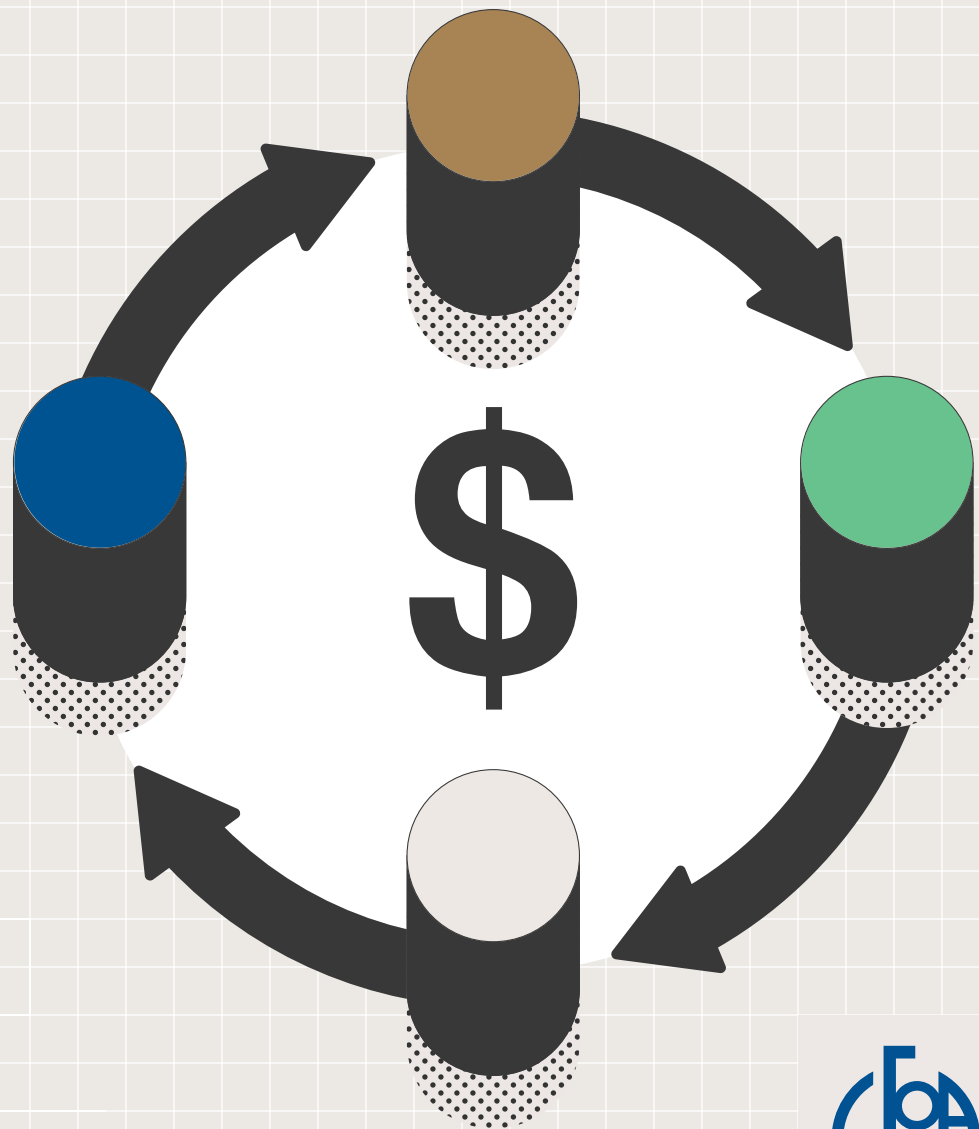


LIFE CYCLE COSTING

**PROMOTING LONG-TERM THINKING
AND EQUITABLE DISTRIBUTION OF
RESOURCES IN ASSET MAINTENANCE**

BY SHAYNE C. KAVANAGH



Government Finance
Officers Association



The Government Finance Officers Association (GFOA) represents approximately 20,000 public finance officers throughout the United States and Canada. GFOA's mission is to promote excellence in state and local government financial management. GFOA views its role as a resource, educator, facilitator, and advocate for both its members and the governments they serve and provides best practice guidance, leadership, professional development, resources and tools, networking opportunities, award programs, and advisory services.

The acquisition cost of an asset is just a portion of the total cost of owning it. Ongoing maintenance significantly adds to that cost; and for a long-lived asset, that cost can be much greater than the initial design, construction, and installation cost. Moreover, failure to keep up with regular asset maintenance can result in premature deterioration and an increased risk of failure, leading to even greater maintenance and rehabilitation costs.

This presents challenges to maintaining a strong financial foundation for a local government. First, it requires a multiyear strategy to keep assets in good condition at a reasonable cost. Second, the amount of money needed to maintain assets in good condition is not uniform across the local government's geographic areas. Local governments often mistake equality for equity when they distribute the same amount of money to different areas (districts, wards, etc.) each year for street repair, for example. However, assets do not deteriorate at uniform rates. Therefore, an optimal asset management strategy must distribute money to where it is most needed so that all citizens can enjoy quality infrastructure and see the value from their tax dollars.

A tool that helps solve this challenge is life cycle costing. Life cycle cost analysis considers the entire cost of owning the asset over its useful life. One of the primary

benefits of life cycle costing for capital assets is that during initial asset acquisition, the analysis shows which asset is the most cost effective over the long term, not just which is the cheapest to acquire. In addition, after the asset has been acquired, life cycle cost analysis can be used to budget and plan for the most cost-effective maintenance strategies.

Pavement was one of the first asset classes to which governments applied life cycle cost analysis.ⁱ This is because pavement is a relatively simple asset to analyze and because of the large cost of paving in government budgets. This article will provide an introduction to life cycle cost analysis, using pavement and the City/County of San Francisco, California, as an illustration.

In 2010, the city found that the cost of underfunded preventative maintenance on its streets had resulted in the streets deteriorating to the point where almost half of them would require costly reconstruction. In fact, the city found that, without preventative maintenance, a San Francisco street would cost four times more over the course of 70 years than if it had been maintained regularly.ⁱⁱ The city had a 10-year capital improvement plan that emphasized the need to find a financially sustainable way to keep the streets in acceptable condition.ⁱⁱⁱ To do so, the city turned to life cycle cost analysis.

BUILDING LIFE CYCLE COST ANALYSIS

San Francisco first needed a basic model for how streets deteriorate and how performance and remediation costs change at different points in the asset's life cycle. The city built its model around the pavement condition index, or PCI, which is an industry-standard measure of street quality. Under PCI, a street is rated 0 to 100, where 100 is the best condition. A measure of asset condition is essential for life cycle cost analysis because an asset might require more or less costly maintenance treatments at different conditions. For example, the city found that the average cost to maintain a street block is between \$15,000 and \$37,000^{iv} when the PCI of that street is between 79 and 60. However, when the PCI dips below 60, the same routine maintenance is no longer sufficient to make a meaningful repair. Instead, when the PCI is between 59 and 50, the road must be resurfaced, at a cost of \$144,000 per block. Below 50 PCI, the road must

be reconstructed. This can be quite costly. Reconstructing a road between 0 and 24 PCI costs approximately \$510,000. Reconstructing a road between 49 and 25 PCI is less costly but still considerable at \$167,000. Obviously, if the city allowed its streets to deteriorate too much, the long-term cost would be enormous.

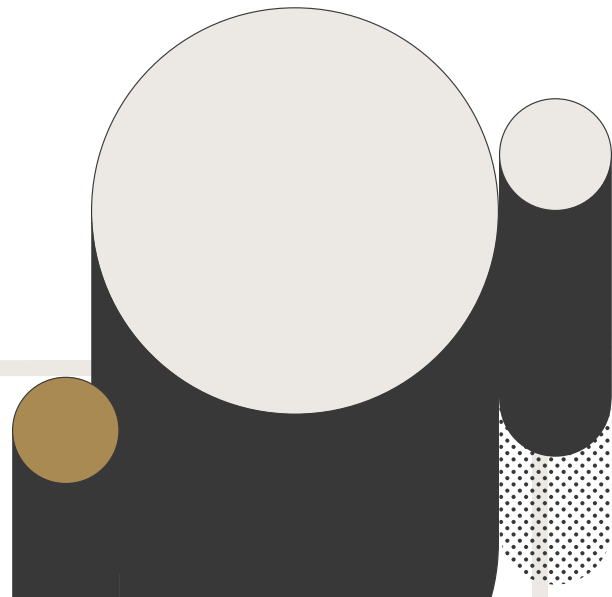
The city's model of street deterioration needs to be informed by an understanding of the local conditions that contribute to street deterioration: primarily, traffic patterns and weather.

For traffic, the city takes into account traffic flows and utilization. The city considers three types of roads, using categories that are common to urban planning: residential (least busy), collectors, and arterials (busiest). The city also accounts for what kind of vehicles (e.g., trucks versus automobiles) use a road as a proxy for determining weight loads, which have a significant impact on how quickly a street deteriorates.

With respect to weather, San Francisco's streets are exposed to salt water and fog, especially near the ocean coastline. Humidity accelerates the deterioration of streets. Fortunately for the city, San Francisco's streets do not experience exposure to ice, snow, or extreme hot and cold temperatures—all of which have a significant negative impact on pavement.

All these variables help the city identify a deterioration curve, which is a model for how quickly a given street will deteriorate over time. Deterioration curves are necessary for life cycle cost analysis of any type of asset because the curve reveals the most cost-effective point at which to perform a maintenance project. To develop a curve, you need a robust set of historical condition, age, and failure data, which suggests how quickly the asset deteriorates. The data also allows a government to differentiate the performance of different types of assets. For example, the data might show that an asphalt street will deteriorate faster than a concrete one. The factors that influence deterioration, other than age, also need to be accounted for. Traffic volume, weight, and environmental factors are most important for roads. Other assets might be affected by operating hours, peak loads, and operating pressure. In some cases, the materials involved, technologies/design standards, and even specific equipment manufacturer and models might have a significant impact on the size and shape of the deterioration curve. We'll see San Francisco's curve, combined with cost data, in the next section of this article.

The final piece of the foundation for life cycle cost analysis is historical costs, which are used to model expected future costs. The city takes historical costs from completed street maintenance projects. City staff also speak with local contractors and other people with knowledge of the construction market to get a sense of the direction costs are headed. For example, petroleum is a key ingredient in street repair, so if the price of oil rises, street repair costs will, too.

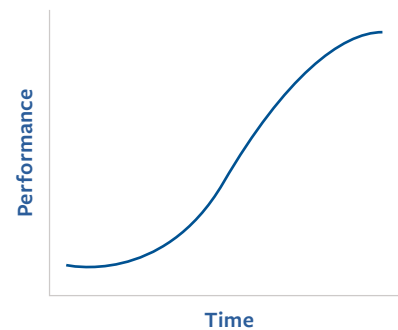


USING LIFE CYCLE COSTING TO GUIDE DECISION-MAKING

Making decisions with life cycle cost analysis requires fashioning the elements described earlier into a decision framework. San Francisco combines its deterioration curve with cost data to create one of their primary decision tools: an “S curve.” An S curve is a common statistical method, so called because of the S-like shape of the curve. It is flatter at the beginning and end and steeper in the middle (see Exhibit 1). S curves are often used in engineering and business applications. For example, a new product may not sell briskly at first because it needs to find its market. This would be represented by the lower left-hand portion of the line in Exhibit 1. At some point, sales increase more rapidly (the middle of the line). Eventually, sales level off as the market becomes saturated (the upper right-hand portion of the line). An S curve could be oriented like a standard S, as in Exhibit 1, or a backward S, like we will soon see.

San Francisco’s S curve (shown in Exhibit 2) is a little more complex than that shown in Exhibit 1, but the basic concept is the same. We see that at the top of the curve, the rate of deterioration is slower and, thus, the line is flatter. Then the rate of deterioration increases and the line gets steeper. Finally, as we approach a PCI of zero, the line flattens out

Exhibit 1 | An S Curve Archetype



again. Exhibit 2 shows that quality drops much more rapidly after the road deteriorates beyond a certain point (60 PCI). It also shows the cost to restore the road to 100 PCI is at least five times greater when the PCI drops to 20 versus when it drops to 60. The shape of the S curve varies for different kinds of streets. A street with more traffic, which is used by heavier vehicles, or a street that is closer to the ocean and thus exposed to more fog and salt water, deteriorates more rapidly than a street that is not exposed to these conditions, all else being equal.

Exhibit 2 | Pavement Life Cycle for a Street in San Francisco

Pavement Life Cycle

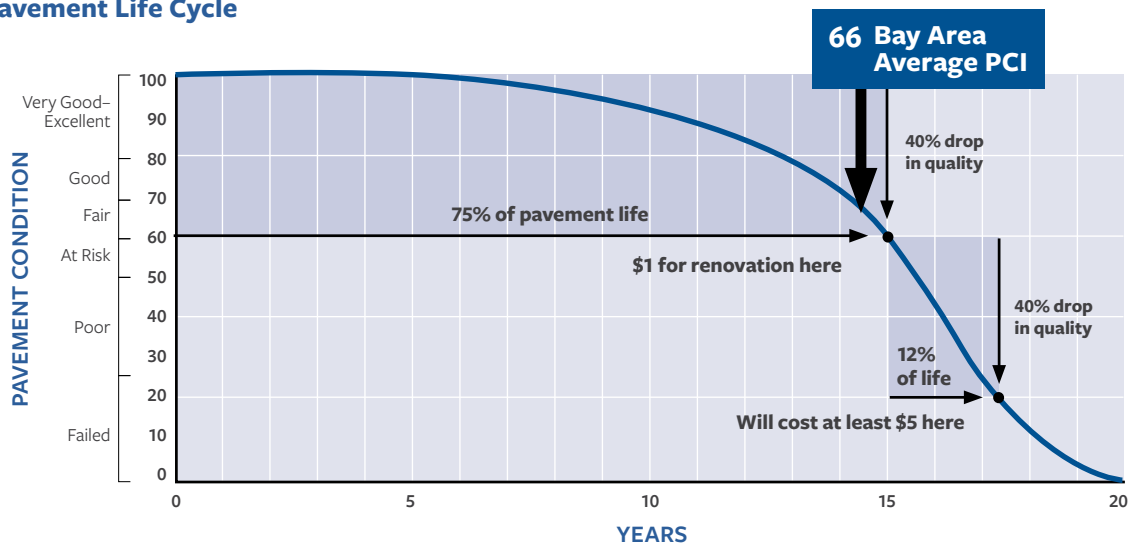
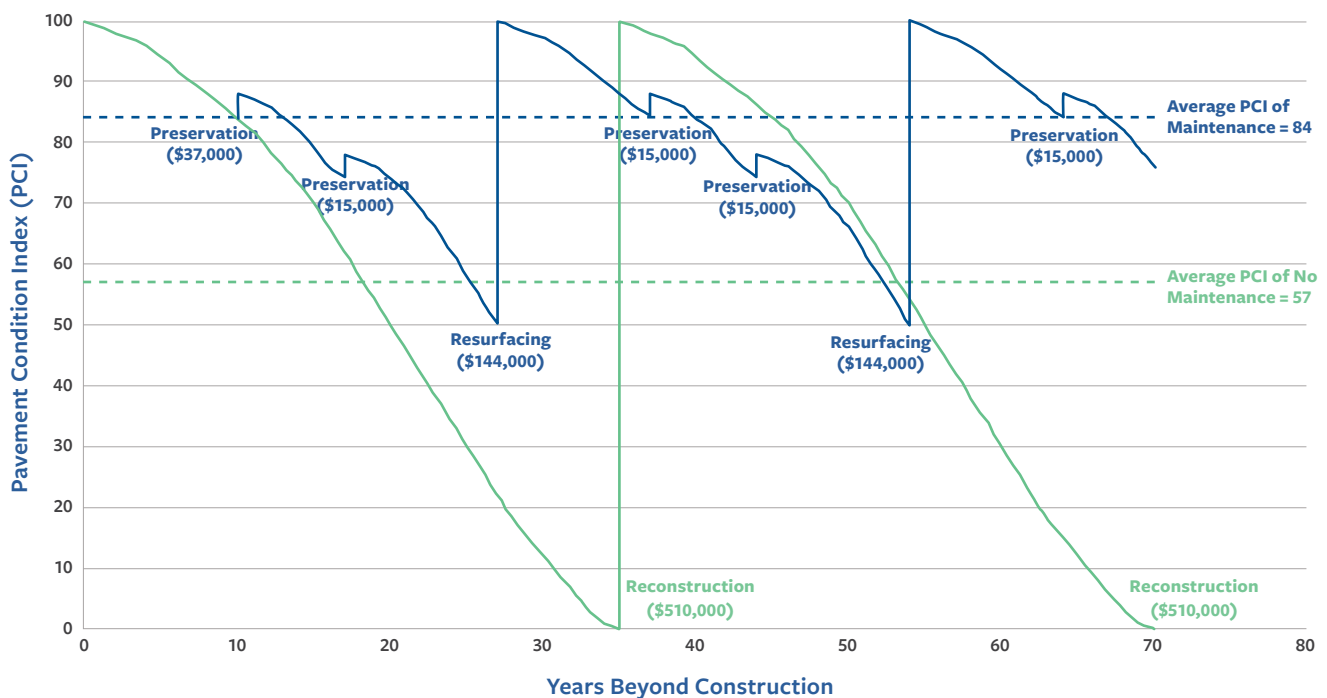


Exhibit 3 links multiple S curves together for a more sophisticated life cycle cost analysis. In Exhibit 3, the green line is two S curves. It shows a hypothetical case where the city conducts no maintenance and simply lets a road deteriorate to the point of complete collapse and then rebuilds it twice over a 70-year period. The blue lines show several smaller S curves that represent a more proactive maintenance strategy. Here, a road deteriorates until it reaches a PCI in the mid-80s. Then a minor preservation project is sufficient to restore some of the road's condition. This repeats when the road reaches a PCI in the mid-70s. Once the road reaches a PCI of 50, a paving project restores the road to a PCI of 100. Hence, the road never reaches the point (PCI of 49 or below) where reconstruction is needed.

The S curve shows that the total cost of street maintenance over 70 years is less with the strategy described by the blue line. The total cost of the projects contemplated by the blue line is \$385,000, while the total cost of the projects contemplated by the green line is more than \$1 million! Of course, the residents of and visitors to San Francisco also enjoy substantially better street quality with the strategy shown by the blue line, which delivers an average PCI of 84 over the 70 years. The average PCI for the “no maintenance” scenario is 57.

This same model could be used to consider other approaches as well. For example, if the city only did paving projects and did no interim preservation projects, it would need to do four paving projects during the 70-year period to stay above 50 PCI. This would come to \$576,000. (This scenario is not depicted in Exhibit 3.)

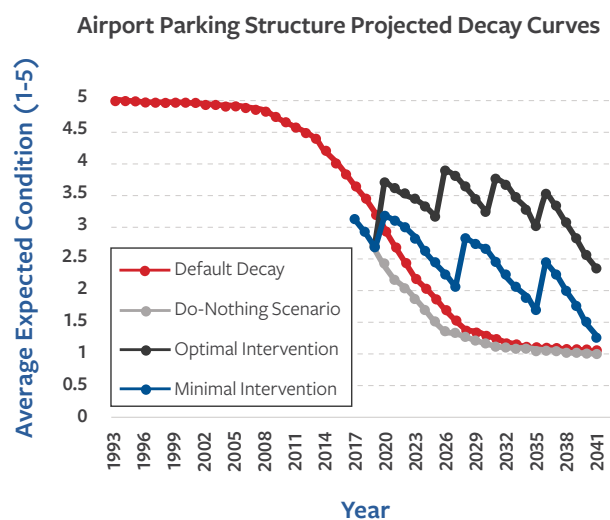
Exhibit 3 | San Francisco's Pavement S Curve for Life Cycle Costing Over a 70-Year Period



The S curve for life cycle costing has helped the city find the most cost-effective approach to maintaining its streets. First, it clearly shows what happens if the city fails to maintain its streets: The PCI will fall below 50, thereby necessitating costly reconstruction. This highlights the need to direct adequate funding to street maintenance in order to prevent this from happening. In fact, City Council members now explicitly ask how potential cuts in funding would impact PCI. Second, discussions on which area of the city should receive street maintenance dollars can be grounded in objective data. There is a compelling case for directing funding to streets where PCIs are in danger of falling below 50 or where it is otherwise cost effective to perform a maintenance project. This brings more equity in spending because discussion is focused on maintaining acceptable street quality in all neighborhoods. Finally, the life cycle cost analysis spurred a discussion about new funding sources for street maintenance so the city could bring its worst streets above 50 PCI and eventually get all streets on a cost-effective maintenance program.

S curves can be used for asset classes other than streets. Exhibit 4 shows a set of curves used by an airport to help make a rehabilitate-versus-replace decision for 25-year-old parking garages. The airport compared the garages' current condition to industry standard deterioration curves. This allowed the airport to examine the cost/benefit of multiple investment scenarios. These scenarios ranged from "do nothing" to complete replacement to an optimal maintenance intervention for the existing garages. The life cycle cost analysis was used to justify investments over the remaining 25 to 30 years of life of the garages. Continued investments under the "minimal" and "optimal" intervention scenarios were determined to be four to five times more cost effective than building a new structure.

Exhibit 4 | S Curves for a Parking Structure



LESSONS LEARNED

San Francisco's experience with life cycle costing holds a number of lessons for other local governments that would like to improve their financial decision-making when it comes to asset acquisition and maintenance.

Get started with life cycle cost analysis on pavement or another easy-to-model asset.

- Pavement is a relatively simple asset, where the condition of the asset is easy to measure, historical maintenance costs are widely available, and the conditions that contribute to deterioration of the asset are well known. Further, street maintenance is often a large budget item for local governments, so the potential financial benefits of better decision-making is substantial. But pavement is not necessarily the only asset that has these characteristics. Other assets might include pipelines and mechanical equipment (e.g., pumps or motors).

Find a compelling question to answer with life cycle costing analysis.

- In San Francisco, street conditions had become a high-profile issue, and people wanted to know the best way to keep the streets in good repair and in which parts of the city public funds would be best used. Life cycle costing answered that question. If a compelling question exists for an asset class other than pavement, that asset class might be a good starting point for life cycle costing.

Use a measure of asset condition that speaks to the public's experience.

- Life cycle cost is an abstract concept, but the quality of the ride on a road is concrete. PCI is a direct indicator of the quality of the experience the public will have when using roads. This makes discussion of road maintenance more meaningful for elected officials and others and, therefore, makes life cycle cost analysis more compelling.

Develop an easily understood decision framework.

- San Francisco's S curve shows how pavement quality relates to potential investment decisions at all points in the asset life cycle. The S curve helps everyone involved in the decision process understand the implications of life cycle costing analysis.

NOTES

- i “Maximizing the Value of Investments Using Life Cycle Cost Analysis,” American Society of Civil Engineers and Eno Center for Transportation. 2014.
- ii “Between a Pothole and a Hard Place: Funding Options for San Francisco’s Street Resurfacing Program,” City and County of San Francisco. June 8, 2010.
- iii Available at onesanfrancisco.org/the-plan/overview.
- iv The first instance of a Pavement Condition Index preservation project on a new street entails certain costs that do not have to be incurred again in subsequent preservation projects.

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