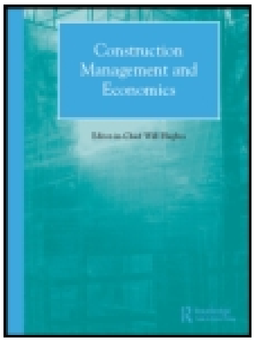

Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

The environment: the fourth construction project objective?

George Ofori

To cite this article: George Ofori (1992) The environment: the fourth construction project objective?, Construction Management and Economics, 10:5, 369-395, DOI: 10.1080/01446199200000037

To link to this article: https://doi.org/10.1080/01446199200000037

Construction Management and Economics, 1992, **10**, 369–395

The environment: the fourth construction project objective?

GEORGE OFORI

Construction Management and Economics Research Unit, National University of Singapore, 10 Kent Ridge Crescent, Singapore 0511

The objectives of construction projects, from the client's point of view, are well known, and techniques have been developed to help practitioners achieve them. Ensuring that projects contribute towards protecting the environment is not yet one of these objectives. However, in almost all countries, issues relating to the environment are receiving attention from governments, non-governmental institutions and commercial organizations in most sectors of the economy, as well as from the general public. Statutory measures are being taken by governments to effect pollution control, resource conservation and protection of natural ecosystems. Productive enterprises are reviewing, and where necessary, changing aspects of their operations to address these concerns and comply with the increasingly more stringent requirements. Many environment-related statutes, regulations, codes and general policies have implications for the construction industry, affecting where constructed items are located, how they are planned and designed, the materials and components used, the techniques and equipment adopted, and how the completed facilities are maintained, altered and, ultimately, demolished.

After giving an overview of the factors contributing to, and the nature of, general developments relating to the environment (especially in the area of government policy), the implications of these trends for the construction industry are considered. Actions being taken by the industry in these regards are next discussed. It is suggested that the consideration of issues relating to the environment should be part of the culture of the construction industry everywhere, and that there is a case for making the environment the fourth client objective on construction projects.

Keywords: Objectives, client, project management, environment, policy, control.

Introduction

Construction project objectives and need for change

The well-accepted objectives of every construction project, from the point of view of the client, are time, cost and quality (Stuckenbruck, 1981; Bennett, 1983; Walker, 1990). Techniques and procedures have been developed and progressively refined to achieve each of these objectives, more (and higher quality) of the required information is being provided, and there are changes to practices including the reallocation of professional roles (Construction Industry Development Board, 1989; Chow, 1990). However, approaches differ from one country to another, and also from project to project. Although not specifically stated, the implication is that efficiency on projects would lead to an effective and efficient construction industry (Ofori, 1990).

Until recently, environmental considerations were not accorded importance on construction projects. So far, such issues are effectively considered only at the planning stage of major (mainly public sector) construction projects, or in relation to particular situations – with respect to specific materials or equipment, or in reaction to statutes or regulations after they are implemented. Where attempts have been made to study the situation in a wider manner, it has largely been undertaken from the perspective of a particular profession (Chartered Institute of Building, 1989; Infrastructure Policy Group, 1990). The factors which are cited as hindering technology development in construction may be partly blamed for this Hillebrandt, 1984; Nam and Tatum, 1988; Ofori, 1990). These include the reliance of the industry on other sectors of the economy for its inputs and its lack of control over its outputs, which are mainly used by other sectors.

However, with the increasing attention being paid by governments, non-governmental institutions, global agencies and the general public to issues relating to the environment, it is important for the construction industry to take measures to consider them throughout the construction process in a comprehensive and co-ordinated manner. The industry needs to act for at least three reasons: (*defensive*) to take proactive measures to foresee and forestall unfavourable consequences, for the industry, of the increasing array of environment-related statutes, regulations and policies; (*offensive* and *economic*) to anticipate opportunities and prepare to meet the changed nature of the items it will be required to design, construct and manage, the new materials it might have to use and the processes it would have to adopt; and (*social* but not completely altruistic) to make its contribution to the overall effort being made to address environmental issues.

After a brief outline of the history of the consideration of environmental issues in general and discussion of the concept of sustainable development, this paper gives an overview of initiatives being taken in various countries to address the matter. The implications these have for the construction industry, and how these are being attended to, are outlined. The need for further action to make the consideration of issues of the environment a culture in the construction industry is next discussed.

History

The reasons which are cited to explain the concern with the nature and quality of the environment – which appears to be generally acknowledged to have started in the 1970s – include:

(i) the oil crises during the early and latter part of the 1970s;
(ii) the many books which emerged from around the mid-1960s and drew attention to the fragility of the world's ecosystems and the finite nature of its resources;
(iii) popular pressure on governments from consumers and other groups especially in the West, which called for action to limit – and correct – the harmful effects of intensive farming, certain types of industrial production, high-consumption lifestyles, danger to flora and fauna from encroachment on wilderness areas, unsatisfactory waste disposal methods and rapid growth in human population; and
(iv) the realization, following some accidents, of the potential dangers from such processes as the production and handling of chemicals and the generation of nuclear power.

The United Nations Conference on the Human Environment of 1972 led to the establishment of the United Nations Environment Programme (UNEP). A series of best-selling books including *Only One Earth* (Ward and Dubos, 1972) and *The Limits to Growth* (Behrens, 1974) brought the matter to the attention of a much wider audience. More recent works include the *Blueprint for a Green Economy* (Pearce *et al.*, 1989). Issues relating to the environment have been intensively researched and debated (at district, national and international levels). A conference of the leaders of the leading industrialized countries in 1989 was devoted to a consideration of environmental issues. The World Commission on Environment and Development, set up by the United Nations, published *Our Common Future* in 1987. *Signs of Hope* (Starke, 1990) was a follow-up to that book. The United Nations has passed several resolutions on environmental issues including that on the *Environmental Perspective to the Year 2000 and Beyond* (United Nations, 1987), and that on *A United Nations Conference on Environment and Development* (United Nations, 1988), a world summit to be held in 1992.

Sustainability

Environmental issues have many aspects and dimensions. These are encapsulated in the concept of *sustainability*. Sustainable development embraces the concept of (increasing) human needs and the idea of limitations which are imposed by technology and society on the ability of the environment to meet those needs (World Commission on Environment and Development, 1987). It has recently been adopted by most countries, which are making efforts to ensure that economic growth is achieved without unduly eroding the resource base, causing environmental pollution or upsetting any existing ecosystem, i.e. the countries seek to 'ensure that micro- and macro-level decisions are compatible with the goal of environmentally compatible development' (Economic Commission for Europe, 1990, p. 1). Although arguments about causes, effects, acceptable levels and desirable measures in relation to environmental issues continue, the need for a careful monitoring of the situation, development of better understanding of the complex processes inovolved and adoption of suitable strategies appear to be beyond dispute (Pugh, 1990). Regular state of the environment reports covering various specific issues are published (Convention on Long-range Transboundary Air Pollution, 1989; Economic Commission for Europe, 1989; World Meterological Organization and United Nations Environment Programme, 1989). Many countries, institutions and individuals appear to have assumed the worst and are planning, or taking, appropriate action.

The concept of sustainability has psychological, social, cultural and other dimensions. However, the discussion in this paper will be limited to the physical milieu. Various definitions of sustainable development have been offered (Redclift, 1987; Pearce *et al.*, 1989; Mitlin and Satterthwaite, 1990). Simply put, the concept of sustainability involves the comprehensive 'assessment of all the costs and benefits of economic activities including externalities, to obtain an efficient allocation of resources and an improved quality of life' (Economic Commission for Europe, 1990, p. 1). White and Whitney (1990) suggest that the sustainability of systems, from a physical point of view, requires the presence of four conditions:

(a) inputs of energy (including food) and matter from the biological and physical environment;

(b) flows within the system that are used for function, growth and activity maintenance;
(c) outflows of waste energy and matter from (b) above that are loaded on the environment; and
(d) flows within the system's environment that assimilate, purify and recycle wastes into the new inputs for the system.

In the long term, outflows must be balanced by inflows for sustainability to occur.

There are great disparities between the industrialized and developing countries in terms of levels of consumption of resources and the production of harmful by-products. This implies, first, that the process of socio-economic development in the emergent countries cannot be based on present consumption levels and patterns; and second, that deep cuts are required in the prevailing levels in the industrialized countries if global targets are to be met. For example, it is estimated that to achieve the target of a 20% reduction in atmospheric carbon dioxide agreed upon at the international conference in Toronto in 1988, a cut of 40% will be necessary in the industrialized countries to enable the developing nations to increase their emission levels slightly as they develop. Thus, Weissman (1976) suggests that some preconceived ideas should be overcome: historic determinism which holds that all development must follow the patterns evolved in the industrialized countries; economic determinism, which holds that economic efficiency motivates and guides development, which in turn must produce economic benefits as large and fast as is feasible; technological determinism which holds that effective use of modern technology requires even greater concentrations of production and services and even larger agglomerations of people and facilities; and the theory of equilbrium which holds that the free market is a self-regulating socio-economic system.

Achieving sustainable development requires a '. . . fundamental reappraisal of our situation' (White and Whitney, 1990, p. 46). It would require not only significant changes in lifestyle, in national economic development objectives and programmes, and corporate policies and procedures, but also the acceleration of scientific and technological progress. More appropriate materials and processes for most productive activites need to be developed. Knowledge of the trade-offs between economy and ecology needs to be increased; more information and suitable methods of analysis are required. It would involve some costs to, and sacrifices from, all sections of society. For example, although, under the widely applied *Polluter Pays Principle*, taxation and other measures are used by many governments to ensure that the originator of any harmful effects compensates the society, a loss of between 1 and 1.5% of disposable income is expected in some European countries as a result of the adoption of necessary environment-related measures (Economic Commission for Europe, 1990).

The calls for further action have been taken up at various levels in different countries. An overview of the measures which have recently been taken, or are being taken, in various groups of countries (especially by governments) to address environmental issues is now provided.

Environmental considerations in various groups of countries

The industrialized countries

The governments of most industrialized countries have established advisory and executive institutions charged with various aspects of environmental issues, such as the Environmental Protection Agency of the US and the proposed body to be formed by merging Her Majesty's Inspectorate of Pollution and the National Rivers Authority in the UK, and are specifically allocating resources to the preservation of the environment. A combination of measures including tax incentives, grants, subsidies, reward systems, auctioning schemes, funding of research and development (R&D), and appropriate pricing of resources are being used to promote the development and use of environmentally-sound (low- and non-waste technologies) technologies. Programmes for raising public awareness of enviroment issues are being implemented, and there is increasingly greater co-operation among governments and relevant non-governmental organizations. Enterprises are becoming more conscious of their responsibilities. Environmental auditing systems are being adopted in many large manufacturing enterprises. Being identified as an 'environment-conscious organization' appears to have positive commercial advantages. Co-operation among companies on environmental issues is increasingly common.

As most pollution crosses boundaries, regional initiatives are being taken. These include the establishment of the European Environmental Agency, which undertakes research, disseminates information and provides advice on policy formulation; the Network for Environmental Technology Transfer; and the Science and Technology for Environmental Protection programme, 1989–92. Several common European standards on the environment have been formulated (for example, environmental impact assessment is compulsory for all construction projects). The European Community recommends that these should be enforced by an indpendent Environmental Protection Agency. Under the Construction Products Directive, which came into effect in the member countries in June, 1991, buildings and works must meet 'essential requirements' with regard to: mechanical resistance and stability; safety in case of fire; hygiene, health and environment; protection against noise; and energy economy and heat retention (Thomas, 1990). The Community's Specific Actions for Vigorous Energy Efficiency proposes that directives should be formulated on a wide range of issues including machine performance, minimum standards for building insulation, energy-consumption labels on domestic appliances, compulsory energy audits and mandatory energy certification for dwelling units offered for sale.

Environmental concerns are also being increasingly reflected in international trade. For example, the United States has banned the importation of raw logs of timber, and many other industrialized countries are taking such measures as importing timber only from countries with approved regeneration programmes. Despite the efforts in Europe to harmonize requirements, a great deal of friction is being generated among trading nations (including members of the European Community), owing to the lack of standardization of regulations and differences in the assistance offered to enterprises to promote pollution-control measures (*The Straits Times*, 1991). Similar trends are evident in the aid offered by the industrialized countries to the developing ones. Projects for preserving (or addressing past mistakes affecting) the environment in the latter are receiving priority. Debt for environmental-protection swaps are being arranged and technology transfer is being monitored to limit the proliferation of wasteful or pollutive technologies.

Some progress has been made. In member countries of the Organization for Economic Co-operation and Development, during the past 15 to 20 years, urban concentrations of sulphur dioxide have fallen by 30–75%, airborne dust and grit by 40–50%, and lead concentrations by up to 85% in large cities in North America and 50% in those in Europe (Cairncross, 1991). However, much more needs to be done. In eastern Europe environmental awareness is a relatively new phenomenon. In 1990, the European Commission received 480 complaints on infringements of its environment-related regulations by member countries. For example, the mandatory environmental impact assessments were not undertaken: in the UK on the new sections of the M2 and M3 motorways; in Spain and Portugal, for the motorway linking Barcelona with the Algarve; and on the new roads and railways in eastern Germany (*The Economist*, 1991a). Naturally, achievements have not been the same in all countries or sectors of the economy. Considering energy conservation, several countries are introducing more stringent building regulations on energy consumption, promoting more effective liaison between the energy companies, designers and building control authorities, and stepping up R&D effort on energy-efficient and pollution-reducing technologies. However, whereas in Cyprus, solar energy systems provide 90 and 50% of water heating individual homes, and in hotels and apartments respectively, in other countries:

> . . . renewable energy technologies have been widely demonstrated but . . . have not precolated through to small and medium-sized enterprises . . . in some cases the replication of proven technologies has not been successful. At least one country, Canada, has found that there are barriers to the proper functioning of the market in introducing some new technologies, such as the inability of manufacturers to fully capture the benefits of research and development, uncertainty and risk associated with technology development, imperfect information about available opportunties, inadequate access to capital markets and inertia due to market structure, and the practices of established institutions or counteracting policies (Economic Commission for Europe, 1990, p. 11).

Furthermore, at the corporate level, a recent study showed that whereas the 'environmental manager' is becoming more easily identifiable in many enterprises, such a person is overwhelmed with compliance with regulations, is caught between environmental and production goals, and lacks a clear place in the corporate heirarchy (*Engineering News Record*, 1991).

Newly-industrializing countries

The newly-industrialized countries have had environmental policies and controls for some years now. Statutory and administrative developments in Singapore may be used to indicate the situation in these countries. An array of legislation, regulations and codes of practice have underpinned Singapore's achievements in developing and maintaining a clean and green environment. The relevant statutes include the Clean Air Act, the Water Pollution Control and Drainage Act and the Environmental Public Health Act. Among the regulations are the Factories (Asbestos) and Factories (Sand Blasting) Regulations; and the codes include the Code of Practice for Noise Control on Site published by the Singapore Institute for Standards and Industrial Research. The Ministry of the Environment of Singapore has recently set up a new division to plan for, and administer the country's progress towards its aim of becoming an Environment City. The Environmental Policy and Management Division comprises the following departments (Nathan, 1990):

(a) Strategic Planning and R&D department, to formulate a strategic plan for the ministry with emphasis on minimizing the environmental impact from pollution and waste, and conduct relevant R&D;
(b) International Environment and Policy department, to consider regional and global

environmental issues and promote Singapore as an environmentally-responsible nation and a base for environmental technology; and

(c) Pollution Control department, to plan for, and implement programmes to control hazardous substances and toxic wastes, and monitor water and air pollution.

The developing countries

Progress in the developing countries in relation to concern with environmental issues is relatively limited owing to factors including (Katerere, 1990):

(i) the need to export some 'environmental' resources (such as timber);
(ii) unwillingness to reform policies which govern resource allocation and distribution;
(iii) lack of financial and technical resources;
(iv) the influence of interest groups at home and abroad;
(v) lack of government commitment and investment; and
(vi) inadequate administrative structures (Katerere, 1990).

However, governments and the general public in these countries are becoming increasingly aware of the matter. Some developing countries, such as Indonesia, Malaysia and the Philippines have banned the export of raw logs, a move opposed by Japan which traditionally uses much timber in construction, and imports almost all its timber (*The Straits Times*, 1991). Environmental impact studies are now undertaken routinely on large projects in many developing countries, including Indonesia, Malaysia and Thailand, and are recommended for incorporation into the national physical planning process (UNEP, 1980; Ayanda, 1988). Environmental impact analysis and post-completion audits have been an integral part of World Bank funded works since 1975; the Bank suggests that 5% of construction project costs should be spent on feasibility studies (Baum and Tolbert, 1985).

Energy-related issues in Southern Africa may be used to illustrate the present situation with regard to concern about the environment in the developing countries (Kaale, 1990). Biomass fuels account for about 80% of the total energy consumed in the region; their scarcity threatens to hinder national development. There is a lack of energy for household use, as well as environmental effects such as soil erosion, floods, drought and desertification due to loss of vegetation cover. Of the region's hydropower potential of about 45 970 MW, only 5154 MW are installed. Proven coal reserves amount to about 11 808 million tonnes with an average annual consumption of 5 million tonnes; natural gas, and solar and wind power are also available in large quantities but have not been developed due to financial and technical constraints. Despite efforts including the institution of a five-year regional woodfuel strategy in 1988 (involving policy, planning and publicity; human-resource and institutional development; and R&D), the biomass fuel programmes of the states are inadequate. For example, Tanzania plants less than 5% of its goal of trees per year; Lesotho has a target 7500 hectares of trees per annum, but on average planted about 1000 ha per year over the past decade. The programmes are not co-ordinated, and face constraints including lack of funds, trained manpower and inter-agency experience. For example, Angola needs 356 skilled workers, but currently has 24; Botswana needs 57 but has 5; Zimbabwe needs 598 but has 43. Research is taking place on a small scale in all the states (on species trails, seed production, improved management of indigenous woodlands, agroforestry, improved stoves and charcoal production) but is not co-ordinated.

Less developed countries

The environmental issues facing the less developed countries (of which there are 42) are even more severe (UNCTAD, 1990). Most of these countries have very fragile environments; many are faced with aridity, or have extensive mountainous terrain whose cultivation leads to erosion from the slopes, and some of the island states are made up of atolls. Some of these countries are very vulnerable to the projected (but still debated) increases in sea levels as a result of global warming. Some 50% of Bangladesh is already subject to regular flooding; and the highest parts of the Maldives are currently only 2–3 m above sea level (Pugh, 1990). Forests, which comprise 21% of the land area of these countries, are being depleted at an average rate of 0.6% per annum (and in some countries up to 4%). The electricity production of these countries is less than 10% of that for developing countries as a whole, and most of it is from thermal sources (UNCTAD, 1990). The countries have to contend with soil degradation from loss of vegatation cover, scarcity of water owing to pollution of natural sources, and loss of their previously diverse biological resources. In addition, they will be exposed to environmental damage resulting from industrial and other activities elsewhere.

The environment and construction

Effects of the concern about the environment on construction

The measures being taken in relation to environmental issues have had many consequences for the construction industry. The Economic Commission for Europe (1986) considered these to be felt mostly through an increase in investment costs and a lengthening of the process of design, planning and carrying out of construction. The lengthened planning periods for such projects as dams, nuclear power stations, waste-handling facilities, chemical factories and airports are well-documented (Ofori, 1990). In the UK, the modification of the design of British Rail's high-speed rail link to the Channel Tunnel (to put 36.8 of the 108.8 km in tunnels, with just over 35 km in cutting) as a result of pressure, mainly from alliances of residents of districts traversed by the proposed route and non-governmental organizations, is estimated to have added some US$1.4 billion to the total construction cost.

The construction industry may be 'denied' access to some of its vital resources. For example, the UK faces a shortage of coarse aggregate: in south-east England, the shortfall is forecast at 12 million tonnes by the year 2000, rising to 40 million by 2010. The plans to relieve this shortage by opening costal super-quarries (and constructing access roads) in parts of Scotland, Ireland and the Iberian peninsula, some of which (in Scotland) are classified as 'national scenic areas', are being strongly resisted by some residents and environmentalists (Clouston, 1991). As mentioned above, may countries have passed energy-related building regulations. These include guidelines on the thermal transmittance of building envelopes. In some cases, life-cycle costing of certain categories of buildings is a statutory requirement at the building design approval stage (Picken, 1990). The increased interest in energy auditing, energy management and building automation systems is a manifestation of the impact of the statutory controls (and client's awareness of the benefits from appropriate action).

The increasingly stringent environmental requirements are having a marked impact on construction operations. A pertinent issue is noise control. The EC Directive 86/188/EEC on the protection of construction workers from the risks relating to exposure to noise on site requires assessments to be made of site noise levels and specifies action at the L_{eq}(8 h) 80 and 90 dBA levels. This was a stringent requirement since a study in the UK (where they were introduced by legislation in January 1990) found that most site workers were exposed to levels above the former mark, and a high proportion of them were subject to the latter (CIRIA, 1984).

Protests over their environmental effects have led to the abandonment of many projects which were at various stages of completion. They resulted in the cancellation, in 1989, of work on the Nagymaros dam in Hungary, which formed part of a massive joint scheme with Czechoslovakia. They have also hindered India's hydro-electric power development programme. The Indira-Zavorava scheme was cancelled. The 2400 MW Tehri dam at the confluence of the Bhagirathi and Bhilagana rivers, which was started in the 1970s, has met considerable opposition from local residents, environmental groups and geologists (who fear that it poses the danger of reservoir-induced seismicity as it is in a seismically-active region of shear zones and fissures). Design modifications had to be made to improve safety (Swan, 1988). The active environmental pressure groups in Austria prevented the opening of Austria's only nuclear power station in the 1970s; the government lost a national referendum on the issue. The groups are adamant that no more hydro-electric power stations be built, although Austria uses such energy sources for three-quarters of its power, and is a net importer of power. Environmental pressure also forced the abandonment of the construction of a barrage across the Danube at Hainburg after the contractor's plant had been brought to the site (Swan, 1988).

The impact of environmental considerations may go beyond particular projects or types of constructed items. The construction industry in the then West Germany had to mount a major campaign in the mid-1980s to counter that of the country's influential environmentalist lobby which called for a halt to all new construction, asserting that the country had sufficient volumes of all constructed items, and should not further develop the greatly diminished green areas.

The effect of construction on the environment

Gunnerson (1988) cites various instances from the industrial sector where environmental issues were not recognized until they were unavoidable, and very expensive to remedy. There were usually time lags between the following successive occurrences: the event which causes the environmental problem, the recognition of the problem, its acceptance (or apportioning of blame), and its resolution. Examples abound of instances where construction projects have had undesirable effects on the environment. Seemingly desirable schemes like the settlement of nomads can have dramatic effects on the environment (in this case, overgrazing). The construction of the Volta Dam in Ghana created the largest artificial lake in the world, and had a considerable economic impact through its use to generate power which supports various productive activities, in addition to its direct use for fishing, water supply, irrigation and transportation. It also had some social consequences, such as resettlement of large numbers of people and disruption in their life patterns, some of which were addressed. The loss of flora and fauna was foreseen but not tackled. But completely unforeseen were the serious health hazards, as the lake spawned the insect which causes river blindness, a disease which is afflicting many of the residents of the banks of the lake. To cite another example, out-of-town shopping centres and 'dormitory' towns and suburbs lead to car-intensive lifestyles (Hill, 1991). Efforts to address these problems (for example, through improved urban and regional planning, greater use of telecommunication, reform of work and living patterns to reduce the need for travel, and development of means of transport other than vehicles) will influence the demand for construction activity in various ways.

The possible effect of construction on the environment has implications for the form which the monitoring and enforcement process of environmental regulations for construction should take. For example, a road project is lowering the water table of the Santona marshes where large flocks of migratory birds seek shelter in winter. In 1987, the European Community warned the Spanish government about its breach of a 1979 directive on the protection of bird habitats; the case was heard in the European Court later in 1991. By the time it is concluded most of the wetlands would have been lost (*The Economist*, 1991a). Given the close relationship between constructed items and most human activities (Nam and Tatum, 1988), the consideration of environmental issues should permeate all aspects of construction. Several steps have been taken in the right direction. The Man and the Biosphere programme of UNESCO, launched in 1970, investigates, among many other issues, the relationship between major engineering works and environmental pollution and conservation of natural areas. The research projects and case studies under the programme include studies of logging on natural forests in the Ivory Coast, East Kalimantan (Indonesia) and Papua New Guinea, and work in the Ivory Coast to predict what might happen after the construction of a dam (Behrman, 1979).

Ramachandran (1990) observes that the traditional concern of designers and builders had been the protection of constructed items from the effects of the environment. However, following the realization that construction projects may have environmental implications from the materials used, the nature of the design, the method of construction, the location and layout, the physical structure itself or the use to which it is put, the effect of construction operations and products on the environment has recently received much attention. Ramachandran (1990) categorizes these effects:

(a) *resource deterioration*; depletion of forest resources caused by the use of timber; dereliction of land caused by quarrying, extraction of sand, clay and other deposits such as limestone; use of energy in the production and transportation of materials and in site construction activity;

(b) *physical disruption*; dams cause diversion of natural waterways, loss of several flora and fauna in the inundated areas, and upsetting of the ecological balance with possible health hazards; building in urban areas causes noise pollution; highway construction can adversely affect the stability of fragile hillsides; generally, development leads to loss of agricultural land, possible deforestation, soil erosion, silting of reservoirs, disruption of ecosystems and long-term climatic changes; and

(c) *chemical pollution*; particles released in the production and transportation of materials such as cement and quarry products; pollutants produced in the production of building materials; fibres released during working with asbestos products; accidental spillage of chemicals on site and careless disposal of waste.

Other impacts of construction on the environment include social disruption and undesirable visual impact on the environment from temporary structures, hoardings, uncompleted buildings and untidy sites. As mentioned above, dams involve the resettlement of several communities (and possibly loss of livelihood) and the construction or maintenance of roads may affect travel patterns and lengthen travelling times.

Of the direct relationships between aspects of construction activity and the environment, one of the most important is that of construction materials and components. Some common materials may be harmful to the workers handling them, and/or occupants of buildings. For example, it is estimated that some 50 000 people in the UK and 2 million in the US would die from diseases relating to (the widely used) asbestos in the 30-year period after 1985 (French, 1986). Control limits for exposure to various types of asbestos have been set (e.g. 0.2 fibre/ml over any 4 h period in the UK) and very large sums of money are being spent in many industrialized countries to remove, seal or encapsulate asbestos in places where it is considered to be a hazard (by skilled contractors using special plant and operational techniques, and following specified codes, because removal can generate high concentrations of asbestos dust in the air). Another example is that of paints: among the constituents of commonly used paints, first lead, and later, benzene and formaldehyde, have been identified as health hazards (Jackson, 1990).

Whereas 'alternative' energy sources, such as solar, wind and wave power are being invented and increasingly improved upon, they tend to have potential only in certain places, are suitable only for certain purposes, and the energy they produce tends to be limited. While efforts are being made to reduce the cost, and improve the viability, of these alternative sources, projections show that fuel-based sources will continue to be the most important in future. Thus, the conservation of energy is a major issue: wastage through losses during transmission alone, is estimated to constitute between 10 and 15% of world consumption (UNCHS, 1990b). Construction is an important energy consumer. Much energy is used in the production of materials such as cement, steel, aluminium – it is estimated that an aluminum flashing requires 11 times more energy to produce than its steel counterpart (Rosenbaum, 1991) – wood products, plastics and paints; in the movement of the generally bulky materials and components to widely dispersed sites; in the operation of plant and equipment on site; and in the heating or cooling, or running of the machinery in completed buildings. The maintenance of comfort and hygiene in buildings alone accounts for about half of the world's energy consumption with the industrialized countries accounting for a disproportionately large share (Burberry, 1991; UNCHS, 1990b). Moreover, considerations of the use of energy in buildings transcend the resource–conservation aspect. About 50% of atmospheric carbon dioxide is emitted from buildings (Smith, 1991). Thus, the construction industry has an important role to play in the effort to control global carbon dioxide levels through deep cuts in emissions.

About 50% of all CFCs, which contribute to the long-term depletion of stratospheric ozone (as well as global warming) are used in building services: in refrigeration and chillers for air conditioning units (Curwell, 1990), as well as in some insulation materials. Some chemical manufacturers have CFC-recycling programmes. Work is also underway to develop refrigerants with lower concentrations of CFCs. CFC-free insulation materials are also available (some mineral fibres and polystyrene) but some of these are hazardous in their use and difficult to dispose of safely. Construction practitioners need to follow these developments to increase their knowledge of alternatives and endeavour to design buildings to reduce the need for air conditioning while maintaining the comfort of occupants.

A major concern, of late, has been pollution within buildings. Studies in the UK in 1988 found that over half the offices in the country could be suffering from *sick building syndrome*, where poor air quality (ventilation, temperature, air movement and humidity) and lighting, and airborne pollution lead to sore eyes and throats, headaches, nausea, fatigue and respiratory problems. In the Netherlands, estimates put the annual loss to the economy in terms of lost worker productivity at over US$1 billion, as some 20% of office workers complain about the indoor environment (De Jonge, 1990). Defining health as the complete physical, mental and social well-being of occupants, the World Health Organization considers the rate of incidence to be so high that the syndrome can be classified as a world problem. Poorly designed and maintained air-conditioning systems serve as incubators for bacteria and fungi which live in the dirt and water which collect within the systems, and can be spread quickly throughout the ventilation system. Although it is most often associated with air-conditioned buildings, the syndrome can also occur in naturally ventilated buildings (*Construction*, 1988; Sykes, 1988). Other indoor pollutants which have recently been identified include:

(i) the preservatives used on timber;
(ii) chemicals used in cleaning the interior of buildings, the fixtures and furniture;
(iii) substances used in photocopying and printing; and
(iv) chemicals emitted by soft furnishings such as carpets.

Further knowledge of the long-term effects of exposure to commonly-used materials (and how the materials act in combination) is essential.

The management of human waste is largely an urban problem (which is increasing rapidly with further development, the spread of high-consumption lifestyles and increasing urbanization). Refuse collection is costly in both financial and human terms. In Western Europe alone, refuse disposal cost some US$30 million in 1989 (Steadman, 1990). Proper solid waste management is necessary to avoid the breeding of pests and bacteria, contamination of water resources, atmospheric pollution, waste of land resources and failure to recycle valuable items. Apart from the increasing volume of waste which requires handling, the problem is being exacerbated, as the options are increasingly being narrowed by the passing of laws to protect the environment. This task is also becoming more complex as changes in technology lead to the development and use of new materials which require special methods to handle, treat, and dispose of, or recycle. Good planning and design of all buildings, especially, dwellings, can facilitate refuse handling and collection. In industrial production, the use of new technologies and equipment, such as particulate removers and gas scrubbers, and of efficient-burning energy sources can reduce air pollution, whereas industrial effluent may be treated in several different (physical, chemical and biological) ways (Holding, 1990). The construction industry is a major 'producer' of the wastes that need special attention in their disposal. Construction debris is a significant fraction of the wastes handled in places (such as the main cities of the industrialized countries) where major redevelopment schemes are undertaken.

Contribution of the construction industry to environmental protection and control

Required contribution of construction

The construction industry will have to contribute, in an active and positive manner, towards the general effort to address environmental issues through such actions as:

(a) arresting deforestation and desertfication (by economizing on the use of timber, finding alternatives for it and investigating the industry's role in forest regeneration) and attending to the depletion of other resources (through economy in the use, and recycling, of materials and the use of renewable varieties);

(b) addressing concentrated heavy rain and rising sea levels (through designing protection systems and developing materials and techniques suitable for construction, and able to perform satisfactorily, under such conditions);

(c) prevention of pollution (through handling and monitoring of waste, the development and use of 'safe', nonpolluting materials, and of suitable techniques for construction, maintenance and demolition); attending to the effect of pollution (through the development and utilization of materials able to withstand harsh atmospheric conditions such as the action of acid rain and other toxic substances);

(d) dealing with inadequate drainage, soil erosion and excessive salination of sea water (through the appropriate design of constructed items, and design and construction of protection systems);

(e) reducing the pressure on available land, and encroachment on green areas and places of natural beauty (by developing technologies for rehabilitating existing buildings and for bringing into use derelict, contaminated or naturally-delicate land, and assessing the environmental impact of construction projects); and

(f) finding secure and stable sources of energy for the extraction and production of materials, for construction activity, and for the use and maintenance of constructed items.

A number of writers have considered how the industry can make such contributions. Carlsson (1976) observes that certain problems relating to construction and the environment are common worldwide, whereas others are unique to particular areas. Some general global principles can be formulated but priorities must be set regionally. Existing knowledge and research should be fully utilized, and new approaches found to

> . . . manage wisely our existing environmental resources . . . and to constantly innovate and to recycle so as to do more with less, if our communities are to be truly livable. This will require immense efforts to foster innovating technology and to implant new systems and techniques (p. xviii).

Changes in attitudes and perspectives are required. Construction should not be viewed simply as a passive industry fulfilling the needs of clients and subject to external influences (Groak and Ive, 1986; Nam and Tatum, 1988). For example, Curwell (1990) observes that designers' action can help to:

(i) minimize energy consumption;
(ii) avoid the release of CFCs;
(iii) use less toxic materials and preservatives; and
(iv) minimize harbourages for pests and biological hazards.

The UNCHS (1990) suggests that the (physical) development sector can promote sustainable development through:

(a) devising settlement and neighbourhood plans which lead to resource-efficient and affordable transport patterns;

(b) developing programmes for increasing the use of renewable energy systems and economizing on the use of non-renewable energy sources;
(c) providing infrastructural services such as water-supply, sanitation and waste-processing/recycling systems which meet basic needs in a resource conserving manner;
(d) promoting the use of indigenous building materials and appropriate construction technologies.

In the developing countries, the contribution which construction is required to make is fundamental. In these nations, inadequate infrastructure poses considerable environmental problems. The task is urgent but difficult, as the constraints and problems which have hindered efforts to address the situation persist. It is estimated that some 55% of rural and 40% or urban populations lack access to adequate, safe water. About 80% of all diseases – and a third of all deaths – in developing countries are attributed to the ingestion of contaminated water (UNCHS, 1990b). Satisfactory levels of sanitation are essential to prevent danger to human health through the faecal/oral route. The disposal of industrial effluents requires attention, to prevent contamination of water resources and land, and air pollution. Studies show that less than half of urban wastes are collected by the relevant authorities; coverage is also uneven among income groups. Some 2.3 billion persons may be without sanitation by the year 2000 (UNCHS, 1988). Despite massive investments in recent decades and a substantial increase in power generated, only 4% of dewellings in the rural areas of sub-Saharan Africa have access to electricity (Flavin, 1986; Jackson, 1986). Several potential consumers cannot afford the cost of a connection to existing supplies or the normal periodic bills. It is widely acknowledged that the developing countries lack the resources which would be required to effect an improvement in the situation. For example, between 1 and 6% of national budgets are estimated to be spent on water supply: the bulk of the capital for new installations come from external sources which are becoming increasingly rarer (UNCHs, 1989). In many developing countries, prevention of loss of water through leakage (estimated to be as high as 50% in some cases) would save costs, enable wider coverage of supply and reduce the rate at which water resources are depleted. There is a need for appropriate, low-cost sanitation technologies based on non-water borne systems which are cheap and easy to maintain.

Ramachandran (1990) suggests that construction activities should progressively harmonize with environmental needs. To achieve this, construction should be viewed in its true perspective: 'a major consumer of natural resources, a potential polluter of the environment, and yet, indispensable for development' (p. 8). The major gaps in objective information on the environmental implications of construction products and processes should be bridged and such information widely disseminated among practitioners and the public. This would lead to the formulation of environmental policy, development of standards, enforcement through legislation, and finally to improved construction practices.

The Economic Commission for Europe (1986) believes that all urban development will be subject to the following requirements in future:

(a) overall environmental planning with clear and specific spatial and temporal objectives;
(b) compatibility of consumer needs of society with the requirements of rational use or resources, so as to preserve and renew the natural environment;
(c) priority to development measures establishing objectives and locating activities so as to guarantee the prevention of adverse effects on the environment;

(d) safeguarding the genetic heritage and planned restitution of soils and forests;
(e) orientation towards low-pollution or no-waste technologies, and recycling of resources; and
(f) development of public transport for urban, inter-urban and international journeys.

Alterations to the structure and form of constructed items were required. Changes in the way these were planned, designed, constructed, operated and kept up were necessary. Limited land resources constituted an important constraint on development and had to be protected. More importance would have to be attributed to the multidisciplinary approach to urban and regional planning, design and construction.

Professional bodies and trade associations in many countries are bringing these issues to the attention of their members and proposing appropriate courses of action. The Royal Institute of British Architects, in its 'policy paper' on global warming and ozone depletion, recognizes that '. . . with the increasing understanding of the effect of human activity on the viability of the planet, a new dimension has been added to the responsibilities of the architect' (Curwell, 1990). In its aptly titled work, *What Are You Doing About the Environment*, the Chartered Institute of Building (1989) urges specifiers constantly to seek to reduce the dependence on, and choose alternatives to, environmentally-unfriendly materials. The construction industry as a whole should take proactive action under a comprehensive strategy which anticipated environmental trends, rather than reacting to external pressure. The leadership vacuum should be filled, and there should be better co-ordination of all initiatives. The professional bodies should initiate more R&D on environmental issues and formulate guidelines for best practice. The Infrastructure Policy Group (1990) (of the Institution of Civil Engineers) observed that pollution can never be completely eliminated. The essential aim should be to match short-term needs for development with long-term enivornmental reaction to attain a balance between an optimal level of pollution, sustainable development and maintenance of the quality of life. The Group considered the role of governments to be vital (owing to the ineffectiveness of market forces and need for a multi-disiplinary approach to the interrelated relevant issues); so was international co-operation. Construction practitioners should be aware of the impact of their work on the environment and be able, and willing, to make (or accept) proposals which minimize pollution. Those working in the developing countries should be even more sensitive to such issues, as most of the worst-affected countries are least able to deal with the problems (Gibb, 1990). The American Institute of Architects is preparing an Environmental Resource Guide, to be published in 1995, which will contain 'how-to' notes on design.

Appropriate courses of action at the national level have also been suggested. The United Nations Centre for Human Settlements (UNCHS) (1990b) offers a list of recommendations of areas of action by various groups of countries.

(1) Each developing country should formulate a coherent national strategy for the indigenization of construction factor inputs, supporting R&D on clean and energy-efficient technologies which can be used on a small-scale basis, utilizing indigenous materials and methods. Appropriate standards specifications and other regulatory measures should be adopted to support the use of such technologies. Land-use policies and planning regulations should be introduced to protect eco-sensitive zones against physical disruption by construction activities.

(2) The industrialized countries should introduce legislation and financial incentives to

promote the recycling of energy-intensive materials in construction and conservation of energy in the production of building materials; introduce regulatory measures, such as certification and eco-labelling schemes, to restrict the use, in construction, of non-renewable natural resources; and use economic instruments, such as product charges, to discourage the use of construction materials and products which create pollution during their life cycles.

(3) The international community should support initiatives of developing countries to achieve sustainable development through: local capacity building for environment-impact assessment of construction activities; transfer of low-waste, non-waste and clean technologies for building materials production, and of those for resource management in construction; and promotion of multilateral funding to meet environment-protection expenditures.

The need for international co-operation had been highlighted by several other writers. The United Nations Advisory Group on Human Settlements (Bell, 1976) recommended that the main objectives of effort to develop and improve the technologies used in the planning, design, construction and management of human settlements should be to identify a global network of leading institutions in the field and organize them on an ecosystem and regional basis; establish the necessary mechanisms for co-ordinating and promoting the activities of these institutions; collect and disseminate all data in the field; and promote the use of environmentally-sound technologies.

Construction industry's response

Some of the issues raised above have been, or are being addressed by the construction industry in many countries. As the examples below show, these have generally involved conscious efforts to find practical solutions to real situations and problems, involving or resulting in considerable innovation.

Production and use of materials. In a method developed in Germany, argillaceous slates are substituted for clay in the production of heat insulating bricks. This reduces the amount of clay required and clears the unsightly coal dumps. Part of the energy in the slates are used in firing the bricks. The bricks contain 8% of tailings by weight. This method leads to a reduction in energy usage of some 43%. Savings in clay are about 1800 tonnes per million bricks (*International Construction*, 1988).

The recycling of construction materials, from glass to dug-up asphaltic road surfaces, is becoming increasingly common. However, in most cases, the crushing of asphalt for recycling is undertaken off-site. On-site recycling of asphalt was used in Germany in the renovation of part of the A1 Autobahn in 1988. The 20 cm surfacing over a 1.5 km stretch of road was broken up, crushed on site and relaid as a 230 mm thick base course. This method led to a 30% direct cost saving (in comparison with the use of 'new' resurfacing materials), in addition to the environmental benefits (*International Construction*, 1989).

Construction equipment. Many items of demolition equipment which may be used in heavily-populated urban areas, and within occupied buildings, are now very versatile, highly productive, vibration-free, fume-free, dust-free, noise-free and safe (especially those used in hazardous conditions, such as in nuclear stations). Various techniques which are more suitable for today's urban conditions, such as hydro-demolition, have also been developed (Magowen, 1989).

A German equipment manufacturer has developed a diesel engine which can run on methane gas. Compactors working on refuse tips can run on the methane produced on the site. The gas is pumped off, cleaned and stored at a station. The compactors carry eight bottles of pressurized methane, sufficient for a day's work. A special electronic valve feeds the gas to the engine. By monitoring a display panel, the operator can switch to diesel if necessary. As diesel is only required to start the engine, fuel consumption is reduced by 80–90%. The compactor produces less noise, emits little smoke and has low operating costs. The installation costs are recovered over a short period of operation (*International Construction*, 1989a).

Protecting the environment. The Oosterschelde storm-flood barrier in the Netherlands has been purpose-designed to allow the tides to ebb and flow, thus preserving the ecosystem of the sea delta. However, its 64 'normally open' gates – 40 m wide, up to 12 m high and weighing 500 tonnes each – will close in an emergency to protect both land and people from devastation in a storm (*The Economist*, 1990).

Improving the environment. The Saltsjotunnel (7.5 m long, 60 m below the ground), part of a major enviromental project to improve Lake Malaren, from which the Swedish capital, Stockholm, obtains its drinking water, was completed in 1989. It required innovative tunnelling techniques through difficult ground conditions including granite, gneiss and other rocks. The tunnel conveys treated sewage water to the sea rather than the lake. Along the way energy is extracted from the water at a heat pump station (*International Construction*, 1989b).

Research and specialization. Construction-related research on the effects of environmental pollution is notable. For example, with respect to construction materials work, is underway to develop:

(i) alternative materials;
(ii) ways of effectively and efficiently recycling materials and using industrial, agricultural and household wastes;
(iii) alternative sources of energy for their production; and
(iv) transportation and storage methods which limit pollution.

Two projects of the Construction Industry Research and Information Association (CIRIA) in the UK are worth considering.

Methane gas, which is given off by decomposing organic materials in refuse dumps, is odourless, colourless, non-toxic and sightly soluble in water. It is a major hazard during and after construction on land-fill sites as it is an asphyxiant and explosive which can permeate the ground and collect in poorly-ventilated areas. CIRIA has studied ways and means of dealing effectively with the gas at all stages of the construction process (*CIRIA News*, 1988). The Association has also worked on the planning, engineering, environmental and contractural matters relating to the redevelopment of derelict industrial sites, a topical issue owing to social and political pressures and incentives offered by governments. Estimates put the total area of such sites in the UK at between 50 000 and 200 000 acres (*The Economist*, 1991b). Whereas many of these sites are quite well-located, there are often hazards (to the safety of construction personnel, users, and material durability) from chemical contamination from production, storage or disposal of raw materials and waste products or spoil; and land-fill gas migration. To supplement the growing body of technical documentation on the subject, it is necessary to identify, assess and quantify the issues and the risks to developers and contractors (Barry, 1988).

The appropriate energy sources developed for the developing countries (where needs are greatest) are particularly pertinent. A micro-hydro plant may be constructed of local materials at a relatively resonable cost of between US$1000 and 2000 per kW h, in places with adequate rainfall and small rivers. However, it requires technical expertise for its operation. The system is widely used in rural China. Biomass systems using various kinds of fuel, mainly agricultural wastes such as coconut husks and rice hulls, are being developed, as are biogas systems using various types of animals waste. Wind pumps are useful where the physical conditions are suitable. Solar-powered photovoltaic systems are relatively expensive but are effective in applications requiring only small amounts of power, such as telecommunications and refrigeration of highly-perishable essential items.

There is a noticeable trend towards the development of environment-related specialization in some construction professions. For example, environmental architecture is gaining ground. Its principles include the design of buildings to fit into (rather than replace) the natural environment, the use of alternative materials which are naturally occurring and do not involve chemicals, energy conservation within buildings, and the design of the layout and fittings to suit the physiological, psychological and social needs of users. The 'pioneers' point out that it is possible to design well-lit, workable spaces in an environmentally appropriate way '. . . using available technology, not cutting edge, unavailable, proto-typical [ones] (Rosenbaum, 1991, p. 28). Specific proposals include: using solid wood instead of formaldehyde-emitting plasterboard; using secondary species of timber to help create a market for them, thus reducing clear cutting of forests; avoiding the use of oil-based paints; tacking down carpets instead of gluing them; and ensuring sufficient ventilation within the building (Rosenbaum, 1991).

The future

Project-level perspective

From the discussion so far, it is clear that the construction industry should play a more positive role in the efforts being made to address issues relating to the environment. In each country, a comprehensive strategy, involving all aspects of construction activity with initiatives at all levels of the industry and at every stage of a construction project, should be adopted. Despite the efforts made so far, achievements remain *ad hoc* and limited. In this section, the issue is considered at the level of a project and from the perspective of the client. It is necessary for environmental issues to be effectively considered and addressed in a routine manner on all construction projects (Curwell *et al.*, 1990; Burberry, 1991). Sustainable development, insofar as construction is concerned, can best be achieved through appropriate resource development and allocation, and the perspective of the project is most relevant. Curwell (1990) suggests that construction practitioners need to evaluate the full effects of buildings on

> the global and local environment, the occupants and operative of the building . . . from winning the raw materials, manufacture of components, construction and use of buildings, through to demolition, recycling and, ultimately, final disposal of waste (pp. 45–46).

Suitable techniques for study in the relationship between each project, or part(s) of it, and the environment should be developed. There is a strong case for consciously treating the environment as the fourth construction project constraint from the client's point of view.

In this context, the environment may be defined in terms of the following criteria:

(i) resource conservation,
(ii) prevention of pollution of all types,
(iii) protection and preservation of natural ecosystems,
(iv) safeguarding the fabric of the constructed structure in changing atmospheric conditions,
(v) promotion of the health and well-being of users, and
(vi) development of environmentally-conscious lifestyles.

These criteria should be met while seeking to give clients good value for the money spent. The frame of activity should be the entire construction process:

(a) extraction of raw materials, and manufacture, transportation and storage of materials and components;
(b) planning, design and construction of buildings;
(c) operation and alteration of buildings; and
(d) demolition of buildings and disposal of waste.

Materials, components, systems, techniques, practices and organizational arrangements which will enable the construction industry to respond to the challenges of the era of environmental awareness are required. The professional institutions and trade associations have a key role to play in these efforts. Appropriate education, continuing professional development and publicity programmes, and information systems are essential.

It may be argued that clients' construction project objectives are short-term and narrow ('internal'), whereas environment issues are longer-term and mainly wide ('external' to clients). However, the trend in most countries pursuing environment-related policies is to endeavour to internalize the externalities to the particular producer or consumer. The statutory framework relating to the environment is developing so rapidly that it will soon constitute a real constraint on construction projects. Owing to users' interest in environment issues, developers need to take them into consideration. The topical field of professional liability also makes it necessary that practitioners avail themselves of, and consider, the most relevant and current information, including knowledge relating to the environment. Construction practitioners have the responsibility to inform users and the general public of the scientific, environmental and other dimensions of their decisions and activities, especially those relating to hazardous technologies.

> Society [is] demanding that the engineering profession, among others, improve its performance and do a better job of anticipating, as well as preventing, the hazards brought about by its apparent success. Because of these higher societal expectations regarding the standard of care, more engineers may now be held accountable for their actions or inactions (Paustenbach, 1987, pp. 96–97.).

Guidelines on codes of professional ethics are required. Considering the wide range of professional skills, a unified body, such as the American Association of Engineering Societies, has a key role to play in each country (Broome, 1987). *The Economist* (1991b) observes that in the UK, the Environmental Protection Act of 1990 and the principle of *caveat emptor* make owners of land responsible for cleaning them up, no matter when the contamination occurred, and the one(s) who caused it. This is a potentially serious situation considering the cost of cleaning up and the unwillingness of insurance companies to provide the necessary cover.

Practitioners need to analyse a considerable amount of information on existing materials, components, techniques, plant and equipment, and to (anticipate and) acquaint themselves with new developments. A balance often needs to be struck between the positive and negative aspects of each issue. For example, some measures which are taken to reduce environmental noise (such as shielding) tend to increase site noise levels (CIRIA, 1984). Attempting to conserve energy by reducing the flow of fresh air into a building increases the possibility of *building sickness*. Again, bricks are very durable if used correctly, are not hazardous to health, can be recycled and can be disposed of safely in a cheap manner. On the other hand, the extraction of clay for brickmaking can cause damage to the local ecology and adversely affect the visual environment, and the firing and transportation of bricks require large amounts of energy (Curwell, 1990).

Previous work

Various writers have studied the potential role of construction in the environmental-awareness era at the project level. As discussed above, the Chartered Institute of Building (1989) proposed an approach to the specification of construction materials. March and Curwell (1986) offer a matrix for assessing the potential health hazards which might be posed by building materials:

(1) *form and condition of material*: whether it is loose and friable, contains volatile elements, emits toxic fumes, is combustible or contains naturally-radioactive elements;

(2) *position within building*: whether it might come in contact with the water supply or foodstuffs, whether it is exposed and poses danger from physical contact;

(3) *means of degradation*: abrasion – normal weathering or wear and tear, chemical action – corrosion, drying, gas emission;

(4) *ventilation*: air change rate;

(5) *lifestyles*: periods of occupation of building, time factor governing exposure; and

(6) *maintenance cycles*: possibility of toxic chemicals or dust being introduced during maintenance.

Burberry (1991) provides a useful guide for energy-conscious design:

(i) good location – minimum exposure, minimum natural shading of building, minimum noise, good fuel availability;
(ii) minimum volume and surface area;
(iii) minimum heat transfer through fabric;
(iv) minimum ventilation and infiltration;
(v) occupancy and thermal response – relate occupancy pattern to thermal response of fabric and heat emitters;
(vi) fuel – economical energy sources, efficient conservation and distribution;

(vii) controls – adequate time and temperature controls, information on operation for occupants;
(viii) allowance for future changes – fuel types, services installations, internal layout;
(ix) adequate workmanship, commissioning and maintenance; and
(x) multiple use of building space.

Burberry (1991) provides a more detailed checklist at the strategic planning, detailed design, construction and operation stages.

As a corollary to operational monitoring, White (1988) advocates systematic multidisciplinary postaudits which involve a fundamental reappraisal of the objectives and assumptions of the project. To be effective and useful, adequate time, financial and human resources should be devoted to the audits, and their results should be published in full.

Further action

Pre-design. Some fundamental questions should be posed before each project is embarked upon. The first of the three established axioms of project selection: 'the right project, in the right place, at the right time' (Henwood, 1984), should be modified. Right, in this case, should include whether the project is necessary; this can be deduced from a consideration of whether a new constructed item (or any project involving construction activity) is the best answer to the client's needs. Whereas it may be aruged that this is done as a matter of course in 'rent or buy', 'refurbish or redevelop' and so on considerations, the environmental perspective should, henceforth, feature prominently in such decisions, following the criteria outlined above. Important issues here include: adaptive reuse or new construction; long-term projection of demand and of technologies to reduce the pace of obsolescence; alternative sites and the visual impact of the building; and appropriate handling and disposal of the products, by-products and wastes made in the constructed item. It will be necessary to undertake more rigorous economic evaluations of projects in order to align supply more closely with demand and, thereby, avoid the waste implied in the oversupply of constructed items for significant periods of time.

Project feasibility studies should consider the environmental aspects of the project, both internally and externally, in addition to the normal financial and technical viability considerations. User-requirement studies should pay greater attention to the physical and psychological health and social needs of the occupants and the general public. Environmental impact analysis, following common specified criteria (albeit specially developed for each country or region, for example, in the developing countries, involving finding answers to simple, standard questions relating to the project), should be routinely undertaken for each construction project (other than relatively minor works using simple, well-tried technologies). A statement of such an analysis could be made a statutory component of all applications for planning approval (Infrastructure Policy Group, 1990). Such analyses could be based on the established concepts of the technique of environmental impact assessment which, in essence, involves (UNEP, 1980):

(a) a description of the proposed action as well as alternatives;
(b) an estimate of the nature and magnitude of likely environmental changes;
(c) identification of relevant human concerns;

(d) definition of the criteria to be used in measuring the significance of environmental changes, including relevant weighting;
(e) estimate of the significance of the predicted environmental changes;
(f) recommendation for acceptance of the project, remedial action, choice of one of more alternatives, or rejection; and
(g) recommendation of monitoring and inspection procedures to be followed during the implementation, and after the compeltion of the action.

Design, construction and maintenance. Especially in the case of proposed civil engineering projects, the potential threat to existing ecosystems requires careful attention during the development of the design. The fundamental consideration of the nature and form of the proposed building or works is vital in some cases. During design, construction, maintenance and demolition, environmental appropriateness should be of paramount importance in the choice of layouts, building forms, materials, components, systems and methods. Design should positively seek to protect and enhance the environment. The use of safe materials and those produced from renewable (natural or recycled) raw materials, mechanical and engineering installations and construction equipment economizing in the consumption of energy, and so on, should be major considerations.

Project evaluation, planning and monitoring from the perspective of both the client and the contractor should have four objectives: cost, time, quality and the environment. Considerations in relation to the last of these requires new attitudes, perceptions and knowledge. The project co-ordinator should ensure that systems and procedures are set up (at all stages of the project) to attempt to seek these objectives, and to monitor such efforts. A great deal of discipline is required of practitioners and researchers if they are to be able to seek answers to basic questions posed consciously from an environmental perspective. The structured concept of value engineering has particular merit in this new approach. However, some of its basic orientations should be amended as shown below.

(1) *What is it?* should have a corollary: *What is it made of?*

(2) *What is it worth?* and *How much does it cost?* should be related to an assessment not just of the value, and capital and running costs of the item, but its *overall environmental value or cost.*

(3) *What else will do?* and *What does it cost?* should also have the respective corollary and considerations outlined in (1) and (2).

This concept should be applied both during design and construction – in such areas as specification of materials, components and systems, and choice of contractor's plant and equipment – and in the operation of the building – for example, in assessing the merits of new knowledge on energy source and waste disposal. There is a case for making a structured post-occupancy evaluation a routine component of each construction project (Duffy, 1991). It may also be worthwhile, especially for owners of large buildings, to adopt a policy of periodic (for example, 5-yearly) evaluations.

Implementation. For the new orientation of practitioners on projects to be successful further studies to increase knowledge in many areas are required. Some existing concepts, techniques, regulations and codes need to be revised. For example, life-cycle costing (and codes on energy conservation) should be further developed to embrace a consideration of the energy embodied in the materials and components of the building. R&D should be intensified to make more environmentally-suitable materials and components available. For example, techniques for developing environmentally-fragile sites are required. In the developing countries, simple, low-cost technologies are necessary if the critical issue of inadequate infrastructure is to be effectively addressed. Organizational systems which would enable project teams to respond to environment issues are necessary (Morris, 1983). Educational syllabuses should be revised to reflect the environmental perspective. Academics need to increase their knowledge of relevant issues by availing themselves of the existing large, and rapidly expanding, body of information on the environment and how construction activities relate to it. Professional bodies and trade associations should take positive steps to inculcate in their members an environment culture, undertaking, sponsoring or promoting R&D; preparing suitable educational material and practical handbooks; and running continuing professional development courses.

Experience has shown that techniques and tools for improving on practitioners' performance on projects are most likely to be adopted if the client insists on it. This, in turn, is likely if the client is convinced that the technique will improve upon the commercial (or utility) potential of the project (Picken, 1990). Thus, clients will play an essential role in the effort to incorporate the environment into construction project objectives. Public-sector projects may be used to demonstrate how this can be achieved. Where they exist, clients' associations should continuously bring environment issues to the attention of building owners. Governments should educate clients about the usefulness of their insistence on the inclusion of the environment among project objectives. Appropriate administrative infrastructure and mechanisms for formulating, implementing and monitoring the required policies and mounting the necessary publicity programmes are needed. International co-operation and the sharing of ideas among all nations would be beneficial. The developing nations should monitor developments in the industrialized countries, seeking ideas which they can adopt. Finally, the developing countries would require technical assistance to build up the necessary expertise and administrative infrastructure.

Conclusion

Governments' statutory and regulatory controls in relation to environmental issues affect construction in many ways. Some of these measures (and their implications for construction) include regulations on the use of renewable resources (choice of appropriate materials and components); control of air pollution and wastes (production, transportation and use of materials, construction techniques, especially those for repair, maintenance and demolition); control of noise pollution (construction equipment and techniques); and energy conservation (design of buildings, choice of materials and systems). As the regulations and codes are refined and developed further, they will tend to be wider in scope and generally more stringent. Actions by non-governmental organizations also have (often adverse) consequences for construction activity. Owing to programmes launched by governments and organized activities of consumers' and other groups, the general public (and hence potential construction clients and users) are becoming increasingly more aware of issues concerning the environment.

Although the construction industry has taken measures to respond to these developments, the need for further action, at the level of projects, professions and trades, industries, countries, and also at the global level, is clearly evident. It would appear that success in these would be most likely if taking the environment into consideration in a conscious manner and endeavouring to make a positive contribution to the overall efforts to protect the environment becomes part of the culture of every practitioner in the construction industry. Since the activities of such practitioners are aimed at achieving the objectives of clients on construction projects, adopting the environment as a project objective would be the best way by which this can be brought about.

References

Ayanda, J.O. (1988) Incorporating environmental impact assessment in the Nigerian planning process: needs and procedure, *Third World Planning Review*, **10**, 51–64.

Baum, W.C. and Tolbert, S.M. (1985) *Investing in Development: Lessons of World Bank Experience.* Oxford University Press, New York.

Behrens, W.W., III (1974) *The Limits to Growth.* Pan, London.

Behrman, D. (1979) *Science and Technology in Development: A UNESCO approach.* UNESCO, Paris.

Bell, G. (ed.) (1976) *Strategies for Human Settlements: Habitat and Environment.* University Press of Hawaii, Honolulu, pp. 115–20.

Bennett, J. (1983) Project management in construction, *Construction Management and Economics*, **1**, 183–97.

Bennett, J. (1985) *Construction Project Management.* Butterworths, London.

Broome, T.H. (1987) Engineering responsibility for hazardous technologies, *Journal of Professional Issues in Engineering*, **(113)2**, 139–49.

Burbery, P. (1991) Saving energy: what matters most. *Architects' Journal*, 13 February, 55–59.

Burke, T. and Hill, J. (1990) *Ethics, Environment and the Company.* Institute of Business Ethics, London.

Carlsson, E. (1976) Preface. In *Strategies for Human Settlements: Habitat and Environment* (edited by G. Bell). University Press of Hawaii, Honolulu, pp. xi–xix.

Chartered Institute of Building (1989) *What Are You Doing About the Environment.* London.

Chow, K.F. (1990) *The Construction Agenda: Development of the Construction Industry in Singapore.* Construction Industry Development Board, Singapore.

CIRIA News (1988) Planning for quieter construction. No. 6, 1988, p. 1.

Clouston, E. (1991) Cracking up under the strain, *The Guardian*, 7 June, p. 17.

Construction (1988) (Journal of the Property Services Agency, UK), Issue No. 64, p. 4.

Construction Industry Development Board (1989) *Report on the Cost Competitiveness of the Construction Industry in Singapore.* Singapore.

Construction Industry Research and Information Association (CIRIA) (1984) *Exposure of Construction Workers to Noise.* Technical Note 115.

Convention on Long-range Transboundary Air Pollution (1989) *Forest Damage and Air Pollution: Report of the 1988 Forest Damage Survey in Europe.* Global Environment Monitoring System, Geneva.

Curwell, S. (1990) Greenprint for the future: environmental design, *Architects Journal*, 12 December, pp. 45–48.

Curwell, S., March C. and Venables, R. (1990) *Buildings and Health: The Rosehaugh Guide to Good Design, Construction, Use and Management of Buildings.* RIBA Publications, London.

De Jonge, H. (1990) The philosophy and practice of maintenance and modernisation. In *Building Maintenance and Modernisation Worldwide* (edited by L.K. Quah), Vol. 1. Longman, Singapore, pp. xvii–xxxi.

Duffy, F. (1991) What price commmodity: evaluating buildings, *Architect's Journal*, 6 February, pp. 45–7.

Economic Commission for Europe (1986) *Long-term Perspectives for Human Settlements Development in the ECE Region.* (A report prepared by S. Staynov and K. Baumgarter.) United Nations, New York.

Economic Commission for Europe (1989) *The State of Transboundary Air Pollution: Effects and Control.* Air Pollution Studies No. 5. United Nations, New York.

Economic Commission for Europe (1990) *Synthesis Paper Based on the National Reports Submitted by ECE Member Countries.* Regional Conference at Ministerial Level on the Follow-up to the Report of the World Commission on Environment and Development in the ECE Region. Bergen, Norway, May.

Engineering News Record (1991) 24 June, p. 10.

Flavin, C. (1986) *Electricity for a Developing World.* Paper No. 70, Worldwatch Institute, Washington DC.

French, M. (1986) Asbestos removal, *Chartered Quantity Surveyor*, **9** (3), October, 18–20.

Gibb, Sir F. (1990) Pollution and its containment, *Overseas Brief*, September, 1–2.

Groàk, S. and Ive, G. (1986) Economics and technical change: some implications for the study of the building industry, *Habitat International*, **10** (4), 115–32.

Gunnerson, C.G. (1988) Environmental issues for 21st Century engineers, *Journal of Professional Issues in Engineering*, **114** (3), 287–301.

Henwood, N.L. (1984) Pre-evaluation of buildings, *The Building Economist*, September, 3–4.

Hill, S. (1991) *Energy Conscious Planning.* Council for the Protection of Rural England, London.

Hillebrandt, P.M. (1984) *Economic Theory and the Construction Industry.* Macmillan, London.

Holding, J. (1990) Varied treatment, *Construction Today*, December, 24.

Infrastructure Policy Group (1990) *Pollution and Its Containment.* Institution of Civil Engineers, London.

International Construction (1988) Bricks from coal, **27** (12), December, 14.

International Construction (1989a) No wasted energy, **28** (1), January, 15.

International Construction (1989b) Stockholm tunnel completed, **28** (4), April, 8.

Jackson, R. (1986) The varied career of rural electrification, *Appropriate Technology*, **13** (2), 5–7.

Jackson, J.A. (1990) Choosing paint systems, *The Canadian Architect*, May, 49–50.

Kaale, B.K. (1990) Sustainable biomass fuels development in the SADCC region. In *Energy and the Environment: Into the 1990s*, Proceedings of the 1st World Rewenable Energy Congress, Reading, UK, September, Vol. 3 (edited by A.A.M. Sayigh). Pergamon, Oxford, pp. 1817–22.

Katerere, Y. (1990) Trees in the farming system. In *Energy and the Environment: Into the 1990s*, Proceedings of the 1st World Renewable Energy Congress, Reading, UK, September, Vol. 3 (edited by A.A.M. Sayigh). Pergamon, Oxford, pp. 1800–6.

Magowen, C. (1989) Concern for the environment, *International Construction*, **28** (1), January, 57–65.

March, C. and Curwell, S. (1986) Assessing the health hazards posed by building materials, *International Journal of Housing Science and its Applications*, **10** (2), 147–56.

Mitlin, D. and Satterthwaite, D. (1990) *Human Settlements and Sustainable Development: The Role of Human Settlements and of Human Settlement Policies in Meeting Development Goals and in Addressing the Issues of Sustainability at Global and Local Levels.* A Report Prepared for the United Nations Centre for Human Settlements, Nairobi.

Morris, P.W.G. (1983) Project management organisation, *Construction Papers*, **2** (1), 5–18.

Nam, C.H. and Tatum, C.B. (1988) Major characteristics of constructed products and resulting limitations of construction technology, *Construction Management and Economics*, **6**, 133–48.

Nathan, D. (1990) New division to map out Environment City strategy, *The Straits Times*, November, p. 1.

Ofori, G. (1990) *The Construction Industry: Aspects of its Economics and Management.* Singapore University Press, Singapore.

Paustenbach, D.J. (1987) Should engineering schools address environmental and occupational health issues? *Journal of Professional Issues in Construction*, **113** (2), April, 93–111.

Pearce, D., Markandya, A. and Barbier, E.B. (1989) *Blueprint for a Green Economy*. Earthscan Publications, London.

Picken, D.H. (1990) Lifecycle costing: a tentative causal model. In Proceedings of the CIB 90 Joint Symposium on Building Economics and Construction Management, Sydney, March, Vol. 2, pp. 217–33.

Pugh, D.T. (1990) Is there a sea-level problem? In *Proceedings of the Institution of Civil Engineers*, Part 1, 88, June, 327–66.

Ramachandran, A. (1990) The impact of construction technology on the environment. Keynote address, XVIII IAHS World Congress, Rio de Janeiro, October.

Redclift, M. (1987) *Sustainable Development: Exploring the Contradicitions*. Routledge, London.

Rosenbaum, D.B. (1991) Pioneers plead for green design, *Engineering News Record*, 13 May, 26–8.

Smith, P. (1991) Power points in the battle to build a safer future for all, *The Guardian*, 7 June, 17.

Starke, L. (1990) *Signs of Hope: Working Towards our Common Future*. Oxford University Press, Oxford.

Steadman, R. (1990) Burning issue, *Construction Today*, December, 22–3.

Stuckenbruck, L. (1981) *The Implementation of Project Management*, Addison Wesley, New York.

Swan, R. (1988) Occupying the centre ground, *International Construction*, October, **27** (10), pp. 43–5.

Sykes, J. (1988) *Sick Building Syndrome*. Health and Safety Executive, London.

The Economist (1990) Mannesman's decisive edge: modern technology tames nature's temperament but leaves it unharmed, 15 December, 24–5.

The Economist (1991a) The dirty dozen, 20 July, 50.

The Economist (1991b) Nightmare in Acacia Avenue, 20 July, 73–4.

The Straits Times (1991) Green issues complicate drive for freer world trade, 12 February, 8.

Thomas, A. (1990) Harmonising building products, *Chartered Quantity Surveyor*, **13** (3), November, 15.

United Nations (1987) *General Assembly Resolution 42/146 of 11 December on the Environmental Perspective to the Year 2000 and Beyond*.

United Nations (1988) *A United Nations Conference on Environment and Development*, General Assembly Resolution 43/196 of 20 December.

United Nations Centre for Human Settlements (UNCHS) (1988) *Development of the Construction Industry for Low-Cost Shelter and Infrastructure*, Nairobi. HS/120/87E.

UNCHS (1989) *The Conservation of Drinking-Water Supplies: Techniques for Low-Income Settlements*. Nairobi. HS/175/89.

UNCHS (1990a) *People, Settlements and Sustainable Development*. Paper prepared for the Intergovernmental Meeting on Human Settlements and Sustainable Development, The Hague, Netherlands, November, 1990.

UNCHS (1990b) *People, Settlements, Environment and Development*. Nairobi.

United Nations Conference on Trade and Development (UNCTAD) (1990) *The Least Developed Countries: 1989 Report*. United Nations, New York. TD/B/1248.

United Nations Environmental Programme (1980) *Industry and Environment*, Special Issue, No. 1.

Walker, A. (1990) *Project Management in Construction*. Granada, London.

Ward, B. and Dubos, R. (1972) *Only One Earth: Care and Maintenance of a Small Planet*. Penguin, Harmondsworth.

Weissman, E. (1976) Rethinking a framework for settlement planning. In *Strategies for Human Settlements: Habitat and Environment*, (edited by G. Bell). University Press of Hawaii, Honolulu, pp. 15–18.

White, G. F. (1988) When may a postaudit teach a lesson? In *Proceedings, Flood Control Challenge*. American Public Works Association, New York.

White, R. and Whitney, J. (1990) Human settlements and sustainable development: an overview. A Paper Prepared for the Colloquium on Human Settlements and Sustainable Development, Toronto, June.

World Commission on Environment and Development (1987) *Our Common future*. Oxford University Press, Oxford.

World Meterological Organization and United Nations Environment Programme (1989) *The Global Climate System: Climate System Monitoring June 1986 to November 1988*. Geneva.