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# EFFECTIVE COST MODELING ON THE FACTORY FLOOR: TAKING SIMULATION TO THE BOTTOM LINE (PANEL)

**Chair**

John S. Zuk

AT&T Bell Laboratories
Room 3B-341
600 Mountain Avenue
Murray Hill, New Jersey 07974

**Panelists**

George B. Kleindorfer

Dept. of Quantitative Business Analysis
College of Business Administration
Pennsylvania State University
University Park, Pennsylvania 16802

Robert D. Moore

Harris Semiconductor Corporation
P.O. Box 883
Melbourne, Florida 32901

William B. Nordgren

Production Modeling
Corporation of Utah
1875 South State Street, Suite 3400
Orem, Utah 84058

Don T. Phillips

Department of Industrial Engineering
Texas A&M University
College Station, Texas 77843-3131

## JOHN S. ZUK

### 1. STATEMENT OF PURPOSE

The purpose of this panel is to discuss the effective implementation of cost modeling methodologies on the factory floor. Our target audience is industrial and manufacturing engineers that are experienced in simulation modeling and are familiar with manufacturing cost issues.

### 2. MANUFACTURING COST ACCOUNTING - THE ARENA

In todays competitive manufacturing environment, engineers are often required to provide performance analysis metrics in terms of actual dollars - the bottom line. No longer can the engineer provide simulation results in terms of reduced work-in-process (WIP) or increased capacity; managers are demanding that quantitative (dollar) calculations on factory performance be provided before projects are approved. This requirement is further complicated, as recent studies have demonstrated that the financial information maintained by accounting personnel is inadequate or even incorrect in properly evaluating these systems. Outdated accounting principles that were developed during the industrial revolution are being improperly applied in the evaluation of today's complex manufacturing systems. Thus, engineers are required to develop their own techniques and tools to accurately evaluate the financial impact of such technologies as Total Quality Control (TQC) and Just in Time (JIT) manufacturing.

### 3. COST MEASUREMENT VERSUS COST MODELING

Cost modeling differs from economic reporting in much the same way as performance modeling differs from on-line performance measurement systems. On-line systems are effective in providing precise information in an up to the minute fashion. They can report exact amounts of wip, track specific manufacturing yield, etc. On-line accounting systems can measure the costs associated with a certain product or process - although they require the maintenance of copius quantities of data. Modeled systems, by comparison, are effective for performing what-if analysis on a simulated system. A verified/validated model may be used to accurately assess the benefits of an additional machine, or quantify the impact of process variability on throughput. These systems also involve large amounts of performance data - but are easily maintained and manipulated as they are typically not directly associated with on-line information systems. A number of manufacturing and service firms have successfully developed simulation models that include economic analysis. In addition, a number of simulation software packages provide constructs for economic modeling.

### 4. COST MANAGEMENT - SOME CURRENT ISSUES

Financial information has traditionally been associated solely with accounting personnel; hence, manufacturing cost management is a relatively new concept. The development of new costing philosophies based on logical management rules as opposed to general accounting principles is still a novel idea to many people. Just as any novel methodology (JIT, TQC) needs to be accepted by all members of the manufacturing environment before benefits are fully realized, manufacturing cost accounting must be accepted by engineers, operators, managers and accountants before it can truly impact performance. A great deal of research and development work has been performed by such noted academicians as Robert S. Kaplan (Harvard Business School) and Peter B. B. Turney (Portland State). Although their work has successfully explored cost theory and the development of Activity Based Costing Systems, they have not directly addressed the issue of effective vehicles for transferring cost technology across the manufacturing arena. I challenge panelists and conference attendees to champion this quest towards manufacturing excellence.

## GEORGE B. KLEINDORFER

There are two closely connected problems involved in analyzing the costs of a manufacturing system. One has to do with accurately allocating the costs of the system to the products manufactured by it. The other has to do with accurately analyzing the system as an investment. The problem with modern systems is that their flexibility makes it difficult to handle either problem. Primarily I want to discuss here a framework that would empower simulators to address the investment decision, although the costing of products cannot be distant from the same considerations.

I want to propose a dynamic modeling framework that includes interaction between the various operational aspects of the manufacturing system and the financial variables of cost- accounting fitted to that system. I want to get beyond the traditional static investment analyses of manufacturing systems in which the period by period flows of costs and revenues that accrue to the system are calculated, simulated, or projected based on gross aggregate estimates of the operational side of the system and then the usual indicators are evaluated like net present value, payback period, etc.

Ideally, I would like to see a framework that possesses the general modeling capability of a discrete-event language in which one can represent the details of material flows, equipment usage, and human resources. Added to such a system would be a structure much like that found in financial planning languages (IFPS, SIMPLAN, FOCUS, etc.) in which periodic calculations are made using financial variables. I think that these two different simulation structures, the physical flow and the financial flow, can be effectively and practically built on the base of a general discrete-event language. The calendar mechanism of such a system can be used to integrate the timing of the operational details of a manufacturing system: queuing, scheduling, logistics, reliability, and so on. But in addition to these well-known components of discrete-event simulation, this format can also include the periodic calculation and reporting of financial variables affecting and affected by the production system. It may seem at first blush that such an integration into a single system of such diverse aspects as the short-term random-time parallel-processing details of a manufacturing system could not be practically combined with the long-term, periodic, accounting and financial calculations involved in costing production systems out. But the generalized capability of the timing mechanism of a discrete-event language together with the computing power of microprocessors and miniprocessors makes such a comprehensive model both possible and practical. I can only mention a few of the factors involved here:

1. One of the most common means of allocating costs to products has been based on proportioning them on direct labor costs, even though in modern highly mechanized systems direct labor costs may only be a small fraction of total cost. Kaplan, Cooper, and others have advocated allocating costs based on factors that are much closer to the transactions involved in processing the product in the operational system. A simulation model that includes the description of such transactions can also be used as a basis for defining and calculating these costs as the product moves through the system. These costs may be associated with stations in the simulation model through which the product passes and may include the contribution to cost of added materials, of set-up transactions, of frequency in handling, and other detailed considerations that realistically add to the cost of manufacturing.

2. The discrete-event model is a natural format for the inclusion of scheduling networks, PERT networks, and other such means for representing planned changes to the system like the introduction of new equipment or the launching of new product manufacturing. The costs of these events and activities can also be included, and the outcomes of these networks can be used to directly affect the processing capabilities of the manufacturing system as it is represented in the simulation model.

3. In the discrete event model, daily, weekly, monthly, quarterly, and annual financial events can be scheduled, at which time the accumulation of discounted financial flows can be reported. It is important to note that these flows can themselves have been calculated based on the detailed simulation of the manufacturing system including effects brought about by scheduling, queuing, differentiated machining demands by product, machine reliability and maintenance.

4. The statistical analysis involved in such combined models would differ somewhat from that usually carried out in the simulation of manufacturing systems. Typically, planners have been concerned with designing a system so that material flows smoothly, without direct or explicit concern for costs. Thus, treated as a nonterminating simulation, a system can be brought up to steady-state operation where that steady-state is visualized as the smooth flow and the balanced allocation of equipment that the traditional cost-unconscious designer desires. However, in the combined models that I am describing that include the costing aspects of the system, the horizon of the simulation might most suitably be the whole life of the project. Time-wise this simulation may have to include manufacturing processes, emergency and planned maintenance, daily start-ups and shut- downs, week-end wage reports, monthly costs and revenues, and quarterly earnings. Each one of these processes will have to be adequately and accurately modeled and replicate runs of the total model performed as terminating simulations for the projected life of the project.

This is a lot of modeling and a lot of calculation but this is what we might have to resort to if we really want to obtain accurate estimates of the financial aspects of a sophisticated manufacturing system. Finally, I want to say that such a combined dynamic model is practical maybe not for a whole manufacturing facility but at least for substantial parts of it that a planner may want to price out. We are getting to the point in discrete-event simulation where the software has been efficiently and parsimoniously designed, and where the hardware can be operated unattended in order to carry out such extended simulation exercises inexpensively.

Any ideas that I have presented here that are sensible have been developed in my discussions of these problems with David Christy and Richard Kilgore. The misconceptions are my own.

## ROBERT D. MOORE

### 1. INTRODUCTION

Accurate determination of cost components for the operation of a factory can contribute greatly to that factory's success. In understanding where actual costs are being incurred, a manager can determine where to apply resources to reduce those costs. Current methods of accounting in use in most factories do not accurately describe or allocate costs where they belong. Including costs as part of other capacity modeling and simulation activities provides an effective implementation of cost modeling methodologies on the factory floor.

We must first understand that there is a difference between cost (or managerial) accounting which is necessary for controlling the factory and the financial accounting which is necessary for reporting a company's performance to the public (stockholders and the IRS). What we are seeking is a way to determine where actual costs are being incurred and to measure progress against reducing these costs. Managerial accounting methods have a certain freedom associated with them. This freedom is not shared by the financial accounting methods which are strictly governed by the Generally Accepted Accounting Principles (GAAP). We should not (for example) confuse the useful (or productive) lifetime of a machine with its depreciation period for taxing purposes. Similarly, we should not oversimplify the (real) mixture of production and engineering costs with the financial accounting concept of "Cost of Goods Sold".

I will touch upon four areas which I currently consider to be most important to an effective cost modeling and reporting strategy. I don't have answers to all of the issues, and so I hope that the panel and the audience can shed some light on these issues.

## 2. ALLOCATING COSTS WHERE THEY BELONG

One of the first places where improvement may be made in the area of cost modeling is to "throw out" the traditional method of labor based accounting used in so many companies today. Many costs are incurred through heavy capital investments with short effective lives. Cost accounting models which tally the direct labor (for example) and then adjust by 800 - 1500% for overhead provide little or no information to the manager who is trying to control his or her factory. A method is needed which allows all the various cost factors to be allocated in a way that is consistent with how they are actually used. For example, a machine that is used only for the production of "next generation" products should not burden the cost of "previous generation" products manufactured in the same factory.

Through the use of modeling and simulation, the usage of each resource by each product may be captured. This provides the ability to investigate different methods for allocating costs for different purposes where necessary. Clearly defined "cost models" will define which statistics must be kept during a simulation.

## 3. ALLOCATING THE "UNALLOCABLE" COSTS

A major difficulty that exists in allocating costs is what to do with the "leftover" costs that cannot be attributed to a particular activity. Examples of this include idle machine time, idle labor time, and facility space that is not directly associated with a particular machine or process. It is clear that these do represent real costs to the factory and will therefore contribute to the real cost of manufacturing product.

Should we gather these cost components into a bucket called "wasted dollars" (or "overhead"), or should we try to do something more intelligent with them? If we try to allocate these components back to machines or products specifically, what are some of the problems we face? For example:

1) If a product does not require a particular machine to be used during its fabrication, is it fair to then allocate "overhead" to that product which includes the idle time for that machine?

2) If a machine is blocked in a "pull" system due to a downstream operation being unavailable, should the blocked machine accumulate the idle time cost, or should the machine that is blocking accumulate that cost?

It is perhaps too simple (and maybe even counterproductive) to try to artificially allocate these costs directly either to the cost of ownership of a machine or to the cost of a product. Perhaps leaving them unallocated but clearly identifying them is the best solution.

## 4. WHAT ABOUT THE BENEFITS SIDE OF THINGS?

It is clear that knowing the costs associated with a new activity is more important now than ever before. However, in determining whether a new project should be undertaken, it is necessary to understand not only the costs but also the benefits. To do any project will cost more than to not do the same project. The real issue is whether the benefits outweigh the costs. It used to be (and still is in most cases) relatively easy to determine relative advantage of one strategy over a second. At that point, the decision to do something had already been made. The question is not "If ... ?" but rather "Which ... ?".

Many decisions today focus on the "If ... ?" question with a very intangible value to be placed on the benefits side. For example, it may be "important" to introduce JIT methods to reduce the cycle time of product through the factory. Simulations can tell us how much the program will affect the cost of the product (compared to the existing cost of the product). But what is the actual financial benefit of implementing JIT? For example:

1) How much is it worth to be able to predict with a high degree of accuracy the delivery date of a product to the customer?

2) How much is it worth to be able to turn orders around 2 - 3 times faster than can presently be done?

The answers to these questions cannot be determined to the same degree of accuracy to which costs can be predicted using techniques described above. Until these benefits can be better quantified, knowing the costs may be better used for controlling and monitoring programs rather than determining whether or not to pursue them.

## 5. COST MODELING - ON-LINE OR OFF-LINE?

The final issue that I wish to discuss is where the determination of costs should occur when modeling: during the simulation or after the simulation. I argue that cost determination should occur after simulation for the following reasons:

1) Calculation of cumulative costs during the simulations takes up precious space (in the form of additional attributes for the resources) and computational cycles (in the form of cost calculations) at each step. This increases the time for long simulations of detailed models of an entire factory by 20-50 per cent. This is significant if a simulation which doesn't include costs already runs for several hours.

2) The information is non-reusable. That is, once the simulation has been completed, to evaluate the effects of changes in the cost factors requires another complete simulation run. When the function of cost determination is separated from the rest of the simulation, "what if ..." scenarios on the cost factors alone do not require re- simulation. A calculation that would require several hours to re-simulate only takes a few minutes to re-calculate from already good simulation statistics.

3) The "unallocatable" costs mentioned above are not known as well during the simulation as they are after the simulation. This makes the allocation (or accumulation) of these factors even more difficult that it already is!

4) Finally (and perhaps most importantly), if an adequate cost model can be developed independent of the actual simulation (but fed by statistics from the simulation), then that same cost model could be used in conjunction with a real-time collection system. Then the cost model is not only useful for evaluating simulations, but it becomes a useful management tool for controlling the real factory as well!

**WILLIAM B. NORDGREN**

## 1. INTRODUCTION

Within the environment of manufacturing simulation, determining the cost of products is just as important as determining equipment utilization, throughput, system performance, and scheduling practices. It is obvious that no company can remain profitable without knowing the costs associated with the production of products. Current accounting methods are unable to account for many of the costs incurred in production because of the difficulty in tracking the parts through the entire production operation. Simulation provides the ideal tool for cost estimating since it provides a complete summary of production activity.

## 2. OPPORTUNITIES

In the development of simulation studies, a sizable amount of data is required to define the operating characteristics of a particular system. This data is the same type of data that is used to determine costing. Generally the engineer will gather the data for the simulation, and accounting will gather the same data for costing. The same data is used for both functions and then altered to achieve the most optimum results for each activity, which may or may not be in agreement. Using costing in simulation creates the opportunity for manufacturing and costing to come together, which in theory will allow for more accurate representation of costs and manufacturing data. By having built in constructs within simulation software that allow the modeler to define how costs are measured and allocated, simulation studies can provide information for both operational and financial optimization.

## 3. CHALLENGES

Several challenges exist in the development, implementation, and use of costing in simulation. Furthermore, to have such a system be accepted by the accounting powers within a company, whose recommendations have considerable weight when important decisions on product mix are made, could be a difficult task. In addition, many of the activity times on which costs are based can only be accurately estimated through the use of simulation. Without addressing the challenges of getting accounting to buy into such a system, the specific challenges faced by the engineer who is responsible for the simulation study will now be addressed.

The input and structure of defining simulation studies lend itself to defining costs in the actual production of parts to Activity Based Costing (ABC). Parts will have specific times allocated for operations, moves, assembly, queuing, and storage. Parts can be assigned a cost at each location depending on the amount of time it spends there, and from the cost pool that has been defined for that location. The problem comes in the assignment of overhead that is not assigned to any specific machine or part family. Simulation software must allow the user to decide how overhead will be distributed.

The modeler's ability to correctly model costs is another concern. The modeler must have a knowledge of how to correctly assign costs in order for the model to be valid. Simulation software must have on line support as well as documentation to allow users to make correct decisions, and make the features easy to use without having a degree in accounting or programming.

Output reports need to be easy to read, and in an acceptable format. The modeler should not have to spend a lot of time preparing reports for presentation. The simulation software must make it easy for the engineer to succeed in the presentation of results as well as in the modeling activity.

## 4. CONCLUSION

Production Modeling Corporation believes that costing is an important part of a simulation project. The addition of cost estimating to ProModel is an important step in the evolution of simulation software which will enable the assessment of the total project.

DON T. PHILLIPS

## 1. INTRODUCTION

The motivation for this discourse is the basic premise that most current managerial product costing systems inaccurately reflect true product costs, and fail to link technological and engineering "opportunity costs" to the managerial decision making process. During the last few years, it has become obvious that labor based accounting methodologies are no longer an accurate way to predict product costs. The advent of flexible machining centers, cluster tools, robotic controlled system, and "lights out" manufacturing cells require new and innovative methods to accurately determine product costs. In addition to the impact of manufacturing modernization, the economic impact of new philosophies such as JIT, TQC, group technology, Kanban, and other production control methodologies are not clearly reflected in today's business accounting.

We will discuss two alternatives to traditional cost accounting: stand-alone cell costing modules and discrete systems simulation.

## 2. DISCUSSION OF THE PROBLEM

Robert S. Kaplan (Harvard Business School) has popularized a concept called activity based accounting (ABC) in which costs are based upon the proportion of time a product spends in each activity, multiplied by an appropriate time based cost. The term "activity" includes transport, set-up, WIP costs, processing, maintenance and quality control. The fundamental change in product cost structure is a result of how burden, indirect, and product intensive costs are allocated to products.

## 3. RELATIONSHIP TO MANUFACTURING

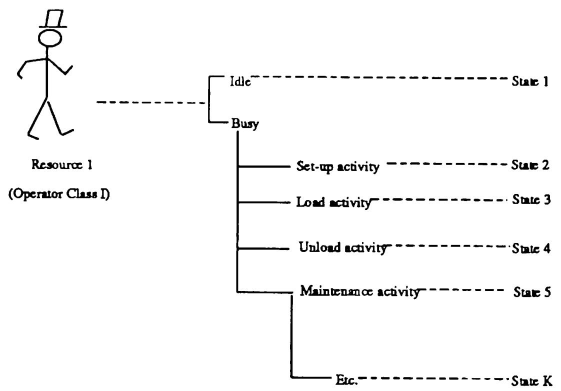
A concept which is driving much DLA, DARPA, and USAF research is the notion of CONCURRENT ENGINEERING. Companies are now realizing that product design and manufacturability are not independent activities. Concurrent engineering is an attempt to link changes, modifications, and new concepts in the product design phase to associated requirements in manufacturing. Activity based accounting is the vehicle through which technological requirements can be associated with product costs. Any engineering design change is always accompanied by corresponding change(s) in manufacturing activities. Activity based accounting is capable of accurately reflecting "as-is" and "to-be" costs and relating these costs to concurrent engineering.

A more subtle implication of technological innovation occurs anytime technology changes in a manufacturing system. Consider a simple case where a new machine controller reduces process cycle time from 2 hours to 1.5 hours. This "local change" actually affects the entire sequencing of the manufacturing system. At best, processing steps immediately preceding or following the process improvement station will exhibit a change in WIP behavior. Based upon traditional product costing systems, this technological change may be poorly reflected or absorbed in "purchase cost". Conversely, activity based product costing will properly balance system costs against technology improvement costs.

## 4. SIMULATION VERSUS ANALYTICAL COSTING

There are two ways to accurately reflect product costs using ABC. The first is to supplement traditional time-based digital simulation analysis with appropriate cost collection modules. Digital or next-event simulation languages are ideally suited to this application since simulation time is always advanced from event to event. Standard statistical collection procedures involve computational updates at each event. It is relatively straightforward to construct cost calculation routines which simultaneously calculate and accumulate cost profiles. This usually requires user-written code and language augmentation. The real weakness involves the cost activity categorization. Normally, resource usage is directly associated with activity or delay. Resources (machines, operators, mask sets, WIP storage locations, etc.) are SEIZED and used (DELAY) in the simulation model. Standard simulation constructs reflect resource usage as BUSY or IDLE. Costs are usually categorized as FIXED (non-time varying) or VARIABLE (cost per time unit). This activity/cost relationship is probably adequate for global analysis, but more detailed categorization is required for activity based cost analysis.

A key concept is one of VECTORIZED RESOURCES. A vectorized resource is one in which the resource resides in one of several states at all times. For example, consider a process operator.




Hence, when a resource is requested, two parameters are necessary: (1) the type of resource, and (2) the state in which this resource will reside. This type of identification scheme has direct implications to two important uses of simulation analysis: (1) identification of those activities which from a time standpoint should be addressed, and (2) identification of those activities which from a cost standpoint should be addressed. It is important to note that these two issues MAY OR MAY NOT CORRESPOND TO ONE ANOTHER. Both are certainly related to time and costs, but improvement of one may not significantly affect the other. This conflict gives rise to a whole new arena of decision support.

* Does time reduction significantly effect product costs?

* Does cost reduction effect cycle times?

* What is the time/cost trade-off?

* How should one rank/implement technological improvements from the joint viewpoint?

* How are market impact and opportunity costs effected?

There are other questions which might be addressed/discussed in the panel discussion.

The conflicts discussed and the categorization of costs required by simulation analysis are also relevant to analytical cost models. I would propose to develop an activity based cost analysis system for each area or cell in the factory. To capture, categorize, and manipulate manufacturing data, relational data base (RDB) systems are ideally suited to ABC analysis. The front-end task is to build a taxonomy of cost drivers and relate this taxonomy to products and shop floor activities. The translation to RDB/SQL data base structures naturally follows this product cost taxonomy. A good relational data base system (DBASE, RBASE, ORACLE, INGRES, etc.) provides maximum flexibility to manage and manipulate cost-activity relationships. Either through built-in statistical collection systems or a statistical post-processor, many cost-time profiles can be produced. Of course, individual area ABC profiles can be combined to form product (multi-area) profiles.

## 5. INDIRECT VERSUS DIRECT COSTS

Indirect and overhead costs present a related but different problem. These costs can be allocated to processes, products, or activities in any reasonable fashion, but this allocation should be done in a TWO-PHASE allocation which appropriately utilizes ABC.

## 6. SUMMARY AND CONCLUSIONS

I have discussed and presented a wide spectrum of viewpoints which reflect a belief that activity-based product costing more accurately reflects true manufacturing costs than traditional accounting methods. Indirect costs should also be proportioned to products according to burden/activities rather than product mix or other similar indicators. These thoughts are from an industrial engineer, and must be tempered appropriately.