Frankfurt School of Finance & Management
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Examination in the Bachelor of Science
Course title: Operations Management
Semester: Winter 2014/2015
Lecturer: Kremer/Müller/Strohhecker
Group: IBA, BBA, BWL, BWL-AIS, WI-AIS

Aids: Casio fx 82 solar, Casio fx 85 MS, Casio fx 85 GT plus, Dictionary, 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 5 questions of which you will have to answer **4** questions. If you answer all **5** questions only the first **4** will be evaluated. You have **80** minutes to complete the examination. The maximum of points to be reached is **80**. 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	**Total**
Possible points:	20	20	20	20	20	
Points achieved:						

Question 1 (20 points)

The local Department of Motor Vehicles issues new licenses and renews licenses. The office receives 110 customers per hours. All customers first see a receptionist. The receptionist directs them in one of three directions. 75% go directly to Issue License (staffed by 9 workers) where a new photo and license are done. 15% are required to take an eye test (staffed by one worker) and 10% must first take a multiple-choice electronic written test (on one of three computers). Only 85% of people pass the eye test and the remaining 15% exit. The customers who pass the eye test proceed on to the Written Test. 10% of the people who take the written test fail it, while 90% pass the test and then proceed to Issue License.

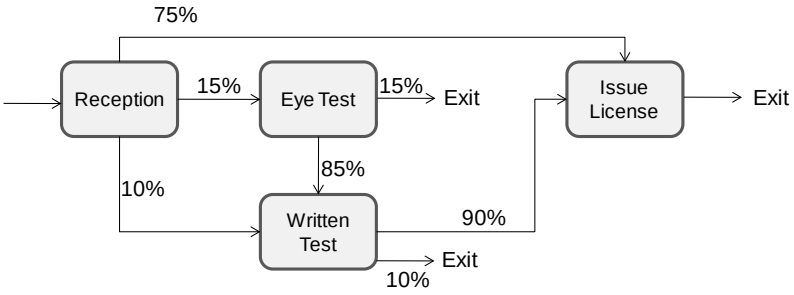
Data on each station are provided in the following table:

	Workers	Activity time per worker (min)
Reception	1	0.4
Eye Test	1	5
Written Test	3	15
Issue License	9	6

Part a) (6 points)

Develop a process flow diagram that shows the percentages.

Solution:



Buffers could be added before processes.

Part b) (4 points)

Determine each of the four station's capacity (in customers per hour)?

Capacity per station is determined as:

*1/processing time (min) * 60 min per hour * no of workers*

For instance, issuing licences:

*1/6 *60 *9 = 90*

	Workers	*Processing time (min)*	*Capacity per hour*
Reception	*1*	*0.4*	*150*
Eye Test	*1*	*5*	*12*
Written Test	*3*	*15*	*12*
Issue License	*9*	*6*	*90*

Part c) (10 points)

What is the implied utilization at the four stations (as a %)? Where is the bottleneck station? Explain!

Solution:

$$\text{Implied utilization} = \frac{\text{Capacity requested by demand}}{\text{Available capacity}}$$

Available capacity is calculated in a)

Demand capacity has to be determined as follows:

Demand rate = 110 customers per hour

Demand rate at reception = demand rate = 110 cust/h *1P*

*Eye test = 110 * 0.1 = 16.5 cust/h* *1P*

*Written test = 110 * 0.1 + 16.5 * 0.85 = 25.025 cust/h* *1P*

*Issue license = 110*0.75+25.025*0.9=105.0225 cust/h* *1P*

Implied utilizations are calculated using the formula above as follows:

Reception = 110 / 150 = 0.73 = 73 % *1P*

Eye Test = 16.5 / 12 = 138% *1P*

Written Test = 25.025 / 12 = 209% *1P*

Issue License = 105.0225/90 = 117% *1P*

The bottleneck station is the station with the highest implied utilization. Based on the results shown above the station "written test" is the bottleneck station. *2P*

Question 2 (20 points)

Joe needs to purchase malt for his micro-brew production. His supplier charges $35 per delivery (no matter how much is delivered) and $1.20 per gallon. Joe's annual holding cost per unit is 35% of the dollar value of the unit. Joe uses 5000 gallons of malt per week.

Part a) (5 points)

How many gallons should Joe order from his supplier with each order? What are minimal annual inventory holding cost and minimal annual delivery cost?

$$\text{Economic order quantity} = \sqrt{\frac{2 \times \text{Setup cost} \times \text{Flow rate}}{\text{Holding cost}}}$$

Suppose Joe orders x gallons per order.

$$\text{Economic order quantity} = \sqrt{\frac{2 \times 35 \times 5000 \times 52}{1.2 \times 0.35}} = \sqrt{\frac{18200000}{0.42}} = 6582.8$$

(3P)

Alternative way:

*The fixed portion of the delivering cost is $35*5000*52/x per year = $9,100,000/x.*

*The average annual inventory holding cost is x/2*1.2*35% = x/0.84.*

*Then the total weekly cost is $35 * 5000 * 52/x + x/2*1.2*35%.*

*The cost is minimized at x = sqrt(35*5000*52/(0.6*35%))=6583 gallons.*

*Minimal annual inventory holding cost: 6583/2 * 1.2 * 35% = 1382.43 (1 P)*

*Minimal annual delivery cost = $35 *5000*52 / 6583 = 1382.35 (1 P)*

*It is correct to also include purchasing cost in the annual delivery cost: 1382.35 + 5000 * 52 * 1.2 = 313382.35*

Part b) (2 points)

Suppose Joe were to order 3800 gallons each time he orders. How many orders per year would he place on average? What time would lay in-between two orders?

*Number of orders per year = 5000 *52 /3800=68.42 (1 P)*

*Time between two orders = 3800/(5000*52) = 0.014615 years = 0.76 weeks (1P)*

Alternative solution = 52 / 68.42 = 0.76 weeks

Part c) (7 points)

If Joe places an order for 15000 gallons, then he will receive a 4% discount off the regular price of $1.20. If Joe were to do this with each order, what would be his average weekly <u>total</u> cost (in $s)? When compared to your solution in a), what would you suggest? Order 15000 gallons and take the 4% discount or use the optimal order quantity calculated in a)?

With a 4% discount, the malt is 1.2(1-0.04)=$1.152 per gallon.* *(1P)*

*Weekly purchase cost= $1.152*5000=$5760.* *(1 P)*

Weekly delivery charges = 5000/15000 $35=$11.67.* *(1 P)*

*Weekly inventory holding cost = 15000/2 * $1.152 * (35%/52)=$58.15.* *(1 P)*

Total cost = $5760 +$11.67 + $58.15=$5830 *(1 P)*

Total weekly cost based on the EOQ of 6583 is

Annual total cost from a)

*Annual inventory holding cost: 6583/2 * 1.2 * 35% = 1382.43*

*Annual delivery cost including purchasing cost = $35 *5000*52 / 6583 + 5000 * 52 * 1.2 = 313382.35*

Annual total cost = $314764.78 converted to weekly cost = $6053.17 *(1 P)*

Joe is better off placing orders of 15000 gallons and taking the 4% discount than using EOQ as
$5830 < $6053.17 *(1 P)*

Part d) (3 points)

It is costly to hold inventory (e.g., storage costs, obsolescence costs, etc.) but inventory can also be useful in a process. What is the major advantage of including buffers in-between process steps?

Adding inventory (or adding buffer) reduces chances that the process starving for items to work on, thus improve the process capacity.

Part e) (3 points)

Henry Ford famously proclaimed "You can have any color you want, as long as it is black". What had the introduction of different colors done to the car production capacity? Explain!

With more than one color, the process would have to switch from one color to another, which would incur idle time on switchovers and utilization would decrease.

Question 3 (20 points)

Not relevant any more.

Question 4 (20 points)

Radio Shack sells a 128 GB USB 3.0 flash drive for $39 per unit. Weekly demand for the flash drive in one of their stores is Poisson distributed with a mean of 1.25. The store places orders weekly and there is a one week lead time to receive orders. Inventory holding cost at the stores level is $5 per week. If no flash drives are in stock, customers buying a unit receive free-of charge express shipping as soon as new items are available at a cost of $12.50 per unit.

Part a) (2 points)

On average, how many units will the store have on order?

Expected number of units on order = expected demand in one period x lead time = 1.25 units per period x 1 period = 1.25

Part b) (2 points)

Suppose that they have 5.5 units of this flash drive on average in inventory in the store. What is the annual turns of this item in this store? Assume 52 weeks per year.

Annual sales = 1.25 x 52 = 65 units (1P)

=> annual turns = 65/5.5 = 11.82 (1P)

Part c) (4 points)

Suppose they operate with a base stock level of 4. What in-stock probability would they achieve?

Lead time is 1 period (one week) => l+1 = 2. (1P)

So the in-stock probability is the probability that demand over 2 periods (two weeks) is less than or equal to 4. The demand over two weeks is Poisson distributed with mean 2 x 1.25 = 2.5. (1P)

Use the Poisson function table with μ = 2.5 and S = 4 to find
F(S) = 0.8911 = 89.1% (2P)

{If l instead of l+1 is used: 2P)

Part d) (5 points)

Given their cost and price for the flash drive, what is the optimal order-up-to level the Radio Shak store should target?

Answer: The optimal in-stock probability is equal to the critical ratio, which is given as

CR= (backordering cost)/(backordering cost +holding cost) 1P

Backordering cost = $12.50 per unit

Holding cost = $5 per unit and week

=(12.50)/(12.50 + 5)=0.714 2P

Use the Poisson function table with μ = 2.5 and to find F(3) = 0.75758, which is larger than the critical ration of 0.714. Therefore, optimal order-up-to level is 3. 2 P

{If l instead of l+1 is used: 1P)

Part d) (7 points)

Radio Shack sells the same 128GB flash drive on their e-commerce site which has a single distribution center. Daily demand at their e-commerce DC is forecasted to be normally distributed with a mean of 150 and a standard deviation of 75. The lead time to receive a replenishment at the distribution center from their supplier is 2 days. They review their inventory and place orders every two days, on the same day that they receive deliveries of new inventory. They operate 7 days a week. If they were to implement an order-up-to model, what base stock level should they choose for the DC if they want to achieve a 99.3% in-stock probability? (Leave your answer in decimal form, i.e., no need to round to an integer value.)

Notice that Radio Shack reviews their inventory and places orders every two days so one period is two days.

The mean and standard deviation for demand over one period are therefore

2 x 150 = 300 and *1P*

sqrt(2) x 75, respectively. *2P*

The lead time is 2 days, namely 1 period => l =1 => demand over l+1 = 2 periods is then normally distributed with mean 2 x 300 = 600 and standard deviation sqrt(2) x sqrt(2) x 75 = 150. *2P*

Finally, $\Phi(z) = 0.993 \Rightarrow z = 2.46$. *1P*

$S = \mu + z \times \sigma = 600 + 2.46 \times 150 = 969$ *1P*

Question 5 (20 points)

The airport branch of a car rental company maintains a fleet of 50 SUVs. The interarrival time between requests for an SUV is 2.4 hours, on average, with a standard deviation of 2.4 hours. There is no indication of a systematic arrival pattern over the course of a day. Assume that, if all SUVs are rented, customers are willing to wait until there is an SUV available. An SUV is rented, on average, for 3 days, with a standard deviation of 1 day.

Part a) (6 points)

What is the average number of SUVs parked in the company's lot?

We approach this problem as though the rental car is the "server".

We know that
a = 2.4 hours,
*p = 3*24 = 72 hours,* *1P*
CVa = (2.4/2.4) = 1, *1P*
CVp = (24/72) = 0.33, and *1P*
m = 50 cars.

To determine the number of cars on the lot, we can look at the utilization rate of our "servers" = (1/a) / (m/p) = (1/2.4) / (50/72) = 60%. *2P*

Therefore, on average 60% of the cars are in use or 30 cars, so on average 20 cars are in the lot. *1P*

Part b) (7 points)

Through a marketing survey, the company has discovered that if it reduces its daily rental price of $80 by $25, the average demand would increase to 12 rental requests per day and the average rental duration will become 4 days (without changing the standard deviations). Is this price decrease warranted? Provide an analysis!

We assume that the standard deviations DO NOT change.

If the average demand is increased to 12 rentals per day, then a = 2 hours. *1P*

If the average rental duration increases to 4 days, then p = 96 hours. *1P*

These values raise the utilization rate to (1/2) / (50/96) = 96%. *1P*

This means that 48 cars are rented on average. *1P*

*With the initial rate average revenue per day = $80*30 cars = $2400.* *1P*

*With the proposed rate average revenue per day = $55*48 = $2640.* *1P*

Therefore, the company should make the proposed changes. *1P*

Part c) (4 points)

What is the average time a customer has to wait to rent an SUV? Please use the initial parameters rather than the information in part (b)

$$T_q = \left(\frac{\text{Processing time}}{m}\right) \times \left(\frac{\text{Utilization}^{\sqrt{2(m+1)}-1}}{1 - \text{Utilization}}\right) \times \left(\frac{CV_a^2 + CVp^2}{2}\right)$$

Using the wait time formula, the average wait time = 0.019 hours or 1.15 minutes.

Part d) (3 points)

How would the waiting time change if the company decides to limit all SUV rentals to *exactly* 4 days? Assume that if such a restriction is imposed, the average interarrival time will increase to 3 hours, with the standard deviation changing to 3 hours.

Using the wait time formula the average wait time is computed as 0.046 hours.