Six Sigma: Week 7

MAN 3520
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Fall 2020

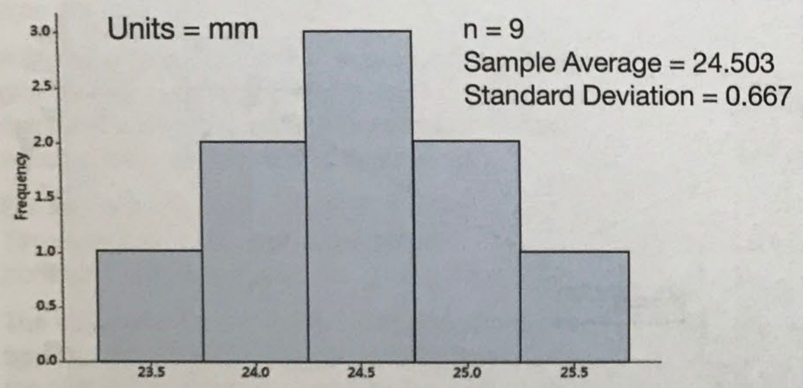
Agenda: Week 7

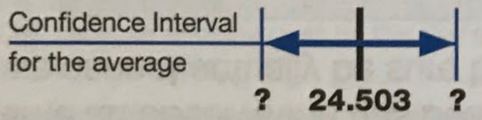
- Brief review of confidence intervals with example to ensure understanding
  - LSSM text pages 151-152
- Project Discovery/Selection
- Affinity Diagram (including video from Arizona Public Health)
- Customer Requirements Tree (LS Text pg. 259); Critical to Quality Tree (LSSM Text pg. 23)
- Process Mapping
- Cause and Effect (Fishbone) Diagram
- Mid-term exam – Session 2
  - Topics we have covered so far

Confidence Intervals (CIs)

Instead of assuming a statistic is absolutely accurate, Confidence Intervals can be used to provide a range within which the true process statistic will fall (with a specific level of confidence).

Example:
A saw mill is trying to estimate the average thickness of its 25mm plywood, to see if it really is 25mm! Nine sheets of plywood are taken randomly from the process, their thickness measured, and the histogram plotted, as shown below:





The average thickness of the sample turns out to be 24.503mm, not 25mm, and so it **appears** that the plywood sheets are too thin. But does this mean that the whole process is too thin, or that we just happened to select a sample of nine sheets that were on the thin side?

Confidence Intervals can be used to help decide (right).

(Simplified) mathematical equation for a Confidence Interval:

$$\text{95\% Confidence Interval for the average of the Population} = \text{Sample Average} \pm \text{`t'} \left(\frac{\text{Sample Sigma}}{\sqrt{n}} \right)$$

The equation above says that a confidence interval is dependant on:

- **The sample average:** This is a good starting point!
- **The sample size (n):** As sample size decreases, the confidence interval gets bigger (exponentially) to cope with the fact that less data was collected.
- **The Process variation (Sample Sigma):** The higher the process variation (estimated from the sample) the bigger the confidence interval.
- **The Confidence level required (t):** The value of 't' is taken from statistical tables similar to the Z-table. If a 99% Confidence Interval were required, then the value of 't' would be larger, to increase the interval.

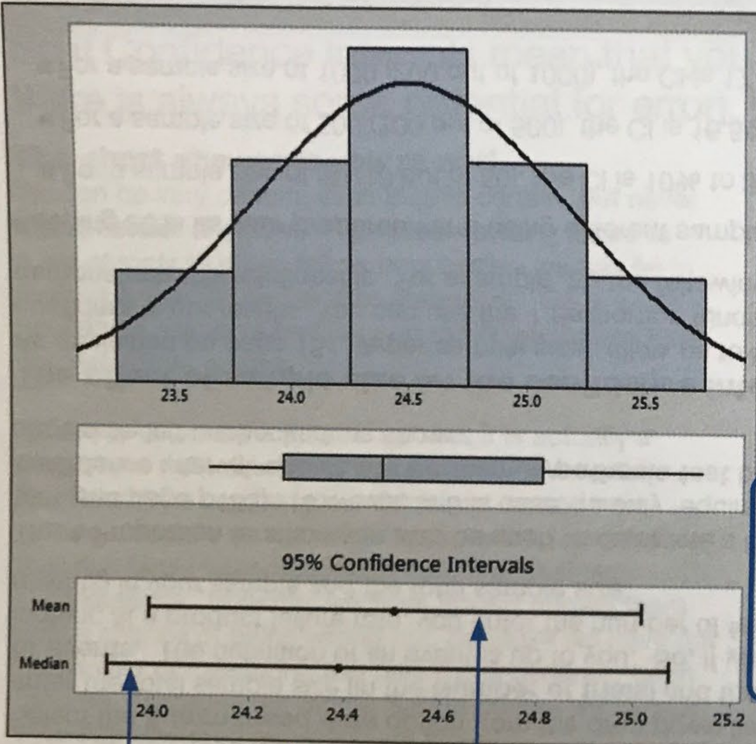
Using the equation above, and a 't' constant of 2.306 (tables not provided), the 95% CI for the average plywood thickness can be calculated as follows:

95% CI = 24.503 +/- (2.306 x (0.667 / √9)) = 24.503 +/- 0.5127
= **23.99mm to 25.02mm**

So, we can be 95% confident that the average thickness of the process is between 23.99 and 25.02mm. Since this includes the target of 25mm, there is a **chance** that the process is producing an average thickness of 25mm after all.

LYTECHNIC

Confidence Intervals within Minitab's Graphical Summary



Anderson-Darling Normality Test	
A-Squared	0.30
P-Value	0.505
Mean	24.503
StDev	0.667
Variance	0.445
Skewness	0.694460
Kurtosis	-0.115432
N	9
Minimum	23.654
1st Quartile	23.972
Median	24.390
3rd Quartile	25.064
Maximum	25.742
95% Confidence Interval for Mean	
23.990	25.016
95% Confidence Interval for Median	
23.904	25.075
95% Confidence Interval for StDev	
0.450	1.278

Median C.I. **Average C.I.**

The Confidence Intervals for the Median and Average are also shown graphically here. (NB: The scale is not shared with the histogram).

Wood Thickness.mpj

Minitab's Graphical Summary function (see page 126) provides Confidence Intervals for the average, median and standard deviation of the process, as shown here for the plywood thickness example introduced on the previous page.

Converting statistics into 'real' language is an important skill for a Six Sigma analyst. The Confidence Intervals shown here can be interpreted into everyday language as follows:

We can be 95% confident that:

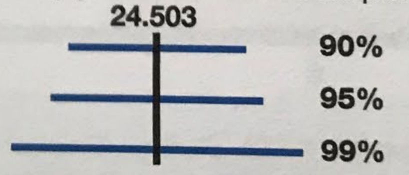
- The **average** thickness of the plywood is somewhere between 23.99 and 25.016 (or 25.02mm rounded).
- The **median** thickness of the plywood is somewhere between 23.904 and 25.075.
- The **standard deviation** of the plywood thickness is somewhere between 0.45 and 1.278.

The Confidence Level of the intervals (in this case 95%) can be adjusted in Minitab's Graphical Summary function. As the confidence level is increased, the size of the Confidence Intervals increases, because you are demanding **more** confidence that the value is within the interval (this can seem a little counter intuitive). So, for the plywood thickness example:

The 90% CI for the average = 24.1 to 24.9

The 95% CI for the average = 24.0 to 25.0

The 99% CI for the average = 23.7 to 25.2



Introduction to Project Discovery

- A process is a sequence of activities with a definite beginning and end, including defined deliverables
- A “something” travels through a sequence of steps
- If a process does not have a start, and end, deliverables or an entity, it probably should not be selected as an improvement project
- For some processes, it is not obvious where the project should focus
  - Data collection/analysis and focus on customer needs helps to clarify this

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Tools to be Applied During Project Discovery

- Project Charter
- SIPOC
- Value Stream Map
- Core Process Map
- Process Scorecard – Key Process Output Variables (KPOVs)
  – Identify the “Y” and the “Xs”; Y is based on customer requirements
- Data Collection Plan
- Customer Interviewing & Surveys
- Affinity Diagramming
- Customer Requirements Trees / 5 Whys
- Gap Analysis

LS Text (Wedgwood) Chapter 5

General Guidelines for Project Selection*

- Any project should have identifiable process inputs and outputs.
- A good Six Sigma project should never have a pre-determined solution.
- If you already know the answer, then just go fix it!
- For projects that have operator or operator training as an input, focus on ways to reduce operator variation, therefore making your process more robust to different or untrained operators.
- All projects need to be approached from the perspective of understanding the variation in process inputs (inputs from SIPOC), controlling them, and eliminating the defects.

*Source: isixsigma.com

https://www.isixsigma.com/implementation/project-selection-tracking/finding-and-selecting-good-six-sigma-projects/

General Guidelines for Project Selection*

Example #1

- Problem: *We are experiencing slow cycle time at Station 30 because we are getting bad parts from Station 20 and need to rework them.*
- Non-Six Sigma Solution: Rebalance the line in order to do the rework and keep your cycle time below specifications while not spending extra labor cost.
- Six Sigma Solution: Investigate and control key inputs that contribute to making a bad part production at Station 20.

*Source: isixsigma.com

https://www.isixsigma.com/implementation/project-selection-tracking/finding-and-selecting-good-six-sigma-projects/

General Guidelines for Project Selection*

Example #2

- Problem: *We have had two quality related issues reported this year for missing armrest screws.*

- Non-Six Sigma Solution: Add sensors to detect screws further down the line. If screws are missing, operator manually fixes.
- Six Sigma Solution: Determine process inputs causing missing screws. For example, auto gun does not always feed correctly due to air pressure variation. Either study range required for 100 percent operation and control in that range, or find way to make gun more robust to compensate for air pressure variation.

*Source: isixsigma.com

https://www.isixsigma.com/implementation/project-selection-tracking/finding-and-selecting-good-six-sigma-projects/

Affinity Diagram

https://www.youtube.com/watch?v=jvTSsJrDZec

http://www.discover6sigma.org/post/2009/02/affinity-diagram/

Affinity Diagram – Part 1 (Making Pizzas)

Affinity Diagram – Part 2 (Making Pizzas)

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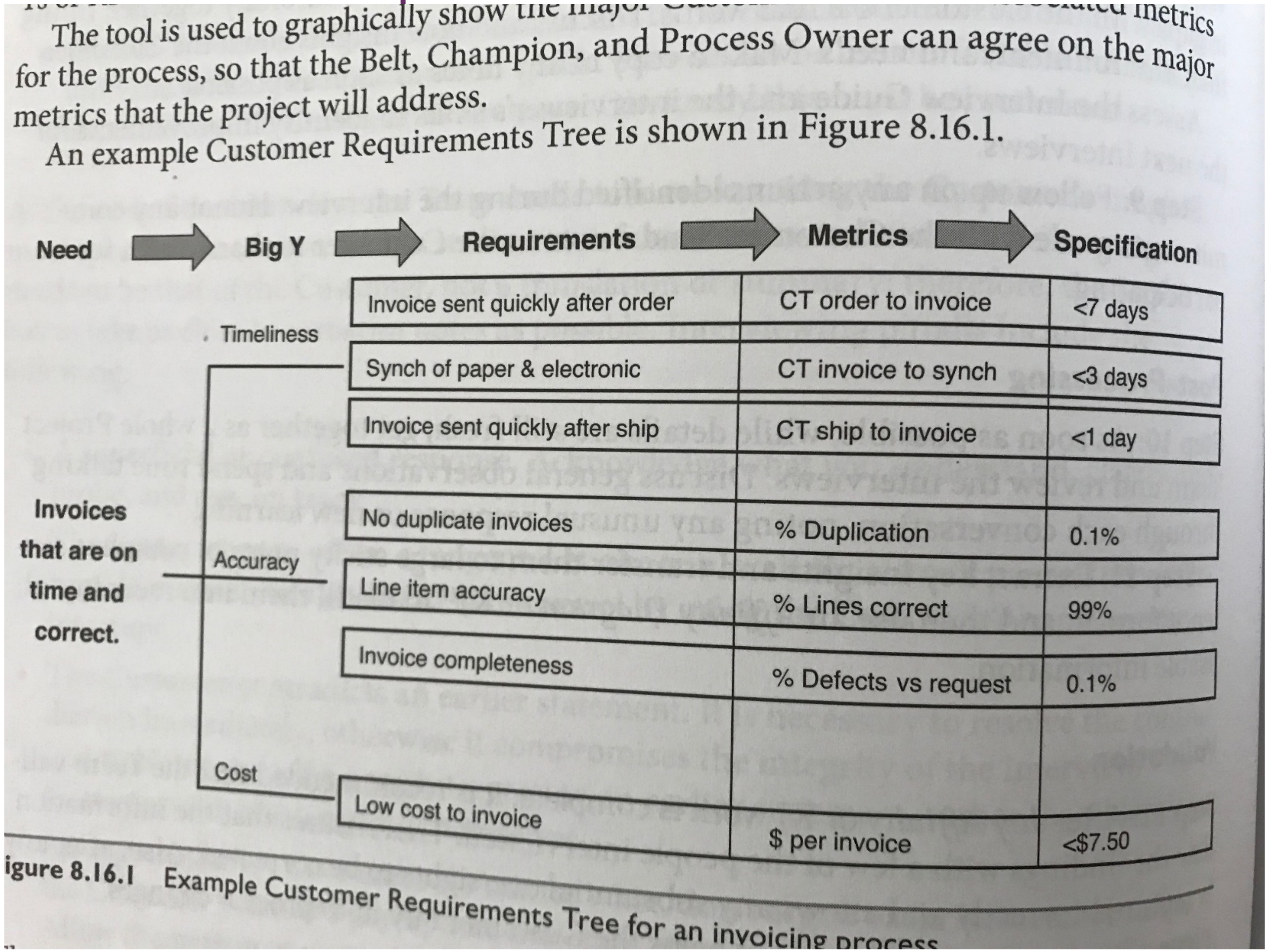
Kitchen	Delivery	HR	New Initiatives	Call Center
Reorganize kitchen layout for faster flow	Maintain 2-wheelers in good running condition	Recruit more delivery persons	Get easy to fold & pack cardboard boxes	Verify customer address & order
Maintain pre-folded packs	Optimization of routes based on delivery locations	Proper training on neighboring routes	Get GPRS devices	
Keep pre-baked pizza bases of fast moving varieties	Carry adequate change for faster settlement of bill			

Customer Requirements Tree



The tool is used to graphically show the major Custo... ...associated metrics for the process, so that the Belt, Champion, and Process Owner can agree on the major metrics that the project will address.

An example Customer Requirements Tree is shown in Figure 8.16.1.

Need	Big Y	Requirements	Metrics	Specification
Invoices that are on time and correct.	Timeliness	Invoice sent quickly after order	CT order to invoice	<7 days
		Synch of paper & electronic	CT invoice to synch	<3 days
		Invoice sent quickly after ship	CT ship to invoice	<1 day
	Accuracy	No duplicate invoices	% Duplication	0.1%
		Line item accuracy	% Lines correct	99%
		Invoice completeness	% Defects vs request	0.1%
	Cost	Low cost to invoice	$ per invoice	<$7.50

igure 8.16.1 Example Customer Requirements Tree for an invoicing process

Customer Requirements Tree

ROADMAP

The roadmap to constructing the Customer Requirements Tree starts much earlier, with the outputs from interviews and surveys being organized logically in an *Affinity Diagram* as shown graphically in Figure 8.16.2.

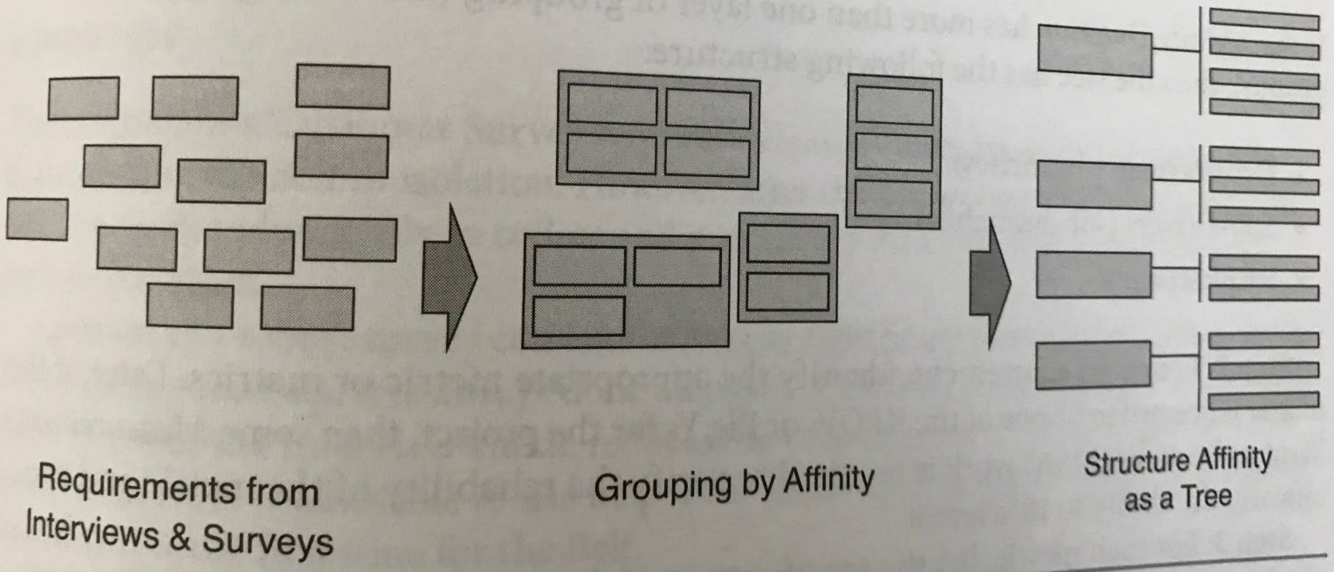
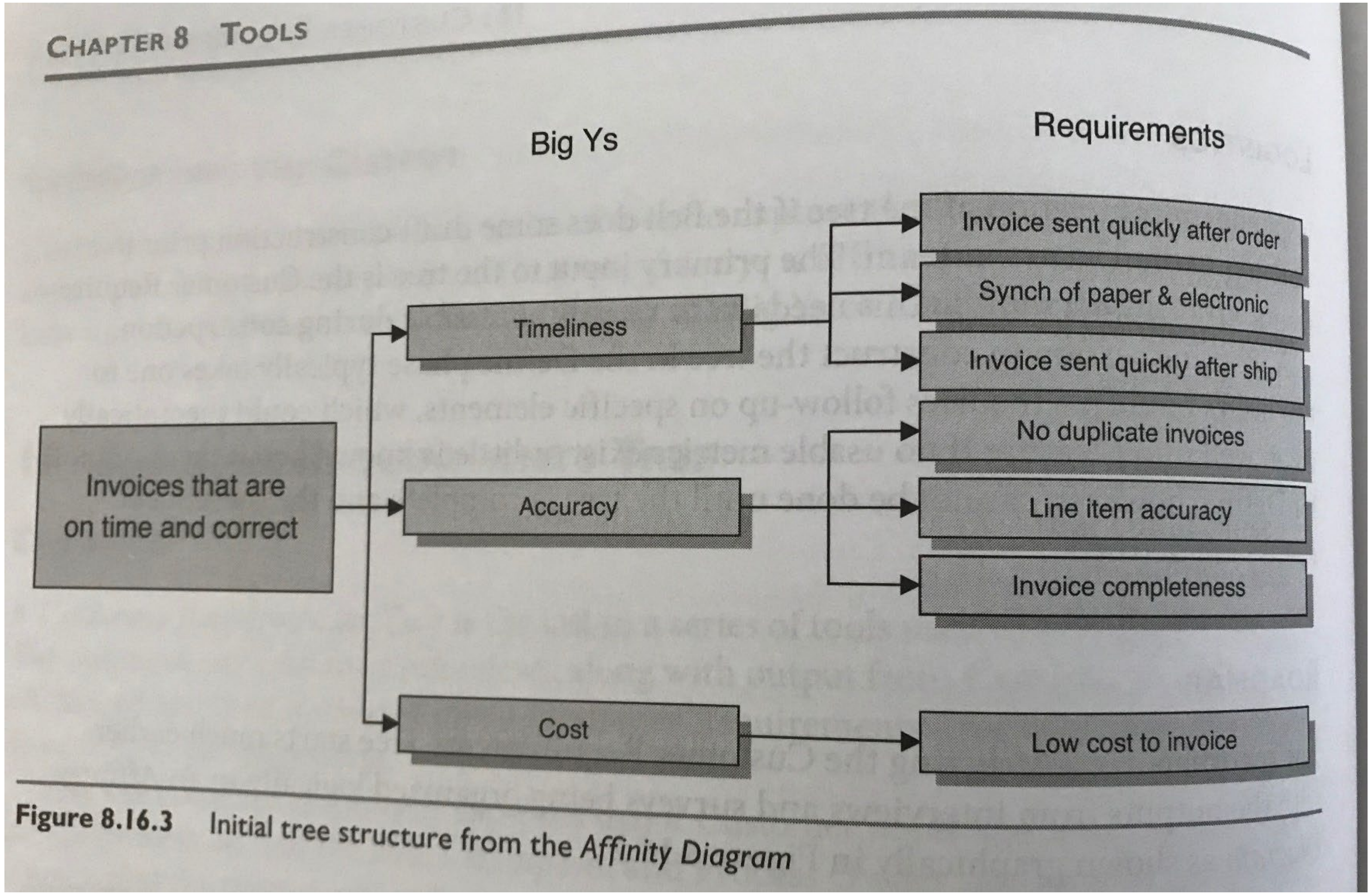


Figure 8.16.2 Construction of a Customer Requirements Tree

Customer Requirements Tree



Critical to Quality (CTQ) Tree

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The process for developing a Critical to Quality Tree:

Define the specific event:
At the top of the CTQ Tree is the specific event that is experienced by the customer. It's worth trying to define an event rather than a process, to avoid the CTQ Tree being too vague. So, the example on the next page focuses on *'fixing a fault on a residential broad service'* rather than just the *'fault repair process'*.

↓

Identify the customer's broad requirements:
It's usually possible to summarise the customers expectations into three or four broad requirements, such as *'easy reporting'* or *'getting back on-line fast'*.

↓

Break the broad requirements down into specific CTQs:
The next step is to break each broad requirement down into more specific requirements that provide more detail on the customer's expectations.

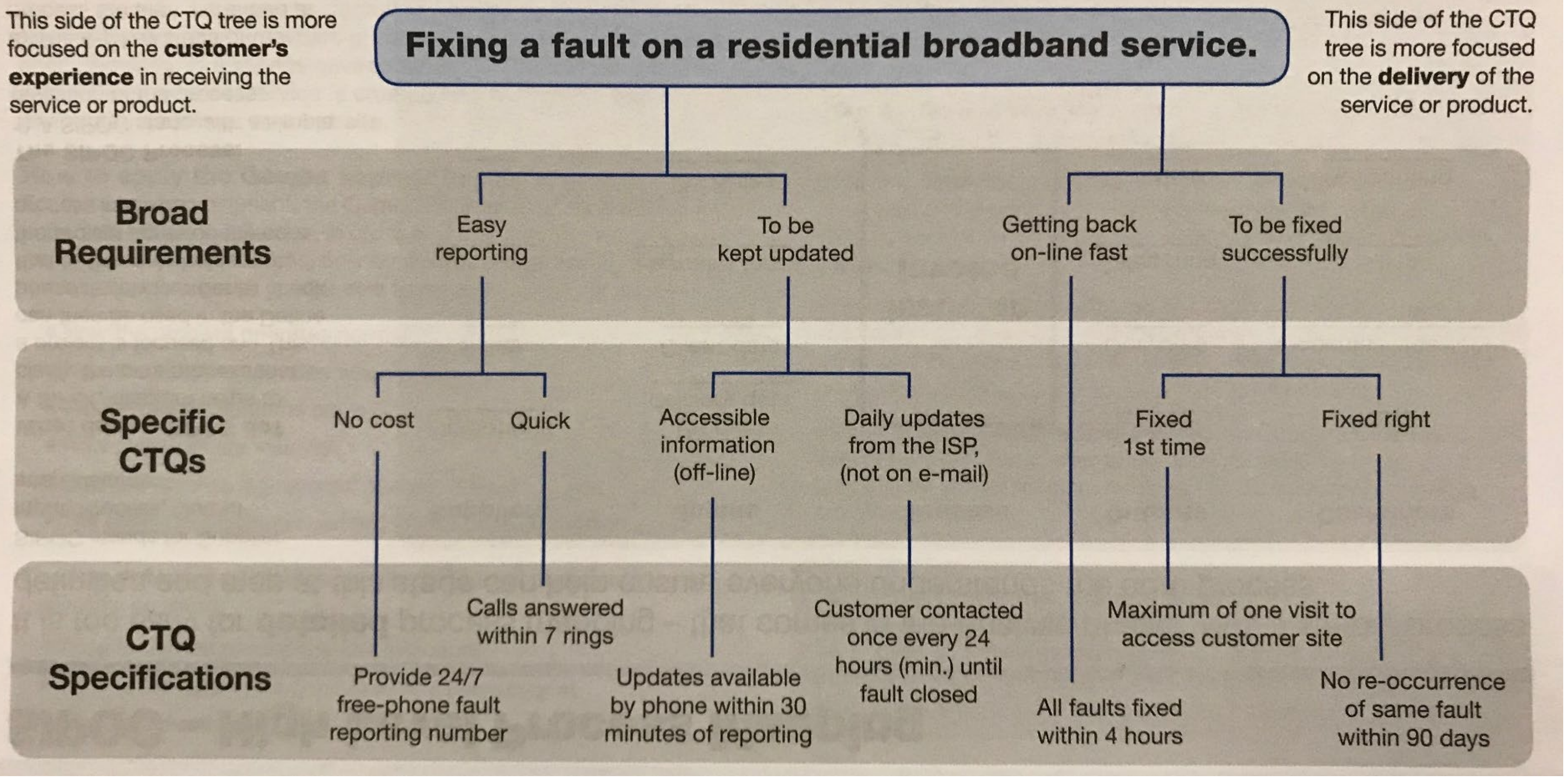
↓

Develop CTQ Specifications:
Finally, each specific CTQ is translated into a measurable characteristic such as *'fix fault within 4 hours'*. These CTQ Specifications will be used later in the Measure phase, to develop customer driven KPIs (see page 35).

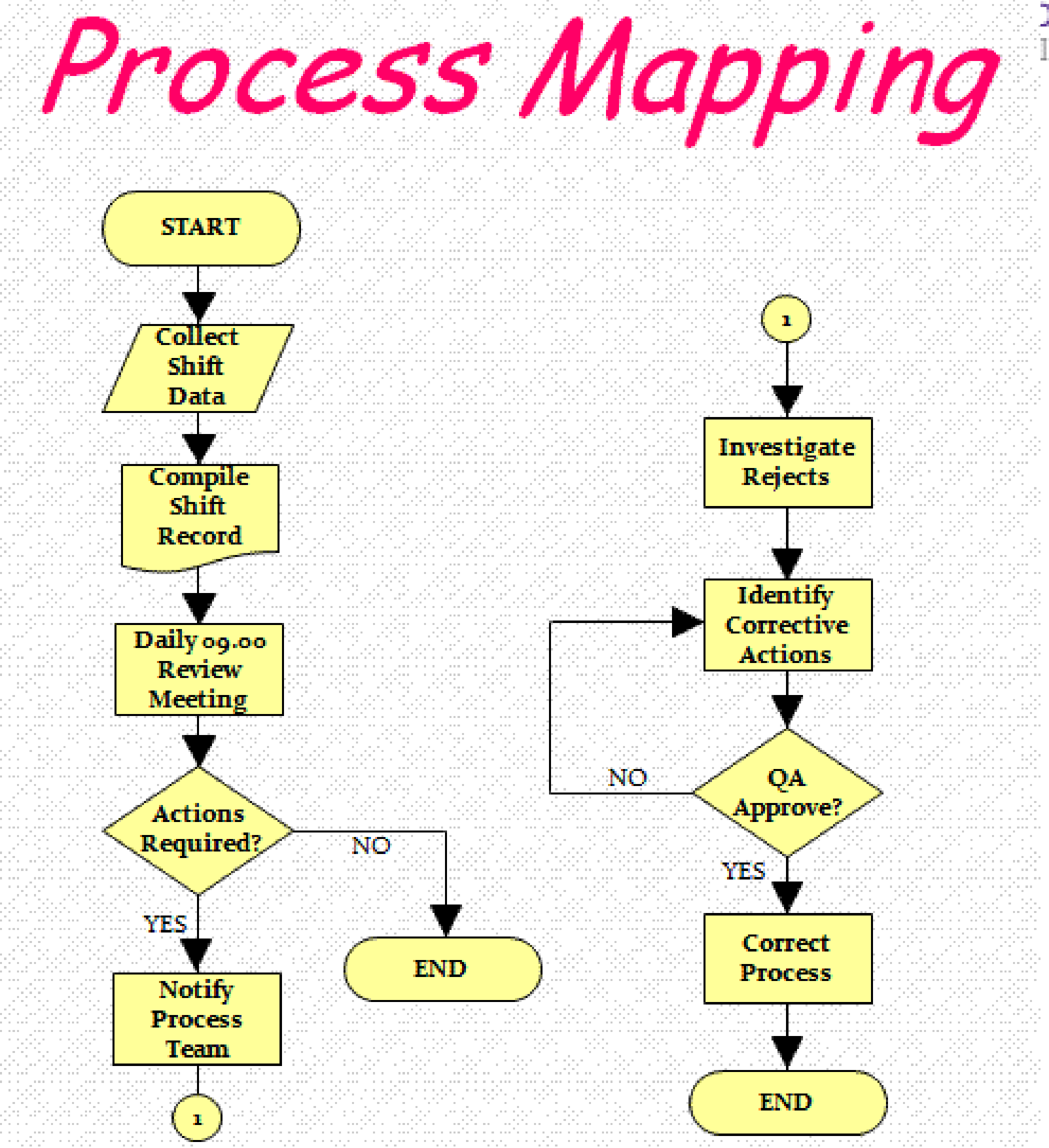
Critical to Quality (CTQ) Tree

Critical To Quality (CTQ) Trees (cont.)

The CTQ Tree example below is for the process of fixing a fault on a residential broadband service. It provides a structured view of the customers' expectations and requirements when having a broadband fault fixed.

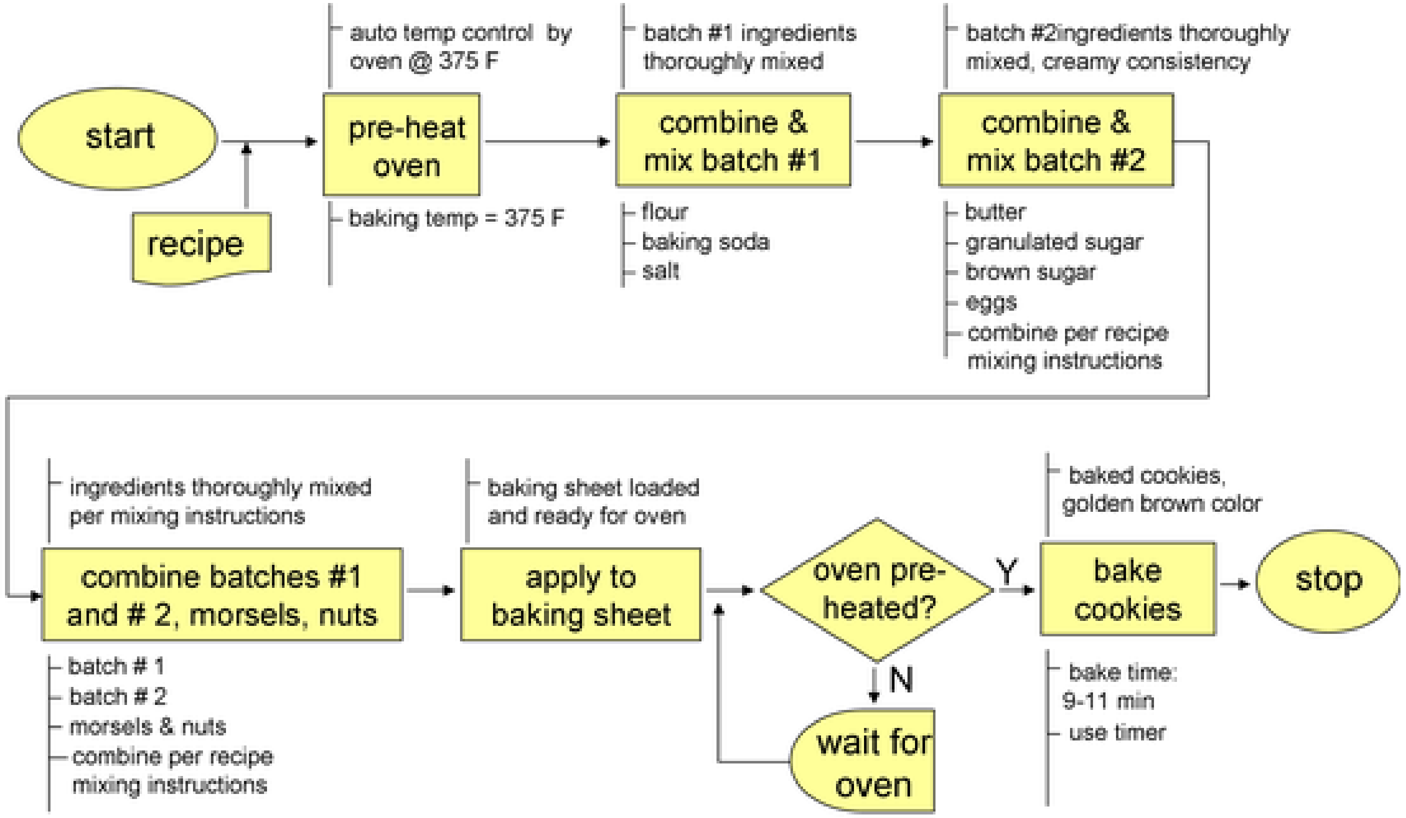


Process Mapping



Process Mapping

Process Flowchart – Nestle® Tollhouse Choc Chip Cookies



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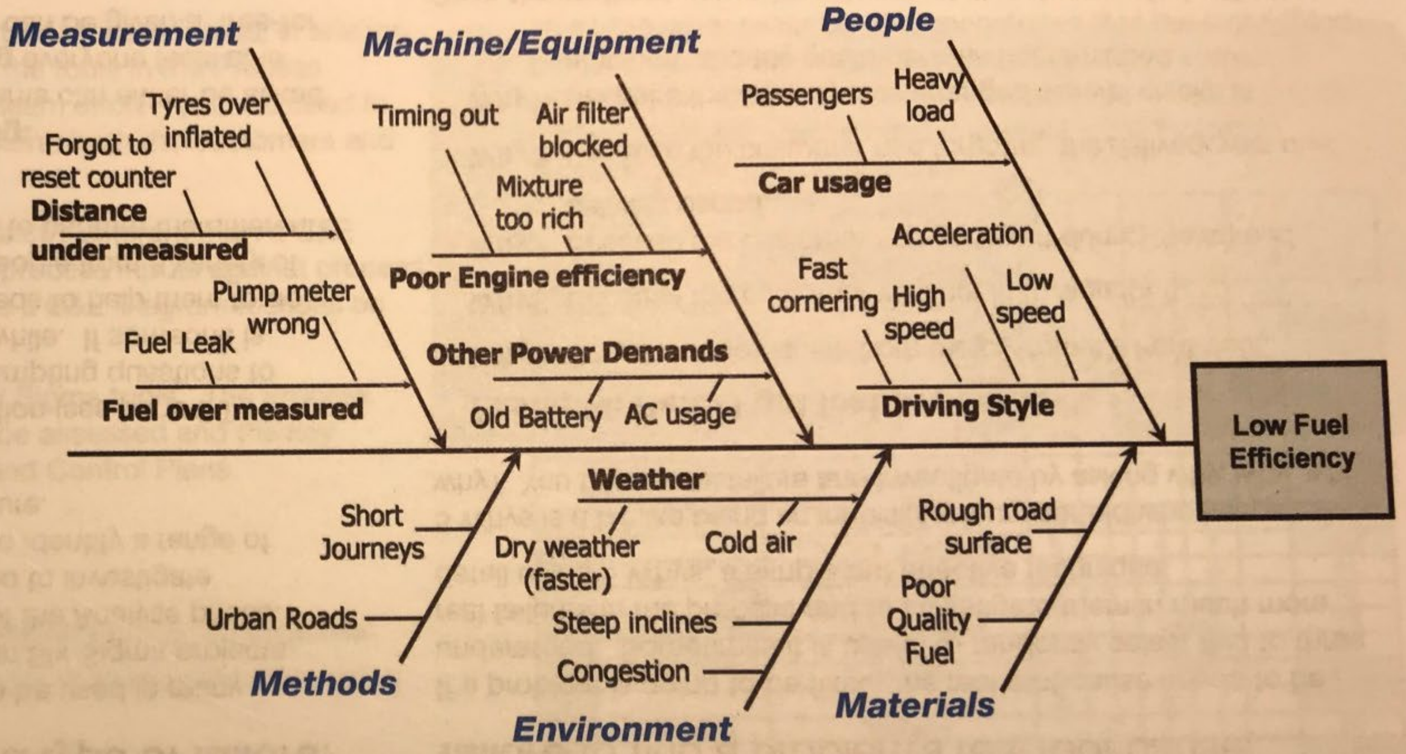
Cause and Effect (Fishbone) Diagram

- Use Cause-and-Effect Diagram to organize brainstorming information about the potential causes of a problem.
- Developing a cause-and-effect diagram with your team can help you compare the relative importance of different causes.
- A cause-and-effect diagram is also called a C&E diagram, a fishbone diagram, or an Ishikawa diagram.
- Review examples from Minitab and LSSM test

Fishbone diagrams are usually used during brainstorming, to identify root causes. However, they can be also be used throughout the Analyse phase as a great tool for structuring a team's thoughts.

Fishbone diagrams are an effective tool to help facilitate brainstorming sessions. The example shown here is the output of a brainstorming session on the causes of low fuel efficiency in a car.



Categories on Fishbone diagrams:
There are many different versions of Fishbone diagrams – with different branch names (people, methods etc). This is because there are no right or wrong ones; just use those that are appropriate to your project, or create your own.

Other uses of Fishbone diagrams:
As projects move into the Analyse phase, they usually start to have several specific areas of investigation. Although not technically being used for 'root cause analysis', a Fishbone diagram can provide clarity by being used to document the structure of the project, with each area of investigation represented by a different branch.

How to document a Fishbone diagram:
The best way to start a Fishbone diagram is with a large piece of paper on the wall or a white board (a pretty Fishbone diagram is not your first objective!). Companion by Minitab can also be used to document your results and has a brainstorming function too, which works alongside the Fishbone tool – see the Manage section of this guide for more detail.

Cause and Effect (C&E) Matrix

			1	2	3	
		Rating of importance to customer	8	8	10	
		Key Process outputs	Meet product specifications	Meet the delivery data	Waste	
	Process step	Process input				Total
2	get customer orders	tolerances	9	9	9	**234**
3	planning for cutting and send the order to the cutting warehouse	customer orders' specifications	9	9	9	**234**
5	prioritize the orders	customer orders to be processed	9	9	9	**234**
8	check availability of product type in the stock	stock data available on the information system	9	9	9	**234**
9	get the tubes from the stock	order available to be executed	3	9	9	**186**
12	cut the tubes in fixed lengths	long tubes to be cut	9	3	9	**186**
18	evaluate the waste (store it for future orders or throw it away)	waste data	9	3	9	**186**
19	evaluate the waste (store it for future orders or throw it away)	customer orders	9	3	9	**186**
11	cut the tubes in fixed lengths	cutting machine set up	9	1	9	**170**
4	planning for cutting and send the order to the cutting warehouse	order management policy	0	9	9	**162**
6	prioritize the orders	operators' knowledge/experience	3	3	9	**138**
15	register data	order data	3	3	9	**138**
17	evaluate the waste (store it for future orders or throw it away)	waste	3	3	9	**138**
20	evaluate the waste (store it for future orders or throw it away)	operators' knowledge/experience	3	3	9	**138**
14	evaluate the waste	remaining material	0	3	9	**114**
1	get customer orders	customer specifications	9	3	3	**126**
7	check availability of product type in the stock	priority order	3	9	3	**126**
16	register data	waste data	1	1	9	**106**
13	evaluate the waste	tube cut in fixed lengths according to be specifications	0	0	9	**90**
10	cut the tubes in fixed lengths	cutting machine available	1	3	1	**42**
Total			**808**	**760**	**1600**	

Assign score of 1-10 for each output

Areas of focus

Assign score of Blank, 1, 3, or 9 for each input

Hypothesis testing will be used to validate if the correct focus areas were identified.

Cause and Effect (C&E) Matrix

Cause and Effect (C&E) Matrix

Having identified inputs and outputs during process mapping, a C&E Matrix can be used to identify which of the process inputs are most important in relation to the customers requirements (outputs).

What is a C&E Matrix?

A C&E Matrix helps to identify the most important process inputs, in relation to the customers requirements. Like many of the tools in the Process Door of the Analyse phase, a C&E Matrix is a team effort – you will need to assemble a cross-functional team that understand both the customers and the process itself.

It's important to note that a C&E Matrix is distinctly different from a C&E Diagram (Fishbone). A C&E Matrix prioritises process inputs against process outputs (from the customer perspective), while a C&E Diagram focuses on root causes to a particular problem or defect.

A C&E Matrix links with several other Lean Six Sigma tools. The Process Capability of the key process outputs should be assessed and the key process inputs should be used within FMEA and Control Plans.

How to complete a C&E Matrix:

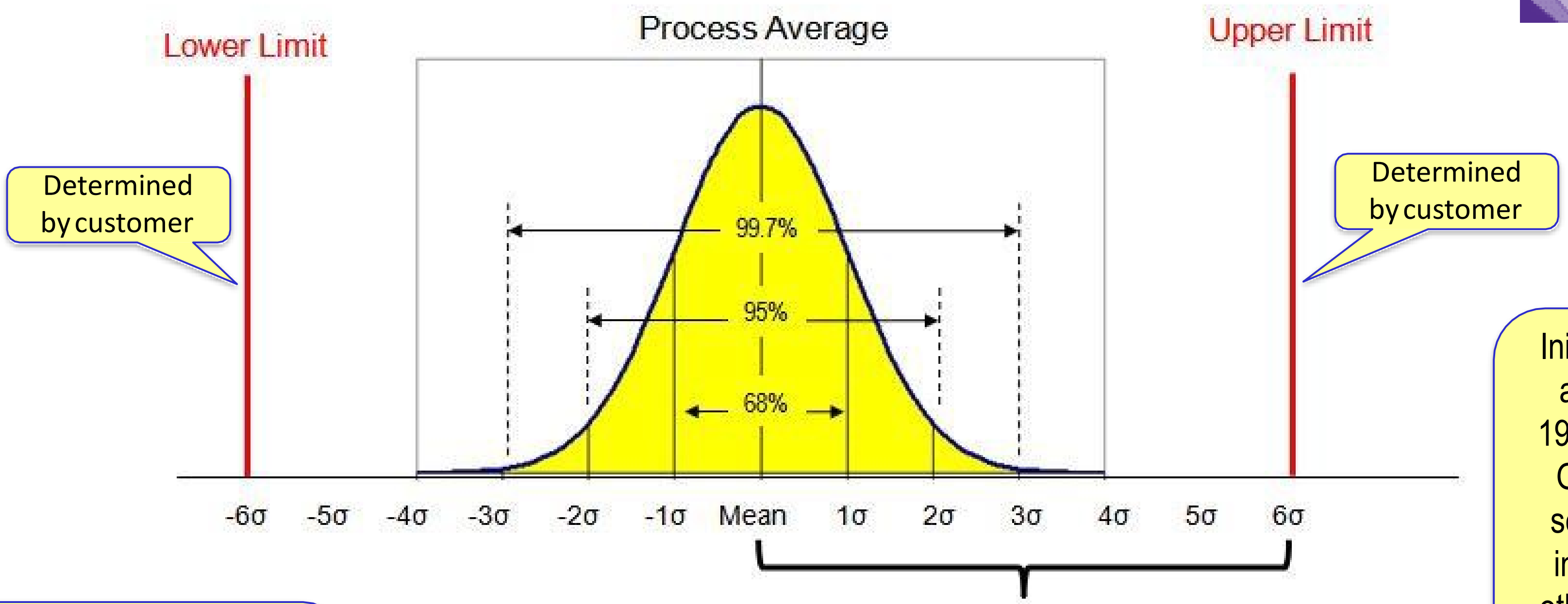
1) Identify the process outputs.
2) Rate each process output in terms of its importance to the customer.
3) Identify the process steps, and the inputs for each process step, using the process map.
4) Rate the correlation between each process input and output (a low score means that the input has little effect on the output, and vice versa).
5) Multiply each correlation value by the same outputs importance and add up the results for each row (i.e. for each process input).

And finally, act on the results! You should focus on controlling (or improving) the few process inputs that have the highest total scores.

Example: The C&E Matrix below has been completed for an online order process. It demonstrates that the highlighted process inputs (correct product codes/quantity, correct picking lists, adequate inventory, suitable boxes and correct printed invoices) are the most important input factors in relation to customer satisfaction.

		Rating of Importance to Customer	10	8	5	7		
		Process Outputs	Correct products	Effective packaging	On time delivery	Correct invoice		Total
	Process Step	Process Input						
1	Receive Order	Product codes	10	1	4	7		177
2		Product quantities	8	1	4	7		157
3		Delivery address	1	1	9	3		84
4		Invoice address	1	1	1	8		79
5		Payment details	1	1	5	5		78
6	Pick order	Operator	6	1	[illegible]	[illegible]		80
7		Picking list	8	1	4	1		115
8		Inventory	5	1	8	1		105
9	Package	Operator	1	7	2	1		83
10		Boxes	1	9	4	1		109
11		Bubble wrap	1	6	2	1		75
12		Filler	1	8	1	1		86
13	Ship	Courier	1	1	10	1		75
14		Delivery address	1	1	9	1		70
15		Weight / dimensions	1	1	7	2		67
16		Agreed delivery	1	1	9	3		84
17		Printed invoice	1	1	6	9		111
Total			490	344	430	371		

Six Sigma Defined Visually (cont'd)



Initially deployed at Motorola in 1986. Adopted at GE at a global scale in 1990s; inspiring many other companies to follow.

Example: In a 2 Sigma process, 95% of the measured values taken in a process will be within two standard deviations from the process average.

Within in a standard normal distribution:
- 68% of the data points will fall within ± one standard deviation from the mean
- 95% will fall within ± two standard deviations
- 99.73% of the data points will fall within ± three standard deviations from the mean

σ = Standard Deviation