Module 2 Assignment | Project: Benefit-Cost Analysis of Construction Projects

Trang Tran

CPS, Northeastern University

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Professor Andrew Kinley

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Introduction

Blue Sky Corporation is currently assessing two green energy projects: a wind project in northern Maine and a solar project in Southern Indiana. Benefits considered include customer base expansion, power generation, carbon offsets, job creation, green energy incentives, and commercial development. For each benefit, minimum, most likely, and maximum estimates are available. Capital costs, annualized over 30 years, and annual operations and maintenance costs are also factors.

Corporations rely on benefit-cost analysis to evaluate and select projects. The benefit-cost ratio, derived by comparing total benefits to total costs, helps prioritize projects. A ratio above 1.0 indicates benefits outweigh costs, with higher ratios favoring project selection. In the following sections, we will examine the benefit and cost estimations for both projects, facilitating a comprehensive comparison.

Analysis and Interpretation

Part 1: Creation and Analysis of a Monte Carlo Simulation

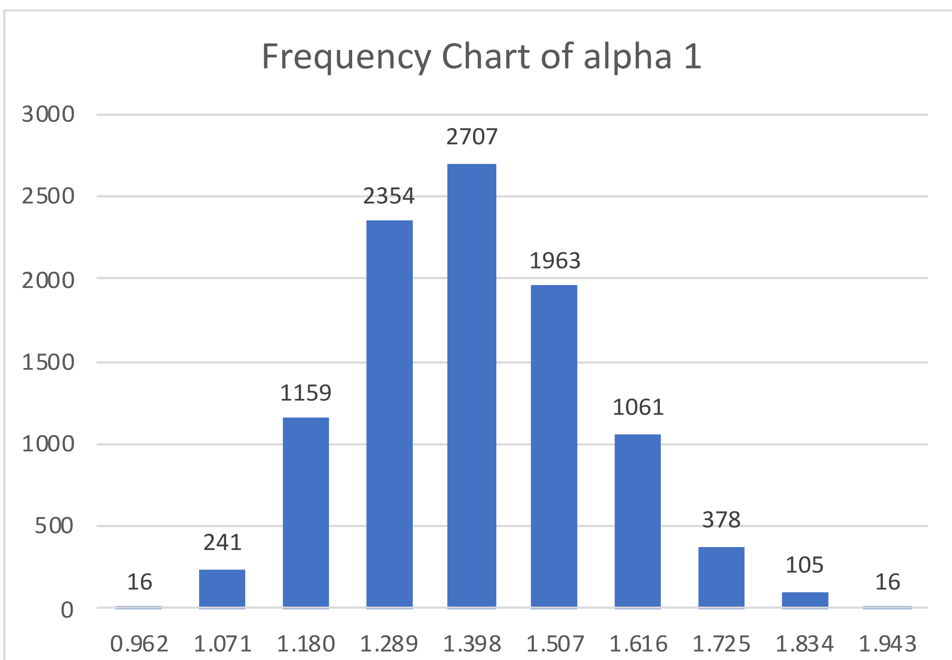
(i) *The Simulate 10,000 benefit-cost ratios for the Wind project and 10,000 benefit-cost ratios for the Solar project. (In the attached Excel file)*

- In the first step, we use triangular distribution and triangular random number generation for 06 areas of benefits and 2 types of costs for both projects.
- Then we have 10,000 simulation values of benefit-cost ratios per each project.

(ii) *Construct a tabular frequency distribution and a histogram for $\alpha 1$ and $\alpha 2$*

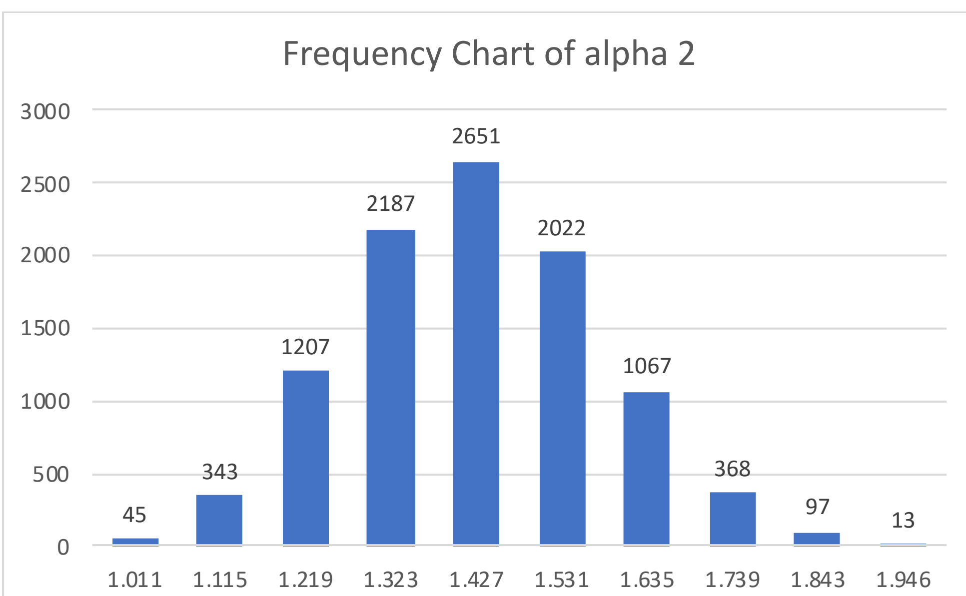
Wind Project

Class left	Class right	Class midpoint	Class Frequency
0.907	1.016	0.962	16
1.016	1.125	1.071	241
1.125	1.234	1.180	1159
1.234	1.343	1.289	2354
1.343	1.452	1.398	2707
1.452	1.561	1.507	1963
1.561	1.670	1.616	1061
1.670	1.779	1.725	378
1.779	1.888	1.834	105
1.888	1.997	1.943	16



Solar Project

Class left	Class right	Class midpoint	Class Frequency
0.959	1.063	1.011	45
1.063	1.167	1.115	343
1.167	1.271	1.219	1207
1.271	1.375	1.323	2187
1.375	1.479	1.427	2651
1.479	1.583	1.531	2022
1.583	1.687	1.635	1067
1.687	1.791	1.739	368
1.791	1.895	1.843	97
1.895	1.998	1.946	13



Both histograms exhibit a bell-shaped curve, but the alpha 1 frequency distribution is more prominently right-skewed compared to the alpha 2 distribution.

(iii) Tables of descriptive statistics

The observed values closely align with the theoretical values in both projects, indicating that the simulation using the triangular distribution is an appropriate fit for the scenarios of these projects.

Wind Project	Observed	Theoretical
Mean of the Total Benefits	**30.698**	**30.700**
SD of the Total Benefits	**2.399**	**2.410**
Mean of the Total Cost	**22.061**	**22.067**
SD of the Total Cost	**1.722**	**1.727**
Mean of the Benefit-cost Ratio	**1.400**	X
SD of the Benefit-cost Ratio	**0.154**	X

Solar Project	Observed	Theoretical
Mean of the Total Benefits	**29.474**	**29.467**
SD of the Total Benefits	**2.311**	**2.307**
Mean of the Total Cost	**20.787**	**20.767**
SD of the Total Cost	**1.523**	**1.521**
Mean of the Benefit-cost Ratio	**1.425**	X
SD of the Benefit-cost Ratio	**0.152**	X

Part 2: Analysis of a probability distribution

I select two types of theoretical distributions to test a good fit for the distribution of alpha 1.

1. Null hypothesis: the distribution of alpha 1 is a normal distribution.

   The normal distribution key parameters are all available in our previous calculation. So we easily create the theoretical distribution using the norm.dist() function, and then get the expected frequency values.

   - Chi-squared Test Statistic (using traditional formula): 157.657
   - Chi-squared P-value (using CHISQ.DIST.RT function): 0.00

   ⇨ Since the P-value << 0.05 (significant level), we reject the null hypothesis that it's a normal distribution. So we can conclude that the alpha 1 distribution follows a different type of distribution with a 95% confidence level.

2. Null hypothesis: the distribution of alpha 1 is a lognormal distribution.

   Based on my research, it is common to assume a log-normal distribution for benefit-cost analysis due to its ability to capture the positive skewness often observed in economic data. The log-normal distribution's characteristic long right tail makes it suitable for modeling variables that are the product of many independent, positive factors, which aligns well with the nature of the benefit-cost analysis.

   With the lognormal distribution, we need to create more key parameters on:

   - mean: The mean of the logarithm of the distribution.
   - SD: The standard deviation of the logarithm of the distribution.

   We compute the chi-squared goodness of fit test and obtain the following results:

   - Chi-squared Test Statistic (using traditional formula): 14.163
   - Chi-squared P-value (using CHISQ.DIST.RT function): 0.117

- ⇨ P-value > 0.05 (significant level), so we do not have enough evidence to reject the null hypothesis. We can conclude that the lognormal distribution is quite a good fit for the distribution of alpha 1 with 95% confidence.

Part 3: Comparison of the results

The following table presents a comprehensive comparison of key statistical values for the benefit-cost ratios of both projects. P(a1 > a2): The probability that the Wind project has a higher ratio than the Solar project is 0.4506, suggesting that there is roughly a 45% chance that the Wind project outperforms the Solar project in terms of the benefit-cost ratio. In addition, most of the indicators for $\alpha 2$ are slightly higher than those for $\alpha 1$.

Considering these factors, Project $\alpha 2$ (Solar project) appears to have a slight advantage in terms of higher mean and median benefit-cost ratios, a lower skewness value indicating a more balanced distribution, and a higher probability of outperforming Project $\alpha 1$ (Wind project).

	$\alpha 1$	$\alpha 2$
Minimum	0.907	0.959
Maximum	1.997	1.998
Mean	1.400	1.425
Median	1.391	1.421
Variance	0.024	0.023
Standard Deviation	0.154	0.152
SKEWNESS	0.290	0.175
$P(a_i > 2)$	0	0
$P(a_i > 1.8)$	0.0088	0.0095
$P(a_i > 1.5)$	0.250	0.305
$P(a_i > 1.2)$	0.9093	0.9364

P(a_i > 1)	0.9993	0.9994
P(a_1 > a_2)	0.4506	

Conclusion & recommendation

Based on the observations and results obtained in parts 1-3, I would recommend the Solar Project ($\alpha 2$) to the management. Here are the rationales for this recommendation:

1. Benefit-Cost Ratio Comparison: there is more than a 50% chance that the Solar project outperforms the Wind project in terms of the benefit-cost ratio since P($\alpha 1$ > $\alpha 2$) = ~ 45%. This suggests that, on average, Project 2 may generate better economic returns relative to costs.
2. Skewness: Both projects show positive skewness, but Project $\alpha 2$ has a slightly lower skewness value compared to Project $\alpha 1$. This suggests that Project $\alpha 2$ has a relatively more symmetrical distribution, which may indicate a more stable and predictable outcome.

References

Evans, J. R. (2013). Statistics, data analysis, and decision modeling. Pearson Education.