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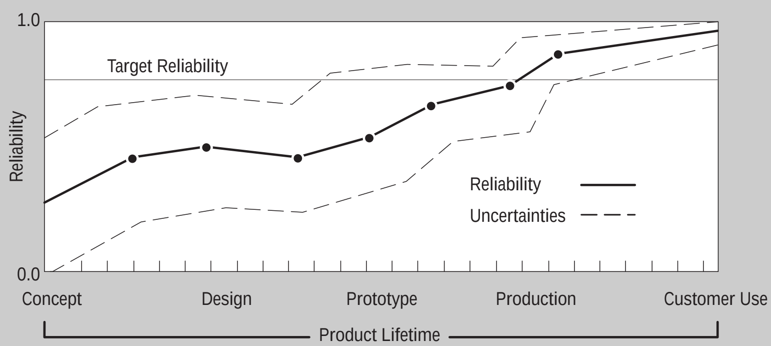
1999



PREDICT's calculations guide a product's development and eventually document its lifetime performance from original concept through customer use. PREDICT users can track the product's increasing reliability along with decreasing uncertainty about its performance. Data input is drawn from quantified expert knowledge, mathematically run design changes, prototype test results, and warranty figures.

PREDICT: A New Approach to Product Development

Los Alamos National Laboratory and Delphi Automotive Systems

Industry gauges a new product's reliability (the probability that it will function as required) by testing prototypes or large numbers of the products themselves. In short, performance is evaluated only after development is well advanced or complete. So, when problems do arise, they may require expensive manufacturing changes or even more-expensive product recalls. PREDICT minimizes or prevents such costly "surprises" by forecasting reliability, beginning with the initial concept.

PREDICT (Performance and Reliability Evaluation with Diverse Information Combination and Tracking) is a set of formal, structured techniques for eliciting, quantifying, and analyzing an often-undocumented asset: the knowledge that resides with a company's designers, engineers, and scientists. This expert knowledge—PREDICT enables its quantification for the first time—can be used to guide design changes and improve product reliability before test data are available.

The Invention—Characteristics and Advantages

PREDICT users first establish a target reliability requirement and then generate a "logic model," which is a spreadsheet, diagram, or flowchart that documents the product's parts and their logical relationships in a manner appropriate for the particular product.

Experts in all the parts of the logic model are then identified and presented with formalized questions that elicit quantitative and qualitative (descriptive) estimates of performance. Answers must reflect uncertainty—for example, the long-term durability of a new material or the effects of extreme environments may be unknown—so all answers are either *taken as* a range of values or *converted to* a range of values. Answers also cover possible causes of failure (failure modes), such as manufacturing error or component aging, which relate to a product's performance over time. This detailed questioning is key to PREDICT's versatility because users create and structure their own questions, tailoring them to the specific product and its performance metrics. In this way, PREDICT is fully customized to the product.

Next, through Monte Carlo computer simulations, the collected answers are transformed into graphs known as probability distributions for the individual parts and for the whole product. If the product's reliability falls short of the target, the individual distributions reveal what changes might be made to improve performance. Equations such as Bayes Theorem then allow users to update PREDICT's calculations by incorporating possible design changes as "what if" cases—"What if we build 40 prototypes of these components, and they all pass the stress test?" "What if we use aluminum instead of plastic?" and so forth. Each new calculation results in a new probability distribution for the part in question and, from that, a new full-product distribution. And each new full-product distribution becomes a point on an evolving reliability growth chart (see figure), which documents the product's increasing improvement.

As a result of this work, users can target the parts that should be prototyped and/or tested. Data from prototype testing and later from warranty data on the finished product also become a part of PREDICT's calculations as the product's lifetime performance is documented. With this knowledge stored in a knowledge base, engineers can track long-term performance issues back to specific decisions and components and then use that information as part of the expert knowledge that drives future product development.

PREDICT's strength lies in its permanence. Users establish a core of expertise and perpetuate PREDICT as a permanent shift in company culture. Because of that shift, PREDICT could conceivably revolutionize the way products are developed and analyzed.

Applications

Reliability of Products in Development. PREDICT places performance analysis of new products ahead of both prototyping and production. As a result, PREDICT provides long-range economic benefits. A company can save millions of dollars over time by reducing or eliminating manufacturing problems and product recalls. For example, members of the U.S. auto industry estimate that it costs $300,000 to fix a single flaw recognized during manufacture. The same flaw can cost $5 million if it results in a recall. Delphi Automotive Systems (formerly the systems/components divisions of General Motors) has used PREDICT on four automotive systems and is planning to use it for all of its future concept/development systems.

Reliability of Existing Products. PREDICT can also be used for existing, one-of-a kind products and systems that must be guaranteed reliable and for which test data are sparse or nonexistent. For example, it is an ideal match for aircraft, ships, conventional weapons, power plants, space missions, space vehicles, oil platforms, computers, telecommunication equipment, semiconductors, and robotic systems. A project of Los Alamos National Laboratory is using PREDICT to estimate the reliability of its aging nuclear weapons, which cannot be tested but whose reliability must be certified.

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RN99-230-023

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LALP-99-184 August 1999

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