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Int. J. Production Economics 83 (2003) 169–183

international journal of production economics

www.elsevier.com/locate/dsw

Activity-based cost management for design and development stage

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Received 1 October 2001; accepted 1 July 2002

Abstract

The fierce global competition in the international markets forces manufacturers to compete in quality, cost, and the time to market aspects of their products. Knowing the cost of the manufactured components is essential for efficient operation and competitive production.

The current evolution of competitive manufacturing requires a shorter market life span of products—emphasizing the design and development phase of the product life cycle. Thus, it has become more important to analyze the cost of the design and development phase accurately.

Activity-based costing (ABC) has become a mature cost estimation and accounting methodology. Using ABC for cost estimation of manufactured parts is being practiced today with acceptable rate of success. Cost estimation of the design activity on the other hand, has been nebulous and hard to implement.

This paper presents a methodology of using ABC 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; Activity modeling; Cost estimation

1. Introduction

Modern-day manufacturing operations are facing a fierce global competition and 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, p. 9)

- check quotations from suppliers,
- aid the make-or-buy decision,
- evaluate product design alternatives; cost estimations 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 systems are known to distort the cost information by using traditional overhead

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0925-5273/03/$ - see front matter
PII: S0925-5273(02)00323-7

allocation methods (that rely on direct resources such as labor hours). Activity-based costing (ABC), on the other hand, has gained the recognition of a more accurate cost estimation and calculation method.

The ABC method traces the cost via activities performed on the 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).

The demands of the market keep reducing the life expectancy of products, causing the design and development phase to become more pronounced in the overall product life cycle. Thus, in order to correctly account for the product costs, the design and development cost have to be accurately measured. The design and development phases include all the activities starting with the requirements of the customer, through the design of the part, its process planning and finally the making of a prototype.

This paper demonstrates the application of ABC towards analysis of the design and development costs. The methodology follows these steps:

1. Identify the resource centers used for the design and development.
2. Identify the overall cost associated with these resource centers.
3. Find the cost drivers for the resource centers.
4. Identify the activities that participate in the design and development process. These activities are analyzed using the $IDEF_0$ methodology (Ang et al., 1994).
5. Calculate the cost of the activities based on resource consumption.
6. Find the activity cost drivers and calculate their values.
7. Calculate the overall process costs based on the activities performed.

This paper is structured as follows:

Section 2 provides the background and literature review of cost estimation. Section 3 describes the ABC methods implemented in this study. Section 4 provides an example of cost analysis of the activities involved with the product development process of rotational parts. Section 5 provides a more detailed analysis of some activities with their associated costs, and Section 6 provides a summary and future research.

2. Literature review and background

Cost estimation methods can be classified as: intuitive, analogical, parametric, and analytical methods. The intuitive methods are based on past experience of the estimator. The analogical methods estimate the cost of products using similarity to other products with known cost. The parametric methods estimate the costs of a product from parameters, which are usually used by the designers. These parameters influence the cost in a known way represented usually by a simple equation. Analytical methods such as ABC allow evaluation of the cost of a product from a decomposition of the work required into elementary tasks, operations or activities with known (or easily calculated) cost.

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 a flexible manufacturing system based on ABC 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.

Different cost models have been developed for various manufacturing applications. Examples include injection molding process, PCB manufacturing and assembly (Ong, 1995), and gear drive manufacturing (Yang and Lin, 1997). Geiger and Dilts (1996) presented an automated design-to-cost model by integrating costing into the design decision. Aseiedu et al. (2000) considered the uncertainties associated with the cost model parameters such as time, inflation, labor rates, and failure rates by employing non-parametric estimation techniques.

Some cost analysis of manufacturing operations use features technology. This approach is useful especially when the designer uses features as the design building blocks. Feng et al. (1996) presented a feature-based cost evaluation model in which the geometry of features and relationships between features are used for cost estimation. Yang and Lin (1997) proposed a framework for feature-based early cost estimation according to the shapes and precision of features. Zhang and Fuh (1997) used a back-propagation neural network for a feature-based cost estimation. Veeramani and Joshi (1997) used characteristics of several features (such as dimensions and surface finish requirement) to directly determine the total resource requirement for manufacturing the feature. Roberts and Hermosillo (2000) estimated time and cost for small surface units, called primitives, using approximated tool paths and process parameters for available factory resources.

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 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. ABC 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 structurally 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 Institute of Management 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.

The ABC method models the usage of the organization resouces by the activities performed and then links the cost of these activities to outputs, such as products, customers, and services.

In traditional cost sytems, direct materials and labor are the only costs traced directly to the product. Manufacturing overhead costs are not traced, but allocated to the production departments. They may be traced to an activity or a service department or some other cost objective, but not to the product itself. The ABC method identifies the activities that drive costs by consuming resources. Cost drivers are items such as number of units produced, labor hours, hours of equipment time, or number of orders received.

ABC assigns activities' cost to units of production, or other cost objects such as customers, services, etc. Activities can be categorized into four classes: unit-level activities, batch-level activities, product-sustaining activities that are associated with a given product as a whole, and facility-sustaining activities, which cannot be directly linked to any one product. Examples of the later are building maintenance, or general management activities.

The advantages of ABC include the following: improve the accuracy and relevance of products costing, provide timely cost information suitable for decision-making and allowing more detailed tracking of indirect cost-to-cost objectives.

The shortcomings of the of ABC methods include the following: doing little to change old management behavior, not driving companies to change their fundamental views about how to organize work and to satisfy customers efficiently. Finally, the ABC method requires additional effort and expense in obtaining the information required for the analysis (Lewis, 1995).

Examples for applications of ABC are presented by Lee and Sullivan (1998) who developed an ABC model to estimate product cost at the conceptual level of PCBs design. In their work, cost drivers are related to the design parameters established during the conceptual design stage. Tseng and Jiang (2000) developed an ABC analysis model for evaluating the different manufacturing costs for multiple feature-based machining methods. The activities in the mode include tool setups, fixturing setups, and machining tool paths. The shape of the parts is restricted to prismatic parts and prismatic features suitable for machining on 3-axis milling center.

3. Implementation of the ABC method

In this research, the ABC method for cost estimating is implemented using the steps presented in Fig. 1 (modified from Cooper and Kaplan, 1999, p. 210).

The implementation of the ABC approach follows these steps:

3.1. 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 the vertical milling machining center, CMM center, laser cutting center, material handling center, tooling center, and others.

3.2. 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 1 year.

The indirect resource rate is calculated by

$$\text{RR(resource rate)} = \frac{\text{Total cost for 1 year}}{\text{Resouce drivers spent in 1 year (RD)}}. \quad (1)$$

3.3. 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 resource cost drivers.

In this step the total cost for each cost center is calculated. Then 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.

The total cost for each cost center in 1 year can be given by

$$\text{Total annual cost for cost center} = \sum_{i=1}^{\text{number of resources}} \text{RR} \times \text{RD} \quad (2)$$

and RD is the amount if each resource driver spent by the cost center in 1 year.

$$\text{CCR(Cost centre rate)} = \frac{\text{Annual cost of center}}{\text{Cost center drivers spent in 1 year (CCD)}}. \quad (3)$$

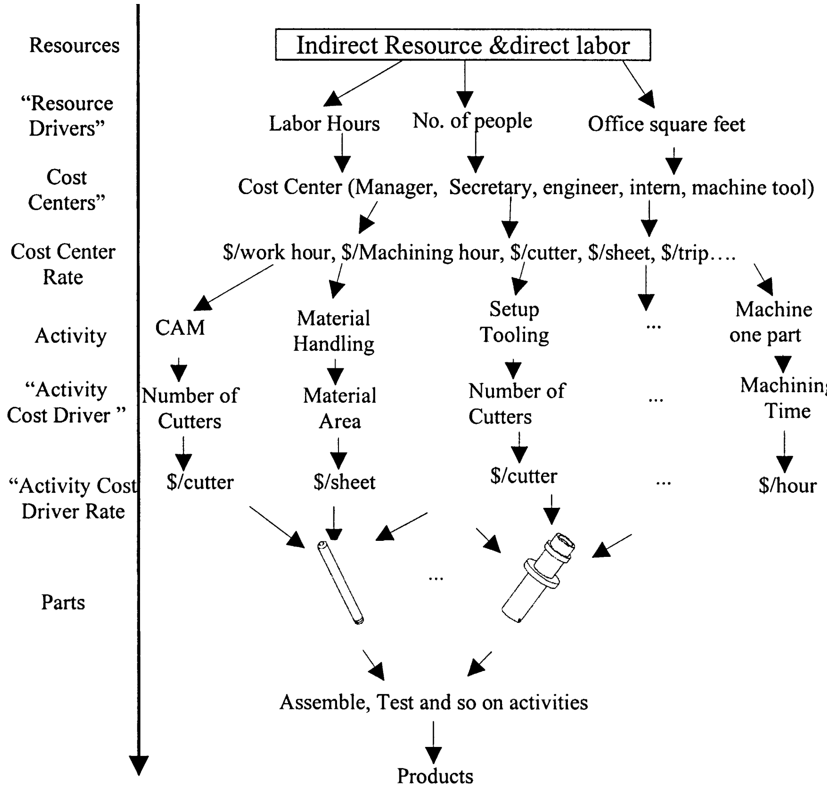


Fig. 1. ABC implementation: Flow of expenses from resources to activities to products.

3.4. 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, which are presented in the next section.

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

Based on cost-center resources devoted to 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.

3.6. 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 systems 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 (ACDR) is obtained by dividing the total cost for each activity by the magnitude of the activity cost driver.

The ACDR for one activity is calculated using the following equation:

$$\text{ACDR} = \frac{\text{Cost of one activity}}{\text{Activity cost driver spent}} = \frac{\sum_{i=1}^{\text{number of cost centers used}} (\text{CCR}_i \times \text{CCD}_i)}{\text{ACD}}, \quad (4)$$

where CCD_i is the amount of the driver of center i used for the activity, and ACD is the amount of the activity's cost driver used. ACDR is the activity cost-driver rate cost.

3.7. 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

$$\text{Total cost of one part} = \sum_{i=1}^{\text{number of activities}} (\text{ACD}_i \times \text{ACDR}_i). \quad (5)$$

3.8. Difference and similaritiy between this implementation and traditonal ABC implementation

In this implementation there is an added stage for allocating the indirect costs to the products, namely the cost centers and their cost drivers. In this method, the indirect expenses such as gas and building cost are divided to the cost centers, and each center is assigned a cost driver. These cost centers are then associated with the activities, and activities cost drivers are computed. These activity cost-drivers are then used to find the cost of the complete product.

The translation of the indirect costs to cost centers follows the traditional cost accounting. This makes cost estimating simpler and easily understood by users, especially users with traditional cost accounting background.

In a traditional ABC system, all the indirect expenses including utilities, computers, and CNC machines and tools may participate directly in activities, making the analysis more complex or less accurate.

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. More specifically, the analysis describes the cost of designing and developing the part described in Fig. 2.

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 all indirect resources and resource drivers employed in the shop. The resource cost-drivers rate is calculated from Eq. (1).

4.2. Design and development cost centers (direct resources)

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

- Engineering:
  - Design center,
  - Project manager,
  - Manufacturing engineer,
  - Technician,
- Vertical milling center,
- 3-Axis mill-turn center,
- Laser cutting machine,
- Water-jet cutting machine,
- Sandblasting machine,
- Welding center,
- Tooling center,
- CMM machine,
- Rapid prototyping machine,
- Material handling center.

The indirect expenses assigned to the machines include annualized depreciation calculated as $(Pi(1+i)^n)/((1+i)^n-1)$ where P is the current sum paid for the equipment, i is the interest rate,

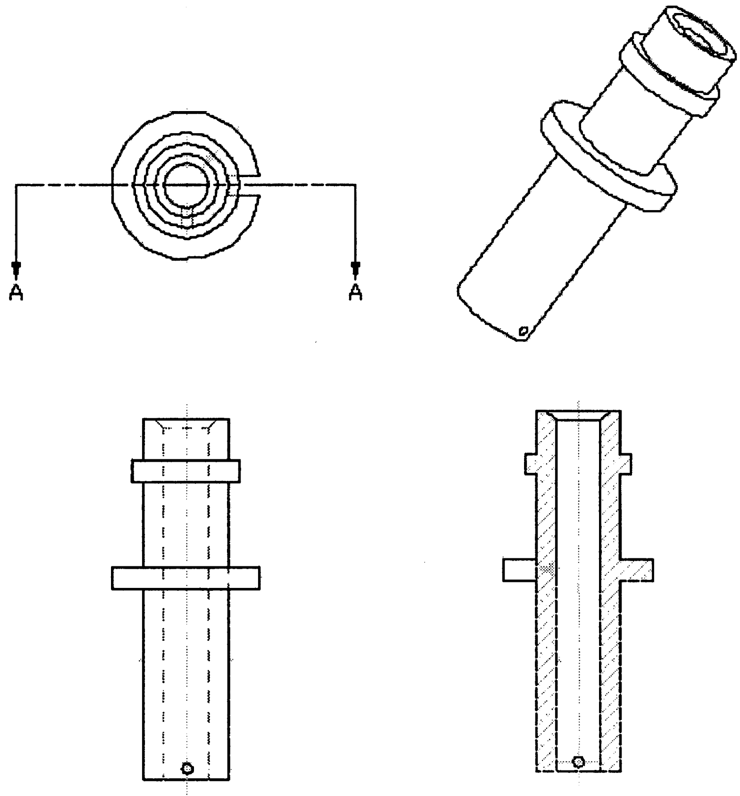


Fig. 2. Description of the example part.

and n is the economical life of the equipment (assume $i = 6\%$, and $n = 7$).

4.2.1. Rates for cost centers

Total cost of cost centers for 1 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 coordinator, 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. The cost-center rate is calculated from Eqs. (2) and (3).

4.3. 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 one rotational part, and Figs. 4–8, in Appendix A, present the corresponding $IDEF_0$ diagrams.

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 discussing time is determined mainly by the complexity of the part to be machined. It has been

Table 1
Resources and their cost drivers in the shop

Resources	Resource cost driver
General ad. salary	Labor hours
Administrator	Labor hours
Secretary salary	Labor hours
Human resource	Labor hours
Electrical power cost	Number of people
Building rent cost	Square feet
Water cost	Number of people
Gas (heat) cost	Square feet
Building clean-up	Square feet
Phone cost	Number of people
Cleanup cost	Room Square feet
Building maintenance	Square feet
Computer cost	Number of people
Network cost	Using hour
SE maintainence	Number of people
Gerneral software cost	Using hour
AutoCAD cost	Using hour
Pro/e cost	Using hour
SmartCAM/SurfCAM	Using hour
Printer (+ink.) cost	Number of people
Paper cost	Number of people
Fax machine cost	Number of projects
Copy machine cost	Number of projects
Training Cost	Direct cost
Travel fee	Direct cost
Machine maintenance	Direct cost
Tooling cost	Direct cost

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

found that a good estimator of the discussion time is the number of tool changes that take place during the machining stage.

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 development. 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) uses 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, recode the NC programs, and perform similar adjustments before full production can start. Thus the activity cost-driver "Machining time" can be further refined.

4.4. Results

4.4.1. 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.

From ACDRs in Table 4, the total costs for design and development of the sample rotational

Table 3
Activities for design and development of a rotational part

Activities for design and development	Activity driver	$IDEF_0$ ID	Cost centers used
Design part	Hours	A2	Design engineer
Discuss product	Number of tool changes	A3111	Project manager, designer, coordinator
Generate NC code via CAM software	Number of tool changes	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 tool changes	A31342	Technician
Run test part (recode, redesign fixture)	Machining time	A31343	Coordinator, turning center, tooling
Machine proptotype	Machining time	A31344	Technician, turning center, tooling
Debur and clean part	Number of parts	A3141	Technician

Table 4
Activity cost driver rates for the example part

Activity for part	Total cost for part ($)	Activity driver	Activity driver spent	Rate
Discuss product	17.52	Number of tool changes	6	2.919 ($/cutter)
Generate NC code via CAM software	16.39	Number of tool changes	6	2.732 ($/cutter)
Generate quote for part	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 ($/in)
Setup fixture	3.14	Number of setups	2	1.567 ($)
Setup tooling	5.64	Number of tool changes	6.	0.940 ($/cutter)
Run test part (recode, redesign fixture)	162.76	Machining time	0.21	773.453 ($/h)
Machine prototype	33.49	Machining time	0.21	159.477 ($/h)
Debur & Clean part	0.63	Number of Parts	1	0.627 ($/part)
Total Cost for one part	241.76			

part is given by

$$\begin{aligned}\text{Total cost} = {} & 6.59 \times \text{Number of cutters} + 934.54 \\ & \times \text{Machining hour} + 0.22 \times \text{Part length} \\ & + 0.38 \times \text{Number of order} + 1.57 \\ & \times \text{Number of setups} + 1.45 \\ & = \$241.76. \end{aligned} \tag{6}$$

This analysis leads to the conclusion that the main resource spent by the part is the cost of manufacturing coordinator, which occupied about half of the total machining cost. In terms of activities, *Run Test Part*, *Machine Prorotype* and *Discuss Product* used most of the resources and thus the cost.

This data is presented in Fig. 3.

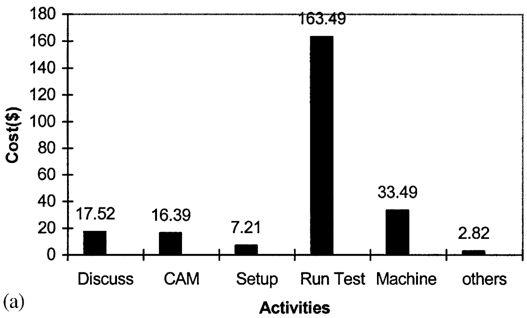
Fig. 3(a) is derived directly from Table 4. The cost of the cost centers as presented in Fig. 3(b) is derived from a more detailed description of each cost center and the activities that it supports. This straightforward analysis is omitted for sake of brevity.

4.5. Comparison between ABC and traditional cost

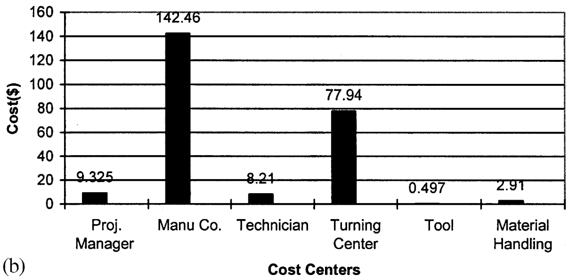
In order to compare the cost calculated using the ABC approach to the cost calculated using traditional methods, three sample parts were used. The cost comparison of the parts is presented in Table 5. The table shows a moderate difference between the ABC and the traditional cost estimates.

In the traditional cost estimation method we only consider the machining time, as an instrument to load overhead, without considering the activities performed in more detail.

The traditional system tends to underestimate the time it takes to make a prototype part, and to adjust the manufacturing parameters (which is the major part of the cost). The discrepency between the ABC and traditional cost estimates grows as the parts become more complex, which require more extensive development and experimentation with the manufacturing procedures.



(a)



(b)

Fig. 3. (a) Cost of various activities. (b) Cost of cost centers.

Table 5
Cost comparisons for three sample parts

Parts number	ABC cost per part ($)	Traditional cost ($)
Wg-065	89.69	94.77
Wg-075	24.26	29.25
Wg-183	241.76	140.0

5. Decomposition of activites

5.1. Decomposite the activity: run test part

In order to enhance the precision of the cost analysis, the more crucial activities can be broken into more detailed elements, allowing a more accurate tracking of the cost. As mentioned above, the *Run Test* activity consumes the lion-share of the cost for machining. Thus, in order to allow for a better analysis of the cost elements, the activity is divided into more detailed elements shown in Table 6.

Based on Table 6, a more precise way to calculate the actvity's cost is

$$\begin{aligned}&\text{Cost for Run Test of one part}\\&= 0.07 \times \text{Number of cutters}\\&\quad + 766.77 \times \text{Machining hour}\\&\quad + 0.18 \times \text{Number of dimensions} + 0.11. \qquad (7)\end{aligned}$$

Then the total cost in Eq. (6) can be expressed now in more detail by

$$\begin{aligned}\text{Total cost} &= 6.66 \times \text{Number of cutters} + 926.25\\&\quad \times \text{Machining hour} + 0.22\\&\quad \times \text{Part length} + 0.38\\&\quad \times \text{Number of order} + 1.57\\&\quad \times \text{Number of setups} + 0.18\\&\quad \times \text{Number of dimension} + 1.66\\&= \$241.76. \qquad (8)\end{aligned}$$

Table 6
Activity cost analysis for run test part activity

Activity	Coordinator time(min)	Machine time	Tool	Cost ($)	Driver	Driver spent	Rate
Download NC code	0.2	0	0	0.11	Per operation	1	0.11
Chang codes for cutters	1.5	0	0	0.42	Number of cutters	6	0.07
Simulate the part	25.2	12.6	0	30.33	Machining time	0.21	144.44
machine part	62.4	49.8	0.11	130.69	Machining time	0.21	622.33
Measure the dimension	2.20	0	0	1.21	Number of dimensions	11	0.11
Change codes	1.34	0	0	0.77	Number of dimensions	11	0.07
Total	93.84	64.89	0.11	163.53	Machining time	0.21	775.06

Table 7
Activity cost analysis for Machine Prototype activity

Activity	Technician	Machine time	Tool	Cost ($)	Driver	Driver spent	Rate
Setup a part	0.1	0	0	0.11	Per setup	1	0.11
Run codes	12.6	12.6	0.11	24.11	Machining time	0.21	114.81
Measure the dimension	2.2	0	0	3.63	Number of dimensions	11	0.11
Setup tooling	18	0	0	5.64	Number of cutters	6	0.940
Total	32.9	12.6	0.11	33.49	Machining time	0.21	159.48

This cost is calculated by replacing the cost of Run Test Part activity in Table 4 with Eq. (7).

5.2. Decomposite the activity: Machine Prototype

Similarly, a more detailed analysis of the activity *Machine Prototype* is provided in Table 7.

Based on Table 7, we have the following equation to calculate the cost for running test part

$$\begin{aligned}\text{Cost for Machine Prototype}\\ &= 0.94 \times \text{Number of cutters}\\ &\quad + 114.81 \times \text{Machining hour}\\ &\quad + 0.11 \times \text{Number of dimensions} + 0.11. \qquad (9)\end{aligned}$$

The total cost in Eq. (8) can now be expressed in more detail as

$$\begin{aligned}\text{Total cost} &= 7.6 \times \text{Number of cutters} + 870.68\\ &\quad \times \text{Machining hour} + 0.22\\ &\quad \times \text{Part length} + 1.57\\ &\quad \times \text{Number of setups} + 0.29\\ &\quad \times \text{Number of dimensions} + 2.04\\ &= \$241.76. \qquad (10)\end{aligned}$$

This cost is found by replacing the Machine Prototype activity in Table 4, with more detailed description of Table 7. These costs are added to Eq. (8). This detailed view of the activities allows much better tracking of cost, value-added and non-value-added activities and the resources' usage and efficiencies.

6. 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 of many activities that are not directly linked to the finished product.

This paper presents a modified 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 rates 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 methodology is demonstrated and verified using sample rotational parts developed in a controlled manufacturing environment.

The method appears to be more accurate than 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 at the causes of the cost. This can provide a valuable insight into the factors that cause the cost, helping to better manage these activities.

The methodology can be extended by using feature-based cost estimation in coordination

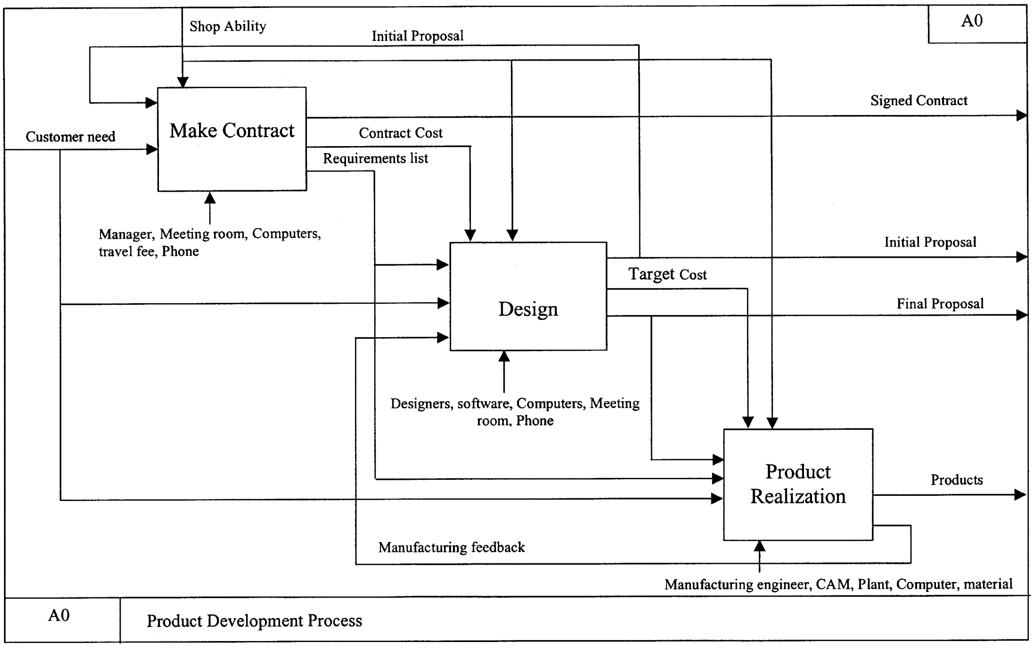
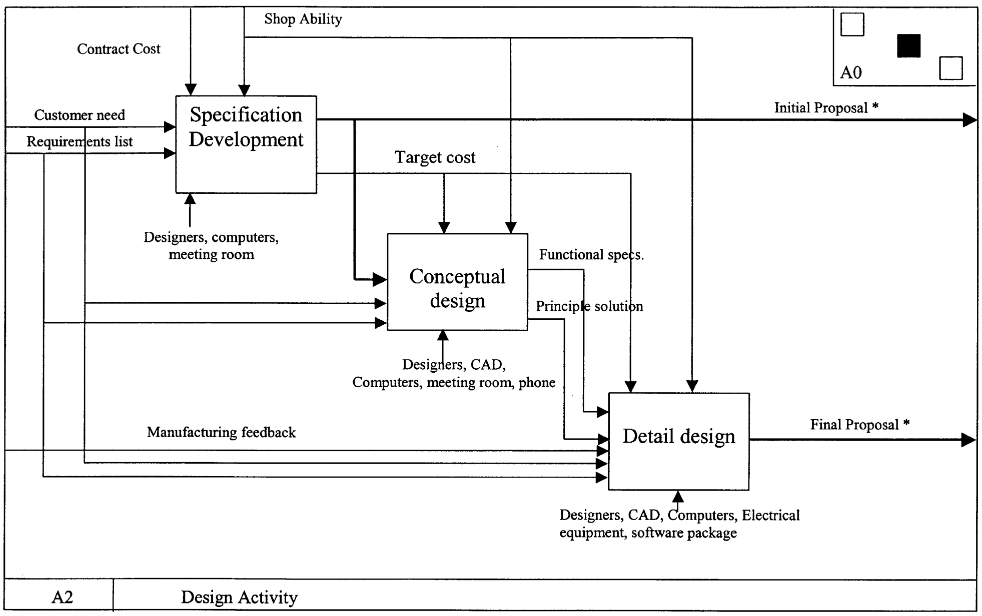


Fig. 4. Product development process.



Initial Proposal: Scope of work, Product development specification, Development guidelines & specification

Final Proposal: Final Design documentation for separate module , system integration documentation & cost estimate documentation

Fig. 5. The design activity.

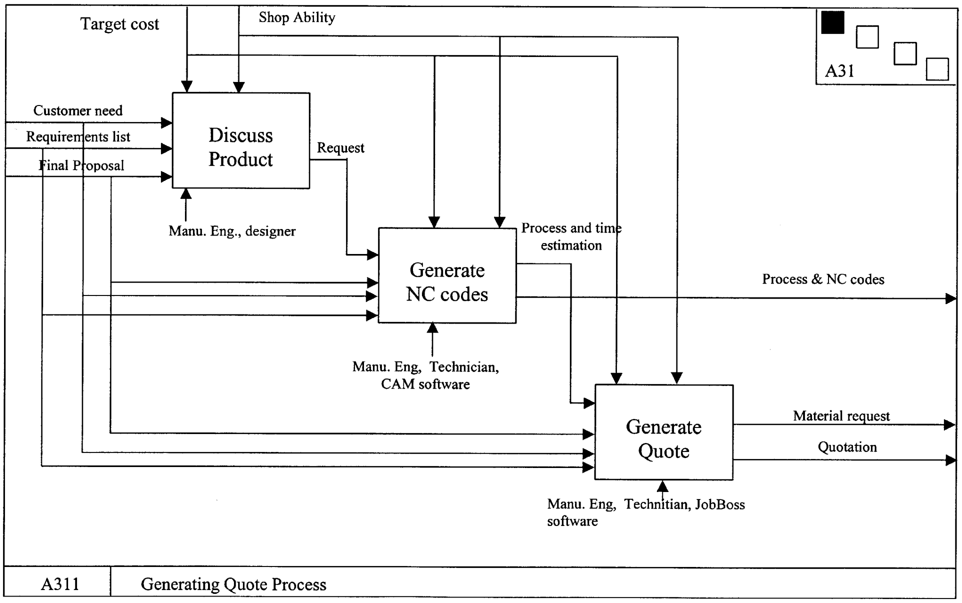


Fig. 6. Generating price quotations.

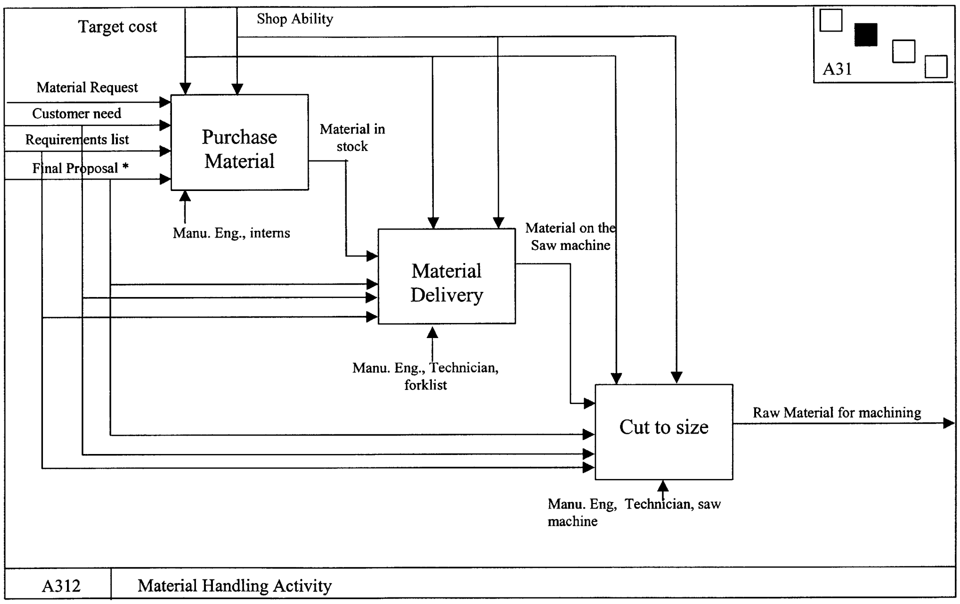


Fig. 7. The material handling activity.

with ABC. This will allow designers to evaluate the cost of a product very early during the design stage based on committed geometrical properties.

Appendix A. $IDEF_0$ modeling of selected activities

The activities involved in the design and development of a product are modeled using

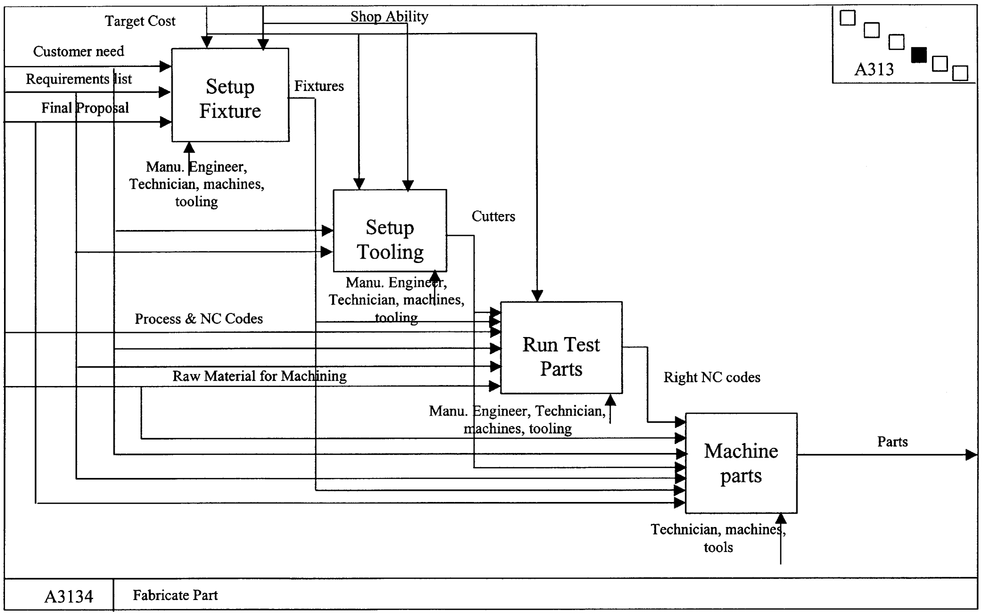


Fig. 8. The machining activity.

IDEF$_0$ diagrams. Figs. 4–8 present the corresponding IDEF$_0$ diagrams.

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