Activity based costing using simulation for cost estimation in manufacturing environments

Mohamed Abdel Gawad Mostafa
Industrial Engineering Department, Faculty of Engineering, Zagazig University,Zagazig, Egypt.
E-Mail: m0108679231@yahoo.com

Abstract

Activity based costing (ABC) has revolutionized product costing, planning, and forecasting in the last decade. It is based on a philosophy of estimation that it is better to be approximately right, than precisely wrong.. The philosophy of discrete-event simulation modeling follows a similar tack, where statistical inference and the stochastic nature of processes are used to replicate the behavior of a physical system. This paper illustrates the benefits of activity-based management and presents an example of how activity-based costing concepts were integrated into a model of discrete-event simulation and linked to provide an improved costing, planning, and forecasting tool. Numerous point cost estimates are generated by the ABC model, using driver values obtained from a discrete-event simulation of the process. The various cost estimates can be used to produce confidence interval estimates of both the physical system and underlying cost structure. Rather than having a single point estimate of a product.s cost, it is now possible to produce the range of costs to be expected as process conditions vary. This improved cost estimate will support more informed operational and strategic decisions.

Keywords: activity-based costing, simulation model, production processes, decision-making

1. Introduction

Despite the use of traditional absorption-based accounting methods at the company level, activity-based cost management (ABCM) techniques can be effectively used at lower levels to gain insight into the total costs of manufacturing. By taking an ABCM view of the production environment, a process simulation model can be a valuable tool when analyzing an area for potential improvement. Traditional accounting systems were designed during a period of time when manufacturing was labor intensive, there was little emphasis on product cycle time, and overhead costs were only a small percentage of the total product cost. Today's automated environment has resulted in higher overhead costs with direct labor comprising as little as five percent of the total costs. Competitive environments have also turned attention to the need for shorter and shorter manufacturing cycle times. The ever-increasing portion of cost that is overhead becomes the "hidden factory" and becomes more and more difficult to address (1). The goal of activity-based costing (ABC) is to identify the relationship of costs to activities and treat as many of the costs as possible as variable. In that way, the "hidden factory" becomes visible.

ABCM is an approach to management that is specifically focused on providing the information needed to improve business processes. It is a management technique that uses ABC as a tool, but it is more than an accounting system. The ABCM system provides information on opportunities for improvement based on the true cost drivers of an organization. It also focuses on providing performance metrics that monitor progress, ensuring that once improvements have been made they are being sustained (2).

1.1 Activity-Based Cost management

Although ABC is just another accounting system, it differs from other accounting methods in that it focuses on activities rather than the costs. Similarly, the system of ABCM aims at controlling the activities, thereby controlling costs. ABCM is a control system that focuses on doing the right things and doing them well. It directs attention to process value, then utilizes ABC for process and product costing and performance measurement. ABCM begins by looking at all of the activities involved in a work package and separating them into value-added and non-value-added categories (3). This is an important step in truly understanding the cost of a product and making informed decisions. If resources are being consumed, costs are increasing. If a value-added activity is being per-formed, costs are increasing but so is the value of the product. With a non-value-added activity, however, costs increase but the value of the product does not. Identifying, reporting and controlling non-value-added activities is an important aspect of ABCM.

It is assumed that the reader is familiar with the concepts of discrete-event simulation and is referred to a standard simulation textbook such as Law and Kelton (7). Proponents of ABCM claim that it will shed light on the true cost of products and help management make better decisions with this improved cost picture. The ABC accounting model can provide a more detailed look at how resources are consumed in a production process. An ABC model is made up of resources, activities and cost objects. These are then linked by resource cost drivers and activity cost drivers respectively, as shown in Fig. (1).

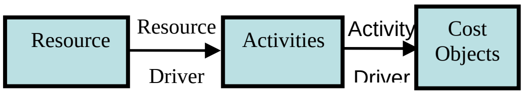

Fig. (1) ABC Cost Flow

Opponents of ABC feel that it is expensive to implement, and it just shuffles the costs of doing business from one category to another rather than improving them. Skeptics of ABC point out that in most cases, market conditions and the demand for products determine the selling price, so that allocating costs at such low levels of detail does not necessarily improve decision-making. In addition, there is some justification for considering all costs except materials as fixed. Most companies do not send their employees home if there is temporarily no work for them. Most companies recognize the value of their work force and retain all personnel through periods of slight slowdown. They have to work on rush jobs during busy times and other times they work a little slowly because there are not many tasks to do. But the employees, as well as their supervision, will most likely be there and be paid for 40 hours per week despite irregular work loads. Similarly, plant maintenance, utilities, and machine maintenance are other examples of costs that must be incurred, independent of how many units of what products are being manufactured (4).

1.2 Activity-Based Costing

Traditional costing methods, such as absorption-based costing, track only the direct labor hours or machine hours and material costs for each product. These cost elements form the allocation base for distributing the remaining costs associated with all other aspects of production. With absorption-based costing, these operating costs, or overhead items, are distributed across each product, according to some formula based on a percentage of direct hours or material dollars. Support organizations, such as Industrial Engineering, Design, Quality Assurance, or Procurement, as well as facilities items such as electricity, water and rent are priced as a factor applied to the touch labor hours.

With ABC, the actions that take place are first categorized into activities. Some examples of activities are "purchase raw material," "machine part A," or "write production planning." Resources, items that are used or consumed in the performance of an activity, are then identified. With an ABC system, costs are collected and reported against the activities. To accomplish this cost collection, a primary cost driver is selected for each activity (5). A cost driver is an item that has a direct relationship to the consumption of resources. For example, in the Procurement environment, one activity would be "buy raw materials." The resource would be the labor hours of the Buyers. The primary cost driver for the activity of buying raw material might be the number of purchase orders placed. A direct relationship can be drawn between the number of orders placed and the number of Buyer resources spent on this activity. If the cost of procuring raw materials is $50,000 per year, and 500 purchase orders were placed, the cost per purchase order would be $100.

The cost of Procurement can now be treated as a variable cost for a product. Since a relationship has been identified between placing a purchase order and the cost of a Buyer, by tracking the number of purchase orders placed for a given product line the cost of Procurement can be allocated according to actual usage of the department, rather than as an arbitrary percentage. By setting up a system of activities, resources and cost drivers, many of the cost components typically considered to be overhead can be attributed to the product as a function of usage rather than as a proportion of direct labor.

2- ABC and simulation

Simulation modeling is a useful tool for emphasizing the concepts of ABCM. The elements of a model are direct parallels to the elements of ABC. In a simulation model, it is necessary to define the activities that occur in the system, determine the resources required to perform each activity, and decide what variables or factors are important measures of performance. Because of the use of traditional, absorption-based methods of cost collection, however, the tendency when creating and analyzing a model of a manufacturing area is to focus on the utilization of direct touch labor resources and the total cycle time of the product. Also, in a typical manufacturing company, the largest amount of information exists regarding the direct touch labor element of the cost.

Since Arena can easily track a large number of variables and attributes, it is an easy matter to accumulate costs by category and track the number of occurrences of cost driver items. By keeping the ABCM objectives in mind while constructing the model, performance measures can be selected that help assess the value of processes. For example, in a manufacturing facility that uses absorption-based accounting, items like the cost of travel between work areas, the cost of inspections, or the cost of documents like quality discrepancy reports, are lost in overhead accounts. By tracking the number of moves between work centers, the amount of time a part spends in inspection, or the number of inspection rejections that occur, a different picture of costs can be presented by the simulation model. Maintaining an ABCM approach in the model can highlight areas for improvement that are not readily apparent from the traditional accounting information.

3-Cost flow vs. entity flow

Both discrete-event simulation and ABC are based on the concept of entities flowing through the system. In a discrete-event simulation, physical items flow through the sequence of manufacturing operations. In ABC, costs flow through the model driven by defined activity drivers. In a simulation model, a billet of metal may flow through the system. The billet is loaded into a lathe, turned, drilled, tapped, packed in a box with 24 others and transported into finished goods storage. The focus is on the billet and the sequence of activities needed to produce the end product. In an ABC model, one follows the cost of a resource through the system. The monthly depreciation of the forklift is a cost, which is assigned to moving the finished product to the warehouse. If the driver for this activity is number of pallets, then one can work out how much each pallet costs to move and eventually arrive at a cost to move each billet from start to finish. A closer examination of these two concepts reveals that they have a common intersection . the activity. Fig.(2) graphically illustrates this intersection and sheds some light on how the two can be combined. Initially, the flow of product through the system and the flow of resources through a costing system may seem to be very far apart. A closer look reveals that they can be combined for the purpose of producing a better cost estimate.

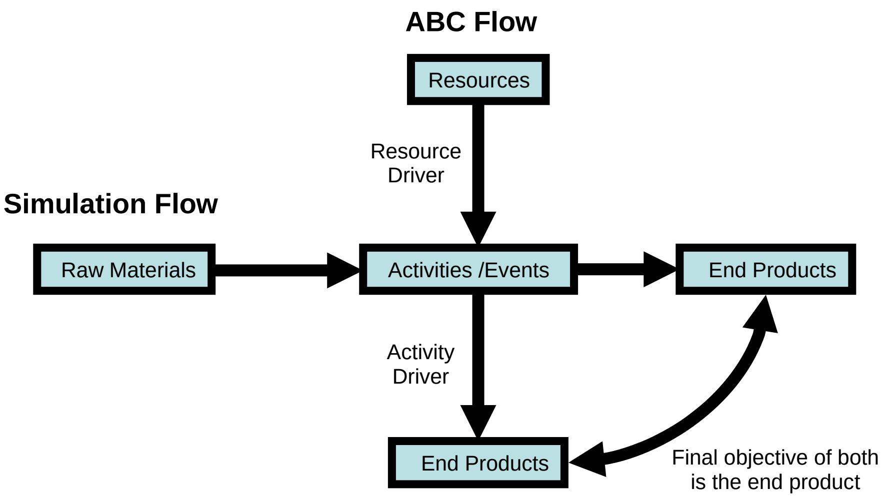

Fig.(2) The intersection of ABC and simulation model flow adapted from Ostrenga et al. (8)

4. Modeling Outline

In this section, an overview of the steps to follow in combining ABC and discrete-event simulation will be presented. What we essentially have is an ABC model built in Excel or an ABC program and a model of the same system built in a simulation program. The ABC model contains the costs and activities of the system and the simulation is able to model the stochastic nature of these activities. The steps that were followed in combining ABC costs with a simulation model of the process are listed below:

1. Develop an activity dictionary.
2. Build an ABC Model.
3. Decide on the most important activity drivers.
4. Gather performance data on the drivers and develop statistical distributions for the drivers.
5. Build a simulation model, making provision for the drivers identified above.
6. Run a static simulation to validate the simulation model and static ABC driver values obtained. In other words, the point estimate used in the first ABC model is obtained by the simulation with no stochastic variation.
7. Repeatedly run the model using the stochastic distributions for the cost drivers.
8. Produce confidence interval estimates of product costs using simulation data.

It is important to note that one run includes running the simulation, entering the driver values obtained from the simulation into the ABC model, and recording the resulting product costs.

5 Application example

An illustration of how simulation can improve cost estimates within ABC will be presented here. The case study that was used was developed by Jung, J., Y.(6). The case involves a pen factory that manufactures black, blue, red and purple pens. An ABC model of the factory is built in order to estimate the cost to produce each type of pen. In this paper, the analysis is extended to incorporate simulation and produce interval cost estimates for different production scenarios.

5.1 Problem Outline

The stochastic element that was modeled was an empirical distribution for the amount of orders received for each type of pen: 33.3% for blue, 33.3% for black, 25.4% for red and 8% for purple. Simulation runtime was constant for each scenario. Activities such as setup time (which was different for each type of pen) and assembly time were assumed to be constant. It should be noted that the effect of changes in these factors on production cost could have been studied by introducing stochastic setup times and processing times. That was not the purpose of this effort however. Thus in the simulation, only the number of orders was monitored. All other driver values such as number produced, machine hours and setup time could be computed (as they were all a constant multiplied by the number of orders processed for each pen color.). The simulation ran the factory for a period of one year. The structure of the ABC model cost flow is shown in Fig.(3).

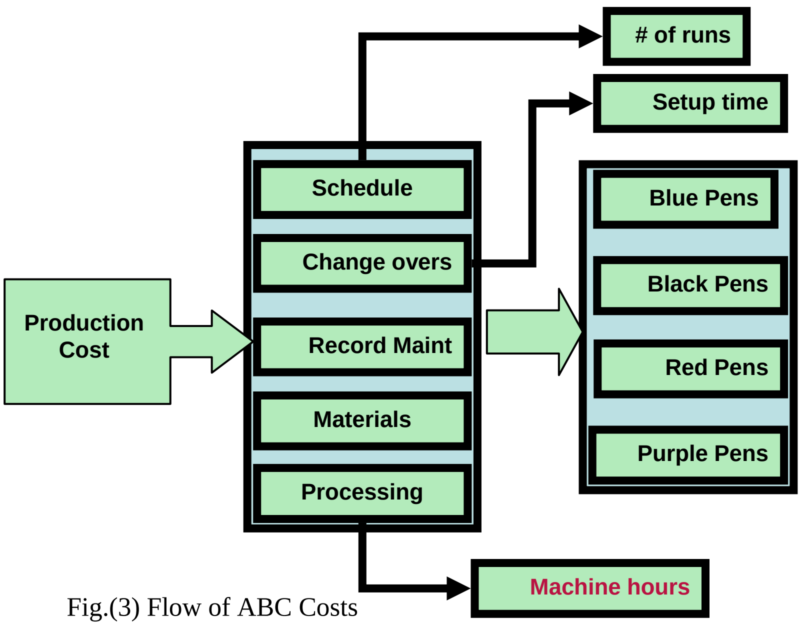

Fig.(3) Flow of ABC Costs

Easy ABC was exported and opened in Excel. This provided the structure for the data to be imported. Taylor ED then updated only the driver cells in Excel. The outline that was to be updated is shown in Fig.(4). The cells that were updated by the simulation program are shaded in gray. The updated cost drivers were saved in a *.csv format from Excel and imported into the model. Once in the model, all the cost allocations were recalculated and the resulting product cost saved in a scenario.

5.2 Results

A summary of the results obtained is shown in Table 2. It is clear that the blue and black pens (products produced in large batches of 1000 and 800 each - high volumes) experienced the smallest variation in their costs. Red and Purple pens (products produced in batches of 240 and 85 respectively - low volumes) experienced a large variation in their production costs.

The range of costs incurred by each color of pen were:

Blue Pen $1.15 to $1.24

Black Pen $1.15 to $1.21

Purple Pen $1.61 to $2.33

Red Pen $3.30 to $5.50

```
 EasyABC
VERSION 4.1
ACTIVITY
DRIVER_QUANTITIES_ACTUAL
PERIOD Scenario1
SHARED_DRIVER_QUANTITIES
# of runs
        1 Blue    COST_OBJECT      50
        2 Black   COST_OBJECT      50
        3 Red     COST_OBJECT      38
        4 Purple  COST_OBJECT      12
Machine Hrs.
        1 Blue    COST_OBJECT      5000
        2 Black   COST_OBJECT      4000
        3 Red     COST_OBJECT      9000
        4 Purple  COST_OBJECT      1000
Setup Time
        1 Blue    COST_OBJECT      200
        2 Black   COST_OBJECT      50
        3 Red     COST_OBJECT      228
        4 Purple  COST_OBJECT      48
UNIQUE_DRIVER_QUANTITIES
```

Fig.(4) Easy ABC activity driver file

The Blue, Red, and Purple pens each had setup times of 4 hours and over, while the Black pens only required a 1 hour setup. This can greatly influence the amount of orders that could be processed in the fixed time available. Furthermore, record maintenance was divided equally among the four pen types, thus this cost varies significantly for the pens that are produced in lower volumes.

5-3 Benefits of approach

When all costs are defined as a percentage of direct labor costs, the tendency is to focus on reducing the number of direct labor hours required to make the product. By definition, all other costs are reduced since they are a proportion of direct labor costs. This is not always the case in practice, however. Reducing the labor costs generally does not result in a true reduction in the support costs. Unless supporting headcount is reduced, or inspection times are improved, or rework is eliminated, the actual cost in these support areas remains unchanged. The true effect is an increase in the allocation percentage that must be used.

6. Conclusion

Point estimation in simple ABC models does not provide information on the sensitivity of product costs to process variation. In this paper it was shown that by combining ABC concepts with a discrete-event simulation model the range of expected product costs may be obtained. Activity cost driver values and their interactions can be successfully integrated and then used to repeatedly estimate true product cost. Engineers and accountants can use this output to make a more informed decision about operational procedures and corporate strategy.

7. Acknowledgements

Many thanks are due to Dr Gamal Nawara, I would like to express my gratitude for his support. I'm deeply indebted to everyone taught me.

8. References

1. Younossi.o..,and Graser,J.,C., "Military Jet Engine Acquisition technology basics and cost-estimating methodology", U.S.A. Force, Editor. 2002, RAND. p. 153
2. Clarke, Paul and Robin Bellis-Jones (1996), "Activity-Based Cost Management in the Management of Change," The TQM Magazine, vol. 8, no. 2, pp. 43-48.
3. Doost, Roger K. (1997), "Viewpoint: My Sons and Me and ABC Costing," Managerial Auditing Journa*l*, vol. 12, no. 7, pp.354-357.
4. David , R., G. "What is Cost Risk?" in NASA risk management conference. 2005
5. Curan, R., "Review of aerospace engineering cost modeling" The genetic causal approach. Progress in Aerospace Sciences, 2004. **40**(8): p. 487-534.
6. Jung, J., Y., "Manufacturing Cost estimation for machined parts based on manufacturing features", Journal of Intelligent Manufacturing, 2002. **13**(4): p. 227-238.
7. Law, A. M. and Kelton, W. D., 2000. "*Simulation Modeling and Analysis*", Third Edition, New York: McGraw-Hill, Inc.
8. Hicks, D.T., 1992. "*Activity-based Costing for Small and Mid-Sized Businesses*", New York: JohnWiley and Sons.

Period:	1 cost	2 cost	3 cost	4 cost	5 cost	6 cost	7 cost	8 cost	9 cost	10 cost	MIN	MAX	STD
Blue	$1.18	$1.20	$1.16	$1.18	$1.17	$1.17	$1.15	$1.24	$1.2	$1.19	$1.15	$1.24	0.025
Scheduling & Handling	$0.15	$0.15	$0.14	$0.15	$0.15	$0.15	$0.15	$0.17	$0.16	$0.15	$0.14	$0.17	0.009
Changeovers	$0.09	$0.10	$0.08	$0.09	$0.08	$0.08	$0.08	$0.10	$0.10	$0.09	$0.08	$0.10	0.009
Record Maintenance	$0.02	$0.03	$0.03	$0.02	$0.02	$0.02	$0.02	$0.03	$0.02	$0.03	$0.02	$0.03	0.005
Processing	$0.42	$0.42	$0.41	$0.41	$0.42	$0.42	$0.41	$0.45	$0.42	$0.42	$0.41	$0.41	0.012
Blue Materials	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Cost	$1.18	$1.20	$1.16	$1.18	$1.17	$1.17	$1.15	$1.24	$1.20	$1.19	$1.15	$1.24	0.025
Total Bill of Costs	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Assigned Cost	$0.68	$0.70	$0.66	$0.68	$0.67	$0.67	$0.65	$0.74	$0.70	$0.69	$0.65	$0.74	0.025
Black	$1.15	$1.16	$1.15	$1.17	$1.15	$1.15	$1.16	$1.21	$1.16	$1.15	$1.15	$1.21	0.025
Scheduling & Handling	$0.15	$0.15	$0.14	$0.15	$0.15	$0.15	$0.15	$0.17	$0.16	$0.15	$0.14	$0.17	0.009
Changeovers	$0.09	$0.10	$0.08	$0.09	$0.08	$0.08	$0.08	$0.10	$0.10	$0.09	$0.08	$0.10	0.009
Record Maintenance	$0.02	$0.03	$0.03	$0.02	$0.02	$0.02	$0.02	$0.03	$0.02	$0.03	$0.02	$0.03	0.005
Processing	$0.42	$0.42	$0.41	$0.41	$0.42	$0.42	$0.41	$0.45	$0.42	$0.42	$0.41	$0.41	0.012
Black Materials	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Cost	$1.18	$1.20	$1.16	$1.18	$1.17	$1.17	$1.15	$1.24	$1.20	$1.19	$1.15	$1.24	0.025
Total Bill of Costs	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Assigned Cost	$0.68	$0.70	$0.66	$0.68	$0.67	$0.67	$0.65	$0.74	$0.70	$0.69	$0.65	$0.74	0.025
Red	$2.20	$2.31	$2.13	$2.29	$2.13	$2.19	$2.09	$1.61	$2.23	$2.23	$1.61	$2.23	0.207
Scheduling & Handling	$0.15	$0.15	$0.14	$0.15	$0.15	$0.15	$0.15	$0.17	$0.16	$0.15	$0.14	$0.17	0.07
Changeovers	$0.09	$0.10	$0.08	$0.09	$0.08	$0.08	$0.08	$0.10	$0.10	$0.09	$0.08	$0.10	60.07
Record Maintenance	$0.02	$0.03	$0.03	$0.02	$0.02	$0.02	$0.02	$0.03	$0.02	$0.03	$0.02	$0.03	0.025
Processing	$0.42	$0.42	$0.41	$0.41	$0.42	$0.42	$0.41	$0.45	$0.42	$0.42	$0.41	$0.41	0.051
Red Materials	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Cost	$1.18	$1.20	$1.16	$1.18	$1.17	$1.17	$1.15	$1.24	$1.20	$1.19	$1.15	$1.24	0.207
Total Bill of Costs	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Assigned Cost	$0.68	$0.70	$0.66	$0.68	$0.67	$0.67	$0.65	$0.74	$0.70	$0.69	$0.65	$0.74	0.207
Purple	$4.66	$5.13	$4.41	$5.39	$4.63	$5.44	$4.66	$3.33	$5.45	$5.5	$3.3	$5.5	0.684
Scheduling & Handling	$0.15	$0.15	$0.14	$0.15	$0.15	$0.15	$0.15	$0.17	$0.16	$0.15	$0.14	$0.17	0.231
Changeovers	$0.09	$0.10	$0.08	$0.09	$0.08	$0.08	$0.08	$0.10	$0.10	$0.09	$0.08	$0.10	0.144
Record Maintenance	$0.02	$0.03	$0.03	$0.02	$0.02	$0.02	$0.02	$0.03	$0.02	$0.03	$0.02	$0.03	0.344
Processing	$0.42	$0.42	$0.41	$0.41	$0.42	$0.42	$0.41	$0.45	$0.42	$0.42	$0.41	$0.41	0.057
Purple													
Purple Materials	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Cost	$1.18	$1.20	$1.16	$1.18	$1.17	$1.17	$1.15	$1.24	$1.20	$1.19	$1.15	$1.24	0.684
Total Bill of Costs	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	0
Total Assigned Cost	$0.68	$0.70	$0.66	$0.68	$0.67	$0.67	$0.65	$0.74	$0.70	$0.69	$0.65	$0.74	0.684

Table 1: Pen factory simulated ABC costing results