RELIABILITY PREDICTION METHOD FOR ELECTRONIC SYSTEMS

A COMPARATIVE RELIABILITY ASSESSMENT METHOD

Richard Yu, Department of Defense

ABSTRACT

This paper describes a proposed research in defining a new reliability prediction methodology that may be used to evaluate the reliability of computer and electronic systems. The proposed methodology will attempt to minimize the deficiencies of the traditional reliability prediction methods. The deficiencies include: the use of generic failure rates for reliability prediction; and, the lack of realism of the reliability prediction in various operational environment. The proposed methodology will employ the use of Analytical Hierarchy Process, a decision tool, to incorporate the qualitative and quantitative data that are most prevalent to the reliability performance of the system under study. This methodology will analyze the reliability of the system under study by comparing its performance characteristics against its predecessor system (or a similar system) with known reliability performance. The resultant analysis will yield a reliability ratio between the two systems and the ratio may be used to describe system's reliability under various operational environments. The key traits of the proposed methodology are its ability to incorporate all relevant failure modes that are prevalent to reliability performance and the use of realistic data that will provide realism of the predicted reliability.

BACKGROUND

Recent studies indicate a growing concern over the effectiveness of the reliability prediction methodologies for electronic systems. The concern largely stems from the prediction tools' inability to account for system's attributes other than design characteristics (i.e., manufacturing defects). Reliability prediction methodology, such as the one advocated by Mil-Hdbk-217, may be inaccurate due to its technique of *averaging* a set of *generic* failure rates for a specific system. A secondary concern regarding such methodology is the applicability of the derived failure rates (i.e., mean time between failures) in operational environment. This paper describes a proposed research that attempts to address these.

PROBLEM STATEMENT

The effectiveness of the reliability estimation depends upon the prediction methodology and the data used in the prediction. If the methodology only produces a snap shot of the system reliability and if the data used in the prediction do not reflect the relevant failure mode of the system, the estimated value will be inaccurate.

The traditional reliability prediction methodologies often have inherent deficiencies that provide less-than accurate reliability estimation. These deficiencies are resulted from the failure data used in the prediction and the lack of realism of the derived Mean Time Between Failure (MTBF). Following paragraphs capture the nature of the deficiencies:

1. The failure rate data used in the predictions are often collected by pooling the failure data of generic set of equipments and parts. For instance, the failure data in Mil-Hdbk-217 were derived from conducting stress testing of “representative” parts to failure to derive the MTBF. These failure modes are often not representative of the failure modes experienced by the actual systems under study.
2. The traditional reliability prediction yields the mean time between failure (MTBF) that are not directly applicable to the operational environment. For instance, one MTBF estimation is often used to describe the reliability performance of the system that may be operate in two extreme environments. In other words, an equipment operated in arctic-like environment may not experience the same reliability performance as the same equipment operate in a tropical environment.

PROPOSED RESEARCH

The proposed research will minimize the effects of the aforementioned deficiencies by incorporating all relevant failure modes in the reliability prediction. The proposed approach will maximize the use of the failure data of the predecessor system to identify the most prevalent failure modes experienced in its operation (of the predecessor or similar system). The research will utilize a proven comparative evaluation tool to combine both the qualitative and quantitative failure modes to provide a most comprehensive evaluation of the successor’s reliability.

The proposed research will employ Analytical Hierarchy Process (AHP) as the analysis tool to incorporate the qualitative and quantitative data for the reliability prediction. The AHP is a technique used for dealing with problems which involve the consideration of multiple criteria simultaneously. It is unique in its ability to deal with intangible attributes and to monitor the consistency with which a decision (or comparison) may be made. AHP is commonly used to aid the decision making process due to its ability to “quantify” the intangible attributes and integrating with the tangible (or measurable) attributes.

The proposed reliability prediction methodology will be demonstrated using a simplified example in this section. In this demonstration, the system under test will be evaluated based on its similarity to its predecessor system which is assumed to have a thorough operational data.

Problem Statement for the Demonstration

Company XYZ is in the process of developing a new communication system called NEWCOM to replace an existing communication system, named OLDCOM, which is reaching its useful life. NEWCOM is still currently in its preliminary design phases with only a few prototypes available for test and evaluation. The objective of this analysis is to determine the reliability of the NEWCOM.

Assumptions used for the Analysis

Following assumptions are listed to prescribe the parameters of the evaluation. It is critical that the assumptions should be validated to ensure the accuracy of the prediction.

1. NEWCOM will replace OLDCOM as the radio equipment installed in the delivery trucks around the world. Hence, the operational environment for NEWCOM and OLDCOM is the same. The operational environment ranges from arctic-like climate to tropical climate.
2. NEWCOM and OLDCOM will be developed and manufactured by the same vendor – company XYZ.
3. Company XYZ has detail reliability performance of OLDCOM in its operational environment.
4. NEWCOM design is based on mature, off-the-shelf technologies and design architectures.

Step 1 Determine the Prevalent Design Weakness and Failure Modes

Based on the evaluation of OLDCOM's operational performance characteristics, Company XYZ has determined that four failure modes attribute to over 80% of total failures. These failure modes are listed in the Table 1.

Table 1 OLDCOM's Operational Reliability Performance Characteristics

	Failure Mode	Number of Failures	% of Total Failure
1	Broken solder joints	530	38%
2	Input power fluctuation	400	29%
3	Broken face plate of the radio	250	18%
4	Misc.	208	15%
	Total Failures	1388	100%

Detail analysis of the failure modes revealed the following conclusions:

1. Failure Mode #1 is attributed to poor *manufacturing* process in which the production of OLDCOM employed low-reliability soldering techniques.
2. Failure Mode #2 is attributed to poor *design* technique in which the OLDCOM design did not use a power cleaner to ensure the stability of input power.
3. Failure Mode #3 is attributed to operator's *mishandling* of OLDCOM. The failures had been caused by operators inadvertently hitting the face plate of OLDCOM when entering the vehicle.

Based on the analysis, the designers of NEWCOM decided to use the aforementioned failure modes as the most prevalent reliability contributor for the prediction.

Step 2 Baseline the Reliability Comparison of the Failure Modes

In this phase, a comparative matrix will be determined to baseline the reliability evaluation. The comparative matrix is determined by the identifying the failure modes that are most prevalent to the baseline system's, OLDCOM, operational performance. Three failure modes identified in *Step 1* forms the baseline comparison matrix. The comparison matrix is shown in the Figure 1.

Figure 1 Comparison Matrix

Step 3 Comparison of NEWCOM with OLDCOM using AHP

Once the comparison matrix is established, AHP may be used to compare the performance/design characteristics of NEWCOM against OLDCOM. The relative reliability estimation is based on two values derived from the analysis – the weight of the comparative factors (failure modes) and the relative value derived from comparing NEWCOM versus OLDCOM for each of the failure modes. The weights used in this reliability prediction is the normalized percentage of the failures attributed to the individual failure modes. Hence, the weights for the failure modes are calculated and presented in the Table 2.

Table 2 Weighted Factors for the Comparative Matrix

Failure Mode	Actual % Rate	Normalized
Solder	38%	45%
Power Anomaly	29%	34%
Face Plate	18%	21%

The relative value used for the reliability prediction is derived by comparing the design traits of NEWCOM against the OLDCOM. The AHP tool will be used for this comparison. This paper will not prove the underlying theory of the AHP; rather, this paper will only show the result of such comparison based on the comparative analysis provided in the Table 3.

Table 3 Relative Values of NEWCOM vs. OLDCOM for Each Comparative Matrix

Failure Mode	Description of the Comparison	Relative Value*
FM #1 Solder	NEWCOM manufacturing facility just recently employed a new production technique with high reliability soldering. This facility upgrade has demonstrated improvement over the old manufacturing process used for OLDCOM by a factor of 7.	7
FM #2 Power	NEWCOM design will incorporate a “power cleaner” to stabilize the input voltage from the vehicle battery. This improvement provides better protection to NEWCOM circuitry by a factor 6 when compared to OLDCOM design.	6
FM #3	NEWCOM design incorporates a new mechanical shield to protect the face plate from being shocked by the operator. The NEWCOM design will prevent the operator from inadvertently hitting the face plate, hence, eliminating the failure mode.	9

NOTE: * The Relative Value used in this table should be supported by the qualitative and/or quantitative data to ensure the accuracy of the evaluation. The scale used for the relative number is determined by AHP parameters.

Step 4 Determination of the NEWCOM Reliability

Based on the weights for the comparative factors and the relative values defined in *Step 3*, AHP is used to determine the relative reliability of NEWCOM and OLDCOM. The outcome indicates that NEWCOM is approximately three times as reliable as OLDCOM.

CONCLUSION

The proposed research seeks to evaluate a new prediction methodology that will minimize two deficiencies experienced by the traditional methodologies. The proposed methodology will utilize a comparative matrix to incorporate all relevant failure modes that are prevalent to system's reliability performance. The proposed research will be comprised developing a study case to demonstrate the validity and the utility of the proposed reliability prediction methodology.