the boundaries between public and private areas. These three methods work together to create an environment in which people feel safe to live, work, travel, or visit.

Conclusion

The purpose of the current study was to provide a conceptual framework for sustainable design based on three main principle of sustainability, includes resource conservation, life cycle design, and design for human adaptation. The framework has considerable potential to accelerate the understanding and implementation of sustainability in building construction. It provides a brief overview of sustainability principles, strategies and methods, and emphasizes the need for an integrated and holistic approach for implementing sustainability in building projects. It is intended to provide a general framework for improving the quality and comparability of

methods for assessing the environmental performance of buildings. It identifies and describes issues to be taken into account when using methods for the assessment of environmental performance for new or existing building properties in the design, construction, operation, refurbishment and deconstruction stages. It is not an assessment system in itself but is intended to be used in conjunction with, and complimentary to existing assessment systems. And finally this framework is intended to help designer seek solution rather than giving them a set of solution. Specific design solution compatible with a given design problem will emanate from these principles.

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