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Economic Analysis of P2


(Identifying and Quantifying Relevant Operating Costs)




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Overview



- Identification of operating costs
 - Major operating cost groups
 - Individual costs within cost groups – primary and hidden costs
- Comparing costs of alternative systems
- Worked example – manual solvents parts cleaner vs. agitating ultrasonic parts washer
- Measures of profitability



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Major Operating Cost Groups

- Energy
- Labor
- Materials
- Waste disposal
- Capital
- Maintenance
- Quality





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Primary Energy Costs

- Electricity
 - Heat and air conditioning
 - Pumps and motors
 - Lights and control panels
- Fuel (natural gas, propane, coal, oil, steam)
 - Heat
- Compressed air





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Hidden Energy Costs

- Additional loads to HVAC systems (e.g. heated parts coming out of dryers)
- Overnight uses of energy (e.g. solvent washer distillation units, heat, lights)
- Infiltration losses from stacks
- Rework, damaged parts, warranty returns, and overprocessing
- Idle time from bottlenecks
- Poorly maintained equipment





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Primary Labor Costs

- Direct labor (manual operations)
- Loading and unloading of parts
- Monitoring of machine operation
- Supervision
- Pretreatment processes





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Hidden Labor Costs

- Excess handling and storage
- Cleaning up messy operations
- Poorly maintained equipment
- Rework, damaged parts, warranty returns, and overprocessing
- Idle time from bottlenecks
- Poorly designed manufacturing operations and workflow patterns





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Primary Materials Costs

- Raw materials
- Supplies and consumables
- Cleaning chemistries
- Water




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Hidden Materials Costs

- Absorbent media for spills
- Poorly maintained equipment
- Rework, damaged parts, warranty returns, and overprocessing
- Losses due to shelf life expiration
- Test equipment
- Packaging





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Primary Waste Disposal Costs

- Waste disposal charges for drums and dumpsters
- Waste characterization (e.g. TCLP testing)
- Disposal costs for empty barrels
- Sewer use charges



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Hidden Waste Disposal Costs

- Regulatory compliance fees (e.g. air permits)
- Other pretreatment costs (filters, etc)
- Operating costs of on-site wastewater treatment plant
- Poorly maintained equipment
- Cleaning compounds and absorbents for spills
- Rework, damaged parts, warranty returns, and overprocessing





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Primary Capital Costs

- Purchased cost of equipment
- Installation costs (e.g. plumbing, wiring, sewer, stacks)
- Engineering studies
- Other contractor's fees
- Training costs





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Hidden Capital Costs

- Prepurchase costs (e.g. testing, cleaning assessments)
- Learning curve effects for training
- Permits and regulatory approvals
- Required EH&S modifications (e.g. safety showers)
- Required testing equipment
- Disposal cost of old systems





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Maintenance Costs

- Labor
- Materials (oil, paint, etc)
- Outside services
- Special tooling
- Lost revenue from unscheduled shutdowns

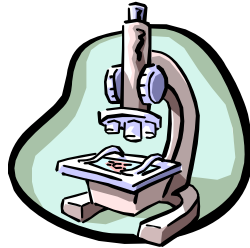



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Costs of Quality

- Rework of parts already manufactured
- Loss of revenue from parts damaged during processing
- Warranty returns
- Overprocessing
- Maintenance of monitoring systems





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Other Operating Costs

- Workmen's compensation claims
- Other regulatory compliance costs
- Potential lawsuits from improper disposal of waste
- Liability and fire insurance
- Real estate (footprint)
- Lost revenue from aesthetics




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Comparing the Costs of Alternative Systems


- Total cost method – add up all operating costs for each system and compare the results
- Incremental cost method – add up only the operating costs that are different for each system, and compare the results

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Total Cost Method


- Pros
 - provides managers with a total cost figure for system operations
 - ideal for determining whether or not manufacturing operations should be outsourced
- Cons
 - more difficult to quantify than incremental costs - more calculations needed

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Incremental Cost Method


- Pros
 - ideal for determining which of two manufacturing methods should be used
 - easier to calculate - can disregard common operations between alternatives (e.g. disassembly)
- Cons
 - does not provide the total cost or impact of a single manufacturing operation


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Worked Example for Incremental Cost Method

- Surface Cleaning Process for Carburetor Remanufacturer
 - Existing cleaning system is a manual solvents parts washer
 - Alternative cleaning system is an agitating ultrasonics parts washer
 - What savings can be obtained if the existing system is replaced?




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Spreadsheet Analysis

- Evaluate incremental costs using Excel spreadsheets
 - Determine costs for each major cost group
 - Sum costs and compare totals
 - Compare relative profitability of systems using different metrics
 - Details of calculations will not be discussed, but are presented to show what items have been included in the analysis




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General Information – Manual System

General

cycle time for manual parts washer	18	min/cycle
load/unload time	1	min/cycle
<i>total cycle time</i>	19	min/cycle
tank capacity	42	gallons/drum
batch size	1	parts/batch
# batches per day	44	batches/day
lifetime of cleaning bath (changeover period)	300	# cycles
working days per week	5	days/week
working weeks per year	50	weeks/year
<i>batches cleaned per year</i>	11000	batches/year
<i>parts cleaned per year</i>	11000	parts/year






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General Information – Ultrasonic System

General

cycle time for ultrasonics	15	min/cycle
load/unload time	2	min/cycle
delay time	1	min/cycle
<i>total cycle time</i>	18	min/cycle
tank capacity	110	gallons/tank
batch size	3	parts/batch
# batches per day	15	# cycles
lifetime of cleaning bath (changeover period)	300	# cycles
working days per week	5	days/week
working weeks per year	50	weeks/year
<i>batches per year</i>	3750	batches/year
<i>parts cleaned per year</i>	11250	parts/year







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Energy Costs – Manual System

Energy		
average power requirement while operating	0.2	KW
average run time per work day	8	hours/day
<i>total energy consumed per work day</i>	1.60	KWH/day
cost of electricity	\$0.10	\$/KWH
<i>cost of energy per day</i>	\$0.16	\$/cycle
<i>annual cost of energy</i>	\$40	\$/year







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Energy Costs (1) – Ultrasonic System

Energy		
# generators	4	#
power rating per generator	1.00	KW
<i>energy for ultrasonics consumed</i>	1.00	KWH/cycle
horsepower rating of pump	1	hp
mechanical efficiency	75.00%	%
<i>energy for pump consumed</i>	0.05	KWH/cycle
other power req (except heat)	0.1	KW
<i>other energy (except heat) consumed</i>	0.03	KWH/cycle






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Energy Costs (2) – Ultrasonic System

bath temperature	160	deg F
temperature of bath at startup	115	deg F
<i>initial heating energy consumed</i>	12.10	KWH
reheat adjustment factor	25.00%	% of single heat
<i>reheat energy consumed per cycle</i>	3.02	KWH/cycle
<i>total heat energy consumed per cycle</i>	3.83	KWH/cycle
<i>total energy consumed per cycle</i>	4.91	KWH/cycle
cost of electricity	\$0.10	\$/KWH
<i>cost of energy per cycle</i>	\$0.49	\$/cycle
<i>annual cost of energy</i>	\$1,841	\$/year

Energy Costs:

- Manual – \$40/year
- Ultrasonic – \$1,841/year





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Labor Costs – Manual System

Labor		
direct labor hours per cycle	19	min/cycle
direct labor hours per changeover	30	min/changeover
<i>total labor hours per cycle</i>	19.1	min/cycle
fully burdened labor rate	\$15.00	\$/hour
<i>cost of labor per cycle</i>	\$4.78	\$/cycle
annual cost of labor	\$52,525	\$/year



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Labor Costs – Ultrasonic System

Labor		
direct labor hours per cycle	2	min/cycle
direct labor hours per changeover	60	min/changeover
<i>total labor hours per cycle</i>	2.2	min/cycle
fully burdened labor rate	\$15.00	\$/hour
<i>cost of labor per cycle</i>	\$0.55	\$/cycle
annual cost of labor	\$2,063	\$/year

Labor Costs:


- Manual – \$52,525/year
- Ultrasonic – \$2,063/year




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Materials Costs – Manual System

Materials		
purchase and disposal cost per drum	\$130.00	\$/42-gal drum
<i>number of changeovers per year</i>	37	changeovers/year
<i>total materials cost per year</i>	\$4,767	\$/year







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Materials Costs (1) – Ultrasonic System

Materials		
cost of cleaning agent	\$13.00	\$/gallon
concentration by volume	6.67%	% by volume
# replenishments between changeovers	1	# replenishments
replenishment quantity added	0.5	gal/replenishment
cost of water	\$2.00	\$/Kgal
water loss per cycle	2.50%	% of total solution
cost of other materials per changeover	\$6.00	\$/changeover
<i>cost of initial charge of cleaning agent</i>	\$95.38	\$/changeover
<i>cost of replenishments</i>	\$6.50	\$/changeover
<i>total cost of cleaning agent per cycle</i>	\$0.34	\$/cycle






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Materials Costs (2) – Ultrasonic System

<i>cost of initial charge of water</i>	\$0.21	\$/changeover
<i>cost of makeup water per cycle</i>	\$0.01	\$/cycle
<i>total cost of water per cycle</i>	\$0.01	\$/cycle
<i>cost of other materials per cycle</i>	\$0.02	\$/cycle
<i>total materials cost per cycle</i>	\$0.37	\$/cycle
<i>total materials cost per year</i>	\$1,372	\$/year

Materials Costs:


- Manual – \$4,767/year
- Ultrasonic – \$1,372/year




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Waste Disposal Costs – Manual System

Waste Disposal		
<i>waste disposal cost included in lease</i>	\$0	\$/year



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Waste Disposal Costs – Ultrasonic System

Waste Disposal		
wastewater disposal costs	\$150.00	\$/55-gal drum
waste disposal costs per changeover	\$300.00	\$/changeover
waste disposal costs per cycle	\$1.00	\$/cycle
annual cost of waste disposal	\$3,750	\$/year

Waste Disposal Costs:

- Manual – \$0/year (included in lease)
- Ultrasonic – \$3,750/year







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Capital Costs – Manual System

Capital Costs		
leased equipment - no capital cost	\$0	\$/year







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Capital Costs – Ultrasonic System

Capital Costs		
purchased cost of machinery	\$15,000	\$
installation costs	\$3,000	\$
cost of initial training	\$500	\$
<i>total installed cost of equipment</i>	\$18,500	\$
cost of capital	15.00%	% per annum
life of equipment	10	years
salvage value at end of life	\$1,500	\$
<i>capital recovery factor</i>	0.199252	-
<i>discount factor for salvage value</i>	0.049252	-
<i>equivalent annual installed cost of equipment</i>	\$3,686	\$/year
<i>equivalent annual salvage value</i>	\$74	\$/year
<i>equivalent annual cost of equipment</i>	\$3,612	\$/year

Capital Costs:



- Manual – \$0/year (included in lease)
- Ultrasonic – \$3,612/year

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Maintenance Costs – Manual System

Maintenance Costs		
<i>maintenance cost included in lease</i>	\$0	\$/year


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Maintenance Costs – Ultrasonic System

Maintenance Costs		
maintenance costs per year, materials & services	\$500	\$/year
maintenance labor per year, duration	20	hours/year
maintenance labor per year, cost	\$300	\$/year
total maintenance costs per year	\$800	\$/year

Maintenance Costs:



- Manual – \$0/year (included in lease)
- Ultrasonic – \$800/year



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Costs of Quality – Manual System

Cost of Quality		
fraction of cleaned parts returned for recleaning	1.00%	%
cost of warranty returns	\$200.00	\$/part
fraction of warranty returns related to cleaning	0.50%	%
fraction of parts damaged in cleaning	2.34%	%
resale value of parts	\$100.00	\$/part
<i>parts cleaned per batch</i>	0.99	parts/batch
<i>parts cleaned per year</i>	10,890	parts/year
<i>annual warranty returns due to cleaning</i>	54	parts/year
<i>parts damaged in cleaning</i>	255	parts/year
<i>saleable parts cleaned per year</i>	10,635	parts/year
<i>annual cost of warranty returns</i>	\$10,800	\$/year
<i>lost revenue from damaged parts</i>	\$25,500	\$/year
annual cost of quality	\$36,300	\$/year



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Costs of Quality – Ultrasonic System

Cost of Quality		
fraction of cleaned parts returned for recleaning	5.00%	%
cost of warranty returns	\$200.00	\$/part
fraction of warranty returns related to cleaning	0.25%	%
fraction of parts damaged in cleaning	0.50%	%
resale value of parts	\$100.00	\$/part
<i>parts cleaned per batch</i>	2.85	parts/batch
<i>parts cleaned per year</i>	10,688	parts/year
<i>annual warranty returns due to cleaning</i>	27	parts/year
<i>parts damaged in cleaning</i>	53	parts/year
<i>saleable parts cleaned per year</i>	10,635	parts/year
<i>annual cost of warranty returns</i>	\$5,400	\$/year
<i>lost revenue from damaged parts</i>	\$5,300	\$/year
annual cost of quality	\$10,700	\$/year

Cost of Quality:



- Manual – \$36,300/year
- Ultrasonic – \$10,700/year

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Other Costs – Manual System

Other Costs		
liability insurance	\$500	\$/year
regulatory compliance	\$500	\$/year
fire insurance	\$300	\$/year
other costs	\$1,300	\$/year


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Other Costs – Ultrasonic System

Other Costs		
liability insurance	\$200	\$/year
regulatory compliance	\$250	\$/year
fire insurance	\$100	\$/year
other costs	\$550	\$/year

Other Costs:


- Manual – \$1,300/year
- Ultrasonic – \$550/year




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Incremental Cleaning Costs – Manual System

Summary - Annual Basis		
<i>energy</i>	\$40	\$/year
<i>labor</i>	\$52,525	\$/year
<i>materials</i>	\$4,767	\$/year
<i>waste disposal</i>	\$0	\$/year
<i>capital costs</i>	\$0	\$/year
<i>maintenance</i>	\$0	\$/year
<i>cost of quality</i>	\$36,300	\$/year
<i>other costs</i>	\$1,300	\$/year
INCREMENTAL CLEANING COST PER YEAR	\$94,932	\$/year





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Incremental Cleaning Costs – Ultrasonic System

Summary - Annual Basis		
<i>energy</i>	\$1,841	\$/year
<i>labor</i>	\$2,063	\$/year
<i>materials</i>	\$1,372	\$/year
<i>waste disposal</i>	\$3,750	\$/year
<i>capital costs</i>	\$3,612	\$/year
<i>maintenance</i>	\$800	\$/year
<i>cost of quality</i>	\$10,700	\$/year
<i>other costs</i>	\$550	\$/year
TOTAL CLEANING COST PER YEAR	\$24,688	\$/year

Total Incremental Cleaning Costs:



- Manual – \$94,932/year
- Ultrasonic – \$24,688/year

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Comparison of Incremental Cleaning Costs

Total Incremental Cleaning Costs	Solvent	Ultrasonic	Savings
<i>energy</i>	\$40	\$1,841	-\$1,801
<i>labor</i>	\$52,525	\$2,063	\$50,463
<i>materials</i>	\$4,767	\$1,372	\$3,395
<i>waste disposal</i>	\$0	\$3,750	-\$3,750
<i>capital costs</i>	\$0	\$3,612	-\$3,612
<i>maintenance</i>	\$0	\$800	-\$800
<i>cost of quality</i>	\$36,300	\$10,700	\$25,600
<i>other costs</i>	\$1,300	\$550	\$750
TOTAL INCREMENTAL COSTS	\$94,932	\$24,688	\$70,244

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Profitability Method #1

- Comparison of Incremental Cleaning Costs

Manual Solvents Parts Washer	\$94,932
Ultrasonic System	\$24,688
Difference (Savings)	\$70,244

- Ultrasonic system is less expensive cleaning technology for this application





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Profitability Method #2

- Simple payback period (SPP)
 - Difference in incremental costs between systems (excluding capital costs) is \$73,856
 - Capital cost for ultrasonic system is \$18,500
 - $SPP = (\text{Capital Investment} / \text{Annual Savings})$
 - \$18,500 divided by \$73,069 = 0.250 years, or 3 months




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Discounted Cash Flow Analysis


- Net Present Value (NPV) and Internal Rate of Return (IRR)
 - NPV and IRR are discounted cash flow analysis methods
 - Account for the time value of money
 - Need to know when cash is received, and what the appropriate discount rate is
 - IRR loosely corresponds to payback period
 - Many people do not understand these methods, with the result that they are not widely used in P2

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Discounted Cash Flow Analysis


- Net Present Value (NPV) and Internal Rate of Return (IRR)
 - Suppose someone gives you \$100 today, and you invest it at 10% interest (compounded annually) for 2 years
 - In 2 years, you will have $\$100 \times (1+10\%) \times (1+10\%)$ which is equal to \$121.00
 - So, \$121 received 2 years from today is worth $\$121 / [(1+10\%)^2]$ or \$100
 - The quantity $1 / [(1+10\%)^2]$ or $1 / 1.21$ or 0.8264 is known as the discount factor
 - In general, the discount factor is equal to $1 / [(1+i)^j]$ where i is equal to the interest rate and j is the year in which the cash flow is received

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Discounted Cash Flow Analysis


Year	Cash Flow	Rate	DCF	Rate	DCF
		@ 10%	@ 10%	@ 20%	@ 20%
0	-\$50,000	1.0000	-\$50,000	1.0000	-\$50,000
1	\$5,000	0.9091	\$4,545	0.8333	\$4,167
2	\$8,000	0.8264	\$6,612	0.6944	\$5,556
3	\$10,000	0.7513	\$7,513	0.5787	\$5,787
4	\$12,000	0.6830	\$8,196	0.4823	\$5,787
5	\$15,000	0.6209	\$9,314	0.4019	\$6,028
6	\$15,000	0.5645	\$8,467	0.3349	\$5,023
7	\$15,000	0.5132	\$7,697	0.2791	\$4,186
8	\$15,000	0.4665	\$6,998	0.2326	\$3,489
9	\$15,000	0.4241	\$6,361	0.1938	\$2,907
10	\$15,000	0.3855	\$5,783	0.1615	\$2,423
Total			\$21,487		-\$4,648


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Profitability Method #3

- Net Present Value (NPV)
 - Assume 10 year life for equipment
 - Assume borrowing rate is 15% per year
 - Difference in incremental costs between systems (excluding capital costs) is \$73,856
 - Capital cost for ultrasonic system is \$18,500
 - NPV for this investment is \$352,000




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Profitability Method #3


Year	Cash Flow	Rate	DCF
		@ 15%	@ 15%
0	-\$18,500	1.0000	-\$18,500
1	\$73,856	0.8696	\$64,223
2	\$73,856	0.7561	\$55,846
3	\$73,856	0.6575	\$48,562
4	\$73,856	0.5718	\$42,227
5	\$73,856	0.4972	\$36,719
6	\$73,856	0.4323	\$31,930
7	\$73,856	0.3759	\$27,765
8	\$73,856	0.3269	\$24,144
9	\$73,856	0.2843	\$20,994
10	\$73,856	0.2472	\$18,256
Total			\$352,166


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Profitability Method #4

- Internal Rate of Return (IRR)
 - IRR is the annual rate of return of this investment
 - It is equal to the interest rate that sets the NPV of the investment equal to zero
 - If all cash flows after year 0 are not equal, the IRR can only be determined through trial and error




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Discounted Cash Flow Analysis


		Rate	DCF	Rate	DCF	Rate	DCF
Year	Cash Flow	@ 10%	@ 10%	@ 20%	@ 20%	@ 17.68%	@ 17.68%
0	-\$50,000	1.0000	-\$50,000	1.0000	-\$50,000	1.0000	-\$50,000
1	\$5,000	0.9091	\$4,545	0.8333	\$4,167	0.8498	\$4,249
2	\$8,000	0.8264	\$6,612	0.6944	\$5,556	0.7221	\$5,777
3	\$10,000	0.7513	\$7,513	0.5787	\$5,787	0.6136	\$6,136
4	\$12,000	0.6830	\$8,196	0.4823	\$5,787	0.5214	\$6,257
5	\$15,000	0.6209	\$9,314	0.4019	\$6,028	0.4431	\$6,646
6	\$15,000	0.5645	\$8,467	0.3349	\$5,023	0.3765	\$5,648
7	\$15,000	0.5132	\$7,697	0.2791	\$4,186	0.3199	\$4,799
8	\$15,000	0.4665	\$6,998	0.2326	\$3,489	0.2719	\$4,078
9	\$15,000	0.4241	\$6,361	0.1938	\$2,907	0.2310	\$3,466
10	\$15,000	0.3855	\$5,783	0.1615	\$2,423	0.1963	\$2,945
Total			\$21,487		-\$4,648		\$1


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Profitability Method #4

- Internal Rate of Return (IRR)
 - IRR is the annual rate of return of this investment
 - Assume 10 year life for equipment
 - Difference in incremental costs between systems (excluding capital costs) is \$73,856
 - Capital cost for ultrasonic system is \$18,500
 - IRR for this investment is 399%!




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Profitability Method #4


Year	Cash Flow	Rate	DCF	Rate	DCF
		@ 15%	@ 15%	@ 399%	@ 399%
0	-\$18,500	1.0000	-\$18,500	1.0000	-\$18,500
1	\$73,856	0.8696	\$64,223	0.2000	\$14,774
2	\$73,856	0.7561	\$55,846	0.0400	\$2,955
3	\$73,856	0.6575	\$48,562	0.0080	\$591
4	\$73,856	0.5718	\$42,227	0.0016	\$118
5	\$73,856	0.4972	\$36,719	0.0003	\$24
6	\$73,856	0.4323	\$31,930	0.0001	\$5
7	\$73,856	0.3759	\$27,765	0.0000	\$1
8	\$73,856	0.3269	\$24,144	0.0000	\$0
9	\$73,856	0.2843	\$20,994	0.0000	\$0
10	\$73,856	0.2472	\$18,256	0.0000	\$0
Total			\$352,166		-\$31


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Recap

- Identification of operating costs
 - Major operating cost groups
 - Individual costs within cost groups – primary and hidden costs
- Comparing costs of alternative systems
- Worked example – manual solvents parts cleaner vs. agitating ultrasonic parts washer
- Measures of profitability



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