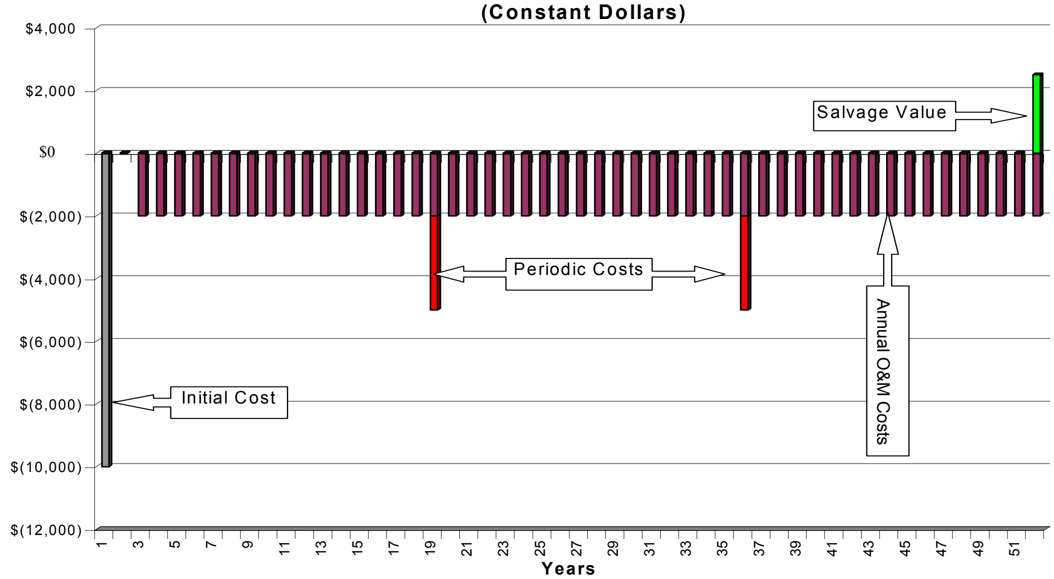
LIFE CYCLE COSTS
FOR GRAVINA ACCESS PROJECT

Part 1: Explanation of Life Cycle Costs

Definition of Life Cycle Cost
Life Cycle Cost is defined as the overall estimated cost of a single project alternative over the life of the project or a defined period. All of the income and expenses associated with the project that occur during its life are used to calculate the life cycle cost. Comparing their life cycle costs is a common way to evaluate different alternatives. Life Cycle Costs can be compared using Present Worth (P/W), Future Value (F/V), or Annual Costs. For the Gravina Access Project, present worth is used to compare the life cycle costs of different alternatives.

Cash Flow
A cash flow diagram is often used to show how money is spent and earned. A simple cash flow diagram is shown in Figure 1. In this figure, each vertical bar represents the net expense or income for a single year. A vertical bar below the $0-line indicates that money is spent on the project and a bar above the $0-line indicates that money is earned or gained. The cash flow

Figure 1 - Cash Flow Diagram for Life Cycle Costs
(Constant Dollars)



includes initial costs, annual operating and maintenance (O&M) costs, periodic maintenance costs, and salvage values. "***Constant dollars***" are used in this diagram, which means that the income and expenses do not include the effects of inflation. Also, annual operating and maintenance costs actually occur throughout the year, but in this cash flow diagram they are shown as a lump sum at the end of the year. A cash flow diagram similar to this was used for Gravina Access Project alternatives. Using a car as an example, the following shows the components of a cash flow diagram.

Car Example 1: The cash flow diagram for an automobile paid in full on the day of purchase includes the following costs:

- The *initial cost* is the price that is paid for the vehicle and any taxes and fees paid at the time of purchase.
- *Annual operating and maintenance costs* include the annual cost of fuel, oil, fluids, insurance and other costs that occur every year.
- *Periodic maintenance costs* include new tires, new brakes, new batteries and other maintenance costs that occur throughout the life of the vehicle to keep the vehicle in service.
- The *salvage value* is the price that the vehicle is sold for at the end of its useful life.

Time Value of Money

When dealing with money or finances for a project over a long period, the time value of money must be considered. The value of money changes over time due to inflation and interest rates.

Inflation decreases the value of money over time by increasing the cost of goods and services. When we say, "A dollar today isn't worth what it used to be," we are usually referring to the loss in a dollar's value due to inflation. If we have $100 dollars to buy an item today, the same item 50 years ago would have cost $37, assuming a 2% inflation rate. Similarly, an item that costs $100 in the Year 2000 will cost about $270 in the Year 2050 at a 2% inflation rate.

Interest accrued over time increases the amount of money. Another way to think about this is that you can "make money" with the money you have in hand today. For example, suppose you put $10 into a bank account that pays 6.3% annual interest. If you leave the account alone and let that original $10 and the interest accumulate, it will be worth $212 in 50 years.

Because the value of money changes over time, it is very important to specify the year that the dollars are stated in. In the previous example, the $100 price for the item is stated in Year 2000 dollars. When inflation is used to calculate the future cost, the $270 price is in Year 2050 dollars.

Present Worth

Inflation and interest rates are combined to determine the ***present worth*** of an item. First, we assume that the price of the item purchased today is known. Second, an inflation rate is used to determine the future cost. The interest rate is used to determine how much money would have to be set aside today to pay for the item in the future. Together these factors determine the present worth of the item. Figure 2 shows the simplified cash flow diagram from Figure 1, but with the effects of inflation.

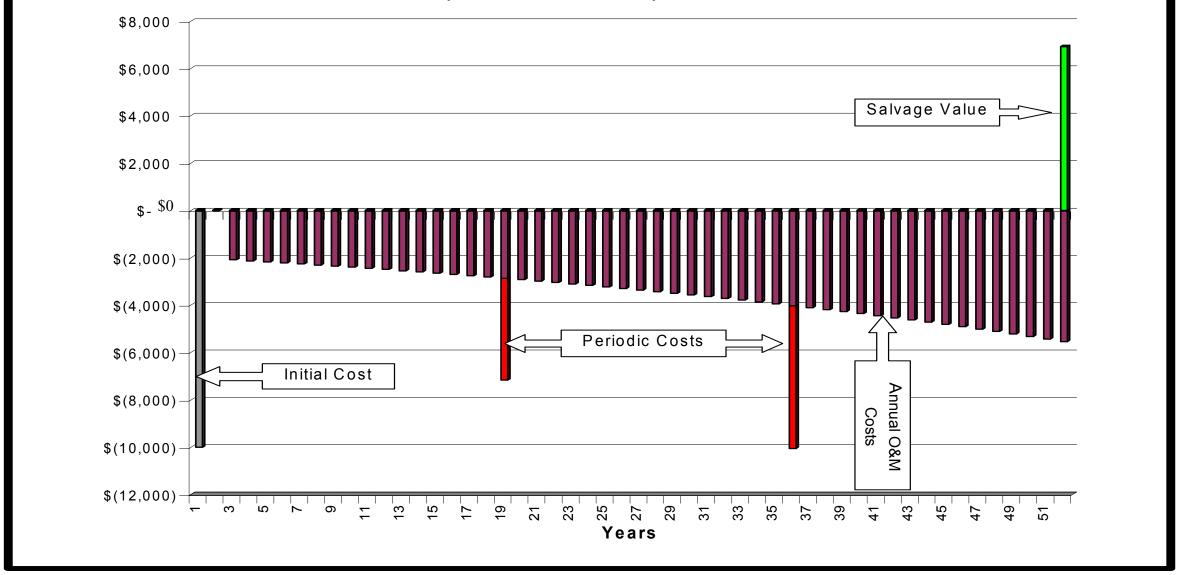


Figure 2 - Cash Flow Diagram for Life Cycle Costs
(Includes Inflation)

The equation for calculating the future cost for an item is:

$$\text{Future Cost} = \text{Present Cost} \times \underbrace{(1 + \text{inflation rate})^{t}}_{\text{Inflation}} \qquad \text{where } t = \text{number of years.}$$

The present worth of a future transaction is:

$$\text{Present Worth} = \text{Future Cost} \times \underbrace{(1 + \text{interest rate})^{-t}}_{\text{Discount Factor}}$$

Car Example 2: You decide that you want to purchase a new vehicle in 5 years. The 2000 model is currently selling for $20,000 (in Year 2000 dollars). With 2% inflation you can assume that when you buy the new 2005 model it is going to cost $22,082 (in Year 2005 dollars). Today, if you deposit $16,269 (Year 2000 dollars) in an account that generates 6.3% interest and the account balance is allowed to accumulate, you would have enough money for the new vehicle in 5 years. $16,269 (in Year 2000 dollars) is the present worth of the 2005 model.

The associated calculations are:

$$\text{Future Cost} = \$20{,}000 \times (1 + 0.02)^{5} = \$22{,}082$$

$$\text{Present Worth} = \$22{,}082 \times (1 + 0.063)^{-5} = \$16{,}269$$

Salvage Value

The salvage value is the value of an item at the end of the life span. The straight-line method of depreciation is the method that is used to determine the salvage value for this project. This method states the value of an item decreases in value at a constant rate until it reaches the end of its life span, at which point in time the value of the item is zero. Hence, when the item is halfway through the life span, the item is worth half of its original price. When the item is 75% through its life, its salvage value is 25% of its original price.

Salvage Value = Cost of Item x (1 – n / Life of Item)

where n = the time at which the salvage value is calculated.

Example 3: An item is purchased for $1,000. It has a life span of 50 years and zero salvage value at the end of its life. If you sold the item in 20 years the salvage value of the item would be $600.

Calculations:
Salvage Value in 20 years = $1,000 x (1 – 20 / 50) = $600

In the example above, a salvage value is calculated for an item that is purchased and sold. There is also salvage value associated with periodic maintenance. An item is worth more if it is maintained. The value of the maintenance performed is greater immediately after it is maintained and the value diminishes as you get closer to the next required maintenance. The straight-line method of depreciation described above is also used to determine the salvage value of periodic maintenance.

Car Example 4: You own an old car in desperate need of a new engine. The cost of purchasing and installing a new engine is $5,000. The engine must be replaced every 15 years. If the car is sold 5 years after the engine is replaced, the salvage value the new engine adds to the value of the car is $3,333.

Calculations:
Periodic Maintenance Cost = $5,000
Salvage Value in 5 years = $5,000 x (1 – 5/15) = $3,333

Part II: Calculating Life Cycle Costs for Gravina Access Project:

Life cycle costs for the Gravina Access Project alternatives were determined using the present worth value for the Life Cycle Cost analysis. Because construction is scheduled to start in the Year 2003, the life cycle costs for all alternatives were computed in Year 2003 dollars.

The calculations were performed using a cash flow diagram in constant 2003. For example, repaving of the bridges is planned to occur once every 20 years at a cost of $13 per square meter (2003 dollars). This means that at Years 2026, 2046, 2066, etc., an expense of $13 per square meter will be included as a project expense. Present worth is calculated using a nominal interest rate of 6.3% and an inflation rate of 2% for all alternatives.[1]

The same evaluation period was used for all alternatives so that the comparison between alternatives is fair. The project period used for this evaluation is 50 years, which is the expected life span of the ferry vessels. Hence, for the Gravina Access Project, the 50 year life span starts at the beginning of Year 2006 and terminates at the end of 2055.

As is commonly done in life cycle cost studies, the salvage value at the end of the project life span for structures such as bridges and tunnels is established using a straight-line method of depreciation, based on the life of the structure.

Initial cost of Construction: Construction is expected to begin in 2003 and to last for approximately three years. The initial cost of construction and project development was distributed over the construction period and occurs at the beginning of the year (2003 to 2005). Construction is expected to be complete at the end of 2005.

Annual Operating and Maintenance Costs: Annual costs are lumped at the end of the year beginning at the end of 2006 (beginning of 2007) and the final cost occurs at the end of 2055 (beginning of 2056).

Periodic Maintenance Costs: Periodic maintenance costs include repaving, mechanical/ electrical equipment replacement, and terminal maintenance. Each of these maintenance items occurs at its respective frequency **f**. The first cost occurs **f** years after the beginning of 2006. Salvage value of the periodic maintenance costs after the 50^{th} year is determined using the straight-line method of depreciation.

Structure Options: The proposed bridges have an expected life of 75 years and the proposed tunnels have an expected life of 75 years. Salvage value for bridges and tunnels after the 50^{th} year is determined using the straight-line method of depreciation.

Ferry Options: It was assumed that with proper maintenance, the useful life of the proposed ferry vessels is 50 years. It was assumed that the ferry vessel has zero salvage value at the end of its 50-year life. It was assumed that one of the existing ferry vessels will be replaced at the beginning of the project life in 2006 and that the other existing ferry vessel will be replaced at the 10^{th} year of the project life. The salvage value of all the ferry vessels at the end of the 50-year project life was calculated using the straight-line method of depreciation.

[1] Federal Highway Administration – Office of management and Budget (OMB) Circular No. A-94, Appendix C. January 2000.

Summary of Alternatives and their Cash Flow Components (in constant Year 2003 dollars):

Bridge alternatives

- Initial Cost of Construction
- Annual Operating and Maintenance Costs
- Periodic Maintenance Costs:
  - Repaving
- Salvage Value
  - Value of periodic maintenance costs after the 50th year.
  - Value of bridges after the 50th year

Moveable Bridge alternative

- Initial Cost of Construction
- Annual Operating and Maintenance Costs
- Periodic Maintenance Costs:
  - Repaving
  - Electrical equipment replacement on moveable bridges
- Salvage Value
  - Value of periodic maintenance costs after the 50th year.
  - Value of bridges after the 50th year

Tunnel alternatives

- Initial Cost of Construction
- Annual Operating and Maintenance Costs
- Periodic Maintenance Costs:
  - Repaving
  - Mechanical equipment replacement
- Salvage Value
  - Value of periodic maintenance costs after the 50th year.
  - Value of tunnel after the 50th year

Ferry alternatives

- Initial Cost of Construction
  - Construction
  - Ferry system acquisition
- Annual Operating and Maintenance Costs
- Periodic Maintenance Costs:
  - Repaving
  - Marine terminal fender/dolphin replacement cost
  - Ferry main propulsion and generator replacement costs
  - Existing ferry replacement at the 10th year
  - Salvage Value
  - Value of periodic maintenance costs after the 50th year.
  - Value of vessel after the 50th year.