COST-BENEFIT ANALYSIS

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INSIGHTS:

Given, to conduct a cost-benefit analysis using triangular probability distribution. Firstly, we'll have to calculate the values of c-a, b-a, b-c for various benefits and costs, as shown below, there are two cost-benefit analysis which must be done one is alpha 1, and alpha 2., given the upper limit, lower limit and the peak which is a,b and c.

Dam #1: Benefits & Costs

	Estimate		
Benefit	***Minimum***	***Mode***	***Maximum***
Improved navigation **B1**	1.1	2	2.8
Hydroelectric power **B2**	8	12	14.9
Fish and wildlife **B3**	1.4	1.4	2.2
Recreation **B4**	6.5	9.8	14.6
Flood control **B5**	1.7	2.4	3.6
Commercial development **B6**	0	1.6	2.4

Cost	***Minimum***	***Mode***	***Maximum***
Annualized capital cost **C1**	13.2	14.2	19.1
Operations & Maintenance **C2**	3.5	4.9	7.4

Dam # 2: Benefits & Costs

	Estimate		
Benefit	***Minimum***	***Mode***	***Maximum***
Improved navigation **B1**	2.1	3	4.8
Hydroelectric power **B2**	8.7	12.2	13.6
Fish and wildlife **B3**	2.3	3	3
Recreation **B4**	5.9	8.7	15
Flood control **B5**	0	3.4	3.4
Commercial development **B6**	0	1.2	1.8

Cost	***Minimum***	***Mode***	***Maximum***
Annualized capital cost **C1**	12.8	15.8	20.1
Operations & Maintenance **C2**	3.8	5.7	8

Benefits:	**Triangular Distribution:**		
Dam 1:	**left end - a**	**peak - c**	**right end - b**
Improved navigation B1	1.1	2	2.8
Hydroelectric power B2	8	12	14.9
Fish and wildlife B3	1.4	1.4	2.2
Recreation B4	6.5	9.8	14.6
Flood control B5	1.7	2.4	3.6
Commercial development B6	0	1.6	2.4
Costs:			
Dam 1:	**left end - a**	**peak - c**	**right end - b**
Annualized capital cost C1	13.2	14.2	19.1
Operations & Maintenance C2	3.5	4.9	7.4

Benefits:	**Triangular Distribution:**		
Dam 2:	**left end - a**	**peak - c**	**right end - b**
Improved navigation B1	2.1	3	4.8
Hydroelectric power B2	8.7	12.2	13.6
Fish and wildlife B3	2.3	3	3
Recreation B4	5.9	8.7	15
Flood control B5	0	3.4	3.4
Commercial development B6	0	1.2	1.8
Costs:			
Dam 2:	**left end - a**	**peak - c**	**right end - b**
Annualized capital cost C1	12.8	15.8	20.1
Operations & Maintenance C2	3.8	5.7	8

The next step would be calculating the triangular distributions for performing the simulations for 10000 records by generating random numbers by using the minimum, and maximum values which are given in the question, to find out the theoretical mean.

Triangular Distribution:			Triangular Distribution:			Theoretical Mean:
c-a	b-a	b-c	K = (c-a) / (b-a)	M =(b-a) (c-a)	N =(b-a) (b-c)	E(X) = = (a+b+c)/3
0.9	1.7	0.8	0.53	1.53	1.36	1.967
4	6.9	2.9	0.58	27.6	20.01	11.633
0	0.8	0.8	0.00	0	0.64	1.667
3.3	8.1	4.8	0.41	26.73	38.88	10.300
0.7	1.9	1.2	0.37	1.33	2.28	2.567
1.6	2.4	0.8	0.67	3.84	1.92	1.333

c-a	b-a	b-c	K = (c-a) / (b-a)	M =(b-a) (c-a)	N =(b-a) (b-c)	Theoretical E(X)
1	5.9	4.9	0.17	5.9	28.91	15.500
1.4	3.9	2.5	0.36	5.46	9.75	5.267

Triangular Distribution:			Triangular Distribution:			Theoretical Mean:
c-a	b-a	b-c	K = (c-a) / (b-a)	M =(b-a) (c-a)	N =(b-a) (b-c)	E(X) = = (a+b+c)/3
0.9	2.7	1.8	0.33	2.43	4.86	3.300
3.5	4.9	1.4	0.71	17.15	6.86	11.500
0.7	0.7	0	1.00	0.49	0	2.767
2.8	9.1	6.3	0.31	25.48	57.33	9.867
3.4	3.4	0	1.00	11.56	0	2.267
1.2	1.8	0.6	0.67	2.16	1.08	1.000

c-a	b-a	b-c	K = (c-a) / (b-a)	M =(b-a) (c-a)	N =(b-a) (b-c)	Theoretical E(X)
3	7.3	4.3	0.41	21.9	31.39	16.233
1.9	4.2	2.3	0.45	7.98	9.66	5.833

The next step is generating random numbers and performing the triangular distribution using the random numbers, and the left end, right end and the peak values for both Dam 1 and Dam 2.

		Benefits											Total Benefits	Costs				Total Costs
Simulation #	r_B1	B1	r_B2	B2	r_B3	B3	r_B4	B4	r_B5	B5	r_B6	B6		r_C1	C1	r_C2	C2	
1	2.6729	1.29	10.7360	0.94	1.6323	1.56	9.5695	-3.65	2.1794	1.96	1.9947	1.02	3.12	15.1981	-1.16	3.9990	1.99	0.83
2	2.2694	1.49	8.4919	2.66	1.8247	1.47	13.2394	-7.21	2.0052	2.09	2.2640	0.84	1.33	17.3768	-2.66	6.0881	0.36	-2.30
3	1.8109	1.75	13.3161	-0.80	2.1976	1.32	12.9799	-6.98	3.1462	1.39	0.2748	1.03	-2.29	16.4758	-2.05	7.3053	-0.44	-2.49
4	2.4214	1.41	8.6054	2.56	1.9559	1.42	6.9776	-0.65	3.0638	1.43	0.6231	1.55	7.72	15.4253	-1.32	6.1294	0.33	-0.99
5	2.2787	1.48	12.0494	0.03	1.6501	1.55	7.3891	-1.16	2.6390	1.67	1.4159	1.51	5.08	17.1642	-2.52	6.4161	0.13	-2.38
6	1.1243	2.39	9.4967	1.86	1.6252	1.57	6.5044	-0.03	1.9351	2.14	1.5228	1.40	9.33	17.1339	-2.50	4.3491	1.69	-0.81
7	1.2196	2.25	11.8723	0.15	1.7263	1.52	10.1601	-4.27	2.3115	1.87	2.1695	0.90	2.42	17.5441	-2.77	6.5001	0.08	-2.69
8	1.8270	1.74	13.7580	-1.08	1.6817	1.54	12.1235	-6.20	2.5658	1.71	2.3041	0.82	-1.47	14.9367	-0.97	3.9454	2.04	1.07
9	2.0443	1.61	9.9523	1.52	2.0156	1.39	13.3262	-7.29	3.1152	1.40	2.1819	0.89	-0.48	15.8791	-1.64	5.6466	0.67	-0.97
10	2.7411	1.26	13.2103	-0.73	2.1593	1.34	9.9524	-4.06	2.9249	1.51	2.1841	0.89	0.21	13.2379	0.29	4.0999	1.90	2.19
11	1.9814	1.64	9.6295	1.76	1.9360	1.43	11.7244	-5.82	2.0832	2.03	1.1987	1.78	2.82	17.0915	-2.47	5.9335	0.46	-2.00
12	1.8839	1.70	8.1011	2.98	1.4855	1.64	8.9737	-3.01	3.3048	1.31	1.5667	1.36	5.98	15.1637	-1.14	5.5233	0.76	-0.38
13	1.8640	1.72	10.0266	1.46	2.0573	1.38	14.1019	-7.97	2.2968	1.88	1.8859	1.10	-0.44	18.6086	-3.46	6.4349	0.12	-3.34
14	1.1733	2.31	10.5958	1.04	1.5151	1.63	10.5491	-4.67	2.0730	2.04	2.3889	0.77	3.12	16.4499	-2.03	3.6902	2.28	0.24

The next step is calculating the benefit-cost ratio, after calculating total costs and total benefits., further for frequency distributions, we'll have to find out the minimum and maximum, range, class width values of both the dams.

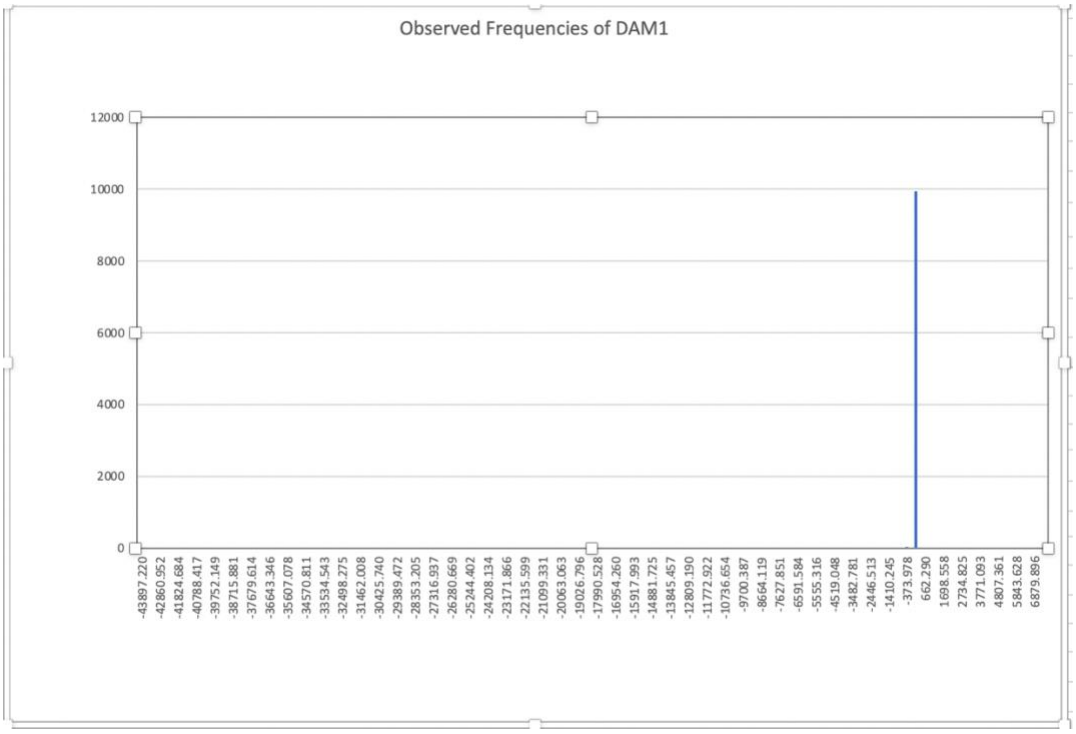
MIN	-44156.287
MAX	7657.097
RANGE	51813.383
CLASSES/BINS	100.000
CLASS WIDTH	518.134
COUNT	10000.000

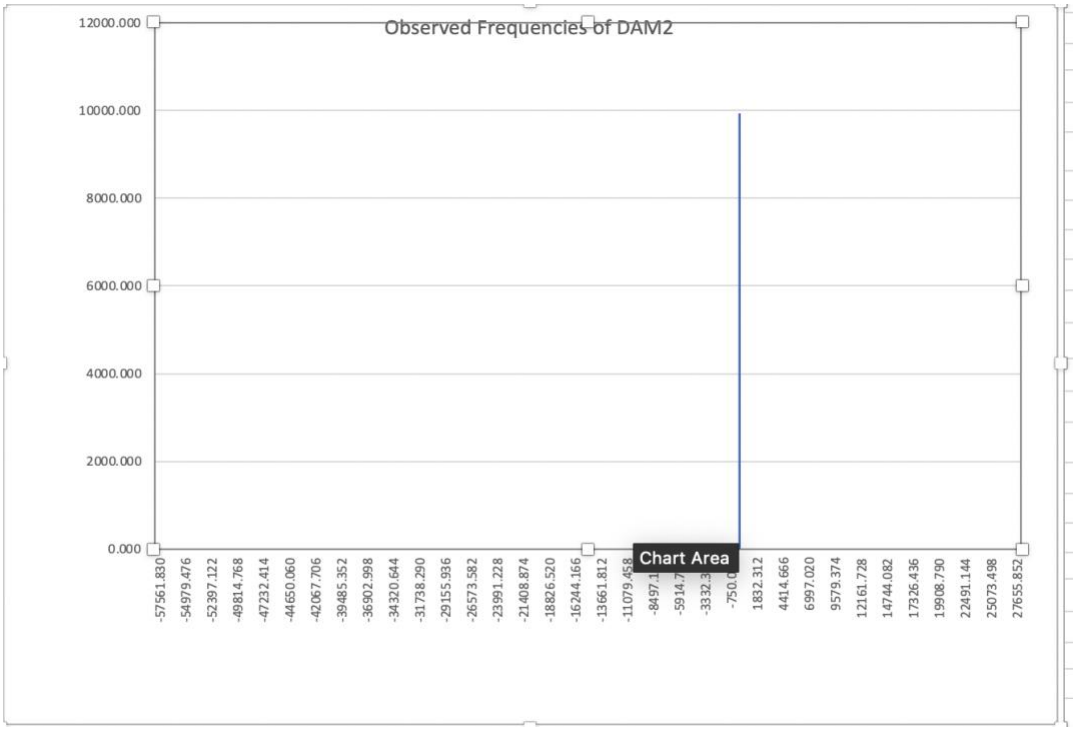
With these parameters we can find out the frequency distributions of the dams separately, by finding out the class left, class right, class midpoint, and class frequency.

Frequency Distributions:

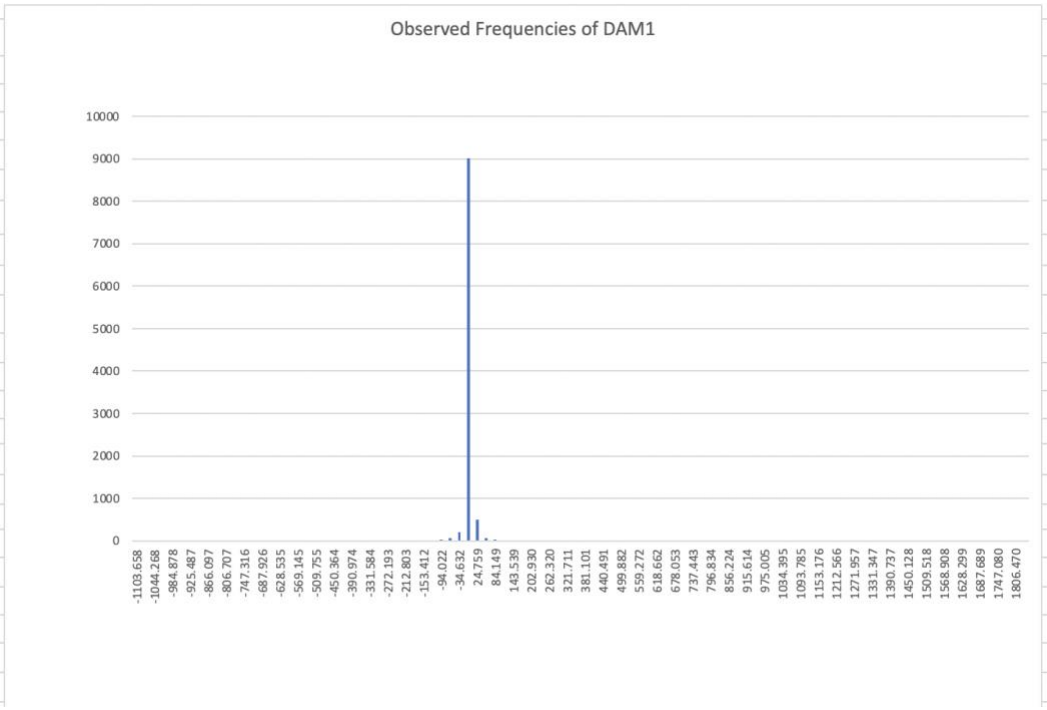
DAM 1:	Class left	Class right	Class midpoint	Class Frequency
	-44156.287	-43638.153	-43897.220	1
	-43638.153	-43120.019	-43379.086	0
	-43120.019	-42601.885	-42860.952	0
	-42601.885	-42083.751	-42342.818	0
	-42083.751	-41565.617	-41824.684	0
	-41565.617	-41047.484	-41306.550	0
	-41047.484	-40529.350	-40788.417	0
	-40529.350	-40011.216	-40270.283	0
	-40011.216	-39493.082	-39752.149	0
	-39493.082	-38974.948	-39234.015	0
	-38974.948	-38456.814	-38715.881	0
	-38456.814	-37938.681	-38197.747	0
	-37938.681	-37420.547	-37679.614	0
	-37420.547	-36902.413	-37161.480	0
	-36902.413	-36384.279	-36643.346	0
	-36384.279	-35866.145	-36125.212	0
	-35866.145	-35348.011	-35607.078	0
	-35348.011	-34829.878	-35088.944	0
	-34829.878	-34311.744	-34570.811	0
	-34311.744	-33793.610	-34052.677	0
	-33793.610	-33275.476	-33534.543	0
	-33275.476	-32757.342	-33016.409	0
	-32757.342	-32239.208	-32498.275	0

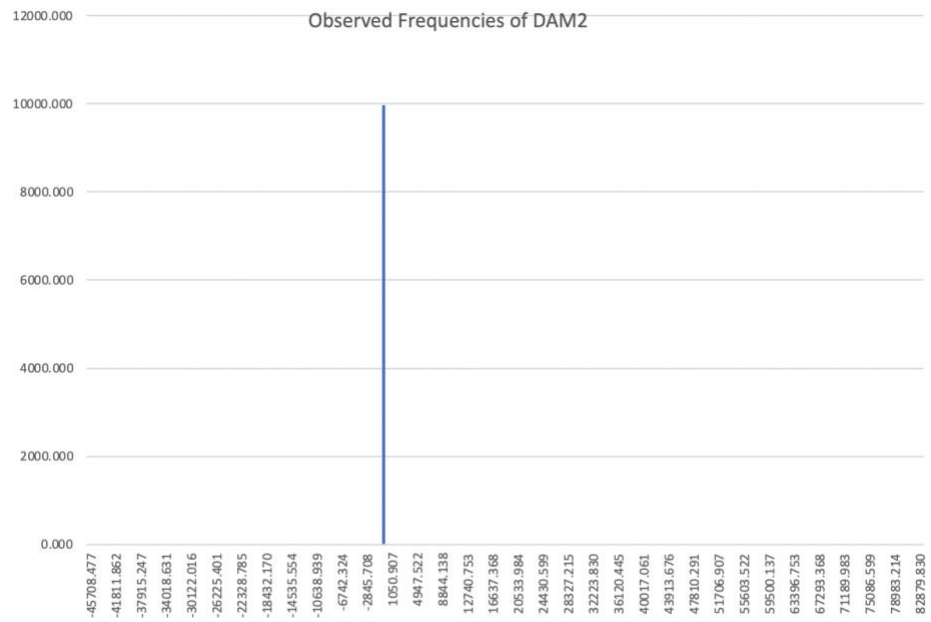
With these values, we can now generate a graph for both the DAM's for alpha 1 and alpha 2.





A tabular and graphical frequency distributions are generated for both Dam #1 and Dam #2. The graphs generated are below





By observing the above graphs, we can see that the distribution is close to a Triangular Probability Distribution.

To validate if the Triangular probability is a good fit, we test it by Chi-square goodness fit test .

NULL Hypothesis : Triangular Distribution is a good fit.
Alternative Hypothesis : Triangular Distribution is NOT a good fit.

By calculating, we get the Chi-square test statistic value = 867164.3.

The P-value is close to 0. As it is < 0.05, we can reject the NULL hypothesis.

Few more calculations are done on the two projects to check which takes precedence over the other.

	α_1	α_2
Minimum	-22872.771	-166037.237
Maximum	11049.066	10195.244
Mean	-0.864	-17.065
Median	-0.751	-1.623
Variance	86880.99293	2815488.48
Standard Deviation	294.7558192	1677.941739
SKEWNESS	-38.45631948	-96.9509427
$P(\alpha_i > 2)$	0.1861	0.2939
$P(\alpha_i > 1.8)$	0.1968	0.3015
$P(\alpha_i > 1.5)$	0.2123	0.3114
$P(\alpha_i > 1.2)$	0.2346	0.3223
$P(\alpha_i > 1)$	0.2524	0.3299
$P(\alpha_1 > \alpha_2)$	**0.355**	

From the above figure, we can see that the probability of $\alpha 2$ is greater than probability of $\alpha 1$. Hence we can say that $\alpha 2$ has a higher chance of producing better results over $\alpha 1$.

References :

triangular distribution [SOLVED]. (n.d.). https://www.excelforum.com/excel-general/494381-triangular-distribution.html