# How To Justify Equipment Improvements Using Life Cycle Costs & Reliability Principles

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# Definitions

- **Reliability--The probability that a component, device, system, or process will perform its intended function without failure for a given time when operated correctly in a specified environment**
- **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. The lowest long term cost of ownership is a frequent goal.**
- **Net Present Value-- NPV is a financial tool for evaluating economic value added. The present value of an investment's future net cash flows minus the initial investment for a given hurdle discount rate are summed for the net.**

# Similarities: Safety & Reliability

Safety

- Safety policies plan for zero accidents
- Safety issues involve human learning
- Safety involves altruism and money

Reliability

- Reliability issues plan for zero failures
- Reliability issues involve entropy deterioration often caused by aging effects
- Reliability involves money and alternatives

Alternatives is a plural word!!




# Reliability vs Maintenance

- **Reliability-**
  - Long range strategic approach
  - **Dedicated to forecasting and avoiding failures**
- **Maintenance-**
  - Short range adrenaline driven tactical approach
  - Dedicated to restoring equipment quickly
- **Both areas have similarities and interests. Each relies on the other**

## Why Work On LCC

- **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**
- **Sales aids for the Rainmakers**




## Rainmakers

- **Rainmakers have magic for American Indians**
  - No rain, no crops, no life
- **Rainmakers are important sales people:**
  - **No orders, no revenue, no business, no future**
- **Rain is the customers money**
- **Rainmakers are your few ace sales people**
- **Rainmakers are not born.  They are made.  Life cycle cost can be a powerful tool for $'s**

## Rainmakers Credo*

- Cherish customers—treat them as best friends
- Listen to customers—make/provide what they want
- Monetize product values—show customers the value of what they get from your product
- Make your product the way customers want it and deliver it to match their needs
- Remind customers of the monetized value received
- Give customers more than expected and help them pay without embarrassment—ask to do it again

*** How To Become A Rainmaker,**
Jeffrey J. Fox, Hyperion Press, NY, 2000
ISBN 0-7868-6595-4




## Monetize Details For Rainmakers

- Describe in money the product value to the customer
- Price is the universal comparator for two products
- Focusing only on price is myopic if the true goal is the lowest long term cost of ownership (a LCC statement)
- Engineers must price-out the value for benefits—better, faster, lighter, more reliability must be quantified in monetary terms—not just in golly, gee whiz things!
- The three most important words for rainmakers: money, money, money—explained in customer terms!
- Use reliability tools to get to the money!

## Why Work On Reliability Issues?

- **Solving reliability problems solves cost problems**
- **Solving reliability problems requires new tools to both predict and solve root causes of failures to solve costly old unresolved problems**
- **Most reliability issues require models, based on actual data, to forecast future performance and predict failures that drive the money issues**
- **Make reliability improvements pay their way by working toward the lowest life cycle cost**
- **Reliability tools predict when failures will occur which permit use of life cycle cost techniques**




## Why Is Reliability a Business Issue?

- Equipment failures cost money for repairs
- System failures stop cash inflows plus incur repair costs
- Business needs equipment and processes that are
  - **available** ← ready for duty when needed
  - **reliable** ← free of system failures
  - **maintenance** ← few maintenance interventions
  - **affordable** ← lowest long term cost of ownership
- We speak of technology and reliability but the main issue is money--which infers life cycle costs based on knowing when failures occur!

# RAM Models

- Reliability and maintainability answer the questions about:
  - **R**eliability
  - **A**vailability
  - **M**aintenance

Software sources for no-cost tool:
www.barringer1.com/raptor.htm

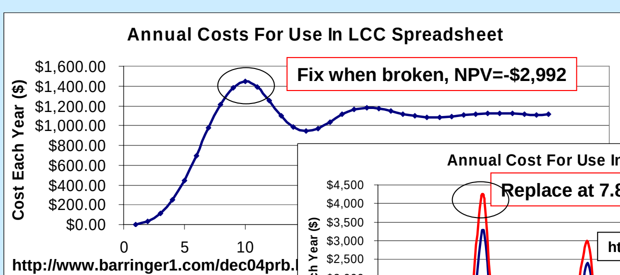
- RAM models outputs drive operational costs which is connected to acquisition costs

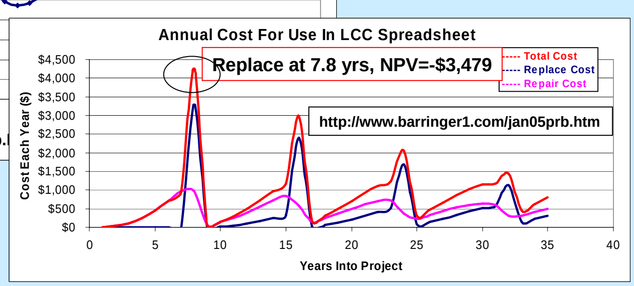



# Maintenance Strategies

- Fix when broken? Timed replacements?

Weibull failure details:
$\beta$=3.5, $\eta$=10,
Planned replacement cost = $5,000
Unplanned cost = $10,000

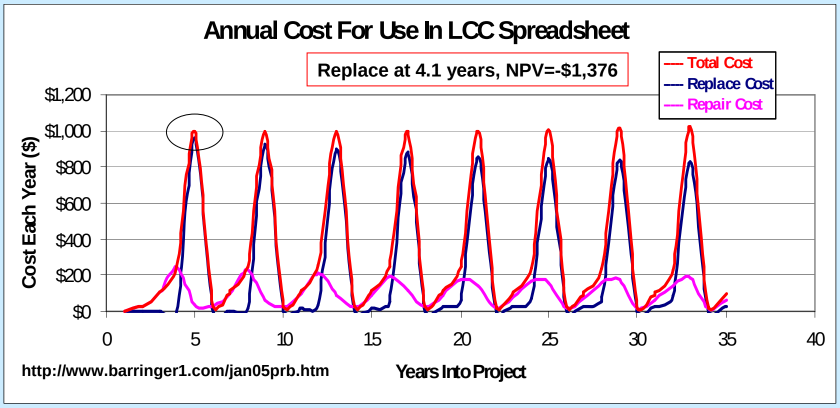


# More Maintenance Strategies

- Different costs structure

Weibull failure details:
$\beta$=3.5, $\eta$=10,
Planned replacement cost = $1,000
Unplanned cost = $10,000



# The Problem To Address

- We have two pumps of equal size in parallel. Years ago we operated them as 1 out of 2.
- With de-bottlenecking, we now need 2 out of 2.
- One pump is correctly installed with long life. Other pump is poorly installed with shorter life. Typical maintenance costs are $10,000/failure
- The application is high temp--space is cramped
- Need IRR > 50% with discount rate = 12%

# The Problem To Address-contd

- Long life pump has a Weibull characteristics: beta = 2.067, eta = 478 days
- Short life pump has a Weibull characteristics: beta = 0.667, eta = 174 days
- Repair time is lognormal with 1.6667 days of downtime and standard deviation is 2.0
- Cutback losses are $3,000/hr when 1 out of 2 survive or $10,000/hr when 0 out of 2 survive

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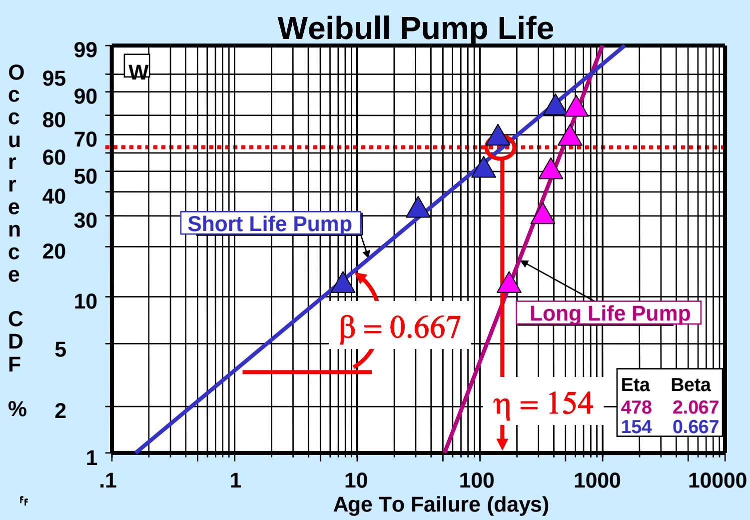
# Weibull Plot Of Life

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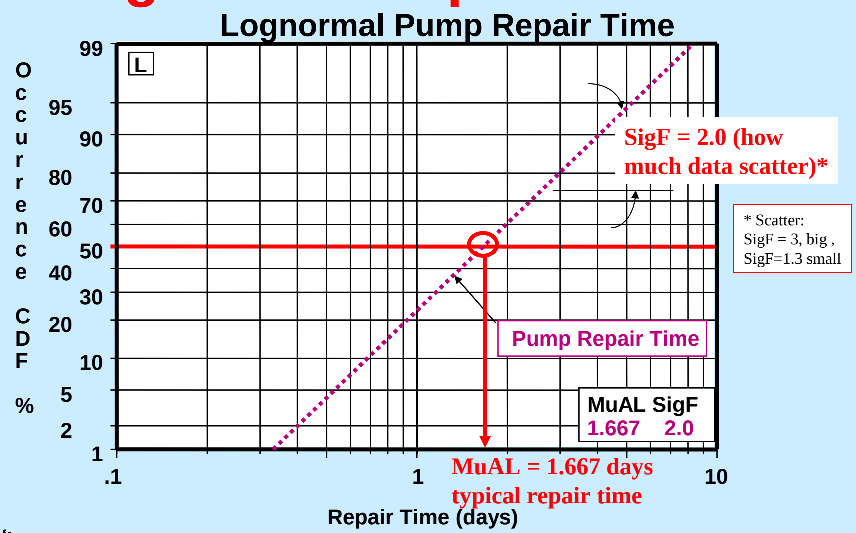
# Lognormal Repair Time

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# The Problem To Address-contd

- **Option 1**: **Do nothing**. Live with two old pumps requiring 2 out of 2. Find the costs
- **Option 2**: **Add a big new pump** in parallel with two old pumps. Cost is $75,000. Repair cost is $12,000/failure. No change in repair time and life is same as good pump.
- **Option 3**: **Add a third small pump** for 2 out of 3. Cost is $50,000. Life is like good pump & repair time is same.

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# What Reliability Prediction Tools To Use?

**Table 1**

**Short List Of Reliability Engineering Principles Tools**

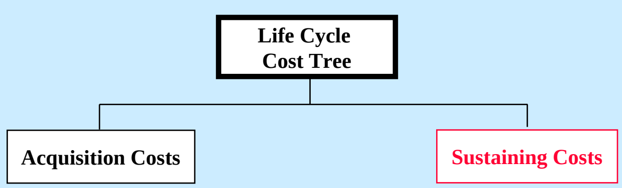
- ✓ Mean time between failures indices
- TPM and reliability principles
- ✓ Preparing reliability data for analysis
- Decision trees merging reliability and costs
- ✓ Weibull, normal, & log-normal probability plots
- Corrective action for Weibull failure
- ✓ Models & Monte Carlo simulations
- Pareto distributions for vital problems
- Fault tree analysis
- Design review
- Load/strength interactions
- Software reliability tools
- Sudden death and simultaneous testing
- ✓ Failure recording, analysis and corrective action
- Failure mode effect analysis

- Bathtub curves for modes of failure
- Availability, maintainability, capability
- Critical items significantly affecting safety/costs
- Quality function deployment
- Mechanical components testing for interactions
- Electronic device screening and de-rating
- Quality function deployment
- Reliability testing strategies
- Accelerated testing
- Contracting for reliability
- Reliability growth models and displays
- Cost of unreliability
- Reliability policies and specifications
- Reliability audits
- ✓ Management's role in reliability improvements

# Life Cycle Cost Elements

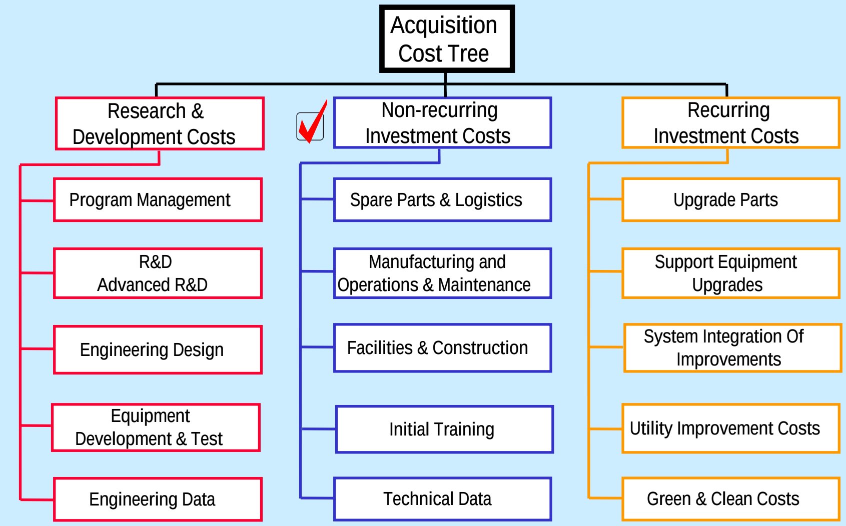
- LCC = Acquisition + Sustaining Costs




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

# Branches For Acquisition Tree

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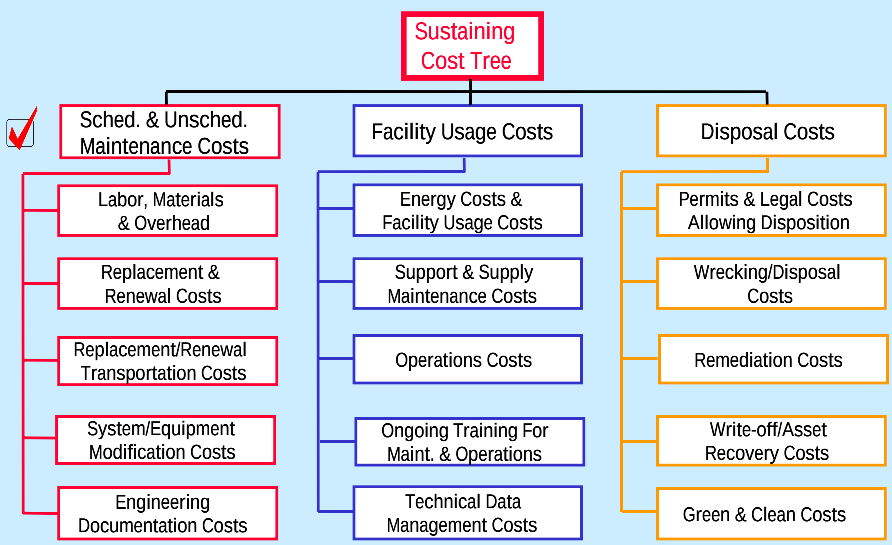
# Branches For Sustaining Tree

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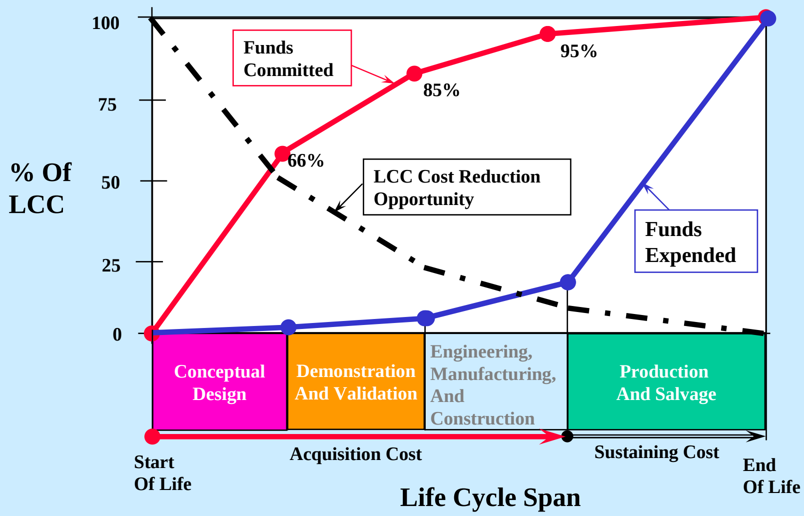
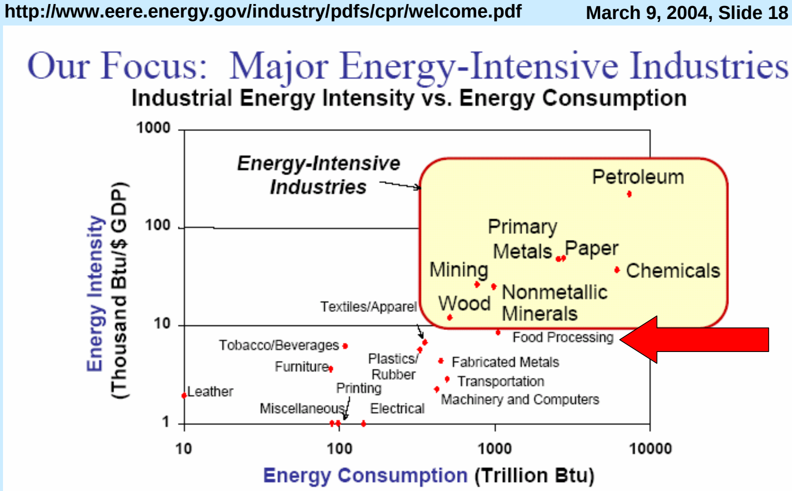
# Commitments & Expenditures



# Don't Forget Energy Costs

http://www.eere.energy.gov/industry/pdfs/cpr/welcome.pdf March 9, 2004, Slide 18



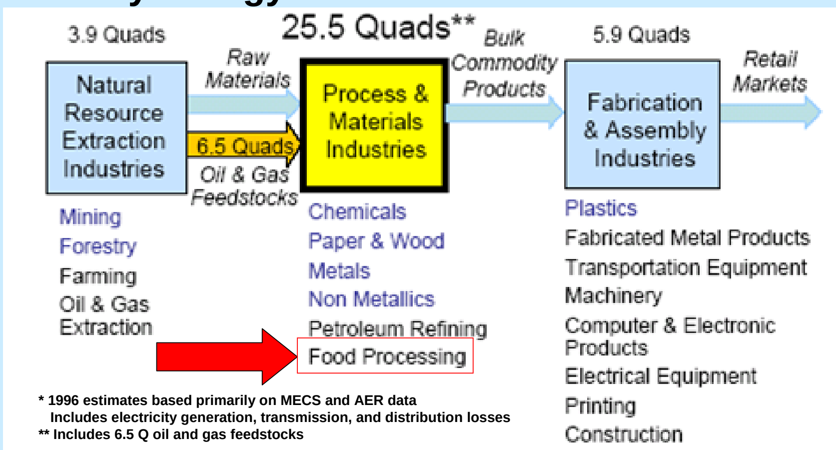

Sources: EIA 2001, 1998 Manufacturing Energy Consumption Survey; U.S. DOE 2002, Energy and Environmental Profile of the U.S. Mining Industry

# Food Processing Is In The Energy Consumption/Cost Bullseye!

http://www.eere.energy.gov/industry/pdfs/cpr/welcome.pdf March 9, 2004, Slide 19

## Heavy Energy Use in Process Industries*



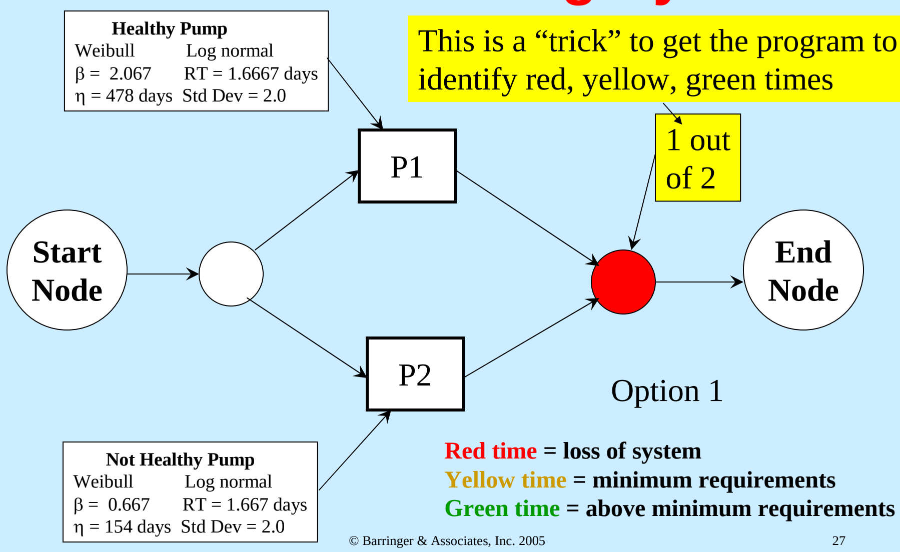

 

# How To Solve The Problem?

- Build a Monte Carlo model using the no-cost PC based RAPTOR model with hyperlinks from **http://www.barringer1.com/raptor.htm**
- RAPTOR is a reliability and maintainability model using reliability block diagrams
- Output from RAPTOR gives time lost and number of repairs each year with data by year so time buckets are correct for LCC spreadsheets

# Model For Existing System



# Model Output--Option 1

**Final Results**

Results from 1000 run(s):

| Parameter | Minimum | Mean | Maximum | Standard Dev |
|---|---|---|---|---|
| Total Costs | 1462.00 | 181818.43 | 1176257.03 | 130780.67 |
| Ao | 0.981704109 | 0.999956007 | 1.0000000000 | 0.000631445 |
| MTBDE | 358.322000 | >724.143943 | >730.000000 | n/a |
| MDT (16 runs) | 0.041639 | 1.003582 | 6.678000 | 1.526086 |
| MTBM | 30.416667 | >225.740270 | >730.000000 | n/a |
| MRT (921 runs) | 0.000000 | 1.599825 | 14.450437 | 1.246611 |
| %Green Time | 91.854515 | 98.834532 | 100.000000 | 1.136733 |
| %Yellow Time | 0.000000 | 1.161069 | 8.145485 | 1.128653 |
| % Red Time | 0.000000 | 0.004399 | 1.829589 | 0.063145 |
| Failures After Reset | 0 | 0.016000 | 1 | 0.125475 |

Total Sim Time=730.000000, Time After Stats Reset=365.000000

Option 1

Note Time Span

# Summary Of Facts-Option 1

**Table 3**

**Datum Case: Do Nothing Alternative--Failure Costs For The Status Quo**

All results based on 1000 trials for each year---statistical data reported for only the year studied.

| Year | Days | Mean Red Time (two pumps down at same time), **(%)** | Mean Red Time Converted To Down Time For Total System Failures, **(hrs/year)** | Mean Number of Red Event System Failures. **(#)** | Mean Red Time For Complete System Failures Converted To Gross Margin Money Lost ($/year) | Mean Yellow Time (Cutback zone-one survives out of two) **(%)** | Mean Yellow Time For Cutbacks Converted To Downtown **(hours/yr)** | Mean Repair Time **(days/ failure)** | Average Number of Cutback Failures Per Year **(#/yr)** | Cutback Conditions Gross Margin Failure Cost Losses **($/yr)** | Gross Margin Losses From Cutbacks and Total System Failures **($/yr)** | Pump Mainte-nance Repair Costs **($/yr)** | Sum Of Gross Margin Losses & Repair Costs **($/yr)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a** | **b** | **c** | **d** | **e** | **f** | **g** | **h** | **I** | **j** | **k** | **l** | **m** | **n** |
| | | From RAPTOR | 365*(c/100)*24 | From RAPTOR | $10,000*d | From RAPTOR | 365*(g/100)*24 | From RAPTOR | h/(I*24) | $3,000*h | f + k | $10,000*(e + J) | L + N |
| 1 | 365 | 0.002144 | 0.187814 | 0.009 | $1,878 | 1.279285 | 112.0654 | 1.674760 | 2.788095 | $336,196 | $338,074 | $27,971 | $366,045 |
| 2 | 730 | 0.004399 | 0.385352 | 0.016 | $3,854 | 1.161069 | 101.7096 | 1.599825 | 2.648978 | $305,129 | $308,982 | $26,650 | $335,632 |
| 3 | 1095 | 0.002880 | 0.252288 | 0.016 | $2,523 | 1.174653 | 102.8996 | 1.646313 | 2.604294 | $308,699 | $311,222 | $26,203 | $337,425 |
| 4 | 1460 | 0.002312 | 0.202531 | 0.013 | $2,025 | 1.218289 | 106.7221 | 1.638230 | 2.714365 | $320,166 | $322,192 | $27,274 | $349,465 |
| 5 | 1825 | 0.002606 | 0.228286 | 0.012 | $2,283 | 1.167023 | 102.2312 | 1.659235 | 2.567228 | $306,694 | $308,977 | $25,792 | $334,769 |
| 6 | 2190 | 0.001404 | 0.122990 | 0.007 | $1,230 | 1.198115 | 104.9549 | 1.700919 | 2.571034 | $314,865 | $316,095 | $25,780 | $341,875 |
| 7 | 2555 | 0.003302 | 0.289255 | 0.02 | $2,893 | 1.191764 | 104.3985 | 1.654584 | 2.629023 | $313,196 | $316,088 | $26,490 | $342,578 |
| 8 | 2920 | 0.001809 | 0.158468 | 0.014 | $1,585 | 1.173470 | 102.7960 | 1.707165 | 2.508935 | $308,388 | $309,973 | $25,229 | $335,202 |
| 9 | 3285 | 0.002225 | 0.194910 | 0.014 | $1,949 | 1.222295 | 107.0730 | 1.712634 | 2.604980 | $321,219 | $323,168 | $26,190 | $349,358 |
| 10 | 3650 | 0.002040 | 0.178704 | 0.007 | $1,787 | 1.188088 | 104.0765 | 1.659607 | 2.612981 | $312,230 | $314,017 | $26,200 | $340,216 |
| 11 | 4015 | 0.005804 | 0.508430 | 0.021 | $5,084 | 1.197460 | 104.8975 | 1.779037 | 2.456795 | $314,692 | $319,777 | $24,778 | $344,555 |
| 12 | 4380 | 0.001773 | 0.155315 | 0.012 | $1,553 | 1.175174 | 102.9452 | 1.707771 | 2.511686 | $308,836 | $310,389 | $25,237 | $335,626 |
| 13 | 4745 | 0.002105 | 0.184398 | 0.009 | $1,844 | 1.224117 | 107.2326 | 1.649817 | 2.708196 | $321,698 | $323,542 | $27,172 | $350,714 |
| 14 | 5110 | 0.001496 | 0.131050 | 0.009 | $1,310 | 1.196564 | 104.8190 | 1.587960 | 2.750358 | $314,457 | $315,768 | $27,594 | $343,361 |
| 15 | 5475 | 0.002415 | 0.211554 | 0.009 | $2,116 | 1.133094 | 99.2590 | 1.619986 | 2.552981 | $297,777 | $299,893 | $25,620 | $325,512 |
| 16 | 5840 | 0.002512 | 0.220051 | 0.013 | $2,201 | 1.160906 | 101.6954 | 1.601372 | 2.646048 | $305,086 | $307,287 | $26,590 | $333,877 |
| 17 | 6205 | 0.005928 | 0.519293 | 0.01 | $5,193 | 1.167567 | 102.2789 | 1.663234 | 2.562249 | $306,837 | $312,030 | $25,722 | $337,752 |
| 18 | 6570 | 0.003201 | 0.280408 | 0.016 | $2,804 | 1.265275 | 110.8381 | 1.725613 | 2.676297 | $332,514 | $335,318 | $26,923 | $362,241 |
| 19 | 6935 | 0.004091 | 0.358372 | 0.015 | $3,584 | 1.122020 | 98.2890 | 1.567801 | 2.612177 | $294,867 | $298,451 | $26,272 | $324,722 |
| 20 | 7300 | 0.004691 | 0.410932 | 0.015 | $4,109 | 1.254588 | 109.9019 | 1.795161 | 2.550883 | $329,706 | $333,815 | $25,659 | $359,474 |
| | | | **Average =** | **0.013** | **$2,590** | | | | **2.614** | **$313,663** | **$316,253** | **$26,267** | **$342,520** |

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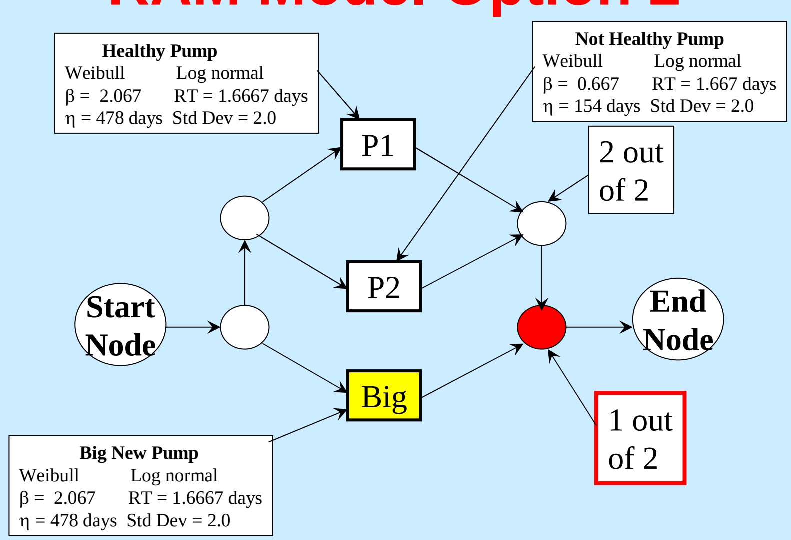
# RAM Model Option 2

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# Summary Of Facts-Option 2

**Table 4 - Failure Cost Details**

**Alternate #1: Add Large New Pump For $75,000 Capital Addition**

All results based on 1000 trials for each year---statistical data reported for only the year studied.

| Year | Days | Mean Red Time (two pumps down at same time), **(%)** | Mean Red Time Converted To Down Time For Total System Failures, **(hrs/year)** | Mean Number of Red Event System Failures. **(#)** | Mean Red Time For Complete System Failures Converted To Gross Margin Money Lost **($/year)** | Mean Yellow Time (System survives on 1 out of two) **(%)** | Mean Yellow Time For Cutbacks Converted To Downtown **(hours/yr)** | Mean Repair Time **(days/ failure)** | Maintenance Actions From Table 3 **(#/yr)** | Cutback Conditions Gross Margin Failure Cost Losses **($/yr)** | Gross Margin Losses From Cutbacks and Total System Failures **($/yr)** | Pump Mainte-nance Repair Costs **($/yr)** | Sum Of Gross Margin Losses & Repair Costs **($/yr)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a** | **b** | **c** | **d** | **e** | **f** | **g** | **h** | **I** | **j** | **k** | **l** | **m** | **n** |
| | | From RAPTOR | 365*(c/100)*24 | From RAPTOR | $10,000*d | From RAPTOR | 365*(g/100)*24 | From RAPTOR | h/(I*24) | $3,000*h | f + k | $10,000*(e + | L + N |
| 1 | 365 | 0.002808 | 0.245981 | 0.009 | $2,460 | 1.496662 | 0.0000 | 1.621665 | 2.788095 | $0 | $2,460 | $27,971 | $30,431 |
| 2 | 730 | 0.003180 | 0.278568 | 0.018 | $2,786 | 1.525694 | 0.0000 | 1.645328 | 2.648978 | $0 | $2,786 | $26,670 | $29,455 |
| 3 | 1095 | 0.002636 | 0.230914 | 0.016 | $2,309 | 1.523991 | 0.0000 | 1.591735 | 2.604294 | $0 | $2,309 | $26,203 | $28,512 |
| 4 | 1460 | 0.002888 | 0.252989 | 0.013 | $2,530 | 1.540243 | 0.0000 | 1.641320 | 2.714365 | $0 | $2,530 | $27,274 | $29,804 |
| 5 | 1825 | 0.003342 | 0.292759 | 0.018 | $2,928 | 1.558373 | 0.0000 | 1.658373 | 2.567228 | $0 | $2,928 | $25,852 | $28,780 |
| 6 | 2190 | 0.005548 | 0.486005 | 0.024 | $4,860 | 1.652372 | 0.0000 | 1.680495 | 2.571034 | $0 | $4,860 | $25,950 | $30,810 |
| 7 | 2555 | 0.003415 | 0.299154 | 0.019 | $2,992 | 1.588985 | 0.0000 | 1.692783 | 2.629023 | $0 | $2,992 | $26,480 | $29,472 |
| 8 | 2920 | 0.006000 | 0.525600 | 0.019 | $5,256 | 1.676827 | 0.0000 | 1.759163 | 2.508935 | $0 | $5,256 | $25,279 | $30,535 |
| 9 | 3285 | 0.004139 | 0.362576 | 0.025 | $3,626 | 1.534075 | 134.3850 | 1.708342 | 2.604980 | $0 | $3,626 | $26,300 | $29,926 |
| 10 | 3650 | 0.002161 | 0.189304 | 0.016 | $1,893 | 1.586171 | 138.9486 | 1.618912 | 2.612981 | $0 | $1,893 | $26,290 | $28,183 |
| 11 | 4015 | 0.008591 | 0.752572 | 0.034 | $7,526 | 1.530274 | 134.0520 | 1.643702 | 2.456795 | $0 | $7,526 | $24,908 | $32,434 |
| 12 | 4380 | 0.003305 | 0.289518 | 0.019 | $2,895 | 1.507384 | 132.0468 | 1.568182 | 2.511686 | $0 | $2,895 | $25,307 | $28,202 |
| 13 | 4745 | 0.004369 | 0.382724 | 0.018 | $3,827 | 1.560153 | 136.6694 | 1.629170 | 2.708196 | $0 | $3,827 | $27,262 | $31,089 |
| 14 | 5110 | 0.004655 | 0.407778 | 0.023 | $4,078 | 1.607977 | 140.8588 | 1.725438 | 2.750358 | $0 | $4,078 | $27,734 | $31,811 |
| 15 | 5475 | 0.005434 | 0.476018 | 0.022 | $4,760 | 1.678712 | 147.0552 | 1.694653 | 2.552981 | $0 | $4,760 | $25,750 | $30,510 |
| 16 | 5840 | 0.005960 | 0.522096 | 0.019 | $5,221 | 1.566482 | 137.2238 | 1.145008 | 2.646048 | $0 | $5,221 | $26,650 | $31,871 |
| 17 | 6205 | 0.005148 | 0.450965 | 0.019 | $4,510 | 1.566820 | 137.2534 | 1.641916 | 2.562249 | $0 | $4,510 | $25,812 | $30,322 |
| 18 | 6570 | 0.005380 | 0.471288 | 0.23 | $4,713 | 1.500112 | 131.4098 | 1.612780 | 2.676297 | $0 | $4,713 | $29,063 | $33,776 |
| 19 | 6935 | 0.005484 | 0.480398 | 0.019 | $4,804 | 1.556089 | 136.3134 | 1.646546 | 2.612177 | $0 | $4,804 | $26,312 | $31,116 |
| 20 | 7300 | 0.002263 | 0.198239 | 0.013 | $1,982 | 1.525871 | 133.6663 | 1.696846 | 2.550883 | $0 | $1,982 | $25,639 | $27,621 |
| | | | **Average =** | **0.030** | **$3,798** | | | | **2.614** | **$0** | **$3,798** | **$26,435** | **$30,233** |

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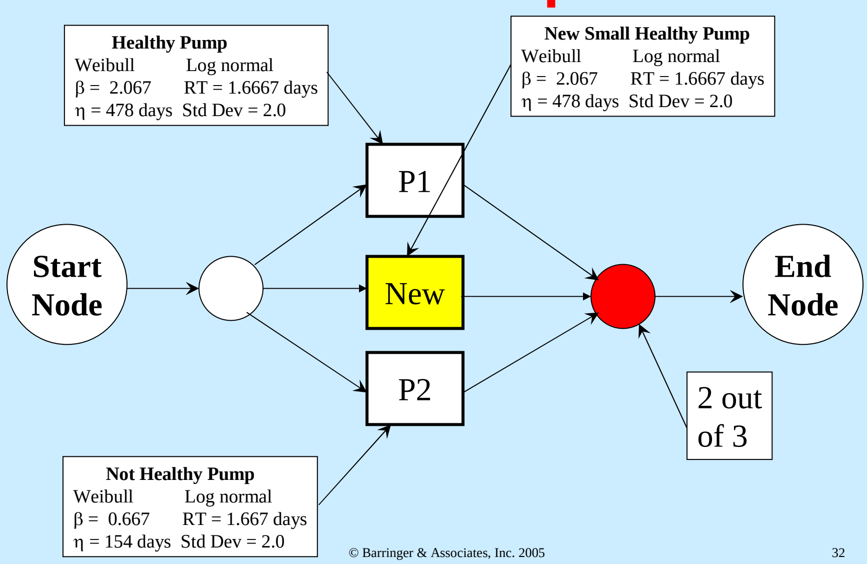
# RAM Model-Option 3

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# Summary Of Facts-Option 3

**Table 5-Failure Cost Details By Year**

**Alternate #2: Add Third Small Pump For $50,000 capital addition**

All results based on 1000 trials for each year---statistical data reported for only the year studied.

| Year | Days | Mean Red Time (two pumps down at same time), **(%)** | Mean Red Time Converted To Down Time For Total System Failures, **(hrs/year)** | Mean Number of Red Event System Failures. **(#)** | Mean Red Time For Complete System Failures Converted To Gross Margin Money Lost **($/year)** | Mean Yellow Time (System survives on 1 out of two) **(%)** | Mean Yellow Time For Cutbacks Converted To Downtown **(hours/yr)** | Mean Repair Time **(days/ failure)** | Maintenance Actions From Table 3 **(#/yr)** | Cutback Conditions Gross Margin Failure Cost Losses **($/yr)** | Gross Margin Losses From Cutbacks and Total System Failures **($/yr)** | Pump Mainte-nance Repair Costs **($/yr)** | Sum Of Gross Margin Losses & Repair Costs **($/yr)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a** | **b** | **c** | **d** | **e** | **f** | **g** | **h** | **I** | **j** | **k** | **l** | **m** | **n** |
| | | From RAPTOR | 365*(c/100)*24 | | $10,000*d | From RAPTOR | 365*(g/100)*24 | From RAPTOR | h/(I*24) | $3,000*h | f + k | $10,000*(e + J | L + N |
| 1 | 365 | 0.005631 | 0.493276 | 0.024 | $4,933 | 1.493357 | 0.0000 | 1.621734 | 2.788095 | $0 | $4,933 | $28,121 | $33,054 |
| 2 | 730 | 0.006598 | 0.577985 | 0.034 | $5,780 | 1.522276 | 0.0000 | 1.645328 | 2.648978 | $0 | $5,780 | $26,830 | $32,610 |
| 3 | 1095 | 0.006315 | 0.553194 | 0.027 | $5,532 | 1.511053 | 0.0000 | 1.588076 | 2.604294 | $0 | $5,532 | $26,313 | $31,845 |
| 4 | 1460 | 0.005134 | 0.449738 | 0.023 | $4,497 | 1.542650 | 0.0000 | 1.641561 | 2.714365 | $0 | $4,497 | $27,374 | $31,871 |
| 5 | 1825 | 0.007489 | 0.656036 | 0.029 | $6,560 | 1.557925 | 0.0000 | 1.626821 | 2.567228 | $0 | $6,560 | $25,962 | $32,523 |
| 6 | 2190 | 0.008598 | 0.753185 | 0.041 | $7,532 | 1.640525 | 0.0000 | 1.679492 | 2.571034 | $0 | $7,532 | $26,120 | $33,652 |
| 7 | 2555 | 0.006485 | 0.568086 | 0.03 | $5,681 | 1.585399 | 0.0000 | 1.692950 | 2.629023 | $0 | $5,681 | $26,590 | $32,271 |
| 8 | 2920 | 0.007761 | 0.679864 | 0.032 | $6,799 | 1.646099 | 0.0000 | 1.748673 | 2.508935 | $0 | $6,799 | $25,409 | $32,208 |
| 9 | 3285 | 0.006247 | 0.547237 | 0.038 | $5,472 | 1.506308 | 131.9526 | 1.669873 | 2.604980 | $0 | $5,472 | $26,430 | $31,902 |
| 10 | 3650 | 0.004558 | 0.399281 | 0.032 | $3,993 | 1.561381 | 136.7770 | 1.621280 | 2.612981 | $0 | $3,993 | $26,450 | $30,443 |
| 11 | 4015 | 0.011695 | 1.024482 | 0.05 | $10,245 | 1.534922 | 134.4592 | 1.644482 | 2.456795 | $0 | $10,245 | $25,068 | $35,313 |
| 12 | 4380 | 0.008187 | 0.717181 | 0.035 | $7,172 | 1.548677 | 135.6641 | 1.609311 | 2.511686 | $0 | $7,172 | $25,467 | $32,639 |
| 13 | 4745 | 0.007047 | 0.617317 | 0.028 | $6,173 | 1.557050 | 136.3976 | 1.643827 | 2.708196 | $0 | $6,173 | $27,362 | $33,535 |
| 14 | 5110 | 0.008371 | 0.733300 | 0.036 | $7,333 | 1.606874 | 140.7622 | 1.707090 | 2.750358 | $0 | $7,333 | $27,864 | $35,197 |
| 15 | 5475 | 0.012698 | 1.112345 | 0.042 | $11,123 | 1.643722 | 143.9900 | 1.690501 | 2.552981 | $0 | $11,123 | $25,950 | $37,073 |
| 16 | 5840 | 0.009475 | 0.830010 | 0.028 | $8,300 | 1.598046 | 139.9888 | 1.654809 | 2.646048 | $0 | $8,300 | $26,740 | $35,041 |
| 17 | 6205 | 0.010576 | 0.926458 | 0.035 | $9,265 | 1.558653 | 0.0000 | 1.634686 | 2.562249 | $0 | $9,265 | $25,972 | $35,237 |
| 18 | 6570 | 0.007056 | 0.618106 | 0.036 | $6,181 | 1.506175 | 0.0000 | 1.612697 | 2.676297 | $0 | $6,181 | $27,123 | $33,304 |
| 19 | 6935 | 0.005098 | 0.446585 | 0.025 | $4,466 | 1.560881 | 0.0000 | 1.641412 | 2.612177 | $0 | $4,466 | $26,372 | $30,838 |
| 20 | 7300 | 0.009203 | 0.806183 | 0.038 | $8,062 | 1.604712 | 140.5728 | 1.675225 | 2.550883 | $0 | $8,062 | $25,889 | $33,951 |
| | | | **Average =** | **0.033** | **$6,755** | | | | **2.614** | **$0** | **$6,755** | **$26,470** | **$33,225** |





# Details For Life Cycle Cost

**Table 6: Cost Summary Data For Life Cycle Cost Calculations**

| | **Cost Details** | | | | **Savings** | |
|---|---|---|---|---|---|---|
| Year | Original Installation | After debottle-necking | Big new pump @ $75K | Little new pump @ $50K | Big new pump @ $75K | Little new pump @ $50K |
| 1 | $29,849 | $366,045 | $30,431 | $33,054 | $335,614 | $332,991 |
| 2 | $30,503 | $335,632 | $29,455 | $32,610 | $306,177 | $303,023 |
| 3 | $28,726 | $337,425 | $28,512 | $31,845 | $308,913 | $305,580 |
| 4 | $29,299 | $349,465 | $29,804 | $31,871 | $319,662 | $317,594 |
| 5 | $28,075 | $334,769 | $28,780 | $32,523 | $305,989 | $302,246 |
| 6 | $27,010 | $341,875 | $30,810 | $33,652 | $311,064 | $308,223 |
| 7 | $29,383 | $342,578 | $29,472 | $32,271 | $313,107 | $310,307 |
| 8 | $26,814 | $335,202 | $30,535 | $32,208 | $304,667 | $302,994 |
| 9 | $28,139 | $349,358 | $29,926 | $31,902 | $319,432 | $317,456 |
| 10 | $27,987 | $340,216 | $28,183 | $30,443 | $312,034 | $309,774 |
| 11 | $29,862 | $344,555 | $32,434 | $35,313 | $312,121 | $309,242 |
| 12 | $26,790 | $335,626 | $28,202 | $32,639 | $307,424 | $302,987 |
| 13 | $29,016 | $350,714 | $31,089 | $33,535 | $319,625 | $317,179 |
| 14 | $28,904 | $343,361 | $31,811 | $35,197 | $311,550 | $308,165 |
| 15 | $27,735 | $325,512 | $30,510 | $37,073 | $295,002 | $288,439 |
| 16 | $28,791 | $333,877 | $31,871 | $35,041 | $302,006 | $298,837 |
| 17 | $30,915 | $337,752 | $30,322 | $35,237 | $307,430 | $302,515 |
| 18 | $29,727 | $362,241 | $33,776 | $33,304 | $328,465 | $328,937 |
| 19 | $29,855 | $324,722 | $31,116 | $30,838 | $293,607 | $293,885 |
| 20 | $29,768 | $359,474 | $27,621 | $33,951 | $331,853 | $325,523 |
| **Average=** | $28,857 | **$342,520** | $30,233 | $33,225 | **$312,287** | **$309,295** |
| | **Cost Data** | | | | **Savings From Debottlnecking Datum** | |

# Final Results Of LCC Analysis

| Table 7: Financial Summary | | |
|---|---|---|
| Project Summary Based On Failure Data | | |
| | NPV | IRR |
| Big New Pump @ $75K | $1,388,368 | 233.1% |
| Small New Pump @ $50K | $1,400,134 | 354.1% |

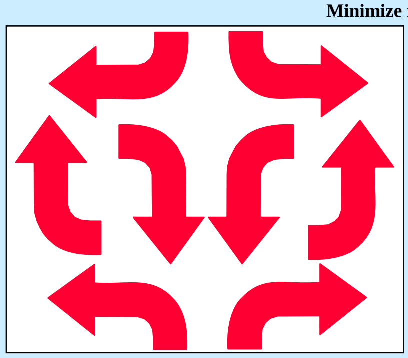
- NPV is positive. IRR exceeds 50%--winner is addition of a single small new pump




# Conflicting LCC 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

# Engineers Must Quantify All Life Cycle Costs

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

 **Think NPV & IRR** 37

# 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

| Step | Task |
|---|---|
| 1 | Define the problem requiring LCC |
| 2 | Alternatives and acquisition/sustaining costs |
| 3 | Prepare cost breakdown structure/tree |
| 4 | Choose analytical cost model |
| 5 | Gather cost estimates and cost models |
| 6 | Make cost profiles for each year of study |
| 7 | Make break-even charts for alternatives |
| 8 | Pareto charts of vital few cost contributors |
| 9 | Sensitivity analysis of high costs and reasons |
| 10 | Study risks of high cost items and occurences |
| 11 | Select preferred course of action using LCC |

Feedback

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## LCC Thumbnail

- Life cycle costs include cradle to grave costs
- Including failures into LCC decisions:
  - Engineering quantities of maintenance manpower,
  - Identify spare parts requirements + other resources
  - Use data for a rational decision rather than emotion
- LCC provides details for trade-off studies and uses NPV for sound decisions
- Monte Carlo models add realism to numbers and help find trade-off values




## Remember---

- **Reliability engineering** tools analyze failure data to predict when failures will occur and the costs.
- You can't make a good life cycle cost analysis from poor data--LCC requires a team approach using many different sources of information and no one ever becomes a true LCC expert
- **LCC business decisions result in lower cost operating plants that are truly cost effective rather than just paper effective plants!**

# Questions?

- Questions?

- For more examples and LCC aids visit: **http://www.barringer1.com**
- Download the LCC paper and slides as PDF files from **http://www.barringer1.com/Papers.htm**