AMU | AMERICAN MERIDIAN UNIVERSITY

Black Belt Review

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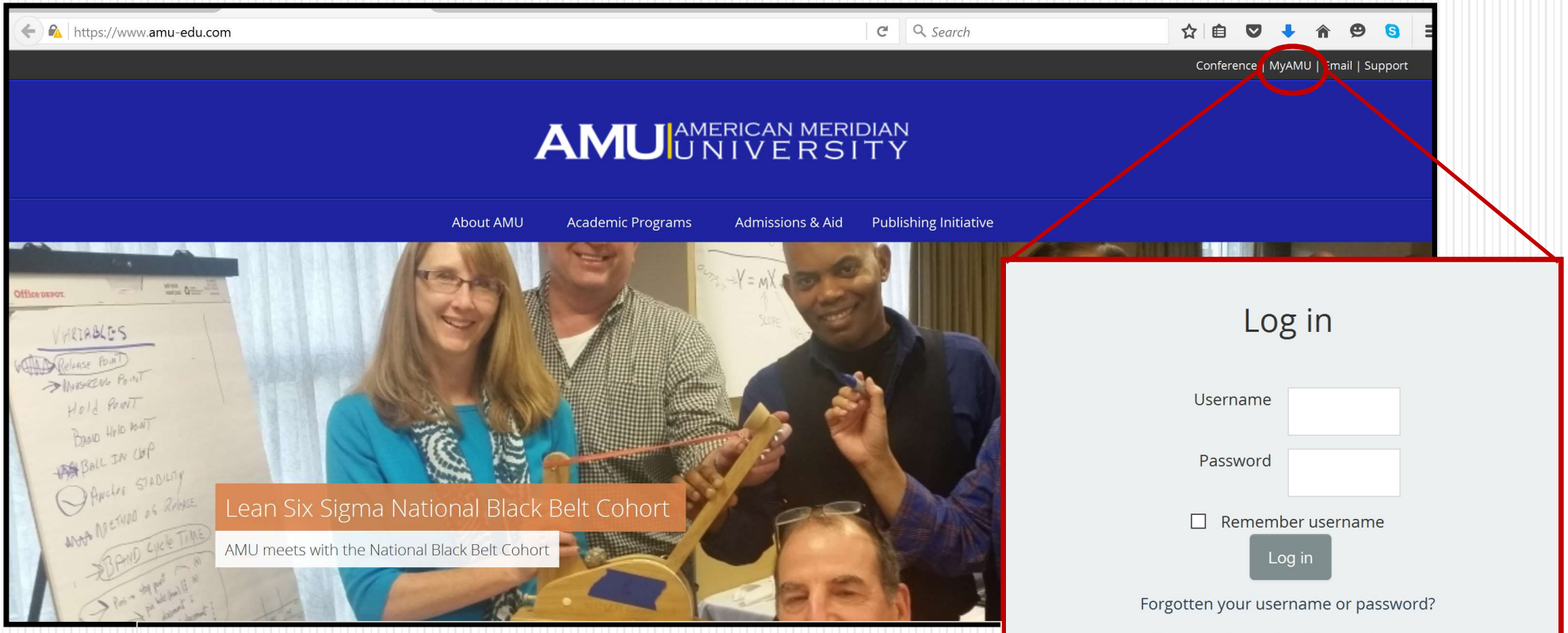
BB Exam Logistics

- Exam class begins at **8pm (EST)** next Thursday, January 28, 2016
- Exam is 60 multiple choice questions
- All questions are equally weighted
- There is no penalty for guessing
- Exam is open books and open notes, but closed neighbor (You may use whatever references you want, but you may **not** "*phone a friend*")
- Faculty will be dialed in and available to assist you if you have any questions
- Please do not be late
- Total expected exam duration is two (2) hours. You may take longer
- Once you begin the exam, you will have 24 hours to complete it
- You are not required to begin the exam on Thursday night, January 28th, 2016
- You ARE required to complete and submit the exam prior to midnight on Thursday, February 4th, 2016
- **If you do not intend to begin the exam at the scheduled time** on the evening of January 28th, 2016 you must notify Prof. Journigan and Dean Bonney immediately to schedule your exam starting time
- You must have an approved AMU Faculty member present with you when you begin the exam
- You are *strongly encouraged* to "get it done" and take / complete the exam on January 28th

BB Exam Logistics

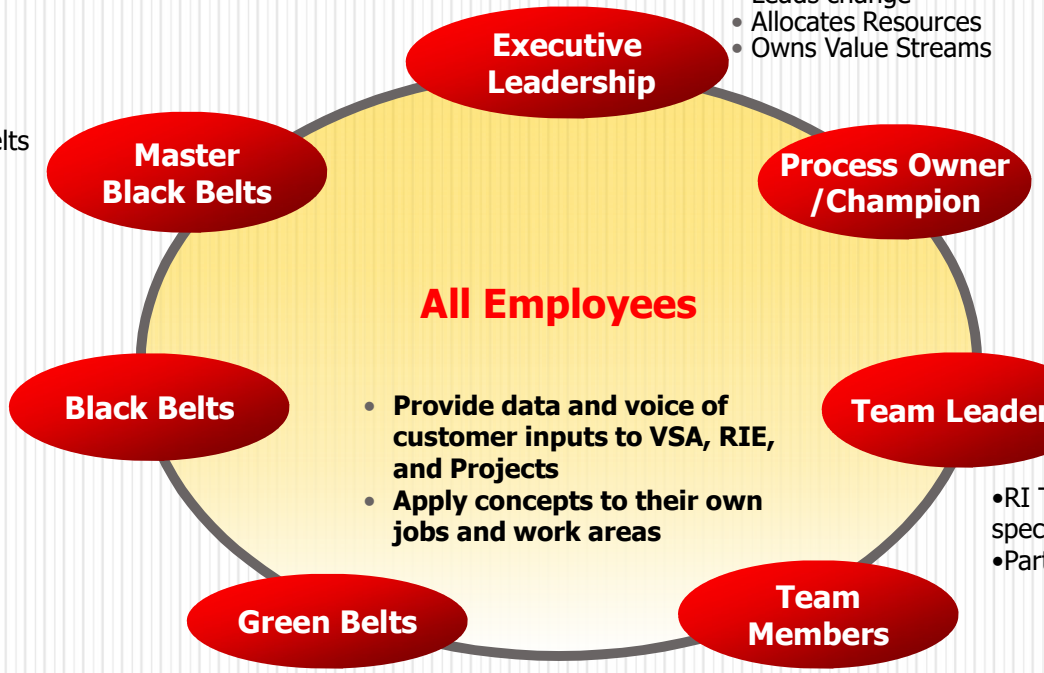
- Exam class begins at **8pm (EST)** next Thursday, January 28, 2016
  (yes, we said this already – but it's earlier than you're used to, so please write it down, set your alarms, have a friend remind you!)
- Prior to class, you will need to…
  - Watch for the email with your password (arriving by close of business Friday)
  - Log onto **https://www.AMU-EDU.com** and select "MyAMU"
  - Sign in with your AMU email address and assigned password
  - You will be prompted to change your password
  - You will see AMU's new Learning Management System
  - This is where you will need to go on exam night. If you can log onto the site this week, you can log on for the exam. If you CAN'T log on this week, notify Willie, Scott, and gregory.sanders@amu-edu.com

BB Exam Logistics (cont.)



For details, watch for the email with your password, and watch the Exam Logistics video on the student website!

Lean Deployment Roles



- Owns vision, direction, business results
- Leads change
- Allocates Resources
- Owns Value Streams

- Trains Black Belts / Green Belts
- Leads Complex Projects
- Full-time position

- Owns Rapid Improvement Plan
- Owns the process (approval authority)
- Owns Communication Plan
- Owns financial results
- Removes Barriers

- Experts on principles and tools
- Leads larger projects
- Coaches Green Belts
- Full-time position

- RI Team or Project specific support
- Part-time

- Lead small-moderate projects
- Execute Kaizens
- Full time or part time role

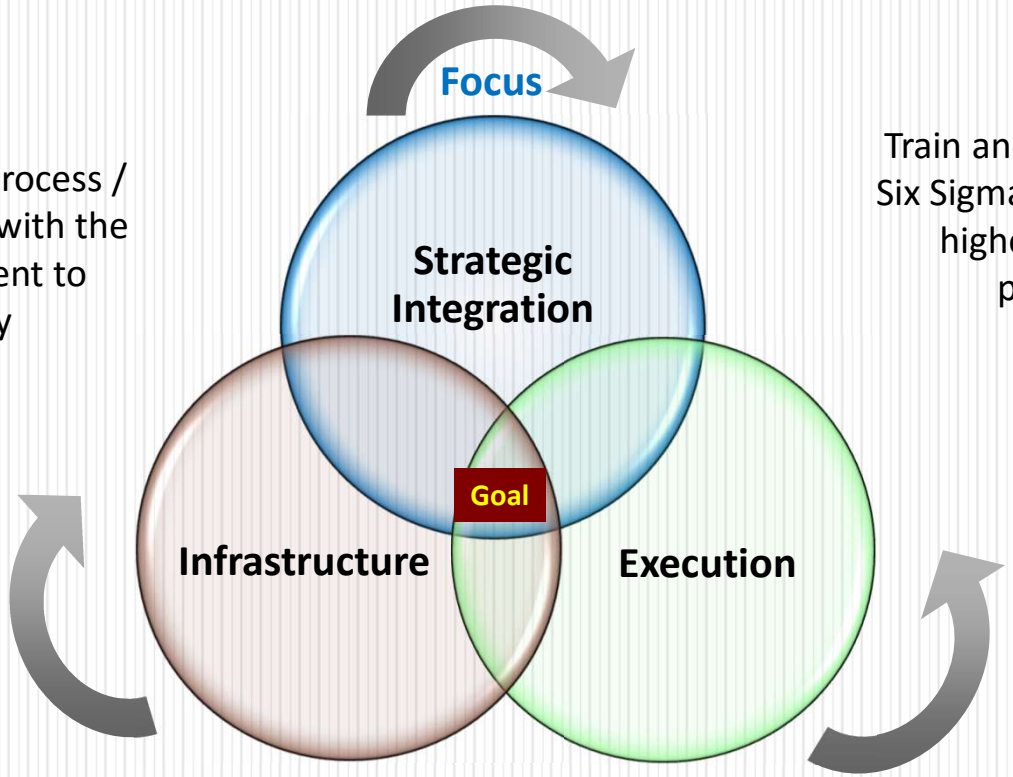
- RI Team or Project specific support
- Part time

Successful Deployment Requires Organization-wide Involvement

Deployment Process for Driving Sustainable Results

Prioritize the process / value streams with the best alignment to Strategy

Train and Deploy Lean Six Sigma teams on the highest priority projects



Management engagement, resource commitment, productive teams

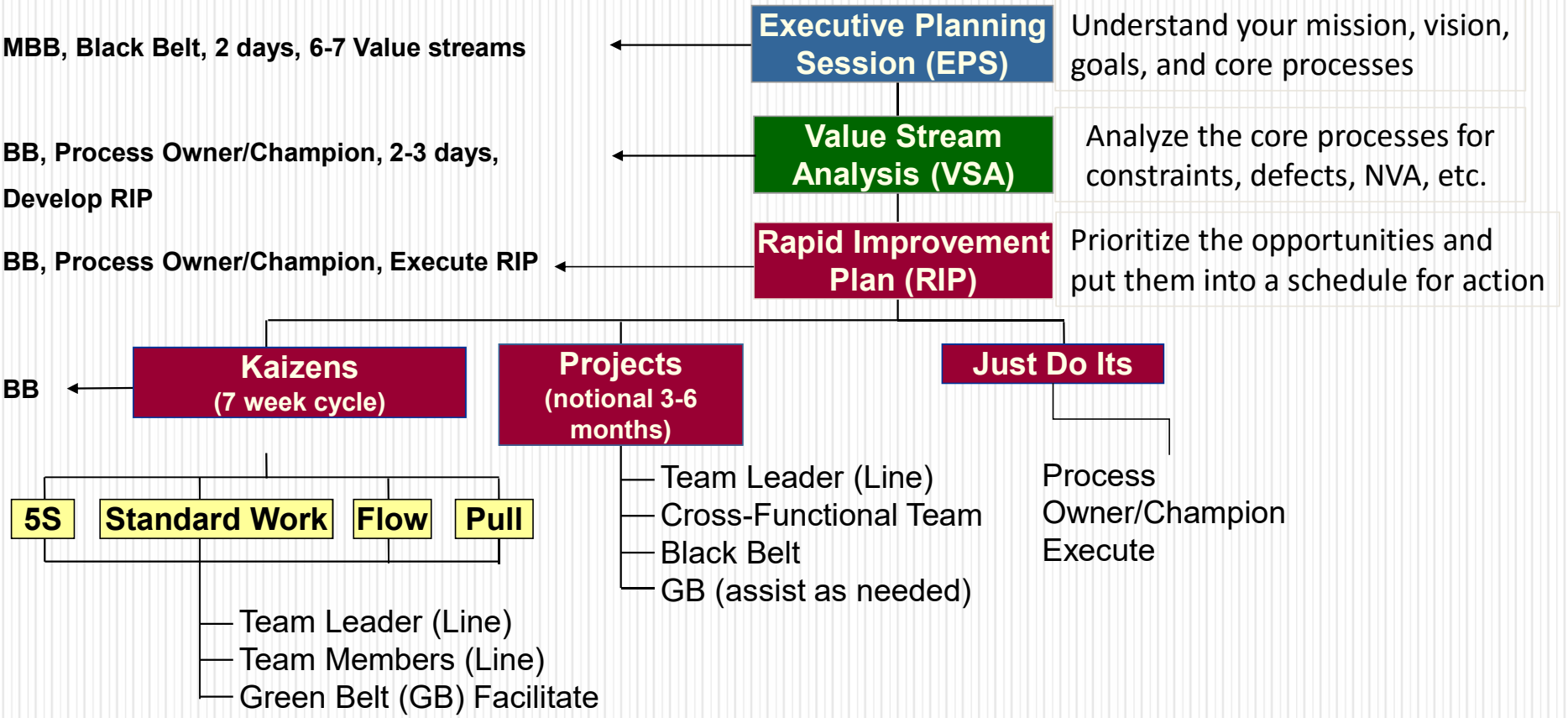
Bottom Line: For enterprise-wide CPI/LSS to succeed, it must focus resources on strategically-selected core value streams that tie directly to the organization's Mission and Vision, and EXECUTE those critical projects!

Executive Planning Session Objectives

- Align Lean efforts with Corporate Priorities and Guidance
- Identify core value streams and funding flow
- Prioritize based on value to Customers
- Develop charters/plans that address resources (Champions, BBs, GBs), improvement objectives and metrics, and schedule

Note: It sounds intimidating, but the core tool to facilitate an effective Executive Planning Session is just a simple SIPOC / SIPOOC. Call your MBB for help the first time, and you can run the next one all by yourself.

Deployment Strategy



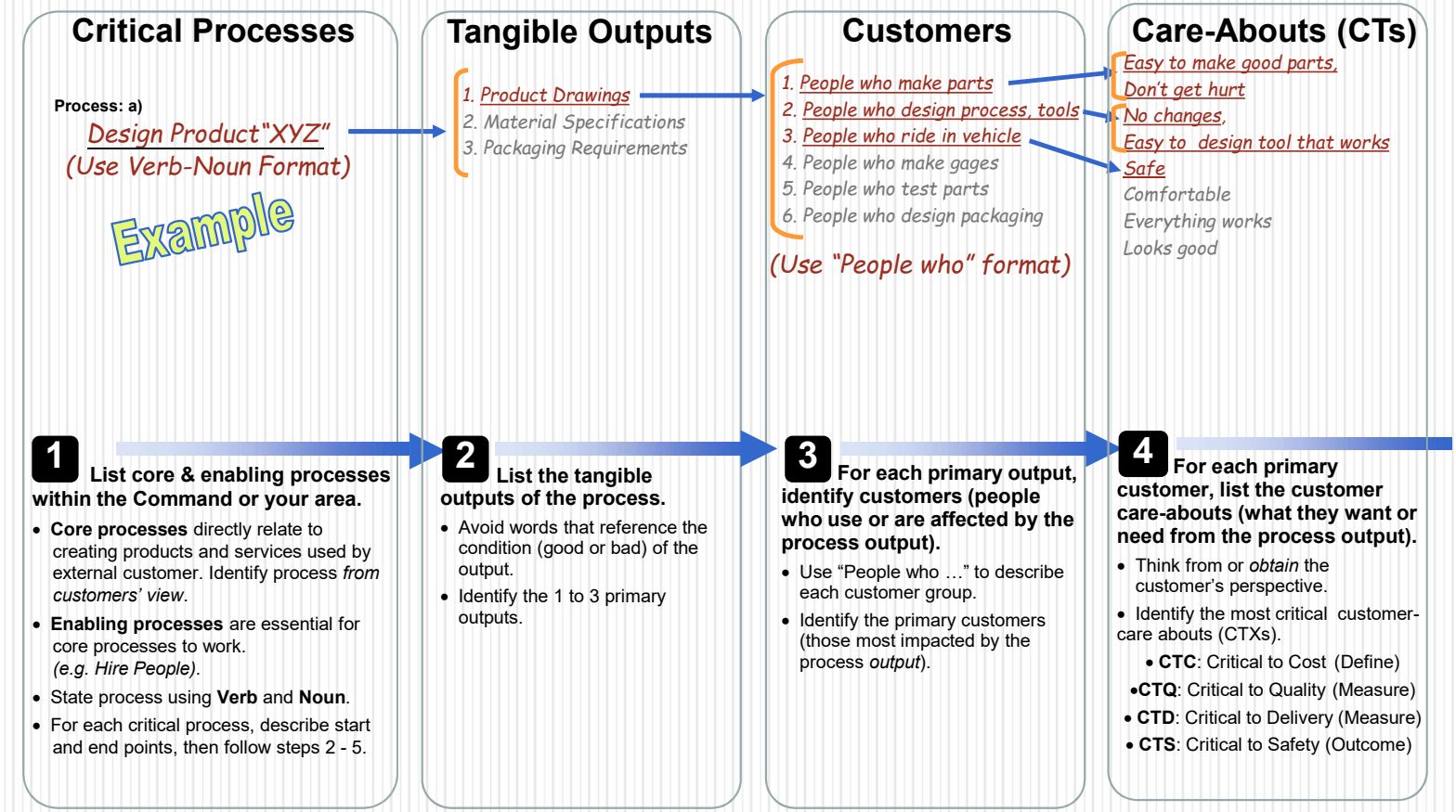
SIPOC Overview – High Level

- Acronym meaning:
  - **S**uppliers
  - **I**nputs
  - **P**rocess
  - **O**utputs
  - **O**utcomes
  - **C**ustomers (Clients)
- Represents the chain of elements to put a service or product into customer possession
- The heart of any SIPOOC is “IPO” and the Suppliers help us think about upstream inputs while Customers help us think about downstream outputs
- Always consider including “Supplier” and “Customer” representatives on your team
- Provides end-to-end context for your project scope and boundaries

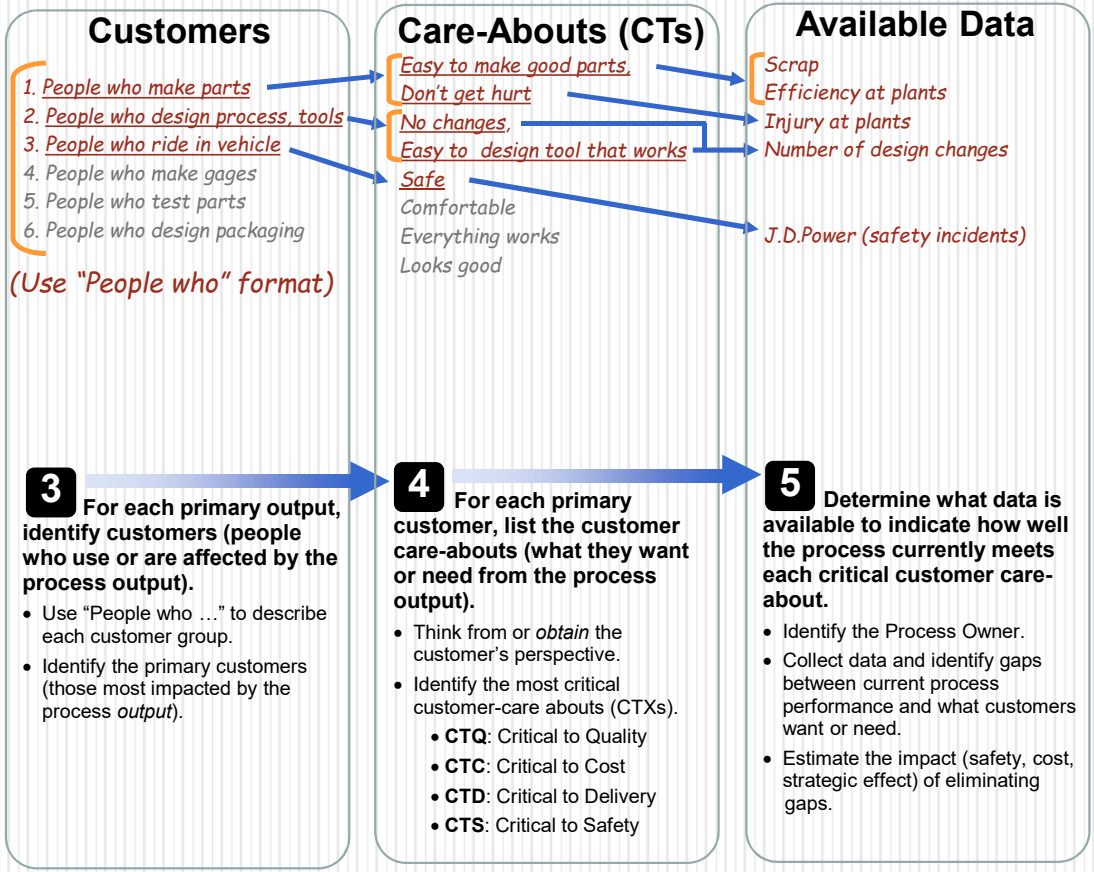
Traditional SIPOOC Layout

S	I	P	O	O	C
Customers Fulfillment Department	Customer Order Customer Invoice Requirements Invoicing System Shipment Verification	Receive Order Enter Order Validate Shipment Create Invoice Send Invoice Revise Invoice Receive Payment	Invoice Payment	Invoice Payment	Customer Accounts Receivable

Connecting VOC to the Value Stream



Converting VOC to Metrics



3 **For each primary output, identify customers (people who use or are affected by the process output).**

- Use "People who …" to describe each customer group.
- Identify the primary customers (those most impacted by the process *output*).

4 **For each primary customer, list the customer care-abouts (what they want or need from the process output).**

- Think from or *obtain* the customer's perspective.
- Identify the most critical customer-care abouts (CTXs).
  - **CTQ**: Critical to Quality
  - **CTC**: Critical to Cost
  - **CTD**: Critical to Delivery
  - **CTS**: Critical to Safety

5 **Determine what data is available to indicate how well the process currently meets each critical customer care-about.**

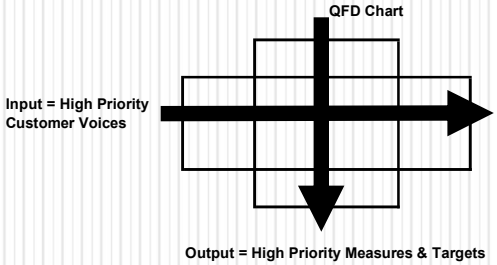
- Identify the Process Owner.
- Collect data and identify gaps between current process performance and what customers want or need.
- Estimate the impact (safety, cost, strategic effect) of eliminating gaps.

Where Do We Use QFD?

- QFD begins with the Customer in order to:
  - *Develop* new products and / or services
  - *Improve* existing products and / or services
- Every new product, process, or service should *improve customer satisfaction*
- Every modification to an existing product, process, or service should *improve customer satisfaction*
- Customers include external and internal Customers.

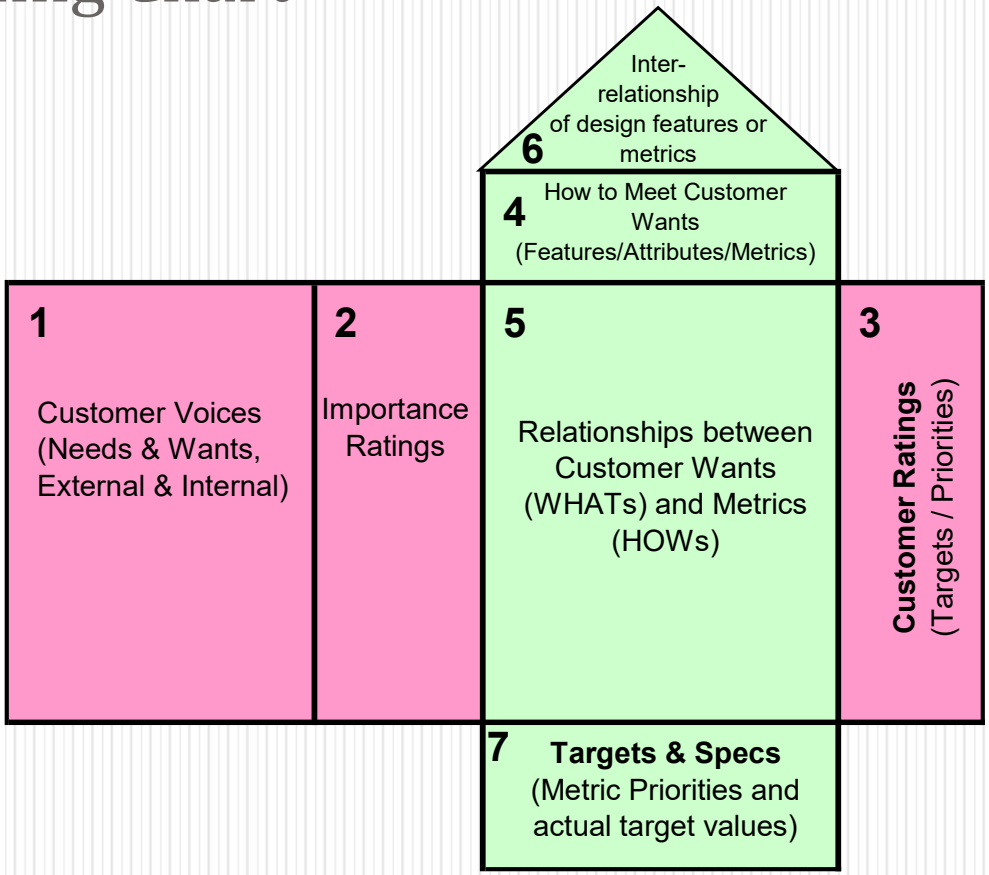
Internal Customers and/or stakeholders should all be represented during the development of the QFD matrix.

Building the "House of Quality"
The Product Planning Chart

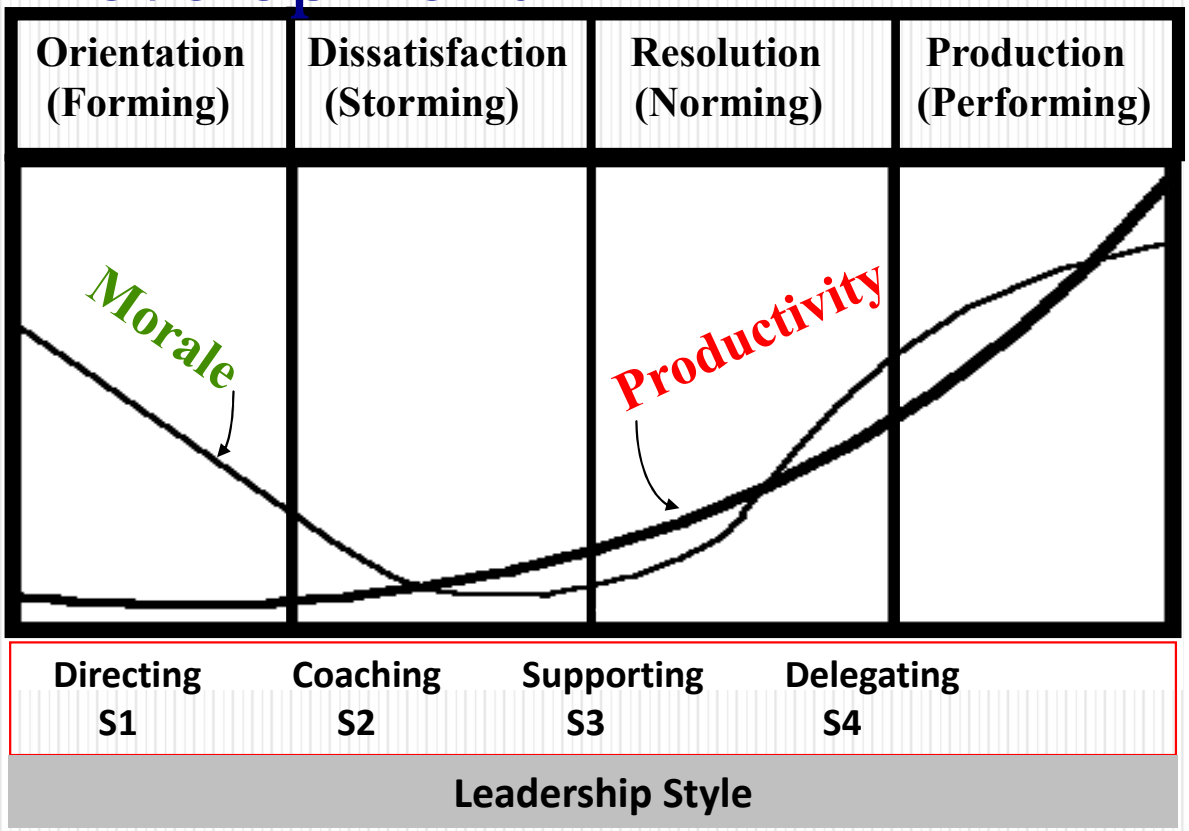


Information in rooms 1, 2, & 3 must come *from the customer(s)*

Information in rooms 4 – 7 represent the organization's response to customer wants & needs



Team Development



Beware! Teams that appear to be high performing, and never argue or "storm" may have fallen victim to "Group Think", where they no longer challenge each other's assumptions.

Brainstorming

- Discuss the ground rules
  - No judgements
- Determine the method
  - Chaos, Nominal Group Technique (NGT), Round Robin
- State the question
  - Write it down in front of the room
- Restate the question
  - Necessary if the group seems too far afield
- Capture all ideas
  - Summarize and Reflect
  - Tag-team
- Immediate enforcement of rules
  - Keep it safe

Brainstorming

- Legibility is the victim of SPEED
- Facilitation is not NEAT
- Chaos is FUN
- Take pride in your ignorance
- Always forget to combine
- Assert
- Laughter fans the flames of creativity
- Chaos is FUN

Affinity

- Combine like items
- Group ideas by function or other logical categories

What is Multivoting?

Multi-voting is a group decision-making technique used to reduce a long list of items to a manageable number by means of a structured series of votes.

The result is a short list identifying what is important to the team.

When should a team use Multivoting?

- Use multivoting whenever a brainstorming session has generated a list of items that is *too extensive* for all items to be addressed at once
- Multivoting provides a quick and easy way for a team to identify the most popular or highest priority items on a list, those that are worthy of immediate attention
- When you need to prioritize a large list without creating a situation in which there are *winners* and *losers* in the group that generated the list

Prioritization

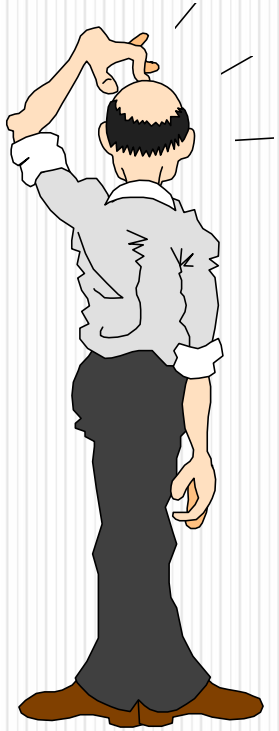
- Used to decide on which items of the short list should be worked first
- ALL items are important and should be worked
- The team has some opinionated members who think they know the most important problem
- Several team members are not speaking

Prioritization

- Several team members are not speaking

Each team member writes the letters A through G on a piece of paper

Then, each member ranks each issue from 1 to 7 (with the most important receiving 7 and the least important receiving 1), using each number only once



Quad Chart

Project Title: XXXXX

DBBC: (Department Business Benefits Coordinator)

Quad Sheet Template
PHNSY & IMF

Serial Number: (Provided by C100PI)
Status Date: DDMmmYYYY
Lean Event: PROJ / RIE / JDI / No
Nuclear: Yes / No

I. Project Description: XXXXX

Project Outcome: XXXXX

POC: (Name / Code / Shop / Phone Number)

Lean Facilitator: (Name / Code / Shop / Phone Number)

II. Status:

Month Year	Event or Milestone	Status
XXXXXXX	XXXXX	Pending / Active / Completed

III. Metrics / Benefits:

Metric	Units	Baseline	Proj	Proj % Change	Actual	Actual % Change
Throughput	Units/Day					
Cycle Time	Min-Sec					
Touch Time	Min-Sec					
Man Hours	Hours					

EXAMPLE

(Describe Benefits)

Notes: XXXXX

IV. Cost & Benefits:

Projected Cost: XXXXX

Projected Benefits: XXXXX

Validated Benefits: XXXXX

Remember:

- While not a required tool, the quad chart is an *excellent* one-page summary of key project objectives and accomplishments
- If you can't summarize your project on a quad chart in a way that makes sense to everyone, you probably don't understand your own project

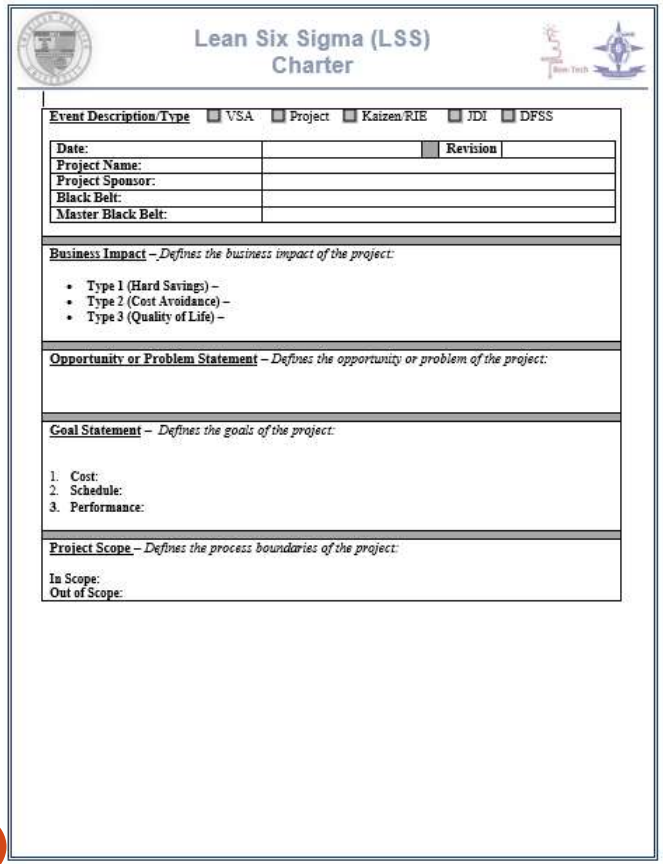
LSS Charter Overview

- Charter is your contract for success
  - You are the author of your charter and its associated success
  - Project Sponsor / Champion is the Owner of the Charter
  - Structure the charter (contract) so that you are successful
  - Specify boundaries, requisite resources, and support needed
  - Do ***NOT*** include solutions. If the solution is known and agreed to, by definition it is a JDI and you do NOT need LSS. Just Do It!
- Download and use current LSS Charter Template from Bon-Tech.org Website

LSS Charter Overview

- Charter is an organic, living document
  - Charter transforms as LSS team gets “smarter” on project
  - Organic nature assures success
- Begin crafting charter at project inception
  - Preliminary data needed
  - Use the “Library” vs. “Laboratory” approach
    - Library approach – data elements exist… somewhere Find Them
    - Laboratory approach – original research (avoid whenever possible)

Lean Six Sigma Charter



Lean Six Sigma (LSS)
Charter

Event Description/Type ☐ VSA ☐ Project ☐ Kaizen/RIE ☐ JDI ☐ DFSS

Date:		**Revision**	
Project Name:			
Project Sponsor:			
Black Belt:			
Master Black Belt:			

Business Impact – *Defines the business impact of the project:*

- **Type 1 (Hard Savings) –**
- **Type 2 (Cost Avoidance) –**
- **Type 3 (Quality of Life) –**

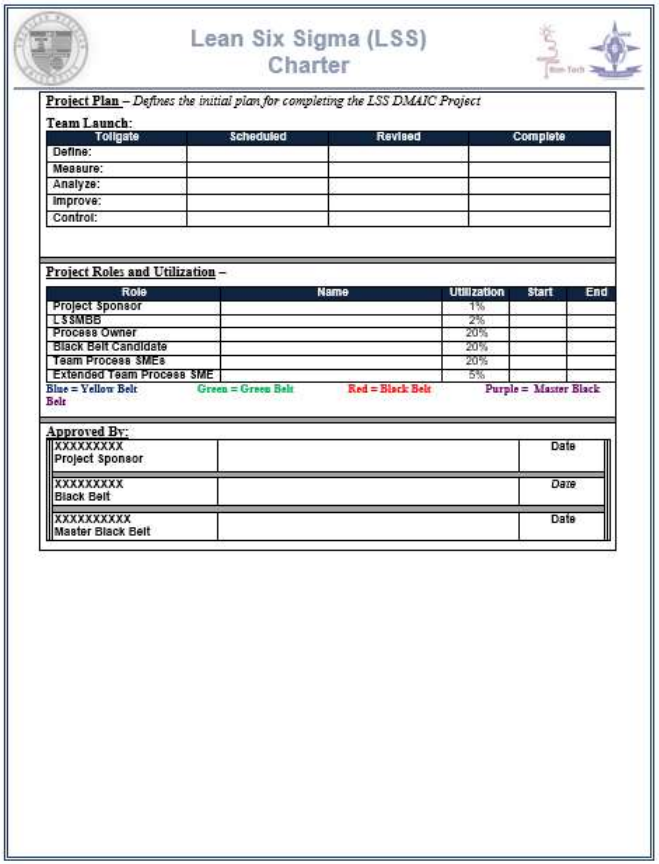
Opportunity or Problem Statement – *Defines the opportunity or problem of the project:*

Goal Statement – *Defines the goals of the project:*

1. **Cost:**
2. **Schedule:**
3. **Performance:**

Project Scope – *Defines the process boundaries of the project:*

In Scope:
Out of Scope:



Lean Six Sigma (LSS)
Charter

Project Plan – *Defines the initial plan for completing the LSS DMAIC Project*

Team Launch:

Tollgate	Scheduled	Revised	Complete
Define:			
Measure:			
Analyze:			
Improve:			
Control:			

Project Roles and Utilization –

Role	Name	Utilization	Start	End
Project Sponsor		1%		
LSSMBB		2%		
Process Owner		20%		
Black Belt Candidate		20%		
Team Process SMEs		20%		
Extended Team Process SME		5%		

Blue = Yellow Belt Green = Green Belt Red = Black Belt Purple = Master Black Belt

Approved By:

XXXXXXXXX Project Sponsor		Date
XXXXXXXXX Black Belt		Date
XXXXXXXXXX Master Black Belt		Date

3

Remember:

- The probability of a team's success can be directly tied to clearly established purpose and goals
- A Charter is more than just a LSS tool, it is a Project Management tool. Every project, every Kaizen, every Rapid Improvement Event should have a Charter
- There is a guide on the student web page that gives examples of good problem statements and goal statements. This is a very useful reference. It is important to know good problem statements and goal statements looks like.

Population Mean Formula

- The population mean is calculated using a formula:

$$\mu = \frac{\sum x}{n}$$

- μ (mu) is the symbol for the population mean
- "sum all the observations of x, and divide by n"

Sample Mean Formula

- The sample mean is calculated using a formula:

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

- $\overline{X}$ is the symbol for the sample mean
- “sum all the observations of x, and divide by n”

Range, Variance, and Standard Deviation

Range: highest value – lowest value

Variance (σ^2 or S^2) = $\sigma^2 = \frac{\sum_{i=1}^{n}(X - \mu)^2}{N}$ **or** $S^2 = \frac{\sum_{i=1}^{n}(X - \bar{X})^2}{n-1}$

Standard deviation is simply the square root of Variance:

$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(X - \mu)^2}{N}}$ ***Or*** $S = \sqrt{\frac{\sum_{i=1}^{n}(X - \bar{X})^2}{n-1}}$

Population	Sample
μ = *Mean*	$\bar{X}$ = *Mean*
σ^2 = *Variance*	S^2 = *Variance*
σ = *Standard Deviation*	S = *Standard Deviation*

Stats Trivia:

Question: Population standard deviation divides by the population size (N). Sample standard deviation divides by sample size minus one (n-1). Why?

Answer: The sample is unlikely to include the very large and very small values from the population (the "tails" on the bell curve). The formula use n-1 to slightly widen the estimated variation to take this into account.

Answers:
Measures of Spread or Dispersion

- Data: (8, 9, 12, 13, 14, 15, 16, 16, 16, 17, 17, 22, 33, 34, 45)

Range: 45 - 8 = $37K difference between highest and lowest price

- Std Deviation of entire population:

$$\sqrt{\left[(8-\mathbf{19.13})^2 + (9-\mathbf{19.13})^2 + \ldots (45-\mathbf{19.13})^2 \right] / 15}$$

Number of Data Points

Every data point above minus the mean

Mean = $19.13K calculated earlier

σ = $**9.96K**

- Std Deviation of population sample: *(assumed by Minitab or Excel)*

$$\sqrt{\left[(8-19.13)^2 + (9-19.13)^2 + \ldots (45-19.13)^2 \right] / 14}$$

s = $**10.31K**

Number of Data Points - 1

Process Capability

- **Cp** relates to a process' *potential* to meet customer requirements (width of the customer specification vs. width of process performance)
- Understand the two components of C_p
  - Tolerance width = Customer Requirements = Size of the specification window (Upper Spec Limit minus Lower Spec Limit)
  - Process width = size of the process = 6σ (remember, $\pm 3\sigma$ includes 99.7% of the process)
- Thus, Cp = (USL-LSL) / 6s

Application: Calculate Cp if USL = 12, LSL = 4, $\sigma = 1$

- $Cp = \frac{USL - LSL}{6\sigma} = \frac{12 - 4}{6} = 1.33$
- This is good! You want the width of the spec to be wider than the width of the process (ie. Cp>1.0)

Process Capability (cont.)

- **Cpk** relates to a process' *actual* ability to meet customer requirements (width of the process from the process average to the nearest spec limit)
- Understand the two components of C_{pk}
  - Distance to the nearest spec limit = either Average minus LSL or USL minus average
  - Half the process width = 3σ
- Thus, Cpk = the lesser of either $\bar{X}$-LSL) / 3σ or USL-$\bar{X}$ / 3σ

Application: Calculate Cpk if USL = 12, LSL = 4, $\sigma = 1$, $\bar{X} = 6$

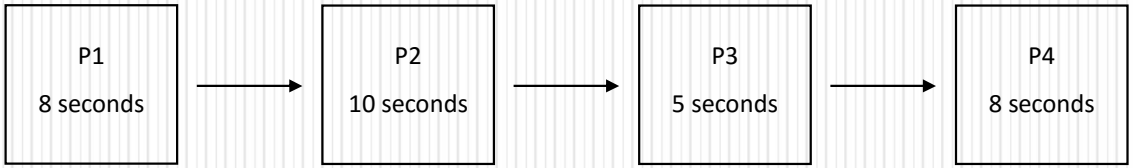
- Cpk = lesser of either $\frac{USL - \bar{X}}{3\sigma}$ or $\frac{\bar{X} - LSL}{3\sigma} = \frac{12-6}{3x1}$ or $\frac{6-4}{3x1}$

  = lesser of either 6/3 = 2 or 2/3 = 0.667 thus, Cpk = 0.667
- This is bad! You want the width of the spec to be wider (>100% or >1.0) than the width of the process on the side of the closest spec (ie. Cpk>1.0)

Exercise

Unsure of definitions for these terms? See definitions sheet!

- Consider the following set of processes
- Customer needs 25 units in 15 minutes
- Order entry takes 20 seconds, delivery takes 10 minutes



- Where is the constraint? P2
- TAKT Time = 15 mins / 25 units = 0.6 minutes or 36 seconds / unit
- Exit Time = 10 seconds
- Throughput Time = 8 + 10 + 5 + 8 = 31 seconds
- Lead Time = 20 secs + 31 secs + (24 x 10 secs) + 600 secs = 14:51

Note: Takt *Time* is always in time per unit (eg. 36 seconds per unit).
Takt *Rate* is always in units per time (eg. 100 units per hour)

Poka Yoke

- Japanese term meaning “Mistake-Proof” or “Error-Proof”
- A better way to prevent mistakes
  - Remove the opportunity for error (PREVENTION; most effective)
    - Improve the process
    - Make wrong actions more difficult
  - Make the error easy to detect (DETECTION; less effective, but still good)
    - If you cannot remove the opportunity for error, modify the process to make the error obvious
    - Obvious mistakes may be quickly corrected.

Detection Example

- My car beeps if I leave the key in the ignition

Other poka yoke Examples

Locking devices on filing cabinet prevents opening multiple drawers which would lead to tipping

Other poka yoke Examples

Gas pumps are equipped with hose couplings that break-away and quickly shut-off the flow of gasoline

Other poka yoke Examples

This rental truck has a door latch which will not allow the loading ramp to slide out while the latch is in the closed position

Theory of Constraints

- Stuff piles up at the constraint (look for the WIP!)
- If you don't break the constraint, you don't improve throughput. Period.
- Remember, "WIP" may be subtle, depending on what your process produces.
  - In manufacturing, WIP is piles of stuff.
  - In Project Management, WIP is time.
  - In marching a bunch of scouts through the woods, WIP is the space between the scouts (piles of "time" that show up as gaps).
  - There is ALWAYS inventory, and there is ALWAYS a constraint. You may have to be creative to figure out what to look for, but once you figure it out, identifying the constraint becomes super easy every time.

Note: According to ToC, a little WIP may actually be a good thing in front of the constraint, since it ensures that the constraint will never want for work to do (ie. It keeps the constraint fully utilized). This is NOT part of typical Lean thinking.

ToC Terms: In Lean and Six Sigma the core process that produces the product or service for the customer is referred to as the "core value stream". In ToC, this is referred to as the "Critical Path". Thus, CPI/LSS work not done on the "critical path" will have virtually no impact on productivity.

Value Stream & Process Mapping

- Help to see the full process from beginning to end
- Help the team to clearly distinguish between Value-Added and Non-Value-Added steps
- Can help to visually display constraints in time or flow (if data blocks are attached to the map)
- It will NOT identify where the root causes of your problem occur.

Remember, a high level process map is a sub-set (the “P”) of the SIPOC or SIPOOC that you do at the very start of every project or strategic planning session. The SIPOC/SIPOOC shows you the strategic context, then you expand it during the Measure phase to understand the details.

Value-Added vs. Non-Value-Added

"Value-Added" requires three things

- The customer wants you to do that process step (enough to pay for it!)
- The process step changes the form, fit, or function of the product or service
- You do the process step correctly the first time

ALL THREE must be present if a process step is to be considered "Value-Added"

Note: Some schools of thought would add a sub-category of NVA, called NVA-R. "Non-Value-Added but Required" is still NVA, but recognizes that a step may be required by law or contract, and therefore very difficult to eliminate. However, "NVA is NVA" and legal requirements do NOT make a process step Value-Added.

Data collection

- Make sure your data accurately reflects your process. If you make 5 variations of a product, make sure they are all represented in your sample, in appropriate proportions. If your sample doesn't accurately reflect your population, your statistical inferences will be wrong.
-

Data types

- Qualitative: Fuzzy and non-quantified
  - "I'm cold!"
- Quantitative:
  - Discrete / Attribute Data
    - Binomial (only two categories; Defective vs. Not Defective)
      - Good / bad, Go / No-Go, Pass / Fail
    - Poisson (count data; counts the number of Defects)
      - 3 defects on this product, 5 defects on the next product, …
  - Continuous / Variable data
    - Measured with a measurement device (thermometer, chronometer, micrometer, voltmeter)
    - Can be broken into "infinitely small" pieces (eg. time, distance, cost)

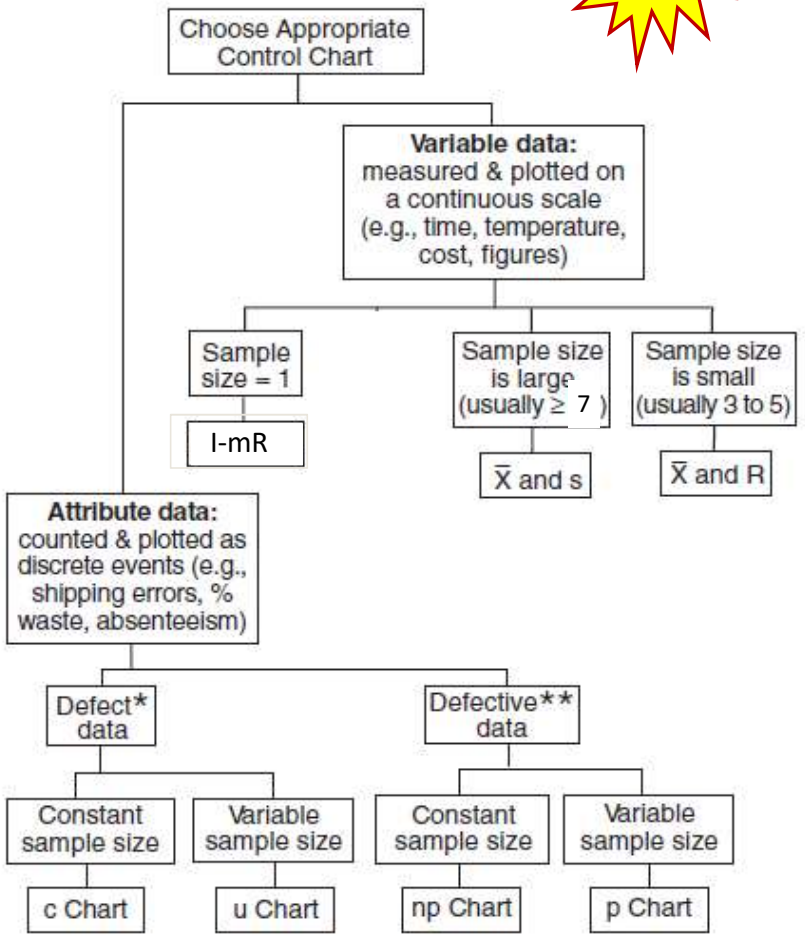
Which is "best"? Continuous is most powerful, but "best" is whatever is most appropriate to the situation.

Variables Control Charts

Lesson 12, slide 37

Note that Control Charts are, by design, "distribution independent". This means that they will always work regardless of whether your data are normally distributed or not.

With this understood, control charts are more "sensitive" for data that are normally distributed, or that are normalized due to a larger sample size. Control Charts that use the power of the central limit theorem to "normalize" their data, and thereby produce more sensitive results, include the x-bar/R chart and the x-bar/s chart.



Hypothesis Testing Decision Trees

Ref. Lesson 10, slides 23-30

Key Tools

- To graphically show center and spread of your continuous data, use a **Histogram** ("bell curve" graph)
- To show data in time-order, use a **Control chart** or **Run chart**
- To identify root causes, use a **Fishbone Diagram**
- To *map* a high-level end-to-end process, use a **SIPOC**
  - To *identify & map* high / Organizational-level strategic value streams, use a **SIPOOC**
- To identify process flow and decision points, use a **Process Map**
- To identify waste in a process use a specialized version of a process map like:
  - **Value Stream Map** (Generally used for high level end-to-end org mapping)
  - **Spaghetti Diagram** (shows motion and/or transportation)
  - **Circle Diagram** (shows hand-offs)
  - **Process Map** with VA/NVA added (shows all 8 types of waste)
- To prioritize data by category, use a **Pareto chart**

Hypothesis Testing

- **P-values**
  - P-value is a "probability" value. It shows the probability, from 0% to 100%, that the null hypothesis is true.
  - There is always risk. In general, we want to be 95% confident (5% risk) in our decisions. Therefore, if the probability that the null is true remains greater than 5%, we are not willing to reject it. But, if $p<0.05$ (that is, if p is "low" compared to our acceptable risk of 0.05), we reject the null. Thus, we say, "If p is low, the null must go!" and we accept that alternative hypothesis
- **Null & Alternative Hypothesis**
  - Null always includes the "equal sign" and assumes there is no difference between two conditions (eg. "the average time to complete the process before we did our project *equals* the average time to complete the process after we did our project")
  - Alternative hypothesis is always *not equal* (eg. "the average time to complete the process before we did our project *equals* the average time to complete the process after we did our project")
  - In general, we hope for a low p-value, so we can reject the null and accept the alternative hypothesis that there is a different between the two conditions being evaluating at a statistically significant level.

Cost of Quality

- It costs to send bad quality to the customer (EXPENSIVE!)
- It costs to inspect quality at the end of the production process
- It costs less to inspect at the point of doing each step
- It costs even less to prevent the defect in the first place

Which is cheapest? Prevention. But it DOES cost (this may be an expense in your LSS project, but the cost is always well worth it!)

Visual Display of Information

- A picture tells 1000 words
- Visual comparison
  - before vs. after
  - Good vs. bad examples
  - Best practice is to show examples side by side, within the eye-span

    (eg. Show “good” right next to “bad”; show “before” right next to “after”)
  - Always display your images in context

    (eg. Going from 100 defects / day to 50 defects / day should be displayed using a scale that begins at zero, not at 40)
  - Best practice is simple, clean, clear images, not complicated by lots of colors and fonts and unnecessary distractions
  - Minitab is a GREAT way to visually display your information

Measurement System Analysis

- Measurement System Analysis (MSA) evaluates the accuracy of your data collection methods, including looking at factors like bias, linearity, repeatability, reproducibility, etc. MSA should always be evaluated on every project, even if it's just talking to the people who collect the data about how they collect it, how they record it, what tools they use, how often, definitions of terms, etc.
- Gage Repeatability and Reproducibility (GR&R) is a specialized, extremely rigorous method for evaluating measurement differences between measurement devices (gages), individual's abilities to consistently take measurements (repeatability), and differences between different people's measurements (reproducibility). GR&R is complex and is usually not required for projects to move forward.
- When conducting a GR&R, let Minitab do the math, but remember:
  - <10% Gage Repeatability / Reproducibility (GR&R) is good
  - 10%-30% is marginal, but generally acceptable, recognizing the measurement process will need to be improved as part of the overall process improvement project
  - >30% is BAD and unacceptable. If GR&R is greater than 30%, you cannot use the data that has been collected using this method; it is unreliable and should not be used for any kind of analysis.

7 Wastes (plus 1)

- TIM WOOD (U)
- Transportation (stuff moving)
- Inventory (stuff not being worked on)
- Motion (people moving)
- Waiting (people not working)
- Overproduction (making stuff no one needs)
- Overprocessing (making higher quality than required)
- Defects (making lower quality than required)
- Plus "Underutilization of people" as the "8th waste" (using people "from the neck down" and not taking best advantage of their minds and skills)

Design of Experiments

- Factors = Process inputs (x's) that may impact the output
- Levels = Two values of a given X that we intend to test
- Eg. Does tire pressure effect my fuel efficiency?
  - Factor = Tire pressure
  - Levels: Two levels might be 25PSI and 40PSI
- How do you calculate number of runs required for an experiment?
  L^F = Levels ^ Factors, where L or "Levels" always equals 2 (a low and a high level, like 25 PSI and 40 PSI)
- Thus, how many runs are required for a 5 factor DOE?
  - 2^5 = 2x2x2x2x2 = 32 runs
- How many runs are required for a 5 factor ½ fraction screening DOE?
  - 2^5 = 2x2x2x2x2 = 32 runs. ½ of 32 = 16 runs
- How many runs are required for a 5 factor ½ fraction screening DOE with 3 replications?
  - 2^5 = 2x2x2x2x2 = 32 runs. ½ = 16 runs. 16 runs replicated 3 times each = 48 total runs

Design of Experiments (cont.)

- Full Factorial DOE = every combination of factors
- Fractional DOE (also known as a Screening DOE) = a fraction of the total runs = a fraction of the total number of combinations
- >4 factors? Recommend a fractional DOE to “screen out” factors that don’t matter
- 2-4 factors? Go with a “Full factorial” DOE
- Remember, when running a fractional DOE, resolution becomes important (if you don’t run a full DOE, you miss some data, and missing some data means you don’t see the whole picture. Can you trust a picture with low resolution? Maybe…)
- Rule of thumb: Higher resolution is clearer. Never trust an experiment with Resolution of 3 or below.

Correlation & Regression

- NOTE: Before you even start looking at correlation or regression analysis, if p-value is >0.05, do not bother, because there is no significant correlation. But, if p<0.05, then the correlation is statistically significant; proceed to look at r and/or R^2
- r = Correlation Coefficient
  - Negative value = negative correlation (as X gets bigger, Y gets smaller)
  - Positive value = positive correlation (as X gets bigger, Y gets bigger)
  - Close to zero (0) means nearly zero correlation
  - Close to 1 or -1 = close to 100% correlation
  - Correlation Coefficient is not a linear relationship to correlation, for that, use R^2
- R^2 = the square of the Correlation Coefficient (r^2)
- R^2 is always positive, so indicates % correlation, but NOT whether it is positive or negative

Effective Utilization:

Effective Utilization is both a concept and a mathematical formula

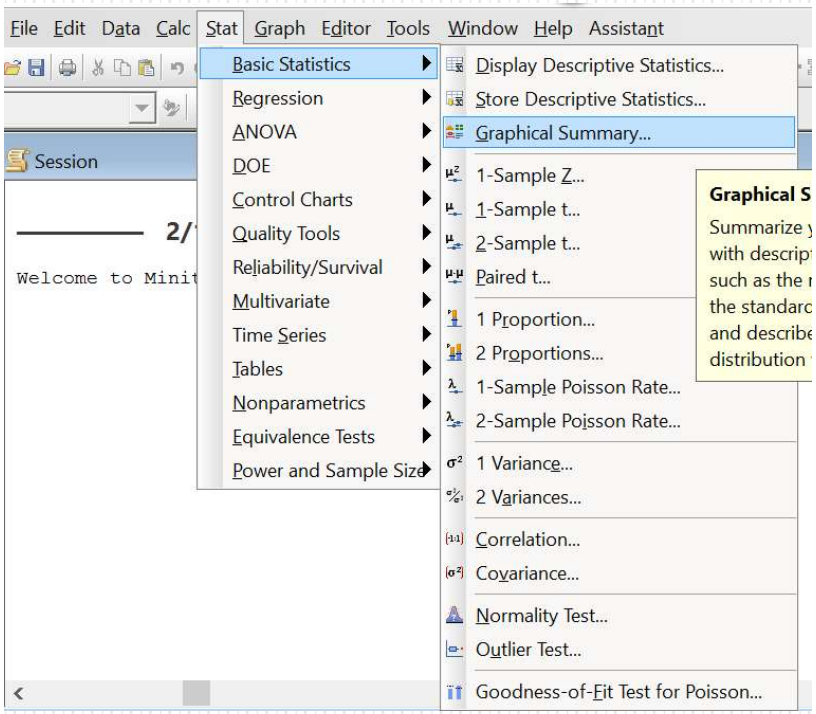
- Formula: Time required to do the work divided by time available
- Key components:
  - Time required to do the work (includes VA and NVA time)
  - Time available to do the work (actual labor time; excludes nights/weekends/non-working time)
- Concept:
  - If effective utilization exceeds 80%, small variations begin to have a big, negative impact on productivity
  - To improve effective utilization, reduce the time it takes to do the work (eg. Eliminate NVA steps) or increase available work time (add a 2nd shift, move part-time employees to full-time, etc.)

Change Agent

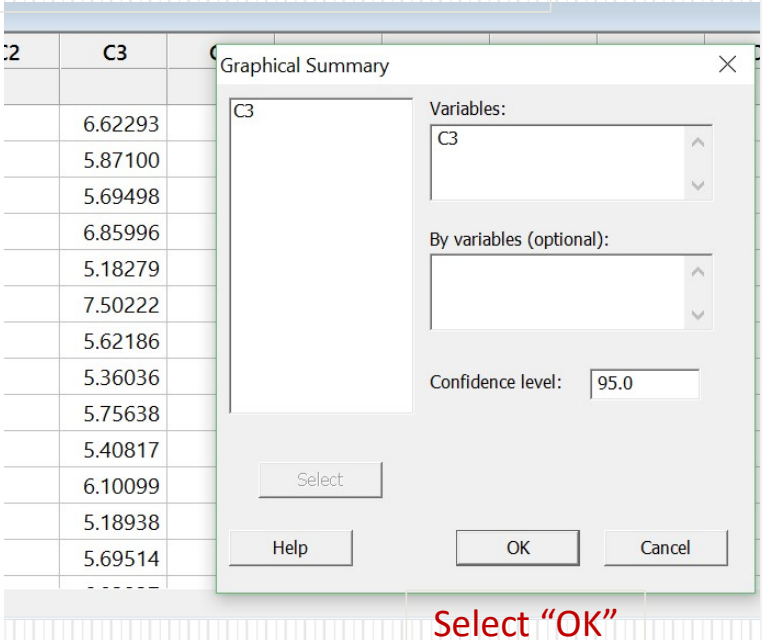
- A Change Agent is more than just a BB or a Champion or a supportive Executive.
- A Change Agent is anyone who consistently strives to improve process performance
- Anyone can be a change agent
- If anyone in a key role on your team is not a Change Agent, your task is to work with them to help them change their perspective to have a positive view of change.
- To effectively facilitate change, you must first effectively facilitate creating change agents!

Minitab Reminders: Normality example: Continuous data

Select Stat> Basic Statistics> Graphical Summary



Select the column where your continuous data is saved



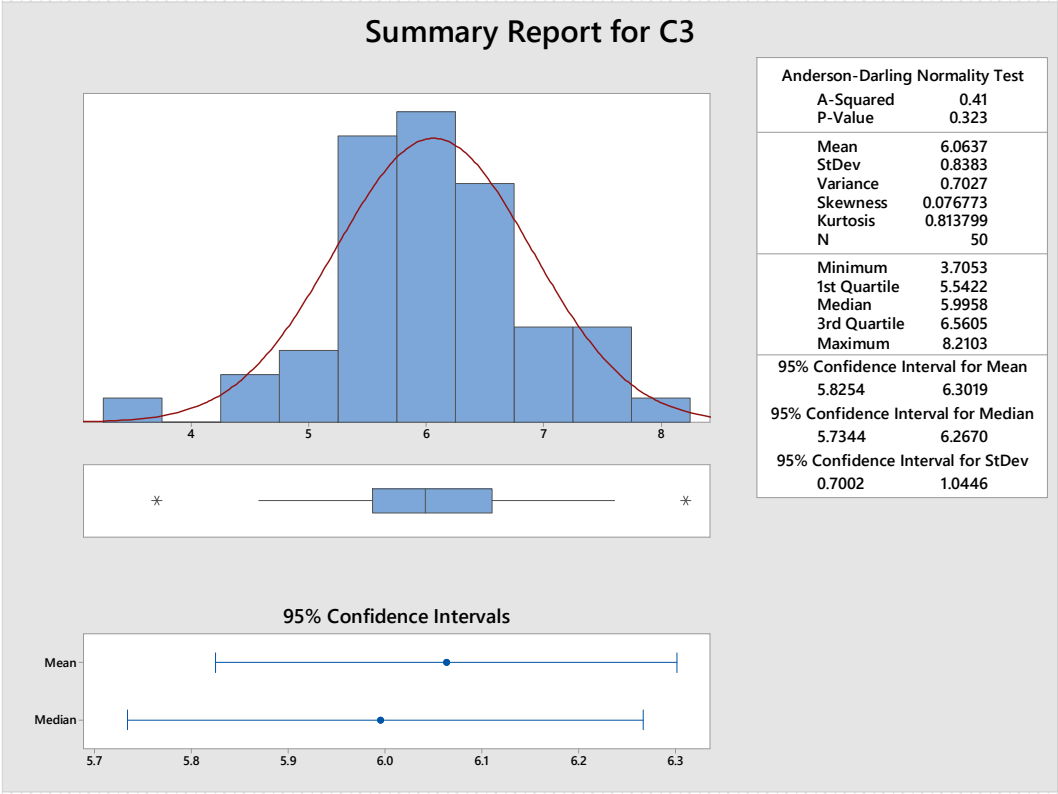
Select "OK"

Minitab Reminders: Normality:

Interpretation:

Is your data normally distributed?

1. When running a normality test, the null hypothesis is always that the data are normally distributed
2. The p-value shows the probability that the null is true. Thus a high p-value means the probability that the null is true (ie. That the data are normally distributed) is also high
3. If p is low, the null must go. Is p-value lower than 5% (ie. Are you 95% sure that the data are NOT normal), then reject the null and accept the alternative that the data are NOT normally distributed
4. In this case, p=0.323. So, since p>0.05, this data set is normally distributed.



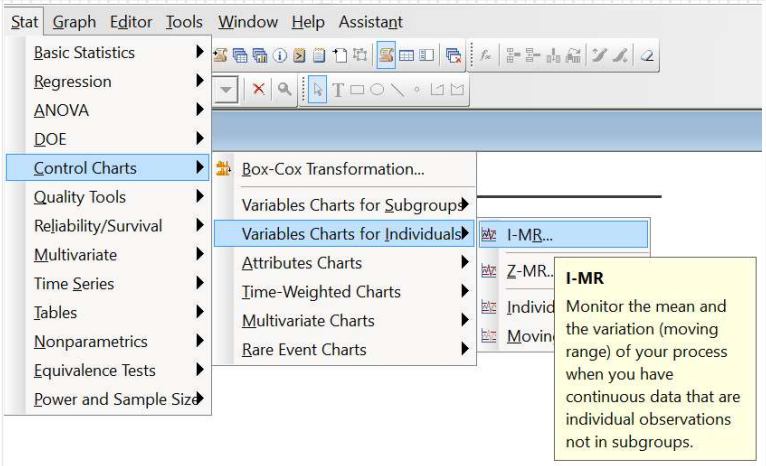
Minitab Reminders: Stability: Same example

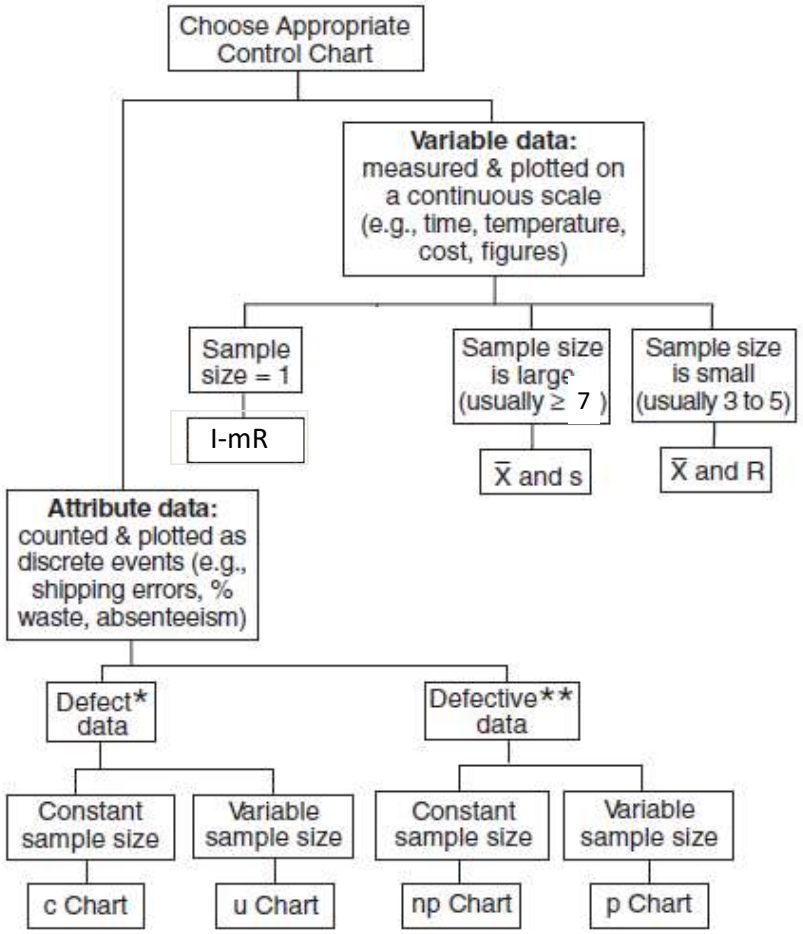
1. Pick your Control Chart

Example: Continuous data, 50 individual values collected in time-order. Therefore:

Variable Data>Sample Size=1> I-mR Chart

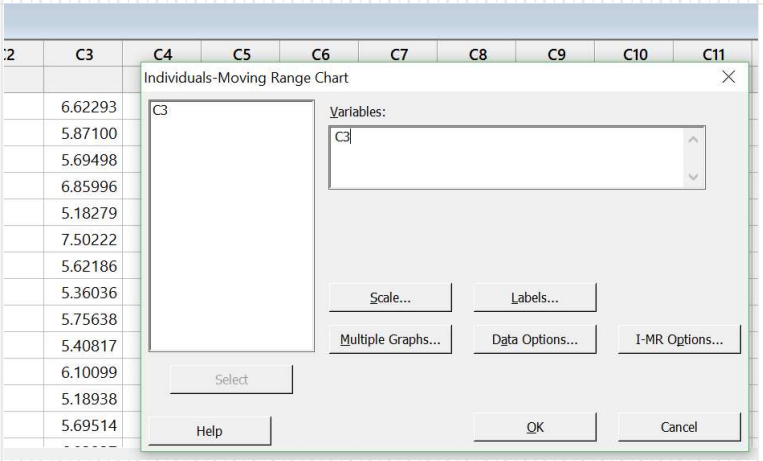
2. Select Stat> Control Charts> Variables Charts for Individuals> I-MR

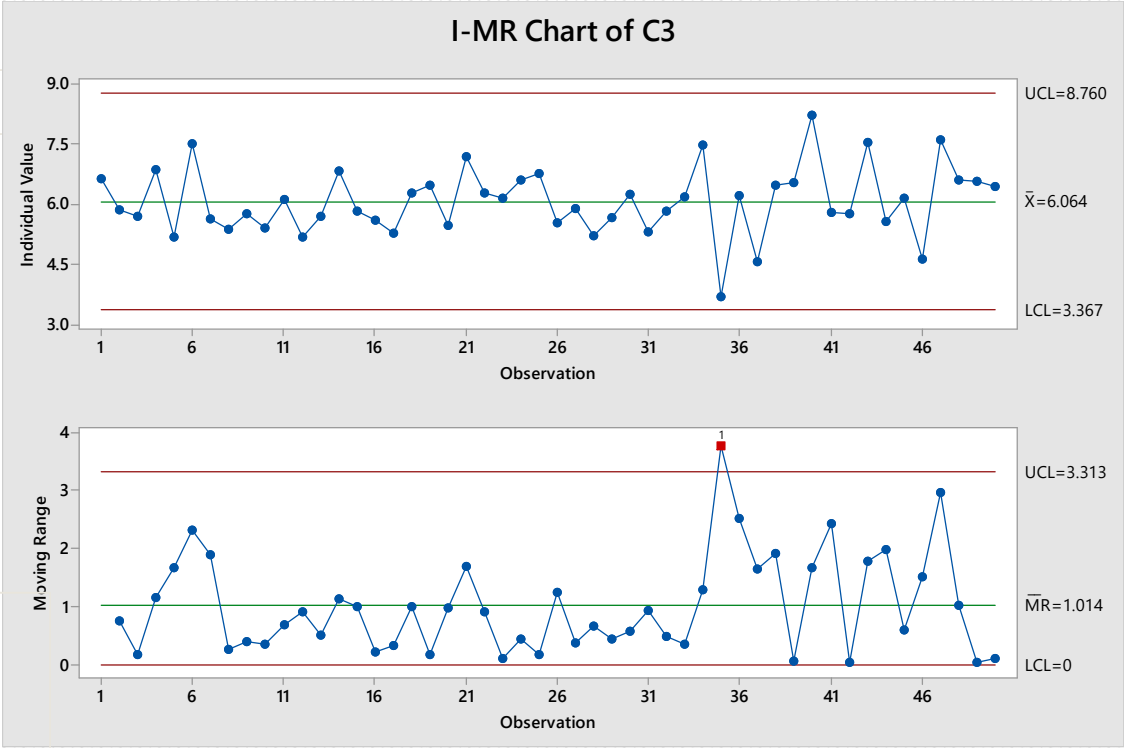




Minitab Reminders: Stability:

3. Select your data and click "OK"





Interpretation

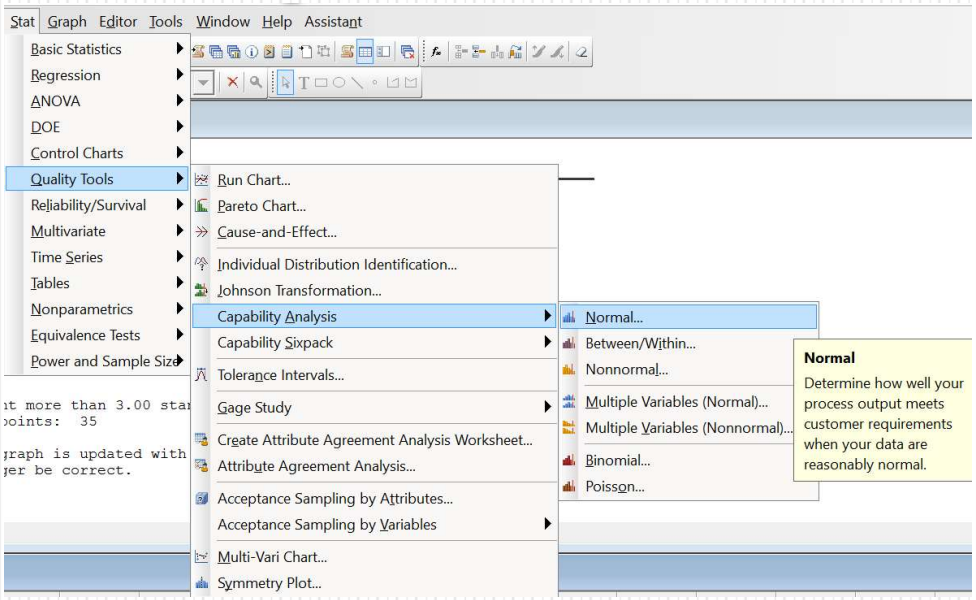
- Individual values appear to be randomly distributed around the mean, with all points between Upper and Lower Control Limits. Good!

- Moving Range chart shows one data point above the Upper Control Limit. This implies that something unusual happened at point 35. Ask the process SMEs what happened that might explain this.

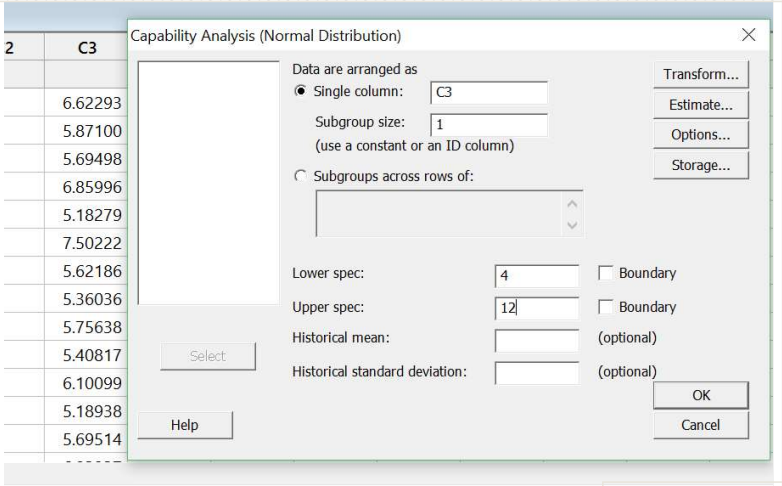
Minitab Reminders: Capability: Same example

- Assume the data represents days to review and submit RFQ documents
- Assume internal target is 8 days plus/minus 3 days

1. Stat> Quality Tools> Capability Analysis> Normal

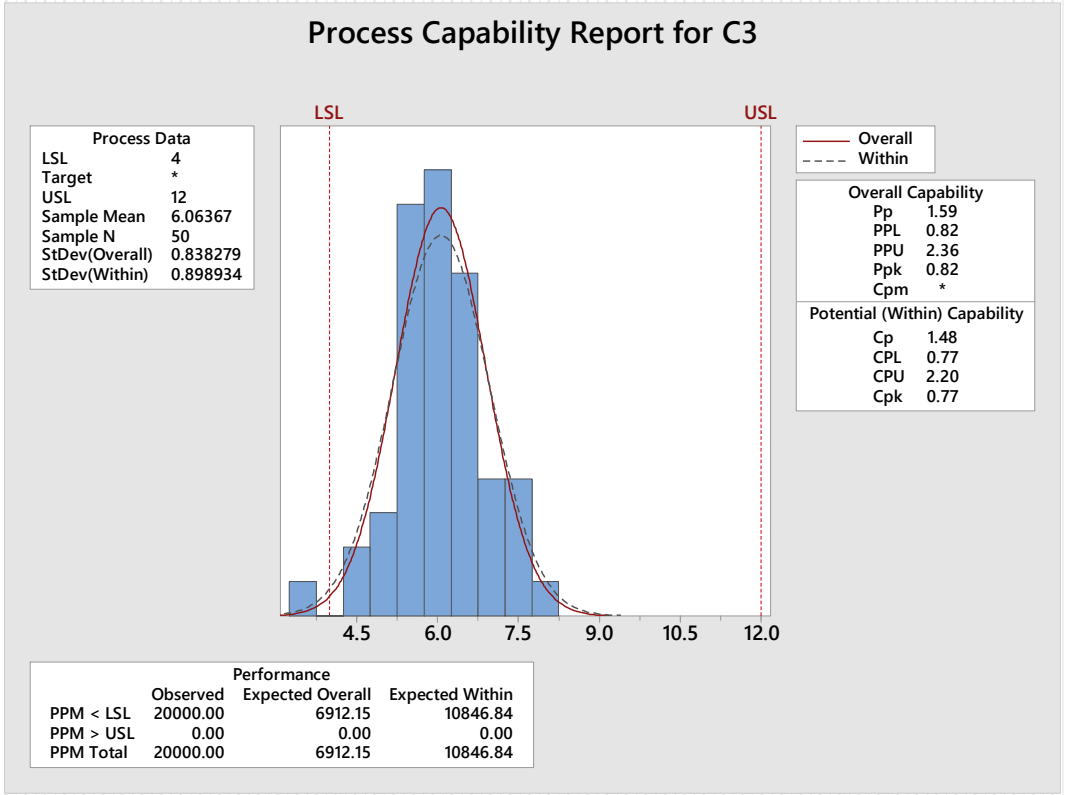


2. Populate the data box with your data column, subgroup size (data were collected as individual values, not in sets, so sub-group size is 1), and USL / LSL values



3. Click "OK"

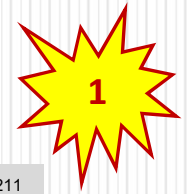
Minitab Reminders: Capability:



Interpretation:

1. Cp = 1.48 (that's good, right?)
2. Cpk = 0.77 (that's bad, right?)
3. Expected performance is 10,846.84 out of spec. (below the Lower Spec Limit of 4 days) for every 1,000,000 RFQ documents reviewed (roughly 1%)

Minitab Reminders:
Hypothesis Testing: Continuous Data

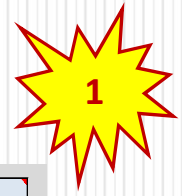


Hypothesis Testing In Minitab

Revision 20160211

Data Type	Measure	# of Samples (levels)	Distribution: Normal (AD>0.05)	Distribution: Not-normal (AD<0.05)*	Exceptions
Continuous (Variable)	Center (Mean or Median)	1 sample (level)	**1-sample t-test** (robust against normality assumption) (Use z-test for samples >30) Stat>Basic Statistics>1-Sample t-test or Stat>Basic Statistics>1-Sample z-test	**1-sample Wilcoxon** (assumes symmetry (symmetric boxplot or, more liberally, w/o outliers)) Stat>Nonparametrics>1-Sample Wilcoxon	Assymmetric distribution / outliers?: **1-sample Sign** Stat>Nonparametrics>1-Sample Sign
		2 samples (levels)	Paired data? See Exception ---> **2-sample t-test** (Use F-test to determine if Variances are equal; if not equal, do not assume equal variances) Stat>Basic Statistics>2-Sample t	Paired data? See Exception ---> Assumes same shape (Visual) & equal variance (2 Variances test) Stat>Basic Statistics>2 Variance Test **2-sample Mann-Whitney** Stat>Nonparametrics>Mann-Whitney	**Paired Data?** Both paired data sets Normally distributed? **Paired t-test**** (extremely robust against assumptions of normality, shape, and differences in variance. May be used as a non-parametric test) Stat>Basic Statistics>Paired t
		3 or more samples (levels)	**ANOVA (plus Tukey)** (robust against normality and equal variances, but recommend checking) Stat>ANOVA>One-way - Select Tukeys comparisons	**Kruskal-Wallis** (assumes non-normal (AD<0.05), no outliers (Boxplot), same shape (Visual) Stat>Nonparametrics>Kruskal-Wallis Note: Based on poisson distribution but works for continuous data	Not normal (AD>0.05) and includes outliers (boxplot)? **Mood's Median** (Assumes same shape (visual / boxplot)) Stat>Nonparametrics> Mood's Median test Note: Based on poisson distribution but works for continuous data
	Spread (Variance or standard deviation)	1 sample (level)	**Chi-Square Method** Stat>Basic Statistics>1 Variance (read p-value from "chi square method")	**Bonett Method** Stat>Basic Statistics>1 Variance (read p-value from "Bonett method")	
		2 samples (levels)	**F-test** Stat>Basic Statistics>2 Variances (read p-value from F-test)	**Levene's test** Stat>Basic Statistics>2 Variances (read p-value from Levene's test)	
		3 or more samples (levels)	**Bartlett's test** Stat>ANOVA>Test for Equal Variances (read p-value from Bartlett's test)	**Levene's test** Stat>ANOVA>Test for Equal Variances (read p-value from Levene's test)	

Minitab Reminders: Hypothesis Testing: Discrete Data

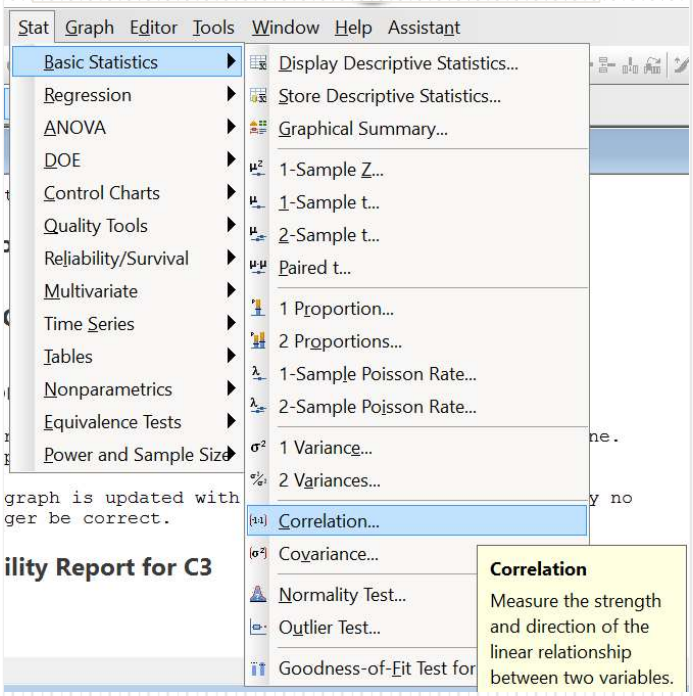


Discrete (Attribute) (Poisson / Count / Ordinal / Defects)	Count	1 sample (level)	**1-sample t-test** (robust against normality assumption) (requires > 5 distinct categories) **Stat>Basic Statistics>1-Sample t-test** **or** **Stat>Basic Statistics>1-Sample z-test**	**1-sample Wilcoxon** (assumes symmetry (symmetric boxplot or, more liberally, w/o outliers), requiers > 5 distinct categories. **Stat>Nonparametrics>1-Sample Wilcoxon**	Assymmetric distribution / outliers? Fewer than 5 distinct categories? No problem! **1-sample Sign** **Stat>Nonparametrics>1-Sample Sign**
		2 samples (levels)	Paired data? See "Exception" --->**2 Sample t-test** (Caution: No extreme outliers! (**Graph>Box Plot**) **Stat>Basic Stats>2-sample Poisson Rate** Based on continuous distribution, but appropriate for poisson data	Paired data? See "Exception" --->Same shape & Variance? **2-sample Mann-Whitney** **Stat>Nonparametrics>Mann-Whitney** Different shape or Variance? Hmmm….	**Paired Data?** Normal data not required Same shape not required Same variance not required **Paired t-test**** (robust against normality, shape, and differences in variance) **Stat>Basic Statistics>Paired t**
		3 or more samples (levels)	**One-Way ANOVA** Caution: No extreme outliers! Check boxplot) **Stat>ANOVA>One-way** Note: One-way ANOVA presumes one X factor with 3 or more levels. Rarely, we may have two X factors, where at least one of the factors has at least three factors. In these cases, use Two-way ANOVA or DOE.	**Kruskal-Wallis** Assumes no outliers (check boxplot) Assumes same shape (visual check) **Stat>Nonparametrics>** **Kruskal-Wallis** Note: This is a Poisson distribution test often used for non-normal continuous data without outliers	Includes outliers? No problem! **Mood's Median** Robust against outliers Assumes same shape **Stat>Nonparametrics>** **Mood's Median test** Note: This is a Poisson distribution test often used for non-normal continuous data with outliers

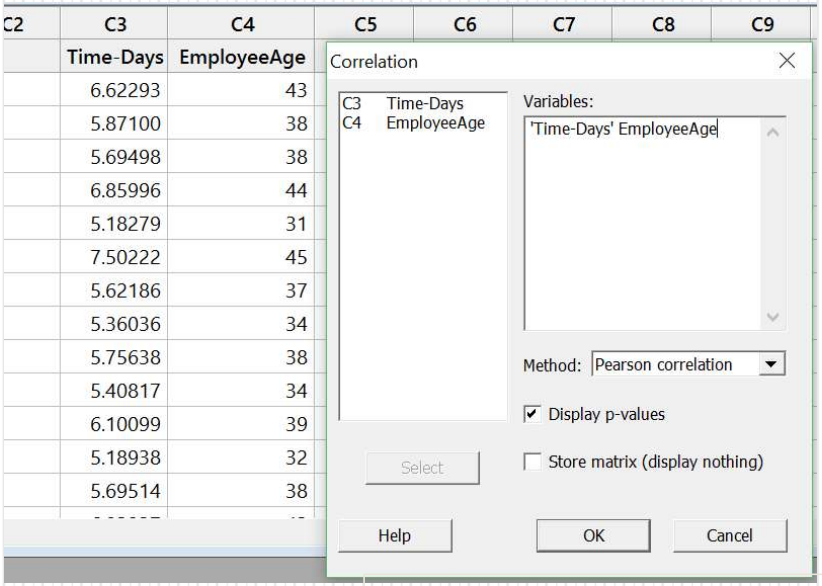
Discrete (Attribute) (Binomial / go/no-go / defective)	Proportion	1 sample (level)	**1-Proportion test** **Stat>Basic Statistics>1-Proportion**
		2 samples (levels)	**2-Proportion test** **Stat>Basic Statistics>2-Proportion** **- Select Options>pooled p**
		3 or more samples (levels)	**Chi-Square test** **Stat>Tables>Chi-square Goodness of Fit Test (one variable)**

Minitab Reminders: Correlation:

Stat> Basic Statistics> Correlation



Select your X and Y factors



Click “OK”

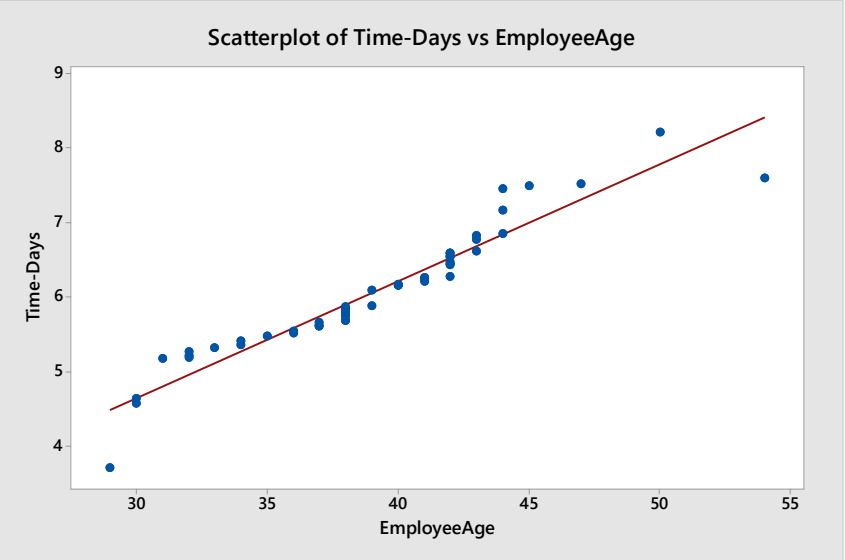
Minitab Reminders: Correlation:

Interpretation:

Correlation: Time-Days, EmployeeAge

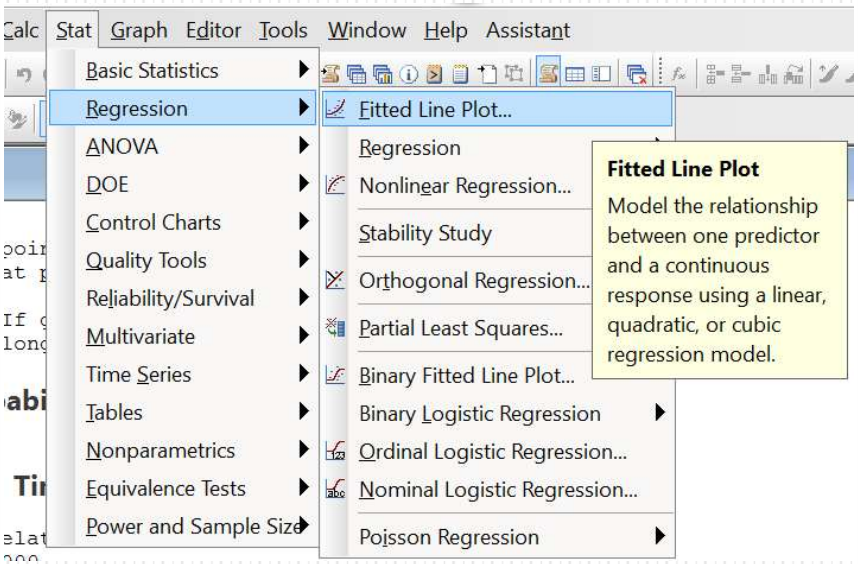
Pearson correlation of Time-Days and EmployeeAge = 0.954
P-Value = 0.000

1. If p-value is > 0.05, the correlation is not statistically significant, so no significant correlation exists
2. If p-value is <0.05, the correlation is statistically significant, so a significant correlation does exist
3. Since p=0.000, there is a statistically significant correlation between X and Y
4. Pierson correlation coefficient (r) = 0.954, therefore there is a very strong positive correlation between X-value (age of employee) and Y-value (time to complete RFQ reviews)

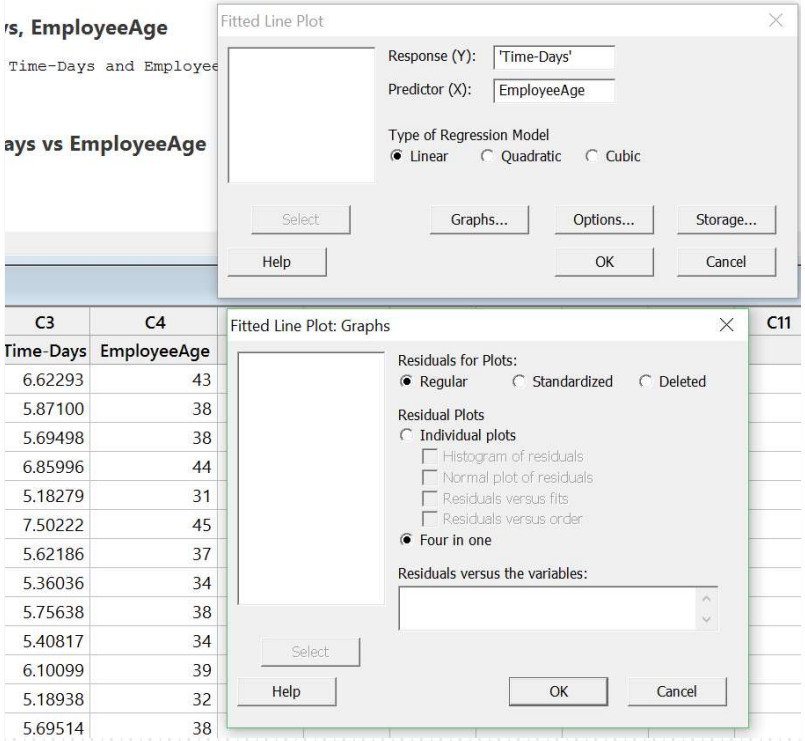


Minitab Reminders: Regression:

Stat> Regression> Fitted Line Plot



Enter your Y and X values
Select Graphs and choose "Four in One"



C3	C4
Time-Days	EmployeeAge
6.62293	43
5.87100	38
5.69498	38
6.85996	44
5.18279	31
7.50222	45
5.62186	37
5.36036	34
5.75638	38
5.40817	34
6.10099	39
5.18938	32
5.69514	38

Click "OK" and "OK"

Minitab Reminders: Regression:

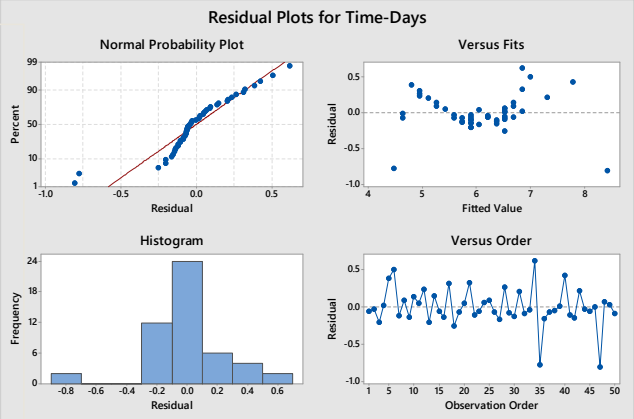
Regression Analysis: Time-Days versus EmployeeAge

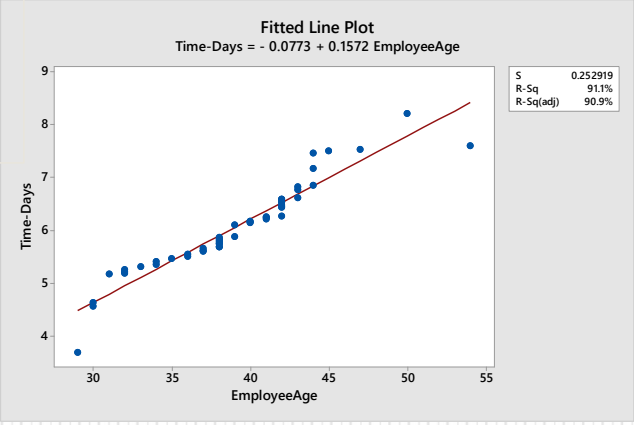
The regression equation is
Time-Days = - 0.0773 + 0.1572 EmployeeAge

S = 0.252919 R-Sq = 91.1% R-Sq(adj) = 90.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	31.3624	31.3624	490.28	0.000
Error	48	3.0705	0.0640		
Total	49	34.4328			



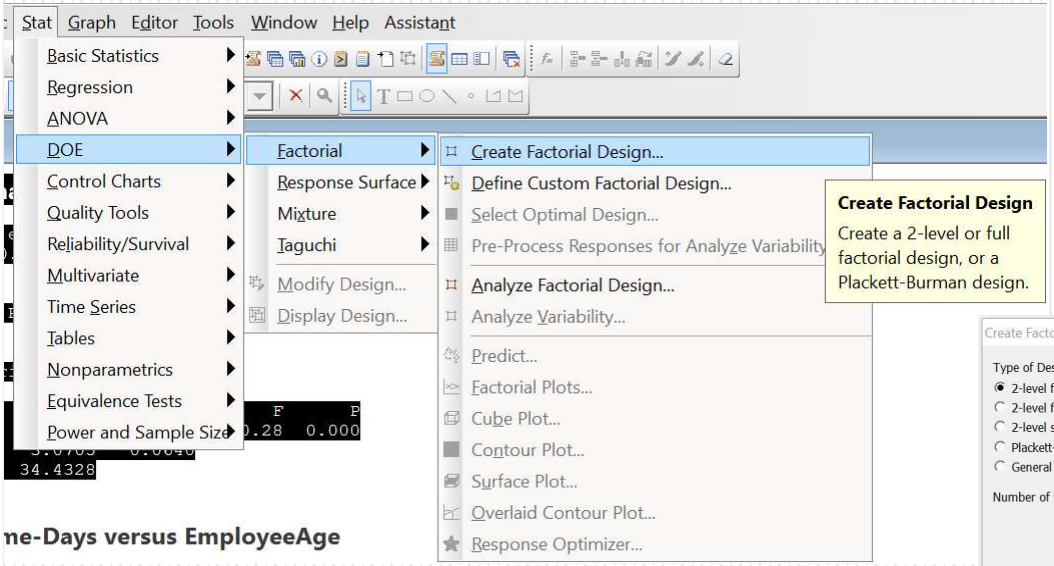


Interpretation:

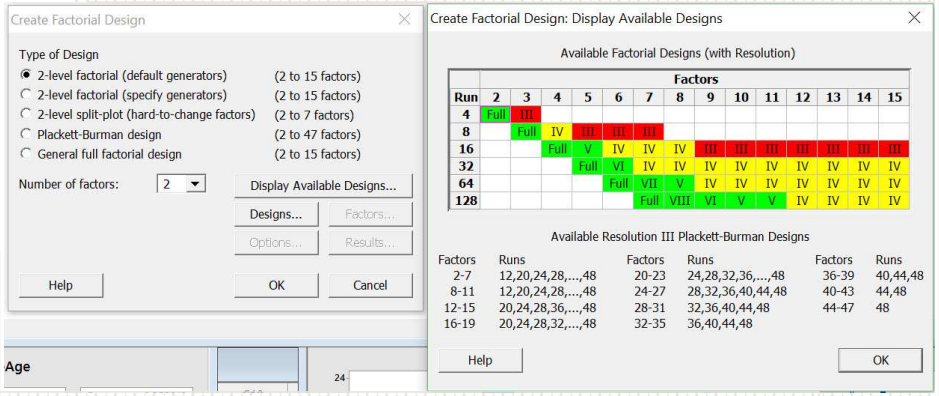
- If P.0.05, stop. There is no significant X-Y relationship
- If p<0.05, there is a statistically significant relationship between X and Y
- R-sq (R^2) shows the amount of variation in Y that can be correlated to variation in X. In this example, 91.1% of the variation in production time correlates to the age of the employee doing the review.
- The residual plot shows distance of each individual X-Y value from the predicted line. If the residuals don't appear to be normal, there may be a non-linear relationship. Call your MBB!

Minitab Reminders:
Design of Experiments:

Stat> DOE> Factorial> Create Factorial Design



Select number of factors you want
If required, select an appropriate fractional design
(for screening DOEs, ensure Resolution > 3)



Enter your factors and levels, then select “OK”