

MODELING OF CONSTRUCTION FIRMS SUSTAINABILITY

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ABSTRACT

Sustainability is a hot debatable issue over the world, constantly being discussed by huge number of professionals'. It is an important issue for the construction industry as the industry takes up a lot of un-renewable resources and is the main contributor to the depletion of natural resources. Developing a standard measure contributes to achieving sustainability in all forms. In addition, it provides decision and policy makers with all data and information of interest to draw plans to achieve the principles of sustainable development. Though the construction industry is important for the development of every society but is also considered as the main contributor of natural resources depletion and responsible for high levels of pollution. It is also considered one of the attributes that pose climate changes and other environmental threats. Consequently, the achievement of sustainable construction poses stiff challenges. Therefore, there is a need to look into the fundamentals of sustainability to achieve sustainable construction. There is a wide belief which requires for individuals, companies and societies to find models, metrics and tools to articulate the extent and the ways in which, current activities are unsustainable. This paper attempts to determine the indicators to assess construction sustainability. These indicators will include an integration of all fundamentals that contribute to a sustainable development, which are, environmental, economic and social factors. These factors will form the framework in which is to be used to assess the construction firms in Malaysia. This paper attempts to propose a new framework to assess sustainability of the construction industry in Malaysia.

KEY WORDS: *Sustainability, construction industry, indicators, assessment.*

INTRODUCTION

Sustainability is a hot debatable issue over the world, constantly being discussed by huge numbers of people. There is growing realization among leading scientists, the public and politicians that we are using the planet's resources in ways which exceed its long-term capacity of use and undermines the vital life support system of the planet. In the last decade the difference in living conditions between rich and poor people, both between and within countries, has also widened, exacerbating environmental damage (TCPA, 2003). Ugwu & Haupt (2007) and Ugwu et al. (2006b) pointed out that sustainability is considered as a global issue that requires a global solution. However, the impacts of some global issues such as global warming and ozone depletion requires a local solution (Fricker, 1998). Abidin & Pasquire (2007) states that there is increasing pressure on the need to achieve sustainability and the relevant authorities must formulate effective ways to achieve sustainability and to be implemented as a cornerstone for future policies (Kühtz, 2007). This is what makes sustainability an important issue being debated in large scale of interests all over the world. In other words, it's a concept where people of interest discuss about the future (Newman &

Kenworthy, 1999). In conclusion, sustainability issues are very important to all society.

In the report titled "Our Common Future", sustainable development is defined as, "... *the development that meets the needs of the presents without compromising the ability of future generations to meet their own needs*" (WCED, 1987) which can be inferred as the fundamentals of the sustainable development concept (George, 1999). This concept focuses equally on the economic, environmental and social values (Ding, 2008). By reviewing previous studies on the subject of sustainability, most scholars use the definition that emerged from the Brundtland Commission "Our Common Future" with regards to sustainability. Many of the articles adopted this definition where is it subsequently used to base foundations to support the fundamentals of sustainability which is; environment, society and economy. In review of the concept of "Our Common Future" which remains as the 'benchmark' definition (Bentivegna et al., 2002). 'Future generations' is the main concern of sustainable development concept (Klostermann & Cramer, 2007). The integration among the three sustainable fundamentals make sustainability a holistic concept (Spilanis et al., 2009). It is a long term exercise to achieve sustainability (Fricker, 1998). These exercises should have concerted efforts among people who are interested in sustainability. The construction industry should take into account the concept of sustainability to promote a positive society development and at the same time keep at bay the negative impacts that construction may have towards the environment.

All academic fields and disciplines agree that sustainability issues concerns the planet future. Bearing that in mind, protecting and conserving the environment will have to coincide with satisfying the stakeholders' needs (Boyko, Cooper, Davey, & Wootton, 2006). The Commission definition considers the fundamental target of the construction industry is to achieve sustainability as well as playing the role as economic driver for the society. The principles of sustainable construction projects attempts to adhere to the definition of sustainable development by protecting the environment and enabling all people to improve their life through the pursuit of economic and social objectives.

These principles are (Alameda County, 2002):

- Build for the long term – construct buildings that are durable and long lasting.
- Build for our children – make their environment safe.
- Build for the planet – make the materials from sustainable resources.

The matter at hand is how to sustain the construction industry as economic driver for the

society as well as working friendly with the environment. A panacea in the form of a tool or technique that help enable the construction industry to function in both way, as an economic driver and being environmentally friendly should be created. A Sustained construction industry is reflected by the progress of sustainable development fundamentals; which are social and economic factors alongside with the environmental factor. Therefore, there is a need for developing countries, i.e. Malaysia to have the ability in assessing sustainability of their projects (Ugwu & Haupt, 2007), by using a combination of environmental, social and economic factors. The danger of implementing a sustainable development strategy and policy arises when the policy does not practice a uniform or parallel emphasis of sustainability fundamentals; for instance; to emphasize on the technological advancement while neglecting the environmental issues. To avoid this, indicators specifically designed for Malaysian scenario should be formulated and implemented to ensure a more structured and balanced approach towards achieving sustainability in the construction industry. Previous studies pointed out the benefits of formulating the right indicators and assessment framework in order to improve construction sustainability. The previous studies done, is considered as a contribution towards sustainability science in translating the global objectives of sustainability into project level decision-making to achieve a sustainable construction environment, making (Ugwua & Hauptb, 2007). Sustainability an important element in project decisions (Ding, 2008).

CONSTRUCTION INDUSTRY AND ITS IMPACT ON ENVIRONMENT

Construction activities are considered as a major contributor to environmental pollution (Augenbroe & Pearce, 1998; Chan & Chan, 2004; Ding, 2005; Hendrickson & Horvath, 2000; Yahya & Boussabaine, 2006; Yao, Shen, Hao, & Yam, 2007; Zimmermann, Althaus, & Haas, 2005). In addition to that, the industry consumes huge portions of raw materials (Augenbroe & Pearce, 1998; Ding, 2005; Nelms, Russell, & Lence, 2007; Yahya & Boussabaine, 2006). The impact of construction industry is produces undesirable remnants (Augenbroe & Pearce, 1998; Adisa Azapagic, 2004; Hill & Bowen, 1997; Nelms et al., 2007; San-Jose, Losada, Cuadrado, & Garrucho, 2007). which includes depletion of non-renewable resources, destruction of landscapes and creation of health and safety problem both relating directly & indirectly to the people involved with the construction industry (Adisa Azapagic, 2004; San-Jose et al., 2007).

Cost, time and quality is the outcome of project performance (Shen, Wu, Chan, & Hao, 2005). Though the construction industry is considered important for the progress of a society (Ding, 2005; Patermann, 1999), but at the same time it should pay attention for environmental protection (Ding, 2005) in order to achieve sustainability. Application of the

sustainability concept to project development requires great effort from different disciplines (Ding, 2005; Ding, 2008).

A sustainable development should take account analyzing the various construction activities. This is because there is a strong relationship construction industry and the different aspects of sustainable development (CIB, 1998). Bon & Hutchinson (2000) confirm that in efforts to achieve sustainability, minimizing pollution and waste production itself is inadequate. Formulation of policies that gives change to economic market forces, are required to govern the activities of professionals in the construction industry (Bon & Hutchinson, 2000). Economic growth development and the long-term effects on living standards are the few concerns for people in present and future (Ding, 2008). Environmental issues are a global concern (Chan & Chan, 2004). Also, protecting the environment is a main issue in construction industry (Ding, 2005; Yahya & Boussabaine, 2006). Efforts put in by all the parties concerned in the construction industry, has made the negative environmental impacts of construction projects to be wider better understood by architects, engineers, operators, and owners (TCPA, 2003). The Malaysian context CIB report (1998) raised the issue of protecting the environment during construction process.

THE IMPORTANCE OF SUSTAINABILITY

Sustainability plays a powerful role in the social level, i.e. having the ability to provide access to good education, creating goodwill, improving community consultation and promoting interest in various fields. Firstly one should consider the significant issues influence the area such as poor health, crime and social exceptions, before any actions to make an area more sustainable can be taken (Boyko et al., 2006). Therefore, it is very important to consider the best criteria during the assessment, which will in turn reflect the success rate of achieving sustainability. To deal effectively with sustainability issues, one should consider the need for extra knowledge, identification of knowledge database and be resourceful to put to practice new skills to support this process. By improving the current situation, it will in turn help to develop capabilities of management and leadership to support the promises to sustainable development (Gloet, 2006). Sustainable development is important for management and protection of the environment (Ding, 2005; Ding, 2008). The issues of sustainability deals with a wide range of factors within the local and global level (Gloet, 2006), making sustainability a common issue to different business (Azapagic, 2003), which in turn poses differences in practices of work often seen in many cases (Gloet, 2006). Therefore, there is a need to be aware to design and construct for sustainability bearing in mind the challenge in achieving the objectives at the micro level (Ugwu & Haupt, 2007). It must account for the integration of social needs, economic and environmental impacts of the sustainability to

chose the strategy (Kühtz, 2007). From the construction point of view, measurement is essential in order to have good management and performance improvement (Torbett, Salter, Gann, & Hobday, 2001). In addition to that, measuring is also used to ensure that sustainability objectives are being met (Azapagic, 2003). This statement is also applicable in the implementation of sustainable development policies and initiatives in construction industry. Most of the sustainability assessment methods developed by previous researchers only concentrated on environmental elements. Long term effects can be seen as one of the main the perpetrators of environmental problems, the fiercely competitive construction industry may find it difficult to mend their ways.

The perception towards sustainability within the industry is that, environmental protection can only drive their costs up, and hence affecting their competitive edge. Because of this, an assessment method integrating environmental, economic and social factors needs to be developed so that the industry could see the benefits of implementing sustainable development strategies and policies. Hence, it is imperative to develop a framework specifically tailored to the Malaysian scenario because as a developing country with its own unique characteristics, the newly developed framework could answer a multitude of problems in relation to construction sustainability in the country.

The developed Malaysian framework could be the right impetus to give momentum to promoting sustainable development amongst the country's construction companies. It is hoped that construction companies will not be scared and put off by the term "sustainable development", perceiving it to be cost additions. Rather, with an assessment tool integrating all the fundamentals of sustainable development (environmental, economic and social), the companies will form a learned judgments towards construction sustainability. This paper attempts to review the concept of sustainability issues in the Malaysian construction industry context; and suggest a framework for sustainability of construction firms in Malaysia. The framework will include an integrated assessment of all fundamentals in the sustainable development. There have been researches conducted in this industry within different disciplines.

SUSTAINABLE CONSTRUCTION

Countries that faces declining trend in construction, sustainability is an important issue for them (Bon & Hutchinson, 2000). Construction is important to the economical growth of every country (Raynsford, 1999; Seaden & Manseau, 2001). The construction industry consumes large quantity of environmental resource and is also one of the largest polluters of the environment (Ding, 2008; Shen et al., 2005). In brief, sustainable construction is the

construction that contributes to the sustainable development. With the implementation of sustainable construction, the construction industry is bound to bring about positive changes; i.e. less pollution, waste and even constitutes to the well-being of future generations. The industry contributes to economic development of Malaysia by developing infrastructures in all phases of development which in turn spurs economical growth. The construction industry is primarily responsible for putting together all necessary resources and production facilities or structure. Lack of awareness for sustainable development principle is one of the barriers of sustainability (Azapagic, 2003). In efforts to increase awareness, the Malaysian Report (CIB, 1998), introduced steps to reduce environmental impact that results from construction. Addressing sustainable development requires companies to provide equal opportunities to all (Adisa Azapagic, 2004). There are some weaknesses with the current framework and processes, where the framework only concentrates on a wider national level, failing to address micro-level integrated decision-making issues (Ugwu & Haupt, 2007; Ugwu, Kumaraswamy, Wong, & Ng, 2006b). Therefore it can be inferred that the framework is only effective for macro level decision issues while for the micro level, it is best to use a holistic approach to facilitate decision making (Ugwu & Haupt, 2007; Ugwu et al., 2006b).

SUSTAINABILITY ASSESSMENT

A number of sustainability assessment framework has been used to evaluate companies performance (Singh, Murty, Gupta, & Dikshit, 2009), and the integration of the three bottom line concept assessment is necessary to demonstrate that a project can be classed as sustainable development (George, 1999). To ensure optimize and effective steps towards sustainability are carried out, the progress and shortcomings require to be measured and monitored (Singh et al., 2009). Measuring and monitoring will be through the assessment of sustainability based on the combination of indicators for the fundamentals of sustainable development. Ding (2008) shows that multiple dimensional models were based on embracing economic, social and environmental values.

Therefore, the construction industry sustainability index can be developed to model the important criteria for construction-related decision (Ding, 2005). The index captures the complexities of the ecosystem, yet remains simple enough to be used (Ding, 2005). The development of a sustainability index is a way to address multiple criteria in relation to project decision-making (Ding, 2005; Ding, 2008). Lutzkendorf & Lorenz (2006) pointed out, that there is a demand for complicated as well as simple assessment process and presentation of assessment results. The assessment functions in several ways in providing a common set of standards and changing goals. Consequently, the assessment will play a good role in creating the body of knowledge and expertise within the design team of building and building

industry (Cole, 1998). The integration of assessment tools have to include all the dimensions of sustainable development (Lutzkendorf & Lorenz, 2006). Also, sustainability assessment then acts as a means for education and empowerment (Mathur, Price, & Austin, 2008). To be successful, all sectors of the economy must take action. Since a significant amount of Malaysia's emissions come from the housing sector, raising the environmental standards in this sector has the potential for making a significant contribution to efforts of creating sustainability.

DISCUSSIONS

There is insufficient effort to measure sustainability with integral approach that encompasses environmental, economic and social aspects (Singh et al., 2009).Ugwu and Haupt (2007), Ugwu et al. (2006b) confirmed that sustainability is a global issue which requires a concentrated global solution. The challenge of sustainable development for any business is to acquire present quality of life without compromising the quality of life of future generation (Azapagic, 2003). Sustainable construction can be achieved based on willingness and ability of the construction industry to drive much change (Bourdeau, 1999). Consequently, success of construction firms depends on environmental management (Christini, Fetsko, & Hendrickson, 2004). To sustain the success of the construction firm, information is crucial for creating a consensus for a sustainability assessment (Gomes & Silva, 2005). In addition to that, an effective stakeholder participation is needed to develop custom indicators in developing countries to address sustainability (Ugwu & Haupt, 2007), and Malaysia is considered one of the developing countries with its own custom features. By developing an indicator system which suits the construction industry, present problems can be identified and the solution can be subsequently proposed.

Selecting indicators of the framework will depend on a number of factors such as availability of data and complexity of the analysis (Azapagic & Perdan, 2000). Also, it plays a role to develop suitable measures that reflects sustainability objectives (Christini et al., 2004). As defined by Guy & Kibert (1998) Indicators represent the method to measure sustainability progress in an easy and understandable way. These indicators set are aimed to measure positive movement towards sustainable activities for the systems to be measured (Guy & Kibert, 1998), which is in this case, the construction industry. Critical indications of sustainable construction will focus on issues such as land use (Guy & Kibert, 1998), in addition to water, energy and material use (Adisa Azapagic, 2004; Bentivegna et al., 2002; Guy & Kibert, 1998; Sjoström & Bakens, 1999). Therefore, quantifying the amounts and types to these indicators in construction can provide the framework to develop sustainable construction indicators (Guy & Kibert, 1998). To conclude, sustainable construction is

achieved in different ways and have different priorities in different countries where some identify economic, social and cultural as part of their sustainable framework of the construction (Bourdeau, 1999). The importance of indicators is to monitor the progress, understand sustainability and to educate the stakeholders involved in the process. The goal for sustainability indicators development are to be applied in real situations, where, the usability considers underpinning principle in the indicators of development (Ugwu, Kumaraswamy, Wong, & Ng, 2006a), selected by experts and stakeholders (Spilanis et al., 2009), as well as playing the role to translate sustainability issues into quantifiable measures of the integration of the three bottom line factors (Azapagic, 2004). Indicators are also considered as a tool for policy making (Singh et al., 2009).

Indicators must have the ability to translate both internally-relevant and externally-important sustainability issues into the representative measures of performance (Azapagic, 2004). The framework includes economic, environmental and social indicators. Fricker (1998) shows that environmental and social indicators are seldom expressed as a single index. This means that, the framework should provide a holistic assessment for a sustainability level and reduce the number of criteria to help decision-makers (Azapagic, 2004). The literature shows that experts agree and emphasizes more on the environmental measure of performance rather than social and economic indicators (Azapagic, 2004). While the social indicators have both integration of the other two types and sustainability measures too (Fricker, 1998).

CONCLUSIONS

In order to encourage sustainability practice in the construction industry, incentives and rewards should be awarded to the rightful party who practices sustainability. Despite the governmental support, the application of sustainable principles will still result in an increased cost and subsequently an increased price for the clients. There is no doubt that the government plays an important role in achieving environmental sustainability through the development and enforcement of the rules and laws that must be abided by the end user which is in this case the construction industry because of its significant impact on the environment. To conclude, in order to achieve sustainable construction, the industry must face stiff challenges. The integration among the three fundamentals of sustainability considers a comprehensive framework, which encompasses other aspects of performance and quality in construction. Therefore, achieving sustainability means achieving quality of life. There is no doubt that sustainability issues are regarded as a problem at global and local levels. In light of the terrible overpopulation and limited resources and the depletion of natural resources has led the world population to address this problem and to realise the seriousness of the current situation. Therefore, we must take preventive measures to reduce

this problem to ensure a decent living for future generations. The study attempts to produce a model can be used in the construction firms. This model will serve the three fundamentals of sustainability. The outcome of the study will be reported in the next paper. This model can be applied to the construction industry of Malaysia and elsewhere in the world; which has the same characteristics as the Malaysian construction industry. Incentives, either from the government or the owner is vital to the efforts of promoting a sustainable practice in construction firms. To initiate sustainability principles, it will indefinitely result in an increase in cost and price. Therefore, to minimize the cost impact, sustainability must be taken into account during the design phase whilst at the same time, not to disregard the satisfaction of the end user; which is one of the important elements to achieve sustainability. The benefit of this study is not only environmental protection, rather it is a combination of benefits which includes internal and external interests for the company, for the employee, owners and investors. These combination of benefits reflect social, economical and environmental protection and at the same time maximizing profits while keeping the cost of input to a minimum.

REFERENCES

- Alameda County. (2002). Alameda County Waste Management Authority. New House Construction: Green Buildings Guidelines, Alameda County Waste Management Authority, California, USA.
- Augenbroe, G., & Pearce, A. R. (1998). *Sustainable Construction in the United States of America A perspective to the year 2010* □□□ □□□□□□
- Azapagic, & Perdan, S. (2000). Indicators of Sustainable Development for Industry: A General Framework. *Process Safety and Environmental Protection*, 78(4), 243-261.
- Azapagic, A. (2003). Systems Approach to Corporate Sustainability: A General Management Framework. *Process Safety and Environmental Protection*, 81(5), 303-316.
- Azapagic, A. (2004). Developing a framework for sustainable development indicators for the mining and minerals industry. *Journal of Cleaner Production*, 12(6), 639-662.
- Bentivegna, V., Curwell, S., Deakin, M., Lombardi, P., Mitchell, G., & Nijkamp, P. (2002). A vision and methodology for integrated sustainable urban development: BEQUEST. *Building Research & Information*, 30(2), 83-94.
- Bon, R., & Hutchinson, K. (2000). Sustainable construction: some economic challenges. *Building Research & Information*, 28(5), 310-314.
- Bourdeau, L. (1999). Sustainable development and the future of construction: a comparison of visions from various countries. *Building Research & Information*, 27(6), 354-366.
- Boyko, C., Cooper, R., Davey, C., & Wootton, A. (2006). Addressing sustainability early in the urban design process. *Management of Environmental Quality: An International*

Journal, 17(6), 689-706.

- Chan, A., & Chan, A. (2004). Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, 11(2), 203-221.
- Christini, G., Fetsko, M., & Hendrickson, C. (2004). Environmental Management Systems and ISO 14001 Certification for Construction Firms. *Journal of Construction Engineering and Management*, 130(3), 330-336.
- Ding. (2005). Developing a multicriteria approach for the measurement of sustainable performance. *Building Research & Information* 33(1), 3-16.
- Ding, G. K. C. (2008). Sustainable construction--The role of environmental assessment tools. *Journal of Environmental Management*, 86(3), 451-464.
- Editorial understanding the social and economic value of construction. (2006). *Building Research & Information*, 34(3), 191 - 196.
- Fricker, A. (1998). Measuring up to sustainability. *Futures*, 30(4), 367-375.
- George, C. (1999). Testing For Sustainable Development through Environmental Assessment. *ENVIRON IMPACT ASSESS REV* 19, 175-200.
- Gloet, M. (2006). 'knowledge management and the links to hrm developing leadership and management capabilities to support sustainability'. *Management Research News*, 29(7), 402-413.
- Gomes, V., & Silva, M. G. d. (2005). Exploring sustainable construction: implications from Latin America. *Building Research & Information*, 33(5), 428-440.
- Guy, G. B., & Kibert, C. J. (1998). Developing indicators of sustainability: US experience *Building Research & Information*, 39-45(1), 26.
- Hendrickson, C., & Horvath, A. (2000). Resource Use and Environmental Emissions of U.S. Construction Sectors. *Journal of Construction Engineering and Management*, 126(1), 38-44.
- Hill, R., & Bowen, P. A. (1997). sustainable construction: principles and framework for attainment. *Construction Management and Economics*, 15, 223-239.
- Kaatz, E., David, S. R., Paul, A. B., & Richard, C. H. (2006). Advancing key outcomes of sustainability building assessment. *BUILDING RESEARCH & INFORMATION* 34(4), 308-320.
- Klostermann, J. E. M., & Cramer, J. (2007). Social construction of sustainability in water companies in the Dutch coastal zone. *Journal of Cleaner Production*, 15(16), 1573-1584.
- Kühtz, S. (2007). Adoption of sustainable development schemes and behaviours in Italy Barriers and solutions – what can educators do? *International Journal of Sustainability in Higher Education*, 8(2), 155-169.
- Mathur, V. N., Price, A. D. F., & Austin, S. (2008). Conceptualizing stakeholder engagement in the context of sustainability and its assessment. *Construction Management and Economics*, 26(6), 601-609.

- Nelms, C. E., Russell, A. D., & Lence, B. J. (2007). Assessing the performance of sustainable technologies: a framework and its application. *Building Research & Information*, 35(3), 237-251.
- Newman, P., & Kenworthy, J. (1999). *Sustainability and cities overcoming automobile dependence*. Washington, DC: Island Press.
- Patermann, C. (1999). The fifth EU framework programme and its consequences for the construction industry. *Building Research & Information*, 27(6), 412-418.
- Raynsford, N. (1999). The UK's approach to sustainable development in construction. *Building Research & Information*, 27(6), 419 - 423.
- San-Jose, J. T., Losada, R., Cuadrado, J., & Garrucho, I. (2007). Approach to the quantification of the sustainable value in industrial buildings. *Building and Environment* 42, 916–3923.
- Seaden, G., & Manseau, A. (2001). Public policy and construction innovation. *Building Research & Information*, 29 (3), 182-196.
- Shen, L. Y., Wu, Y. Z., Chan, E. H. W., & Hao, J. L. (2005). Application of system dynamics for assessment of sustainable performance of construction projects. *Journal of Zhejiang University SCIENCE*, 6A(4), 339-349.
- Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators*, 9(2), 189-212.
- Sjostrom, C., & Bakens, W. (1999). CIB Agenda 21 for sustainable construction: why, how and what. *Building Research & Information*, 27(6), 347-353.
- Spilanis, I., Kizos, T., Koulouri, M., Kondyli, J., Vakoufaris, H., & Gatsis, I. (2009). Monitoring sustainability in insular areas. *Ecological Indicators*, 9(1), 179-187.
- TCPA. (2003). Town and Country Planning Association. Building sustainability: How to plan and construct new housing for 21st century, TCPA, London, UK.
- Torbett, R., Salter, A., J., Gann, D., M., & Hobday, M. (2001). *Design Performance Measurement in the Construction Sector: A Pilot Study* University of Sussex, SPRU - Science and Technology Policy Research
- Ugwu, & Haupt, T. C. (2007). Key performance indicators and assessment methods for infrastructure sustainability--a South African construction industry perspective. *Building and Environment*, 42(2), 665-680.
- Ugwu, Kumaraswamy, Wong, & Ng. (2006a). Sustainability appraisal in infrastructure projects (SUSAIP): Part 1. Development of indicators and computational methods. *Automation in Construction*, 15(2), 239-251.
- Ugwu, Kumaraswamy, Wong, & Ng. (2006b). Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design. *Automation in Construction*, 15(2), 229-238.
- WCED. (1987). *Our Common Future*. Oxford University Press. Oxford and New York.
- Wilkinson, A., Hill, M., & Gollan, P. (2001). The sustainability debate. *International Journal of*

Operational & Production Management, Vol. 21(No. 12), pp. 1492-3577.

Yahya, K., & Boussabaine, A. H. (2006). Eco-costing of construction waste. *Management of Environmental Quality: An International Journal*, 17(1), 6-19.

Yao, H., Shen, L.-Y., Hao, J., & Yam, C.-h. M. (2007). A Fuzzy-Analysis-Based Method For Measuring Contractors' Environmental Performance. *Management of Environmental Quality: An International Journal*, 18(4), 442-458.

Zimmermann, M., Althaus, H. J., & Haas, A. (2005). Benchmarks for sustainable construction: A contribution to develop a standard. *Energy and Buildings*, 37(11), 1147-1157.