Chapter I
Sustainable Construction

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1 Sustainable development

During the course of last century, the rapid advance of scientific and technological knowledge has provided humankind with the power to drastically alter planetary systems. This power, together with increasing human numbers, has led to the excessive exploitation of renewable natural resources such as fish, wildlife and forests. There is growing scientific consensus that vast stocks of biological diversity are in danger of disappearing just as science is learning how to exploit this diversity through genetic engineering (WCED, 1987).

By the middle of last century, people were starting to question the capability of the earth to sustain the affluent lifestyle of the developed world. This question was raised from the view that technology development was largely responsible for the escalation of environmental degradation. Since then, people have been encouraged to embrace a lifestyle that shows more care for the environment and contributes to the reduction of the environmental impacts caused by materials- and energy-intensive developments. Researchers sowed the seeds of the environmental movement by advocating the development which gave precedence to spiritual and psychological needs over materials satisfactions, the so-called 'post-materialistic society' (Gardner, 1989).

In the developed world, the public concern for the environment increased throughout the decade of the 1960s, and the first Earth Day was celebrated in April 1970 in Vermont, United States of America (Fuggle et al., 1992). The international concern on the environment was reflected in the United Nations Conference on the Human Environment which was held in Stockholm in 1972. The conception of eco-development emerged from this conference as 'an approach to development aimed at harmonizing social and economic objectives with ecologically sound management' (Gardner, 1989, Sachs, 1978).

Eco-development since then became the precursor of the concept of sustainable development.

In the same year to the Stockholm Conference in 1972, the Club of Rome published *The Limits to Growth*, which emphasized that concerns about pollution, environmental degradation and natural resource depletion were crucial to the long-term future of humanity (Meadows et al., 1972). This development led to an alternative view of the limits-to-growth perspective. The limits-to-growth perspective challenged the pro-growth perspective rooted in previous decades, and received wide range of responses. A synthesis of the two conflicting perspectives eventually emerged in the perspective of sustainable development. Stockdale (1989) pointed out that this synthesis may be more usefully described as a continuum of perspectives in the middle ground between the extremes of the limits-to-growth perspective and the pro-growth perspective. The concept of sustainable development is value laden although differing perspectives of sustainable development have been grasped by both environmentalists and the proponents of development to support their respective viewpoints.

In line with the growing of the limits-to-growth in the 1970s, the practice of nature conservation embraced a preservationist philosophy, which suggests that nature could and should be conserved within the clearly demarcated boundaries of conservation areas. As a result, development and conservation were seen as two ideas which were in direct conflict with one another. In mitigating this conflict, the International Union for the Conservation of Nature and Natural Resources (IUCN) published the World Conservation Strategy (IUCN, 1980). The Strategy marked a significant shift in conservation, from focusing solely on the practice of fencing off nature reserves to balancing conservation and development. The Strategy defined development as 'modification to the biosphere to satisfy human needs', and conservation as 'the management of human use of the biosphere to yield the greatest sustainable benefit to present and future generations'(IUCN, 1980).

At practical level, the World Conservation Society translated the concern for the conservation of life support systems, ecological processes and genetic diversity into priorities for action. The priority requirements for the conservation of genetic diversity are defined in the report called the Genetic Management Iceberg (IUCN, 1980). The report describes that the efforts to conserve biodiversity in zoos, botanical gardens, seed and sperm banks, and even in National Parks and nature reserves, only reflect the tip of the 'iceberg'. More meaningful contribution to conserving genetic diversity and ecological processes requests for the efforts to deal with the bulk of the 'iceberg', which is hidden from view. For example, conservation management in implementing construction projects presents great potential of contributing to the conservation of resources through sound planning, allocation and management of water and land uses (IUCN, 1980). In other words, construction activities can make important contribution to the conservation of biodiversity by applying environmental management in the execution of projects.

In 1987, the World Commission on Environment and Development (WCED) published the report Our Common Future (WCED, 1987), wihich is commonly referred as 'Brundtland Report'. The report particularly concerns with the ecological crises which have close association with the poverty and inequity. Sustainable development is defined in the report as meeting the basic needs of all people and extending to all the opportunity to satisfy their aspirations for a better life without compromising the ability of future generations to meet their own needs. In this definition, the emphasis is placed on the balance between social development, economic development and environmental sustainability. Various interests have been aroused about the meaning of 'sustainability'. A typical interpretation of sustainability is the 'sustainable utilization' of natural resources. However, question can be raised on such interpretation. For example, how can we have sustainable utilization of those non-renewable resources, such as oil and minerals. It is hard for 'sustainable' and 'non-renewable' to be paralleled. Therefore, 'sustainable utilization' is limited to the application of renewable natural resources, for example, water resources, plants and animals, implying to use resources at the rates within their capacity of renewal.

Nevertheless, criticism has been received about the term 'sustainable development' as that the term is ambiguous and open to a range of interpretations, many of which were contradictory. This is considered as the results that the term has been used interchangeably with other terms such as 'sustainable growth'. The term sustainable growth is a contradiction itself because nothing physical can grow indefinitely, whereas sustainable development is defined in the report Caring for the Earth as the development which 'improves the quality of human life while living within the carrying capacity of supporting eco-systems'(IUCN, 1991). Nevertheless, the practice of the term remains contentious because of the difficulties in determining the 'carrying capacity of supporting eco-systems' and the difficulties in identifying the causes undermining ecosystems. Accusations between the nations of the North and the South over who is undermining the carrying capacity of local and global systems have become habitual, which was the main topic for the heated debate at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro.

In fact, the divergence of opinions about the term 'sustainability' is so broad that a single definition cannot adequately capture all the nuances of the concept. However, it appears that the controversy has been replaced by a sustainable development synthesis where a general agreement exists that uncontrolled exploitation of natural resources is not beneficial to humankind in the long term. Research works have been attempted to look at the implication of sustainability. Solow (1993) argued that development will inevitably cause at least some drawdown of current stocks of non-renewable resources, and that sustainability should mean more than just the preservation of natural resources. To maintain the capacity to meet the needs of future generations, concern is required for society' s total capital, taking into account the substitutional possibilities between natural and other forms of capital. Solow proposed that fairness towards future generations requires that some of the proceeds from the exploitation and depletion of non-renewable resources should be invested on other assets, which could include social or human-made capital (e.g. education and factories), to maintain productive capacity to meet the needs of future generations (Solow, 1993).

2 Concepts of sustainable construction

The construction industry and the built environment must be counted as key areas if we are to attain a sustainable development in our societies. As an example quoted in a report (CIB, 1999), in the European Union, buildings were responsible for more than 40% of the total energy consumption and the construction sector was estimated to generate approximately 40% of all man-made wastes. In addition, the construction sector was the Union's largest industrial sector, contributing with approximately 11% to the GNP and having more than 25 million people directly and indirectly engaged.

The November 1994 issue of the journal World Watch noted that Homo sapiens have become a super species through the use of buildings, capable of adapting to life anywhere on the planet. This ability to shape one's surroundings has obvious financial and environmental costs. According to World Watch, one-tenth of the global economy is dedicated to constructing, operating and equipping homes and offices. These activities account for roughly 40% of the materials flow entering into the world economy, with much of the rest destined for roads, bridges and vehicles to connect the buildings (Roodman and Lenssen, 1994).

The international effort to shift construction industry onto a path parallel to the overarching sustainable development movement is only about a decade old, leading to the emergence of sustainable construction. This new area addresses the entire life cycle of building, including project planning, design, construction, operation, modifications, renovation, retrofit, and ultimate disposal. The term 'sustainable construction' was originally proposed to mainly describe the responsibility of the construction industry in attaining 'sustainability'. November 1994 evidenced the the First International Conference on Sustainable Construction in Tampa, Florida, United States of America. The conference led to the wide recognition of sustainable construction as a new discipline (Kibert, 1994a). The conference convener, Kibert (1994b), described sustainable construction as 'creating a healthy built environment using resource-efficient, ecologically-based principles'. This emphasizes the adoption of design and construction methods that are resource efficient and that will not compromise the health of the environment or the associated health of the building occupants, builders, the general public or future generations. Fig.1-1 depicts the relationship of the various life cycle stages, required resources, and proposed principles of Sustainable Construction (Kibert, 1994c).

The basic 'stuff' or resources needed for construction are materials, energy, water, land, and, in the spirit of sustainability, ecological systems. The latter is included because it is becoming ever more apparent that ecosystems can and should be integrated with buildings to provide a wide range of services such as heating, cooling, storm-water uptake, environmental amenity, waste processing, and even food. The timeline for the built environment runs from planning through deconstruction or building disassembly. The principles proposed for Sustainable Construction include to minimize resource consumption (Conserve), maximize resource reuse (Reuse), use renewable or recyclable resources (Renew/Recycle), protect the natural environment (protect nature), create a healthy and non-toxic environment (Non-Toxics), apply life cycle cost analysis and true costs (Economics), and pursue quality in creating the built environment (Quality).

The understanding of sustainable construction has likewise experienced a number of years. Initially, the study was focused on the issue of limited natural resources, especially energy, and the way of reducing the construction impacts on the natural environment. In 1990s, research emphasis was placed mainly on the technical issues such as the environmental impacts from materials appliance, building components, and construction technologies. In line with the development of research, it has been now realized that the non-technical issues such as regulations, codes of practice, management skills, and others, are becoming pressing issues affecting the contribution to sustainable development, And the implication of sustainable construction has been extended to the contribution to social and economic sustainability. For example, the cultural heritage is widely considered as an important dimension of social sustainability that must be included in pursuing sustainable construction.

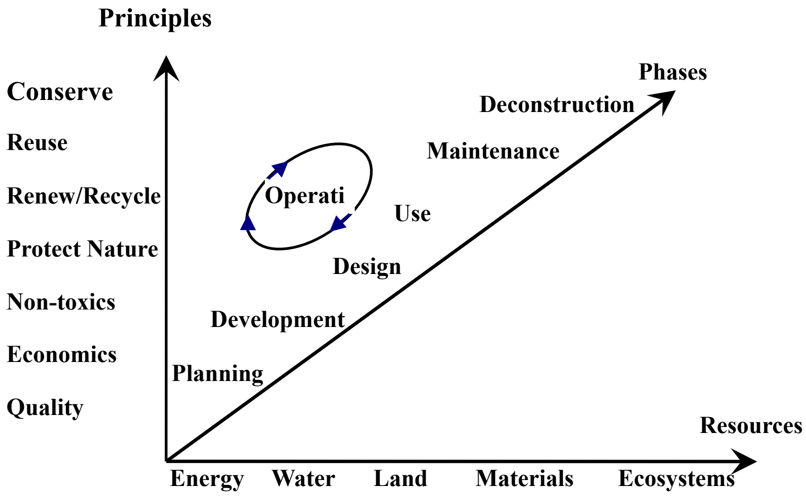

Fig.1-1 Sustainable Construction: Life cycle stages, Principles and Resources

(Source: Kibert, C.J., 1994c, "Establishing principles and a Model for Sustainable Construction", *Proceedings of First International Conference of CIB TG 16 on Sustainable Construction*, Tampa, Florida, 6-9 November, pp.3-12.)

3 Issues and challenges of sustainable construction

Management and organization

Management and organization are the foundations for implementing the principle of sustainable construction, concerning with not only technical supports, but also social, legal, economic and political supports. An organization framework in committing construction activities must be built up to allow for planning, design, construction, and operation to contribute collectively to the attainment of sustainable construction. And management methods need to be adopted within the organization framework.

<u>Construction Products</u>

Construction products vary and they have different impacts on the attainment of sustainable development. The characteristics of construction products should be optimized towards improving their sustainability performance, with considering the variables such as climate, culture, advancement of industrial development, and others.

Quality of indoor environment

Sustainable construction aims for obtaining the best internal environment quality including indoor air quality, thermal, acoustic and lighting environment. Both the design of the mechanical environment and aesthetic factors are significant to affect the quality of indoor environment, which are commonly the causes for work-stress and psychological problems.

Manufacturing of construction components

The construction industry is a large consumer of energy-intensive manufactured materials such as iron, steel and cement for various construction components such as structural elements, glass for windows, and synthetic materials for sealing and insulation. The production of these materials affects the environment in multiple dimensions. In fact, production of construction materials contributes largely to the depletion of non-renewable resources. Nevertheless, manufacturing of construction components can contribute to improving sustainable performance in various ways, typically including (1) to reduce the embodied energy of the components; (2) to mitigate the emissions from producing construction components; (3) to improve the repairability (design for disassembly and repair in the factory) and recyclability (used products to be returned to their producer) of the construction components.

Resources consumption

In the report by CIB (1999), resources consumption in construction concerns with a wide range of aspect, as shown in Figure 1-2. The ineffectiveness of resources consumption in the practice presents immense challenges to sustainable performance in construction industry. Energy saving measures, extensive retrofit programs and transport needs present challenges to energy consumption. Reduction in the use of mineral resources and conservation of the life support function of the environment require using renewable and recyclable materials.Water saving in buildings challenges the management system of using water in operating construction products. The construction in the process of urbanization is challenged by the limitation of land resources.

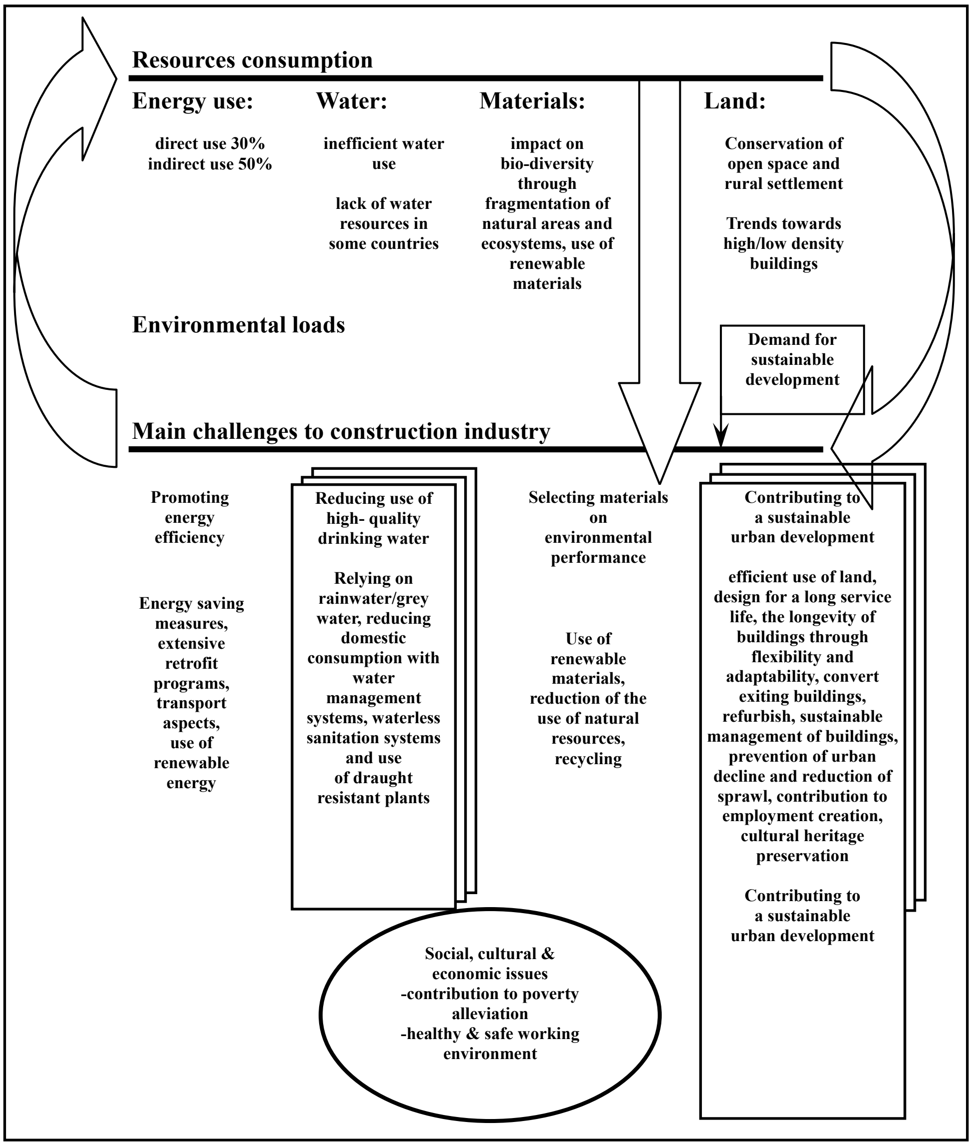

Fig.1-2 Issues and challenges of sustainable construction in resources consumption (Source: CIB, 1999, *Agenda 21 on Sustainable Construction*, CIB Report Publication pp.237)

Energy use

Various management systems have been developed for providing solutions of reducing energy use in new buildings. It seems that limited efforts have been contributed to finding solutions of saving energy in operating the existing buildings. A major concern is the costs for updating the management and operational systems in these existing buildings. There is a need for new retrofit technologies that are economically affordable to building owners. The use of renewable energies in most countries has yet to advance.

Water

Lack of water resources in many countries, leakage from distribution systems in many practices, and inefficient water use in almost all countries are typical problems which continue to grow. The conservation of drinking water and the reduction of sewage water can be contributed through water saving equipment in new buildings. The advancement of water management methods in existing buildings can lead to substantial water savings, for example, using rainwater and grey water storage, providing water saving guidelines for building managers, using low flow showerheads, dual flush toilets and self-composting toilets, and others. There are countries or regions where water resources are very scarce, other water management practice should be considered, such as using waterless sanitation systems and landscaping with drought-resistant plants.

Materials

Materials consumption in implementing construction works has a direct impact on natural bio-diversity due to the fragmentation of natural areas and ecosystems caused by construction activities. In particular, 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 nonrenewable materials. This should be incorporated for consideration at the project initiative and design phases, where the selection of materials is very important and the choice should be based on the materials' environmental impacts. At the construction and deconstruction phases, various methods can also be used for reducing the impacts of materials consumption on the natural environment, for example, materials recycling and reuse, construction-for-disassembly by using modular, using the materials and components available locally.

Land

Land resources are of limitation and nonrenewable. Therefore, the urbanization process particularly in those developing countries and regions has caused concerns world wide. In the Western and Eastern European countries, conservation of open space and safeguarding the structure of rural settlements are among the priorities in policy-making. Construction industry has a major role to play in protecting land resources by using land efficiently, designing products for long service life, and using and maintaining the existing buildings efficiently. Other design solutions include to combine more building functions, to use underground space, and to optimize the use of the roof surface. The choice of land for construction has not only the local environmental effects, but also social and economic impacts. In particular, efficient use of land is vital for those countries and regions where population density is high and mainly confined to urban areas.

Waste generation

Construction industry is a major contributor to waste generation particularly for solid waste. It is estimated that about 13% of all solid wastes deposited in landfills world-wide comes from construction and demolition waste with a ratio of about 1:2 between construction and demolition waste. On the other hand, a large part of greenhouse gases comes from the energy use in building and transport activities, and they contribute to the air emissions, causing ozone depletion. Construction activities also generate liquid wastes. Typical impacts of the wastes generated from construction activities on the environment include the pollution and the damages to the landscape and agricultural land.

Social and economic contribution

Sustainable construction can make contribution to poverty alleviation by promoting social benefits from undertaking construction activities, and to the improvement of quality of life by creating healthy and pleasant and living and working environment. The implementation of construction works provides employment opportunities, thus contributes to the development of human resources. The Habitat II Agenda emphasizes that the construction industry is a major contributor to socio-economic development in every country. It articulates that government should encourage the construction industry to promote "locally available, appropriate, affordable, safe, efficient and environmentally sound construction methods and technologies in all countries, particularly in the developing countries, ate the local, national, regional and sub-regional levels to emphasis optimal use of local human resources and encourage energy-saving methods and are protective of human health".

4 Strategies and actions for sustainable construction

Strategies

CIB (1999) has suggested strategies and actions for sustainable development in its report Agenda 21 on Sustainable Construction, as shown in Figure 1-3. This framework lays down valuable principles of how different organizations can adopt sustainable construction practices and thereby contribute to sustainable development. The strategies and actions for sustainable construction need to take into account of many variables such as climate, culture, building traditions, nature of construction works, and progress of industrial development. The challenges from implementing these strategies to construction sector are not only to determine the right balance between various constraints of the construction works (technical, architectural, social or economic constraints), but also to act for "decisions without regret" in compromising various solutions across the life cycle of a building, and especially in the construction phase.

Regulation

Regulations are fundamental strategies and measures for ensuring the implementation of sustainable construction, such as various building or energy use codes. For example, energy pricing is powerful lever to encourage improving energy use performance. It is widely considered that the energy price is currently cheap and not at an appropriate level, thus can not present energy users a meaningful finance commitment. This is particularly the case in North America.

Nevertheless, it should be noted that regulations in general represent a consensus on the minimum standard of necessary performance, thus they can be revised and or updated when necessary. In application, organizations have different strategies. As some construction organizations consider the compliance with regulations as extra costs, their performance often aims for meeting the minimum requirements imposed by regulations. This practice is considered defensive, resulting in the occurrence of non-compliance with regulations in construction industry. Other construction firms take a more positive strategy to respond to the introduction of regulations, for example by using environmentally friendly materials or construction methods. This is a more cooperative strategy, which can allow organizations to gain a competitive advantage from the viewpoint of long term as construction market has become increasingly favorable to environmentally friendly products.

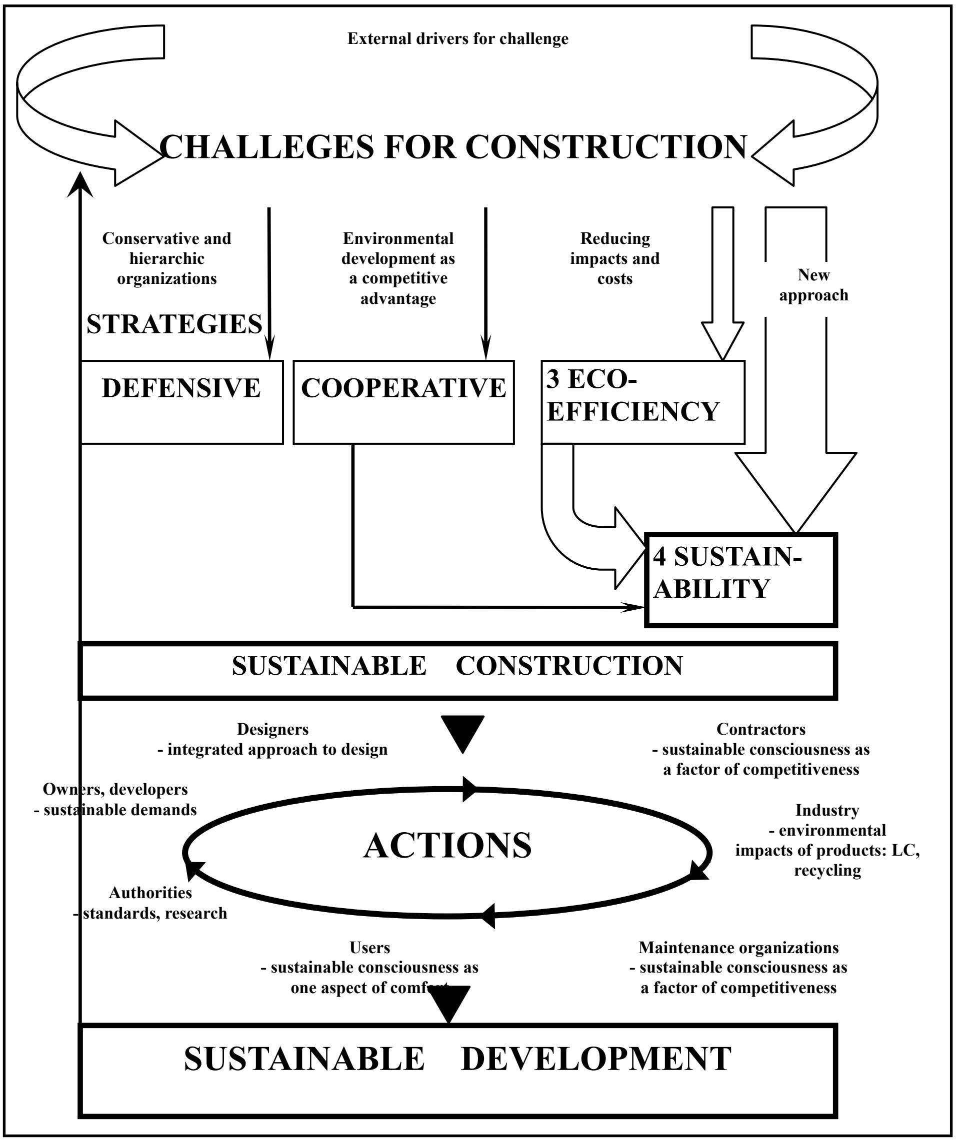

Fig.1-3 The strategies and actions for sustainable development
(Source: CIB, 1999, *Agenda 21 on Sustainable Construction*, CIB Report Publication pp. 237.)

Enabling and supporting mechanisms

Enabling and supporting mechanisms, such as information networking, training programs, technology transfer, are necessary to assist the construction industry in contributing to sustainable development. For example, information technology can provide timely the information about new materials, technologies and managements for improving the efficiency or level of performance contributable to sustainable development. Training programs can empower construction stakeholders to understand their roles and benefits from implementing sustainable construction practice.

Technology transfer can advance the operational skills particularly in those less developed countries or regions, and improve the overall contribution to sustainable development.

Incentives and example demonstrations

Incentives and example demonstrations can stimulate a broader range of construction clients to develop to higher standards of sustainable performance. However, such methods are usually costly, and incentives can cause negative effects on the marketing mechanism if they are not adopted properly. Incentive policy should be designed to aim for win-win outcome, by which the environmental impacts from construction practice can be reduced, and additional benefits can be brought to organizations. On the other hand, it is considered that example demonstration program can exert a positive effect on promoting sustainable construction.

Partnership

The implementation of sustainable construction practice requests for the cooperative participation from all construction stakeholders. As construction activities across the life cycle of any construction products have an association in different formats with social, economic and environmental impacts, all construction related parties, including clients, users, builders, architects, engineers, suppliers, have various roles that can help to contribute to the attainment of sustainable construction. Thus all construction stakeholders need to work in partnership towards the same goal.

Actions by major parties

Clients (owners, developers, investors, users)

Clients play a very important role in promoting and implementing sustainable construction since they determine what construction products and performance should be delivered. Construction clients have various ways for improving the sustainable performance in construction industry for example by specifying clearly environmental specifications for the parties involved in design and construction processes, by giving higher priority to environmental performance when recruiting builders, and by using or operating the construction products environmentally friendly.

Authorities

Governmental authorities provide driving force to implement sustainable construction by issuing various regulations and policies which guide all construction stakeholders to contribute to the attainment of sustainable construction. The authorities can also take actions when necessary to ensure that organizations' performance meets the requirements specified in regulations and policies.

Designers

Designers have the role to affect directly the construction practice through choosing the layouts of construction products, construction methods and construction materials. These attributes affect directly the construction buildability during construction stage, the maintenance during project operation, and the environmental performance of the built products.

Materials suppliers

Materials can contribute to improving sustainable construction by manufacturing and providing environmentally friendly construction materials or components. These materials and components are expected to have better durability and repairability. Materials suppliers are in good position to promote materials recycling and reuse.

Contractors

Contractors' performance is more tangible in association with the environmental impacts. They can contribute to attaining sustainable construction across all their activities, typically including site operations, materials procurement and handling, waste handling, and coordination among various suppliers and subcontractors. Environmental management should be considered as one of contractors' major objectives.

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