INTEGRATING FIELD FAILURE DATA AND ACCELERATED LIFE TESTING BY BAYESIAN METHODS FOR PRODUCT RELIABILITY INFERENCE

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DEDICATION

To

my wife, Sandra;

my son, Erick;

and

my parents, Juan and Blanca.

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by

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ABSTRACT

A Bayesian statistical approach is proposed to improve the prediction of product reliability by using field performance data and accelerated life testing results. This approach develops the calculation of a calibration factor that compensates the very broad variation in field conditions to the controlled conditions in a laboratory setting. An example, based on temperature stress and the Arrhenius function, is developed to instruct on how to estimate the calibration factor and other important life distribution parameters in different scenarios. The Winbugs program was used to do the simulations to find the parameter estimates when closed-form posterior distributions are not feasible.

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CHAPTER 1. INTRODUCTION

The performance of a product over time is known as the reliability of that product. It is very important for manufacturers to infer the reliability of their products in order to succeed in their endeavors. Inference of product reliability is a difficult task because it is to predict product performance in the future.

According to Meeker and Escobar (1998) rapid advances in technology, development of highly sophisticated products, intense global competition, and increasing customer expectations have put stronger pressures on manufacturers to produce high-quality products. Customers expect purchased products to be reliable and safe. Systems, vehicles, machines, devices, and so on, should, with high probability, be able to perform their intended designed function under usual operating conditions, for some specified minimum period of time.

Technically, reliability is often defined as the probability that a system will perform its intended designed function under operating conditions, for a specified period of time (Meeker and Escobar, 1998). Condra (1993) emphasizes that "reliability is quality over time".

Modern programs for improving reliability of existing products and for assuring continued high reliability for the next generation of products require quantitative methods for predicting and assessing various aspects of product reliability. In most cases this will involve the collection of reliability data from studies such as laboratory tests (or designed experiments) of materials, devices, and components, tests on early prototype units, careful monitoring of early-production units in the field, analysis of warranty data, and systematic longer-term tracking of products in the field (Meeker and Escobar, 1998). This thesis aims to develop a methodology of integrating laboratory testing data, such as those from accelerated life tests, and field performance data, such as those from warranty, to improve the reliability

prediction for existing or modified products. The three statistical fields - warranty data analysis, ALT and Bayesian methodology - will be combined to obtain predictions on product reliability.

1.1 Accelerated Life Testing

Accelerated Life Testing (ALT) is a technique often used in engineering to evaluate the reliability degree of a product. ALT exposes products to higher stress than in normal conditions in order to fail the product in a reasonable time period. The main benefit of evaluating the product reliability before release to market is to assure that the product will function as intended for a minimum period of time.

The purpose of ALT analysis is to infer the lifetime distribution when a system, vehicle, device or part is put in service under normal conditions (field environment). Nevertheless, current analysis of the relationship function of the failure rate and stress levels cannot actually capture the real, complicated environmental effects on the failure distribution when the system, vehicle, device or part is used in the field.

This thesis will propose a method for predicting product reliability by analyzing the results from ALT in combination with warranty data using Bayesian methodology.

1.2 Field Performance Data

Field failure data is usually collected by companies in the form of careful monitoring of early-production units in the field, analysis of warranty data, and systematic longer-term tracking of products in the field. Warranty data is usually analyzed by manufacturing companies to monitor the field performance of their products. These manufacturing companies will design new products or improve current ones with higher reliability expectations than predecessor products. The warranty analysis of predecessor products can be used to improve the reliability assessment of the new products before users start experiencing product failures on the field.

Warranty data usually comes with unclean and incomplete data. A typical example is found in automobile industry. According to Rai and Singh (2004), the causes for unclean data in automobile warranty data are customer behavior, service quality and unintended data entry errors as shown in Figure 1. Customers may respond differently to different types of failures observed during the warranty period. For catastrophic failures that make a vehicle unusable until repaired such as engine breakdown, the time gap between occurrence of failure and reporting of failure at an authorized dealership is likely to be very short. On the other hand, consider a soft failure such as a transmission fluid leak that occurs at a rate of about a drop every 24 hours of driving the vehicle. The probability of such an event being noticed by the customer is very low. Even after noticing a drop of transmission fluid on garage-floor, the owner may choose to report it at the time of next oil change or may finally report it when warranty period is about to expire. Similarly, customer tolerance level to soft failures may vary with time. For example, a customer may be very concerned about a minor transmission leak occurring in his one month old vehicle, but may not be as concerned about a similar problem when the vehicle is 10 years old (Rai and Singh, 2004).

Another cause for unclean warranty data is service quality. The process of fault identification and correction largely depends on the capability of the repairing process. Often the number of repeated repairs for the same failure mode is a function of repair quality apart from the design and manufacturing quality. Hence, in order to separate manufacturer quality from service quality, use of time or mileage to first warranty claim is recommended (Rai and Singh, 2004).

The last listed cause for unclean data is the unintended data entry errors. When a vehicle fails within warranty period, data/information in excess of 50 different kinds are obtained. Although most part of the data entry process is computerized, there are certain repair related entries that the repair technician is required to carry out. Due to human-intensive nature of data entry, unintended data entry errors could also lead to unclean warranty data (Rai and Singh, 2004).

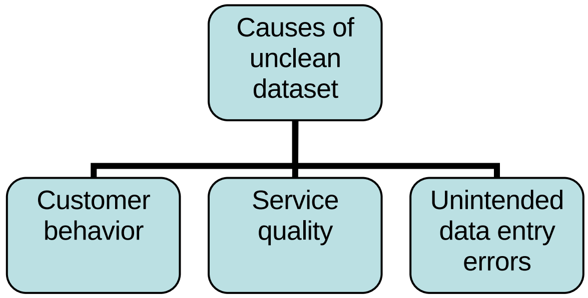

Figure 1. Causes of unclean warranty data.

In general, incompleteness of failure data can also be broadly classified into three categories as shown in Figure 2.

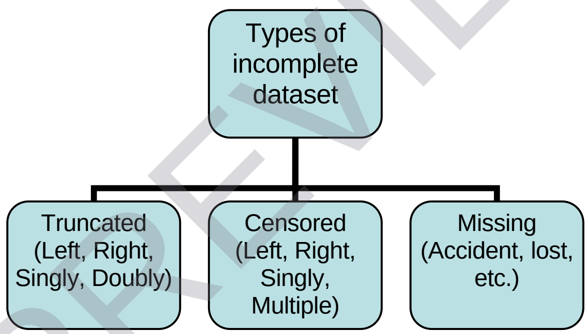

Figure 2. Three types of incomplete warranty data.

Truncated data from a dataset are those purposefully not considered data from certain point before or after or both. Data not considered before a certain point is left truncated data. Data not considered after a certain point is right truncated data. Datasets that are both left and right truncated are said to be doubly truncated datasets. Datasets that are either right truncated or left truncated are said to be singly truncated datasets.