Global Advanced Research Journal of Management and Business Studies (ISSN: 2315-5086) Vol. 3(10) pp.445-456, October, 2014
Available online http://garj.org/garjmbs/index.htm

Full Length Research Paper

An Activity Based Costing-based : A Case Study of a Taiwanese Gudeng Precision Company

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Accepted 22 October 2014

Traditional cost accounting allocation of manufacturing costs is not rigorous enough, resulting in product cost structure distortions. This responsibility for company operation should be internalized into business operations--prior to production--in order to reflect the true cost of the final product. Due to the use of traditional cost accounting, many organizations have not estimated their productional costs precisely. In this paper, we propose an integrated concept the Activity-Based Costing approached to solve the problem of manufacturing and cost evaluation. We include a case study of an Gudeng Precision Company (Semiconductor Process Equipment Factory) in Taiwan to show that the activity-based costing method estimates semiconductor front-end equipment manufacturing costs of a final product more accurately than traditional approaches do. The method can, therefore, provide information for use in existing manufacturing accounting systems and help managers incorporate manufacturing costs into their decision-making

processes.

Keywords: Activity-Based Costing, manufacturing cost, Semiconductor Process Equipment Factory

INTRODUCTION

Presently, the semiconductor manufacturing industry has been growing at a moderate pace in Taiwan. Both the OEM of semiconductor manufacturing industry outputting value of 15,987 billion in 2012 (accounting for 73% of the world) and IC packaging testing industry were the world's first. In the TSMC(Taiwan Semiconductor Manufacturing Company) and UMC (United Microelectronics Corporation) of semiconductor manufacturing company, there were more than 60% of the global market share ranking the global IC manufacturing championship(SIPO ,2012). From this reason, the Gudeng Precision Company (Semiconductor Process Equipment Factory, SPEF) were benefited from the semiconductor manufacturing industry.

The process of IC chip manufacturing was mask circuit from wafer in wafer lab. In method of oxidation, diffusion, CVD, etch, ion implantation, the components of the circuit on the wafer were produced. Through completion of the wafer testing, packaging and other steps, the IC chip will be finished (Figure 1). Because the IC circuit design is a layered structure, A complete integrated circuits were repeated through the step of several mask input, graphics production, and the formation of lines. In this research, The Gudeng Precision Company of main production were Photo mask case and Mask package shipping box. The IC chip was placed in the Photo mask case for the process of transportation and storage to maintain its cleanliness protected against air dust pollution and electrostatic damage. Finally, The IC chip would improve its yield under the lithography process. The Photo mask case was made of ether ketone thermoplastic material from Victrex plc., LTD. The Photo mask case is used to generate from High Performance Engineering Plastics and Specialty Compound **by** Asiatech Co., LTD. Due to the expensive raw materials, there are two reason for this research: (1)There has been increasing concerns of rising cost during the past decade. There are no record statics on the profit margin of the SPEF.It is only slightly higher compared to other manufacturing industries.

The traditional cost of the product is divided into direct materials (such as wafers), direct labors (for example, the production line operator) and manufacturing costs (such as depreciation, utilities, rent, etc.). The cost of direct materials and direct labors can be directly attributable to individual products. The manufacturing cost is based on a simple ratio allocated to the product. Under the rapid progress of semiconductor manufacturing technology, The more wafer process (such as 6-inch, 8-inch, 12-inch) is complex, the more cost of the products is sophisticated. The cost of the product has been distorted. Surprisingly, there has been no formal methodology for estimating the product costs in the SPEF in Taiwan. As a result, the actual product costs are unknown. The management specifies the product costs and selling prices of each product based on their experience and competitor's strategies. The factory would change the prices of the products often to compete with its competitors. Therefore, a more accurate costing system is

needed for estimating product costs in this industry.

Activity-based costing (ABC) is an accounting technique that allows an organization to assign costs to products based on the resources they consume. It recognizes the causal relationship between cost drivers and cost activities by measuring the cost and performance of process-related activities and cost objects (MacArthur,1996).ABC has been implemented successfully in various service and manufacturing industries. In the major book manufacturing firm, this industry can effectively apply cost to activities of the planning process for each individual job as a direct cost, rather than an indirect one(Walker et al,2000). The ABC measurement which can measure the treatment activities more precisely(Tsai and Hung,2009) The main motivation for a company to implement ABC is the need for reliable cost information.Cost accounting literature has argued that traditional cost accounting systems are obsolete in a new environment characterized by modern production technology; ABC has been offered as a solution (Cooper & Kaplan,1991) . ABC systems differ from traditional costing systems in how they are able to model the use of all resources in all the activities performed by these resources, and then link the cost of these activities to products (Hundal,1997;Park &Simpson,2008). In the ABC system, costs are traced by activities across departments or cost centers(Cao et al, 2006;Lin et al, 2007). ABC provides information about a product's cost based on the resources used in its production(Kee & Matherly,2003). The causal relationship between products and customers that consume resources is determined by tracing the cost of the factor (cost driver) that is caused by (or correlates highly with) a product's or customer's use of an activity's resources(Kee & Schmidt, 2007) . Traditional cost accounting methods do not accurately reflect the contributions of indirect costs to individual activities. Instead, they pool all indirect costs and allocate them to various products (services) in proportion to product (service) volume or direct costs(Kee, 1995). ABC solves this problem by estimating the cost of the activities that consume resources and by linking these costs to the products (services) that are provided(Cao et al, 2006;Lin et al, 2007). ABC products provides a better estimate of product cost as well as the cost of the individual activities used in its production (Kee, 1995). Surveys and interviews with managers who use ABC indicate that it is used to support a wide range of economic activities, such as environmental management (Tsai et al, 2009) and other activities in the environmental field. A detailed cost assignment view of ABC is shown in Figure. 2 (Tsai,2010). ABC focuses on the accurate cost assignment of overheads to products. In the cost assignment view, the assignment of costs through the ABC method occurs in two stages: At the first stage, resource costs are assigned to various activities by creating resource drivers. Each type of resource traced to an activity becomes a cost element of an activity cost pool. An activity cost pool therefore represents the total costs identified with an activity or activity center, which is usually clustered by function or process. At the second stage, the costs in each activity cost pool are allocated to cost objects by an activity driver which is used to measure the consumption of activities by the cost objects.

Previous studies have shown the feasibility of using the ABC in both service and manufacturing environments (Helmi,1991). However, most of the studies discussed benefits and implementation of the ABC in general. Only a few of these studies use real cost data to examine the difference between the ABC and the traditional costing system in a manufacturing environment. Furthermore,

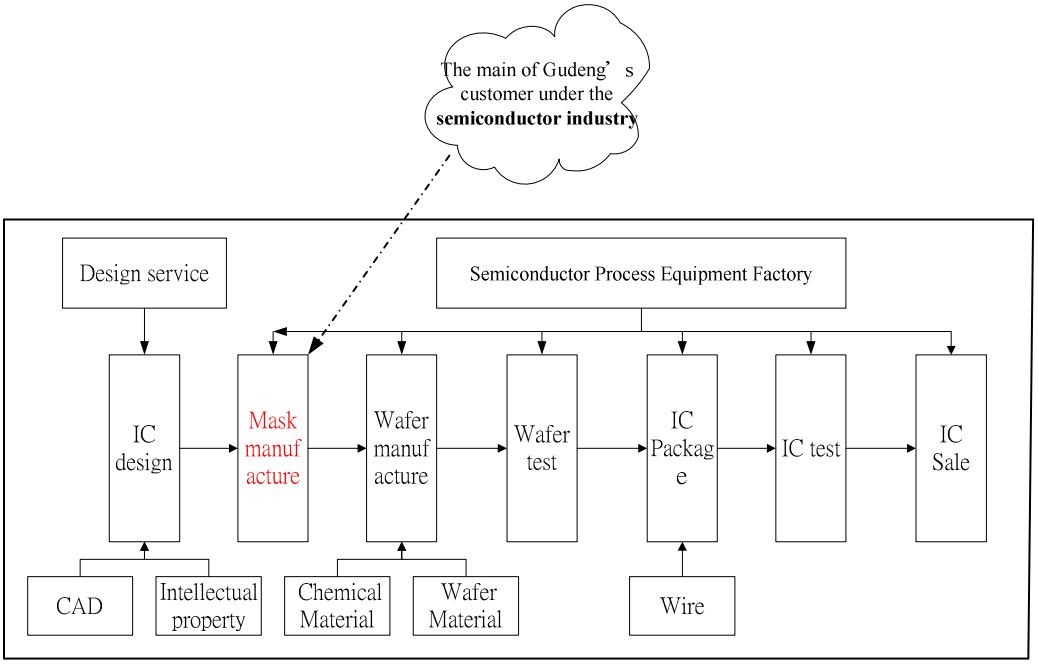

Figure 1. Taiwan's semiconductor industry structure diagram
Source: SIPO (2012)

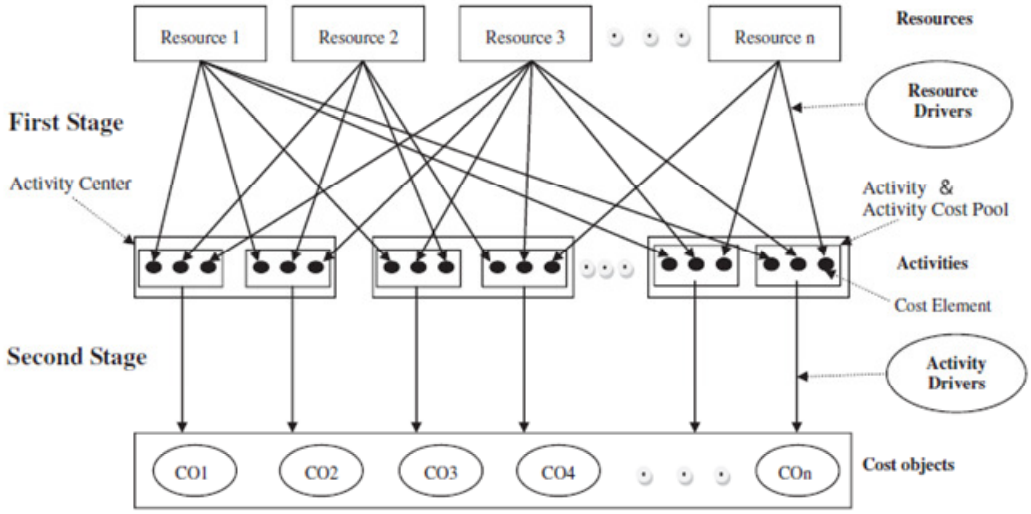

Figure 2. Detailed cost assignment view of ABC.

there has been no study in the application of the ABC to a SPEF . The primary objective of this research is to investigate the feasibility of applying ABC to a SPEF. A semiconductor services factory has been selected because its demand has been rapidly increasing during the past decade. Moreover, there has been widespread concern of high competition and rising costs, and its unique characteristics (for example, shape, size, component, color, etc.) make for a special challenge. As mentioned earlier, there has been no formal methodology

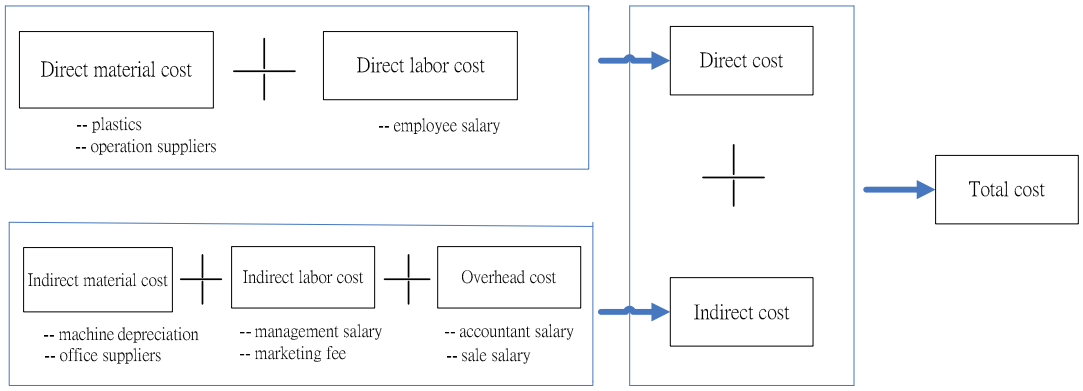

Figure 3. Analysis of the SPEF cost.

Table 1. Costs of Selected Products at the SPEF Using the Traditional Costing Method (December, 2012)

Product	Photo mask cases	Reticle SMIF pods	Mask clearners	Wafer cassetles	Wafer shopping boxes
Amount(number of units)	7,526	6,272	6,859	7,243	7,460
Sales($)	368,407	291,270	286,561	285,812	278,719
Direct material($/unit)	33.63	32.13	29.14	28.65	27.84
Direct labor($/unit)	6.3	5.67	4.97	4.12	3.76
Total direct($/unit)	39.93	37.8	34.11	32.77	31.6
Indirect material($/unit)	3.12	2.98	2.56	2.15	1.87
Indirect labor($/unit)	2.78	2.65	2.13	1.98	1.76
General overhead($/unit)	3.12	3.01	2.98	2.56	2.13
Total indirect($/unit)	9.02	8.64	7.67	6.69	5.76
Unit cost($/unit)	48.95	46.44	41.78	39.46	37.36

for estimating the product costs in a SPEF. Consequently, the actual product cost, which is the most essential information for pricing strategy, is unknown. For this reason, the ABC system is needed to improve the product costing/pricing.

METHODOLOGY

This research is concern with the development of a proper ABC model for the SPEF. There are four main steps in accomplishing this research. First, the product, process, and current cost system of the SPEF must be studied and analyzed. Second, a suitable ABC model must be developed and implemented at the factory.Third, a comparison between the current costing system and the ABC system has to be made. Finally, the benefits and obstacles in the application of the ABC system in the SPEF must be analyzed.

Table 2. Activity-Based Costing for a semiconductor services company

Costing item	Costing driver	Photo mask cases	Reticle SMIF pods	Mask clearners	wafer cassetles	wafer shopping boxes
Direct material	amount of usages	21.56	18.43	20.32	22.12	22.12
Direct labor	labor time(hr)	5.02	4.89	4.56	5.13	3.23
Depreciation	machine time	0.78	0.67	0.67	0.78	0.68
Fabricate	number of setup	0.23	0.21	0.18	0.23	0.21
Transportation	number of ship	0.18	0.13	0.21	0.18	0.29
Storage	space	0.05	0.04	0.03	0.05	0.04
Maintenance	machine time(hr)	0.21	0.18	0.2	0.21	0.18
Accounting	percentage of sale(%)	0.19	0.15	0.17	0.19	0.21
Marketing	percentage of sale(%)	0.24	0.22	0.26	0.24	0.23
Research &patent	percentage of sale(%)	0.41	0.43	0.44	0.41	0.39
Human resources	labor time(hr)	0.15	0.13	0.14	0.15	0.16
Procurement	percentage of sale(%)	0.31	0.28	0.32	0.31	0.3
Environmental protection	percentage of sale(%)	0.02	0.018	0.02	0.018	0.017
Miscellaneous	labor time(hr)	0.19	0.15	0.18	0.19	0.21
Unit cost		29.54	25.928	27.7	30.208	28.267

The Company Background

At this research, this company (SME) employed about 250 workers and focused on the semiconductor front-end lithography process equipment, parts sector, R & D photolithography process components. The Company of main production were Photo mask case and Mask package shipping box. The IC chip was placed in the Photo mask case for the process of transportation and storage to maintain its cleanliness protected against air dust pollution and electrostatic damage. In the market share of mask box products, The company provide the high-end masks carrier solutions for the TSMC company in the mask box products and become market leader in the world. Under the strategic superiority of the company's innovative service model, The company pays attention to the request of the complete supply chain of the world's semiconductor manufacturers, cooperation through various successful development of high value-added products and technologies. In 2012 year, This company won many reward, such as National Quality Award , National Industrial Innovation Award, Innovation Research Award, and Taiwan Excellence Award.

To better understand the company costs in general, an analysis and classification of the costs was made (Figure 3). There are two major cost components: indirect costs and direct costs. Indirect costs consist of indirect material cost (i.e., Mask Package , screws), indirect labor cost, as well as general overhead cost. Direct costs include direct material cost and direct labor cost.

Traditional Cost System for the SPEF

With respect to the traditional cost system for SPEF, the cost elements are broken down into direct and indirect costs. The direct costs are directly assigned to the product according to actual consumption rate. On the other hand,

Table 3. A Comparison between Activity-Based Costing and Traditional Costing System for the semiconductor services company

Product	Traditional cost system($)	ABC($)	Difference	
			($)	(%)
Photo mask cases	48.95	29.54	19.41	39.65
Reticle SMIF pods	46.44	25.93	20.51	44.17
Mask clearners	41.78	27.70	14.08	33.70
wafer cassetles	39.46	30.21	9.25	23.45
wafer shopping boxes	37.36	28.27	9.09	24.34

Table 4. A Comparison in Profits between the ABC System and the Traditional Costing System for the semiconductor services company

Product	sale Price ($/unit)	Traditional cost system($)			ABC($)		
		Cost ($/unit)	Profit ($/unit)	Profit (%)	Cost ($/unit)	Profit ($/unit)	Profit (%)
Photo mask cases	50.21	48.95	1.26	2.51	29.54	20.67	41.17
Reticle SMIF pods	48.43	46.44	1.99	4.11	25.93	22.50	46.46
Mask clearners	42.37	41.78	0.59	1.39	27.70	14.67	34.62
wafer cassetles	40.67	39.46	1.21	2.98	30.21	10.46	25.72
wafer shopping boxes	38.97	37.36	1.61	4.13	28.27	10.70	27.46

the indirect costs are allocated to each product using sale values in cost application (as shown in Equation (1)). The cost per product is expressed as follows:

$$UC_i = D_i + [\frac{TI}{TS} * \frac{TS_i}{N_i}] --(1)$$

Where UC_i is cost per unit for product i ($/unit) ; D_i is the amount of direct cost consumed by product i ($); TI is total indirect cost per month ($); TS is total sales (all products) per month ($); TS_i is total sales of product i per month ($); N_i is amount of product i (number of units); and i is individual product. Based on the traditional cost system (Table 1), the cost of each product can be averaged to get the average cost per unit. Thus, the cost per unit for Photo mask case (using Equation (1)) in this example is $48.95: [$37.32 + (266,111/1,510,769) × (368,407/7,526)]. The major problem in this approach is that it assumes that all products are alike (the indirect costs are equally assigned to each product based on sale values). This is an unreasonable assumption, because the resources (indirect costs) consumed by the product may vary significantly from product to product. This may lead to inefficiency in making decisions due to less accurate information.

Application of Activity-Based Costing in the SPEF

To improve the traditional costing system, the ABC system was adapted for this research (Figure 3). The cost per unit using the ABC system was calculated as follow:

$$UC_i = \mathrm{L}_i + \mathrm{M}_i + \sum_{j=1}^{m} X_{ji} \quad --(2)$$

where UC_i is cost per unit for product i ($/unit); X_{ji} is the amount of direct labor cost consumed by product i ($) ; L_i is the amount of direct material cost consumed by product i ($); M_i are costs associated with activity j assigned to product i (based on a specific cost driver, $); j is individual activity, 1, 2, 3, . . . , m; and i is individual product.

Implementation Procedure for Activity-Based Costing for the SPEF

There are six steps involved in adapting the ABC system to the ***SPEF*** in this research. There are outlined as follows:

Step 1. Identifying Products for Analysis

The first step is to select the products for this analysis. The selection may be based on volume (high volume), financial impact (high cost, low profitability), special interest (new product), or variance measures (high variance from cost estimation). For the purpose of illustration, the top five products accounting for 78.45% of all sales are considered for this research. They are Photo mask cases, Reticle SMIF pods,Mask clearners,Wafer cassetles, and Wafer shopping boxes.

Step 2. Reviewing the Company's Financial Information

Most of the needed financial information can be obtained from the company's income statement, balance sheet, production reports and other materials. Yet, some information could be obtained by direct observations such as production operations, machine setup activities, and transportation.

Step 3. Identifying and Classifying of Activities (Activities Analysis)

All activities associated with the products are identified and classified. The activities are further categorized into direct activities and indirect activities. Direct activities are those that can be directly assigned and linked to the products. Indirect activities are those that are not directly associated with the products (i.e., administration, depreciation, etc.). To optimize decision making efficiency, the direct activities are further grouped into two major categories: direct labor (number of hours of operations) and direct materials (amount of plastics usages). This is because the labor and materials, altogether, account for more than 87% of the total cost.

Step 4. Determining Operating Cost for Each Activity

Once the activities are clearly identified, the operating costs are calculated for each activity. These costs should represent resource consumption by each activity.

Step 5. Selecting the Cost Drivers

Cost drivers are used to trace the cost of each activity to a product based on its consumption rate. As the indirect activities for operating the factory are identified, they are

linked to each product based on the activities undertaken to produce each of the specific products. For illustration, determining the cost of machine maintenance using the value of sales is an inappropriate method. A more accurate calculation can be obtained by using the actual number of machine hours in operation (operating time). This is because the more one uses a machine, the more maintenance, rental, and replacement one would require. In addition, direct labor hours are appropriate for applying costs of administration, professional fees, recruitment, and employee training, because these activities are associated with direct labor.

Step 6. Calculating Product Costs

Finally, all activities are traced to the products using different cost drivers in order to obtain the final costs.

RESULTS

Table 2 illustrates the cost per unit for the previously selected products using the ABC system. Only the major cost drivers (main activities) are presented in this table. With the use of the ABC method, the unit cost for the Photo mask cases, Reticle SMIF pods , Mask clearners , wafer cassetles , and wafer shopping boxes are $29.54, $25.928, $27.7, $30.208, and $28.267, respectively. To discuss this in more detail, the cost per unit for Photo mask cases consists of the following major costing categories: direct material, direct labor, depreciation, Fabricate , transportation, storage, maintenance, accounting,marketing, research & patent ,human resources, procurement, environmental protection, and miscellaneous for $21.56, $5.02, $0.78, $0.23, $0.18, $0.05, $0.21, $0.19, $0.24, $0.41, $0.15,$0.31,$0.02 and $0.19, respectively. As illustrated in the *semiconductor services company* example, various cost drivers can be chosen by applying indirect activities to the products under ABC as long as a cause–effect relationship is evident. Traditional costing, on the other hand, uses values of sales-related allocation based on amount of sales per month in its cost application.

A comparison between the ABC and the traditional costing system for the semiconductor services company is presented in Table 3. As expected, the costs computed by the two approaches are different. The costs under the ABC system are lower than the traditional cost system. The difference is most significant for the Reticle SMIF pods , showing a $20.51 decrease (–44.17%).

With respect to the product pricing, the results indicate that the prices of all products are higher than their costs under the traditional costing system (Table 4). The profit margin is significant for wafer shopping boxes (4.13%) and Reticle SMIF pods (4.11%). However, the difference is only 1.39% (price of $42.37, cost of $41.78) for the Mask clearners and 2.98% for the wafer cassetles (price of $40.67, cost of $39.46). In other words, the factory obtains a profit from all products under the current costing system. With regards to the ABC system, the prices of five products are higher than their costs. Following the same trend as the traditional costing system, the profit margin is considerable for the Reticle SMIF pods (46.46%) and the Photo mask cases (41.17%).

Finally, the result of ABC analysis indicates that the material cost has the greatest influence on the cost structure. For example, the costs of Mask Package per product for Photo mask cases , Reticle SMIF pods , Mask

clearners, wafer cassetles and wafer shopping boxes are 72.99 ,71.08, 73.36,73.23, and 78.25 of the total cost, respectively. In other words, the average cost of Mask Package material is about 73.78% of the total cost. In contrast, the indirect cost has the least impact on the overall cost structure, accounting for 17.55% of the total cost. Clearly, the first priority should be concerned with cost reduction by minimizing the cost of Mask Package.

DISCUSSIONS AND MANAGERIAL IMPLICATIONS

The semiconductor services company has the capacity and capability of producing many kinds of products, but it is unsure what products and quantities it should produce in order to become more profitable. Currently there are many products that are overpriced (Photo mask cases , Reticle SMIF pods , Mask clearners, wafer cassetles and wafer shopping boxes). Based on this research, the factory seems to obtain a profit from Photo mask cases , Reticle SMIF pods , Mask clearners, wafer cassetles and wafer shopping boxes. The most significantly overpriced item is the Reticle SMIF pods , at 46.46% above the current selling price. Another highly profitable item is the Photo mask cases, at 41.17% above the selling price. For a particular example, the cost of the Reticle SMIF pods using the traditional costing system is $46.44, whereas the cost using the ABC is $25.93.

With the actual price being $48.43, the factory will gain more profit using the ABC system, and the customers will be at a disadvantage. However, competitors can take advantage of the factory's poor decisions based on inaccurate cost information (higher than actual) by reducing the price of the Reticle SMIF pods to make it more appealing to customers. This means that the factory will likely not be as competitive and will lose their business. A significant lesson learned from this research is that the allocation of sales can distort product costs by shifting the activity costs involved with relatively low sale values to those with high sale values. The problem worsens when the lower sale value products are small in number and production runs must be set up frequently, whereas the higher sale value items involve long running times, infrequent setups, and are considered standard products that require no special handling or attention. Producing these low-volume products means that the time that could be used for processing a value-added activity must be used to set up a non-value-added activity, consequently causing the manufacturing overhead to rise.

In addition, by applying ABC, the factory can identify non-value-added activities that consume resources without adding value to the products. This assists management in effectively reducing costs by focusing on the non value- added activities. The identification of the non-value-added activities occurs through this process with a clarity that allows management to eliminate them and, at the same time, delivers the products to the customers with greater efficiency. For illustration, methods studies and ergonomic principles should be applied to reduce or eliminate the non-value-added activities, such as setups, idle time, and preparation. For a specific example, the number of machine setups may be reduced by better production planning. The operator's idle time can be reduced by proper line balancing. At the same time, the useless scrap can be reduced by better production design and appropriate sawing techniques.

There are numerous challenges in implementing the ABC system in a manufacturing environment. First, collecting the data needed to establish the ABC system is time consuming and expensive. For example, in order to

determine the labor cost for the Mask clearners , it takes around 250 h to determine the processing time in each production task. The ABC system is much more complex in detail than the traditional cost system, because costs are allocated to different activity pools that are further broken down into several separate activities. This requires detailed analysis of financial accounting records, as well as diligent observations to identify and gather costs and other information regarding specific activities. Also, the statistical analysis (i.e., sampling techniques, concept of estimation, and numerical descriptive measures) required to allocate costs is much more complex for the ABC system. For instance, the sampling technique is employed to identify the method of data collection for determining standard time in production processes. The major advantage of the ABC method lies in a more accurate cost computation, especially in situations in which product diversity is important and in which the indirect costs represent an important proportion of the total cost. Although the indirect cost, which has the most impact on the ABC approach, accounts for only 17.65% in the semiconductor services company, its trend will be steadily increasing. This is because the semiconductor services companies have been constantly changing from labor orientation to high-technology manufacturing environments. As discussed by Ruhl and Bailey (1994), in a business environment characterized by high technology, overhead cost is a large percentage of the total manufacturing cost.

CONCLUSION

As discussed in this article, the ABC system provides more accurate product costing information than a traditional costing system (Park & Simpson, 2008; REZAIE et al, 2008). The ABC model has decided to acquire a new type of equipment/technology to improve a process and deliver a superior performance to its customers, and suppose that this change requires in turn the acquisition of one or more individual competencies (Cannavacciuolo et al,2012). It also provides insight into the product cost structure. Furthermore, it allows managements to identify costly and unprofitable products. Once the costly products are identified, other industrial engineering techniques can be applied to either reduce or eliminate the non-value-added activities for such products. This integration might offer significant opportunity for cost reduction. However, the ABC system is a time-consuming, labor-intensive process, and its success depends on the total participation of every unit in the organization. Managers who recognize the need for the ABC may be apprehensive of the changes brought by a new system and may resist that change. In such cases, organizations may miss out on significant improvement opportunities.Therefore, it is important to consider the phenomenon of resistance to change by individuals and organizations in the context of the ABC. All in all, it should be acknowledged that the ABC system is a useful tool for better management of the business. It would be an important aid in making management decisions, particularly for improving pricing practices by making costing more accurate. Thus, it can play a significant role in a factory's success.

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