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Fuzzy decision approach for selection of most suitable construction method of Green Buildings

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Abstract

A big challenge in sustainable projects is selection of appropriate construction method and is considered to be the decisive factor for its success. Many environment friendly prefabricated elements are entering into the market at an increasing pace. This has increased the workload and inquisitiveness of the stakeholders who will need information about their environmental, technical and esthetic aspects. The use of prefabrication in sustainable construction is advantageous but appropriate decision criteria and their weightage for applicability assessments for a project from every stakeholder's perspective is found to be deficient. Decisions to use prefabricated elements are still largely based on anecdotal evidence or cost-based evaluation rather than holistic sustainable performance. But authenticated information is seldom available and suitability within the project requirements is always debatable. Environmental decisions, being closely coupled with society's built-in uncertainties and risks, are uncertain since ecological systems as well as social systems change in the future. Thus the selection of a suitable construction method has been perceived as a multi-criteria decision-making problem highly intensive in knowledge with partial information and uncertainty. This knowledge or perception base from the minds of experts has to be collected and processed for a decision. Fuzzy synthetic evaluation method using analytic hierarchy process by Saaty has been adopted to provide an analytical tool to evaluate the applicability of prefabricated or on-site construction method.

Keywords: Buildings; Cast-in-situ construction; Precast construction environment; Mathematical modeling; Sustainability

1. Introduction

With mounting threats of environmental pollution, natural resource depletion and accompanying social problems, sustainable development in construction has become a growing concern (Neama, 2012). Construction of Green Buildings has now become a flagship of Sustainable Development in construction sector and offers an opportunity to create environmentally responsible and occupant friendly buildings. However, definition, scope and various approaches of Green Buildings compared to conventional buildings is still not well understood. Also, little emphasis has been laid on the importance of selecting more environment friendly designs during the project appraisal stage

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Notation

$u_1,u_2,\ldots,u_n$	are a set of evaluation factors or criteria
$v_1,v_2,\ldots,v_m$	are a set of evaluation grades
V_i	is a probable evaluation which can be described as excellent, good, normal, poor or very poor
R	fuzzy relation matrix from U to V
r_{ij}	is the membership degree ($i = 1,2,\ldots n$; $j = 1,2,\ldots m$)
N	is the number of appraisal stakeholders
x_{ij}	is the number of the appraisal commissioners
W	is the weight set
$w_1, w_2,\ldots w_n$	weights for evaluation criteria
D	is called the decision making set
CM	is the construction method
W_{ECO}	is the Weight vector for economic criteria
W_{ENV}	is the Weight vector for environmental criteria
W_{SOC}	is the Weight vector for Social criteria
D_{PC1}, D_{PC2} and D_{PC3}	are the decision making sets for Precast
D_{CS1}, D_{CS2}, D_{CS3}	are the decision making sets for Cast in Situ
$R_{PC\text{-}ECO}$, $R_{PC\text{-}ENV}$, $R_{PC\text{-}SOC}$	are the Fuzzy Relation Sets for Precast construction
$R_{CS\text{-}ECO}$, $R_{CS\text{-}ENV}$, $R_{CS\text{-}SOC}$	are the Fuzzy Relation Sets for Cast in Situ construction

when environmental matters are best incorporated. Project appraisal based on a multi-dimensional approach would need a sustainability model to allow the alternatives to be ranked (Ding, 2008).

Conventional on-site construction methods have long been criticized for non-sustainability, low productivity, poor quality and safety records, long construction time, and large quantities of waste in the industry (Abioye, 2015; Agamuthu, 2008). Prefabrication is a manufacturing process, taking place at a specialized facility, to form component parts of the final installation. Several benefits of applying prefabrication technology in construction are commonly listed as- shortened construction time, lower overall construction cost, improved quality, enhanced durability, better architectural appearance, enhanced occupational health and safety, material conservation, less construction site waste, less environmental emissions, and reduction of energy and water consumption (Yee and Hon, 2001; Blismas et al., 2006).

Pasquire demonstrated that decisions to use precast elements are still largely based on anecdotal evidence rather than rigorous data, as no formal measurement criteria are available (Blismas et al., 2006). Gluch and Baumann also indicated that holistic and methodical assessments of the precast applicability to a particular project have been found to be deficient, and common methods of evaluation simply take material, time, labor and transportation costs into account when comparing various construction methods, without explicit regard for the sustainability, long-term cost or soft issues, such as health and safety of workers, energy consumption, and environmental impacts of a project (Gluch and Baumann, 2004). Also, for individual building projects, precast technology is not always the only available option, nor is it always better than on-site construction method due to various project characteristics and available resources. If not employed appropriately, change orders, severe delays in production, erection schedules, substantial cost overruns, and constructability problems may be encountered in the use of precast concrete systems (Sacks et al., 2004). The selection of appropriate construction method of a project, considered to be a decisive factor for its success, is perceived as a knowledge problem. The construction companies do not have formal systems to collect, process and manage this knowledge held in the minds of the professionals (Murtaza et al., 1993; Ferrada and Serpell, 2014). Ying Chen identified 33 performance criteria based on the sustainable triple bottom line and requirements of different project stakeholders, consisting of 16 economic criteria, 8 social criteria, and 9 environmental criteria (Chen et al., 2010). Wei Pan and Andrew Dainty developed 50 criteria grouped under cost, time, quality, health and safety, sustainability, etc. but cost was again ranked most important and sustainability, process and procurement were weighted lower. All of these demonstrate that criteria for decisions regarding construction methods are unclear and unrecorded. But considering the relative importance or weightage of each criteria from the perspective of every stakeholder in the decision making process is a difficult task. Thus the selection of a CM among alternative CMs is a multicriteria decision-making problem including both quantitative and qualitative criteria. In decisions related to environment and social factors, the values of the qualitative criteria are often imprecisely defined for the decision-makers. The conventional approaches to CM selection problem tend to be less effective in dealing with the imprecise or vague nature of the linguistic assessment. Thus we have a mix of both tangibles like cost and time and intangibles relating to subjective ideas and beliefs of the individual and the world of experience. So we need to use a coherent theory that can deal with both these worlds of reality without compromising either (Saaty, 1987). The Analytical Hierarchy Process formulates and analyzes decisions by simplifying a complex multi-criteria decision problem and uses the numerical ratings from the pair-wise comparisons to establish an importance weight for each criterion. The aim of this paper is to solve CM selection problem using approach of fuzzy synthetic evaluation group decision-making (Kahraman et al., 2003). Criteria derived from prior studies have been employed in the model developed to support and automate

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