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Applications

Reinventing Warranty at HP: an Engineering Approach to Warranty

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The mechanisms used to understand and reduce warranty costs often focus exclusively on the analysis of product failures. However, warranty costs can also be incurred by events such as support calls that do not involve a product failure. We describe a method used by a major electronics manufacturer to understand warranty costs by modeling warranty events. Furthermore, event modeling that uses a time-dependent warranty event rate instead of the more standard average rate of failure allows the improved prediction of warranty costs and better accruals. As a result of the modeling, warranty engineers can help product managers more accurately predict the costs associated with removing certain warranty events, changing warranty policies and offering extended warranties for their electronic products. Copyright © 2003 John Wiley & Sons, Ltd.

KEY WORDS: warranty event-related database; warranty event prediction; warranty cost prediction; accruals; time- and usage-based warranty policy; time dependent failure rate

INTRODUCTION

In 1998, the Hewlett-Packard Company (HP) introduced a new line of Color LaserJet printers, expecting high reliability. Quality and reliability engineers were immediately surprised with very high warranty costs per unit. In fact, following initial product introduction, the new color LaserJets represented only ∼3% of HP high-end department LaserJet units, but accounted for ∼25% of the total warranty dollars.

Quality and reliability engineers from HP's Color LaserJet group approached the Strategic Planning and Modeling (SPaM) team for assistance. SPaM is a small team of operations research specialists within HP whose task is to provide internal support to HP product divisions to improve the efficiency, cost-effectiveness and profitability of HP's product lines. SPaM worked together with engineers at Color LaserJet to create the quantitative warranty cost modeling approach described in this article.

BACKGROUND

AT Kearney Consultants report that many companies are moving towards attacking warranty cost as margins for electronic products decrease[1]. Warranty costs are incurred by 'warranty events'. Unfortunately, when they

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hear ‘warranty’ many people only think of ‘product reliability’ and, thus, to them a warranty event always refers to a hardware failure. However, not all warranty events turn out to be due to a product failure, although they usually require some diagnostic action (which may also incur a warranty cost) to determine whether the reported problem is due to a product failure or not. Other causes of reported problems include user errors, network failures that are not directly related to the product, or the need for some routine maintenance task (toner cartridge replacement, for example) that can be performed by a user without the onsite assistance of a field support engineer.

Thus, improving product reliability does not always solve a warranty problem; there are many other things that can create increased warranty costs. Aside from user-fixable problems, other factors contributing to warranty costs include sub-optimal service and support logistics (over-stocking of expensive but infrequently used replacement components, for example), poorly designed and managed warranty policies and inadequate solution testing (analyzing product use in a particular solution).

The initial investigation with HP Color LaserJet uncovered the following symptoms.

1. Product reliability was not the problem[2]. Warranty costs were being driven by something more than product failures, at least in terms of how we had traditionally defined ‘product failures’.
2. The quality engineers were focused on product failures rather than warranty events, which also included problems not caused by product failures. An example of a non-failure-related ‘warranty event’ would be a call to the support hotline reporting a printer failure when the actual cause turned out to be ‘local area network cable not plugged in to the printer’—in other words, an operator error.
3. There was a limited focus on how the warranty policies were designed and managed.
4. Service requirements for the new Color LaserJets were somewhat different from those for other LaserJets. Service mechanisms and warranty policies were designed to handle high volumes of ‘foolproof’ products similar to monochrome LaserJets, not the increasing volume of ‘high performance–high touch’ products like Color LaserJets. In addition to this, our installed base for the new product was growing rapidly, further adding to warranty-related costs.

PROBLEMS WITH PAST APPROACHES

Financial planning has been limited

Reliability modeling is well-known as an engineering practice, but is seldom used for financial planning purposes[3]. Data collected regarding the performance and failure of a product is often used directly by design and manufacturing engineering, but such data is typically condensed or filtered when used by financial planning organizations, if it is used at all. Because the data for reliability modeling is typically drawn from historical sources, it provides a poor basis for obtaining an understanding of contemporary cost behavior or accurate predictions in time. Furthermore, reliability data is focused on product failures, rather than on the exact number (instances) of events that incur warranty costs.

New warranty policies carry significant risks as well as opportunities

The opportunity consists of the product warranty’s role as a sales differentiator. When two products are similar in performance and cost, the difference between warranties can be a decisive sales factor. The risk comes from adopting a new and presumably more attractive warranty policy in order to compete in the market, without being able to assess the cost associated with the newly adopted policy. Marketing groups, being focused on sales growth but not on warranty costs, tend to focus on keeping the warranty policies as attractive as possible; they need clear and convincing proof of both short- and long-term financial impacts before they will consider changing a warranty policy. To properly assess these impacts, we need a rigorous quantitative method of predicting the outcome of changes in the warranty policy for a product so that associated financial risks can be assessed. We also need the capability to plan and allocate service and support resources for products under warranty.

Analysis can be slow

Conventional cost management techniques use mostly time-integrated or time-averaged data. In other words, they assume a constant rate or likelihood of failure for a product, regardless of how long the unit has been in service or how much use it receives. This type of analysis requires historical data gathered over a significant period of time in order to have enough data points to produce a robust initial set of time-averaged or time-integrated data. The time lag required to collect sufficient data for averaging can introduce inaccuracies into the initial financial planning period, when sufficient data points are not yet available and these planning inaccuracies can in turn lead to inaccurate predictions. An improved approach to warranty financial planning based upon product data that is more specific than time-averaged or time-integrated data can reduce the time required to generate more accurate and usable warranty cost projections.

AN INTEGRATED RELIABILITY AND FINANCIAL PLANNING SYSTEM

As we mentioned earlier, different functional groups tend to have specific definitions of what ‘warranty’ means to them. On the one hand we have marketing professionals, who view the warranty as a selling attribute (a product feature). On the other hand, we have engineers who see the warranty as a ‘material’ or ‘component’ issue. In this investigation, we deviated from the traditional warranty views of both marketing and engineering to embrace a broader and more holistic approach.

We expected that the information required to provide an answer would not reside in any one organization within HP. Instead, different pieces of the puzzle would likely reside in various organizations including marketing, service and support, R&D and manufacturing and finance. Because a considerable amount of money was at stake, all these groups had an interest in improving the warranty planning process. Thus, we were able to put a diverse team together with good project leadership and sponsorship—conditions that are essential for success in this type of investigation. Figure 1 shows the different organizations that collaborated in our investigation, as well as the perspectives that each group brought to the table.

The manner in which the organizations collaborated was as follows:

- *Service and support* traditionally has the most ‘ownership’ of warranty. This organization closely measures warranty cost and has the most control over how warranty services are delivered. This group also generally has the most data on product failures and warranty events.
- *Marketing* sees the warranty as a ‘feature’ of the product. In general, marketing is happy if a longer or more attractive warranty policy is offered because doing so makes it easier to sell the product. Reducing or changing the warranty in other ways requires involvement from marketing because product sales may decrease.
- *R&D and manufacturing* view warranty in the form of ‘product reliability’ and ‘quality’. This organization is measured on product failures and has some control over product reliability because its teams determine how products are designed and what manufacturing methods are employed.
- *Finance* acts as an important data source for analysis. They also often serve as the arbitrator in cross-functional decisions because they are often the most neutral party. While one organization may maintain ‘This product is unreliable!’ and another may blame cost overruns on ‘inefficient delivery of service and support’, finance focuses on overall cost analysis and tries to develop an accurate picture of where those costs come from.

Once these organizations were committed to the project (with project resources assigned) we began work. Early in the investigation we made some important discoveries.

- The best predictions were factored in time dependency rather than assuming a constant likelihood of failure over time. Prior to this point, the HP organizations were using a constant failure rate that was easy to calculate but not as accurate as a time-dependent one. Methods for improving our prediction of ‘warranty events’ are described in a related article[4].

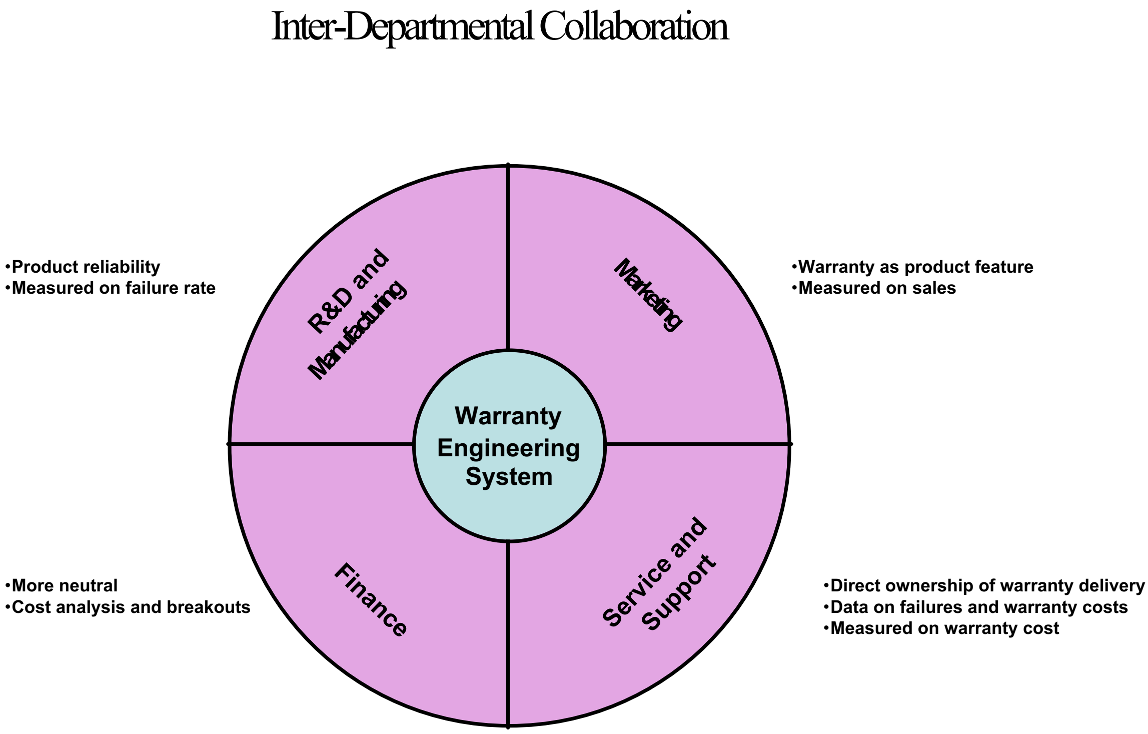


Figure 1. Organizational alignment on an engineering warranty is essential to successfully control warranty cost

- There was no prior experience in HP (and generally in commercial electronics) of viewing the warranty as a complete set of products and policies. When product managers were asked what the warranty should be for their new product they answered ‘two years—it always has been’. The time- and usage-based methods employed by the auto industry (such as ‘three years or 30 000 miles, whichever comes first’) were very useful in helping us to think of new methods[5,6]. To translate this into printer terms, a time- and usage-based policy might be something like six months or n pages printed.
- We had very limited data on usage patterns, defined as how many pages were being printed each year, across different HP customers. Did most customers use the product with the same frequency or were there big differences in how many pages different customer groups printed each year? As it turned out, usage patterns could vary by product and some products had usage patterns which were much more variable than others.
- There was no clear ownership of warranty, a difficulty seen in many businesses managed with a front-end/back-end structure. Unclear warranty ownership made decision-making slower than it could have been and encouraged focus on narrower issues where there *was* clear ownership (e.g., product quality) instead of on the larger issue of warranty cost management as a whole.

The first thing we had to do was validate some of our assumptions about the importance of time- and usage-based warranties within our own industry. To do this, we needed to capture a variety of factors and create valid warranty scenarios that would allow us to compare the cost impact of each warranty type. We developed a warranty modeling system based upon warranty event prediction data that would be capable of more accurate, time-based warranty event prediction. We used this event prediction model to provide planning for warranty accruals, to examine alternative scenarios based upon simulated data and to aid in the marketing and pricing strategies. Our initial exercises used historical warranty event data for selected Color LaserJet models that were currently being supported.

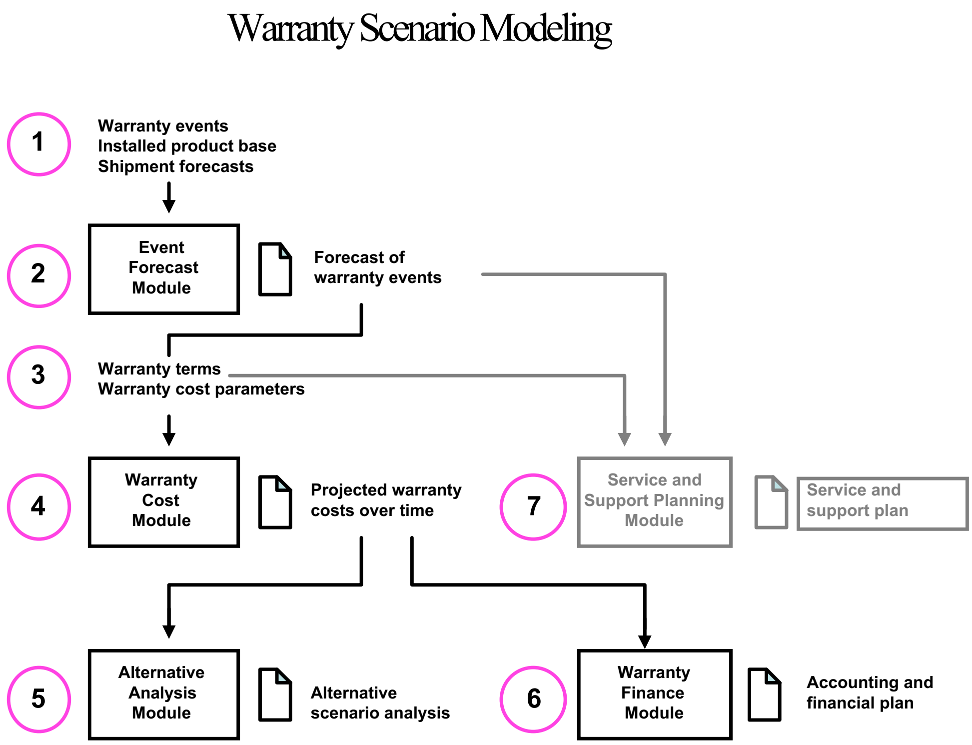


Figure 2. A system embodiment of the approach

The warranty modeling system uses product and warranty data combined with analytical techniques. Each analysis module has a distinct set of inputs and outputs, as shown in Figure 2.

Product data

Product data (1 in Figure 2) includes past warranty events for installed products plus projected shipments.

- Warranty event data includes information about customer service events due to both real and perceived product failures. Event data includes the date of occurrence and non-failure events that require service nonetheless.
- Product 'installed base' data includes information regarding when each item was shipped. The installed base describes the product population that is under warranty; this is derived from the number of units shipped, minus those that have been removed from service or are no longer under warranty or service.
- Product shipment forecast data includes information regarding units for which there are firm orders or reliable forecasts, but where the product has not yet been delivered. This data is particularly useful in situations where establishment of service and support requires significant lead-time.

Event Forecast Module

The Event Forecast Module (2) uses the product data to create estimates of future warranty events over time. Product data is input into this module based upon discrete events localized in time. The Event Forecast Module then performs a statistical analysis[7,8] of the data and produces a 'best fit' model for the event rate of failure and non-failure warranty events. Linear, power, exponential and logarithmic functions are examples of functions that can be used individually or in combinations to provide a 'best fit'. An event rate model that is time-dependent rather than constant requires a sophisticated convolutionary method[4,9] in order to translate the forecasted event rate to 'events'. The event rate is then forecast as a function of time. The events are not usually forecasted at a fixed rate, because as a product spends more time in service, it is more likely to fail.

Warranty input parameters

This set of inputs (3) includes information such as the cost of replacement parts, labor costs and terms of the warranty (what is covered under the warranty and for how long). The time-related parameters include time-normalized data. Actual field data was used to develop the cost parameters.

Warranty Cost Module

Based upon the warranty cost, the Warranty Cost Module (4) calculates[4,10] the expected warranty cost over time.

Alternative Analysis Module

The Alternative Analysis Module (5) provides scenario-planning capabilities to test alternative warranty strategies. This capability is recursive; the input and functions have a means for producing incremental variations in the input data and parameters.

Warranty Finance Module

The Warranty Finance Module (6) plans and aggregates accruals and de-accruals for expect warranty expenses. It includes a monitoring system that issues warnings when realized warranty costs exceed preset control limits.

Service and Support Planning Module

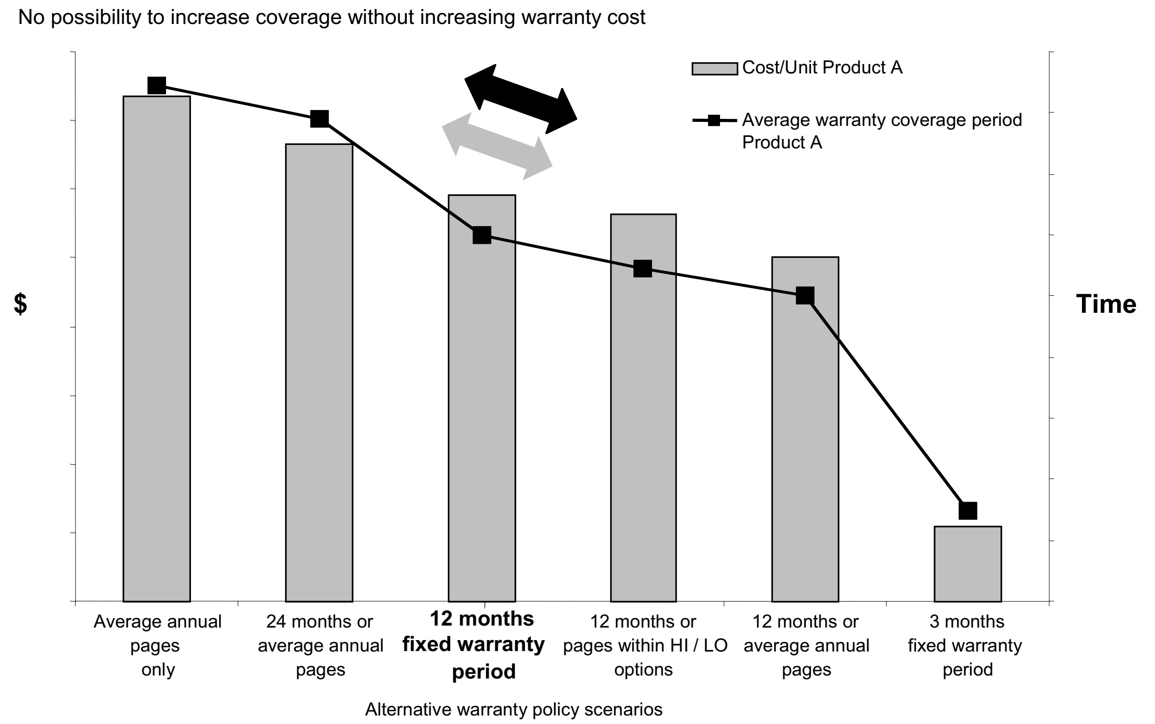
This module (7) is currently under development. With a systematic approach and a more holistic method of predicting costs, it is easier to design service contracts that can be sold as separate products. This module will eventually work in parallel with the rest of the warranty modeling system, using predicted events as a function of the warranty policy to design profitable service contracts. In this way, an engineering approach to warranty transforms something that traditionally has been viewed as a cost into a revenue generator.

We validated our model using historical data from previous products and improved the model's performance during our investigation by tracking predictions and adjusting the model based on actual results.

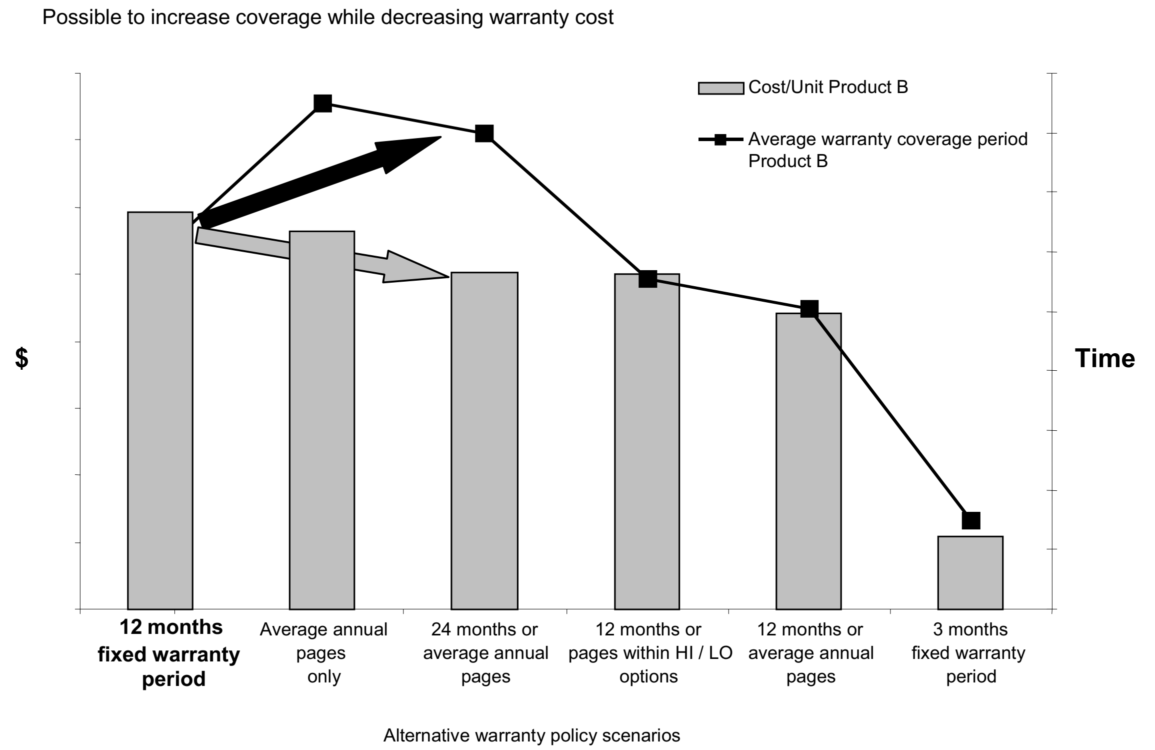
RESULTS

1. Moving from a constant to a variable failure rate output utilizing a statistical model improved the prediction of warranty costs for new platforms.
2. Modeling the pricing and expected failures for a new HP extended warranty showed that at the price for which HP had planned to sell the units, HP would *lose* money on the warranty. This helped management to set a more appropriate price.
3. We confirmed that usage plays an important role in warranty planning and identified methods to increase warranty periods while reducing warranty costs by structuring different warranties for different user groups (see Figures 3(a) and 3(b)).

Figures 3(a) and 3(b) show the results of simulating cost and warranty periods for two actual products, product A and product B, for six different warranty scenarios. Products A and B are similar models within the high-end Color LaserJet product line, but have slightly different feature sets and target markets. For the



(a)



(b)

Figure 3. Example cost and expected warranty coverage in time for (a) product A and (b) product B

purposes of warranty modeling, the most important differentiator between these two products is in the typical usage pattern.

- Product A is characterized by a relatively predictable usage pattern, meaning that most of the customers who purchase this model are likely to show similar levels of usage over time.
- Product B has a highly variable usage pattern, meaning that some customers may use it much more heavily than others.

We used historical warranty event data for each of these products to model what would have happened under various time and usage-based warranty scenarios. For the usage-based scenarios, the 'average page rate' is the average total pages printed by that unit at the time that the unit exited the warranty period.

The questions we were trying to answer for products A and B were as follows.

- How much would each type of warranty cost per unit?
- How long would that unit stay under warranty?

The axes shown in Figures 3(a) and 3(b) are as follows.

- The X-axis shows six alternative warranty policies combining various elements of time, usage or both.
- The Y-axis on the left corresponds to the bar charts and shows HP's cost experiences, which is the total warranty cost per unit.
- The Y-axis on the right corresponds to the points on the chart and shows how long that unit would be covered under warranty for each warranty plan. Expected warranty coverage in time is the volume-weighted average based on all users in the installed base. This vector is most relevant for those warranty policies that combine both time and usage factors.

The warranty scenarios modeled on the X-axis fall into three main categories.

- *Exclusively time-based.* Two of the scenarios simply guarantee the product for the first three or 12 months of service, respectively, regardless of how much the printer is used.
- *Exclusively usage-based.* One of the scenarios covers the product until X pages have been printed. Once that threshold is reached, warranty coverage for that unit is ended. In this scenario, a heavily used printer would exit its warranty period far sooner than one with light usage.
- *Time/usage combination.* These scenarios contain some variant of 'X months or X pages, whichever is first'. The 'hi/lo page rate' scenario actually includes two options that the customer can choose from. In the 'hi' option, a customer who expects heavy usage would opt for a longer period combined with a higher usage threshold than for the 'lo' option.

The simulation shows significant differences in the warranty impact between the two products.

- For product A, the current time-based policy is effective. There is no gain in customer experience of warranty time coverage without an increase in warranty cost.
- For product B, however, a time- and usage-based policy increases the warranty coverage for the 'average' user, while dramatically reducing the warranty cost. For this product the current policy is sub-optimal. There is another time- and usage-based policy which achieves better customer experience with less cost.

The reason for the difference between products A and B is the usage patterns across the two products. Customers of product A use the printer with similar frequencies. Customers of product B use the printer very differently; a small percentage of users print many more pages than the 'average' user and generate more warranty events and expenses than customers who use the printer less frequently. Since all customers pay the same price for the printer, the customers who use the printer less frequently effectively 'subsidize' the warranty cost for the customers who use the printer more. Changing to a time- and usage-based policy for product B creates a more equitable warranty coverage for all customers. It allows the 'typical' user to enjoy a long warranty period and removes the 'high-volume' user from warranty coverage once they have printed an average number of pages.

Perhaps the most exciting result of our work was that the team initially chartered with this ‘investigation’ was committed long-term and management made this approach a leading effort to cut warranty costs. The project leader and sponsor reported that the ‘level of detail we developed and the systems view allows us to explore broader questions and look at warranty trade offs from a total systems perspective’. They feel the real power comes from making decisions for future products.

FUTURE PLANS

Now that the proof-of-concept stage is successfully completed, what is the next step? The focus of ongoing work is in the following areas.

1. Change the model’s structure to make it more intuitive to use and more useful for the product development teams.
2. Change the focus to rely on data generated during the product development process rather than historical data, to allow warranty planning to occur early enough in the product’s life cycle that appropriate warranty policies can be in place at the time of product introduction.
3. Roll out to other products as we demonstrate successes with new products under development.
4. Eventually, we would like to include parameters that allow for different behaviors in different markets and to model the cost of quality, rather than just modeling warranty costs.

CONCLUSION

By looking at the totality of warranty events instead of focusing solely on hardware failures, our team developed promising new ways to manage warranties and warranty costs. We benefited tremendously from the involvement of people from across different disciplines and organizations: manufacturing, marketing, support, quality, R&D and strategic planning groups. Management sponsorship from these different organizations along with a firm commitment of resources made the work possible. Data availability was a challenge for our team, as we expect it will be for most teams that take a similar approach. Data may not be available, or it may be available in disparate systems and databases, which often means significant effort is required to capture, understand and use the data for modeling.

This work was difficult, but we feel the results have been worth the effort. In many ways, we see warranty engineering at HP as similar to supply chain engineering ten years ago. There are many reliability engineers, but few warranty engineers predicting how warranty will be affected by different product designs, policies and service methods working together. It is integrated modeling like this that we find so promising and exciting at Hewlett-Packard.

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Authors' biographies

Steve Kakouros is a Process Technology Manager in Hewlett-Packard's Strategic Planning and Modeling (SPaM) team. He works with all HP businesses to improve their management and engineering processes by engaging in rigorous analysis and applying state of the art technologies. He has extensive experience in supply chain management at HP. His most recent research has focused on the areas of forecasting and planning and product warranty and reliability. His work has been published in *Operations Research/Management Science Today* and HP internal publications. He is the author of several patents in the area of supply chain modeling. He has been with SPaM since 1997. Prior to working with SPaM, he consulted with Oracle and SPOAR investments. He has an MS in Operations Research from Stanford University and a Diploma in Applied Mathematics from the Aristotle University, Thessaloniki, Greece.

Brian Cargille is the Europe, Middle East, Africa and Personal Systems Group Account Manager in Hewlett-Packard's Strategic Planning and Modeling (SPaM) team. He has worked with most of HP's product lines since joining the company 1991. During his time with SPaM he has led the design and/or redesign of numerous supply chains, business processes and products to improve operational performance and has created numerous supply chain and operations management innovations that are currently in use at HP around the world. Brian studied Economics at the University of California, Instructional Technology at Indiana University and Industrial Engineering/Engineering Management at Stanford University. His articles have appeared in a variety of journals including *Performance Improvement Quarterly*, *Operations Research/Management Science Today* and *Supply Chain Management Review*.

Marcos Esterman is a Quality and Reliability Program Manager in HP's LaserJet products group. He has focused on the development and implementation of warranty models to guide product development decisions. He has worked at HP since 1997 on various aspects of the Color LaserJet product development. His office is located in Boise, Idaho. Prior to joining HP, he worked for General Electric Medical Systems in Milwaukee, Wisconsin working on the development and manufacture of x-ray tubes. He holds a PhD in Mechanical Engineering from Stanford University and an MS and BS in Mechanical Engineering from MIT.

