

APPENDIX I: SAMPLE CALCULATIONS FOR CHAPTER 5

Metal Finishing A Project

Metal Finishing A had an intern perform technical assistance on issues in their galvanization building in 2002. In 2003 the project was reassessed for actual implementation and savings. In 2004 some follow up questions were asked of Metal Finishing A to help identify fuzzy membership functions of indirect and future liability reduction savings. This appendix steps through the calculations needed to analyze this project's impact. A graphical depiction of the fuzzy membership functions are presented in Figure I.1. after the set of calculations.

Direct Savings

<i>Purchase Savings</i> = Given = \$10,380/yr
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<i>Disposal Savings</i> = Given = \$6,560/yr

Time Savings

Research Savings

- A range is given but it is a symmetrical triangular shape. The fuzzy value by the centroid method would be the average value.

Total staff time saved per 5 years = 275 hr / 5 yr

Normalized time saved per year = 55 hr / yr

Cost of saved time = \$45 / hr

Research savings = (\$45 / hr)x(55 hr / yr) = **\$2,475 / yr**

Operating Cost Savings

- Time is saved by not having to use labor to change out the flux bath as often.
- A range is given but it is a symmetrical triangular shape. The fuzzy value by the centroid method would be the average value.

Total staff time saved per year = 96 hr / yr

Cost of saved time = \$45 / hr

Operational cost savings = (\$45 / hr)x(96 hr / yr) = **\$4,320 / yr**

Regulatory Burden Savings

- Less time is spent manifesting shipments of galvanization flux.

Total staff time saved per year = 2 hr / yr

Cost of saved time = \$45 / hr

Regulatory cost savings - less manifesting = $(\$45 / \text{hr}) \times (2 \text{ hr} / \text{yr}) = \mathbf{\$90 / \text{yr}}$

Regulatory Burden Savings

- Less time is spent placarding and labeling shipments of galvanization flux.

Total staff time saved per year = 2 hr / yr

Cost of saved time = \$45 / hr

Regulatory cost savings - less labeling = $(\$45 / \text{hr}) \times (2 \text{ hr} / \text{yr}) = \mathbf{\$90 / \text{yr}}$

Regulatory Burden Savings

- Less time is spent with paperwork from inspection reporting
- A range is given but it is a symmetrical triangular shape. The fuzzy value by the centroid method would be the average value.

Total staff time saved per 20 years = 80 hr / 20 yr

Normalized time saved per year = 4 hr / yr

Cost of saved time = \$45 / hr

Regulatory savings - less inspection reports = $(\$45 / \text{hr}) \times (4 \text{ hr} / \text{yr}) = \mathbf{\$180 / \text{yr}}$

Future Liability Reduction Savings*Soil & Waste Removal and Treatment Savings*

$$8.9 \times a \times b \times Q = \mathbf{\$6}$$

a = correction factor = 1

D = distance to treatment or disposal facility (miles) = 725 miles

b = fraction of the annual quantity transported that is expected to be released

$$b = 2.4 \times 10^{-6} \times D + 2.9 \times 10^{-4} = 0.000076475$$

Q = total quantity of waste transported (kgal/yr) = 6

Possibility of Damage Occurring

- Fuzzy variables are given. Only the most credible situation will be given to minimize redundancy.

Number of releases reported = 110 / yr

Number of facilities in Nebraska with the potential for a release = 4,000

Possibility of a release into the environment = $(110 \text{ releases} / \text{yr}) / (4,000) = \mathbf{0.028}$

Expected Year in which Liability Occurs During Transportation

- Fuzzy variables are given. Only the most credible situation will be given to minimize redundancy.

$$\text{Year} = \text{Time} + (D \times \text{RF})/V = \mathbf{1 \text{ yr}}$$

Time = expected lapse between the start of a project and initial release (yr) = 1 yr

D = Distance to nearest drinking water well (m) = 0 m

RF = Retardation factor for waste = 20

V = Ground water velocity (m / yr) = 300 m / yr

Expected Year in which Liability Occurs During Tank Storage

- Fuzzy variables are given. Only the most credible situation will be given to minimize redundancy.

$$\text{Year} = \text{Time} + (D \times \text{RF})/V = \mathbf{25 \text{ yr}}$$

Time = expected lapse between the start of a project and initial release (yr) = 20 yr

D = Distance to nearest drinking water well (m) = 1500 m

RF = Retardation factor for waste = 20

V = Ground water velocity (m / yr) = 300 m / yr

Ground Water Removal and Treatment

- Fuzzy variables are given. Only the most credible situation will be given to minimize redundancy.

$$\text{Cost} = [a + (b \times c)] \times 1,000 = \$1,726,708 / \text{yr}$$

D = Distance to nearest drinking water well (m) = 1,500 m

W = Width of ground water plume at facility boundary (m) = 48 m

V = Ground water velocity (m / yr) = 70 m / yr

CC = unit capital cost of ground water treatment (\$/m³/d) = 440 \$/m³/d

OM = unit operating and maintenance cost of ground-water treatment = ((\$/yr)/(m³/d))
= 120 (\$/yr)/(m³/d)

c = multiplicative factor to determine present value of all O&M costs

a = capital costs (\$) =

$$91 + [(.025 \times D \times W) + 0.08D^2 + 137W + 91D + (0.015 \times \text{CC} \times V \times W) + (0.005 \times \text{CC} \times V \times D)] / 1,000 = \$685$$

Ground Water Removal and Treatment Continued

b = O&M costs (\$) =

$$92 + [11W + 8D + (0.015 \times \text{OM} \times V \times W) + (0.005 \times \text{OM} \times V \times D)] / 1,000 = \$174$$

$$\text{Adjusted Cost} = \text{Cost} \times (\text{chance of occurrence} / \text{year liability occurs}) = \$1,899 / \text{yr}$$

Cost = removal and treatment if damage occurs each year = \$1,726,708 / yr
 Chance of occurrence = Possibility of damage occurring = 2.8%
 Year liability occurs = 25 yr

$$\text{Adjusted Cost 2004} = \text{Adjusted Cost} \times (\text{CCI 2004} / \text{CCI 1989}) = \$2,839 / \text{yr}$$

Adjusted Cost = cost considering probability of damage occurring = \$1,899 / yr
 CCI 2004 = 2004 construction cost index = 6899
 CCI 1989 = 1989 construction cost index = 4615

Natural Resource Damage during Tank Storage

- Fuzzy variables are given. Only the most credible situation will be given to minimize redundancy.

$$\text{Cost} = a \times b \times 1000 = \$1,800,000 / \text{yr}$$

a = unit cost to dredge and dispose of material plus cost of fish killed (k\$/acre) = \$900,000 / acre

b = area of surface water contaminated (acres) = 2 acres

$$\text{Adjusted Cost} = \text{Cost} \times (\text{chance of occurrence} / \text{year liability occurs}) = \$1,980 / \text{yr}$$

Cost = removal and treatment if damage occurs each year = \$1,800,000 / yr
 Chance of occurrence = Possibility of damage occurring = 2.8%
 Year liability occurs = 25 yr

$$\text{Adjusted Cost 2004} = \text{Adjusted Cost} \times (\text{CCI 2004} / \text{CCI 1989}) = \$2,863 / \text{yr}$$

Adjusted Cost = cost considering probability of damage occurring = \$1,980 / yr
 CCI 2004 = 2004 construction cost index = 6899, CCI 1989 = 4615

Natural Resource Damage during Transportation

- Fuzzy variables are given. Only the most credible situation will be given to minimize redundancy.

$$\text{Cost} = a \times b \times 1000 = \$20 / \text{yr}$$

a = unit cost to dredge and dispose of material plus cost of fish killed (k\$/acre) = \$900,000 / acre

D = distance to treatment of disposal facility (miles) = 725 miles

d = quantity expected to be released as a fraction of annual quantity transported = $0.5 \times 10^{-8} \times D + 7.6 \times 10^{-6} = 0.000011225$

b = area of surface water contaminated (acres) = $2 \times d = 0.00002245$ acres

$$\text{Adjusted Cost} = \text{Cost} \times (\text{chance of occurrence} / \text{year liability occurs}) = \$1 / \text{yr}$$

Cost = removal and treatment if damage occurs each year = \$20 / yr
 Chance of occurrence = Possibility of damage occurring = 2.8%
 Year liability occurs = 1 yr

Adjusted Cost 2004 = Adjusted Cost x (CCI 2004 / CCI 1989) = \$1 / yr

Adjusted Cost = cost considering probability of damage occurring = \$1 / yr
 CCI 2004 = 2004 construction cost index = 6899
 CCI 1989 = 1989 construction cost index = 4615

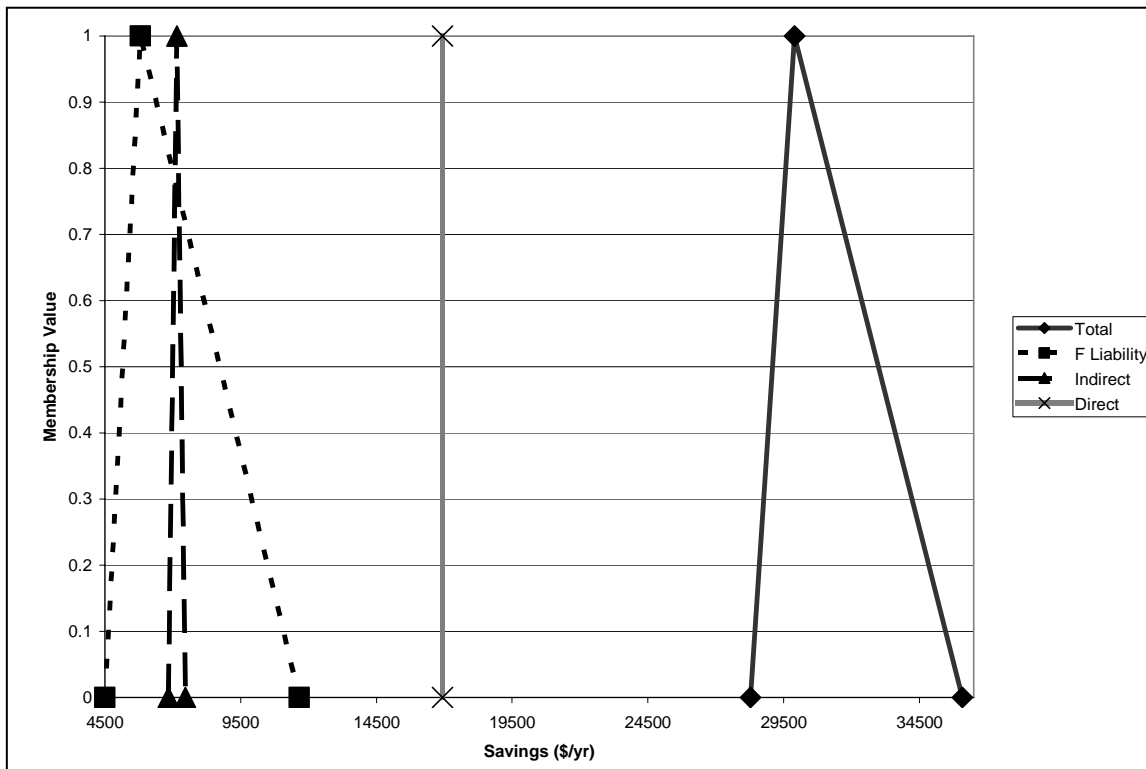


Figure I.1. Metal Finishing A Direct and Indirect Savings.