Cost-Benefit Analysis of Dam Construction

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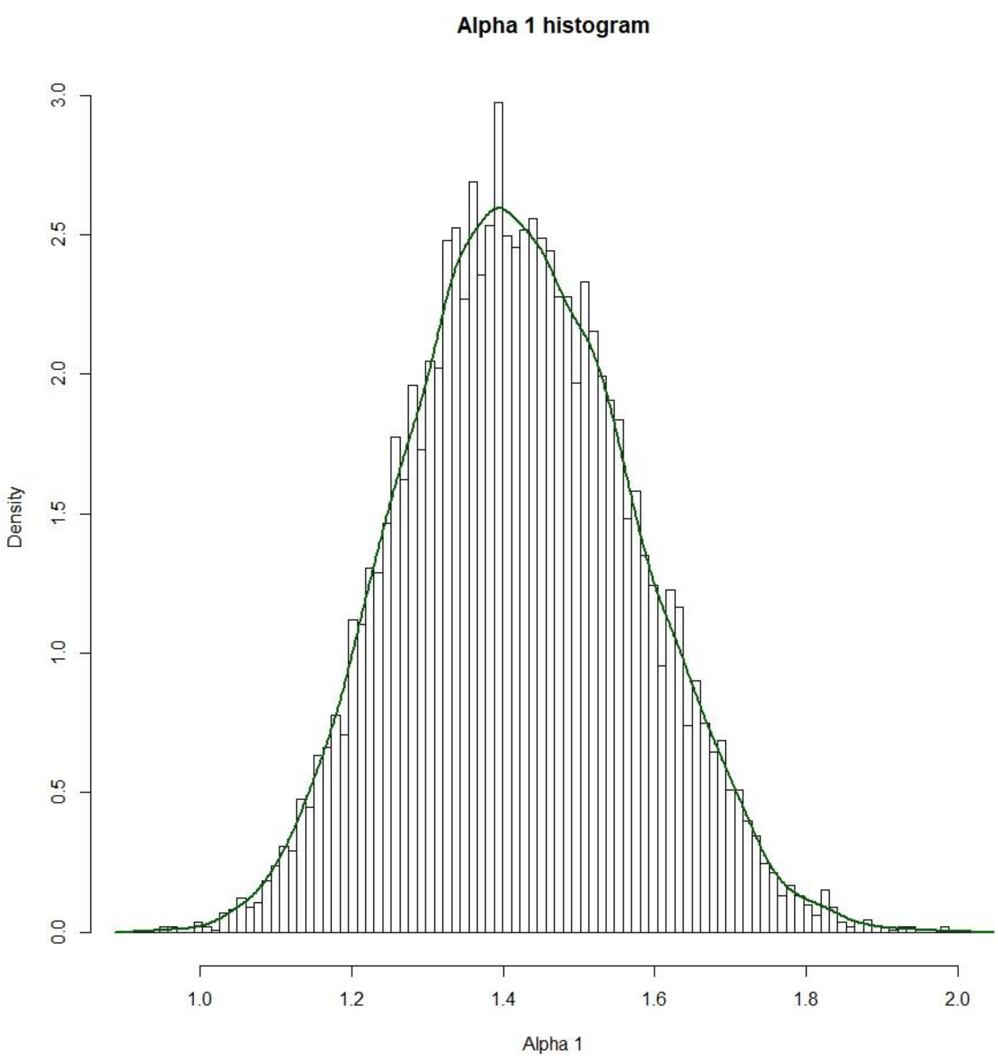
This project contains a cost-benefit analysis of two potential dam constructions based around a total of eight parameters. The six areas identified as benefits are improved navigation, hydroelectric power, fish and wildlife, recreation, flood control, and commercial development. The costs that were taken into consideration were a capital cost annualized over 30 years, and operations and maintenance costs. Each of these parameters have an estimated minimum, maximum, and mode value in millions of dollars for each dam.

In my report, I will provide an estimated cost-benefit analysis based on 10,000 simulated outcomes for each dam construction project. This will provide the most likely expected outcome for each dam project, and determine which project is statistically more likely to provide the best outcome based on the cost-benefit analysis.

Below is the graphical distribution alongside a tabular distribution of the initial 10,000 simulations on the first dam project. For these analyses, the cost benefit ratio will be referred to as “Alpha.” In the tabular distribution the range of the outcome bins can be seen alongside a frequency, frequency probability, and cumulative probability.

d1.cut	Freq	Freq.Prob	Cum.Prob
(0.9,0.95]	0	0.0000	0.0000
(0.95,1]	7	0.0007	0.0007
1.05]	22	0.0022	0.0029
05,1.1]	68	0.0068	0.0097
1,1.15]	185	0.0185	0.0282
15,1.2]	354	0.0354	0.0636
2,1.25]	645	0.0645	0.1281
25,1.3]	878	0.0878	0.2159
3,1.35]	1150	0.1150	0.3309
35,1.4]	1293	0.1293	0.4602
4,1.45]	1261	0.1261	0.5863
45,1.5]	1140	0.1140	0.7003
5,1.55]	1028	0.1028	0.8031
55,1.6]	750	0.0750	0.8781
5,1.65]	520	0.0520	0.9301
55,1.7]	359	0.0359	0.9660
7,1.75]	198	0.0198	0.9858
75,1.8]	76	0.0076	0.9934
3,1.85]	44	0.0044	0.9978
35,1.9]	13	0.0013	0.9991
9,1.95]	7	0.0007	0.9998
95,2]	2	0.0002	1.0000
2.05]	0	0.0000	1.0000
05,2.1]	0	0.0000	1.0000



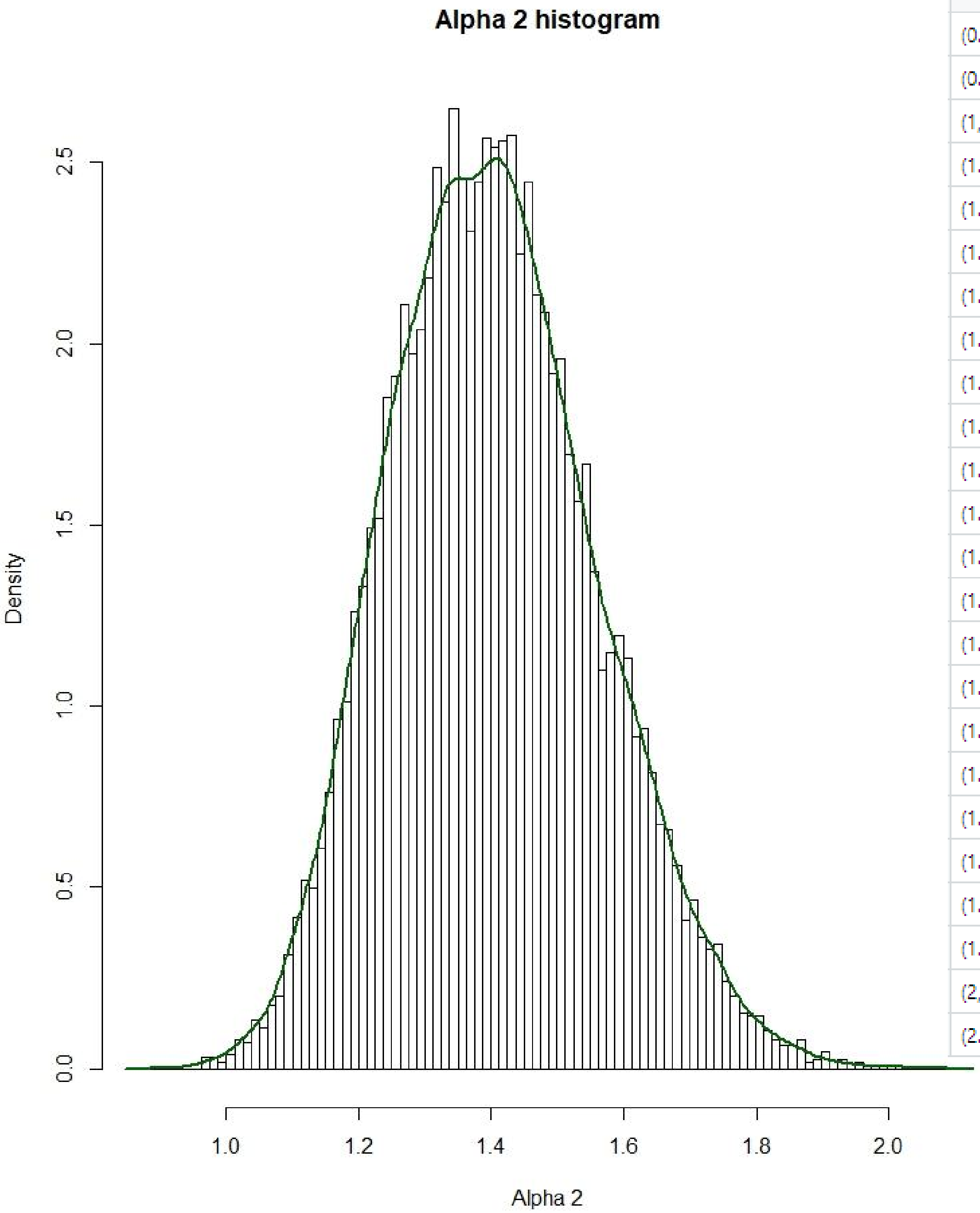
From this initially it is easy to see that there are very few instances where Alpha 1 drops below 1, 0.07% of the total outcomes. There are also no outcomes where Alpha 1 is above 2. The majority of the simulations seem to have an Alpha 1 value between 1.2 and 1.6. In order to better understand this distribution, I calculated some descriptive statistics on these simulations. The results can be seen in Table 1 below. The mean total benefit and cost are very close to our expected values at 29.4 and 20.8. The expected Alpha (Line 5) is about 1.415. From our simulation, the mean alpha value was 1.421 with a standard deviation of 0.149. This confirms our visual analysis that a majority of the Alpha 1 values fall in the interval of one standard deviation. A table of standard deviation ranges for Alpha 1 can also be found in Table 1

	row.names	d1.observed	d1.expected
1	Mean of Total Benefit	29.4046934840633	29.4
2	SD of Total Benefit	1.51838731437972	2.30410262117139
3	Mean of Total Cost	20.8012864104367	20.7666666666667
4	SD of Total Cost	1.51838731437972	1.52059929706094
5	Mean Benefit/Mean Cost	1.41359976031626	1.41573033707865
6	Mean of Benefit-Cost Ratio	1.42091902061199	NA
7	SD of Benefit-cost Ratio	0.149348391212342	NA

1 SD	1.272 - 1.570
2 SD	1.123 - 1.719
3 SD	0.974 - 1.868

Table 1

This same set of exercises was performed for the second dam project, with these values being referred to as Alpha 2. Looking at the tabular frequencies of Alpha 2, there seems to be a greater spread of alpha values, with a 0.12% chance of Alpha 2 falling below 1, and a 0.03% chance that it exceeds 2. These are obviously very low probability outcomes, but indicates that this project may be slightly riskier in its outcomes in general. A majority of the data is still focused between 1.2 and 1.6. Exploring Table 2 showing calculated values, the expected value of Alpha 2 is slightly lower than Alpha 1, at 1.391 (Line 5). In our simulation, we observed a mean Alpha 2 of 1.402 with a standard deviation of .156. This confirms our suspicion that there is a slightly greater risk with the second construction project. A table of standard deviation ranges for Alpha 2 can also be found in Table 2



d2.cut	Freq	Freq.Prob	Cum.Prob
(0.9,0.95]	1	0.0001	0.0001
(0.95,1]	10	0.0010	0.0011
(1,1.05]	41	0.0041	0.0052
(1.05,1.1]	100	0.0100	0.0152
(1.1,1.15]	253	0.0253	0.0405
(1.15,1.2]	500	0.0500	0.0905
(1.2,1.25]	775	0.0775	0.1680
(1.25,1.3]	999	0.0999	0.2679
(1.3,1.35]	1218	0.1218	0.3897
(1.35,1.4]	1222	0.1222	0.5119
(1.4,1.45]	1246	0.1246	0.6365
(1.45,1.5]	1062	0.1062	0.7427
(1.5,1.55]	857	0.0857	0.8284
(1.55,1.6]	596	0.0596	0.8880
(1.6,1.65]	473	0.0473	0.9353
(1.65,1.7]	287	0.0287	0.9640
(1.7,1.75]	185	0.0185	0.9825
(1.75,1.8]	89	0.0089	0.9914
(1.8,1.85]	48	0.0048	0.9962
(1.85,1.9]	22	0.0022	0.9984
(1.9,1.95]	10	0.0010	0.9994
(1.95,2]	3	0.0003	0.9997
(2,2.05]	2	0.0002	0.9999
(2.05,2.1]	1	0.0001	1.0000

	row.names	d2.observed	d2.expected
1	Mean of Total Benefit	30.7222171972507	30.7
2	SD of Total Benefit	1.72909717168733	2.40970260959038
3	Mean of Total Cost	22.0418959914985	22.0666666666667
4	SD of Total Cost	1.72909717168733	1.72658944486265
5	Mean Benefit/Mean Cost	1.39381009733012	1.39123867069486
6	Mean of Benefit-Cost Ratio	1.40228356018966	NA
7	SD of Benefit-cost Ratio	0.155589609235934	NA

1 SD	1.246 - 1.558
2 SD	1.09 - 1.714
3 SD	0.934 - 1.870

Table 2

Comparing these ranges of standard deviations to those of Alpha 1, it seems that generally there are similar upper limits to each interval, with significant differences in the lower limits. The ranges of these intervals means that the construction of the second project is riskier, with a similar cost-benefit ratio in the best case scenarios.

p3.row.names	a1.table	a2.table
Minimum	0.951048574185635	0.913600032434269
Maximum	1.98428985630623	2.0597014687753
Mean	1.42091902061199	1.40228356018966
Median	1.41601753014473	1.39554915957627
Variance	0.0223049419577149	0.0242081265021905
Standard Deviation	0.149348391212342	0.155589609235934
Skewness	0.146141762734985	0.281159216707193
P(Alpha > 2)	0	3e-04
P(Alpha > 1.8)	0.0066	0.0086
P(Alpha > 1.5)	0.2997	0.2573
P(Alpha > 1.2)	0.9364	0.9095
P(Alpha > 1)	0.9993	0.9989

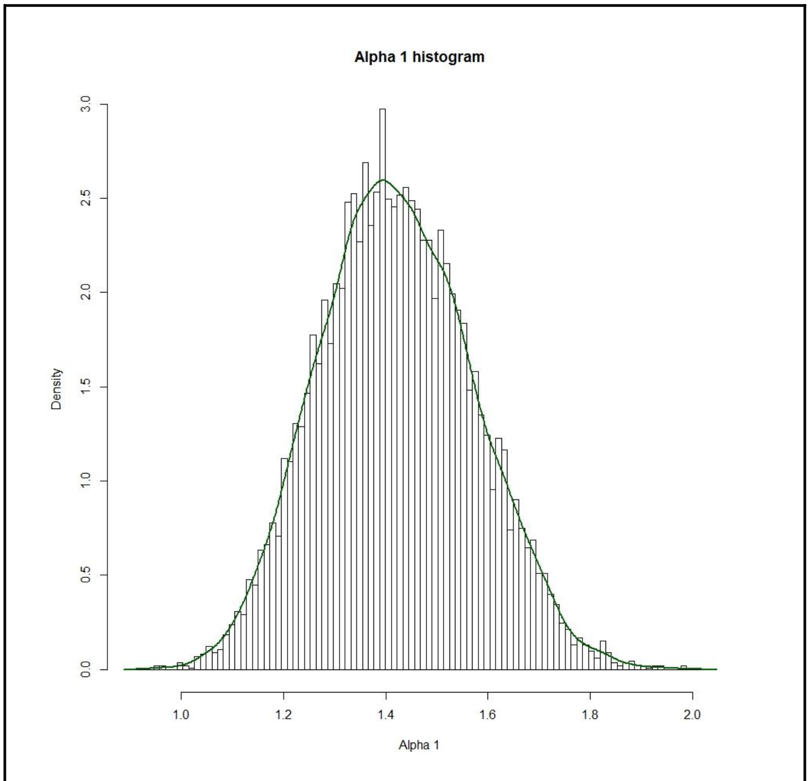
Table 3

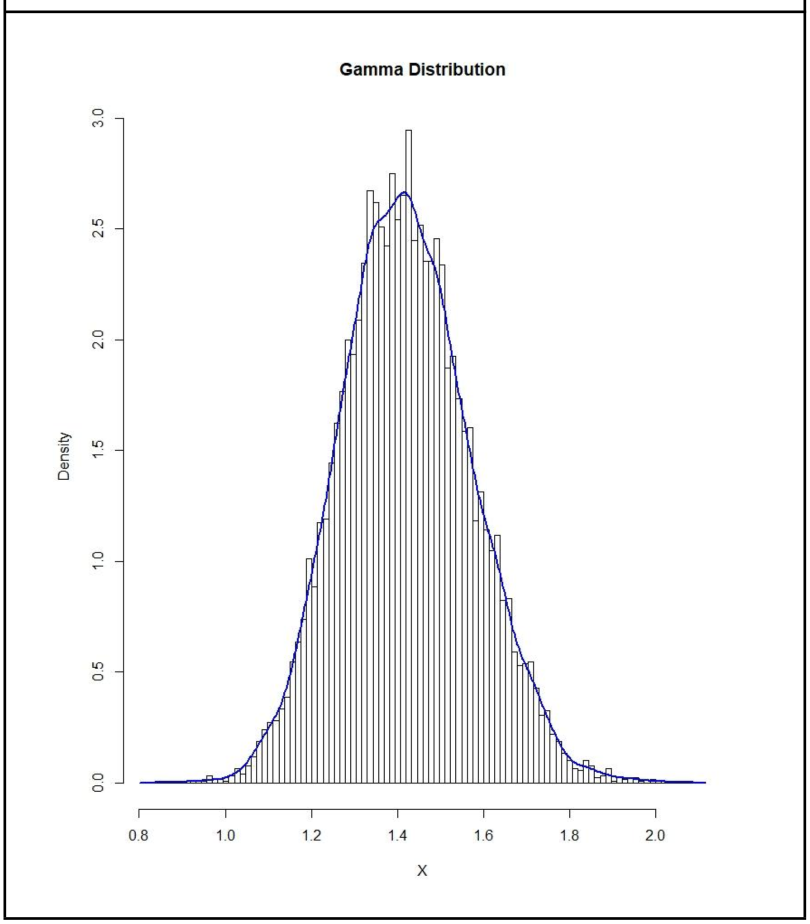
In a final comparison of Alpha values between the two projects, Table 3 above was created. This shows various statistical calculations of each Alpha distribution, along with the probability of Alpha exceeding certain breakpoints. Both distributions are fairly unlikely to be greater than 1.8, however Alpha 1 is significantly more likely to be greater than 1.5 than Alpha 2. The same is true at 1.2, but both distributions are 99.9% likely to be greater than 1. This means that without risking any additional downside, the first project and the Alpha 1 distribution provide a better potential for upside in the majority of cases. 53.51% of the time Alpha 1 values were greater than Alpha 2, providing a 7 point gap in favor of the first distribution. For this reason, I recommend investment into the first of the two dam projects.

Alpha 1 will be higher than Alpha 2 in 53.51% of cases based on these simulations

After recommendation of dam project 1, I conducted testing to understand the distribution that Alpha 1 belongs to. The best fit that was found was a Gamma distribution. A simulated Gamma distribution was created using the parameters found in the Alpha 1 distribution. This distribution is shown below alongside the Alpha 1 distribution. I conducted a chi-square goodness of fit test on the Alpha 1 distribution to determine whether it fit the simulated Gamma distribution. The null hypothesis of the chi-square test was confirmed with a p.value of .997, and a test statistic of 7396.7. The full results of the chi-square test are also pictured below. Using this knowledge we can use the Gamma distribution in order to better understand the behavior of the Alpha 1 distribution in the future.

c2test	list [9] (S3: htest)	List of length 9
statistic	double [1]	7396.697
parameter	integer [1]	7735
p.value	double [1]	0.9970678


Alpha 1 histogram
Density
Alpha 1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
1.0
1.2
1.4
1.6
1.8
2.0


Gamma Distribution
Density
X
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.8
1.0
1.2
1.4
1.6
1.8
2.0