Quantifying and assessing impacts of building processes in a ‘triple bottom line approach

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Extended abstract

Ecologically sustainable development is a major concern, and embodies both environmental protection and management. The concept of sustainable development is broad and concerns attitudes and judgments that help ensure long-term growth and prosperity. Project development contributes to the economic and social advancement of society, enhancing the standard of living. Often associated with the impairment of the environment, project development may result in the loss of valuable agricultural land, forests and wildernesses, contributing to the pollution of both land and water, generating noise, consuming non-renewable natural resources and minerals and consuming large amounts of energy. In order to make a real difference in the future, project development process must become more sympathetic to sustainability ideals and actions are needed to make these construction activities more sustainable.

Sustainability in construction is often used as a buzz word rather than implemented as an actual practice. Environmental building assessment tools have been developed and used to assist planning and design of sustainable buildings. With increasing attention being paid on building sustainability performance, current environmental building assessment tools are criticized as being ineffective and inefficient in addressing the sustainability issues. Indeed, most of the tools available only focus on assessing a building’s performance on a set of pre-determined criteria and the assessment does not sufficiently take into consideration economic and social issues. Sustainability is like a three-legged stool, with each leg representing areas: environment, economic and society. Any leg missing from the ‘sustainability stool’ will cause instability because the three components are intricately linked together. Therefore the challenge of sustainability in construction nowadays is to integrate and manage these aspects in the building life-cycle that leads to sustainable results other than just focusing on the planning and design stages of a building.

Further criticism to the current environmental building assessment tools relates to the fact that these tools hide the real mass and energy flows which are critical in the determination of effective environmental impacts. They do not help to reveal the carrying capacity of the environment. Therefore no real comparison can be made to compare the impacts created by buildings during their life cycle. Additionally, the current environmental building assessment tools do not consider the impacts associated with the process of manufacturing products and transporting them to the site, ongoing operations and maintenance, and the disposal of waste at end-of-life. Public participation in the assessment process is also an area of concern as there are insufficient avenues for the wider community to be involved in the decision-making process.

As the goal of sustainable construction is to balance environmental protection with economic growth and social well-being, further improvement to the current environmental building assessment tools is needed in order to deal with more sophisticated circumstances in the decision-making process. The improvement includes taking the assessment from a triple bottom line approach that considers economic analysis to be as equally important as both social and environmental assessments and providing avenues for public participation.

As suggested in the literature, economic, social and environmental impacts associated with project development will vary at different stages throughout its life cycle. Consequently, assessing and incorporating sustainability performance into building process is essential. The impacts during the life cycle of a project are highly inter-dependent, as one phase can influence one or more of the other phases. Therefore, when the sustainability performance of a construction project is examined, project stages and associated major activities must be specified first, so that issues affecting the project characteristics for each stage can be identified and improved.

Given the previous discussion on the importance of incorporating economic, social and environmental assessments into the building process, a model has been developed to facilitate the assessment which aids decision making. In the paper the building process assessment model is established to reflect the achievement of sustainable development principles in a project's life cycle. The project life cycle includes the inception, design, construction, operation and demolition stages. At each stage economic, social and environmental impacts will be analyzed and assessed. The model includes the quantification of both objective and subjective measures which give a complete life cycle analysis of the buildings analyzed. The model recognizes the importance and usefulness of conventional methods of economic analysis. It utilizes monetary values as a unit for measuring resource efficiencies as it is readily understood by the decision makers and stakeholders. In addition the subjective aspects of social and environmental issues are quantified using value scores such as multi-criteria analysis to maximize their subjective attributes. The model presents an alternative approach for assessing the feasibility of a built project during its life cycle in attaining sustainable development. Based on the modeling principles, judgments can be made as to whether or not the development of a built project is in line with sustainable development principles and where improvements can be made accordingly. It reveals the sustainability performance at various stages of the development so that resources can be focused on the stage that has the most significant impacts in need for improvement. This way time, cost and resources can be utilized more efficiently and effectively.

The paper is based on a research project undertaken by the University of Technology, Sydney in examining the integration of economic, social and environmental considerations throughout the building process of a development. The project comprises the first stage, a literature review and model development, followed by the second stage, model implementation through case studies. The paper presents the first stage of the research project in a literature review and model development. The paper reviews the current application of environmental building assessment tools and their impacts on the construction industry. The importance of building process in environmental assessment is also indicated. The paper also seeks to analyze building performance using a triple bottom line approach on a life cycle perspective. The major activities in the building process are identified and presented on how they influence sustainable performance. Finally the paper presents a model that combines economic, social and environmental assessments into a single indicator to aid decision making.

Key words: Building sustainability; Triple bottom line; life-cycle analysis; Environmental building assessment; Building process

1. Introduction

Ecologically sustainable development has become a concern for people from all disciplines and in all countries. The concept of sustainability in the context of the environment has been defined by the World Commission on Environment and Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. Ecologically sustainable development, from a project development point-of-view, is thus concerned with the efficient utilization of resources, in order to meet the requirements and needs of present and future generations, minimizing adverse effects on the natural environment. Project development contributes to the economic and social advancement of society, enhancing the standard of living. Often also associated with the impairment of the environment, project development may result in the loss of valuable agricultural land, forest and wilderness, contributing to the pollution of land and water, generating noise, consuming non-renewable natural resources and minerals and consuming large amounts of energy.

Buildings have direct impact on the environment, ranging from the use of raw materials for construction and renovation, to the emission of harmful substances during their entire life span [2]. According to UNEP [3], the building and construction sector in the Organization for Economic Co-operation and Development countries consumes 25-40% of all energy used, and accounts for 40% of the world's greenhouse gas emissions. In response to minimizing environmental impacts of the industry, sustainable construction has become the main focus of research and development and is considered to be a way for the industry to achieve the goal for sustainable development. It is also a way to establish the construction industry's responsibility towards protecting the environment [4]. An important achievement in sustainable construction includes the development of environmental assessment tools for buildings as a benchmark for best practices in sustainable design and construction of buildings [5].

Nowadays, almost every country or region has at least one environmental assessment tool to improve sustainable performance of buildings. Initially, these tools focused on environmental impacts, but this has now been extended into the wider domain of social and economic impacts. According to Cole the specific definition of the term "building performance" is complex since different stakeholders in the building sector have differing interests and requirements [6]. Economic performance, health and comfort related issues, social stability, biodiversity conservation, and so forth are all significant when environmental building performance is considered.

The tools developed currently vary a great deal, ranging from tools for individual building components to a whole building assessment. They consider environmental issues at local, regional and, in some cases, even global perspectives. However, few take economic and social aspects into consideration. Since the release of the BREEAM in 1990 the environmental building assessment tools have been multiplying throughout the world. There are growing concerns about the effectiveness of building assessment methods as they are typically concerned with their consequences on buildings as completed products. However, more attention is now also paid to the impacts in the building process throughout the building's life cycle [7, 8].

This paper is based on a research project undertaken by the University of Technology, Sydney in examining the integration of economic, social and environmental considerations into the building process to demonstrate the extent of sustainable performance to aid decision making. The project comprises the first stage of literature review and model development, followed by the second stage of model implementation through case studies. The paper presents the first stage of the research project in a literature review and model development. The paper aims to review the current application of environmental building assessment tools and their impacts on the construction industry. The importance of the building process in the environmental assessment is also reviewed. The paper also seeks to analyze building performance using a triple bottom line approach on a life cycle perspective. The major activities in the building process are identified and presented on how they influence sustainable performance. Finally the paper presents a model that combines economic, social and environmental assessments into a single indicator to aid decision making.

2. Review on environmental building assessment tools and their impacts in the construction industry.

Building designers and occupants have long been concerned about building performance in relation to user comfort and health [9, 10]. Considerable work has gone into developing systems to measure a building's environmental performance over its life span. They have been developed to evaluate how successful any development is with regards to balancing energy, environment and ecology, taking into account both the social and technology aspects of projects.

Currently a number of different rating systems are used to rate the environmental performance of buildings. These include but are not limited to: Green Star (Australia), CASBEE (Japan), BREEAM (UK), and LEED (USA) and BEPAC (Canada). In 1990, BREEAM was developed in the UK and was the first assessment tool. It uses a scoring system and sets and maintains a robust technical standard with rigorous quality assurance and certification. BEPAC in Canada was launched in 1993. It is a voluntary tool that comprises a comprehensive set of environmental criteria and these criteria have been structured in five major topics (ozone layer protection, environmental impacts of energy use, indoor environmental quality, resource conservation and site, and transportation). In 1995, the GB Tool was launched as the first internationally developed tool. It is a rating system that handles both new building and renovation projects for multi-unit residential, office and school developments. Potential energy and environmental performance of buildings are assessed in this system using four levels of parameters. Green star has been used in Australia since 2003. It is a voluntary rating system used for many different types of buildings incorporating seven assessment criteria. CASBEE, which originated in Japan 2004, considers regional characters and assessing impacts for four phases of buildings. The LEED in the US consists of four levels of certification and five overarching categories correspond to the specialties that are available under the LEED Accredited Professional program.

These tools are only representatives of some of the most popular tools that are used in the construction industry that have been successfully implemented as an instrument to communicate product information and environmental awareness to stakeholders in this industry. However there is a growing concern that these tools may not fully support the sustainable development agenda in the industry. Kaatz et al. support this view and state that current environmental assessment tools are green building assessment tools which assess building performance against a pre-determined set of environmental criteria but the assessment methods should go beyond this to address a broader set of environmental, social and economic issues [11]. In addition, a majority of the tools are designed to support decision making during the planning and design stages of a building. However for the sustainability agenda to be maintained, a holistic building life-cycle must be considered. The building life-cycle is usually portrayed as planning, design, construction, operation, and deconstruction. However a full life-cycle of a building must be extended to include upstream acquisition of raw materials and downstream disposal in landfill or reuse or recycling of materials and these are largely ignored in the assessment of environmental performance in buildings.

The activities during these phases will influence the building performance in various magnitudes in terms of economic, social and environmental aspects. Therefore environmental building assessment tools may not be used solely to evaluate the quality of building performance but rather, it should also be used to transform the contents of methods by incorporating the principles of sustainable development directly into the building development process through information exchange and knowledge transfer. As a result, it will help to influence the ways the buildings are designed, constructed, used and demolished. The structure of the building process influences the available opportunities for exploiting economics of scale. The incorporation of sustainability measures into the building process are often more effective [12]. Greater emphasis should be placed on the process and transformation that occur within a building system to reflect sustainability values and principles of construction [7, 11, 13]. Indeed building environmental assessments will need to be considered throughout the entire life span of a development. Through a close integration of building assessments with the building process, sustainability principles can be explicitly integrated with a building’s objective and goals.

3. The challenges of assessing building sustainability

The goal of sustainable construction is to balance environmental protection with economic growth and social well-being [14]. Some suggest that the sustainability domain of current environmental building assessment tools is to establish an overarching sustainability framework of environmental, social and economic criteria [15, 16]. This view supports the idea that sustainable construction does not imply a complete halt to irreversible change in the natural environment. Some conversion of natural into man-made capital is acceptable providing that the depletion rate of the world’s natural capital does not exceed the rate of accumulation of man-made capital of lasting value. Sustainability is like a three-legged stool, with a leg each representing the areas environment, economy and society, and any leg missing from the ‘sustainability stool’ will cause instability because the three components are intricately linked together [17]. Therefore the challenge of sustainable construction nowadays is to integrate and manage these aspects during the building life-cycle that leads to sustainable results. The challenge will rely on a holistic sustainable thinking and incorporation of these three aspects into the building process.

There is a great number of environmental assessment tools for buildings [18] and these tools are designed to help improve overall environmental awareness amongst construction professionals towards sustainable practices and to achieve the goal of sustainability in the construction industry. Environmental building assessment tools have moved beyond the voluntary market place mechanism as they are now increasingly being specified as performance requirements, and are being considered as potential incentives for development approval [19]. Some countries or regions have even made environmental assessments of building projects mandatory at some stages of a development, such as BASIX in Australia and EcoHomes in the UK for residential developments, and Green Mark for all types of constructions in Singapore. They are expected to contribute in reducing environmental impacts, increasing economic viability and satisfying client's development objectives.

The criticism of current environmental assessment tools state that most of the assessment systems are relative, not absolute, by assessing building performance against a set of pre-determined criteria and their corresponding weights determined by subjective judgments [20]. The subjective nature of the tools has attracted much criticism due to lack of realistic basis [210]. Kohler goes on to criticize the current assessment tools in hiding the real mass and energy flows of a development [9], which are critical in the determination of effective environmental impacts. They do not help to reveal the real carrying capacity of the environment and therefore no real comparison can be made to compare the impacts created by buildings during their life cycle in different contexts.

Furthermore, the current environmental assessment tools do not consider the impacts associated with the processes of manufacturing products and transporting them to the site, ongoing operations and maintenance, and the disposal of waste at end-of-life. The challenges of existing environmental building assessment tools will focus on further improvements in order to deal with the increasing readiness of its target market for a more sophisticated discourse with respect to the understanding of sustainability issues and in facilitating the integration of sustainability consideration in construction decision-making [11, 22]. Stakeholders' participation in the assessment process is to be encouraged in order to respond effectively to the new challenges and requirements posed by the sustainability agenda. In other words further improvement in building sustainability assessment may be promoted as collaborative activities among building stakeholders in order that the vision of sustainable construction can be valued and realized [11, 22, 23].

Project performance traditionally refers to the outcomes of construction time, cost and quality. According to WCED [1] the concerns of building performance in line with the goal of sustainable development includes the sustainability criteria of economic, social and environmental development across the entire life span of a project. These three principles will have different impacts at various stages of a development. As a result it will be essential to assess a development to the entire building process [7, 11]. Van Paumgartten states that the performance of both economic and environmental aspects of a development can be maximised through the integration of sustainable principles into the building process [24]. Kaatz et al. suggest that the use of environmental assessments will enhance its ability to impact the design and construction practice challenging the existing norms and values of those responsible for the delivery of buildings [11]. It is beyond the current narrow technical focus and provides opportunities for a more conscious use of such methods to influence the quality of a building project through the building process. This is so that sustainability can be integrated into the project life cycle and communicated in a structured way for a more inclusive stakeholder representation during the building process.

4. Environmental building assessment - the building process approach

Traditional procurement systems focus on optimizing cost, time and quality and they are used to benchmark project success. This is often expressed by forecasting project benefits received and project costs incurred in undertaking a project. The appraisal of the relationship between these two elements is an important step in decision making. However this viewpoint limits the capacity for performance improvement and restricts buildings of to achieve sustainability performance. Following a decision by the developer with respect to the desired direction of investment, the next phase is to discuss the project with the planning and pollution-control authorities. In many cases an environmental impact statement may be required and there is always the possibility of a public inquiry. The ultimate aim is to combine economic viability with environmental quality [25]. The pursuance of sustainable development presents a challenge that sustainability of a construction project development must be assessed before its commencement. That is to assess the feasibility of a project investment by investigating into its economic ability as well as social and environmental viability to determine whether a project is worth going ahead.

The impact caused by construction activities on the environment occurs throughout a project's life cycle. At the stages of inception and design, a construction project consumes many types of environmental resources including both renewable and non-renewable resources. During the construction stage, typical environmental impacts occur from implementing a project such as air pollution, the degradation of water quality, noise pollution, and the generation of solid wastes. During its operation, a project consumes a vast amount of energy and natural resources for maintenance and refurbishment. At the end of a construction project's life cycle, the demolition activities generate a large volume of solid wastes and emissions. The assessment of various impacts from construction activities during the building process shows potential opportunities for making significant contributions to protecting the environment and attaining sustainable development by properly implementing a construction project [13].

Kaatz et al. state that the fragmented nature of the construction industry is a barrier to achieve sustainable construction and the fragmented nature has been the outcome of a variety of stakeholders involved in the development process. Sustainable construction requires the collaboration of the stakeholders at a very early stage of the development [8]. They go on to discuss that effective implementation of the sustainable construction agenda requires that the principles of sustainable development are to be reflected in the building processes [8]. If the building sustainability assessment is to transform the quality of construction practice positively, it has to be closely integrated with the building process.

There is no existing assessment tools that provide integration of building sustainability into the building process and the impacts at various stages of a building have not been considered in most environmental building assessment tools. Life cycle impacts are highly inter-dependent, as one phase can influence one or more of the others. For instance, a careful selection of building materials can reduce energy requirements, but might also increase construction cost and transport cost or affect the aesthetic of building, and could even influence the generation of recyclable waste. Therefore when sustainability performance of a construction project is examined, project stages and hence the major activities in each phase must be specified first, so that the proper factors inflecting the project characteristics of each stage can be identified. Table 2 summarizes the economic, social and environmental impacts of a project at various stages of a development.

Table 2 – Summary of the sustainable impacts of major activities in each phase

Development stages	Major activities	Impacts		
		Environmental	**Economic**	**Social**
Inception	Establish project proposal and undertake feasibility studies	Site selection, biodiversity, natural habitat	Land cost, loan payment	Cultural and heritage protection, infrastructure and public facilities, neighborhood and safety
Design	Preliminary and detail design	Resource depletion, energy consumption, aesthetics/visual impact	Development cost (e.g.labour, plant & equipment, fees)	Quality of life, traffic problems, loss of income, productivity reduction, social integrity
Construction	Site activities	Land use, site dereliction, embodied energy, emissions to air, land and water, construction waste	Construction costs (labour, plants and materials)	Employment, facilities, property integrity

Operation	Management, operation & maintenance	Resource consumption, pollutant emissions	Maintenance cost, salary, utility bills	Health and safety of occupants, employment opportunity
Demolition	Demolition & disposal	Operation of demolition machinery, waste disposal, landfill	Waste disposal fees, labor cost, energy cost, deployment of staff, land redevelopment, valued residues	Community betterment, safety and security

5. A building process model for assessing building performance

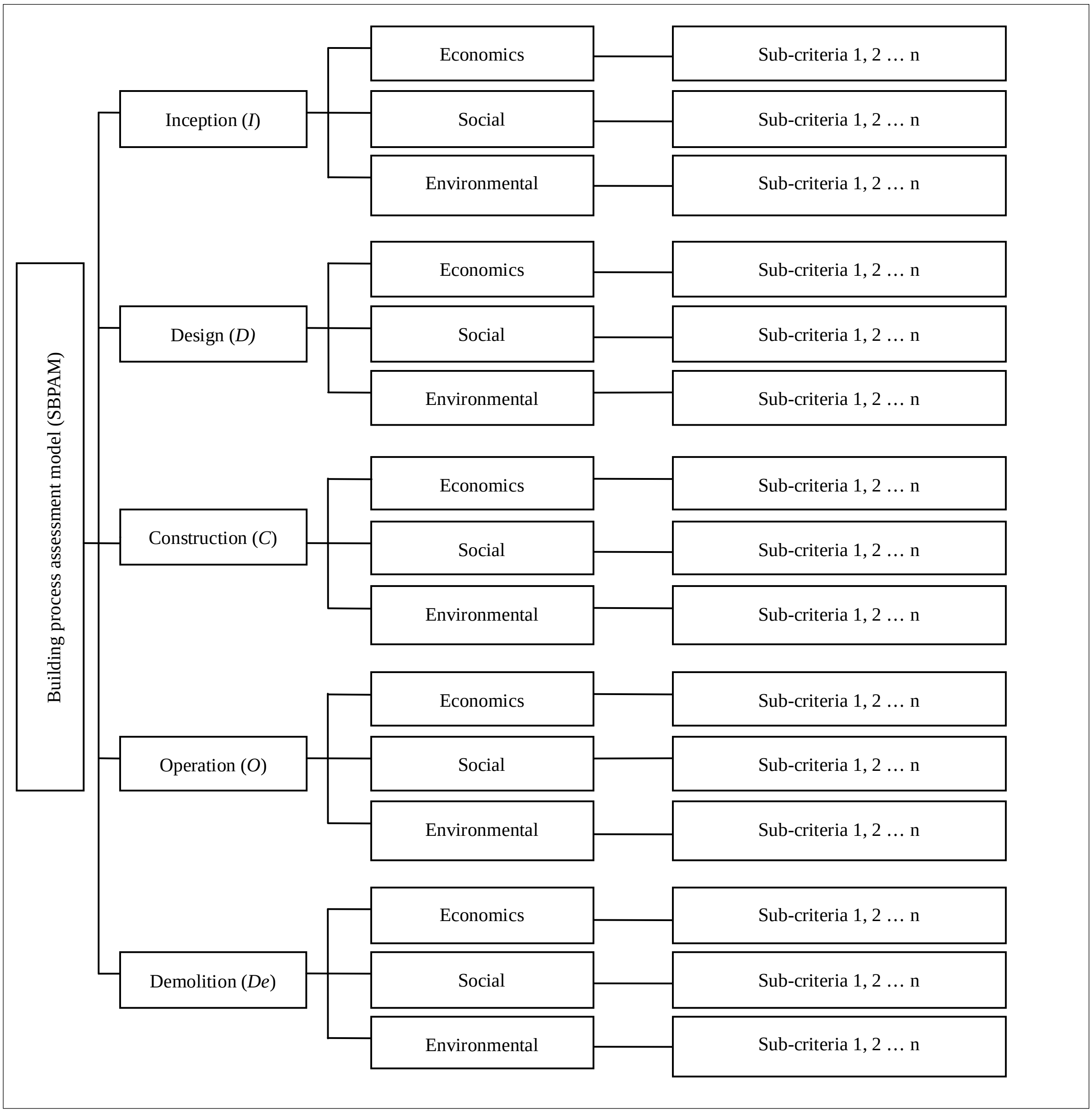
Given the previous discussion on the importance of incorporating economic, social and environmental assessments into the building process, it is necessary to develop a model to facilitate the assessment to aid decision making. With respect to this, the environmental building assessment may be considered as a continuous process, which takes place during the early stages of a development. Generally, the environmental assessment goes through several distinctive and inter-related stages. Figure 1 shows the building process assessment model (BPAM) for buildings. The model breaks the development process down into various levels of hierarchical criteria. Level one shows the various stages during a building's life cycle and level two shows the associated impacts in terms of economic, social and environmental performance. Finally each criterion is further broken down into sub-criteria for detail assessment. At each stage of the assessment public participation can be incorporated into the decision making process. This is a significant part of the process as it is the public who will suffer any long-term effects arising from decisions regarding new developments [8, 26].

The BPAM of a construction project is the value attributable to building project that reflects the achievement of sustainable development principles in the inception, design, construction, operation and demolition of built projects. As derived from related literature, the major principle of sustainable development is a three-dimensional aspect. The three pillar model of sustainable development was first introduced in 1987 which has formed the basis of almost every subsequent framework [14, 27]. Based on this principle, the three dimensions are variables that affect the level of contribution from a construction project viewpoint to achieve the goal of sustainable development. Therefore, BPAM can be used to indicate the significance of developing a construction project and its attainment of the three dimensions of sustainable development. BPAM is the function of sustainability performance at various stages of a project and can be expressed as follows:

$$BPAM = \int_{LifeCycle} f\{S_I, S_D, \mathrm{S_C}, \mathrm{S_O}, \mathrm{S_{De}}\} \qquad (1)$$

Where: BPAM = Building process assessment model
S_I = Sustainability performance at inception stage
S_D = Sustainability performance at design stage
S_C = Sustainability performance at construction stage
S_O = Sustainability performance at operation stage
S_{De} = Sustainability performance at demolition stage

Figure 1 The building process assessment model for buildings



BPAM is measured for the five stages and it is a step function which assumes different values at different stages of a project life process. This step function can be written in model (2):

$$BPAM = \left\{ \begin{array}{l} S_I = f\{E_I, So_I, Ev_I\}(t = inception) \\ S_D = f\{E_D, So_D, Ev_D\}(t = design) \\ S_C = f\{E_C, So_C, Ev_C\}(t = construction) \\ S_O = f\{E_O, So_O, Ev_O\}(t = operation) \\ S_{De} = f\{E_D, So_D, Ev_D\}(t = demolition) \end{array} \right\} \quad (2)$$

S_I is the sustainability performance at inception stage and it is the function of economic (E_I), social (So_I) and environmental (Ev_I). Similar models can be developed for other stages of the life cycle.

$$S_I = f\{Ec_I, So_I, Ev_I\} \quad (3)$$

$$E_I = \sum_{i=1}^{n} Ec_I^i W_i \quad (4)$$

where E_I = the performance of economic sustainability criteria at inception stage
Ec_I^i = the performance of economic sustainability criteria for sub-criteria *i*
(where i = 1, 2, …n)
W_i = Weight of criterion for sub-criteria *i*

The building process assessment model includes the quantification of both objective and subjective measures which gives a full life cycle analysis of buildings. The model respects the importance and usefulness of conventional methods of economic analysis. It recognizes the need to use monetary values as a unit of measuring resource efficiencies and it is readily understood by the decision makers and stakeholders. In addition the subjective criteria of social and environmental issues are quantified using methods such as multi-criteria analysis to best suit their subjective nature.

At the second stage of the project the model will be applied to assess the sustainability of a project over its entire project life cycle and different design options will be assessed to reveal the best option in balancing economic, social and environmental impacts.

5. Conclusion

Ecologically sustainable development is a major concern, and embodies both environmental protection and management. The concept of sustainable development is broad and concerns attitudes and judgment to help ensure long-term growth and prosperity. The implementation of a construction project will have various economic, social, and environmental impacts at different stages across its life cycle. After reviewing the current assessment methods, it can be concluded that there is a need to establish a model which considers the three impacts of a building from a life cycle perspective. This building process assessment model is established to bridge the gap.

Whilst construction activities have been contributing to the development of modern societies, they are also contributing adversely on the natural and man-made environment. Traditional construction practices assess the viability of a built project mainly using economic feasibility. This paper reveals that proper development consideration at an outset can make a significant contribution to achieving better sustainability, in particular the goal of ecologically sustainable development. Most of the existing environmental performance assessment approaches assess the overall performance of a project but do not take into consideration the impact that may have at various stages across a building’s life cycle. In achieving the goal of advancing the sustainability performance of building practices, the building sustainability assessment should be integrated into the building process. The model BPAM in this paper has been developed and presented to fill the gap. The model presents an alternative approach for assessing the feasibility of a built project during its life cycle in attaining the principle of sustainable development. Based on the modelling principles, the judgement can be made as to whether or not the development of a built project is in line with sustainable development principles and improvements can be made accordingly. The model offers opportunities to reveal the sustainability performance at various stages of a development so that resources can be focused on the stage that has the most significant impacts in need for improvement. This way time, cost and resources can be utilised more efficiently and effectively.

6. Reference

[1] WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, “Our common future”, *Oxford University*, Oxford, 1986.

[2] BALARAS C.A., DROUTSA K., DASCALAKI E. and KONTOYIANNIDIS S., “Heating energy consumption and resulting environment impact of European apartment buildings”, *Energy and Building*, Vol. 37, No. 5, 2005, pp. 429-442

[3] UNEP, “Sustainable building and construction”, *Industry and Environment*, 2003

[4] SPENCE R. and MULLIGAN, H., “Sustainable development and the construction industry”, *Habitat International,* Vol. 19, No. 3, 1995, pp. 279-292.

[5] BOSSINK B.A.G., “A Dutch public-private strategy for innovation in sustainable construction”, *Construction Management and Economics*, Vol. 20, 2002, pp.633-642.

[6] COLE R.J., “Emerging trend in building environmental assessment methods”, *Building Research & Information*, Vol. 26, 1998, pp.3-16.

[7] SHEN L.Y., WU M. and WANG J.Y., "A model of assessing the feasibility of construction project in contribution to the attainment of sustainable development", *Journal of Construction Research*, Vol. 3, No. 2, 2002, pp.255-269.

[8] KAATZ E., ROOT D. and BOWEN A., "Broadening project participation through a modified building sustainability assessment", *Building Research & Information*, Vol. 33, No. 5, 2005, pp. 441-454.

[9] KOHLER N., "The relevance of Green Building Challenge: An observer's perspective", *Building Research & Information*, Vol. 27, No.4/5, 1999, pp. 309-320.

[10] FINNVEDEN G. and MOBERG A., "Environmental systems analysis tools – An overview", *Journal of Cleaner Production*, Vol. 13, 2005, pp. 1165-1193.

[11] KAATZ E., ROOT D.S., BOWEN P.A. and HILL R.C., "Advancing key outcomes of sustainability building assessment", *Building Research & Information*, Vol. 34, No. 4, 2006, pp.308-320.

[12] VAN BUREREN E. and DE JONG J., "Establishing sustainability: policy successes and failures", *Building Reseach & Information*, Vol. 35, No. 5, 2007, pp.543-556.

[13] SHEN L.Y., WU Y.Z., CHAN E.H.W. and HAO J.L., "Application of system dynamics for assessment of sustainable performance of construction projects", *Journal of Zhejiang University Science*, Vol. 6A, No. 4, 2005, pp. 339-349.

[14] DE PLESSIS C., "A strategic framework for sustainable construction in developing countries", *Construction Management & Economics*, Vol. 25, January, 2007, pp. 67-76.

[15] COLE R.J., "Building environmental assessment methods: redefining intentions and roles", *Building Research & Information*, Vol. 35, No. 5, 2005, pp. 455-467.

[16] LUTZKENDORF T. and LORENZ D.P., "Using an integrated performance approach in building assessment tools", *Building Research & Information,* Vol. 34, No. 4, 2006, pp. 334-356.

[17] YOUNG A., "Is there really spare land? A critique of estimates of available cultivatable land in developing countries", *Environment, Development and Sustainability*, Vol. 1, No. 1, 1997, pp. 3-18.

[18] FORSBERG A. and VON MALMBORG F., "Tools for environmental assessment of the building environment", *Building and Environment*, Vol. 30, 2004, pp. 223-228.

[19] COLE R.J. and HOWAES N., "Building environmental assessment tools: current and future roles", *proceedings of World Sustainable Building Conference in Tokyo September 27-29,* 2005.

[20] COOPER I., "Which focus for building assessment methods – environmental performance or sustainability", *Building Research & Information*, Vol. 27, No. 4/5, 1999, pp. 321-331.

[21] RETZLAFF R. C., "The use of LEED in planning and development regulation" *Journal of Planning Education and Research,* Vol. 29, No. 1, 2009, pp. 67-77.

[22] ZIMMERMAN A. and KILBERT C.J., "Informing LEED's next generation with the natural step", *Building Research & Information*, Vol. 35, No. 6, 2007, pp. 681-689.

[23] OFORI G. and HO K.K., "Translating Singapore architects' environmental awareness into decision making", *Building Research & Information*, Vol. 34, No. 1, 2004, pp. 27-37.

[24] VAN PAUMGARTTEN P., "The business case for high-performance green buildings: sustainability and its financial impact", *Journal of Facilities Management*, Vol. 2, No. 1, 2003, pp. 26-34.

[25] CIB, "Agenda on sustainable construction", *CIB Report Publications*, USA, 1999, pp. 41-43.

[26]] JOUBERT R.A., LEIMAN A., DE KLERK H.M., KARAU S. and AGGENBACH J.C., "Fynbos (fine ash) vegetation and the supply of water: a comparison of multi-criteria decision analysis and cost-benefit analysis", *Ecological Economics*, Vol. 22, No. 2, 1997, pp. 123-140.

[27] BARBIER E.B., "The concept of sustainable economic development", *Environmental Conservation*, Vol. 14, No. 2, pp. 101-110.