Reliability Leadership

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Key words: Executive training, Reliability training, Models, Graphical methods, Training effectiveness, Lessons learned, Management information, and Supplier training

SUMMARY AND CONCLUSIONS

Reliability engineers often have difficulty educating senior management on reliability issues and communicating effectively with them. Senior leaders, while bright and informed, frequently lack the technical training to follow the arguments. This paper discusses an executive short course developed at the request of a "big three" automaker, which teaches executives about reliability using only graphical methods. This allows engineers, leaders, and general managers to communicate using the same medium. In particular, managers are taught which graphs to request, how to interpret them, and what to avoid. Case studies are used extensively. Experience suggests that this is an effective way to develop better technical understanding by managers and better communication with their reliability professionals.

1. INTRODUCTION

Reliability engineering is becoming increasingly important for the competitive success of industry. Effective reliability estimation and improvement requires a fairly sophisticated set of skills. While reliability engineers frequently possess these skills, it is often the case that senior leaders and managers in an organization do not. This can lead to organizational problems in several ways.

Leaders at every level frame issues, assign resources, approve metrics, and make decisions. To do an effective job for the organization, these tasks must be performed intelligently. This requires knowledge of basic reliability principles up and down the chain of command. Lacking that knowledge, senior leaders can have trouble in several areas. Leaders may not understand the issues involved in estimation, particularly the relationship between cost, sample sizes, and precision of estimates. Leaders may not understand the appropriate metrics for reporting reliability results. Leaders may have unreasonable expectations about the effectiveness of accelerated testing. Leaders may not know the right questions to ask and when to ask them.

This paper reports on a course specifically developed to educate organizational leaders on reliability issues. The course was developed at the suggestion of a major automobile company, which was in the process of implementing reliability and availability requirements for its machine tool suppliers. It was imperative that there was a common understanding of the issues and the metrics. Moreover, since key customer supplier relations were involved, it was not an issue that would be merely delegated to the engineering staff. Leaders at all levels were required to become intelligently involved.

The program extends to 32 major machine tool suppliers who build the components for major assembly lines. Annual purchases from these suppliers exceed 4 billion dollars for the automobile manufacturer. This is big business.

The success of this course spread by word of mouth, and now other manufacturing companies are using it.

2. ESSENTIAL CONCEPTS

In training leaders, the course focuses on what we consider the essential concepts for this audience: reliability, availability, models, metrics, confidence, and business impact. This section is not a chronological syllabus, as the concepts are interwoven throughout the course and imbedded in the case studies. Throughout the discussion of the concepts, we focus on what the leader needs to know about:

- Problem definition
- Data
- Models
- Diagnostics
- Predictions
- Decisions

To get this information, the leader must ask the right questions. The case studies focus on what should have been asked, by whom, and when.

2.1 Reliability

A common definition of reliability is used: the probability that an object will function satisfactorily under given conditions for a given time without failure. The definition is broken down and examined in detail, as the organizational leadership must specify many of the terms in the definition. For example, the definition of “function satisfactorily” can mean different things to different people, and the leader must decide. The role of specified conditions is extremely important, and is illustrated by the case studies. Usual use conditions also form the basis for accelerated testing models. The student learns that reliability is a function of time conditioned on the operating environment, and that time forms the basis for many of the most important reliability metrics.

The presentation and examples avoid mathematical notation here, and emphasize the concept and its implications. We motivate the probabilistic treatment with several simple examples, showing that even nominally identical items will have different failure times, leading to the idea of a chance distribution.

2.2 Availability

For our major audience, availability is an important metric, since the assembly lines stations are subject to repair or component replacement. The availability of each supplier’s machine will contribute to the overall availability of the line. Here, definitions are also important, and the instructional team discusses several different definitions of reliability: inherent, achieved, operational, steady-state, and point. Suppliers tend to be very interested in the various definitions. Suppliers tend to point out that they should only be responsible for inherent availability. The role of effective design for maintenance (both preventive and unscheduled) also causes spirited discussion, with customers pointing out that well-designed products can be much more easily maintained. Horror stories are used liberally to illustrate these issues. The pitfalls of using formulas derived for the exponential distribution to assess availability for other distributions are discussed, again with examples. We leave the leader with an understanding of the importance of using the appropriate definition, and why suppliers prefer inherent availability and customers prefer achieved availability.

2.2 Models

A key decision is to choose an appropriate life model for the data. We illustrate this with simple data sets. For a given data set, the leaders compare the effects of modeling the data with the Weibull, normal, lognormal, and exponential distributions, comparing Mean-time-between-failure or Mean-time-to-failure (MTBF/MTTF), and failure rates. In particular, leaders see that modeling data with the lognormal distribution gives longer MTBF than using the Weibull distribution for a given data set. We also discuss the implications of using distributions that allow negative life times.

Students see graphically the fundamentally different failure rate behavior for the lognormal and Weibull models, and discuss the implications.

The purpose of discussing these issues is to make the leader aware that there can be reasons other than goodness of fit for choosing among models. Some of the reasons may be suspect --- like choosing the model with greatest MTBF --- but others can be benign – like choosing a model with the most plausible failure rate behavior.

2.3 Metrics

The prevalence of MTBF/MTTF as a reliability metric requires discussion. If the data is well modeled by the exponential distribution, the mean completely characterizes the distribution. However, if the data is modeled by another distribution, the mean is not sufficient to describe the data. This is demonstrated using an example of several models with identical means, but widely differing behavior. This generates discussion of better metrics, and leads to reliability at a given time (R(T)) and the time by which reliability drops to given level (B(X)) as metrics.

We also discuss the difference between the various definitions of availability. One case study makes the point that using steady state models can grossly misrepresent initial availability during a warranty period.

2.4 Confidence

Using examples, we make the point that large data sets give more precision in estimates than small data sets. This introduces the idea of a confidence interval. By discussing which errors really concern us, the idea of one-sided confidence intervals is developed. We avoid much of the technical discussion of confidence limits except to make the point that coverage properties do not always achieve nominal levels. Confidence concepts are illustrated graphically.

Leaders learn that the greater the extrapolation, the greater the uncertainty. Confidence bounds capture this issue. Uncertainty due to extrapolation is paid particular attention during discussions of accelerated testing.

2.5 Business impact

The business impact of a successful reliability engineering program interests executives. In the course, we discuss warranty costs, service costs, design costs, availability issues, product liability, and market share as examples of how reliability affects the bottom line. Each of the four case studies emphasizes a different aspect of the business impact of reliability.

The discussion of bottom line impact is essential to get leaders' attention to reliability.

3. GRAPHICAL APPROACH

We use an exclusively graphical approach. We do not show formulas, which can be barriers to understanding for the uninitiated. We find that graphs using confidence bounds convey information about the precision in the model and estimates much better than reporting numerical confidence intervals.

We focus on five graphs:

- plot of the data and the model with confidence bound(s) on the appropriate plotting paper,
- plot of the data and the model with confidence bound(s) on linear scaled paper,
- plot of the failure rate of the model,
- plots of data and models on plotting paper at different environmental conditions, and
- plots of inherent availability and steady state availability versus time.

3.1 Plot of the data and the model with confidence bounds on the appropriate plotting paper

This plot serves several purposes. We spend a great deal of time orienting the leader to the scaling, practicing reading off points to get the time-reliability ordered pairs of values. Comparing the model with the plotted data points allows the decision maker to see the goodness of fit of the model. In particular, he/she can see if curvature in the plotted points indicates a poor model fit.

3.2 Plot of the data and the model with confidence bounds on linear plotting paper

Leaders are taught to read the model from linear paper. Although there is less of a chance to visualize model goodness-of-fit, this plot is easier to explain: it has standard horizontal and vertical scales. The confidence bounds emphasize the precision in the data.

3.3 Plot of the failure rate of the model versus time

The failure rate plot is a key plot. We teach the leaders that this is the best plot to distinguish among the qualitative differences of competing models. The class learns the definition of an instantaneous failure rate. Leaders are quick to see that a constant failure rate is a strong assumption, and that the asymptotic behavior of the failure rate of the lognormal distribution is often not credible. A discussion of the ways that the "bath-tub" curve can arise follows.

3.4 Plots of data and models at various environmental conditions

Survival plots at different conditions introduce the idea of accelerated testing. For certain objects and stresses it is reasonable to assume that only the scale parameter of a model varies with the stress. This is easily seen with simple graphical methods, which can also check the assumption. Graphs are presented that illustrate when the assumption fails to hold. We stress the importance of obtaining and interpreting the correct graphical evidence. A spirited discussion of the implications of environmental conditions and life follows, usually focusing on SUV tires.

3.5 Availability versus time

Instantaneous availability and steady-state availability are different quantities, as are operational and achieved availability. To make the point, leaders work an example and plot all four metrics on a single plot versus time, and then discuss the consequences of using each metric.

4. CASE STUDIES AND EXAMPLES

The course uses four case studies to make the points in this course. The first is an example from the automobile manufacturer's assembly lines, where availability is very low. We discuss the costs of this, and look for opportunities to begin corrective action. Additional insights from this example come from the mis-communication of the operating conditions on the line, and the confusion between the different definitions of availability.

The second example is from a major router company that naively used exponential models for estimating warranty returns when they actually had a severe infant mortality problem. This had a major impact on warranty costs, and illustrates the importance of both model selection and failure rate behavior.

The third case is an example of software reliability, where defining the usual operating conditions is difficult and where reliability growth is a major issue.

The fourth case is an examination of the reliability and liability issues from the Ford Pinto gas tank problems in the 1970's. The intangible costs of an unreliable product are often hard to predict, and cost-benefit analyses can be severely flawed.

Three of the case studies are grounded in the author's consulting work, and all are illustrated with the appropriate pictures, graphs, and charts.

5. RESULTS AND CONCLUSIONS

The course has been offered several times, yet remains very much a work in progress. Customer feedback is driving continuous improvement. Initial reaction from senior leaders, engineering leaders, and engineers has been uniformly favorable. Improved communication throughout the organization has resulted. Reliability engineers in particular reported increased confidence that the senior management would understand and, hence, support their efforts better.

The increased understanding and support of senior management has had rapid payoff. One company invited the author for an additional week of follow-up discussions, as the class prompted an immediate top-to-bottom review of the reliability program. A second company used the course as the "kick-off" event to starting a reliability management program.

BIOGRAPHY

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Dr. Olwell holds a PhD in Statistics (1996) and a master's in Mathematics (1989) from the University of Minnesota, and earned a bachelor of science degree from the United States Military Academy at West Point (1980) . He taught mathematics and statistics at West Point for six years, where he also directed the Mathematical Sciences Center of Excellence. He was associate chair of operations research at the Naval Postgraduate School, where he taught reliability, statistics, and quantitative methods. He is the author of several books and numerous papers. Dr. Olwell has taught dozens of seminars on reliability for industry and consults widely for both government and industrial clients.