Life Cycle Cost—Who Does What

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Definitions

- **Life Cycle Costs (LCC)--All costs associated with the acquisition and ownership of a system over its full life. The usual figure of merit is net present value.**
- **Net Present Value (NPV)-- A financial tool for evaluating economic value added from expenditures over time.**

LCC Cost Drivers

Life cycle costs are affected by three issues:
1) installation and use practices-
influenced by operations and engineering,
2) component life and death-
influenced by grade of equipment and loads,
3) load profiles-
during various segments of use.

Who Does What?

- **Engineering thinks accounting should do LCC because they know about $'s**
- **Accounting thinks engineering must do LCC because they set system entropy and the details driving costs**
- **The right answer: Engineering must do LCC and present details for audit by Accounting**

The Engineering Paradox

- **Universities** teach engineers to build things that never fail--but they fail!
- **Universities** teach engineers about entropy--but most engineers can't calculate maintenance demands to prevent or overcome deterioration
- **Propaganda** traps us into "dynamic inaction"—we look busy but no LCC

Breaking The Paradox

- **Reliability** is the probability that a device, system, or process will perform it's prescribed duty without failure for a given time when operated correctly in a specified environment
- **Reliability** problems are entropy driven failures which cost money and require trade-off considerations based on LCC

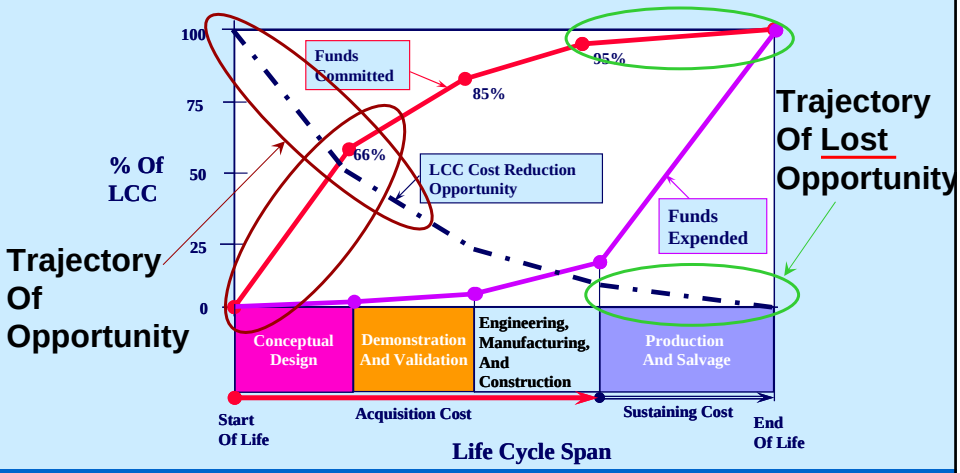
The Pragmatic View

- **Failures** occur when a product or process cannot perform the intended function
- **Failures** cost money over the life cycle
- **Failure** generate down time and cost
- **Failures** degrade paychecks for plants and we need failure free processes
- **Failures** have different cost structures, must be managed, prevented, and reduced

SAE's Approach To LCC

- **Reliability and maintainability calculations** are made up-front to justify decisions—make calculations not proclamations
- **Design out failures** for productivity gains
- **Improve up-time** with less failures
- **Make trade-off decisions early** by calculations—not late by emotion

Early Decisions Are Very Important

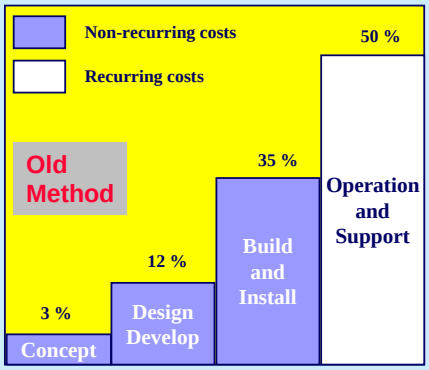


Start LCC W/Design Objectives

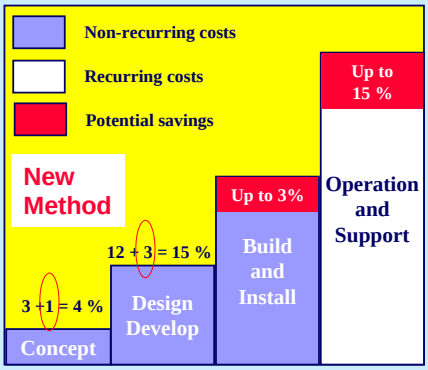
- **Define availability, reliability, and maintainability goals—an up-front business decision**
- **Engineering implements the goals by design numbers—not opinions**
- **Work for the lowest long term cost of ownership—a LCC statement**

SAE's Up-Front Work Cost $'s

Save up front and defer costs until later by holding down engineering costs



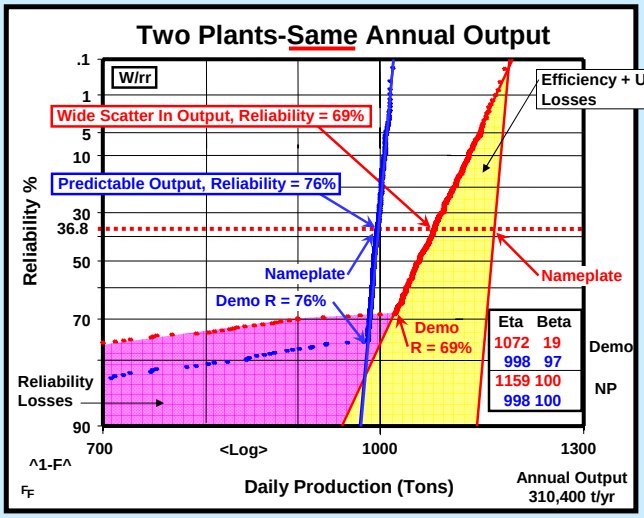
Use R&M engineering tools to reduce largest cost components and reduce LCC



RAM Implementation

- **Up-front RAM requirements lead to the lowest long term cost of ownership**
- **Buying cheap is usually not a bargain for the long term**
- **Implementing RAM requires: commitment, strategy, and action at various phases of projects to achieve the lowest long term cost of ownership**

Design For Process Reliability



Wide Scatter + Poor Reliabililty Requires (1159-998)/998 = 16.1% More Plant To Achieve Same Production Output

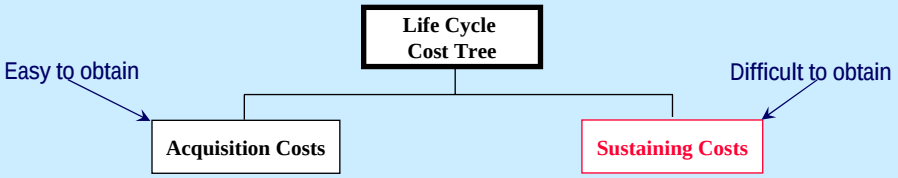
Short List Of RAM Tasks

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases

The Big PictureTasks	Concept & Proposal Phase	Design & Development Phase	Build & Install Phase	Operation & Support Phase	Conversion Or Decomm. Phase
Set Availability Requirements	X				
Set Reliability Requirements	X				
Set Maintainability Requirements	X				
Define Functional Failures	X				
Define Environment/Usage	X				
Define Capital Budgets and Make TradeOff Decisions	X	X			
Set Design Margins		X			
Design For Maintainability		X			
Make Reliability Predictions		X			
Do FMEA & Fault Tree Analysis		X			
Do Preliminary Cost Of Unreliability		X			
Conduct Design Reviews		X			
Make Machinery Parts Selections		X			
Do Tolerance/Process Studies		X			
Do Critical Parts Stress Analysis		X			
Do Reliability Qualification Testing			X		
Do Reliability Acceptance Testing			X		
Do Reliability/Maintainability Growth Improvement		X	X	X	
Collect Failure Reports & Analize			X	X	
Provide Data Feedback	X	X	X	X	X

Tailor the matrix to avoid too little or too much emphasis on R&M but meet the needs of the business to make the effort cost effective

Life Cycle Cost Tree



This portion of the tree usually has quotations and fewer details than Sustaining

The devil lives in the details of this tree and many details are inferred from records in maintenance & process.

Details: Phases For Tasks

1. **Concept & Proposal Phase**
2. **Design & Development Phase**
3. **Build & Install Phase**
4. **Operate & Support Phase**
5. **Conversion & Decommission Phase**

Concept & Proposal Task For Big Picture-Phase 1

R&M Practices For Concept & Proposal Phase

Tasks For Phase 1: Concepts And Proposal	User	Supplier
Preliminary Availabilitly, Reliability, and Maintainability Planning	X	X
Define The Availability, Reliability, and Maintainability Plan	X	X
Implement Lessons Learned	X	X
Specify Availability, Reliability, and Maintainability Requirements	X	
Define How Machinery Will Be Used	X	
Specify Duty Cycles For Equipment	X	
Define Environment For Machinery	X	
Define Continuous Improvement Monitoring	X	X
Define Equipment Life In Throughput Terms	X	
Establish Data Collection Details For R&M	X	X
Develop Application Specific R&M Program Matrix	X	
Develop R&M Program Planning Worksheet Details	X	
Establish Criteria For R&M In Design Reviews	X	X

Tailor the details to avoid too little or too much emphasis on R&M. Meet needs of the business. Make the effort cost effective! Keep profitability in mind.

Design Review Objectives

Concept Review: Focuses on feasibility of the proposed design approach with budget restrictions

Preliminary Design Review: Verifies adaptability of evolving design to meet technical requirements

Final Design Review: Validates the design and analysis are complete and accurate

Build: Addresses issues from equipment build and runoff testing

Installation: Do failure investigation of problems--Do continuous improvement

Roles & Responsibilities For Concept & Proposal-Phase 1

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases

Legend: L = Lead Responsibility, S = Support The Process, I = Input To the Process, A = Approval Responsibility

		Users		
Tasks For Phase 1: Concept And Proposal	Supplier	Engineering	Operations	Purchasing
Set Availability and Reliability Requirements		L	S	S
Set Maintainability Requirements		L	S	S
Define Functional Failures		S	L	
Define Environment/Usage		S	L	
Set Design Margins	I	L	S	
Design For Maintainability	I	S	L	
Make Reliability Predictions and Validate Availability Targets	I	L	I	
Do FMEA & Fault Tree Analysis		L		
Do Preliminary Cost Of Unreliability	I	S	I	
Conduct Design Reviews	L	A	S	S
Make Machinery Parts Selections	L	S		
Do Tolerance/Process Studies	L	S		
Do Critical Parts Stress Analysis	L	S		
Do Reliability Qualification Testing	S	L	I	
Do Reliability Acceptance Testing	S	L	I	
Do Reliability/Maintainability Growth Improvement	I	S	L	
Collect Failure Reports & Analize For Lessons Learned	S	L	S	
Provide Data Feedback	L	I	S	
Assess Lessons Learned	S	L	S	
Define Machinery Use	S	L	S	S
Define Machinery Duty Cycle		L	S	S
Define Machinery Environment		L	S	S
Share Continuous Improvement Information With Suppliers		L	S	
Define Life In Terms Of Throughput		L	S	S
Specify Data Collection System	S	L	S	S
Prepare Procurement Documents		S	S	L
Prepare LCC Objectives	I	S	L	
Prepare And Submit Reliability & Maintainability Plan	L	A	S	S
Prepare Life Cycle Cost Projections	I	L	S	

Design & Development Tasks: Phase 2

Reliability & Maintainability Practices For Design & Development Phase

Tasks For Phase 2: Design And Development	User	Supplier
Verify Design Margins (Safety Factors) & Do Stress Analysis		X
Specify How Critical Machinery Components Will Be Selected		X
Do Failure Modes and Effects Analysis:		X
Process FMEA	X	
Machinery FMEA		X
Do Fault Tree Analysis & HAZOPS	X	
Do Design Reviews		X
Do Tolerance/Process Studies		X
Generate Reliability Block Diagrams For Reliability Analysis		X
Do Accelerated Testing To Validate Critical Equipment Details		X
Do Maintainability Design Details To Minimize Downtime/Meet Max Time Limits		X
Define Maintenance Manuals, PM Requirments & CM Details		X
Prepare Spare Parts List & Spare Parts Inventory Plans	X	X
Prepares Details of Built-In Diagnostic Equipment For Maintainabiltiy	X	X
Prepares Details of Captive Hardware For Rapid Maintainability	X	X
Identify Spare Parts To Be Managed Based On Criticality	X	X
Define Maintenance Procedures For Adjustments/Replacements/Repairs	X	X
Define Visual Management Techniques For Workplace Awareness	X	X
Define Modularity Of Physical and Functional Units For Removal/Replacement		X

Roles & Responsibilities Design & Development: Phase 2

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases

Legend: L = Lead Responsibility, S = Support The Process, I = Input To the Process, A = Approval Responsibility

		Users		
Tasks For Phase 2: Design And Development	Supplier	Engineering	Operations	Purchasing
Verify Design Margins (Safety Factors) & Do Stress Analysis	L	S		
Specify How Critical Machinery Components Will Be Selected	L	S	S	
Do Failure Modes and Effects Analysis:				
Process FMEA	S	S	L	
Machinery FMEA	L	S	S	
Do Fault Tree Analysis & HAZOPS	L-FTA	S	L-HAZOPS	
Do Design Reviews	L	S	S	
Do Tolerance/Process Studies	L	S	S	
Generate Reliability Block Diagrams For Reliability Analysis	L	S	S	
Do Accelerated Testing To Validate Critical Equipment Details	L	S		
Do Maintainability Design Details To Minimize Downtime	L	S	S	
Defines Maintenance Manuals, PM Requirments & CM Details	L	S	S	
Prepare Spare Parts List & Spare Parts Inventory Plans	L	S	S	
Prepares Details of Built-In Diagnostic Equipment For Maintainabiltiy	L	S	S	
Prepares Details of Captive Hardware For Rapid Maintainability	L	S	S	
Identify Spare Parts To Be Managed Based On Criticality	S	S	L	
Define Maintenance Procedures For Adjustments/Replacements/Repairs	L	S	S	
Define Visual Management Techniques For Workplace Awareness	L	I	I	
Define Modularity Of Physical and Functional Units For Removal/Replacement	L	i	i	
Define Accessibility Parameters	L	S	S	
Consider Life Cycle Cost Impact In Machinery Design	L	I	I	

Build & Install Tasks: Phase 3

Reliability & Maintainability Practices For Build & Install Phase

Tasks For Phase 3: Build And Install	User	Supplier
Verify Attainment Of Specific R&M Goals During Testing		X
Do Preliminary Evaluation Of Process Performance To Eliminate Infant Mortality		X
Do Dry Run Testing In Vendors Facilities For A Set Duration (e.g., 1-day no failures)		X
Collect Reliability Data During Supplier Acceptance Testing As Future Precursor	X	X
Collect Reliability Data During Acceptance Testing In User's Plant After Installation	X	X
Do Root Cause Failure Analysis To Permanently Eliminate Failures		X

Roles & Responsibilities Build & Install : Phase 3

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases

Legend: L = Lead Responsibility, S = Support The Process, I = Input To the Process, A = Approval Responsibility

		Users		
Tasks For Phase 3: Build And Install	Supplier	Engineering	Operations	Purchasing
Verify Attainment Of Specific R&M Goals During Testing	L	A	A	
Do Preliminary Evaluation Of Process Performance To Eliminate Infant Mortality	L	I	I	
Do Dry Run Testing In Vendors Facilities For A Specified Duration (e.g., 1-day no failure	L	A	A	
Perform Acceptance Tests	L	A	A	
Collect Reliability Data During Supplier Acceptance Testing As Future Precursor	L	S	S	
Collect Reliability Data During Acceptance Testing And In User's Plant After Installation	S	S	L	
Do Root Cause Failure Analysis To Permanently Eliminate Failures	L	S	S	
Collect Life Cycle Cost Data	I	L	S	

Operation & Support Tasks: Phase 4

Reliability & Maintainability Practices For Operation And Support Phase

Tasks For Phase 4: Operation And Support	User	Supplier
Implement R&M Data Collection, Analysis, & Feedback System From Start Up	X	X
Implement Proactive Planned Maintenance Program For PM and PdM	X	
Implement R&M Growth Program Using Data, RCA, & Visual Displays Of Data	X	X
Implement Closed Loop Failure Reporting & Corrective Action System	X	X
Implement User/Supplier Data Exchange Of R&M Data To Reduce Cost On Both Sides	X	X
Implement Feedback Model On R&M Issues For User/Supplier Benefit	X	

Roles & Responsibilities Operation & Support: Phase 4

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases

Legend: L = Lead Responsibility, S = Support The Process, I = Input To the Process, A = Approval Responsibility

		Users		
Tasks For Phase 4: Operations And Support	Supplier	Engineering	Operations	Purchasing
Implement R&M Data Collection, Analysis, & Feedback System From Start Up	S	S	L	
Implement Proactive Planned Maintenance Program For PM and PdM	S	S	L	
Implement R&M Growth Program Using Data, RCA, & Visual Displays Of Data	S	S	L	
Implement Closed Loop Failure Reporting & Corrective Action System	S	S	L	
Implement User/Supplier Data Exchange Of R&M Data To Reduce Cost On Both Sides	L	S	S	
Implement Feedback Model On R&M Issues For User/Supplier Benefit	S	S	L	
Collect Life Cycle Cost Data	I	S	L	

Conversion/Decommission Tasks: Phase 5

Reliability & Maintainability Practices For Conversion And Decommission Phase

Tasks For Phase 5: End Of Life Decisions For Conversion And/Or Decommission	User	Supplier
Implement Retool Decisions For Make/Buy/Modify/Sell	X	X
Implement Remanufacture Decisions For Make/Buy/Modify/Sell	X	X
Implement Rebuild Decisions For Make/Buy/Modify/Sell	X	X
Imprelemt Retrofit Decisions For Make/Buy/Modify/Sell	X	X
Implement Rework Decisions For Make/Buy/Modify/Sell	X	X
Implement Lessons Learned For Future Plant Improvements	X	X
Decontaminate/dispose Of Unneeded Assets With Permits As Required	X	

Roles & Responsibilities Conversion/Decommission : Phase 5

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases

Legend: L = Lead Responsibility, S = Support The Process, I = Input To the Process, A = Approval Responsibility

		Users		
Tasks For Phase 5: End Of Life Conversions And/Or Decomission	Supplier	Engineering	Operations	Purchasing
Implement Retool Decisions For Make/Buy/Modify/Sell	I	S	L	
Implement Remanufacture Decisions For Make/Buy/Modify/Sell	I	S	L	
Implement Rebuild Decisions For Make/Buy/Modify/Sell	I	S	L	
Imprelemt Retrofit Decisions For Make/Buy/Modify/Sell	I	S	L	
Implement Rework Decisions For Make/Buy/Modify/Sell	I	S	L	
Implement Lessons Learned For Future Plant Improvements	I	S	L	
Decontaminate/dispose Of Unneeded Assets With Permits As Required	I	I	L	
Characterize Equipment Reliability And Maintainability	I	L	S	
Collect All Data And Lessons Learned	I	S	L	
Total Life Cycle Costs And Compare To Original LCC Objectives	I	L	S	
Adjust Methodoloty If Required	I	L	S	

How Do You Get Started: Set The Objective

- **Objective: We will build an economical and failure-free process which will operate for 5 years between planned outages with an availability of 98% (including lost production time during turnarounds) and 80% of all component failures must be capable of being repaired in less than 24 hours.**

Why Would You Get Started: Set The Purpose

- **Purpose: We will build a failure-free process to increase manufacturing productivity and throughput recognizing the process is the king and the pawns are individual equipment for a strategy that plans for highly available processes which keep the money machine operating smoothly.**

Why Would You Get Started: Consider Maintainability

- **Objective: We will set maintainability requirements for repair times and turnaround intervals to manage plant availability for safely repairing equipment to standards for reducing downtime and the $risk for exposure to hazards of the process and safety risk to our employees to reduce financial damages.**

Why Would You Get Started: Money Is The Driver For LCC

- **Objective: We will build processes and plants for the lowest long term cost of ownership for our stockholders or owners so they are economically sound investments considering that the use of money has many alternatives.**

A Summary--In Few Words

- LCC is the new cost path—the bar is raised
- RAM technology aids cost reductions, but calls for knowing, understanding, and using new technology to aid LCC by calculation
- Better designed plants are more stable, productive, and cost effective leading toward a new wave of improvements
- World class plants are now using the tools