# Quality improvement process to reduce inventories

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*ABSTRACT: This paper reviews one company's commitment, strategy, and action to accelerate quality improvement. Completed projects have reaped quality improvements in products and services in addition to stability and cost savings as the byproducts of more efficient processes. An interdepartmental team achieved results by creating a process to measure collective risk and use it to set prudent inventory targets. Implementation included a control strategy to retain the gains.*

*KEYWORDS: Company profiles, integrated mills, inventory control, management, materials, mills (factories), raw materials, TQM, Wisconsin.*

Consolidated Papers, Inc. (CPI) was similar to many U.S. companies in exercising quality planning in capital projects and market strategies. Their familiarity with quality control gave them a reputation for quality products and services in the 1980s. Quality improvement came at a steady pace.

The management of CPI decided, however, that the evolutionary rate of improvement that had served well in the past would not be adequate for the 1990s and beyond. After reviewing the prevailing quality management philosophies, they chose the revolutionary quality improvement process promoted by the Juran Institute, Inc. They felt that Joseph M. Juran's teachings centering on the quality trilogy could best exploit the strengths of the existing corporate culture. The components of this trilogy are quality planning, control, and improvement.[1]

In 1988, the Juran Institute trained key CPI managers to organize for quality improvement. These managers built an infrastructure of steering councils to guide the improvement process. Selected employees have continued to attend the Juran Institute for formal facilitator training.

These facilitators created an in-house training program for team leaders to assume responsibility for project planning, effective project meetings, and project results. Facilitators not only train and coach teams but also provide liaison to the councils. Team members have knowledge of the affected departments and can contribute necessary skills. They receive in-house quality improvement process (QIP) training before and during the project lifetime. They learn to use a standard process sequence to accomplish their missions. Many of the teams use a flowchart to document their progress and assemble their final report.

A natural consequence of the process was the formation of a group of facilitators. This group provided education for new facilitators. This group evolved into a valuable advisory body of QIP "shepherds" involved in the following activities:

- Troubleshooting the existing process
- Petitioning the councils to correct problems
- Exploring paradigms that limit process improvement
- Envisioning the optimum direction for the QIP process
- Promoting these visions with the councils.

Note that these activities fall into groups designated as control, improvement, and planning activities.

## BICEP

Better Inventory Control Equals Profit (BICEP) was the name for a support department QIP project introduced to reduce raw materials inventory safely. The group comprised people from industrial engineering,

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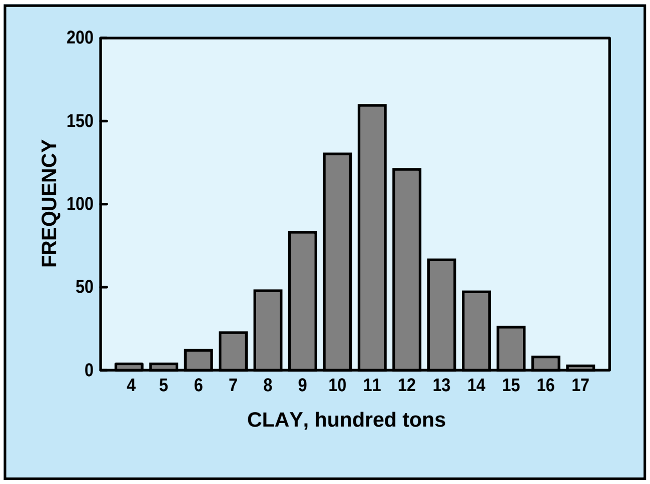
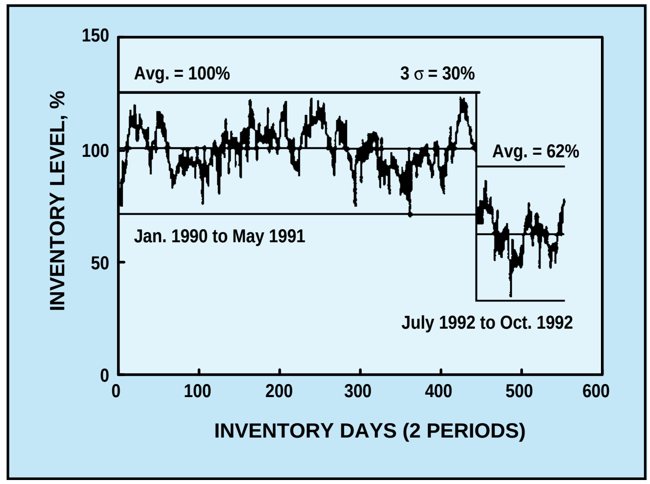
[1]Juran, J. M., *Quality Control Handbook*, 4th edn., McGraw-Hill, New York, 1988, p. 2.7.

**1.** Histogram of clay inventory for 747 days




**2.** Clay inventory showing percentage of historical average




purchasing, transportation, timberlands, research and development, accounting, and quality systems departments. They had the following mission:

- Identify a process to review and evaluate inventory levels to minimize costs. Develop a systematic approach in setting minimum and maximum inventory levels and apply it to clay, pulpwood, and pulp.

## Analyze symptoms

The BICEP team immediately found symptoms. Inventories and associated costs were increasing. Interviews with inventory managers elicited only one strategy, "Don't run out!" Although everyone focused on the risk of running out, no one could quantify the risk or define excess inventory. The team summarized the prevailing attitudes:

- Inventories cover risk
- Estimating risk is an art not a science
- Large inventories avoid any problems.

## Theories of cause

The key to a rational inventory strategy was a process to quantify risk. This was also the process necessary to satisfy the BICEP team mission. When the team brainstormed the meanings of risk, the definitions were legion: fire, flood, strikes, broken equipment, erroneous production forecasts, late deliveries, and all manner of human error. These did not include positive risk factors of countermeasure options or the collective management skills at applying them. Capturing this entire group of individual risk factors in a process model seemed hopeless.

## Breakthrough concepts

All the positive and negative influences that could occur in the future have also probably happened in the past. The net effect of those events was increasing or decreasing inventories. The past events that influenced inventory level fluctuations were one entity or variability. Risk was therefore merely the probability of running out. Since statistics is a tool to study variability, application of this science could quantify risk.

Past inventory level measurements and calculations were available for study. Plotting these observations could show their distribution or pattern of variability. This would provide a statistical model to predict future variability.[2]

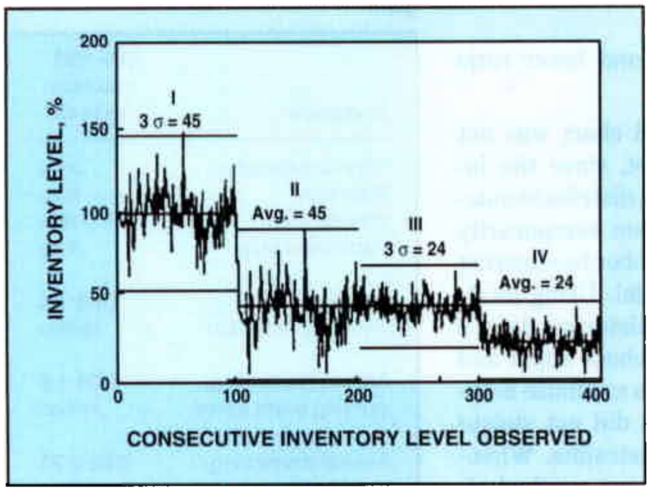
## Implementing solutions for clay

The mission required a process and a demonstration of its effectiveness on clay, pulpwood, and pulp. For the first trial, the team chose clay as the best controlled inventory. Delivery was historically reliable, use projections were simple, and most importantly the reorder interval was only one week. The inventory data appeared to fit a random, normal distribution. **Figure 1** is a histogram showing typical clay inventory distribution. This closely approximates the familiar, bell-shaped curve.

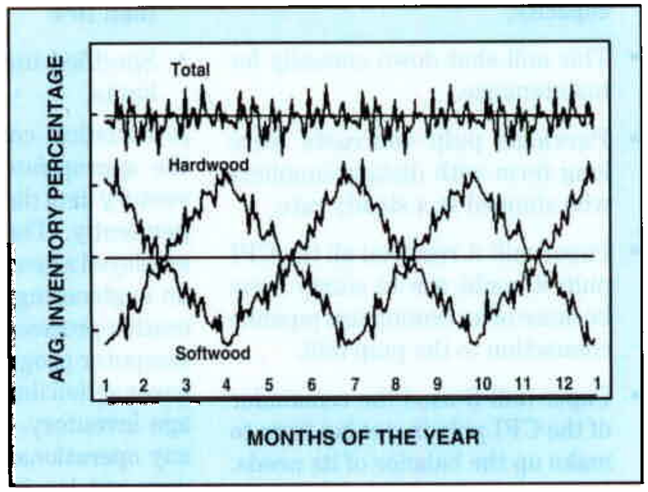
This was good news, because it would legitimize a standard control chart approach. It specifically meant that it was possible to calculate the probability of an inventory randomly fluctuating any given distance from its process average. For example, there is a 99.7% probability that events will occur within ± 3 standard deviations ($3\sigma$) from the process mean. Knowing this, one could set the inventory target average at $3\sigma$ and expect only a 0.15% probability of running out. The remaining 0.15% is the probability of exceeding the average plus $3\sigma$. Managers preferring lower odds of running out could choose larger multiples of $\sigma$.

[2] Warner, D. S., *Pulp & Paper* 67(10):75(1993).

3. 3σ inventory process




4. "Twin peaks" pulpwood strategy




Reorder strategy was the key to controlling inventory averages to a target level. Orders had to include the new usage forecast plus a correction for the error in the last forecast. It was easy to measure that error as the difference between actual inventory and target inventory at the end of the last forecast period. This changed from past practice by requiring a target of 3σ.

In anticipation of major, nonrandom events such as strikes, business conditions, or Wisconsin weather, managers could adjust the orders at their discretion. Managers made another critical decision in choosing the inventory period to sample for an estimate of the standard deviation. If conditions were stable, a long sample period gave the best estimate of collective risk. If the business climate was changing rapidly, then a more recent period would give the best prediction for variability of the immediate future. The simple 3σ system was a tool for good management decisions, but it was not a replacement for them.

**Figure 2** shows a single clay inventory from one division with 3σ limits drawn around the average. This single inventory showed potential for a 70% reduction. After the team reported its findings, management implemented a stepwise reduction in clay inventories. They were justifiably cautious in watching the variation stabilize after each step before further inventory reductions. Figure 2 also illustrates the first step reduction.

Taken to its limit in **Fig. 3**, the 3σ system is a model for continuous process improvement:

- Measure the variability in phase I
- Reduce the inventory average to 3σ in phase II
- Study the variability for clues to reducing it in phase III
- Repeat the process by reducing the inventory average in phase IV to the new, reduced 3σ.

## Implementing solutions for pulpwood

The BICEP team then focused on the pulpwood inventory. As expected, this was not under good control. The complexities included multiple contracts to small suppliers, variations in consumption rate, variations in delivery schedule, inaccurate consumption forecasts, and inventory inaccuracy. Long reorder intervals and weather constraints exacerbated all these.

Over a short time period, the inventory might drop due to higher than expected consumption coupled with difficult wood delivery conditions. The same conditions could occur over the next short time period. This could continue until the next opportunity to reorder and correct the downward inventory trend back to target. The risk of running out could accumulate dangerously between long reorder contracts. Today's inventory varies around yesterday's inventory instead of around the average. This is random walk variation.

Weather constraints on timber access caused much of the drift. Suppliers had varying difficulty getting heavy equipment into hardwood growth areas in the spring and fall. Fortunately softwood grew in areas more accessible during these seasons. This led to the procurement strategy of **Fig. 4** named the "twin peaks system." Softwood and hardwood inventories increased or decreased in opposite seasons. This maintained the lowest total wood inventory while addressing seasonal risks for each species. The minimum target inventory in the valleys was 3σ. The height of the peaks will decrease as experience and confidence in the system increases.

## Implementing solutions for pulp

Two sources of chemical pulp were internal manufacture and external purchase. A host of operating restraints made it the most complex inventory to manage:

- The CPI pulp mill ran only at full capacity.
- This mill shut down annually for maintenance.
- Purchase pulp contracts were long term with distant suppliers who shipped at a steady rate.
- Paper mill A received all the CPI pulp it could use in slurry form because of an economical pipeline connection to the pulp mill.
- Paper mill B used the remainder of the CPI pulp in wet lap form to make up the balance of its needs.
- Paper mill B desired a stable blend of wet lap to purchased pulp that required warehousing both pulps and reshipping them at the rate of consumption.

Warehouse space and reshipping were very expensive items requiring excellent management of this inventory. The 3σ approach still seemed the best way to set average inventory targets with a small increase of wet lap inventory before the planned pulp mill downtimes. If targets seemed easy, control seemed impossible. There were no controls to regulate wet lap flow into or out of the warehouse. Opportunities to change purchased pulp contracts were very limited. Large inventories seemed the only hedge against production forecast errors.

## Resistance to change

Adjusting the ratio of wet lap to purchased pulp ratio in paper mill B was the only possible control for wet lap inventory. The ratio had changed historically when inventories had threatened either to exceed storage capacity or to run out. Management agreed with this control technique. They also added a second tier of constraints to protect paper machine stability and product quality:

- No ratio changes more frequently than 15 days
- No single ratio changes greater than 10%
- Specified upper and lower ratio limits.

A statistical control chart was not the appropriate tool, since the inventory data did not distribute independently. The team temporarily employed a new member to construct an engineering model. Using an iterative process on historical data, a computer program chose upper and lower action limits to minimize average inventory. This did not violate any operational constraints. Whenever wet lap inventory reached either action limit, the model checked constraints. It then advised inventory managers of a necessary pulp ratio change.

The engineering model allowed a potential 50% reduction in working wet lap inventory. An unexpected bonus was an increase in paper machine stability over the old system. Past resistance to pulp ratio changes had actually intensified the size and frequency of changes precipitated by inventory extremes.

Contracting about 10% under needs forecasts and fine tuning with “spot market” purchases achieved purchased pulp control. This strategy will change with future pulp market conditions. A new rail contract reduced double handling costs. A new decision point upstream from the mills allowed last minute destination changes directly to mills needing pulp from the warehouse. New stability in the wet lap inventory also helped reduce the variability in the purchased lap inventory. This allowed a lower target average.

**Table I** shows the results of the BICEP inventory reduction project. The results indicate that the two years of project work accomplished the goal of the mission statement.

**I.** Results of BICEP inventory reduction program

| *Inventories* | *1990–1992 inventory reduction* |
|---|---|
| Clay (2 mills only) | 35% |
| Pulpwood | 40% |
| Wet lap pulp | 18% |
| Purchased pulp | 37% |
| Total (one time) inventory reduction | US$ 7.5 million |
| Annual (continuing) carrying costs saved | US$ 1.5 million |
| Annual (continuing) distribution costs saved | US$ 0.37 million |

## Holding the gains

All QIP teams at CPI must have a “hold the gains” strategy in place before project closure. The BICEP team created a computerized inventory control system that connected the operating divisions to the purchasing department. This system provides the following:

- Accepts and stores inventory data
- Charts inventory levels with averages and control limits for any selected time interval
- Calculates new 3σ limits over any selected time interval
- Allows purchasing to review the status of all mill inventories
- Prints inventory graphs for reports.

This program is expandable to as many inventory items as necessary. It is possible to clone the BICEP strategies to manage all corporate inventories. The team estimated an additional potential savings of several million dollars.

Phase II of this system will eventually convert sales forecasts into inventory replenishment needs. This feature will further reduce the labor and error costs of inventory management. TJ

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