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INTRODUCTION TO LIFE CYCLE COST ANALYSIS

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INTRODUCTION TO LIFE CYCLE COST ANALYSIS

TCM Framework: 2.3 – Strategic Asset Management Process Map
3.3 – Investment Decision Making
5.1 – Asset Cost Accounting
7.3 – Cost Estimating and Budgeting
11.5 – Value Management and Value Improving Practices (VIPs)
11.6 – Environment, Health, and Safety Management

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1. INTRODUCTION

Life cycle cost analysis (LCCA) is a comprehensive economic assessment method used to evaluate the total cost of owning, operating, maintaining, refurbishing, and disposing of an asset over its expected life span. LCCA extends beyond initial acquisition or construction costs to include all subsequent expenses, such as operation, maintenance, upgrades, and eventual disposal costs, as well as the potential savings or benefits over the asset's life. The primary purpose of LCCA is to assist decision-makers in choosing the most cost-effective option among different competing alternatives. By evaluating the total cost of ownership of a project, asset, or system over its entire lifespan, LCCA enables informed decision-making that balances initial investment costs with long-term operational, maintenance, and disposal costs.

The AACE International Total Cost Management Framework states that "the most important business requirement for most enterprises, and the basis for their asset investment decisions, where applicable, is a measure of economic return on investment; a single measure that expresses in monetary terms the value of investment over its life cycle to the enterprise." [1, p. Section 5.1.1.1] A goal of cost engineering[1] is to support decision-making, ensuring that the best option among competing alternatives is selected, followed by effectively managing project execution to realize all project goals and objectives. Support for early investment decisions should place a focus on determining the optimal life cycle cost option. The result of an effective LCCA provides that single monetary measure of value, which should underpin the selection of a preferred alternative or the decision to approve (or disapprove) a final capital investment decision. There are times when other constraints, such as limited capital funds, may not support the lowest life cycle cost option; however, due diligence should always encourage life cycle cost analysis as a part of the decision-making process.

Life cycle cost analysis is important in supporting overall investment decisions that underpin effective strategic asset management, "the macro process of managing the total life cycle cost investment of resources in an enterprise's portfolio of strategic assets." [1, p. Section 2.1.1] However, LCCA can be just as important in selecting an optimal technology during the project development process for an asset (value engineering) as it may be in choosing the preferred replacement pump during the operation and maintenance of an asset. LCCA enables value-driven decision-making by identifying the most cost-effective option among competing alternatives, focusing on total cost of ownership rather than just initial capital expenditures. This approach is especially critical in infrastructure, industrial, and public sector projects where long-term costs can significantly exceed initial capital costs.

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Primary Objectives of LCCA:

- Optimize long-term investment decisions by comparing alternatives based on total life cycle costs, rather than acquisition price alone.
- Identify cost-saving opportunities through design, material, or system selections that minimize operational or maintenance demands.
- Enhance sustainability by incorporating energy consumption, maintenance requirements, rehabilitation needs, and end-of-life considerations.
- Strengthen funding justification and compliance with regulatory and stakeholder requirements for both public and private sector capital projects.
- Quantify trade-offs between competing priorities such as durability, quality, and environmental impact and other competing priorities to inform balanced decision-making.

Life cycle cost analysis is best understood as one tool within the broader framework of organizational investment decision-making and engineering economic analysis. Enterprises routinely face competing demands for limited capital and must weigh options that differ not only in initial cost but also in long-term economic impact. In this

[1] Using the term broadly to describe the skill areas of estimating, scheduling, project controls, risk management, etc.

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context, LCCA provides a structured, quantitative basis for comparing alternatives on the grounds of total cost of ownership, ensuring that decisions are not driven solely by near-term affordability but by overall value to the enterprise.

Within the engineering economics discipline, LCCA complements methods such as net present value, internal rate of return, and benefit-cost analysis by focusing specifically on the full spectrum of asset costs across its life span. Where financial metrics help evaluate return on investment at the portfolio or program level, LCCA offers the detailed cost visibility needed to support asset-level trade-offs, technology selection, and design optimization. When embedded in stage-gate processes, portfolio prioritization, or value engineering studies, LCCA ensures that strategic asset management decisions are informed by both immediate budgetary considerations and long-term operational performance. In this way, LCCA bridges engineering, finance, and management disciplines by linking technical alternatives with economic criteria and aligning project-level choices with organizational strategy.

This recommended practice (RP) of AACE International introduces life cycle cost analysis as a crucial tool for assessing the total cost of ownership of assets over their lifecycle. It will address the concept, purpose, methodologies, and application of life cycle cost analysis. It will also address life cycle cost estimating, which is a key step in the overall LCCA process.

This document is not intended to be a standard. It is intended to provide a guideline that most practitioners would consider as good practices, which can be relied upon and recommended for use where applicable.

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2. RECOMMENDED PRACTICE

2.1. Key Definitions

Life cycle costs (LCC) are "the total capital and expense costs involved in the lifetime ownership of an asset, including the costs of acquisition, lifetime operations, lifetime maintenance, refurbishment, and disposal costs, less the costs of any residual salvage value." [2]

Life cycle cost analysis is "an economic evaluation method for assessing the total cost of lifetime ownership of an asset. It considers all costs (capital and expense) of acquiring, operating, maintaining, and eventually disposing of an asset. When focused on the selection between competing alternatives, life cycle cost analysis may include only the lifetime costs of the specific variables between the alternatives (all other costs being equal)." [2]

A life cycle cost estimate (LCCE) is "an estimate prepared in support of life cycle cost analysis. A life cycle cost estimate will provide a prediction of probable costs for the development of an asset from initial concept development through the asset's end of life (including any costs associated with asset demolition and disposal)." [2]

2.2. Asset Life Cycle

An asset is a unique physical or intellectual property that is of long-term or lasting value to an organization or enterprise. Although generally referring to capital assets, the term includes assets developed under expense costs. Typical examples of an asset include a building, a process plant, a software product, an airplane, or a theatrical play. The term asset lifecycle refers to "the sequence of stages that an organization's assets will go through from the initial identification of the need for an asset through its development and creation, operation and maintenance, and eventual retirement of the asset." [2] Organizations may acquire assets in many ways, including through development, purchase, or lease.

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Many projects employ a stage-gate system of project development that supports decision-making leading up to the development or construction of a physical asset. Project development teams are often interested in optimizing the capital costs of asset creation, sometimes without considering the costs of asset operation and maintenance. However, for most long-term assets, the stage of asset utilization that includes operation, modification, and maintenance costs may easily exceed the initial cost of asset investment, sometimes by multiples of the original asset investment cost. Figure 1 illustrates these concepts.

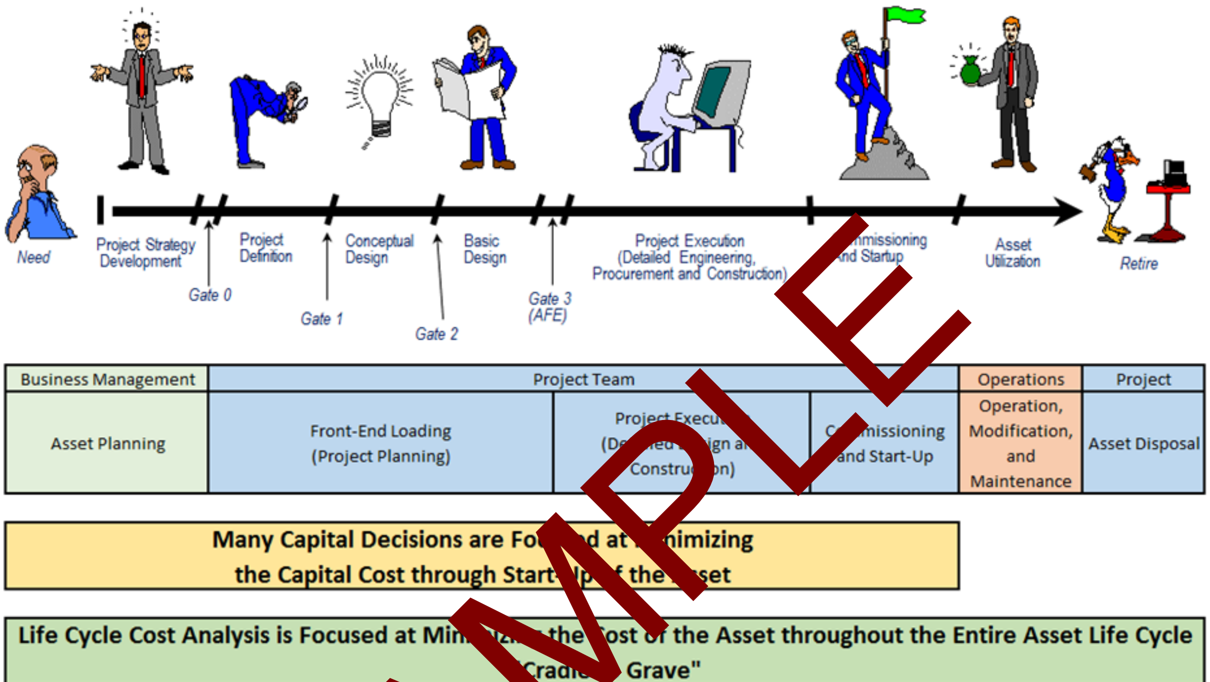

Figure 1: Asset Life Cycle and LCCA

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LCCA emphasizes the importance of considering not just the initial acquisition costs of an asset but also the operational, maintenance, and disposal costs when making informed financial investment decisions. Figure 2 illustrates that the cost of operating, maintaining, and retiring an asset may dwarf the cost of asset acquisition (procuring or constructing an asset).

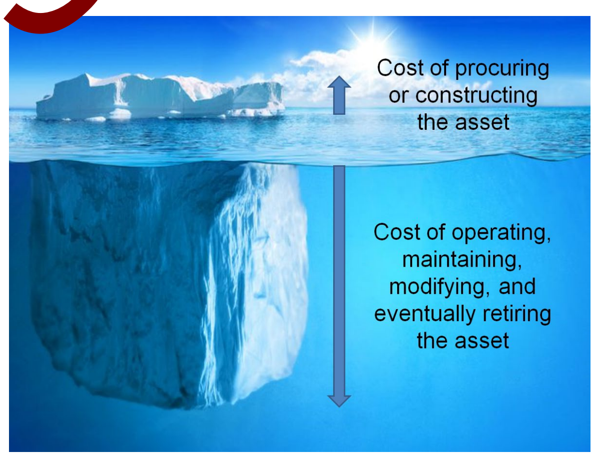

Figure 2: The LCCA Iceberg Metaphor

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Too often, investment decisions for capital projects are based on examining only the tip of the iceberg. The cost of operating the asset is often not considered as thoroughly as it should be. For example, for an operating process facility, the operation and sustaining capital costs over the asset's lifetime may be multiples of the initial capital investment cost. Operating costs typically include items such as operating plant personnel, fuel or other energy costs, and ongoing maintenance costs. Sustaining capital costs typically include refurbishments, modifications, and replacements of the facility's components. As shown in Figure 2, the costs of operating, maintaining, and retiring an asset may be multiples of the cost of creating it.

2.4. LCCA Methodology

A typical process for conducting a life cycle cost analysis is outlined below. While these steps are typical, each LCCA should be tailored with organizational policies and industry-specific best practices. Equally important is securing stakeholder buy-in on the purpose, methodology, and expected outputs of the analysis at the outset of the process.

1. Identify and Define the Problem Requiring an LCCA and the Approach to Conducting the LCCA:
    a. Identify the Opportunity: Recognize the opportunity or problem, such as creating a new asset, modifying an existing asset, or retiring an asset. Clearly define the scope and objectives of the analysis, ensuring alignment with the organization's broader strategic goals, operational needs, and long-term value drivers.
    b. Define the Study Period: Consider the asset or project's life span to determine the relevant time horizons for the analysis.
    c. Establish the Methodology to be Used in Conducting the LCCA: Clearly document the LCCA process, using a structured approach such as the one outlined here, and define the key ground rules and assumptions that will frame the study. Ensure all stakeholders agree on the selected methodology before proceeding.
    d. Establish Decision Criteria: Establish the financial or other criteria for decision-making, such as present value versus future value and the discount rate to be used. This step ensures that all stakeholders agree on the parameters and expectations of the LCCA, and that the financial decision criteria reflect the organization's investment priorities, risk tolerance, and performance objectives outlined in its strategic plan.
2. Develop Potential Alternatives/Solutions:
    a. Identify Alternatives: Define and investigate viable alternatives that may have economic impacts to be considered in the analysis. This may include capital-intensive solutions, non-capital solutions, or maintaining the status quo. An LCCA may include a wide variety of alternatives. For example, alternatives as diverse as land acquisition and construction, facility leasing, and continuing with the status quo might all be included in a single study.
    b. Assess Viability and Scope: Assess the feasibility of each alternative, ensuring that each option is practical and within the scope of the analysis.
3. Develop the Cost Breakdown to Support the Analysis:
    a. Define a Cost Structure: Develop a comprehensive cost breakdown structure that includes acquisition costs (e.g., planning, procurement, construction) and sustaining costs (e.g., operating, utility, maintenance, repair).
    b. Develop Appropriate Categorization: Categorize costs in a manner that aligns with the specific problem and alternatives, providing a clear and detailed cost analysis framework.
4. Collect Data and Information to Support Cost and Benefit Values:
    a. Collect Data: Gather extensive data to ensure reasonable and unbiased estimates for all elements of the cost breakdown structure.
    b. Ensure Comprehensive Coverage: Address all elements of acquisition and sustaining costs for each alternative, aiming for accuracy and reliability in cost and benefit estimates.
5. Prepare Cost Profiles and LCCA Model Estimates for Each Alternative:

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   a. Identify Cost Profiles: Develop detailed cost/benefit profiles over time for each alternative, showing the financial impacts across the asset's lifecycle.
   b. Develop LCCA Model Estimates: Prepare LCCA model estimates using appropriate discount formulas to support financial analysis, ensuring the models are sufficiently detailed to capture significant cost and benefit impacts without unnecessary complexity.
6. Analyze Results:
   a. Validate Reasonableness: Analyze the results for reasonableness and consistency, ensuring that the outcomes are logical and aligned with expectations.
   b. Develop Supporting Analyses: Prepare additional analyses, such as Pareto charts to identify key cost drivers or break-even analyses to determine critical points. Conduct sensitivity analyses to test the significance of cost drivers under various assumptions, incorporating uncertainty into the model as necessary.
   c. Recycle as Warranted: Revisit and refine previous steps as needed to adjust the model based on findings and ensure the analysis remains robust.
7. Communicate Results and Determine the Course of Action:
   a. Prepare Reports: Prepare detailed reports that communicate the LCCA results effectively to decision-makers. Highlight key findings, uncertainties, and recommended actions based on the analysis.
   b. Support Decision-Making: Use the analysis to inform decision-making, providing clear and actionable insights that support strategic planning and resource allocation.

By following these steps, organizations can conduct thorough and effective life cycle cost analyses, support informed decision-making, and optimize the economic outcomes of their projects and investments.

Life cycle cost analysis is intended to measure the cradle-to-grave costs associated with the asset or activity under consideration. By capturing all relevant costs over the full life span—from acquisition through operation, maintenance, and disposal—LCCA enables the identification of key cost drivers that influence overall profitability and highlights the trade-offs between competing alternatives. As a foundational tool in Total Cost Management (TCM), LCCA enhances decision-making by shifting focus from short-term expenditures to long-term cost-effectiveness, supporting choices that align with an organization's strategic objectives and value delivery goals.

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The most effective impact from life cycle cost analysis is obtained when it is employed as a value-enhancing practice during the early stages of project planning. It requires identifying alternatives, and reasonable alternatives often require creative ideas. Focus on sufficient complexity to support the decision to be made. LCCA models should be flexible, traceable, and scalable, with supporting data that is quantifiable and defensible.

The techniques for performing life cycle cost analysis are not complex; however, they do require meticulous attention to detail to meet the analysis's objectives. When performed well, they support better decision-making by focusing on long-term costs and benefits to maximize capital investment performance.

2.5. Discounting

Discounting is the general term for converting benefits or costs over time to a consistent basis to support evaluations of alternatives. Discount formulas enable the conversion of benefits and costs that occur at varying times during an asset's lifecycle to a common timeframe. See Appendix A for a more detailed explanation of discounting.

The primary purpose of discounting in life cycle cost analysis is to account for the time value of money, recognizing that a dollar today is worth more than a dollar in the future due to its earning potential. By discounting future costs and benefits to their present values, decision-makers can accurately compare and evaluate the financial implications of different project alternatives over their entire life cycles. However, LCCA is also beneficial when evaluating only a single alternative.

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Key Purposes:

1. Time Value of Money:
    - Present Value Comparison: Most life cycle cost analyses use present value as the common basis for the analysis.[2] Discounting facilitates the conversion of future costs and benefits into present value terms, enabling an apples-to-apples comparison. This helps in understanding a project's real cost or benefit when considering inflation, interest rates, and the opportunity cost of capital.
2. Economic Feasibility:
    - Investment Decisions: By evaluating the present value of life cycle costs and benefits, organizations can determine the economic feasibility of projects. This helps determine whether the expected future benefits justify the initial and life cycle costs. This is true for evaluating a single option or selecting the best alternative among competing options.
3. Accurate Financial Planning:
    - Budget Allocation: Discounting helps in accurate financial planning and budget allocation by providing a clearer picture of the project's financial impact over time. This ensures that resources are appropriately allocated to projects that offer the best value for monetary investment.
4. Evaluating Alternatives:
    - Evaluating alternatives by using discounting to develop a consistent cost basis of comparison allows decision-makers to determine which option provides the best return on investment. The alternative with the highest net present value is generally desirable.[3]

Discounting is a crucial component of all life cycle cost analyses. It enables organizations to make informed decisions by accurately comparing the present value of future costs and benefits. By selecting suitable discount rates and applying relevant discount formulas, decision-makers can accurately assess the true economic impact of projects, ensuring efficient resource allocation and optimal investment performance.

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2.6. Components of Life Cycle Cost Analysis

The components of the analysis include:

1. The cost elements required for the LCCA:
    a. Capital and expense costs of acquisition.
    b. Lifetime operating costs.
    c. Lifetime maintenance costs (including repairs).
    d. Refurbishment[4], if applicable.
    e. Asset disposal costs (at retirement of the asset).
    f. Remaining salvage or residual value (at retirement of the asset).
    g. Any positive cost credits generated during the life of the asset (e.g., reclaimed by-products, tax credits, etc.)
2. The discount rate to be used in the analysis.
3. The escalation rates to be used in the analysis (which may vary by cost element).
4. The study period.

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[2] If consistent discount factors are applied, whether the analysis is expressed in present value or in future value terms, the rank ordering of alternatives will remain unchanged, and the same option will emerge as the "lowest cost" alternative.

[3] Lowest cost may not be the only important element in a decision, so although the lowest present value alternative is often the basis of a decision, other factors (such as other measures of value, shortest break-even duration, limited capital constraints, etc. may also affect the final selection of a preferred alternative).

[4] Refurbishment may include costs that go well-beyond regular maintenance. In some cases, it may rise to the level of a significant capitalized project, requiring the preparation of a separate cost estimate.

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2.6.1. Cost Element Breakdown

At its highest level, the cost breakdown structure for the components of the analysis typically includes:

a. Acquisition costs: Initial (time = 0) costs to develop, create, and/or purchase the asset.
b. Sustaining cost: Future static and recurring costs occurring after acquisition (during the operating stage or use of the asset, including disposal and salvage costs).

As an example, for a car purchase, the buyer may consider the cost elements identified in Table 1.

Acquisition Cost Breakdown	Sustaining Cost Breakdown
Car Purchase Price	Fuel Costs
Car Accessories Price	Insurance Costs
	Maintenance Costs
	Planned Repair Costs
	Unplanned Repair Costs
	Planned Replacement/Refurbishment Costs
	Salvage/Resale/Trade-In Cost
	Other Planned Operating Costs (such as insurance, parking, licenses)
	Unplanned Operating Costs (such as the costs of traffic infractions and parking violations)

Table 1 – Sample Car Purchased Cost Breakdown Structure

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For a facility project, the project owner may consider the cost elements identified in Table 2.

Acquisition Cost Breakdown	Sustaining Cost Breakdown
Asset Planning	Operations Personnel Costs
Project Planning (FEL 1, 2, 3)	Feedstock Costs
Detailed Engineering	Fuel/Energy/Utility Costs
Procurement/Fabrication	Planned Maintenance Costs
Construction	Unscheduled Maintenance Costs
Commissioning/Start-up	Planned Replacement/Refurbishment Costs
	Unscheduled Replacement/Refurbishment Costs
	Disposal Costs (including remediation)
	Salvage (asset recovery costs)

Table 2 – Sample Facility Project Cost Breakdown Structure

2.6.2. Selecting a Discount Rate

For the discount rate, the car buyer may simply use the interest rate that he/she might obtain from their personal bank savings account. Individuals and many smaller organizations will often simply use the current interest rate (the cost of current financing or the rate obtained from typical savings options) as the discount rate.

Certain industries or organizations may require the use of a prescribed discount rate. For example, government projects often mandate that the discount rate be based on a specific standard, policy, or guidebook. Stakeholders should be aware of such requirements and ensure that policy-driven discount rates are applied where applicable.

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For larger business organizations, selecting a discount rate is a more complex process. They will often establish the discount rate as a minimum acceptable rate of return (MARR). The MARR represents the lowest acceptable rate of return that the organization is willing to consider for its projects. This rate is key for evaluating the feasibility and attractiveness of the organization's investments.

Selecting the MARR for Large Organizations:

1. Determining Factors:
    a. Cost of Capital: The MARR often includes the cost of capital, which is the weighted average cost of debt and equity financing. This ensures the rate reflects the opportunity cost of using capital in a project rather than other potential investments.
    b. Risk Premium: A risk premium may be added to account for the specific risks associated with the project. Higher-risk projects typically require a higher MARR to justify the potential uncertainties related to the project's potential cost.
    c. Market Conditions: Current market interest rates, inflation expectations, and economic conditions also influence the MARR. Organizations will adjust the rate based on the prevailing financial environment.
    d. Corporate Strategy: The organization's strategic objectives and investment criteria play a role in setting the MARR. Firms with aggressive growth strategies may opt for a lower MARR to pursue more projects, while conservative firms may set a higher MARR , resulting in a smaller number of approved projects.
2. Selecting the Rate:
    a. Benchmarking: The organization will often benchmark the MARR against industry standards or competitors to determine the appropriate MARR.
    b. Board Approval: The selected rate is often subject to approval by the board of directors or a finance committee to ensure that it aligns with the organization's financial goals and risk tolerance.
    c. Regular Review: The MARR is generally reviewed periodically and adjusted based on changes in the internal and external business environment.

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Impacts of Setting the MARR:

1. Setting the MARR Too Low:
    a. Increased Project Acceptance: A lower MARR makes more projects appear financially viable, potentially leading to over-investment. This can result in the acceptance of projects with lower returns, which may not adequately compensate for their risks.
    b. Misallocation of Capital: Setting the MARR to low may lead to inefficient capital allocation, where funds are invested in less profitable projects, impacting overall financial performance.
    c. Lower Shareholder Value: If returns on investments are lower than the company's actual cost of capital, shareholder value can be eroded over time.
2. Setting the MARR Too High:
    a. Reduced Project Acceptance: A higher MARR results in fewer projects meeting the required return threshold, potentially leading to underinvestment. This can result in missed opportunities for profitable investments.
    b. Excess Cash Reserves: The company may accumulate excess cash reserves that are not effectively utilized, impacting growth and competitive positioning.
    c. Conservative Growth Strategy: Setting a high MARR generally reflects a conservative growth strategy, which could limit the company's ability to expand and innovate in dynamic markets.

Establishing an appropriate discount rate is critical for all LCCAs as it can significantly impact the analysis results. Thus, it directly influences the resulting investment decision.

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