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ABSTRACT

The use of robots to supplant direct labor, automated materials handling, computer controlled flexible manufacturing systems which are capable of producing a number of products within the same product line, and just-in-time production and distribution are creating a new manufacturing environment. As in the past, the need for assignment and control of direct material costs remains; however, the allocation and control of conversion costs can no longer be based on direct labor hours or labor costs. Further, since different products are produced in the same assembly line, the allocation and control of conversion costs, based on the materials used or units produced, is not possible. A machine cost per minute is, therefore, developed in order to allocate conversion costs to products and to effectuate control over such costs.

INTRODUCTION

The emergence of fully automated flexible manufacturing systems is creating a unique manufacturing environment. Flexible manufacturing systems (FMS) are capable of producing a number of products within a "family of products." In such a system, the major cost element is factory "overhead" rather than the "prime costs" of direct materials and labor. Further, the incidence of costs shifts from variable costs to fixed costs. These costs are best controlled by top management before they are incurred or committed to be incurred. While short-term profits are important, the emphasis now should be on profitability over the long term. The role of a management accountant employed in such a system changes from a passive reporter and exegete of past events to an active participant in decision making.

THE FLEXIBLE MANUFACTURING SYSTEMS (FMS)

Robotics, automated materials handling, and computer controlled machine tools are all part of the changing manufacturing technology. The integration of this technology into a unified production system in order to manufacture a number of products within a "family of products" is what is known as a flexible manufacturing system (FMS).

The essence of such a system is a self-contained grouping of machinery — machine tools, robots, etc.—that can perform all the operations required in the manufacture of a number of products with similar processing requirements. The operations, including transport from one machine to the next, are performed under computer control with minimal (if any) human intervention. Also, the sequence of products processed in the FMS can be random (Young and Green 1986). Using FMS, the General Electric plant at Erie, Pennsylvania is able to manufacture diesel engines of different sizes on the same automated production line without costly retooling and long setup time (Seed 1984).

Automation is not new; however, the increasing dependence on flexible manufacturing equipment is new. With FMS, it is now possible to gear production to the demands of the market place.

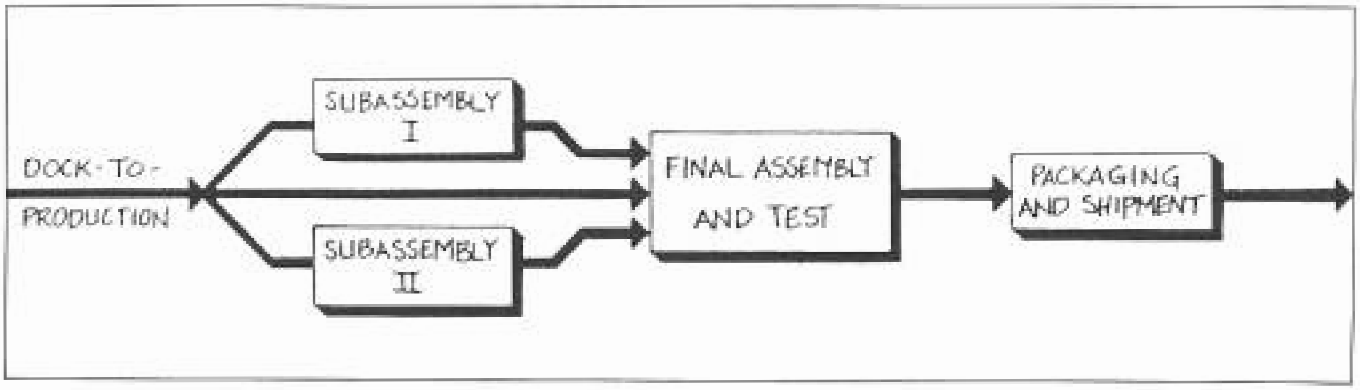
JUST-IN-TIME (JIT) PRODUCTION AND DISTRIBUTION

Often hailed as the best way to manage manufacturing, just-in-time (JIT) means producing exactly as many units of a product as customers demand at any given time. This system allows significant reductions in inventory and smooth uninterrupted production. In such a system, the demand for a unit of finished product activates each preceding link in the production and distribution chain, all the way back to the supplier of materials and component parts. In other words, materials and component parts are placed in the subassembly and final assembly lines directly when received and thence into the distribution channels. The process occurs without any storage at intermediate points.

The system is notable for its simplicity. A small batch of a product or its component is produced only when a command is received that it be produced or moved. JIT requires perfect timing, no wasted motion or wasted material and/or parts, zero inventories of materials and finished goods, and minimum irreducible inventory of work-in-process that is essential to cover the leadtime required for production (see Exhibit 1).

There are three underlying considerations behind JIT: 1) JIT cannot function effectively if setup times are long because that makes small batches impractical and une-

EXHIBIT 1



conomical. 2) Safety stock is undesirable; it costs money and hides problems such as inefficient production practices. 3) Productivity and quality are inseparable (McClain and Thomas 1985). JIT is not possible if low quality components are produced. A firm will not be able to test, rework, and deliver products on a timely basis.

With the advent of programmed flexible manufacturing systems, instantaneous communication, and rapid worldwide transportation, it is no longer necessary to carry inventories of high value durable goods, such as automobiles, machinery and appliances in order to prevent a stock-out or loss in revenue. Demand for a product can be met just-in-time by producing the right product of the right quality without unnecessarily clogging the production and distribution line with a surfeit of materials, work-in-process and finished goods. Hence, FMS and JIT dovetail and complement each other; one is not feasible or necessary without the other.

WHY ADDITIONAL APPROACHES ARE NECESSARY

FMS and JIT manufacturing methods and techniques cause substantial changes in the manufacturing arena:

1. FMS productivity is largely machine determined. Automation shifts the determinants of productivity from people to machines.
2. Almost all labor costs become fixed supervision costs. People either supervise other people or supervise machines.
3. Capital investment decisions become extremely important. Large capital outlays become unavoidable, thus demanding productivity over a long period of time.
4. Control of inventory ordering and carrying costs becomes less important. Investment in inventories at all levels is kept at a minimum through just-in-time production and distribution.
5. Direct labor costs become virtually nonexistent. The majority of conversion costs shift from people to machines. When using FMS, most actual labor is done by robots. Hence, the amount of labor cost per unit of production becomes negligible.
6. Rework and scrap costs are less important. FMS keeps work-in-process inventories at a minimum. Human errors occurring in the physical handling of products do not enter into the production equation. Hence, defective production, if any, can be recognized at the source during the production process.
7. Competitive supplier bidding becomes less important. With emphasis placed upon just-in-time inventory control and total quality control, there is a movement to single or very few sources of supply.

Using FMS, Product Costs Are Machine Determined

Manufacturing conversion costs are largely determined by the equipment itself, since productivity, investment, direct labor costs (if any), and quality control costs are machine determined. Machine-determined costs are creating a new role for the management accountant. Under the traditional standard costing system, control was exercised through the analysis of price and usage variances for materials, direct labor, and factory overhead. Formerly, costs were controlled through management by exception. Management's focus was upon those variances which happened to be unusual.

As a result of the changed emphasis on automation, efficiency is centered in the equipment; conversion costs are now largely fixed (Seed 1984). FMS allows little flexibility to changes in production levels. Manufacturers with heavy capital investment in state-of-the-art equipment are highly cost conscious when there is a ready market for the products they are capable of producing. However, when new technology in the hands of competitors brings lower costs, there is little flexibility to adapt. Considering these newer techniques and methods and their attendant problems, what is the role of the management accountant in the flexible manufacturing environment?

INVOLVEMENT OF THE ACCOUNTANT IN THE PLANNING STAGE

In a machine-paced production situation human labor is replaced by machines and robots. Substantial investment in capital assets becomes essential. These costs become sunk costs once the necessary assets are acquired. The accountant must become actively involved in the planning stages of capital investment, screening potential material and parts suppliers, and in new product development. Though productivity still requires monitoring, the emphasis has shifted from reactive controls to proactive decision making (Littrell 1984). However, once production starts, control of costs can be exercised by establishing standards for product's costs and through the analysis of variances from the standards set.

Standards For Direct Material Costs

Even in a fully automated production situation, when different products are manufactured, the kind of materials and parts used, the quality needed to make a product, and the material costs will differ from product to product. The standard quantity of materials and parts required to produce a finished unit and the standard price at which these are to be acquired can be predetermined. Hence, when materials are purchased and used in production, the price variance and usage variance can be identified and controlled. This type of analysis and control of material costs is the same irrespective of whether production is machine-paced or not.

Conversion Costs — Standard Cost/Minute

In a fully automated production environment, it would seem most appropriate to develop a standard conversion cost per hour or minute and cost products on this basis (Seed 1984). As robots replace direct labor, setting standards and controlling conversion costs on the basis of direct labor hours or labor cost is no longer valid. Since different products are produced from the same assembly line under FMS, allocation and control of conversion costs on the basis of materials used or units produced is also not possible.

Conversion costs fall under two categories: 1) idle-time costs and 2) operation-time costs. Idle-time costs are those conversion costs incurred in order to maintain a factory in a running condition irrespective of whether it is productively engaged or not. Hence, idle-time costs tend to remain fixed in their totality. On the other hand, operation-time costs are incurred only when a plant is actively producing; therefore, these costs tend to vary directly in relation to activity.

The authors prefer to categorize and identify conversion costs as idle-time costs and operation-time costs rather than as fixed and variable overhead costs. The term overhead implies that such costs are of minor significance (the tip of the iceberg of costs) compared to prime costs which consist of direct material and direct labor costs. The concept of prime cost as the major cost element is valid only in the context of a labor-intensive production system. In a fully-automated production system, conversion cost is the major component of a product's cost, despite the absence of a direct labor content. Even in such a system, the term conversion cost, without direct labor, is an appropriate usage that would aptly identify those costs incurred to convert direct materials and parts into finished products. The term overhead does not convey this meaning.

Unlike fixed and variable selling and administrative expenses, conversion costs create form utility and become an integral part of the cost of a product manufactured. Hence, conversion costs can be inventoried using generally accepted accounting principles. It is, therefore, desirable to distinguish conversion costs from those fixed and variable costs which are expended during an accounting period. Further, the term fixed cost per minute or hour is a contradiction in terms; it is the total cost that remains fixed and not the cost per unit of activity. In addition, total fixed cost remains constant only in the context of a relevant range and only for the short run. Conversely, variable costs change in relation to activity, while the unit cost remains fixed in the short run.

The terms idle-time costs and operation-time costs do not denote any of these contradictions. Perhaps more significantly, the term idle-time costs highlights the fact that every moment a plant remains idle, these costs remain underapplied to production, resulting in a loss to a firm.

Identification of unabsorbed idle-time costs is of crucial importance to management, especially in a capital intensive production system such as FMS. Accordingly, the authors suggest a combined conversion cost per minute, separately classified as idle-time cost per minute and operation-time cost per minute, for use in product costing and control under FMS. A format for developing such costs is suggested in Exhibit 2.

EXHIBIT 2

STANDARD COST PER MINUTE

IDLE-TIME COSTS:	
Indirect Materials Costs (Fixed Element)	$_____
Direct Machine Supervision Costs (Fixed Element)	_____
Indirect Supervision Costs	_____
Building Occupancy Costs	_____
Insurance Costs	_____
Depreciation Costs	_____
Service Center Allocation Costs	_____
Total Idle-Time Costs	$_____
Divided by Budgeted Machine Activity (Minutes)	_____
Equals Idle-Time Cost/Minute	$_____
OPERATION-TIME COSTS:	
Energy Costs	$_____
Indirect Materials Costs (Variable Element)	_____
Repair and Maintenance Costs (Variable Element)	_____
Direct and Indirect Supervision (Variable Element)	_____
All other Variable Conversion Costs	_____
Total Operation-Time Costs	$_____
Divided by Budgeted Machine Activity (Minutes)	_____
Equals Operation-Time Cost/Minute	_____
TOTAL CONVERSION COST/MINUTE	$_____

Source: Mathew et al. 1986.

Using this format the standard cost of a unit may then be compiled and accounted for on the basis of the standard quantity of materials needed, times the standard price, plus the standard time required to convert the materials into the finished product, times the total conversion cost per minute. That is

Standard cost = (Standard materials × standard price)
+ (Standard conversion time × cost/minute)

The variances between actual conversion costs and the standard conversion costs for each product manufactured could be identified and controlled using the variance analysis methods now in vogue, in the same way as factory overhead variances are analyzed (Horngren and Foster 1987).

THE ADVANTAGES OF COST/MINUTE COMPUTATION

Important advantages accrue as a result of charging conversion costs to products on a cost/minute basis. The method is simple to use and direct in its application. Unlike direct materials and direct labor costs, conversion costs are indirect costs which are not traceable to specific products. In an automated flexible manufacturing system a number of products using different materials in differing quantities are produced in the assembly line. In such a system direct labor is virtually nonexistent. Hence, the appropriate activity on the basis of which conversion costs can be charged to products is machine time utilized.

Applying conversion costs on a cost-per-minute basis will cause all such costs to flow out to the products produced using machine time as a means of accumulation, assignment and control of costs. This will be a logical and consistent development as the manufacturing environment shifts to a machine-paced production. Setup time, run time and normal downtime costs could be passed on to the inventoriable products, while abnormal machine downtime would be expensed to the period in a manner similar to the traditional treatment of normal and abnormal spoilage. When operating at normal capacity, the manufacturing costs would appear in the income statement as cost of goods sold. Machine shutdowns due to either excess capacity or quality problems would be separated and highlighted in an expense account which could be titled "Idle-Time Loss."

Computation and Comparison of Productivity Ratings

In an automated factory, the machine supervisor does not operate the machines in the traditional sense, but supervises the operation of the robots. Since human intervention is not the expected role of labor, productivity in a highly automated manufacturing system is machine determined. Hence, machines become the logical point at which to evaluate productivity (Brayton 1985). Productivity is the value of the machine output divided by the cost of the machine inputs. The cost of the inputs would be the cost as developed in the proposed "Standard Cost/Minute" format. For example, a machine which has a cost of $125/minute and a production with a value of $175/minute has a productivity rating of 1.4.

This calculated productivity ratio would be useful in the evaluation of new capital investment alternatives or to determine whether existing equipment must be replaced in order to remain competitive in the market place. When new state-of-the-art technology which significantly improves productivity becomes available, it becomes necessary that old equipment and plants be replaced in a machine-paced environment. Otherwise, a competitor will gain a sufficient cost advantage and drive the present manufacturer out of the market place.

When evaluating new equipment it is critical to remember that, as more costs become fixed, there is less flexibility to respond to shrinking markets. When a machine is shut down, most of the conversion costs keep accumulating. When comparing two machines with the same productivity, it is essential to realize that the machine capable of achieving this productivity with the smallest proportion of fixed costs to total costs allows for a greater reduction in input costs before financial losses are incurred.

It would appear that the establishment of smaller, compact plants located in strategic market areas, as compared to the continuation of "Steel" cities and "Automobile" cities, is the wave of the future. Further, if a firm is to generate profits over a long period of time, short-run profitability ought to give way to the goals of greater market share and long-term profitability in a capital intensive production system.

Productivity and Break-Even Analysis

A useful calculation in the evaluation of productivity factors would be the percent operating time necessary to break even. This calculation is the reciprocal of the productivity rating times one hundred. However, we must remember that the value of the production in FMS depends upon the expected product mix (Dilts and Russell 1985). As the proportion of the individual product being produced changes due to the FMS introduced within the family of products, the average value of production will also change. Not only would machine costs per minute be used as a method of evaluating new equipment, but it would also be applied for control purposes of the existing equipment.

As historical cost data are gathered from the operating equipment, these data could be judged against the developed standard (Brayton 1985). Each item in the Standard Cost/Minute would be analyzed. The total variance from the standard would be broken down into quantity and rate variances. This procedure would flag problem areas where management expertise could improve productivity. Favorable variances would also be analyzed to discover why the operation was more efficient than expected. These efficiencies might then be extended to other areas. While control standards are less important in a machine-paced environment, they are still a useful tool.

Highlighting of Setup and Idle-time Costs

Another advantage of directing conversion costs through the machines would be the emphasis placed upon setup costs and idle-time costs. In an effort to reduce the costs associated with production, the newer manufacturing methods (FMS and JIT) allow "product demand" to pull production through the system on an "as needed" basis. Work stations are required to have the necessary flexibility to shift from product to product with minimum setup time. In this pull-through system, the earlier work station's output is determined by the next work station's input requirements. Inventory cost saving is offset, at least in part, by setup and idle-time costs. By using the equipment to accumulate all conversion costs, downtime costs are kept in the forefront of management thought.

Idle-time costs are also important when considering the newer manufacturing methods with regard to total quality control (TQC). Since inventories do not accumulate along the production line, it becomes possible to continually monitor the quality of the products being produced and to immediately shut down the production line when the supervisors realize that the process is producing defects (Hunt, Garret, and Merz 1985). This emphasis on total quality control allows a reduction in rework expense. Normally expected setup and idle-time costs could be passed along to the products. Abnormal downtime could be allocated to the period in order to further emphasize the costs associated with machine shut down.

Inventory Valuation

The FMS with its shorter runs and variety of products passing through the same work stations could present a problem in inventory valuation. Accumulation of conversion costs on a cost-per-minute basis allows a simple but effective means of inventory valuation. Time meters could account for setup time and idle-time in order to evaluate the cost of production, or the predetermined standard times could be used to determine a standard cost per unit. This method would serve as a control device to evaluate the actual cost incurred. While there are other inventory evaluation methods being developed by firms operating in the highly automated systems (Hunt, Garret and Merz 1985), the proposed cost per machine minute method is simple to use. It also maintains the advantage of standards for control purposes.

CONCLUSION

The management accountant has a crucial role to play in a flexible manufacturing system which is synchronized with just-in-time production and distribution. The accountant is involved in the determination and control of costs and in the decision-making process which will reduce uncertainty. As more costs become fixed and productivity is largely determined by the equipment, management's highest priority becomes the need to monitor the environment surrounding the manufacturing process. There needs to be a constant assessment of current technology, existing and potential markets, as well as existing and potential suppliers. The management accountant possesses the knowledge and skill levels required to help make these assessments. To accomplish these goals the accountant needs new tools to meet new situations. Equipment cost per minute is proposed as one such tool.

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empirical data to support the effectiveness of the use of the power index in practical situations. A full test of the validity of the approach would require an empirical test of this nature.

CONCLUSION

This paper has illustrated how the power index can be used to evaluate the distribution of influence on a committee. The power index provides an objective, quantitative measure of the power of subsets of a committee to influence voting outcomes. As such, it can provide useful inputs into decisions concerning the design and evaluation of committees.

It goes without saying that committees should consist of competent members. Beyond this, a committee's decisions would depend on the self-interests or special expertise of its members. For example, divisional managers on a capital budgeting committee may be motivated to approve projects from their own divisions. Similarly, EDP executives on an EDP Committee may promote a larger and more sophisticated system than the organization needs. In cases like these, the expertise of the committee members needs to be balanced against their apparent self-interests.

Yet in other cases, top management may actually want certain positions to predominate. For example, suppose a committee is created to oversee the development of an entirely new product. In the beginning stages of the developmental process, it may be desirable to rely heavily on inputs from the research staff. As the product takes shape, perhaps the views of the production and marketing functions should be emphasized. Regardless of management's desire, it needs a way to assess the relative influences of special interest (or expertise) groups on a committee. In this paper, we have illustrated how a "power index" can be calculated and used to address this issue.

APPENDIX

THE VOTING SEQUENCE, THE PIVOT, AND THE POWER INDEX

A] Assume four VOTING BLOCKS, A B C & D, with 5, 3, 4, and 2 members respectively, for a total of fourteen committee members.

B] A VOTING SEQUENCE is an ordered listing of voting blocks; for example, (5, 2, 4, 3). In this example, the voting block with five members was the first to be persuaded to vote for the item in question, the two member block was the second, the four member block was the third and the three member block was last.

C] Assume the rule is that a simple majority is sufficient for a successful vote, in this case eight votes. Looking to the (5, 2, 4, 3) voting sequence example above, we say that the four member block is a PIVOT, since it is the last block to join the successful vote, that is, to have eight or more votes.

D] If we list all possible sequences, and find which voting block is the pivot in each, we can obtain the POWER INDEX for each voting block, as follows:

$$\text{for voting block ``A''} = \frac{\text{Number of voting sequences in which ``A'' is the pivot}}{\text{Total number of voting sequences}}$$

E] Characteristics of the Power Index

1. The power index is a number between zero and one.
2. The sum of the power index values of all voting blocks equals one.
3. The total number of voting sequences is the factorial of the number of voting blocks; for example, with four voting blocks, the number of voting sequences is $4! = 4 \times 3 \times 2 \times 1 = 24$.

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