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Evaluating the Cost Effectiveness of Environmental Projects: Case Studies in Aerospace and Defense

by
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Abstract

Using the replacement technology of high pressure waterjet decoating systems as an example, a simple methodology is presented for developing a cost effectiveness model. The model uses a four-step process to formulate an economic justification designed for presentation to decision makers as an assessment of the value of the replacement technology over conventional methods. Three case studies from major U. S. and international airlines are used to illustrate the methodology and resulting model. Tax and depreciation impacts are also presented as potential additions to the model.

Introduction (Charts 1 & 2)

The purpose of this paper is to present a simple methodology for constructing a cost effectiveness model designed to compare, in economic terms, the value of a potential replacement technology with conventional methods. The replacement technology of high pressure waterjet decoating will be used as an example because it is rapidly gaining acceptance as a cost-effective alternative to chemical stripping, abrasive grit blasting, machining, and hand sanding. Since the current major user of waterjet decoating systems is the aviation industry, the case studies will be drawn from data collected by major airlines.

1-PURPOSE

DEVISE A SIMPLE METHODOLOGY FOR CONSTRUCTING A COST-EFFECTIVENESS MODEL TO COMPARE REPLACEMENT TECHNOLOGIES WITH CONVENTIONAL ONES TO ASSESS THEIR VALUE FOR DECISION MAKERS.

HIGH PRESSURE WATERJET DECOATING SYSTEMS WILL BE USED AS A SPECIFIC.

2-CONTENTS

- OVERVIEW
- OBJECTIVES
- COST EFFECTIVENESS MODEL
- CASE STUDIES
- ECONOMIC ANALYSIS
- SUMMARY

Although waterjet decoating systems will be used as the example replacement technology, the methodology developed is applicable to any situation where a sound, economic basis is needed for comparing two technologies capable of performing the same tasks.

Overview (Chart 3)

Waterjet coating removal system do provide a good example for cost effectiveness modeling because they offer an alternative to a number of both labor intensive and potentially environmentally hazardous methods now in common use in many industries. The major attractions of waterjet decoating are high coating removal rates, low potential for damage to the substrate material, and environmental safety since the only waste products from the process are the coatings removed. All processing water is normally collected, filtered, reclaimed, and reused in the high pressure pumps.

3-OVERVIEW

- **Waterjet coating removal is a rapidly emerging niche area of waterjet machining technology.**
- **Waterjet Systems is a technology spin-off company based on transfer of waterjet decoating expertise from NASA.**
- **High pressure waterjet technology is an environmentally sound alternative to conventional waste-generating technologies of:**
  ...Gritblasting.
  ...Chemical immersion/stripping.
  ...Machining.
  ...Hand sanding.
- **The only waste products are the coatings removed. All process water is recovered, reconditioned and reused.**

Objectives (Chart 4)

Although the focus of this paper is economic justification because of today's priority on enhancing productivity in our highly competitive global environment, a total assessment that includes both tangible and intangible benefits should be presented to decision makers as measure of the total value of a replacement technology.

4-OBJECTIVES

- **THE OBJECTIVES OF THE COST EFFECTIVENESS MODEL WILL BE TWOFOLD:**
  1-Assess the value of a replacement technology as an alternative process.
  2-Provide a sound, economic basis for justifying to decision-makers the capital funds needed to purchase the replacement.
- **THE END RESULT WILL BE SIMPLE MODEL WITH A FRAMEWORK SUITABLE FOR A WIDE VARIETY OF PROJECTS THAT CONTRAST ONE TECHNOLOGY TO ANOTHER.**

Cost Effectiveness Model (Chart 5)

This is the four-step methodology used to develop a cost-effectiveness model. In step one, not all the elements listed can contribute to the economic analysis; however, some may be very important in assessing the total value of the alternative. In the aviation industry, for example, the intangible factor of passenger safety can override all economic factors in a decision.

5-COST EFFECTIVENESS MODEL

- **ESTABLISH CURRENT METHOD BASELINE:**
  ...Costs.
  ...Turn-time.
  ...Material.
  ...Intangibles.
- **DEVELOP POTENTIAL BASELINE FOR NEW METHOD USING SAME CRITERIA.**
- **QUANTIFY DIFFERENCES TO ASSESS VALUE OF NEW METHOD OVER CURRENT ONE.**
- **CONVERT DATA TO MEANINGFUL ANALYSES FOR DECISION MAKERS:**
  ...Payback period.
  ...Return on Investment (ROI).
  ...Internal Rate of Return (IRR).

Step two can be difficult unless data are available on the replacement technology. There is danger, for example, in comparing actual data from the workplace with "paper data" generated with only cursory testing. The credibility of the entire analysis is based on the validity of the data used.

Step four is the most important, because the results of the model must be presented to decision makers in a form they can easily understand. Customarily, all such economic analyses use a common measure of economic value - payback period, for example - so that one capital investment can be compared to another and prioritized to compete for limited capital funds. The process varies from one company to another, and may vary for different types of equipment as well.

Benefits Analysis - Tangible vs. Intangible (Chart 6)

The compilation of tangible and intangible benefits is generalized for replacement technologies; however, some benefits listed as intangible could be quantified and used in the economic analysis, if needed. For our waterjet example, it is possible to replace girt blasting booths, chemical treatment tanks, and some machining lathes with a single waterjet system. The savings in replacing these three systems, therefore, could be

6-BENEFITS ANALYSIS - TANGIBLE VS. INTANGIBLE

TANGIBLE	INTANGIBLE
• LABOR HOUR (MANPOWER) SAVINGS	• BETTER COMPANY IMAGE
• REDUCED WASTE DISPOSAL COSTS	• BETTER WORKPLACE & COMMUNITY ENVIRONMENT
• MATERIAL COSTS	• PROCESS REPLACEMENT
• OPPORTUNITY COSTS	• REDUCED COMPLIANCE DOCUMENTATION

quantified but the mechanics are complex because of complicating factors such as equipment age, removal costs, salvage value, etc.

On the tangible benefits side, material costs represent the savings in processing costs. In our waterjet example, these savings would include the cost of grit, chemical replenishment, machining tools, etc. Our case study analysis, for simplicity, will focus on labor cost savings.

Case Study #1 - Major U. S. Airline (Chart 7)

These are representative comparison data from an airline that uses high pressure waterjet equipment to process a large variety of jet engine parts. The current labor costs are compared with waterjet processing costs to compute the per part labor savings as well as the annual hourly savings expected for each specific part.

7-CASE STUDY #1 - MAJOR U. S. AIRLINE

PART IDENT.	CURRENT (HR)	WATERJET (HR)	SAVINGS (HR)	PARTS/YR	SAV./YR (HR)
JT8 BURNER CAN	2.16	0.5	1.66	3,000	4,980
JT8 1ST STAGE STATOR CASE	46	0.5	45.5	463	21,066.5
JT8 FWD FAN CASE	5.4	0.5	4.9	370	1,813
JT8 REAR FAN CASE	1.2	0.3	0.9	370	333
JT8 DIFFUSER CASE	4	0.5	3.5	370	1,295
JT8 FWD TURBINE CASE	6	0.5	5.5	370	2,035
JT8 REAR TURBINE CASE	5	0.5	4.5	370	1,665
JT8 ALUM. 2ND STG STATOR CASE	2	0.5	1.5	370	555
JT8 2ND STG COMP. STATOR CASE	2	0.5	1.5	370	555
JT8 4TH STG LPT AIR SEAL RING	2	0.5	1.5	370	555
JT8 13TH STG AIR SEAL RING	2	0.5	1.5	370	555
JT8 2ND STG AIR SEAL RING	2	0.5	1.5	370	555
JT8 #5 BEARING HOUSING	4	0.25	3.75	370	1,387.5
JT8 REAR COMPRESSOR INLET CASE	3.2	0.5	2.7	370	999
JT8 FAN FWD STATOR CASE	5	0.5	4.5	370	1,665
GE OUTER COMBUSTOR LINER	3	1	2	251	502
GE INNER COMBUSTOR LINER	3	1	2	251	502
GE COMBUSTOR ASSEMBLIES	3	0.5	2.5	251	627.5
GE FRONT STATOR CASE	2	0.75	1.25	251	313.75
GE REAR STATOR CASE	6	3	3	251	753
GE 3-9 STG COMPRESSOR SPOOL	4	1.5	2.5	251	627.5
GE11-13 STG COMPRESSOR SPOOL	3	0.5	2.5	251	627.5
GE 14-16 STGCOMPRESSOR SPOOL	3	0.5	2.5	251	627.5
GE 1ST STG HPT SUPPORT	2	0.5	1.5	251	376.5
GE 2ND STG HPT SUPPORT	2	0.5	1.5	251	376.5
GE 1ST STGNOZZLE IMPING. RING	2	0.5	1.5	251	376.5
GE #4 BEARING SEAL	2	0.5	1.5	251	376.5
GE 2ND STG NOZZLE	4	0.25	3.75	251	941.25
GE 1ST STG COMPRESSOR HUB	2	0.5	1.5	251	376.5
GE TURBINE MID FRAME	2	1	1	251	251

Case Study #2 - Major International Airline (Chart 8)

This airline processes a smaller variety of parts, but overall, these parts are more labor intensive than in Case #1.

8-CASE STUDY #2 - MAJOR INTERNATIONAL AIRLINE

PART IDENT.	CURRENT (HR)	WATERJET (HR)	SAVINGS (HR)
BOOSTER SHROUD	10	0.7	9.3
HPC DISK	5	0.1	4.9
SPOOL	122	0.8	121.2
HPC STATOR CASE	144	0.8	143.2
TURBINE MID-FRAME	5.5	0.7	4.8
COMPRESSOR REAR FRAME	4	0.8	3.2
SUMP	3	0.7	2.3
THERMAL SHIELD	24	0.8	23.2
LOW-PRESS. TURBINE CASE	4	1.0	3.0

Case Study #3 - Major U. S. Airline (Chart 9)

Our third airline justified the waterjet investment based on processing only inlet fan cases. The environmental concerns associated with the conventional method combined with the high labor costs combined to provide the needed justification. A variety of other parts are also being processed since the backlog of inlet fan cases no longer exists.

9-CASE STUDY #3 - MAJOR U. S. AIRLINE

PART IDENT.	CURRENT (HR)	WATERJET (HR)	SAVINGS (HR)
INLET FAN CASE	22	2	20
MISC. PARTS (AVG.)	--	--	5

Economic Analysis - Key Data (Chart 10)

If the data from the three case studies shown are combined with data from another airline and two engine part manufacturing plants, the key data shown here are representative of the replacement technology. These key data are critical in the analysis because they establish the expected part capacity of the equipment and the expected labor savings as a function of the operational use of the equipment.

10-ECONOMIC ANALYSIS • KEY DATA

- AVERAGE PROCESSING TIME FOR ENGINE PART DECOATED USING HIGH PRESSURE WATERJET:

  40 MINUTES PER PART

- AVERAGE LABOR HOUR SAVINGS FOR WATERJET DECOATING COMPARED TO CONVENTIONAL MEANS:

  4.8 MANHOURS PER PART

- DATA BASED ON WATERJET PROCESSING OF OVER 100 DIFFERENT ENGINE PARTS FROM FOUR MAJOR AIRLINES AND TWO PRATT & WHITNEY PLANTS.

Economic Analysis - Manpower Savings (Chart 11)

These calculations are necessary to establish the baseline and savings then possible with the new waterjet equipment. Note that although 12 parts per shift is the potential maximum throughput, only 10 parts per shift was used to allow for "friction," such as part change, fixturing, and unexpected maintenance. Normal preventive maintenance is performed on an idle shift.

11-ECONOMIC ANALYSIS • MANPOWER SAVINGS

- CELL AVAILABILITY
  ...5 days/wk ...52 weeks/yr ...260 days/yr operation
- PART CAPACITY
  ...8 hours/day per shift
  ...40 min./part for processing
  ...12 parts/day top capacity
  ...(Use 10 parts/day to offset handling/fixturing time)
- LABOR SAVINGS • SINGLE SHIFT
  ...260 days/year available X 10 parts/day = 2600 parts/yr
  ...2600 parts/yr X 4.8 hrs saved/part = 12,500 hrs/yr
- LABOR SAVINGS • DOUBLE SHIFT
  ...260 days/yr available X 20 parts/day = 5200 parts/yr
  ...5200 parts/yr X 4.8 hours saved/part = 25,000 hours/yr

The key findings are a labor savings of 25,000 labor hours per year per double-shift operation and 12,500 labor hours for single-shift operation.

Economic Analysis - Payback Period (Chart 12)

The chart shows a 5-year analysis of the cost factors involved with the new waterjet equipment. An original investment of $800,000 is assumed with an annual maintenance cost of approximately 5% of the purchase price for both parts and labor. An average hourly wate (fully burdened with benefits, etc.) of $20 per hour was assumed. This will be varied, since $20 per hour may not be representative of other companies.

12-ECONOMIC ANALYSIS • PAYBACK PERIOD

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
MHRS SAVED	25,000	25,000	25,000	25,000	25,000
AVG. HRLY WAGE	$20	$20	$20	$20	$20
LABOR SAVINGS	$500,000	$500,000	$500,000	$500,000	$500,000
MAINT. COST	($40,000)	($40,000)	($40,000)	($40,000)	($40,000)
WTRJET EQUIP.	($800,000)	0	0	0	0
YRLY SAVINGS	($340,000)	$460,000	$460,000	$460,000	$460,000
CUM. SAVINGS (AFTER PAYBACK)	($340,000)	$120,000	$580,000	$1,040,000	$1,500,000

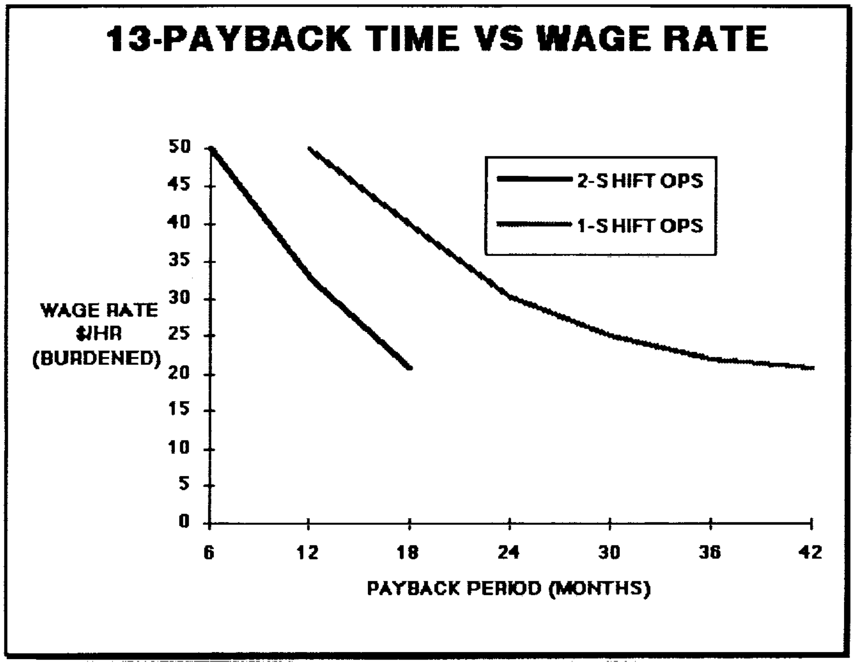
ASSUMPTIONS: 1 - DOUBLE-SHIFT OPERATION
2 - MAINT. COST = 5% OF PURCHASE PRICE
3 - TAX IMPACTS NOT INCLUDED:
a - DEPRECIATION (+)
b - SAVINGS ARE TAXABLE (–)

The yearly labor savings of $500,000 are reduced each year by maintenance costs and, in the initial 2 years, by the cost of the capital equipment itself. For this particular labor cost, the equipment is paid for in 18 months of operation and, by the end of the 5-year period, has earned $1.5 million.

To reduce complexity, several factors such as tax impacts are not included. Depreciation, for example, would provide a tax benefit for several years. On the other hand, the labor savings would accrue to the bottom line and be taxed as additional profits. The value of the out-year dollar savings should also be reduced by inflation since they will be worth less when finally received.

Payback Time vs. Wage Rate (Chart 13)

The two curves shown allow for calculations of the payback period (for single and double-shift operation) as a function of burdened labor wage rates. For the more typical $35 per hour wage rate in the aerospace/aviation business, a waterjet investment could be paid back in less then one year in double-shift operations, as shown.



Variations for the Purist (Chart 14)

14-VARIATIONS FOR THE PURISTS

- **TAX IMPACTS:**
  - **...Depreciation expense.**
  - **...Labor savings are taxable.**
- **FUTURE VALUE OF MONEY**
- **MATERIAL & WASTE DISPOSAL COST AVOIDANCE**
- **OPPORTUNITY COSTS:**
  - **...Additional capacity.**
  - **...Turn-time reduction.**
  - **...Process replacement.**

There are a number of complicating factors that can be added to the analysis, a few of which are listed. Tax considerations, for example, can work in different ways. For tax purposes, the capital expenditure can be depreciated over a number of years to provide a tax credit. On the other hand, the money saved using the equipment increases profits which are, in turn, taxed. The future value of many can also be a consideration, since savings received in the outyears will be worth less than those saved in the current year because of inflation. Opportunity costs can also be significant in some cases. In our waterjet example, we were able to save 4.8 man-hours, on average, for every part processed. This can translate to additional throughput capacity for the facility allowing them to accept third-party work and further increase profits.

Summary (Chart 15)

In summary, we have described a relatively simple methodology for developing a cost effectiveness analysis that can be used to compare a replacement technology with a conventional one. The end result of the work is an economic basis for justifying the use of a replacement technology based on tangible benefits. To assess the value of the replacement technology requires consideration of intangible benefits as well.

15-SUMMARY

- **FRAMEWORK FOR PERFORMING ELEMENTARY COST EFFECTIVENESS ANALYSES IS APPLICABLE TO MOST TECHNOLOGY-REPLACEMENT ALTERNATIVES.**
- **FOUR-STEP PROCESS:**
  1-Establish current procedure baseline.
  2-Develop replacement technology baseline.
  3-Quantify differences.
  4-Convert to meaningful analyses.
- **METHODOLOGY WILL BE ROBUST ENOUGH TO ALLOW FOR ADDITION OF MORE COMPLEX FACTORS.**