

# LEAN SIX SIGMA

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# CHAPTER 1

## An Introduction to Six Sigma

---

fig. 1

**Continuous efforts to achieve stable and predictable process results are of vital importance to business success.**

**Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled.**

**Achieving sustained quality improvement requires commitment from the entire organization, particularly from top level management.**

fig. 2

$$\sigma = \sqrt{\frac{\sum (X - \bar{X})^2}{n}}$$



fig. 3

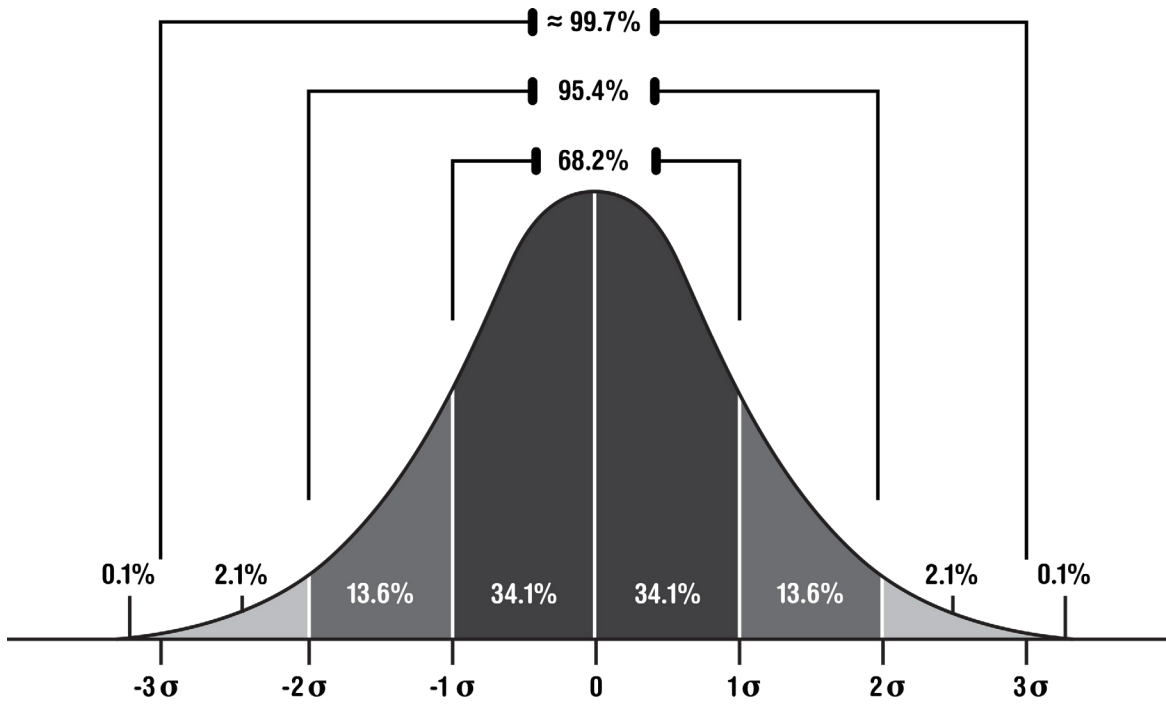


fig. 4

<b>D</b>	<b>Define - the system, goals, requirements, and the voice of the customer.</b>
<b>M</b>	<b>Measure - critical elements of the process and collect necessary data.</b>
<b>A</b>	<b>Analyze - collected data to identify root causes of defects and relationships between all factors.</b>
<b>I</b>	<b>Improve - the process using Six Sigma and other innovation tools based on collection data.</b>
<b>C</b>	<b>Control - the process during future executions to ensure consistent adherence to quality standards.</b>

fig. 5

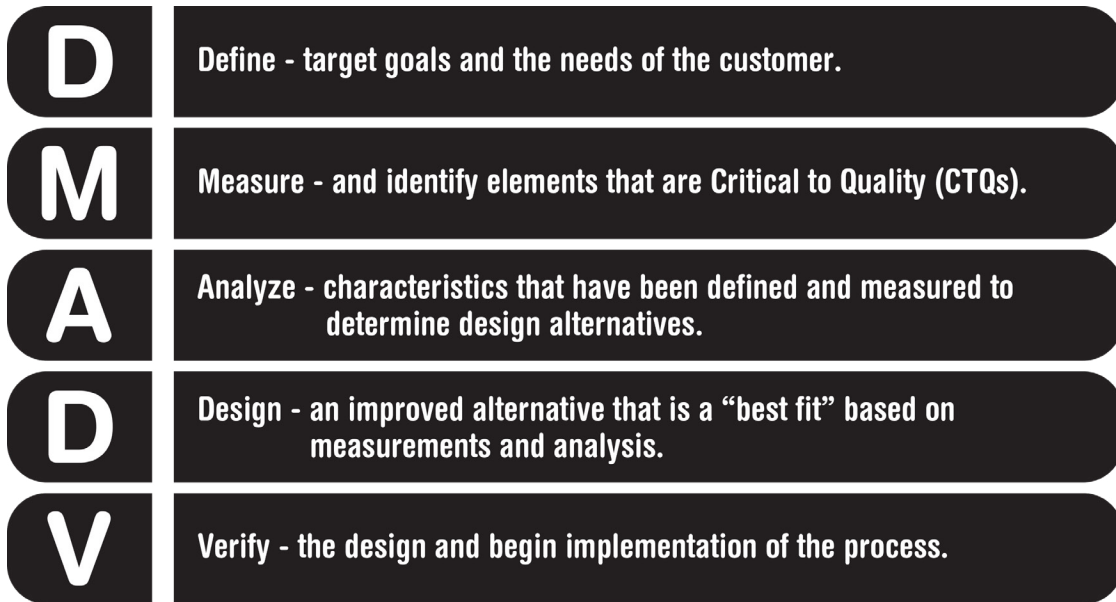
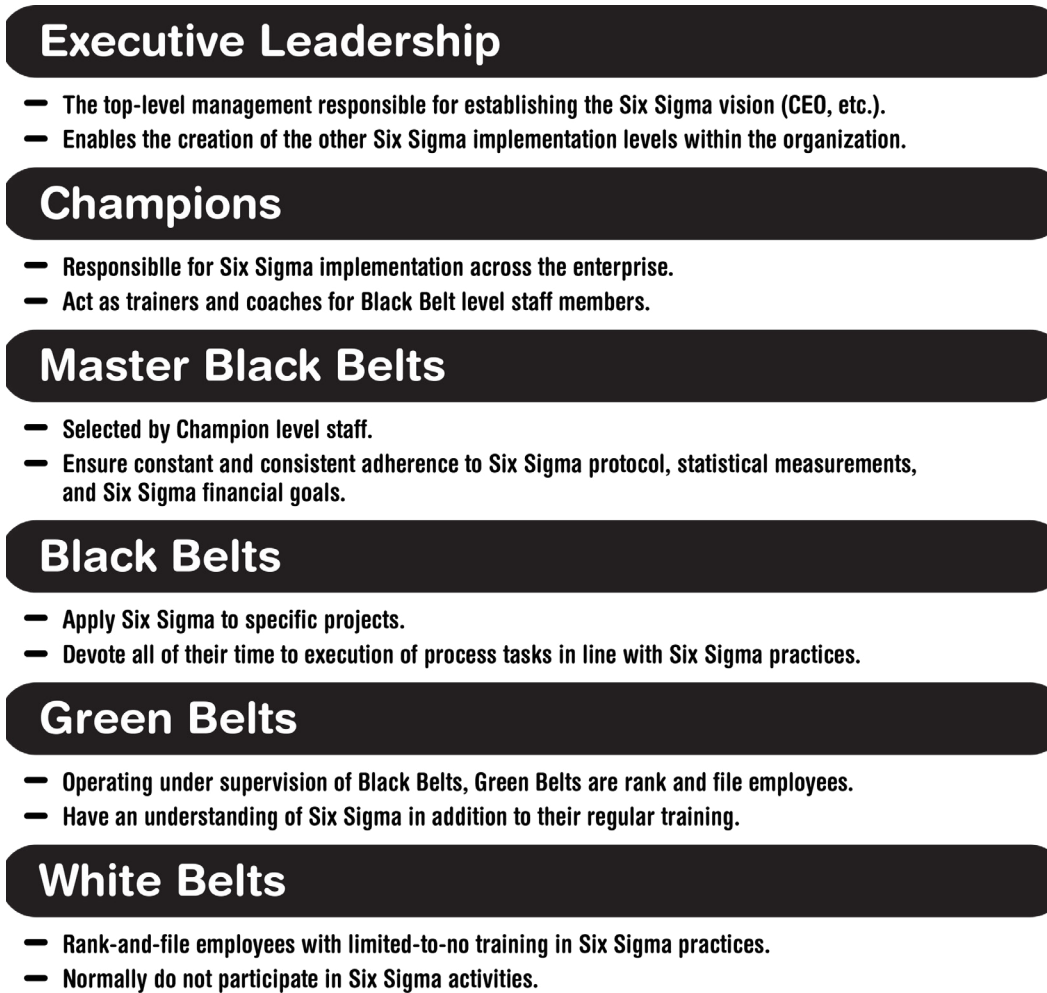


fig. 6



## CHAPTER 2

### Six Sigma: Key Tools & Processes

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fig. 7

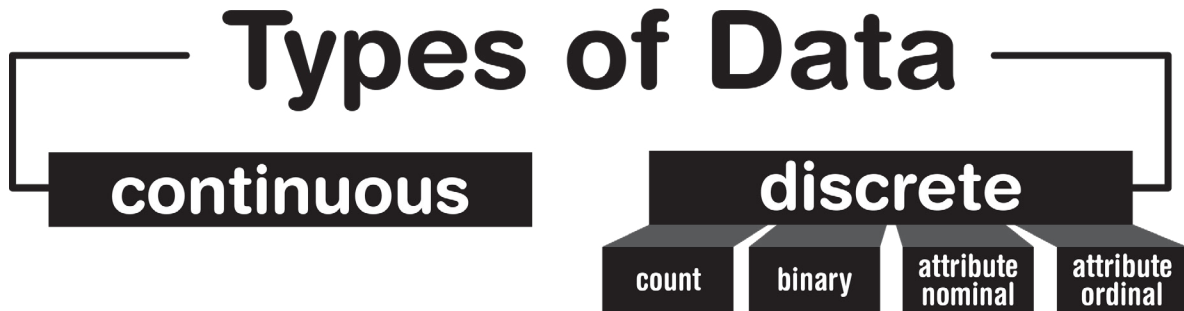


fig. 8



fig. 9



fig. 10

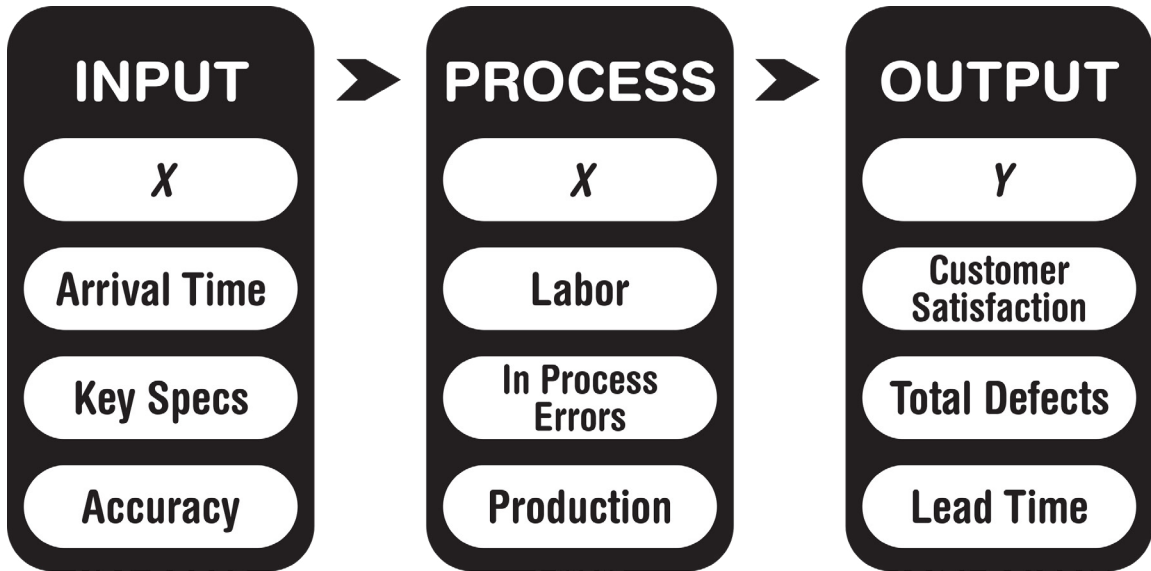


fig. 11

Data Collection Plan							
Type	Metric <sup>1</sup>	Stratification Factors <sup>2</sup>	Operational Factors <sup>3</sup>	Sample Size <sup>4</sup>	Source & Location <sup>5</sup>	Collection Method <sup>6</sup>	Who Will Collect <sup>7</sup>
<i>Input</i>							
<i>Process</i>							
<i>Output</i>							
How Will Data Be Used? <sup>8</sup>				How Will Data Be Displayed? <sup>9</sup>			

fig. 12

CUSTOMER REQUIREMENTS	OUTPUT MEASURES					
	Delivery w/in 2 mins	% of cones that match order on delivery	% of cones that match order before delivery	# of complaints about cone consistency	Temp on delivery less than 10°F	# of customer complaints about quality
On-Time Delivery	<b>S</b>	<b>W</b>	<b>W</b>	<b>W</b>	<b>W</b>	<b>M</b>
Right Ingredients		<b>S</b>	<b>S</b>	<b>M</b>		<b>M</b>
Cold	<b>M</b>		<b>W</b>	<b>M</b>	<b>S</b>	<b>M</b>
Attractive Presentation	<b>W</b>		<b>W</b>	<b>M</b>	<b>W</b>	<b>M</b>
S = Strong      M = Moderate      W = Weak						

fig. 13

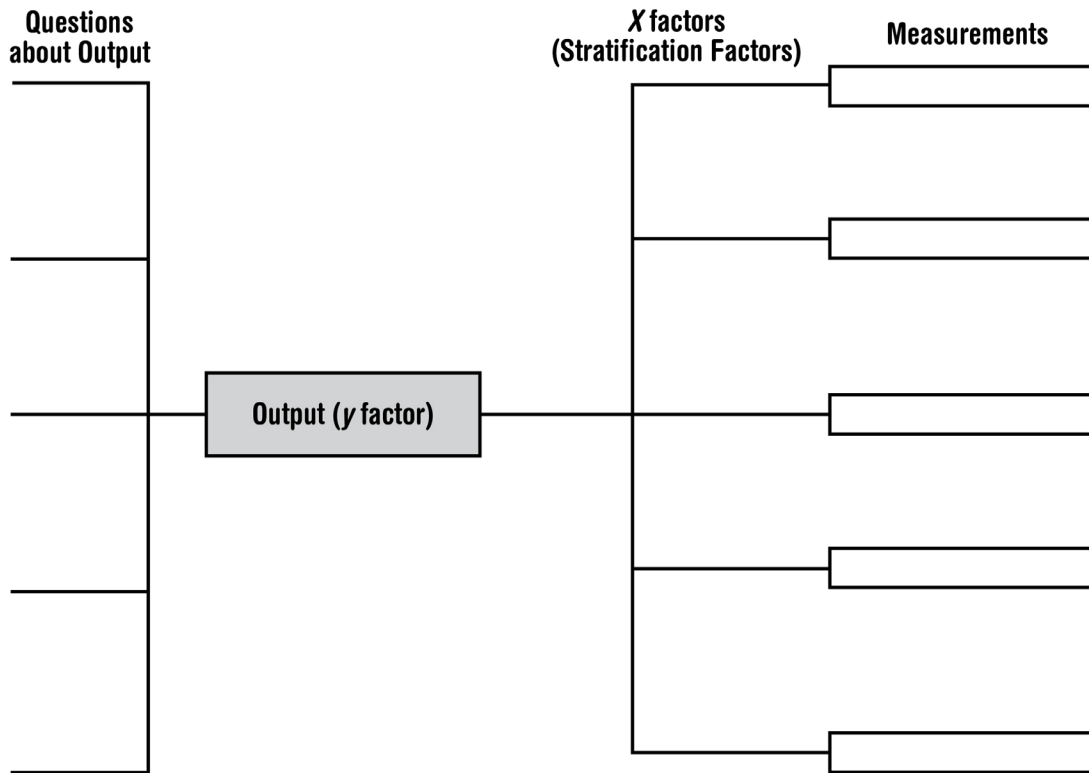


fig. 14

$$\overline{X} = \frac{\sum X}{n}$$

fig. 15

## Collection of 30 Performance Scores\*

\*scores are out of 50 possible points

24	15	38
36	8	6
21	30	14
35	16	27
17	49	36
50	7	17
27	8	21
26	23	29
49	4	17
22	41	39

fig. 16

$$s^2 = \frac{\text{sum of squares}}{n - 1} = \frac{\sum (x_i - \bar{X})^2}{n - 1}$$

fig. 17

<b>Data Point</b>	<b>xi - x</b>	<b>Result<sup>2</sup></b>
4	-21.7	472.34
6	-19.7	389.40
7	-18.7	350.94
8	-17.7	314.47
8	-17.7	314.47
...	...	...
41	15.3	233.07
46	20.3	410.74
49	23.3	541.34
49	23.3	541.34
50	24.3	588.87

$$\Sigma = 5457.87$$

$$\Sigma / n-1 = 188.20^*$$

fig. 18

$$\sigma = \sqrt{\frac{\Sigma (X - \bar{X})^2}{n - 1}}$$

fig. 19

### Box Plot of 30 Performance Scores Sample Data

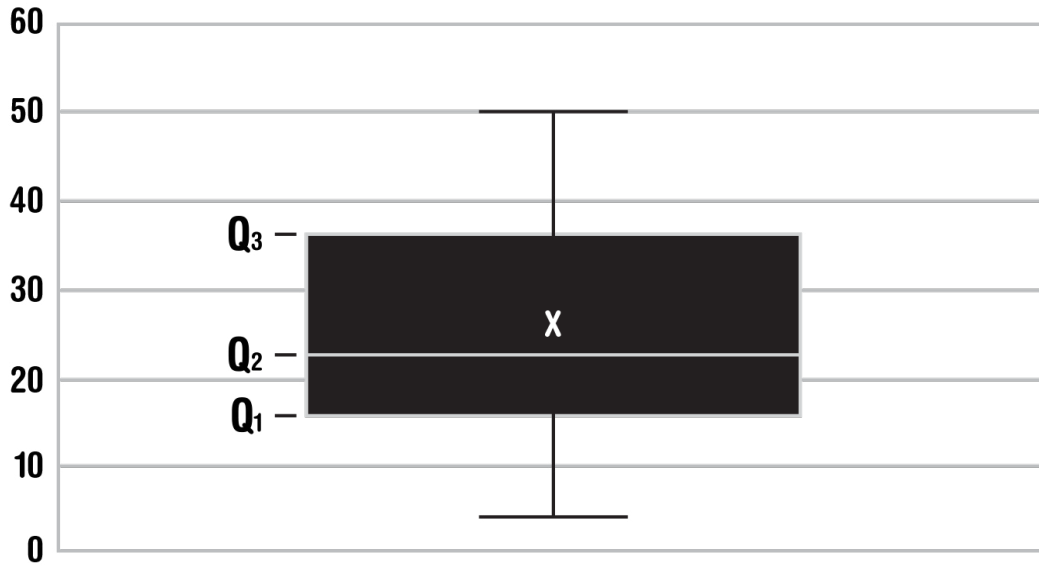


fig. 20

4, 6, 7, 8, 8, 14, 15, | 16, 17, 17, 17, 21, 21, 22, 23, | 24, 27, 27, 29, 30, 35, 36, | 36, 38, 39, 41, 46, 49, 49, 50

Becomes:

**Q<sub>1</sub>**
**Q<sub>2</sub>**
**Q<sub>3</sub>**  
 4, 6, 7, 8, 8, 14, 15, | 16, 17, 17, 17, 21, 21, 22, 23, | 24, 27, 27, 29, 30, 35, 36, | 36, 38, 39, 41, 46, 49, 49, 50

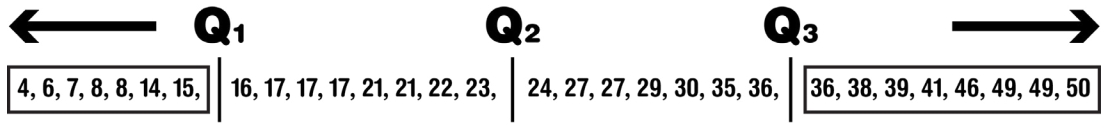
fig. 21

**Q<sub>1</sub>**
**Q<sub>2</sub>**
**Q<sub>3</sub>**  
 4, 6, 7, 8, 8, 14, 15, | 16, 17, 17, 17, 21, 21, 22, 23, | 24, 27, 27, 29, 30, 35, 36, | 36, 38, 39, 41, 46, 49, 49, 50

\* shown as the shaded portion of the box plot



fig. 22



\* the remaining 50% of the data is plotted inside the whiskers

fig. 23

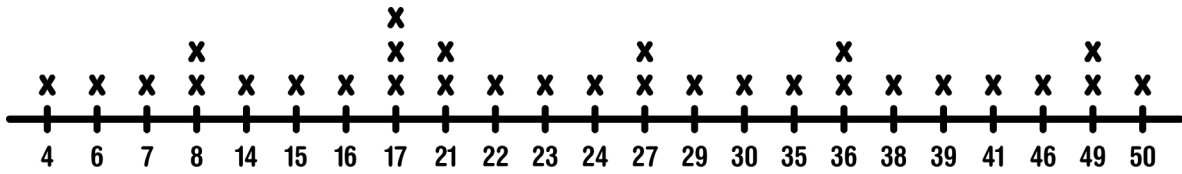


fig. 24

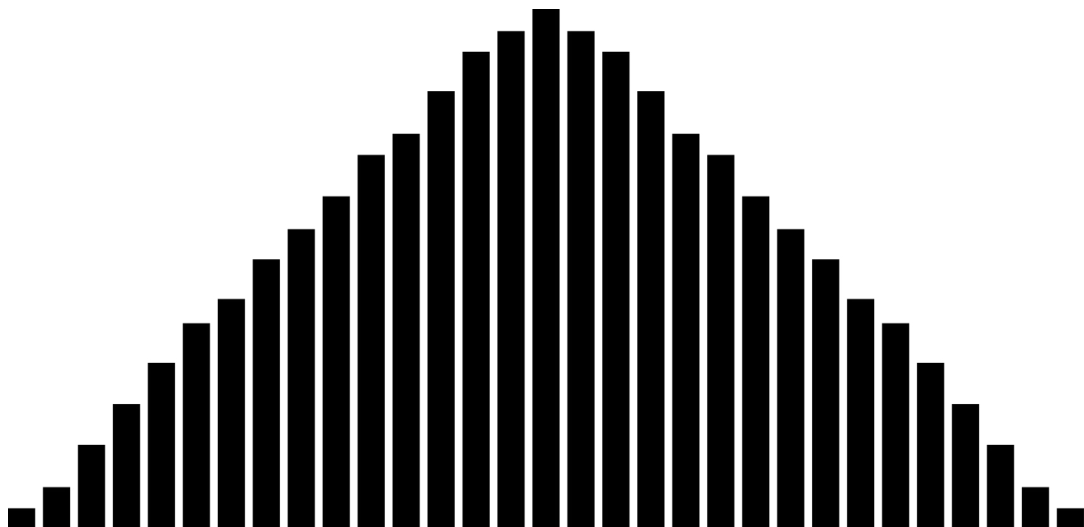


fig. 25

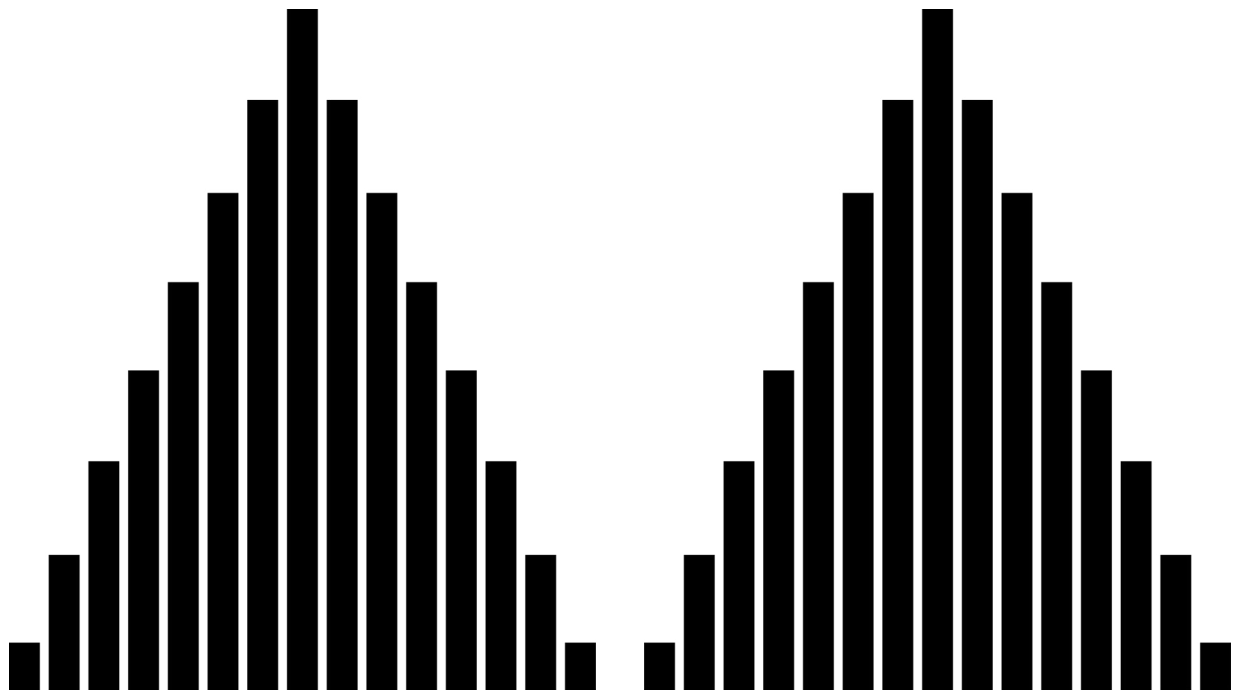


fig. 26

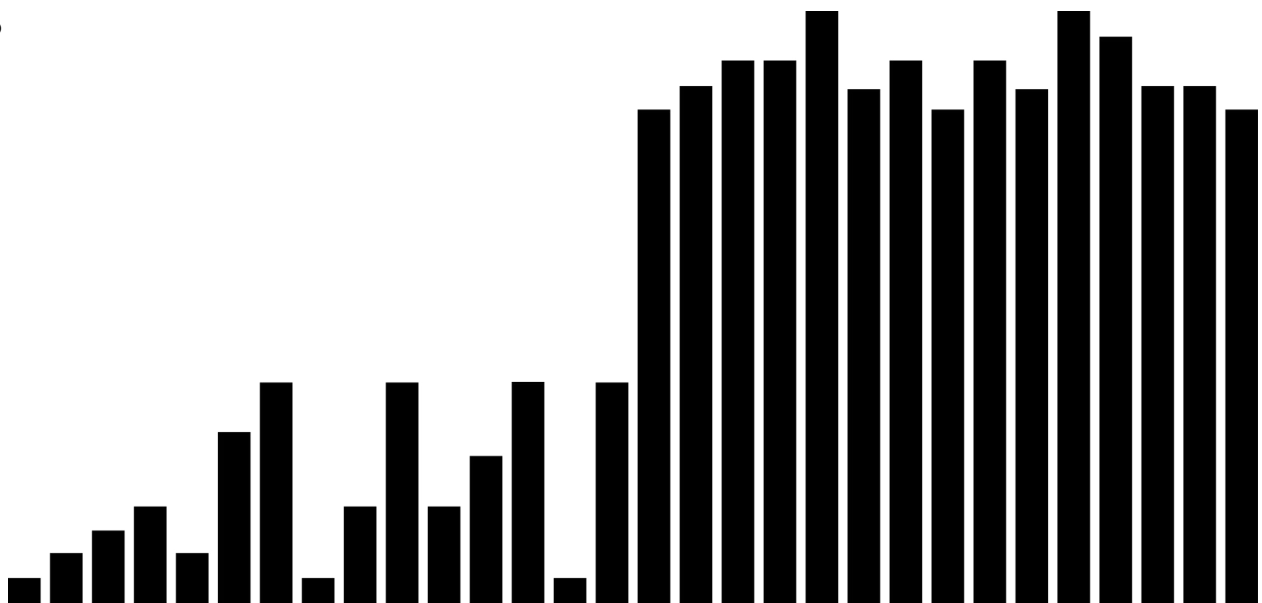
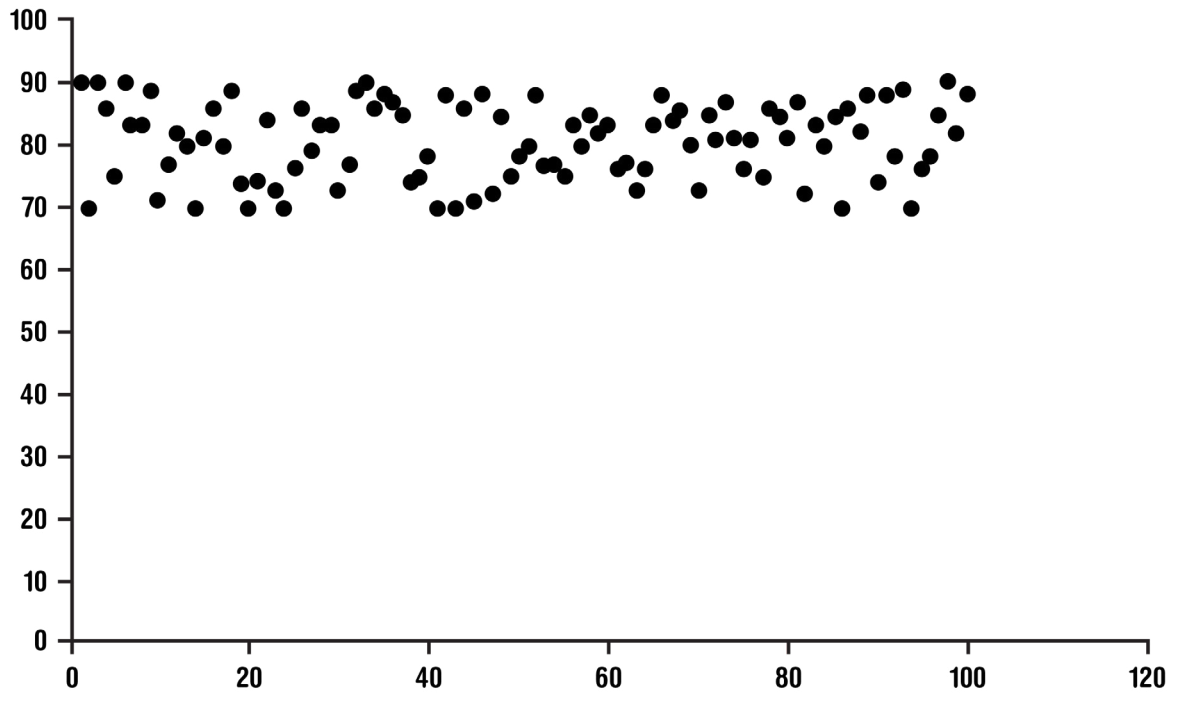


fig. 27



## CHAPTER 3

### An Introduction to Lean Production

---

fig. 28

<b>D</b>	<b>Defective Production</b> Defects incur unnecessary costs, both tangible and intangible.
<b>O</b>	<b>Overprocessing</b> There is no need to further apply processes to a part that meets the customer's specs.
<b>W</b>	<b>Waiting</b> Waiting is a non-value-added activity. No matter how long a part has been "waiting," that time cannot be billed to the customer.
<b>N</b>	<b>Non-Used Employee Talent</b> Underutilized employee talent represents cost and waste for the organization.
<b>T</b>	<b>Transportation</b> Defects incur unnecessary costs, both tangible and intangible.
<b>I</b>	<b>Inventory</b> Maintaining an on-hand inventory incurs costs and waste in other areas.
<b>M</b>	<b>Motion</b> Unneeded motion, in the form of processing or movement of parts, creates waste events.
<b>E</b>	<b>Excessive Production</b> Production that outpaces demand creates costs and waste.

fig. 29

## 1. Continual Elimination of Waste

- Identify the eight sources of waste (DOWNTIME)
- Differentiate between value-added and non-value-added activities

## 2. Goals with a Broad View

- Goals drive tasks
- Tasks are matched with organizational objectives at all levels

## 3. Simplicity

- Simpler solutions are better solutions
- Complex problems can be broken down into simpler, smaller problems

## 4. Continuous Improvement

- Learning from the past is growth
- Understand how all six philosophies are related and interdependent
- Understand that what you build today is the foundation for tomorrow

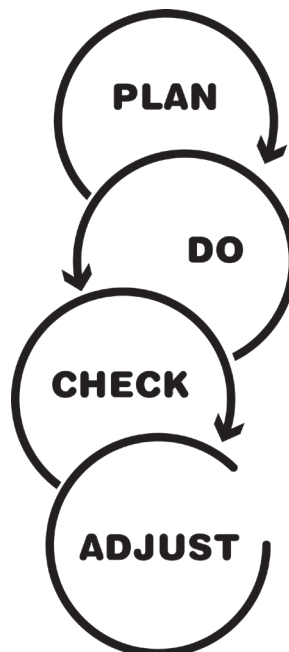
## 5. Organizational Visibility

- Visible problems are solvable; invisible problems are not
- Visibility at all levels encourages continuous improvement

## 6. Flexibility

- The organization must be ready to respond to a changing market environment
- The organization must be ready to respond to changing customer needs
- The organization must be prepared to restructure to survive

fig. 30



# CHAPTER 4

## Lean: Key Tools & Processes

fig. 31

### The Pull Production System



fig. 32

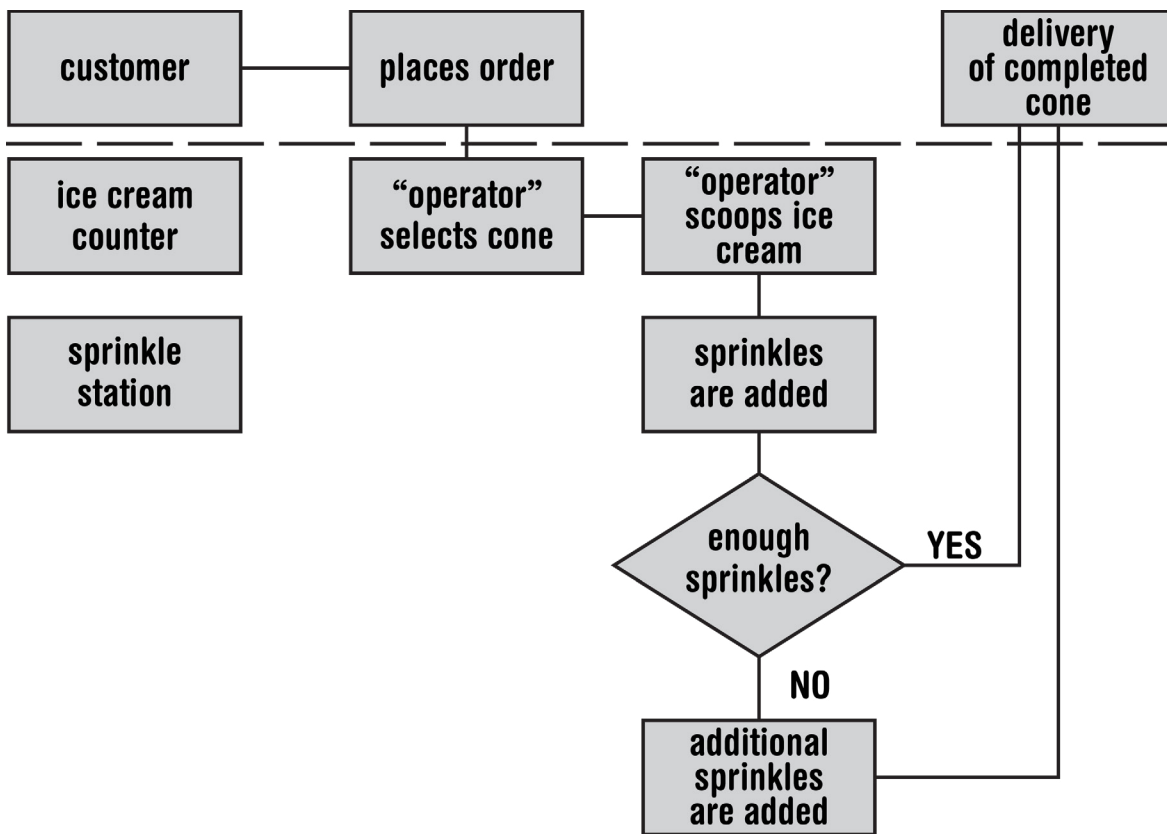


fig. 33

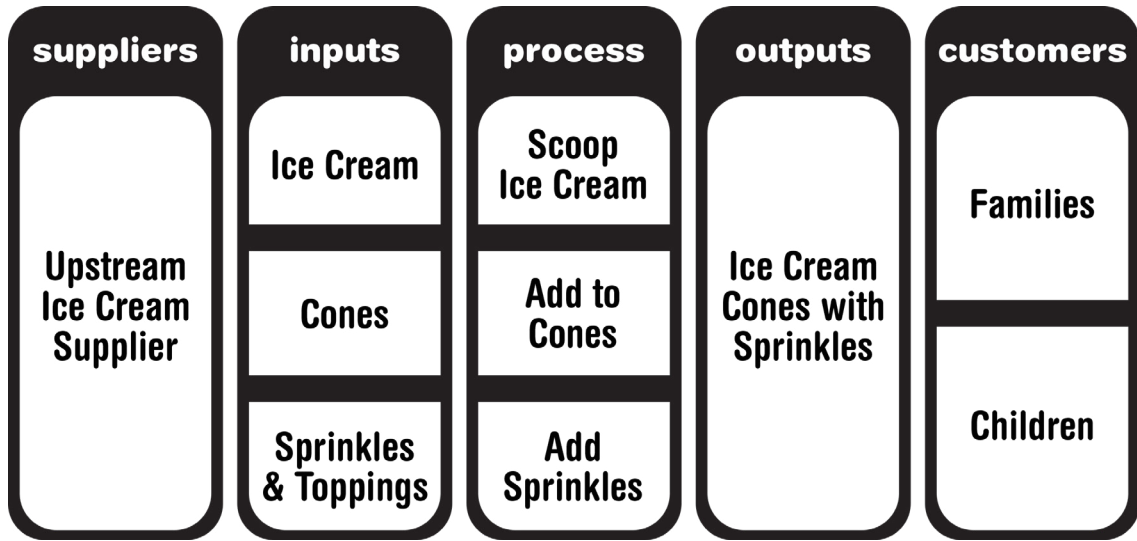


fig. 34

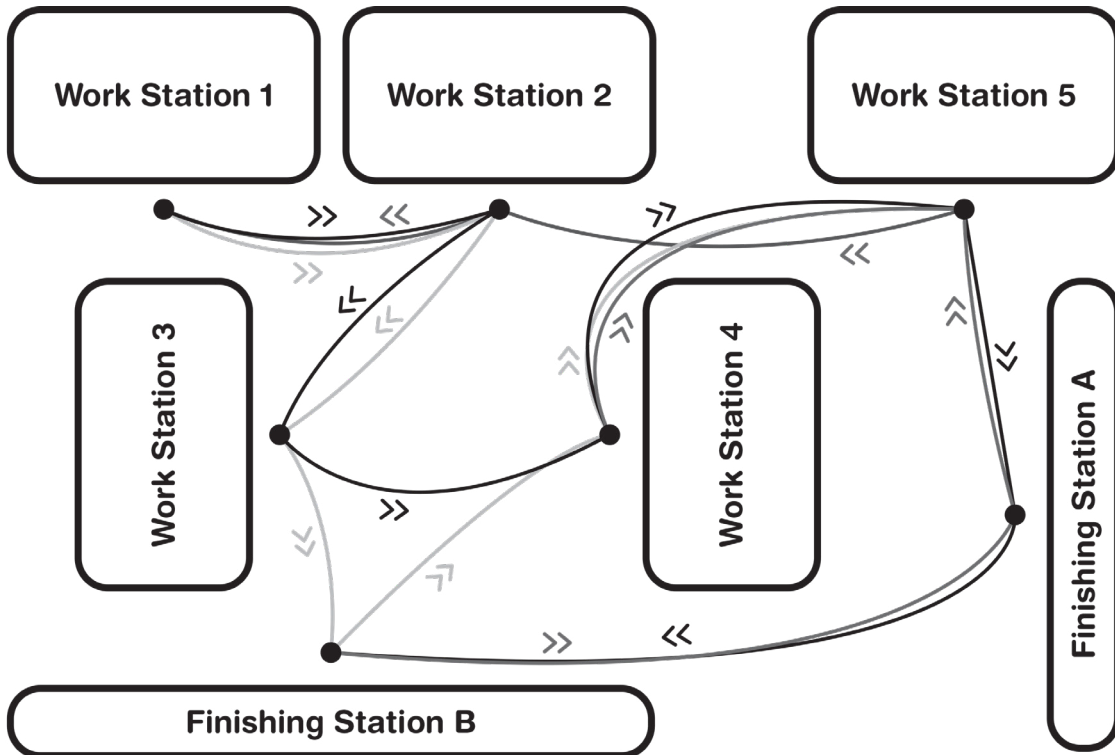


fig. 35

$$T = \frac{T_a}{D}$$

fig. 36

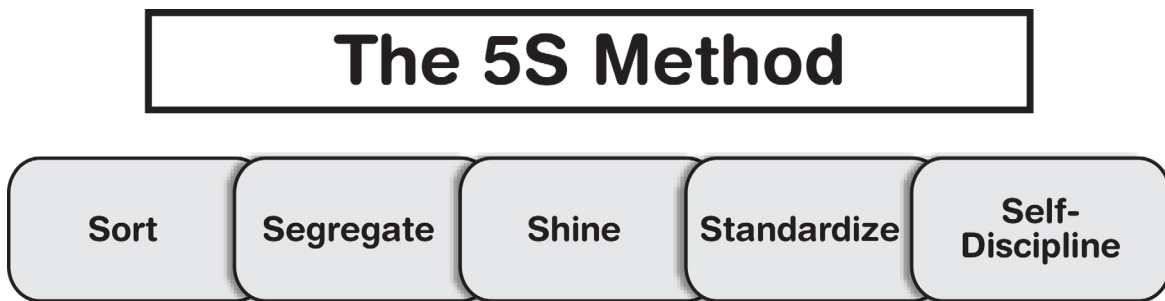


fig. 37

$$\text{process cycle efficiency} = \frac{\text{value-add time}}{\text{process lead time}}$$



fig. 38

$$\text{process lead time} = \frac{\text{number of things in process}}{\text{average completion rate}}$$

fig. 39

$$\text{WTT}_k = \sum [(\text{setup time}_i) + (\text{process time}_i * \text{batch size}_i)]$$

fig. 40

<b>Availability</b>		
<b>A</b>	<b>Total Time Available</b>	(mins)
<b>B</b>	<b>Planned Downtime</b>	(breaks, meetings, scheduled maintenance), (mins)
<b>C</b>	<b>Run Time</b>	(A-B), (mins)
<b>D</b>	<b>Unplanned Downtime</b>	(D <sub>1</sub> + D <sub>2</sub> + D <sub>3</sub> ), (mins)
<b>D<sub>1</sub></b>	<b>Breakdowns</b>	(mins)
<b>D<sub>2</sub></b>	<b>Changeovers</b>	(mins)
<b>D<sub>3</sub></b>	<b>Minor Stoppages</b>	(mins)
<b>E</b>	<b>Net Operating Time</b>	(C-D), (mins)
<b>F</b>	<b>Available Percentage</b>	[(E/C) * 100%]
<b>Performance</b>		
<b>G</b>	<b>Processed Amount</b>	(total units)
<b>H</b>	<b>Design Lead Time</b>	(ideal), (min/unit)
<b>I</b>	<b>Performance Percentage</b>	[(H*G)/E] * 100 (expressed as %)
<b>Quality</b>		
<b>J</b>	<b>Total Rejects</b>	(units)
<b>K</b>	<b>Quality Percentage</b>	[(G-J)/G]*100 (expressed as %)
<b>OEE (Overall Equipment Effectiveness)</b>		<b>(F*I*K) (expressed as %)</b>

# CHAPTER 5

## The Hybrid Approach: Lean Six Sigma

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fig. 41

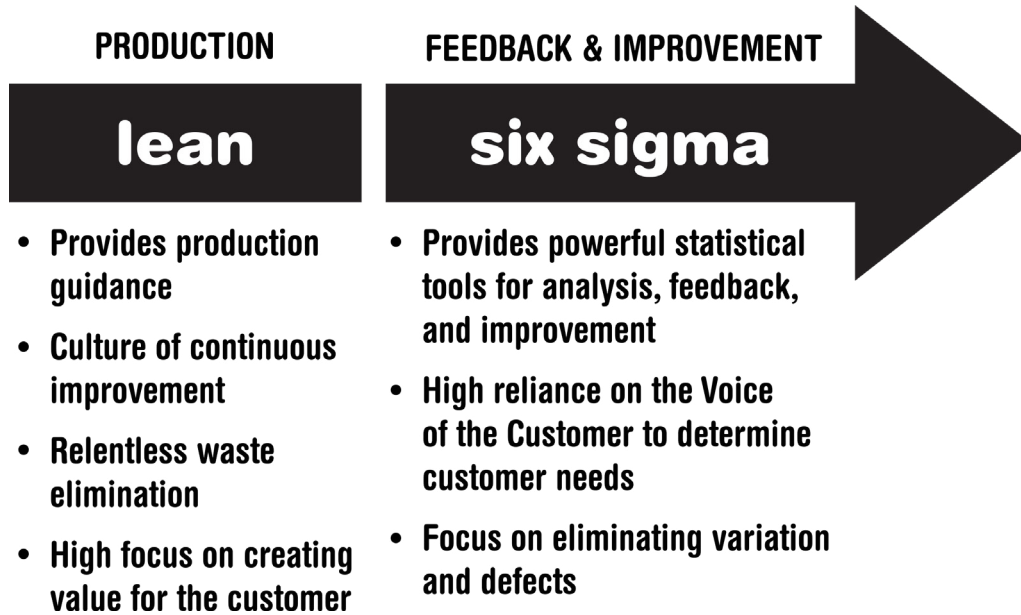


fig. 42

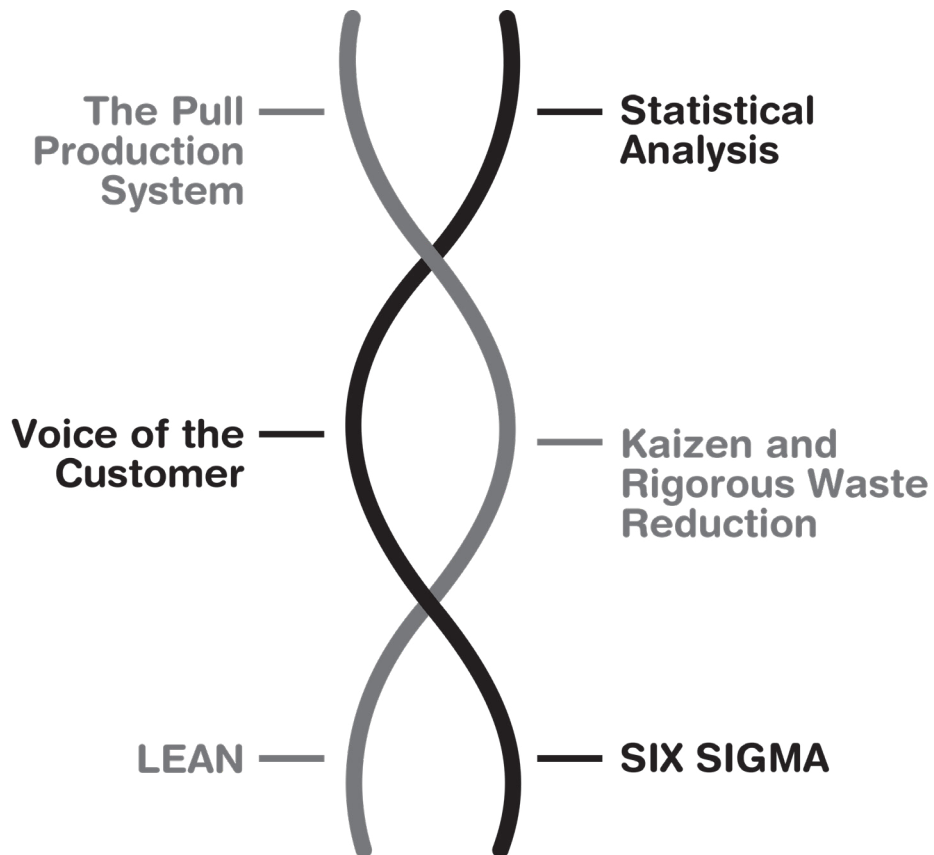


fig. 43

<p><b>interviews</b></p> <ul style="list-style-type: none"> <li>• Unique Perspectives</li> <li>• Open-Ended Questions</li> <li>• In-Depth Insight</li> </ul>	<p><b>point-of-use observation</b></p> <ul style="list-style-type: none"> <li>• Customer Perspective</li> <li>• Observe Customer Interaction with Product &amp; Brand</li> <li>• Interaction Occurs in “Natural Environment”</li> </ul>
<p><b>focus groups</b></p> <ul style="list-style-type: none"> <li>• Cost-Effective vs. Interviews</li> <li>• Group Environment Means Unique Perspectives</li> <li>• Can Be a Single Segment or Mixed</li> </ul>	<p><b>surveys</b></p> <ul style="list-style-type: none"> <li>• Very Cost-Effective</li> <li>• Quantitative Data</li> <li>• Large Amounts of Statistically Actionable Data</li> </ul>

fig. 44

**Answers to Negative Questions**

	like	normal	don't care	don't like
like		Delighter	Delighter	Satisfier
normal				Dissatisfier
don't care				Dissatisfier
don't like				

fig. 45

initial statement	underlying cause	key attribute	refined goal
"I feel like I'm not getting a good value."	Price-Related Concerns	Price is higher than the competition by 20%	Reduce price to customer by <i>at least</i> 20%
"This is a good product that functions well."	Feature-Related	Lasts for entire lifespan	Maintain lifespan of 3 years/30,000 cycles
"I wish there was more functionality."	Feature-Related Concerns	Cannot easily collaborate with other users worldwide	Increase global compatibility and match product to popular platforms

fig. 46

	Process Steps/Ingredients							family
	cone	waffle cone	dish	soft serve machine	regular ice cream	hot fudge	sprinkles	
Soft Serve Cone	X			X				A
Soft Serve Dish			X	X				B
Regular Cone	X				X			A
Regular Dish			X		X			B
Soft Serve Waffle		X		X				C
Regular Waffle		X			X			C
Sundae			X		X	X	X	D
Dip Cone	X				X	X	X	A
Dip Waffle		X			X	X	X	B

fig. 47

$$\text{PCE} = \frac{2V(1 - x - PD)}{N(2A + 1)S}$$

fig. 48

$$\text{PCED} = \frac{\frac{\text{PCE of all steps except target} - (\text{PCE baseline})}{\text{PCE baseline}} (100)}{\text{demand}}$$

fig. 49

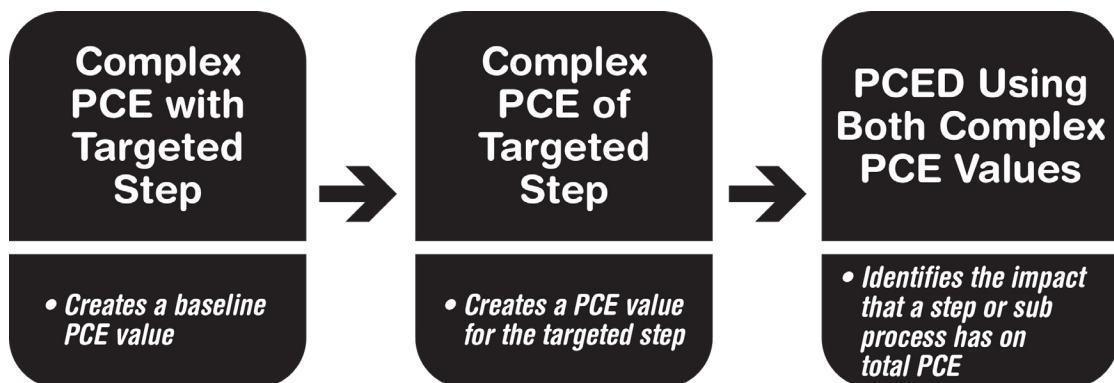


fig. 50

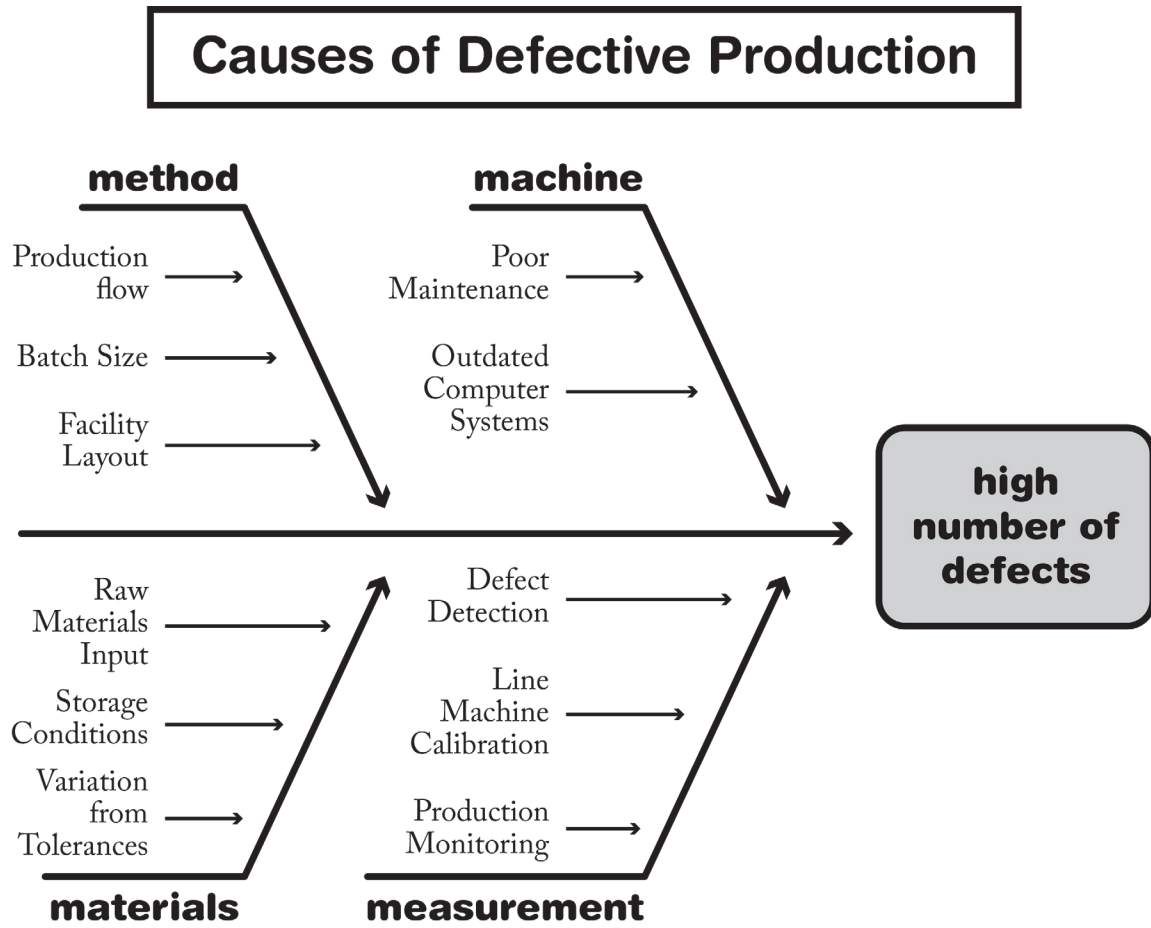


fig. 51

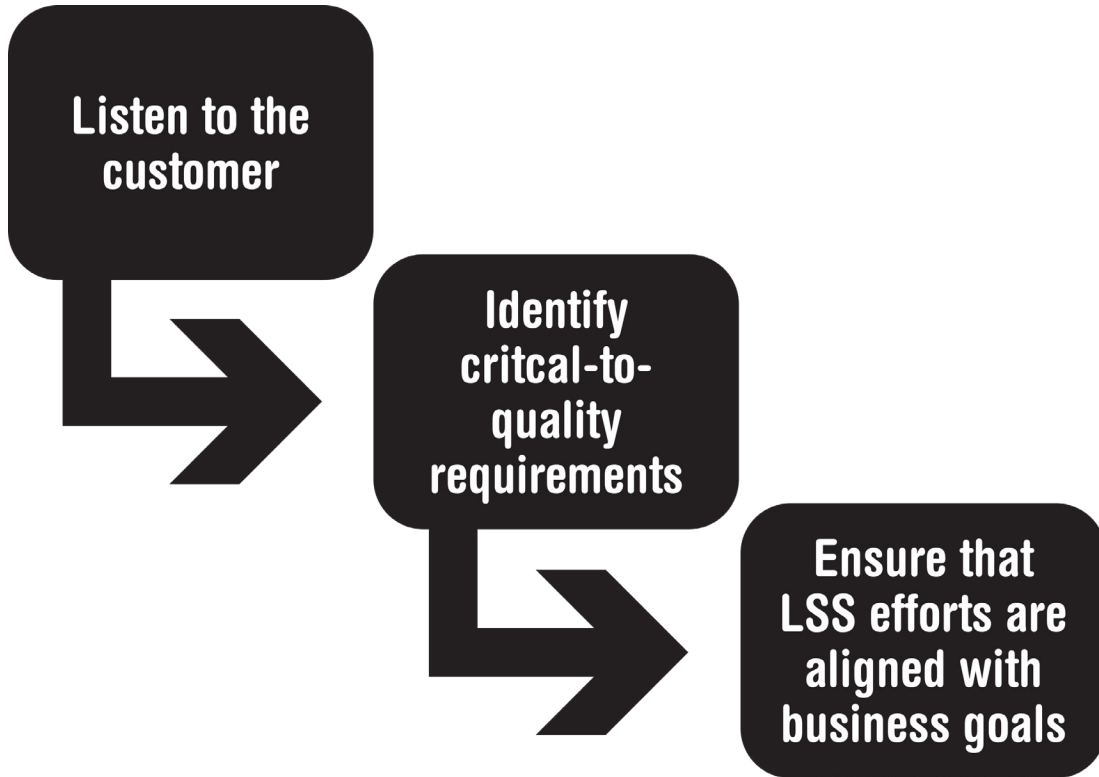
$$\mu_i - \mu_j$$

## **CHAPTER 6**

### Lean Six Sigma Implementation

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fig. 52



# APPENDIX A

## Value Stream Mapping Sample

fig. 53

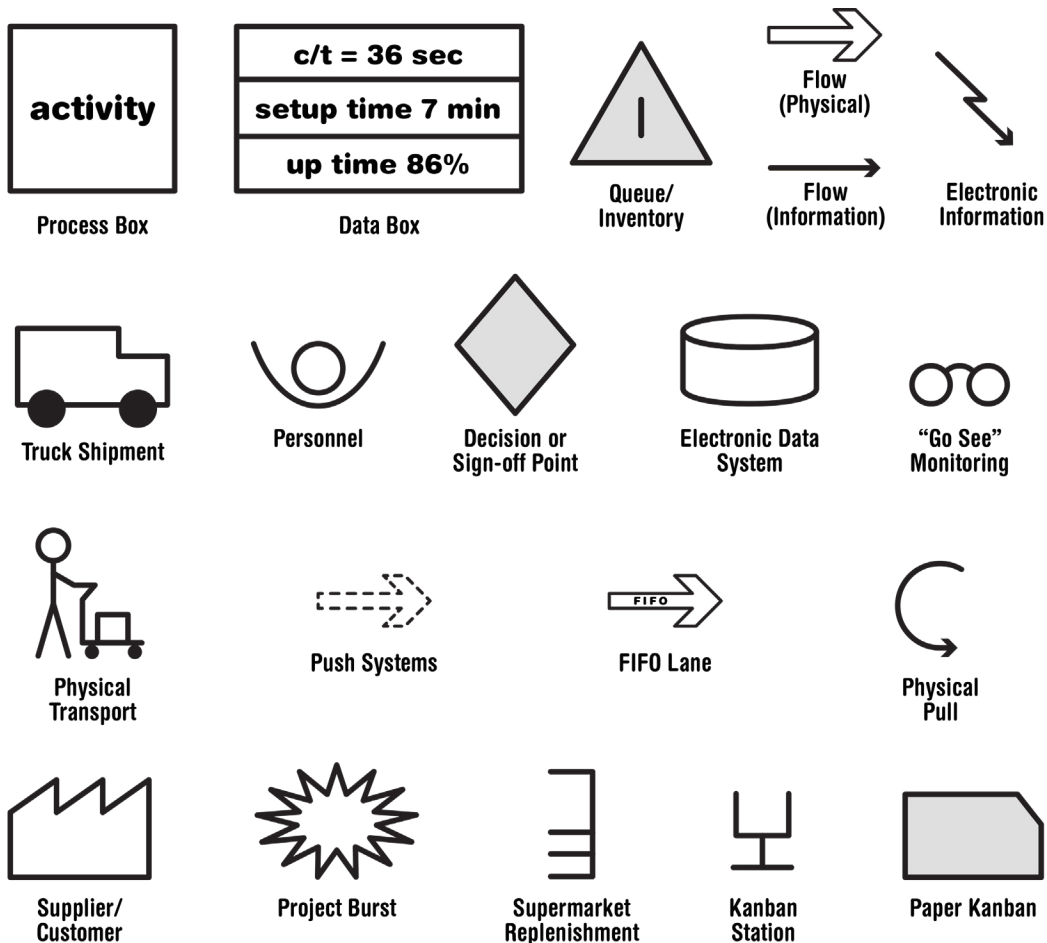


fig. 54

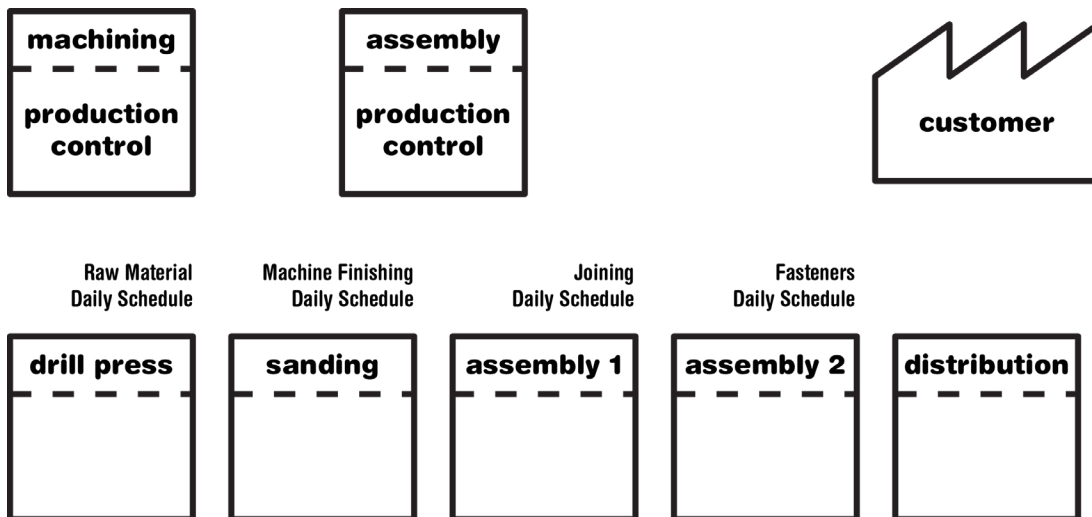




fig. 55

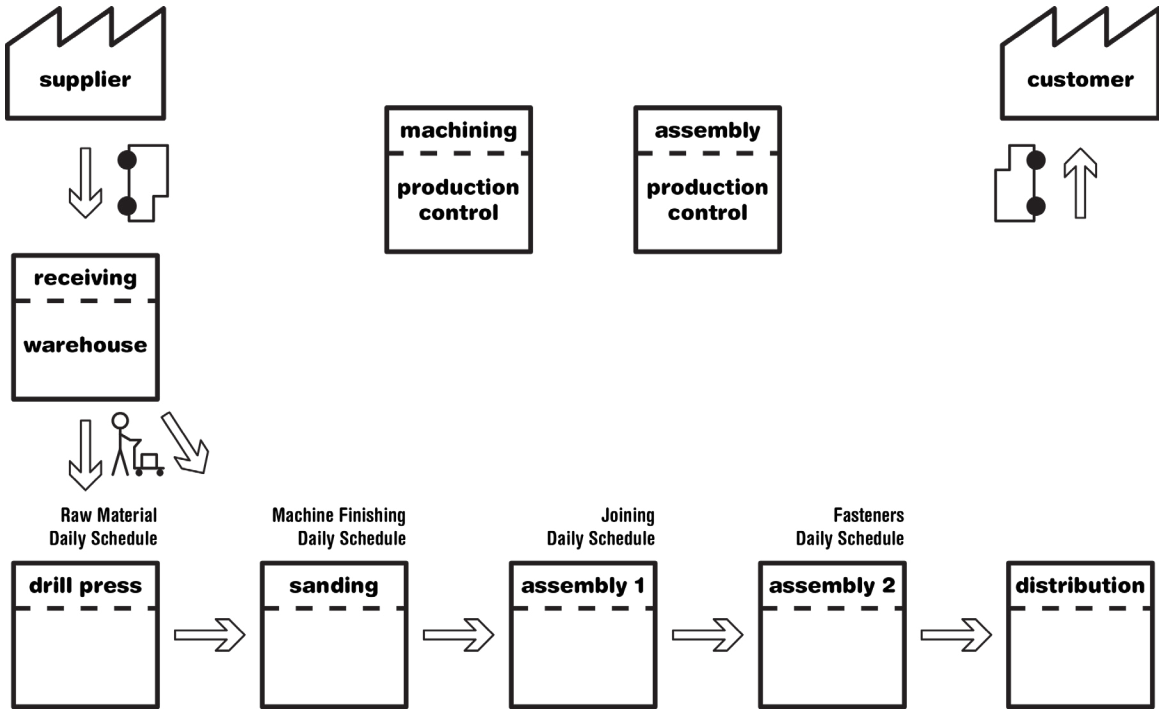


fig. 56

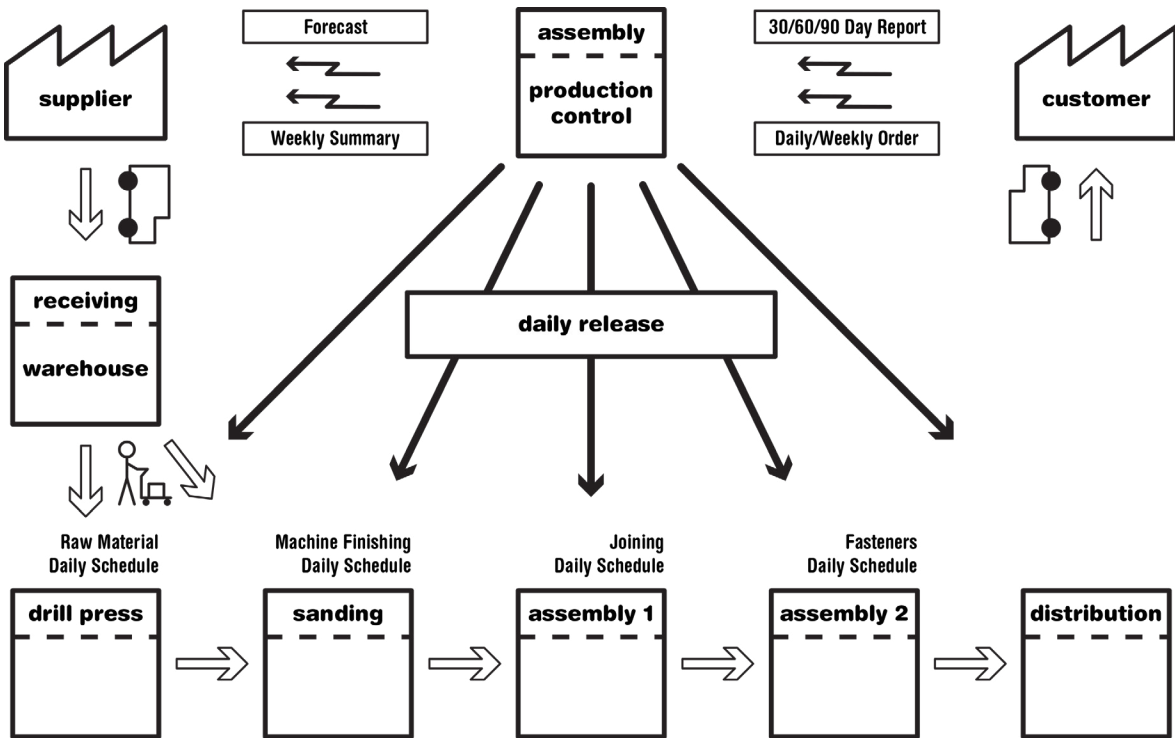
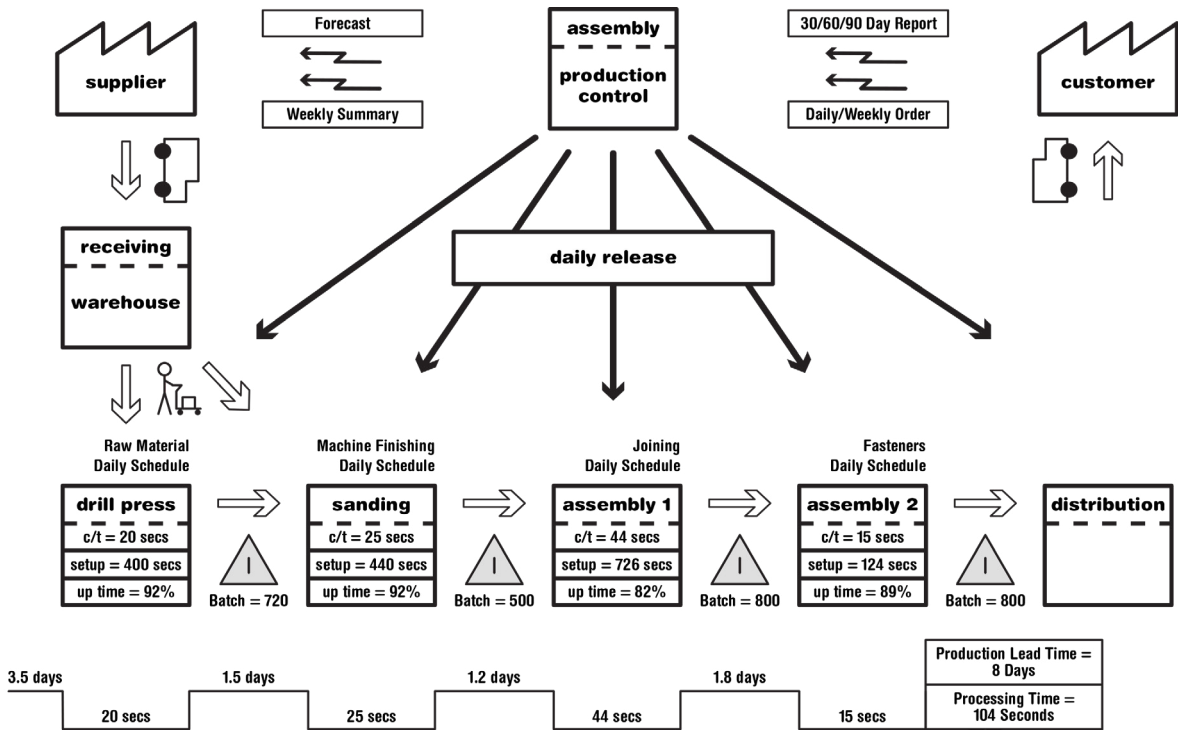


fig. 57



## APPENDIX B

---

fig. 58

defect	week					Total
	1	2	3	4	Total	
Ice Cream Too Soft	xx		x	xxxxx		8
Sprinkles Clumped Together	x	xxxxx	x	xx		9
Soft Serve Machine Jammed	x	x				2
Out of Stock on a Popular Flavor			x			1

fig. 59

Completed Calls for Dept. A								Total
week of 6/2 – 6/7								
6/2	X	X	X	X	X	X	X	7
6/3	X	X	X					3
6/4	X	X	X	X				4
6/5	X	X	X	X	X			5
6/6	X							1
6/7	X	X	X	X	X	X	X	7
								<u>27</u>

fig. 60

<b>Data Point</b>	<b><math>x_i - \bar{x}</math></b>	<b>Result<sup>2</sup></b>
4	-21.7	472.34
6	-19.7	389.40
7	-18.7	350.94
8	-17.7	314.47
8	-17.7	314.47
14	-11.7	137.67
15	-10.7	115.20
16	-9.7	94.74
17	-8.7	76.27
17	-8.7	76.27
17	-8.7	76.27
21	-4.7	22.40
21	-4.7	22.40
22	-3.7	13.94
23	-2.7	7.47
24	-1.7	3.00
27	1.3	1.60
27	1.3	1.60
29	3.3	10.67
30	4.3	18.20
35	9.3	85.87
36	10.3	105.40
36	10.3	105.40
38	12.3	150.47
39	13.3	176.00
41	15.3	233.07
46	20.3	410.74
49	23.3	541.34
49	23.3	541.34
50	24.3	588.87

# GLOSSARY

---

## 5 Whys

A cause and effect investigative tool that consists of a progressive iteration of the question “why?”.

## 5M

The 5 M’s of manufacturing. The 5 M’s represent the primary categories of causal effects that should be considered when brainstorming potential causes for inclusion in a fishbone diagram. The 5 M’s are as follows: machine, method, material, manpower, and measurement.

## 5S Method

A process-oriented program of workplace organization. The 5S method standardizes best practices for the efficient execution of day-to-day activities. The 5 S’s are as follows: sort, segregate, shine, standardize, and self-discipline.

## ANOVA

Analysis of Variables. A software-based statistical comparison of two sets of data to identify significant variation. ANOVA analyses identify variation between two sets, but do not identify which elements vary from one another. A Tukey’s Pairwise Comparison is often also required to identify specific areas of variation.

## Attribute Nominal Data

Discrete datum points that are labels without a relevant order or measurable magnitude. Labels are important aspects of information gathering, but attempting to derive insights from attribute nominal data is useless—they do not represent concrete data within the real world. Example: Dept. A, Dept. B, Dept. C...

## Attribute Ordinal Data

Discrete datum points that are labels with relevant order that conforms to an ordinal scale. Attribute ordinal data does not provide a scale or magnitude in the sense that the difference between each of the values is not measurable and the impact of each value is poorly defined. Example: Poor, Satisfactory, Good, Outstanding.

## Binary Data

Discrete data that can only be expressed as one of two possible outcomes. Example: Yes/No, Pass/Fail.

## Box Plots

Visual representations of data that can be used to quickly compare two data sets and identify outliers. Box plots represent 50% of the data that falls inside the IQR (interquartile range) as a shaded box, then the remaining 50% is displayed outside the box. 1.5x the IQR in either direction is represented by terminating lines known as whiskers. Any outliers are plotted as individual points outside these whiskers.

## Checksheets

Organized data collection forms that are designed to simplify and standardize the data collection process. Checksheets should be created specifically for the data collection use at hand to ensure that critical observations are recorded on a consistent basis.

## Colored Belt System

The organizational hierarchy prescribed by the Six Sigma program whereby different groups of staff members are identified with colored belts or ranks similar to martial arts programs. These rank assignments reflect that group’s involvement in the Six Sigma process.

## Continuous Data

Data that can be measured on a continuum scale and can be divided infinitely. Example: call duration, temperature, lead time.

## Convenience (Sampling)

Sampling through convenience is considered a poor method of data collection and should be avoided. Simply only gathering sampling data that can be accessed with convenience does not paint an accurate picture and will not represent the population at large.

## Count Data

Discrete data that represents physical counts. Example: counted number of defects, counted number of calls.

## Critical-to-Quality Requirements

Actionable parameters and specifications that are generated from collected VOC (Voice of the Customer Data). CTQ requirements are the practical application of often vague or poorly defined customer needs.

## Customer Segmentation

The process of classifying and organizing different groups of customers based on their value to the organization and other relevant characteristics. Different segments may have different needs, and therefore may generate different CTQ requirements. Example: B2B customers, B2C customers.

## D.O.W.N.T.I.M.E.

An acronym that represents the eight sources of waste that make up muda, or physical waste within the Lean system. They are defective production, over-processing, waiting, non-used (or underutilized) employee talent, transportation, inventory, motion, and excessive production.

## Defect

Any aspect of a product or service that fails to meet a customer’s needs or does not match specifications. This could be defective production or less tangible defects such as failure to deliver within budget, or late delivery.

## Descriptive Statistics

Statistical analysis of an entire population, as opposed to inferring attributes of that population via a representative sample (inferential statistics).

## Discrete Data

Any data that is not continuous is considered discrete data. Discrete data cannot be measured on a continuum scale, and it cannot be divided infinitely. Discrete data can be broken into four subcategories: count data, binary data, attribute nominal data, and attribute ordinal data.

## DMADV

Also known as Design for Six Sigma, DMADV is a structured approach to the design and introduction of new processes and product lines. DMADV is an acronym meaning design, measure, analyze, design, and verify.

## DMAIC

A core theme to the Six Sigma and Lean Six Sigma programs, DMAIC is a structured improvement program that aims to improve processes through the use of data collection and analysis methods. DMAIC is an acronym that stands for design, measure, analyze, improve, and control.

## **DPMO**

“Defects per million opportunities” or an expression of a processes’ overall defect rate.

## **Economies of Repetition**

The concept that the more frequently a standardized process is completed the higher the degree of accuracy and process adherence is achieved by the staff that performs these activities.

## **Economies of Scale**

The concept that producing larger quantities of goods spreads fixed costs out over a larger number of units therefore decreasing overall cost. This is a common feature of traditional push production systems.

## **Fishbone Diagram**

Also known as an Ishikawa diagram or a herringbone diagram, fishbone diagrams are effective cause and effect tools that can be used to investigate the root causes of unwanted effects.

## **Inferential Statistics**

Statistical analysis of a representative sample instead of an entire population. Inferential methods save data collectors time and increase the speed of the decision making process. The opposite of inferential methods is the practice of descriptive statistics, or the statistical analysis of an entire population at once.

## **Inputs**

Anything that, once processed (run through a process) produces outputs. Inputs can be materials, supplies, effort, administrative duties, or even transportation.

## **Interquartile Range (IQR)**

The IQR is the difference between the upper and lower quartiles. This value is used to identify the upper and lower bounds of a box plot, and the area of 3IQR determines the length of a box plot’s whiskers (1.5IQR in each direction). Any values that fall outside of the whiskers are considered outliers.

## **Ishikawa Diagrams**

See Fishbone Diagrams

## **Judgment (Sampling)**

Sampling through judgment—even best judgment—is considered a poor method of data collection and should be avoided. Simply only gathering the data that a collector feels is appropriate will result in biased and inaccurate data.

## **Just-In-Time**

An inventory and production management system that emphasizes speed and flexibility. Just-in-Time methods rely on tight scheduling to ensure that instead of carrying inventories, the materials for production are delivered in time for production and that finished goods are similarly moved downstream within the supply chain—delivered as needed and not kept in inventory.

## **Kano Analysis**

A refining process that aid decision makers in understanding the relationship between customer requirements and deliverables.

## **Little’s Law**

A formula used to calculate process lead time which is a component of the PCE (process cycle efficiency) calculation.

## **Machine (5M)**

A causal category for the construction of fishbone diagrams. The machine category encompasses any equipment related to the process at hand. This includes computer systems and production tools primarily, but also extends to all tools that may be a part of the production process.

## **Manpower (5M)**

A causal category for the construction of fishbone diagrams. The manpower category encompasses any people who might have a causal impact on the process at hand.

## **Material (5M)**

A causal category for the construction of fishbone diagrams. The material category encompasses any and all materials that are involved in the production cycle and that may have a causal impact on the process at hand.

## **Mean**

The arithmetical average of a set of data.

## **Measurement (5M)**

A causal category for the construction of fishbone diagrams. The measurement category encompasses any and all measurements and data collection that may occur in regard to the process at hand. This includes the accuracy of observations, thoroughness of investigations, and the calibration of data-gathering equipment.

## **Measurement Selection Matrix**

A visual tool that is used to determine which x and y factors relate to which customer requirements. This tool can be helpful when decision makers are attempting to understand which metrics to measure about a process.

## **Measures of Central Tendency**

The tendency of data to cluster around a central point or value. The three most common measures of central tendency are mean, median, and mode.

## **Measures of Spread**

Calculations that identify the variation within a data set. This includes the range, variance, and standard deviation.

## **Median**

A measure of central tendency, the median is the middle number in an ordered data set.

## **Method (5M)**

A causal category for the construction of fishbone diagrams. The method category encompasses the total sum of protocols, process design, and methodology employed for the execution of the process at hand.

## **Mode**

A measure of central tendency. The mode is the most commonly occurring number in a data set.

## **Muda**

One of the three wastes outlined by the Lean production system. Muda translates from Japanese as “futility,” and it represents physical waste.

## **Mura**

One of the three wastes outlined by the Lean production system. Mura represents waste in the form of unevenness.

## **Muri**

One of the three wastes outlined by the Lean production system. Muri represents waste in the form of overburden.

## **Population Sampling**

A component of inferential statistics whereby a representative sample of a population is collected. Insights produced from the analysis of this sample can be inferred to represent the population at large. Sampling and other inferential statistical methods save time during the data collection process and increase the speed of date-informed decisions.

## Predictor Measures

Predictor measures are lead measures that can serve as indicators to the outcome of a process. The “inputs” and “process” segments of a business process (x factors) are predictor measures.

## Process Cycle Efficiency (PCE)

PCE is a concise measurement of a process' efficiency and performance. It is a measure of “value-add time” compared against the lead time for that same process.

## Process Mapping

The visual documentation of a process from start to finish. Process mapping is a flowchart-style representation of a process that has a multitude of uses from internal communication, to external communication, cause and effect investigation, and training. Process mapping is a less involved and less detailed visual aid than the much more complex value stream map.

## Process Sampling

Samples taken from a changing or continuous flow. Process sampling can be described as the sampling of every nth unit, or taking a sample at a regular time or cycle intervals.

## Product Family Grid

A visual tool that organizes products or services into “families” based on similar components such as shared sub processes or common materials.

## Pull Production System

An essential component of the Lean production system, the pull production system is a responsive and flexible manufacturing method that relies on customer demand to “pull” materials through production. Instead of the traditional push production methods of leveraging the economies of scale through large batch sizes and relying on artificial forecasted demand, the pull production system emphasizes meeting the customer's needs through small batch sizes and low-inventory methods such as Just-in-Time.

## Push Production

The push production system is a more traditional approach to manufacturing. Utilizing large batch sizes to leverage the economies of scale, push production manufacturers rely on artificial forecasted demand.

## Range

A measure of spread, the range of a set of data is the lowest value (min) subtracted from the highest value (max).

## Result Measures

Result measures are lag measures that are dependent on predictor measures (lead measures, x factors). Result measures are represented by y factors, and are the outputs of a process.

## Segregate (5S)

A component of the 5S system, segregate is the organization of sorted items, tools, and materials into their most useful and efficient layout or configuration so that the necessary tools are always at hand.

## Self-Discipline (5S)

A component of the 5S system, the self-discipline element ties all of the 5S activities together by generating the standard for regular application and protocol.

## Shine (5S)

A component of the 5S system, the shine element strives to produce a clean and tidy production environment. Clutter creates waste and inefficiency as well as safety hazards. Shine also encompasses the idea of inspection through cleaning, or the regular maintenance of equipment through normal cleaning activities.

## SIPOC Diagram

A SIPOC diagram is a snapshot of a process' suppliers, inputs, processes, outputs, and customers presented in the order in which they interact with one another.

## Sort (5S)

A component of the 5S system, is an everything-has-a-place approach to a clean, efficient, and clutter free workstation. As an activity, sort strives to identify and reduce the number of items that are unnecessary from specific workstations.

## Spaghetti Plots

Also known as workflow diagrams, spaghetti plots are visual diagrams of physical work flow. They present a complete visual picture of how “things” move throughout a process or a space—these “things” could be people, materials, finished goods, or even information and financials.

## Standard Deviation

Standard deviation is the average distribution of variation within a data set, or the average distance that each data point is away from the mean. Standard deviation is represented by the Greek letter lower case sigma ( $\sigma$ ).

## Standardization (5S)

A component of the 5S system, standardization is the process by which the other 5S elements are maintained and regularly applied for best impact.

## Stratification Factors

The contributive factors (known as strata) that can segregate groups of data into subgroups. This method of classification can reduce the complexity of difficult-to-handle problems and allow decision makers to investigate root causes in a more effective and comprehensive way.

## Total Productive Maintenance (TPM)

An in depth and comprehensive program that strives to reduce downtime due to equipment failure or malfunction. Focusing on preventative and predictive maintenance, TPM is a standardized approach to equipment maintenance and care with a wide range of applications.

## Total Quality Management (TQM)

A parallel quality improvement program to Six Sigma that focuses on quality improvement and a customer-centric specification set.

## Tukey's Pairwise Comparison

A follow-up computation of the results of an ANOVA analysis. A pairwise comparison compares every data point within the analyzed sets to identify the exact locations of statistical differences while ANOVA analyses identify statistical differences, they fail to identify the exact location(s) within the compared data sets.

## Value Stream Mapping

A complex and costly examination of a process that provides invaluable insight for decision makers. Produced as a series of steps that overlay one another, a complete value stream map includes the total picture of all of the aspects of a process. While the critical value of a value stream map to decision makers cannot be overstated, the process should be reserved for similarly critical and high volume processes due to the labor intensive nature of this visual aid's construction.

**Variance**

Within the field of statistics, variance is defined as how far away data points are from the mean of the set. Practically speaking, this is the number of units in production that are outside of tolerances.

**Voice of the Customer (VOC)**

A unifying concept between the Lean and Six Sigma programs, VOC data represents the needs of the customer. Once distilled into actionable goals, this raw data becomes the CTQ requirements that drive the definition and identification of defects, as well as the specifications for production. Voice of the Customer data can be collected in a number of ways, such as interviews, focus groups, point-of-use observations, and surveys. Best when used in conjunction with one another, these methods should be tailored to the customer segment.

**Workflow Diagrams**

See Spaghetti Plots