Asphalt compared to Concrete for Highways

An Exploration of Discounted Cash Flow Analysis in Practice

Basic Practical Issue: Which Technology?

- **Technologies often differ in Pattern of Cash Flows. Typically:**
  - **One may cost more to buy, but may save money, last longer**
  - **Another may be cheaper immediately, but cost more to operate, fail earlier**
- **Examples??**
- **Let's look at a major practical case**

Choice of Highway Pavement: Asphalt or Concrete

- Concrete lasts longer -- is more expensive
- Asphalt less expensive to place, but fails earlier
- Both pavements eventually have to be resurfaced - typically with an asphalt coat
- Which technology should be chosen?

What is Life of Technology?

- What is the "life" of equipment?
- At what point does it fail or "die"?
  - Absolute failure?
  - Does not meet technical standards? Which ones?
  - Requires too many repairs?
  - Is there an unambiguous test?

What is Life of Highway Surface?

- **Consider 'statistical' Analysis of US Experience, 1920 - 1950s**
  - **Life of Asphalt ~ 17 years**
  - **Life of Concrete ~ 27 years**
- **Can we believe this?**
  - **What issues arise in analysis?**

Examination of Data on Highway Life

- **1920s -- Boom Period -**
  - **Concrete highways – money was available**
- **1930s -- Depression**
  - **Asphalt highways – budget tight, chose cheaper**
- **1940s -- War**
  - **"Nothing" built**
- **1950s -- Reconstruction**
  - **Average age of concrete: 27 = 1952 - 1925**
  - **Average age of asphalt: 17 = 1952 - 1935**

How might we determine life of project?

- Set up Objective Criteria?
  - Such as?……
- Technologies fail differently… Test for failure of one does not apply to other...
  - Asphalt deforms, ruts
  - Concrete cracks, breaks up
- Ultimately, this is very subjective...

Example Analysis

- Assumed Numbers
  - Asphalt costs 1000/unit initially
  - Concrete costs 20% more, 1200/unit
  - Cost of Resurfacing is 400/unit for each
- See Example

Excel Set up for Analysis

Year	Asphalt	Concrete
0	1000	1200
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	400	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	400
28	0	0
29	0	0
30	0	0
31	0	0
32	0	0
33	0	0
34	400	0
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0

PV of Asphalt (left) vs. Concrete (right) Breakpoint ~ 3.5% (in this example)

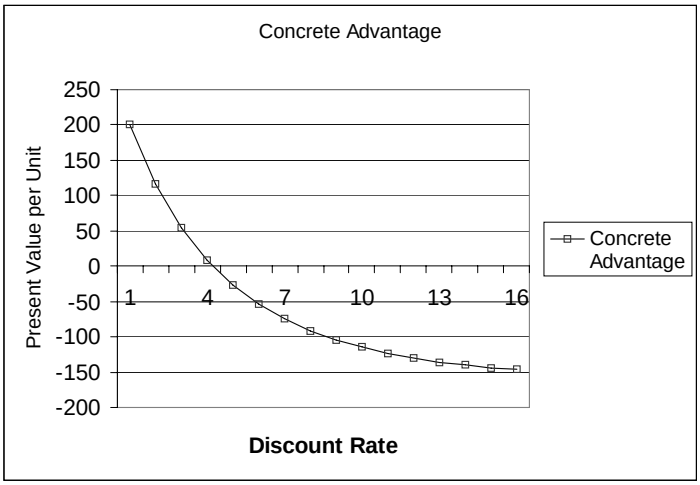
	Base Case		
	-995	-1,119	Delta
0%	-1800	-1600	200
1%	-1607	-1491	116
2%	-1460	-1406	54
3%	-1348	-1340	8
4%	-1260	-1287	-27
5%	-1191	-1245	-54
6%	-1136	-1210	-75
7%	-1090	-1182	-91
8%	-1053	-1157	-104
9%	-1022	-1137	-115
10%	-995	-1119	-123
11%	-972	-1103	-130
12%	-952	-1088	-136
13%	-935	-1075	-140
14%	-919	-1063	-144
15%	-905	-1051	-147

Note:

These calculations used the Excel NPV formula, that assumes that the initial capital expense occurs at the end of the first year (reasonable in this case, since it is normal to pay for work after it is done).

This explains why the NPV at high discount rates can be smaller than the initial cost.

Cost Advantage of Concrete (Chart)



Lesson from Comparison

- **Choice of Technology may depend on choice of discount rate**
- **Those who determine Choice of Discount Rate may be true designers**

- **Why was most of US Interstate Highway System originally built of concrete?**
- **but privately financed toll roads (such as Mass Pike) were not?**

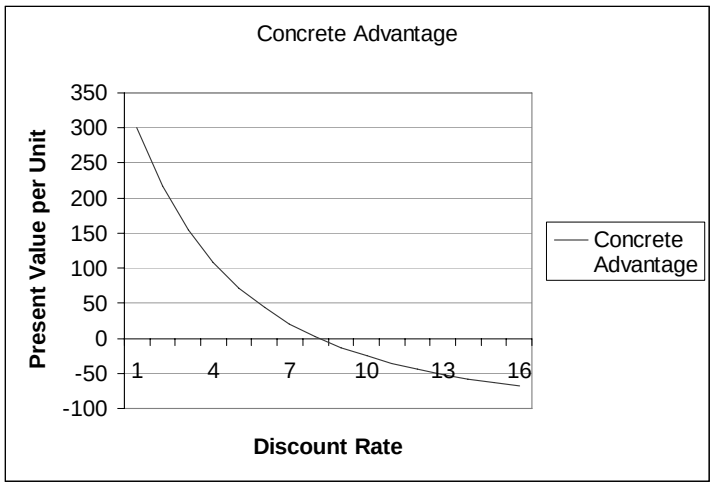
Finance Policies Influence Design

- **Consider standard process in which the central manager subsidizes the construction cost, but not the maintenance costs**
  - **By direct payment or tax credits**
  - **Common in the United States**
  - **Also applies to private organizations (MIT, …)**
- **What is the effect of such policies?**
- **Favors technology that costs more at start**

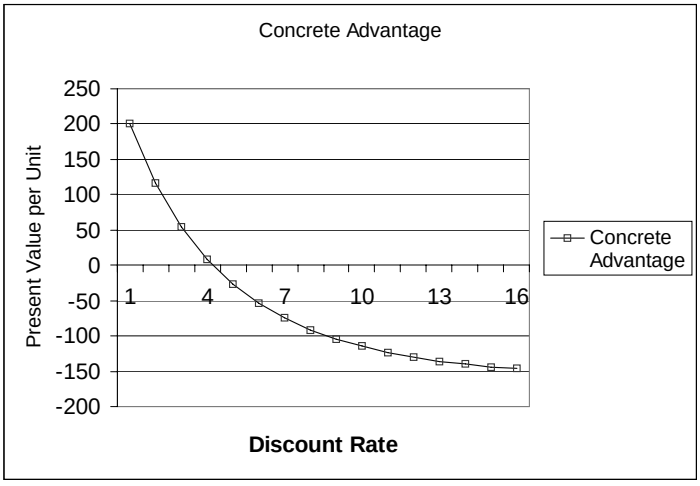
Effect of 50% Subsidy of Investment: breakeven point shifted from 3.5 to ~ 7%

50 % Subsidy of Initial Costs			
	-595	-631	Delta
0%	-1300	-1000	300
1%	-1123	-906	217
2%	-990	-834	155
3%	-888	-780	108
4%	-811	-739	72
5%	-751	-707	44
6%	-704	-683	21
7%	-667	-664	2
8%	-637	-650	-13
9%	-614	-639	-25
10%	-595	-631	-36
11%	-579	-624	-45
12%	-567	-619	-52
13%	-556	-615	-58
14%	-548	-612	-64
15%	-541	-609	-69

Cost Advantage of Concrete (with 50% subsidy)



Cost Advantage of Concrete (no subsidy on construction)



Lesson of Effect of Subsidy

- Policies affecting only part of the cash flow, affect relative merits of technologies.
- Subsidies on Construction costs favor more expensive investments
- US Government used to pay States up to 90% of initial investment for Interstates
- => major reason why System is concrete…

Note on Situation in US

- Policies on subsidy from US Government to States ("federal share") vary… generally every 5 years or so
- For 2005-2010, under SAFETEA-LU ("safe accountable flexible efficient transportation equity act – a legacy for users") the base rate is 80% -- with many adjustments
  - http://www.fhwa.dot.gov/safetealu/factsheets/
- In previous 5 years, under TEA-21 ("t. equity act for the 21st century) it was about 50%

What happens if we change N ?

- **How does this affect relative value?**
- **Is this effect important?**

Importance of Life of Project (20 versus 40 highway life)

Effect of Considering only 20 years

	-981	-1091	Delta (A)	Delta (C)
0%	-1400	-1200	-22%	-25%
1%	-1325	-1188	-18%	-20%
2%	-1260	-1176	-14%	-16%
3%	-1206	-1165	-11%	-13%
4%	-1159	-1154	-8%	-10%
5%	-1119	-1143	-6%	-8%
6%	-1084	-1132	-5%	-6%
7%	-1053	-1121	-3%	-5%
8%	-1026	-1111	-3%	-4%
9%	-1002	-1101	-2%	-3%
10%	-981	-1091	-1%	-2%
11%	-962	-1081	-1%	-2%
12%	-945	-1071	-1%	-2%
13%	-929	-1062	-1%	-1%
14%	-915	-1053	0%	-1%
15%	-902	-1043	0%	-1%

Deltas A and C (for Asphalt and Concrete) are compared to NPV for longer "life".

Note that effect is different for each product.

Lesson from alternative life of projects

- Using higher discount rates makes events in distant future insignificant
- Cut life of project in half (in example) changes Present value by a few percent
  - not significant in terms of accuracy of forecast estimates of costs, benefits
- Exception: If Discount rates < 5% or so

Lessons from Example

- Analyses simple, HOWEVER
- Results depend highly on assumptions
  - About discount rate
  - About tax or subsidy incentives
  - Even about life of project
- Designers of Tax, Economic Programs may be actual System Designers