START
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# Reliability Design for Affordability

***There is a better way - Find it! Thomas A. Edison***

## Introduction

A task force chartered by the Department of Defense (DoD) in 1995 has defined Affordability as "a process for program management that will lead to affordable technology rather than a program for cost reduction." This concern for the process is based on the fact that the conceptual design of a product determines most (one estimate is 85%) of its life cycle costs. Hence, cost reduction programs after design must necessarily be far less effective than a design process which is concerned with affordability. One aspect of design that has a critical impact on affordability is reliability.

DoD's interest in affordability is understandable, given the consistent pressure to reduce the military budget. Commercial industry also has a compelling incentive to design for affordability, in the need to survive in a fiercely competitive market.

## Elements of Affordability

The user of a product should be concerned with its total life cycle cost (LCC) which includes the purchase cost, the operating and maintenance costs, collateral costs, and disposal costs. Since these will affect the selection of a product, suppliers wishing to be competitive should also consider these elements in designing their products.

The purchase price will ordinarily reflect both the cost of development and the cost of production, which are, in turn, determined by the supplier's processes. Elements of production costs are fixed costs and variable costs, including both direct and overhead costs.

Fixed costs are those which must be incurred whether the number of products produced is one or thousands. An example is the cost of tooling. Variable costs include those which are dependent on the number of products made, such as the cost of raw materials. Reliability design efforts ordinarily increase these direct costs. For example, analysis to identify and preclude causes of defects adds to the fixed cost of design, and the use of redundant components increases the variable costs of production. Such efforts are therefore implemented only when the returns from the efforts (reductions in other cost elements) are attractive enough to make them good investments.

Overhead costs are those costs which do not directly contribute to production, but which cannot be avoided, such as the cost of maintaining a plant or environmental protection and cleanup costs. They also include what have been called "hidden costs" resulting from poor reliability. It has been estimated that in a typical plant, rework and scrap will account for at least 25% of production cost. This "hidden factory" results from poor design, unreliable parts, or defect-inducing manufacturing processes, the same factors which degrade reliability in use. Efforts to design and produce a reliable product can therefore have a significant beneficial effect on affordability before the product has even left the factory.

Operating and maintenance costs include the costs of using the product and of corrective and preventive maintenance. Obviously, maintenance costs are a direct function of reliability. In addition, although most products are designed for a specified life, military and commercial products alike are often required to operate far longer than their original design life. The practicality and cost-effectiveness of lifetime extension are also directly correlated to the reliability of the product.

Collateral costs are often neglected in economic analyses, but are quite relevant. These are the costs incurred in the use of a product, outside of the direct operating and maintenance costs. Some are unknowable, like the loss of customers who are dissatisfied with a product (for any reason, including unreliability). A collateral cost directly related to reliability might be the revenue loss when a system is down, such as an airliner (or taxicab) out of service for maintenance. There are unmeasurable losses, such as the cost to the nation when the rescue of the hostages in Iran was aborted by equipment failure. Unfortunately, reliability-related collateral costs can also be measured in lives lost, either directly (e.g., by the crash of a vehicle due to a failure of the vehicle) or indirectly (e.g., crash of a vehicle due to loss of an outside system such as an air traffic control radar.) Collateral costs may also include such costs as the purchase of a back-up system to protect against the failure of a primary system, when the reliability of a product is inadequate foran application.

Disposal costs are those associated with the removal of the product from use. Such costs include the proper containment and handling of any hazardous materials (chemicals, explosives, toxic materials, etc.) contained in the product. Reliability does not ordinarily affect disposal costs.

The relationship between cost elements and the typical impact of reliability efforts on cost are illustrated in Figure 1. It should be noted that there are other ways to relate cost elements, and that program circumstances can alter the usual impacts of reliability efforts. For example, reducing scrap and rework may be vital to success in producing affordable consumer electronic products, but insignificant in building a specialized space system.

## Affordability Initiatives and Reliability Design

Current concepts in product development for affordability include Integrated Product and Process Development (IPPD), re-use of software, employment of commercial-off-the-shelf (COTS) components, and NASA's "faster, better, cheaper" initiative. All of these concepts either foster product reliability or are dependent on it for success.

The goal of IPPD is simply to do it right the first time. By using a design team, all aspects of design and production are considered concurrently. Because the design team includes members skilled in reliability and maintainability, there should be no need for redesign to improve reliability or make the product more testable. Manufacturing specialists on the team will ensure that the design can be produced without difficulty, thus minimizing the potential for manufacturing-induced defects. Hence, IPPD should enhance reliability, reduce lead time, and improve affordability, simultaneously.

The re-use of software modules eliminates some of the development costs of new code, much of which is the cost of debugging. Hence, reuse of software capitalizes on reliability efforts already done in developing the code, and relies on the success of those previous reliability efforts. To be practical, re-use of software requires a structured approach to software development in which software modules are self-contained and their functions well-defined. This approach also enhances software reliability.

The use of COTS components minimizes the cost and time of development. This is a significant benefit, presuming, of course, the COTS components can do the job, including meeting reliability requirements. To ensure the success of a product containing COTS components, the use environment of the product and the reliability of the components in that environment must be understood. Understanding these factors is an essential element of a reliability program, whether COTS is used or not. The use of COTS not only precludes the need for development, but enables a selection from all available technologies. Potential advantages to reliability of COTS are that a reliability history may be available, and that any design weaknesses may have been found and corrected. A potential disadvantage of using COTS is that reliability in the use environment, especially long term durability, may not be known. For example, the purchase of a computer used in a desktop environment for application in an automobile can be risky because the automobile environment is much more severe. If this difference in operating environment is not considered, the money saved by using COTS components might be insignificant compared to the money lost as a result of fielding an unreliable product.

NASA's slogan, "faster, better, cheaper" became well known from the news coverage of the successful landing of the Pathfinder system on Mars. The innovative approaches used in Pathfinder reduced the program cost from an estimated tens of billions of dollars to an affordable hundreds of millions. One well known innovation was the hard landing in which the system was packed in air bags and allowed to bounce to a stop in lieu of the use of a complex and expensive soft landing arrangement. The innovation worked because the system was designed rugged enough to permit it. Much of the cost savings was in the simplification of the system. Simplification is also a reliability enhancing technique. Hence "faster, better, cheaper" relies on, and sometimes contributes to, design for reliability.

## Other Affordability and Reliability Relationships

Other considerations which impact affordability and either enhance or rely on reliability are development for dual-use, avoiding the "last 10% syndrome," robust design, and variation reduction.

Dual-use products are designed for more than one application. Examples are space products which can be used in more than one NASA project, and, more broadly, avionics products which can be used in both civilian and military aircraft. As in the re-use of software or the purchase of COTS, significant savings in development costs can be achieved, and lessons learned in one application can be applied to another. However, once again it is an essential assumption that the product will be acceptably reliable in all its applications. Hence, reliability design becomes an enabling consideration.

Many programs fail because of the so-called "last 10% syndrome." This is the attempt to maximize the

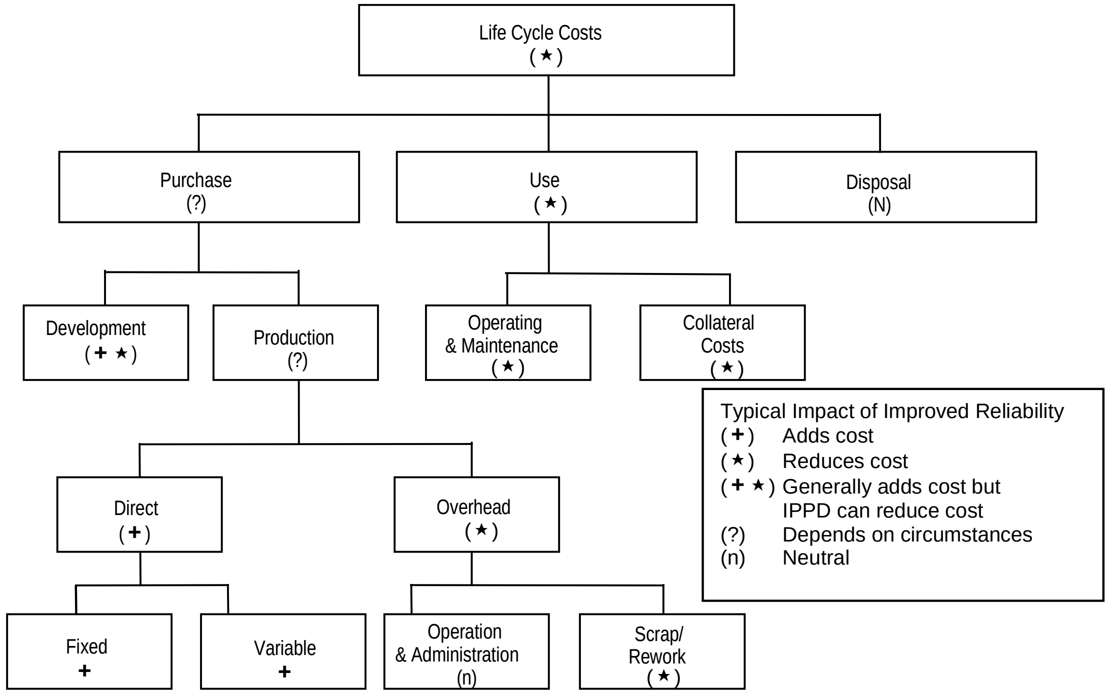


**Figure 1**

performance of a product, such as the effort to obtain the maximum possible speed of a racing car. While this may be necessary in some applications (like racing), it is an expensive approach which often creates a massive reliability problem. In most applications, achieving the last 10% of possible performance is an unnecessary goal. For example, most airliners are subsonic, even though supersonic transports are available. The advantage in speed has not been worth the extra expense for most travelers. In many products, the cost of "pushing the envelope" includes a drastically reduced reliability, caused by increased stress on the product. Both reliability and affordability benefit from a reasonable conservatism in design. (It should perhaps be noted that reliability efforts can also fall into the "last 10% syndrome." For example, there are reliability features in a manned space program, such as triple redundant components, that are not worth doing in other applications).

A robust design is one which is tolerant to variations in its use environment, such as a microcircuit that works acceptably well under the entire range of temperatures it may encounter in use. Here the impact on affordability is simply the avoidance of the cost of failure, and design for reliability through robustness is also design for affordability.

The reduction of variation in products is designed to reduce the number of items produced by a process that have some parameter outside of specified limits. A reduction in variation has an immediate beneficial impact on rework and scrap. Since variations from nominal values are a source of failures, reducing variation also enhances reliability.

## Reliability vs. Affordability?

The preceding discussions show a synergy between reliability and affordability. Yet, there have been times when program managers felt they "could not afford reliability." Comments such as these were often based on a concept of "inspecting in" reliability, in which labor-intensive inspections were used to cull out defective products, rather than the prevention of defects through control of the production process. Also, in the absence of integrated product and process development, reliability reviews were often put in series with design, resulting in a time consuming and expensive review and redesign cycle, or, often, the neglect of reliability considerations entirely. In these cases, reliability efforts could indeed oppose affordability, since their expense raises the purchase price and their inefficiency (relative to other approaches to reliability) does not permit the reduction of the "downstream" costs enough to make them attractive investments.

IPPD, and other reliability design efforts, do require an investment in design time. However, this investment can be recouped in development by the elimination of the need for redesign, be rewarded handsomely during production through the reduction of rework and scrap, and result in an impressive return on investment when life cycle costs are considered.

Done properly, design for reliability is an enabler of affordability.

## For Further Study


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