

# Life Cycle Costs and Weibull Go Together Like PB&J

**Abstract:** Weibull details are needed to predict end of life for components and systems. When the failures/replacements occur will drive costs during specific project intervals. The cost details from Weibull analysis drive life cycle cost decisions for calculating a key performance indicator represented by a single number for net present value (NPV).

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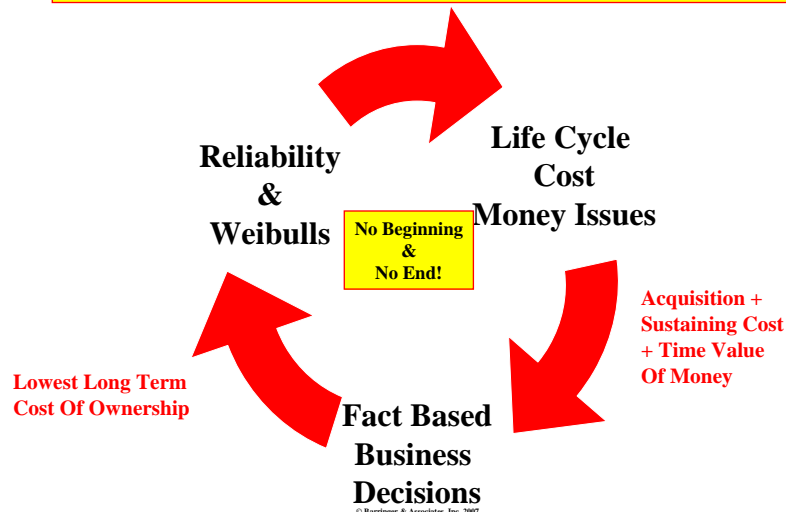
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## Why Do Life Cycle Cost Together and Weibull Distributions Go Together?

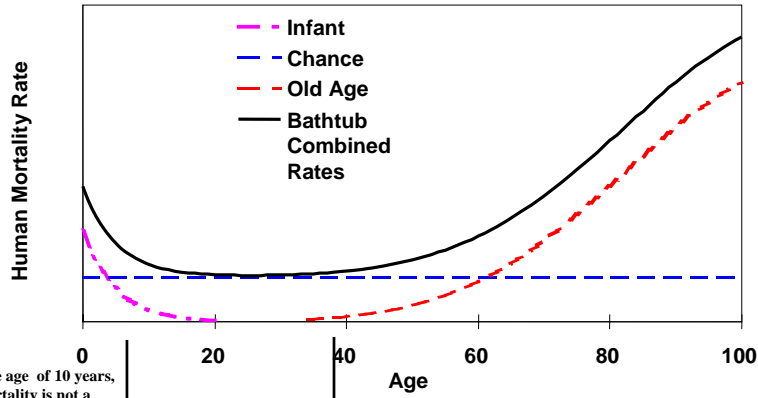
Facts About How Things Live and Die → Weibull Distributions → Money Issues



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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.

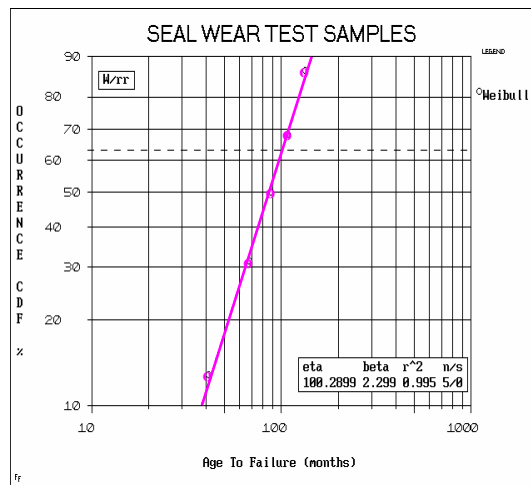
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# Weibull Curves Tell Failure Modes

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.



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

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

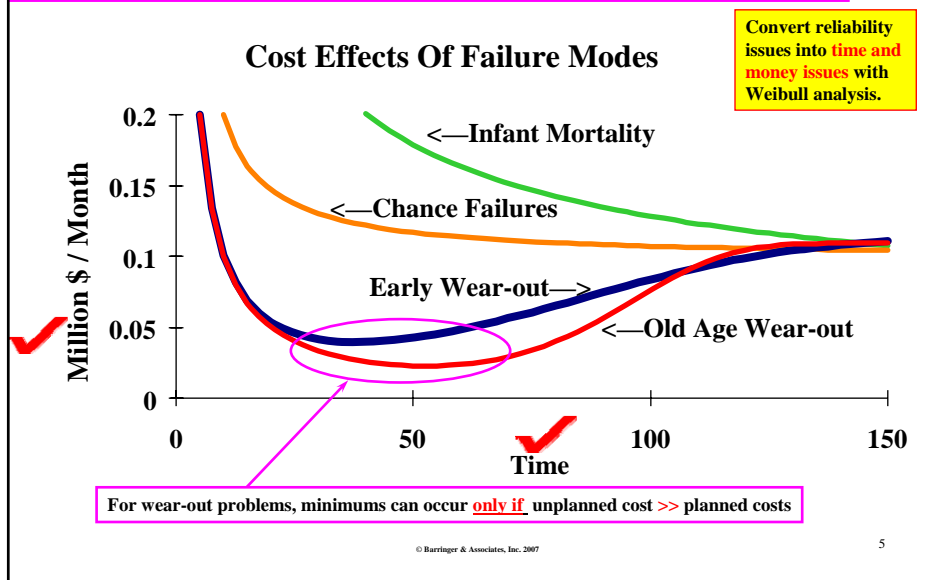
**Eta** tells the characteristic life.

**R<sup>2</sup>** tells the goodness of fit.

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## Maintenance Strategies & Costs



## Solving Reliability Problems With Data

- ◆ Improve reliability by **solving specific problems** —this requires good data and good analysis.
- ◆ Good analysis requires good, clean data with measurement of the aging process.
- ! ◆ Don't confound aging data with event dependent problems from processes or people ! Watch out!
- ◆ Identify failure data (including suspensions) by recognizing competing failure modes.
- ◆ Use Sherlock Holmes methods and dig through failure data to extracting relevant facts.
- ◆ A difficult step of reliability analysis is getting good data—using the data produces better data collection.

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Data from nuclear power plants

## Failures: Roots Of Reliability Problems

### Early Plant Life

- ◆ Design Error
- ◆ Fabrication Error
- ◆ Random Component Failure
- ◆ Operator Error
- ◆ Procedure Error & Unknowns
- ◆ Maintenance Error
- ◆ Unknown

Frequency %

35

Design

1

People

18

12

Component failures

10

12

12

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

100

Don't forget MTBSE!

### Mature Plants

- ◆ People
- ◆ Procedures + Processes
- ◆ Equipment

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People

34

Procedures/Processes

28

Machines

100

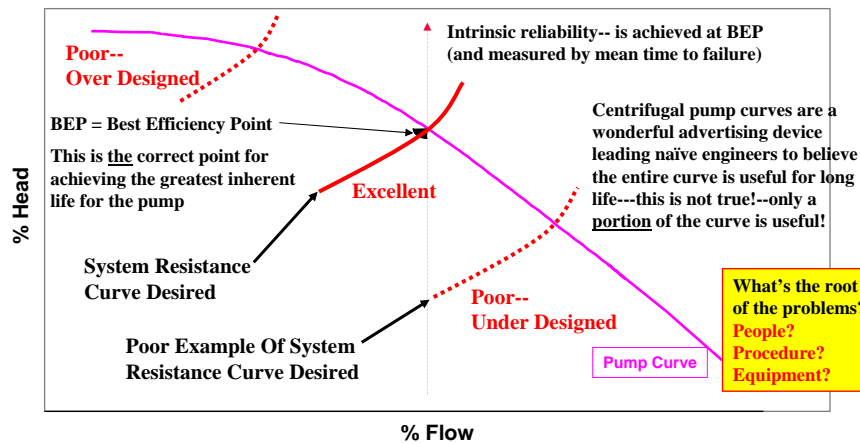
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Who is responsible for correct results:  
At start-up?  
During normal operation  
Corrective action?

## Pump Curve Characteristics

### Pump Curve Sensitivity For Pump Reliability

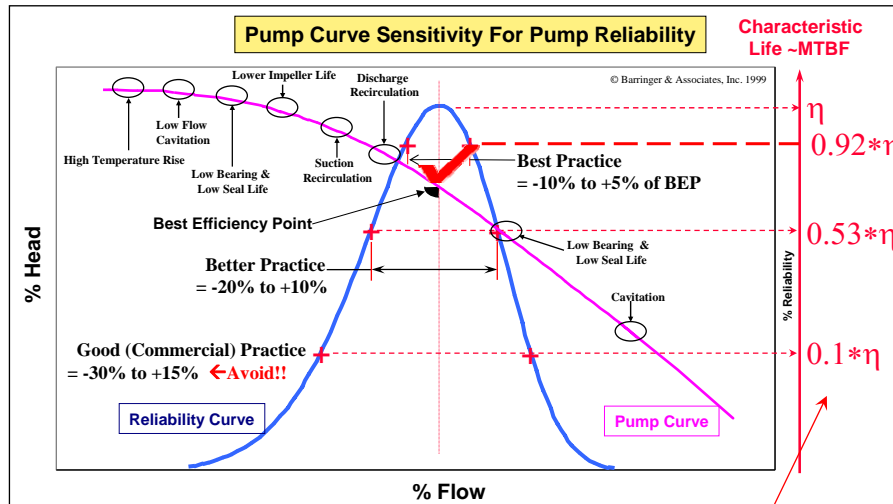


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# Pump Curve Practices--A Model

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



## 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>

# Conflicting Issues--What To Do?

**Project Engineers:**  
Minimize capital expenditures

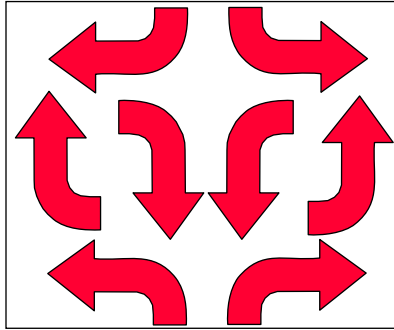
**Maintenance Engineers:**  
Minimize repair hours

**Shareholders**  
Maximize dividends  
and/or share price

**Production:**  
Maximize uptime hours

**Reliability Engineers:**  
Maximize equipment reliability  
to avoid failures

**Accounting:**  
Maximize project net present value



**Buy right? Or Buy Cheap?**

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# Communication Problems--Boring!!

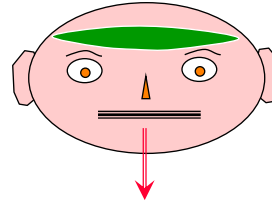
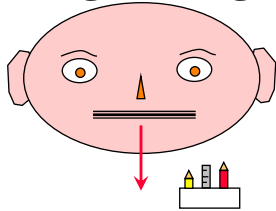
**Boring Beanie Stuff!!!**

Lack Of Communication  
= Anger, Frustration,  
And Lack Of Cooperation

**Boring Techie Stuff!!!**

**Engineering**

**Accounting**



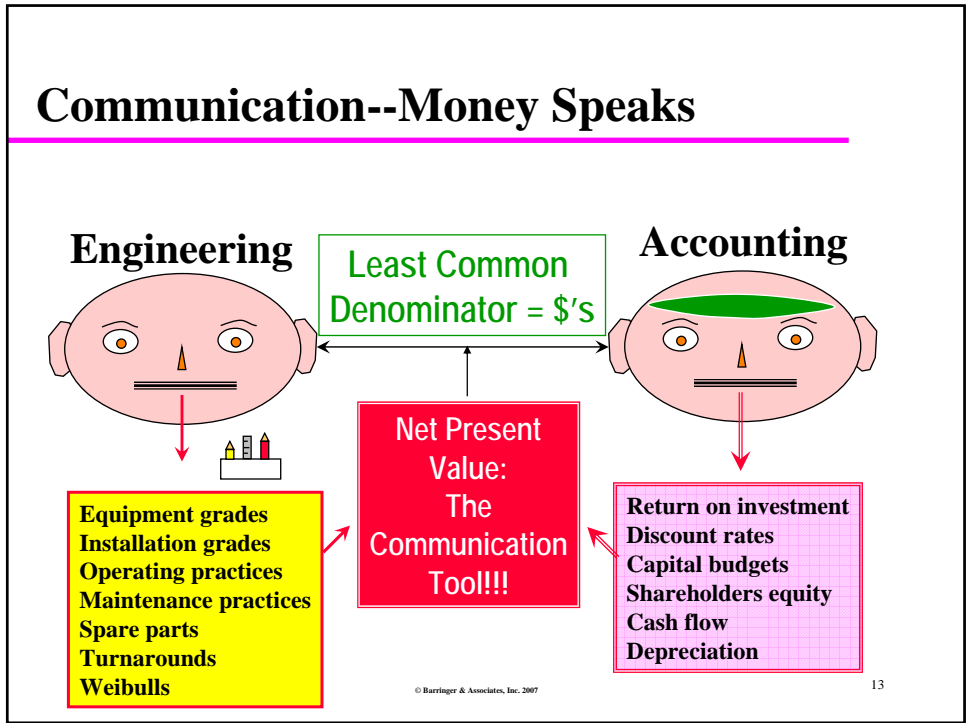
Equipment grades  
Installation grades  
Operating practices  
Maintenance practices  
Spare parts  
Turnarounds

Return on investment  
Discount rates  
Capital budgets  
Shareholders equity  
Cash flow  
Depreciation

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# Communication--Money Speaks



# The Time Value Of Money

Two views of money  
 1. Present value  
 2. Future Value

Time Aspects Of Money											
Discount Rate = 12%											
Years hence	0	1	2	3	4	5	6	7	8	9	10
Present value of US\$1.00	\$ 1.00	\$ 0.89	\$ 0.80	\$ 0.71	\$ 0.64	\$ 0.57	\$ 0.51	\$ 0.45	\$ 0.40	\$ 0.36	\$ 0.32
Future value of US\$1.00	\$ 1.00	\$ 1.12	\$ 1.25	\$ 1.40	\$ 1.57	\$ 1.76	\$ 1.97	\$ 2.21	\$ 2.48	\$ 2.77	\$ 3.11
Present value of US\$1.00 = $1/(1+i)^n$						and Future value of US\$1.00 = $(1+i)^n$					
Years hence	11	12	13	14	15	16	17	18	19	20	
Present value of US\$1.00	\$ 0.29	\$ 0.26	\$ 0.23	\$ 0.20	\$ 0.18	\$ 0.16	\$ 0.15	\$ 0.13	\$ 0.12	\$ 0.10	
Future value of US\$1.00	\$ 3.48	\$ 3.90	\$ 4.36	\$ 4.89	\$ 5.47	\$ 6.13	\$ 6.87	\$ 7.69	\$ 8.61	\$ 9.65	
where i = discount rate and n = number of years into the future											

What is the present value (PV) of US\$1.00 today over time?  
 What is the future value (FV) of US\$1.00 received over time?

“A bird in the hand is worth two in the bush.”  
 “Money is time and time is money.”

## 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

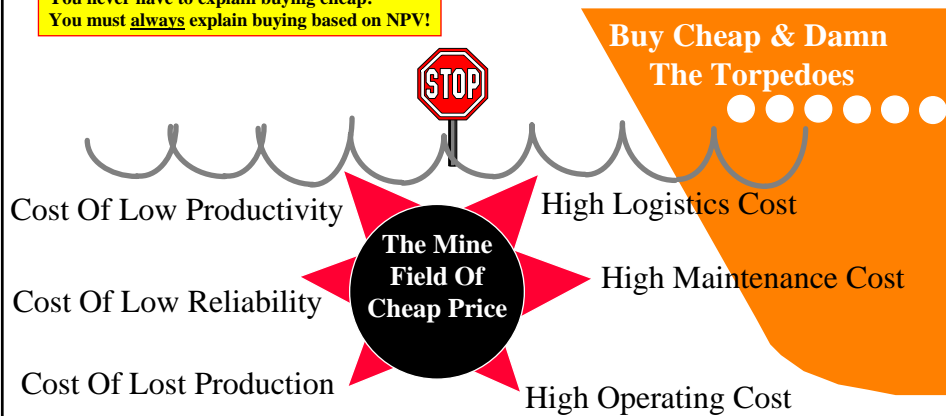
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## First Cost Is Not The Last Cost

◆ Watch out for the lure of cheap first cost!!!!

You never have to explain buying cheap!  
You must always explain buying based on NPV!



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## Why Use LCC

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- ◆ **Affordability studies**
- ◆ **Source selection studies**
- ◆ **Design trade-off studies**
- ◆ **Repair level analysis studies**
- ◆ **Warranty and repair cost studies**
- ◆ **Supplier sales strategies**
- ◆ **Configure for lowest long term cost of ownership**

Most business are in for the long haul so the lowest cost of ownership (NPV) is best for the business.

## LCC Helps Change Perspectives

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- ◆ **Engineering--show non-redundancy costs**
- ◆ **Purchasing--buy right rather than buy cheap**
- ◆ **Process engineering--show operating costs**
- ◆ **Maintenance--calculate maintenance costs**
- ◆ **Reliability engineering--define improvements**
- ◆ **Management--operate for lowest long term cost of ownership rather than cheapest first cost**

Everyone has tradeoffs to make.  
**Don't operate like ENRON.**  
Think about the lowest long term cost of ownership for the stockholders!

## 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!

## Engineers And Spreadsheets

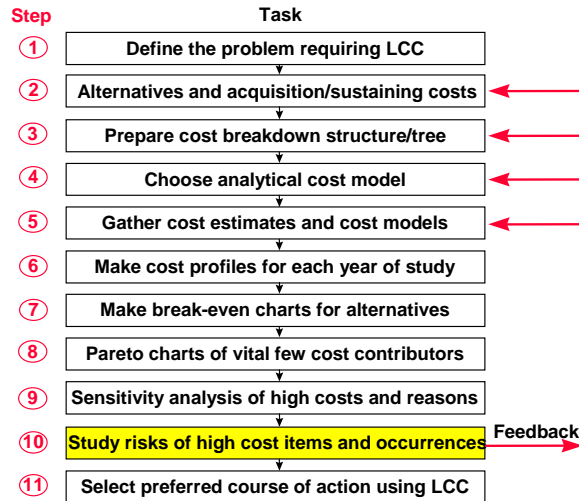
- ◆ Most financial spreadsheets are generalities because engineers do not give accountants specific equipment details for making accurate financial calculations
- ◆ Engineers must add many equipment details to help accountants arrive at the correct economic impact--"I don't have the information" is a 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!

## 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.



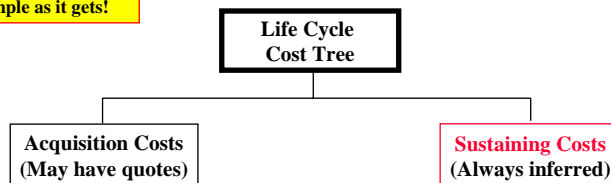
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## Top Levels Of The LCC Tree

- ◆  $LCC = \text{Acquisition Costs} + \text{Sustaining Costs}$

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!

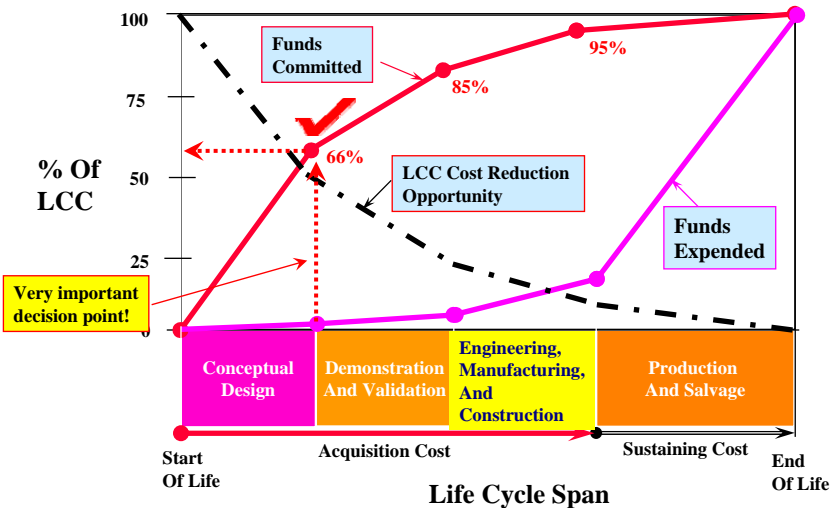
Think long term!

Say it in NPV

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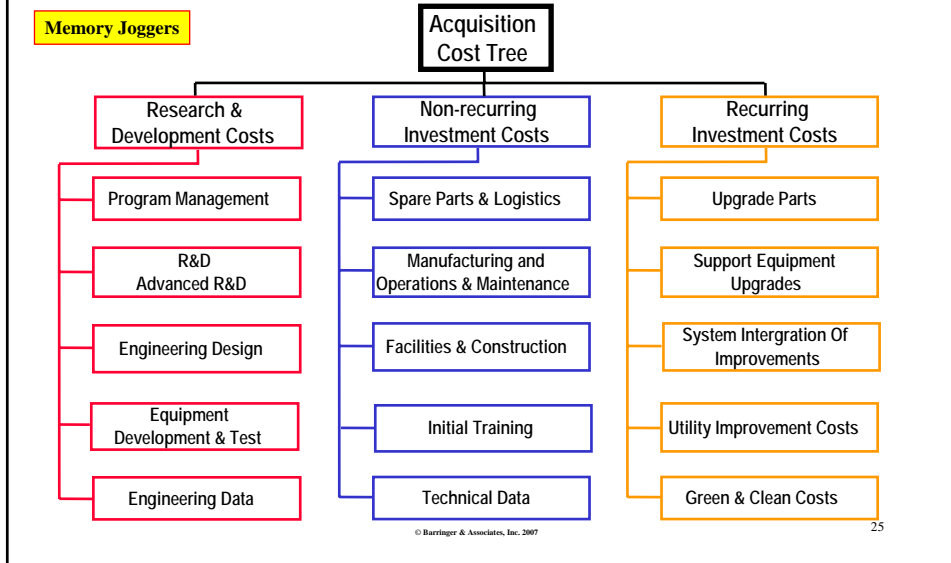
# Commitments And Expenditures



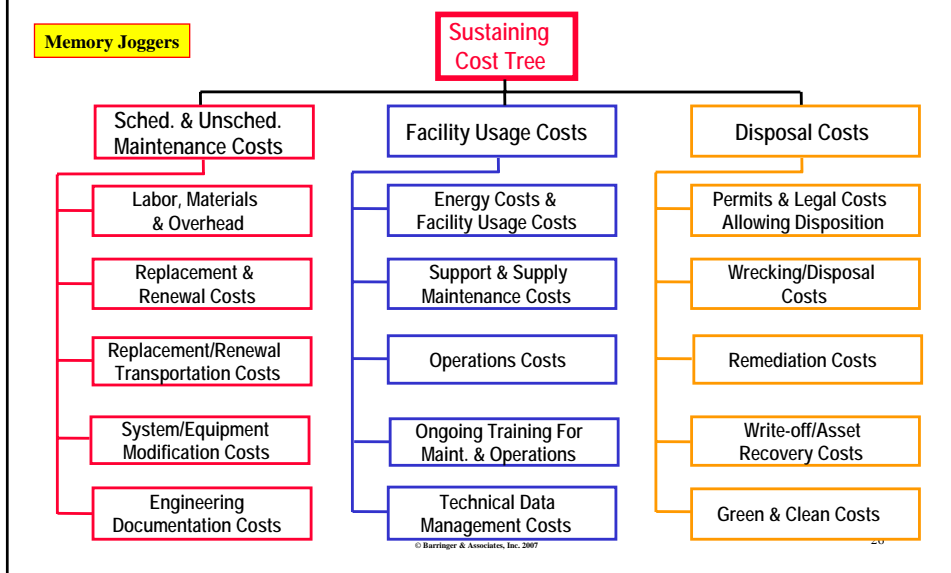
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## Branches For The Acquisition Tree



## Branches For The Sustaining Tree



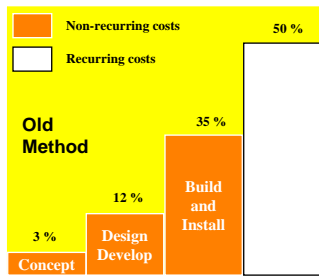
# What Costs Goes Where?

- ◆ Use common sense
- ◆ Each case is special
- ◆ 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

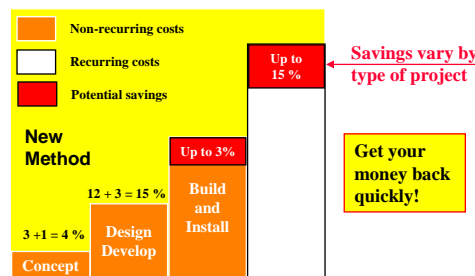
Don't make this a career to complete the tasks!

# A New View Of R&M Influence On LCC

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

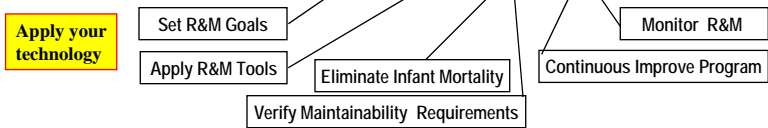


Use strong R&M engineering tools to reduce the largest cost components and reduce LCC



Savings vary by type of project

Get your money back quickly!



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

# The Big Picture For Each Phase

Short List Of Reliability & Maintainability Activities Over The Life Cycle Phases					
The Big Picture Tasks	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 & Analyze			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

## Phase 1—Concept/Proposal

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.

R&M Practices For Concept & Proposal Phase		
Tasks For Phase 1: Concepts And Proposal	User	Supplier
Preliminary Availability, 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
<b>Design Review Objectives</b>		
<b>Concept Review:</b> Focuses on feasibility of the proposed design approach with budget restrictions ✓		
<b>Preliminary Design Review:</b> Verifies adaptability of evolving design to meet technical requirements		
<b>Final Design Review:</b> Validates the design and analysis are complete and accurate		
<b>Build:</b> Addresses issues from equipment build and runoff testing		
<b>Installation:</b> Do failure investigation of problems--Do continuous improvement		

## Phase 2—Design & Develop

### 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 Requirements & CM Details		X
Prepare Spare Parts List & Spare Parts Inventory Plans	X	X
Prepares Details of Built-In Diagnostic Equipment For Maintainability	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	X

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## 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?

# Reliability Models & Costs--Life-Cycle 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?	____%	____%	____%
Number of failures in 20 years?	# ____	# ____	# ____
20 year failure costs @\$5,000/failure?	\$ ____	\$ ____	\$ ____
Equipment overhaul required every	5 yr	10	10
Each overhaul cost is	\$10,000	\$20,000	\$45,000
20 year number of overhauls & costs? #	\$ ____	# ____ \$ ____	# ____ \$ ____
Operating/routine maintenance costs	\$1.00/hr	\$0.90/hr	\$0.90/hr
20 year operating/routine maintenance costs	\$ ____	\$ ____	\$ ____
Disposal cost at retirement	\$ 5,000	\$ 5,000	\$ 5,000
Total life time costs (ex depreciation, etc)	\$ ____	\$ ____	\$ ____

**A quick arithmetic effort with these details can help your NPV decisions?**

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

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	1	1
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
<b>Total long term costs (ex depreciation, etc)</b>	<b>\$ 698,200</b>	<b>\$ 345,280</b>	<b>\$ 366,440</b>

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

Save \$352,920 (from Good to Better)  
Save \$21,160 (from Better to Best)

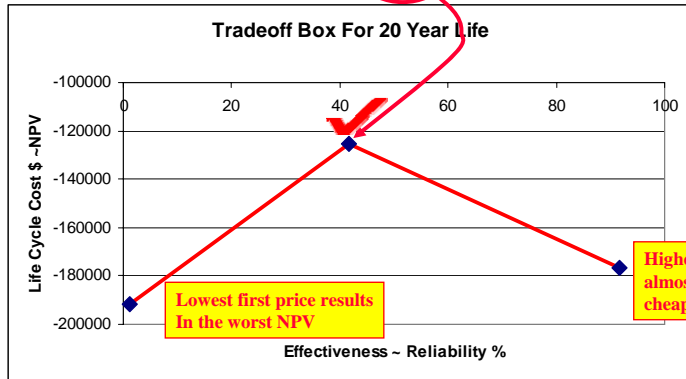
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## NPV For Simple LCC Models--

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%



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## Difficulty Of Cost Problems

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- ◆ 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).
- ◆ Some costs can be estimated, others must be calculated
- ◆ Next we go to more difficult problems--finding the data

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## Adding Uncertainty Into LCC

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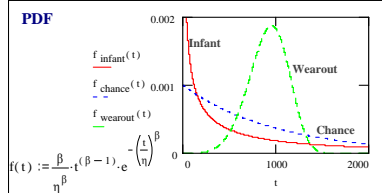
- ◆ All LCC numbers are uncertain--how much and where is important for final outcomes of cost
- ◆ Nothing fails on schedule & nothing runs forever
- ◆ Nothing gets repaired in exactly the same time interval
- ◆ Failure modes are not always exactly repeated and they are vitally important for RCM strategies
- ◆ Uncertainty calculations require use of statistical distributions and Monte Carlo simulations which are best used with Weibull database information

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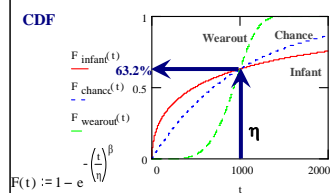
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# Weibull Statistics: Important LCC Tools

Probability distribution function,  $f(t)$

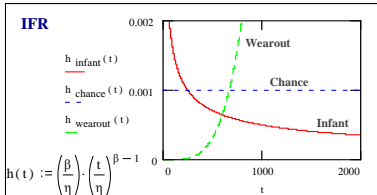


Cumulative distribution function,  $F(t)$

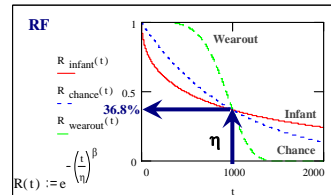


$\eta = 1000$  ← Characteristic life  
 $\beta = 5$  ← Shape factor  
 $\beta$  has literal interpretations for individual component failures  
 MTBF or MTF =  $\eta \Gamma(1/\beta + 1)$  and when  $\beta = 1$  then  $\eta = \Theta$   
 Values used for plots:  
 $\beta = 0.5$  for infant mortality,  
 $1.0$  for chance failures  
 $5.0$  for wear-out failures  
 $\eta = 1000$  for the characteristic life

Instantaneous failure rate,  $h(t)$



Reliability function,  $R(t) = 1 - F(t)$



← Weibull failure rates can represent: infant failure modes, chance failure modes, or wearout failure modes.

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See Weibull database at: <http://www.barringer1.com/wdbase.htm>

## Weibull Failure Databases

Item	Beta Values (Weibull Shape Factors)			Eta Values (Weibull Characteristic Life--hrs)		
	Low	Typical	High	Low	Typical	High
Ball Bearings	0.7	1.3	3.5	14000	40000	250000
Couplings	0.8	2	6	25000	75000	333000
Housing						
Impeller	0.5	2.5	6	125000	150000	1400000
Motors	0.5	1.2	3	1000	100000	200000
Seals	0.8	1.4	4	3000	25000	50000
Shafts	0.8	1.2	3	50000	50000	300000

◆ Use Weibull data and equations to find random times to failure using Monte Carlo methods

$$\text{Age-to-failure} = t = \eta * \{\ln(1/(1-\text{CDF}))\}^{1/\beta}$$

$$= \eta * \{-\ln(1-\text{CDF})\}^{1/\beta}$$

← Less computer intensive

substitute the Excel function **RAND()** for CDF

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Download this Excel model from [http://www.barringer1.com/MC\\_files/LCC-Simple-Monte-Carlo-Model.zip](http://www.barringer1.com/MC_files/LCC-Simple-Monte-Carlo-Model.zip)

## Monte Carlo Failures Find Costs

Individual Failure Iteration---->

Cumulative Iterations---->

Annualized Failures---->

Costs Of Failures---->

Solo ANSI Pump Fix When Broken Life Cycle Cost Simulation in an Excel Spreadsheet											
Cost Element		n	β	1	2	3	4	5	6	7	8
Electricity	3	1.4	1097	3651	3466	3575	3617	3647	3681	3684	3633
Shaft	18	1.2	296	383	432	516	463	390	519	659	538
Housing	12	2.5	19	42	207	301	460	575	700	780	891
Pump Bearings	4	1.3	593	284	2526	2632	2659	2591	2730	2711	2684
Motor	12	1.2	1731	0	0	0	0	0	0	0	0
Coupling	8	2.0	583	0	0	0	0	0	1	0	0
Hold Down Wtr For 720 Sessions		0.00	8.00	16.00	0.00	0.00	8.00	0.00	8.00	0.00	16.00
Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
Cost Element		n	β	1	2	3	4	5	6	7	8
Electricity	3	1.4	1097	3651	3466	3575	3617	3647	3681	3684	3633
Shaft	18	1.2	296	383	432	516	463	390	519	659	538
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Motor	12	1.2	1731	0	0	0	0	0	0	0	0
Coupling	8	2.0	583	0	0	0	0	0	1	0	0
Hold Down Wtr For 720 Sessions		0.00	8.00	16.00	0.00	0.00	8.00	0.00	8.00	0.00	16.00
Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
Cost Element		n	β	1	2	3	4	5	6	7	8
Electricity	3	1.4	0.200	0.305	0.347	0.357	0.362	0.365	0.368	0.366	0.364
Shaft	18	1.2	0.030	0.038	0.043	0.052	0.046	0.050	0.052	0.051	0.054
Housing	12	2.5	0.002	0.008	0.021	0.030	0.046	0.058	0.070	0.078	0.090
Pump Bearings	4	1.3	0.022	0.032	0.040	0.048	0.046	0.049	0.053	0.054	0.051
Motor	12	1.2	0.158	0.028	0.253	0.263	0.266	0.259	0.272	0.271	0.269
Coupling	8	2.0	0.050	0.063	0.075	0.070	0.078	0.080	0.079	0.081	0.079
Average Number Of Failures For 720 Sessions		0.39	8.02	7.17	7.89	7.37	8.25	8.32	8.74	8.36	8.33
Average Number Of Failures For Each Time Interval		0.47	9.72	8.86	9.47	9.26	10.04	10.02	10.64	10.05	10.06
Cost Element		n	β	1	2	3	4	5	6	7	8
Electricity	3	1.4	1097	3651	3466	3575	3617	3647	3681	3684	3633
Shaft	18	1.2	296	383	432	516	463	390	519	659	538
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Motor	12	1.2	1731	0	0	0	0	0	0	0	0
Coupling	8	2.0	583	0	0	0	0	0	1	0	0
Hold Down Wtr For 720 Sessions		0.00	8.00	16.00	0.00	0.00	8.00	0.00	8.00	0.00	16.00
Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
Cost Element		n	β	1	2	3	4	5	6	7	8
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Coupling	8	2.0	583	0	0	0	0	0	1	0	0
Hold Down Wtr For 720 Sessions		0.00	8.00	16.00	0.00	0.00	8.00	0.00	8.00	0.00	16.00
Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
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Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
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Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
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Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
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Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
Cumulative Number Of Substitutions		0	0	0	0	0	0	0	0	0	0
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Number Of Failures For 720 Sessions		0	1	2	0	0	1	0	1	0	2
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Cost Element		n	β	1	2	3	4	5	6	7	8
Electricity	3	1.4	1097	3651	3466	3575	3617	3647	3681	3684	3633
Shaft	18	1.2	296	383	432	516					