ESTABLISHING AVAILABILITY REQUIREMENTS USING CHARACTERISTICS FACTORS AND EXPERT OPINION

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1. INTRODUCTION

System design engineers must translate permitted overall facility downtime into detailed design and operating specifications for numerous systems and subsystems that make up the facility. The process of assigning reliability and maintainability requirements to individual equipment systems to attain a desired overall availability is known as availability apportionment. Apportionment is normally required early in conceptual design when little or no hardware information is available. Apportionment, when coupled with availability prediction, enables the selection of viable alternative configurations, identifies problem areas, and provides redirection of the program into more productive areas as necessary. A method for apportioning, or budgeting, overall facility availability requirements among systems and subsystems is presented. An example of applying this methodology to the Spallation Neutron Source (SNS) facility is given.[1]

Availability criteria for individual systems is often established using a "bottom-up" approach when a detailed design is available. A "top-down" approach is intuitively more satisfying for less defined facilities.[2] This method takes an overall facility requirement and divides it first among facility systems and then among subsystems. The overall facility availability requirement is distributed proportionately among facility systems, based on each system's capability for meeting a design objective. The approach imposes (a) higher availability requirements on those systems in which an incremental increase in availability is easier to achieve and (b) lower availability requirements when an increase is more difficult and costly. Optimizations such as these result in lower facility costs.

2. DETERMINATIONS OF WEIGHTING FACTORS

Characteristics that influence equipment reliability and maintainability are described. Experts, using engineering judgment, score each characteristic for each system whose availability design goal is to be established. The Analytic Hierarchy Process[3] is used to produce a set of weighted ranks for each characteristic of each alternative system. Expert elicitation relies on a series of exhaustive judgements that compare pairs of characteristics.

Characteristics chosen that influence reliability are system complexity, design immaturity, and stressful operating environment. System complexity may be evaluated by considering the probable number of parts or components that make up the system—the higher the number of parts the more likely there will be failures. The lack of a proven design increases the probable number of failures. Components operating in stressful conditions (e.g., high temperatures, vibration, and radiation fields) have more failures than those operating in benign environments.

Characteristics that influence maintenance are the elements of repair time: fault detection and diagnosis time, preparation time to conduct the repair, fault correction time itself, and time to restart the system once the fault is corrected.

3. PAIRED-COMPARISON METHOD OF DETERMINING WEIGHTING FACTORS

The Analytic Hierarchy Process is used to produce sets of weighting factors for each alternative. The paired comparison procedure is implemented in two phases. During the first phase, relative importances of "characteristics" are established. Experts are asked, for example, to compare complexity and design maturity with respect to their importance in apportioning reliability. The pairs (complexity and design immaturity in this example) are compared (i.e., given a score, using a scale from 1 to 9). The second phase compares pairs of systems for each characteristic. For example for the SNS, experts would be asked to compare the complexity of the ring and linear accelerator systems on a scale of 1 to 9. All pairs are compared for each characteristic. For the SNS, six systems were compared for each of the three characteristics of reliability. The entire procedure is repeated twice—first for reliability and then for maintainability. Availability is allocated based on a joint consideration of reliability and maintainability. The Expert Choice[4] commercial software package was used to assist experts in working through the Analytic Hierarchy Process method.

A principal technical expert was chosen to represent each system. A structured interview was conducted for each expert individually. Team aggregation and final adjustments of availability allocations were performed at the conclusion of the structured interviews, and results were reviewed.

4. APPLICATION TO THE SNS PROJECT

The SNS is a new accelerator-based, neutron-scattering facility to provide special scientific and research capabilities serving the needs of the nation's universities, industries, private and national laboratories, and others involved in the development and application of neutron-based research. The SNS is a collaborative effort among five national laboratories for the design, construction, installation, and commissioning of the facility. The SNS project is divided into systems according to the responsibilities of each national laboratory. With responsibilities widely distributed around the country, it is essential that the 90% overall facility inherent availability requirement be apportioned among systems in order to have a clearly defined availability design criteria for each major system. Design and construction of the facility at Oak Ridge, Tennessee, are expected to be completed in the year 2005 and to cost about $1.3 billion.

5. RESULTS

This method of apportioning overall 90% facility availability gave the following results: front-end systems, 99.5%; linear accelerator, 97.5%; ring and transfer line systems, 96.9%; target, 96.3%; experiments systems, 100%; conventional facilities, 99.7%; and control systems, 99.7%.

Correlation analysis demonstrate a high consistency in weighted ranks of SNS systems. The range of correlations among expert pairs was from 0.685 to 0.985, with 73% of the correlations above 0.800. The correlations of expert's weighted ranks with the aggregate scores ranged from 0.742 to 0.988. Availability scores for each expert were submitted to a principal components analysis in order to represent expert judgment in a lower dimensional space. Three natural clusters emerged. The largest cluster consisted of experts representing the ring, target, and conventional facilities as well as the aggregate scores. In summary, the aggregate apportioned availability among systems represents each individual expert's responses very well.

6. REFERENCES

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