

Forecasting Warranty Cost for Vehicle Handling Using the Mahalanobis-Taguchi System

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ABSTRACT

Consumers judge quality and performance at the system level, but important cost-effective decisions at the sub-system or component level must be made by the producer in order to economically satisfy consumer's needs by providing affordable and high quality products. Mahalanobis distance (MD) is a distance measure that is based on correlations between variables and the different patterns that can be identified and analyzed with respect to a reference population. MD is a discriminant analysis tool, which will be used to predict warranty cost using multiple characteristics at all levels of a hardware set. The Mahalanobis-Taguchi System is a diagnosis and forecasting method for multivariate data. The Mahalanobis-Taguchi System is of interest because of its reported accuracy in forecasting small, correlated data sets. This is the type of data that is encountered with consumer vehicle ratings. This paper presents the application of the Mahalanobis-Taguchi System in multidimensional systems to forecast warranty cost. The proposed methodology uses a pattern recognition scheme known as the Mahalanobis-Taguchi System to translate the performance of lower level elements into an estimate of warranty cost at the system level. An automotive case study involving vehicle handling is provided to illustrate the proposed methodology.

INTRODUCTION

The purpose of this research is to develop a relationship between vehicle attributes and warranty cost for the purpose of understanding and improving customer driven quality. The Mahalanobis-Taguchi System (MTS) enables a reduction in dimensionality and the ability to develop a scale based on Mahalanobis distance (MD) values [Taguchi, 2002].

Consumers assess and perceive quality and performance at the vehicle level, but important cost-effective decisions at the sub-system or component level must be made by the producer in order to economically satisfy consumer needs by providing affordable products.

Consumers evaluate vehicle attributes such as ride, handling, roominess, braking and acceleration. These vehicle level attributes are influenced by factors at all levels of the vehicle architecture, and these factors are often correlated. The goal of this research is to efficiently forecast warranty cost measured as a function of available vehicle level performance data. By predicting the origin of warranty claims, organizations can focus efforts on significantly reducing products costs in conceptual design and, therefore, increase profitability.

The role of a warranty is becoming increasingly important to both the consumer and the supplier. A warranty is a supplier's commitment to repair or replace a product during a specified time frame. Customers seek assurance that the complex and expensive products they purchase will be durable. Suppliers may utilize warranties when competing products are nearly indistinguishable to gain a competitive advantage. Warranty management must be a strategic approach, which encompasses the entire product life cycle.

The strategic approach for warranty management and warranty avoidance must provide a balance of cost and performance to tolerance design. Companies cannot solely focus efforts on warranty avoidance. They must also learn from customer experience. This information and data must then be managed and translated back into product performance, tolerance design and process capability with regard to cost.

In order to reduce warranty costs long term, quality must be considered at design conception. Approximately 70 percent of a product's total cost is determined by its design. Reliability predictions can be based on past experiences with similar products and further refined during product development. Companies need to be able to predict failure rates as a function of time based on analysis of product and process testing. This data will enable companies to predict and evaluate warranty costs.

Warranty is also simply lost revenue. According to a report by the Original Equipment Suppliers Association (OESA), North American automotive warranty costs are \$10 billion per year (www.oesa.org). OESA examined the North American warranty management programs for nearly a year at BMW, DaimlerChrysler, Ford, General Motors, Nissan and, Toyota. This study clearly shows the need to focus on eliminating warranty concerns. In order for North American automakers to remain competitive and profitable, focus and effort must divert to predicting warranty and subsequently eliminating warranty.

MTS can be used to minimize the number of variables required to forecast the performance of a system. The steps of the MTS analysis for vehicle handling are outlined in this paper. The objective of the MTS analysis for vehicle handling is to explain the relationship between the vehicle handling parameters and warranty cost. The purpose is to provide an understanding of the relationship and provide an opportunity to efficiently reduce warranty cost.

REVIEW OF RELEVANT LITERATURE

Considerable research is available utilizing MD for determining the similarities of values from known and unknown samples. However, existing research uses MD to consider measurable and distinct variables. Consumer requirements or inputs to the research were concrete and clearly defined. However, this research will create a methodology to translate lower level characteristics using MD into an estimate of warranty cost.

MD is utilized to determine the misclassification of samples in research by Shen et al. [2003]. Two processes for tablet production are evaluated in this research including wet granulation and direct compression which are the two main methods used in tablet preparation. Pyrolysis-gas chromatography-mass spectrometry was used to discriminate the two processes. First, samples were removed that did not contain at least half the number of samples for one of the two classes. Principal components analysis (PCA) was then employed to determine the main principal components. Based on the PCA analysis, three factors and one sample were excluded. The data was further processed using Fisher discriminant analysis to classify the sample using unsupervised and supervised classification methods. Fisher discriminant analysis is an approach that is commonly used for feature extraction between groups. The results were evaluated using MD to determine the misclassification rate.

Taguchi [2000] utilized MTS for diagnosis and pattern recognition. His research discussed a case study involving liver disease diagnosis in Tokyo, Japan using fifteen variables. The normal group consisted of 200 people that were determined to not have liver disease. For each abnormal group, he determined which variables were significant. In his research, Taguchi developed an

eight-step procedure titled "Mahalanobis Distance for Diagnosis and Pattern Recognition System Optimization Procedure".

MD was used to maximize productivity in a new manufacturing control system by Hayashi et al. [2001]. The research used MD as a core to their manufacturing control system because of the method's ability to recognize patterns. Due to a very high utilization of certain processes, one of the manufacturing areas for wafers was experiencing a bottleneck. Approximately 50% of the primary tools in this manufacturing area had over 90% utilization. MD was used in conjunction with manufacturing administrators to focus on routes that involve the shortest cycle time to reduce labor costs. The new system detected deviations from normal productivity much earlier, enabled root cause identification and prioritized resolution.

Asada [2001] used MTS to forecast the yield of wafers. Yield of wafers is determined by the variability of electrical characteristics and dust. The research focused on one wafer product with a high yield. MD was calculated on various wafers to compare the relationship between yield and distance. The signal-to-noise ratios were used to indicate the capability of forecasting and the effect of the parameters.

Pattern recognition using MD was demonstrated in the work of Wu [1996]. In this research, pattern recognition was used to diagnose human health. The results of tests from a regular physical check-up were used as the characteristics. The correlation between different tests was shown. MD was used to summarize the multi-dimensional characteristics into one scale. In this research the base point was difficult to define because it was a healthy person. People who were judged to be healthy for the past two years were considered to be healthy. The research considered diagnosis of liver function with the objective of forecasting serious disease until the next check-up. The approach provided a more efficient method and also avoided inhuman treatment which was previously used in double blind tests.

In the research of Hussain and Murthy [1998], the warranty costs are shown to be dependent on product reliability and quality uncertainty. The use of redundancies or quality control techniques is shown to reduce warranty costs. Hussain and Murthy developed a model to determine a trade-off between manufacturing costs and warranty costs. From the model, the optimal redundancy and quality control strategies can be determined.

Warranty has also been shown to signal quality in oligopolistic markets. Gal-or [1989] illustrates that warranties can act as perfect signal for products with intrinsic attributes that are not widely spaced or clustered. Other market mechanisms providing information about product durability include reputation, advertising, and product-specific investment. Gal-or investigates providing warranties or service contracts as