Sustainable Development and Sustainable Construction

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Introduction

The awareness about sustainable development is growing around the globe for last few decades. The UN Summit on Environment and Development in 1972, 'Agenda 21', the closing document of the UN 'Earth Summit' in 1992 in Rio de Janerio, followed by many other international and national meetings and conferences show the growing concerned for protecting the environment for the future generations by introducing sustainable development concept [1].

In the ideal world painted by Chaharbaghi and Willis [2], there exists a society in which people everywhere live in peace and security, breathe fresh air, drink clean water and eat uncontaminated food. They have livelihoods that allow them to enjoy life, raising healthy, contented and educated children. They leave behind them a stock of wealth comprising man-made and environmental assets for the next generation, no less than they inherited from the previous generation. The real world, however, is far from this ideal. There is a growing concern about the long-term future, the resources of the planet, the environment and high levels of poverty, which are linked with the spread of disease, social unrest, population growth and environmental degradation. Sustainable development has come to prominence, not as a sudden fad nor a silly fashion, but rather to bridge the gap between the ideal and real worlds [2].

Sustainable Development

There are many definitions to describe sustainable development. A few of them are presented here. According to Sage [3], sustainable development refers to the fulfilment of human needs through simultaneous socio-economic and technological progress and conservation of the earth's natural systems. Sustainable world progress is dependent upon continued economic, social, cultural, and technological progress. To achieve this, careful attention must also be paid to preservation of the earth's natural resources. Sustainable development is a term generally associated with the achievement of increased techno-economic growth coupled with preservation of the natural capital that is comprised of environmental and natural resources. It requires the development of enlightened institutions and infrastructure and appropriate management of risks, uncertainties, and information and knowledge imperfections to assure intergenerational equity, intragenerational equity, and conservation of the ability of earth's natural systems to serve humankind [3].

Another definition of sustainable development, by Forum of the Future, the UK's sustainable development charity, states it as [4]:

"Sustainable development is a process which enables all people to realise their potential and improve their quality of life in ways that simultaneously protect and enhance the Earth's life-support systems".

Chaharbaghi and Willis [2] have presented different perspectives of sustainable development, shown in Figure 1.

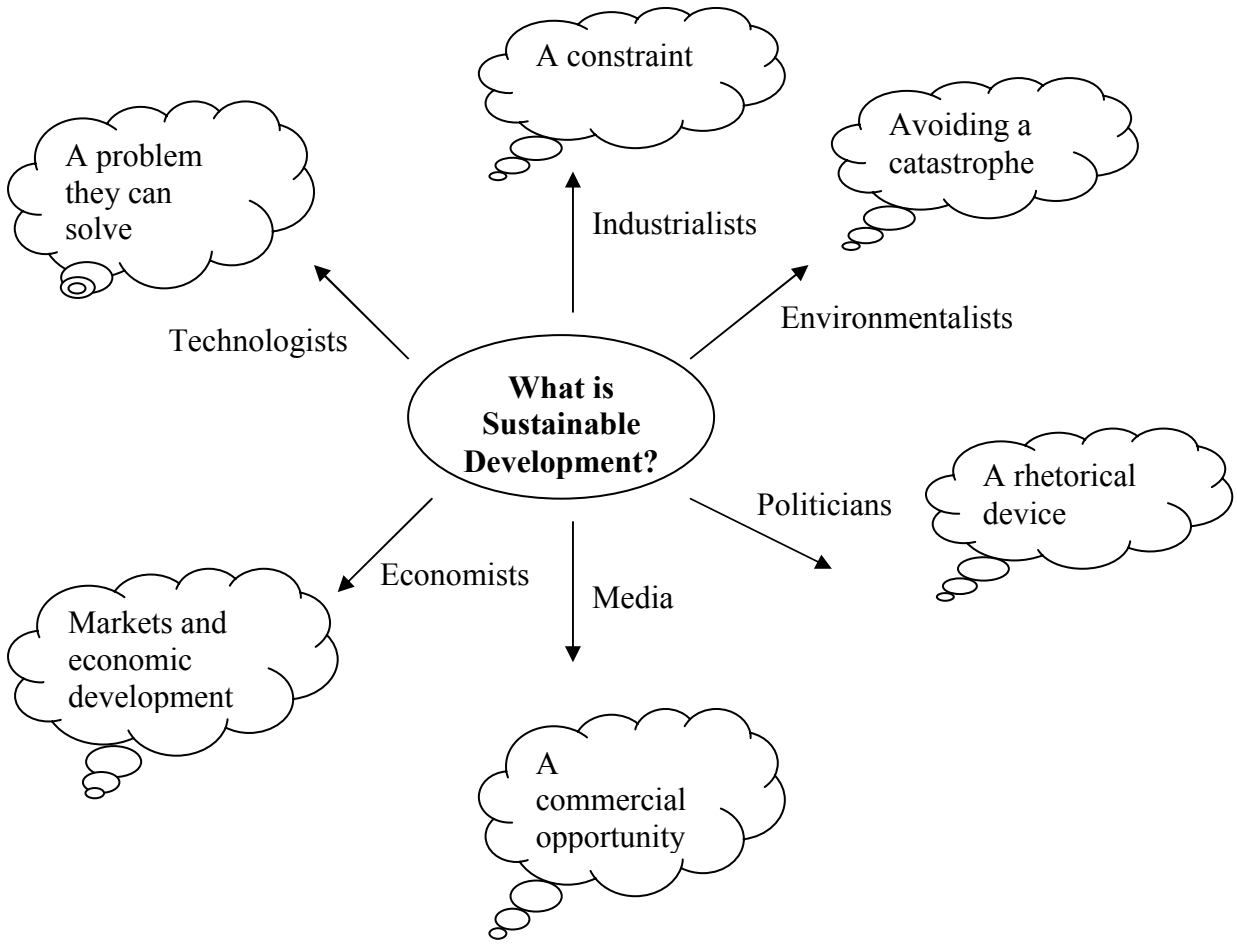

Figure 1: Images of Sustainable Development [2]

According to DETR literature, sustainable development is all about ensuring a better quality of life for everyone, now and for generation to come, through [5]:

- Social progress which recognises the needs of everyone;
- Effective protection of the environment;

- Prudent use of natural resources; and
- Maintenance of high and stable levels of economic growth and employment.

There is also a common definition for sustainable development, which was formulated by the World Commission on Environment and Development (WCED), led by the Norwegian Prime Minister Gro Harlem Brundtland, in 1983. It states that [2]:

"Sustainable development is development, which meets the needs of the present without compromising the ability of future generation to meet their own needs."

The word 'development' in this definition implicates two important aspects of the concept: Firstly it cannot be limited to a number of disciplines or areas, but it is applicable to the whole world and everyone and everything on it, now and in the future. Secondly, there is no set aim, but the continuation of development is the aim of the development. The definition is based on two concepts [6]:

- The concept of ***needs***, comprising of the conditions for maintaining an acceptable life standard for all people, and

- The concept of ***limits*** of the capacity of the environment to fulfil the needs of the present and the future, determined by the state of technology and social organisation.

The needs consist firstly of basic needs such as food, clothing, housing and employment. Secondly, every individual, in every part of the world should have the opportunity to try and raise his/her life standard above this absolute minimum. The limits consist of natural

limitations like finite resources, but also of declining productivity caused by over-exploitation of resources, declining quality of water, and shrinking of bio-diversity. For our common future, it would therefore be best *if needs are best fulfilled while limits are not increased, but preferably decreased*. This would lead to the conclusion that all environmental, economic, political, technical, and social developments can easily be evaluated in the light of sustainable development by these two arguments. Any development should help fulfil needs and should not increase limitations.

Themes of Sustainable Development

Triple Bottom Line

Sustainable development comprises of the three broad themes of social, environmental, and economic accountability, often known as the 'triple bottom line' [7]. These themes are also shown in Figure 2 and Figure 3, and outlined in Table 1. A brief description of these themes is also presented.

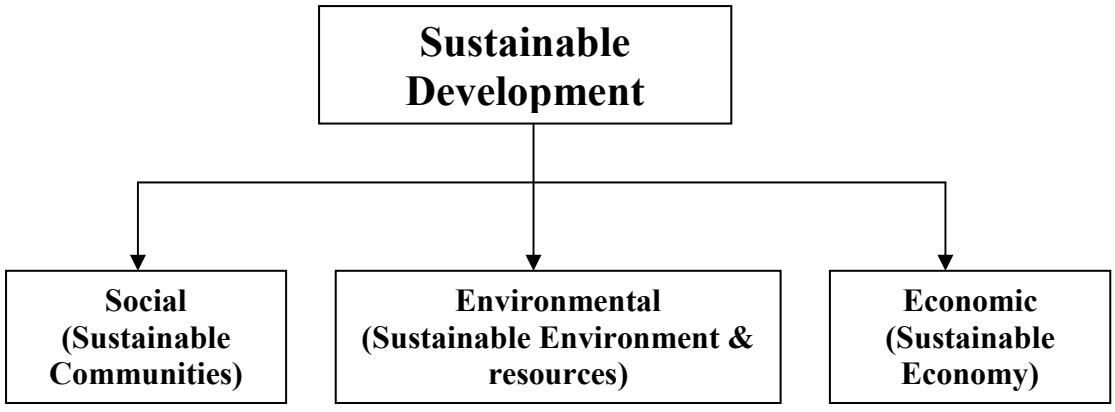

Figure 2: The three themes of sustainable development

Table 1: A tabular representation of the three themes of sustainable development

Theme	**Social**	**Environmental**	**Economic**
Sub-theme	❑ Equity ❑ Community ❑ Etc.	❑ Global ❑ Local and site ❑ Internal ❑ Etc.	❑ Construction ❑ Materials ❑ Infrastructure ❑ Etc.
Issues	❑ Poverty ❑ Minorities ❑ Inner cities ❑ Transport ❑ Communications ❑ Etc.	❑ Climate change ❑ Resources ❑ Construction ❑ Internal environment ❑ External environment ❑ Wildlife ❑ Etc.	❑ Profitability ❑ Employment ❑ Productivity ❑ Transport and utilities ❑ Building stock value ❑ Etc.

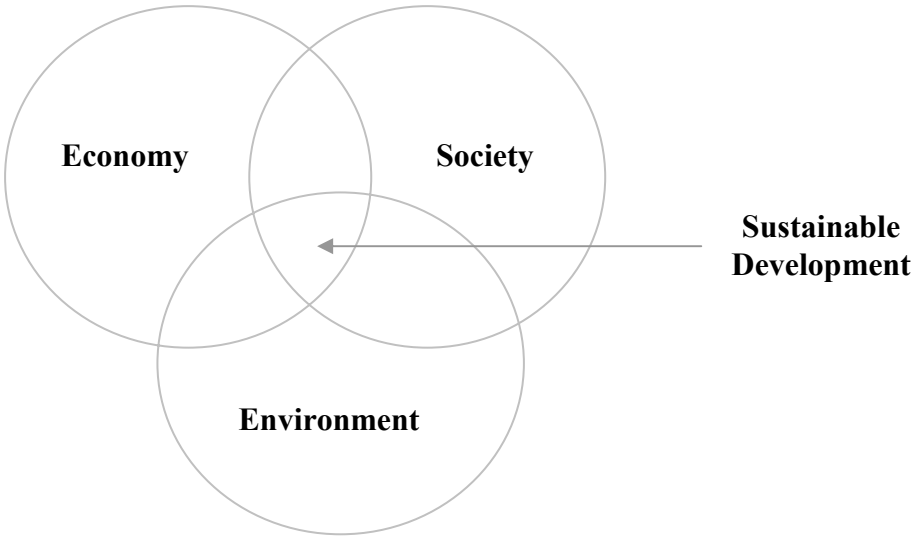

Figure 3: Themes of sustainable development

Sustainable Communities

The following sub-themes and issues fall under this theme: Education, Food, Health, Water, Poverty, Housing, Fuel Planning, Employment, Transportation, Construction of buildings that work well, Settlement and growth of community, Meeting local needs locally, Skills development, Empowering community, Opportunities for cultural, leisure & recreational activities, Worker health and safety, Impacts on local communities, Quality of life, Benefits to disadvantaged groups e.g. disabled, Reduce level of crime, etc.

Sustainable Environment

The philosophy of environmental sustainability is to leave the Earth in as good or better shape for future generations than we found it for ourselves. By a definition, human activity is only environmentally sustainable when it can be performed or maintained indefinitely without depleting natural resources or degrading the natural environment. This includes Resource consumption to be minimal, Materials consumed should be made entirely of 100% post-consumer recycled materials or from renewable resources (which were harvested without harm to the environment and without depletion of the resource base), Recycling of waste streams should be 100%, Energy should be conserved and energy supplies should be entirely renewable and non-polluting (solar thermal and electric, wind power, bio-mass, etc.), Use of natural resources efficiently, Minimisation of waste and pollution, Protect natural diversity, Reduce green house gases' emission, Reduce road traffic, Good quality of rivers; Population of wild birds, Building new homes on brown field, Reduced waste, effluent generation, and

emissions to environment, Reduced impact on human health, Use of renewable raw materials, Elimination of toxic substances, etc.

Sustainable Economy

Sustainable economy is consist of sub-themes, such as Investment in people and equipment for a competitive economy, Job opportunities, Vibrant local economy, Services are accessible which reduces use of car, Creation of new markets and opportunities for sales growth, Cost reduction through efficiency improvements and reduced energy and raw material inputs, Creation of additional added value, etc. Sustainable development should not be at the cost of spending more in order to achieve all above-mentioned and much more.

The Live Capital Model of Sustainability

The model includes five capitals, which actually represent all the resources available to a society for achieving sustainable development, and presented by Parkin [4]. These five capitals are natural capital, human capital, social capital, manufactured capital, and financial capital.

Natural capital

Natural capital which is also referred to as environmental or ecological capital, represents the stock of environmentally provided assets. It includes renewable and non-renewable resources, and services such as the natural waste processing system.

Human capital

Human capital consists of the health, knowledge, skills, motivation, and spiritual ease of people. All things that enable people to feel good about themselves, each other and to participate in society and contribute productively towards its well-being and wealth.

Social capital

Social capital is all the different cooperative systems and organisational frameworks people use to live and work together, such as families, communities, governments, businesses, schools, trade unions, voluntary groups, etc.

Manufactured capital

Manufactured capital comprises all of the human fabricated infrastructure that is already in existence: the tools, machines, roads, buildings in which we live and work, and so on.

Financial capital

Financial capital has no intrinsic value; whether in shares, bonds or banknotes, its value is purely representative of natural, human, social or manufactured capital. It's a very important capital as it reflects the productive power of the other type of capital, and enables them to be owned or traded.

According to Parkin [4], each capital is represented by stocks in economic jargon, in which we may or may not invest, and from which we expect a range of benefits to flow. Following figure (Figure 4) shows capital stocks and flow of benefits.

Sustainable Development Aspects	*Type of Capital*	*Stock*	*Flow of Benefits*
Environmental →	**Natural**	Soil, sea, air, ecological systems	Energy, food, water, climate, waste disposal
Social →	**Human**	Health, knowledge, motivation, spiritual ease	Energy, work, creativity, innovation, love, happiness
Social →	**Social**	Government systems, families, communities, organisations	Security, shared goods, (e.g. culture, education), inclusion
Economic →	**Manufactured**	Existing tools, infrastructure, buildings	Living/work/leisure places, access, material resources
Economic →	**Financial**	Money, stocks, bonds	Means of valuing, owning, exchanging other four capitals

Figure 4: Capital stock and flows of benefits: a modernised economic model for sustainable development [4]

Achieving Sustainable Development

Although the concept of sustainable development is now being addressed significantly, however, this concept is often achieved only partially. The main reasons for this are as follows [8]:

- Problems in providing quantitative estimates of savings which can be gained;

- Problems in the attribution of accurate economic costs to these products; and
- Problems in identifying the regulations and laws which provide suitable guidelines to new buildings and refurbishment.

According to Dincer and Rosen [9], a society seeking sustainable development ideally must utilise only energy resources which have no environmental impact, e.g. which release no emission to the environment. They have also discussed relation between energy efficiency and environmental impact since, for the same services or products, less resource utilization and pollution is normally associated with increased energy efficiency. Since energy is noticed as the central theme to achieve the goals of sustainable development, therefore, the main thrust of sustainable development is the maintenance of these valuable assets [10].

Achieving solutions to environmental problems that this world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions [11]. That is why there is an intimate connection between renewable energy and sustainable development. The renewable energy resources also have potential to reduce acid precipitation, stratospheric ozone depletion and the greenhouse effect [11].

Agenda 21

Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment in order to achieve sustainable development[12].

Agenda 21, the Rio Declaration on Environment and Development, and the Statement of principles for the Sustainable Management of Forests were adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, 3 to 14 June 1992.

The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up of UNCED, to monitor and report on implementation of the agreements at the local, national, regional and international levels. It was agreed that a five year review of Earth Summit progress would be made in 1997 by the United Nations General Assembly meeting in special session.

The 55th General Assembly session decided in December 2000 that the CSD would serve as the central organizing body for the 2002 World Summit on Sustainable Development, which will be held in Johannesburg, South Africa.

Agenda 21 explains that population, consumption and technology are the primary driving forces of environmental change. It sets out what needs to be done to reduce wasteful and inefficient consumption patterns in some parts of the world while encouraging increased but sustainable development in others. It offers policies and programmes to achieve a sustainable balance between consumption, population and the Earth's life-supporting capacity. It describes some of technologies and techniques that need to be developed to provide for human needs while carefully managing natural resources.

Agenda 21 provides options for combating degradation of the land, air and water, conserving forests and the diversity of species of life. It deals with poverty and excessive consumption,

health and education, cities and farmers. There are roles for everyone: governments, business people, trade unions, scientists, teachers, indigenous people, women, youth and children. Agenda 21 does not shun business. It says that sustainable development is the way to reverse both poverty and environmental destruction.

A major theme of Agenda 21 is the need to eradicate poverty by giving poor people more access to the resources they need to live sustainably. By adopting Agenda 21, industrialized countries recognized that they have a greater role in cleaning up the environment than poor nations, who produce relatively less pollution. The richer nations also promised more funding to help other nations develop in ways that have lower environmental impacts. Beyond funding, nations need help in building the expertise— the capacity— to plan and carry out sustainable development decisions. This will require the transfer of information and skills [13].

The Agenda 21 called on all countries to introduce National Strategies for Sustainable Development (NSSD). Since then, two international targets have been set: a Special Session of the UN General Assembly (Rio +5) set a target date of 2002 for NSSDs to be introduced; while the OECD Development Assistance Committee (DAC) has set a target date of 2005 for NSSDs to be in the process of implementation [14].

For additional reading material please see references and bibliography at the end of this review. The next section will present literature review on sustainable construction, one of the most important themes of sustainable development.

Sustainable Construction

Sustainable construction could be defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles" [6].

Sustainable construction is generally used to describe the application of sustainable development to the construction industry. The construction industry is defined as all who produce, develop, plan, design, build, alter, or maintain the built environment, and includes building material suppliers and manufacturers as well as clients, end users and occupiers. Therefore, sustainable construction could be best described as a subset of sustainable development, which encircles matters such as tendering, site planning and organisation, material selection, recycling, and waste minimisation [15].

Principles of Sustainable Construction

There are six principles for the sustainable construction, proposed by C. J. Kibert [16]:

1. Minimisation of resource consumption;
2. Maximisation of resource reuse;
3. Use renewable and recyclable resources;
4. Protect the natural environment;
5. Create a healthy and non-toxic environment; and
6. Pursue quality in creating the built environment.

Towards Sustainable Construction

There are three ways by which the civil engineering and construction industry can act to realise sustainable construction [16]:

- Creating built environments;
- Restoring damaged and/or polluted environments; and
- Improving arid environments.

Miyatake [16] suggests that everybody has to realise now that in order to achieve sustainable construction, the industry must change the processes of creating the built environments. This could be coined as bringing change from linear processes to cyclic processes within the construction industry. This means that the industry has to change the way in which all the construction activities are undertaken. The industry is using energy, material, and other resources to create buildings and other civil engineering projects, and the end result of all these activities is huge volume of discharge waste during and at the end of the facility's life. Therefore, changing this linear process into cyclic process will bring increased use of recycle, renewed and reused resources, and decrease in significant use of energy and other natural resources.

On the other hand, in order to restore damaged and polluted environments, efforts have been done such as treatments of damaged and contaminated soils, water and air. The idea behind improving arid environments is to improve large scale arid environments like deserts and making them habitable for plants, animals and human beings. But it is suggested [16] to give

priority to improve the built environments in order to transform its linear process into cyclic processes.

If we look at where the UK construction industry stands as far as sustainable development is concerned, we would need to look at the environmental reports for the UK. According to one of the CIRIA Reports [17], the construction industry is recognised for having profound economic (the industry accounts for 8% of UK GDP), social (the sector employs 1.4 million people) and environmental (30% of UK controlled wastes result from the construction process) impacts.

Construction Process

Let us look at the whole construction process itself. It could be divided into three distinct phases; pre-construction phase, construction phase, and post construction phase as shown in Figure 5.

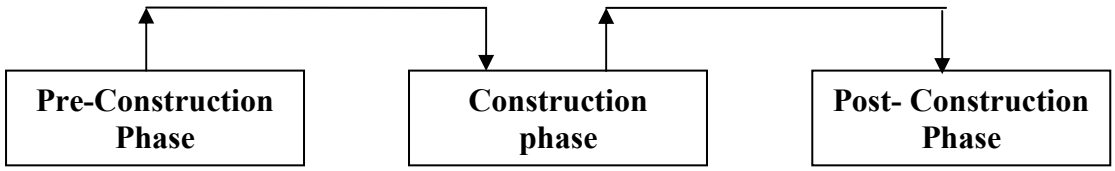

Figure 5: Different Phases of Linear Construction Process

Figure 5 shows the different phases of the construction of any facility. The pre-construction phase could also be sub-divided into two phases: the pre-project phase and pre-construction phase itself [18].

Pre-construction Phase

This phase includes the Procurement Process, the Costing of the Project, Quantity Surveying, Design of the Facility, User's Requirements, Client's Awareness and Involvement, etc.

Construction Phase

This phase includes the On-site Construction Process, Waste Management and Re-cycling, Supply and Management of Construction Material, etc. This also includes Involvement of whole Supply Chain during the Construction of the Project.

Post-construction Phase

This phase involves the Maintenance Period of a facility, life-cycle cost/economy and efficiency, including the demolition of a facility.

Therefore, in order to bring improvements within the built environments, the construction industry has to pay attentions to all the activities carried out in each of the above mentioned phases.

A Strategy for Sustainable Construction

The UK Government has taken sustainable development on board and it is also firmly on the agenda for the construction industry. The government considers sustainable construction as a set of processes by which a profitable and competitive industry delivers built assets (building, civil engineering structures, supporting infrastructure, and their immediate surroundings) which [19]:

- Enhance quality of life and offer customer satisfaction;
- Offer flexibility and the potential to cater for user changes in the future;
- Provide and support desirable natural and social environments; and
- Maximise the efficient use of resources.

The strategy developed for sustainable construction highlights the importance of design in order to achieve greater sustainability, because buildings or any other facility are the end product of all the design decisions taken at the outset of a project. According to Raynsford [19], design impacts in a variety of ways. For example, the choice of material and their applications have a significant environmental impact, depending on the sources of materials, their durability, and potential reuse. Civil engineers should also build on their strengths of design of the environment grounded in physical science, by analysing the entire environmental management system, thinking in terms of outcomes, and considering a broad range of alternatives. For example, civil engineers need to attend more closely to sustainable development and pollution prevention as substantive areas for engagement beyond the traditional design of waste treatment systems [20].

The UK Governmental initiatives towards sustainable construction are reflected from the following examples [1]:

- Sir John Egan's Construction Task Force published 'Rethinking Construction' in 1998;
- Movement for Innovation (M4I) was launched after the above mentioned report to identify and disseminate examples of good practice. One such example is the Queen Margaret Hospital in Swindon [21];
- A Government's sectoral strategy for construction industry came out in April 2000;
- Report: 'A better quality of life'; Foreword by the Prime Minister Tony Blair [22];
- Work done by 'Green Ministers' , including the publications produced by DETR [5];
- The Government target of 60% of new homes to be built on previously developed land is a significant initiative to encourage brown-field sites redevelopment with its aim of reducing development pressure on the green-field, initiating urban regeneration, and achieving a more sustainable programme [23].

Achieving Sustainable Construction

Green Building

Buildings have a tremendous impact on the environment – both during construction and through out their operation. "Green building" is a loosely defined collection of land-use, building design, and construction strategies that reduce these environmental impacts [24]. The green building approach to the built environment involves a holistic approach to the design of

buildings. All the resources that go into a building, be they materials, fuels or the contribution of the users need to be considered if a sustainable architecture is to be produced. Producing green buildings involve resolving many conflicting issues and requirements. Each design decision has environmental implications. Measures for green buildings can be divided into four areas [6]:

- Reducing embodied energy and resource depletion;
- Reducing energy in use;
- Minimising external pollution and environmental damage; and
- Minimising internal pollution and damage to health

What Makes a Building Green?

A "green" building places a high priority on health, environmental and resource conservation performance over its life cycle. These new priorities expand and complement the classical building design concerns: economy, utility, durability, and delight. Green design emphasises a number of new environmental, resource and occupant health concerns such as[6]:

- Reduction of human exposure to noxious materials;
- Conservation of non-renewable energy and scarce materials;
- Minimisation of life-cycle ecological impact of energy and materials used;
- Use of renewable energy and materials that are sustainably harvested;
- Protect and restore local air, water, soils, flora and fauna; and
- Support pedestrians, bicycles, mass transit and other alternatives to fossil-fuelled vehicles.

Most green buildings are high-quality buildings; they last longer, cost less to operate and maintain, and provide greater occupant satisfaction than standard developments. Sophisticated buyers and lessors prefer them, and are often willing to pay a premium for their advantages. What surprises many people unfamiliar with this design movement is that good green buildings often cost little or no more to build than conventional designs. Commitment to better performance, close teamwork throughout the design process, openness to new approaches, and information on how these are best applied are more important than a large construction budget [6, 25].

Sustainable Design

This section contains a literature review on sustainable design, which is the first step towards the sustainable construction. Sustainable design requires innovative solutions to technical problems. These solutions should always take into account the impact upon the environment. Innovative solutions which cost less, conserve energy, and natural materials, reduce pollution while providing healthier, more comfortable internal environment can only meet with success. The effect on building elements and services could be as follows [26]:

- Building envelope;
- Air-conditioning system;
- Security and fire control;
- Lighting system;
- Power and communication systems; and
- Integration of building and services

Therefore, it could be said that sustainable design is a thoughtful integration of architecture with electrical, mechanical, and structural engineering. In addition to concern for the traditional aesthetics of massing, proportion, scale, texture, shadow, and light, the facility design team needs to be concerned with long term costs: environmental, economic, and human.

The Rocky Mountain Institute outlines five elements for sustainable design [6]:

- Planning and design should be thorough. Sustainable design is "front loaded" compared with traditional design. Early decisions have the greatest impact on energy efficiency, passive solar design, day lighting, and natural cooling.
- Sustainable design is more of a philosophy of building than a prescriptive building style. Sustainable buildings do not have any particular look or style.
- Sustainable buildings do not have to cost more, nor are they more complicated than traditional construction.
- Integrated design, that is design where each component is considered part of a greater whole, is critical to successful sustainable design.
- Minimising energy consumption and promoting human health should be the organising principles of sustainable design. The other elements of design can be organised: energy saving architectural features, energy conserving building envelope, and energy-efficient and health-promoting mechanical, electrical, and plumbing systems.

Sustainable designed buildings aim to lessen their impact on the environment through energy and resource efficiency and includes the following principles [6]; minimising non-renewable

resource consumption; enhancing the natural environment; and eliminating or minimising the use of toxins.

According to an OECD project [27], sustainably designed building can be defined as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global setting. Sustainably designed building may be defined as building practices, which strive for integral quality (including economic, social and environmental performance) in a very broad way. Thus, the rational use of natural resources and appropriate management of the building stock will contribute to saving scarce resources, reducing energy consumption (energy conservation), and improving environmental quality.

Sustainable designed building involves considering the entire life cycle of buildings, taking environmental quality, functional quality and future values into account. In the past, attention has been primarily focused on the size of the building stock in many countries. Quality issues have hardly played a significant role. However, in strict quantity terms, the building and housing market is now saturated in most countries, and the demand for quality is growing in importance. Accordingly, policies that contribute to the sustainability of building practices should be implemented, with recognition of the importance of existing market conditions. Both the environmental initiatives of the construction sector and the demands of users are key factors in the market. Governments will be able to give a considerable impulse to sustainable buildings by encouraging these developments. The OECD project has identified five objectives for sustainably designed buildings:

- Resource Efficiency;
- Energy Efficiency (including Greenhouse Gas Emissions Reduction);

- Pollution Prevention (including Indoor Air Quality and Noise Abatement);
- Harmonisation with Environment (including Environmental Assessment); and
- Integrated and Systemic Approaches (including Environmental Management System).

According to Bai [28],it is an important subject in the building community to study the contribution to improving the earth environment and sustainable development from an architectural perspective.

Five Principles of Sustainable Design and Environmental Architecture

Five principles of sustainable design and environmental architecture, outlined by Fisher [29], are presented here:

- ***Healthy Interior Environment***. All possible measures are to be taken to ensure that materials and building systems do not emit toxic substances and gasses into the interior atmosphere. Additional measures are to be taken to clean and revitalise interior air with filtration and plantings.

- ***Energy Efficiency***. All possible measures are to be taken to ensure that the building's use of energy is minimal. Cooling, heating and lighting systems are to use methods and products that conserve or eliminate energy use.

- ***Ecologically Benign Materials***. All possible measures are to be taken to use building materials and products that minimise destruction of the global environment. Wood is

to be selected based on non-destructive forestry practices. Other materials and products are to be considered based on the toxic waste out put of production.

- ***Environmental Form***. All possible measures are to be taken to relate the form and plan of the design to the site, the region and the climate. Measures are to be taken to "heal" and augment the ecology of the site. Accommodations are to be made for recycling and energy efficiency. Measures are to be taken to relate the form of building to a harmonious relationship between the inhabitants and nature.

- ***Good Design***. All possible measures are to be taken to achieve an efficient, long lasting and elegant relationship of use areas, circulation, building form, mechanical systems and construction technology. Finished buildings shall be well built, easy to use and beautiful.

An Example of Sustainably Designed Building

There was a need to build a new office building at Building Research Establishment (BRE) Garston site, and this need became an ideal opportunity for BRE to put new ideas of sustainably designed building to the test and set example for the professional related to the built environment [30]. The brief for architects Feilden Clegg of Bath called for the use of natural ventilation, maximum use of day lighting, maximum use of the building's mass to moderate temperature, and controls that would let the building meet its environmental targets but keep its occupants happy. In addition, maximum use was made of recycled and waste materials and the building was designed in such a way to score the highest possible BREEAM rating of 'Excellent' [30].

See *Appendix 1* for the checklist for environmentally responsible design and construction [31].

Environmental Assessment: Tools and Standards

BREEAM

BREEAM (Building Research Establishment Environmental Assessment Method) is a tool that allows the owners, designers, and users of buildings to review and improve environmental performance throughout the life of a building [32]. It is a widely accepted and respected scheme that sets a benchmark for environmental performance and provides a wide range of benefits. It is independent and authoritative, being based on many years of construction and environmental research carried out at the Building Research Establishment (BRE) together with the input and experience of the construction and property industries, Government and building regulators. BREEAM is regularly updated to take advantage of new research, to reflect changing priorities in regulations and in the market place and to build on experience gained. The aim is to ensure that BREEAM continues to represent current best practice, going beyond what is required by regulations.

This latest version of BREEAM Offices (BREEAM 2002), launched in August 2001, includes major changes in the way BREEAM operates, and incorporates several major environmental issues [33].

EcoHomes

EcoHomes is a straightforward, flexible and independently verified environmental assessment method for homes, with environmental performance expressed on a scale of Pass to Excellent [34]. EcoHomes, sponsored by NHBC, is the homes version of BREEAM (the BRE Environmental Assessment Method). BREEAM leads the world in setting benchmarks for the environmental performance of buildings. It is independent, authoritative and based on many years of construction and environmental research carried out by BRE, the construction industry and Government.

EcoHomes is an easily understood, credible label for new and renovated homes including houses, apartments and sheltered accommodation. It rewards developers who improve environmental performance through good design, rather than high capital cost solutions. Benefits include

- Demonstrating sustainability credentials to planning authorities to assist a smooth passage through the planning process;
- Demonstrating “green” credentials to investors helps to minimise investment risk and increase the appeal to ethical investors;
- Demonstrating superior environmental design to customers, resulting in:
- Reduced running costs through greater energy and water efficiency, and reduced maintenance;
- Healthy, comfortable and flexible internal environments;
- Access to local amenities;
- Less dependence on the car; and

- Allowing developers to be one step ahead of regulation.

EcoHomes assessments can be carried out at the design stage. Every house type on a site is considered, but the award is given for the whole development. This enables developers to use the result to promote whole sites – every house that is part of the development has the same rating.

EcoHomes considers the broad environmental concerns of climate change, resource use and impact on wildlife, and balances these against the need for a high quality of life, and a safe and healthy internal environment. All the issues in EcoHomes are optional, making it flexible and enabling developers to adopt the most appropriate aspects of sustainability for their particular development and market.

The issues assessed are grouped into the seven categories below:

1. Energy
2. Transport
3. Water
4. Ecology and land use
5. Pollution
6. Health and well being
7. Materials

Life Cycle Costing (LCC) and Life Cycle Assessment (LCA)

Tools are needed to evaluate the performance of a building at any stage during its design and operation. Among these, Life Cycle Costing (LCC) is becoming increasingly popular for assessing economic implication and should be extended to consider the costs or benefits of deconstruction and the management of waste [35]. Life Cycle Analysis (LCA) is available to systematically consider the environmental impacts of the whole construction process and has already produced some important results within the concrete industry. LCA methodologies and other concepts such as clean technology, reveal opportunities for improved performance of existing products and processes and also encourage developing innovative new opportunities [1, 35], As yet, however, there is no tool for measuring the third indicator of sustainability – social aspect [35, 36].

Standards

ISO 14001 is a standard titled *Environmental management systems – specification with guidance for use*. This standard contains all the requirements for an organization to implement an environmental management system. The current version of the standard is 1996 version. ISO/TC207 is the ISO technical committee responsible for developing and maintaining the 14000 standards. In addition to the 14001 standard, there are other 14000 standards, which provide guidance on principles, systems and supporting techniques (14004), environmental auditing (14010), environmental management vocabulary (14050) to name but a few [37].

Following are some of the examples of 14000 series standards for environmental management (sustainable development and sustainable construction):

- Environmental management systems – Specification with guidance for use (ISO 14001:1996)
- Environmental management – Life cycle assessment – Principles and framework (ISO 14040:1997)
- Environmental management – Life cycle assessment – Goals and scope definition and inventory analysis (ISO 14041:1998)
- Environmental management – Life cycle assessment – Life cycle impact assessment (ISO 14042:2000)

In order to get a free assessment software, visit this web-site: http://www.iso14000.org/

Summary

As discussed above, one of the most important aspects of sustainable development is sustainable construction. The three basic themes of the sustainable construction; social, environmental, and economic; were also discussed. It is to note that the whole process of the construction project developed should be planned in such a way that in each phase of the project, sustainability issues are kept in mind. So for instance at the design stage, the facility is designed in such a way that sustainable design issues are incorporated within the design. These issues include natural light; natural ventilation; thermal mass; embodied energy; profile of the building; elevation of the building; colour/shape of the building; use of solar power if possible; minimal life cycle costs/ low running cost of construction and all the installations;

low energy/energy conservation during and after construction; producing low pollution during and after construction; providing healthier and safer internal environment; etc.

There are other issues which should be considered in order to address sustainable construction. This includes energy efficiency during the construction and post construction period of a facility; minimisation of green house gas emissions; design and construction of the facility is done in such a way that it encourages green transport and water conservation; waste minimisation and management during the construction and at the time of demolition; consideration given to the wild life and local nuisance during the design and construction phases; etc.

Cook [38] has summarised in ten ways, how to achieve sustainable construction:

- Re-use old buildings;
- Recycle waste materials;
- Use salvaged material;
- If one must build new, check how much energy was used to produce the materials;
- Consider low energy design;
- Design buildings that are cheap to run;
- Design building that will be cherished to increase the chance of re-use;
- Design for flexible buildings;
- Design and construct with health and safety in mind; and
- Make a profit – otherwise it is not sustainable.

Although, lots of things have been said, written, and available in the literature. Now the important thing is to implement those, bringing them into the real world in order to save our

planet, and in order to bring the concept of sustainable development and sustainable construction into practice.

For further readings on these topics, please see the attached reference and bibliography.

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Appendix 1

Checklist for Environmentally Responsible Design and Construction

DESIGN

*** Smaller is better:** Optimize use of interior space through careful design so that the overall building size--and resource use in constructing and operating it--are kept to a minimum.

*** Design an energy-efficient building**: Use high levels of insulation, high-performance windows, and tight construction. In southern climates, choose glazings with low solar heat gain.

*** Design buildings to use renewable energy:** Passive solar heating, day lighting, and natural cooling can be incorporated cost-effectively into most buildings. Also consider solar water heating and photovoltaics--or design buildings for future solar installations.

*** Optimize material use:** Minimize waste by designing for standard ceiling heights and building dimensions. Avoid waste from structural over-design (use optimum-value engineering/advanced framing). Simplify building geometry.

*** Design water-efficient, low-maintenance landscaping**: Conventional lawns have a high impact because of water use, pesticide use, and pollution generated from mowing. Landscape with drought-resistant native plants and perennial groundcovers.

*** Make it easy for occupants to recycle waste:** Make provisions for storage and processing of recyclables: recycling bins near the kitchen, under sink compost receptacles, and the like.

*** Look into the feasibility of graywater:** Water from sinks, showers, or clothes washers (graywater) can be recycled for irrigation in some areas. If current codes prevent graywater recycling, consider designing the plumbing for easy future adaptation.

*** Design for durability:** To spread the environmental impacts of building over as long a period as possible, the structure must be durable. A building with a durable style ("timeless architecture") will be more likely to realize a long life.

*** Design for future reuse and adaptability:** Make the structure adaptable to other uses, and choose materials and components that can be reused or recycled.

*** Avoid potential health hazards: radon, mold, pesticides:** Follow recommended practices to minimize radon entry into the building and provide for future mitigation if necessary. Provide detailing that will avoid moisture problems, which could cause mold and mildew growth. Design insect-resistant detailing that will require minimal use of pesticides.

SITING & LAND USE

*** Renovate older buildings:** Conscientiously renovating existing buildings is the most sustainable construction.

*** Create community:** Development patterns can either inhibit or contribute to the establishment of strong communities and neighbourhoods. Creation of cohesive communities should be a high priority.

*** Encourage in-fill and mixed-use development:** In-fill development that increases density is inherently better than building on undeveloped (greenfield) sites. Mixed-use development, in which residential and commercial uses are intermingled, can reduce automobile use and help to create healthy communities.

*** Minimize automobile dependence:** Locate buildings to provide access to public transportation, bicycle paths, and walking access to basic services. Commuting can also be reduced by working at home--consider home office needs with layout and wiring.

*** Value site resources:** Early in the sitting process carry out a careful site evaluation: solar access, soils, vegetation, water resources, important natural areas, etc., and let this information guide the design.

*** Locate buildings to minimize environmental impact:** Cluster buildings or build attached units to preserve open space and wildlife habitats, avoid especially sensitive areas including wetlands, and keep roads and service lines short. Leave the most pristine areas untouched, and look for areas that have been previously damaged to build on. Seek to restore damaged ecosystems.

*** Provide responsible on-site water management:** Design landscapes to absorb rainwater runoff (storm water) rather than having to carry it off-site in storm sewers. In arid areas, rooftop water catchment systems should be considered for collecting rainwater and using it for landscape irrigation.

*** Situate buildings to benefit from existing vegetation:** Trees on the east and west sides of a building can dramatically reduce cooling loads. Hedge rows and shrubbery can block cold winter winds or help channel cool summer breezes into buildings.

MATERIALS

*** Avoid ozone-depleting chemicals in mechanical equipment and insulation:** CFCs have been phased out, but their primary replacements--HCFCs--also damage the ozone layer and should be avoided where possible. Avoid foam insulation made with HCFCs. Reclaim CFCs when servicing or disposing of equipment.

*** Use durable products and materials:** Because manufacturing is very energy-intensive, a product that lasts longer or requires less maintenance usually saves energy. Durable products also contribute less to our solid waste problems.

*** Choose low-maintenance building materials:** Where possible, select building materials that will require little maintenance (painting, retreatment, waterproofing, etc.), or whose maintenance will have minimal environmental impact.

*** Choose building materials with low embodied energy:** Heavily processed or manufactured products and materials are usually more energy intensive. As long as durability and performance will not be sacrificed, choose low-embodied-energy materials.

*** Buy locally produced building materials:** Transportation is costly in both energy use and pollution generation. Look for locally produced materials. Local hardwoods, for example, are preferable to tropical woods.

*** Use building products made from recycled materials:** Building products made from recycled materials reduce solid waste problems, cut energy consumption in manufacturing, and save on natural resource use. A few examples of materials with recycled content are cellulose insulation, Homasote®, Thermo-ply®, floor tile made from ground glass, and recycled plastic lumber.

*** Use salvaged building materials when possible:** Reduce landfill pressure and save natural resources by using salvaged materials: lumber, millwork, certain plumbing fixtures, and hardware, for example. Make sure these materials are safe (test for lead paint and asbestos), and don't sacrifice energy efficiency or water efficiency by reusing old windows or toilets.

*** Seek responsible wood supplies:** Use lumber from independently certified well-managed forests. Avoid lumber products produced from old-growth timber unless they are certified. Engineered wood can be substituted for old-growth Douglas fir, for example. Don't buy tropical hardwoods unless the seller can document that the wood comes from well-managed forests.

*** Avoid materials that will off gas pollutants:** Solvent-based finishes, adhesives, carpeting, particleboard, and many other building products release formaldehyde and volatile organic compounds (VOCs) into the air. These chemicals can affect workers' and occupants' health as well as contribute to smog and ground-level ozone pollution outside.

*** Minimize use of pressure-treated lumber:** Use detailing that will prevent soil contact and rot. Where possible, use alternatives such as recycled plastic lumber. Take measures to protect workers when cutting and handling pressure-treated wood. Scraps should never be incinerated.

*** Minimize packaging waste:** Avoid excessive packaging, such as plastic-wrapped plumbing fixtures or fasteners that aren't available in bulk. Tell your supplier why you are avoiding over-packaged products. Keep in mind, however, that some products must be carefully packaged to prevent damage--and resulting waste.

EQUIPMENT

*** Install high-efficiency heating and cooling equipment:** Well-designed high-efficiency furnaces, boilers, and air conditioners (and distribution systems) not only save the building occupants money, but also produce less pollution during operation. Install equipment with minimal risk of combustion gas spillage, such as sealed-combustion appliances.

*** Install high-efficiency lights and appliances:** Fluorescent lighting has improved dramatically in recent years and is now suitable for homes. High-efficiency appliances offer both economic and environmental advantages over their conventional counterparts.

*** Install water-efficient equipment:** Water-conserving toilets, showerheads, and faucet aerators not only reduce water use, they also reduce demand on septic systems or sewage treatment plants. Reducing hot water use also saves energy.

*** Install mechanical ventilation equipment:** Mechanical ventilation is usually required to ensure safe, healthy indoor air. Heat recovery ventilators should be considered in cold climates because of energy savings, but simpler, less expensive exhaust-only ventilation systems are also adequate.

JOB SITE & BUSINESS

*** Protect trees and topsoil during site work:** Protect trees from damage during construction by fencing off the "drip line" around them and avoiding major changes to surface grade.

*** Avoid use of pesticides and other chemicals that may leach into the groundwater:** Look into less toxic termite treatments, and keep exposed frost walls free from obstructions to discourage insects. When backfilling a foundation or grading around a house, do not bury any construction debris.

*** Minimize job-site waste:** Centralize cutting operations to reduce waste and simplify sorting. Set up clearly marked bins for different types of usable waste (wood scraps for kindling, sawdust for compost, etc.). Find out where different materials can be taken for recycling, and educate your crew about recycling procedures. Donate salvaged materials to low-income housing projects, theatre groups, etc.

*** Make your business operations more environmentally responsible:** Make your office as energy efficient as possible, purchase energy-efficient vehicles, arrange carpools to job sites, and schedule site visits and errands to minimize unnecessary driving. In your office, purchase recycled office paper and supplies, recycle office paper, use coffee mugs instead of disposable cups. On the job, recycle beverage containers.

*** Make education a part of your daily practice:** Use the design and construction process to educate clients, employees, subcontractors, and the general public about environmental impacts of buildings and how these impacts can be minimized.