UNIVERSITEIT VAN AMSTERDAM

IBIS UvA

Lean Six Sigma
Trial Exam

Black Belt

Name of the Black Belt:

……

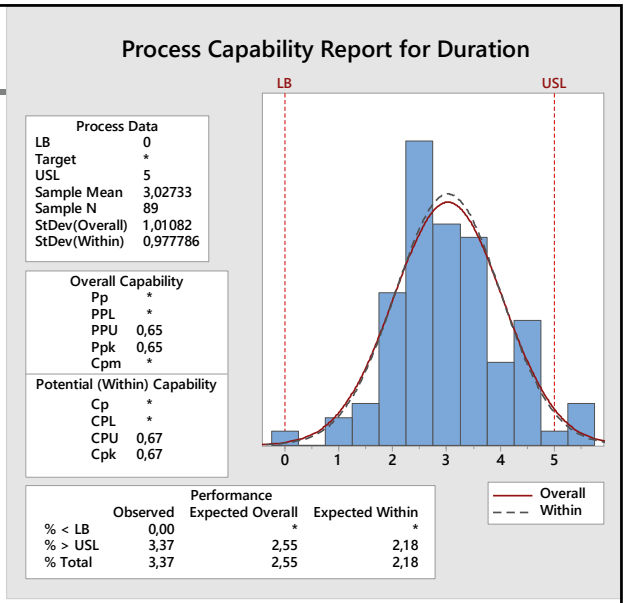
Please check you are taking the correct exam.

This is an open-book exam. You are allowed to use books and notes.
You are **not** allowed to use a calculator, telephone, tablet or computer.
Please circle your answer.

Calculation of points
Score = 10(#correct – 10) / 30
The score will be rounded to halves, with the exception of 5.5.
The exam consists of 40 questions.

1

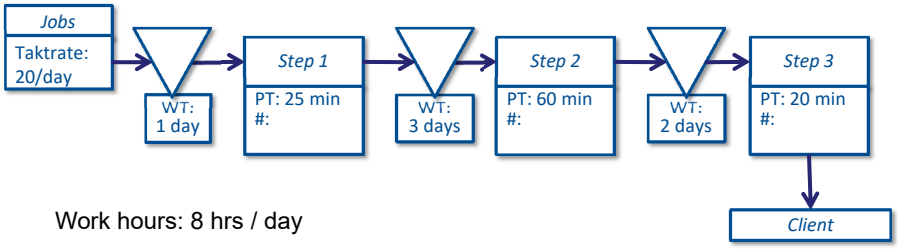
On the right you find a process capability analysis of the *Duration* of telephone calls in a call centre.



What can be concluded from this analysis?

a) 2.55% of all calls is longer than the norm of 5 minutes.
b) The average duration of a call is too high.
c) The call duration does not follow a normal distribution.
d) A call centre employee can handle around 12 calls per hour.

2



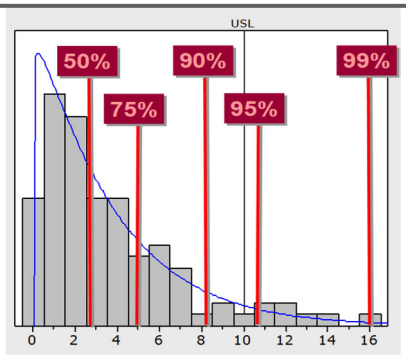
Work hours: 8 hrs / day

Jobs are processed in three steps. The average processing time of each step is given (*PT*). In practice, there are fluctuations in workload and processing times.

What is the impact of variation on the required capacity to handle this process?

a) It will increase the overall average processing time (*PT*), and therefore the number of resources.
b) It will increase the number of resources required to maintain a predetermined service level.
c) On average the impact will be small, as due to the different process steps variation will diminish.
d) The number of jobs in the process will increase, but the impact on the capacity will be nil.

3



Throughput times:
- 50% shorter than 2.6 days
- 75% shorter than 5.1 days
- 90% shorter than 8.3 days
- 95% shorter than 10.6 days
- 99% shorter than 16.0 days

Above is given a slide that is presented as part of DMAIC 3: Analyze the current process.

What should a Black Belt (BB) do next?

a) Find out whether a normal distribution fits the data well.
b) Understand where the remaining 1% went to.
c) Make an empirical cumulative distribution function.
d) Decide whether the performance of the throughput times should be improved, or is already acceptable.

4

What is the key factor for the success of 'Lean' and 'Six Sigma' as an integrated approach to organize improvement projects?

a) Because both Lean and Six Sigma are based on facts rather than gut feelings.
b) Because Six Sigma provides methods to find problems, and Lean consequently provides best practices to solve them.
c) Because Six Sigma provides a rigid framework called DMAIC in which Lean is integrated with various best practices.
d) Because Lean is focused on the so called low hanging fruit, while Six Sigma tackles fundamental problems.

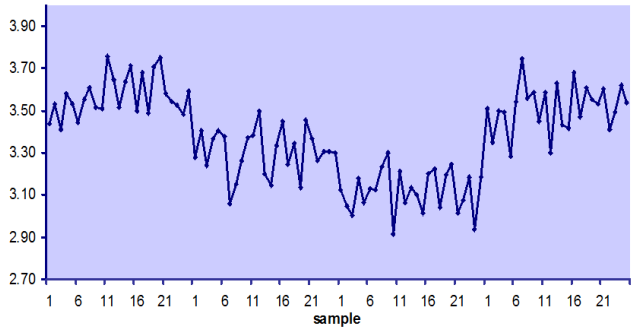
5

The throughput time of a service process that handles declarations follows a normal distribution with mean 10 minutes, and standard deviation 2 minutes.

Suppose we collect the throughput times of 1000 declarations. Which of the following statements is **false**?

a) Of the 1000 declarations, around 25 have a throughput time smaller than 6 minutes.
b) Around 500 declarations have a throughput time smaller than 10 minutes.
c) Around 950 have a throughput time between 8 and 12 minutes.
d) The average of the 1000 lengths is about equal to their median.

6



A Black Belt collects 25 samples per day for four (consecutive) days and measures an important characteristic, for example a CTQ. The corresponding LSL and USL are 3 and 4.

What is likely to be true?

a) The estimated within and overall standard deviation will almost be the same.
b) The data contains many outliers and other contaminations, that do not correspond with the true performance of the process.
c) The within standard deviation will be larger than the standard deviation overall.
d) The short term performance will be better than the long term performance.

7

A BB has done a regression analysis to study the effect of an X onto his CTQ. The result is displayed below.

Regression Analysis: CTQ versus X

The regression equation is

CTQ = 0.65 + 0.70 X

S = 1.40 R-Sq = 34.8% R-Sq(adj) = 32.5 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	29.1469	29.1469	14.9743	0.001
Error	28	54.5010	1.9465		
Total	29	83.6478			

Which is **not** true?

a) X has a significant effect on the CTQ.
b) The predicted value for X = 6 equals CTQ = 4.85.
c) The model gives precise predictions about the CTQ.
d) For fixed X, the CTQ has a standard deviation of about 1.40.

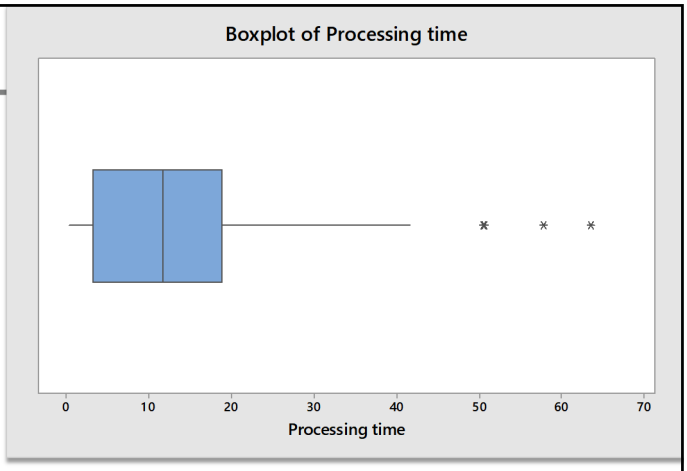
8

In line with the Theory of Constraints an organization can improve (either reduce or increase) in 3 fundamental directions to increase profit.

Which are these directions?

a) Throughput, inventory, operational expenses.
b) Resources, products, overhead.
c) Finished goods, fixed costs, variable costs.
d) Processing time, throughput time, number of jobs.

9



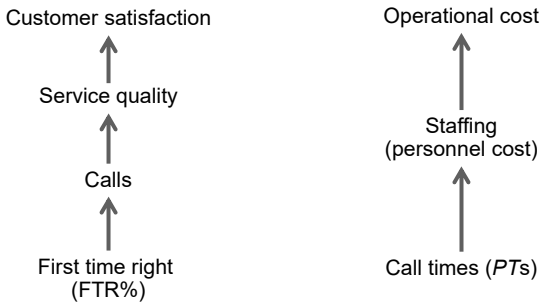
Descriptive Statistics: Processing time

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Processing time	55	2	15.01	2.04	15.11	0.45	3.26	11.67	18.86	63.47

The norm for the processing times equals 20 minutes. What is true about the processing times based on the boxplot and descriptive statistics above?

a) It is likely that the data follow a normal distribution.
b) About 50% of the data equals 11.67.
c) At least 75% of the data is below the norm.
d) There are 2 'real' outliers indicated by N*.

10



Consider the CTQ flowdown above about a project in a call centre. *FTR%* displays the percentage of calls that is handled at once, so that an additional call either by the client or employee is not needed.

Is the CTQ flowdown above acceptable?

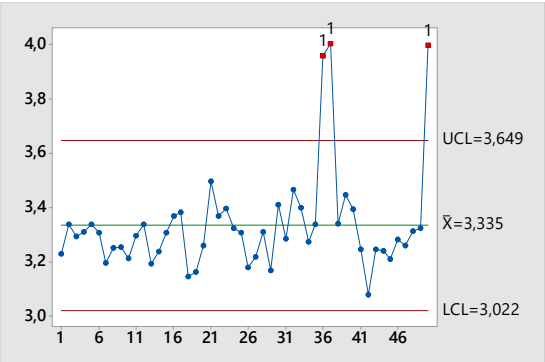
a) Yes, the flowdown is good as it is.
b) No, *FTR%* should be connected to *Service quality* directly.
c) No, *FTR%* should also be connected to *Call times*.
d) No, *Calls* should also be connected to *Staffing*.

11

For validation of a historical dataset in DMAIC 2, the BB considers the following approaches. Which approach will be most useful?

a) Face validity check in combination with autopsies.
b) Devil's advocate brainstorm session during data collection.
c) Gage R&R study to find out whether the measurement system used was good enough.
d) An FMEA to investigate failure modes during data collection.

12



As part of DMAIC 3, the BB makes a control chart, see above.

What should the BB do next?

a) The process is out of control, so proceed to the Control phase of DMAIC.
b) Find out what caused these outliers.
c) Perform a Box-Cox transformation as the data are skewed.
d) Determine the customer specification limits (USL and LSL).

13

A municipal health service handles clients. The process is as follows:

1. Clients are registered at reception desk and get a serial number (*PT* = 3 min / client).
2. Clients wait in a waiting room (*WT* = 20 min on average).
3. Clients have an interview with a health advisor (*PT* = 10 min / client), who prescribes one or more vaccinations.
4. Clients pay for the vaccinations at a cashier (*PT* = 2 min / client).
5. Clients get the prescribed vaccination(s) from a nurse (*PT* = 5 min / client) and leave the process.

Assume that there is one receptionist, one health advisor, one cashier, and one nurse.
PT = processing time, *WT* = waiting time.

What is the design capacity of this process?

a) 3 clients / hr.
b) 6 clients / hr.
c) 10 clients / hr.
d) 30 clients / hr.

14

In a warehouse, a BB wants to measure both the daily work volume and the employees' picking times of products.

She has a database in which she can find the work volumes (categorized by product type) per day, and she is going to measure the employees' picking times by means of time sheets.

What type of variables is the BB dealing with?

a) Work volume is categorical, and picking time is categorical.
b) Work volume is categorical, and picking time is numerical.
c) Work volume is numerical, and picking time is categorical.
d) Work volume is numerical, and picking time is numerical.

15

Results: agreement analysis (nominal data)

Agreement means that different appraisers are consistent in categorizing objects.

Inter-rater analysis

P_a: 0,600

Given an arbitrary object, there is a 060% chance that two appraisers assign the same value to it.
This probability is called the probability of agreement (P_a)

$P_{a|chance}$: 0,200

Even purely random categorization would have a probability of agreement of 020%.

κ (kappa): 0,500

Kappa is probability of agreement normalized for agreement by chance:

Kappa = $(P_a - P_{a|chance}) / (1 - P_{a|chance})$

Kappa = 1 is a perfectly consistent measurement. Kappa = 0 are random measurements.

Intra-rater analysis

Appraiser 1:	P_a:	0,867	κ:	0,833
Appraiser 2:	P_a:	0,733	κ:	0,667
Appraiser 3:	P_a:	0,667	κ:	0,583
Appraiser 4:	P_a:	0,867	κ:	0,833
Average intra-rater P_a:		0,783		
Average intra-rater κ:		0,729		

As a step in DMAIC 2, the BB does an agreement study to investigate whether complaints can be categorized consistently. If multiple persons categorize complaints, how consistent will they be? If we correct for consistency by chance.

a) 20%.
b) 50%.
c) 72.9%.
d) 78.3%.

16

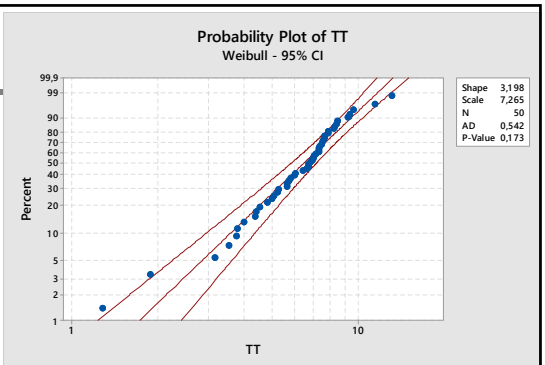
DMAIC 7: Improve process control
The BB finds that new standard operating procedures should be implemented. To enforce a proper implementation she organizes weekly coach/sit-in sessions. In such session a team leader checks by shadowing whether the employee follows the procedures, and if not helps to achieve those or in some cases makes sure that procedures are updated accordingly.

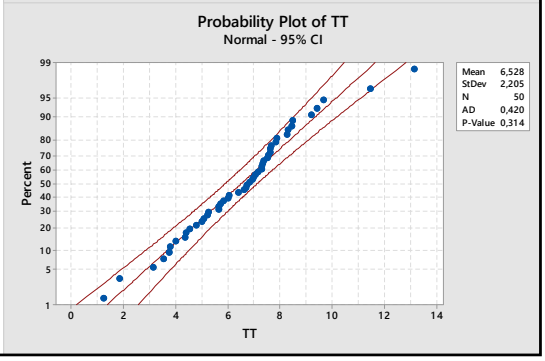
According to theory of Juran, this is an example of…

a) Visual management.
b) Quality improvement, in which management continuously improve the work floor.
c) Quality control, in which management checks and facilitates employees.
d) A control chart with a feedback loop.

17

On the right we find two probability plots that fit to the throughput times that are collected for a service process.





What can be concluded based on these two probability plots?

a) The data follow a Weibull distribution, because it has the lower p-value.
b) The data follow a normal distribution, because it has the lower AD value.
c) The data do not follow a Weibull or a normal distribution as both p-values are above 5%.
d) We should remove outliers first and then redo the analysis.

18

Process variability can manifest itself in different forms, for example, in the form of variation in workload or processing times.

What is **not** an effect of increased variability in a services process which handles clients' requests?

a) The order decoupling point shifts downward.
b) Large buffers of work in process (large WIP).
c) Lower utilization of resources in the process.
d) Higher average throughput times of requests.

19

What is the main benefit of experimenting (such as by means of DOE) over collecting observational data?

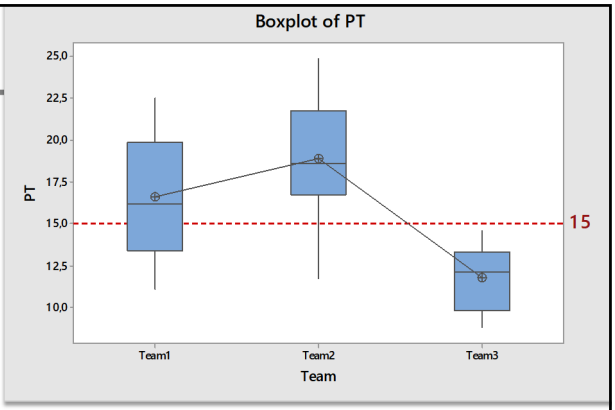
a) A higher R^2 (R-Squared).
b) More data points.
c) More p-values.
d) More control over the Xs (influence factors).

20

In a dataset ready to be analyzed (for example in Minitab):
- the … (i) are in the rows, and;
- the … (ii) are in the columns.

a) (i) Observed units; (ii) Variables.
b) (i) CTQs; (ii) Influence factors.
c) (i) Observed units; (ii) Measured units.
d) (i) CTQs; (ii) Observed units.

21



In the figure above we see differences between teams in terms of processing times (*PT*). The norm equals 15 minutes and team 3 seems to perform within the norm. Techniques from ANOVA are further used to analyze these data.

Based on the outputs presented on the **next slide**, what is the correct conclusion?

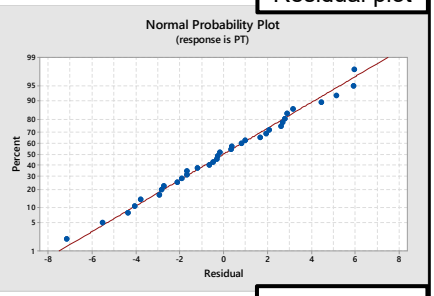
a) Although we observe differences between teams, the evidence in the data is not significant, indicated by the low p-values.
b) Although we observe difference between teams, the data cannot be used as the group sizes are unequal.
c) The mean processing times differ significantly between teams.
d) The high p-value for the variances test suggests that we should have performed another test to compare teams.

21 – output

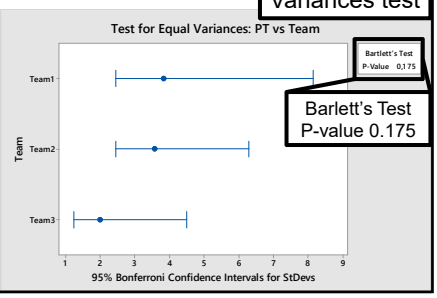
One-way ANOVA: PT versus Team

```
Factor  Levels  Values
Team         3  Team1; Team2; Team3


Analysis of Variance
Source  DF  Adj SS  Adj MS  F-Value  P-Value
Team     2   286.8  143.39    13.03    0.000
Error   31   341.0   11.00
Total   33   627.8


Model Summary
      S    R-sq  R-sq(adj)  R-sq(pred)
3.31674  45.68%     42.18%      35.23%


Means
Team    N    Mean   StDev        95% CI
Team1  10   16.57    3.83  ( 14.43;  18.71)
Team2  15  18.869   3.563  (17.122; 20.616)
Team3   9  11.741   1.983  ( 9.486; 13.996)

Pooled StDev = 3.31674
```

Residual plot



Variances test



Barlett's Test
P-value 0.175

22

In DMAIC 5 a BB wants to find evidence for the most important influence factors that determine the handling time of a request in *Minutes*. She performs the following analysis, see **next slide**. Complexity is ranked on a 10-point scale, experience is the number of years working with the firm.

The BB knows that the complexity of a case, the number of pages, experience of the employee, and salary are all significant if they are tested as the only influence factor on the CTQ. Unfortunately, doing the joint analysis shows that only two of these factors are significant.

What is the likely explanation that only two of these four influence factors show up to be significant in this analysis?

a) Two influence factors dominate the rest.
b) There is some multicollinearity.
c) Interaction distorts the analysis.
d) There are significant outliers in the data.

22 – output

General Linear Model: Minutes versus Salary; Experience; Number of pages; Complexity

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Complexity	1	113,8	113,77	1,11	0,298
Number of pages	1	3896,7	3896,68	37,94	0,000
Experience	1	704,4	704,36	6,86	0,012
Salary	1	70,1	70,13	0,68	0,413
Error	45	4621,7	102,70		
Total	49	40082,0			

Model Summary

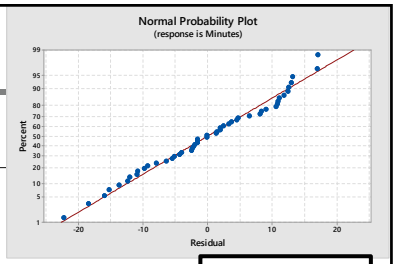
S	R-sq	R-sq(adj)	R-sq(pred)
10,1343	88,47%	87,44%	85,75%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	19,2	16,2	1,18	0,244	
Complexity	-2,16	2,05	-1,05	0,298	10,56
Number of pages	9,93	1,61	6,16	0,000	10,79
Experience	-2,90	1,11	-2,62	0,012	19,72
Salary	0,000243	0,000293	0,83	0,413	19,79

Regression Equation

Minutes = 19,2 - 2,16 Complexity + 9,93 Number of pages - 2,90 Experience
+ 0,000243 Salary



Residual plot

23

A service provider offers a standardized service that by nature has to be handled by different specialists in the process. The process suffers from excessive throughput times.

Which one of the following approaches is **unlikely** to reduce throughput time?

a) Incorporate a CONWIP system (constant work in process).
b) Incorporate a sequencing rule such as FIFO (first in, first out).
c) Use critical path analysis to decide which tasks can be done in parallel.
d) Implement a push-control system.

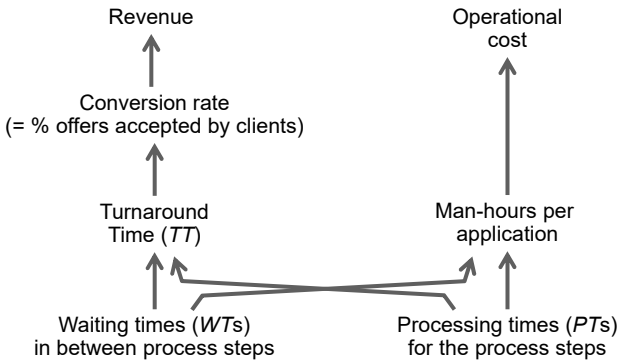
Reducing turnaround time for mortgage offers
*Questions **24** through **40** all relate to this case.*

We consider an administrative process in a bank. The process handles applications for mortgages, and in case the application is accepted, produces an offer.

On average 40 applications enter the process each day. In the first stage, they are handled by 4 coordinators, who check applications for completeness, and collect additional information from the Real Property Registration (Kadaster).
Next, the coordinators send the application to one of 3 rate officers. They judge whether the applicant qualifies for a loan, and they determine the interest rate that is offered.
Applications involving a higher loan sum (25% of the applications) are then sent to an underwriter, who assesses the risk and decides on a rejection or acceptance.
In the end, 10% of the applications are rejected, in which case a secretary writes a rejection letter. For the accepted applications (90%), the secretary prepares the offer and sends it to the applicant.

The company is losing business due to the rather long turnaround times (total throughput time) of the process. If applicants do not receive an offer within a few working days, they simply give up and apply at another bank. This results in a poor conversion rate (= the percentage of offers accepted by applicants).

24



Is the CTQ flowdown above acceptable?

a) Yes, the flowdown is good as it is.
b) No, Waiting Times (*WT*s) should not be connected to *Man-hours per application*.
c) No, Processing Times (*PT*s) should not be connected to *Man-hours per application*.
d) No, *Conversion Rate* should be replaced with *Quality and Efficiency*.

25

What is a practical and effective way to measure the *PT*s and *WT*s?

a) “Travel-sheet”: follow a sample of applications through the process, while employees place time-stamps when they start or complete a task.
b) “Day-in-the-life-of” (“multi-moment-opname”): follow a number of employees over a day. Each 15 minutes, they indicate on a check sheet what sort of task they are performing.
c) “Time-study”: Have an employee perform the first task in the process for 10 applications and measure the processing times with a stopwatch. The same for the second step in the process, and so on.
d) “Process-study”: Measure on what moments an application arrives in the first process step, then in the second step, and so on.

26

DMAIC 2: Validate the measurement procedures
The BB wants to validate the measurement methods and measurement plan that she has devised for determining the *WT*s and *PT*s.

Which of these techniques is **not** relevant for validating the measurement plan?

a) Gage R&R study.
b) Do a test measurement.
c) After the data have been collected: check face validity of the results.
d) Control chart.

27

Gage R&R

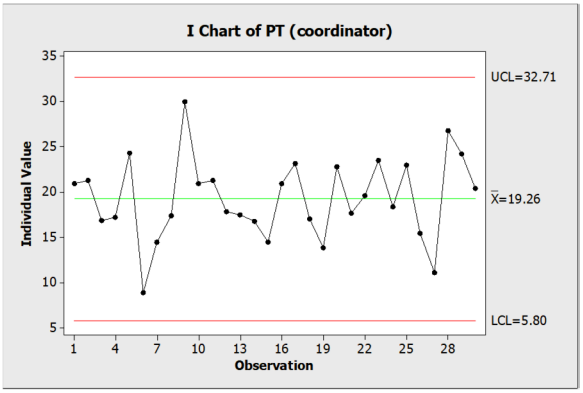
Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.32292	6.20
Repeatability	0.24965	4.79
Reproducibility	0.07327	1.41
Measurer	0.07327	1.41
Part-To-Part	4.88506	93.80
Total Variation	5.20798	100.00

Source	StdDev (SD)	Study Var (5.15 * SD)	%Study Var (%SV)
Total Gage R&R	0.56826	2.9265	24.90
Repeatability	0.49965	2.5732	21.89
Reproducibility	0.27068	1.3940	11.86
Measurer	0.27068	1.3940	11.86
Part-To-Part	2.21022	11.3826	96.85
Total Variation	2.28210	11.7528	100.00

Given the results above, what are the 99% uncertainty margins (precision) for the time measurements?

a) ± 0.323
b) ± 0.568
c) ± 1.46
d) ± 2.28

28



On the basis of 30 measurements, the BB makes a control chart for the *PT* of the coordinators (see above). What can she conclude?

a) The processing times of the coordinators are acceptable.
b) The *PT*s of the coordinators are **not** in statistical control.
c) There is no evidence for trends or outliers (the *PT*s are stable).
d) All of the *PT*s of the coordinators are within the norms as agreed in the SLA (Service Level Agreement).

29

The BB wishes to determine whether the *WT*s have a normal, lognormal or Weibull distribution, or maybe even an altogether different distribution.

What is the best tool to study the distribution of the data?

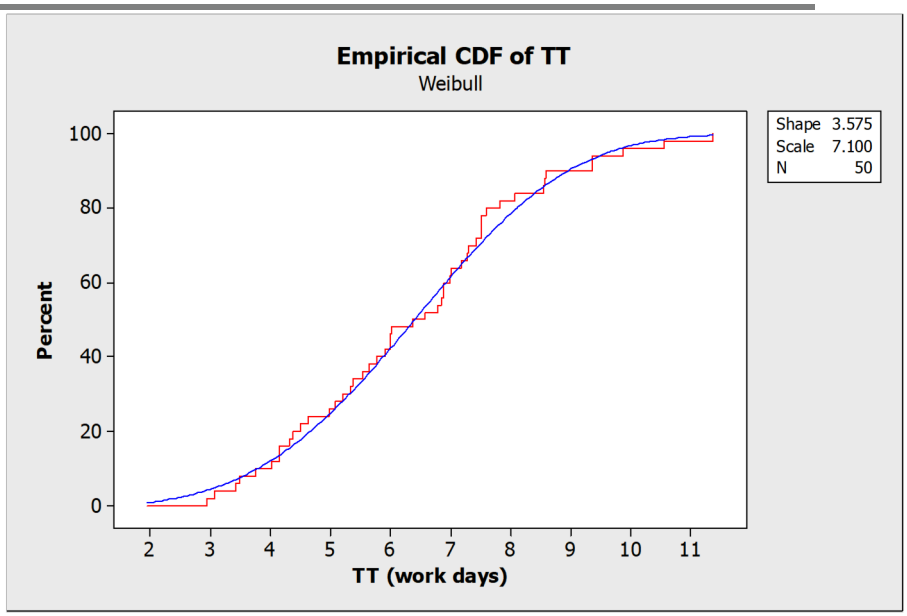
a) The empirical CDF (cumulative distribution function).
b) The histogram.
c) The control chart.
d) The probability plot.

30

The BB makes an empirical CDF graph of 50 observations of the Turnaround Time (*TT*); see **next slide**.

What can she conclude from this graph?

a) About 4% of applications are longer than 10 work days in the process.
b) About 24% of the applications has a turnaround time of 5 days.
c) The Weibull distribution is not a good fit, as the data are not on a straight line.
d) The effect of *TT* is not linear.



31

DMAIC 4: Identify potential influence factors.
Trying to get the *TT*s down to more acceptable levels, the BB considers doing an FMEA with the employees working in the process.

Is it useful, in this project, to do an FMEA?

a) No, since the objectives of the project are not about risks.
b) No, because an FMEA is used to identify failure modes (possible malfunctions) in products.
c) Yes, provided that part of the long *TT*s are caused by errors and mistakes.
d) Yes, as it helps to identify the bottleneck in the process.

32

DMAIC 4: Identify potential influence factors.
The BB organizes a brainstorming meeting with the employees in the process. The goal of the meeting is to identify the causes of long *TT*s and to devise possible solutions.

The meeting is quite successful and results in 64 ideas.

According to the DMAIC model, what should the BB do with these ideas?

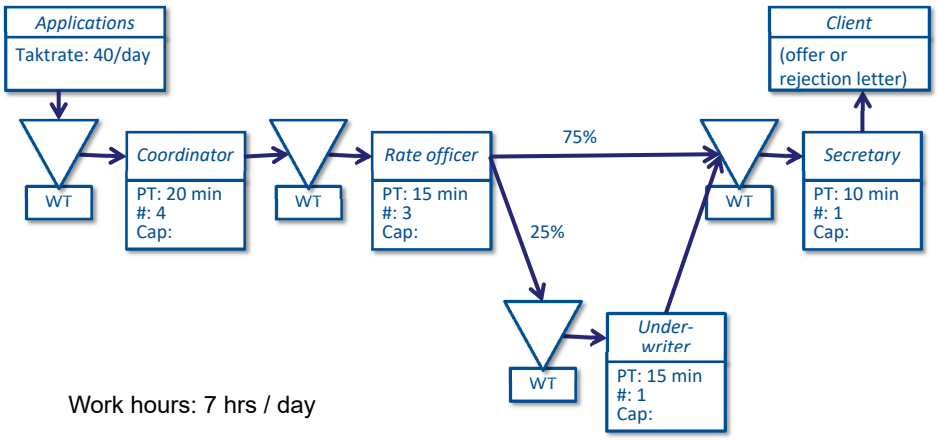
a) Participants vote about the value of these ideas, and the ideas with the most votes are implemented (“multi-voting”).
b) Find evidence for the effects of these candidate causes and ideas.
c) Delegate: let the participants decide which ideas they want to implement.
d) Brainstorming sessions are not based on data. Therefore, it is not a very suitable technique, and the BB should be very suspicious about the results.

33

Based on the measurements, the BB makes a value stream map (next page).

What are the capacities of the coordinators and the secretary?

a) Coordinators: *Cap* = 3 applications/day;
   Secretary: *Cap* = 6.
b) Coordinators: *Cap* = 21;
   Secretary: *Cap* = 6.
c) Coordinators: *Cap* = 21;
   Secretary: *Cap* = 42.
d) Coordinators: *Cap* = 84;
   Secretary: *Cap* = 42.



Work hours: 7 hrs / day

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Which resource is the bottleneck in this process? (That is, which bottleneck will have the highest utilization?)

a) The coordinators.
b) The rate officers.
c) The underwriter.
d) The secretary.

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The arrival rate of 40 applications per day is an average. Arrivals are not spread evenly over a day and over a week. Also the given *PT*s are averages, but there is some variability in the processing times of applications.

Will there be long waiting queues in the process (large *WT*s)?

a) No, as the capacities of the process steps are larger than the workload.
b) No; some resources have a capacity lower than the workload, other resources have a capacity higher than the workload. But the average capacity is large enough to handle the workload.
c) Yes, there will be a long waiting time especially before the bottleneck resource.
d) Yes, there will be long waiting times before all resources (all *WT*s are the same order of magnitude).

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The waiting times in the Value Stream Map are not given. We do know the average throughput time equals 6 days, and we also know that the process is able to handle the number of applications that come in each day, that is 40. Furthermore, it is given that a day consists of 7 work hours.

Assume that the processing time of the bottleneck resource equals 10 minutes (capacity 6 per hour).

Can we determine the average work in process?

a) No, we have to measure the work in process.
b) No, we have to measure the waiting times from which we deduce the number of jobs waiting in each queue and sum these up.
c) Yes, by means of Little's Law we know that the average work in process equals the throughput rate multiplied by the throughput time, which results in 240 jobs (40×6).
d) Yes, by means of Little's Law we know that the average work in process equals the capacity of the bottleneck resource multiplied by the number of work hours, which results in 42 jobs (6×7).

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```
Two-sample T for Offer vs Rejection

           N    Mean  StDev  SE Mean
Offer      6   8,754  0,820     0,33
Rejection  6  12,063  0,846     0,35

Difference = mu (Offer) - mu (Rejection)
Estimate for difference:  -3,309
95% CI for difference:  (-4,396; -2,221)
T-Test of difference = 0 (vs not =):
T-Value = -6,88  P-Value = 0,000  DF = 9
```

The BB does a small study. For six accepted applications, she records how long it takes (*PT*) the secretary to compose the offer. Also, for six rejected applications, she records how long it takes to write the rejection letter.

Assuming a normal distribution for the data, what can she conclude from the analysis above?

a) The time it takes to compose an offer is significantly shorter than the time to write a rejection letter.
b) The sample sizes in the study are too small to make reliable conclusions.
c) The means and the variances differ significantly between the two groups.
d) No conclusions are possible, as the BB should have used the ANOVA technique.

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The BB wants to determine the relationship between the waiting time *WT* in the work-queue before the coordinators, and the workload *WL* (the number of applications submitted per day).

On 20 different days, she records the number of applications that have been submitted. And she also records, for a randomly selected application, how long it spends in the coordinators' queue.

See the regression analysis on the **next slide**.

Is this a good fit?

a) Yes, there is no evidence for a poor fit.
b) No, a quadratic fitted line is not needed, a linear line would have been just as good.
c) No, the relationship is not significant.
d) No, there are outliers.

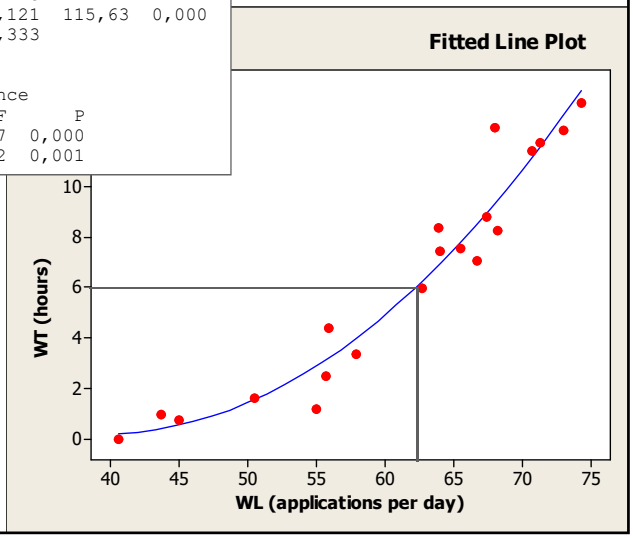
```
Polynomial Regression Analysis: WT versus WL

The regression equation is
WT = 24,64 - 1,091 WL + 0,01276 WL**2

S = 1,15449   R-Sq = 96,3%   R-Sq(adj) = 95,4%

Analysis of Variance
Source       DF       SS        MS       F      P
Regression    2  308,243  154,121  115,63  0,000
Error         9   11,996    1,333
Total        11  320,238

Sequential Analysis of Variance
Source     DF       SS      F      P
Linear      1  278,632  66,97  0,000
Quadratic   1   29,611  22,22  0,001
```



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Is the workload (*WL*) the most important influence factor for the waiting time (*WT*) before the coordinators?

a) Yes, the small p-value indicates that this is the vital influence factor having the largest impact.
b) The high R^2-value (R-Sq) indicates that this factor explains almost all differences in *WT* observed in the regular process.
c) No, there is considerable random scatter of the observations around the fitted curve.
d) To make that conclusion, one should include other potential influence factors in the regression analysis as well.

40

Suppose that the workload is *WL* = 62.5 applications per day.
What can you say about the waiting time in the coordinators' queue?

a) In that case, 95% of all applications will spend about 6 hours in the queue before the coordinators.
b) 95% of the applications will have a waiting time below 8.3 hours.
c) There is a 50% chance that *WT* will be above 6 hours.
d) 95% of the applications have a waiting time in between 4.85 and 7.15 hrs.

This is the end of the exam

Please check:

- Did you answer all questions?
- Have you filled in your name on the front sheet?

If you are finished before XX:XX hours then you may quietly leave the examination room and hand in your exam to one of the examiners.

If you are finished after XX:XX hours then you should wait until the examiners collected all exams at YY:YY hours.

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Answers

Question	Answer	Question	Answer	Question	Answer	Question	Answer
1	A	11	A	21	C	31	C
2	B	12	B	22	B	32	B
3	D	13	B	23	D	33	D
4	C	14	D	24	B	34	D
5	C	15	B	25	A	35	C
6	D	16	C	26	D	36	C
7	C	17	B	27	C	37	A
8	A	18	A	28	C	38	A
9	C	19	D	29	D	39	B
10	D	20	A	30	A	40	C