- **Course Title:** Engineering Cost Analysis & Economy (ENGR 222)
- **Session:** Fall 2024
- **Instructor:** Sudipta Chowdhury (chowdhurys@marshall.edu)
- **Class Time: TR 9.30 AM-10.45 AM**
- **Office hours: TR 11.00 AM-12.30 PM**

Benefit-cost Analysis

Differences: Public vs. Private Projects

Characteristic	Public	Private
Size of Investment	Large	Small, medium, large
Life	Longer (30 – 50+ years)	Shorter (2 – 25 years)
Annual CF	No profit	Profit-driven
Funding	Taxes, fees, bonds, etc.	Stocks, bonds, loans, etc.
Interest rate	Lower	Higher
Selection criteria	Multiple criteria	Primarily ROR
Environment of evaluation	Politically inclined	Economic

Cash Flow Classifications

Must identify each cash flow as either benefit, disbenefit, or cost

Benefit (B) -- Advantages to the *public*

Disbenefit (D) -- Disadvantages to the *public*

Cost (C) -- Expenditures by the *government*

Note: Savings to government are subtracted from costs

B/C Relations

$$B/C = \frac{PW or\ AW\ or\ FW\ of\ benefits}{PW\ or\ AW\ or\ FW\ of\ costs}$$

Note 1: All terms must be expressed in *same units*, i.e., PW, AW, or FW

Note 2: *Do not use minus sign* ahead of costs

Note 3: AW is preferred

If B/C $\geq$ 1.0, project **is** economically justified discount rate applied

If B/C $<$ 1.0, project **is not** economically acceptable

B/C Relations

Conventional B/C ratio $= (B - D) / C$

Modified B/C ratio $= [(B - D) -$ **M&O cost]** / **Initial Investment**

Example 1. Officials from the City of Galveston and State of Texas gathered to celebrate the start of a beach restoration project that involves dumping sand and adding anti-erosion structures. The first cost of the project is $30 million with annual maintenance estimated at $340,000. If the restored/expanded beaches attract visitors who will spend $6.2 million per year, what is the conventional B/C ratio at the social discount rate of 8% per year? Assume the State wants to recover the investment in 20 years.

8%	Compound Interest Factors								8%
	Single Payment		Uniform Payment Series				Arithmetic Gradient		
n	Compound Amount Factor Find F Given P F/P	Present Worth Factor Find P Given F P/F	Sinking Fund Factor Find A Given F A/F	Capital Recovery Factor Find A Given P A/P	Compound Amount Factor Find F Given A F/A	Present Worth Factor Find P Given A P/A	Gradient Uniform Series Find A Given G A/G	Gradient Present Worth Find P Given G P/G	n
1	1.080	.9259	1.0000	1.0800	1.000	0.926	0	0	1
2	1.166	.8573	.4808	.5608	2.080	1.783	0.481	0.857	2
3	1.260	.7938	.3080	.3880	3.246	2.577	0.949	2.445	3
4	1.360	.7350	.2219	.3019	4.506	3.312	1.404	4.650	4
5	1.469	.6806	.1705	.2505	5.867	3.993	1.846	7.372	5
6	1.587	.6302	.1363	.2163	7.336	4.623	2.276	10.523	6
7	1.714	.5835	.1121	.1921	8.923	5.206	2.694	14.024	7
8	1.851	.5403	.0940	.1740	10.637	5.747	3.099	17.806	8
9	1.999	.5002	.0801	.1601	12.488	6.247	3.491	21.808	9
10	2.159	.4632	.0690	.1490	14.487	6.710	3.871	25.977	10
11	2.332	.4289	.0601	.1401	16.645	7.139	4.240	30.266	11
12	2.518	.3971	.0527	.1327	18.977	7.536	4.596	34.634	12
13	2.720	.3677	.0465	.1265	21.495	7.904	4.940	39.046	13
14	2.937	.3405	.0413	.1213	24.215	8.244	5.273	43.472	14
15	3.172	.3152	.0368	.1168	27.152	8.559	5.594	47.886	15
16	3.426	.2919	.0330	.1130	30.324	8.851	5.905	52.264	16
17	3.700	.2703	.0296	.1096	33.750	9.122	6.204	56.588	17
18	3.996	.2502	.0267	.1067	37.450	9.372	6.492	60.843	18
19	4.316	.2317	.0241	.1041	41.446	9.604	6.770	65.013	19
20	4.661	.2145	.0219	.1019	45.762	9.818	7.037	69.090	20

Example 2. A consultant, after 3 months of work, reported that the modified B/C ratio for a city-owned hospital heliport project is 1.7. If the initial cost is $1 million and the annual benefits are $150,000, what is the amount of the annual M&O costs used in the calculation? The report stated that a discount rate of 6% per year and an estimated life of 30 years were used.

6%	Compound Interest Factors								6%
	Single Payment		Uniform Payment Series				Arithmetic Gradient		
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Capital Recovery Factor	Compound Amount Factor	Present Worth Factor	Gradient Uniform Series	Gradient Present Worth	
	Find *F* Given *P*	Find *P* Given *F*	Find *A* Given *F*	Find *A* Given *P*	Find *F* Given *A*	Find *P* Given *A*	Find *A* Given *G*	Find *P* Given *G*	
n	*F/P*	*P/F*	*A/F*	*A/P*	*F/A*	*P/A*	*A/G*	*P/G*	*n*
1	1.060	.9434	1.0000	1.0600	1.000	0.943	0	0	1
2	1.124	.8900	.4854	.5454	2.060	1.833	0.485	0.890	2
3	1.191	.8396	.3141	.3741	3.184	2.673	0.961	2.569	3
4	1.262	.7921	.2286	.2886	4.375	3.465	1.427	4.945	4
5	1.338	.7473	.1774	.2374	5.637	4.212	1.884	7.934	5
6	1.419	.7050	.1434	.2034	6.975	4.917	2.330	11.459	6
7	1.504	.6651	.1191	.1791	8.394	5.582	2.768	15.450	7
8	1.594	.6274	.1010	.1610	9.897	6.210	3.195	19.841	8
9	1.689	.5919	.0870	.1470	11.491	6.802	3.613	24.577	9
10	1.791	.5584	.0759	.1359	13.181	7.360	4.022	29.602	10
11	1.898	.5268	.0668	.1268	14.972	7.887	4.421	34.870	11
12	2.012	.4970	.0593	.1193	16.870	8.384	4.811	40.337	12
13	2.133	.4688	.0530	.1130	18.882	8.853	5.192	45.963	13
14	2.261	.4423	.0476	.1076	21.015	9.295	5.564	51.713	14
15	2.397	.4173	.0430	.1030	23.276	9.712	5.926	57.554	15
16	2.540	.3936	.0390	.0990	25.672	10.106	6.279	63.459	16
17	2.693	.3714	.0354	.0954	28.213	10.477	6.624	69.401	17
18	2.854	.3503	.0324	.0924	30.906	10.828	6.960	75.357	18
19	3.026	.3305	.0296	.0896	33.760	11.158	7.287	81.306	19
20	3.207	.3118	.0272	.0872	36.786	11.470	7.605	87.230	20
21	3.400	.2942	.0250	.0850	39.993	11.764	7.915	93.113	21
22	3.604	.2775	.0230	.0830	43.392	12.042	8.217	98.941	22
23	3.820	.2618	.0213	.0813	46.996	12.303	8.510	104.700	23
24	4.049	.2470	.0197	.0797	50.815	12.550	8.795	110.381	24
25	4.292	.2330	.0182	.0782	54.864	12.783	9.072	115.973	25
26	4.549	.2198	.0169	.0769	59.156	13.003	9.341	121.468	26
27	4.822	.2074	.0157	.0757	63.706	13.211	9.603	126.860	27
28	5.112	.1956	.0146	.0746	68.528	13.406	9.857	132.142	28
29	5.418	.1846	.0136	.0736	73.640	13.591	10.103	137.309	29
30	5.743	.1741	.0126	.0726	79.058	13.765	10.342	142.359	30

Example 3.

Calculate the B/C ratio for the following cash flow estimates at a discount rate of 10% per year. Is the project justified?

Item	Estimate
PW of benefits, $	3,800,000
AW of disbenefits, $/year	45,000
First cost, $	1,200,000
M&O costs, $/year	300,000
Life, years	20

10%	Compound Interest Factors								10%
	Single Payment		Uniform Payment Series				Arithmetic Gradient		
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Capital Recovery Factor	Compound Amount Factor	Present Worth Factor	Gradient Uniform Series	Gradient Present Worth	
	Find *F* Given *P*	Find *P* Given *F*	Find *A* Given *F*	Find *A* Given *P*	Find *F* Given *A*	Find *P* Given *A*	Find *A* Given *G*	Find *P* Given *G*	
n	*F/P*	*P/F*	*A/F*	*A/P*	*F/A*	*P/A*	*A/G*	*P/G*	*n*
1	1.100	.9091	1.0000	1.1000	1.000	0.909	0	0	1
2	1.210	.8264	.4762	.5762	2.100	1.736	0.476	0.826	2
3	1.331	.7513	.3021	.4021	3.310	2.487	0.937	2.329	3
4	1.464	.6830	.2155	.3155	4.641	3.170	1.381	4.378	4
5	1.611	.6209	.1638	.2638	6.105	3.791	1.810	6.862	5
6	1.772	.5645	.1296	.2296	7.716	4.355	2.224	9.684	6
7	1.949	.5132	.1054	.2054	9.487	4.868	2.622	12.763	7
8	2.144	.4665	.0874	.1874	11.436	5.335	3.004	16.029	8
9	2.358	.4241	.0736	.1736	13.579	5.759	3.372	19.421	9
10	2.594	.3855	.0627	.1627	15.937	6.145	3.725	22.891	10
11	2.853	.3505	.0540	.1540	18.531	6.495	4.064	26.396	11
12	3.138	.3186	.0468	.1468	21.384	6.814	4.388	29.901	12
13	3.452	.2897	.0408	.1408	24.523	7.103	4.699	33.377	13
14	3.797	.2633	.0357	.1357	27.975	7.367	4.996	36.801	14
15	4.177	.2394	.0315	.1315	31.772	7.606	5.279	40.152	15
16	4.595	.2176	.0278	.1278	35.950	7.824	5.549	43.416	16
17	5.054	.1978	.0247	.1247	40.545	8.022	5.807	46.582	17
18	5.560	.1799	.0219	.1219	45.599	8.201	6.053	49.640	18
19	6.116	.1635	.0195	.1195	51.159	8.365	6.286	52.583	19
20	6.728	.1486	.0175	.1175	57.275	8.514	6.508	55.407	20

Profitability index analysis of revenue projects

If PI $\geq$ 1.0, project is economically justified at discount rate applied

If PI $<$ 1.0, project is not economically acceptable

$$\text{Conventional B/C ratio} = \frac{B - D}{C}$$

$$\text{Modified B/C ratio} = \frac{B - D - M\&O}{initial\ Investment}$$

If B/C $\geq$ 1.0, accept project; otherwise, reject

$$PI = \frac{\text{PW of NCF}}{\text{PW of initial investment}}$$

Example 4. Dickinson, a large oil and gas drilling and operating corporation, has invested over the past 6 years in the installation and operation of a FOUNDATION Fieldbus H1 (FF H1) system developed by Pepperl+Fuchs of Germany. A project engineer has collected information on annual net cash flow increases (ΔNCF) generated by the FF H1 system and the annual investments made by Dickinson in the system. At an interest rate of 10% per year, determine the PI of this endeavor. Has it proven to be economically worthwhile?

Year	0	1	2	3	4	5	6
ΔNCF, $10,000 per year	0	5	7	9	11	13	20
Investment, $10,000	15	8	10	0	0	5	10

10%	Compound Interest Factors								10%
	Single Payment		Uniform Payment Series				Arithmetic Gradient		
n	Compound Amount Factor Find *F* Given *P* *F/P*	Present Worth Factor Find *P* Given *F* *P/F*	Sinking Fund Factor Find *A* Given *F* *A/F*	Capital Recovery Factor Find *A* Given *P* *A/P*	Compound Amount Factor Find *F* Given *A* *F/A*	Present Worth Factor Find *P* Given *A* *P/A*	Gradient Uniform Series Find *A* Given *G* *A/G*	Gradient Present Worth Find *P* Given *G* *P/G*	n
1	1.100	.9091	1.0000	1.1000	1.000	0.909	0	0	1
2	1.210	.8264	.4762	.5762	2.100	1.736	0.476	0.826	2
3	1.331	.7513	.3021	.4021	3.310	2.487	0.937	2.329	3
4	1.464	.6830	.2155	.3155	4.641	3.170	1.381	4.378	4
5	1.611	.6209	.1638	.2638	6.105	3.791	1.810	6.862	5
6	1.772	.5645	.1296	.2296	7.716	4.355	2.224	9.684	6
7	1.949	.5132	.1054	.2054	9.487	4.868	2.622	12.763	7
8	2.144	.4665	.0874	.1874	11.436	5.335	3.004	16.029	8
9	2.358	.4241	.0736	.1736	13.579	5.759	3.372	19.421	9
10	2.594	.3855	.0627	.1627	15.937	6.145	3.725	22.891	10

Evaluation of Alternatives

General approach for incremental B/C analysis of two ME alternatives:

- Lower total cost alternative is first compared to ***Do-nothing (DN)***
- If B/C for the lower cost alternative is < 1.0, the DN option is compared to conventional B/C ratio (Δ***B/C***) of the higher-cost alternative
- If both alternatives lose out to DN option, DN prevails, unless overriding needs requires selection of one of the alternatives

Example 5. Compare two alternatives using i = 10% and B/C ratio

Alternative	X	Y
First cost, $	320,000	540,000
M&O costs, $/year	45,000	35,000
Benefits, $/year	110,000	150,000
Disbenefits, $/year	20,000	45,000
Life, years	10	20

Solution: First, calculate equivalent total cost

$$\text{AW of costs}_X = 320{,}000(A/P, 10\%, 10) + 45{,}000 = \$97{,}080$$

$$\text{AW of costs}_Y = 540{,}000(A/P, 10\%, 20) + 35{,}000 = \$98{,}428$$

Order of analysis is X, then Y

X vs. DN: $(B - D)/C = (110{,}000 - 20{,}000) \,/\, 97{,}080 = 0.93$ **Eliminate X**

Y vs. DN: $(150{,}000 - 45{,}000) \,/\, 98{,}428 = 1.07$ **Eliminate DN**

Select Y

Example 6. **Must select one of two alternatives** using i= 10% and ΔB/C ratio

Alternative	X	Y
First cost, $	320,000	540,000
M&O costs, $/year	45,000	35,000
Benefits, $/year	110,000	150,000
Disbenefits, $/year	20,000	45,000
Life, years	10	20

Solution: Must select X or Y; DN not an option, ***compare Y to X***

AW of $\text{costs}_X = \$97{,}080$ AW of $\text{costs}_Y = \$98{,}428$

Incremental values: $\Delta B = 150{,}000 - 110{,}000 = \$40{,}000$

$\Delta D = 45{,}000 - 20{,}000 = \$25{,}000$

$\Delta C = 98{,}428 - 97{,}080 = \$1{,}348$

Y vs. X: $(\Delta B - \Delta D)/\Delta C = (40{,}000 - 25{,}000)/1{,}348 = 11.1$ **Eliminate X**

Select Y

QUESTIONS?