LA-UR-03 – 02145

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Title: RESOURCE ALLOCATION USING RISK ANALYSIS

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Submitted to: The Annual Reliability and Maintainability Symposium
Los Angeles, CA
January 26-29, 2004

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Form 836 (8/00)

Title: Resource Allocation Using Risk Analysis

Categories: System Safety, Effective Risk Assessment, Risk and Safety Management

Problem Statement: Allocating limited resources among competing priorities is an important problem in management. In this paper we describe an approach to resource allocation using risk as a metric. We call this approach the Logic-Evolved Decision (LED) approach because we use logic-models to generate an exhaustive set of competing options and to describe the often highly complex model used for evaluating the risk reduction achieved by different resource allocations among these options. The risk evaluation then proceeds using probabilistic or linguistic input data.

Work to be described: We describe the LED approach through a pair of examples. In the first example which utilizes quantitative probabilistic data, competing lightning risk management options are evaluated in order to ensure that risk during explosives handling operations is maintained at acceptable levels while minimizing the impacts of these measures on cost and operational time delays. The first step in our analysis was to collect all the available information on lightning hazards that we could and organize it using a logic model. The paths of this logic model describe possible lightning injury scenarios. We also developed a logic model that described how various factors combined to determine the risk posed by lightning. The combination of these logic models led to a lighting risk model. In this case, considerable quantitative data is available from the National Lightning Detection Network. This data forms the basis of a Monte Carlo simulation of lightning flash time-position distributions. These distributions are used to determine the probability of lightning strikes in the work area as a function of the date and time of the operations. The flash time-position approach allows us to model complex evacuation processes based on lightning detection and warning systems. The model also provides for phased-mission analysis where the risk posed by lightning strikes varies with the phase of the operation. We consider both injury arising from direct lightning effects on workers and injury occurring from lightning actuation of the explosives being handled. The complete model provides a means for assessing risk reduction associated with various lightning management strategies including combinations of evacuation of work sites and engineered lightning mitigation features.

In the second example, which utilizes linguistic information, resources are to be allocated among competing safety research programs. In the situation under consideration, operations with a complex system were greatly impacted by many controls imposed or safety reasons. In many cases, the basis for the controls was very uncertain, and conservative controls were instituted. A better characterization and understanding of the safety issues could probably lead to relaxed and less onerous controls for many issues. The purpose of the study was to determine where research into safety issues could lead to a relaxation of controls without compromising safety. In this study, little or no quantitative data was available, but considerable qualitative knowledge was applicable in the form of theoretical principals, experience and common sense. We began the analysis by using a logic model to identify and organize safety issues of concern for a complex system. Each path for this model represented an accident sequence. We then developed a logic model that incorporated the factors we wished to include when comparing the risk reduction and productivity gain potentially achieved by undertaking research that addressed each of these scenarios. In place of the probability distribution used in the lightning risk study, we used qualitative descriptions of the variables that affected the risk. These qualitative measures were expressed using linguistic values. Uncertainty was represented by treating the linguistic values as

fuzzy subsets of the variable. Risk estimates were inferred from input linguistic values using rule bases, with outputs expressed as linguistic values and uncertainty propagated from the inputs to the outputs using fuzzy sets mathematics.

Conclusions: Difficult and complex resource allocation problems can be addressed in a systematic and traceable manner using logic models to guide the analytical models. The logic models provide an efficient means for organizing and manipulating large amounts of data and knowledge. Complex processes can be evaluated and rational resource allocations determined for problems with either predominantly quantitative data, predominantly qualitative knowledge, or a mixture. In all cases uncertainty in the results can be meaningfully captured and expressed. The results of the analyses provide guidance to decision makers concerning resource allocations according to a traceable and defensible methodology. This not only leads to better decisions concerning resource allocation but also provides some shielding of the decision maker from second-guessing. When a rigorous and traceable methodology is employed in determining priorities, the burden of proof shifts substantially to the critics of the decision.