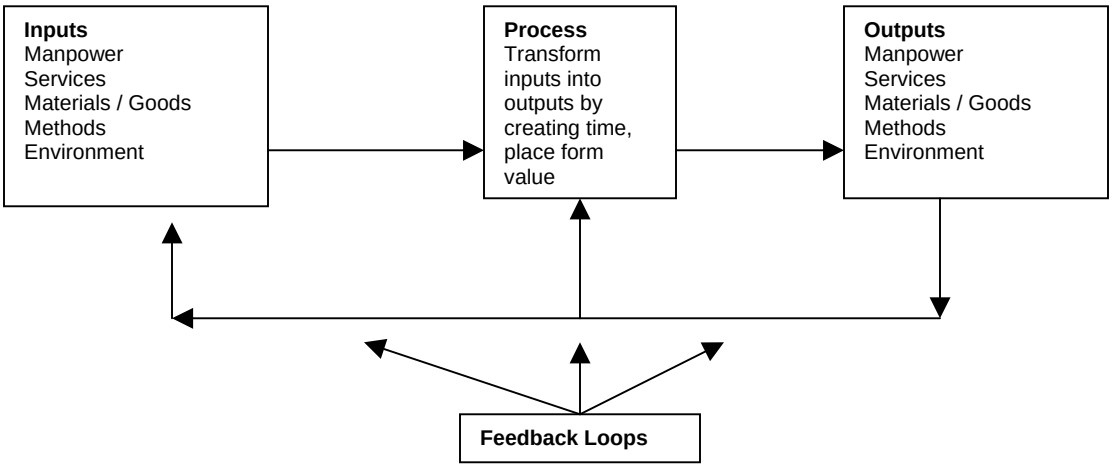
Sample Green Belt Certification Examination Questions with Answers

(Green Belt certification examinations assume that that the participant has successfully completed the Champion certification examination at the University of Miami. This section only presents questions beyond the Champion certification level. However, Green Belt certification examinations are cumulative in that they cover the material required for both Champion and Green Belt certification.)

QUESTION: Provide a non-technical definition for "Six Sigma" management.
Answer: It is an organizational initiative designed to create breakthrough improvements in manufacturing, service and administrative processes. For example, Motorola established a goal to reduce defects 10-fold with a 50% reduction in cycle time every 2 years.

QUESTION: Define a process. Draw a picture.
Answer: A process is the vehicle for transforming inputs into outputs, see figure below. Feedback loops are used to move data to appropriate points in the process for decision making purposes.

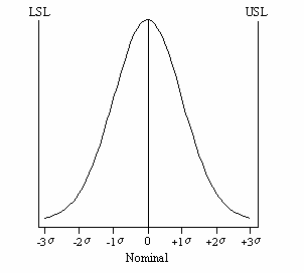
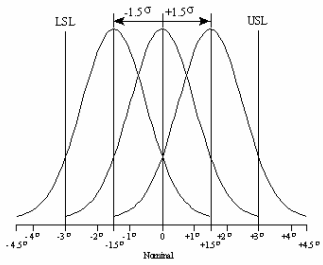


QUESTION: Describe the three types of feedback loops. (None, Special only, Common and Special cause)
Answer:

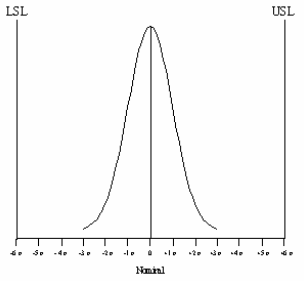
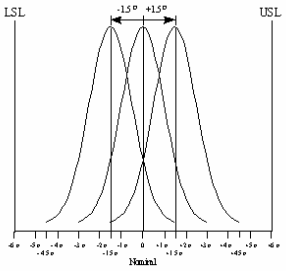
- *No feedback loop: A process without a feedback loop will deteriorate and decay due to entropy.*
- *Special cause only feedback loop: A process in which all feedback is treated as special will exhibit a doubling or explosion in the variation of its output.*
- *Special and common cause feedback loop: A process in which feedback is statistically recognized as common or special will experience improvement of its output.*

QUESTION: Explain the origin of the "6" and "3.4" in Six Sigma management. Use a diagram that includes the Voice of the Customer and the Voice of the Process.

Answer:

Voice of Customer equals Voice of Process *- Process is stable and centered on nominal.* *- 0.0 sigma shift in the mean results in 2,700 DPMO.*	*Voice of Customer equals Voice of Process* *- Process is stable.* *- 1.5 sigma shift in the mean results in 66,807 DPMO.*
	

Through the continuous process improvement, the variation of process is reduced. Thus, the relationship between Voice of Customer and Voice of Process moves to a better level, Voice of Process is half the Voice of Customer, that is --- the process improves from a 3-sigma process to a ***6****-sigma process.*

Voice of Process is half Voice of Customer *- Process is stable and centered on nominal.* *- 0.0 sigma shift in the mean results in 2 defects per billion opportunities.*	*Voice of Process is half Voice of Customer* *- Process is stable.* *- 1.5 sigma shift in the mean results in* ***3.4 DPMO.***
	

QUESTION: Describe the roles and responsibilities of a process owner.

Answer:

1. *A Process Owner has the authority to change a process.*
2. *A Process Owner should be identified and designated early in a Six Sigma project.*
3. *A Process Owner is responsible for managing and holding the gains for the improved process, and for improving and innovating the process in the future.*
4. *A Process Owner empowers people in the process.*
5. *A Process Owner works with the project team. (This can also be a champion role.)*
6. *A Process Owner coordinates team logistics. . (This can also be a MBB or BB role.)*
7. *A Process Owner negotiates resources for team. . (This can also be a champion role.)*
8. *A Process Owner links process and organizational objectives.*

A Process Owner understands their process' capability and its relationship to the organization.

9. *A Process Owner ensures that customer's needs take priority. (This is also mainly the responsibility of the top executives of an organization.)*
10. *Process owner optimizes the entire process, not just component of the process.*

QUESTION: Describe the roles and responsibilities of a champion.

Answer:

1. *A Champion should be a member of the Executive Committee, or at least a trusted direct report of a member of the Executive Committee. Champions take a very active sponsorship and leadership role in implementing Six Sigma projects.*
2. *A Champion translates strategic measures into a project (coordinates with Executive Committee).*
3. *A Champion selects the team leader.*
4. *A Champion develops and negotiates the project charter.*
5. *A Champion removes obstacles to the project.*
6. *A Champion obtains resources and helps the team control the budget.*
7. *A Champion reviews team progress.*
8. *A Champion helps keep the team focused.*
9. *A Champion assures use of Six Sigma methods and tools.*
10. *Champion is the liaison between executive management and the project leader.*

QUESTION: Describe the roles and responsibilities of a black belt.

Answer:

1. *A Black Belt is a full-time change agent who may not be an expert in the process under study.*
2. *A Black Belt serves as team leader.*
3. *A Black Belt is a master of the DMAIC model.*
4. *A Black Belt provides guidance and training to team members.*
5. *A Black Belt helps the team refine a project charter (assumes Champion / Process Owner drafted the initial charter)*
6. *A Black Belt interfaces with the champion and MBB.*
7. *A Black Belt leads the project team.*
8. *A Black Belt helps the team analyze data and design experiments.*
9. *A Black Belt provides training in tools and team functions.*
10. *A Black Belt helps the team prepare for reviews.*
11. *A Black Belt recommends strategic Six Sigma projects.*
12. *A Black Belt leads and coaches Green Belts leading lower-level teams.*

QUESTION: Describe the roles and responsibilities of a Green Belt.

Answer:

1. *A Green Belt is a part-time (25%) project leader or member and provides most of the functions of a Black Belt (team leader) for lower-level project teams.*
2. *Green Belts are the "work horses" of strategic Six Sigma Management efforts. Most managers should be or become Green Belts.*
3. *For lower level teams, a Green Belt*

- *Refines a draft project charter (process owners and champions should coauthor the first draft)*
- *Reviews the draft charter with Champion*
- *Selects team members*
- *Facilitates the team*
- *Communicates with the Champion and other stakeholders of the process*
- *Analyzes data*
- *Provides training in basic tools*
- *Coordinates team efforts with higher level teams*
- *Completes documentation*
- *Completes the control plan*
- *Spreads the lessons learned*

QUESTION: Describe the roles and responsibilities of a Master black belt

Answer: A Master Black Belt is a proven leader and change agent for Six Sigma management. A Master Black Belt provides technical expertise in Six Sigma management.

1. *Teaches Black Belts and Green Belts.*
2. *Mentors Black Belts and Green Belts.*
3. *Coordinates several Black Belt projects simultaneously.*
4. *Improves and innovates the Six Sigma process.*
5. *Counsels top management on Six Sigma management.*

QUESTION: Create a service example to explain rolled throughput yield, DPO, DPMO, process sigma.

Answer: A service has 4 steps and each step has only one opportunity for a defect. The yield of step 1 is 0.99, the yield of step 2 is 0.95, the yield of step 3 is 0.99, and the yield of step 4 is 0.97. The four steps are independent of each other. What is the rolled throughput yield (RTY), the DPO, the DPMO, and the process sigma?

RTY=.99x.95x.99x.97=.903

DPO=1.0-RTY=.097

DPMO=97,000

Process Sigma=approx 2.8

QUESTION: Construct a table that shows how to prioritize potential Strategic Six Sigma projects based on their relationships with business objectives. Explain how the table functions to accomplish its aim.

Answer:

				Six Sigma Project			
				Project 1	Project 2		Project 11
B O	BO1	WEIGHTS	W1				
	BO2		W2				
					1=weak		
	BOm		Wm		3=moderate		
	Weighted Average of CTQs				9=strong		

- *W_is are developed by the Finance Department. The sum of W_i = 1.0.*
- *Cell values are determined by team members with the strong guidance of the finance department.*

The weighted averages that are shown in the last row of the columns are ranked from smallest to largest. The largest average is considered the highest priority project. Alternatively, a control chart could be used to find a project with a weighted average that is out of control on the high side from the other project's averages.

QUESTION: Give an example of a project charter. Label each of the 5 parts of the project charter.
Answer: Decrease (direction) of the number of customer complaints (CTQ measure) caused by at-home repairs (process) from 20 per day to 0 per day (CTQ target) by March 1, 2004 (deadline).

QUESTION: Explain the term "SIPOC analysis." Construct a chart to illustrate your explanation.
*Answer: A SIPOC analysis is a simple tool for identifying the **S**uppliers and their **I**nputs into a **P**rocess, the high level steps of a process, the **O**utputs of the process, and the **C**ustomers (market) segments interested in the outputs.*

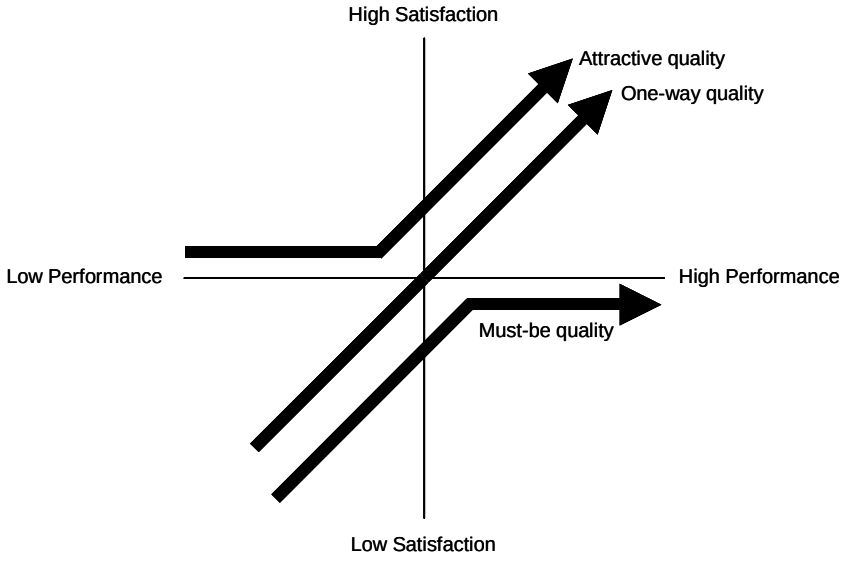
QUESTION: Define "CTQ." Relate your answer to a SIPOC analysis.
Answer: CTQ stands for Critical to Quality characteristic. It is a characteristic of a process, product or service that is critical to the satisfaction of a stakeholder.

QUESTION: Define "*X*" in respect to a SIPOC analysis.
Answer: Xs are the inputs and process steps that cause variation in the outputs of a process (CTQs).

QUESTION: What is the tactic of Six Sigma management in respect to *X*s?
Answer:
- Define vital few Xs
- Identify level of critical Xs
- Select best actions needed to implement levels of critical Xs
- Implement critical Xs and test for best levels of critical Xs that minimize variation in the CTQs

\QUESTION: Define must-be, one way, and attractive quality that can result from a Kano survey. Make sure your answer is based on the dimensions of performance and satisfaction. Draw a picture to illustrate your explanation.
Answer:
Must-be- User satisfaction is not proportional to the performance of the feature. The lower the performance, the lower the user satisfaction, but high performance creates feelings of indifference to the feature.
One-way - User satisfaction is proportional to the performance of the feature; the less performance the less user satisfaction, and the more performance, the more user satisfaction.

<u>Attractive -</u> User satisfaction is not proportional to the performance of the feature; low levels of performance create feelings of indifference to the feature, but high levels of performance create feelings of delight to the feature.



QUESTION: Provide an example of a question on a Kano survey.
Answer:

Column 1	*Column 2*	*Column 3*	*Column 4*
CTQs	*How would you feel if the following CTQ were **present**?*	*How would you feel if the CTQ were **not present**?*	*What percentage cost increase, over current costs, would you be willing to pay for this CTQ?*
Study Center in the dormitory	*Delighted [ ]* *Expect it and like it [ ]* *No feeling [ ]* *Live with it [ ]* *Do not like it [ ]* *Other [ ]*	*Delighted [ ]* *Expect it and like it [ ]* *No feeling [ ]* *Live with it [ ]* *Do not like it [ ]* *Other [ ]*	*0% _____* *10% _____* *20% _____* *30% _____* *40% or more _____*

QUESTION: Give examples of classification attribute data. Explain why each example is classification attribute data.
Answer: Examples of classification attribute data: classifying employees by department, classifying cars by makers, and so on. Each example is classification attribute data because items are classified into one of two or more categories.

QUESTION: Give examples of count (area of opportunity) attribute data. Explain why each example is area of opportunity attribute data.
Answer: Examples of count attribute data: number of union grievances per week, number of type errors in a page, number of chocolate chips in a cookie. Each example is count attribute data because it is from counts of the number of occurrences per unit.

QUESTION: Give examples of measurement data. Explain why each example is measurement data.
Answer: Examples of measurement data: cycle time, weight, and temperature. Measurement data are continuous data.

QUESTION: What is the purpose of an operational definition.
Answer: An operational definition promotes effective communication between people by putting communicable meaning into an adjective.

QUESTION: Create an operational definition for "12 pound bar" that results in attribute data.
Answer:
Criteria: Select a bar from inventory. Place it on a digital scale. If the digital readout is between 11.999 and 12.001, inclusive, then the bar is classified as 12 pounds. If the digital readout is not between 11.999 and 12.001, inclusive, then the bar is classified as not 12 pounds.
Test: Select a particular bar and put it on the scale. Record the digital readout.
Decision:
If 11.999 ≤ digital readout ≤ 12.001, then bar = 12 pounds.
If digital readout < 11.999 or digital readout >12.001, then bar ≠ 12 pounds.

QUESTION: Create an operational definition for "12 pound bar" that results in measurement data.
Answer:
Criteria: Use a digital scale to weigh a bar.
Test: Select a particular bar and put it on the digital scale. Record the digital readout.
Decision: Use bar based on digital readout.

QUESTION: A customer wants to buy chocolate bars with a nominal weight of 6.0 ounces and will accept a tolerance of 0.05 ounces either side of nominal. As a supplier of chocolate bars you want to understand your process. Your process produces chocolate rectangles that are cut from larger blocks of chocolate and then packaged as six-ounce bars. Every 15 minutes, three chocolate bars are weighed, prior to packaging. The chart below shows the weights for each bar examined in a seven-hour day.

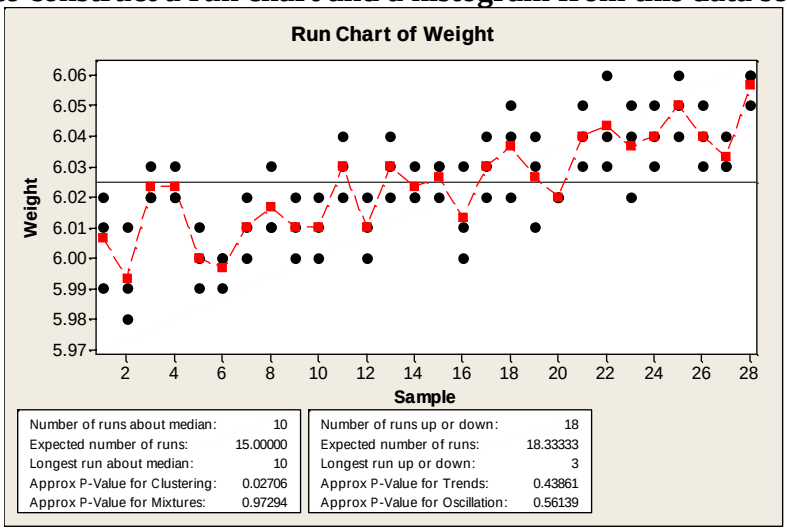
Time	Observation #	Weight (oz)
9:15	1	6.01
	2	5.99
	3	6.02
9:30	1	5.98
	2	5.99
	3	6.01
9:45	1	6.03
	2	6.02
	3	6.02
	1	6.02

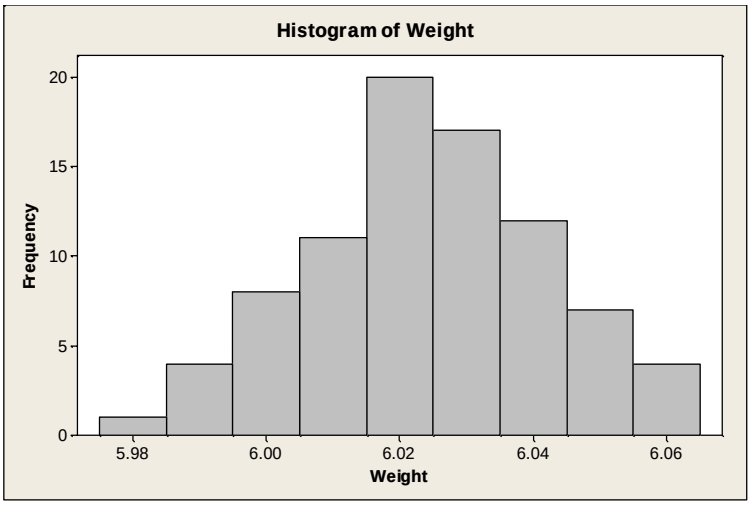
10:00	2	6.03
	3	6.02
10:15	1	6.00
	2	5.99
	3	6.01
10:30	1	5.99
	2	6.00
	3	6.00
10:45	1	6.02
	2	6.01
	3	6.00
11:00	1	6.01
	2	6.03
	3	6.01
11:15	1	6.01
	2	6.02
	3	6.00
11:30	1	6.00
	2	6.02
	3	6.01
11:45	1	6.04
	2	6.02
	3	6.03
12:00	1	6.02
	2	6.01
	3	6.00
12:15	1	6.03
	2	6.02
	3	6.04
12:30	1	6.02
	2	6.02
	3	6.03
12:45	1	6.03
	2	6.02
	3	6.03
1:00	1	6.03
	2	6.00
	3	6.01
1:15	1	6.04
	2	6.02
	3	6.03
1:30	1	6.05
	2	6.02
	3	6.04
1:45	1	6.03
	2	6.04

	3	6.01
2:00	1 2 3	6.02 6.02 6.02
2:15	1 2 3	6.04 6.05 6.03
2:30	1 2 3	6.06 6.03 6.04
2:45	1 2 3	6.05 6.04 6.02
3:00	1 2 3	6.05 6.04 6.03
3:15	1 2 3	6.04 6.06 6.05
3:30	1 2 3	6.05 6.03 6.04
3:45	1 2 3	6.03 6.04 6.03
4:00	1 2 3	6.06 6.06 6.05

Answer:

Use Minitab to construct a run chart and a histogram from this data set.

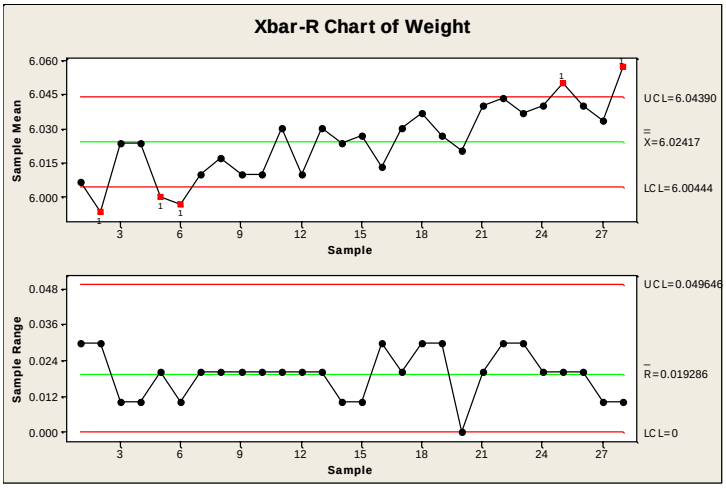




Interpret the charts. What conclusions about the distribution of the weights can you reach based on these charts?

Answer: The histogram shows that the most of chocolate bars weigh more than 6.00 ounces. The run chart shows that the observed weights plotted over time have upward drift in the weights of chocolate bars throughout the day. The run chart also indicates the need for action on the process.

Use Minitab to construct an $\bar{X}$ and R-chart from this data set. Is the process stable? If no, at what times is it unstable?



No, when 9:30am, 10:15am, 10:30am, 3:15pm and 4:00pm.

What is the overall process mean?

6.024

What is the estimate of the process standard deviation?

$(0.019286/d_2) = (0.019286/1.693) = 0.01139$.

Show the formula you used to estimate the process standard deviation.

$(\bar{R} \div d_2)$

Why did you use this formula versus another formula?

$(\bar{R} \div d_2)$ was used instead of the formula for the sample standard deviation because $(\bar{R} \div d_2)$ considers only short term variation, while the formula for the sample standard considers long term variation. $(\bar{R} \div d_2)$ assumes that the process is stable. If the process

is not stable, the out of control points will jump out of the control limits based on ($\overline{R} \div d_2$). The ($\overline{R} \div d_2$) limits are tighter than limits based on the sample standard deviation.

State the LSL and USL for the above process.

LSL = 5.95 and USL = 6.05

Calculate the actual process yield using the empirical data.

80 ÷ 84 = 0.952

Calculate the theoretical process yield using the normal distribution. Is this a reasonable calculation? If yes, why? If no, why not?

Z_{LSL}= (5.95 – 6.024)/ 0.01139 = -6.4969, hence, P(X < -6.4969) = 0.0000

Z_{USL}= (6.05 – 6.024)/ 0.01139 = 2.2827, hence, P(X > -2.2827) = 0.0112

P (5.95 ≤ X ≤ 6.05) = 0.0000 + 0.0112 = 0.0112

The above calculation is not reasonable because the process is not in statistical control.

Compute the actual DPMO from the empirical data.

DPO = 1 – RTY = 1 – 0.952 = 0.048

DPMO = 1,000,000 x DPO = 1,000,000 x 0.048 = 48,000 DPMO

Compute the theoretical DPMO using the normal distribution. Is this a reasonable calculation? If yes, why? If no, why not?

DPO = 0.0112

DPMO = 1,000,000 x 0.0112 = 11,200

The DPMO calculation is not reasonable because the process is not stable at this time.

Compute the Process Sigma. Which DPMO should you use? Why?

Process sigma assuming a 1.5 sigma shift in the mean for the empirical DPMO of 11,200 is 3.1 to 3.2.

Process sigma assuming a 1.5 sigma shift in the mean for the theoretical DPMO of 48,000 is 3.7 to 3.8.

Neither DPMO should be used because the process is not stable. A process sigma calculation is not appropriate for this process at this time.

QUESTION: Construct a control chart from the following data.

Day	Number of Entries Inspected	Number of Defective Entries	Fraction of Defective Entries
1	200	6	0.03
2	200	6	0.03
3	200	6	0.03
4	200	5	0.025
5	200	0	0
6	200	0	0
7	200	6	0.03
8	200	14	0.07
9	200	4	0.02
10	200	0	0
11	200	1	0.005
12	200	8	0.04
13	200	2	0.01
14	200	4	0.02
15	200	7	0.035
16	200	1	0.005

17	200	3	0.015
18	200	1	0.005
19	200	4	0.02
20	200	0	0
21	200	4	0.02
22	200	15	0.075
23	200	4	0.02
24	200	1	0.005
Totals	4800	102	

Answer:

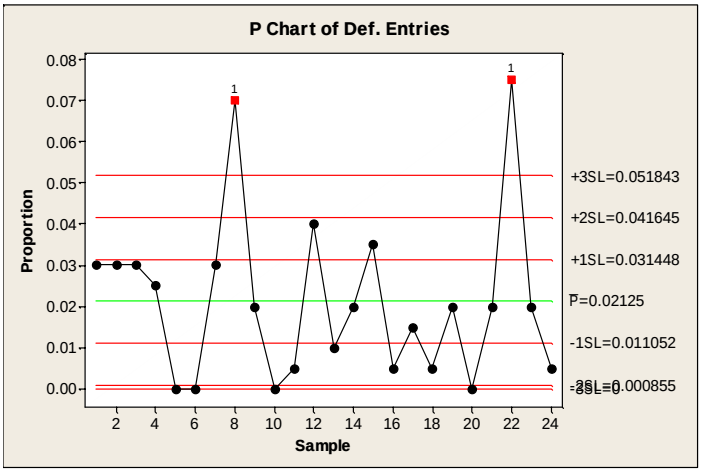
What type of data is in the above matrix?

Classification type attribute data

What type of control chart should be used to study the above data?

p chart with constant subgroup size

Use Minitab to construct a control chart for the above data.



Is the process stable? If not, on what days is it not stable?

Days 8 and 22 are beyond the upper control limit.

QUESTION: Analyze the following data set using a control chart.

Monthly accident data is listed across the rows for 36 months

25 22 22 14 21 14 19 17 13 22 18 22 23 26 21
26 15 26 16 31 19 16 27 24 13 22 24 24 25 22
17 27 24 22 24 21

Answer:

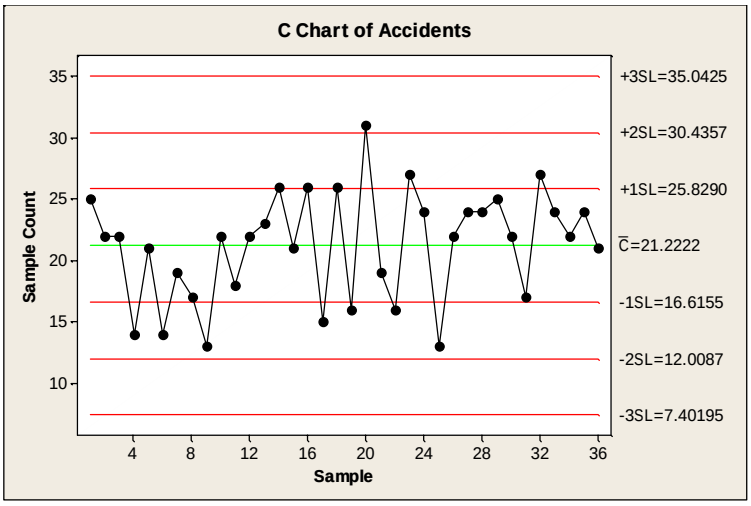
What type of data is in the above matrix?

Count type attribute data

What type of control chart should be used to study the above data?

c-chart

Use Minitab to construct a control chart for the above data.



Is the process stable? If not, in what months is it not stable?

Yes

QUESTION: Construct a control chart for the following 3 years of weekly sales data for the Latin American Division of a hospital supply company.

Weekly Hospital Supply data is listed across the rows for 3 years

20 ,594.0	39,447.7	34,884.9	30,895.5	24,420.5	25,774.4	21,847.8
32,095.5	37,328.1	26,053.5	34,475.1	23,539.9	29,721.0	36,508.4
31,972.7	20,496.3	31,970.9	21,406.3	20,123.7	25,977.4	22,057.3
29,258.7	27,054.7	19,044.3	19,096.2	12,629.3	21,780.3	8,161.7
29,876.2	30,136.4	26,456.7	30,099.8	20,265.1	30,219.2	18,621.7
30,116.9	22,898.7	23,167.3	12,889.2	22,943.3	26,445.9	17,671.1
22,689.7	32,186.2	27,144.3	40,109.7	23,210.1	24,863.2	16,859.6
23,640.8	32,579.6	16,155.0	29,424.0	19,994.2	37,201.9	36,673.1
24,034.6	20,082.6	31,597.9	12,122.8	15,737.4	35,017.2	16,550.8
19,720.4	21,028.6	22,531.0	29,792.0	17,870.4	25,190.8	26,550.6
13,394.4	29,292.0	29,478.6	11,839.4	26,331.7	29,647.5	24,929.8
24,959.7	6,594.5	17,086.2	4,945.2	23,232.7	17,871.3	22,874.1
28,181.8	26,110.9	18,595.0	28,770.3	18,607.7	38,645.3	21,746.6
23,092.9	32,058.7	31,578.4	29,364.7	6,872.8	13,886.7	38,049.8
32,245.3	26,072.7	27,118.6	24,881.4	27,277.2	30,522.2	33,493.6
35,899.3	27,833.8	20,321.1	36,236.4	29,992.1	25,029.5	23,004.0
33,282.1	28,741.1	17,702.2	25,963.0	13,915.7	25,416.9	21,448.6
27,494.1	21,020.7	33,265.4	35,491.0	27,897.6	19,611.2	14,903.2
30,608.8	14,694.7	29,046.7	36,153.4	34,614.4	24,937.3	28,996.3
5,991.3	9,056.1	31,705.0	32,959.2	11,831.6	24,567.5	21,397.9
21,335.7	19,655.3	27,238.7	19,239.4	31,899.1	22,663.4	18,906.8
14,227.5	29,180.8	25,484.7	23,547.2	25,919.4	14,761.7	18,666.0
26,977.7	17,805.9					

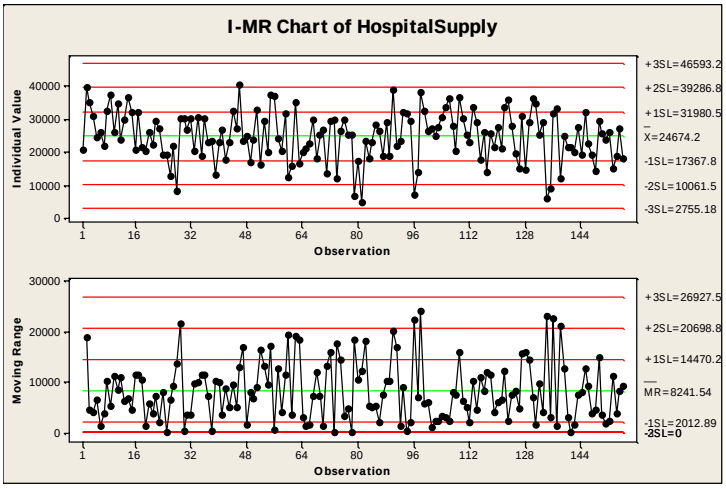
Answer:

What type of data is in the above matrix?

Measurement data

What type of control chart should be used to study the above data?

An I-MR chart should be used dues to measurement data and a subgroup size of one.
Use Minitab to construct a control chart for the above data.



Is the process stable? If not, in what weeks is it not stable?
The process is stable.

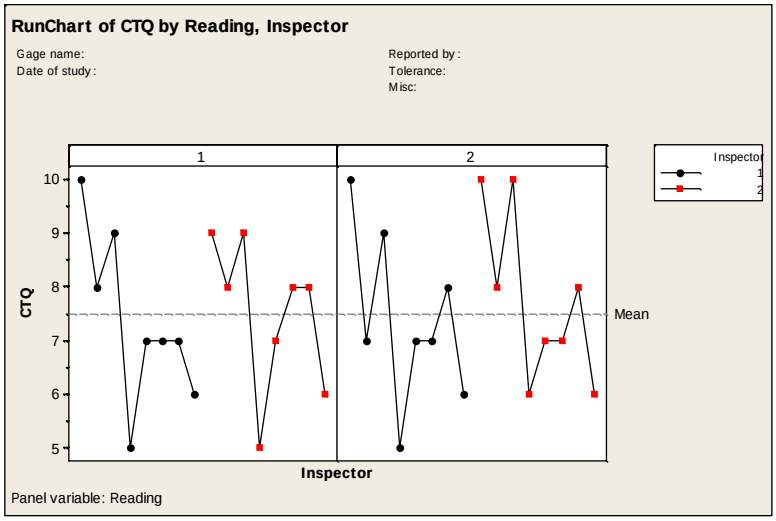
QUESTION: Explain the purpose of a Gage R&R study.
Answer: The purpose of a Gage R&R study is to define the validity of a measurement system, specifically, to estimate the proportion of observed variation due to unit-to-unit variation and measurement variation.

QUESTION: Construct a Gage R&R run chart from the following data.

Inspector	Reading	CTQ
1	1	10
1	2	10
2	1	9
2	2	10
1	1	8
1	2	7
2	1	8
2	2	8
1	1	9
1	2	9
2	1	9
2	2	10
1	1	5
1	2	5
2	1	5
2	2	6
1	1	7
1	2	7
2	1	7
2	2	7
1	1	7

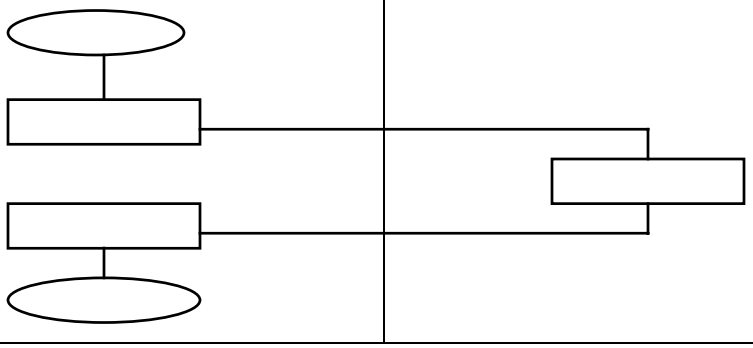
1	2	7
2	1	8
2	2	7
1	1	7
1	2	8
2	1	8
2	2	8
1	1	6
1	2	6
2	1	6
2	2	6

Answer:



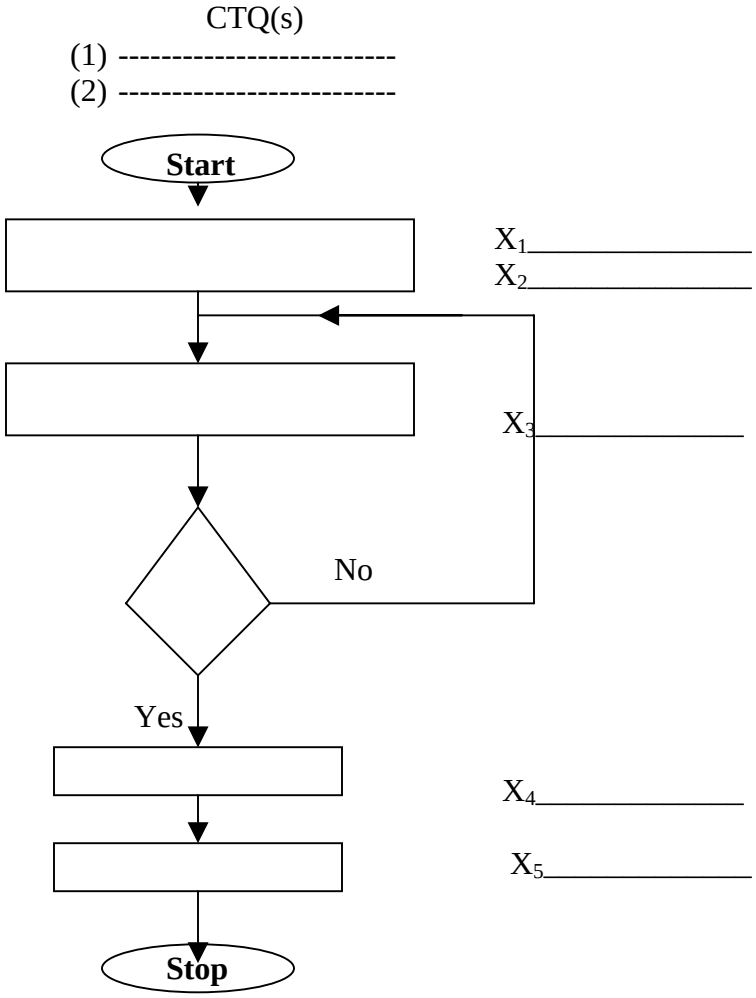
QUESTION: Explain how flowcharts can be constructed to identify and highlight the non-value added steps in a process.

Answer:

Value Added Steps or Xs	Non Value Added Steps or Xs
	
NOTE: Show cycle times for each step or X.	

QUESTION: Explain the relationship between *Y* = f(*X*) and a flowchart in respect to Six Sigma management.

Answer: As you can see from the following figure, $CTQ_1 = f(X_1, X_2, X_3, X_4, X_5)$ and $CTQ_2 = f(X_1, X_2, X_3, X_4, X_5)$



QUESTION: Explain how Failure Modes and Effects Analysis (FMEA) is used to identify the *X*s that cause CTQs to be out of specification. Construct a table to illustrate your explanation.

Answer: Failure Mode and Effects Analysis (FMEA) is used to identify, estimate, prioritize, and reduce the risk of failure in CTQs through the development of countermeasures based on Xs. There are 10 steps to conducting a FMEA. First, team members identify the critical parameters and their potential failure modes through brainstorming or other tools, that is, ways in which the design might fail (columns 1 and 2 of the table below). Second, team members identify the potential effect of each failure (consequences of that failure) and rate its severity (columns 3 and 4 of the table below). The definition of the severity scale is shown below. Third, team members identify causes of the effects and rate their likelihood of occurrence (columns 5 and 6 of the table below). The definition of the likelihood of occurrence scale is shown below. Fifth, team members

identify the current controls for detecting each failure mode and rate the organization's ability to detect each failure mode (columns 7 and 8 of the table below). The definition of the detection scale is shown below. Sixth, team members calculate the RPN (Risk Priority Number) for each failure mode by multiplying the values in columns 4, 6 and 8 (column 9 of the table below). Seventh, team members identify recommended actions and contingency plans, persons responsible, and target completion dates for reducing or eliminating each failure mode (columns 10 and 11 of the table below). Eight, team members identify the date the action was taken to reduce or eliminate each failure mode (column 12 of the table below). Ninth, team members rank the severity (column 12 of the table below), occurrence (column 13 of the table below) and detection (column 14 of the table below) of each failure mode after the recommended action (column 10 of the table below) has been put into motion. Tenth, team members multiple the values in columns 13, 14 and 15 of the table below to calculate the RPN (Risk Priority Number) for each failure mode after the recommended action (column 16 of the table below) has been put into motion.

Format for a FMEA

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
Critical Para-Meter	*Potential Failure mode*	*Potential Failure Effect*	*Severity*	*Potential Causes*	*Occurrence*	*Current Controls*	*Detection*	*RPN*	*Recommended Action*	*Respon-sibility and Target Date*	*Action Taken*	*Severity*	*Occurrence*	*Detection*	*RPN*
Before RPN =									*After RPN =*						

Definition of "severity" scale = likely impact of failure

Impact	*Rating*	*Criteria: A failure could…*
Bad	*10*	*Injure a customer or employee*
V	*9*	*Be illegal*
V	*8*	*Render the unit unfit for use*

V	7	Cause extreme customer dissatisfaction
V	6	Result in partial malfunction
V	5	Cause a loss of performance likely to result in a complaint
V	4	Cause minor performance loss
V	3	Cause a minor nuisance; can be overcome with no loss
V	2	Be unnoticed; minor effect on performance
Good	1	Be unnoticed and not effect the performance

Definition of "Occurrence" scale = frequency of failure

Impact	Rating	Time Period	Probability of occurrence
Bad	10	More than once per day	> 30%
V	9	Once every 3-4 days	< = 30%
V	8	Once per week	< = 5%
V	7	Once per month	< = 1%
V	6	Once every 3 months	< = .3 per 1,000
V	5	Once every 6 months	< = 1 per 10,000
V	4	Once per year	< = 6 per 100,00
V	3	Once every 1-3 years	< = 6 per million (approx. Six Sigma)
V	2	Once every 3-6 years	< = 3 per ten million
Good	1	Once every 6-100 years	< = 2 per billion

Definition of "Detection" scale = ability to detect failure

Impact	Rating	Definition
Bad	10	Defect caused by failure is not detectable
V	9	Occasional units are checked for defects
V	8	Units are systematically sampled and inspected
V	7	All units are manually inspected
V	6	manual inspection with mistake proofing modifications
V	5	process in monitored with control charts and manually inspected
V	4	control charts used with an immediate reaction to out of control condition
V	3	control charts used as above with 100% inspection surrounding out of control condition
V	2	all units automatically inspected or control charts used to improve the process
Good	1	defect is obvious and can be kept from the customer or control charts are used for process improvement to yield a no inspection system with routine monitoring

QUESTION: Define "capability of the process" in statistical terms.

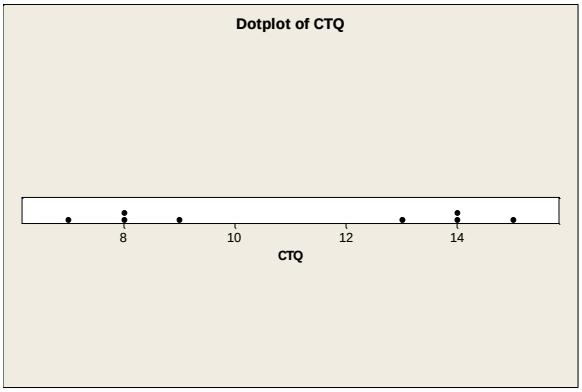
Answer: Capability is a measure of the relative relationship between the "Voice of the Process" and the "Voice of the Customer." This relationship considers the differential between the mean and nominal of the process. The capability of a stable and normally distributed process is defined as 99.73% of its output will be in the interval between LNL

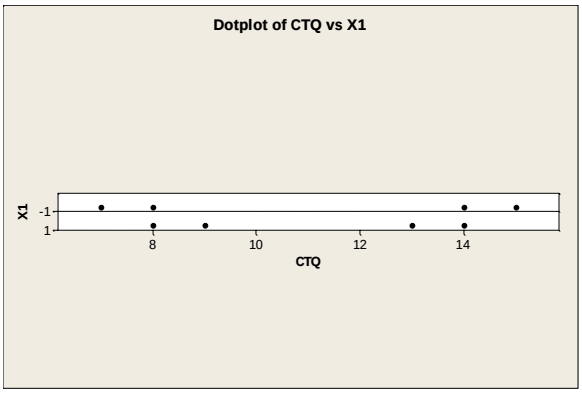
(mean + 3[$\bar{R}$ /d_2]) and UNL (mean - 3[$\bar{R}$ /d_2]), given measurement data and a subgroup size between 2 and 10 inclusive.

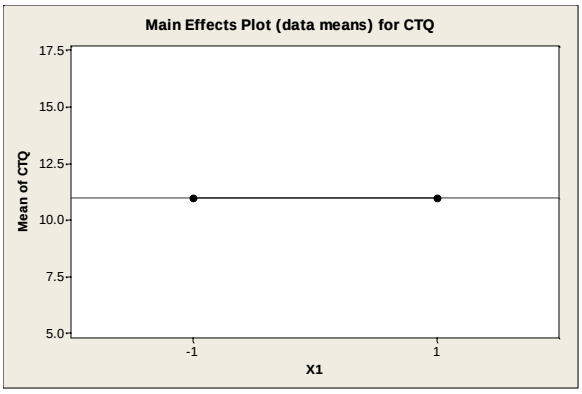
QUESTION: Construct a dot plot for the CTQ. Construct dot plots to study the CTQ for the different levels of X_1 and X_2. Construct main effects plots and interaction plots for the following data set.

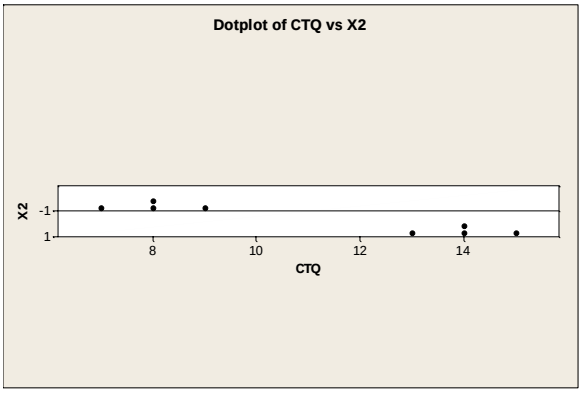
X_1	X_2	CTQ
-1	-1	8
+1	-1	9
-1	+1	14
+1	+1	13
-1	-1	7
+1	-1	8
-1	+1	15
+1	+1	14

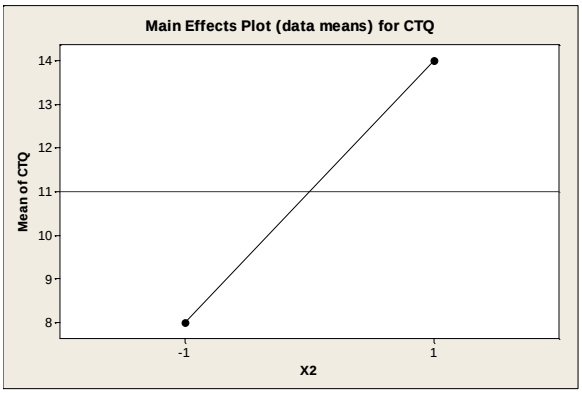
Answer:

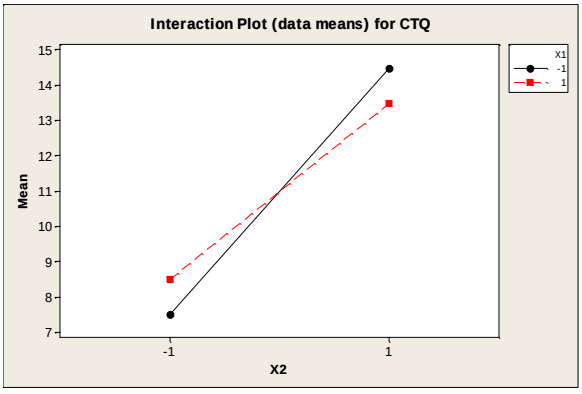












There is a significant interaction between X1 and X2 that will affect the CTQ. The interaction is seen in the crossed lines.

QUESTION: Explain the purpose of a 2^k full factorial design.
Answer: The purpose of a 2^k full factorial design is to understand the relationships between a set of Xs each with only two levels, and the interactions of the X's, on the CTQ's.

QUESTION: Create the standard order matrix for a 2^3 full factorial design.
Answer:

Test	X_1	X_2	X_3
1	-	-	-
2	+	-	-
3	-	+	-
4	+	+	-
5	-	-	+
6	+	-	+
7	-	+	+
8	+	+	+

QUESTION: Explain how the standard order matrix for a 2^3 full factorial design is used to estimate the effects of one main factor on the CTQ.
Answer: Add up the values of the CTQ for which the X is +, then add up the values of the CTQ for which X is -, finally, divide the difference of the sums by the number of plus signs.

QUESTION: Explain how the coefficient pattern for a 2^3 full factorial design is used to estimate the effects of one interaction factor (X_iX_j) on the CTQ.
Answer: Multiply the signs of X_i and X_j to create a new variable, X_iX_j. Next, add up the values of the CTQ for which the interaction X_iX_j is +, then add up the values of the CTQ for which X_iX_j is -, finally, divide the difference of the sums by the number of plus signs.

QUESTION: Why randomize runs in an experimental design.
Answer: Randomization is done in experimental designs to remove the effects of lurking variables.

MULTIPLE CHOICE QUESTIONS (correct answer is in boldface type):
Answers:
1. A 2^3 full factorial design with 2 replications provides information about:
   a) main factor effects
   b) two way interactions
   c) three way interaction
   d) all of the above
2. A 2^3 full factorial design attempts to prevent the effect of lurking variables by
   a) replication
   b) randomization
   c) interaction
   d) none of the above

e) all of the above

3. A 2^3 full factorial design with 2 replications per cell requires _____ runs.
   a) 2
   b) 3
   c) 4
   d) 8
   e) 16
4. A 2^3 full factorial design can be physically represented by which shape?
   a) square
   b) cube
   c) rectangle
   d) circle
   e) none of the above
5. The purpose of a full factorial design is to:
   a) provide information on the effects of main factors
   b) provide information on the effects of interactions
   c) if possible, remove the effects of lurking
   d) all of the above
   e) none of the above
6. Use the following design matrix display to answer the following questions.

Test	X1	X2	X3	CTQ
1	-	-	-	6
2	+	-	-	7
3	-	+	-	8
4	+	+	-	7
5	-	-	+	3
6	+	-	+	4
7	-	+	+	4
8	+	+	+	5

7. The above design matrix layout is called:
   a) random order
   b) run order
   c) standard order
   d) none of the above
   e) all of the above
8. Compute the average effect of X3:
   a) +12
   b) -3
   c) -4
   d) +15
   e) none of the above

   [3+4+4+5]/4-{6+7+8+7]/4= 4-7 = -3
9. Compute the average effect of the interaction between X1 and X3.
   a) -2
   b) +1/2
   c) +3

d) 1/3
e) none of the above
[6+8+4+5]/4-[7+7+3+4]/4=23/4-21/4=1/2

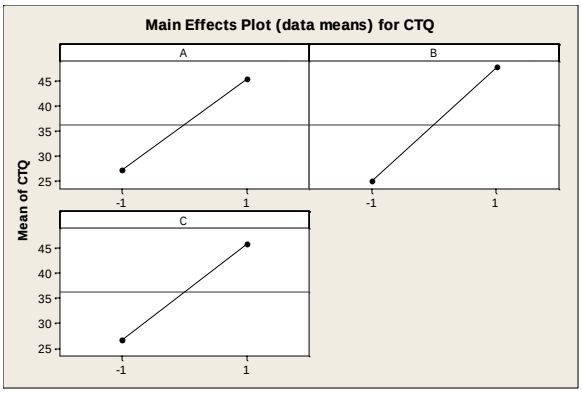
QUESTION: Explain the purpose of a pilot test.
Answer: A pilot test serves four purposes. First, it validates a revised best practices method. Second, it highlights the risks (e.g., FMEA) involved in using the revised best practice method. Third, it promotes a smooth implementation of the revised best practice method. Finally, it facilitates buy-in by the stakeholders of revised best practice method.

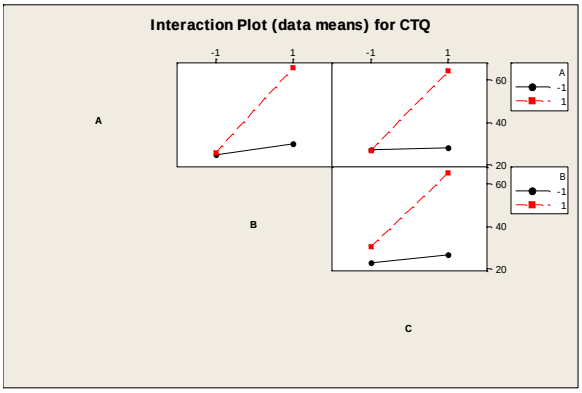
QUESTION: Analyze the following 2^3 full factorial design with 2 replications data using Minitab.

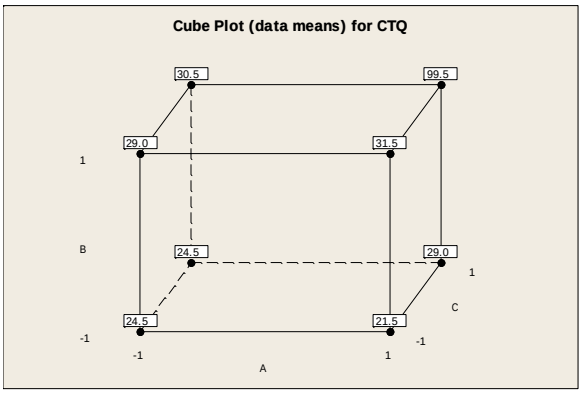
StdOrder	RunOrder	CenterPt	Blocks	A	B	C	CTQ
15	1	1	1	-1	1	1	30
1	2	1	1	-1	-1	-1	21
8	3	1	1	1	1	1	100
12	4	1	1	1	1	-1	29
3	5	1	1	-1	1	-1	26
2	6	1	1	1	-1	-1	23
13	7	1	1	-1	-1	1	19
16	8	1	1	1	1	1	99
7	9	1	1	-1	1	1	31
11	10	1	1	-1	1	-1	32
14	11	1	1	1	-1	1	24
10	12	1	1	1	-1	-1	20
4	13	1	1	1	1	-1	34
6	14	1	1	1	-1	1	34
9	15	1	1	-1	-1	-1	28
5	16	1	1	-1	-1	1	30

Answer:
Analysis of Variance for CTQ (coded units)

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*
Main Effects	*3*	*4884.7*	*4884.7*	*1628.25*	*76.18*	*0.000*
2-Way Interactions	*3*	*3555.0*	*3555.0*	*1185.00*	*55.44*	*0.000*
3-Way Interactions	*1*	*870.2*	*870.2*	*870.25*	*40.71*	*0.000*
Residual Error	*8*	*171.0*	*171.0*	*21.37*		
Pure Error	*8*	*171.0*	*171.0*	*21.38*		
Total	*15*	*9481.0*				







The high-high-high 3-way interaction rules the experiment. To maximize CTQ, set all factors at the high level.

QUESTION: Explain the purpose of "risk management."
Answer: The purpose of risk management is to maintain control and minimize the risk of failure of product, service or process by using risk abatement plans.

QUESTION: List the steps involved in developing a "risk abatement" plan.
Answer: Team members construct risk abatement plans for risk elements with high and medium risk elements; that is, a risk element score of 16 to 25. Team members identify process, product or service changes to reduce the risk for each high and medium risk element (Xs). Next, team members estimate the risk element score after the risk abatement plan is set into motion. Team members identify the risk element owner and set

a completion date for the risk abatement plan to become operational. Finally, team members document the risk abatement plans.
A format for a risk abatement plan is shown below.

Potential Risk Element	*Potential Harm*	*Measure for Risk Element*	*Risk Element Score*		*Countermeasure*	*Risk Owner*	*Completion Date for Countermeasure*
			Before	*After*			

Team members carry out all risk abatement plans. They document the lessons learned for each risk element and transfer the knowledge to other relevant risk elements. Next, team members incorporate the risk abatement plans into a control plan for the process owner. Team members turn the process control plan over to the process owner. Finally, the process owner continuously turns the PDSA cycle to continue improving the process, product, or service.

QUESTION: Explain the purpose of "mistake proofing." Explain the functioning of mistake proofing.
Answer: Mistake proofing is used to create "robust steps" in a process or service, or components of a product, denoted as Xs, which are not susceptible to human error. It is used on the critical parameters shown in column 1 in the table below and on the potential failure modes shown in column 2 of the table below. Column 12 in the table below is used to list a mistake proofing solution to potential failure modes (column 2). There are many types of mistake proofing solutions to prevent failure modes, for example, alarms that indicate danger to an operator, color coding medical records by type (green for pediatric and orange for geriatric), or a hand harness for a press to prevent an operator from getting his/her hands crushed in the press. Team members can brainstorm for mistake proofing solutions to potential failure modes, or they can review the literature on mistake proofing techniques.

Format for a FMEA

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
Critical Parameter	*Potential Failure mode*	*Potential Failure Effect*	*Severity*	*Potential Causes*	*Occurrence*	*Current Controls*	*Detection*	*RPN*	*Recommended Action*	*Responsibility and Target Date*	*Action Taken*	*Severity*	*Occurrence*	*Detection*	*RPN*
Before RPN =									*After RPN =*						

QUESTION: Explain why standardization is such an important part of Six Sigma.
Answer: Standardization of a process creates a known best practice flowchart that can be improved by one or more employees, perhaps a Six Sigma project team. There are multiple variations of a process without standardization. The lack of standardization

makes process improvement very difficult because there is not one process to be improved, rather, there are many versions of the same process needed improvement.

QUESTION: Explain the function of control charts in the Control phase of the DMAIC model.
Answer: Control charts are important in the Control Phase of the DMAIC model because they can be used to monitor stability of the Xs and the CTQs. Also, control charts promote process monitoring and work towards the elimination of mass inspection methods.

QUESTION: Explain the purpose of a QC process chart. Draw a QC chart to illustrate your explanation.
Answer: The purpose of a QC process chart is to monitor implementation of revised best practice method.

PLAN/DO		STUDY			ACT		
Flowchart		CTQs and Xs			Corrective action		
Revised best practice flowchart for doing the process.	Show how revised step should be done or provide a reference that describes the revised step.	Identify CTQs and Xs.	Specify CTQs and Xs.	Describe CTQs and/or Xs should be monitored (e.g., run chart). Who should monitor?	State corrective actions to prevent future problem.	Formalize procedures for operators enabling them to deal with problems.	Who needs what data to improve the best practice method?
					What should be done with defective output? Who should do it?	Update the training process to include revised best practice.	
						Update training manual.	
						Use statistical methods to determine if and when an employee reaches a state of statistical control from a particular training program.	

QUESTION: Explain the purpose of documentation in Six Sigma management.
Answer: Documentation has at least 4 purposes in Six Sigma. First, it provides a permanent record of the project and details for the future owner of the process. Second, it ensures that the improvement and rationale is documented so that the problem does not come back. Third, it ensures that the knowledge gained by the team is saved and shared. Finally, it documents vital information about the project from which others can benefit.