Mock Examination in the Bachelor of Science
Course title: Operations Management
Semester: Winter 2020
Lecturer: Strohhecker/Müller/Makowski
Group: All BSc Groups

Aids: Non-programmable calculator (e.g., Casio fx 82 solar, Casio fx 85 MS, Casio fx 85 GT plus), dictionary (in German modules), collection of formulae and statistical tables

Please enter your student ID (matriculation number) and your group!

Student ID	Group

Please note:

The exam consists of 6 questions of which you will have to answer 6 questions. You have **120** minutes to complete the examination. The maximum of points to be reached is **120**. Please use the enclosed answer sheet to answer your questions and add your student ID on its cover.

Please always explain your solution in adequate depth with comments for each important step!

We wish you all the best for your examination!

Internal use only!

Question	1	2	3	4	5	6	**Total**
Possible points:	20	20	20	20	20	20	**120**
Points achieved:							

Question 1 **(20 points)**

Part a) (4 points)

Butternut is a ski resort in Massachusetts. One of their triple chair lifts unloads 1296 skiers per hour at the top of the slope. (A triple chair lift can carry three passengers per chair.) The ride from the bottom to the top takes 5 minutes. How many skiers are riding on the lift at any one time?

Answer:

*Use Little's Law. 1296 skier/hour * 5/60 = 108 skiers*

There are 108 skiers ,on average, riding on the lift at any time.

Part b) (4 points)

A company's holding cost is 16% per year. Its annual inventory turns are 9.5. The company buys an item for $50. What is the average cost ($s), to hold this item in inventory?

Answer:

*The item will be turned 9.5 times a year. Thus, for each turn it stays in inventory, the holding cost is 16%/9.5 of the cost of the item. Thus, the average cost to hold this item in inventory is $50 * (16%/9.5) = $0.84*

Part c) (5 points)

Sarah's Organic Soap Company makes four kinds of organic liquid soap- "regular", "lavender", "citrus" and "tea tree". Demand for the four scents are 150, 120, 75 and 50 kgs per hour respectively. Sarah's production process can produce any soap at the rate of 450 kgs per hour but 1.5 hours are needed to switch between scents. During those switchover times, the process doesn't produce any soap. Sarah wants to choose a production schedule that (i) cycles repeatedly through the four scents, (ii) meets the required demand and (iii) minimizes the amount of inventory held.

How many kgs of "regular" should Sarah produce before switching over to another scent?

Answer:

*Total setup time = 1.5 * 4 = 6 hours. Total demand for all four scents per hour = 150 + 120 + 75 + 50 = 395 kgs/hour. The process capacity equals the demand, which is 395* *kgs/hr. Processing time = 1/ 450 hr. Batch Size = capacity * setup time / (1- capacity * processing time) = (395 * 6) / (1- 395/450)= 19390.91 kgs.*

*In each batch, 150/395*19390.91 = 7363.636kgs of "regular" should be produced.*

Part d) (3 points)

Sarah needs to purchase organic Palm oil to make her soaps. She needs 1,000 kgs of Palm oil per day on average. The supplier charges a $60 delivery fee per order (which is independent of the order size) and $4.75 per kg. Sarah's annual holding cost is 25%. Assume 52 weeks per year and 5 days per week. If Sarah wants to minimize inventory holding and ordering costs, how much Palm oil should she purchase with each order (in kgs)?

Answer:

Use the EOQ formula, $Q^* = \sqrt{\frac{2KR}{h}}$: $Q^* = \sqrt{\frac{2*60*1000}{(4.75*(\frac{0.25}{52*5})}}$ *= 5125.786*

Given the objective to minimize inventory holding and ordering costs, Sarah should purchase 5125.786 kgs per order.

Part e) (4 points)

Which of the following most directly expresses the motivation behind the expression "Do not block the bottleneck!"? Please justify your answer in 2 – 3 sentences.

a) If the bottleneck has nothing to work on, the overall capacity of the process will be lower than it could be.
b) If the bottleneck is prevented from working (e.g., it has nowhere to put its output), the overall capacity will be reduced.
c) Blocking the bottleneck will increase the coefficient of variation of the arrival process, which decreases capacity.
d) Blocking the bottleneck increases inventory turns, which increases the annual holding costs.
e) It is not good to block the bottleneck because there are economies of scale in inventory management.

Answer: B. You would have to explain why B is correct and why the others are not.

Question 2 (20 points)

Furniture Face Lift refinishes old wood furniture. Their process for refinishing chairs has 8 workers and 4 stations. Each chair starts at the Stripping station, then goes to Priming, then to Painting and finally to Inspection. Where there are multiple workers within a station, each worker works independently on his/her own chair. Assume inventory buffers are allowed between each station.

Station	Staffing	Processing time (hours per chair per worker)
Stripping	3	2.5
Priming	2	1.5
Painting	2	1.75
Inspection	1	0.8

Part a) (5 points)

What is the maximum number of chairs per hour that can be produced? Assume they start the day with inventory at each station to work on.

Answer:

The average times needed to finish one chair at each station are as follows,

Capacity = staffing/processing time:

Station	Staffing	Activity time (hours)	Capacity=staffing (m)/processing time
Stripping	3	2.5	1.2
Priming	2	1.5	1.333333333
Painting	2	1.75	1.142857143
Inspection	1	0.8	1.25

Painting is the bottleneck since it has the lowest capacity. The process capacity is the capacity of the bottleneck. Thus, the process capacity is 1.14 chairs/hour.

Part b) (5 points)

Suppose at the start of the day there is no inventory of chairs in the shop. That is, there are no chairs within any of the stations or between them in any buffer. A truck loaded with 15 chairs arrives. How many hours will it take them to complete these 15 chairs?

Answer:

*It will take 2.5 + 1.5 + 1.75 + 0.8 = 6.55 hours for the first chair to be produced. It takes 1/1.14 hours for each of the subsequent chairs. In total, it takes 6.55 + 1/1.14 * 14 = 18.8 hours to complete 15 chairs.*

Part c) (5 points)

Suppose now that each worker is trained to do all tasks and each worker works on a chair from start to finish, i.e., each worker does Stripping, Priming, Painting and Inspection. What is the maximum capacity of the process in <u>chairs per hour?</u>

Answer:

In this system, there will be no bottleneck, i.e., every worker is working at their full capacity. It takes each worker 2.5 + 1.5 + 1.75 + 0.8 = 6.55 hours to finish one chair. 3 + 2 + 2 + 1 = 8 workers can complete 8/6.55 = 1.22chairs/hour.

Part d) (5 points)

Which production system is able to produce the chair with lower cost, if the "specialized" workers are paid with $19 per hour and the "universal" workers are paid with $20 per hour?

Answer:

System 1, specialized: capacity = 1.14 chairs/hour, time = 1/1,14hours/chair,

*cost per chair = 8workers/chair * 19$/hour and worker * 1/1,14hours/chair = 133$.*

System 2, universal: capacity = 1.22 chairs/hour, time = 1/1,22hours/chair,

*cost per chair = 8 workers/chair * 20$/hour and worker * 1/1,22hours/chair = 131$.*

Production system 2 is able to produce the chair at lower cost.

Question 3 (20 points)

The following situation refers to Tom Opim, a first-year MBA student. In order to pay the rent, Tom decides to take a job in the computer department of a local department store. His only responsibility is to answer telephone calls to the department, most of which are inquiries about store hours and product availability. As Tom is the only person answering calls, the manager of the store is concerned about queuing problems.

Currently, the computer department receives an average of one call every three minutes, with a standard deviation in this interarrival time of 3 minutes. Tom requires an average of 2 minutes to handle a call. The standard deviation in this processing time is 1 minute. The telephone company charges $5.00 per hour for the telephone lines whenever they are in use (either while a customer is in conversation with Tom or while waiting to be helped).

Assume that there are no limits on the number of customers that can be on hold and that customers do not hang up even if forced to wait a long time.

Part a) (3 points)

For one of his courses, Tom has to read a book (The pole, by E. Silvermouse). He can read one page per minute. Tom’s boss has agreed that Tom could use his idle time for studying, as long as he drops the book as soon as a call comes in. How many pages can Tom read during an 8-hour shift?

Answer:

*Idle time = 1 min / 3 min * 8 hours = 160 min*

*Pages read = 160 min * 1 page/min = 160 pages*

On average, Tom can read 160 pages during an 8-hour shift.

Part b) (3 points)

How long does a customer have to wait, on average, before talking to Tom?

Answer:

Inter-arrival time: 1 call / 3 min

a = 3 min, CVa = 3 min / 3 min = 1

Processing time: p = 2 min, CVp = 1 min / 2 min = 0.5

Waiting time =

$$T_q = 2 * \frac{0.667}{1 - 0.667} * \frac{1^2 + 0.5^2}{2} = 2.5\, min$$

On average, customers have to wait 2.5 minutes before talking to Tom.

Part c) (4 points)

What is the average total cost of telephone lines over an 8-hour shift? Note that the department store is billed whenever a line is in use, including when a line is used to put customers on hold.

Answer:

*The average total time a line is used per customer = average wait time + average processing time. In this case, the average total time per customer = 2.5 + 2 = 4.5 minutes per customer. On average, 20 customers per hour call Tom, so the average number of minutes per hour = 20 * 4.5 = 90 minutes. Thus, the total per hour charge is: (90/60) * $5 = $7.50 per hour or $60 for 8 hours.*

*Another way to approach the same problem is to look at the average number of callers at any given time = average number of callers on hold at any given time (Iq) + average number of callers talking to Tom at any given time. We can calculate Iq = R * Tq where the flow rate = 1call / 3 minutes and Tq = 2.5 minutes. Thus, Iq = 0.83 calls. The average number of callers talking to Tom must be a number between 0 and 1, and is equal to Tom's utilization = 0.67. So, the average number of callers at any given time = 0.83 + 0.67 = 1.5 callers. The line charge for 8 hours = $5*8 = $40 per line. Therefore the total cost over an 8-hour shift is: 1.5*40 = $60.*

Part d) (4 points)

Three months later there is a big raise of the incoming calls. The average interarrival time decreases to 1 minute with a standard deviation of 1. What is the consequence?

Answer:

The new interarrival time is: a_new = 1min. Hence, the new utilization is: u,new = 2/1 = 2 = 200%. Accordingly, the waiting time will grow to infinite and the system is said to "explode."

Part e) (6 point)

How many additional students must be hired (in addition to Tom) to reach the same utilization as before (with Tom only and interarrival time = 3 minutes, see Part c)? Does the average customer waiting time remain constant (i.e., as in Part C) or does it change?

Answer:

*Two additional students must be hired to achieve the same utilization as in Part C: u = p/(m*a) = 2/(3*1). If a=3, it is m=1 (Tom); if a=1 it must be m=3.*

Regarding the waiting time:

$$\text{Time in queue} = \left(\frac{\text{Processing time}}{\text{m}}\right) \times \left(\frac{\text{Utilization}^{\sqrt{2(m+1)}-1}}{1-\text{Utilization}}\right) \times \left(\frac{CV_a^2 + CV_p^2}{2}\right)$$

$$T_q = \frac{2}{3} * \frac{0.667^{\sqrt{2(3+1)}-1}}{1-0.667} * \frac{1^2+0.5^2}{2} = 0.6\ min$$

Thus, Tq=0.6 minutes. The new waiting time is significantly shorter (0.6 minutes) compared to the scenario with one server, Tom, (which was 2.5 minutes) while the average server utilization remains identical.

Question 4 (20 points)

Dan McClure owns a thriving independent bookstore in artsy New Hope, Pennsylvania. He must decide how many copies to order of a new book, Power and Self Destruction, an exposé on a famous politician's lurid affairs. Interest in the book will be intense at first and then fizzle quickly as attention turns to other celebrities. The book's retail price is \$20, and the wholesale price is \$12. The publisher will buy-back the retailer's leftover copies at a full refund, but McClure Books incurs \$4 in shipping and handling costs for each book returned to the publisher. Dan believes his demand forecast can be represented by a Normal distribution with mean 200 and standard deviation 80.

Part a) (3 points)

Dan will consider this book to be a blockbuster for him if it sells more than 400 units. What is the probability Power and Self Destruction will be a blockbuster?

Answer:

We first find the z-statistic for 400 (Dan's blockbuster threshold); z = (400 – 200) /80 = 2.50. From the standard normal distribution function table, we see that $\Phi(2.50)$ = 0.9938. So there is a 99.38 percent chance demand is 400 or fewer. Demand is greater than 400 with probability 1 – $\Phi(2.50)$ = 0.0062; that is, there is only a 0.62 percent chance this is a blockbuster.

Part b) (3 points)

Dan consider a book a "dog" if it sells less than 50% of his mean forecast. What is the probability this exposé is a "dog"?

Answer:

We first find the z-statistic for 100 units (Dan's dog threshold): z = (100 – 200)/80 = -1.25. From the standard normal distribution function table, we see that $\Phi(-1.25)$ = 0.1056. So there is a 10.56 percent chance demand is 100 or fewer; that is, there is a 10.56 percent chance this book is a dog.

Part c) (4 points)

What order quantity maximizes Dan's expected profit?

Answer:

The underage cost is C_u = 20 – 12 = 8. The salvage value is 12 – 4 = 8 because Dan can return leftover books for a full refund (\$12) but incurs a \$4 cost of shipping and handling. Thus, the overage cost is cost minus salvage value: C_o = 12 – 8 = 4. The critical ratio is C_u / (C_u + C_o) = 8 / 12 = 0.6667. In the standard normal distribution function table, we see that $\Phi(0.43)$ = 0.6664 and $\Phi(0.44)$ = 0.6700, so use the round-

up rule and choose $z = 0.44$. Now convert z into the order quantity for the actual demand distribution: $Q = \mu + z * \sigma = 200 + 0.44 * 80 = 235.2$.

Part d) (3 points)

Dan prides himself on good customer service. In fact, his motto is "McClure's got what you want to read." How many books should Dan order if he wants to achieve a 95% in-stock probability?

Answer:

We want to find a z such that $\Phi(z) = 0.95$. In the standard normal distribution function table, we see that $\Phi(1.64) = 0.9495$ and $\Phi(1.65) = 0.9505$. Using the round-up rule, we can determine that Dan should order $200 + 1.65 * 80 = 332$ books.

Part e) (3 points)

If Dan orders the quantity chosen in Part d) to achieve a 95 percent in-stock probability, then what is the probability that "Dan won't have what some customers wants to read" (i.e., what is the probability some customer won't be able to purchase a copy of the book)?

Answer:

If the in-stock probability is 95 percent, then the stockout probability (which is what we are looking for) is 1 minus the in-stock probability, that is, $1 – 0.95 = 5$ percent. Thus, there is a 5 percent chance that customers won't be able to purchase a copy of the book.

Part f) (4 points)

Suppose Dan orders 300 copies of the book. What would Dan's expected profit be in this case?

Answer:

The z-statistic for 300 units is $z = (300 – 200)/80 = 1.25$. From the standard normal inventory function table, we see that $L(1.25) = 1.3006$. Expected inventory is $\sigma * I(1.25) = 80 * 1.3006 = 104.05$. Expected sales are $300 – 104.05 = 195.95$, and:

Expected profit =

*(Price – Cost) * Expected Sales – (Cost – Salvage value) * Expected leftover inventory = $(20-12) * 195.95 – (12 – 8) * 104.05 = 1151.4$. Therefore, Dan's expected profit would be \$1151.40.*

Alternatively, after calculating Expected Lost Sales = μ - Expected sales = $200 – 195.95 = 4.05$ Expected profit = Maximum Profit – Mismatch Costs

*Mismatch Costs = C_u * Expected Lost Sales + C_o * Expected leftover inventory = 8 * 4.05 + 4 * 104.05 = 448.60.*
*Maximum Profit = μ * C_u = 200 * 8 = 1,600.*

Therefore, Dan's expected profit would be 1,600 – 448.60 = 1151.40.

Question 5 (20 points)

Part a) (4 points)

In order to make reactive capacity useful,

a) the unit cost of the second order must not be higher than that of the first order.
b) the critical ratios of different products must be different.
c) the coefficient of variation (COV) of different products must be different.
d) the mismatch costs of different products must be different.
e) the lead time of the second order is not too long.
f) all the above are needed.
g) none of the above is needed.

Please justify your choice with 3 – 4 sentences.

Answer e) is correct. If the lead time of the second order is long enough, regular capacity would be adequate, and reactive capacity would not be needed. Choices a) through d) are red herrings, and not necessary to make reactive capacity useful. Choice d (and partially, choices b and c) are relevant only for the production of multiple products, whereas reactive capacity can be useful in a single-product context as well.

Part b) (4 points)

A retailer is considering two possible definitions of "in-stock":

(I) a product is in-stock if it has at least one unit on-hand at the end of the day.
(II) a product is in-stock if it has satisfied all demand during a day.

For a given order-up-to level, which definition yields the higher in-stock probability? Please justify your choice with 2 – 3 sentences.

a) Definition I, because if one unit is on-hand, then all demand must have been satisfied.
b) Definition II, because the firm is more likely to satisfy all demand than to end the day with one unit on hand.
c) Definition II, because if all demand is satisfied, then there must be some inventory left over.
d) Either one is possible, because it will depend on the particular order-up-to policy chosen, the distribution function of demand and the lead time.

Answer b is correct. Definition II yields higher in-stock, because there will be days when there are no items left over, but all the demand was satisfied. In such cases, Definition II will be in-stock, but we will be out of stock by Defintion I.

Part c) (4 points)

A firm uses the order-up-to model to manage its inventory. It wants to increase its in-stock probability while decrease its holding costs (i.e., reduce its average inventory). Which of the following will help to achieve this goal? (Consider each one on its own.)

i. Decrease the lead time.
ii. Increase the base stock level.
iii. Increase the average quantity on-order.

a) Only (i)
b) Only (ii)
c) Only (iii)
d) (i) and (ii)
e) (i) and (iii)
f) (ii) and (iii)
g) Any of them will help (that is (i), (ii) or (iii))
h) None of them will help

Answer:

Option a is correct. (i) decreasing the lead time will reduce inventory for a given base stock level and increase the in-stock probability. The others are not correct. If the base stock, S, is increased, the in-stock (probability) will increase but so will inventory. If the average quantity on-order increases, then it must be that the average lead time increases, which is not good for the in-stock (probability).

Part d) (8 points)

Suppose you are managing inventory using the order-up-to model, the order-up-to quantity is 10 and you have already received several replenishments. Which of the following statements is definitely false? (Consider each one on its own and provide an in-depth explanation.)

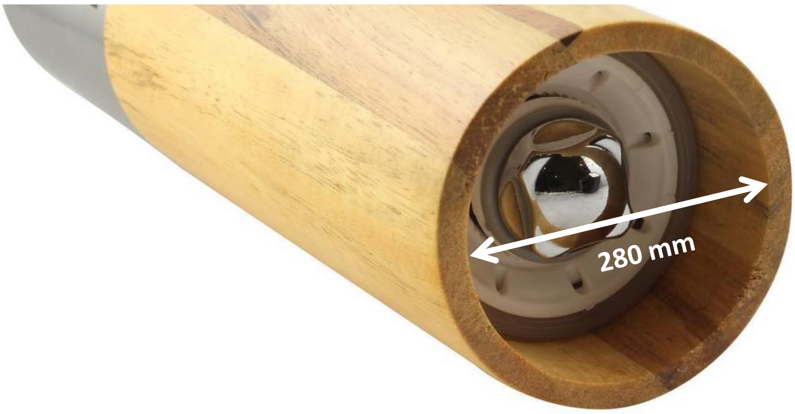
a) On-order inventory is 9.
b) Inventory position is 9.
c) Backorder is 11.
d) On-hand inventory is 11.
e) Inventory position is -11.
f) Pipeline inventory is 11.

Answer:

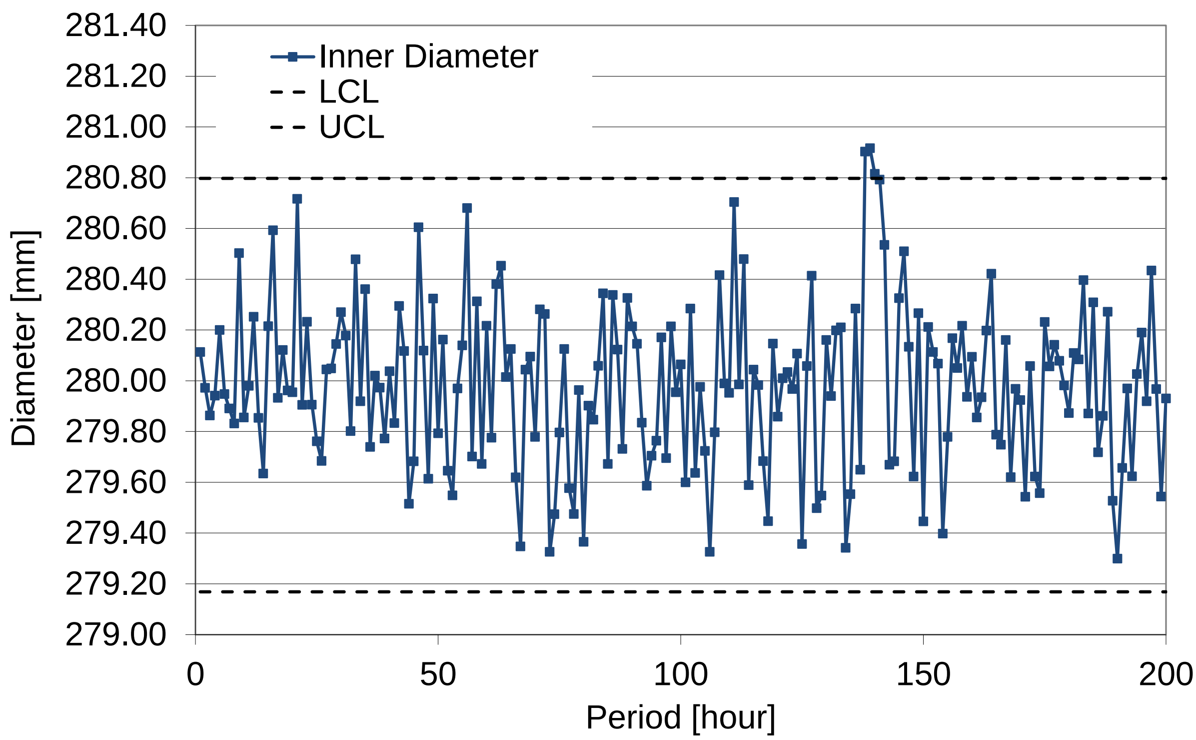
Order-up-to level = Inventory on hand + on order inventory – backorders. On-hand inventory cannot be greater than the order-up-to level. So (d) is definitely false. On-hand inventory is less than the order-up-to level, so (a) is true. The inventory position can be lower than the order-up-to level before ordering; hence (b) can be true. Backorders can be arbitrarily large. The inventory position can be negative (before ordering) because of *large backorders. Hence (c) and (e) could be true. The pipeline inventory can be 11 (for e.g. if there is no on-hand inventory and there are 11 backorders. So the order quantity would be 11 units, and the pipeline inventory would be greater than or equal to 11). So (f) could be true.*

Question 6 (20 points)

Luxory Pepper Mill Manufacturing (LPM) company produces a range of pepper mills that combine wooden and metal parts. The inner diameter of the wooden casing of the Frankfurt pepper mill shown below has a mean of 280 mm, an upper specification limit of 280.75 mm and a lower specification limit of 279.5 mm.



The quality inspector draws a sample of the wooden casing every hour. After 200 collected observations, he creates the following control chart:



The mean inner diameter is obtained as 279.9828 mm and the standard deviation is estimated 0.3259 mm. The upper (lower) control limit in the chart is set to the mean plus (minus) 2.5 of the estimated standard deviation.

Part a) (5 points)

Please explain briefly what the quality inspector can learn from a using a quality control chart in general. What conclusions should he draw from the chart shown above?

Solution:

Control charts are graphical tools to statistically distinguish between assignable and common causes of variation. *(2P)*

The chart shows a couple of out of control events between hour 145 and 150. *(1P)*

This indicates that there was an assignable cause of variation. *(1P)*

This assignable cause has to be detected, for instance by using the Ishikawa diagram method. *(1P)*

Part b) (2 points)

What is the difference between an upper control limit and an upper specification limit?

Solution:

The upper control limit is set based on how the process performed in the past.

The upper specification limit is defined by engineers based on the needs of the downstream processes or by the end customer.

Part c) (4 points)

Please calculate the process capability index for manufacturing the wooden casing. Is it adequate when compared to recommendations of quality experts?

Solution:

The process capability index is defined as follows:

$$\text{Process capability index} = \frac{\text{USL} - \text{LSL}}{6\sigma}$$

Upper specification limit of 280.75 mm and a lower specification limit of 279.5 mm

Standard deviation is estimated 0.325899932 mm

$$\text{Process capability index} = \frac{280.75 - 279.5}{6 \times 0.325899932} = \frac{1.25}{1.955399592} = 0{,}6393$$

(3P)

Compared to the general recommendation of quality experts (CP at least 1.333), the calculated index of 0.6393 is bad. *(1 P)*

Part d) (4 points)

What is the probability that the inner diameter of the casing is wider than the upper specification limit (280.75)? Assume that the collected data follow a normal distribution.

Solution:

We have normally distributed diameters with

Mean = 279.9828 mm

Standard deviation = 0.3259

We want to know the probability that a diameter is > 280.75, that is 1- p that the diameter is ≤ 280.75

We calculate the z-value:

(280.75 - 279.9828478) / 0.325899932 = 2.353950025

For z = 2.36 (round-up rule) we find using the standard normal distribution function table 0.9909. Therefore, the probability that the diameter is > 280.75 is

1 – 0.9909 = 0,0091

Part e) (5 points)

Please explain briefly the core ideas of the JIDOKA quality management concept.

Solution:

The core aim of the Jidoka concept is rapid defect detection. It includes three elements: Detect – Stop – Alert

- ➔ *Monitor the quality of the process continuously, e.g. by using control charts*
- ➔ *Stop the process immediately whenever a defect is detected and alert the supervisor.*
- ➔ *Machine shut down can be done automatically (original concept) or manually (e.g., by using an Andon cord).*