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While the world's attention is focused on the fight to increase productivity and develop new technologies, manufacturing managers—especially those in the electronics and mechanical equipment (machinery) industries—are quietly waging a different battle: the battle to conquer overhead costs. Indeed, our research shows that overhead costs rank behind only quality and getting new products out on schedule as a primary concern of manufacturing executives.

The reason for this concern is obvious: high manufacturing overhead has a dramatic effect on profit and competitiveness, and manufacturing managers believe themselves to be poorly equipped to manage these costs well. As one senior executive told us, "We've been brought up to manage in a world where burden rates [the ratios of overhead costs to direct labor costs] are 100% to 200% or so. But now some of our plants are running with burden rates of over 1,000%. We don't even know what that means!"

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We are convinced that this renewed attention to overhead is not a cyclical phenomenon. No doubt, low capacity utilization accounted for some increase in awareness during the last recession; even so, awareness has remained high throughout the recovery. Overhead costs as a percentage of value added in American industry and as a percentage of overall manufacturing costs have been rising steadily for more than 100 years as the ratio of direct labor costs to value added has declined (see *Exhibit I*). Moreover, in today's environment, production managers have more direct leverage on improving productivity through cutting overhead than they do through pruning direct labor.

As America's factories step up the pace of automation, they find that they are being hit twice: first, overhead costs grow in percentage terms as direct labor costs fall (everything has to add up to 100%); and second, overhead costs grow in real terms because of the increased support costs associated with maintaining and running automated equipment.

Exhibit II shows how overhead as a percentage of value added increases as a representative industry—electronics—moves down its product-process life cycle.[1] Highly customized and low-volume specialty businesses, such as those in the government systems segment of the industry, run job-shop-type opera-

1 See Steven C. Wheelwright and Robert H. Hayes, "Link Manufacturing Process and Product Life Cycles," HBR January–February 1979, p. 133, and "The Dynamics of Process-Product Life Cycles," HBR March–April 1979, p. 127.

Exhibit I Components of value added

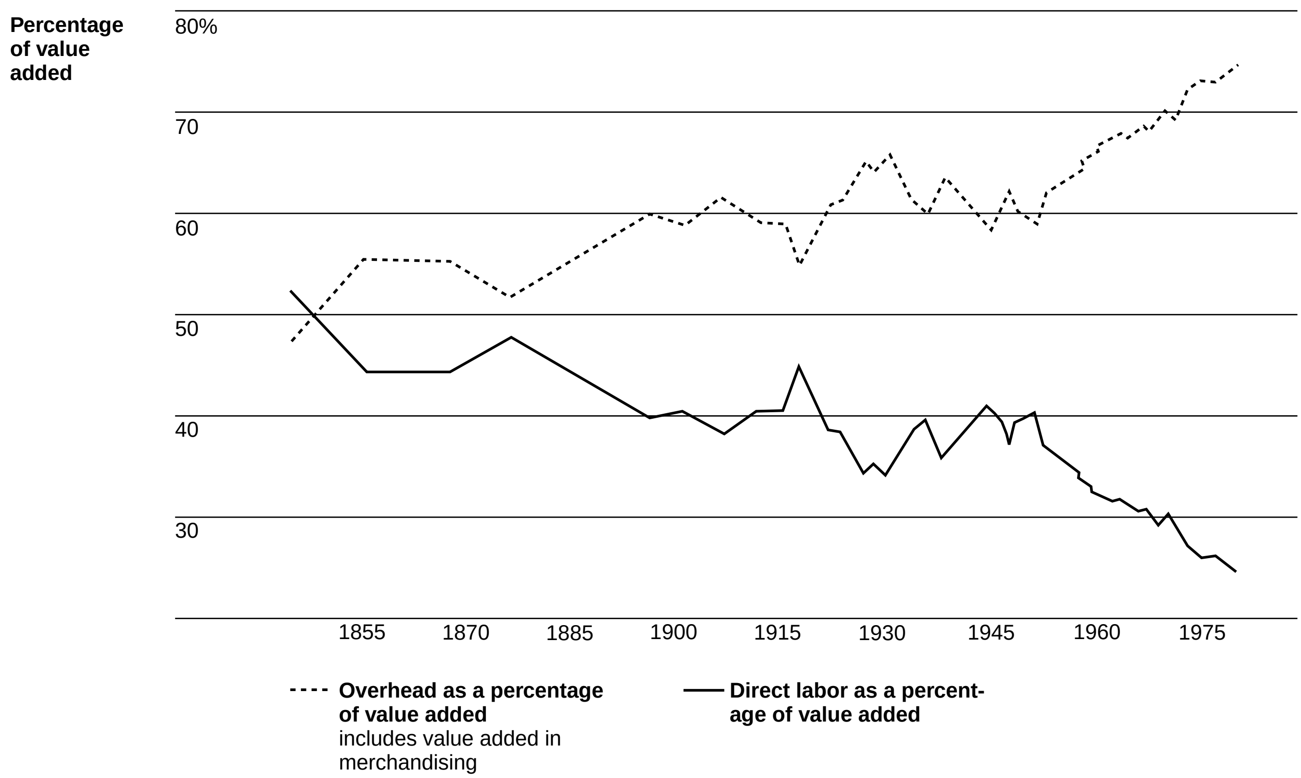
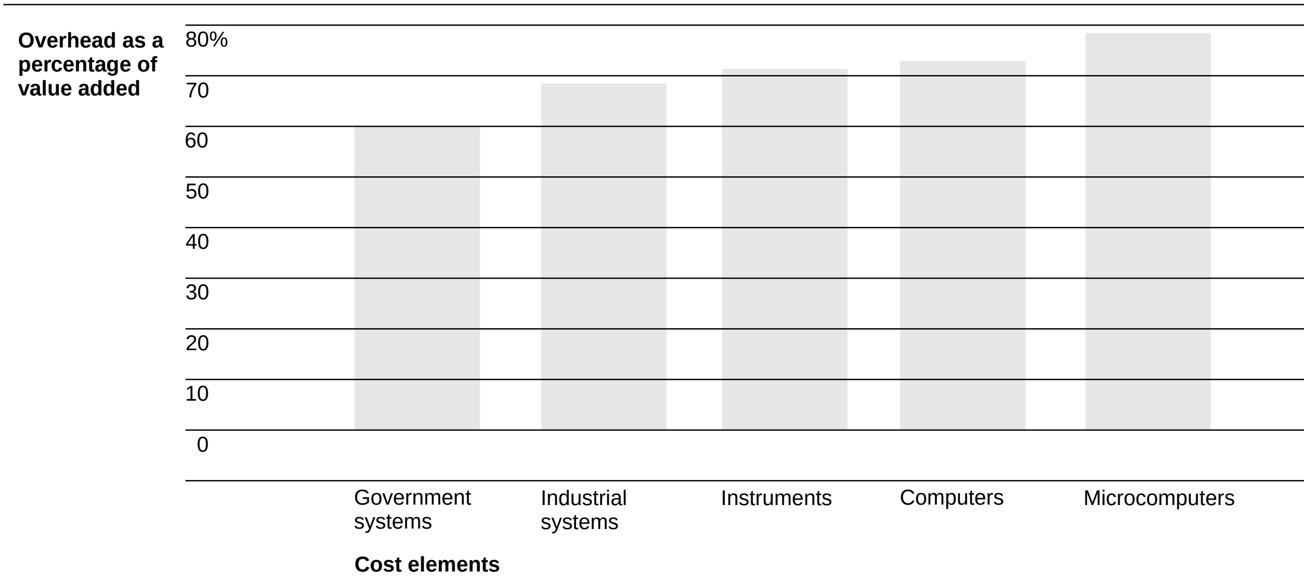


Exhibit II Overhead as a percentage of value added in five segments of the electronics industry



Source: Developed from data in the 1983 report of the American Electronics Association.

tions with a relatively low ratio of overhead to direct labor. By contrast, in businesses producing high-volume standardized products in automated environments, as in the microcomputer segment of the industry, the ratio of overhead to direct labor cost is notably greater.

Our data suggest that across the spectrum of U.S. industry, manufacturing overhead averages 35% of production costs; the comparable figure for Japanese products is 26%, despite the fact that the Japanese have been rapidly automating. The differential is particularly large in the electronics and machinery industries, where American overhead accounts for 70% to 75% of value added, and Japan's for 50% to 60%. (See the insert entitled "Research Methods" for a description of the methods and data we used.)

A focus on transactions

For managers, the critical step in controlling overhead costs lies in developing a model that relates these costs to the forces behind them. Most production managers understand what it is that drives direct labor and materials costs, but they are much less aware of what drives overhead costs. True, we do have models that accountants use—as they do engineering standards and bills of material—to relate overhead costs to products produced. But these models do not so much *explain* overhead costs as *allocate* them.

Most of these efforts use the engineering standards and bills of material models that we do understand as the basis for allocating overhead costs that we do not understand. These efforts base overhead burden rates on direct labor, materials, or machine hours. The problem with this approach is that the driving force behind most overhead costs is not unit output or direct labor. Overhead costs do usually correlate with unit outputs, but that does not mean that unit outputs "cause" overhead costs. In fact, acting as though they were causally related leads managers to concentrate on output measures or on direct labor rather than on the structural activities that determine overhead costs. (See the insert entitled "Overhead Costs Defined.")

Unit output drives direct labor and materials inputs on the actual shop floor that we all think of when we envision a factory. But in the "hidden factory," where the bulk of manufacturing overhead costs accumulates, the real driving force comes from transactions, not physical products. These transactions involve exchanges of the materials and/or information necessary to move production along but do not directly result in physical products. Rather, these transactions are responsible for aspects of the "augmented product," or "bundle of goods," that customers purchase—such aspects as on-time delivery, quality, variety, and improved design.

To see clearly how the hidden factory creates overhead costs, we must identify the basic types of transaction that are carried out there by the people whose wages and salaries account for the following costs.

Logistical transactions, which order, execute, and confirm the movement of materials from one location to another. These transactions are processed, tracked, and analyzed by many of the indirect workers on the shop floor as well as by people in receiving, expediting, shipping, data entry, data processing, and accounting. For the electronics industry, we estimate that processing such transactions accounts for 10% to 20% of total manufacturing overhead.

Balancing transactions, which ensure that the supplies of materials, labor, and capacity are equal to the demand. These result in the movement orders and authorizations that generate logistical transactions.

The people involved in processing such transactions include purchasing, materials planning, and control personnel (who convert master schedules and customer orders into materials requirements and purchase and shop orders) as well as human resource staff (who convert these demands into labor requirements). Also included are managers who process and authorize forecasts and who turn orders into production plans and master schedules. We estimate that these transactions also account for 10% to 20% of manufacturing overhead in electronics manufacturing.

Quality transactions, which extend far beyond what we usually think of as quality control, indirect engineering, and procurement to include the identification and communication of specifications, the certification that other transactions have taken place as they were supposed to, and the development and recording of relevant data. In the electronics industry, quality transactions add up to some 25% to 40% of manufacturing overhead.

Change transactions, which update basic manufacturing information systems to accommodate changes in engineering designs, schedules, routings, standards, materials specifications, and bills of material. These transactions involve the work of manufacturing, industrial, and quality engineers, along with a portion of the effort expended in purchasing, materials control, data entry, and data processing.

Change transactions can occur over and over again. The first time you design a product, for example, you transact a bill of materials; every time you process an engineering change order (ECO) for that product,

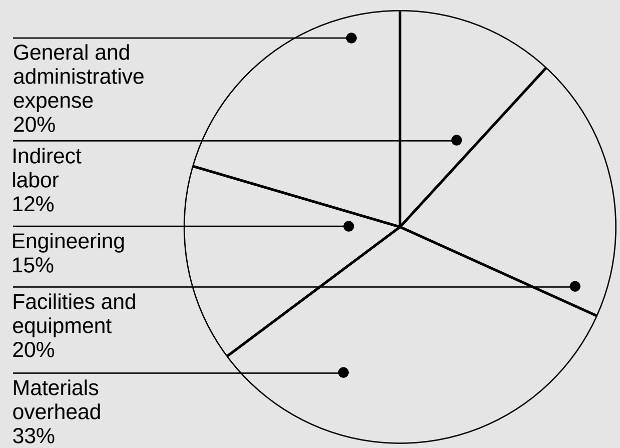
Overhead costs defined

In principle, manufacturing overhead is easy to define: it includes all the direct and allocated costs of manufacture other than direct labor and purchased materials. Among these costs are:

- Indirect labor, including the wages of hourly workers who do not directly contribute to the manufacture of a product but consisting mostly of labor dedicated to materials handling, maintenance, quality control, and inspection.
- General and administrative expenses such as personnel administration, cost accounting, security, salaries for plant management, and direct labor supervision as well as corporate allocations for shared services and corporate staff.
- Facilities and equipment costs such as insurance, depreciation of plant equipment, and tooling. These costs also include rents and other facilities-related expenses such as energy and utility costs. (Note that in process-based industries, energy costs may comprise the single largest component of overhead and total costs. Our data suggest that energy accounts for about 4% of the total manufacturing costs for a typical plant in the electronics or machinery industries.)
- Engineering costs such as the salaries of manufacturing, industrial, and other engineers concerned with the design and maintenance of the production process itself.
- Materials overhead costs, including those related to the procurement, movement (with the exception of those shop floor materials-handling costs relegated to the indirect labor category), and coordination of raw materials, components, subassemblies, and finished products. These costs also include the salaries of purchasing, production planning, receiving, stockroom, traffic, and manufacturing systems personnel.

This figure shows the average distribution of these cost categories in the four electronics plants we examined. None of these plants kept its overhead accounts in exactly the fashion we have described. Although their basic categories were the same, each had invented a somewhat different nomenclature and taxonomy for keeping track of these costs. To arrive at a relatively consistent—and comparable—set of numbers, we had to recast the costs at each of these plants.

Table Manufacturing overhead cost elements in the electronics industry



you have to transact the bill again. The doing and undoing of logistical, balancing, and quality transactions that result from change transactions lead companies to incur overhead costs twice, three times, or more, depending on the stability of their manufacturing environments. Overall, change transactions represent 20% to 40% of overhead costs in electronics manufacturing.

Managing overhead transactions

If, as we believe, transactions are responsible for most overhead costs in the hidden factory, then the key to managing overheads is to control the transactions that drive them. By *managing transactions,* we mean thinking consciously and carefully about which transactions are appropriate and which are not and about how to do the important transactions most effectively. Manufacturers have rigorously applied this type of analysis to direct labor since the days of Frederick Taylor. Now that overhead costs far exceed direct labor costs, however, managers should redirect their analytical efforts.

Transaction analysis

The design criteria used in developing most products and production processes rarely take overhead costs into account, let alone the transaction costs involved in alternative designs. It is possible, for ex-

Authors' note on research methods

The research on which the data and conclusions in this article rest comes from two different sources. Most of the quantitative data come from the 1984 "North American Manufacturing Futures Survey," which we administer. Insights into overhead cost structures in the electronics industry—and the managerial problems and issues surrounding them—come from structured interviews and data analysis of four electronics factories in the United States and from subsequent follow-up visits to numerous other plants in the electronics and other industries in the United States and the Far East. The Boston University Manufacturing Roundtable sponsored both of these data-gathering efforts.

The Manufacturing Futures Project is an annual survey of the competitive strategies, concerns, recent activities, and plans that North American manufacturers are making to improve their operational effectiveness. In the 1984 survey, respondents included more than 200 senior manufacturing executives in as many different business units (the typical title of the respondents was vice president of manufacturing). Participating business units came from a broad range of industries, which we categorized in five classes: electronics, consumer packaged goods, machinery, basic industries (chemicals, metals, paper), and other industrial goods. In 1984, the third consecutive year we administered the survey in North America, it was also administered to more than 200 business units in both Japan and Europe by our collaborators at Waseda University in Tokyo and at INSEAD in France.

The "Manufacturing Futures Survey" contains more than 50 multiple-part questions. A small number (those relating to managing overheads) formed the basis for the analysis in this article. For example, one survey question required respondents to indicate on a five-point scale the degree of their concern about 32 potential problem areas. The top five concerns were as follows (the number in parentheses indicates the mean scaled score given each potential concern across all respondents to the survey):

1. Producing to high quality standards (3.98).
2. Introducing new products on schedule (3.56).
3. High or rising overhead costs (3.55).
4. Low indirect labor productivity, including white-collar work (3.44).
5. Yield problems and rejects (3.28).

People in the electronics and machinery industries were the most concerned with overhead costs and indirect labor productivity, although concern about these areas was high in all five industry groups analyzed. To narrow the focus of our subsequent investigations, we decided to concentrate on the problems of managing overhead in the electronics industry. Our rationale was that this industry group had proved to be something of a bellwether for other industries during the history of the Manufacturing Futures Project.

Moreover, numerous plant visits convinced us that many of the problems in managing overhead in this fast-changing industry were reflected in other industries, especially in the machinery group. The very high levels of capital investment and energy consumption required in the basic and consumer goods industry groups substantially change the cost structure (and thus the nature of the problems of managing overhead), although we think that much of what we have to say is relevant for those groups.

Our field investigations included extensive tours and interviews at four plants in the electronics industry—two focused on components manufacture and two on the assembly of high-volume equipment. Needless to say, we also spent considerable time discussing overhead costs with both accountants and managers from the plants.

To develop comparable data on overhead costs, we followed several conventions. First, we lumped all overhead costs into one pool. Second, we unbundled all costs so that they fell into mutually exclusive categories. For example, we put all depreciation and space costs in the "facilities" category, even though a particular company might follow the practice of allocating depreciation costs to organizational subunits like purchasing and rolling them up into a total purchasing cost (which we would put in the "materials overhead" category).

ample, to eliminate numerous transactions by designing short-cycle production processes without any work-in-process (WIP) inventory that would require logistical, balancing, or quality transactions. This is what the Japanese have done with their "just-in-time" philosophy of process design, which "pulls" work through the factory only as needed by operations downstream. This approach eliminates much of the need for elaborate and time-consuming WIP-tracking or shop-floor control systems.

One electronics product that was redesigned to meet competitive pressures provides a vivid example of what a low-transaction production system can do. Prior to the redesign, the product contained more than 700 parts, most of which had to be ordered from a supplier on a weekly basis and then placed in a materials inventory before being withdrawn in batches and taken to the final assembly area. The plant shipped each week's output to a finished goods inventory in the company's distribution system. A count of the number of monthly transactions required by this system is as follows:

Ordering transactions	=	700 parts	× 4		=	2,800 transactions
Receiving transactions	=	700	× 4		=	2,800
Materials transactions (in and out of inventory)	=	700	× 4	× 2	=	5,600
Materials authorizations	=	700	× 4		=	2,800
Total transactions					=	14,000 per month

After careful study, management decided that:

1. Changes in product design and vendor specifications could reduce the part count from 700 to 200.
2. The factory could issue blanket orders instead of separate purchase orders for materials and could provide vendors with monthly shipping rates. The need for additional parts would be signaled by the return of an empty container of standard size.
3. A simple receiving and inspection procedure that calls for the packing slip to be sent directly to accounting on receipt of the container could replace the current complicated process. As a result, the company would need to send only one check per month to each vendor for goods actually received.
4. Delivering parts directly to the floor could eliminate the materials inventory, the necessity of putting materials away, the issuing of authorizations to withdraw them, and the work of pulling the materials out again.
5. A smoothed production flow would make quality problems immediately apparent and change management's focus from extensive record keeping to prevention and immediate correction.

This factory is now well on its way to implementing a production system with far fewer monthly transactions:

Ordering transactions	= 200 parts × 1	= 200 transactions per month.
Receiving transactions	= 200 × 20 days × 2	= 8,000.
Materials authorizations	= 0	= 0.
Materials transactions	= 0	= 0.
Total transactions		= 8,200.

Needless to say, the overhead costs of this factory have plummeted, as have inventory costs. In some areas—receiving, for example—the number of transactions has actually increased, but a painstaking examination of the steps involved in carrying out transactions in the hidden factory has greatly simplified the flow of work and cut total transaction costs. Managers had only to study the transaction process of the hidden factory in the same way they have long examined the production process of the visible factory.

Another way to improve transaction based overhead is to reduce the "granularity" of the data that are reported. Every manufacturing system embodies decisions about how finely and how frequently transaction data are to be reported. It makes no sense to process more data than needed or more often than needed.

One company, for example, found that its quality transaction system was collecting and keeping quality data on every possible activity—despite the very poor quality of its products. The quality department often complained that it never had time to analyze the data, which just sat in file cabinets and computer files, because it spent all its time collecting. By focusing on the few key areas where most of the quality problems existed, the department was able to improve quality dramatically while it reduced costs. It processed quality transactions more intensively in the key areas and much less intensively where things were running smoothly.

Stability

Perhaps the simplest way to reduce the number of transactions is to stabilize the manufacturing environment. Many American companies are now aggressively trying to implement Japanese just-in-time approaches, but visitors from Japan are often quite surprised at what they see here. In Japan, the first principle is stability, and great effort goes into engineering the process down to the finest detail and into training workers to follow instructions to the letter. Level loads, balanced work flows, and good housekeeping all help ensure that the unexpected does not destabilize the operations.

Every time an ECO is issued, a schedule breaks down, or a quality problem erupts, a wave of new transactions flows through a plant. The policy of "making it right the first time" applies to the processing of transactions just as it does to the making of products. Not only do these changes increase the number of transactions; they also have an important secondary effect. Instability in plant schedules and performance causes many plant managers to overstaff their work forces so that the plants can react to unexpected peak loads in transaction volume. As one veteran plant manager said, "You've got to keep shock troops in ready reserve to handle the problems that come up."

One reason for the low percentage of value added attributed to overhead in Japanese factories is that their plants are more stable than ours. Their way of handling ECOs is a case in point. *Exhibit III* shows the frequency with which Japanese and U.S. electronics plants authorize design changes. The Japanese process fewer ECOs than do their American counterparts (about two-thirds fewer) and authorize these changes much further in advance and thus allow for more stable, level transaction loads. With more planning, there are fewer errors.

Automation

One of the most frequently discussed ways to reduce the overhead costs associated with the hidden factory is automation. Robots can have a role in sophisticated materials control systems that automate logistical transactions; lasers can read bar codes and eliminate the need for data entry operators to record movement transactions manually; computer-aided inspection can help reduce the costs of processing quality transactions; a smoothly running materials requirements planning system can make the processing of balancing transactions cheaper.

The cost of processing transactions manually can easily be ten times as great as processing them automatically. The issue is not only the cost of the transaction, however, but also the effectiveness of the transaction process. In addition to the costs of reading, distributing, filing, and retrieving, manual transactions often have a much more serious problem: they take too long. Response time is clearly a major issue in American manufacturing today, yet we know of companies that take 5 to 15 working days to turn a customer order into the proper form for manufacturing. A manual transaction based on retrieving information from a file cabinet, reading the document to understand the conditions, making the transaction, dispatching the results, and refiling can easily take 100 times longer than a comparable transaction done in a computer-supported environment.

Perhaps the most important means of automating transactions is using computer systems that are so well integrated that data need only be entered once. In virtually every large company, however, there is still a massive redundancy of transactions due to the existence of subsystems that cannot "talk" to one another. These problems exist both within manufacturing and between manufacturing and other functions.

Integrated systems offer more than efficiency; they can also improve accuracy and understanding. When the same data are kept in several places and separate organizational units independently calculate such facts as monthly shipments, the result is redundant records, redundant transaction processing, and general confusion. It is not unusual for managers to ask production, marketing, and finance to provide the unit shipment data for one product and to get three different answers.

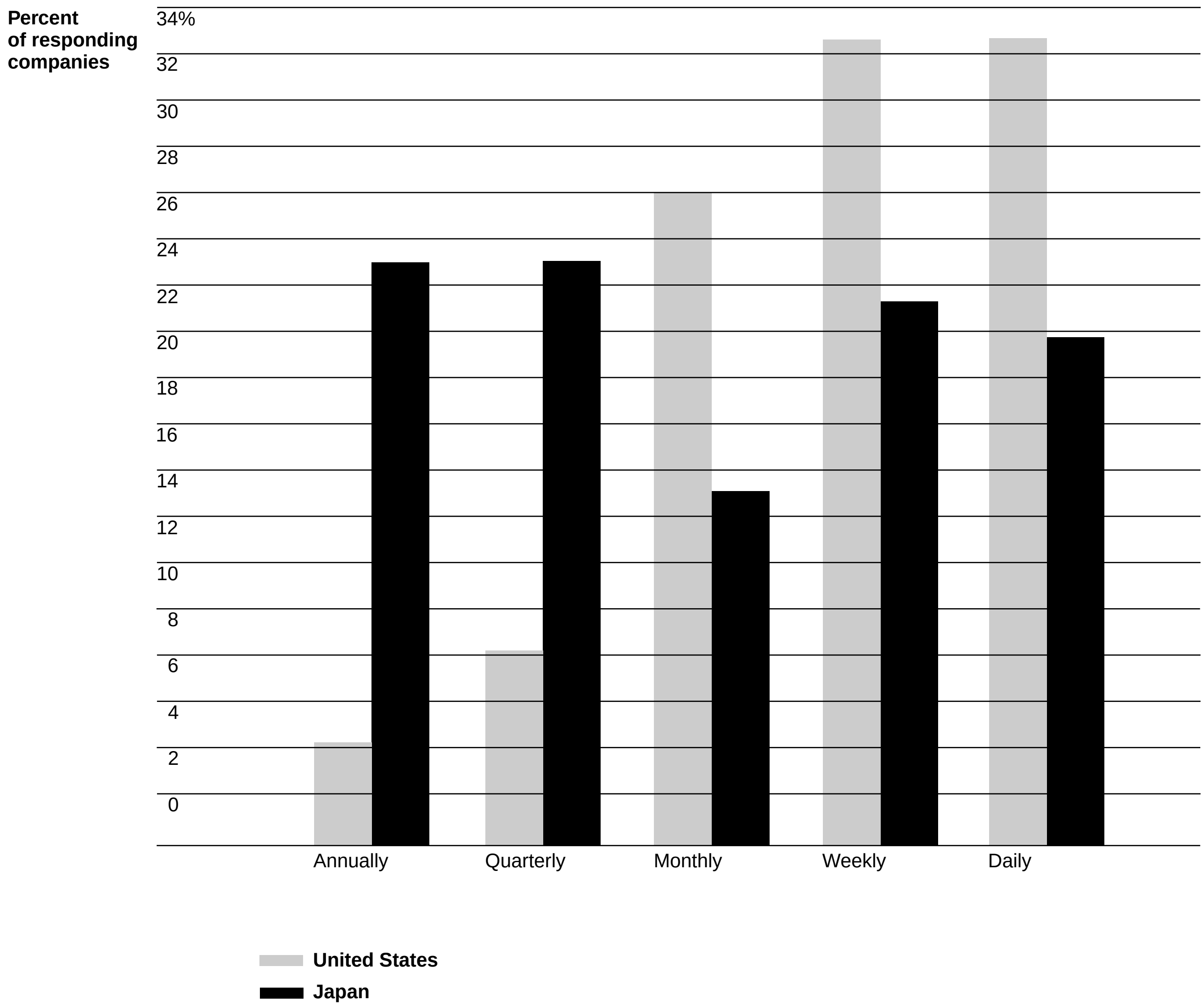
Properly designed and integrated computer systems should lead to transactions being made only once—and to less confusion. Good systems adhere to the rule of encoding only new data: never design a transaction so that it requires data already in a computer to be reentered by hand. In far too many factories, we see people typing in data like part numbers while they look at computer-generated documents for the numbers.

Another type of data integration unites manufacturing data bases with those of other functional areas. Most familiar is the link between engineering and manufacturing established by CAD/CAM systems, but there are others with equal or greater potential impact. One company, for example, is integrating its complex multiplant network with an equally complex order entry and customer service network so as to reduce overhead costs, increase delivery speed and effectiveness, and improve the accuracy of its order entry—configuration processes (a major source of quality problems). Another company is seeking to improve the efficiency of its large financial staff by linking its financial data base with its manufacturing data base and thereby to eliminate double entries and boost its ability to relate manufacturing plans to financial performance.

A balanced approach

There are, then, three general approaches to managing overhead costs more effectively: (1) analyzing which transactions are necessary and improving the methods used to carry them out, (2) increasing the stability of operations, and (3) relying on automation and systems integration. Of the three, U.S. manufacturers seem most enamored of the last.

Exhibit III **The frequency of ECO authorizations in the U.S. and the Japanese electronics industries**



Selectively applied, transaction automation and integration can be an important tool for reducing overall costs and for raising competitiveness in other dimensions as well. In too many instances, however, this tool has the reverse effect. Managers frequently justify this approach on the basis of substituting capital for labor, but they often forget that they are also replacing direct labor with overhead expense. As one operations manager has complained, "All that we succeeded in doing with our monstrous new computer system was to replace $10–an-hour workers with $30-to-$50-an-hour technicians whom we can't hire anyway because of their scarcity." According to another operations manager, "When we automated, direct labor expense was reduced, but total costs increased because of the increase in overheads."

In many of these instances, no one bothered to do a complete analysis of the impact on transaction volumes and costs as activities moved to middle management levels. Some companies even applied their old burden rates to the direct labor costs projected after automation.

A second and perhaps more serious problem occurs when manufacturers automate transactions that are not really necessary in the first place. One company that had recently built an advanced "factory of the future" later removed the automated guided vehicle system and a major portion of the automatic storage and retrieval systems that it had installed in order to reduce the cost of its internal logistical transactions. After installation the company found that it had simplified the transaction flow so much that no automation was necessary after all.

Another company, while evaluating a bar code system, recently discovered that its justification for the system disappeared when it eliminated the needless paperwork that had flowed among receiving, inspection, accounting, and production. The original projection had been for a two-year payback on the bar code system (based on the elimination of the clerical workers needed to produce the paperwork), but closer examination showed that most of that clerical reduction would come from just eliminating the unnecessary transactions.

The lesson, then, is to seek a balanced approach to managing overhead. Automation does not solve all problems; in fact, it may create some unless handled carefully.

As American managers face up to the task of controlling manufacturing overhead, they will have to go beyond process analysis in its usual sense and learn how to analyze transactional processes. Managers will also have to learn when and where to automate the transaction process, how to integrate it in manufacturing and across functions, and how and where to stabilize that process to its greatest strategic effect.

Finally, manufacturing managers will have to look beyond accounting conventions to analyze and categorize costs in a way that has functional meaning. We believe that the answer does not lie in inventing new accounting systems alone. This is a problem for the accountants to solve if they can; certainly it will help if they do. But no amount of bookkeeping magic will let manufacturing managers avoid one of the strategic necessities of the future: understanding how to manage the hidden factory.