



THE ROLE OF LIFE CYCLE UNDERSTANDING IN RELIABILITY IMPROVING PROCESS OF ROBOTIC EQUIPMENT

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Abstract: Optimal benefits from use of the reliability improvement process are clearly realized when the process is applied to equipment in the concept and feasibility phase of the life cycle and then continuously applied thereafter. Benefits can also be realized when the improvement process is applied to equipment that is in some advanced phase of its life cycle. It is important to address equipment reliability throughout the life cycle. The *reliability improvement process* and the *equipment life cycle* form the basis for these guidelines and are introduced in this paper.

Key words: Key words: Life Cycle, Reliability, Roboticequipment, Design, Product development.

1. INTRODUCTION

The *reliability improvement process* and the *equipment life cycle* form the basis for these guidelines and are introduced in this paper.

The reliability improvement process is an iterative process that provides:

- An effective and systematic way to include reliability in equipment design
- A structure for making reliability improvements throughout the equipment life cycle.

Life cycle costs provide a perspective on the impact of initiating the reliability improvement process early in the equipment life cycle. A thorough knowledge of life cycle costs and life cycle phase relationships helps to achieve better equipment at lower total costs.

2. CONTENT

2.1. The Equipment Life Cycle

The equipment *life cycle* begins when the idea for the equipment is conceived and ends when the equipment is no longer useful. The life cycle consists of *phases* that describe the state of design, process of development, and production of the equipment. A working knowledge of these phases enables proper planning and execution of the activities and functions necessary for designing,

manufacturing, and operating reliable equipment in a cost effective manner.

2.2. Life Cycle Phases

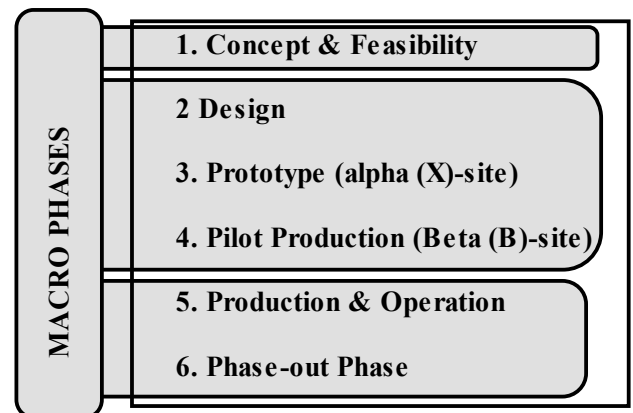


Fig. 1. The six Life Cycle phases and three macro-phases

The life cycle has been divided into the six phases listed in figure 1. As indicated, these six phases can be grouped under three macro phases.

The three macro phases are sometimes used in place of the six phases for illustrative purposes; this in no way impacts the concepts and methodology presented.

2.2.1. Concept and Feasibility

The life cycle begins with this phase; the need for new equipment is identified and alternative approaches to fulfilling that need are

explored. The need for new equipment may be based on existing equipment that can no longer perform its intended function or on customer requirements for which the necessary equipment does not exist.

During this phase, marketing and sales personnel, customer service representatives, design and reliability engineers, and manufacturing engineers work together with the customer to achieve actions shown in figure 2.

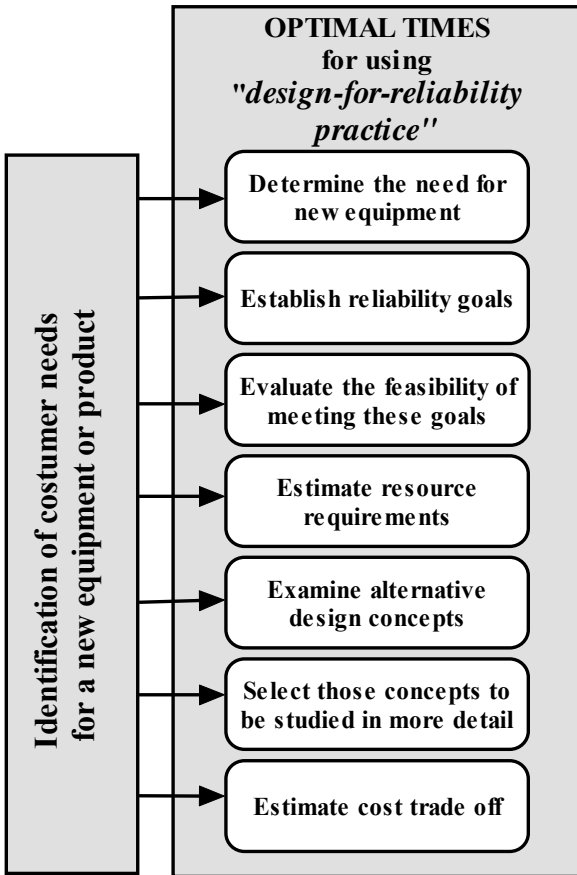


Fig. 2. The necessary activities to be accomplished to meet customer requirements

2.2.2. Design

The alternative design concepts selected during the concept and feasibility phase are explored in more detail by the design engineers during this phase of the life cycle. A design disclosure package is prepared and evaluated by all concerned parties.

Also, reliability goals set for the equipment during the concept and feasibility phase are translated into requirements very early in the design phase. Requirements are useful in making preliminary reliability allocations to subsystems and components to understand cost

impacts. This phase of the life cycle can be separated into two parts: *preliminary design* and *final design* (see figures 3 and 4).

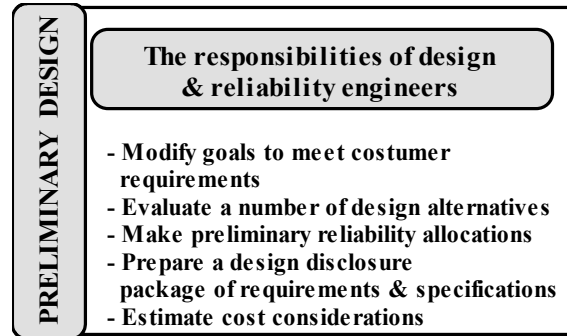


Fig. 3. The necessary actions in the preliminary design phase

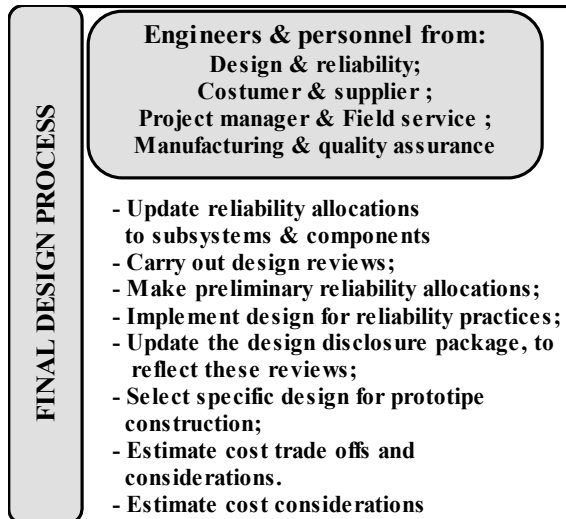


Fig. 4. The necessary actions in the final design process

Several iterations of design review and redesign are usually required before a design is ready for prototype construction.

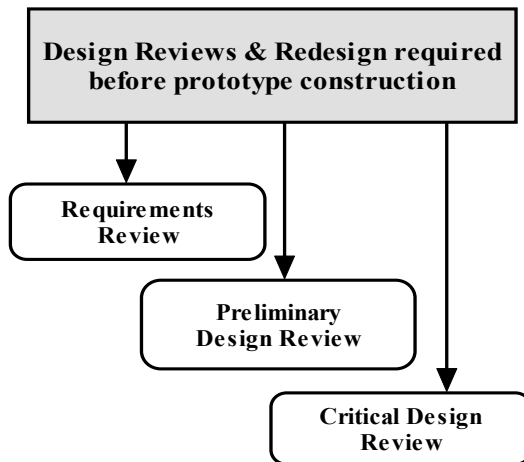


Fig. 5. The reviews which have to comply in parallel with design process

Design reviews are important in measuring the progress against design requirements and gaining management approval to proceed with the prototype phase of the life cycle. These reviews are carried out in parallel with the design process and are often categorized as shown in figure 5:

2.2.3. Prototype

Specific designs selected during the design phase are built and tested during this phase to determine if all design requirements will be met. The prototype phase provides the first opportunity to validate the entire design, and is therefore commonly called *alpha-site evaluation*. Selected customers are included in alpha-site evaluations and are asked to provide feedback on all aspects of the equipment.

Multiple design alternatives may require prototyping and testing if serious questions exist about the best overall choice. During the prototype phase, design, reliability, test, and manufacturing engineers, as well as quality assurance personnel:

- Build and test one or more prototypes of a design;
- Present the test results for a pilot production design review;
- Redesign as needed to fix weaknesses or make other desirable changes;
- Conduct additional design reviews as appropriate.

The design reviews should include another *critical design review* to give the customer an opportunity to review the latest design being considered.

2.2.4. Pilot Production

This phase of the life cycle serves as a bridge between the prototype phase and the production and operation phase. This is the first opportunity for the equipment to be evaluated in an extended customer environment, and is therefore commonly called *beta-site evaluation*. In fact, it may be the first time that the equipment is exposed to a customer's processes.

The purpose of the pilot production phase is to help identify and correct problems with the equipment before full-scale production begins.

Design and reliability engineers should evaluate the actual level of equipment reliability and determine what needs to be accomplished to meet requirements in a cost effective manner.

During the pilot production phase, project management, reliability engineers, manufacturing and test personnel, have to solve the problems shown in figure 6.

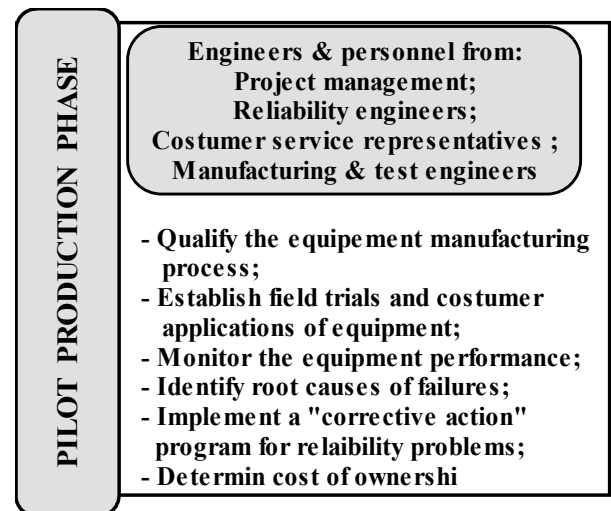


Fig. 6. The necessary actions in the pilot production phase

Prior to the production and operation phase of the life cycle, reliability and design engineers should evaluate equipment reliability and make the appropriate recommendations. This is the last opportunity to make design changes and other improvements before full-scale production.

Design reviews conducted at this point are often broken down into:

- *Qualification Review* - verify that the final design meets requirements
- *Production Readiness Review* - to determine the readiness of full production
- *Reliability Budget Review* - verify the reliability goal allocations.

If any design changes were made at this point, another *critical design review* may be appropriate.

2.2.5. Production and Operation

This phase of the life cycle represents the time when units are produced and sold. All major reliability problems should have been identified and corrected prior to the production and operation phase. A formal program must be

in place for collecting and analyzing field service data and performance data for the customer's unit as well as for the cost impact.



Fig. 7. The necessary actions in the final design process

During the production and operation phase, field service personnel, management, quality assurance personnel, and reliability engineers have to solve the problems shown in figure 7.

Recorded failure data should account for uncertainty due to variations in site, product vintage, and customer procedures. After proper review, decisions are made for resource allocation for continuous improvement in the reliability process. Once equipment is in the field, it is important to continually monitor reliability, analyze failures and identify root causes, implement corrective actions, and improve known causes of failures both for the current and the next generation of equipment.

2.2.6. Phase Out

The equipment product line is approaching the end of its useful life during this final phase of the life cycle. The end of useful life naturally occurs earlier for the supplier than it does for the customer. The end of useful equipment life for the customer can occur due to obsolescence, wear, or a change in business plans. To remain competitive, the supplier must make plans for the next generation of equipment before phasing out current generation production.

The information gained during the six phases of the life cycle should be retained so that it can be used to improve future

generations of similar or new equipment. This completes the life cycle for the current generation of equipment. Each new generation of equipment would experience basically the same life cycle.

2.3. Supplier Cost Implications

The early life cycle phases typically represent the smallest portion of those total life cycle costs borne by the supplier, yet generally represent the region where the greatest impact on equipment reliability can be made. As a design moves toward completion, design details become increasingly fixed. Thus, the cost in time and money to correct reliability problems increases. Figure 8 shows that typically, toward the end of the design/development macro phase of the life cycle, only 15% of the life cycle costs are consumed, but approximately 95% of the total life cycle costs have been determined (i.e., locked in).[2] This is not meant to imply that equipment already in the production/operation macro phase should be ignored in terms of improving reliability. Reliability improvement activities should continue throughout the life cycle.

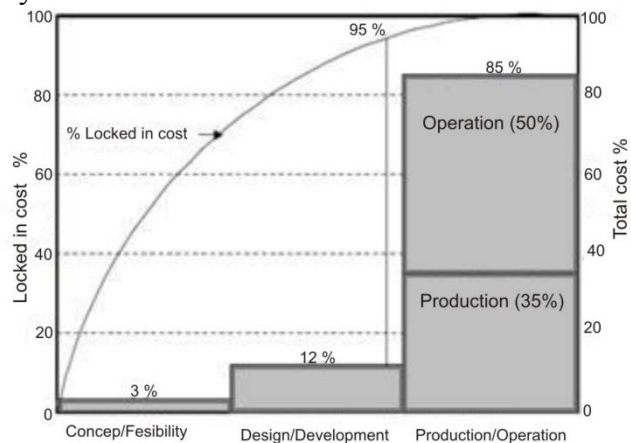


Fig.8. Percent of Total Life Cycle Costs vs. Locked-in Costs

2.4. Life Cycle Cost

Two criteria used by electronic equipment manufacturers to select equipment for a manufacturing step or processes are:

1. Technical
2. Economical[1]

The question asked for the economical criterion is, "Does the result of the

manufacturing process justify or support the cost and on-going expense of a particular piece of equipment or equipment line?"

Customers consider not only the initial purchase price, but the costs associated with equipment operations over its entire life (i.e., *lifecycle costs*).

Life cycle costs include both equipment supplier costs, which are passed on to the customer in the purchase price of the equipment, and all costs incurred by the customer over the equipment life. Supplier costs plus the supplier's gross profit margin are referred to as *acquisition costs*, are shown in figure 9.

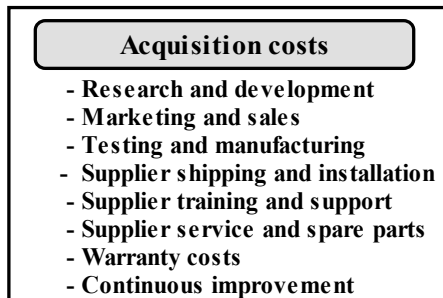


Fig. 9. All the acquisition costs

Costs incurred by the customer are referred to as *operational costs*, are shown in figure 10.

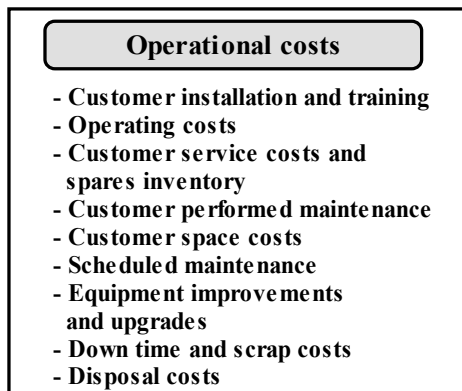


Fig. 10. All the operational costs

Life cycle costs implications to both the supplier and the customer are discussed in the following.

2.5. Customer Cost Implications

Improvements in reliability made by the supplier early in the equipment life cycle may result in higher development costs being passed on to the customer in the equipment acquisition costs. However, this can be more than offset as the customer benefits by having lower

operational costs with increased reliability and up time that results in greater productivity.

Figure 11 illustrates how a reliability program impacts acquisition and operational costs.

As this figure indicates, acquisition costs may increase due to efforts to improve reliability.

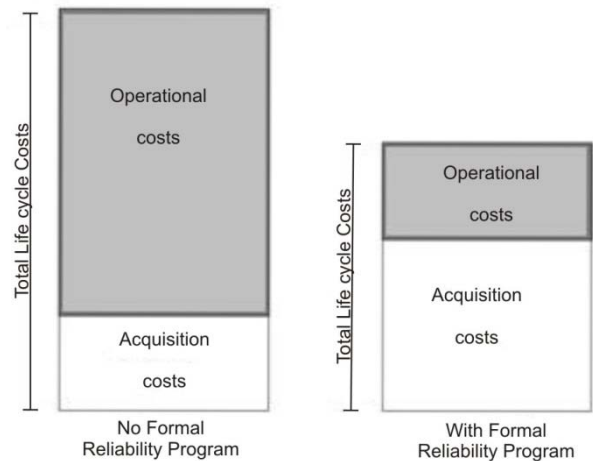


Fig.11. Impact of a reliability program on life cycle cost

However, operational costs, and even more important, total life cycle costs decrease. It is important for the customer to make equipment purchase decisions based on total life cycle costs and not just on initial purchase price.

2.6. Optimizing Life Cycle Costs

Increasing acquisition costs to improve equipment reliability and lower operational and total life cycle costs are clearly a recommended practice (see figure 12 and 13). However, there is a point at which increasing acquisition costs to obtain higher levels of reliability is no longer beneficial.

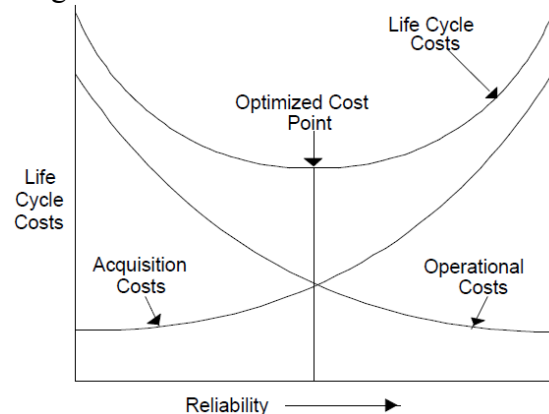


Fig.12. Optimizing Life Cycle Costs

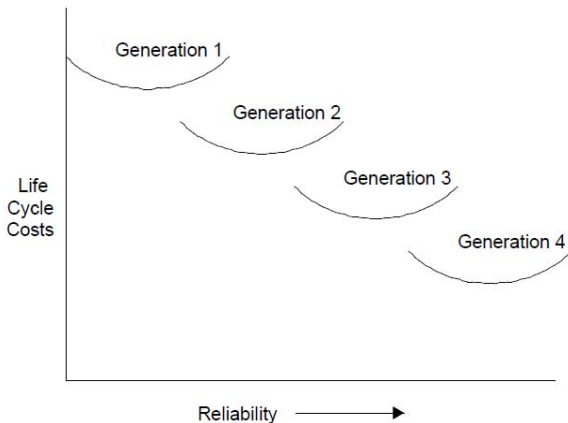


Fig. 13. Decrease in Life Cycle Costs in New Generations of Equipment

3. CONCLUSION

The reliability improvement process provides a means for making revolutionary advancements when it is applied to equipment early in the design stage, or during major design upgrades, or for making evolutionary improvements to existing equipment. Knowledge of the equipment life cycle is important because it provides:

- The framework for applying the reliability improvement process.
- A basis for understanding the best practice for improving equipment reliability and the cost of the improvement.

4. REFERENCES

1. SI Staff, "Selecting a Product: The Task at Hand," *Semiconductor International*, March 1991, pages 7-8.
2. J. E. Arsenault and J. A. Roberts, *Reliability and Maintainability of Electronic Systems*, Potomac, MD:Computer Science Press, 1980.
3. W. Grant Ireson and Clyde F. Coombs, Jr., *Handbook of Reliability Engineering and Management*, Editors in Chief, McGraw-Hill, 1988.
4. P.D.T. O'Connor. *Practical Reliability Engineering*. John Wiley & Sons, Ltd. 2002.
5. H. Pham. *Reliability Engineering*. Springer . 2003

Rolul cunoașterii ciclului de viață în procesul de îmbunătățire a fiabilității echipamentelor robotice

Cele mai semnificative beneficii ale procesului de îmbunătățire a fiabilității echipamentelor de automatizare sunt obținute în mod cert când procesul este inițiat încă de la faza de concept și fezabilitate a ciclului de viață și aplicat în mod continuu pe toată durata de viață a produsului. Dar îmbunătățirile fiabilității sunt mai sigure atunci când procesul este aplicat cu preponderență în fazele primare ale ciclului de viață. În baza acestor idei, lucrarea prezintă liniile directoare ale procesului de îmbunătățire a fiabilității, prin acțiuni concrete ce trebuie corelate cu fazele ciclului de viață în care se afla echipamentul, la orice moment.

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