IE375 Spring 2020

Case 1: Solution and Comments

(Explains the attached Excel Computation Sheets)

General Comments:

I am very happy with your performance. The case is not genuine, but I believe it represents more-or-less a very realistic setting.

Two comments:

1) Computational work: You better use a spreadsheet or a program to compute similar things over and over again. Some of you looked very hesitant to use any supporting tool. Of course, when you use such a tool, you need to clearly describe the formulas you have used. This is what I did in this document which states the solution.

2) When you are working with numbers, make sure that you used a reasonable number of digits after the decimal point (and be consistent). The reason is obvious: The readers want to get an insight looking at the numbers and you need to facilitate their understanding by only presenting the more significant part. It is also important that you understand those numbers and realize any peculiarities (mostly computational errors).

3) If you are using a program, to submit a spread-sheet or a computer program output without any explanation is not acceptable.

4) Make sure that you have your names written on the report.

Below find relevant statistics regarding grades received.

	Exam
Average	86.24
Std. Dev.	12.81
MAX	100
MIN	43

Range	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Freq.	0	0	0	0	2	0	2	10	14	23

Formulas Implemented in Excel:

Equation 1) $$h'_j = h_j(1-\lambda_j / P_j)$$

Equation 2) $$Q_j = \lambda_j T$$

Equation 3) $$G(Qj) = K_j \lambda_j / Q_j + h'_j Q_j / 2$$

Equation 4) $$G(T) = \sum_{j=1}^{n} \left(K_j / T + h'_j \lambda_j T / 2 \right)$$

Equation 5) $$T^* = \sqrt{\frac{2\sum_{j=1}^{n} K_j}{\sum_{j=1}^{n} h'_j \lambda_j}}$$

Equation 6) $$\sum_{j=1}^{n} \left(s_j + Q_j / P_j \right) \leq T$$

Equation 7) $$T \geq \frac{\sum_{j=1}^{n} s_j}{1-\sum_{j=1}^{n} (\lambda_j / P_j)} = T_{\min}$$

Equation 8) $$\text{Choose } \max(T^*, T_{\min})$$

Description of the Solution presented in Excel and Comments

Part A.a)

First table is organized way of presenting the data given. Units for each column is important to write as it is needed to guarantee consistency in the formulas applied. Only the fifth column of the table is computed –the ratio of demand rate to production rate is used to compute h' values **(Equation 1)** to be used.

Tmin in the Excel is computed using **Equation 7**. Note that you can represent the time in units of years or days. T is computed using **Equation 5**. Note that you can represent this time in units of years or days as well. Finally, the optimal value which can be implemented is computed using **Equation 8**.

Type	Annual Sales	Daily Sales	Prod. Rate (u/day)	Daily Sales/ Prod. Rate	Setup Time (Hrs)	Setup Cost ($)	Variable Cost ($)	Holding Cost ($ per unit/year)
A	25,900	104	4,000	0.03	6	120	0.003	0.00061
B	42,000	168	2,750	0.06	4	80	0.002	0.00039
C	14,400	58	1,650	0.03	8	160	0.008	0.00162
D	46,000	184	1,600	0.12	4	80	0.002	0.00037
E	12,500	50	900	0.06	5	100	0.01	0.00198
F	100,000	400	1,950	0.21	2	40	0.005	0.00083
G	100,000	400	1,450	0.28	1	20	0.004	0.00061
H	18,900	76	600	0.13	5	100	0.007	0.00128
		# of working days/year:	250					
		# of working hours/day	8					
		setup cost $/hr	20					
		inventory holding cost/$/year	0.21					
	Tmin=	43.51	days		T=	2.29	years	
	Tmin=	0.17	years		T=	573.25	days	
		T* = max(Tmin, T) =	2.29	years				

Part A.b) Lot sizes are computed using **Equation 2**.

Type	Lot Size
A	59389.04
B	96306.55
C	33019.39
D	105478.6
E	28662.66
F	229301.3
G	229301.3
H	43337.95

Part A.c) Average setup cost for an item is computed using the first term of **Equation 3**. Average holding cost is computed using the second term of **Equation 3**. Average Total Cost is the sum of all individual costs, as stated in **Equation 4**.

Some of you missed the computation (and check) for T_{min}, and hence lost points.

Type	Average Setup Cost	Average Holding Cost	Average Total Cost
A	52.33	18.22	70.56
B	34.89	18.99	53.88
C	69.78	26.77	96.55
D	34.89	19.60	54.49
E	43.61	28.42	72.03
F	17.44	95.69	113.13
G	8.72	69.74	78.46
H	43.61	27.84	71.45
	Average Total Cost:		610.55

Part B.a) b) c)

Remember that **Equation 4** is a convex function and hence given the restriction T is now calculated to be 1 year. Hence we repeat all the calculations using the formulas stated in **Part A** with **T=1**

Most of you missed the convexity notion. Do not forget, you learned all the math and will become engineers – hence simplify your life and use the notions that you have been familiar with.

PART B - a)						
Convex function, hence the upper limit is optimal for the restricted problem.						
Toptimal=	1	year				
PART B - b)						
	Type	**Lot Size**				
	A	25,900				
	B	42,000				
	C	14,400				
	D	46,000				
	E	12,500				
	F	100,000				
	G	100,000				
	H	18,900				
PART B - c)						
		Average	**Average**	**Average**		
		Setup	**Holding**	**Total**		
	Type	**Cost**	**Cost**	**Cost**		
	A	120.00	7.95	127.95		
	B	80.00	8.28	88.28		
	C	160.00	11.67	171.67		
	D	80.00	8.55	88.55		
	E	100.00	12.40	112.40		
	F	40.00	41.73	81.73		
	G	20.00	30.41	50.41		
	H	100.00	12.14	112.14		
		Average Total Cost:		833.13		

Part C

This part was asked to understand what you lose with such a restriction. The Excel Table shows % increase in the Average Total Cost for each item separately. The comment given in the Excel Sheet is very important – you need to follow that in order to have an approach for **Part D**.

I was expecting you to comment on the results – unfortunately some of you didn't. You need to "read" the numbers and understand their implications.

PART C)	Type	Average Total Cost (PART A)	Average Total Cost (PART B)	% Change
	A	70.56	127.95	81.34
	B	53.88	88.28	63.86
	C	96.55	171.67	77.82
	D	54.49	88.55	62.50
	E	72.03	112.40	56.03
	F	113.13	81.73	-27.76
	G	78.46	50.41	-35.75
	H	71.45	112.14	56.95
	TOTAL	610.55	833.13	36.46

Except Buttons F and G, all the individual average costs have increased. However, the limitation resulted in average cost decrease for F and G. We see that by forcing all the buttons in a common cycle is not necessarily meaningful as item characteristics are different. Check their individual EOQ and TEOQ values. You will see that F and G have small TEOQ values, whereas the others have much larger ones.

Part D.a)

This part of the question is not a straightforward. It requires you to understand the result of **Part C**, (or equivalently solve each item for their EOQ and compare their "optimal" cycle times, T_{EOQ}). This means that given the parameters, some items prefer smaller cycle times compared to the others. The solution in Part A forces all the items to have the same cycle time (this is rotation cycle policy). As a result given all these details, **Part D** asks you to find a better solution, if possible.

My solution proposal follows the results presented in the last column of the table for **Part C**: I suggest that we consider completely independent groups (as if there was not a common resource used). Hence the solution in **Part D.b)** onwards (until **Part D.e)** will assume these two independent group of items.

I planned to accept any logical (logical meaning that it is based on something that you know or observe from the numbers) grouping idea for this section. I was very glad to see that most of you had the same grouping as I suggested.

PART D - a)
Already described in Part C). Solve for individual EOQ's to group.
Group 1: Buttons F and G
Group 2: Remaining Buttons

Part D.b) c) d)

Hence we repeat all the calculations using the formulas stated in **Part A.a) through Part A.c) for each group** with their T values. Note that the Average Total Cost computed in **Part D.d)** is much less than what we have found in **Part A.c).** However, the solution with less cost likely to be infeasible as we will not be able to match production and setup requirements with the available capacity.

Remarkably, most of you did as suggested in the solution. However, a few of you decided not to use any formulas related to rotational cycle, but stick to the T values found in the previous parts.

PART D - b)								
Group 1:								
E	100,000	400	1,950	0.21	2	40	0.005	0.00083
F	100,000	400	1,450	0.28	1	20	0.004	0.00061
	Tmin=	0.72	days		T=	0.91	years	
	Tmin=	0.0029	years		T=	227.99	days	
	T* = max(Tmin, T) =		0.91	years				
Group 2:								
A	25,900	104	4,000	0.03	6	120	0.003	0.00061
B	42,000	168	2,750	0.06	4	80	0.002	0.00039
C	14,400	58	1,650	0.03	8	160	0.008	0.00162
D	46,000	184	1,600	0.12	4	80	0.002	0.00037
E	12,500	50	900	0.06	5	100	0.01	0.00198
H	18,900	76	600	0.13	5	100	0.007	0.00128
	Tmin=	6.88	days		T=	3.24	years	
	Tmin=	0.03	years		T=	809.85	days	
	T* = max (Tmin, T) =		3.24	years				

PART D - c)		
Group 1	Type	Lot Size
	F	91195.59
	G	91195.59
Group 2	A	83900.93
	B	136055.6
	C	46647.62
	D	149013.2
	E	40492.73
	H	61225

PART D - d)				
Group 1	Type			
	F	43.86	38.06	81.92
	G	21.93	27.74	49.67
Group 2	A	37.04	25.74	62.79
	B	24.70	26.83	51.52
	C	49.39	37.82	87.21
	D	24.70	27.69	52.39
	E	30.87	40.16	71.03
	H	30.87	39.33	70.20
		Average Total Cost:		526.72

Part D.e)

The answer to the question is "no", as we wouldn't know how to fit the production within the constraint of the common resource. Some of you had reasonable explanations and got the full grade.

I'll go on further with the answer, although this was not asked.

This part is challenging, but I think very educational.

My Suggestion: Have Group 1 Buttons manufactured twice in a cycle while Group 2 Buttons are manufactured once.

This is simpler to implement as the solution above didn't result in cycle time for Group 2 which is an integer multiple of Group 1 cycle time. Hence My Suggestion seems to be reasonable as it is close to what we have obtained for each group.

Hence, I suggest utilize the larger T as the cycle time. What I compute the total time requirements of production I simply use **Equation 6** (you can follow it in the Excel output. So we find that it is feasible.

However, we need to go one more step: We need to see that Group 1 Buttons will be feasibly allocated within the cycle with equally spaced two production instances. The last part of the Excel shows that it can be done.

Please compute the Average Total Cost of My Suggestion.

Further, see if you can have 3 separate setups for Group 1 buttons and 1 for the others in a cycle: you can check it in the same way as I did for My Suggestion.

Note that the optimal solution of the problem requires a method which will check all possible combinations which are feasible. This problem is very hard (integer decisions variables with non-linear objective function).

Part D-e)							
Of course, this solution is very promising as total average cost is much less. However,							
there is no quarantee that it is feasible. Try to draw the cycles on a time graph.							
My solution: May be it will be simpler if we think Group 1 to be ordering twice while							
Group 2 buttons are ordering once in a cycle.							
How do you check the feasibility?							

Production time + setup time							
Group 1	Type	setup	total setup	prod time	total	each	
	F	2	4	0.37	0.3761	0.3006	
	G	1	2	0.50	0.5041	0.4034	
				years			
Group 2	A	6	6	0.08	0.0838		
	B	4	4	0.20	0.1926		
	C	8	8	0.11	0.1129		
	D	4	4	0.37	0.3608		
	E	5	5	0.18	0.1758		
	H	5	5	0.13	0.1235		
				total time=	1.9297	< 3.12	
	So total timewise it fits the cycle time and is feasible.						
	However, actual production times within the year should be checked.						

	The following order looks feasible:						
Order:	D F G A B C E						
	0.3608	0.3006	0.4034	0.0838	0.1926	0.1129	0.1758
	CUM:	0.6614	1.0648	1.1486	1.3412	1.4541	1.6300
wait until	1.980496		idle time:	0.3505			
Order:	F G H						
	0.3006	0.4034	0.1235				
CUM:	2.2811	2.6845	2.8080				
wait until	3.24		idle time:	0.4314			
	Of course other possibilities exist. Find some others.						