Optimizing and Controlling Processes through Statistical Process Control (SPC)

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Agenda

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2. Rationale for SPC
3. Control Chart Development
4. Management's Role in SPC
5. Role of the Total Quality Tools
6. Authority over Processes and Production
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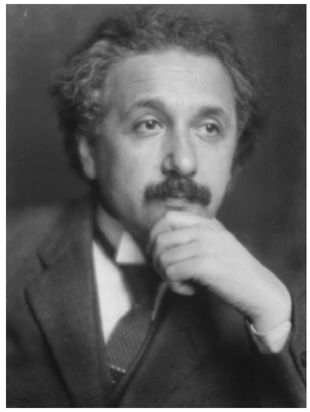
"In the middle of difficulty lies opportunity."
Albert Einstein



http://dracus.wordpress.com/tag/albert-einstein/

Statistical Process Control Defined

The origin of what is now called statistical process control (SPC) dates to 1931 and Dr. Walter Shewhart's book "The Economic Control of Quality of Manufactured Product". Shewhart, a Bell Laboratories statistician, was the first to recognize that industrial processes themselves could yield data, which, through the use of statistical methods, could signal that the process was in control or was being affected by special causes (causes beyond the natural, predictable variation). The control charts used today are based on Shewhart's work. These control charts are the very heart of SPC. What may not be as obvious is that Shewhart's work became the catalyst for the quality revolution in Japan and the entire movement now called total quality. We tend to look at SPC as one piece of the whole total quality picture, and it is, but it is also the genesis of total quality.

Statistical Process Control Defined

Statistical process control (SPC) is a statistical method of separating variation resulting from special causes from variation resulting from natural causes in order to eliminate the special causes and to establish and maintain consistency in the process, enabling process improvement.

Five-Year Quality Performance Improvement by Auto Manufacturers in Problems per 100 Vehicles (PP100)

	1999 PP100	2004 PP100	Percentage of Improvement
Japanese	144	111	23
Korean	227	117	48
European	171	122	29
Domestic	177	123	30

Source: J. D. Power and Associates, *Initial Quality Study*, 2004.

Rationale for SPC

1. Control of variation
2. Continual improvement
3. Predictability of processes
4. Elimination of waste
5. Product inspection

Rationale for SPC

Control of variation

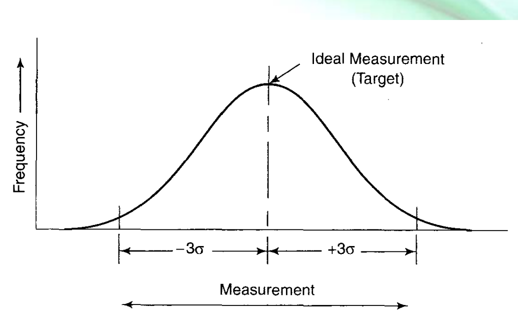


Figure 18–1
Frequency Distribution Curve:
Normal Curve

Rationale for SPC

Control of variation

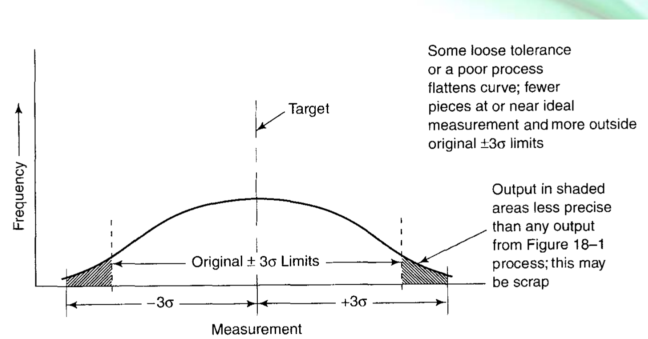


Figure 18–2
Frequency Distribution Curve: Process Not as Precise as Figure 18–1

Rationale for SPC

Control of variation

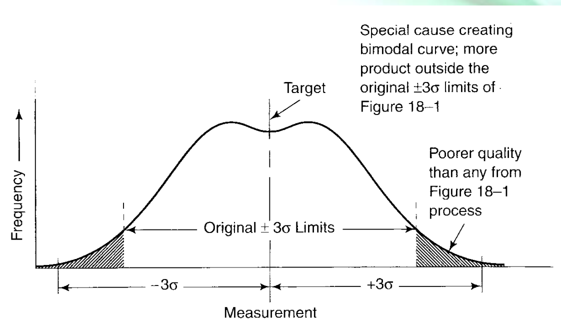


Figure 18-3
Bimodal Frequency Distribution Curve

Rationale for SPC

Control of variation

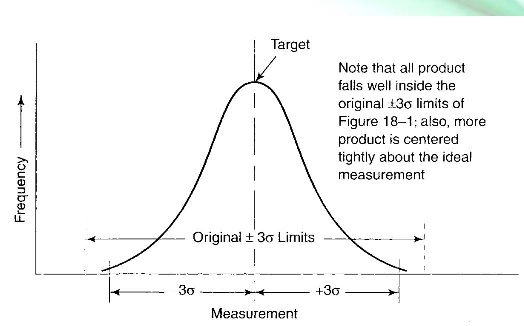


Figure 18–4
Frequency Distribution Curve: Narrowed (Less Variation) Relative to Figure 18–1

Rationale for SPC

Continual improvement

Before a process can be improved, it is necessary to understand it, identify the external factors that may generate special causes of variation, and eliminate any special causes that are in play. Then, and only then, can we observe the process in operation and determine its natural variation. Once a process is in this state of statistical control, it can be tracked, using control charts, for any trends or newly introduced special causes. Process improvements can be implemented and monitored. Without SPC, process improvement takes on a hit-or-miss methodology, the results of which are often obscured by variation stemming from undetected factors (special causes). SPC lets improvements be applied in a controlled environment, measuring results scientifically and with assurance.

Rationale for SPC

Predictability of processes

Few things in the world of manufacturing are worse than an undependable process. Manufacturing management spends half its time making commitments and the other half living up to them. If the commitments are made based on unpredictable processes, living up to them will be a problem. The only chance manufacturing managers have when their processes are not predictable is to be especially conservative when making commitments. Instead of keying on the best past performance, they look at the worst production month and base their commitments on that. This approach can relieve a lot of stress but can also lose a lot of business. In today's highly competitive marketplace (whether for a manufactured product or a service) organizations must have predictable, stable, consistent processes. This can be achieved and maintained through SPC.

Rationale for SPC

Elimination of waste

Statistical process control is the key to eliminating waste in production processes. It can do the same in virtually any kind of process. The inherent nature of process improvement is such that as waste is eliminated, the quality of the process output is correspondingly increased.

Rationale for SPC

Product inspection

After supplier processes are under control and being tracked with control charts, manufacturers can back off the customary incoming inspection of materials, resorting instead to the far less costly procedure of periodically auditing the supplier's processes. SPC must first be in place, and the supplier's processes must be shown to be capable of meeting the customer's specifications.

This also applies internally. When a company's processes are determined to be capable of producing acceptable products, and after they are in control using SPC, the internal quality assurance organization can reduce its inspection and process surveillance efforts, relying to a greater degree on a planned program of process audits. This reduces quality assurance costs and, with it, the cost of quality.

Control Chart Development

Control Chart Development for Variables Data (Measured Values)

Consider an example using $\bar{x}$ charts and R-charts. These charts are individual, directly related graphs plotting the mean (average) of samples ($\bar{x}$) over time and the variation in each sample (R) over time. The basic steps for developing a control chart for data with measured values are these:

1. Determine sampling procedure.

Control Chart Development

Control Chart Development for Variables Data (Measured Values)

2. Collect initial data of 100 or so individual data points in k subgroups of n measurements.
   - The process must not be tinkered with during this time—let it run.
   - Don’t use old data—they may be irrelevant to the current process.
   - Take notes on anything that may have significance.
   - Log data on a data sheet designed for control chart use.

Control Chart Development

Control Chart Development for Variables Data (Measured Values)

3. Calculate the mean (average) values of the data in each subgroup ($\bar{x}$).
4. Calculate the data range for each subgroup (R).
5. Calculate the average of the subgroup averages ($\bar{\bar{x}}$). This is the process average and will be the centerline for the $\bar{x}$ chart.
6. Calculate the average of the subgroup ranges ($\bar{R}$). This will be the centerline for the R-chart.

Control Chart Development

Control Chart Development for Variables Data (Measured Values)

7. Calculate UCL and LCL. UCL and LCL represent the ±3σ limits of the process averages and are drawn as dashed lines on the control charts.
8. Draw the control chart to fit the calculated values.
9. Plot the data on the chart.

Control Chart Development

Control Chart Development for Variables Data (Measured Values)

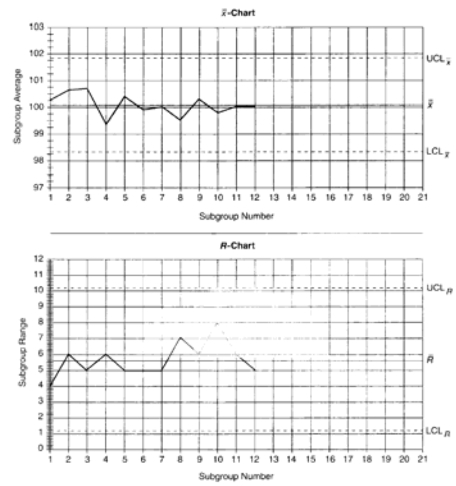


Figure 18–7
x̄- and R-Charts

Control Chart Development

Control Chart Development for Attributes Data (Counted Data)

The p-Chart

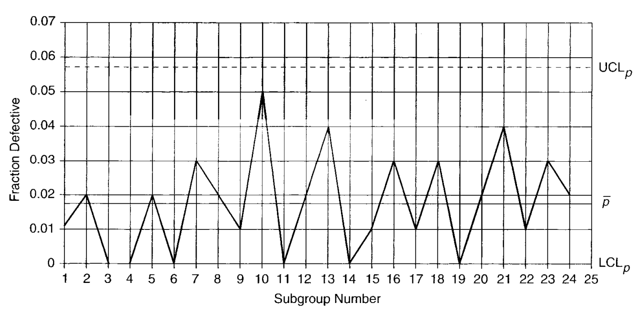


Figure 18–14
p-Chart

Control Chart Development

Control Chart Development for Attributes Data (Counted Data)

The c-Chart

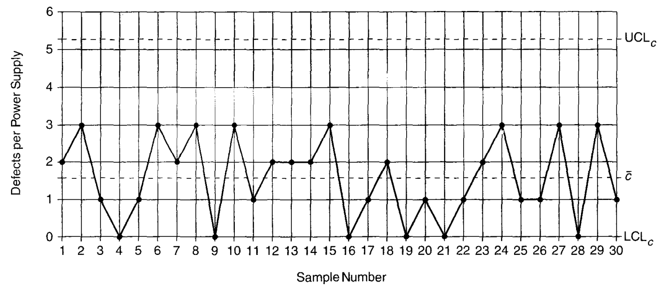


Figure 18–17
c-Chart: Power Supply Defects

Control Chart Development

The Control Chart as a Tool for Continual Improvement

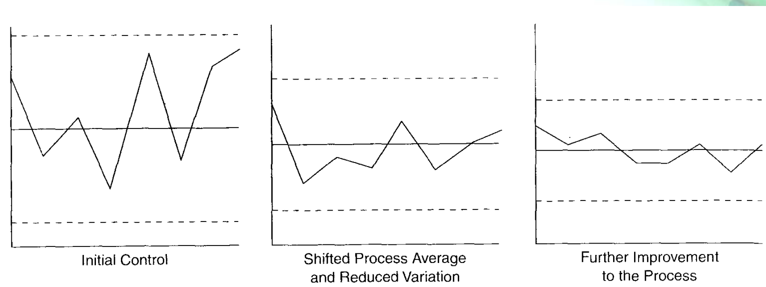


Figure 18–18
Succession of Control Charts

Control Chart Development

Data Category	Chart Type	Statistical Quantity	Application
Variables (measured values)	*x bar-R* ($\bar{x}$ & *R*)	Mean value and range	Charts dimensions and their precision, weight, time, strength, and other measurable quantities. Example: Anything physically measurable.
	x tilde-R ($\tilde{x}$ & *R*)	Median and range	Charts measurable quantities, similar to $\bar{x}$ & *R*, but requires fewer calculations to plot. Example: As above.
	x-Rs (also called *x-chart*)	Individual measured values	Used with long sample intervals; when subgrouping not possible. Example: Products made in batches such as solutions, coatings, etc., or grouping too expensive (e.g., destructive testing). Histogram must be normal.
Attributes (counted values)	*p-chart*	Percentage defective (also *fraction* defective)	Charts the number of defects in samples of varying size as a percentage or fraction. Example: Anywhere defects can be counted.
	np-chart (also *pn*)	Number of defective pieces	Charts the number of defective pieces in samples of fixed size. Example: As above, but in fixed-size samples.
	c-chart	Number of defects	Charts the number of defects in a product (single piece) of fixed size (i.e., like products). Example: Specific assemblies or products (e.g., PC boards, tires).
	u-chart	Number of defects per unit area, time, length, etc.	Charts the number of defects in a product of varying size (i.e., unlike products). Example: Carpet (area), extrusions (length).

Figure 18–19
Common Control Charts and Their Applications

Control Chart Development

Statistical Control Versus Capability

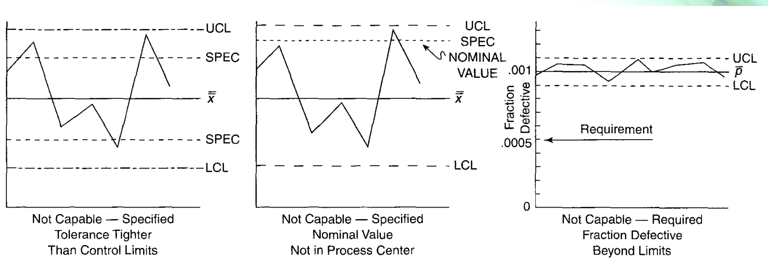


Figure 18–20
In Control and *Capable* Are Not the Same Thing

Management's Role in SPC

As in other aspects of total quality, management has a definite role to play in SPC. In the first place, as Deming has pointed out, only management can establish the production quality level. Second, SPC and the continual improvement that results from it will transcend department lines, making it necessary for top management involvement. Third, budgets must be established and spent, something else that can be done only by management.

Role of the Total Quality Tools

Some may consider it inappropriate to include tools other than control charts in a discussion of SPC. However, we take the broader view and include several tools:

- Pareto charts
- Cause-and-effect diagrams
- Stratification
- Check sheets
- Histograms
- Scatter diagrams
- Run charts and control charts
- Flowcharts
- Design of experiments
- Failure mode and effects analysis (FMEA)

Role of the Total Quality Tools

SPC does not start the moment a control chart is employed. Before SPC can be fully implemented, a lot of work must be done to eliminate the special causes of variation in the process concerned. Consequently, several quality tools will be used before it is time to develop and implement a control chart. When does SPC start? It starts when someone begins cleaning up the process. In the final analysis, this question is not that important because the quality tools come into play either to support SPC or to be part of the SPC package, depending on the definition used.

Role of the Total Quality Tools

With SPC, the total quality tools have a dual role. First, they help eliminate special causes from the process so that the process can be brought under control. (Remember that a process that is in control has no special causes acting on it.) Only then can the control charts be developed for the process and the process monitored by the control charts. Their second role comes into play when, from time to time, the control chart reveals a new special cause or when the operator wants to improve a process that is in control.

Authority over Processes and Production

Operators who use SPC to keep track of their processes must have the authority to stop the production process when SPC tells them something is wrong. As long as the plots on the control chart vary about the process average but do not break through a control limit, the process is in control and is being influenced by the common causes of variation only. Once a incursion is made or the operator sees a run of several plots all on one side of the process average, he or she has good reason to believe that the process needs attention. The operator should be able to stop the process immediately.

Authority over Processes and Production

Two Attitudes Toward Line Stoppages

Stopping production lines is seen differently by the traditional factory and the total quality factory.

Traditional Factory

- *Line stops because:* Broken machine, missing or incorrect parts, operator problem, and so forth.
- *Reaction:* Find a quick fix; get line moving again. Try to determine and correct the cause later.
- *Result:* Production of defective products and propensity for recurrence.
- *Attitude:* Line stoppages are to be avoided at nearly any cost.

Total Quality Factory

- *Line stops because:* Operator detected an indication of a process problem (e.g., SPC limit penetration or a run).
- *Reaction:* Determine cause and eliminate before restoring production.
- *Result:* Minimizes production of defective product; process becomes more robust.
- *Attitude:* Line stops represent opportunities for improvement.

Source: Stanley Davis.

Implementation and Deployment of SPC

Phase	Responsibility	Action
Preparation	Top management	(1) Commit to SPC
	Top management	(2) Organize SPC committee
	Consultant or in-house expert	(3) Train SPC committee
Planning	SPC committee assisted by consultant or expert	(4) Set SPC objectives
		(5) Identify target processes
	Consultant or in-house expert	(6) Train appropriate operators and support personnel
	QA	(7) Ensure repeatability and reproducibility of instruments and methods
	Management	(8) Delegate responsibility for operators to play key role
Execution	SPC committee, operator, suppliers, customers	(9) Flowchart the process
	Operator w/ expert assistance	(10) Eliminate the special causes of variation
	Consultant or in-house expert	(11) Develop control chart(s)
	Operator	(12) Collect and plot SPC data; monitor
	Operator w/ expert assistance	(13) Determine process capability*
	Operator	(14) Respond to trends and out-of-limits data
	SPC committee and management	(15) Track SPC data
	Operator w/ assistance as required	(16) Eliminate root causes of any new special causes of variation
	All	(17) Continually improve the process (narrow the limits)

Figure 18–21
The SPC Implementation Road Map
*If the process is not capable of meeting requirements, it must be changed or replaced; go back to step 9.

Inhibitors of SPC

A number of factors can inhibit the implementation of SPC. With SPC, there is not usually the kind of philosophical resistance that is common with some aspects of TQM. However, it is true even with SPC that there must be a management commitment because there will be start-up costs associated with implementation. The most common inhibitor of SPC is lack of resources.

Inhibitors of SPC

Other important SPC inhibitors are:

- Capability in Statistics
- Misdirected Responsibility for SPC
- Failure to Understand the Target Process
- Failure to Have Processes Under Control
- Inadequate Training and Discipline
- Measurement Repeatability and Reproducibility
- Low Production Rates

References

Quality Management for Organizational Excellence: Introduction to Total Quality, 6th Edition, David Goetsch and Stanley Davis, copyright 2010, Pearson, ISBN: 978-0-13-501967-2.

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