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Warranty cost estimation using simulation

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ABSTRACT

The purpose of this paper is to consider a warranty estimation problem using a simulation approach. Prior research has estimated warranty costs using mathematical expectations. In the simulated approach, the time to failure has been assumed to be exponentially distributed. Three different rebate functions are considered: a linear pro rata rebate, a lump-sum rebate, and a full rebate up to a certain point and a linear pro rata from then until the warranty expires.

INTRODUCTION

Almost all products, whether sold directly to the customer or to a producer for assembly into a consumer product, now carry a warranty of some kind. The nature and extent of the warranty affect the sales, market share, costs, and profits of many businesses. A warranty can be defined as an assurance from a seller to a buyer that the product sold under warranty is guaranteed to perform satisfactorily up to a certain length of time, the warranty period. Moreover, the seller promises to replace or repair the product in the event it fails to conform to a performance standard during the warranty period.

Warranties are important to buyers and sellers alike. Buyers need warranties to satisfy their need for assurance that the product will perform satisfactorily. There are a number of reasons why a buyer is skeptical about satisfactory performance of the product. Some of the reasons are imperfect standardizations, imperfections due to product innovation, inability on the part of the buyer to determine the quality of the product, and so on.

Warranties are equally important to the seller. Sellers use warranties mainly for promotional and protectional purposes. A statement of the warranty can be included in the sales material to encourage buyers by reducing consumer risks. As a result, sales are increased by converting potential sales into actual sales. Warranties that involve a refund of the purchase price or a replacement have exceedingly strong promotional characteristics. In effect, the promotional characteristics of a warranty may tend to increase the demand for the product.

A protective warranty is designed to guard sellers from unreasonable claims of purchasers. Essentially, it is an instrument that explicitly defines and thus limits the responsibility that the seller assumes in regard to a product subsequent to sale. The manufacturer will accept the responsibility to see that users get expected utility from the product. He will accept the responsibility on his own terms which will protect him against unreasonable demands.

A seller creates a liability when he sells a product and offers some type of warranty to a customer. A liability is an obligation based on a transaction or an event in the past or present to convey assets or perform services at some time in the future. The knowledge of total expected warranty liability will help manufacturers plan operations more effectively, since an accurate knowledge of warranty costs allows more accurate profit expectations that may, in turn, lead to unanticipated marketing advantages. Also, the tax laws force manufacturers to report total warranty liability on their financial statements. Failure to record estimated warranty liability will overestimate income and underestimate liability. An intelligent estimate of the warranty liability will inevitably produce less misleading information than no estimate at all [1].

The purpose of this paper is to estimate warranty costs using a simulation approach. Past researchers have estimated warranty costs using mathematical expectations and they may not be practical in all situations, particularly when the probability distributions are complex.

LITERATURE REVIEW

Past literature on warranties was concerned with the estimation of warranty reserves necessary to meet the warranty obligations [5]. The present value concept is incorporated to account for the time value of money [2,3]. Linear pro rata rebates, as well as lump sum rebates were considered by various authors [2,3,5,7]. Heschel considered the expected repair cost to the consumer over the life of the product [4]. Mitra and Patankar used a goal programming approach to explore the warranty cost problem [6]. The literature also indicates that some qualitative aspects of warranties are of importance, such as the necessity to have a product warranty, the environment for success of a warranty program, and the consumer's attitude toward warranty programs [7].

SIMULATION AND RESULTS

The use of mathematical functions to determine the life of a product and ultimately the cost of a specific rebate plan enables the user to have a very precise answer. If the life of a product cannot be written in a mathematical formula format, where the probability of occurrence is obtained through integration, then the function would be declared to be inappropriate. With such restrictions placed on the format that the "life of the product" can have, there is a great reduction in the possibilities that an organization may desire to investigate for their product. However, there do not have to be such stringent rules if the distribution of the life of the product were to be simulated.

The basic thrust of the simulated approach is the building of a cumulative probability distribution that basically represents the complete length of life of a product. The next step is the selection of random numbers, according to the Monte Carlo sampling technique, determining the length of life of an individual product. Depending on where the random number falls in the cumulative distribution, a dollar cost is assigned for that failure. If, of course, it falls outside the warranty period, the cost assigned would be $0. The simulation is run for a specified number of units, and the individual warranty costs are accumulated for all the units and represent a part of the output at the completion of the simulation.

In 1981, Patankar and Worm [8] indicated the annualized payouts for a warranty plan, where the life of the product was exponentially distributed with a mean product life of 10 years and a payout beginning at $10.00 and diminishing to $0.00 at the end of a five-year warranty period. The expected payouts for each of the five years are shown in Table 1. In addition, the article provides a 95% confidence interval on each yearly payout. However, there is no information with regard to the number of units that is expected to fail in any given year or the total number that is expected to fail during the life of the warranty.

Table 1: Warranty Payouts for a Five Year Period: Mathematical Orientation

Year	1st	2nd	3rd	4th	5th	Total
Dollars	4288	3019	1954	1062	324	10647

To illustrate the power of simulation to duplicate the mathematical function and produce similar results, a step-wise cumulative exponential function was constructed. The breakpoints in the distribution for the first five years were done on a monthly basis, and the warranty cost of failure was begun at $10.00 and diminished monthly to $0.00. Each simulation was run for a total of 5000 units, a comparable figure that produced the results in Table 1, and 50 different runs were completed. The program was written in General Purpose Simulation System (GPSS) language and was run on a large mainframe system. The resulting payouts, as indicated by the average of the 50 simulated runs, are shown in Table 2. Although these average values do not reflect the precise figures of Table 1, in a test of the means, no significant difference was indicated as noted by the t values in Table 2.

Table 2: Warranty Payouts for a Five Year Period: Simulation Orientation

Year	1st	2nd	3rd	4th	5th	Total
Dollars	4352	3069	2036	1065	353	10875
t CALC.	.394	.407	.891	.047	1.557	.958

There are many side benefits to be gained in the use of simulation that are not present in the straight mathematical approach. As can be seen in Figure 1, there is the availability of the maximum and minimum payouts for each year, as well as the average payout. The use of simulation has also provided information regarding the number of units that failed in each timeframe. This information was determined for each month of the five-year warranty payout periods and was done for each of the 50 simulated runs. The maximum, minimum, and average number of units is shown on a yearly basis in Table 3. With these kinds of information, a firm would have an idea of what to expect in the way of actual product returns.

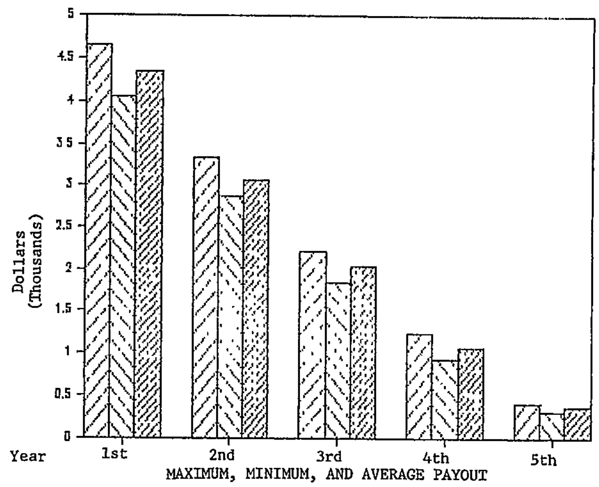

Figure 1: Rebate Plan: $10.00 Diminishing to $0.00 for the Five Year Period

Table 3: Product Unit Failures for a Five Year Period: Simulated Orientation

Year	1st	2nd	3rd	4th	5th	Total
Max.	514	469	433	394	361	2171
Min.	445	404	360	299	289	1797
Avg.	478	423	399	344	320	1973

The use of simulation allows the pursuit of optional payout procedures while still maintaining the same product life distribution. Such information is shown in Tables 4 and 5. In Table 4, the payout is a straight $5.00 for each failure for the five year warranty period, and in Table 5, the payout is $10.00 for each occurrence for the first two and one-half years, diminishing to $0.00 for the next two and one-half years.

Table 4: Maximum, Minimum, and Average Dollar Payout Based on a \$5.00 Lump Sum for all Occurrences

Year	1st	2nd	3rd	4th	5th	Total
Max.	2680	2355	2150	1915	1745	10845
Min.	2235	1895	1845	1520	1425	8920
Avg.	2392	2161	1987	1716	1575	9831

Table 5: Maximum, Minimum, and Average Dollar Payout Based on \$10.00 for 2-1/2 Years Diminishing to \$0 for the Remaining 2-1/2 Years

Year	1st	2nd	3rd	4th	5th	Total
Max.	5250	4650	4038	2472	758	17168
Min.	4150	3670	3228	1769	578	13395
Avg.	4787	4282	3708	2103	677	15557

Although the information is not shown, the number of units failing on a monthly basis was also accumulated.

CONCLUSIONS

The use of simulation has been demonstrated to provide results that are statistically comparable to the results derived through mathematical procedures. However, the use of simulation can provide additional information that is not available in adhering to a strict mathematical approach. The total number of units was able to be determined and the maximum and minimum values were also provided by the simulation. It has been demonstrated that other warranty payout plans can also be investigated. In addition, if a product life cycle does not lend itself to a well behaved mathematical function, it would be somewhat difficult to make a warranty analysis using a mathematical approach. This would not be true in a simulated environment.

Although these simulations were run on a mainframe system, GPSS is available on the PC and would permit the instant analysis of alternate payout plans and alternative length of life distributions. For this type of analysis, one is not restricted to the use of GPSS as a simulation language but could use other simulation languages or even write a simulation program using Fortran or APL as programming languages.

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