An Integrated Approach to Enhance Sustainability in Industrialised Building Systems

Riduan Yunus
School of Urban Development,
Queensland University of Technology, Brisbane,
Queensland, Australia
Faculty of Civil Engineering and Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, Malaysia
r.yunus@student.qut.edu.au

Jay Yang
Professor,
School of Urban Development,
Queensland University of Technology, Brisbane,
Queensland, Australia
j.yang@qut.edu.au

Abstract—**Building prefabrication is known as Industrialised Building Systems (IBS) in Malaysia. This construction method possesses unique characteristics that are central to sustainable construction. For example, offsite construction enables efficient management of construction wastage by identifying major causes of waste arising during both the design and construction stages. These causes may then be eliminated by the improvement process in IBS component's manufacturing. However, current decisions on using IBS are typically financial driven and hinder the wider ranged adoption. In addition, current IBS misconceptions and the failure of rating schemes in evaluating the sustainability of IBS affect its implementation. A new approach is required to provide better understanding on the sustainability potential of IBS among stakeholders. Such approach should also help project the outcomes of each levels of decision-making to respond to social, economy and environmental challenges. This paper presents interim findings of research aimed at developing a framework for sustainable IBS development and suggests a more holistic approach to achieve sustainability. A framework of embedding sustainability factors is considered in three main phases of IBS construction; 1) Pre-construction, 2) Construction and 3) Post-construction phase. SWOT analysis was used to evaluate the strengths, weaknesses, opportunities and threats involved in the IBS implementations. The action plans are formulated from the analysis of sustainable objectives. This approach will show where and how sustainability should be integrated to improve IBS construction. A mix of quantitative and qualitative methodology was used in this research to explore the potential of IBS in integrating sustainability. The tools used in the study are questionnaires and semi-structured interviews. Outcomes from these tools lead to the identification of viable approaches involving 18 critical factors to improve sustainability in IBS constructions. Finally, guidelines for decision-making are being developed to provide a useful source of information and support to mutual benefit of the stakeholders in integrating sustainability issues and concepts into IBS applications.**

Keywords-sustainability; Industrialised Building System; integration; decision support

I. INTRODUCTION

Over the last 25 years, sustainable development has gained a good reputation in improving quality of life and providing better living for next generations. In the construction industry, the opportunities to integrate sustainability are widely open and new innovation and technologies make this thing possible. Industrialised Building System (IBS), also known as prefabrication, is a construction technique that has a lot of advantages to improve sustainability such as reducing construction time, minimising construction waste, and providing more environmentally friendly conditions during construction operations. Due to the unique characteristics of IBS, it has the potential to enhance sustainability and quality of the built products. More will be discussed in the next section.

However, the adoption of IBS in Malaysia is low if compared to other developed countries such as the United States of America, United Kingdom, and Japan. According to previous reports, the usage level of IBS in Malaysian construction industry stands not more than 15%. Possible reasons include limited understanding among stakeholders and inadequate tools to evaluate the sustainability effectively. Moreover, most of the current decisions on using this technology are typically financially driven. Therefore, decision making in the selection of IBS methods is not made consistently and thus giving bad reputations to this promising construction technology.

The objectives of this paper are to review and analyse the current sustainable IBS assessment methods and related literature in terms of their characteristics and limitations in assessing sustainability in IBS buildings. This paper presents an integrated assessment process and an effective collaboration between key stakeholders on the key attributes and evaluation of sustainability factors that can work towards sustainable IBS delivery. Guidelines for decision making are developed to provide a useful source of information and support for the mutual benefit of the stakeholders in integrating sustainability issues and concepts into IBS applications.

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II. IBS AND SUSTAINABILITY

IBS has been identified as an alternative construction method in providing more sustainable solutions. The IBS employed off-site productions and reducing unpredicted problems such as bad weather, design failure, and traffic congestion for material deliveries. The number of labours in the construction site is also reduced tremendously. As concluded by previous studies, the most advantageous solution to reduce construction waste is by adopting IBS construction (Jaillon et al. 2009; Baldwin et al. 2009). On the other hand, the conventional on-site construction methods have long been criticised for imposing rigorous labour, neglecting human health and safety risk, as well as causing significant environmental destruction (Jaillon and Poon 2008).

Previous researchers have identified the needs to improve the efficiency of IBS construction by considering total integration of sustainable elements (Chen et al. 2010b; Jaillon and Poon 2008; Tam et al. 2007; Van Egmond 2010). Intensive planning and strategies are required to prevent unnecessary additional cost, unpleasant community disturbance, and degradation of environmental performance. In this research, an effective sustainable IBS implementation is integrating environmental, social, economic and institutional criteria. The examples of these criteria in improving sustainability for each perspective in IBS implementation are discussed below.

A. From The Environment Perspective

IBS is accountable for the significant reduction of wastages and reduction of the consumption of natural resources to preserve our environment. As commonly agreed, conventional on-site work normally involves intense activities on the site that cause constant nuisances to local communities such as disorganised environment, traffic chaos, noise, and air pollution (Yee 2001). Jaillon et al. (2009) estimated that the average wastage reduction level due to the implementation of IBS is about 52%. This is a rather remarkable rate compared to constructions without IBS operation.

B. From The Economic Perspective

IBS is able to ensure the financial affordability to the stakeholders and clients, employment opportunities, and competitiveness, and it maintains the needs of future generations (Shen et al. 2007). This can certainly be achieved by incorporating IBS in the project as IBS does not only benefit the environment, but it also promises profitable returns to the stakeholders and clients. Yee (2001) stated that IBS projects can be more profitable than the non-IBS ones as they can reduce the use of concrete and reinforce the structural components.

C. From The Social Perspective

IBS contributes to the social aspect by improving the quality of human life, skills training, and capacity enhancement of the disadvantaged. It also seeks fair and equal distribution of construction social costs and intergenerational equity (Shen et al. 2007). On the same hand, Blismas and Wakefield (2009) mentioned that the IBS has the potential to support local communities by diversifying the economy and creating more local employment opportunities.

D. From The Instituional Perspective

IBS is able to provide standard procedures for more organised construction works. With the support from the Government, IBS has the potential to improve Gross Domestic Product (GDP) and strengten the contract administration. Incentive and policy provided by the Government are catalysing the IBS adoption. Simplification in design and implementation of standardisation is promoting an 'open system', which will encourage the construction players to involve in the global market.

III. THE THREE MAIN PHASES IN THE IBS CONSTRUCTION

The first phase in the IBS construction is pre-construction phase. This is the phase where client's needs were identified. Then, the appropriate solutions were proposed by the consultants. Contracts need to be managed efficiently in selecting resources for the proposed IBS project. Communication and co-ordination between the project's participants are very important to ensure the achievement of sustainable goals. The integration of sustainability in the IBS projects has failed because of lack of consideration and inadequate information at the early stage (Chen et al. 2010a).

The second phase is construction. This phase commences after the plan and design have been agreed. Defect and damages will reduce structural performance of the IBS elements, and consequently will increase the maintenance and operation costs. Simplification in IBS design assists the contractor to organise activities involved in the appropriate sequence of work efficiently. IBS implementation will affect the labour consumption (Tam 2002).

The final phase in IBS construction is post-construction phase. This phase starts when the construction work has been finished. After the completion, the IBS projects will be handed over to the clients to be occupied and to function as expected. To avoid problems in the constructed building, designers should consider the service life of the IBS buildings and minimise whole-life costs.

IV. RESEARCH GAP

The adoption of IBS in Malaysia is still low compared to other developed countries. Even with enormous supports from the Government, the conventional construction is still preferable compared to IBS methods. This is surprising because the benefits offered by this system, especially in promoting sustainability, are enormous compared to the conventional construction. Previous research has highlighted that this scenario may happen because of the misconceptions about the benefits of IBS, and because the stakeholders have failed to foresee the benefits of IBS due to insufficient information that can support the feasible changes offered by the IBS (Abd Hamid et al. 2008). In addition, inappropriate method selections hindered the successful implementation of IBS and cause unwanted problems such as changing orders, substantial cost overruns, and constructability conflicts (Chen et al.

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2010b). Therefore, it is vital to solve the existing research gap in order to improve efficiency of IBS implementation.

V. THE INTEGRATED APPROACH

To respond to the challenges discussed above and to provide decision making assistance for designer, the common understanding on key IBS capabilities and collaboration among key stakeholders are necessary. Critical factors that have the potential to improve sustainability for IBS implementation should be investigated. This is to ensure that they have common views and follow commonly agreed approaches in IBS implementation. Based on the comprehensive literature review, a questionnaire was designed to identify the critical factors that have the potential to improve sustainability for IBS implementation. The research framework was developed based on its result before semi-structured interviews took place. The outcomes were extracted, and the strategy was presented through decision support tools. The research development process is shown in Figure 1.

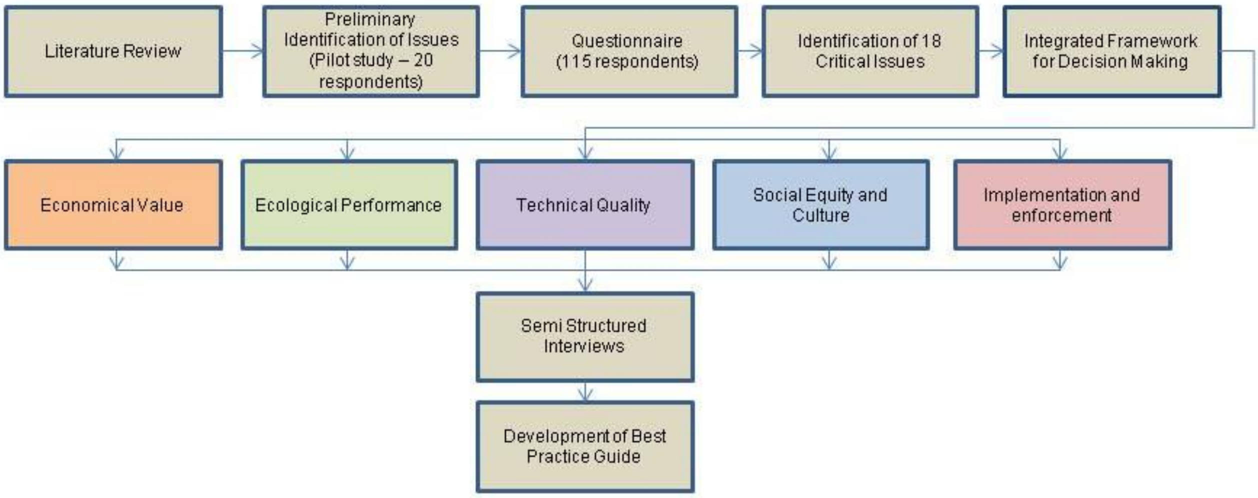

Figure 1 Research Development Process

A. Questionnaire

Questionnaire was selected as the primary tool to identify the critical factors to improve sustainability for IBS implementation. The questionnaire was designed based on the literature review and existing tools that have been discussed in previous section. The clarity, comprehensiveness, acceptability, and suitability of the questionnaire were tested through a pilot study. In this stage, 20 respondents were selected to test the suitability of the questionnaire to be used in achieving the research objectives. The questionnaire comprised five parts; 1) Respondents' demography, 2) Potential of sustainable factors, 3) Impact of potential sustainable factors, 4) Comments/Suggestion, and 5) Participation invitation for future investigation.

The respondents can be categorised into seven groups based on their organisation type. The groups are from designer/consultant companies, manufacturer companies, contractor companies, user or facility management companies, client/developer companies, research/academic institutions, and authority/government agencies. A total of 300 copies of the questionnaire were distributed using mail, online survey, and face-to-face consultation. As a result, 115 questionnaires were returned and used in the analysis, representing a response rate of 38%, which is acceptable based on Akintoye (2000).

B. Semi structured interviews

Semi-structured interviews were used to explore detailed information for each critical factor identified in previous stage. The questions were pre-formulated based on the framework developed. The flexibility of semi-structured interviews gave additional space to the interviewees to provide detailed information based on their capability. It also allowed the researcher to guide and focus on achieving the research objectives. As a result, the interviewees could answer the questions in depth and detail.

Twenty respondents were selected as the participant in the semi-structured interviews session. These respondents belonged to the seven groups based on their organisation type. The organisation types were same with the questionnaire. The respondents were filtered based on their experiences in IBS and sustainability. Before the interview was conducted, invitation letter, consent form, research framework, and main questions were sent to the potential respondents to make sure they agreed to participate and to give them general ideas about the objectives of the interview. This is important to reduce interview time and to allow respondents to answer the questions more accurately.

C. SWOT (Strengths, Weaknesses, Opportunities, and Treats) Analysis

Strategic management provides a systematic approach and support for decision making in early stage. The most popular technique to analyse the process of strategic management is SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis (Babaesmailli et al. 2012). This technique allows the decision makers to discover and collect facts that have been resulted from internal and external analyses. Internal analysis

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is to identify the weaknesses and strengths of the project, while external analysis is to help the decision makers to identify the opportunities and threats of the project (Stewart et al. 2002). In this research, a combination of strengths, weaknesses, opportunities, and threats, which were collected from qualitative analysis, was used to analyse the potential of each critical factor in IBS in improving sustainability.

Eighteen critical issues were examined and analysed from the semi-structured interviews. The research team developed an integrated mapping of these issues according to three major phases of IBS project development. This approach provided the integration among issues of all key stakeholders for the whole life cycle of IBS implementation. The researcher extracted information from the interviews by using codifying and categorising techniques for qualitative data. In order to develop efficient practice guidelines, strengths, weaknesses, opportunities, and threats for each issue were highlighted before the actions plans were formulated. The result of this integration process is discussed in the next section of this paper.

VI. Research Findings

Questionnaire survey was used as the main tool to identify the critical factors that have the potential to improve sustainability in IBS implementation. Then, the critical factors identified were validated and explored in depth by the respondents who involved in construction industry using semi-structured interviews. This method allowed the respondents to have an overall view about the objectives of this research. As a result, the critical factors identified were integrated in the preliminary conceptual model and divided into three major phases in the IBS construction namely pre-construction, construction, and post-construction as discussed below. Relevant deliverables such as preliminary framework for sustainable IBS and best practice guidelines are also discussed.

A. *Integrated decision support models*

The integration of potential factors to improve sustainability is very important for holistic consideration and problem solving at the project level. In this research, preliminary framework for sustainable IBS has been developed based on quantitative analysis (Figure 2).

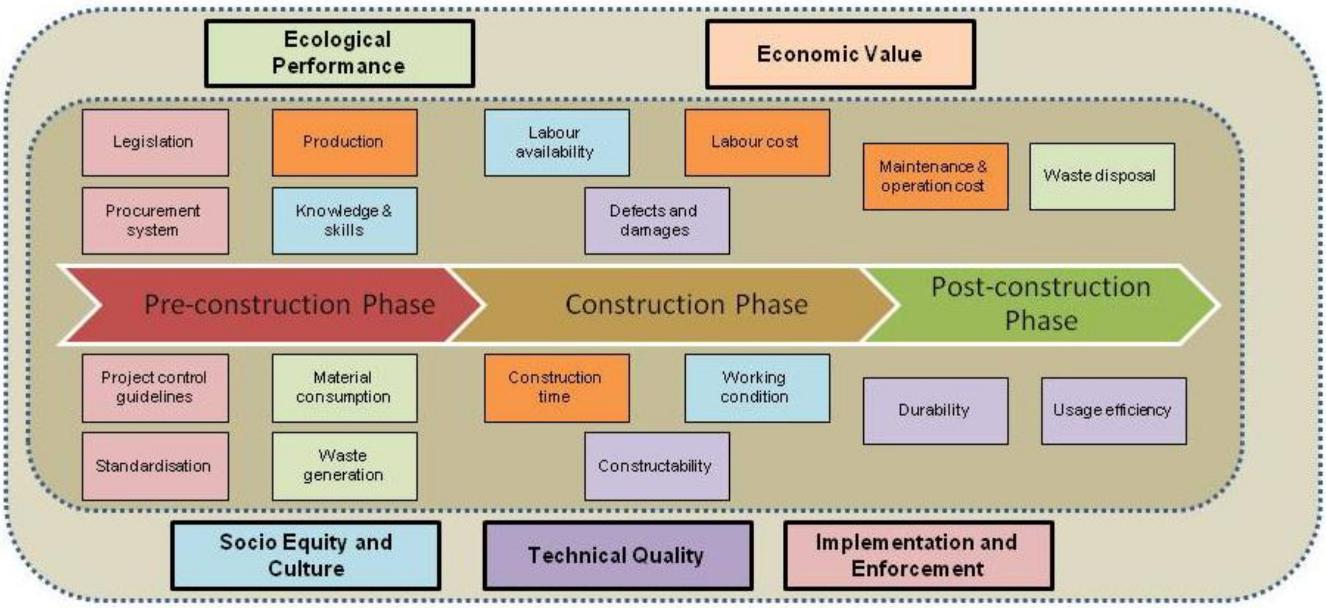

Figure 2 Preliminary Framework for Sustainable IBS

In the pre-construction phase, the issues are legislation, project control guidelines, procurement system, standardisation, material cost, production, knowledge and skills, material consumption, and waste generation. In the construction phase, the issues are labour availability, labour cost, defects and damages, construction time, and working condition. The final phase in IBS lifecycle is the post-construction phase. The issues are durability, maintenance and operation cost, usage efficiency, and waste disposal. All issues in the framework proposed were categorised into five major sustainable factors for IBS implementation. The major sustainable factors are economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement. This framework used in the interview sessions to formulate sustainable guidelines from agreeable perspectives during the early stage of construction.

B. *Best Practices Guidelines*

The information and ideas from the respondents in semi-structured interview sessions are important to get an insight view about the issues and factors in improving sustainability. A set of questions were asked to the respondents on how to improve sustainability in IBS implementation for each issue. SWOT (strengths, weaknesses, opportunities, and threats) analysis helped to make actions plans in a strategic way. Figure 3 shows one of the 18 issues investigated in this research, which is legislation. The action plans were

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formulated based on the SWOT analysis and justifications from the respondents in the interviews. The Best Practices Guidelines were considered highly valuable in improving sustainability for IBS implementation. The designer able to integrate sustainability by considering action plans and critical sustainability factors identified in this study. These guides provided a systematic tool to holistically evaluate potential of each aspect of construction as soon as at the early stage, unlike impulsive decision and self-centred estimation.

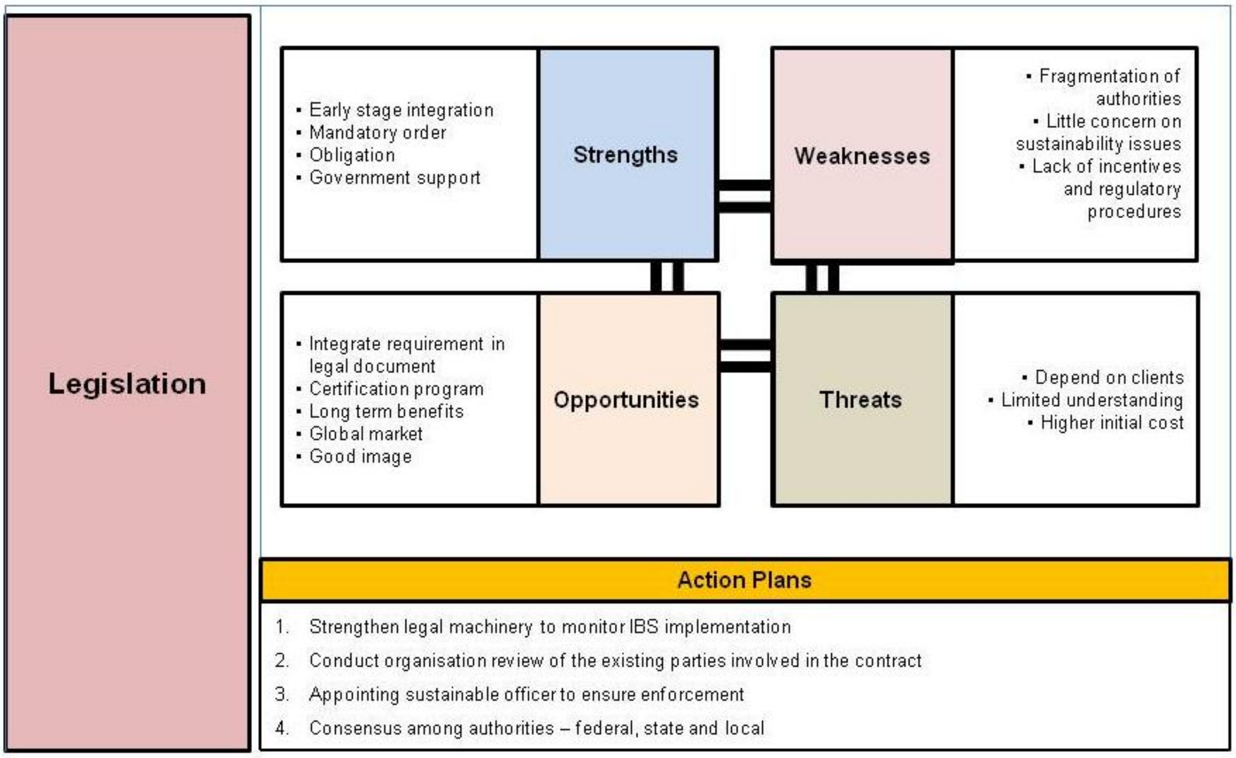

Figure 3 An Example of the Output Module of the Best Practice Guidelines

VII. CONCLUSION

There is an increasing level of awareness to incorporate sustainability principles into construction practices globally. In developing countries such as Malaysia, the pressure to improve construction efficiency is getting stronger. With such a backdrop, the timely issue of decision making and knowledge support for Industrialised Building System based construction are discussed in this paper. 18 critical issues were identified from the questionnaires and then further explored using semi-structured interviews. They are categorised into five main factors; 1) Economic value, 2) Ecological performance, 3) Technical quality, 4) Socio equity and culture, and 5) Implementation and enforcement. The outcomes were extracted and incorporated into the development of best practice guidelines to assist the decision-making process. In this paper, one of the factors from implementation and enforcement, which is legislation, is shown to demonstrate an effectiveness of guidelines developed in improving sustainable deliverables for IBS construction. These tools provided an integrated and consistent way of examining the whole life issues of IBS buildings, thus ad hoc decisions by individual stakeholders can be avoided. It is expected that these guidelines will aid the designers to make front end decisions for an IBS project by covering all stakeholders' sustainability requirements.

REFERENCES

Abd Hamid, Z., K. A. M. Kamar, M. Z. M. Zain, M. K. Ghani and A. H. A. Rahim. 2008. Industrialised Building System (IBS) in Malaysia: The Current State and R&D Initiatives *Malaysian Construction Research Journal (MCRJ)* 1 (2):1-11.

Akintoye, A. 2000. Analysis of factors influencing project cost estimating practice. *Construction Management and Economics* 18 (1):77-89.

Babaesmailli, M., B. Arbabshirani and V. Golmah. 2012. Integrating analytical network process and fuzzy logic to prioritize the strategies – A case study for tile manufacturing firm. *Expert Systems with Applications* 39 (1):925-935.

Baldwin, A., C.-S. Poon, L.-Y. Shen, S. Austin and I. Wong. 2009. Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional construction. *Renewable Energy* 34 (9):2067-2073.

ISSN XXXX-XXXX

Blismas, N. and R. Wakefield. 2009. Drivers, constraints and the future of offsite manufacture in Australia. *Construction Innovation* 9 (1):72-83.

Chen, Y., G. E. Okudan and D. R. Riley. 2010a. Decision support for construction method selection in concrete buildings: Prefabrication adoption and optimization. *Automation in Construction* 19 (6):665-675.

Chen, Y., G. E. Okudan and D. R. Riley. 2010b. Sustainable performance criteria for construction method selection in concrete buildings. *Automation in Construction* 19 (2):235-244.

Jaillon, L. and C. S. Poon. 2008. Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study. *Construction Management and Economics* 26 (9):953 - 966.

Jaillon, L., C. S. Poon and Y. H. Chiang. 2009. Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. *Waste Management* 29 (1):309-320.

Shen, L.-Y., J. L. Hao, V. W.-Y. Tam and H. Yao. 2007. A checklist for assessing sustainability performance of construction projects. *Journal of Civil Engineering and Management* XIII (4):273-281.

Stewart, R. A., S. Mohamed and R. Daet. 2002. Strategic implementation of IT/IS projects in construction: a case study. *Automation in Construction* 11 (6):681-694.

Tam, C. M. 2002. Impact on structure of labour market resulting from large-scale implementation of prefabrication. In *Advances in Building Technology.* eds. M. Anson, J. M. Ko and E. S. S. Lam, 399-403. Oxford: Elsevier.

Tam, V. W. Y., C. M. Tam, S. X. Zeng and W. C. Y. Ng. 2007. Towards adoption of prefabrication in construction. *Building and Environment* 42 (10):3642-3654.

Van Egmond, d. W. d. L. 2010. Industrialization for sustainable construction? In *CIB 2010 World Congress, United Kingdom, 10-13 May.* eds. P. Barret, D. Amaratunga, R. Haigh, K. Keraminiyage and C. Pathirage: CIB.

Yee, A. A. 2001. Social and environmental benefits of precast concrete technology. *PCI Journal* 5-6:14-20.

ISSN XXXX-XXXX