Abstract

The life cycle cost (LCC) refers to all the costs that will be incurred over the whole life cycle of a single product. The components of a life cycle cost analysis typically include initial costs, installation and commissioning costs, energy costs, operation costs, maintenance and repair costs, down time costs, environmental costs, and disposal costs. Studies have proven that a significant portion of a product life cycle cost is affected by decisions made at the early design stage. Most researchers agree that decisions made during the early stages of design determine more than 80 percent of the life cycle cost. Product designers are therefore in a position to substantially reduce the life cycle cost of the product they design by giving due consideration to the life cycle cost implications of the design decisions they make. Thus, a proper product cost estimate during the product design stage will help to reveal the relationship between costs and design parameters so that high cost contributors can be easily identified. This thesis provides an integrative approach so that product life cycle costs can be considerably reduced by assessing the impact of product life cycle costs during product design stage itself.

In general, the life cycle cost of products is estimated using life cycle cost models. There are different approaches to developing cost models for LCC analysis. Most LCC models are structured along three general lines such as conceptual, analytical and heuristic. Conceptual models consist of a set of hypothesized relationships expressed in a qualitative framework. They are generally very flexible and can accommodate a wide range of systems. These models are generally constructed at macro level. They allow a minimum of details and little ability to quantify cost characteristics of a system. Analytical models are usually based on mathematical relationships which are designed to describe a certain aspect of a system/product under certain conditions/assumptions. Heuristic models are not as general as analytical models and can normally only be used for the specific situation for which they are intended. Thus, the LCC modeling approaches can be classified into specific life cycle cost models and non-specific life cycle cost models. The specific LCC models are developed for a particular product or system. The non-specific models are not tied to any specific product or system.

A close study of such models with regard to the life cycle phases and the life cycle cost components identified by these models reveals that the LCC modeling practices have certain limitations. Most of the models are product specific, consider only major cost elements and are based on certain assumptions such as there is no preventive
maintenance, no failures occur in standby, perfect switching occurs with negligible down-time, the annual operating requirements are constant and all the units are identical and acquired at the same time. Most of the costing models only focus on estimating product costs for a particular stage of a product life cycle, e.g., manufacturing cost. They cannot be applied to other stages of product life cycle to calculate the entire life cycle cost.

As the literature reveals and as stated above, it has been recognized that the design process needs cost models that take into account the complete life cycle of products and can be used at very early stages of design. Some efforts have been made towards providing the designer with cost information during the design process. While most of these authors recognize the need for a LCC model, however the models developed are restricted to specific processes, simple operations or one phase of the life cycle. A large number of these efforts have been for the production and construction phase of the product life cycle. On the other hand, the models that treat the product at the system level seldom treat the end-of-life of the product. To overcome some of these limitations, a more generalized comprehensive life cycle cost model for repairable and non-repairable products based on reliability and maintainability aspects is attempted in this work. The model is comprehensive in that it considers several aspects of product’s life cycle. However, the main focus is on modeling the post-manufacturing activities in the life cycle of a product including end-of-life of the product.

The mathematical equations to estimate individual cost components of the proposed model have been formulated for the acquisition, installation and commissioning, operation, maintenance and repair and disposal phases in the life cycle of a repairable system. To model maintenance and repair costs, the stochastic point process approach is employed. The renewal process (as-good-as-new after repair state) and minimal repair process (as-bad-as-old after repair state) have been evaluated from LCC perspective. The maintenance and repair cost is modeled using the expected number of failures estimated for the renewal and minimal repair process. A methodology to decide whether a renewal approach or minimal repair approach should be planned for a particular component/product is also presented. This model can be applied at the product design stage to estimate and compare the life cycle cost of different design alternatives. The model is validated using the data for two different repairable systems namely an industrial pump and BOXN wagons used by Indian railways. Some useful insights are also provided on how cost driving events are related to the characteristics of failure distributions and the product lifetime (design life) in case of repairable systems.
When dealing with reliability field data, proper selection of models for time-to-failure data is quite essential as it affects the expected number of failures. Hence time-to-failure models form critical constituents of any reliability analysis. Many times conventional time-to-failure analysis techniques are adopted and the analyses rely on false premises such as independent and identically distributed (iid) time between failures assumption which is, in fact, not appropriate for all systems. For many systems, there may be presence of system ageing or reliability growth with time (the practical situation). Under such circumstances, the successive failure times may neither be independent nor identically distributed and the above assumption may not hold good. This can lead to erroneous model selection for time-to-failure of a particular component or system leading to erroneous estimates of life cycle costs and in turn wrong conclusions and decisions. To overcome this, in this thesis, a LCC model framework directed towards proper selection of time-to-failure model and a methodology for LCC analysis at product design stage is presented. The model discriminates between the renewal process approach (iid assumption) and minimal repair process approach (presence of system ageing and reliability growth) based on assessment of existence of trend or time dependency in failure data.

This thesis also presents a LCC modeling approach for estimating life cycle cost of pumps using activity based costing (ABC) methodology. Activity based costing methodology has emerged as one of the several innovative and more accurate costing methods in recent years. It is based on the principle that products or services necessitate activities and activities consume resources that generate costs. Thus, the ABC system focuses on calculating the costs incurred on performing the activities to manufacture a product. The study was conducted in a large pump manufacturing company from India that has significant global standing within its industry. Firstly, all the activities and cost drivers associated with the life cycle of a pump have been identified. A methodology for LCC analysis using ABC is then developed and it is applied to two different pumps manufactured by the same industry and the results obtained are presented. The model is developed using activity based costing method and is based on the wider life cycle perspective. The maintenance and repair cost is one of the significant components of product LCC. In view of this, three different maintenance and repair strategies/policies have been analyzed from LCC perspective; the renewal/replacement upon failure strategy, minimal repair upon failure strategy and combination strategy. The developed methodology is found useful and applicable for all types of pumps produced by the concerned pump manufacturer.