Business Process Control: The Outer Loop

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Abstract

Business process control (BPC) applies the principles of chemical process control (CPC) to enable an entire enterprise to achieve peak performance. Viewed from the chemical process perspective, BPC is the outer loop that manages the CPC targets with a specific objective of meeting and exceeding business targets. Viewed from the business process perspective, CPC is one specific set of the many inner loops requiring strategic direction. Typically, CPC is the set of inner loops that is extensively automated with valves, switches, sensors, and analyzers. CPC has sophisticated, usually computerized, control algorithms. However, its ability to influence the enterprise is limited to what can be accomplished by moving valves and switches.

Characteristics of BPC loops are: enterprise-wide scope; information systems as feedback sensors; and, knowledge workers as control strategists and as actuators. The scope of influence on the enterprise is everything that can be affected by humans, which scope is virtually unlimited. This paper will review the current state of BPC with some example applications. A key theme is to note that the shift in scope from the valves and switches of the automated inner loops, to the enterprise-wide business processes of the outer loops, increases the potential benefits by orders of magnitude. The CPC professional community is the main repository of intellectual capital required to translate and extend the mature CPC technology to the emerging BPC discipline.

Keywords

Business process control, Value metrics, Project planning, Project scheduling

Overview of Business Process Control

The premises of Business Process Control are:

- Most enterprises have untapped potential value
- Potential value and current value can be measured
- There is a gap between potential and current value
- Increasing stakeholder value to its full potential is an enterprise goal
- The goal is reachable when knowledge workers can observe both the current gap, and the reduction in the gap that results from their activities

Business process control (BPC) is the management science that employs measurements of the gap between current and potential value to create new value.

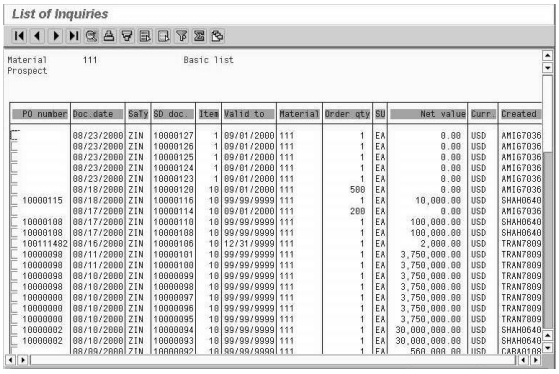
Measurement is key to BPC. Value Metrics provide measurements needed to create new value. We will give several examples of Value Metrics.

Knowledge workers at all levels of the enterprise use metrics to decide and to perform value-creating actions. People manage the enterprise as controllers and actuators in BPC loops.

The basic structure of BPC is identical to the proven structure of a classical feedback loop. Metrics are the feedback sensors. Knowledge workers and decision support tools are the controllers and actuators.

Value Metrics

Enterprises are increasingly deploying key performance indicators (KPIs) as they recognize that measurement is a prerequisite to improvement. A recent book on the subject became a best seller ("Balanced Scorecard").


List of Inquiries

Material 111 Basic list
Prospect

PO number	Doc. date	SaTy	SD doc.	Item	Valid to	Material	Order qty	SU	Net value	Curr.	Created
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	08/23/2000	ZIN	10000126	1	09/01/2000	111	1	EA	0.00	USD	AMI67036
	08/23/2000	ZIN	10000125	1	09/01/2000	111	1	EA	0.00	USD	AMI67036
	08/23/2000	ZIN	10000124	1	09/01/2000	111	1	EA	0.00	USD	AMI67036
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10000002	08/10/2000	ZIN	10000094	10	99/99/9999	111	1	EA	30,000,000.00	USD	SHAH0640
10000002	08/10/2000	ZIN	10000093	10	99/99/9999	111	1	EA	30,000,000.00	USD	SHAH0640
	08/09/2000	ZIN	10000092	10	99/99/9999	111	1	EA	560,000.00	USD	CARA0108

Figure 1: Conventional KPI listing customer inquiries and their resolution.

Value Metrics are a distinctive class of KPI. The distinct characteristics of Value Metrics are

- Direct economic measure
- Root-cause analysis
- Defined business process

We next present examples of metrics. The examples will illustrate these distinct characteristics, and how they significantly increase value creation, compared to the capabilities of conventional KPIs.

Direct Economic Measure

We first consider the importance of direct economic measure. The business process is Customer Service. Figure 1 shows a conventional KPI. It reports Customer Inquiries

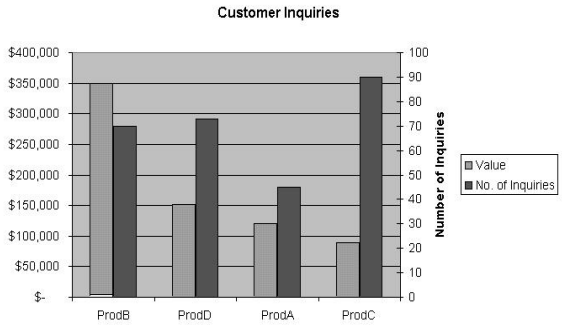

Figure 2: Pareto chart indicating the total lost *value* due to inquiries on each product.

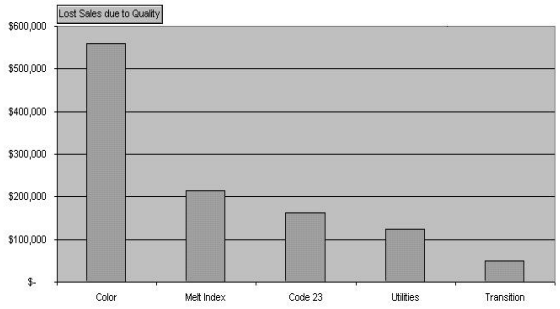

Figure 3: For the current week, Color quality is the leading cause of value loss.

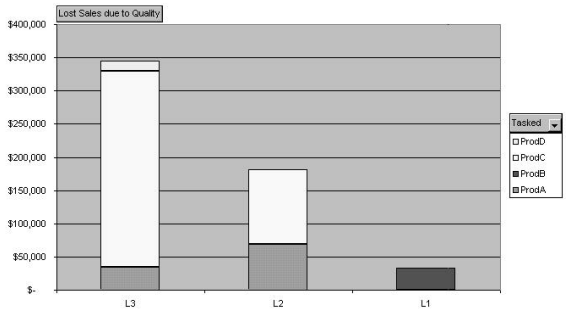

Figure 4: The bulk of the problem occurs when Product C is being made on Line 3.

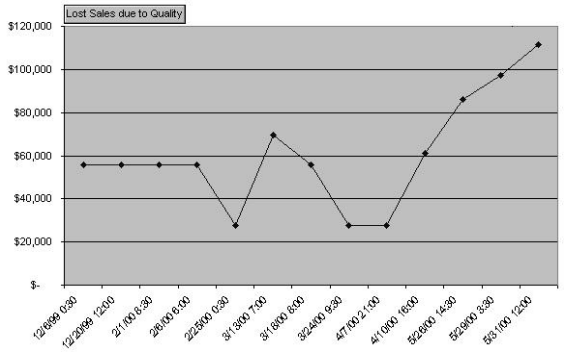

Figure 5: Metric trend plot for Product C.

and their resolution. Each inquiry is valued in terms of product weight, and directly converted to USD. However, this does not necessarily reflect the value of the inquiry.

The Pareto chart in Figure 2 shows a metric that supersedes this KPI. The left ordinate is a metric, indicating the total lost value due to inquiries on each product. The right ordinate is a conventional KPI, indicating only the number of inquiries.

The metric reflects the value of each inquiry and its resolution. It considers not only obvious factors such as weight of product, magnitude of price reduction, and extra shipping and handling costs. It also considers the value of the particular customer's annual revenue stream, the goals and current status of market penetration in the specific product line, and possibly other business-related factors.

The difference between the blue bars representing value, versus the red bars representing frequency, shows one difference between a Value Metric and a conventional KPI. A Customer Service manager using the conventional KPI would be influenced by problems in Product C, the squeaky wheel, rather than by the problems in Product B. But, problems in Product B are contributing three to four times as much to the enterprise value gap than are the more frequent problems in Product C.

Root Cause Analysis

Feedback measurements that lead to root cause detection give knowledge workers important support toward their control of the business process. Value Metrics provide feedback with as much detail as is practical to understand the cause of an observed value loss.

The next example relates to the business process of Quality Management. The metric illustrated in Figure 3 feeds back that, for the current week, Color quality is the leading cause of value loss.

BPC occurs when the knowledge worker determines the cause, and corrects the problem. Choosing Color for the first drill down produces the metric shown in Figure 4. It shows that the bulk of the problem occurs when Product C is being made on Line 3.

To further trace the cause we drill-down by choosing Product C for the metric trend plot shown Figure 5.

This metric identifies the problem as a new one. Each piece of additional information from the metric helps move people to the ultimate goal—BPC to recapture the lost value.

The drill down can go a step further, providing de-

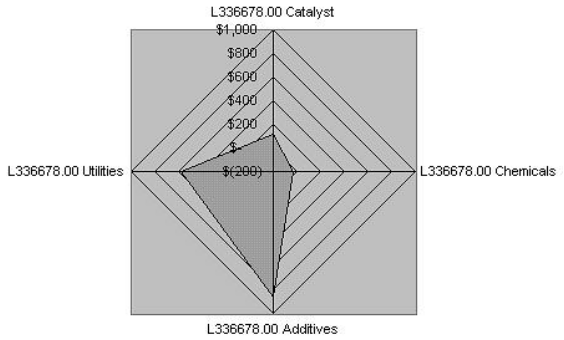

Figure 6: Variable cost components—planned vs. actual.

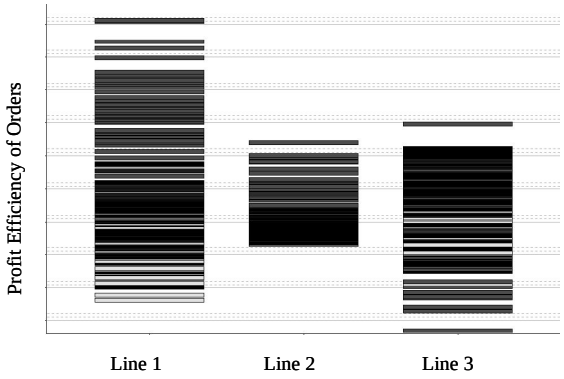

Figure 7: A metric for production management.

tailed feedback on each batch shown on the metric trend. The most recent batch, shown by the arrow, is the likely drill-down candidate.

The spider-web metric shown in Figure 6 displays the results. This metric shows deviation of actual versus planned for each variable cost component.

The root-cause feedback suggests that excess additives may have caused the original color quality losses. Value is being lost both through excess additive cost and possibly through reduced revenues due to the impact on color quality.

Defined Business Processes

The Value Metrics drill-down sequence discussed above is an example of defined business processes. In other words, for the specific example cited above, the defined business process that becomes the best practice for the knowledge worker is:

1. Identify site-wide lost sales due to quality
2. Identify on which production line and product the largest losses were incurred for a specific quality code
3. Identify specific batches within this line/product combination that led to these losses
4. Identify feedstock components that could be associated with the quality issue

Other business processes defined for this metric include specification of the decision and correction/actuation tasks, and their ownership, that will follow each type of feedback signal received from the metric.

Business process definition serves three key purposes:

- Business process definition is essential to forecasting the actual value creation capabilities of a metric. In other words, the defined business processes are the basis for estimating the benefits of implementing a metric.
- Value Metrics with defined business processes are better designed. The requirement to specify in advance exactly how people will use the information leads to better information design.
- Value Metrics with pre-defined business processes have longer useful lifecycles. Execution of the value-creating decision tasks in the initially defined business processes stimulates knowledge workers to devise new business processes for the metric. The discipline of this best practice is rewarded by continual creation of new value, steadily moving the enterprise assets toward their full potential.

Current Applications

We next give three illustrations of current practice in Business Process Control, and the role of metrics. The illustrations progress from substantial automation content, with limited knowledge worker involvement, to zero automation content, with full decision and actuation by knowledge workers.

Production Management

The business process to be controlled in this simple example is execution of an order to produce a specified quantity of specified product for a specified customer on a specified production line at a specified time.

A production order appears at the knowledge worker's station. The automated production management system has filled in most, possibly all, of the information required to fulfill the order. The information is sometimes referred to as the recipe, and includes target values to be downloaded to the process controlling field devices.

The knowledge worker adjusts the information based on his/her experience with value creation for this combination of product, customer, and line. He/she approves the information and triggers its download for execution.

During execution, the knowledge worker monitors and adjusts the recipe and targets based on feedback from the field devices. In most cases, these are not Value Met-

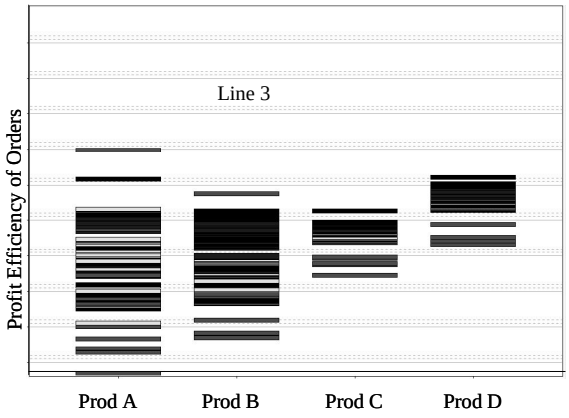

Figure 8: Products A and B are the source of value loss on Line 3.

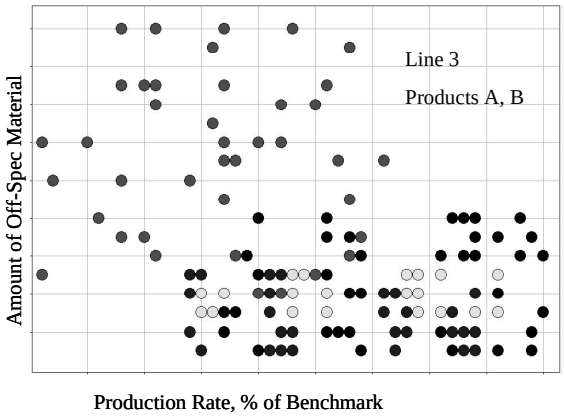

Figure 9: The Red Team is consistently under performing the others on both quality and rate.

rics because they are in physical, rather than economic, units.

A metric for Production Management is illustrated in Figure 7, built on production data collected for each order produced during the previous month.

The direct economic unit on the ordinate is the profit efficiency of each order, defined as the fractional deviation of actual profit from recipe profit. Profit efficiency is sorted against the production lines, and color-coded by the Team responsible for the production order. This metric provides Production Management knowledge workers with the information they need to add value by improving Lines, Teams, and business processes.

A drill down into the relatively poor performance of Line 3 produces the metric shown in Figure 8.

This drill down focuses attention on Products A and B as the source of value loss on Line 3.

The drill-down shown in Figure 9 looks at Products A and B on Line 3. It shows that the Red Team is consistently under performing the others on both quality and rate. This last view is not strictly a Value Metric, because it shows physical rather than economic measures.

However, the previous metrics led the way to this view, which provides Production Management knowledge workers with feedback information for exercising BPC and creating value.

Production Planning

Production planning is a BPC activity. A decision support tool such as a linear program can provide knowledge workers with the feedback information required to set the production plan.

The purpose of this example is to illustrate the advantage of using a true Value Metric as the feedback measurement.

Production planning requires specification of minimum and maximum inventory levels. Often these are set qualitatively, based on experience. The linear (or other) programming tool requires a quantitative objective function to optimize the production plan. The challenge is to choose inventory constraint levels on true economic grounds.

In addition to the obvious requirements that storage facilities be neither flooded nor drained, it is desirable to have a business-driven basis for setting minimum and maximum inventory constraints. These will be targets such as less than an $x\%$ chance that any customer orders will go unfilled, and less than a $y\%$ chance that any supplier receipts must be delayed.

Here is one set of defined business processes and metric to support Production Planning BPC.

- Customer orders and supplier receipts are specified as distributions rather than as fixed numbers. Examples are expected values with standard deviations; or, minimum, likely, and maximum values.
- The optimization is nested. The outer optimization chooses a set of inventory constraints for the inner optimization. The inner optimization optimizes a criterion such as expected profit, or median profit, for the given set of constraints.
- The outer optimization drives to maximum expected profit or similar business-driven criterion. It does this by choosing inventory policy.

Note the absence of any artificial penalty functions on inventory violations. All specifications are expressed in actual business targets.

The metric shown in Figure 10 illustrates the feedback for BPC. It is a plot of the expected profit as a function of the inventory constraint on one particular item, with all other inventory constraints held at their overall optimum levels.

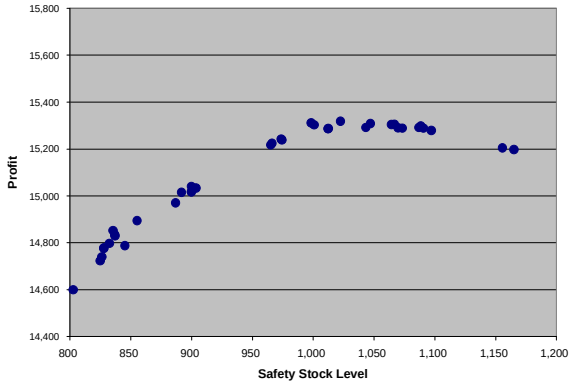

Figure 10: Expected profit as a function of the inventory constraint on one particular item, with all other inventory constraints held at their overall optimum levels.

Project ID	Project Title	Cost, thousands			Benefits, thousands/yr			Duration Quarters			Required Precedents
		Minimum	Forecasted	Maximum	Minimum	Forecasted	Maximum	Minimum	Forecasted	Maximum	
1	Database	970	970	1,940	0	0	0	3	3	5	
2	Production Management System	1,390	1,390	2,780	0	1,710	1,710	6	6	8	1
3	Dock Scheduling System Migration	1,000	1,000	1,400	500	1,000	1,000	3	3	4	
4	Shipments and Receipts System Integration	220	220	440	0	2,780	2,780	3	3	5	2
5	Order Entry System Integration	100	100	200	0	7,320	7,320	3	3	5	2
6	Operations Scheduling System										8
7	Operations Scheduling System Integration										2,7
8	Production Planning System Integration										2
9	Lab System Integration										2
10	Environmental Monitoring and Reporting System										
11	Energy and Utility Management System										
12	Maintenance System Integration				Data not copied to protect client confidentiality						2
13	Materials Procurement System Integration										2
14	Financial Systems Integration										2
15	Health and Safety Management System										14
16	HR Systems Migration to Corporate System										
17	Document Management System										
18	Technology Management System										17

Figure 11: Sample of data on projects that were candidates for capital.

Project Scheduling and Capital Allocation

Allocation of capital to projects and planning their rollout is an ongoing business process. Projects are often prioritized on the basis of their individual cost/benefit attributes because these individual metrics are readily available.

This example presents a metric that evaluates the total slate of candidate projects to support BPC on allocation and scheduling. The metric also has the quality of reflecting uncertainties in the expected costs, benefits, and durations of the individual projects.

Figure 11 is a sample of data on projects that were candidates for capital.

A program of 18 projects over 5 years was proposed to create a site wide information system. Figure 11 shows costs, benefits, durations, and precedents for each project. Some points to note:

- The site preferred conservative uncertainty ranges.
- Actual costs, benefits, and durations were assumed to be equally likely to end up anywhere in between the minimum and maximum levels shown. Other less conservative distributions could have been chosen so that actual outcomes were more likely to be near the forecasted value than near the range extremes.
- Project 1, a database infrastructure project, was assigned no direct benefits at all. However, it is a prerequisite for Project 2, which in turn is a prerequisite for seven other benefit-producing projects. This is a realistic way to handle the benefits of infrastructure projects.
- The numbers shown represent 1991 dollars.

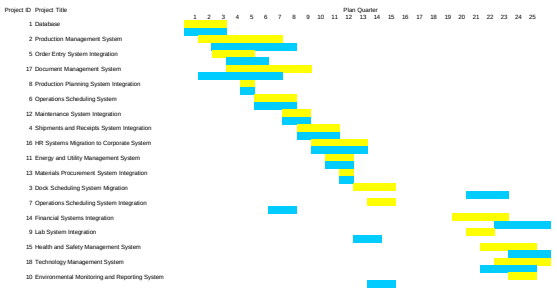

Figure 12: Initial project plan (yellow) and optimized project plan (blue) found by BPC using the feedback from the metric.

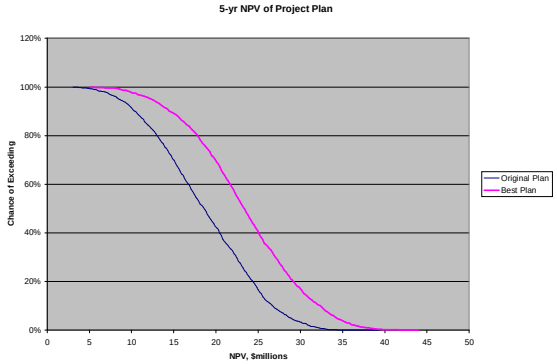

Figure 13: The metric that supported the BPC comparing the distributions of the original plan and the plan that maximized the median value of the NPV.

Figure 12 shows in yellow the initial project plan, and in blue the optimized project plan found by BPC using the feedback from the metric.

BPC reinstated projects 7, 9, and 10, originally omitted from the 5-yr plan. Projects 3 and 14 were removed from the 5-yr plan by BPC.

The metric that supported the BPC is illustrated in Figure 13. The direct economic unit is the 5-year Net Present Value (NPV) of the project plan. The Value Metric compares the distributions of the original plan, and the plan that maximizes the median value of the NPV. The best plan adds about 25% to the NPV.

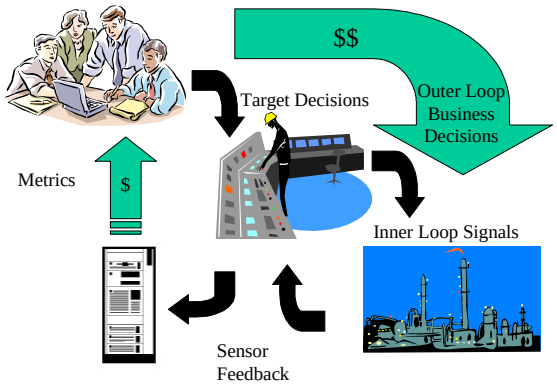

Figure 14: The outer and inner loops that form the familiar cascade configuration.

Cascade Control

The outer and inner loops we have discussed form the familiar cascade configuration shown in Figure 14.

Summary

Table 1 summarizes the diverse business processes considered here, and the Value Metrics that were used.

The unifying theme is BPC. To control each of these business processes requires a feedback metric. Attempting to control without a metric loses value for the enterprise, just as does attempting CPC without valid feedback sensors.

Opportunity

The unifying theme of BPC is Value Metric feedback supporting decision and control/actuation by knowledge workers. The scope covers virtually all enterprise business processes. The potential value creation for this scope far exceeds that of the scope of traditional process control.

An opportunity lies in translating the science of control from chemical processes to business processes. In the near term, it should be possible to develop algorithms that support knowledge workers use of the metrics feedback, by narrowing the possible control actions to those most likely to succeed in value creation. In the long term, once we get the metric feedback right, much more is possible.

Intellectual capital to achieve these goals lies in the community of researchers on CPC. A key goal of this paper is to make a case for the much greater value creation opportunity in BPC than in CPC. The scope of economic influence of knowledge workers far exceeds that of valves and switches.

Business Process	Value Metric
Customer Service	Value of each incident
Quality Management	Value of lost sales
Production Management	Order profit efficiency
Production Planning	Expected plan profit
Capital Project Planning	Expected NPV

Table 1: Summary of the diverse business processes considered and the Value Metrics that were used.