Environmental Sustainability: A Framework for Environmental Assessment Schemes

Thilini Jayawickrama[1], George Ofori[2], Sui Pheng Low[3]

Abstract

Rising environmental issues in all socioeconomic systems have led to continuous discussions on the concept of Sustainable Development (SD). The construction sector and the built environment have been accused of causing a range of environmental problems and are faced with the challenge of translating strategic sustainability objectives into concrete actions at project level. There is an increased involvement of accreditation bodies, both commercial and governmental research and administrative organizations, in the introduction of third party environmental assessment schemes to assess and promote sustainability performance in construction and the built environment. However, these are not without criticisms and previous studies have identified a range of shortcomings related to criteria selection, weighing, coverage, and methodological transparency. Also, no theoretical base has been established for environmental assessment schemes, and it is evident that theory lags behind practice. To contribute to efforts to address this gap, this paper proposes a theoretical framework for Environmental Sustainability (ES) which can be used as a base for selecting, and giving weights to the criteria in environmental assessment schemes. The literature on SD and ES was reviewed to understand their objectives and relevant aspects which should be applied at the project level. While the concept of SD is always defined as the balance between three sectors; economic, environment and social, the Environmental Economists have begun to emphasize the importance of ES. Based on this emphasis, the paper discusses the interactions between the natural environment and the economic system to highlight the important requirements of ES which are to be addressed on today's construction and built environment projects and a theoretical framework is presented.

Keywords: Sustainable Development, Economic system, Environmental goods and services, Environmental Sustainability, Environmental Assessment schemes

1. Introduction

People experience the clear symptoms of environmental un-sustainability today: climate change, ozone layer depletion, pollution, resource depletion, food shortages, health problems, and so on. Most of these are results of growing economic activities which are not compatible with the capabilities of the natural environment which provides all the goods and

[1] PhD Candidate, Department of Building, National University of Singapore, 4 Architecture Drive, Singapore 117566, Singapore, a0066405@nus.edu.sg

[2] Professor, Department of Building, National University of Singapore, 4 Architecture Drive, Singapore 117566, Singapore, bdgofori@nus.edu.sg

[3] Professor, Department of Building, National University of Singapore, 4 Architecture Drive, Singapore 117566, Singapore, bdglowsp@nus.edu.sg

services to almost all economic activities. These rising environmental issues in all socioeconomic systems have led to continuous discussions on the concept of SD. The construction industry and the built environment have been accused of causing a range of environmental problems including excessive consumption of natural resources and the pollution of the natural environment throughout their life-cycle (Sev, 2011). Therefore, the demand for a sustainable built environment has increased (Abdalla et al., 2011) and the industry is now faced with the challenge of translating strategic sustainability objectives into concrete actions at the project level (Ugwu and Haupt, 2007).

In this vein, environmental assessment methods play an essential role in evaluating and therefore encouraging the implementation of the sustainability principles in construction and built environment projects and a number of methods have been developed for evaluating the sustainability performances of those projects. Crawley and Aho (1999) note that environmental assessment methods range from life cycle assessment (LCA) methods to environmental impact assessment (EIA) methods. While the former consider the building or other construction project as a product and assess the life cycle environmental impacts, non-site specific, the latter evaluate the broader impacts of construction projects on the environment. Moreover, Crawley and Aho (1999) observe that between these two are environmental assessment methods such as Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy and Environmental Design (LEED) in the USA, Building and Construction Authority Green Mark (BCA-GM) in Singapore, and National Australian Building Environment Rating System (NABERS) in Australia.

Cole (2005) shows that the terms ‘method’ and ‘tool’ are used interchangeably to describe building environmental assessment techniques and also the terms ‘certification’, ‘rating’ or ‘labelling’ are also used interchangeably to indicate extended outputs from the assessment process. Cole (2005) considers ‘tools’ to describe a technique that predicts, calculates or estimates environmental performance characteristics of buildings or construction products which is similar to that of LCA methods explained by Crawley and Aho (1999). Cole (2005) uses the words ‘method’, ‘system’ or ‘scheme’ to describe assessment techniques relating to scoring performance and derivation of weightings which is the focus of this paper and are referred to as ‘environmental assessment schemes’. Since the introduction of the UK’s BREEAM in 1990, the first environmental assessment method worldwide for buildings (Haapio and Viitaniemi, 2008; Abdalla et al., 2011), there has been increased involvement of accreditation bodies, both commercial and governmental administrative and research organizations in the introduction of third party certification (Cole, 2005; Xiaoping et al., 2009) to assess and promote sustainability performances in construction and the built environment (Glavinich, 2008; Abdalla et al., 2011). Environmental assessment schemes have been formulated not only to be used to assess buildings but also infrastructure projects which cover a wide range of projects in the built environment. These schemes include Civil Engineering Environmental Quality Assessment and Awards Scheme (CEEQUAL) in the UK, BCA Green Mark for Infrastructure in Singapore, and the Australian Green Infrastructure Council rating system.

Despite the increased interest in, and development of, environmental assessment schemes worldwide, these are not without criticisms and previous studies present a range of shortcomings in these schemes. These include lack of overall transparency (Inbuilt, 2010 cited by Alyami and Rezgui, 2012), failure to cover some important criteria (Haapio and Viitaniemi, 2008; Abdalla et al., 2011), lack of an objective basis for the weighting system (Alyami and Rezgui, 2012) and lack of a clear path towards establishing an applicable environmental assessment method (Alyami and Rezgui, 2012) for a specific sector in a specific region. Also no theoretical base has been established for environmental assessment schemes in general (Cole, 1998; Retzlaff, 2009). Thus, in this area, theory lags behind practice. Crawley and Aho (1999) identified methodological transparency as an important requirement in developing environmental assessment tools, from both a philosophical and a practical point of view. However, previous studies have followed a process of listing sustainability criteria and sub-criteria under broad categories (such as project management, energy, materials use, ecology, waste and so on) and ranked them with expert evaluation. These rankings are not based on a theoretical base for ES and their assessment over actual environmental impacts are not transparent.

To contribute towards efforts to address this gap between theory and practice, this paper proposes a theoretical framework for ES with direct relevance to the construction and built environment items which can be used as a base for selecting and weighting the criteria in environmental assessment schemes.

2. Method and layout

Owing to the importance of the natural environment for almost all socioeconomic activities, the literature on Environmental Economics related to interactions between the economic system and the natural environment was adopted as the main basis for this research. These interactions were reviewed to determine a set of requirements that should be considered in order to achieve ES.

3. Sustainable development

SD is often presented as comprising three sectors; economic, environmental and social and often presented as three equal-sized interconnected rings (Giddings et al., 2002) as shown in Figure 3.1.a. Giddings et al. (2002) pointed out several weaknesses of the ring model which shows three rings in a symmetrical interconnection that leads one to assume the the three sectors are separate or even autonomous from each other. Furthermore, Giddings et al. (2002) claims that the model shows possible trade-offs that can be made among the three sectors, similar to that of the concept of “weak sustainability” which assumes that man-made capital can be used to replace or substituted for natural resources and systems (Neumayer, 1999 cited in Giddings et al., 2002; Daly, 1994) which is far beyond the reality considering real physical environmental limits.

In reality, the economic system depends on society and the environment and both the economic system and society depend on the natural environment ultimately. The natural environment is the core of any economy and economies cannot be sustained without environmental goods and services. Therefore, ES is a necessary condition for economic sustainability (Thampapillai, 2002). Thus, the separation in the ring model underplays the fundamental connections between the economy, society and the environment (Giddings et al., 2002) and it is suggested that the nested model (Figure 3.1.b.) represents the reality of the relationships between economy, society and the natural environment better than the ring model (Giddings et al., 2002).

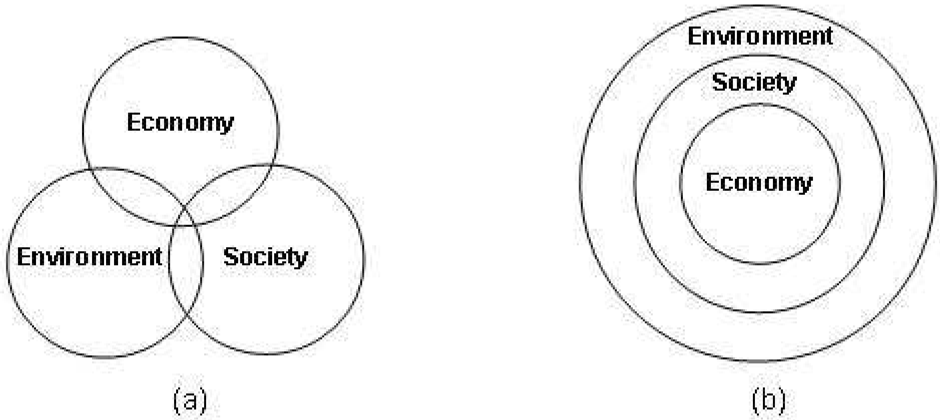

Figure 3:1 Ring model and Nested model (Giddings et al., 2002)

It has been realized today that the term "economic" does not just mean the happenings in the flow of money but also changes in human well-being which comprise not only monetary wealth but also many other services provided by the natural environment. Therefore, effective sustainability approaches need to address the relationships between ecosystems and economic systems (Jansson et al., 1994). The literature on the interactions between the ecological system and the economic system is reviewed in the next section.

4. Interactions between natural environment and economic system

The major interactions between the economic system and the natural environment are discussed to establish the requirements for ES for the proposed model.

Turner et al. (1994) explain the multi-functional nature of environmental resources with a wide range of economically valuable functions and services. Holding similar views, Common and Stagl (2005) and Asafu-Adjaye (2005) illustrate four interactions between human economic activities and the natural environment as (i) resource extraction from the environment for production and consumption, (ii) waste disposal to the environment as a result of both production and consumption, (iii) provision of amenity services, and (iv) life support services by environment. Pearce and Turner (1990) and van den Bergh (1996) also support these interactions. In addition to these four interactions, Hanley et al. (2001) explain an important interaction, the impacts from the economy to the biodiversity of the natural environment.

Including but going beyond these widely discussed interactions, de Groot (1992) developed a system to better explain functional interactions between human society and the natural environment as shown in Figure 4.1 which can be used for assessing the full value of natural systems to human society including both positive and negative aspects.

Figure 4:1 Functional interactions between society and environment (de Groot, 1992)

The main focus of de Groot (1994) is the function concept as an important element which defines environmental functions as “the capacity of natural processes and components to provide goods and services that satisfy human needs directly and/or indirectly” (de Groot, 1992). Also under the ‘natural capitalism’ phenomenon introduce by Lovins et al. (1999), the value of ecosystem services is identified as the largest component of capital. They propose four major shifts to economic activities in order to reduce wasteful and destructive flow of resources from depletion to pollution by reducing resource usage and hence, extraction and waste generation, and at the same time, restoring, sustaining and expanding natural capital to offset environmental impacts caused by economic activities. The latter is also emphasized by Daly’s (1994) notion of moving from an empty world to a full world.

Table 4:1 Summary of literature review of economic - ecosystem interactions

Interactions	Sources
1. Use the environment as a source of land	Pearce and Turner (1990); de Groot (1992); Turner et al. (1994);
2. Use the environment as a source of materials and energy resources	Pearce and Turner (1990); de Groot (1992); Daly (1994); Turner et al. (1994); van den Bergh (1996); Lovins et al. (1999); Hanley et al. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
3. Use the environment as a sink for disposing of waste	Pearce and Turner (1990); de Groot (1992); Daly (1994); Turner et al. (1994); van den Bergh (1996); Lovins et al. 1999); Hanley et al. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
4. Use the environment as a flow of amenities and life support services	de Groot (1992); Turner et al. (1994); Hanley et al. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
5. Invest in natural capital to maintain it	de Groot (1992); Thampapillai (2002)
6. Invest in natural capital to enhance it	de Groot (1992); Daly (1994); Lovins et al. (1999); Thampapillai (2002)
7. Conserve biodiversity	Hanley et al. (2001)
8. Suffer from environmental hazards and risks	de Groot (1992)

Daly (1994) explains that when natural capital is utilized to produce man-made capital continuously, natural capital become scarce and therefore investment in maintaining natural capital stock is of immense importance. Thampapillai (2002) presents two forms of investment in natural capital; restoring lost (non-functional) endowments and maintaining existing (functional) endowments. Thampapillai (2002) emphasizes the need for sharing of income within the economic system with the natural environment to achieve equilibrium between the environment and the economic system.

Table 4.1 summarizes these interactions between the economic system and the ecosystem. Since the concern of this study is in the form of proposing changes to the current patterns of economic activities to achieve sustainability, the interactions are listed from the perspective of activities in the economic system.

5. Theoretical framework for environmental sustainability

In this section, each interaction is defined for the purpose of the current study and major interactions will be determined which provide the basis of the theoretical framework for the assessment of ES of construction and built environment projects.

5.1 Use environment as a source of land

Although land could be considered as a unique resource that it is perfectly inelastic in supply and available to society as a fixed total quantity (Hanley et al., 2001), with the rapidly growing development activities, there is greater concern about changing land quality (FAO, 1997). The way land is used highly affects the future availability of productive land and other natural features inherent in those areas in terms of both quantity and quality.

Therefore, proper management in land use to minimize these effects is considered as one of the major requirements for ES. Here, one aspect is to minimize the need for acquiring new productive land and another aspect is to consider the composition of the land; whether it is a greenery area, wetland, marshy land and so on. During project development and operation, concern must be given in reducing damage to the selected land area and the neighbouring land. These requirements are considered in the proposed theoretical framework.

5.2 Use environment as a source of materials and energy

The environment provides inputs to the economic system; raw materials and energy resources (Hanley et al., 2001) for both production and direct consumption (Common and Stagl, 2005; Asafu-Adjaye, 2005). The earth is considered as a closed system in terms of materials and receives a limited amount of outside energy (solar energy) within a certain period. Therefore, natural resources are considered as scarce resources and with growing economic activities they become more scarce. Harnessing excessive amount of materials and energy resources may reduce the available stocks (Hanley et al., 2001) and cause damage to the environment depending on the type of source and method of extraction. The selection of materials and energy sources and quantity of usage should be decided depending on the potential for the natural growth of different materials and energy sources;

whether non-renewable, exhaustible or renewable (Turner et al., 1994; Hanley et al., 2001). Effective usage would reduce the demand for new materials and energy resources and also the attention should be paid to select the material sources with minimum environmental impacts during extraction and usage. For example, quarries developed in national parks will damage the biodiversity and amenity flow (Hanley et al., 2001) rather than one in a brownfield area. Logging in a rainforest largely impacts biodiversity compared to a logging in a planted forest. It might involve the extraction of the same amount of materials by quantity but it would cause different harms.

Therefore minimizing the usage of materials and energy resources by quantity and minimizing damages during extraction and usage are considered as major requirements for ES in the proposed framework.

5.3 Use environment as a sink for disposing of waste

The economic system uses materials and energy during production and consumption. In production processes, useful products are made and residuals are also generated. When these residuals are not inserted again into the economic system by reusing or recycling, they become waste (Common and Stagl, 2005). Similarly, useful products become waste after consumption. Waste cannot be destroyed in an absolute sense as explained under the first law of thermodynamics, and it is not possible to recycle all waste as explained under the second law of thermodynamics. Therefore, at least some of it will eventually be discharged into the environment (Turner et al., 1994; Thampapillai, 2002). The natural environment has an ability to handle these wastes up to a certain extent which is known as “assimilative capacity” (Thampapillai, 2002). When the disposal of the waste is continuous and intense, this capacity may be exceeded, and the natural environment is no longer able to fulfil its functions as a waste sink (Thampapillai, 2002). This will also affect its other functional performances as well and consequently, imposes limits to the economic activities (Turner et al., 1994; Common and Stagl, 2005). Both the quantity of waste and the quality of waste should be considered. For example, the discharging of non-treated water into a river system is more harmful than that of the same quantity of treated effluent.

The proper usage of the natural environment as a sink for disposing of waste in terms of waste quantity and harm is a major requirement for ES and is considered in the proposed theoretical framework.

5.4 Invest in natural capital to maintain it

It is not possible to attain a target of zero harm to the environment with economic activities. Therefore, a way to compensate the environment should be involved in the economic activities. Thampapillai (2002) suggests that the final output of the economic system (sum total of all income from goods and services) should not be exclusively used up in consumption and investment within the economic system. Instead, a part of this final output must be invested into the environment. Similar to that of the equilibrium of input and output flows between households and firms, the equilibrium between the economic system and environmental system (Thampapillai, 2002) should be attained. One form of investment in natural capital is maintaining the flow of services from endowments that currently provide services (functional). This is similar to offsetting wear and tear of capital goods. An example of this would be periodically treated a river which is getting polluted but still providing services.

Another form of investment in natural capital is to restore the flow of services from endowments which have ceased to provide services (non-functional). This includes restoring previously damaged or lost endowments such as rivers rendered unusable due to algal blooms, reforestation of areas that had been cleared for years (Thampapillai, 2002). Daly (1994) emphasizes the importance of investment in natural capital to enhance its stock, in order to cope with the increasing demand for environmental goods and services.

Therefore, investing in natural capital to maintain its status and to enhance its stock is considered as important requirements for ES and are considered in the proposed theoretical framework.

5.5 Impact biodiversity

According to Hanley et al. (2001), biodiversity loss involves more than the loss of particular species. Direct impacts such as loss of genetic materials for food crops or as a source of medicine, loss of a range of ecosystem services and, impacts on non-use benefits such as aesthetics can also be experienced. Biologically diverse ecosystems provide a greater flow of ecosystem services than non-diverse systems (Parker and Cranford, 2010). Also, diversity provides an important property of natural systems which is known as ‘resilience’, the ability to withstand shocks such as drought and fire (Hanley et al., 2001). Although natural resources are conserved in terms of quantity of total natural capital stock, the diversity of that natural capital stock is of immense importance in order to continue the functionality of the life-supporting ecosystems (Wilson, 1988 cited in Jansson et al., 1994). Hence, conserving biodiversity and reducing negative impacts on biodiversity are regarded as major requirements for ES in the proposed theoretical framework.

5.6 Use environment as a flow of amenities and life support services

People derive utility in terms of happiness and satisfaction (Common and Stagl, 2005; Hanley et al., 2001) through amenity services provided by the natural environment including sightseeing, sunbathing, wilderness recreation and so on (Hanley et al., 2001; Common and Stagl, 2005). Negative impacts on natural resources due to improper land selection, depletion of resources, pollution and loss of biodiversity disturb the functioning of ecological systems and these amenities. Also the natural environment provides biophysical necessities of life such as food, energy, mineral nutrients, air and water (Jansson et al., 1994) through life support services including climate regulation, operation of the water cycle, regulation of atmospheric composition, nutrient cycling, and so on (Hanley et al., 2001). Maintaining the life support services of the environment are important for the survival of humankind.

Since, land use, resource use, waste disposal and loss of biodiversity which are discussed in the sections 5.1 to 5.3 and 5.6, are the causes disrupting the amenities and life support services and controlling those causes during development activities will help continuing the amenities and life support services as well.

5.7 Suffer from environmental hazards and risks

Since this study is focused on ES from the perspective of protecting and enhancing the natural environment, the environmental hazards and risks affecting the economic system from the environment are not considered in the proposed theoretical framework.

5.8 Theoretical framework

Considering the impacts on the natural environment due to economic activities, nine requirements were determined which are important to achieve ES as listed below.

ES1a – Minimize land use in terms of area

ES1b – Minimize qualitative damages to the environment due to land use

ES2a – Minimize use of materials and energy sources in terms of quantity

ES2b – Minimize qualitative damages to the environment due to the usage of materials and energy sources

ES3a – Minimize waste disposal to the environment in terms of quantity

ES3b – Minimize qualitative damages to the environment due to disposing of waste

ES4a – Invest in natural capital to maintain it

ES4b – Invest in natural capital to enhance it

ES5 – Conserve biodiversity

These are the factors to be considered when assessing the environmental performance of development projects, thus providing the theoretical base for Environmental Assessment Schemes which are assessing such projects.

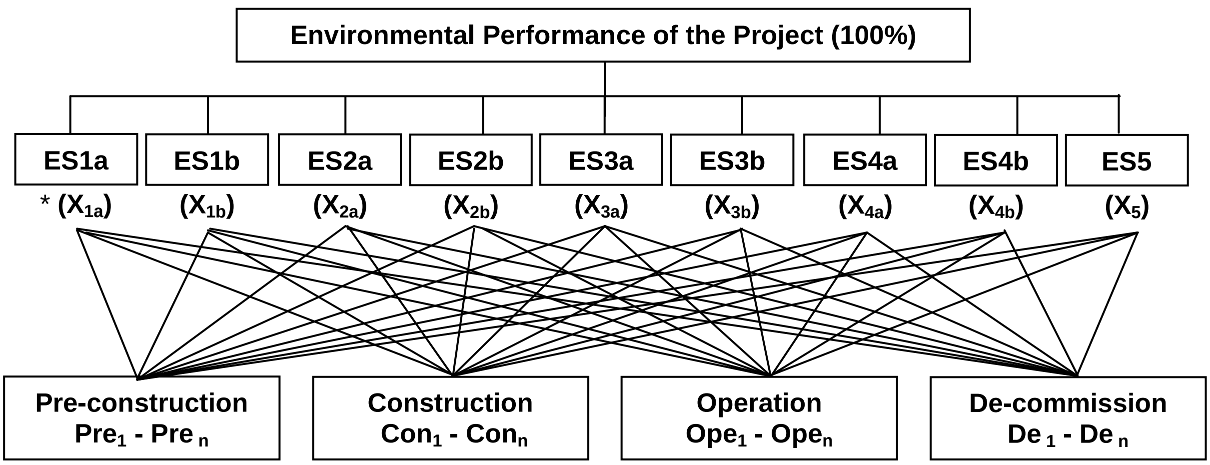

Figure 5:1 Framework for evaluating environmental sustainability

* 100% = $X_{1a} + X_{1b} + X_{2a} + X_{2b} + X_{3a} + X_{3b} + X_{4a} + X_{4b} + X_5$ = Total assessment score

Pre_1 - Pre_n - Criteria in the pre-construction stage

Con_1 - Con_n - Criteria in the construction stage

Ope_1 - Ope_n - Criteria in the operation stage

De_1 - De_n - Criteria in the de-commissioning stage

When developing an environmental assessment scheme for a specific sector in a specific region, the percentage importance of the total score for each factor from ES1a to ES5 for that region should be evaluated first. Then the potential environmental issues and potential positive impacts should be identified at each stage of the project from pre-construction to de-commissioning. Next, the criteria should be determined based on these issues and potential positive impacts and the importance of each criterion at each stage against ES factors (ES1a to ES5) can be evaluated. Finally, a summated value can be assigned to each criterion based on their contributions towards achieving ES. Thus, the theoretical framework of ES factors provides a basis for determining weights for criteria rather than using a simple interval scale to assign weights, or assigning equal values to all criteria.

6. Further research

The proposed framework can be applied in the development of environmental assessment schemes for different types of construction and built environment projects. Likely or existing environmental problems and positive impacts at each stage of a project in the particular sector in the particular region can be identified through a field survey. Then the criteria can be determined and weights assigned to them based on their importance towards the attainment of each ES factor. Systematic, multi-criteria ranking techniques such as Analytic Hierarchy Process (AHP) can be applied in undertaking such an evaluation.

7. Conclusion

Environmental assessment schemes play an important role in the implementation of the sustainability principles in construction and the built environment and a number of such schemes have been introduced around the world. However, there are several criticisms including the absence of a theoretical base for selecting and assigning weights to the criteria for environmental assessment schemes. These schemes need to identify projects with better environmental performance and therefore the weights for each criterion should reflect its contribution towards the achievement of environmental sustainability. Considering this requirement, this study proposed a theoretical base for ES which can be used as the basis for determining weights for the assessment criteria. Also, it presents a systematic method for developing environmental assessment schemes using the proposed theoretical base.

References

Abdalla, G., Maas, G. J., Huyghe, J. and Oostra, M. (2011) Criticism on Environmental Assessment Tools, *Proceeding of 2nd International Conference on Environmental Science and Technology (ICEST 2011)*, February 2011. In Saji Baby and Zygmunt (Eds.), pp. V2-443-V2-446. Singapore: IEEE.

Alyami, S. H., and Rezgui, Y. (2012) Sustainable building assessment tool development approach, *Sustainable Cities and Society*, In Press.

Asafu-Adjaye, J. (2005) *Environmental economics for non-economists: Techniques and Policies for Sustainable Development* (2nd ed.). Singapore: World Scientific Publishing Co. Pte. Ltd.

Cole, R. (1998) Emerging trends in building environmental assessment methods. *Building Research and Information*, 26 (1), 3-16.

Cole, R. J. (2005) Building environmental assessment methods: redefining intentions and roles. *Building Research and Information*, 35 (5), 455-467.

Common, M. S., and Stagl, S. (2005) *Ecological economics: an introduction*. New York: Cambridge University Press.

Crawley, D., and Aho, I. (1999) Building environmental assessment methods: applications and development trends, *Building Research and Information*, 27(4/5), 300–308.

Daly, H.E. (1992) Is the Entropy Law Relevant to the Economics of Natural Resource Scarcity?-Yes, of Course It Is!. *Journal of Environmental Economics and Management*, 23, 91-95.

Daly, H.E. (1994) Operationalizing sustainable development by investing in natural capital. In A. Jansson, M. Hammer, C. Folke and R. Costanza (Eds.), *Investing in Natural Capital: the ecological economics approach to sustainability*. Washington, DC: Island Press.

de Groot, R. S. (1992) *Functions of nature: evaluation of nature in environmental planning, management and decision making*. Wolters-Noordhoff.

de Groot, R. S. (1994) Environmental functions and the economic value of natural ecosystems (pp.). In A. Jansson, M. Hammer, C. Folke, and R. Costanza (Eds.), *Investing in Natural Capital: the ecological economics approach to sustainability*. Washington, D.C.: Island Press.

FAO (1997) *Land quality indicators and their use in sustainable agriculture and rural development (Land and Water Bulletin 5)*. Rome: FAO.

Giddings, B., Hopwood, B., and O'Brien, G. (2002) Environment, economy and society: fitting them together into sustainable development. *Sustainable Development*, 10, 187–196.

Glavinich, T. E. (2008) Contractor's Guide to Green Building Construction: Management, Project Delivery, Documentation, and Risk Reduction. New Jersey: John Wiley and Sons, Inc.

Hanley, N., Shogren, J. F., and White, B. (2001) *Introduction to environmental economics*. New York: Oxford University Press.

Haapio, A., and Vitaniemi, P. (2008) A critical review of building environmental assessment tools, *Environmental Impact Assessment Review*, 28, 469–482.

Jansson, A., Hammer, M., Folke, C., and Costanza, R. (1994) *Investing in Natural Capital: the ecological economics approach to sustainability*. Washington, D.C.: Island Press.

Lovins, A. B., Lovins, L. H., and Hawken (1999) *Natural Capitalism: The Next Industrial Revolution*. London: Earth scan Ltd.

Parker, C., and Cranford, M. (2010) *The Little Biodiversity Finance Book: A guide to proactive investment in natural capital (PINC)*, Oxford: Global Canopy Foundation.

Pearce, D. W., and Turner, R. K. (1990) *Economics of natural resources and the environment*, Baltimore: The Johns Hopkins University Press.

Retzlaff, R. C. (2009) Green buildings and Building Assessment Systems: A new area of interest for planners. *Journal of Planning Literature*, 24 (1), 3-21.

Sev, A. (2011) A comparative analysis of building environmental assessment tools and suggestions for regional adaptations. *Civil engineering and environmental systems*, 28 (3), 231-245.

Thampapillai, D. J. (2002) *Environmental Economics: Concepts, Methods and Policies*, London: Oxford University Press.

Turner, R. K., Pearce, D., and Bateman, I. (1994) *Environmental economics: an elementary introduction*, New York: Harvester Wheatsheaf.

Ugwu, O., and Haupt, T. (2007) Key performance indicators and assessment methods for infrastructure sustainability - a South African construction industry perspective. *Building and Environment*, 42(2) 665-680.

van den Bergh, J.C.J.M. (1996) *Ecological Economics and Sustainable Development: Theory, Methods and Applications*, UK: Edward Elgar Publishing Limited.

Xiaoping, M., Huimin, L., and Qiming, L. (2009) A comparison study of mainstream sustainable/green building rating tools in the world, IEEE, 1-5.