A pragmatic approach to product costing based on standard time estimation

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Abstract *Proposes a pragmatic approach to product costing. The approach involves two stages, namely the preparatory stage and the production stage. In the preparatory stage, standard routings are first extracted from existing products. A generic activity hierarchy is established according to the analysis of standard routings, where cost drivers for each activity are identified and summarized by appropriate Cost-related Design Features (CDFs). Then the Maynard Operation Sequence Technique (MOST) is employed to analyze each operation of standard routings to determine the associated standard time. Historical cost data are analyzed to induce the relationships between the CDFs and standard time, namely Time-Estimating Relationships (TERs). By allocating plant-wide overhead costs to standard routings, the unit price of standard time is established to indicate Cost-Estimating Relationships (CERs). A library of material costs is also summarized from existing products. In the production stage, CDFs are first induced from the schematic of a new design. Then a "dummy process plan" for this design can be inferred and used to retrieve the associated TERs to determine its time estimate. Once a standard time has been estimated, CERs can be applied to compile the total product cost by adding the estimated material costs. A case study conducted in an electronics enterprise is also reported.*

1. Introduction

Manufacturing is often viewed as the entire process of delivering an artifact in response to customer needs. Product design plays the central role within this broad view of manufacturing. It is well known that, particularly in discrete goods manufacturing, a predominant percentage (up to 85 percent) of the manufacturing cost of a product is established through decisions made during the product design stage (Whitney, 1987). This implies that the largest impact on product cost can be made in the design process. Therefore, the ability to make design decisions is dependent upon the availability of cost estimates for each alternative during the early development phase (Ostwald, 1992). Such a process of estimating the final cost of a product at the design stage is often referred to as product costing (Sheldon *et al.*, 1991). Product costing supports the entire product realization in two aspects. First, they make designers aware of a product's suitability for production, thus indicating potential cost reduction areas (Keys *et al.*, 1987). Second, production costs are an important

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part of the total product cost, hence estimation of these costs helps to determine appropriate sales prices (Ostwald, 1992).

Resulting from its paramount importance, product costing has received enormous attention and popularity in industry and academia alike (Sheldon *et al.*, 1991; Ostwald, 1992). Though a number of methods have been proposed and practiced, there is still much to be desired due to the hindrance inherent in the product costing process. Product costing involves quite a few instruments such as the description of the product (the technical system to be made), knowledge about the manufacturing systems and technologies, recognition of the markets regarding raw materials and semi-finished goods, application of cost calculation methods, and so on. The difficulties associated with product costing lie in several aspects including lack of manufacturing knowledge, dependence on detailed design description, no structured mapping between design and production, and contextual heterogeneity. First, cost estimation has traditionally been the province of manufacturing engineering. Typically, the product cost is derived from the summation of various cost components such as materials, machine hours, direct labor, administration, and engineering costs (Ostwald, 1992). However, cost accountants often do not have sufficient knowledge of manufacturing processes and the cost incurred therein (Sheldon *et al.*, 1991). Second, a reliable cost estimation requires detailed knowledge of product design and process plans. Usually, a complete description of the product is not available at the conceptual phase (Hundal, 1993). Third, relationships between design attributes and their cost figures are often not clearly available in the early design stage. It is difficult, if not impossible, to establish accurate cost structures according to the sources from which they arise and approximate cost functions accurately according to actual cost data (Ulrich and Fine, 1990). Lastly, different departments within manufacturing organizations focus on different cost-carrying areas, thus employing different costing methods and using various sets of costing data for different purposes. Cost accountants are always under great pressure to produce a wide variety of cost information for various decision makers and to maintain the coherence of diverse cost structures so that a variety of costing methods can be supported (Sheldon *et al.*, 1993). This is particularly important in the contemporary business environment where there is a growing emphasis on time-based competition as well as a greater degree of customization of products. The emerging paradigm of mass customization emphasizes the coordination among sales, marketing, design, and manufacturing, where cross-functional product costing plays an important role in matching a company's process capabilities with the window of market niches (Tseng and Jiao, 1996).

To address the above issues, this paper proposes a pragmatic approach to product costing prior to the actual production run by adopting the ABC (Activity-Based Costing) concept and utilizing historical cost data. To allow the designers to make a good trade-off decision, this approach emphasizes modeling cost information and identifying the product cost during the early design stage where only a schematic design may be available, yet a large

proportion of the manufacturing cost is still to be determined. The work reported in the paper is summarized from an industrial project with a local electronics enterprise. Its main products are power supplies that represent typical characteristics of electronic product design and manufacturing.

The remainder of the paper proceeds as follows. In the next section, different existing approaches to product costing are summarized. Section 3 presents a Pragmatic Product Costing (PPC) approach along with its systematic framework. A case study of PPC implementation is described in Section 4. Testing results and discussions are also given in Section 4. Finally, conclusions are drawn in Section 5.

2. Literature review

Although there is a considerable amount of literature available on product costing, the first comprehensive work was published by Ehrlenspiel (1985). The book provides guidelines and rules for lowering product costs, and methods for estimating these during the design process. A continual emphasis in the book is on the systematic design method (Pahl and Beitz, 1988). They pointed out that while products are influenced at all stages of their life-cycle – from design order to sales – the most important factors are the concept, size of the product, and number of parts. Ott and Hubka (1985) described a method for calculating the manufacturing cost of weldments based on weld dimensions. They calculated the time requirements for each welding operation. Ostwald (1992) provided a thorough treatment of cost estimating, including the pertinent topics of operation and product cost estimation. A discussion of practices in manufacturing, construction, as well as chemical, electronic and mechanical industries is given by Sheldon *et al.* (1991). Various costing methods can be classified in terms of categorization of manufacturing costs, cost structures, and cost models.

Total manufacturing costs can be classified in several ways (Ostwald, 1992). For example, they may be divided into material and production costs. They may also be categorized as direct costs and overhead costs. Further, the costs may be divided into variable costs that consist of direct costs and variable overhead costs, and fixed costs that remain constant over a period of time. It is the variable costs that can be influenced most at the design stage (Hundal, 1993). The predominant approach conventionally employed in cost estimation is what is termed the “burdened” (Fritz and Kimbler, 1996) or “volume-based” (Fendrock, 1992) costing approach. It uses an allocation base such as direct labor dollars, machine hours, or material dollars to assign indirect costs to products. The assumption is based on the unit-level characteristics of the products where the allocation base is directly proportional to product volume (the number of product units) and resources are consumed in proportion to product volume. In many cases, however, high-volume products are over-costed while low-volume products are under-costed. As argued by Fritz and Kimbler (1996), this method can significantly distort product pricing in

operations that encounter fluctuations in production, volume, complexity, size, materials, and setup, where volume-based allocations are not directly proportional to production volume.

A cost structure shows the breakdown of the product cost according to one of several criteria such as parts, types of cost, functions, production processes, etc. Sheldon *et al.* (1991) classify cost structures into four types: organizational breakdown based on departments and units, general breakdown based on elements and features of the products, functional breakdown based on functions of the products, and work breakdown based on activities. Ehrlenspiel (1985) used a magnitude-based costing analysis to categorize products according to particular properties, such as weight and costs. This approach highlights the more important aspects of the design according to the chosen category. Hundal (1993) emphasized the aid of value analysis to increase the value-to-cost ratio of a product. French (1990) advocated function-costing to provide designers with a technique for estimating costs directly from the specification of a product. Activity-based costing adopts the work (activity) breakdown structure to assign indirect costs more accurately and gives greater visibility to manufacturing activities for planning and control (Innes and Mitchell, 1990).

Among many costing models in design, the most noteworthy are those based on operations, weight, material, throughput parameters, physical relationships, regression analysis, and similarity laws (Ostwald, 1992). The regression approach tries to find the dependence relationships between costs and product characteristics such as size and materials. The coefficients and exponents are derived through the regression analysis of historical cost data (Pscyna *et al.*, 1982). The group technology based approach is based on the similarity principle. It typically uses a basic cost value while taking into account the effects of variable cost factors such as complexity and size. Linear relationships between the final costs and the variable cost factors are always assumed (Hundal, 1993).

In summary, the majority of the literature addressing cost estimating techniques to date focuses primarily on the final production function, i.e. manufacturing. The problem lies in that complete product design information must be available before an estimate can be computed. Current trends towards compression of design to market times have impeded their use as the time required for gathering cost data and performing cost studies is eroded (Bush and Sheldon, 1995). In addition, many cost estimation techniques have been developed for different products based on various cost drivers. The explicit cost drivers, such as material cost, can be obtained directly while the implicit ones, such as design complexity-related costs, have to be derived through analysis of historical cost data. Therefore, the linchpin to product cost estimation is how to use historical cost data to understand the implicit cost drivers. Moreover, in today's manufacturing environment, direct labor costs are decreasing because of the application of advanced manufacturing technologies and management techniques, and costs are shifting from direct to indirect

(Brismon, 1986). Accordingly, traditional costing, mainly using direct labor to allocate the indirect (overhead) costs to products, will distort product costing. In view of this deficiency, activity based costing (ABC) divides the overhead costs into several pools and has been recognized as a more rational approach to determining how and why the overhead costs arise (Innes and Mitchell, 1990). The main disadvantage of ABC is the difficulty in obtaining accurate information which would enable the proper allocations (Hundal, 1997), that is, it is difficult to obtain the cost per unit of the activity's output (unit price of a cost driver). It has also been argued that ABC requires detailed activity analysis, which implies significant changes in existing cost accounting systems (Sheldon *et al.*, 1991).

3. A pragmatic product costing approach

The standpoint of the PPC approach is to utilize historical costing data. The rationale manifests itself through the fact that most engineering designs involve modifying existing products instead of starting from scratch. Accordingly, patterns of cost estimation in existing products are applicable to a new design. For this type of variant design, where similar work has been done before, there is greater knowledge of costs that can be extrapolated to a new product with a higher degree of confidence. Although in the earlier stages of design the cost estimation can only be approximate, decisions made in its absence can be costly (Hundal, 1997).

The PPC approach adopts the ABC concept to identify the underlying activities that drive costs. These activities are then used as building blocks to construct the costs of a given process or work center. However, the hindrance inherent in ABC lies in how to determine the resource consumption in terms of number of cost drivers for each activity and the unit price of each activity with respect to a particular cost driver. Instead of dealing with these trivia, the PPC approach determines resource consumption according to the estimated processing time for each activity timed by the unit price of standard time. This intermediate measurement provides a common, consistent metrology to approximate various cost functions for different activities and cost drivers. The feasibility is embodied by the large amount of effort devoted to standard time estimation from both research and practice, such as work measurement and time study (Hodson, 1992). Table I gives a comparison of ABC and PPC.

Instead of reliance on detailed design information and manufacturing knowledge, the PPC approach aims at a rapid cost estimation without developing detailed process plans. Considering that a large majority of products follows a finite set of process routings, the PPC approach first extracts these standard routings generic to all the products according to historical production documents. Every standard routing is associated with a set of design characteristics that can be employed to determine the possible standard routings applied to manufacturing a given product. These characteristics are

Typical activity-based costing (ABC)				
Operation A	Cost drivers (CDs)	Consumption (# of CDs)	Unit price of cost drivers (\$ per CD)	Calculated costs for each activity
Activity A1	CD_{A1}	X_{A1}	CI_{A1}	$C_{A1} = (X_{A1})^* CI_{A1}$
Activity A2	CD_{A2}	X_{A2}	CI_{A2}	$C_{A2} = (X_{A2})^* CI_{A2}$
Activity A3	CD_{A3}^1	X_{A3}	CI_{A3}^1	$C_{A3}^1 = (X_{A3}^1)^* CI_{A3}^1$
	CD_{A3}^2	X_{A3}^2	CI_{A3}^2	$C_{A3}^2 = (X_{A3}^2)^* CI_{A3}^2$
Ai	CD_{Ai}	X_{Ai}	CI_{Ai}	$C_{Ai} = (X_{Ai})^* CI_{Ai}$
Estimated cost of operation A				$\sum(C_{Ai})$
Pragmatic product costing (PPC)				
Operation A	Cost-related design features	Consumption (# of CDFs)	Time-estimating relationships (TERs) (sec per activity)	Cost-estimating relationships (CERs) (\$ per hour)
Activity 1	CDF_{A1}	X_{A1}	$StdT_{A1} = K_{A1}^* X_{A1}$	y
Activity A2	CDF_{A2}	X_{A2}	$StdT_{A2} = K_{A2}^* X_{A2}$	
Activity A3	CDF_{A3}^1	X_{A3}^1	$StdT_{A3} = K_{A3}^1 * X_{A3}^1$	
	CDF_{A3}^2	X_{A3}^2	$+ K_{A3}^2 * X_{A3}^2$	
Ai	CDF_{Ai}	X_{Ai}	$SdtT_{Ai} = \sum(K_{Aij})$	
Total estimated time of operation A			$SdtT = \sum(StdT_{Ai})$	
Total estimated cost of operation A			$(StdT/60)^* v$	

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Table I.

A comparison of ABC with PPC

referred to as Cost-related Design Features (CDFs) and are treated as indexes to infer a “dummy process plan” for rapid cost estimation in PPC approach. Usually CDFs can be determined from a schematic in an early stage of design.

The PPC approach involves two stages, namely the preparatory stage and the production stage (Figure 1). In the preparatory stage, standard routings are first extracted from existing products and depicted by a Process Flow Diagram (PFD). A generic activity hierarchy is established according to the analysis of standard routings, where cost drivers for each activity are identified and summarized by appropriate CDFs. Then the Maynard Operation Sequence Technique (MOST) is employed to analyze each operation of standard routings to determine the associated standard time. Historical cost data are analyzed to induce the relationships between the CDFs and standard time, namely Time-Estimating Relationships (TERs). By allocating plant-wide overhead costs to standard routings, the unit price of standard time is established to indicate Cost-Estimating Relationships (CERs). A library of material costs is also summarized from existing products. In the production stage, CDFs are first induced from the schematic of a new design. Then a “dummy process plan” for this design can be inferred and used to retrieve the associated TERs to determine its time estimate. Once standard time has been estimated, CERs can be applied to compile the total product cost by adding the estimated material costs.

Figure 1.
Two-stage methodology
of PPC

3.1 Standard routing development

The development of standard routings depends on both the knowledge of domain experts and the product history. An effective approach is first to analyze the product database for standard routings and then to use expert opinion on process plans and cost estimation to consolidate the results. A

Process Flow Diagram (PFD) is suggested to describe standard routings in a formal way. Figure 2 gives an example of such a PFD for the PCB assembly of encapsulated AC/DC converters.

3.2 Activity hierarchy formulation and CDF identification

To establish the cost structure of ABC, each operation in a standard routing is treated as a cost center and analyzed to determine the activities that fulfill this operation. All activities associated with each cost center can be organized by an activity hierarchy. An activity hierarchy adopts a combined decomposition (“a_part_of” link) and classification (“a_kind_of” link) tree to represent various inter-relationships among activities. Figure 3 shows the activity hierarchy for the operation of a heat sink sub-assembly.

The ramifications of an activity hierarchy depend on the identification of cost drivers for each activity. In the PPC approach, cost drivers associated with specific activities are identified according to whether the consumption of an activity can be appropriately expressed in terms of design features instead of adopting the process characteristics as most ABC efforts have practiced. In such a way, a set of Cost-related Design Features (CDFs) performs as the cost drivers to comprise a “dummy process plan” and to indicate the consumption of activities. Figure 3 illustrates the breakdown of an activity hierarchy in parallel to the identification of appropriate CDFs.

3.3 Standard time establishment and TER approximation

The importance of establishing time standards for improving labor efficiency and organizational performance has been well recognized (Kilgore, 1997). In practice, most companies have laid the groundwork for predetermined time standards such as Motion Time Analysis (MTA), Work-Factor (WF), Basic Motion Time Study (BMT), and Methods of Time Measurement (MTM) (Hodson, 1992). The PPC approach aims at taking the advantages of standard data to alleviate difficulties in ABC implementation.

A popular technique for work measurement, namely, the Maynard Operation Sequence Technique (MOST[®]) is adopted as the core in PPC to synthesize the standard time data associated with standard routings. MOST[®] for Windows[™] (Maynard, 1997) is a Windows-based work measurement tool that enables analysts to create and maintain a database of work elements. The software automatically produces the time for each method step and sub-operation based on the keyword method description entered by analysts. Final time standards are developed by further considering the technological and managerial allowances, as shown in Figure 4.

All standard time estimates obtained from MOST[®] are validated according to the actual data of existing products. Accordingly, the Time-Estimating Relationships (TERs) for individual activities are induced in terms of the cost drivers (i.e. CDFs) associated with specific activities. Figure 3 illustrates how the TERs are derived. The derivation of TERs is based on the regression analysis that provides the formula for calculating the time for various elements

Figure 2.
Process flow diagram
(PFD) for the PCB
assembly of encapsulated
AC/DC converters

Figure 4.
Standard time
establishment

contained in the study. The formula is as follows: $StdT_i = K_{i1} * CDF_{i1} + K_{i2} * CDF_{i2} + \dots + B_i$, where $StdT_i$ is the time estimate for activity i , CDF_{ij} is the j -th cost driver associated with activity i , K_{ij} is the coefficient of $StdT_i$ with respect to the CDF_{ij} , and B_i is the intercept. The determination of coefficients is based on the method of least squares, which basically tries to find the line where the sum of the squares of the deviation of each data point from the line is a minimum. Usually, a statistical package, such as Statistica or SAS, can be adopted to simplify this approximation process. More dedicated parametric estimation equations can also be derived by using statistical analysis methods, e.g. $StdT_i = A * (CDF_i)^B$, where A and B are empirically derived constants.

3.4 Overhead cost allocation and CER development

The derivation of Cost-Estimating Relationships (CERs) is based on the allocation of overhead costs at different levels of a company. A good starting point is to use historical cost data along with the collective knowledge of experts from different divisions. The middle portion of Table II depicts a typical cost computation sheet for various cost centers of standard routings, i.e., the indirect cost pool. The right-hand column of Table II calculates the overhead costs at the plant level, such as selling, general and administration (SG&A), that are different from those of cost centers. Table II illustrates how plant-wide overhead costs are translated into the manufacturing cost pool via

Period (96.6-96.12)	Indirect cost pool			Plant-wide overhead costs		
Indirect cost	Work centers in std routings			Selling, general and administration		
Account category	Soldering	Testing	...	Planning	Shipping	...
<i>Salaries and wages</i>						
Indirect labor	a1	b1	...	p1	s1	...
Premium	a2	b2	...	p2	s2	...
Vacations	a3	b3	...	p3	s3	...
<i>Personnel expenses</i>						
Travel		b4	...	p4	s4	...
Training	a4	b5	...	p5	s5	...
Recruiting		b6	...	p6	s6	...
Relocation		b7	...	p7	s7	...
<i>Supplies/services</i>						
Stationery		b8	...	p8	s8	...
General operating	a5	b9	...	p9	s9	...
Maintenance	a6		...	p10	s10	...
Utilities	a7	b10	...	p11	s11	...
<i>Fixed charges</i>						
Depreciation						
Equipment	a8	b12	...	p12		...
Property	a9	b13	...		p13	...
Equipment rental		b14	...			...
Property taxes			...	p14		...
Advertising			...	p15		...
.....	...	...	...	...	...	...
Sub-total	\$a	\$b	...	\$p	\$s	...
	$WCs = a + b...$			$PW = p + s + ...$		
Total indirect costs	$TIC = WCs + PW$					
Total standard time	$StdT = StdT_{Product_1} + StdT_{Product_2} + StdT_{Product_3} + ...$					
Cost per std time	$TIC/StdT$ (\$/hour)					

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Table II.
Overhead cost
allocation and CER
derivation

standard time estimation. In such a way, the overhead costs at different levels ranging from unit level, batch level, product level to plant wide, can be allocated to product activities that actually consume them. The employment of TERs enables the PPC approach to estimate the total product cost, not only the manufacturing cost. In traditional ABC practice, plant-wide activities have to be analyzed in terms of their cost drivers, the unit price of each activity, consumption of each cost driver, and so on. These efforts are deemed to be overwhelming, if not impossible.

Motivated by current global manufacturing trends, most companies are establishing geographically distributed plants to take advantage of different manufacturing sites. In the company under our study, there are two plants, located in Hong Kong and Zhong Shan, respectively. This distributed manufacturing raises more difficulty in allocating overhead costs. The activities, associated with logistics, different plant settings, etc., are very difficult to analyze by following traditional ABC procedures. In the PPC approach, however, TERs play an important role in unifying various activities with respect to different cost drivers. Therefore, dealing with distributed plants

can be simply reflected by inducing the proportion of standard labor hours for each plant, as illustrated in Tables III and IV. Table III summarizes the CERs of our case study. In addition to facilitating the handling of distributed plants, the development of CERs possesses an advantage in considering various volume ranges which are emerging nowadays as one of the important characteristics of mass customization manufacturing.

3.5 Total product cost compilation

The product costing worksheet in Table IV illustrates the procedure of total product cost compilation in the PPC approach. There are three parts of costing, i.e. material costing, direct labor costing, and indirect cost estimation. Material cost is determined by referring to the price library and the component list. Types and quantities of various components can be derived from a design schematic. The price library consists of historical information from suppliers and is established during the preparatory stage. Once the total standard time has been estimated according to CDFs and TERs, the direct labor cost and overhead cost can be derived using appropriate CERs. The equation of total cost compilation is described in Table IV.

4. Implementation and testing results

By following the above procedures, the PPC approach has been implemented in the company under our study. Figure 2 shows the PFD for the PCB assembly of AC/DC converters. Figure 3 illustrates how the costing structure of PPC is developed. Figure 4 shows the considerations given to the establishment of standard time. Table III summarizes CERs for different volume ranges and plants. The Appendix gives an example of standard time calculation sheet. A worksheet of total product cost compilation is given in Table IV.

Material overhead rate: MOH = 12.7 % (per standard unburden material cost)
HK Labor rate: LR1 = 4.750 (per unit std labor in HK plant)
ZS Labor rate: LR2 = 0.830 (per unit std labor hour in ZS plant)

Volume range (VR)	Indirect labor rate (\$ per standard hour)		
	HK (LOH1)	ZS (LOH2)	Mixed (LOH3)
1-1K	7.250	2.850	4.550
1K-10K	3.300	1.550	2.900
10K-20K	2.250	1.250	1.600
20K-50K	1.700	0.900	1.200
50K-100K	1.510	0.600	1.000
100K-200K	1.313	0.550	0.900
200K-300K	1.120	0.450	0.700
300K-400K	1.100	0.300	0.650
Over 400K	1	0.192	0.580

Table III.
CERs for the company

<i>Material costing</i>	ALP45-7608	Product costing
Component list $\{CPI, i = 2, 2, \dots, m\}$ where m = total types of components	Schematic	
Direct material cost (\$): $C_M = \sum(CPI * UPI)$ where UPI = unit price of CPI	14.106	
Material overhead rate (%): MOH	12.7%	
Burdened material cost (\$): $CC_M = C_M^*(1 + MOH)$	15.8975	
<i>Standard time estimation</i>		
Activity hierarchy and TERs	CDFs	
Total stand time (hour): $StdT$	0.5137	751
<i>Direct labor costing</i>		
HK standard hour percent (%) δ	100%	
ZS standard hour percent (%): $1 - \delta$	0	
HK standard labor rate (\$/hour): $LR1^*$	4.750	
ZS standard labor rate (\$/hour): $LR2$	0.830	
Direct labor cost – HK (\$): $C_{DL1} = StdT * \delta * LR1$	2.4401	
Direct labor cost – ZS (\$): $C_{DL2} = StdT * (1 - \delta) * LR2$	0.000	
Total direct labor cost (\$): $CC_{DL} = C_{DL1} + C_{DL2}$	2.4401	
<i>Indirect cost estimation</i>		
Volume range: VR	120K	
Burdened labor rate – HK (\$/hour): $LOH1$	1.313	
Burdened labor rate – ZS (\$/hour): $LOH2$	0.550	
Burdened labor rate – HK/ZS (\$/hour): $LOH3$	0.900	
Total overhead cost (\$): $CC_{OH} = StdT * \delta * LOH1$ $+ StdT * (1 - \delta) * LOH2 + StdT * LOH3$	1.1368	
Total product costs (\$) $C_P = CC_M + CC_{DL} + CC_{OH}$	19.4744	

Table IV.
Product costing
worksheet

To test the potential of the PPC approach, 20 products have been selected as testing samples. The actual cost, estimated cost, and relative deviation for each sample product are shown in Table V. The relative deviation of cost estimation is calculated as:

$$RD = \frac{C(E) - C(A)}{C(A)} \times 100\%$$

where $C(A)$ and $C(E)$ denote the actual costs and the estimated costs, respectively. The average relative deviation of cost estimates is about 10 per cent. From Table V and Figure 5, it can be observed that the relative cost deviations of 19 samples (or 95 per cent of the total samples) are within ± 10 per cent. Cost estimation on 12 samples (or 60 per cent of the total samples) is even within the relative deviation of ± 5 per cent. The maximum cost relative deviation from the actual cost is about 12 per cent, which is still considered acceptable by the company.

5. Conclusions

The major drawbacks of traditional approaches to product costing include lack of manufacturing knowledge, reliance on the detailed design description, poor cost function approximation, and inability to update estimation algorithms by using actual cost data. A pragmatic approach has been proposed by adopting the ABC concept and based on estimated processing time, which shows

Table V.
Testing results

Product model	C(A) (\$)	C(E) (\$)	RD (%)
NFN40-7630E	14.71	13.72	-6.7
NFN40-7632E	10.94	11.15	1.9
NFS40-7608	9.97	1.066	6.9
NFS85-7632	11.46	11.42	-0.3
NFN25-7631E	8.43	8.84	4.9
NFS25-7629	24.01	24.22	0.9
NAN25-7610	7.69	7.73	0.5
NAL40-3215	6.16	6.37	3.4
NFS85-7630	7.45	7.37	-1.1
NAL40-3245	6.50	6.07	-6.6
NFN40-7643E	9.14	9.99	9.3
NAL40-7608D	9.18	8.95	-2.5
NFN40-7636E	6.25	5.98	-4.3
NFS45-7631	4.79	4.68	-2.3
NFS25-7608	8.53	8.39	-1.6
NFS110-7901P	9.00	9.80	8.9
NFS110-7902P	11.59	10.54	9.1
NFS110-7912	12.06	12.03	-0.2
NFS110-7915	10.58	11.47	8.4
NFS40-7644	8.05	7.10	-12
Average relative deviation			-9.35

Figure 5.
Relative deviation of
cost estimates

promise of reducing, if not eliminating, these drawbacks. Standard routings provide a basis for estimating time requirements based on historical data. The activity hierarchy helps to trace the underlying activities that drive costs and identify cost-related design features that enable rapid product costing. The allocation of plant-wide overhead costs to the manufacturing indirect cost pool facilitates total product cost estimation. The discrimination of TERs and CERs not only alleviates the difficulty in cost function approximation, but also simplifies the considerations of volume ranges, distributed manufacturing plants, and so on.

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Appendix: Standard time calculation sheet

STANDARD TIME CALCULATION SHEET FOR AC/DC MODELS										LAST UPDATED: JAN-03-95	
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PART NO.:		724830-251		MODEL NO.:		ALP45-7608				DATE : 10-Jul-97	
STD TIME :		0.5143 HOUR									
NOTE : [M= FREQUENCY OF HANDLING THE PCB UNLESS SPECIFIED OTHERWISE]											
[N= NO. OF COMPONENTS UNLESS SPECIFIED OTHERWISE]											

CODE	DESCRIPTION				CYCLE TIME (SECOND)				TOTAL (SEC)		

WORKCENTRE : PCB PREPARATION											
ST15	SOLDER MASK WITH TAPE [N= NO. OF POINTS]			M =	N =	3.24	M +	10.08	N	0.0	
ST15	ADHERE TAPE ON PCB [N= NO. OF TAPES]			M =	N =	3.24	M +	5.04	N	0.0	
CP21	MOUNT H/S BY POP RIVETS [N= NO. OF RIVETS]				N =			11.99	N	0.0	
CP23	SILK SCREEN PAINTING			M =		83.99	M			0.0	0
WORKCENTRE : AUTO-INSERTION											
AI01	AUTO-INSERT AXIAL COMPONENTS			M =	1	N =	19	24.01	M +	0.94	N 41.9
	[M = NO. OF PCB, N = NO. OF COMPONENTS]										
WORKCENTRE : COMPONENT PREPARATION & STUFFING											
CP02	2-LEAD AXIAL COMPONENT H-M WITH BEND & CUT				N =	1		11.88	N	11.9	
CP02	2-LEAD AXIAL COMPONENT V-M WITH BEND & CUT				N =	6		12.60	N	75.6	
CP02	2-LEAD RADIAL COMPONENT V-M WITH BEND & CUT				N =	14		12.96	N	181.4	
CP02	BRIDGE DIODE V-M				N =			11.16	N	0.0	
ST08	FUSE & FUSE GRIP				N =	1		21.24	N	21.2	
CP02	JUMPER WIRE WITH BENT LEAD (BARE WIRE)				N =	1		23.40	N	23.4	
FA05	TOP WIRE (STRIP + CRIMP + STUFF)			M =	N =		M +	0.00	N		
ST09	[M= NO. OF WIRES , N= TOTAL NO. OF CRIMPED ENDS]										
ST11	INDUCTOR WITH BENT & CUT LEAD				N =	3		21.60	N	64.8	
CP12	CONNECTOR WITH STRAIGHT PIN REMOVED & LEAD TRIMMED				N =	2		13.32	N	26.6	
ST14	TRANSFORMER WITH N LEAD BENT			M =	2	N =	8	12.60	M +	1.44	N 36.7
	[M= NO. OF XFMR, N= TOTAL NO. OF BENT LEADS]										
ST14	INSERT H/S ASSY ONTO PCB			M =	2	N =	3	9.00	M +	5.40	N 34.2
	[M= NO. OF H/S , N= NO. OF TRANSISTOR]										
ST17	INSERT DAUGHTER BOARD				N =	1		5.04	N	5.0	481
WORKCENTRE : H/S SUB-ASSEMBLY											
H/S SUB-ASSEMBLY :											
HS03	1 H/S + N TRANSISTORS (BY SPRING CLIP)			M =	2	N =	3	15.84	M +	23.04	N 100.8
ST12	[M= NO. OF H/S], [N= TOTAL NO. OF XSTR]										
HS03	1 H/S + N TRANSISTORS (BY SCREW MOUNTING)			M =	N =		15.84	M +	32.40	N	0.0
ST12	[M= NO. OF H/S], [N= TOTAL NO. OF XSTR]										
SA20	1 H/S + 1 DIODE (BY DIP SOLDERING) [N= NO. OF H/S ASSY]				N =			27.79	N	0.0	
SA03	1 H/S + N DIODE (BY HAND SOLDERING)			M =	N =		19.80	M +	9.00	N	0.0
ST13	[M= NO. OF H/S], [N= TOTAL NO. OF DIODES]										
SA20	2 H/S + N DIODES			M =	N =		17.28	M +	27.72	N	0.0
ST13	[M= NO. OF PAIRS OF H/S], [N= TOTAL NO. OF DIODES]										
SA20	3 H/S + 4 DIODES [N= NO. OF H/S ASSY]				N =			123.12	N	0.0	100.8
PANEL ASSEMBLY:											
PA01	SOLDER TWO WIRES [N= NO. OF SOLDER JOINTS]				N =			41.76	N	0.0	
PA02	PREPARE TWIN WIRE (MANUAL) + STRIP (4 ENDS)				N =			43.20	N	0.0	
FA05	MANUAL WIRE CRIMPING (CUT/STRIP/CRIMP)			M =	N =	1.44	M +	14.40	N	0.0	
	[N= NO. OF CRIMPED ENDS]										
PA03	MOUNT FUSE SOCKET BY NUT AND INSERT FUSE				N =			75.96	N	0.0	
	[N= NO. OF FUSE]										
PA04	MOUNT LUG BY ELECT. SCREWDRIVER [N= NO. OF LLM =				N =	10.08	M +	25.92	N	0.0	
PA05	MOUNT SOCKET BY ELECT. SCREWDRIVER [N= SCREWS =				N =	10.08	M +	10.08	N	0.0	
PA06	MOUNT SOCKET BY PLUG-IN [N= NO. OF SOCKET]			M =	N =	10.08	M +	6.84	N	0.0	
PA07	PLUG WIRE INTO SOCKET [N= NO. OF WIRES]			M =	N =	4.50	M +	3.24	N	0.0	
PA08	MANUAL SOLDER WIRE TO SOCKET/FUSE/TAB			M =	N =	10.08	M +	28.44	N	0.0	
	[N= NO. OF SOLDER JOINTS]										
PA09	APPLY HEAT-SHRINKABLE TUBE (MANUALLY)				N =			36.00	N	0.0	
PA10	STRIP WIRES [N= NO. OF STRIP WIRES]				N =			5.04	N	0.0	
PA11	PLUG CRIMP WIRE TO PCB [N= NO. OF CRIMPED END:M =				N =	10.08	M +	6.84	N	0.0	
PA12	TEST LED SUB-ASSEMBLY				N =			7.92	N	0.0	

* This sheet has been truncated due to space limitations.