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산업체에서의 데이터와 신뢰성평가

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Data and reliability evaluation in industry

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요 약 제조기업의 경우 여러 종류의 데이터가 수집된다. 이 중 많은 데이터는 약간만 변형하면 제품의 신뢰성 평가에 유용한 정보로 활용될 수 있다. 이 연구에서는 우선 제조기업에서 수집될 수 있는 데이터로 제품, 기술, 재무, 고객 등과 관련된 데이터는 어떤 것이 있는지 살펴본다. 다음으로 데이터가 발생할 수 있는 근원으로서 회사의 비즈니스 매니지먼트 시스템, 과학저널, 시험 및 마케팅조사 데이터 등에 대해 알아본다. 다음으로 제품의 신뢰성평가를 위해 제품수명주기에 걸쳐 어떤 종류의 데이터가 수집되는지 알아본다. 우선 제품의 개발단계에서는 구성요소별로 신뢰성시험을 실시하고, 서브시스템 및 시스템 차원에서도 신뢰성시험을 실시하여 신뢰성 관련 데이터를 수집한다. 한편, 제조단계에서는 제품의 기능시험 및 설계변경시험 등에 관한 데이터를 수집하고, 필드단계에서는 제품의 필드에서 어떤 문제가 일어나는지 파악하여 데이터의 형태로 수집한다. 마지막으로 데이터 수집 시 추후의 합리적인 분석을 위해 들어가야 할 내용이 무엇인지 살펴본다.

주제어 : 산업체, 데이터, 신뢰성 평가, 제조기업

Abstract In the case of manufacturing companies, various types of data are collected. Many of these data can be used as useful information for product reliability evaluation. In this study, we first look at data that can be collected by a manufacturing company and related to products, technology, finance, and customers. Next, we will look at the company's business management system, scientific journals, test and marketing survey data, etc., as sources of data. Next, look at what kind of data is collected over the product life cycle to evaluate the reliability of the product. In the development stage of the product, reliability test is performed for each component, and reliability data is collected by performing reliability test at the subsystem and system level. On the other hand, at the manufacturing stage, data on the functional test and the design change test of the product are collected, and at the field stage, the problem of the product is detected in the field and collected in the form of data. Finally, let's look at what you need to do to make a reasonable analysis later in your data collection.

Key Words : Industry, Data, Reliability Assessment, Manufacturing Enterprise

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1. Introduction

Many different types of data are obtained in a company. Some of the data can be used to provide valuable information on reliability once they are modified (Blischke and Murthy, 1994). But bulk of the data is specific to certain purposes and so it is not easy to transform the data into resources for decision-making. In-house testing data can be used to predict the performance of the product fairly well if they are managed properly. Field data can also be used to confirm the prediction that was made in the lab. However, there is a lot of discrepancy between the two predictions (Kececioglu, 1993). Therefore, in this study different types of data that can arise in a company are reviewed in Sections 2 and 3. In Section 4, life cycle approach to the data that can be generated in a product and appropriate analysis to the data are examined. In Section 5 several different logs for data collections are examined. Summary of the study is given in Section 6.

2. Types of Data

There are many different kinds of data in a company: product related data, technology related data, scientific data etc. These types of data are needed to build models for reliability related decision-making (Nyman, 2009). First of all, the data can be broadly grouped into several different categories as indicated below.

2.1 Product Related Data

This includes the product performance data, design data as well as development data.

Product Performance Data: These can be again divided into (i) reliability related (such as failure times, causes, components replaced or repaired etc.) and (ii) non-reliability related data.

Design Data: Design details are explained in specification.

Development Data: Various kinds of test data are included in the development data. The data can be at the system level or component level. The hierarchy can be separated into as many levels as required - System, Sub-system, Component, Part, Material, etc. For instance in an engine(system) the sub-systems can be front assembly, sealing, cooling, timing, etc. while the front assembly can again be divided into plug assembly spark, sensor crankshaft position, coil assembly etc.

2.2 Technology Related Data

Manufacturing of products involves many different types of technologies. An interesting feature of technologies is that they are changing over time due to scientific advances and technology breakthroughs. Technology related data relevant to manufacturing of new products include the changes in the following technologies.

Material Technologies: There are different kinds material technologies depending on the product considered.

Process Technologies: There are also different kinds process technologies based on the product concerned.

Support Technologies: There are different kinds of technologies to support the various operations such as transportation of material, management of inventories, material flow, etc.

2.3 Commercial Related Data

Commercial data comprise of the following.

Market Related: This includes total sales over time, number of competitors etc.

Competitor Related: This includes sales, price, promotion effort, market share of each of the competitor.

Legislative: This includes various legislative laws relevant to the product. Examples include warranty legislation, health standards for products consumed by humans or animals etc. Industry-wide: Example of the data is trends over time.

2.4 Customer Related Data

There are two different levels of customer related data.

Industry Level: This can be consumption patterns over time, age profile, income distribution etc.

Individual Customer Level: This can be needs, satisfaction with past products, usage mode and intensity, income, satisfaction and dissatisfaction etc.

2.5 Financial Related Data

Financial data comprises of revenue data and cost data. The cost data is comprised of the following costs for past products.

Development cost

Production cost per unit

Life cycle costs

Warranty servicing costs

Cost data can be broadly divided into two categories – as direct and indirect. Direct costs can be described as the cost of materials and labour that result in the final product, and indirect costs are those that are required to support the activities in different phases of the product life cycle. For example, the cost of the metal, plastic, oil, components, technical labour, etc. that make up the product are direct costs; the cost to design the product, set up and maintain the production plant, perform administrative tasks, service, and market the product, and manage the entire process are indirect costs.

2.6 Intuitive Judgemental Data

When hard data are sparse or lacking altogether, it is not unusual to use "engineering judgment" in attempting to predict item characteristics, including reliability. Estimates of this type, based on quantified subjective or partially subjective information, enable the analyst to introduce engineering knowledge and experience into the reliability assessment process. This type of information may also form the basis of an important input element (the "prior distribution") to Bayesian analysis, which provides a method of incorporating this information with test data as it is obtained. Therefore, reliability assessment scheme should include Bayesian approach as one of the tools for investigation.

3. Sources of Data

There are several sources from which data needs to be collected. We discuss briefly some of these. In the process, we highlight some issues of relevance to managing product reliability (Murthy, Rausand and Osteras, 2008).

3.1 Historical Records

Historical records are generated from data obtained from the various business management systems when the product becomes obsolete and is replaced by a new one. The importance of this data in new product development is that a new product that has undergone major design change or is based on completely new designs often has some parts or even major components in common with earlier products. As such, data and information relating to earlier products obtained from historical (archival) records are of importance for reliability assessment of the product.

3.2 Business Management Systems

Businesses use many different kinds of management systems to manage the different activities. These, along with the kind of data they provide, are as follows:

As mentioned earlier, data from such systems for earlier products create the historical records.

As a new product evolves through the different phases of the product life cycle, these systems collect data. Data collected in earlier phases are needed for building and revising models in later phases for effective decision making.

3.3 Scientific Journals and Conference Papers

These provide scientific data and information. There are several search engines and databases that make it easy to obtain the information. Examples of scientific journals and conference papers are Quality and Reliability Engineering International, Reliability Review, Annual Quality Congress, Annual Reliability and Maintainability Symposium, etc.

3.4 Vendors

Vendor data includes components, materials, and/or sub-systems that are purchased from outside the manufacturing organization. Test data from vendors can be obtained and verified by in-house testing, if necessary, and used the same way as historical data.

3.5 Tests

Several different kinds of tests are carried out during the development and production phases of the product life cycle. Test data allow performance to be quantified and reliability to be estimated. Experiments should ideally be designed and carried out under controlled conditions so that the information obtained is meaningful. If the product is complex and expensive, testing may be required at several different levels: material, component, and system. For simple products, it may be adequate to test only the completed product. As the complexity of the product increases, so do the data and analysis required for aggregation of meaningful information.

Random samples are often taken when inspecting items from the production line. The data are used to estimate production quality and other metrics of interest.

Environmental data includes temperatures, stresses, etc. that are encountered during tests or during operational life (if recorded). These variables can be used to evaluate the effect of different environments on product performance.

3.6 Scientific and Technical Handbooks

Handbook data includes specifications and calculations obtained from technical publications. Data of this type may typically include labour costs in certain regions, formulae for various technical relationships, market indices for commodities, and so on.

In theoretical assessments of reliability, for example at the part level, physical failure models are sometimes used. The models typically require inputs such as geometrical configurations, materials and their properties, environments in which the item will be operated, and measures of variability in all of these variables. Much of this information can be obtained from standard engineering, physics and chemistry handbooks. Important data sources are GIDEP, MIL-HDBK-217, Non-Electronic Equipment Reliability Data, BELL Core, etc.

3.7 Market Surveys

Market surveys are carried out to obtain commercial and customer related data. Rarely does one have access to an entire population or the resources to seek the response of every individual. A simple random sample is a sample selected in such a way that every sample of size n drawn from a population of size N is equally likely to be selected. This is done by use of a computer program or a random number table. Another issue is the type of questionnaire used as it can have a significant impact on customer response.

3.8 Warranty Servicing and Field Support

Warranty service and field support (such as spares used) data provide valuable information regarding product performance in field. If the data is collected properly, it also provides useful customer related information such as usage mode and intensity, customer satisfaction and needs.

3.9 Warranty Servicing and Field Support

Customer feedback information is a valuable data source and can provide product related and customer related information.

3.10 Consumer Reports and Magazines

Consumer groups carry out different kinds of tests on similar products and customer surveys. The findings of their study are usually reported in magazines or reports and constitute a valuable source for relative comparison between different products. In the case of cars, Automobile Magazine, Autoweek as well as Car and Driver provide an excellent report on cars and customer's reaction on them.

4. Reliability Data - Life Cycle Approach

Reliability data can be gathered throughout the life cycle of a product (Guangbin, 2009). An important requirement for designing useful reliability is to have a good idea of how the product is actually developed in the laboratory and used in the field. A brief summary of the various types of reliability tests in the development and manufacturing stages and in the field is presented next.

4.1 Development Stage

Reliability testing in the development stage occurs during the early phases of the product's life cycle, usually from project inception to product release. With a multitude of design stages that could affect the product's reliability, it is necessary to closely monitor how the product's reliability grows and changes as the product design matures. A number of different test types that can be run during this stage to provide useful reliability information are as follow:

Component-level testing: Component-level testing is usually carried out during early phase of a product for critical components. There may also be special interest in the performance of a specific component if it has been radically redesigned. With sufficient understanding to characterize the interaction of the components the system-level reliability can be modelled based on the configuration of components. At component level usual survival function can be used to determine the lifetime of the component.

System-level testing: The ideal approach to the system-level testing is to test the entire system, especially when the reliability of the system is specified. System-level testing should be performed immediately prior to the product's release for manufacturing in order to verify reliability.

Environmental and Accelerated Testing: The product may be used in an unfavourable condition. It may be that the product would not normally fail within the time constraints of the test, and so the stress factors must be accelerated to get meaningful data within the reasonable amount of time. Environmental and accelerated testing should be performed properly so as not to induce failure modes that would not normally encountered in the field. Accelerated testing data can be analyzed using stress-strength relationship such as Arrehnius Weibull model.

4.2 Manufacturing Stage

In manufacturing stage, testing takes place during and after the release of the product to measure the performance of the manufacturing process as well as the product. Following types of testing can be performed in this stage:

Functionality Testing: A large number of products are put on a very short test to verify that they are functioning. In some cases they may be run for a predetermined "burn-in" time to weed out early failures in the field.

Design/Process Change Verification Testing: This type of testing occurs at regular intervals during production, or immediately after the design/process change of the manufacturing process.

4.3 Field Stage

The information from the field data is the proper measure of product performance. However, there is usually disconnection between the reliability performance of the product in the field and the results of in-house reliability testing with the performance in the field being very lower that the results in the testing. Major reason is that the product in the field in general receives harsher treatment in the field than in the lab. In addition the units tested in the field are often hand-built or carefully set up prior to testing. Some of the most prevalent forms of field data are as follow:

Sales or Shipping Data: This information provides the analyst with a figure for the population of products in the field, which enables us to do any sort of reliability-oriented calculations.

Warranty Data: Most warranty systems are designed to keep track of finances and not reliability performance. Therefore they do not provide adequate information for reliability performance. For instance it is hard to get accurate time to failure for warranty systems. However, careful handling of the warranty data will allow a crude estimation of reliability.

Field Service Data: Repair technicians manually repair failed products during an 0n-site visit. This gives a potentially powerful source of field reliability information. But the job of the service technician is to restore the customer's equipment to operating condition as quickly as possible, and not necessarily to perform a detailed failure analysis. It may be that only one of the parts that have been replaced had actually failed. From a reliability perspective, it is best to record necessary failure information correctly.

Customer Support Data: Many customers call to solve their problems in the products. It may be related to the field service data in that the customer with a failed product will call to the company. Ideally the customer support and field service data would reside in the same database, but this is not always the case.

5. Data Collection

It is necessary to have an accurate and efficient way of recording data related to reliability. With the decreasing cost and increasing power of computer systems, it is not very difficult to set up a computerized data collection system.

Since many types of reliability testing are performed and data collected, it is important to have certain common elements that extend across all of the different types of tests. It is recommended to have at least three related databases: a test log, a failure log, and a service log.

5.1 Test Log

The structure of the database for test log may depend on the type of products and the testing procedures. Therefore if the product requires a series of inputs during testing the test log should contain all of the pertinent information. For instance the test log should include transaction number, test start date and time, test identifier, test stage and inputs at each stage, operator comments.

5.2 Failure Log

This is a major source of information for reliability analysis. Therefore care has to be taken in constructing the database that captures all pertinent information. For instance the failure log should include transaction number, test log cross-reference (test stage included), failure date and time, symptom code, failure type and code, failed part and relevant failure (or masked parts), resolution, and comments.

5.3 Service Log

Service log is to keep track of service actions on the test units. A service log should be written whenever the item is serviced, installed or upgraded since these actions have a large effect on the performance of the test units. The entries for the service log are

transaction number, test log cross-reference, service date and time, current version identifier (and new version identifier if the service upgraded the test unit), service type, part modified or replaced, comments.

5.4 Field Data

Field data are collected in many different types of formats in companies. The potential drawback to the field data collection is that the data collection system may be focused on field performance rather than on reliability performance. Another difficulty with the field data is that the data may reside in different places and formats depending on whether they are field service data, customer support data, etc. The challenge in this case is to develop a method of gathering the pertinent data from the various sources and databases and put them into one central location where reliability information cab be extracted from it.

6. Summary

A lot of data are gathered in the daily activities of quality management. In-house testing data are useful to provide valuable information on reliability. On the other hand, bulk of the field data are not meant to be used for reliability prediction unless extra care is taken to deal with the data. Field data is to be analyzed for any discrepancy with the lab prediction and data collection methods have to be updated continually.

With the decreasing cost and increasing power of computer systems, it is not difficult to set up a computerized data collection system and automatic analysis for the entire life cycle of a product. But care has to be taken in applying appropriate reliability methods.

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