Life Cycle Costs and Reliability

Abstract: Reliability details are needed to predict end of life for components and systems. Failures and replacements drive costs during specific project intervals. Cost details from reliability analysis drive life cycle decisions for calculating a key financial performance represented by a single number for **net present value (NPV)**.

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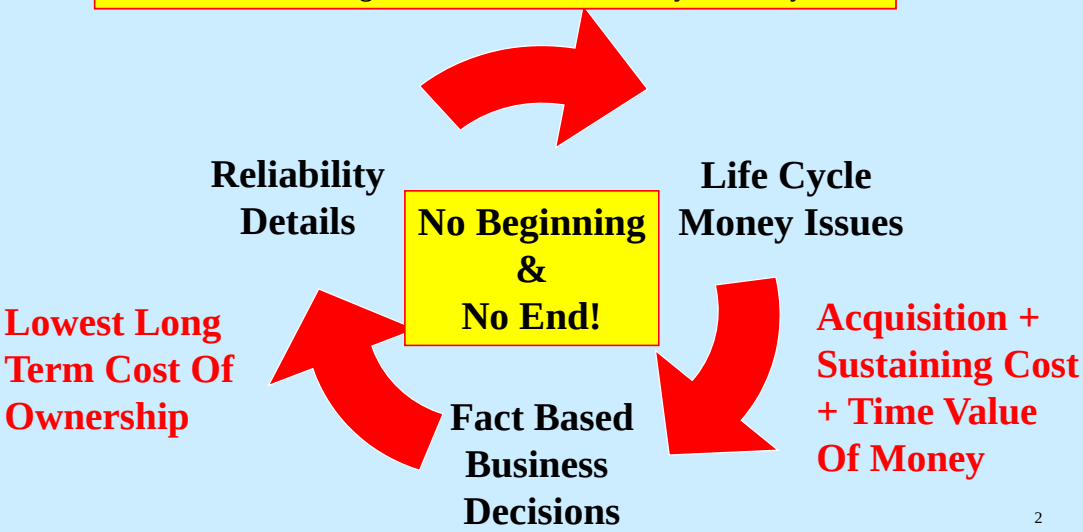
Why Do Life Cycle Cost and Reliability Facts Go Together?

Facts About How Things Live and Die → Reliability → Money Issues



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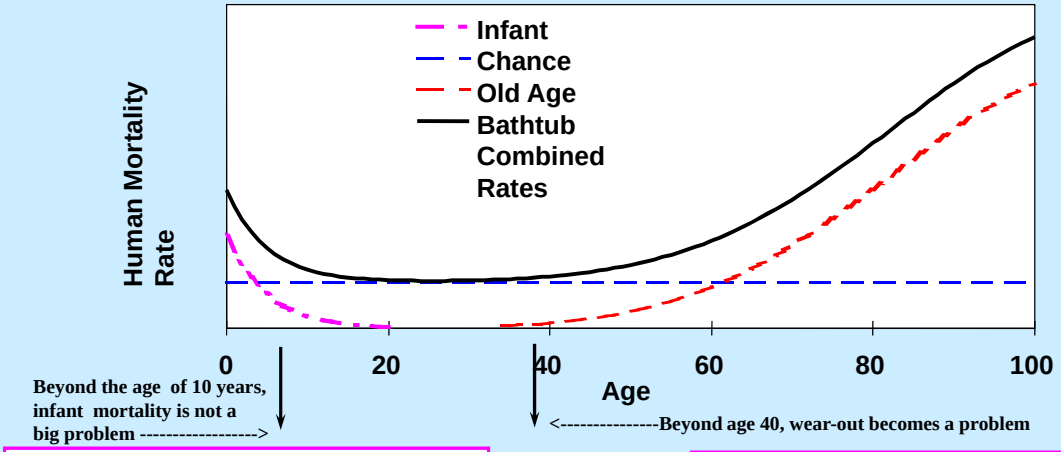
Human Bathtub Curves

From the human experience we get reliability ideas



Beyond the age of 10 years, infant mortality is not a big problem ---------->

<----------Beyond age 40, wear-out becomes a problem

The y-axis is more precisely known as the hazard rate. Hazard rate measures the probability a person will die in the next time interval given they survived up to the beginning of the time interval.

Similar curves exist for hardware. They form a survival signature with indications of survival under specific conditions.

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Weibull Curves Tell Failure Modes

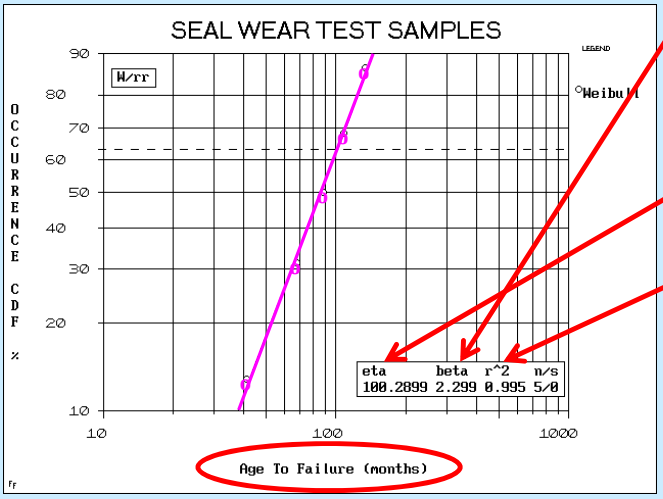
Let Weibull tell you how they died

1. Weibull plots require few data.

2. Weibull plots tell about failure modes.

3. Weibull plots help guide corrective action.

4. Weibull plots are often used with cost data to find least cost actions using risk assessments.



Beta tells the failure mode—infant mortality, chance failure, or wear out.

Eta tells the characteristic life.

R^2 or PVE% tells the goodness of fit.

To an engineer, one Weibull graph equals 1000^+ words from a statistician!!

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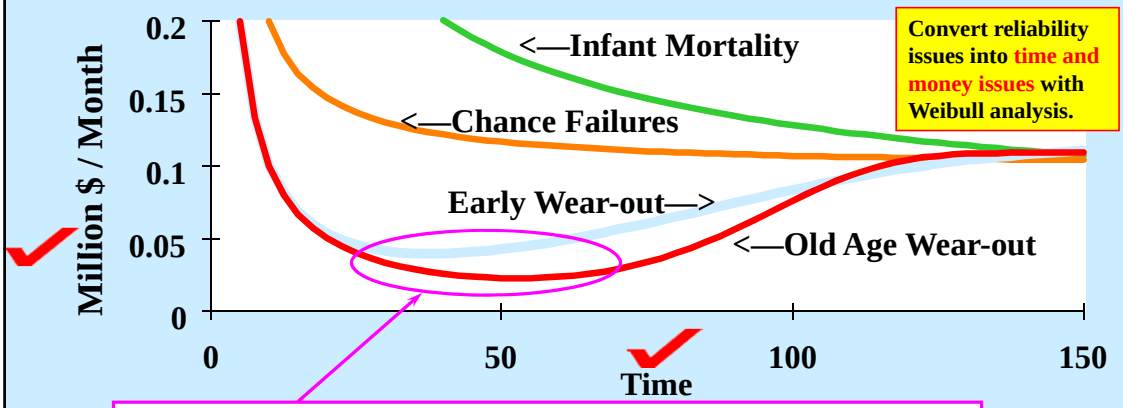
Maintenance Strategies & Costs

Cost Effects Of Failure Modes & Optimum Replacement



Convert reliability issues into time and money issues with Weibull analysis.

For wear-out problems, minimums can occur only if unplanned cost >> planned costs

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Data from nuclear power plants

Failures: Roots Of Reliability Problems

Early Plant Life	Frequency %
Design Error	35
Fabrication Error	1
Random Component Failure	18
Operator Error	12
Procedure Error & Unknowns	10
Maintenance Error	12
Unknown	12
	100

Design

People

Component failures

For a modern example see http://www.bpresponse.com

Don't forget MTBSE!

Mature Plants	
People	38
Procedures + Processes	34
Equipment	28
	100

People

Procedures/Processes

Machines

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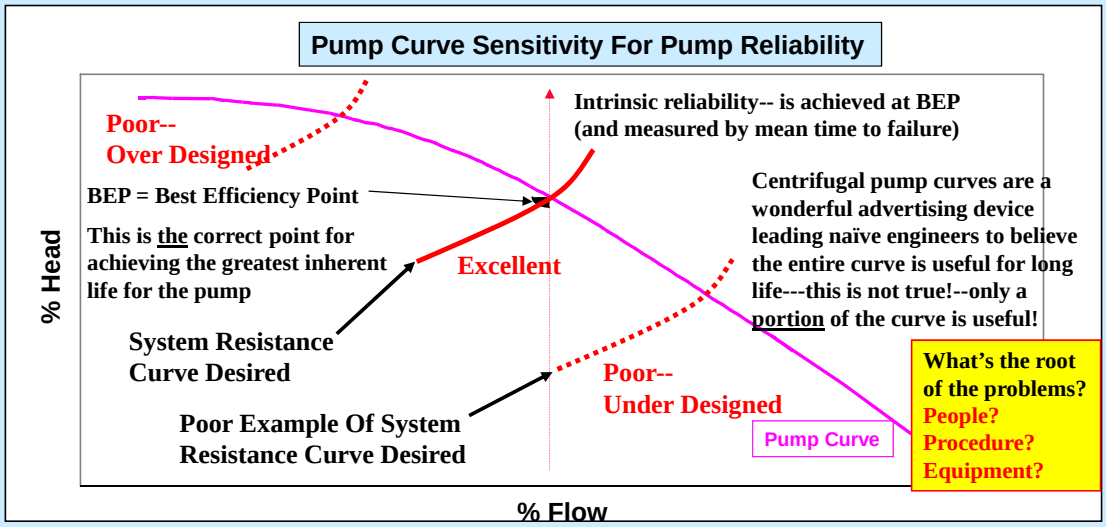
Pump Curve Characteristics

Who is responsible for correct results:
At start-up?
During normal operation
Corrective action?



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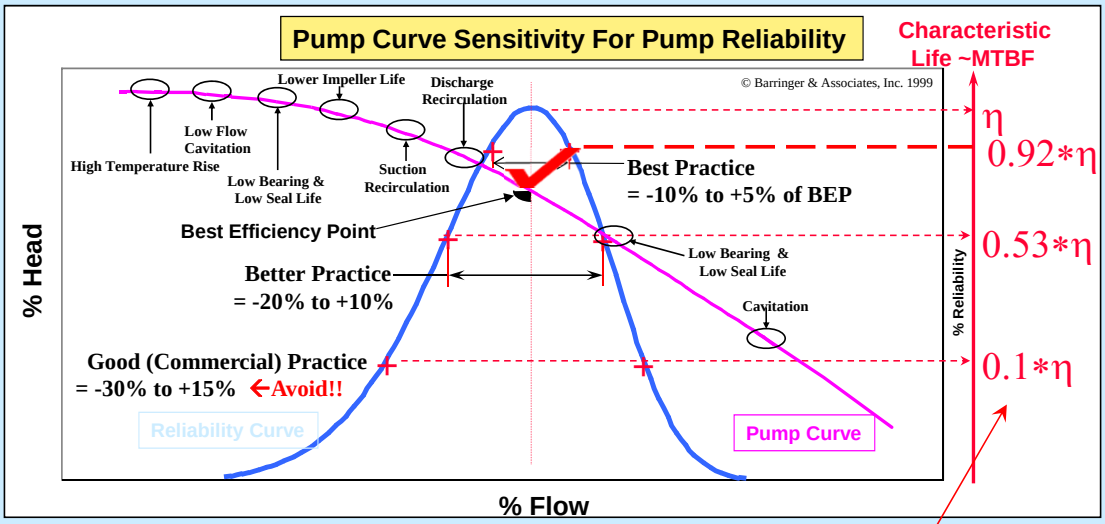
Pump Curve Practices--A Model

Who sets the standard?
Who communicates standards and reasons for conformance?



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Life Cycle Cost Definitions

- **Life Cycle Costs--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 is a financial tool for evaluating economic value added. The present value of an investment's future net cash flows (a measure of a company's financial health) minus the initial investment for a given hurdle discount rate (the interest rate used in discounting future cash flows) are summed for the net.**

Need a life cycle cost Excel work sheet to calculate NPV?
See: http://www.barringer1.com/Anonymous/lcc.xls

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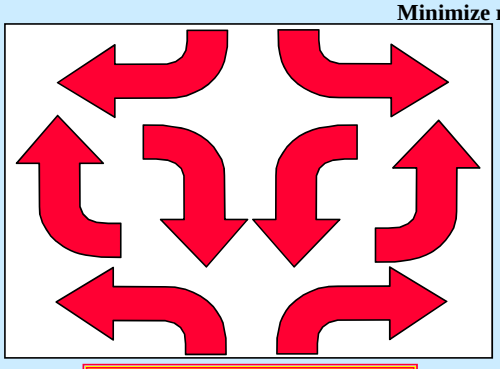
Conflicting Issues--What To Do?

Project Engineers:
Minimize capital expenditures

Maintenance Engineers:
Minimize repair hours



Shareholders:
Maximize dividends and/or share price

Production:
Maximize uptime hours

Reliability Engineers:
Maximize equipment reliability to avoid failures

Buy right? Or Buy Cheap?

Accounting:
Maximize project net present value

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Engineers Must Quantify All Costs

Can you calculate NPV?

Engineers Must Think Like MBA's
And
Act Like Engineers
To Get
Lowest Long Term Cost Of Ownership
Over The Entire Life Cycle

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LCC: A Management Decision Tool

- **Provides a costing discipline**
- **Useful for procurement strategies**
- **Balances acquisition costs and operating costs**
- **Useful for trade-off studies based on facts**
- **Requires engineers to:**
  - **Think like MBAs for cost considerations**
  - **Act like engineers by using numbers for decisions**
- **Requires use of teamwork to generate numbers**

Think smart. Act smart. Be responsible. No one has all the answers. Think and act with a conscience!

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Engineers And Spreadsheets

- Most financial spreadsheets are generalities because engineers do not give accountants specific equipment details for making accurate financial calculations
- Engineers must add many equipment details to help accountants arrive at the correct economic impact--"I don't have the information" is a void in decision process which drives poor decisions toward bad economic results

If you don't have the information do what they taught you at the university:
1. **Make a hypothesis**
2. **Test the hypothesis**
3. **Use your head! "Common sense is an uncommon virtue." Don't wait!**

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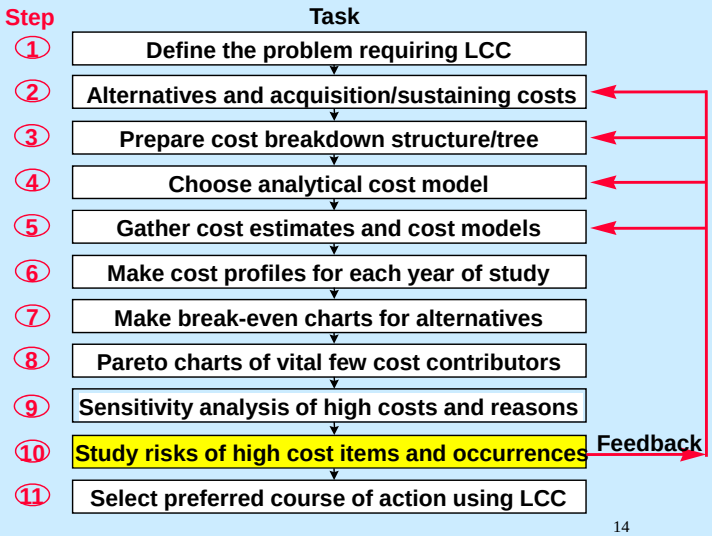
What Goes Into Life Cycle Costs?

- Everything goes into LCC and each case is tailored for individual circumstances
- LCC follows a process that fits a simple tree for acquiring data

Management appreciates you following a process more than you as an engineer may appreciate it.



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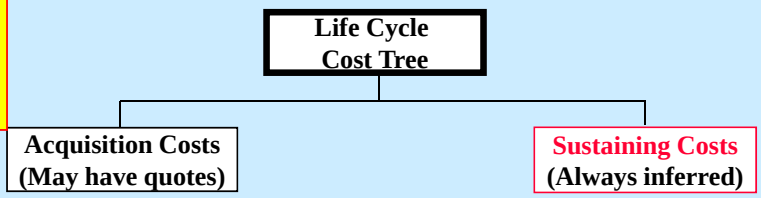
Top Levels Of The LCC Tree

- LCC = Acquisition Costs + Sustaining Costs

This is as simple as it gets!



- Acquisition costs and sustaining costs are not mutually exclusive—find both by gathering correct inputs and identifying cost drivers

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Hidden Costs Found By LCC

- **Often sustaining costs (including hidden costs) are 2-20 times acquisition costs (obvious costs)**
- **About 65%+ of total LCC are fixed by the time equipment is specified (but only a few percent of funds have been expended at this point in time)**
- **Minimizing LCC pushes up NPV and builds stockholder wealth**
- **Finding the lowest long term LCC requires details for both acquisition costs and sustaining costs requires choices between alternatives**

Worry more about sustaining costs!!!

Wham! A key issue!

Think long term!

Say it in NPV

First alternative is the cost of doing nothing!

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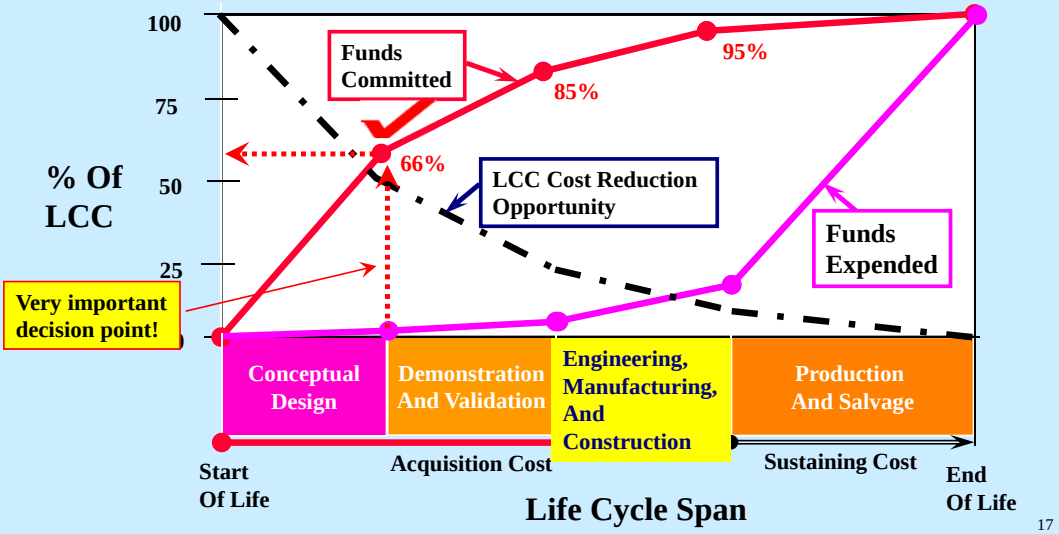
Commitments And Expenditures



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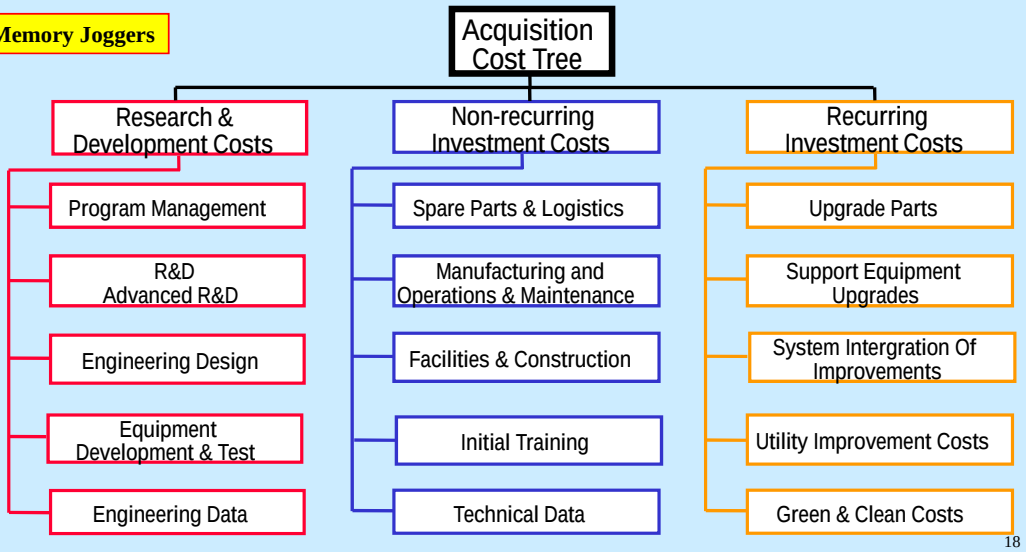
Branches For The Acquisition Tree

Memory Joggers



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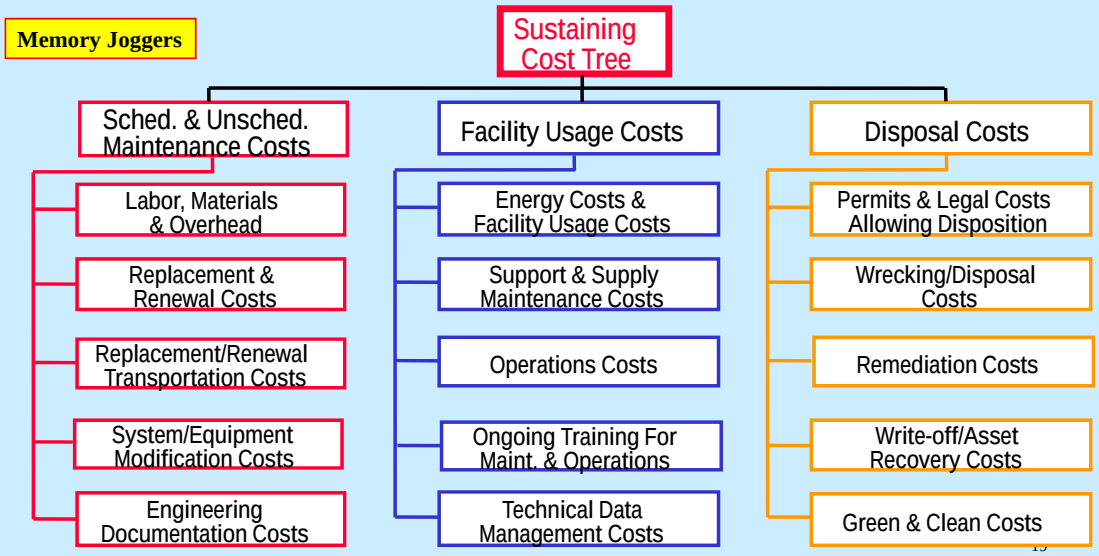
Branches For The Sustaining Tree



What Costs Goes Where?

- Use common sense
- Each case is special

Don't make this a career to complete the tasks!

- Consider the details for **BOTH** acquisition and sustaining costs to develop the cost schedules
- When in doubt, include the costs
- Don't ignore obvious costs or include trivial costs
- Include the appropriate cost elements and discard the trivial elements--use standard models

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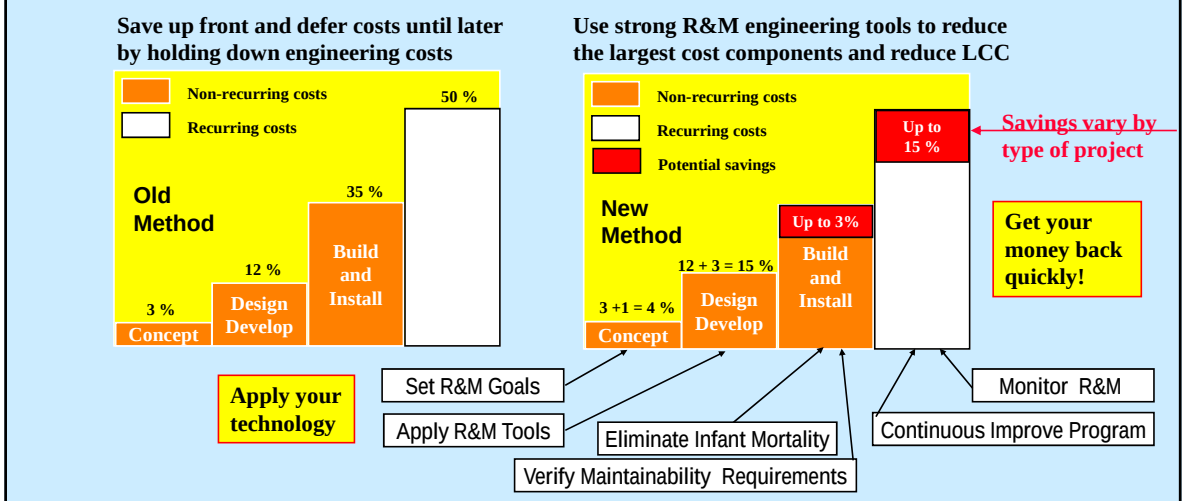
A New View Of R&M Influence On LCC



Source: SAE Reliability and Maintainability Guideline for Manufacturing Machinery and Equipment, 2nd edition, M-110.2

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The Big Picture For Each Phase

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

LCC Requires Facts

- Based on "typical" equipment justifications, equipment "rarely fails"—as maintenance cost is not detailed and not preplanned
- Real equipment needs constant and expensive maintenance activities--CM, PM, and PdM
- Most engineers don't acknowledge failure data exists and lack training in how to use the data
- LCC calculations depend on equipment facts--not opinions—and reliability/maintainability details can decrease life cycle cost per SAE

Get as many facts as you can gather and supplement them with your assumptions. Don't get bogged down in the trivia—keep some altitude!

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Which Equipment To Buy?

A vendor offers three grades of equipment for solving our plant problem. Disregarding depreciation and other accounting details, which grade of equipment should we select for the lowest long term cost of ownership (assume plant life ends after 20 years = 175,200 hours).

	Good	Better	Best
Cost of the new equipment	$50,000 ✓	$75,000	$150,000

Watch out for the lure of cheap first costs!
Which equipment will you buy?--Why
You need details to make the correct decision—
what do you need?

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An Arithmetic Model

Watch out for changes in decisions when discount rates are used by accounting.

Reliability Models & Costs--Life Time Costs

A vendor offers three grades of equipment for solving our plant problem. Disregarding depreciation and other accounting details, which grade of equipment should we select for the lowest long term cost of ownership (assume plant life ends after 20 years = 175,200 hours). What are the savings?

	Good	Better	Best
Cost of the new equipment	$ 50,000	$ 75,000	$ 150,000
Failure rate (failures/hour)	0.0005	0.0001	0.00001
Reliability for a 1 year mission?	1.25%	41.64%	91.61%
Number of failures in 20 years?	# 87.6	# 17.52	# 1.752
20 year failure costs @$5,000/failure?	$ 438,000	$ 87,600	$ 8,760
Equipment overhaul required every	5 yr	10	10
Each overhaul cost is	$10,000	$20,000	$45,000
20 year number of overhauls & costs?	# 3 $ 30,000	# 1 $ 20,000	# 1 $ 45,000
Operating/routine maintenance costs	$1.00/hr	$0.90/hr	$0.90/hr
20 year operating/routine maintenance costs	$ 175,200	$ 157,680	$ 157,680
Disposal cost at retirement	$ 5,000	$ 5,000	$ 5,000
Total long term costs (ex depreciation, etc)	$ 698,200	$ 345,280	$ 366,440

Chance Failures

Wear-out Failures

Save $352,920

Save $21,160

Long term cost of ownership = Initial cost
+ maintenance cost (include spares & outside services)
+ operating costs + disposal costs.

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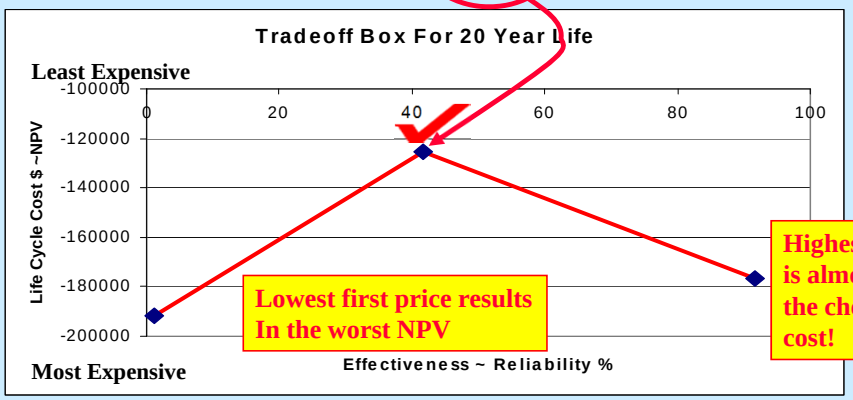
NPV For The Simple Arithmetic Models--

Arithmetic details converted to NPV.

	Alternative 1	Alternative 2	Alternative 3
Grade	Good	Better	Best
NPV	-$191,861	-$125,465	-$176,556
Reliability	1.25%	41.64%	91.61%



Lowest first price results In the worst NPV

Highest first price is almost as bad as the cheapest first cost!

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Difficulty Of Cost Problems

- Problems are easy when the data is "given"
- The hard part is to collect the data
- Some problems are solved at the 65,000' level (few details), the 25,000' level (more details) and most problems are solved at the 2500' level (many details). Few life cycle cost problems are solved at the 6' level.
- Some costs can be estimated, others must be calculated
- Next we go to more difficult problems--finding the data

Conversion:
65,000 feet = 20,000 meters
25,000 feet = 7,600 meters
2,500 feet = 760 meters
6 feet = 1.8 meters

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LCC Summary

Want more to read? See:
http://www.barringer1.com/lcctrng.htm

- Life cycle costs include cradle to grave costs the first cost is not the only cost!
- Include reliability technology into LCC decisions to find quantities of resources required for life
- LCC provides a visualization technique for trade-off studies. Use NPV for sound financial decisions
- Good engineering produces LCC alternatives to search for the lowest long term cost of ownership ← The plural word
- In the end, the effort is all about the money and reliability analysis is a key tool to get to the money!
- Reliability and Life Cycle Cost go together for good business decisions! ✔

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