WHC-SA-1797-FP
Revision 1

Modified Risk Evaluation Method

C. J. Udell
J. A. Tilden
R. T. Toyooka

Date Published
August 1993

To Be Presented at
INMM 34th Annual Meeting
Scottsdale, Arizona
July 18-21, 1993

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse Hanford Company
P.O. Box 1970
Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

MODIFIED RISK EVALUATION METHOD

C. J. Udell, J. A. Tilden, R. T. Toyooka
Security Applications Center
Westinghouse Hanford Company
Richland, WA 99352

ABSTRACT

The purpose of this paper is to provide a structured and cost-oriented process to determine risks associated with nuclear material and other security interests. Financial loss is a continuing concern for U.S. Department of Energy contractors. In this paper risk is equated with uncertainty of cost impacts to material assets or human resources. The concept provides a method for assessing the effectiveness of an integrated protection system, which includes operations, safety, emergency preparedness, and safeguards and security. The concept is suitable for application to sabotage evaluations. The protection of assets is based on risk associated with cost impacts to assets and the potential for undesirable events. This will allow managers to establish protection priorities in terms of the cost and the potential for the event, given the current level of protection.

INTRODUCTION

The method allows managers the flexibility to establish asset protection appropriate to programmatic requirements and priorities and to allocate funding across the spectrum of affected systems. The analytical objective is to provide for a systematic, qualitative "tabletop" process to estimate the potential for an undesirable event and its impacts and to identify inadequate protection and cost-effective solutions.

The method is straightforward. It uses the following: (1) a relational functional hierarchy logic tree to define the asset protection system and facilitate the evaluation, (2) a team of facility experts using questionnaires to make informed judgments and promote sound business decisions, and (3) limited scope tests, if necessary, to validate judgments. The basic evaluation principle is based on the premise that it is not necessary to make precise statements of impact and probability. The current political, economic, and social environment is so fluid and varied that undesirable events are unpredictable. In this context undesirable events are defined as potential occurrences, which could be perpetrated by adversaries, and would result in unacceptable cost and health impacts to material assets or human resources.

The process combines the logic tree structure with a delphi technique. A team of knowledgeable site evaluators is asked to provide subjective ratings through face-to-face interviews using focused, structured questionnaires. The questions, their wording, and their sequence are fixed to control variations in the questions, interview, and discussion. Subjective ratings are assigned to questions and converted to numerical values using a linear, one-dimensional utility function. The utility function provides a method to quantify subjective judgments derived through experience and knowledge. The more experience and knowledge gained, the more accurate the results.

Utility Function

The utility function is based on the multiattribute utility theory postulated by Von Neumann and Morgenstern [1]. The theory provides for combining a number of evaluation attributes into an overall value, provided they are mutually utility independent. The utility function is applied to each of the evaluator ratings and used to determine a numerical value. The sum of the values are averaged to obtain a result.

The utility function is expressed as:

$$U(x) = k\ [(a - x)/b]$$

where,
a = normalization parameter (11)
b = total number of rating categories (10)
x = evaluator assigned rating number (1,2,3, etc.)
k = evaluator weight factor (based on expertise)
U = utility value.

CONCEPT DESCRIPTION

A logical expression of value is required to effectively determine risk. Because risk is based on uncertainty, it is imperative that a knowledge base be developed, questionnaires be used to obtain subjective ratings of expected performance, and a consensus of evaluation conclusions achieved through discussion to obtain the best results. The analysis objective is to determine the following: (1) the potential for an undesirable event, (2) the cost impacts of losing material assets and human resources, and (3) the level of protection provided the assets.

Risk is expressed as:

$$R = e \times c \times [1 - Pe]$$

where,
R = risk
e = event potential
c = cost impact
Pe = protection effectiveness.

PROCESS FOR DETERMINING POTENTIAL FOR AN UNDESIRABLE EVENT

A meaningful benchmark for assuming risk is the logic for determining the potential for an adversary-perpetrated undesirable event. A more realistic approach to determine the potential for occurrence of undesirable events and threats could reduce protection costs significantly. It is not cost effective to assume that all undesirable events will occur and that a high level of asset protection is required to reduce the risk to acceptable levels. Decisions can be made to give less emphasis to protecting assets where there is a diminished potential for some events to occur. Based on this premise, the first step in the process is to assign a rating for potential of occurrence. The team needs to develop adversary sabotage strategies using the relational functional hierarchy logic tree structure to define the asset protection system while considering the attractiveness of the asset to the potential adversaries. The level of impact created by the event is determined through impact analysis, plume or leak path analysis, scenario analysis, etc. Finally, informed judgments are made by expert evaluators to rate the potential for the event. Evaluator knowledge gained through facility experience, researching procedures, plans, work rules, safety analysis reports, etc., and conducting impact analysis serves as the basis of information required to rate the potential for the occurrence.

Table 1 is an example of types of undesirable events that are defined and rated for potential hazardous material events. Table 2 is an example of rating categories to be used by individual evaluators (knowledgeable team members) for rating purposes. The numerical equivalence values are also listed for each rating category.

Based on the event analysis, the potential for an occurrence is rated for the applicable event listed in Table 1. The evaluator ratings are converted to numerical equivalences, averaged, and applied to the risk equation.

An example of a hazardous material asset protection system relational functional hierarchy logic tree is shown in Figures 1, 1a, 1b, 1c, and 1d. The logic tree provides a perspective of an asset protection system that includes operations, safety, emergency, and security systems. The tree is used to develop adversary sabotage strategies, to identify systems that may prevent, detect, delay, respond, and mitigate the undesirable event and to rate protection effectiveness (step 3).

COST IMPACT OF LOSING AN ASSET

The second step of the process is to determine the impacts of losing an asset. In this case, consequences are expressed in terms of cost. To effectively define cost it is imperative that appropriate document research and costing of material assets and human resources be conducted to make an accurate assessment.

Material assets represent real property, high-value items, such as nuclear material, money, precious metals, vital systems, high-value property, or classified or proprietary information, which, if stolen or destroyed, would have unacceptable cost impacts. Cost impacts would include expense and capital, as well as replacement, maintenance, health and insurance costs. Human resources represent people who, if exposed to violent events or hazardous materials, would suffer unacceptable impacts.

The estimated cost impacts determined through this process are rated by the evaluators, based on costing data. Table 3 is an example of costs with associated ratings. The rating result should be based on established monetary values provided by government agencies or private industry.

LEVEL OF PROTECTION PROVIDED AN ASSET

The third and final step of the process is to determine the current level of asset protection.

The measure of effectiveness is based on the expected value of protection provided the asset and determined by applying system- and function-specific questionnaires. Each evaluator provides individual ratings to questions relative to their perception of the effectiveness of each subsystem at the lowest level of the logic tree hierarchy. Ratings are then converted to numerical values using the utility equation and applied to the tree. The average of the sum of the values of the "AND" gate systems and the minimum value of the "OR" gate systems are then propagated from the lowest to the highest level of the tree as shown in Figure 1. The "AND" gates include systems that provide dependent and redundant operating functions, while the "OR" gates include systems that provide independent and separate operating functions. The average taken for "AND" gate systems and the minimum taken for "OR" gate systems provide for a conservative estimate.

The rating concept to determine protection effectiveness is based on the relative capability of active and passive protection functions that are inherent within safety, operations, emergency preparedness, and security systems. Functions include: (1) prevention, (2) detection, (3) delay, (4) response, and (5) mitigation.

The rating objective is to determine the level of protection provided by the asset protection systems relative to the five protection functions listed above. The questionnaires should contain specific questions to stimulate rating responses based on the subjective experiences of the evaluators. An example rating questionnaire is provided in Table 4.

RISK RESULT

The risk result is based on obtaining the product of the cost impact value, the potential-for-event value, and the protection effectiveness value. The risk value is interpreted relative to the rating category range listed in Table 2. A recommendation as to acceptable or unacceptable risk is not provided in this paper because it is our opinion that this guidance should be provided by the user agency or private industry. However, if provided, risk guidance should take into consideration that values are not absolute. They are subjective estimates that are based on many variables and on factoring three elements of a risk equation.

REFERENCE and BIBLIOGRAPHY

1. Von Neumann, J. and O. Morgenstern, 1972, Theory of Games and Economic Behavior, Princeton University Press, Princeton, New Jersey.

2. Keeney, R. and H. Raiffa, 1976, Decisions with Multiple Objectives: Preferences and Value Trade-Offs, John Wiley & Sons, New York.

3. Bright, James, 1968, Technological Forecasting For Industry and Government (Methods and Applications), Harvard University, Prentice Hall, Inc., Englewood Cliff, New Jersey.

Table 1. Example Potential Occurrence of Events by Type.

Type of Undesirable Event	Rating of Potential Occurrence for Event
CATASTROPHIC IMPACT (Event = General Emergency)	
Any release of hazardous material (radiological or nonradiological) that exceeds appropriate Protective Action Guides (PAGs) and/or Emergency Response Planning Guidelines (ERPGs) offsite.	Rate potential for event using Table 2.
HIGH IMPACT (Event = Site Area Emergency)	
Any release of hazardous material that exceeds appropriate PAGs/ERPGs onsite but does not exceed PAG/ERPG levels offsite	Rate potential for event using Table 2.
MODERATE IMPACT (Event = Alert)	
Any release of hazardous material that does not exceed appropriate PAG/ERPG levels onsite and no immediate threat to the general public.	Rate potential for event using Table 2.
LOW IMPACT (Event = Unusual Occurrence)	
Any release of hazardous material that violates environmental requirements in permits, regulations, or DOE limits and/ or which result in adverse physical response requiring medical treatment.	Rate potential for event using Table 2.

NOTE: Each evaluator should use judgment to determine the potential for each event based on all available information and record the associated rating as defined in Table 2., Example Rating Scale. The highest rated event is converted to a numerical value and applied to the risk equation. Potential cost impacts are based on the highest rated event type.

Table 2. Example Rating Scale.

Rating Number	Rating Category	Rating Designator	Numerical Equivalence
1	Very High	VH	0.91 - 1.00
2	High	H	0.81 - 0.90
3	Low High	LH	0.71 - 0.80
4	High Moderate	HM	0.61 - 0.70
5	Moderate	M	0.51 - 0.60
6	Low Moderate	LM	0.41 - 0.50
7	High Low	HL	0.31 - 0.45
8	Low	L	0.21 - 0.30
9	Very Low	VL	0.11 - 0.20
10	Negligible	N	0.00 - 0.10

NOTE: This table is a master to be used to rate the potential for an undesirable event, the cost impacts of losing an asset, the level of protection effectiveness of the protection system, and for determining a risk rating. Numerical equivalence values are not provided to evaluators but are used only for conversion purposes and arithmetic application by the analyst.

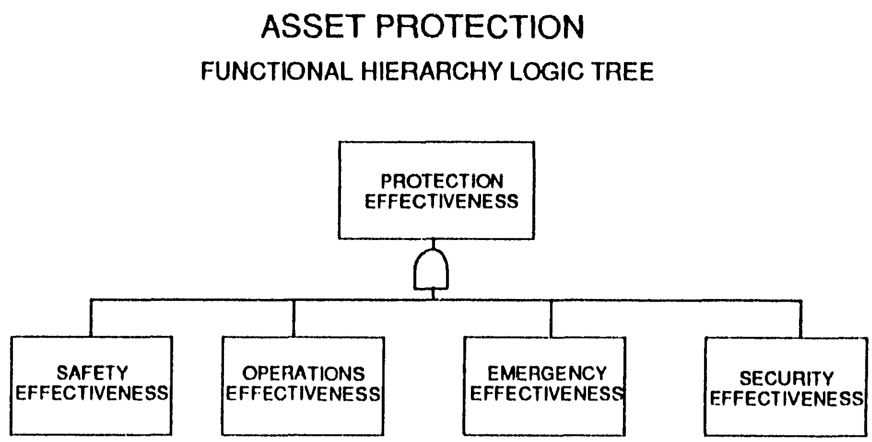

Figure 1. Example Protection System.

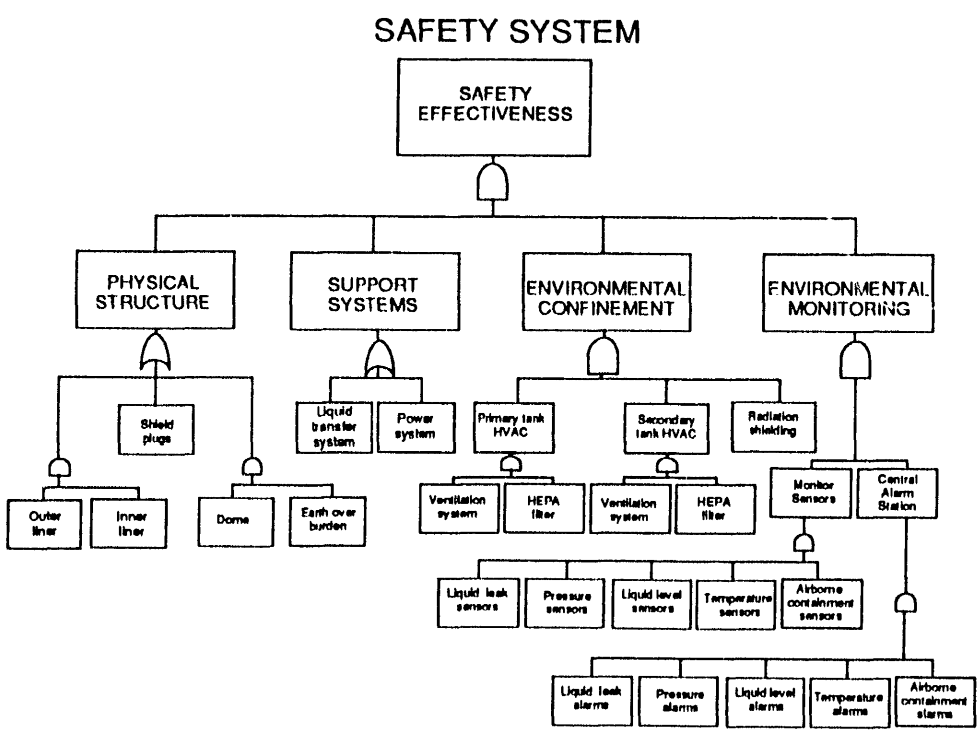

Figure 1a. Example Safety System.

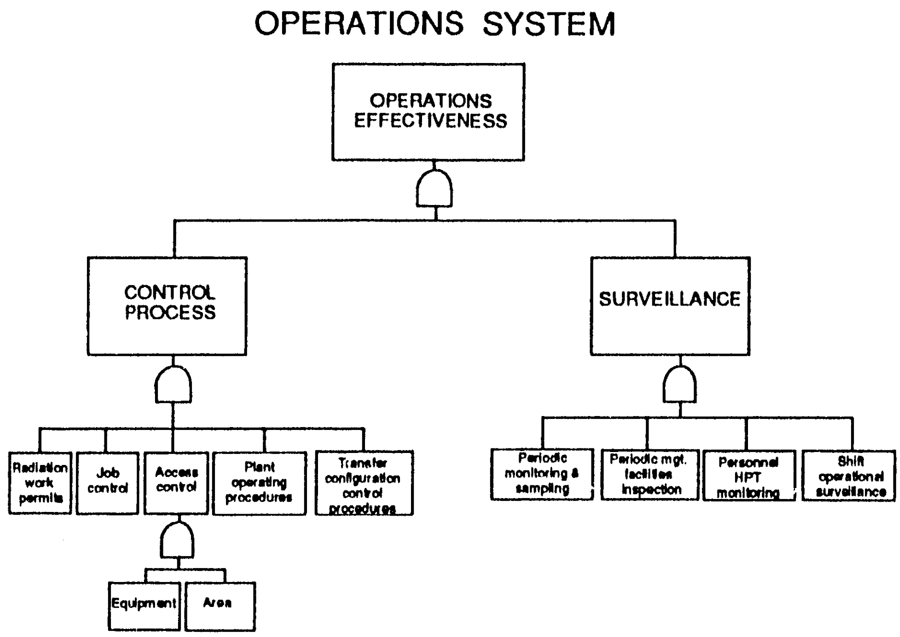

Figure 1b. Example Operations System.

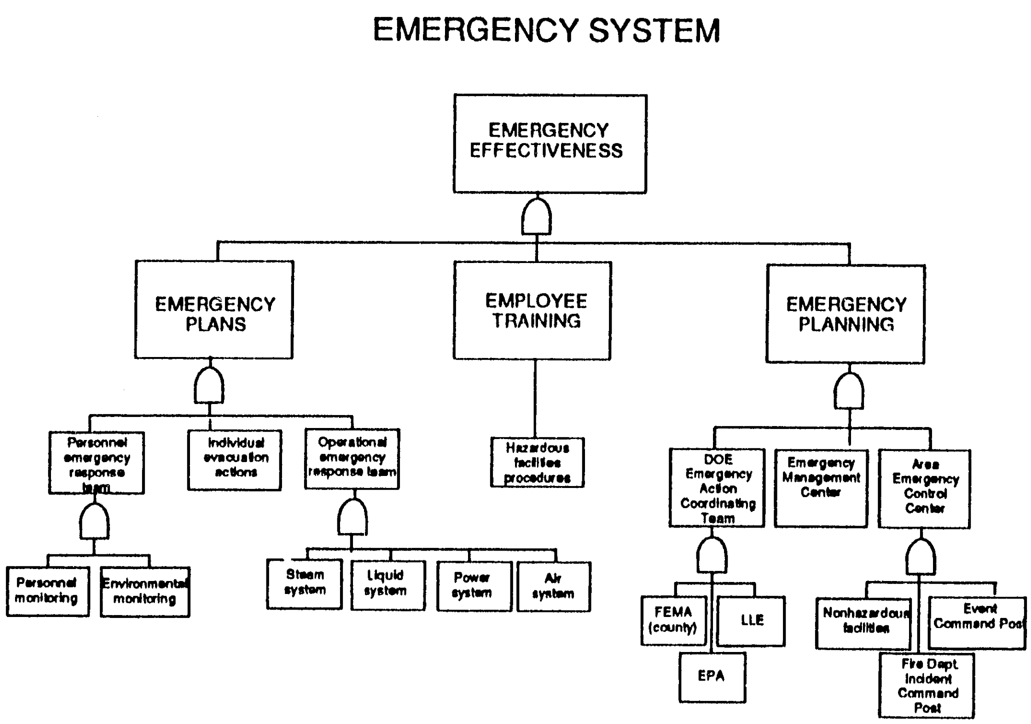

Figure 1c. Example Emergency System.

SECURITY SYSTEM

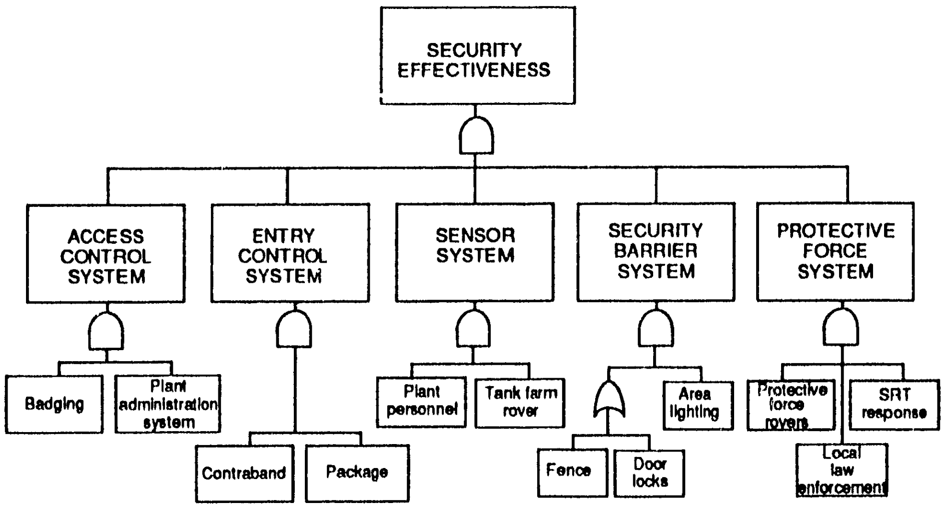

Figure 1d. Example Security System.

Table 3. Example Cost Impact Rating Scale.

Rating Number	Impact Category	Cost Impact ($)
1	Very High	$1 Billion and above
2	High	$500 to $999 Million
3	Low High	$100 to $499 Million
4	High Moderate	$50 to $99 Million
5	Moderate	$10 to $49 Million
6	Low Moderate	$1 to $9 Million
7	High Low	$500 to $999 Thousand
8	Low	$100 to $499 Thousand
9	Very Low	$50 to $99 Thousand
10	Negligible	$49 Thousand and below

Note: Dollar values on this table are established by the user organization. The cost impact of asset loss is determined by the evaluation team through research. Cost impact figures are not subjective ratings.

Table 4. Example Rating Questionnaire.

EVALUATORS NAME____________	DATE____________
SYSTEM: Hazardous Material Protection System	
Question 1: PREVENTION Does the system prevent unauthorized intrusion into the area of the asset? Does the system control unauthorized access to the asset? Does the system prevent the escape of hazardous materials?	Rating ___
Question 2: DETECTION Does the system detect the presence of unauthorized intruders? Does the system detect unauthorized activity? Does the system detect tampering with hazardous material barriers? Does the system detect tampering with hazardous material?	Rating ___
Question 3: DELAY Does the system delay the unauthorized intruders? Does the system delay the release of hazardous materials? Do system measures slow adversary task completion?	Rating ___
Question 4: RESPONSE Does the system have a mechanism to initiate response? Does the system provide for an armed protective force response? Does the system provide for emergency response. Does the system provide for command and control response?	Rating ___
Question 5: MITIGATION Does the system mitigate the impact of the event onsite? Does the system mitigate the impact of the event offsite? Does the system provide for evacuation of the radiation impact areas? Does the system mitigate the long-term impact of the event?	Rating ___
AVERAGE RATING ____	NUMERICAL EQUIVALENCE ____

Note: This is a generic questionnaire to provide an example of questions relative to the five protection functions. Normally, questionnaires are developed for each function and system and provided to each of the evaluators for their individual ratings.

DISTRIBUTION

Number of copies

OFFSITE

1	Institute of Nuclear Materials Management 60 Revere Drive, Suite 500 Northbrook, Illinois 60062 Barbara Scott	

ONSITE

7	U.S. Department of Energy-Richland Operations Office	
	J. L. Spracklen (5)	A6-35
	J. W. Wiley (2)	A6-54
52	Westinghouse Hanford Company	
	W. R. Brooksher (2)	L4-01
	M. P. Billings	L6-10
	P. A. Casey	L6-12
	J. B. Cole	L6-12
	M. R. Duncan (4)	L6-10
	D. W. Engel	L4-11
	M. J. Fisher	A6-35
	G. L. Heid	L6-12
	V. G. Heiman (2)	S2-46
	V. L. Hoefer	X0-42
	B. J. Layman	L6-12
	A. J. Lindsay	L6-12
	D. L. Osowski	L6-10
	D. E. Palmer	L6-09
	D. D. Scott	L6-10
	M. L. Spracklen	L6-11
	F. O. Strankman (2)	L4-05
	J. A. Tilden	L6-12
	R. T. Toyooka	L6-12
	C. J. Udell (20)	L6-12
	C. W. Walton	L6-11
	J. W. Weatherby	L6-12
	D. L Wegener (2)	R1-62
	Information Release Administration (3)	L8-07

END

DATE FILMED

12/29/93