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Value-Impact Analysis of Regulations for the Nuclear Industry

R. Al-Ayat
B. Judd
J. Huntsman

MASTER

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Lawrence Livermore Laboratory

VALUE-IMPACT ANALYSIS OF REGULATIONS FOR THE NUCLEAR INDUSTRY*

By

R. Al-Ayat
Lawrence Livermore National Laboratory

B. Judd and J. Huntsman
Applied Decision Analysis

ABSTRACT

This paper summarizes a quantitative tool developed at Lawrence Livermore National Laboratory to aid the NRC in establishing Material Control & Accounting (MC&A) regulations for safeguarding Special Nuclear Material (SNM). Illustrative Value-Impact results of demonstrating the methodology at a facility handling SNM to evaluate alternative safeguards rules is given. The methodology developed also offers a useful framework for facility designers to choose safeguards measures that meet the NRC's criteria in a cost-effective manner. Furthermore, the methodology requires very modest computing capability and is straightforward to apply.

INTRODUCTION

In its role of regulating the nuclear industry, the U.S. Nuclear Regulatory Commission (NRC) is required to provide a Value-Impact (V-I) analysis for all recommended regulations. To analyze the values (benefits) and impacts (costs) of MC&A regulations we need to systematically integrate information about the threat characteristics, the system designed to safeguard the SNM and the facility's safeguards (S/G) response to the adversaries' attempts.

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VALUE-IMPACT METHODOLOGY

The tool summarized here, and depicted schematically in Figure 1, is designed to assist decision makers in integrating and evaluating these diverse factors. The label Adversary Model refers to a description of the types of adversaries who may pose a threat to the facility under evaluation. The adversaries' descriptions include information on their resources, their strategies for diverting SNM, the quantity of material they desire, and the way they value the possible outcome of an attempt. Examples of generic kinds of adversaries are process technicians/engineers, project supervisors, guards, material custodians, and analytic lab operators.

The box labeled S/G design refers to a description of a baseline S/G system designed to be in compliance with the current regulations. The performance of the baseline S/G design is then evaluated as explained below. A variety of design changes to comply with proposed regulations are then considered and evaluated. To determine the cost effectiveness of these design changes, the incremental costs of implementing the changes are also evaluated.

The performance of these alternate S/G designs against a spectrum of adversary threats is evaluated by our Adversary/Facility Interaction. (This complex interaction is modeled in detail using decision trees.) The effectiveness of a S/G system is judged by a well defined set of performance measures. Table 1 shows in a matrix format an example of the type of performance measures used in the evaluation. The outcome of an evaluation provides a decision-maker with a framework for consistently evaluating the trade-off between the values(benefits) and impact (cost) of various S/G regulations (S/G designs). In the next section we briefly describe the major events considered in the Adversary/Facility interaction box.

Overview of S/G System Performance Evaluation

As mentioned above, the interaction between the facility and the adversary attempting to divert SNM is modeled in some detail with a decision-tree which is based upon the sequence of events in an adversary attempt. The summary tree (each node represents an expanded tree) gives the general direction of the system evaluation for each adversary type in the Adversary Model. For each adversary type, we consider the following major events: (Fig. 2)

Timely Detection: The ability of a S/G system to detect an attempt while it is taking place is modeled. Timely detection consists of two events, first an alarm indicating abnormality and then resolving whether the alarm is real or false. If the adversary knows that an attempt has raised a timely alarm he/she may decide to abort the attempt.

Adversaries are assumed to make this decision depending on their preference for the outcome for success or capture quantified by their utility function.

Late Detection: If no timely alarms were indicated or if the timely alarms were not resolved, a late detection may occur. Again, detection consists of two events an alarm and a resolution that material has not been diverted.

Identification: To capture an adversary or prevent him/her from repeating the attempt, the adversary or adversaries must be identified. The last step in the evaluation is to judge the system's ability to identify the diverter.

CONCLUSION

The methodology summarized above has been demonstrated at two operating facilities.

For each adversary type, expanded trees were generated for each node in Fig. 2 and probabilities were assigned for each branch in the tree. The S/G system performance measures were computed by rolling back these probability trees. Expected times to resolve both timely and late alarms were also calculated. Table 1 shows an illustrative sample result based on our application. The data used is a mix of objective technical data and subjective data elicited from experts; this approach is an advantage of our methodology because subjectivity is explicitly identified and is subjected to further sensitivity analysis. An aggregate measure of the system performance called the diversion index was also computed. This measure represents the expected amount of SNM diverted in a given year. The information displayed in this table aids the decision maker in identifying the alternative that meets the rule in a cost-effective manner. Obviously in making a decision, the regulator/designer must make a trade off between value--represented by the Alarm, Resolution, and Diversion performance measures--and impact or cost.

The demonstration of our value-impact analysis methodology at operating facilities proves the viability of the methodology as an aid to the S/G regulators/designers. The consistent evaluation of S/G rules and the value-impact tradeoffs provided by the analysis identify those regulations that achieve adequate protection within a reasonable cost, hence a rational means of developing and evaluating S/G regulations.

REFERENCES

1. United States Nuclear Regulatory Commission, "Report of the Material Control and Material Accounting Task Force," NUREG-0450 (April, 1978).

2. R. Al-Ayat, B. Judd, J. Huntsman, "Aggregated Systems Model of Nuclear Safeguards," Lawrence Livermore Laboratory, NUREG/CR-0791, UCRL-52712 (April, 1979), 2 volumes.

LIST OF FIGURES

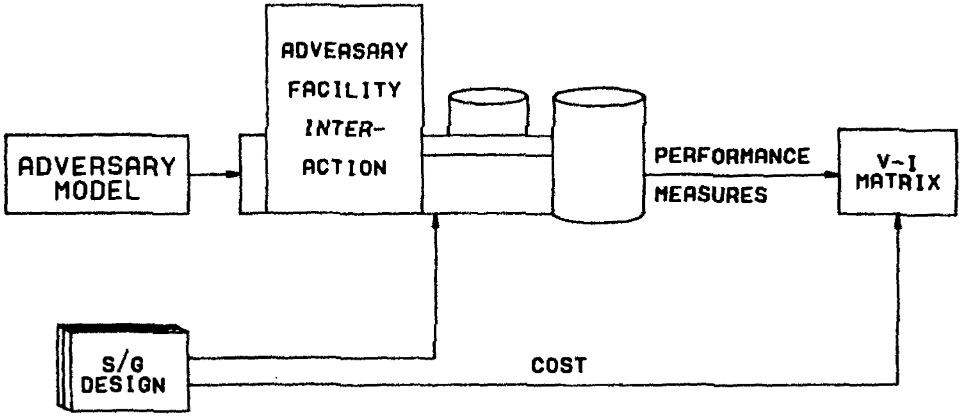

Figure 1. Schematic of Value-Impact Analysis

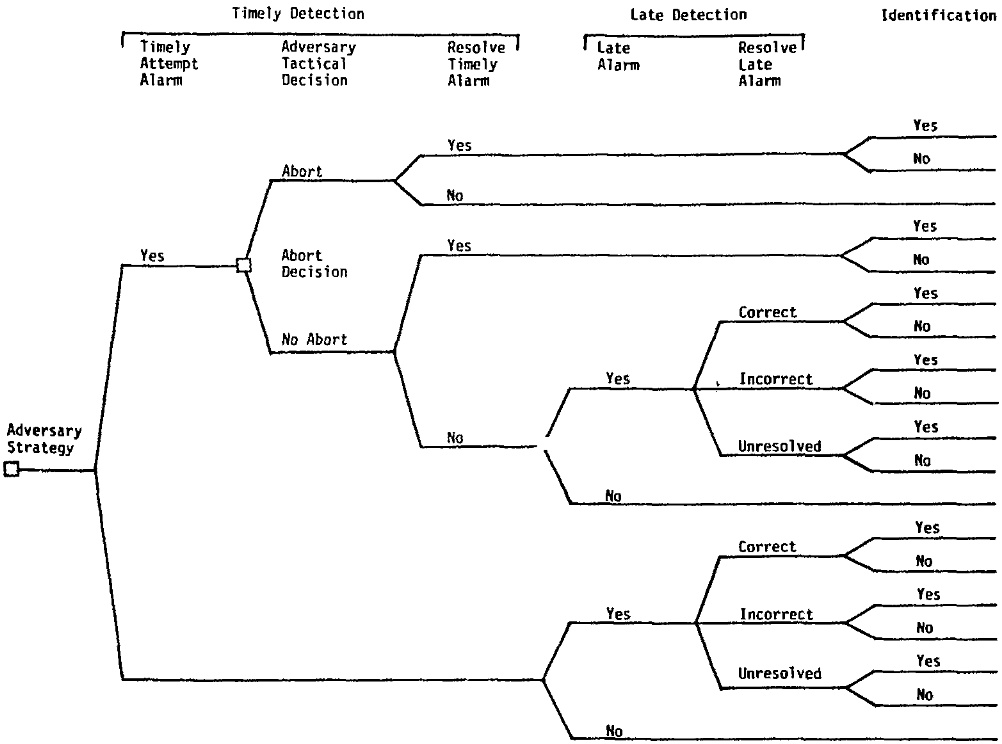

Figure 2. Summary of Major Events in an Attempt

Table 1.

Value-Impact Analysis of Safeguard Rules (Designs)

	Alternative S/G Rules (designs)				
	1**	2	3	4	5
VALUES					
Alarm					
P(Late alarm | No timely alarm)	.78	.69	.91	.91	.78
E(Time to alarm | Late alarm)	16wk	12wk	5wk	15wk	16wk
Resolution					
P(Correct resolution)	.69	.56	.82	.82	.69
E(Time to alarm and res. | Late res.)	16wk	14wk	6wk	15wk	16wk
Diversion index (expected grams year)	15	10	15	15	15
IMPACTS					
Incremental operator cost (person-days/week)	0	1	3	1	1

* Performance measures include probability (P) and mathematical expectation (E).

** Design 1 is the base case.