Available online at www.sciencedirect.com
ScienceDirect
Int. J. Production Economics 113 (2008) 805–818
international journal of production economics
www.elsevier.com/locate/ijpe

Parametric cost estimation based on activity-based costing: A case study for design and development of rotational parts

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Received 20 August 2006; accepted 12 August 2007
Available online 15 December 2007

Abstract

Modern manufacturing systems are facing a globally competitive market to an extent not experienced before. This competitive pressure forces manufacturers to produce more products with shorter life span and better quality, yet at a lower cost. To succeed in this environment, manufacturing firms need to have an accurate estimate of product design and development costs. This is especially important since the shorter life span of products accentuates design and development stages.

This paper presents a cost-estimation model that links activity-based costing (ABC) with parametric cost representations of the design and development phases of machined rotational parts. It also presents several parametric models applicable at design time by using parts' feature geometry. A comparison of various parametric cost models is provided, reflecting on the accuracy of the various approaches. There is an evident trade-off between the details embedded in the parametric representation and the cost-estimation accuracy. Thus, more detailed methods, which can be used later in the life cycle of the product, are more precise, while these methods that can be used as early as design time have a higher but acceptable error rate.

Keywords: Product cost estimation; Activity-based costing (ABC); Parametric cost estimation; Feature-based cost estimation; Machining time estimation; Rotational part

1. Introduction

Product cost estimation is a challenging task, especially during early stages of the design and development phase. This activity is crucial to the financial success of manufacturing firms and is gaining increasing importance in the contemporary competitive environment. This competitive drive forces manufacturing firms to introduce more and more products with shorter life spans and better quality, yet at an increasingly lower price. This competitive pressure propagates through the entire supply chain, requiring accurate cost estimation from all manufacturers on the chain. Traditional cost systems are known to distort the cost information by using traditional overhead allocation methods. Activity-based costing (ABC), on the other hand, has been recognized as a more accurate cost-estimation and calculation method. In our previous work (Ben-Arieh and Qian, 2003a), a modified

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doi:10.1016/j.ijpe.2007.08.010

ABC method is demonstrated and verified using sample rotational parts developed in a controlled manufacturing environment. The method is proved to be more accurate than the traditional cost estimation provided by the shop accountant.

This paper extends previous research by presenting parametric cost representations for the design and development phases of rotational parts based on the ABC method. It presents several approaches towards parametric representation of cost by using parts' feature geometry—allowing fast and accurate calculation of the cost of completing a prototype. The novelty of the approach presented is in combining ABC with the parametric cost representation of design and development activities. These activities are more nebulous and harder to quantify than regular manufacturing activities. These parametric cost-representation methods are tested on real rotational parts developed in a controlled factory environment and are compared to the detailed ABC results. All assorted cost rates in parametric cost models are established in the controlled manufacturing environment, but the method of establishing parametric cost models based on ABC could be extended to a general shop and other manufacturing processes.

The paper is structured as follows: Section 2 reviews literature related to parametric cost estimation, feature-based cost estimation, and ABC systems. Section 3 briefly presents the ABC model implemented before for design and development stages in one manufacturing shop. Section 4 presents three linear parametric models using activity drivers, machining time, part volume, and number of cutters based on the ABC model. Section 5 develops a more detailed parametric model of machining time, number of setups, and number of tools, which are representing in terms of geometrical parameters known at design time. Section 6 presents a comparison of the various cost models. Section 7 provides the summary and possible future research topics.

2. Literature review

Parametric cost-estimation methods seek to evaluate the costs of a product from parameters characterizing the product but without describing it in detail. Parametric methods use the relationship between the physical characteristics of the part, such as mass or volume, and the cost, but with little or no physical relationship to the process. These methods are fast and accurate for well-defined part families but has minimal necessary result justification. As with the previous model, applications of the parametric model vary greatly in complexity from the simple "material model" and "cost-size" model (Creese et al., 1992) to complex parametric equations (Wierda, 1988). The parametric approach is useful for cost estimation during the design stage where many details about the part's structure and manufacturing processes are not yet established.

At least three types of parametric cost-estimation methods have been identified (Duverlie and Castelain, 1999): method of scales, statistical models, and cost-estimation formulae (CEF). The method of scales applies generally to simple products of variable sizes. Using this method, the user identifies the most significant technical parameter of the product analyzed and the ratio of cost to the parameter. Thus, if the leading parameter is weighed, the ratio of cost to weight ($/lb.) is developed. This method is very simple but can produce inaccurate results due to the assumption of a linear relationship between the value of the selected parameter and the cost.

Statistical parametric cost estimation involves collecting and organizing historical information using statistical techniques, and relating this information to the cost being estimated (Malstron, 1984). The most commonly used statistical models are the linear, exponential, and polynomial models (Sheldon et al., 1991). This type of parametric cost model usually cannot be used at the early stages of design activity due to lack of sufficient information.

The CEF method uses simple mathematical relationships connecting the cost of a product to a limited number of technical parameters (physical and dimensioning values) specifying the product. Usually, this method is limited to between two and five parameters. The CEF parametric approach can be used during design stages and can illustrate clearly the influence of various parameters on the cost.

Examples for parametric cost estimation include Boothroyd and Reynolds (1989) which uses volume or weight of typical turned parts for approximate cost estimates and Daschabach and Apgar (1988) in which an empirically derived cost relation is presented. Cavalieri et al. (2004) used one parametric model for estimating unit manufacturing costs of a new type of brake disk. They used the weight of the raw disk, unit cost of raw material,