

Journal of **Cost**  
**Management**

---

A WARREN, GORHAM & LAMONT PUBLICATION

Vol. 10, No. 2 Summer 1996

***Activity-Based Management***

**Projects, Models, and Systems—Where Is ABM Headed?**

**Implementing Activity-Based Management:  
Overcoming the Data Barrier**

**A Case Study in Economic Value Added  
and Activity-Based Management**

**Metrics for the Order Fulfillment Process (Part 1)**

**An Introduction to the Theory of Constraints**

From the Editor / Paul Sharman

Strategic Cost Analysis / John K. Shank

Investment Justification / Ed Heard

Calendar



# Journal of **Cost Management**

Volume 10 Number 2 Summer 1996

---

## ***Activity-Based Management***

---

### **Projects, Models, and Systems—Where is ABM Headed? 5**

James M. Reeve

*Activity-based management (ABM) can be implemented in an organization as an improvement methodology, a costing model, or a cost management system.*

---

### **Implementing Activity-Based Management: Overcoming the Data Barrier 17**

William H. Wiersema

*This article explores a simple alternative approach to designing ABM systems one that leads to more efficient, high quality implementations at a low cost.*

---

### **A Case Study in Economic Value Added and Activity-Based Management 21**

William W. Hubbell, Jr.

*One excellent measure of shareholder economic value is economic value added (EVA), which can be used in combination with activity-based costing (ABC), as shown in this case study.*

---

### **Metrics for the Order Fulfillment Process (Part 1) 30**

Arthur M. Schneiderman

*Metrics can be categorized as results metrics and process metrics. Result metrics are what customers see and what drives their purchase decisions, while process metrics are the drivers of improvement.*

---

### **An Introduction to the Theory of Constraints 43**

Jack M. Ruhl

*The theory of constraints is a systems-management philosophy. This article provides an introduction to the theory of constraints and to the concept of throughput accounting.*

---

### ***From the Editor / Paul Sharman 3***

---

### ***Strategic Cost Analysis / John K. Shank 49***

---

### ***Investment Justification / Ed Heard 60***

---

### ***Calendar 67***

---

# Journal of Cost Management

---

**MANAGING EDITOR**  
DESKTOP ARTIST  
COPY EDITOR

**Barry J. Brinker**  
**Christiane M. Bezerra**  
**Debra Van Bargaen**

---

**EDITORIAL CONSULTATION Consortium for Advanced Manufacturing International (CAM-I)**

---

## BOARD OF ADVISORS AND CONTRIBUTORS

**James P. Bramante**  
Partner  
Coopers At Lybrand LLP

**James A. Brimson**  
President  
Activity Based Management  
Institute

**Robin Cooper**  
Professor of Management  
The Claremont Graduate  
School

**Nicholas Dopuch**  
Professor of Accounting  
Washington University

**Robert G. Eiler**  
National Director of Cost  
Management  
Price Waterhouse LLP

**Eugene H. Flegm**  
General Auditor (ret.)  
General Motors Corp.

**George Foster**  
Wattis Foundation Professor  
of Accounting  
Stanford University

**Randolf Holst**  
Manager  
Society of Management  
Accountants of Canada

**Robert A. Howell**  
President  
Howell Management  
Corporation

**John G. Kammlade**  
Director, Audit and  
Operations Services  
Lexmark International, Inc.

**Robert S. Kaplan**  
Arthur Lowes Dickinson  
Professor of Accounting Har-  
vard University

**Alfred M. King**  
Senior Vice President  
Valuation Research  
Corporation

**Peter M. Lenhardt**  
Principal  
Lenhardt Strategic Services

**Lawrence S. Maisel**  
Managing Director  
Paramount Consulting Group

**Charles A. Marx**  
Partner  
Arthur Andersen LLP

**C.J. McNair**  
Chandor Professor of Account-  
ing  
Babson College

**Robert D. McIlhattan**  
Partner  
Ernst & Young

**Steve Player**  
Firmwide Director of Cost  
Management  
Arthur Andersen LLP

**Tom E. Pryor**  
President  
ICMS, Inc.

**Michael W. Roberts**  
President  
RPM Associates

**Richard J. Schonberger**  
President  
Schonberger & Associates, Inc.

**John K. Shank**  
Noble Foundation Professor of  
Managerial Accounting  
Dartmouth College

**Paul A. Sharman**  
President  
Focused Management  
Information, Inc.

**Lewis J. Soloway**  
Managing Consultant  
A.T. Kearney, Inc.

**Peter B.B. Turney**  
Chief Executive Officer  
Cost Technology, Inc.

**Gene R. Tyndall**  
Partner-in-Charge,  
Distribution Consulting  
Ernst & Young

**Lionel Woodcock**  
Principal  
Proxima AMS

**Pete Zampino**  
Director,  
CAM-I

---

**Subscription, Advertising, and Customer Service Information:** For information about advertising, call Meg Chomicz at (212) 367-6569. For subscription information, call (800) 950-1213; for customer service, call (800) 950-1205. Foreign callers (who cannot use our toll-free numbers) should call (617) 423-2020 or fax (617) 423-2026.

*Journal of Cost Management* (ISSN 0899-5141) is published quarterly by Warren, Gorham & Lamont, The RIA Group, 31 St. James Ave., Boston, MA 02116-4112. **Editorial offices** We encourage readers to offer comments or suggestions to improve the usefulness of future issues. Contact Barry Bunker, Editor, The RIA Group, 395 Hudson St., New York, NY 10014; (212) 367-6376 or fax (212) 367-6305. **Subscription rates:** \$135/year. Printed in U.S.A. Periodical postage paid at Boston, MA. This publication is designed to present accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional services. If legal or accounting advice or other expert assistance is required, the services of a competent professional should be sought.

Copyright © 1996 by Warren, Gorham & Lamont, The RIA Group. All rights reserved. No part of this journal may be reproduced in any form—by microfilm, xerography, or otherwise or incorporated into any information retrieval system without the written permission of the copyright owner. *Requests to reproduce material contained in this publication* should be addressed to Copyright Clearance Center, 222 Rosewood Dr., Danvers, MA 01923, (508) 750-8400, fax (508) 750-4744. Requests to publish material or to incorporate material into computerized databases or any other electronic form, or for other than individual or internal distribution, should be addressed to The RIA Group, 31 St. James Ave., Boston, MA 02116, (800) 950-1205.

Postmaster: Send address changes to *Journal of Cost Management*, The RIA Group, 31 St. James Avenue, Boston, MA 02116.

---

# Metrics for the Order Fulfillment Process (Part I)

Arthur M. Schneiderman

---

## EXECUTIVE SUMMARY

---

- Metrics constitute a small and vital—subset of the nearly infinite number of possible process measures.
  - Metrics can be categorized as *results* metrics and *process* metrics. Results metrics are what customers see and what drives their purchase decisions, while process metrics are the drivers of improvement.
  - Good metrics have the following characteristics:
    - They are linked to stakeholder satisfaction;
    - They have documented, operational definitions; and
    - They derive their usefulness only as part of an improvement process.
  - The creation of a system of metrics requires a process of its own, with built-in means for refining the metrics.
- 

*When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.*  
William Thompson, Lord Kelvin, 1824-1907

Most people will agree with the following statement: “If you don’t measure it, it will not improve. If you don’t monitor it, it will get worse.” But *what* to measure and *how* to monitor what is measured remain more an art than a science. This first part of a two-part series of articles examines *metrics* in terms of how they differ from *measures*. The article distinguishes between results and process metrics, then discusses what constitutes “good” versus “bad” metrics. The article gives an example of a process for the introduction and refinement of metrics.

Metrics are illustrated in this article using a typical order fulfillment process. The second article in the series will describe the resulting metrics and how to integrate metrics into the company’s management system.

### Recognizing the need to improve

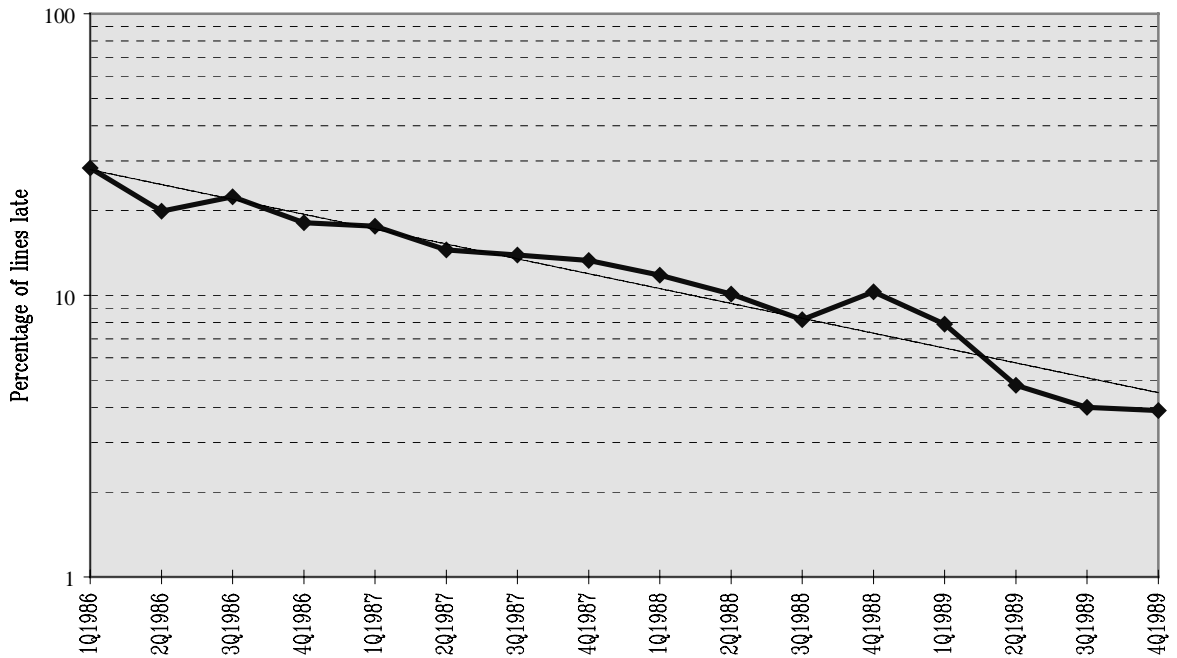
Often the single most important improvement a company can make to increase customer satisfac-

tion is to fix its order fulfillment process. Customers’ expectations about delivery performance have changed dramatically over the last decade. Ten years ago, a good supplier delivered on time about 70 percent of the time. Now standards are closer to 99 percent.

One major step in the continuous improvement process is the identification of key measures of the process, or *metrics*. This article focuses on the development and use of metrics for the order fulfillment process at Analog Devices, Inc. (ADI), a midsize semiconductor manufacturer. As ADI learned, improving the order fulfillment process is a good way to “surface” (i.e., bring to light) other areas in a company that need improvement. Starting with the order fulfillment process is analogous to cutting inventory in a just-in-time management system. As Taiichi Ohno ---the inventor of the *kanban* system at Toyota---pointed out, reducing inventory is like lowering the level of a river: when the water level falls, the rocks and boulders become visible.

*Helping to overcome limitations in other processes.* As delivery performance improves, the limitations imposed by other processes become more visible. These processes include:

Exhibit 1. *Delivery Performance as Measured by ADI*



- Yield enhancement;
- Credit approval;
- Quarterly revenue management (AKA “the hockey stick” or nonlinear shipments—i.e., where a large percentage of a period's shipments occur near the end of the period);
- Df<sub>x</sub> (Design for x, where x stands for manufacturability, testability, usability, serviceability, recyclability, etc.) and
- Management review.

**Principles of metrics**

The comprehensive set of on-time delivery metrics that ADI developed played a critical role in bringing ADI's delivery performance from below 70 percent before 1986 to 96 percent or above by 1990. Exhibit 1 graphs ADI's delivery performance, as expressed in terms of line items on purchase orders that are shipped late. (Generally, separate lines are used on purchase orders for different parts or for different customer request dates.)

**Steps to improve customer satisfaction**

To improve customer satisfaction, ADI established the following corporate-wide customer service commitment:

1. To deliver all orders to all customers complete and when promised and to minimize lateness where we fail.
2. To meet our customers' delivery requirements—always.
3. To offer even shorter lead times if doing so would give us a competitive advantage by reducing total systems costs for us and our customers combined.

ADI recognized that these objectives were likely to be met only one at a time and in the order given. The last commitment assumes that customers always value shorter lead times because it helps them build to order rather than forecast, thus minimizing the excess inventory required to cover forecasting errors.

*Policy manual.* ADI also produced a detailed policy manual that considered market-driven

trends in each area and expanded on each of the customer service commitments. Sample topics included the following:

- Taking all customers into consideration rather than focusing only on the largest;
- Partial shipments;
- Padded lead times with early shipments;
- Informing customers in advance of expected late shipments;
- Customers' needs versus wants; and
- Transit-time responsibility.

The commitments, policy changes, and other improvements helped transform ADI from a company that many of its customers considered difficult to work with to a com-

---

*As delivery performance improves, the limitations imposed by other processes become more visible*

---

pany that one of its largest and most demanding customers ranked as number one. ADI was also selected as Dataquest's "Mid-Size Semiconductor Supplier-of-the Year" for two years running. This award, based on a survey of 300 purchasing decision-makers, recognizes "...manufacturers who exhibit extraordinary dedication to product quality and customer service."

### About metrics

There are several important aspects of metrics:

1. *Metrics vs. measures:* First, a distinction must be made between the infinite number of possible process measures and the much smaller subset of measures that are actually useful to a company's improvement efforts.
2. *Both process and results metrics:* Second, metrics should be categorized as process metrics and results metrics.

This section also enumerates the properties of good metrics.

**Metrics vs. measures.** Confusion often arises over the distinction between *measures* and *metrics*. A *measure* is a numerical representation of one of the attributes of a process. For example, time, temperature, speed, quality,

delay, and machine settings are examples of the essentially limitless number of measures associated with any process.

The science of measures is called *metrology*. It deals with such fundamental aspects of measures as the following:

- Accuracy;
- Precision;
- Bias; and
- Repeatability.

Measures can be used for both process control and process improvement. Used in *process control*, measures characterize the critical nodes in the process. *Critical nodes* represent the small set of sensitive control points that, when held within a prescribed range, assure that the output of the process is stable (i.e., maintained within the control limits).

For purposes of this two-part series of articles, the following definition of *metrics* is used:

Metrics are a subset of measures of those processes whose improvement is critical to the success of the organization.

Practically speaking, a subset is at most three to five measures. A company that uses more than five tends to lose its focus on the vital few opportunities for improvement. A lack of focus leads to diffused efforts and slow progress. One symptom of a failure to make the distinction between measures and metrics is reports with hundreds of measures—all meticulously updated each month—yet the companies in question show few significant improvement trends.

**Stakeholder satisfaction.** Metrics are surrogates for stakeholder satisfaction and delight. (The term *stakeholders* refers to customers, stockholders, employees, communities, suppliers, and even future generations.) As a good metric improves, stakeholder satisfaction will increase, either directly or indirectly. This relationship between improvement of a metric and improvement in stakeholder satisfaction must be significant.

Improvement takes effort and resources. For there to be a payback, metrics must focus on significant gaps in performance things that can make a competitive difference.

*Folk wisdom about metrics.* The importance of metrics is captured well by often-repeated sayings such as the following:

- “You can expect what you inspect”;
- “if you're not keeping score, you're only practicing”; and
- “You get what you measure.”

But each of these sayings is incomplete in itself. Implicit in each is the concept of measurement and the use of measurements in the management process. Stated in another way: “if you don't *measure* it, it will not improve. If you don't *monitor* it, it will get worse.” Why will things “get worse”? Without management attention, performance tends to drift to lower performance—perhaps because lack of attention is interpreted as lack of importance.

Measurement and monitoring are necessary but not sufficient parts of a successful improvement effort, which must also include things like training, goal-setting, and promotion. Nonetheless, measurement and monitoring are the major tools that management can use to overcome a company's “immune system” (i.e., resistance to change). This “immune system” is triggered by the introduction of new performance measures. Effective monitoring (which is discussed later) is a powerful antidote.

### Results vs. process metrics

It is useful to recognize two types of metrics—results and process metrics. *Results* metrics are seen directly by the process's paying customers; they are measures of how *effectively* a process meets the customer's needs. *Process* metrics, on the other hand, are usually invisible to customers; they deal with the inner workings of a process and describe *how* the results are achieved. Process metrics are more related to the *efficiency* of the process. Value is created by increasing either process effectiveness or efficiency.

Internal customers. The concept of internal customers somewhat muddies this distinction, because it can be argued that any process metric is a results metric in the eyes of an internal customer of that subprocess. However, the usefulness of the distinction relies on the ability of a customer to choose

between alternative suppliers, an option that internal customers usually do not have.

*Results metrics.* Customers generally want high quality (as defined by conformance to specification and fitness for use), low cost, and timely availability. Measures of these characteristics are results metrics. To achieve these results, suppliers often focus on the following:

- Short cycle times;
- Inventory management;
- Scrap reduction;
- Training;
- Design for manufacturability;
- Statistical process control (SPC); and
- Market research.

*Process metrics.* Measures of the items listed above are process metrics. Metrics associated with activity, such as the percentage of a company's associates who are on improvement teams or the hours of training per year per employee, are a subset of process metrics.

Results metrics represent the real objective of any process. They are the basis for the customer's decision about suppliers. They are where money can be made or lost. Ultimately, results and process metrics are not independent: they characterize a measurement system for delivering increasing value to customers.

### Properties of good metrics

Metrics can be tested against a set of selection criteria either individually or collectively as part of a system of metrics.

The first requirement for a good metric is that it should be a *reliable proxy* for stakeholder satisfaction. In other words, improvement in the metric should link directly to improved stakeholder satisfaction. This linkage should be clear and uncomplicated. It should also be what mathematicians call *monotonic*—i.e., improvement in the metric should always produce improved stakeholder satisfaction. (See the related discussion of “control limits and variability of processes” below.) There should be no nonzero optimum value for the metric.



For example, lead time defined as “ship date minus order date” fails this test because customers will generally tell their supplier when they want the product. Shipping it early to them (a shorter lead time) simply increases their inventory.

It is becoming more common for customers to “ding” (i. e. penalize) their suppliers for early as well as late shipments. A better metric is excess lead time, which is defined as “supplier-quoted minus customer-requested lead time.” Improving this metric always leads to increased customer satisfaction.

### Overcomplicating metrics

There is a potential danger of overcomplicating metrics to make them a “better” proxy for customer satisfaction. At ADI, for example, a quadratic equation (using what is known as Taguchi’s loss function) was proposed for measuring the impact of late shipments to customers. The equation (which used the number of days the order was late and worked on the assumption that being two weeks late was more than twice as bad as being one week late) used the square of the number of weeks late to measure the impact of the late shipment. Unfortunately, not all managers have the training to work easily with such sophisticated mathematical formulas. Moreover, in this example, no one could produce either a real or hypothetical situation where the resulting action would be different based on the more complicated metric, so simplicity prevailed.

Truly monotonic metrics are often difficult to define. In practice, there can be too much of a good thing. For example, cycle time—a key metric of the manufacturing process—can be reduced to a point where it produces increased value to customers. Beyond that point, however, throughput declines, delivery performance suffers, and value is destroyed. Excess cycle time (i.e., actual minus optimum cycle time) transforms cycle time into a monotonic metric. Also, combined with metrics that characterize the other side of the tradeoff, cycle time can be a useful component of a system of metrics.

### Characteristics of good metrics

Among the characteristics of good metrics are the following:

- *Well-documented, unambiguous operational definitions.*
- *Continuous values:* Metrics should be able to take on continuous values so that incremental improvement can be observed.
- *Metrological standards:* Metrics should also meet such metrology tests as accuracy, precision, reliability, and bias.

**Making metrics useful.** For metrics to be *useful* as part of an improvement effort, they should be all of the following:

- *Oriented toward weaknesses or defects* (i.e., metrics should measure weaknesses or defects in the process);
- *Timely;* and
- *Accessible* to those responsible for improving the process.
- *Linked* to an underlying data system that facilitates the identification of root causes. In other words, if the value of the metric prompts managerial attention, then data should be available so that the responsible person can explain the cause of the variation.

### Different metrics based on the same measure

Different metrics are often calculated using the same or similar measures. It is important that the definition of the measure be the same in each metric. A “late line” (i.e., the merchandise represented by a distinct line-item on a purchase order) should be defined the same way for all metrics based on the number of lines late. A metrics manual that contains the detailed operational definitions of the metrics should maintain this consistency of definition of intermediate measures.

Judgment-based or subjective measures often create difficulties. For example, visual defects (e.g., scratches, chips, discolorations, and bent leads on integrated circuits, which may have no effect on a product’s performance) are often difficult to define. If they are included in the definition of a defect, then objective criteria should be estab-

lished to minimize variation in the metric caused by differences in interpretation.

### **Control limits and variability of processes**

As part of the operational definition of a metrics, control limits should be identified. Metrics, like the underlying process they represent, have inherent variability. Management action should be required only when a change in the metric is statistically significant.

*Limit values.* Limit values of a metric should be well understood. Most processes cannot sustain performance with zero defects (unwanted outcomes) because of their inherent (random) variability.

The process *capability* (or *entitlement* or *theoretical limit*) should be estimated and metrics defined to reflect the gap between actual and theoretical capability. This becomes more important as the limit of a process is approached.

*Example at ADI.* For example, the theoretical capability of ADI's order fulfillment process was limited in reality by its computer technology which constrained the availability of manufacturing plan updates because they were periodic rather than continuous. Updates occurred on weekends, which meant that by the following Friday orders were being quoted against an out-of-date plan.

According to a rough estimate, this computer constraint introduced a 2 percent error into the system and limited sustainable on-time delivery to about 98 percent. At 70 percent on-time delivery, the difference between a correctable gap of 30 percent (zero defects) and 28 percent (actual limit) leads to no actionable consequences. However, at 97 percent on-time delivery, the difference between a goal of an improvement of 3 percent (zero defects) versus a goal of 1 percent (the actual limit) is a factor of three. The targeted incremental improvement for the next year might realistically be only 0.5 percent rather than the theoretical 1.5 percent. If a 0.5 percent improvement is not good enough to meet customer needs, management should consider reengineering (e.g., by

replacing the computer system) rather than trying to achieve continuous improvement of the existing process.

*Statistical process control (SPC).* Traditional control charts provide a methodology for establishing control limits. However, Walter Shewhart, the inventor of SPC and control charts' based most of his work on what he called "a constant system of chance causes."<sup>1</sup> These systems have constant averages and standard deviations. Because metrics are used to drive a process that will produce decreasing averages and reduced variation, the Shewhart model needs to be adjusted for this nonstationary (i.e., time-varying) process based on a realistic improvement model. (An example of this correction is given in Part 2 of this series of articles.)

### **Smoothing**

Smoothing (or averaging) is often used to reduce variability in metrics. For example' "percent late lines" is the number of late lines divided by the number of scheduled lines during the period of measure (e.g., a

---

*Improvement takes effort and resources. For there to be a payback, metrics must focus on significant gaps in performance—things that can make a competitive difference.*

---

day, week, month, or year). The longer the period, the smoother the resulting metric will appear over time. The longer the measurement period, however, the longer the time required to detect trends. It is preferable to use a measurement period that is less than the process cycle time and to smooth the resulting data, if necessary, using exponentially weighted moving averages.

Exponential averaging differs from direct averaging in that it weights the most recent data more heavily than the older data. Although this may sound complicated, the calculation is quite simple. First, a weighting factor,  $\lambda$ , is chosen that has a value

**Exhibit 2.** Ask Why Five Times

Why?	Because:
Why(1) are 20 percent of the orders late?	30 percent of the time they were not released by credit.
Why(2) were orders not released by credit?	45 percent of the time the customer was on credit hold.
Why(3) was the customer on credit hold?	80 percent of the time they had exceeded their credit limit.
Why(4) did they exceed their credit limit?	99 percent of the time we didn't know at the time they placed the order that it would put them over their credit limit?
Why(5) didn't we know?	The order entry system does not tell us the customer's available credit.

between zero and one. It is the fractional weight placed on the current, unsmoothed metric. (For  $\lambda = 1$ , no averaging occurs, while for  $\lambda = 0$ , the current value has no impact on the average.) Then the new averaged value is  $\lambda$  times the current value plus  $(1 - \lambda)$  times the averaged value from the previous period. In equation form, this is as follows:

$$\bar{x}_t = \lambda x_t + (1 - \lambda) \bar{x}_{t-1}$$

A good trial value of  $\lambda$  is 0.2, although some experimenting around this value is usually worthwhile. Control limits for exponentially averaged metrics can be easily calculated.<sup>2</sup>

**Asking "why" five times**

Incremental improvement is based on the ability to “ask why five times.”<sup>3</sup> Exhibit 2 demonstrates application of this technique to late shipments. The point of the exercise is that—by the time the fifth “why” is answered—corrective action (i.e., reversal of the root cause) usually becomes obvious. In the case illustrated in Exhibit 2, the solution is to add available-credit information to the order-entry field and to develop a process for working with customers to increase their credit limits when their orders are entered into the system.

Ideally, metrics and the ability to drill down smoothly to root causes can be integrated into a company's information system so that

managers and associates can use the information for process improvement. Note that it becomes awkward to "ask why five times" when a metric is *strength-oriented* (e.g., the percentage of on-time shipments) rather than *defect-oriented* (e.g., the number of lines shipped late).

**Timeliness**

Timeliness is an important requisite for useful metrics. If the metrics lag the action by too long a period, the trail grows cold and root cause analysis becomes difficult or impossible. For example, a month's delay between the committed shipment date and the reporting of the late shipment makes it difficult for anyone to identify the root cause for that late shipment. Daily reporting of yesterday's late shipments is essential for effective problem solving. Monthly summaries of the same metric are usually all that is required for managers to supervise the improvement process.

*Processes with long cycle times.* Timely results metrics are particularly difficult for processes with long cycle times. The results of new product development (in terms, for example, of return on investment in research and development) are often unknown until years after the investments are made. By then, the original process may have changed

and the individuals involved may have moved to other assignments. Moreover, learning about what failed in yesterday's environment may not help in today's environment.

Results-focused managers—trying to compensate for this delay—often use forecast or prediction-based metrics, such as forecast break-even time or third-year revenue and profits. But these proposed metrics are more applicable to the forecasting process than product generation. Most forecasts are not based on a documented process. Even when they are, the processes have questionable capability (i.e., high inherent variability). All in all, forecast metrics and results metrics for processes with long cycle times are of dubious value except for their use in quantifying forecast variability.

### **Focusing on process, not results**

Does this mean that there are no useful metrics for processes with long cycle times? The Japanese often say, “Focus on process, not on results.” This is particularly good advice for processes with long cycle times. Process metrics such as “percentage of planned milestones missed or rescheduled,” “error-based engineering change orders,” and “forecasting and planning process checklist items not completed” have been used effectively for driving improvement.

It is often tempting to define a metric as the gap between actual and planned results rather than process capability. However, that gap is linked to defects in the planning process or its implementation, not the underlying process itself. In other words, it leads to the question “Why did we not achieve plan?” instead of “Why is the process producing these defects?”

For example, under the Japanese system of *hoshin kanri* (which is usually translated as “policy deployment” and is a major extension of management by objectives), implementation plans are developed based on a thorough understanding of the underlying process, including its defect causes and the required corrective actions.<sup>4</sup> There is a high level of confidence that if the plan is executed, the desired results will be achieved.

Then and only then is a metric based on the deviation from plan useful in improving the *hoshin kanri* process itself.

### **Completeness**

A set of metrics should be *complete*. That is, metrics should be included for all possible undesirable tradeoffs. Many tradeoffs can be anticipated in advance, while others are discovered along the way. With an incomplete set of metrics, intentional or unintentional “gaming” of the metrics can occur (i.e., doing things to improve the metric while decreasing overall stakeholder satisfaction). Thus, for example, extending quoted lead times may improve on-time delivery, but it will usually decrease customer satisfaction.

---

*By focusing on a core business process—order fulfillment— and providing a conceptual framework, this article should equip the reader to extend applications to other areas of interest;.*

---

Perhaps the area in which completeness is most often overlooked is in *training metrics*. “Percentage of employees trained” is often the only metric used. However, without metrics for the *effectiveness* of the training, the value of the training cannot be measured. In education, test scores are used to measure effectiveness. In industry, how the training is applied tells more about its value. A complete set of training metrics includes both the percentage of people trained and, for example, the percentage of trainees who effectively applied what they learned within three months after training.

### **The ADI order fulfillment process**

To illustrate the principles explained so far, consider the order fulfillment process at ADI, where most bookings were for repeat business. These repeat customers had de-

signed an ADI part into their product and made periodic purchases to reflect their production needs. Prices were generally set in advance, so the principal issue for each order was availability.

To start that part of the order fulfillment process at ADI discussed here, two items were entered into the system:

- The order entry date (OED); and
- The customer request date (CRD).

If the product was expected to be available on the CAD, the company committed to that date. If not, the order was referred to the appropriate factory, where the production planners scheduled the order and com-

---

*Even after detailed metrics are developed for the scorecard, they and their associated supplemental metrics must evolve.*

---

mitted to a date. Often they could adjust their production plans to meet the CRD. If not, they quoted a later date. In either case, the factory commit date (FCD) represented ADI's response to the customer's request. Usually customers accepted the FCD proposed and adjusted their own production schedules accordingly.

*Factory commit dates (FCDs).* The FCD represented the date by which ADI committed to ship the customer's entire order. Unless otherwise directed, ADI reserved the right to ship early up to two weeks before the CRD if the product became available sooner than planned.

To be shipped by the FCD, a product had to arrive at ADI's central warehouse before the FCD to allow time to review the customer's credit and complete the various shipping subprocesses. A central warehouse was used because most orders contained products from different manufacturing locations. Customers preferred receiving a single shipment rather than multiple packages from various ADI factories; a single shipment was also cheaper for the customer.

*Subprocesses and administrative lead times (ALTs).* The credit and shipping subprocesses

typically consumed three days for domestic orders and five days on international orders. This administrative lead time (ALT) was subtracted from the FCD to yield the date when the factory was committed to have the product at the warehouse. At this time, the product was assigned to specific orders. This is called the "to-be-assigned" (TBA) date. The actual date on which an order is shipped to the customer is the actual ship date (ASD). Exhibit 3 shows a flowchart of the ADI order fulfillment process. The various milestones on the time line of this process are summarized in Exhibit 4.

In terms of the acronyms of Exhibit 4, ADI's corporate-wide customer service commitment (see the previous discussion) can be restated as follows:

1.  $ASD \Rightarrow FCD$  or  $ASD - FCD \Rightarrow 0$
2.  $FCD \Rightarrow CRD$
3. Required lead time  $< CRD - OED$

#### **A process for defining metrics**

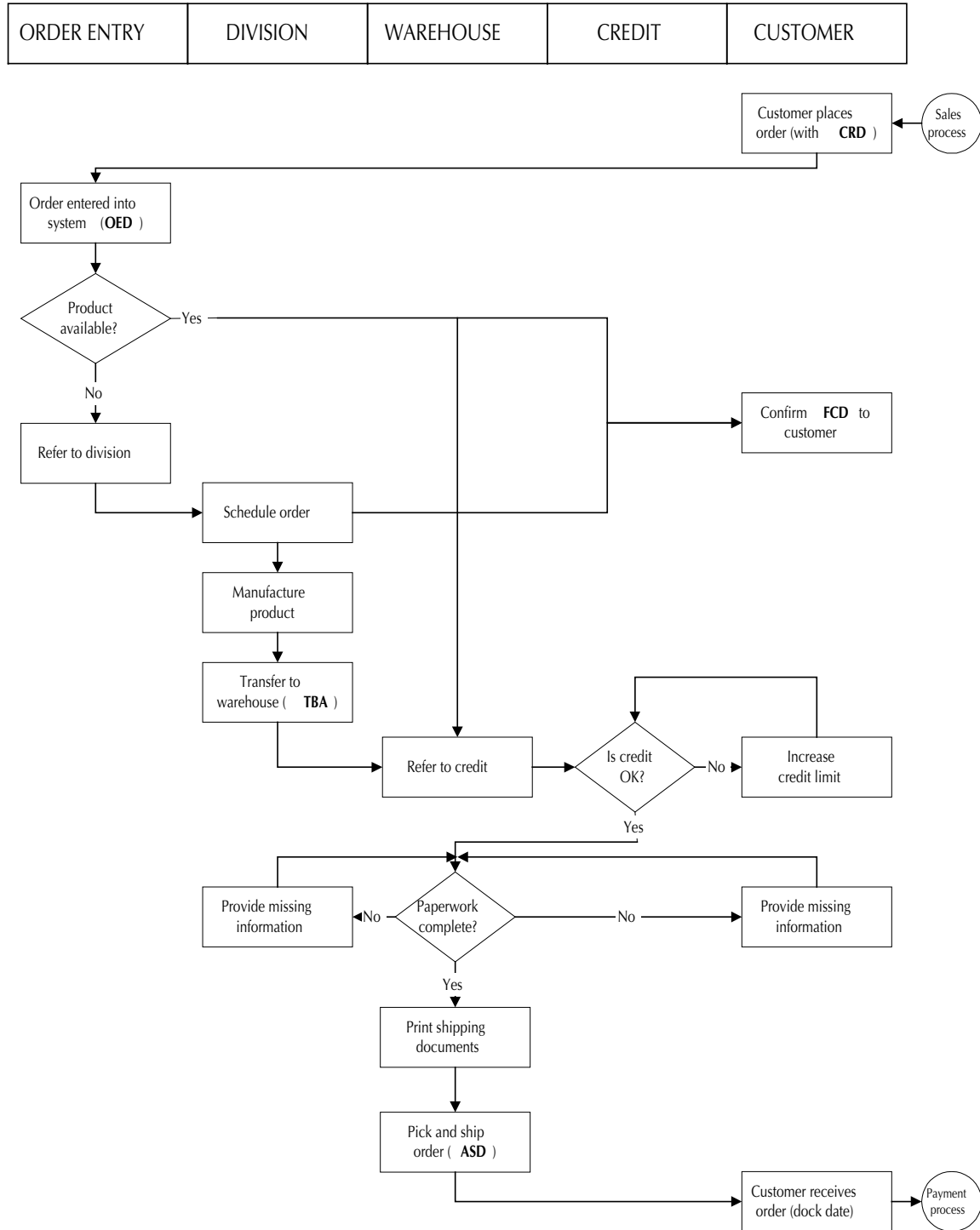
The development of effective metrics is an ongoing process. Each organization needs to create its own approach that is consistent both with the desired results and its unique culture. At ADI the CEO assigned the author (who was vice-president of quality and productivity improvement, or VP/QPI at the time) responsibility for establishing metrics for ADI's key business processes. In today's jargon, the VP/QPI was made process "owner" for nonfinancial performance metrics.

*"Bottom-up" or "top-down."* The first question the VP/QPI faced was whether the metrics should be defined "bottom-up" or "top-down" that is, should the various subprocess owners define their own metric or should the VP/QPI (i.e., a member of the corporate staff) do it for them?

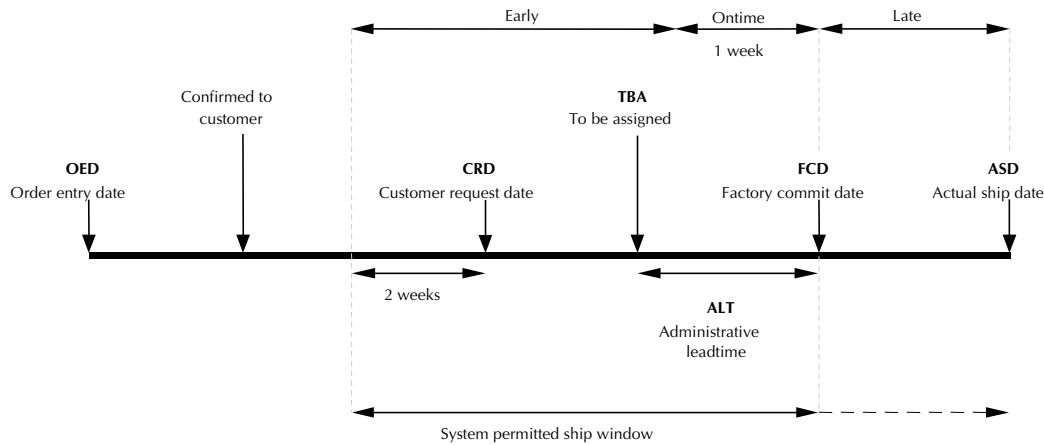
It seemed doubtful that either of these extremes would work. If subprocess owners were allowed to define their own measures, something was likely to be lost from the customer's perspective. The resulting individual metrics might not add up to a system of metrics for improving customer satisfaction. Yet the VP/QPI recognized that he lacked sufficient specific knowledge of the subprocesses and thus risked defining impractical metrics.<sup>5</sup> Furthermore, those responsible for improving their processes

Metrics for the Order Fulfillment Process (Part 1)

Exhibit 3. The Order Fulfillment Process at ADI



**Exhibit 4. ADI's Order Fulfillment Process Metrics Dates**  
(not to scale)



were not likely to feel a sense of ownership if the VP/QPI defined all the metrics.

Ultimately, therefore, the VP/QPI relied on teams of subprocess owners for help in defining the metrics. He chaired these teams and was the final decision maker when they could not reach a consensus. He relied on the appeals process, described below, as the vehicle for continuous improvement of the initial set of metrics.

*Coming up with appropriate metrics.* The VP/QPI did *not* act as a facilitator. People were asked to volunteer to prepare a detailed proposed specification for a given metric. Occasionally, two or more people would volunteer (usually with opposing views), which meant that there were alternatives to evaluate. At other times, no one would volunteer, so the VP/QPI would assume responsibility for developing a proposal. In doing so, he relied heavily on industry benchmarks and definitions used by major ADI customers. If volunteers failed to complete their assignments by the agreed-on date, they were given one more chance, after which the VP/QPI would revert to his own proposal.

The proposals were debated, refined, and eventually accepted. A manual evolved from this process; it defined each metric in equation form and prescribed in detail the fields in the order-entry database (or other source)

that would be used. In this way, there was little, if any, room for interpretation.

At first, the participants were leery of this process. As in most “old way” companies, these managers associated metrics with the stick, not the carrot. A combination of persuasion and decree was needed to complete the definition of metrics within a reasonable time. Even so, it took nearly 18 months to establish the set of metrics initially used at ADI. Perhaps the ultimate test of this process is that, after several reviews, the metrics have remained virtually unchanged since they were first implemented in 1988.

To those who are strong proponents of employee empowerment, this top-down model may seem “disempowering.” However, when process owners and managers form a partnership to act as architects of multiprocess organizations, both parties are ultimately empowered.

#### **Maintaining a focus on weaknesses**

In defining metrics, there is the option of measuring either what went right or what went wrong. From a psychological perspective, Westerners prefer to focus on what they do right, because the opposite often leads to finger-pointing and blame. But, as Chris Argyris, James B. Conant Professor

at the Harvard graduate schools of business and education, has recently pointed out, "In the name of positive thinking . . . managers often censor what everyone needs to say and hear."<sup>6</sup>

To find root causes one must focus on defects (or weaknesses). This conflict can be resolved if the wisdom of Deming and Juran prevails. Both observed that about 95 percent of defects are caused by the process—not the people. Metrics should thus be used as pointers to places in the process that need to be improved. If this ground rule is established, then the orientation of metrics on weaknesses becomes more acceptable.

*Do not rely on averages.* Another danger in defining metrics is the use of averages. For example, *average* excess lead time could be dropping while—for some class of products—the lead time is increasing, thus causing a decline in customer satisfaction for purchasers of these products. Therefore, it is important that both averages and distributions (histograms) be included where appropriate.

### **The metric improvement process**

Metrics evolve over time to reflect both the changing needs of constituents and process learning (i.e., the systematic mastery of a process). While financial measures have been in use for more than a hundred years and are relatively stable, nonfinancial measures need to change to improve an organization's alignment with rapidly changing customer requirements. Two vehicles were developed at ADI to continuously improve the metrics:

- The balanced scorecard; and
- The metrics board of appeals.

*The balanced scorecard.* In 1987 ADI pioneered in the development of a balanced scorecard.<sup>7</sup> The scorecard contains quarterly goals for both financial and nonfinancial metrics and is updated annually as part of the business planning process. At the start of the process, the quality steering council (QSC) chaired by the VP/QPI reviewed the areas addressed on the scorecard to assure that the right things were being

targeted for improved corporate performance. To offset the historic bias in favor of financial measures, an organization is likely to need an unbalanced scorecard at first (i.e., in favor of nonfinancial performance).

The QSC included the following members:

- The CEO;
- The president;
- The vice-presidents of manufacturing, sales, technology, and human resources; and
- Two representative general managers of divisions

This leadership group had the broad and balanced perspective to assure that ADI focused its improvement efforts on the right things.

Nonetheless, even after detailed metrics are developed for a balanced scorecard, they and their associated supplemental metrics must evolve. Nonscorecard (or supplemental) metrics provide checks and can become candidates for future elevation to scorecard status. To this end, "metrics boards of appeal," were established on an ad hoc basis.

*Metrics boards of appeals.* For the order fulfillment metrics, a board of appeals chaired by the VP/QPI was established. This board included the credit and warehouse managers and also operations managers from any affected divisions. Representatives from sales—and anyone else interested—were also invited to participate. The basis for an appeal was that a metric in use inappropriately penalized a subprocess for something either desired by customers or of no importance to them.

To bring an appeal, people had to show that the issue was a significant bar on their Pareto chart (i.e., a rank-ordered bar chart) showing causes of defects. They also had to specify how the definition of the metrics should be changed. Finally, they were required to provide a retrospective before-and-after comparison using actual data. If broader business issues were involved the board's recommendation was reviewed with the COO. One such issue was the changing of FCDs when the customer



changed the CRD. The COO, concerned that the ability to change FCDs could undermine the credibility of the metrics, decided that no FCDs could be changed without his written approval. Late shipments to the original FCD caused by customer changes were tracked, but were never a significant cause of overall lateness.

The boards maintained a bias toward not changing the metrics to keep the definitions stable whenever possible. In this way, trend data were not distorted unduly by repeated changes in definitions of metrics.

*Examples.* One example of an appeal dealt with shipments to ADI's foreign sales affiliates' which were treated by the system as if they were individual customers. Most affiliates wanted their orders held for a single weekly shipment. However, orders were committed for shipment each day of the week. Therefore, an order might be scheduled for Monday shipment to an affiliate who wanted shipment on each Friday. The warehouse would hold the order at the affiliate's request until Friday, which meant that the order would go out "late." Clearly, the metrics tempted the warehouse to ship daily, against the wishes of the customer.

When this issue was first raised, it was not a significant cause of warehouse-controllable lateness, so action was deferred. This decision to defer action established the principle that effort should be focused on process improvement rather than nitpicking about the metrics. As the warehouse improved, foreign shipments eventually became the warehouse's number-two root cause of late shipments. At that time' the appeal was accepted and appropriate changes were made in the order entry system.

In another case, a general manager proposed a new definition for a lead-time metric that he thought would more fairly portray his division's performance. Careful analysis of the proposal, however, showed that adoption of the proposal would have caused the manager's reported lead times to increase unless the metric allowed early

shipment to be used to offset long quoted lead times—a clearly undesirable situation. His proposal was quickly withdrawn.

### Summary

The creation of metrics is itself a process that includes refinement cycles. This article describes the approach ADI used to define metrics, an approach that attempted to balance top-down alignment with bottom-up ownership. The second part of this series of two articles will describe the resulting metrics and the role they play in the day-to-day management of the company.

---

**Arthur M. Schneiderman is an independent consultant in process management. He is located in Boxford, Massachusetts. The author wishes to thank Ray Stata (CEO) and Jerry Fishman (president) of Analog Devices, Inc., for creating the environment and providing the constant encouragement needed to make the metrics and the scorecard a reality. Of the many others at ADI and elsewhere who contributed to this effort, Elizabeth Derwin deserves special acknowledgment.**

### Notes

<sup>1</sup> W. A. Shewhart, *Economic Control of Quality of Manufactured Product* (New York: D. van Nostrand Company, Inc., 1931): 146.

<sup>2</sup> See for example, J. Stuart Hunter, "The Exponentially Weighted Moving Average," *Journal of Quality Technology* (Vol. 18, No. 4, October 1986): 203-210.

<sup>3</sup> See chapter 3, for example, in Kaoru Ishikawa, *Guide to Quality Control* (Tokyo: Asian Productivity Organization, 1982), which was originally published in 1971.

<sup>4</sup> Yoji Akao (ed.) *Hoshin Kanri Policy Deployment for Successful TQM* (Cambridge, MA: Productivity Press, Inc., 1991).

<sup>5</sup> For a useful discussion of operational definitions see W. Edwards Deming, *Out of Crisis* (Cambridge, MA: Massachusetts Institute of Technology, Center for Advanced Engineering Studies, 1982): Chapter 9.

<sup>6</sup> Chris Argyris, "Good Communication That Blocks Learning," *Harvard Business Review* (July-August 1994): 77-85.

<sup>7</sup> Robert S. Kaplan, "Companies as Laboratories," in *The Relevance of a Decade*, Paula Barker Duffy (ed.) (Boston: Harvard Business School Press, 1994): 179-182.