CONCEPTUAL FRAMEWORK FOR DESIGNING SUSTAINABLE BUILDINGS: ENVIRONMENTAL ASSESSMENT OF BIBLIOTHECA ALEXANDRINA

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Abstract— Buildings and the environment are inextricably linked. Water, land, energy and materials are all consumed in the construction and operation of a building. The built structure in turns becomes part of the physical environment, affecting the living conditions, social wellbeing and economic profile. This paper aims to propose a conceptual framework to evaluate the environmental impacts of sustainable buildings design and then measuring the sustainability of Bibliotheca Alexandrina in Alexandria. Egypt can benefit from this framework to develop its buildings in order to achieve the sustainability targets.

Index Terms— Bibliotheca Alexandrina, conceptual framework, design, environmental impact, sustainability.

I. INTRODUCTION

"When you build a thing, you cannot merely build that thing in isolation, but must also repair the world about it, and within it and the thing which you make takes its place in the web of nature" [1].

The concept of sustainability in buildings had evolved over many years. Sustainable building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort [2].

The greatest opportunities for cooperating energy efficient and sustainability in buildings come in the design phase respecting the main aspects of the sustainable development including environmental protection, social development and economic equity.

II. SUSTAINABLE ARCHITECTURE

A. Sustainable Architecture

Sustainable Architecture, variously called ecological, biological, or green. A basic definition extends that of sustainability itself, an architecture that meets the needs of the present without compromising the ability of future generations to meet their own needs. Those needs differ from society to society and region to region and are best defined by people involved [3].

B. The Need to Sustainable Architecture

Modern technology and methods of construction have sadly degraded our natural resources, land, forests, air, and water. Sustainable Architecture declares that this misuse can no longer be sustained, because the World's population is set to more than double in the next fifty years. With the people in the poorest nations of the world pressing for a better life, those who live in industrialized nations can't morally justify continuing to consume the planet's natural resources at the current lopsided Rate [3]. The answer, is not to give up technological advances. However, it is to use the best of them, to combine them with the best traditional methods, and to test every building, every community plan, by green principles. Sustainable Architecture makes a unique contribution to our global community and our future, a future that can be more abundant and prosperous for all of us [3].

C. Sustainable Architecture Principles

Sustainable architecture seeks to create buildings that are more environmental sound and more sustainability responsible [4]. The main principles of sustainable architecture are [5]:

- Designing the building to be integrated with the nature.
- Integrating the building with the site.
- Conserving energy and providing high-energy efficiency.
- Concerning the climate.
- Using locally and non-toxic building materials.
- Respecting the users.
- Taking advantage of traditional local building techniques.

III. ENVIRONMENTAL ASSESSMENT METHODS

The following summarize some methods to assess the environmental impacts of buildings.

A. Methods of building performance

These methods are developed to help planners and designers in assessing environmental impact of a proposed building [6]:

1) *Building Research Establishment Environmental Assessment Methods.* This program was initiated in the United Kingdom in 1990 for new office buildings and currently offers assessments of several building types in which criteria are organized to three scales of Global, Local, and Indoor. 18 categories of criteria, under which another 30 independent, criteria give equal weighting in the overall assessment.
2) *Building Environmental Performance Assessment Criteria.* This program was initiated in Canada in 1993 for new and existing office buildings. Criteria are structured in five major environmental topics of: ozone layer protection, environmental quality, resources conservation, and finally site and transportation. Each topic area contains series of criteria and sub-criteria of total 75. Evaluation is considered on a 0-10 points scale.
3) *Green Builder Program.* This program was initiated for residential buildings. Criteria were structured in four resources issues of: water, energy, building materials, and solid waste. Each topic area contains series of assessed building features totaling 135.

B. Methods of Environmental Building Design

Over the past few years a number of methods of environmental building design have been developed [7]:

1) *Ecological Footprint. It* is a process in which the area of land is required to biologically produce all the resources consumed by a community and to assimilate its wastes is calculated. Methodologically, it is too difficult to be calculated.
2) *Eco Cost.* It is a system that attempts to evaluate the environmental impacts of producing building materials. It measures ecological degradation using Gaia Scale defined between zero and one. A zero score implies a healthy functioning planet while one is equivalent to the highest environmental devastation.
3) *Perspective techniques.* They use perspective methods to explain existing or predicted environmental damage these methods have limitations in their applicability. They are rarely, if ever, accurate. They depend mainly on the skills of the designer and the available time to explore them. The ecological footprint and eco cost approaches rely on a broad range of information and data sources. In fact , the reliable information for making an absolute judgment may never be completely possible

C. Methods of Environmental Impact

These methods include quantitative and subjective or qualitative methods [8].

1) *Checklists.* They serve as reminder of all possible relationships and impacts of a process or an activity, out of which a set of assignments may be chosen. They are designed to establish whether a proposed building is likely to have negative impacts on the environment or it whether has good benefits. There are two kinds of checklists: descriptive, and weighted-scale checklists.
2) *Matrices.* They relate activities to environmental components so that the box at each intersection indicates to a possible impact. They don't have any mathematical implication, but they are merely styles of presentation. There are three types of commonly used matrices: descriptive, symbolized, and numeric and scaled matrices.
3) *Networks.* They are the most obvious descriptive methods. Investigation of linkages in two dimensions can be carried out. They are mainly developed to explicitly consider the secondary, tertiary and higher orders impacts.

IV. PROPOSED FRAMEWORK

It is obvious that there is no single approved method to be used as an acceptable approach in assessing environmental impacts of the building, it seems unlikely that a single method be able to meet all the range of sustainable criteria.

There is a need a framework includes a total set of environmental considerations and sustainable development aspects.

A. Sustainable Building Design Guidelines

There are many guidelines for designing sustainable buildings. But the 4 mains guidelines are: fulfilling design responsibility and respecting law, creating efficiency energy resources, using suitable materials, and fulfilling indoor environmental quality [5].

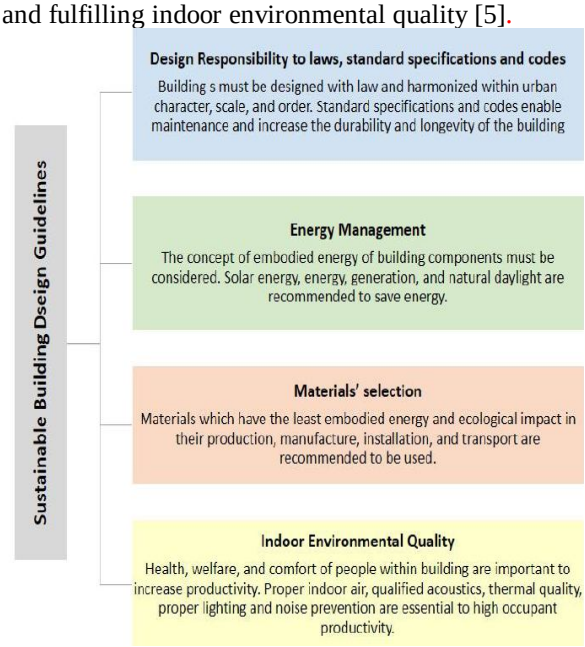


Fig. 1 Sustainable building design guidelines

B. Sustainable Assessment Criteria

1) *Responsibility to Building Law, Standard Specifications and Codes.* Building laws, standard specifications and approved codes must be respected and reviewed in the design phase. Any building must not only harmonize with urban character, scale and order, but also it must built in a way that marinating users' comfort, safety and security [9]. Improper specifications cause many problems during operation or maintenance. Improper equipment and appliances decrease the durability and the longevity of the building.

2) *Energy Management.* Any building consumes energy in a number of ways. Much energy is usually wasted due to unstudied choices made in design. About 40% of the national energy budget is committed to the building process, at least 50% of which can be saved by proper design, construction, and use. Sustainable building design looks to reduce energy consumption in all of these areas. Besides passive solar design, the movement to sustainable building is incorporated with the revolution of new techniques that are aimed to reduce energy consumption [10]. They include intelligent building design techniques and design energy productive buildings techniques.

3) *Materials' selection and furnishing.* Buildings require enormous amounts of materials that depend directly or indirectly on renewable resources and non-renewable resources [11]. Materials are used in buildings in two different shapes, it may be inputs (components of raw materials) or outputs (manufactured products) that need a lot of processing. In each case, they consume energy. On looking at building materials, it is more important to make sense to the entire life cycle of it.

4) *Indoor Environmental Quality*. A building itself isn't really a good building unless it is comfortable, energy efficient, healthy, durable and working functionally. Sustainable building involves that the buildings must serve their function while causing the minimum of harm to the environment [12]. Criteria for indoor environmental quality assessment are broken down into relevant performance processes. Advanced self-tuning techniques (intelligent control techniques) were developed to adjust and modify the building indoor environment while operation. Microcomputer based control systems are the key elements. They include components such as programmed start/stop, duty cycling, set point reset, electric demand limiting, adaptive control, chiller, boiler optimizer and optional energy sourcing.

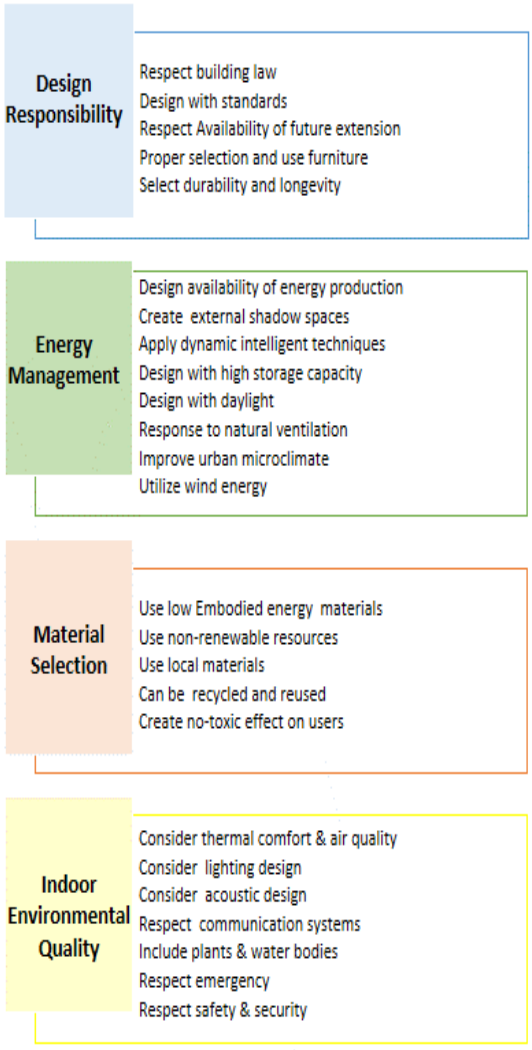


Fig. 2 Sustainable assessment criteria

V. BIBLIOTHECA ALEXANDRINA

A. Bibliotheca Alexandrina

In order to revive the idea of Alexandria ancient library, 2000 years ago, the Arab Republic of Egypt and the UNESCO set out to build Bibliotheca Alexandrina, one of the largest libraries in the world [13].

The building was designed by the Norwegian architectural office firm Snøhetta, winning the open international competition for its design, and it was managed by Prof. Dr. Mohsen Zahran the professor of Architecture in Alexandria University. It was built from 1993 to 2001 and it was opened in October 2003.



Fig.3 Library exterior photos [14]

B. Location

The library is located on a magnificent site in the eastern harbor, facing the Mediterranean Sea on the north, and Alexandria University Complex on its southern side. It overlooks the Silsilah Peninsula very close to the location of the old Library, [15]. The library with its huge mass and anonymity on the site is seen as a landmark for the country as a whole.



Fig. 4 Satelite map showing the library location [16]

The complex comprises three main elements: the pre-existing conference center, the new spherical planetarium, and the new library. They are all connected underground below the plaza into one large functional complex [13].

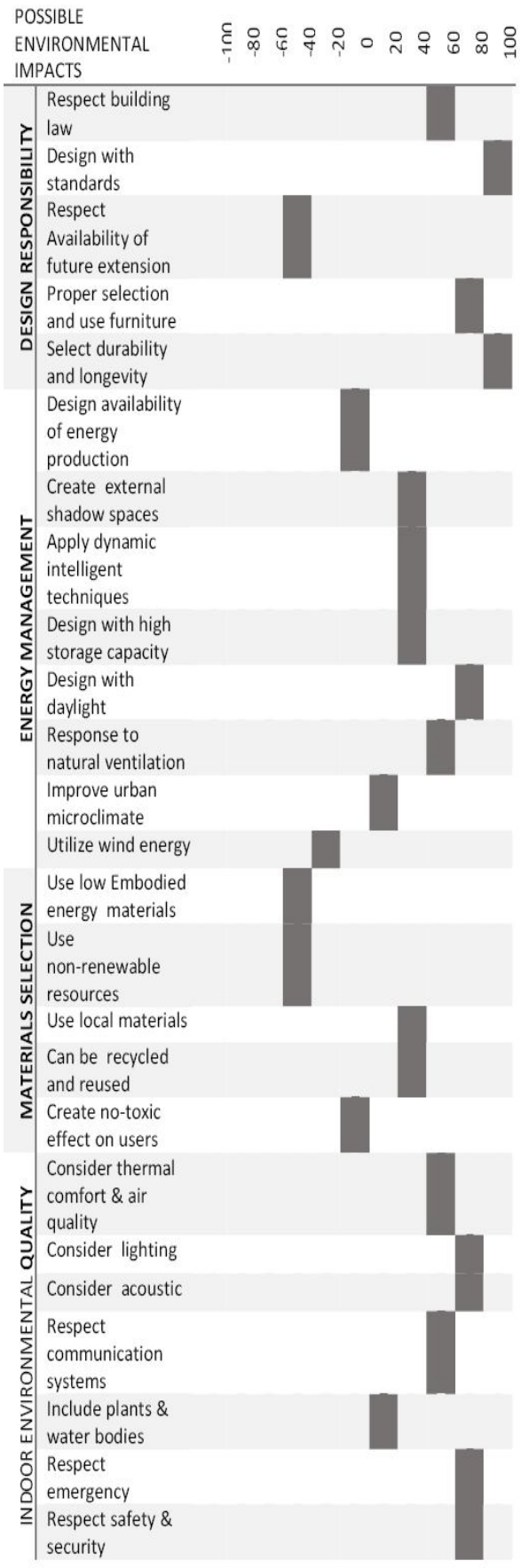


Fig. 5 Library site plan [13]

C. Design Concept

Conceived as a revival of the ancient library in the city. Bibliotheca Alexandrina is one of the most innovative library complexes, it is a contemporary design that contribute meaningfully to students, researchers and the public [14]. The design concept is a simple circle inclined towards the sea, partly submerged in the ground, and covers a stepped reading room over 14 terraces. The building's curve is covered with a beautiful gray granite wall that displays letters from the alphabets of 120 languages.

The design of the library is both timeless and bold. Its vast circular form alongside the circular Alexandrian harbor recalls the cyclical nature of knowledge, fluid throughout time. It's glistening, tilting roof recalls the ancient Alexandrian lighthouse and provides the city with a new symbol for learning and culture [14].



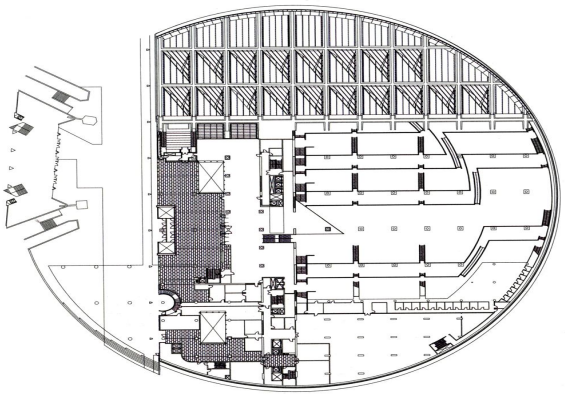


Fig. 6 Library floor plan [17]

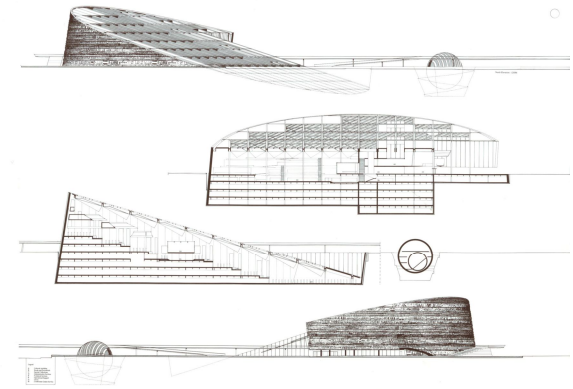


Fig. 7 Library sections [14]





Fig. 8a Library interior photo [14] Fig. 8b Granite wall [14]

VI. APPLYING THE PROPOSED FRAMEWORK

Matrix I illustrates the environmental impact assessment to Bibliotheca Alexandrina design. The assessment highlights: the responsibility to building law, standard specifications and codes, responsibility to materials' selection and management, responsibility to energy management and responsibility to indoor environmental quality.

Matrix I

Proposed Framework

A. Responsibility to Building Law, Standard Specifications and Codes

In respect to the footprint of 2 the building is built on 50% of the site area. Special specifications and high quality assurance were adopted to increase the building durability.

The facility provides a main reading room with seating for 2000 readers, 6 specialist libraries, 3 museums, 7 research centers, 3 permanent galleries, space for temporary exhibitions, a planetarium, a public plaza, offices, cafeterias, restaurants, garage of 600 car parking spaces and all necessary services required for such a complex. In general, the building works functionally well.

B. Energy Management

The building as whole is surprisingly modest. The cylinder truncates and inclines circular form is selected carefully in response to the disadvantage of the ground topography. It is best solution that offers the less catch to the climatic conditions. This option creates protection from sandstorms (coming from the south). Yet, the slope of the building towards the sea (the northwest) besides the flat incidence roof are creating another protection to the building.

A great deal of care was given to the exterior walls. Four thousand granite blocks (from Halaib, 200 km south of Aswan) protect the building façade from saline water, dust, wind and sandstorms. The granite wall itself acts as a heavy base for the building. In addition, plain water (not very deep) encloses the building to limit sand storm effects. It is not certain that this choice is the best as it will involve demanding maintenance problems.

C. *Materials' selection and furnishing*

The library materials are selected for their durability and longevity. The interior walls, screens that surround the ground levels and ground floor are selected carefully to absorb interior noise and sound reverberation in the reading room [18]. The bibliotheca furniture (chairs, tables and shelves) are selected of natural woods, leather and stainless steel.

Cumulative sum of environmental impacts				
Sustainable criteria	Score level	Number of criteria	Sustainability percentage	Notes
Design responsibility	-40	3	12%	UN
Energy management	-20	1	4%	UN
Material selection	0	2	8%	NI
Environmental impact	20	2	8%	ST
	40	5	20%	ST
	60	4	16%	ST
	80	6	24%	ST
	100	2	8%	ST
Study results				
Unsustainable activities **(UN)**			16%	
No significant impact **(NI)**			8%	
Sustainable activities **(ST)**			76%	
Descriptive classifications for identify the performance				
Very poor	Poor	Average	Good	Excellent
			76%	

D. Indoor Environmental Quality

The building is technically outstanding, it could be explained as follows:

- Being responsible for air pollution, precautions have been taken to prevent emissions. Systems with CO2 using

Halon gas are installed to ensure that the building is working within the acceptable document.

- The internal noises were reduced just on a level not exceeding 35 DCD. The roof of double glazing and technical solutions absorbs the external noise and shock of the interior noise.

- The building uses the natural light, drawn in through glazed panels on the roof. The orientation on the roof panels (designed as solar sails) was carefully studied on computer at the design stage to introduce maximum levels of natural light without direct sunlight.

- The library is self-tuning controlled to keep the interior temperature being of 21 C which is an acceptable temperature for human comfort.

- The library is an intelligent building incorporating the latest high-tech equipment and a highly sensitive fire system. Each space is equipped with an automatic system for fire detection. Spatial devices for fire prevention. They are equipped with water of volume not exceeding 7000m to guarantee that it will not flood the books, documents and storage facilities.

- The building is equipped with advanced systems to prevent any estimated flood water. Special foundations were used to keep the library dry and special alarm systems are installed to reveal any steel rust. To resist earthquakes, 50 CEN of high quality concrete is covering the library walls.

- All the units of the bibliotheca are obvious, easy to reach and smoothly connected by short ways of circulation (from the division of the reading hall to distinct sections). It is possible to control flows of users and documents.

- Double internal technical walls which cannot be penetrated protect the library and its collections from theft and vandalism. The double external walls are supported with accesses to the main roads for fast and safe people evacuations. Yet, an advanced technique is used to monitoring entrances, paths and spaces. It is also equipped to monitor the external streets in a circle of 1 km diameter outside the Bibliotheca.

- The water pool that surrounds the library not only plays a great role in protecting the library from theft but also it has a beneficial effect in enhancing the microclimate of the outer space.

CONCLUSION

A table I illustrates the degree of performance for Bibliotheca Alexandrina. By calculating the results of the matrix, it concludes that the library is a good performance building in terms of sustainability which achieve 76% of the suggested criteria and sustainable goals.

Table I: Sustainability performance of Bibliotheca Alexandrina

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