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An Empirical Investigation of Key Pre-project Planning Practices Affecting the Cost Performance of Green Building Projects

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Abstract

The construction industry has been increasingly adopting green building because of its advantages over conventional building. However, implementing successful green building projects entails difficulties in terms of cost performance. The objective of this study is to identify the critical factors that affect the cost performance of green building projects during their pre-project planning phase. This study validates the relationship between certain critical factors and the cost performance of green building projects. Support vector machine-recursive feature elimination (SVM-RFE), a data mining-based feature selection method, is applied to a data set comprising 53 green building projects. The results of the study show that 10 out of 64 project definition rating index (PDRI) factors exert most of the influence on the cost performance of the green building projects. These results will help the project stakeholders deliver green building projects more successfully in terms of cost performance.

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Keywords: cost performance; critical factors; green building project; PDRI; pre-project planning; SVM-RFE

1. Introduction

Green building, a practice that is two decades old, has become more prevalent in recent years. The U.S. Environmental Protection Agency defines “green building” as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s lifecycle, from siting to its design, construction, operation, maintenance, renovation, and demolition [1]. Many countries have adopted green building rating systems such as the Leadership in Energy and Environmental Design developed in the U.S., the Building Research Establishment Environmental Assessment Method developed in the U.K., the Green Star developed in the Australia, the Deutsche Gütesiegel Nachhaltiges Bauen developed in the German, the

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Comprehensive Assessment System for Building Environmental Efficiency developed in the Japan, and the Korean Green Building Certification Criteria developed in the Korea. These systems outline specific guidelines for implementing green practices into the lifecycles of the buildings, thus guiding the stakeholders of building projects through the green delivery of their construction projects.

The economic advantages of green building, such as reduced operating costs, the creation, expansion, and shaping of markets for green products and services, improved occupant productivity, and the optimization of lifecycle economic performance [2], have contributed to the rapid increase in the number of buildings certified by green building rating systems. The total U.S. green building market value is expected to increase from $42 billion in 2008 to $135 billion in 2015 [3]. Despite indications of significant growth, however, green development is not without challenges and barriers, the most common of which are the costs associated with "going green" [4, 5].

This study seeks to identify the critical factors that affect the cost performance of green building projects during their pre-project planning phase using the data mining-based feature selection method (SVM-RFE). After identifying the critical factors, the study examines the relationship between those factors and the cost performance to determine whether the factors indeed affect the cost performance

2. Data collection

To identify the factors that exert a strong influence on cost performance during the pre-project planning phase of a green building project, this study collected data on the cost performances of 53 green building projects and on the 64 project definition rating index (PDRI) factors that need to be defined during the pre-project planning phase of such a project. To collect reliable survey data, this study adopted a structured questionnaire with two main parts: the first comprised items on the cost performance of a green building project, and the second comprised the factors to be defined during the pre-project planning phase.

3. Methodology

3.1. Framework

First, a data set from the 53 cases was randomly divided into 37 training sets and 16 test sets. As the collected data set is small, a bias can be produced during data partition and thus impede the search for appropriate critical factors. Therefore, this study randomly divided the original data set 50 times, into a training set and a test set, to prevent a biased partition. Second, after the repeated partitions, this method learns the training sets, including all the factors, to the SVR model. Third, it computes the ranking criteria of each factor through the trained SVR model, where one finds the weighting vector for the kth factor. At the same time, the test error is estimated using the trained SVR model. Fourth, the method removes the factors with the lowest ranking criteria. Fifth, the process is iterated, with each iteration excluding the factor with the lowest ranking criteria, until all such factors are removed; as the factors that are eliminated later are more important than those eliminated earlier, each factor's importance ranking is obtained from its order of elimination. After this procedure, the factors with the lowest test-error rate are chosen as the most relevant factors in the respective iteration process. As this procedure is repeated 50 times, 50 relevant factor sets showing the lowest test errors are obtained. A factor selected more than 20 times by this calculation of relevant factors is selected as final critical factors.

3.2. SVM-RFE-based Feature Selection.

This study employs the SVM-RFE-based method to select the critical factors that influence the cost performance of green building projects. The SVM-RFE is a state-of-the-art feature selection method based on wrapper-type, as suggested by [6]. The SVM-RFE method identifies the most influential factors affecting the cost performance of a green building project and brings several advantages to this study. First, as it is most useful for selecting critical factors when the number of cases is smaller than the number of factors, it is appropriate for this study [7]. Second, the generalizability of SVM-RFE derived from SVM makes it robust for data overfitting with the selected critical factors [6, 8, 9]. Finally, the model can handle multiple factors simultaneously [10].

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4. Results

4.1. Measurement

Applying the SVM-RFE method to the data enables us to determine the relevant factors influencing the cost performance of green building projects. The error rates, for the selection of the relevant factors, were estimated through mean absolute percentage error (MAPE), mean absolute error (MAE), and root mean squared error (RMSE). Such error rates indicate high accuracy as they approach 0. The MAPE, MAE, and RMSE can be estimated through the following formulas (1)–(3):

$$\mathrm{MAPE} = \frac{1}{m}\sum_{i=1}^{m}\left|\frac{y_i - f(x_i)}{y_i}\right| \times 100 \tag{1}$$

$$\mathrm{MAE} = \frac{1}{m}\sum_{i=1}^{m}\left|y_i - f(x_i)\right| \tag{2}$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(y_i - f(x_i))^2} \tag{3}$$

where m denotes the number of test data, y_i denotes the actual green building project's cost performance, and $f(x_i)$ denotes the predicted green building project's cost performance by SVR.

4.2. Results

As mentioned, SVM-RFE is applied to 50 randomly partitioned data sets. Through those 50 cases, 50 factor rankings were estimated. From the 50 cases of the ranked factors, 50 sets of relevant factors with the lowest errors were selected. Then, the number of times that each factor was selected (as relevant and with a low error) was calculated. A factor selected more than 20 times was selected as a critical factor. Ultimately, ten critical factors were selected that appeared as relevant factors more than 20 times among the 50 cases. Table 1 shows the ten critical factors with the average ranks and number of times they were selected from 50 cases by the SVM-RFE-based feature selection. The A2 (Business Justification) factor was selected in all 50 critical factor sets.

Table 1. Ten Critical Factors Influencing the Green Building Project Success by SVM-RFE-based Feature Selection

Section	Category	Factor	Factor Description	Average	Selected

				Rank	Number
I	Business Strategy	A2	Business Justification	3.98	50
I	Business Strategy	A4	Economic Analysis	16.84	25
I	Owner Philosophies	B1	Reliability Philosophy	14.94	31
I	Project Requirements	C1	Value-Analysis Process	16.27	26
I	Project Requirements	C6	Project Cost Estimate	15.49	27
II	Building Programming	E2	Building Summary Space List	7.37	42
II	Building Programming	E10	Building Finishes	12.12	44
II	Building/Project Design Parameters	F7	Constructability Analysis	21.69	20
III	Project Control	K3	Project Schedule Control	21.25	24
III	Project Execution Plan	L3	Project Delivery Method	15.47	34

Section I denotes *Basis of Project Decision*, Section II denotes *Basis of Design*, and Section III denotes *Execution Approach*.

5. Conclusion

This study has identified the critical factors that influence the cost performance of the pre-project planning phase of green building projects by applying the data mining-based SVM-RFE feature selection. The results provided rankings for the factors to be defined in the pre-project planning phase of the green building projects, based on their impacts on cost performance. These suggested factor rankings were used to identify the factors with the greatest influences on cost performance. The contributions of this study are both theoretical and practical, and they advance the state-of-the-art, successful implementation of green building projects by feature selection.

From a theoretical point of view, this study made contributions to current research by considering the characteristics of the green building projects and identifying the critical factors in their pre-project planning phase. Few research studies on selecting critical factors in the pre-project planning phase of conventional construction projects, to ensure successful implementation, had been conducted. However, the green building projects have unique characteristics, such as the need for additional project players, more design iterations, advanced simulation and analysis, higher construction standards, additional site precautions, and new and unfamiliar materials [11]. Hence, the critical factors regarding the green building projects might not match those for the conventional building projects. In addition, this study has empirically identified the relationship between the pre-project planning phase and the cost performance of the green building projects. The previous studies found that the pre-project planning phase had a significant influence on the cost performance [12]. Robichaud and Anantatmula [5] and Ofori-Boadu et al. [13] have also highlighted the importance of the initial phase in implementing the green building projects with successful cost performance. However, their findings were not validated by empirical research.

From the managerial point of view, this study makes a contribution by guiding the project stakeholders in implementing and executing their green building projects more successfully from the cost performance perspective. This study gives the project stakeholders insight into the importance of the pre-project planning phase of green building projects in improving cost performance. The findings suggest that the Basis of Project Decision has more influence on the green building projects' cost performance than the Basis of Design or the Execution Approach. This means that within the pre-project planning phase, the feasibility and concept development phases have greater influence on the cost performance than does the detailed scope phase, where the Basis of Project Decision is mainly defined. In addition, this study provides guidance concerning the factors that the project stakeholders should define first, especially in the pre-project planning phase. Our results show the factors' priority of importance according to their influences on cost performance. This study allows leaders of those projects that are being delivered under time or other constraints to organize their pre-project planning phases efficiently by prioritizing those green building project factors that have the strongest influence on the project's cost performance.

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