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Important Sustainability Determinants Meeting Sustainability Goals of California Infrastructure Construction Projects †

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Abstract: The United States has developed and is developing multiple rating systems for infrastructure and transportation projects. Although these systems share some commonalities in terms of methods and criteria, decision makers need to deal with which one best fits their project's evaluation and meet their organization goals because the systems are different from one another in certain ways. This paper aims to examine the importance of sustainability determinants and how they affect the success of meeting sustainability goals of infrastructure construction projects. This paper, therefore, presents the statistical results on five major sustainability determinants such as site, water/wastewater, energy, materials/resources, and environmental determinants.

Keywords: sustainability; infrastructure; assessment; determinants; quantitative analysis

1. Introduction

Building assessment systems have been developed to grade performances of building projects based on a specific set of green or sustainable criteria. Several rating systems for infrastructure and transportation projects have been developed or are under development using a point-based system, such as the United States Green Building Council (USGBC)'s LEED system for building construction [1]. However, these sustainability rating systems are not as commonly used in infrastructure construction projects as they are in building construction. While there is limited industry guidance on sustainable transportation construction practices, several states have developed their own transportation rating systems. For example, Simpson [2] and Simpson et al. [3] used 10 existing rating systems to create a framework for several departments of transportation (DOTs), including Colorado, South Dakota, Utah, and Wyoming. Cormack et al. [4] presented a case study that utilized sustainable concepts based on FHWA's INVEST rating system. Bueno et al. reviewed existing tools and methods for sustainability assessments of transport infrastructure projects. Lineburg [5] conducted a comprehensive analysis on transportation rating systems and social sustainability. Chisholm et al. [6] presented sustainable project rating systems including Envision.

Public agencies face a major problem in determining the best rating system for their infrastructure projects in terms of meeting their organization priorities and improving performance. The difficulty lies in adopting an appropriate sustainability rating system for infrastructure construction projects that is also cost-effective method. The paper is motivated by the necessity of developing a framework for infrastructure construction projects. The research hypotheses examine if five sustainability determinants and their associated factors chosen in this paper show any significant differences in terms of meeting the sustainability goals of infrastructure construction projects.

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2. Research Objectives and Methods

The aim of this paper is to examine five major sustainability determinants affecting the success of meeting organizations' sustainability goals for infrastructure construction projects. The authors chose five determinants and related factors from literature reviews on existing sustainability systems available in the U.S.A. The determinants include site, water/wastewater, energy, materials/resources, and environmental determinants. Industry professionals involved in infrastructure construction projects in California were asked to rate five determinants and related factors on a 7-point Likert scale, which is used to rate the survey response, to effectively express their opinions on how important determinants and factors are when successfully meeting sustainability needs in infrastructure construction projects. Statistical methods such as the Kruskal–Wallis test, analysis of variance (ANOVA), and Z-test are used to analyze the responses of survey data.

3. Results

Of the 59 responses received, 25 surveys (42.4%) were used in the data analysis. Participants for the valid surveys had an average experience of 18 years and consisted of engineers/designer, construction managers, and employees of government agencies in proportions of 55.6%, 13.9%, and 30.6%, respectively. The respondents answered nine projects on average and used a sustainability rating system with a median of 3 years.

3.1. Comparison of Medians among Five Major Determinants

The statistical results are shown in Table 1 regarding multiple comparisons for the median values. Kruskal–Wallis tests were used for five major sustainability determinants. For the factors under each determinant, the hypotheses are H0: the medians for five major sustainability determinants are equal and Ha: the medians for five major sustainability determinants are not equal. We cannot reject the null hypothesis because test statistics of H-value are high and because the observed significance values are greater than $\alpha = 0.05$. In other words, no evidence is found to conclude that there is any difference in the median values among five major sustainability determinants.

Table 1. Results for Multiple Comparison of Medians among Five Major Determinants.

Test	Test Statistic (H-Value)		*p* Value		
Determinant	**Not Adjusted for Ties**	**Adjusted for Ties**	**Not Adjusted for Ties**	**Adjusted for Ties**	**Any Difference among Medians?**
Site	6.240	6.750	0.182	0.150	No
Water/Wastewater	4.520	5.180	0.345	0.269	No
Energy	2.290	2.620	0.682	0.623	No
Materials/Resources	2.050	2.240	0.727	0.692	No
Environmental	1.900	2.090	0.755	0.719	No

3.2. Comparison of Means among Five Major Determinants

We compared the mean response rates among five major sustainability determinants using an ANOVA test. The purpose of the test is to see if there is any difference in the extent of how respondents rate the importance level. The null and research hypotheses are H_0: $\mu Ci = 0$ for all i, where i is the determinant, and H_a: at least two mean values among five sustainability determinants differ. The ANOVA results are tabulated in Table 2. Since the p value of 0.244 is not less than $\alpha = 0.05$, the authors cannot find any significant evidence, which means that we cannot reject the null hypothesis. The results show that the mean value of one determinant is statistically equal to those of other determinants. The test results means that the respondents valued all five determinants closely and did not undervalue any one of the determinants.

Table 2. Results of ANOVA for Multiple Comparison of Five Major Determinants.

Source	Degree of Freedom	Adjusted Sum of Squares	Adjusted Mean Squares	F-Value	p Value
Factor	4	7.686	1.922	1.37	0.244
Error	620	871.072	1.405		
Total	624	878.758			

3.3. Importance of Factors Associated with Each Determinant

We examined the importance of factors associated with each determinant using Kruskal–Wallis test. The purpose of this test is to see if respondents prefer a specific factor. The Kruskal–Wallis test is useful because its outcomes generate the mean rank of factors. The mean rank is computed as the average of the all-responses' ranks within each factor and shows its corresponding z-value. If a higher mean rank is shown, this indicates that the observation values in the group are higher than those in the other groups. Additionally, its corresponding z-values show how the average rank for each group compares to the average rank of all the observations. If a factor's average rank is less than the overall average rank, then the corresponding z-value is negative. If a factor's average rank is greater than the overall average rank, then the corresponding z-value is positive. The greater the absolute value, the more distant a factor's average rank is from the overall average rank [7]. As an example, Table 3 tabulates the descriptive statistical results for site-related factors.

Table 3. Results of Responses for Site Factors.

Factor	n	Mode	Median	Mean	Std. Dev.	Mean Rank	Z-Value
(S1) Location of sustainable sites	25	6	6	5.48	1.33	55.6	–1.14
(S2) Effective and efficient design	25	6	6	5.68	1.22	60.5	–0.39
(S3) Mobility enhancement and sustainable transportation	25	7	7	6.28	0.98	78.7	2.42
(S4) Environmental impact reduction on ecology and biodiversity	25	7	6	5.68	1.31	61.6	–0.21
(S5) Noise, vibration, and light pollution minimization	25	5	6	5.64	1.15	58.6	–0.68

The mean ranks having positive z-values indicates their relative importance among the factors under each of the five major sustainability determinants. For the site determinant, the respondents ranked mobility enhancement as well as sustainable transportation as the most important. For the water and wastewater determinant, they put more importance on water quality protection, stormwater treatment and management, and water consumption reduction than others. For the energy determinant, they ranked greenhouse gas emission reduction as the highest factor, followed by pollution reduction. For material and resource determinants, the most important factor was hazardous waste elimination, followed by effective and efficient material utilization. For the environmental determinant, respondents ranked the people's life quality improvement as the most important factor, followed by air quality improvement, factoring in traffic flow, bicycle and pedestrian facilities improvement, and wildlife protection, enhancement, and restoration. The results from respondents show that a few factors under each of five major sustainability determinants received higher ranks than other factors.

4. Concluding Remarks

The authors presented statistical results on sustainability determinants and their associated factors. The results showed that there was no significant difference in the median response values for five major sustainability determinants. The mean response values for the five major sustainability determinants considered showed no statistically significant difference. The pairwise comparison results showed that there was no difference among the five major sustainability determinants. The findings indicated that the determinants considered are equally important for the successful implementation of sustainability in infrastructure construction projects. However, the mean ranks values, determined based on the positive z-values, indicated the relative importance of the factors under each of the five major sustainability determinants. The quantitative analysis results presented in this paper will aid in evaluating the awareness of infrastructure industry professionals regarding key high-performance sustainability requirements that are being incorporated into the design of infrastructure construction projects. The determinants can be used to develop a framework that provides a sustainability rating system for infrastructure construction projects.

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