# Parametric Cost Estimation of Design Activities

**David Ben-Arieh**
**Department of Industrial and Manufacturing Systems Engineering**
**Kansas State University**
**Manhattan, KS, 66506**

## Abstract

The fierce global competition forces manufacturers to compete in quality, cost, and time-to-market aspects of their products. Knowing the cost of the manufactured components is essential for efficient operation and competitive production. Activity Based Costing (ABC) has become a mature cost estimation and accounting methodology, but cost estimation of the design activity has been nebulous and hard to implement. This paper presents a methodology of using Activity Based Costing to evaluate the cost of the design and development activity for machined parts. The methodology is demonstrated on a sample part being produced in a controlled manufacturing facility.

## Keywords
Product development process, $IDEF_0$, activity modeling, cost estimation

## 1. Introduction

Modern-day manufacturing operations are facing a fierce global competition creating the need to increase productivity at reduced cost. Estimating the various manufacturing costs more accurately has become a strategic objective.

The functions of cost estimating include: (Malstron, 1984 ,p9)

- Check quotations from suppliers
- Aid the Make-or-Buy decision
- Evaluate product design alternatives; cost estimation are particularly useful at the early design of a product where 70% of its cost is determined (Duverlie and Castelain, 1999).
- Assist long-term financial planning
- Help control manufacturing cost
- Provide standards for production efficiency

Traditional cost system are known to distort the cost information by using traditional overhead allocation methods. Activity Based Costing (ABC), on the other hand, has gained the recognition of a more accurate cost estimation and calculation method.

ABC method traces the cost via activities performed on cost objectives (production or service activities), giving more accurate and traceable cost information. Using ABC can lead to classifying activities as value-added and non-value-added; and allow for elimination of the non-value-added activities (Gunasekaran and Sarhadi, 1998).

## 2. Background

Some analytical methods for cost estimation advocate integrating process information with product cost information. Luong and Spedding (1995) developed a generic knowledge-based system for process planning and cost estimation for hole making. Takakuwa (1997) utilized simulation to estimate cost for flexible manufacturing system (FMS ) based on activity based cost analysis. Yang et al. (1998) integrated information from process planning, scheduling, and cost accounting to estimate the cost in more detail. In order to determine overall costs for alternative process plans, Kiritsis et al. (1999) used Petri net models to calculate the optimum process planning cost.

Parametric cost estimation methods seek to evaluate the costs of a product from parameters characterizing the product without describing it completely. This method meets the criteria of precision and speed of results with well-defined part families but without good explanation facilities. At least three types of parametric methods have been identified (Duverlie and Castelain, 1999): The method of scales, statistical models, and cost estimation formulae.

Boothroyd and Reynolds (1989) demonstrated the use of volume or weight of typical turned parts as parameters for approximating cost estimates.

A relatively new cost estimation approach is the Activity Based Costing (ABC) method. ABC systems help designers to understand the design parameters that create demands on indirect and support resources. A review and comparison of traditional cost accounting and ABC analysis can be found in Park and Kim (1995).
ABC is often used as a part of total cost management. Activity-based costing system differs from traditional system in two ways: first, cost pools are defined as activities rather than production cost centers and secondly, the cost drivers used to assign activity costs are structurelly different from those used in traditional cost systems (Lewis 1995).

The popularity of ABC has grown at a fast pace in the 1980s due to the promotion of organizations such as computer-aided manufacturing-international (CAM-I) and the national association of accountants.
ABC has been applied to various industries (Tsai, 1996) such as electronics (Merz and Hardy, 1993), automotive (Miller, 1994), aerospace and defense (Soloway, 1993), airplane manufacturing (Haedicke and Feil, 1991), shipbuilding (Porter and Kehoe, 1994), and telecommunication (Hodby, et al., 1994), among many other areas of application.

## 3. Implementation of the ABC Method

The implementation of the BC approach follows these steps:

1. Identify activities

Identify the activities that take place in the product development process. These activities are modeled using $IDEF_0$. Major activities, such as design, and CNC prototype machining are decomposed into more detailed activities.

2. Identify cost centers

Cost centers are the resources that are used directly to produce the end-product. Cost centers include human resources such as design engineers, project managers, manufacturing coordinators, and manufacturing engineers. Additionally, cost centers include major equipment such as machining centers, material handling center, and tooling center.

3. Analyze indirect costs and calculate their cost-drivers rates

Indirect expenses are the overhead costs that need to be allocated to the end products. These expenses include room rent, cleaning, computer purchasing and maintenance, heating gas, water, software, network administration, paper, printers, copy machine toner and lease, and the like.
Indirect resource cost drivers are determined in this step. For example, the resource cost driver for heating gas is the square footage of the cost center, while the network, computer, and computer maintenance costs are allocated by number of user-hours. Each resource cost driver rate is calculated by dividing the total annual cost of the resource by the total number of cost drivers used in one year.

4. Assign resources to each cost center and determine cost center driver rates

In this step, the cost of indirect resources is allocated to cost centers, such as the design engineer, CNC turning center or material handling center, based on the resources cost drivers.
In this step the total cost for each cost center is calculated, and for each cost center one cost driver is identified. For example, the driver for a machining center is the machining time, while the driver for the material handling center is the number of trips. Lastly, in this step, one driver rate is obtained for each cost center.

5. Analyze each activity and find the total cost for each activity

Based on cost-center resources spent on each activity, the total cost for each activity is determined. This cost is calculated by using the cost-center drivers' rates multiplied by the amount of the drivers consumed by each activity.

6. Define activity drivers for each activity and find activity cost-driver rate

An activity cost-driver is any factor that directly explains the cost incurred by the activity. Usually, ABC system use different types of cost drivers such as transaction drivers, which represent the number of times an activity is performed, or duration drivers, which represent the time it takes to perform an activity. Some cost drivers are easy to trace, such as machine hours, which can be used to explain the cost of the machining activity, while other drivers need a more innovative definition.

The activity cost-driver rate is obtained by dividing the total cost for each activity by the magnitude of the activity cost driver.

7. Estimate the cost of new parts via activity cost-drivers spent

Finally, the cost of each product is defined by the activities used, and the magnitude of their cost drivers.

## 4. Example: Design and Development of Rotational Parts

This example demonstrates the cost analysis of rotational parts in a medium size design and development specialty shop.

### 4.1 Cost of indirect resources and their drivers

The expenses of the shop are the costs of indirect labor, materials and supplies, utilities, equipment, buildings, and capital, which appear in the general ledger accounts and are traced to the traditional departments and responsibility centers. Table 1 lists some indirect resources and resource drivers employed in the shop.

Table 1. Resources and their cost drivers in the shop

| Resources | Resource Cost Driver |
|---|---|
| General Ad. Salary | Labor Hours |
| Administrator | Labor Hours |
| Electrical Power Cost | Number of people |
| Building Rent Cost | Square feet |
| Water Cost | Number of people |
| Phone Cost | Number of people |
| Building Maintenance | Square feet |
| Computer Cost | Number of people |
| Network Cost | Using hour |
| Gerneral Software Cost | Using hour |
| AutoCAD Cost | Using hour |
| Printer (+ink.) Cost | Number of people |
| Copy machine cost | Number of projects |
| Training Cost | Direct Cost |
| Machine Maintenance | Direct Cost |
| Tooling Cost | Direct Cost |

### 4.2 Manufacturing Cost Centers (Direct Resources)

The activities performed during the design and development phase can be divided into the following cost centers:

- Engineering centers: design center, project manager, manufacturing engineer, and technician.
- Machining centers: Vertical milling center, 3-Axis mill-turn center, CMM machine, Rapid prototyping machine, and Material Handling Center.

### 4.3 Rates for Cost Centers

Total costs of cost centers for one year is the sum of all expenses (resources) spent by each cost center. These expenses are collected from the traditional costing system. The costs related to the building are allocated by square feet used by each cost center per year, while computer cost related to employees are allocated by number of employee-hours.

Cost drivers for the human resources such as project manager, manufacturing engineer, and technician are labor hours. The cost drivers for the machining centers are the machining hours, while the cost driver for the material handling costs is the number of trips of the forklift. Similarly, the cost driver for the tooling center is the number of tools used. The list of cost centers, their cost driver and the drivers rate is presented in Table 2.

Table 2. Manufacturing cost centers and their drivers

| Manufacturing Cost Center | Cost Driver | Rate ($/units) |
|---|---|---|
| Designer | Design hours | $31.92 |
| Project Manager | Work hours | 37.29 |
| Technician | Work hours | 29.56 |
| Manufacturing Coordinator | Work hours | 32.78 |
| CNC Turning Center | Machining hours | 93.16 |
| Material Handling Center | Number of material moves (trips) | 37.62 |
| Tooling Center | Number of tools used | 0.58 |

**4.4 Activities Analysis**

The activities involved in the design and development of a product are modeled using $IDEF_0$ diagrams. Table 3 lists the activities required to finish the sample part.

Table 3. Activities for design and development of a rotational part

| Activities for Turning part | Activity Driver | $IDEF_0$ ID | Cost centers Used |
|---|---|---|---|
| Design part | Hours | A2 | Design Engineer |
| Discuss Product | Number of cutters | A3111 | Project Manager, Designer, Coordinator |
| Generate NC Code via CAM software | Number of cutters | A3112 | Coordinator |
| Generate Quote for Part | Fixed cost | A3113 | Coordinator |
| Purchase material | Number of Orders | A3121 | Technician |
| Material Delivery | Part Length | A3122 | Coordinator, Technician, Material. Handling |
| Setup Fixture | Number of setups | *A31341* | Technician |
| Setup Tooling | Number of cutters | *A31342* | Technician |
| Run Test Part (Recode, redesign fixture) | Machining time | *A31343* | Coordinator, Turning Center, Tooling |
| Machine parts | Machining time | *A31344* | Technician, Turning Center, Tooling |
| Debur & Clean parts | Number of parts | A3141 | Technician |

As shown in Table 3, the process of product development requires the project manager and the designer to talk to the manufacturing engineer about the part requirements. The cost centers employed in this activity include the designer, project manager and manufacturing coordinator. The discussion time is determined mainly by the complexity of the part to be machined. It has been found that a good estimator of the discussion time is the number of cutters that are used during machining.

After the manufacturing coordinator receives the drawing from the designer, the process plans are generated as well as the NC codes (via CAM software). The time for this activity is similarly determined by the complexity of the part as expressed by the number of tool changes.

After confirmation of the process plan by an inner customer (designer or project manager) or an external customer, the part is ready for production. The following activities are *Purchase Material* (activity A3121) and *Deliver Material* (activity A3122). The material handling center become involved with the material handling activity, using the length of each rotational part as the activity cost-driver. The part's length is a local parameter that correlates with the number of material handling activities (longer parts require more trips).

Before testing the NC program for the part, the manufacturing technician is required to set up the fixtures (activity A31341) and perform the cutter setup (A31342).

The activity *Run Test part* (A31343) spends more resources than other activities, and experience shows that this activity needs more time than the other activities. In this activity there is a need to change the cutting parameters, re-code the NC programs, and perform similar adjustments before full production can start.

### 4.5 Input Parameters

Based on the above analysis the following input parameters are used for estimating the cost of the rotational parts: part length, number of orders, number of cutters, number of setups and machining time (hours). All the activities that participate are driven by those inputs.

The calculated costs of the various activity drivers, the drivers consumed by the example part, and the cost of those activities is presented in Table 4.

Table 4. Activity cost driver rates for the example part

| Activity for Part | Total Cost for Part | Activity Driver | Activity Driver Spent | Rate |
|---|---|---|---|---|
| Discuss Product | 17.52 | Number of cutters | 6. | 2.919 ($/cutter) |
| Generate Code via CAM software | 16.39 | Number of cutters | 6 | 2.732 ($/Cutter) |
| Generate Quote in Job Boss | 0.82 | Per order | 1 | $0.82 |
| Purchase Material | 0.38 | Number of orders | 1 | 0.376 ($/order) |
| Material Delivery | 0.99 | Part length | 4.50 | 0.2199 ($/inch) |
| Setup Fixture | 3.14 | Number of setups | 2 | 1.567 ($) |
| Setup Tooling | 5.64 | Number of cutters | 6. | 0.940 ($/cutter) |
| Run test Part ( Recode, redesign fixture) | 162.76 | Machining Hour | 0.21 | 773.453 ($/hour) |
| Machine prototype | 33.49 | Machining Hour | 0.21 | 159.477 ($/hour) |
| Debur & Clean parts & Clean Machine | 0.63 | Number of Parts | 1 | 0.627 ($/part) |
| **total Cost for one part** | 241.76 | | | |

From activity cost driver rates in Table 4, the total costs for design and development of the sample rotational part is given by:

$$\begin{aligned}\text{Total cost} &= 6.59\times\text{Number of Cutters} + 934.54\times\text{Machining hour} + 0.22\times\text{Part Length}\\ &\quad + 0.38\times\text{Number of Order} + 1.57\times\text{Number of Setup} + 1.45 = \$241.76\end{aligned}$$

## 5. Summary

Modern manufacturing operations face global competition on time to market, cost and product quality, among other issues. With product life span constantly shrinking, the design and development phases become more prominent, and under the need to be better controlled.

Traditional cost estimation methods proved to be inaccurate in allocating overhead costs to products. The costs of the design and development phase are even harder to estimate, since this phase consists on many activities that are not directly linked to the finished product.

This paper presents a modified Activity Based Costing (ABC) method that finds the cost of the design and development phase. The method is demonstrated using a sample part that is produced in a shop specialized in product development (one of a kind production).

The method presented is based on a detailed analysis of the activities that participate in the design and development phase. These activities are modeled using the $IDEF_0$ convention. The cost of the product is found using activity cost drivers consumed by the product. The activities' cost drivers rate are found using cost centers that directly serve those activities. The cost centers in turn are loaded with the direct and indirect costs of the whole facility.

The method appears to be more accurate then the traditional cost estimation provided by the shop accountant. An additional advantage of the method presented is the ability to expand the costly activities and look in more detail in the causes of the cost. This can provide a valuable insight into the factors that cause the cost, helping to better manage these activities.

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