Life-Cycle Costing

Theory and Application to Green Stormwater Infrastructure

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Life-cycle costing (LCC) is an essential element of capital management in public organizations. If public organizations only consider the initial acquisition or construction cost of public capital, they will understate the total cost of the investment decision.

Theory

There are four sets of costs typically involved in LCC calculations:

1. Initial investment cost;
2. Operating costs;
3. Maintenance costs; and
4. Replacement costs (Khan, 2017).

The initial investment cost includes not only the direct cost of capital construction or acquisition but also costs related to design and planning, and training of personnel who will operate the facility. Design and planning costs may be directly observable in the form of costs incurred to contract for planning and design services. They may also be related to the use of personnel in public agencies who must work on the project in question versus work on another project. In this case, the cost is an opportunity cost and a "shadow" cost should be used.[1] Personnel training costs may include costs of personnel obtaining operating licenses or special skills certifications and costs of facilities constructed for training. The latter could be a "shadow" cost if existing facilities are used for training.

Operating costs include costs of utilities, supplies used, and personnel who are not involved in maintenance activities (such as custodial staff). This is another area where "shadow" costing might be necessary to reflect opportunity costs of using resources that could be used for other projects or programs. Maintenance costs include costs of repair and upkeep of the capital project along with costs to maintain facilities housing capital

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[1] Shadow costs are calculated by taking the pro rata share of resource utilization. Therefore, if a design engineer is paid a total compensation of $100,000 per year and the design work on the capital project in question takes 10% of the engineer's time over the course of the year, the cost of the engineer's time for the project is $10,000.

equipment. These may be directly observed if maintenance services are outsourced, or may again be opportunity costs of using existing staff. Replacement costs include all costs related to replacing all or part of the capital item at some point in the future. This can include redesign and planning costs, new capital costs, and installation costs of the new capital.

There are three final considerations before calculating the LCC. First, if a capital asset at the end of its useful life can be disposed of and a financial value received, that "salvage value" or "scrap value" must be accounted for. This is the revenue that can be obtained by the selling the capital asset. Salvage value calculations can be done in one of two ways. Either the value can be subtracted from the replacement cost of the new capital (done if the salvage value is realized at the same time as the replacement) or it can be recognized as a separate item that reduces overall LCC (this is required if the salvage value is realized in a separate year from the replacement). Second, all of the costs except the initial investment cost have to be discounted to the present. Since they are recognized over time, we must apply a "discount rate" to the cost (or salvage value). The discount rate should reflect the opportunity cost of using public resources for other projects or programs. As for the setting of the discount rate, the academic literature is remarkably moot. The starting point for this opportunity cost is the inflation rate (Anderson, 2012). If the project is financed through the use of debt, the cost of borrowing should be the starting point as it represents the inflation rate and the additional cost of using borrowing capacity for other projects and programs.[2] The discount rate may be adjusted according to the perception of the analyst that the public favors the use of resources more or less during different periods of time. This subjectivity is difficult for some and therefore sensitivity analysis of results is recommended. Practically, the borrowing cost used should reflect all costs of borrowing (the "True Interest Cost"). This includes upfront costs of borrowing such as hiring bond counsel and financial advisors, obtaining a credit rating, purchasing bond and other financing related costs. If those costs are not included in the borrowing cost, then they should be added to the initial investment costs described above.

The last consideration is for the time period of analysis. The analysis should be carried out over the life of the project. This does not necessarily coincide with the useful life of the capital asset, requiring the calculation and

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[2] This is due to the famous Fisher (1896) effect.

application of replacement costs. One implication of this is that there will be a residual value at the end of the project analysis, similar to a salvage value that must be calculated

Putting all of these terms together, we arrive at the LCC equation:

$$LCC = C_0 + \left[\sum_{t=1}^{T} \frac{OC_t}{(1+i)^t} + \sum_{t=1}^{T} \frac{MC_t}{(1+i)^t} + \sum_{t=1}^{T} \frac{RC_t}{(1+i)^t}\right] - \sum_{t=1}^{T} \frac{SV_t}{(1+i)^t} \qquad (1)^3$$

where C is the initial investment cost at time 0 (therefore not requiring discounting), OC is the operating cost for each time period t, MC is the maintenance cost, RC is the replacement cost, and SV is the salvage value. The time period of the analysis is denoted by T and the rate used to discount future values is i.

The spreadsheet in Appendix A shows a stylized example of a 10-year LCC calculation for a project with an initial investment cost of $1,000,000, annual operating costs of $25,000, annual maintenance costs of $10,000, a replacement cost of $1,250,000 in year 8, and a residual value in year 10 of $800,000. The discount factor shows the value of a $1 cost or benefit at the indicated number of years into the future (we assumed a discount rate of 5% for this example). The total LCC is calculated as $1,625,179. This is the true cost of the project at the current time. It should be compared to other potential projects, while taking into account the benefits of each of the projects.

Application to Green Stormwater Projects

For the most part, the theory above can be directly applied to green stormwater projects. One of the key inputs for these projects is the useful life of green "infrastructure". A bioretention project has a useful life that is dependent on the climate, soils, and other environmental characteristics of the area. This sentiment was echoed in discussions with water systems in Los Angeles, Phoenix and Washington state, who described how the conditions there affected BMP useful lives. Benchmarking of useful lives is somewhat spotty, although we were able to find work done in Maryland and Delaware that addressed this issue. All of the EPA and state guidance we found recommended adaptive watershed management – project monitoring and

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[3] Adapted from Khan (2017, p. 97). We use t versus T in the equation to represent the fact that the time period of analysis may exceed the life of the capital asset thus requiring replacement costs and salvage values to recognized. So there may be multiple salvage values at, for example t=10 and t=T=20 for a 20-year project analysis.

adjustment of useful lives according to the ability to treat various volumes of runoff.

Another issue with the practical use of LCC that has arisen during the project is the use of "cost curves" for operating and maintenance costs. In this methodology, total operating or maintenance costs per unit of treatment are calculated. This is good for calculating the current value of costs, but less useful in a life-cycle setting due to the lack of time information provided. Essentially these cost curves could be "annualized" to give some sense of what is the cost over time of the project, but in no way do these represent a true discounted cost for LCC calculations. A more robust methodology for calculating lifetime costs is necessary for developing accurate LCC measures.

References

Khan, A. (2017). *Cost and Optimization in Government: An Introduction to Cost Accounting, Operations Management, and Quality Control*. (2nd ed.) New York, NY: Routledge.

Anderson, J. E. (2012). *Public Finance: Principles and Policy*. (2nd ed.). Mason, OH: South-Western.

Fisher, I. (1896). *Appreciation and Interest: A Study of the Influence of Monetary Appreciation and Depreciation on the Rate of Interest with Applications to the Bimetallic Controversy and the Theory of Interest*. New York, NY: American Economic Association.

Appendix A: Spreadsheet Example

Year	C	OC	MC	RC	SV	Discount Factor	Discounted C	Discounted OC	Discounted MC	Discounted RC	Discounted SV
0	$ 1,000,000.00					1.0000	$ 1,000,000.0000	$ -	$ -	$ -	$ -
1		25,000.00	10,000.00			0.9524	$ -	$ 23,809.5238	$ 9,523.8095	$ -	$ -
2		25,000.00	10,000.00			0.9070	$ -	$ 22,675.7370	$ 9,070.2948	$ -	$ -
3		25,000.00	10,000.00			0.8638	$ -	$ 21,595.9400	$ 8,638.3760	$ -	$ -
4		25,000.00	10,000.00			0.8227	$ -	$ 20,567.5619	$ 8,227.0247	$ -	$ -
5		25,000.00	10,000.00			0.7835	$ -	$ 19,588.1542	$ 7,835.2617	$ -	$ -
6		25,000.00	10,000.00			0.7462	$ -	$ 18,655.3849	$ 7,462.1540	$ -	$ -
7		25,000.00	10,000.00			0.7107	$ -	$ 17,767.0333	$ 7,106.8133	$ -	$ -
8		25,000.00	10,000.00	1,250,000.00		0.6768	$ -	$ 16,920.9841	$ 6,768.3936	$ 846,049.2025	$ -
9		25,000.00	10,000.00			0.6446	$ -	$ 16,115.2229	$ 6,446.0892	$ -	$ -
10		25,000.00	10,000.00		-800,000.00	0.6139	$ -	$ 15,347.8313	$ 6,139.1325	$ -	$ (491,130.6028)
Totals							$ 1,000,000.0000	$ 193,043.3732	$ 77,217.3493	$ 846,049.2025	$ (491,130.6028)
LCC (sum of Discounted C+sum of Discounted OC+...)											**$ 1,625,179.3222**