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A new process-based cost estimation and pricing model considering the influences of indirect consumption relationships and quality factors

Suzhou Tang *, Delun Wang, Fong-Yuen Ding

School of Mechanical Engineering, Dalian University of Technology, Dalian 116024, China

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ABSTRACT

In a manufacturing environment containing complex consumption relationships and quality influences, the application of traditional activity-based costing (ABC) method is limited. In this paper, a new improved process-based model for cost estimation and pricing is presented. Through utilizing the input–output analysis method, the complex indirect consumption relationships (such as reciprocal relationships) of a manufacturing system are expressed. By solving these relationships, the consumption characteristics of all production activities (mainly presented by the activity rates) are extracted. Then with the consumption characteristics, the quality characteristics and usage amounts of these activities, the cost prices of products are estimated for their pricing. A case study is given based on the compressor products of a manufacturing company, and its effectiveness is shown. As the cost influences of complex consumption relationships and quality factors are fully considered, the proposed approach has a higher estimation accuracy than the traditional ABC method.

1. Introduction

Cost estimation and pricing is a crucial task in a mechanical manufacturing company. When the costs are overestimated and the products are priced too high, it can result in loss of business and goodwill in the market; however, when the costs are underestimated and the products are priced too low, it may lead to financial losses in a company (Niazi, Dai, Balabani, & Seneviratne, 2006). In recent years, the need for accurate cost estimation and reasonable pricing has increased in order to achieve better customer satisfaction and improve the competitiveness of a company.

Product cost estimation methods can be classified as: parametric, analogical, and analytical methods. In a parametric model, the cost is expressed as a function of some critical parameters of products (such as volume and weight) by applying the statistical methodologies such as regression analysis (Boothroyd & Reynolds, 1989; Cavalieri, Maccarrone, & Pinto, 2004). Thus, the cost of a product can be estimated from these parameters. It is mainly used for fast estimation, but its prediction accuracy is usually not high. The analogical method estimates the cost of products using similarity to other products with known cost (Brinke, Lutters, Streppel, & Kals, 2000; Duverlie & Castelain, 1999). However, the methodology is applicable only when enough similar cases are available.

The analytical approach has been recognized as a more accurate method for cost estimation. In this kind of model, a product is decomposed into elementary units (such as product features and related operations) linked to certain resource consumption, and the cost is expressed as a summation of all these components.

Featured-based approach and activity-based costing (ABC) approach are two important analytical methods. In the featured-based approach, different product features are identified and a relationship from product features to cost consumption is attempted to be established for product cost estimation. Feng, Kusiak, and Huang (1996) presented a featured-based cost evaluation model, in which the relationships among form features and the easy/hard level for manufacturing them were examined for evaluating the cost of features more reasonably. Jung (2002) classified the manufacturing features of machined parts into four categories as rotational, prismatic, slab, and revolving types, and the machining time of each feature category was analyzed for cost estimation. Ou-Yang and Lin (1997) proposed a feature-based analysis model in which the machining time and cost of a product were estimated based on its feature types and parameters.

For estimating the cost more accurately, the analytical model should be process-based and the detailed cost consumption of products in their manufacturing process should be analyzed. A typical process-based estimation method is the ABC approach, which was first discussed by Cooper and Kaplan (1988). The basic notion of ABC is that activities consume resources and products consume activities. It attempts to predict the cost consumption according to its causal consumption relationship, whereby the cost relevance and accuracy of estimation can be significantly strengthened.

* Corresponding author. Tel.: +86 411 84708081; fax: +86 411 84708812.
E-mail addresses: tsz79@163.com (S. Tang), dlunwang@dlut.edu.cn (D. Wang), fongyuending@gmail.com (F.-Y. Ding).

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In the ABC method, the costs of products are estimated based on its activity identification and activity analysis. Aderoba (1997) generally classified the activities of a manufacturing system into machine-based production, labor-intensive production, technical services and administrative services. The costs of new products are then estimated from the resource consumption of these activities. In the analysis process, some information technologies such as IDEF0 methodology (Ang & Gay, 1996; Ben-Arieh & Qian, 2003) and resource-event-agent (REA) method (Grabski & Marsh, 1994) have been used to support the modeling of production activities.

For evaluating the resource consumption of design features properly and estimating the product costs from the design features conveniently, some researchers have attempted to integrate the feature-based costing methodology with the ABC approach. Tseng and Jiang (2000) presented an integrated model to combine these two approaches together, in which the ABC method was used to evaluate multiple different feature-based machining methods to find a better way to produce the parts. H'mida et al. (2006) introduced a new concept of Cost Entity as a cost aggregation associated with resources consumed by an activity, and then established a tight link between the manufacturing features and Cost Entities. Thus, the costs required for manufacturing a product can be directly estimated from these features.

In a process-based analytical model, one important task is to determine the consumption characteristics or cost rates of production activities. The activity cost rates are then used with the activity amount required in the manufacturing process to estimate the cost of new products. However, current studies only considered the condition that there is a direct consumption relationship between production activities and production resources (or there is a direct support relationship from the production resources to production activities) in a manufacturing environment, thus their adaptability in application is limited.

In the industry of mechanical manufacturing, the actual manufacturing environment usually has a high complexity. There are often some production resources that are required to be produced inhouse within a manufacturing system. A production activity might undertake not only the manufacturing of products, but also that of some internal production resources. Thus, inside a manufacturing system, it may contain not only direct consumption relationships but also indirect relationships such as reciprocal relationships, and the total cost consumption relationships can be very complex. In such a complex manufacturing environment, the precise cost consumption characteristics of production activities cannot be accurately obtained, thus to achieve accurate product cost estimation becomes very difficult.

Moreover, when the current process-based analytical method such as the traditional ABC method was used in product cost estimation and pricing, it usually only considers the consumption of products in their regular manufacturing process, but the factors of activity quality and their cost influences have not been given enough attention. Colbert and Spicer (1998) discussed the product pricing based on the ABC method, however, the impact of activity quality factors on the cost prices of products was not taken into account. Kingsman and de Souza (1997) developed a prototype knowledge-based decision support system for cost estimation and pricing decisions. Haji and Assadi (2009) designed a fuzzy expert system for new product pricing. Their efforts mainly focused on the collection and expression of pricing rules; with the estimated cost and market competition, the product prices are then determined based on these rules. In their pricing process, the quality factors were also not considered. As the quality characteristics of the activities and the cost consumed in irregular manufacturing (for example, rework operation cost and loss due to defective products) were not fully considered, the acquired cost information has certain deviation from the actual cost.

In this paper, a new cost estimation and pricing model is established to give an improvement to the traditional ABC method. The complexity of consumption relationships in a manufacturing environment is first discussed. Subsequently, the modeling and solution of these consumption relationships for obtaining the activity consumption characteristics are presented. Then, with the activity consumption characteristics and activity quality characteristics, the cost consumption of products in their whole manufacturing process (including each manufacturing and reworking process) is analyzed; and a product cost price estimation model is established to provide support to the decision-making of product pricing.

2. Modeling complex consumption relationships for activity cost rates analysis

The development of process-based cost estimation model mainly contains two steps: (1) activity cost rates analysis; (2) estimating the cost of products based on the activity cost rates and some process parameters (such as quality and quantity parameters of activities). For evaluating the cost consumption of products properly, the cost rates of production activities should first be determined.

2.1. Framework for activity cost rates analysis

In a manufacturing environment that only contains direct consumption relationships, based the historical data of a recent period of time, the current cost rate r of a production activity can be calculated by

$$r = \frac{c_{\text{sum}}}{y_{\text{sum}}} \tag{1}$$

where y_{sum} is the total output amount of the activity (usually measured by work hours) in the period, and c_{sum} is the total cost of resources (equipment, labor, work space, utility, etc.) consumed by this activity.

However, in a manufacturing environment containing complex indirect consumption relationships, the cost rates of production activities cannot be directly calculated as above. In such relatively complex environment, not only the execution of production activities is supported by the resources, but the fabrication of certain resources is supported by these production activities. Thus, some reciprocal support relationships, and reciprocal consumption relationships, may exist between these activities and resources. For obtaining the cost of these activities and resources, the cost occurred during a period should be allocated between them according to their actual consumption relationships.

Input–output analysis is a modeling method on complex consumption relationships and is usually used in macroeconomic analysis, while its applications on cost analysis of microeconomic systems are still not common (Bulmer-Thomas, 1982; Leontief, 1966). In this paper the input–output analysis method is utilized to model and express the consumption relationships of a manufacturing system within a company between its production resources and production activities.

In the modeling process, each type of resource/activity can be seen as a cost entity or cost pool for cost collection and cost allocation. At the same time, the cost rates of these cost entities are all considered as variables that should be determined. According to the input–output analysis theory, during a period of time the total input cost of a cost entity (or the cost collected or allocated to it) is equal to its total output cost (or the cost allocated from it to the cost objects that it has supported). When a cost entity receives support from other entities, the cost allocated to it can be calculated based on the cost rates of these support entities and the