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Life Cycle Costing: For the Analysis, Management and Maintenance of Civil Engineering Infrastructure

Andrew Lemer

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Book Review

Life Cycle Costing: For the Analysis, Management and Maintenance of Civil Engineering Infrastructure
John W. Bull, Whittles Publishing, Dunbeath, 2015
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The idea that one should give thought during a facility's planning and design to the future use of the facility is not exactly a new one, but it has in recent years begun to generate more 'buzz', as the marketers might say. Many facility managers and owners began to realize the scale of financial problems caused by years of budget-motivate maintenance deferrals, particularly in combination with early decisions to adopt lowest-cost construction options that could have been foreseen to raise future maintenance requirements. Dhillon's (1989) text on life cycle costing represented one of the seminal efforts to lay out in an orderly manner the analysis methods that could be used to show that 'savings' in design and construction could have costly consequences for operations, maintenance, and disposal. The phrase 'pay me now or pay me later' has become a catchy way to characterize for popular presentation the technical trade-offs facing facility owners and their architects and engineers.

Over the past 25 years, increased computing power and better data collection have supported increasingly sophisticated and data-rich methods for analysing exactly what the catchy phrase might mean. In addition, changes in the marketplace for facilities development, ownership, and management: the advent of large investment trusts, public–private partnerships in finance, private operation of public infrastructure, and the like, have encouraged greater use of these methods. The idea that someone can project reliably the costs and returns likely to be associated with construction, operation, maintenance, and removal of a structure over the decades-long period of the structure's 'life cycle' has taken firm root in professional practice.

One might then expect a newly published book with a title like *Life Cycle Costing: For the Analysis, Management and Maintenance of Civil Engineering Infrastructure* to present the latest thinking on the subject and guidance for practitioners. The cover's imagery (apparently an elevated highway structure viewed at night, looking to this viewer rather similar to one of Shanghai's monumentally contrived river crossings) evokes 'infrastructure' of the large-scale, urban sort, certainly a worthy and substantial area of practice. The prominent display of an editor's name on the front cover (John Bull, very English one imagines) suggests a reader may find a coherent, albeit perhaps idiosyncratic, explanation of the book's scope and significance for a target readership.

How quickly I was reminded of the wisdom in the old saying about not judging a book by its cover! The tome is an assemblage of seven rather distinct technical papers, tethered only by the book's binding, contents listing, and a meagre index. The subject matter of the papers ranges from the UK housing stock to rural electric-power generation to protective coatings for bridge structural members. The named editor, identified only by an institutional affiliation listed on the title page, has not provided any explanation of the sources, reasons for selection, or common themes of the book. A brief blurb on the rear cover, perhaps written by the editor, does assert the importance of life cycle cost analysis (LCCA) and whole life costing (WLC), suggests a distinction between the two methodologies, and alerts readers that the examples included in the book are meant to illustrate practical examples of methodology applied. (A primary element common among the papers is their authors' use of the term 'life cycle': it appears in six of the seven titles, while WLC is mentioned, fleetingly, in only in one of the papers.)

The concept underlying 'life cycle' has been expanding in recent years to encompass the transformation of basic materials (iron ore and limestone, for example) to intermediate products (such as steel reinforcing rods and cement) to final products (a bridge or office tower, perhaps) and ultimately to waste or reuse. While the life cycle of a road marker, for instance, will be much briefer and have fewer steps than that of a major motorway, this more expansive perspective has added considerable complexity to the practice of LCCA. The greater complexity has gained proponents particularly among analysts concerned with environmental consequences of facility development and management, the emergent field of industrial ecology, and issues of sustainable growth. The benefits for facility owners and managers are not yet well documented.

My experience has been that the practice of LCCA, or simply life cycle costing (LCC), typically entails estimation of the monetary values of all costs and revenues

or benefits likely to accrue to a facility's production, use, and disposal. These various costs and revenues, call them 'cash flows' for lack of a better term, even though there may be no cash involved, will occur at different times and may accrue to different people or organizations. The cash flows may be actual money transfers (payments to a building's constructor, perhaps, or to the workers who clean the lavatories) or imputed amounts when there is no market transaction involved (estimates of the value of human lives or users' time saved when a winding mountain road is reconstructed, for example).

LCC/LCCA practitioners use the methods of engineering economics to convert these various cash flows to a common base using the principle of 'discounting', most typically, a net present value (NPV), and add them together into a single number. In most applications, NPV greater than zero is good; and the larger the NPV, the better. The most straightforward LCC applications, as typically used in building design and real property management, for example, include only those costs and revenues for which a market-based financial valuation can be estimated, but for civil engineering infrastructure, non-market cash flows are often included (for example, US Department of Transportation, 2002; International Organization for Standardization, 2008). Whatever the application may be, however, market limitations and imperfections confront the analyst with issues of realistic valuation, accurate measurement, and appropriate discounting.

In contrast to LCC or LCCA, 'life cycle analysis' or 'life cycle assessment' (LCA) adopts the broader perspective of life cycle and may use energy consumption, waste or pollution production, or carbon emissions as measures of value, in lieu of or in addition to monetary NPV alone. The International Organization for Standardization, among others, has published guidance intended to encourage LCA use.[1]

An important point here is that the concepts and methods of LCC and LCA are meant not to be the same. One paper in the collection under review, 'Life cycle analysis of highway composite bridges' by H. Gervásio of Portugal, explicitly makes this point and then (despite the paper's title) declares its topic will be LCC, thereby aligning with the book's title, but aims to integrate environmental and social criteria with the LCC. (This author also mentions WLC, explaining that the practice counts 'externalities' neglected by LCC. LCC is declared therefore to be a 'subset' of WLC.) The volume's other authors are less explicit in defining their intent. Clearly there is some confusion among these authors about the meaning and scope of LCC, LCCA, LCA, and WLC. A pedagogical intervention by the editor or some other authority would have been helpful.

The paper by K.K.L. So and M.M.S. Cheung from Hong Kong and Chengdu, respectively, 'Life-cycle management framework for highway bridges', by far the longest of the papers with 71 of the book's 230 pages, is reasonably true to its title, giving a theory-based presentation not easily related to other types of infrastructure. There are no examples of the framework's application or how such application may differ from widespread bridge management practice. The paper's scope and extensive bibliography are suggestive of a graduate dissertation.

Of the five other papers, two concern highway pavements, two address electric-power generation components. These four papers and the one by Gervásio all present analyses of specific situations, thereby qualifying as case studies; they employ LCC principles to consider the relative merits of alternative materials or design choices. They highlight an important fundamental point: life cycle analysis is most useful for comparing alternative designs or operations schemes to inform a design or management decision.

The remaining paper, which actually appears first in the collection, is a 'Life cycle cost analysis of the UK housing stock', by R.M. Cuéllar-Franca and A. Azapagic at the University of Manchester. These authors, citing concern for sustainable development of the UK housing sector, undertake to use LCCA of prototypical dwelling types to shed light on matters of energy efficiency, housing affordability, and opportunities for cost reduction. In the end, the paper's conclusions are vague, although the cumulative life cycle costs of the UK housing stock over a 50-year period seem to add up to a very large number (£3364 billion). As former US Senator Everett Dirksen famously (if apocryphally) remarked: 'A billion here, a billion there, pretty soon, you're talking real money.'

Life Cycle Costing: For the Analysis, Management and Maintenance of Civil Engineering Infrastructure is remarkably free of discussion of the methodological and philosophical issues that confront users of LCC in particular and LCA generally. All of the authors seem willing to assume that prices of commodities and services will remain constant over the course of the multi-decade service lives of their particular infrastructure interest. Setting aside the matter of general price inflation (that is choosing, as LCC analysts often do, to neglect inflation and work in 'constant' currency units), the recent history of petroleum prices and idling of drilling rigs demonstrates how quickly wrong constant-price LCA can go.

All but one of the authors seem willing also to make an unconsidered assumption that discounting should be used for adjusting future 'cash flows' (as the term was adopted earlier in this review) to an equivalent present value, and to accept a single number (perhaps the

assumed value embedded in the software they employed for their analyses). The discount rate has a crucial influence on the computation of life cycle cost. One case reported using 4%, another 2%, and a third (the housing analysis) used 0%. The authors in this latter case explain that they are using 'overnight costs', a term deriving from the idea that the capital cost estimate for a facility is made as though its construction occurs in a single evening. That idea in practice typically means ignoring possible price escalation and borrowing costs. A zero discount rate is really a different concept entirely. The setting of discount rates is a topic worthy of a book of its own.

Good LCC practice generally entails assessing the sensitivity of one's conclusions to changes in the discount rate, factor prices, and other assumptions. This sensitivity analysis provides insight into how robust is the conclusion that one alternative will have a lower life cycle cost than another. However, I could find in only one of the seven papers, 'Case study: life cycle analysis of a community hydroelectric power system in rural Thailand', by A. Pascale and T. Urmee of Murdoch University, and consultant A. Moore, all from Western Australia, any reference to such an assessment.

A crucial hypothesis underlying both LCC and LCA is that we can improve the outcomes of design and management decisions (for example, reduce waste and inefficient resource usage or increase overall return on investments) by identifying and effectively managing the trade-offs among decisions made in separate stages of the life cycle. Changing a product's design, and perhaps accepting some increase in manufacturing cost, may improve the product's future performance and reduce the total amount of energy used or waste produced over the years that the product is in service. Despite this book's other shortcomings, several of the papers do comment on the trade-offs their analyses spotlight.

On the other hand, reduced spending in early stages of the life cycle may mean higher profit for a facility's developer, while the higher costs of later stages in the life cycle become someone else's problem. The institutional environment within which buildings and other civil engineering infrastructure exist challenges the practical value of LCA for more than thought experiments and government policy applications, but none of the book's analyses address the matter.

Taken as a whole, *Life Cycle Costing: For the Analysis, Management and Maintenance of Civil Engineering Infrastructure* plausibly may be of some value to readers with a particular interest in one or another of the case studies presented. However, for me, the book is far from the 'valuable tool' for practitioners, researchers, and advanced students that its cover claims.

Note

1. ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework. http://goo.gl/PTW80O (accessed 10 August 2015).ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines. http://goo.gl/H1mj91 (accessed 10 August 2015).ISO/IEC/IEEE 15288:2015 Systems and software engineering – System life cycle processes. http://goo.gl/DVNM3 V (accessed 10 August 2015).LCA101 Life Cycle Assessment: Principles and Practice, US Environmental Protection Agency. http://goo.gl/Xpz5Cu (accessed 10 August 2015).

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Andrew Lemer
andrewlemer.com

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