Proceedings of the 1994 Winter Simulation Conference
ed. J. D. Tew, S. Manivannan, D. A. Sadowski, and A. F. Seila

USING SIMULATION TO BENCHMARK TRADITIONAL VS. ACTIVITY-BASED COSTING IN PRODUCT MIX DECISIONS

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ABSTRACT

Activity-based costing is being promoted as the most effective method available for predicting costs associated with a variety of business decisions. This paper demonstrates its effectiveness in benchmark tests of activity-based costing versus traditional direct labor based costing in product mix decisions using a simulation model.

1 INTRODUCTION

Decisions with regard to product mix are commonly used as examples in the activity-based costing literature to illustrate the failings of traditional job costing methods (Cooper and Kaplan 1988, 1991; Emig and Mazeffa 1990; Johnson and Kaplan 1987; Kaplan 1988; Ochs and Bicheno 1991). Although these decisions fall into several categories, including:

- focused factory vs. full-line producer,
- introducing new product lines,
- choice of products to outsource, and
- product abandonment,

the failings of traditional job costing practices are the same. These failings are:

- product or job cost distortion due to misallocation of overhead, and
- failure to estimate changes in overhead that are consequences of a product mix decision.

Proponents of activity-based costing claim that cost distortion can be avoided by analyzing activities and choosing appropriate cost drivers for allocation of activity costs. They also claim that activity-based costing is effective for predicting changes in overhead resulting from a product mix decision.

The goal of this paper is to test these claims by benchmarking activity-based costing against traditional costing in a product mix decision. Specifically, traditional and activity-based costing methods are used to estimate the costs of various product mixes. A simulation model is then used to generate performance measures for each product mix which are converted into manufacturing costs.

The simulation model itself is of a simple and fictitious manufacturing system, although its design incorporates characteristics that the authors have seen in real manufacturing systems. Its simplicity allows for ease in varying the parameters that are related to setup cost and the other performance measures used.

2 COST ESTIMATION IN SUPPORT OF A PRODUCT MIX DECISION

Job order costing is used to derive product costs in manufacturing systems where many different products, jobs, or batches are produced in a given time period. The objective is to obtain a unit cost for each product and then to estimate costs and revenues for the various product mix options based on the unit cost. In this section, the traditional method of job costing and activity-based costing are described.

2.1 Traditional Job Costing

Accounting texts (e.g., Garrison 1982) classify manufacturing costs into three broad categories:

1. Direct materials.
2. Direct labor.
3. Manufacturing overhead.

Direct materials are the materials that become an integral part of a finished product and can be conveniently traced to it, such as the sheet steel in a car. Other materials, such as paint on the car, are difficult to trace and are considered *indirect materials* and classified as overhead.

Direct labor is the labor directly traceable to the creation of products such as the labor costs of assembly line workers and machine operators. Labor costs for janitors, supervisors, material handlers, engineers, and security guards cannot be traced directly and are considered *indirect labor* and classified as overhead.

Manufacturing overhead is defined as all manufacturing costs except direct materials and direct labor. This includes indirect materials, indirect labor, heat and light, property taxes, insurance, depreciation on factory facilities, repairs, maintenance, and all other costs of operating the manufacturing division. When the same types of costs are associated with the selling and administrative functions of a company, they are considered to be nonmanufacturing costs and not normally used in the computation of product costs.

Nonmanufacturing costs are classified as:

1. marketing or selling costs, and
2. administrative costs.

Marketing and selling costs include advertising, shipping, sales travel, sales commissions and salaries. Administrative costs include executive compensation, clerical, public relations, and general accounting.

The following steps describe how to estimate the cost of a product mix using traditional job costing methods:

1. *Compute an overhead rate* from existing data.
   a. *Select an activity base.* The most widely used activity bases are direct labor hours and machine hours.
   b. *Determine total manufacturing overhead costs and units in the activity base* from existing data for some time period in the recent past.
   c. *Compute the overhead rate.* Divide the total manufacturing overhead cost by the number of units in the activity base.

$$\frac{\text{Total manufacturing overhead}}{\text{Total units in base}} = \text{Overhead rate}$$

2. *Calculate the number of units of each product* in the mix for the time period whose cost is being estimated.
3. *Calculate the number of units in the activity base* for the product mix and time period whose cost is being estimated.
4. *Compute direct material and direct labor costs* from the estimated product volume and number of units in the activity base.
5. *Compute the overhead cost* by multiplying the number of units in the base from step 3 by the overhead rate in step 1c.
6. *Sum direct material costs, direct labor costs, and overhead* to get total costs for time period and product mix whose cost is being estimated.

The cost estimate is typically presented in the format of an income statement.

The key to estimating the cost of a product mix is finding an activity base that gives an overhead rate which provides an equitable application of overhead among jobs and thus gives an accurate estimate of overhead costs. No accounting texts studied by the authors forbade the use of activity bases other than direct labor hours or machine hours but no accounting text gave an example where other bases were used.

Traditional cost accounting teaches the use of relevant costs in decision making. Relevant costs are defined as all costs except *unavoidable costs.* Unavoidable costs may be classified as:

1. sunk costs (e.g., the book value of an old machine), and
2. future costs that *do not differ* between the alternatives at hand (e.g., regular time labor costs if it is not possible to hire or lay off).

Mixing of relevant and irrelevant costs in a product mix decision can draw the decision maker's attention away from the costs on which the decision has the most impact. For example, reducing direct labor costs is only beneficial if actual costs of labor resources, such as overtime or number of workers, can be reduced. If labor resources cannot actually be eliminated or shifted to a profitable use as a result of direct labor reduction, then the reduction in direct labor cost is shifted to overhead and the total cost does not change.

2.2 Failure of Traditional Job Costing Practices

The problems with estimating product mix costs using traditional job costing are not in the theory, but in how job costing is practiced. These problems are:

1. limiting the activity base to direct labor or machine hours,
2. ignoring nonmanufacturing overhead when it includes relevant costs, and
3. allocating batch and product level expenses to individual units.

The commonly used activity bases, direct labor or machine hours, typically represent only 5-10% of total manufacturing costs (Emig and Mazeffa 1990) where manufacturing overhead may represent 60% or more of total manufacturing costs (Johnson and Kaplan 1987). The direct labor allocation base can distort product costs by shifting costs from relatively low direct labor content products to more labor-intense products. The problem worsens when the less labor intense products are small-volume, frequent setup jobs and the more labor intense products are long-running, infrequent setup standard products that require no special handling or attention (Johnson and Kaplan 1987). Producing these low volume products means that time that could be used for processing, a value added activity, must be used for setup, a non-value added activity, causing the manufacturing overhead to rise.

Nonmanufacturing costs, which traditional job costing does not include in the analysis, may also grow with increased information and scheduling needs, marketing, sales, and support of diverse products. Such costs are often considered fixed, when in the long run, they are not. For example, subcontracting would increase demands on the accounting department and clerical staff and generate shipping costs, all of which are relevant costs that would increase the total cost of running the business (Johnson and Kaplan 1987). More subcontracting could mean more overtime for clerical staff and accounting. Shipping costs normally correlate to the volume shipped. The use of job costing alone for such a decision would ignore these relevant costs.

Manufacturing overhead is a mixture of product and batch costs. When batch and product costs are divided by the number of units produced, managers can get the impression that costs vary with the number of units and can be controlled on the unit level. In reality, quantities of resources consumed at the batch level rise with the number of batches and quantities of resources consumed at the product level increase with the number of products. Thus, trying to control such costs by controlling the number of units while increasing the number of products or batches will have the opposite effect from what is desired (Cooper and Kaplan 1991).

2.3 Activity-Based Costing

Activity-based costing is an attempt to refocus cost accounting on costs relevant to decision-making and to free cost accounting from the notion that direct labor hours and machine hours are the only possible activity bases. It is not a major departure from the theory of cost accounting but it causes major changes in how cost accounting is practiced. Activity-based costing takes advantage of today's information technology to trace costs directly when possible and allocate costs that cannot be traced based on the occurrence of an appropriate cost driver.

A cost driver is simply an unrestricted activity base. It is something that causes products to be different, to have different routings and to generate overhead costs differently. Possible cost drivers include size, type, finish, lead time, processing time, queue time, surface area, weight, routing, complexity, and many more (Gilligan 1990). Overhead may be broken down into various categories to be allocated to products using different drivers and allocation rules that are more sophisticated than simple multiplication. For example, an indirect material such as paint might be allocated on the basis of surface area rather than direct labor. Since the presence of many low volume products would cause many more setups than a product mix of a few high volume products, setup cost might be allocated on the basis of inverse product volume.

Activity-based costing analyses are not restricted to manufacturing costs. They consider all costs relevant to a decision even though some may be nonmanufacturing costs. For example, an activity-based costing analysis for an outsourcing decision would consider increased clerical workload for processing orders for the subcontractor, an increased accounting workload, and other administrative costs normally ignored because they are nonmanufacturing costs.

3 THE USE OF SIMULATION IN PRODUCT MIX DECISIONS

A simulation model can be used to predict performance measures such as throughput, direct labor hours, machine hours, number of setups, time in setup, idle time, resource utilization, time in queue, lengths of queues, and time in system which are related to direct labor, direct material and overhead costs. These performance measures may be translated, postprocess, into costs by applying unit costs inferred from historical data or machine and job specifications.

The advantage of using a simulation to estimate costs is that it considers dynamic, time-oriented aspects of a manufacturing system such as sequencing of jobs, sequence dependent setups, or waiting for all components of an assembly to become available. Simulation data can be used to generate costs without actually changing the product mix.

The information generated by a simulation is limited by the detail level and scope of the model. An example of detail is the following. If setup teams are a constraining resource, they must be modeled. Time in setup is not enough, because it is possible for two machines to be in setup at the same time. To remedy this, a setup team is modeled in such a way that a setup cannot be performed unless the setup team is available. An example of scope is the practice of modeling only the manufacturing operation. A simulation cannot provide information on departments outside the scope of the study. For example, the simulation will not provide information on the impact of outsourcing a product on the accounting department unless the accounting department is modeled.

An apparent limitation of simulation is that each run is just one possible outcome. However, historical data also represents only one possible outcome. The advantage of simulation is that many trials may be run and many possible outcomes examined.

4 AN EXAMPLE MODEL

To explore the role of setup time in a product mix decision several alternatives of a simulation were developed. The simulation model of this example was built using SLAMSYSTEM, a Pritsker Corporation product. The simulation data was exported to a spreadsheet, Microsoft EXCEL, for collation and analysis. Section 4.1 describes the manufacturing system being modeled, the design of the experiment, and the rationale behind model scope and data collection. Section 4.2 summarizes the results of the experiments. Section 4.3 contains comparative financial analysis for the alternatives using traditional and activity-based costing.

4.1 Description and Design of Experiment

The example models a manufacturing system operating at capacity with four possible products, W, X, Y, and Z for which potential demand for the next year exceeds capacity. If the factory is able to meet forecast demand, the percentage of production (in units) contributed by each product is summarized in Table 1. Products W and X have process plans with four operations. Products Y and Z have process plans with three operations. The process plans and mean processing time per piece are summarized in Table 2. The factory layout is shown in Figure 1. The factory is assumed to operate 8 hours per day (one shift), 250 days per year.

The problem addressed in these experiments is how to best deal with the excess demand by means of product mix alternatives (such as outsourcing, target marketing, or some focused factory strategy) rather than adding capacity. Specifically, the objective is to determine what percentage of the production to allocate to each product based on various performance measures. Three alternative product mixes are investigated under three setup time scenarios. The decision alternatives are summarized in Table 3 and the setup time scenarios in Table 4. The independent variables in these experiments are product mix and setup time. The dependent variables are backlog, time in system, and relevant costs. The dependent variables are the performance measures upon which the decision is based. Production level relative to capacity is held constant across all scenarios. The plant must be operating at or above regular time capacity before setup time constrains production and causes setup cost to become relevant to a product mix decision. Table 4 reflects the different levels of actual production needed for each scenario in order to maintain constant production relative to capacity.

Table 2: Routing Specifications

Product	Operation	Machine class	Mean run time/piece
W	OP1	SAW	0.5
	OP2	DRILL	1.0
	OP3	GRIND	4.0
	OP4	FINISH	3.0
X	OP1	SAW	0.5
	OP2	DRILL	1.0
	OP3	GRIND	3.5
	OP4	FINISH	2.5
Y	OP1	SAW	0.5
	OP2	GRIND	3.5
	OP3	FINISH	2.5
Z	OP1	SAW	0.5
	OP2	GRIND	3.0
	OP3	FINISH	2.0

Table 3: Alternative Descriptions

Alternative	Description
A	Meet 80% of demand, all reduction from W
B	Meet 80% of demand, eliminate X
C	Meet 80% of demand, eliminate Y and Z

Each of the decision alternatives involves filling only 80% of forecast demand by means of different product mixes. A company might choose to manage demand by outsourcing or only serving part of the market by choice

Table 1: Demand

Product	Demand
W	60%
X	20%
Y	15%
Z	5%

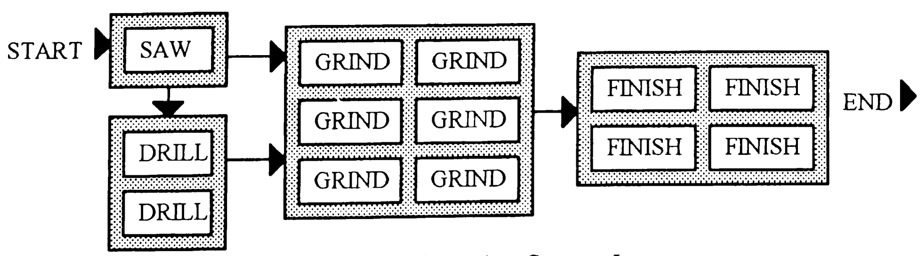

Figure 1: Manufacturing System Layout

Table 4: Setup Times and Production

Scen.	Setup time in minutes (multiple setup times indicate part dependent setups)				Agg. prod.
	SAW	DRILL	GRIND	FINISH	1000s
1	60	6	720 & 960	480	83
2	30	3	360 & 480	240	110
3	15	1.5	180 & 240	120	138

of product mix if there are limitations on overtime or if the expense of hiring another shift with uncertainty about long-term demand seems too risky.

Twenty-five runs of each alternative for each scenario gives a 95% confidence interval error of 5% of the mean for all performance measures except backlog and time in system for alternatives B and C of each scenario. In the latter cases, the error for a 95% confidence interval is 3 days.

4.2 Nonfinancial Performance Measures

The nonfinancial performance measures considered in these experiments are backlog and time in system. In this case backlog was measured as work remaining after the system had been simulated for a year (simulation time). Time in system is a measured attribute in the simulation. Backlog and time in system are both related to customer satisfaction. Backlog must either be worked off with overtime, additional outsourcing, or customers' patience. Time in system is important for time-based competition. Customers are demanding shorter delivery times. To be competitive, a manufacturer must be able to respond to a changing marketplace quickly. Short times in system give a manufacturer flexibility to respond. They are related to quality because less time in system is less opportunity for damage and deterioration.

Experimental results show that product mix choices have a very strong impact on both backlog and time in system when setup times are long compared to per unit processing time and become negligible as the ratio of setup time to processing time diminishes. The results for backlogs are summarized in Table 5 and Figure 2. The results for time in system are summarized in Table 6 and Figure 3.

Table 5: Backlog in Days

	A	B	C
1	152	65	17
2	88	34	12
3	53	27	17

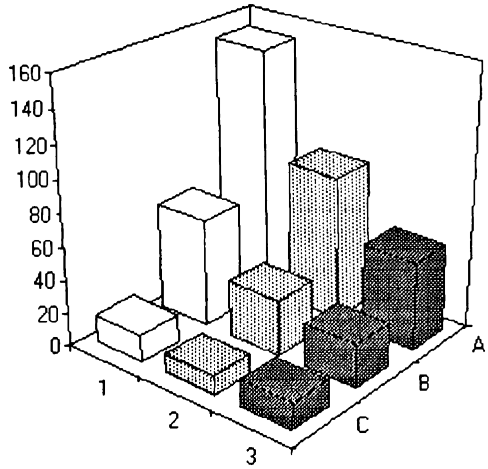

Figure 2: Backlog in Days

Table 6: Days in System

	A	B	C
1	75	32	10
2	44	17	8
3	27	14	10

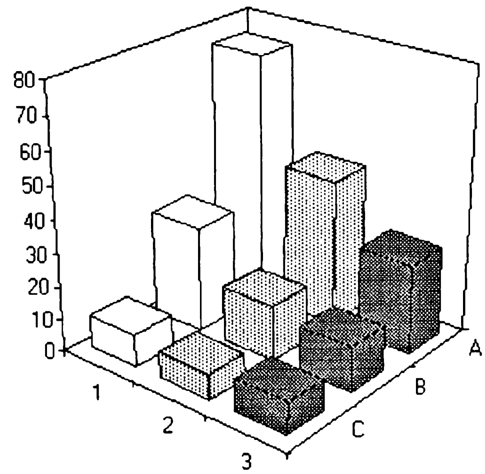

Figure 3: Days in System

4.3 Cost Analysis

The experiments are designed to compare costs of a decision alternative estimated on the basis of:

1. an estimate of labor hours and a predetermined overhead rate (traditional direct labor based), and
2. cost drivers in an activity-based costing analysis.

These estimates are compared to the costs of a decision alternative computed from the performance measures generated by the simulation. The performance measures generated by this simulation model are product volume, processing time, setup time, idle time,

Table 7: Conversion Calculations

Direct materials	$\sum_{\text{all products}}$ (unit direct material cost × product volume)
Direct labor	labor rate × total processing time
Indirect labor	indirect labor rate×(regular time + backlog × overtime multiplier)
Indirect materials	$\sum_{\text{all products}}$ (unit indirect material cost × product volume)
Utilities	fixed rate + constant × time operational + processing time multiplier × processing time
Misc.factory (tooling,lubricants,etc.)	usage rate × processing time
Setup	labor rate × setup time
Idle	labor rate × idle time
Overtime	labor rate × (1−overtime rate) × backlog × number of machines

regular time, and backlog. The calculations for the conversion of simulation performance measures to costs are summarized in Table 7.

The overhead rate for the direct labor costing estimate and the multipliers used in the activity-based costing estimate are obtained from a baseline simulation of each scenario using the production volumes given in Table 4 and the product mix of Table 1. In practice, historical data would be used to generate these factors. The activity based costing estimates use *inverse product volume* to allocate setup and overtime costs. The reason for choosing inverse product volume is that it shifts the cost of setup to the cause - low volume products.

Table 8: Baseline Alternative Costs

Scenario	1	2	3
Direct Materials	$77,513	$103,179	$128,796
Direct Labor	163,556	217,711	271,765
Mfg. overhead			
Indirect labor	69,216	57,149	51,481
Indirect mat'ls	3,264	4,349	5,430
Utilities	66,466	83,714	101,354
Misc. factory	21,807	29,028	36,235
Setup	293,519	197,494	125,234
Idle	122,830	86,263	67,625
Overtime	94,953	55,734	37,312
Total overhead	$673,141	$513,732	$423,591
Total	$913,125	$834,623	$798,533
Processing time	10,904	14,514	18,118
Overhead rate	61.64	35.40	23.44

The costs generated by the three baseline simulations are calculated by the methods of Table 7 and summarized in Table 8. The overhead rates in Table 8 are obtained by dividing the total manufacturing overhead by the total processing time. The allocation rates for the activity-based costing estimates are obtained by the normalizing the inverse product volume percentages as shown in Table 9. The multipliers for the activity-based costing estimates are determined by dividing the fraction of the setup (overtime respectively) cost corresponding to the allocation rate by the volume of product in the baseline simulation.

The three annual cost estimates for each scenario are given in Table 10:

1. traditional direct labor based,
2. activity-based costing with inverse product volume as driver for setup and overtime, and
3. simulation-based as summarized in Table 7.

Table 9: Activity-Based Costing Allocation Rates

Product	% volume	inverse	alloc. rate
W	0.60	1.67	0.05
X	0.20	5.00	0.15
Y	0.15	6.67	0.20
Z	0.05	20.00	0.60

Table 10: Comparative Costs ($1000s)

Scenario	Method	Alt A	Alt B	Alt C
1	direct labor	$894	$923	$959
	activity-based	$902	$812	$565
	simulation	$990	$767	$648
2	direct labor	$816	$844	$876
	activity-based	$897	$836	$642
	simulation	$875	$738	$689
3	direct labor	$808	$834	$866
	activity-based	$904	$874	$726
	simulation	$836	$772	$757

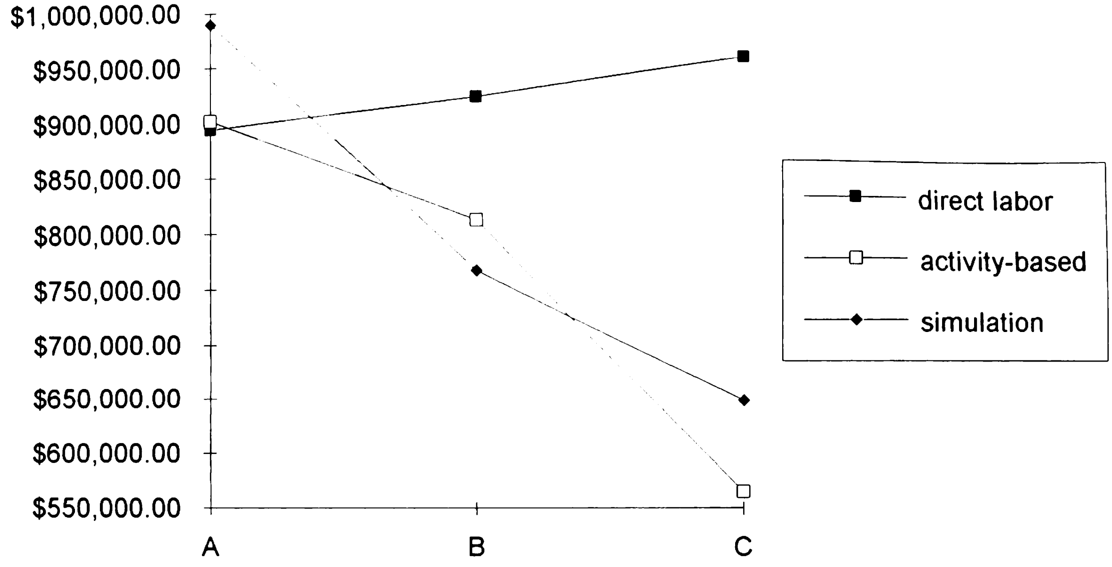

Figure 4: Scenario 1 Comparative Costs

In all three cases, direct labor is calculated from planned product volume and machine time and direct materials from planned product volume. The *direct labor* cost estimate of manufacturing overhead is calculated by multiplying the overhead rate of Table 8 by the direct labor hours calculated from planned product volume and machine times in Table 2. The *activity-based costing* estimates of setup and overtime cost are computed by multiplying the product volume by the multipliers described above. Other overhead costs are calculated from simulation data as in Table 7.

As expected, the activity-based costing estimates rank the alternatives in the some order as the simulation (see Figures 4, 5, and 6) and become closer to the simulation costs as the ratio of setup time to processing time increases.

5 CONCLUSIONS

The experimental data confirm that activity-based costing techniques more closely estimate manufacturing costs than the traditional labor-based methods, although

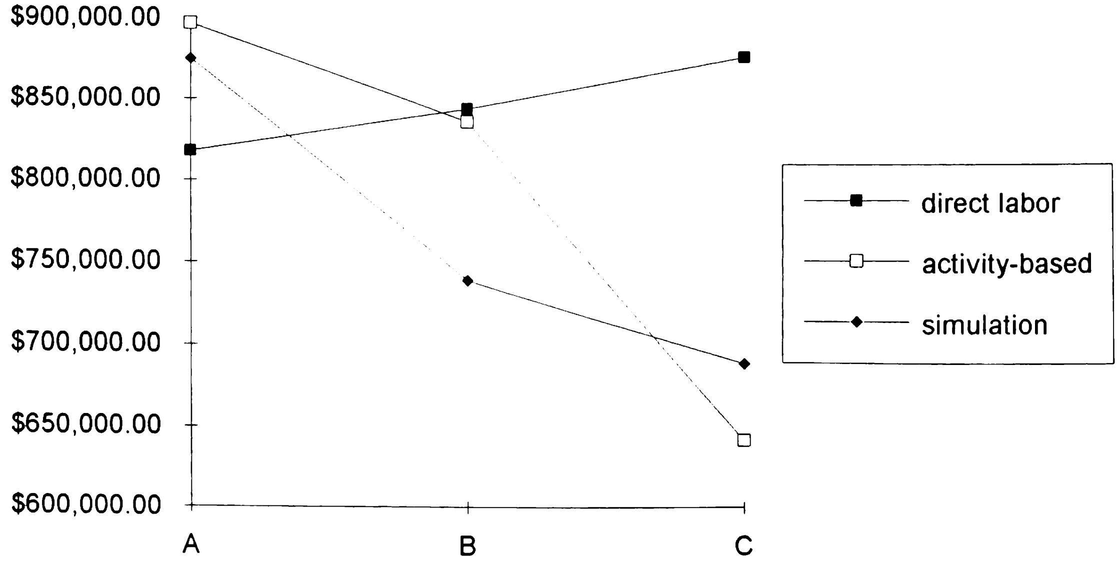

Figure 5: Scenario 2 Comparative Costs

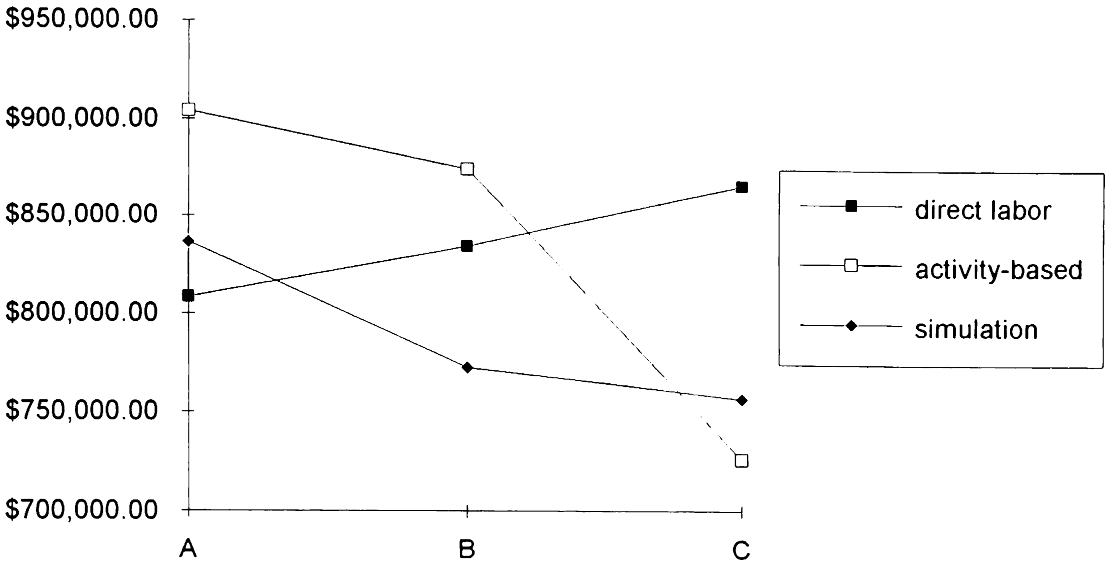

Figure 6: Scenario 3 Comparative Costs

they do not perfectly parallel the simulation data. Simulation data accurately predicts the effect of product mix decisions on manufacturing operations but is limited as a cost estimator because it can only measure costs that are modeled. Simulation does not predict changes in administrative activities, such as the clerical and accounting effort that may be required for outsourcing unless these activities are modeled. To efficiently predict the costs of different product mixes, a combination of simulation and activity-based costing will probably prove most effective.

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