RISK TRADE-OFF ANALYSIS

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ABSTRACT

The objective of a risk/cost trade-off analysis is to aid the decision making process as risk mitigating measures and associated costs are considered. A risk/cost trade-off analysis is most effective when used in conjunction with a process hazards analysis (PHA) that accurately focuses on critical and credible failure scenarios.

Three methods are presented for determining the break-even value for risk reduction costs. Selection of one of the methods depends on the criticality of the failure scenario and the precision required. Risk reduction cost that is less than the break-even value will increase a company's annual cash flow and return on investment. Each method is outlined and associated limitations discussed.

Appropriate hazards analysis and risk/cost trade-off analysis ensure that a company's resources are spent in the areas that are most important for the protection of employees, the public, and the environment while maximizing cost effectiveness.

LEVEL NO. 1 - RISK SCORE ANALYSIS

Risk Score Analysis is a first-cut approach in determining the risk trade-off (DuPont, 1985). The Risk Score is the product of numerical ratings or weights assigned to "Consequences," "Exposure," and "Probability." These assigned values are arbitrary and flexible based on the judgment and experience of the analyst making the calculation. DuPont (1985) outlines the numerical range for each of these areas and the qualitative descriptions. In cases where multiple hazards exist for a given operation, each one is evaluated separately and their Risk Scores added.

Once the Risk Score value is determined, the proposed risk reduction and cost effectiveness can be evaluated. This is done by using the nomograph entitled "Cost Effectiveness Analysis" (DuPont, 1985). The Risk Score, an estimated risk reduction, and an estimated cost for correction are combined to determine the cost effectiveness.

Limitations

The qualitative nature of the approach allows for a substantial range of variability in the analysis results. Example No. 1 illustrates the possible variation of the Risk Score by reasonably varying the Exposure Factor and the Probability (likelihood) Factor. The Costs for Correction may not reflect the costs associated with a specific industry, and the figures are in 1976 dollars.

LEVEL NO. 2 - RISK TRADE-OFF BASED ON FIXED ASSETS

A risk trade-off analysis based on fixed assets provides reasonable results with a minimal amount of effort. It requires that the probability of a major incident (P_{MI}) per operation be established using quantitative risk analysis techniques. The analyst is then required to define the magnitude of the potential damage and loss of fixed assets only (i.e., building, bay, equipment, product, product components, etc.). The dollar value of the direct and indirect cost of these fixed assets is then determined.

The potential Annual Loss (LE), based on fixed assets, is the product of the P_{MI} per operation, the number of operations per year, and the fixed assets at risk.

$$LE = (P_{MI}/op)*(\#\ op/year)*(\$\ Fixed\ Assets\ at\ risk)$$

The Expected Annual Loss for five (5) years is assumed to be the Risk Reduction Costs (RRC) to break-even (RRC_{BE}). Note: 5 years was chosen as an average accepted time period that industry would expect for payback. The time period should be based on the specific company's criteria for time to break-even.

RRC_{BE} = 5*(LE)

Expenditures less than or in close proximity to this amount provide increased Return on Investment (ROI) for the area involved and would be considered a wise investment. If risk reduction requires significantly more than this amount, then a Level No. 3 analysis may be warranted to determine the actual break-even value based on all potential losses.

Limitations

The break-even value for risk reduction expenditures for this level of analysis may be considerably lower than the value calculated for Level No. 3 since only the fixed assets are accounted for. This value should be considered a "ball park" number. If the risk can be reduced to an acceptable level by spending this amount, then one can be assured that the expenditures are well below the actual break-even value.

LEVEL NO. 3 - RISK TRADE-OFF BASED ON ALL POTENTIAL LOSSES

A risk trade-off based on all potential losses is a rigorous approach to determine the break-even value for expenditures for risk reduction. The following is an outline for this approach:

1. Determine the probability of a major incident per operation (P_{MI}/op) using quantitative risk analysis techniques.

2. Define the magnitude of the potential damage and loss (i.e., plant, building, bay, equipment, death, injury, etc.)
3. Determine the associated dollar loss by breaking it down as follows:
   a. Direct and Indirect Fixed Assets
   b. Production/Program Impact Costs
   c. Liability for Personnel Death, Injury, and Damage

      Fatality -

      Injury -

      Personal property damage -

      Change in insurance premiums -
   d. Accident Investigation and Associated Costs

   Major Accident 1,000,000 to $2,500,000 (multiple buildings)

   Moderate Accident $ 250,000 to $1,500,000 (single building)

   Minor Accident $ 100,000 to $ 500,000 (bay and equipment)
4. Calculate the Expected Annual Loss (LE) due to the incident.

   LE = (P_{MI}/op)*(# of op/year)*(Total $ from step 3)
5. Calculate the Annual Cash Flow (ACF) for the affected area.

   ACF = (1 - Tax $Rate_A$)*(Annual Revenue - All Annual Expenses) + (Tax $Rate_B$)*(Annual Depreciation)

Where: Tax Rates A and B may be different

All Annual Expenses	=	Expected Annual Loss (LE) + Maintenance Costs + Operating Costs + Engineering Support + Insurance Costs + ...

Note: This is the Annual Cash Flow at the current level of risk.

6. Calculate the Return on Investment (ROI) at the current level of risk.

ROI = (ACF) / (C + RRC)

Where: C = The total initial capital outlay (from 3a above).

RRC = Risk Reduction Costs.

RRC = 0, since no additional costs have yet occurred to reduce the risk beyond the current level.

7. Recalculate the LE_{b1} and the ACF_{b1} based on Company's acceptable risk level (e.g., P_{MI} = 1E-06/operation). LE_{b1} and ACF_{b1} are the baseline values.

8. Determine the break-even value for the Risk Reduction Costs (RRC_{BE}) using the values from step 7 and the ROI calculated in step 6.

$RRC_{BE} = (ACF_{b1}) / (ROI) - C$

Note: The Return on Investment increases when the actual risk reduction costs are less than the break-even value.

The ROI decreases when the actual RRC are greater than the break-even value.

Limitations

This rigorous analysis is limited by the accuracy and availability of the data obtained from the various groups.

EXAMPLE NO. 1

Risk Score Analysis for Energetic Material Container Filling Operation

Scenario: Operators over-fill energetic material container and fail to properly clean up prior to moving equipment and tooling. Friction initiation of energetic material.

Determine:

A) The Risk Score for the scenario.

B) The Break-even Value for cost effectiveness.

Solution A

1. Simplified Approach

   Consequence Factor = 25

   Fatality; damage greater than $1,000,000

   Exposure Factor = 1.5

   Unusual (Spills have occurred)

   Probability Factor = 1.0

   Would be remotely possible coincidence

   Note: The rating for this could easily vary from 0.5 to 3.0.

Risk Score = (25)*(1.5)*(1.0) = 37.5

2. Consequence Factor Approach Based on Fixed Asset

Consequence Factor = $[(\text{Damage}) / (100)]^{0.4}$

Given: $1,000,000 potential loss of fixed assets

Consequence Factor = $[(1{,}000{,}000) / 100]^{0.4}$ = 40

Exposure Factor = 1.5

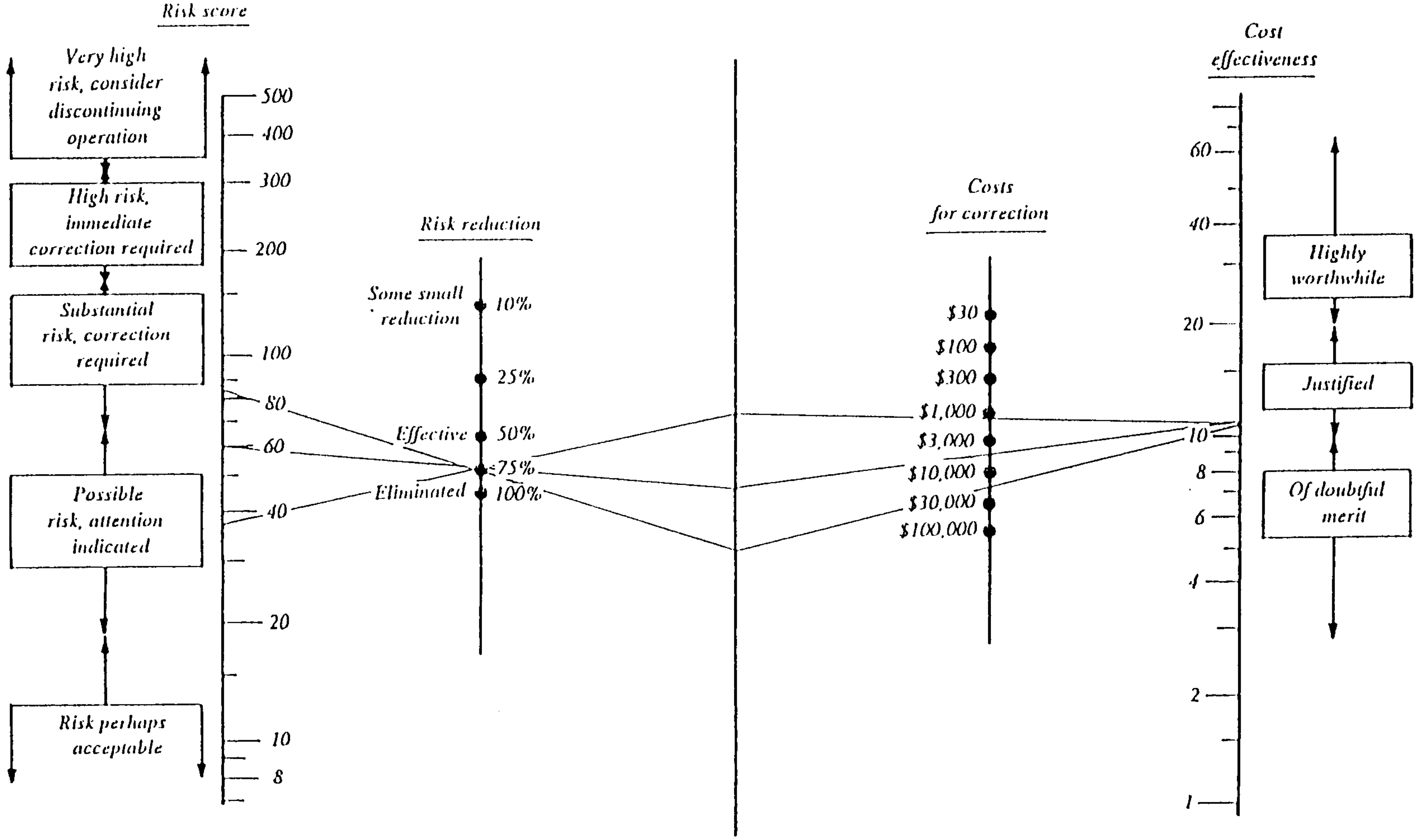
Probability Factor = 1

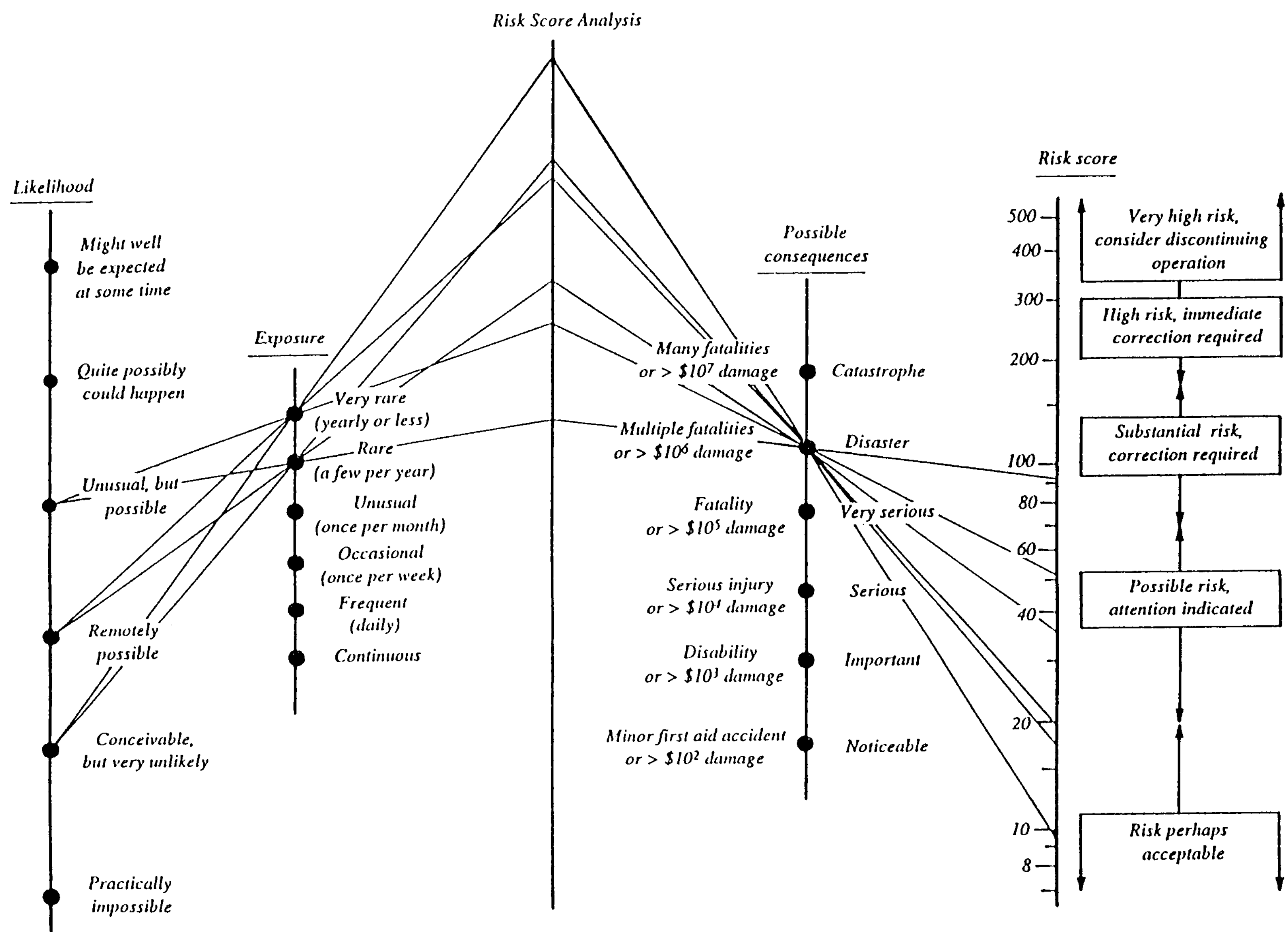
Risk Score = (40)*(1.5)*(1) = 60

3. Graphical Approach

Attached is the graphical solution for this scenario. The Risk Score range is from 10 to 92. This graph clearly illustrates the possible variation of the Risk Score by reasonably varying the Exposure Factor and the Probability (Likelihood) Factor. The risk score is dependent on the background and judgment of the analyst.

Cost Effectiveness Analysis





Risk Score Analysis
Likelihood
Might well be expected at some time
Quite possibly could happen
Unusual, but possible
Remotely possible
Conceivable, but very unlikely
Practically impossible
Exposure
Very rare (yearly or less)
Rare (a few per year)
Unusual (once per month)
Occasional (once per week)
Frequent (daily)
Continuous
Possible consequences
Many fatalities or > $10^7 damage
Catastrophe
Multiple fatalities or > $10^6 damage
Disaster
Fatality or > $10^5 damage
Very serious
Serious injury or > $10^4 damage
Serious
Disability or > $10^3 damage
Important
Minor first aid accident or > $10^2 damage
Noticeable
Risk score
500
400
300
200
100
80
60
40
20
10
8
Very high risk, consider discontinuing operation
High risk, immediate correction required
Substantial risk, correction required
Possible risk, attention indicated
Risk perhaps acceptable

Solution B

Refer to the attached "Cost Effectiveness Analysis" Nomograph. The break-even value for cost effectiveness has a range of $1,200 to $25,000. Based on a risk reduction of 75% and the variability of the Risk Score from Solution A, the cost expenditures are justified.

EXAMPLE NO. 2

Risk Trade-off Based on Fixed Assets

Given:

$P_{MI} = 1.4 \times 10^{-4}$ / op

Number of operations per year = 50 (op/year)

Capital Investment = $1,000,000 (Direct and Indirect Fixed Assets)

Determine: The break-even value for Risk Reduction Costs.

Solution:

LE = (P_{MI}/op)*(# op/year)*($ Fixed Assets at Risk)

Thus,

LE = (1.4×10^{-4}/op)*(50 op/year)*($1,000,000) = $7,000

RRC_{BE} = 5*(LE) = 5*($7,000) = $35,000 = RRC_{BE}

Where: RRC_{BE} is the Break-even Value for Risk Reduction Costs based on fixed assets.

EXAMPLE NO. 3

Risk Trade-off Based on All Potential Losses

Given:

$P_{MI} = 1.4 \times 10^{-4}$/op

Accepted risk = 1×10^{-6}/operation

Annual Depreciation = $100,000

Number of operations per year = 50 op/year

Capital Investment = $1,000,000

Total Revenues - Total Annual Operating Expenses = $250,000

Total loss resulting form an incident = $2,750,000

Assuming:

$1,000,000 Capital costs of new unit without inflation

$ 750,000 Lost product for 3 weeks down time.

$1,000,000 Liability claims for two operators.

$2,750,000

Tax $Rate_A$ = 0.34

Tax $Rate_B$ = 1

Determine: The break-even value for Risk Reduction Costs.

Solution:

1. P_{MI}/Operation = 1.4×10^{-4}/op

2/3. Total Expected Loss = $2,750,000

4. LE = (P_{MI}/op)*(# op/year)*($ Total Expected Loss)

   LE = (1.4×10^{-4}/op)*(50 op/year)*($2,750,000)

LE = $19,250/year

5. $ACF = (1\text{-Tax Rate}_A)[\text{Annual Rev.} - (LE + \text{All Other Annual Expenses})] + (\text{Tax Rate}_B)*(\text{Annual Depreciation})$

ACF = (0.66) [$250,000 - $19,250] + $100,000 = $252,295 = ACF

6. ROI = ACF/(C + RRC)

Where: RRC = 0 and LE = $19,250

ROI = $252,295/($1,000,000) = 0.25 = 25% = ROI

7. $LE_{b1} = (1 \times 10^{-6} / op)*(50\ op/year)*(\$2,750,000)$

LE_{b1} = $137.5/Year

ACF_{b1} = (0.66)($250,000 - $137.5) + 100,000 = $264,909 = ACF_{b1}

Where: LE_{b1} and ACF_{b1} are the baseline values at 1×10^{-6}/op.

8. $RRC_{BE} = [(ACF_{b1})/(ROI)] - C$

RRC_{BE} = [($264,909)/(0.25)] - ($1,000,000) = $59,636 = RRC_{BE}

Where: RRC_{BE} is the Break-even Value for Risk Reduction Costs.

REFERENCE/SOURCE DOCUMENTATION

Dupont, Inc., 1985, "Risk Score Analysis."

Department of Energy, 1982, "Risk Management Guide," (DOE 76-45/11 SSDC 11 Revision I).

U.S. Nuclear Regularity Commission, 1975, Reactor Safety Study - An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, NUREG-75/014, WASH-1400, Washington, D.C.