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An Overview on Cost Estimation of Product Life Cycle

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***Abstract*: Several studies indicated that 70-80% of product cost committed during design and development stage. In this paper, the ever- increasing importance of methods and approaches to forecast the life cycle cost for a new product in the early design stage with accuracy are reviewed. Also, this paper provides a review of hybrid approaches developed in recent years. The review paper presents application areas of techniques along with advantages and limitations.**

***Keywords*: Product life cycle, cost estimation technique, product development, early design**

1. Introduction

In today's global competitive business environment, the manufacturing companies are facing new challenges apart from present goals of high quality, low cost and time to market of products. They are required to produce a variety of products to satisfy individual customer needs and also required to provide after-sale service and maintenance support to the customer expectation level. The effects of short life cycle in the design and development process of a product are alarming. Environmental regulations and laws are forcing them to consider environmental impacts of their manufacturing and production processes and products. Recycling and disposal after use are gradually becoming an additional responsibility of manufacturers [1]. New concepts and approaches such as concurrent engineering, design for manufacturability and assemble, and sustainability, etc. are forcing the companies to extend their operations beyond traditional manufacturing practice. In response to these new challenges, manufacturing companies have to adopt a broader life cycle perspective in product development. This emerging paradigm is imposing a profound change in the way the design processes are approached [2]. Within this context, the life cycle cost approach is applied at the design stage of a product life cycle to drive the costs over the whole life cycle of the product, not only focusing on the production costs. The product's design should insure the highest degree possible of quality and reliability at lowest possible total cost. The total cost of a product includes all of the costs occurring in designing, manufacturing, operating and maintaining, recycling and disposal after its use in the whole life of the product. The life cycle cost is a cost analysis approach that provides cost information to assist the designers or decision makers in performing design trade-off analysis. It develops a system or model of the total cost of a product over its whole life to be used in design decision processes. The system or model is used for estimating the costs involved in the whole life cycle of a product and used in design trade-off studies. Many design decisions are made early stages of the development of a product which have a great impact on the product's whole life cycle cost. It has been shown that 70-80% of the product total costs are committed during the design stage, although only ten to fifteen percent of the costs has been actually incurred in the design stage [3, 4]. The cost estimation system or model is very important and the most difficult to develop in the design stage of a product where partial information of the product is available. The cost estimation of new products affects the performance and effectiveness of manufacturing companies because overestimation can result in a loss of competitiveness and goodwill in the market and underestimation may lead to financial losses in the company. The cost estimate with accuracy is important for designers and decision makers to conduct cost trade-off analysis. Thus, the ever- increasing important of appropriate methods and approaches to forecast the costs of a new product in the early design stage with accuracy. The several researchers have attempted to estimate the cost of products at early design stage using different approaches and methodologies that covers intuitive techniques, analogical techniques, parametric techniques and analytical techniques [5] and a combination of these techniques as hybrid approach. In this paper, the various techniques including combination of techniques as hybrid approach are discussed and reviewed in section 2 with reference to published research work. In section 3, the applications of these techniques and their advantages and limitations are presented. Finally, section 4 provides conclusions of the study.

2. Cost estimation techniques at early design

The cost estimation has been a focal point for design and operational strategies in an organization due to the effect of overestimation and underestimation. Accurate and consistent cost estimates are very important to assess the life cycle cost of a product in the early stages of design where 70-80% of the total cost of the product is committed. The task of accurate cost estimate is difficult during early stages of design where

available knowledge is scare and the level of uncertainty is high. During the last decades, many approaches and methods are used to estimate cost of a product for this analysis. In this section, the various techniques and approaches used in cost estimation model or system for early cost estimation of product are discussed.

A. *Expert judgement/opinion*

Although designers feel more comfortable with the use of methods and approaches, expert opinion for cost estimate is one of the most widely used approaches in the life cycle of a product. The cost is calculated intuitively based on personal domain knowledge and experience. At the early design stage, the product information is limited, expert opinion can be considered for cost estimation. Experts achieve a cost estimate of new product at early design stage based on their knowledge and experience and understanding of the product. It indicated that over half of the production estimates are based on intuitive while approximate 16% of the estimates employ a formalized estimation methodology [6]. The knowledge of experts in the field may be stored in a database to help the designers in the decision-making process and prepare cost estimates for new products based on certain input information. Based on their experience and understanding of the product, experts achieve a cost estimate of the product under design [6]. Delphi technique [7] has been used as an effective way of achieving consensus for expert opinion not only to improve the estimate, but also lower expert biases.

B. *Case-based reasoning*

In this methodology, the basic concept is looking for a similar problem in the case library using inexact matching, takes the solution from the past in order to find the solution to an actual problem. This method attempts to make use of the information contained in previous design cases by adapting a past design from a database that closely matches the attributes of design of new product. The cost estimate of a new product is obtained by combining the historical results with those of the newly designed components and assemblies. The approach is helpful in making good estimates at the early design stage, since the use of the past cost data to generate new estimates greatly minimizes the effort. The approach is applicable only when similar past designs are available and matching with new product designs to incorporate the relevant cost data during the cost estimation for new products. The functions of case-based reasoning such as indexing case, searching case and adapting case are implemented to evaluate the cost of new products [8]. A model of intelligent systems for predicting the manufacturing cost of stamping tool based on the concept of case-based reasoning is presented in [9]. In this system, it prepares the prediction of the cost of new tools on the basis of target and source cases in the form of the CAD model of sheet metal products.

C. *Rule based approach*

The basic idea of this approach is to establish a set of design and/or manufacturing constraints to help manufacturers to select more appropriated manufacturing processes and assemble processes based on product under design in order to calculate the product cost. A rule in the form ‘If premises Then conclusion’ to help select a certain type of production processes to estimate process time and cost based on parts features developed [10]. This means that a product can be separated into different components and features, with each being through a similar process to calculate the cost. Then the total cost of a product can be generated as a sum of the costs of different parts.

D. *Knowledge based approach*

The knowledge-based support systems are helpful in evaluating design alternatives. A generic knowledge-based system is developed and implemented for process planning and cost estimation for hole making processes [11]. The developed knowledge-based cost models for the product cost estimation during early design stages are presented.

E. *Fuzzy-logic approach*

Fuzzy rules are applied to the design and production problem to get more reliable cost estimates. This approach to cost estimation is particularly helpful in handling uncertainty. A decision table provides the set of rules and the relationships between the input and output variables of the system. The fuzzy sets are applied to generate the reliable estimation of cost of component in the flat plate processing industry [12].

F. *Regression analysis models*

In these models, a linear relationship between the product costs for the past design cases and the values of certain selected variables is established. This relationship can be used to forecast the cost of a new product. The effects of variable cost parameters by assuming linear relationships between the final product cost and the cost factors are studied in [13].

G. *Artificial neural network models*

Analogical concept has been adapted for use in cost estimation through the application of neural networks (NNs). One of the most common types of neural networks is the back-propagation neural-network in the product cost estimation process. A back-propagation neural network is composed of an input layer, an output layer, and some hidden layers between the input and output layers. Each layer has a number of processing unit (neuron). A neuron simply computes the sum of their weighted inputs, subtracts its threshold from the sum, and passes the results through its transfer function. The detailed discussion on the application of artificial neural network in cost engineering found in [14]. The back propagation neural network is applied to estimate the cost of assembly systems at the early stage of development [15]. Supervised learning based on historical cost data is used to obtain the relationship between the costs of products and its cost related features. A feature-

Table 1
Advantages and limitations of the techniques

S. No.	Cost Estimation Technique	Application	Advantages	Limitations
1	Expert Judgement/Opinion	High uncertainty information	Easy Innovative	Biased Depends on expert
2	Case-based reasoning	CAD system	The design approach tends to be creative	Rely on past data and previous experience Similarity measure
3	Rule based approach	Rule system	Optimized results	Time consuming
4	Fuzzy logic approach	High decision rules	Uncertainty to produce reliable estimates	Complex feature is often time consuming
5	Regression analysis	New decision makers	Simple	Limited to linearity
6	Back propagation neural network	New decision makers	Uncertainty and non-linearity	Data dependent
7	Hybrid approach	Fast estimation	Accurate results	High integration and approximate

based cost estimation using a back propagation neural network is developed and a prototype system is proposed for estimating the costs of packaging products based on design information only [11]. They established correlation between costs related features and the final cost of the product.

The artificial neural network is applied to estimate the life cycle cost of a product approximately at early design stage of the product [11]. A novel cost modeling technology using artificial neural network is developed to determine the effects of individual network structure elements on the effectiveness of the overall cost modeling within a collaborative manufacturing environment[14].The back propagation neural network based on cost related features is proposed for early cost estimation of strip-steel coiler[12].Studies revealed that the neural network seems better performance in different field and most appropriate for cost estimation of new products at the conceptual design stage, in general context – performance and ease of modelling [12], most appropriate at early design [11], assembly industry [15], automotive industry and engineer-to-order manufacturing system.

H. Hybrid approach

In general, product cost is estimated at early design and development stage of the product by using the above technique or methods. In recent periods, some researchers have been attempted to estimate the product cost by combining the above technique with quantitative techniques [5] used at detailed design stage of product [15] or with other evolutionary methods such as genetic algorithm like hybrid genetic algorithm and artificial neural network, the combination of genetic algorithm and artificial neural network, particle swarm optimization like PSO-based back propagation artificial neural network. A hybrid genetic algorithm and artificial neural network model is proposed to estimate the product life cycle cost at early design stage. This allows the designer or decision maker to make comparative life cycle cost estimation between the different product concepts. Genetic algorithm is employed to select feature sets eliminated irrelevant factors and also to determine the number of hidden neurons in the established neural network model. A genetic algorithm is combined with back propagation neural network to improve the neural network efficiency for cost estimation of product at early design stage. The proposed particle swarm optimization based back propagation neural network is emphasized for the cost estimation of plastic injection products and molds. This proposed hybrid cost estimation approach combines factor analysis, particle swarm optimization and artificial neural network. The results showed the proposed approach is very competitive for the product and mold cost estimation problems of plastic injection molding. Later, the cost estimation system based on proposed integrated particle swarm optimization and back propagation neural network is developed. The optimum parameters of the neural network are obtained by particle swarm optimization and used in neural network model to price quotation estimating for plastic injection molding parts. The intelligent life cycle cost estimation system is proposed for allowing designers or decision makers to alternatively apply activity-based costing technique and machine learning techniques (artificial neural network, support vector machine) to define and estimate life cycle cost elements depending on the information available in a product life cycle database. A framework is developed for cost estimation of feature-based parts using the proposed method of combination of linear regression and data-mining algorithm.

3. Applications of product cost estimation technique

A number of cost estimation techniques and approaches for product life cycle cost at early design stage were developed with reference to particular applications. The application areas of the various techniques which were discussed and reviewed in the previous section is summarized in Table 1. The main advantages and limitations of the techniques also presented in the Table 1.

4. Conclusion

The importance of methods or approaches to estimate the cost for a new product in the conceptual design stage with accuracy is increasing. In this paper, the various techniques and methods including hybrid approaches to be used for cost estimation of product at early design stage are reviewed. The summary of applications of product cost estimation at early design stage presented along with advantages and limitations

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