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PSTAT 140

All code is attached at the end of question 1

1)

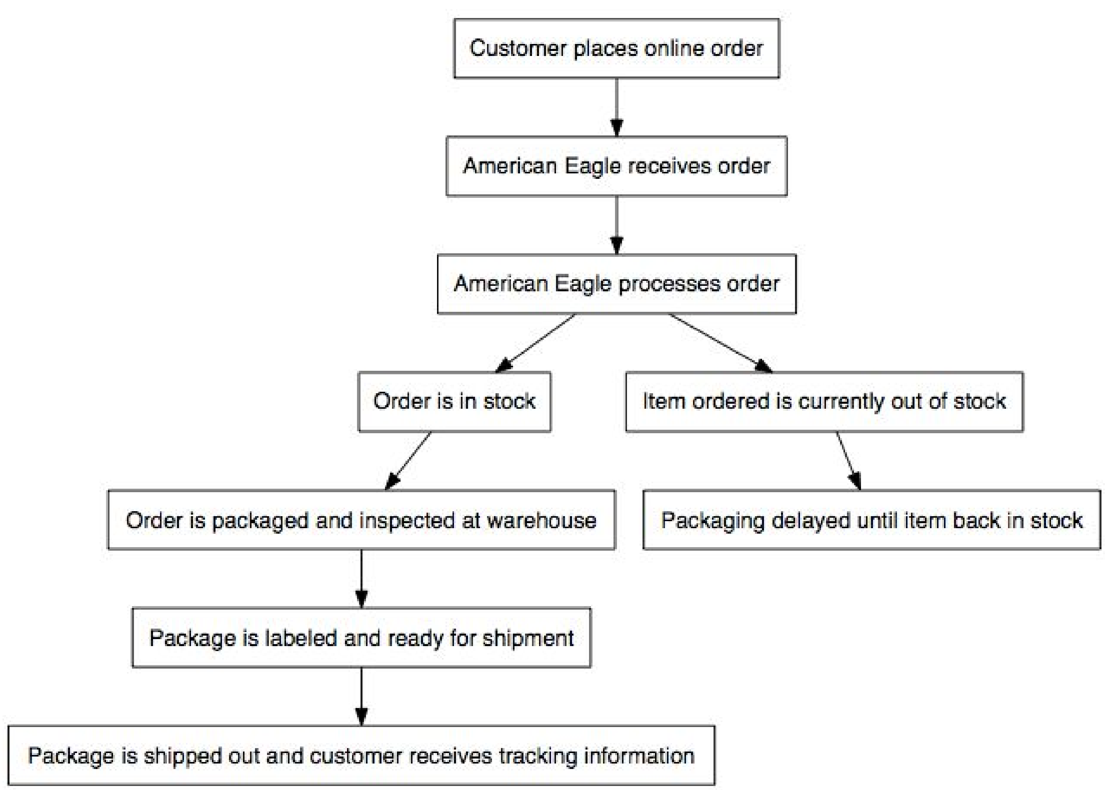
For my course scenario, I chose to study the process through which the clothing company, American Eagle Outfitters, manufactures and delivers their clothing to customers. Much of the company's business comes from online shoppers from all over the world who have their packages shipped to them. Consequently, a possible problem that could arise is late shipment of orders. American Eagle's shipping period is 3-5 days and many customers, including myself, are return customers specifically because of the quick shipping time. Customers receive an email once their package has been shipped and can manually track where it is. Late order fulfillment/ shipping could definitely affect the reception of American Eagle as a brand as quick shipping is an important feature to online shoppers. In this project, I will use DMAIC tools to assess the problem of late shipment of packages and explore possible improvements to the order fulfillment and shipping process.

Define

ii) Flowchart

The first step is to define. The defined problem in this project is late shipment of American Eagle packages. Late shipment could be caused by a number of things and if these issues are not resolved, customers may lose interest in the company and decide to shop somewhere else. We will first look at a possible flowchart for the process of online order fulfillment.

Flowchart for Order Fulfillment



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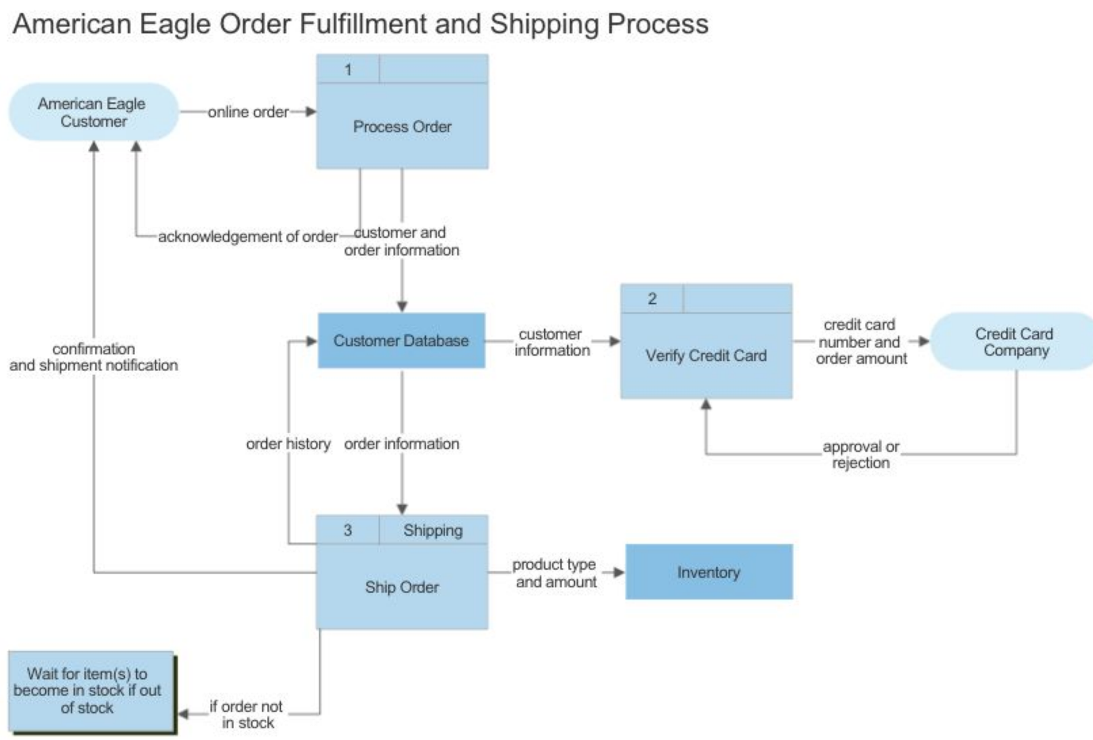
Looking at the above flowchart, value-added steps include ‘Customer places online order’, ‘American Eagle receives order’, ‘American Eagle processes order’, ‘Order is packaged and inspected at warehouse’, ‘Package is labeled and ready for shipment’, and ‘Package is shipped out…’. These steps move the order fulfillment process along smoothly. Non-value-added steps include checking if the ‘Order is in stock’ or ‘Item ordered is currently out of stock’ as well as ‘Packaging delayed until item back in stock’. These steps slow down the process and specifically if the item ordered is out of stock, the shipping process hits a choke point and is delayed.

x) Value Stream Map

A value stream map is another mapping tool used in the define step. It gives us more detail as to *everything* going on in the order fulfillment and shipping process at American Eagle.



iii) CTQ

Some CTQ characteristics of focus in this project are as follows:

- Speed of order fulfillment and shipment
- Consistency of shipment time
- Efficiency of order fulfillment process
- Reliability of order fulfillment process
- Speed of stock replenishment

The above characteristics are essential to the success of American Eagle’s shipment and order fulfillment and consequently, also essential to the perceived quality of the brand by customers.

iv) SIPOC Diagram

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A SIPOC diagram is also a valuable part of our Define step as it helps visualize all the moving parts in our order fulfillment and shipping process.

Supplier	Inputs	Process	Outputs	Customer
American Eagle Outfitters UPS Shipping Company	Clothing items Shipping Materials (boxes, labels) Order information	*Process stated in flowchart*	Orders shipped on time Correctly fulfilled orders	American Eagle shopper

With the use of the SIPOC diagram above, all parts of the process are accounted for and we can move forward in studying the order fulfillment and shipment process. A tollgate should be included now that we have laid out all the relevant defining information. Company managers should be presented the information to review it, ensure that all order fulfillment info for American Eagle has been accounted for, suggest any comments or improvements and give the go-ahead to move forward with the project onto the measurement step.

Measure

The measure step of this DMAIC process would measure how well the CTQ's are currently being met. Because I don't have access to actual data from American Eagle, I will just lay out the process of the measurement step. A project team should look at a large sample of past orders over a significant period of time or take new samples from recently shipped orders, from various geographical areas, and assess the time it takes for orders to be fulfilled and shipped, as well as how often orders are delayed. A representative sample is important as more frequent delays in a certain type of clothing item (such as jeans) may uncover a pattern. Key process input variables such as types of clothing items and key process output variables such as orders shipped on time are relevant variables to studied. Work sampling may also be of use as 'pickers', employees who manually pull items from shelves to prepare orders for packaging and shipment, can also uncover patterns in the shipping process. After collecting a large sample of relevant data, graphs such as histograms of the average times for order fulfillment and the distribution of types of process defects as well as average times for stock replenishment would be of use. Run charts, scatter diagrams, etc. may also be used to visually display the current state of American Eagle's shipping process.

ix) Check Sheet

A check sheet is a tool useful in our measure step to assess the type and number of defects in the order fulfillment and shipping process. By looking at the data collected, a check sheet should be filled out documenting issues in the process. The check sheet will be of use in the analysis step as well.

Check Sheet for Order Fulfillment and Shipping Process over 10 months

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Defect	Month # 1	2	3	4	5	6	7	8	9	10	Total
Mis-labeled Package											
Wrong Order											
Delay due to Out-of-Stock											
Delayed shipment due to weather											
Delay due to slow order pro-cessing											
Delay due to inefficient workers in ware-house											
Delay due to late UPS pickup											
Total											

At this point, another tollgate is necessary before moving onto the analysis step. The project team should present all graphs and data from both the define and measure steps to company managers. Managers will assess the validity of the data and charts, give their personal input, and ask the project team any questions they have about the measurements. They will also assess whether or not the data collected is representative of all types of American Eagle orders (i.e. shirt orders, jean orders, etc.) and if the data comes from different geographical areas (i.e. orders from West Coast, East Coast) The managers will then either suggest changes or allow the project team to move to the analysis step.

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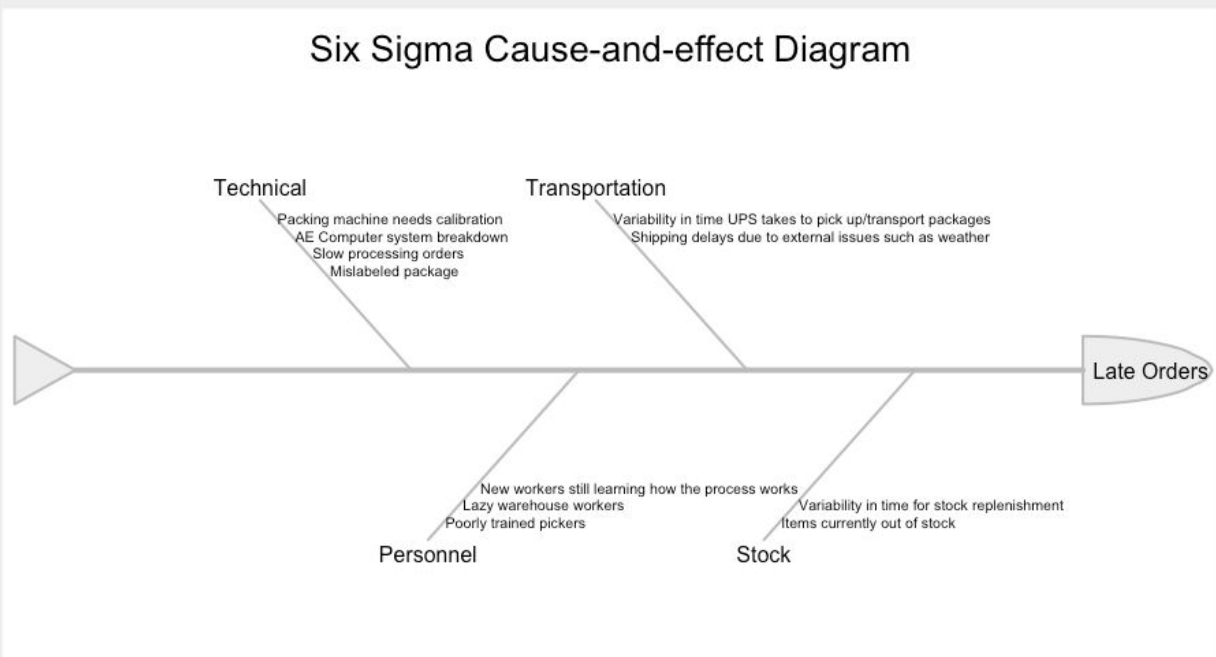
Analyze

v) Causes

Now that the defining and measuring steps are complete, the project team can begin to analyze the measurements to uncover the causes of late order fulfillment and shipping. Some examples of chance causes that affect the order fulfillment/ shipping process include internal issues such as a computer system is slow in processing online orders, variability in the time it takes an item to become back in stock, inadequate training of warehouse ‘pickers’, etc. On the shipment side, UPS itself may have internal issues such as variability in time it takes to pick up and transport orders to their shipment locations. Examples of assignable causes may include external issues that can be eliminated such as certain warehouse pickers that are inefficient/lazy on the job, a system crash that delays the processing of online orders, a labeling or packaging machine that needs to be recalibrated, surge in online orders due to a large sale, a manager that is not doing their job; these are just a few. A graphical representation of possible causes is useful in this step, thus a cause-and-effect diagram should be used. Control charts may also be of use in this step if data was accessible. These charts are helpful in distinguishing chance and assignable causes for late order fulfillment.

vii) Possible Cause-and-Effect Diagram for Late Shipment



Cause-and-Effect for Late Order Fulfillment and Shipping

Hypothesis tests and confidence intervals would also be of use in this step. Hypothesis tests could be used to compare certain operating conditions such as after the packing machine has been recalibrated versus before it has and assess differences in outcomes. Another example could be comparing outcomes when new warehouse workers are working versus when more experienced workers are working to see if workers are being trained properly. Through the use of these tests, the project team can gain insight and possibly uncover breakthroughs into what's causing issues in the order fulfillment and shipping process. After multiple hypothesis tests and regression analysis are completed, the project team would reach a tollgate. They would then present new charts and test results to managers to get their input. Managers may suggest carrying out more tests such as assessing late orders when the weather is clear versus when weather conditions are poor, or comparing orders of say blouses to orders of shoes to see if there is any relation between late orders and article of clothing. The project team should be prepared to present what specific areas they wish to improve upon in the improvement step such as speeding up the packaging machine or remodeling warehouse worker training as well as present any data necessary. After carrying out any additional tests or analysis, managers will review the information, ask the project team any questions they may have, and allow them to move forward to the improvement step.

xi) Demerit System

A demerit system is a useful tool for assessing defects in a product or system and could be included in the measure or analyze step of the DMAIC. For my specific scenario, the following demerit system could be implemented for American Eagle's order fulfillment and shipping process.

Class A - Very Serious	Package is mislabeled by machine and customer never receives it. Package is never picked up from warehouse for shipment.
Class B - Serious	Item(s) ordered are out of stock and new stock doesn't come for weeks. Order fulfillment is severely delayed due to a glitch in order processing
Class C - Moderately Serious	Item(s) ordered are due back in stock in a day, so shipment delayed by one day. Packaging machine needs recalibration as it starts to lag.
Class D - Minor	Package is slightly tarnished after being shipped out (i.e. box slightly dented) Accidental inclusion of one too many items in order.

The weight for a Class A defect should be 100 as one of these defects would result in the customer never receiving their order. This would likely cause the customer to be upset and not shop at American Eagle anymore. For a Class B defect, the weight could be 70 as either of the defects in this class would delay a customer's order for a significant period of time and jeopardize the chance of the customer returning. A Class C defect could carry a weight of 40 as either of defects should only cause at most a day delay in shipment which as a customer of American Eagle myself, I wouldn't see as cause for never shopping there again. Finally, a Class D defect could carry a weight of 2 as either of the defects is a simple inconvenience. For a clothing company, most of their products are soft and not fragile, so minor tarnishing of packaging shouldn't be a problem.

Improve

In the improve step, the project team should implement changes in the current process based on results from the analyze step. For example, let's say that in the analyze step, the project team discovered that the following causes had the most impact on late orders:

- Packing machine needs calibration
- Slow processing orders
- Poorly trained warehouse pickers

The project team should propose solutions to the above problems. A solution to the first issue could be simply recalibrating the packing machine more frequently to speed up the order fulfillment process. If the machine is currently calibrated every 6 months, calibration could be altered to every 3 months. For the second issue, a new system could be designed or new computer software used to speed up the processing of online orders. The current system could be outdated or unable to support the amount of online orders placed at AE every day. A more advanced software could solve this issue. Finally, the third cause could be dealt with by remodeling the training program for warehouse workers. Say for example, currently, new workers are trained in groups for a week. A new system, where each new worker shadows an experienced worker, one-on-one for 2 weeks could be implemented. This more focused training could help new workers really get the detailed training necessary to understand the order fulfillment and shipping process and be able to ask any questions they have on the spot. Pilot tests implementing the above solutions should be carried out and their results recorded. Further adjustment may be necessary to improve the order fulfillment process even more. After completing adequate pilot tests and making necessary adjustments, the project team is ready for another tollgate review. In this tollgate, the project team should present the three causes mentioned above as well as their proposed solutions to the issues. The team should also discuss with managers the alternative solutions they considered before settling on the ones they did. New control charts with the changes should be created and presented to managers. At this point, managers would review the changes and approve them or suggest alterations before implementing them into the current order fulfillment and shipping process at American Eagle. Then, the team moves onto the final step in DMAIC, the control step.

Control

At this point, the remainder of the project should be completed, the changes to the order fulfillment process should be polished and given to managers in charge of the process. A control action plan should also be provided for the managers.

vi) Control action plan

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A control action plan should lay out how to keep the process in control and ensure that the changes to the process benefit American Eagle and improve the order fulfillment process so that late shipments are prevented. An example of part of the control action plan could be monitoring the packaging and labeling machines by taking samples each week to make sure that all the packages are being sealed and labeled in a timely matter and are labeled correctly. Monitoring the computer system processing of orders would also be in the control action plan. For example, those in charge of order processing should keep track of how fast an order is processed by the computer system after it is placed and an alert should be set off if an order takes an unusually long amount of time being processed, thereby pushing back its shipment time. Control charts should be created for the time it takes for orders to be processed as well as the speed and accuracy of packaging/labeling of orders. If the process has out of control points, evaluation of the software should take place and updates/changes should be made to fix the issue and as for the machines, recalibration may be necessary to correct the problem. With the use of the changes and the control action plan, American Eagle's order fulfillment and shipping process should run much more smoothly and keep order shipments to the 3-5 day period promised by the company. A final tollgate should take place where the project team presents ALL information and process changes to the managers in a final report. The managers should assess the changes and evaluate the improvements to the process.

Code for flowchart:

```
install.packages('DiagrammeR')
library(DiagrammeR)
grViz("digraph flowchart {
      node [fontname = Helvetica, shape = rectangle]
      tab1 [label = '@@1']
      tab2 [label = '@@2']
      tab3 [label = '@@3']
      tab4 [label = '@@4']
      tab5 [label = '@@5']
      tab6 [label = '@@6']
      tab7 [label = '@@7']
      tab8 [label = '@@8']
      tab9 [label = '@@9']

      # edge definitions with the node IDs
      tab1 -> tab2;
      tab2 -> tab3;
      tab3 -> tab4 -> tab8 -> tab5 -> tab6;
      tab3 -> tab7 -> tab9;
      }
```

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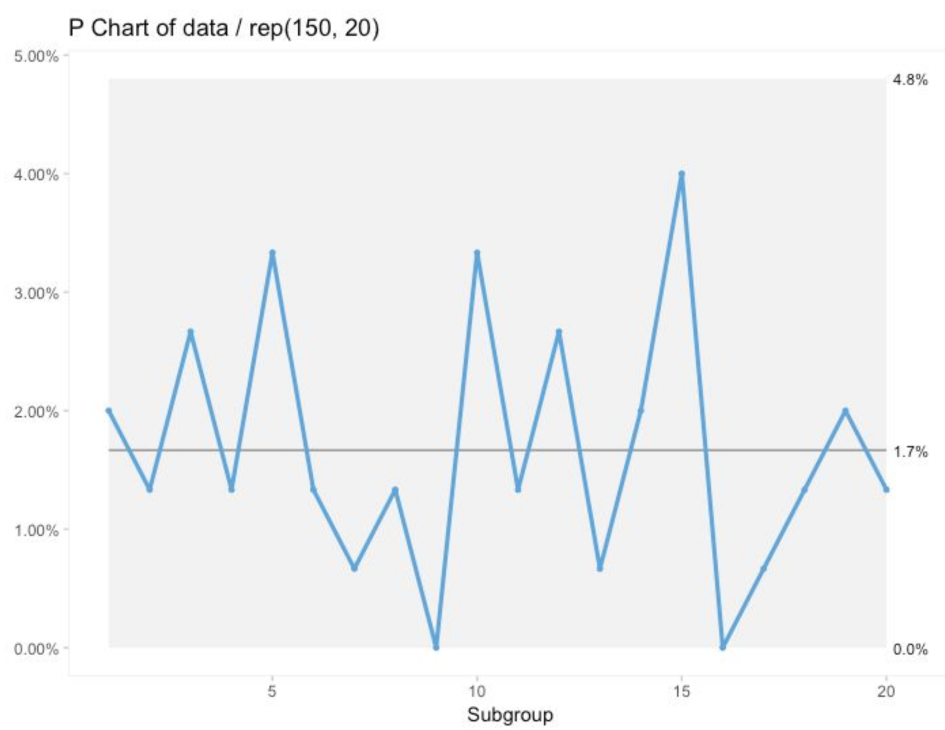
```
        [1]: 'Customer places online order'
        [2]: 'American Eagle receives order'
        [3]: 'American Eagle processes order'
        [4]: 'Order is in stock'
        [5]: 'Package is labeled and ready for shipment'
        [6]: 'Package is shipped out and customer receives tracking information'
        [7]: 'Item ordered is currently out of stock'
        [8]: 'Order is packaged and inspected at warehouse'
        [9]: 'Packaging delayed until item back in stock'
        ")
```

Code for cause-and-effect diagram:

```
install.packages('SixSigma')
library(SixSigma)
effect <- 'Late Orders'
causes.gr <- c('Technical','Transportation','Stock','Personnel')
causes <- vector(mode = 'list',length = length(causes.gr))
causes[1] <- list(c('Packing machine needs calibration','AE Computer system breakdown','Slow processing orders',
                    'Mislabeled package'))
causes[2] <- list(c('Variability in time UPS takes to pick up/transport packages',
                    'Shipping delays due to external issues such as weather'))
causes[3] <- list(c('Items currently out of stock','Variability in time for stock replenishment'))
causes[4] <- list(c('Poorly trained pickers','Lazy warehouse workers','New workers still learning how the process works'))
ss.ceDiag(effect, causes.gr, causes, sub = 'Cause-and-Effect for Late Order Fulfillment and Shipping')
```

2)
A)

```
data <- c(3,2,4,2,5,2,1,2,0,5,2,4,1,3,6,0,1,2,3,2)
qic(data,n=rep(150,20),chart='p')
```



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```
CL <- sum(data)/ (150*20)
UCL <- CL + 3*sqrt(CL*(1-CL)/150)
LCL <- CL - 3*sqrt(CL*(1-CL)/150)
```

```
> UCL
[1] 0.04802481
> LCL
[1] -0.01469148
```

So, CL is 0.0167, UCL is 0.048 and LCL is 0.

B)

For LCL to be > 0, we have to solve for n using our equation for the LCL given by:

LCL = CL - 3 * sqrt(CL*(1 - CL) / n)

0 = 0.0167 - 3 * sqrt(0.0167 * (1 - 0.0167) / n)

Solving for n, we get:

3^2 * (1 - CL) / CL

This comes out as 529.92

So, the smallest sample size that can be used in order for LCL to be positive is 530.

3)

If X double bar is 16, R bar is 7, and A2 for n = 5 is 0.577, the control limits for X bar are as follows:

X bar chart control limits:

```
CL <- 16
UCL <- 16 + 0.577*7
LCL <- 16 - 0.577*7
```

```
> UCL
[1] 20.039
> LCL
[1] 11.961
```

So, the CL is 16, UCL is 20.039, and LCL is 11.961.

R chart control limits:

For D4 = 2.114 and D3 = 0 for n = 5,

```
CL <- 7
UCL <- 2.114*7
LCL <- 0*7
```

```
> UCL
[1] 14.798
> LCL
[1] 0
```

So, the CL is 7, UCL is 14.798, and LCL is 0.

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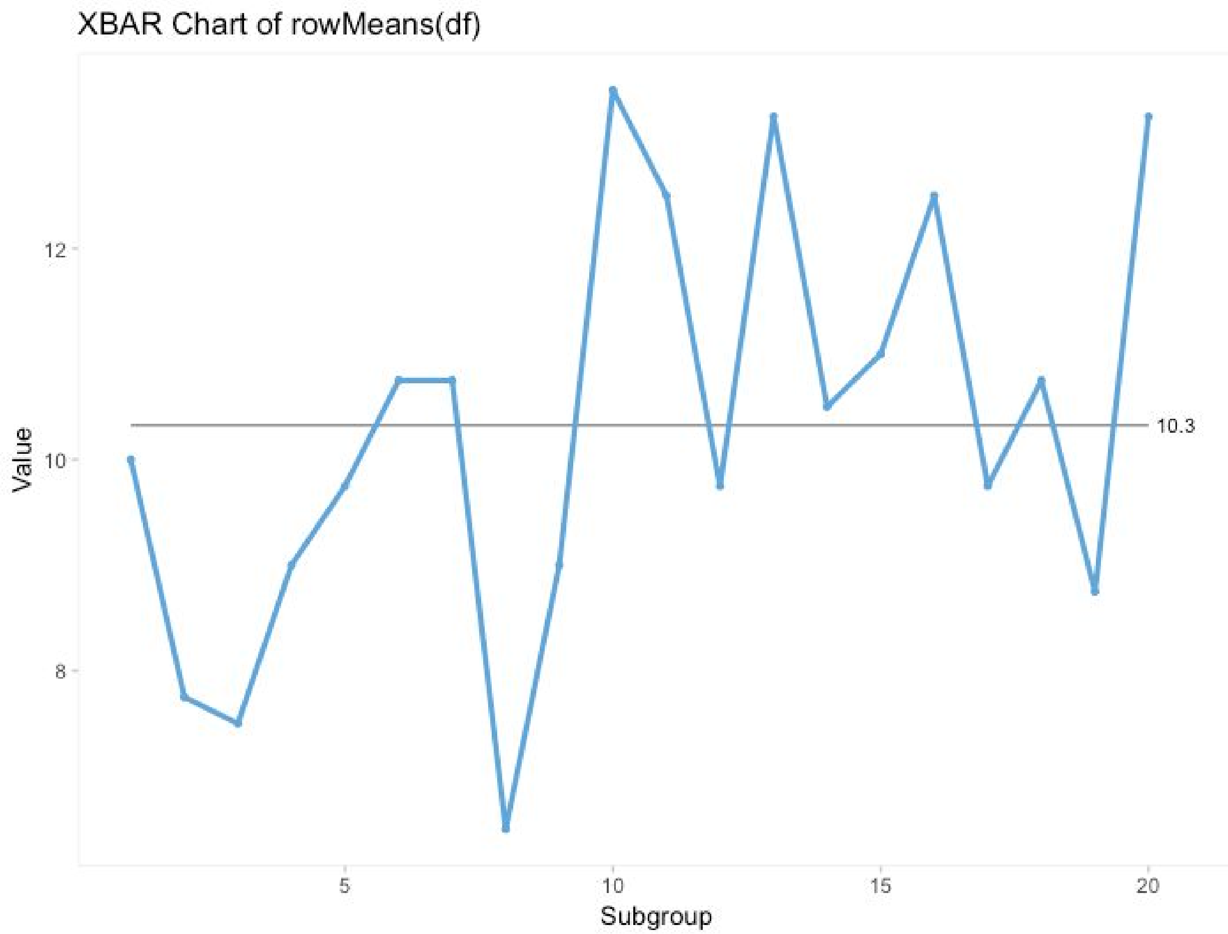
4)
A)

```
data <- c(6,9,10,15,10,4,6,11,7,8,10,5,8,9,6,13,
        9,10,7,13,12,11,10,10,16,10,8,9,7,5,10,
        4,9,7,8,12,15,16,10,13,8,12,14,16,6,13,
        9,11,16,9,13,15,7,13,10,12,11,7,10,16,
        15,10,11,14,9,8,12,10,15,7,10,11,8,6,
        9,12,13,14,11,15)
df <- matrix(data,ncol=4,byrow=TRUE)
df
qic(rowMeans(df),chart='xbar')
```




```
R <- apply(df,1,range)
R
rg <- R[2,] - R[1,]
sum(rg/20)
```

```
> sum(rg/20)
[1] 6.25
```

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```
> sum(rowMeans(df)/20)
[1] 10.325
```

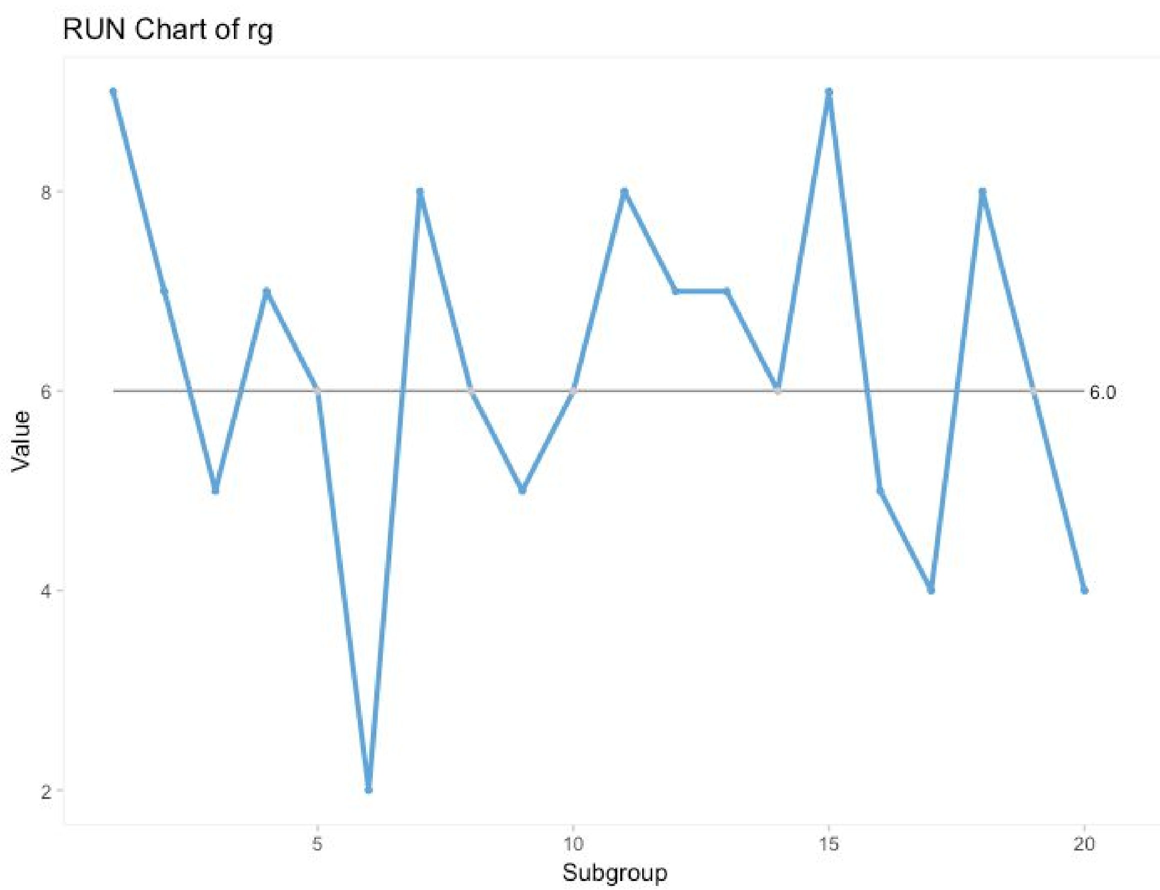
X - double bar = 10.325, R - bar = 6.25, and n = 4, and A2 is 0.729. Given this information, we can calculate the UCL and LCL for X - bar as follows:

```
LCL <- 10.325 - (0.729*6.25)
UCL <- 10.325 + (0.729*6.25)
```

```
> LCL
[1] 5.76875
> UCL
[1] 14.88125
```

So, for the X-bar chart, CL is 10.325, LCL is 5.76875, and UCL is 14.88125.

```
rg <- R[2,] - R[1,]
sum(rg/20)
qic(rg)
```



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R - bar = 6.25, D4 = 2.282 and D3 = 0 for n = 4.

```
LCL <- 6.25*0
UCL <- 6.25*2.282
```

```
> LCL
[1] 0
> UCL
[1] 14.2625
```

So, for the R-chart, CL is 6.25, LCL is 0, and UCL is 14.2625.
Based on the control limits for each of these charts, the process IS in statistical control as all points are within the limits.

B)
The formula for process capability Cp = USL - LSL / 6*sigma where sigma is estimated by R-bar / d2.
We have to adjust the USL and LSL multiplied by 10 because all Xi are multiplied by 10.

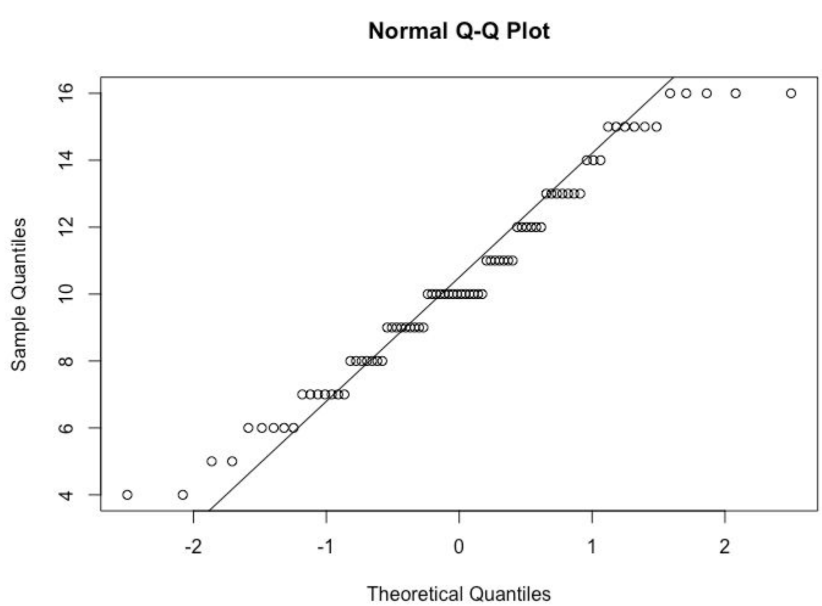
```
> (355-350)*10
[1] 50
> (345-350)*10
[1] -50
```

The LSL will be set to 0 since it is a negative number.

```
> (50 - 0) / (6*(6.25 / 2.059))
[1] 2.745333
```

Cp is 2.74 which is > 1, so the process is capable.

C)



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```
> qqnorm(data)
> qqline(data)
```

Based on the above plot, all the points fall on or near the normal line, so we can assume that voltage is normally distributed.