ISEN-645

LEAN ENGINEERING

HW5

1. Mixed Model Scheduling and Production Leveling
2. Countertop production problem
3. Small process multiple setup capacity and batch size determination

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Question 1: (Part A)

Assume that a process needs to produce A=50, B-25, C-50, and D-10 units of product. The Product dependent Set-up and Changeover times in hours for these four products are as follows.

	A	B	C	D
A	0	1.67	0.87	1.26
B	1.23	0	0.76	1.23
C	1	0.89	0	2.21
D	1.55	1.22	1.1	0

[1] List all the product changeover sequences that are possible and calculate the total time consumed by each. [2] What is the optimal product mix which can be used? (3) How many different subset optimal solutions can be identified?

Ans.

The Total time consumed is calculated by all trying out all the possible product changeover sequences.

SI.No.	Sequence	Process			Changeover time in Hours				Total Time
		1	2	3	1	2	3	4	
1	1234	12	23	34	1.67	0.76	2.21	1.55	6.19
2	1243	12	24	43	1.67	1.23	1.10	1.00	5.00
3	1324	13	32	24	0.87	0.89	1.23	1.55	4.54
4	1342	13	34	42	0.87	2.21	1.22	1.23	5.53
5	1423	14	42	23	1.26	1.22	0.76	1.00	4.24
6	1432	14	43	32	1.26	1.10	0.89	1.23	4.48
7	2134	21	13	34	1.23	0.87	2.21	1.22	5.53
8	2143	21	14	43	1.23	1.26	1.10	0.89	4.48
9	2314	23	31	14	0.76	1.00	1.26	1.22	4.24
10	2341	23	34	41	0.76	2.21	1.55	1.67	6.19
11	2413	24	41	13	1.23	1.55	0.87	0.89	4.54
12	2431	24	43	31	1.23	1.10	1.00	1.67	5.00
13	3124	31	12	24	1.00	1.67	1.23	1.10	5.00
14	3142	31	14	42	1.00	1.26	1.22	0.76	4.24
15	3214	32	21	14	0.89	1.23	1.26	1.10	4.48
16	3241	32	24	41	0.89	1.23	1.55	0.87	4.54
17	3412	34	41	12	2.21	1.55	1.22	0.76	5.74
18	3421	34	42	21	2.21	1.22	1.23	0.87	5.53
19	4123	41	12	23	1.55	1.67	0.76	2.21	6.19
20	4132	41	13	32	1.55	0.87	0.89	1.23	4.54
21	4213	42	21	13	1.22	1.23	0.87	2.21	5.53
22	4231	42	23	31	1.22	0.76	1.00	1.26	4.24
23	4312	43	31	12	1.10	1.00	1.67	1.23	5.00
24	4321	43	32	21	1.10	0.89	1.23	1.26	4.48

[2] Optimal product mix solution

Ans.

The Optimal Solution is the lowest obtained changeover time.

For example, In the example sequence 4231, the lowest changeover time obtained is 4.24 Hrs.

Trial No.	D	B	C	A	Reps	Time (Hrs.)
1	10	25	50	50	1	4.24
2	2	5	10	10	5	4.25*5=21.25

[3] How many different subset optimal solutions can be identified?

Ans.

There are four different optimal solutions.

- 1423
- 2314
- 3142
- 4231

Question 2: (Part B)

Production sequencing and batch determination problem based upon feet of countertop produced.

- For this question, we are considering 4 products, they are A, B, C, and D this can be 4 different soft drinks produced by a company.
- It is assumed to be an 8 hr shift with one 30-minute break & two 15-minute breaks.
- Therefore, the available productive time is 7 Hrs.

SI. #	PRODUCTS	1	2	3	4	5	6	7	8	9	10	DAILY DEMAND
1	A	57	57	58	59	55	57	55	56	59	59	57
2	B	73	79	77	73	75	78	76	79	77	75	76
3	C	89	85	88	87	85	90	85	87	87	86	87
4	D	105	103	105	101	101	100	100	100	102	105	102

- Above are the randomly assumed demands over the period of two weeks and below is the plot of the daily demand (Quantity Vs Days)
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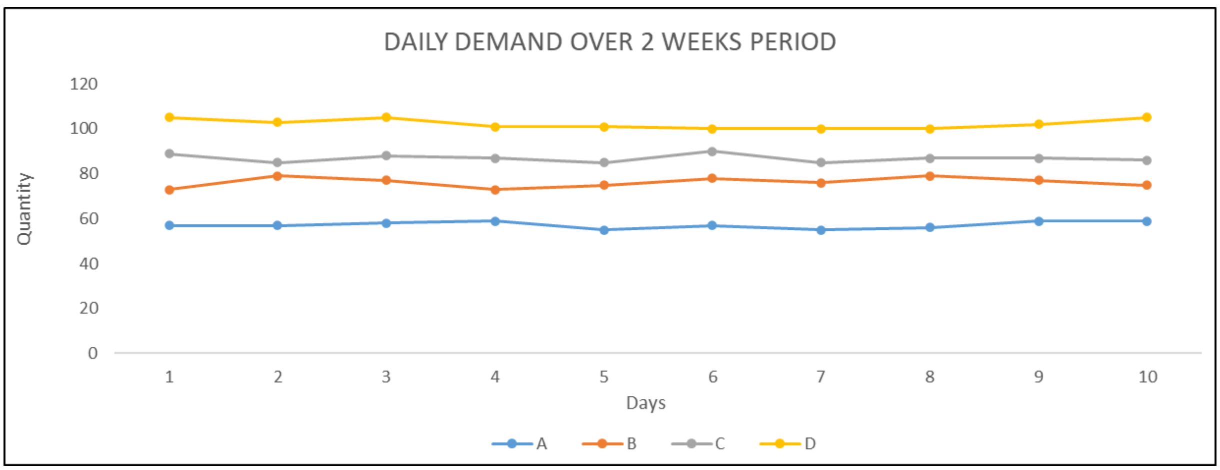
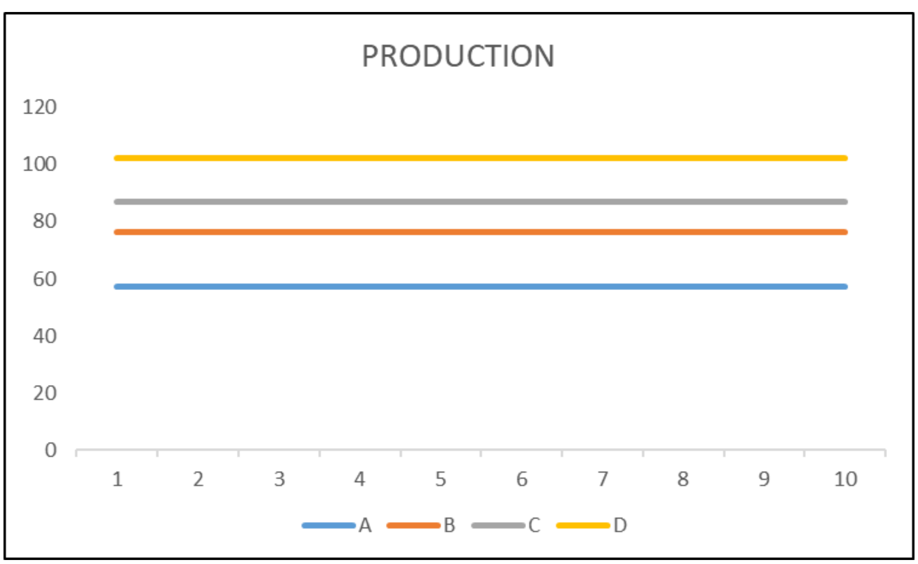




Below is the calculation based on Hamel's approach and, we can see here the cumulative demand and the card adjustments at various cycles. The production ratio is selected to be a multiple of 3 with A, B, C, D as 3,4,4,4.56,5.36 which is rounded off to 3,4,5 &5.

					Takt time		Multiple of production ratio					Selected Production ratio	Adjustment (Ch)			
S.no	Products	Daily Demand	Calculated production ratio	Cumulative demand	Min	Sec	1	2	3	4	5	1	1 card	2 card	3 card	4 card
1	A	57	2	18%	7	441	1.00	2.00	3.00	4.00	5.00	3	N / A	N / A	N / A	N / A
2	B	76	3	41%	6	331	1.33	2.66	4.00	5.33	6.66	4	N / A	N / A	N / A	N / A
3	C	87	3	68%	5	290	1.52	3.04	4.56	6.08	7.60	5	-2.26	-4.52	-6.78	-9.04
4	D	102	4	100%	4	247	1.79	3.57	5.36	7.15	8.93	5	2.51	5.02	N / A	N / A

Based on the card adjustment calculation, to get a better ratio and not produce excess or reduced quantity in the sequence we finalize, we need to follow the below card adjustment in the cycles mentioned.

- For C, every 9 cycles 4 cards are removed,
- For D, every 5 cycles 2 cards are added.

The batch size calculations are given below.

Products	Daily demand	Selected Production ratio	Batch sizes
A	57	3	19
B	76	4	19
C	87	5	17
D	102	5	20

Below table is the assumption for the change over time between the products.

The below table specifies our assumption of changeover time in hrs.:

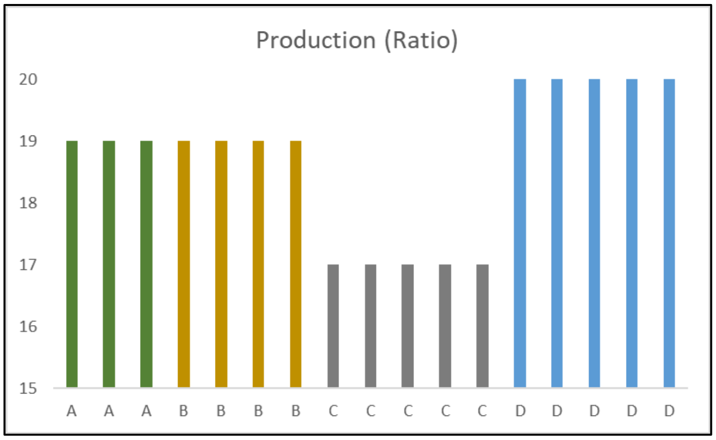
	A	B	C	D
A	0	0.05	0.08	0.1
B	0.1	0	0.02	0.09
C	0.07	0.2	0	0.05
D	0.12	0.04	0.02	0

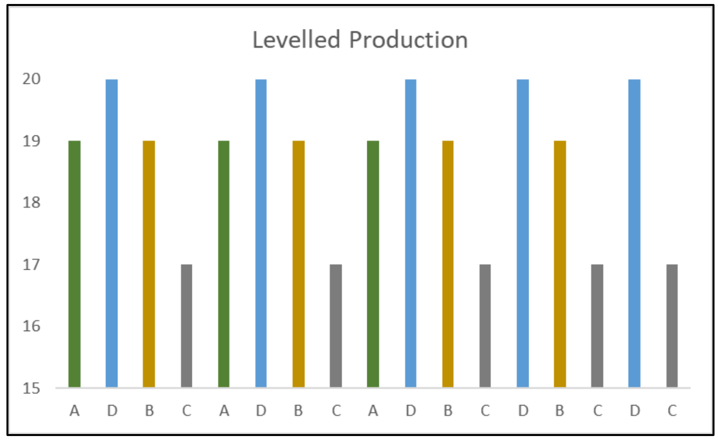
The change over sequence follows the permutation of 4 which is 4! = 4x3x2x1 = 24 types, and they are listed below:

Considering A=1,B=2,C=3,D=4

Sl.No.	Sequence	Process				Changeover time in Hours				Total Time
		1	2	3	4	1	2	3	4	
1	1234	12	23	34	41	0.05	0.02	0.05	0.12	0.24
2	1243	12	24	43	31	0.05	0.09	0.02	0.07	0.23
3	1324	13	32	24	41	0.08	0.20	0.09	0.12	0.49
4	1342	13	34	42	21	0.08	0.05	0.04	0.1	0.27
5	1423	14	42	23	31	0.1	0.04	0.02	0.07	0.23
6	1432	14	43	32	21	0.1	0.02	0.2	0.1	0.42
7	2134	21	13	34	42	0.1	0.08	0.05	0.04	0.27
8	2143	21	14	43	32	0.1	0.1	0.02	0.2	0.42
9	2314	23	31	14	42	0.02	0.07	0.1	0.04	0.23
10	2341	23	34	41	12	0.02	0.05	0.12	0.05	0.24
11	2413	24	41	13	32	0.09	0.12	0.08	0.2	0.49
12	2431	24	43	31	12	0.09	0.02	0.07	0.05	0.23
13	3124	31	12	24	43	0.07	0.05	0.09	0.02	0.23
14	3142	31	14	42	23	0.07	0.1	0.04	0.02	0.23
15	3214	32	21	14	43	0.2	0.1	0.1	0.02	0.42
16	3241	32	24	41	13	0.2	0.09	0.12	0.08	0.49
17	3412	34	41	12	23	0.05	0.12	0.05	0.02	0.24
18	3421	34	42	21	13	0.05	0.04	0.1	0.08	0.27
19	4123	41	12	23	34	0.12	0.05	0.02	0.05	0.24
20	4132	41	13	32	24	0.12	0.08	0.2	0.09	0.49
21	4213	42	21	13	34	0.04	0.1	0.08	0.05	0.27
22	4231	42	23	31	14	0.04	0.02	0.07	0.1	0.23
23	4312	43	31	12	24	0.02	0.07	0.05	0.09	0.23
24	4321	43	32	21	14	0.02	0.2	0.1	0.1	0.42

From the above table, the most optimal changeover combination is 1243 (We are considering this to be the best one) with 0.23 hrs. Once A is completed, D-B-C has the lower time, which is followed by D-C and hence the sequence is followed.





The best change-over sequence is listed below.

PROCESS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	X				X				X								
B			X				X				X			X			
C				X				X				X			X		X
D		X				X				X			X			X	

The Heijunka box is as follows.

PROCESS	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B	X	X	X	X	X	X	X	X	X	X	X	X	X	X
C	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
D	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX

The calculated production available time is 7 hrs. and the actual run time is 6 hours.
Based on the sequence we mentioned, the change over time is calculated to be 0.8 hrs. Thus, we have the production utilization as 6/7 which is 85%.
The EFE is calculated to be 0.8/1 = 0.80 < 1. Thus, there is buffer time available for the changeover, considering a single day.

We can see here, from the finalized sequence that, the change over time between C & A is maximum, with the use of SMED concepts (single minute exchange die) and other kikaku principles, this major changeover time needs to be reduced, which will give a compounding effect over the production run.

Question 3: (Part C) Countertop production problem

VTIp makes 4 types of countertops on one cell, call them A, B, C, and D. It takes 3h to switch from one type of countertop to another. The demand rates for each countertop type in feet/hr are 100, 80, 70, and 50 respectively. When in production the cell can produce 350 feet/hr. Batch sizes are selected to minimize inventory while satisfying demand requirements. The production cycle identified by the staff ISEN is A-B-C-D-A-B-C-D…

[a] What batch size (in feet) is chosen for countertop A?

<u>Ans.</u>

$$Recommended\ batch\ size = \frac{flow\ rate \times changeover\ time}{1 - flow\ rate \times processing\ time}$$

Here,

setup time = 12 Hrs. (Addition of individual changeover time)
flow rate = 350 feet/hr.
processing time = 1/350
= 0.00285714 hr./feet

Recommended batch size = $\frac{300 \times 12}{1-(300 \times 0.00285714)}$
Recommended batch size = 25199.84 feet

Recommended batch size = 25200 feet

Batch Size of A = (25200*100/300) = 8400
Batch Size of B = (25200*80/300) = 6720
Batch Size of C = (25200*70/300) = 5880
Batch Size of D = (25200*50/300) = 4200

	Hourly Demand	Change over	Batch Size
A	100	3	8400
B	80	3	6720
C	70	3	5880
D	50	3	4200
Total	300	12	25200

[b] If VTIp produces 16,800 feet of A in each production cycle and 50,400 feet total in each cycle, what would the average inventory of A be?

__Ans.__

Average Inventory = 0.5*batch size*(1-flow rate*process time) **[Given]**
Batch Size of A = 16800 feet **[Given]**
Total flow rate = 50400 feet **[Given]**

Change in the flow rate for cell A
Batch size of A = Total batch size / Flow rate / Total processing time

Flow rate of A = Total batch size / (Flow rate* Total processing time) = 116.667
Flow rate of A = 16800 / (50400*0.00285714) = 116.6667
Flow rate of A = 116.6667 feet/hrs.

(Flow rate of 166.667 ft/hr)
Average Inventory of A = 0.5*16800*(1-116.6667*0.00285714) = 5599.647 feet
Average Inventory of A = 5600 feet (Approx.)

(Flow rate of 300 ft/hr)
Average Inventory of the system = 0.5*50400*(1-300*0.00285714) = 3600.0216 feet
Average Inventory of the system = 3600 feet (Approx.)

Average Inventory of A = 3600.0216*(16800/50400) = 1200.0072 feet
Average Inventory of A = 1200 feet (Approx.)

If there is no change in the Flow rate.

Average Inventory of A = 0.5*16800*(1-100*0.00285714) = 6000.0024
Average Inventory of A = 6000 feet (Approx.)

Question 4: (Part D) Multiple workstations and setups

Multiple workstation & setups	WS1		WS2		WS3
Processing time (min/unit)	0.25		0.2		0.15
setup time (min)	30		20		45

For the batch flow process above, before a WS can be used it must be setup. While setup in ongoing a WS cannot process any product. Assume a dedicated setup operator exists for each WS.

[a] What is the capacity of WS1 if the batch size for units is 35?

Capacity of workstation = Batch size / (set-up time + Batch size*Processing Time)
Capacity of workstation = 35 / (30 + 35*0.25)
Capacity of workstation = 35 / 38.75
The capacity of workstation = 0.9032 units/minute

[b] For what batch size is WS1 the bottleneck? WS2 the bottleneck? WS3 the bottleneck?

A bottleneck occurs when Demand (Batch size) > capacity.

- **WS1 and WS2:**
  (0.25*Batch size) + 30 = (0.2*Batch size) + 20
  (0.25*Batch size) - (0.2*Batch size) = 20 - 30
  (0.05*Batch size) = -10
  Batch size = -10 / 0.05
  Batch size = -200 units

  In this case, the Batch size is negative, so we can conclude that workstation 2 can never be a bottleneck for workstation 1.

- **WS2 and WS3:**
  (0.2*Batch size) + 20 = (0.15*Batch size) + 45
  (0.2*Batch size) - (0.15*Batch size) = 45 - 20
  (0.05*Batch size) = 25
  Batch size = 25 / 0.05
  Batch size = 500 units

  In this case, the Batch size is 500 units,
  Hence when the batch size is less than 500 then WST-3 is the bottleneck,
  if it is greater than 500 then WST-2 is the bottleneck.

- **WS1 and WS3:**

  (0.25*Batch size) + 30 = (0.15*Batch size) + 45
  (0.25*Batch size) - (0.15*Batch size) = 45 - 30
  (0.1*Batch size) = 15
  Batch size = 15 / 0.1
  Batch size = 150 units

  In this case, the Batch size is 150 units,
  Hence when the batch size is less than 150 then WST-3 is the bottleneck,
  if it is greater than 150 then WST-1 is the bottleneck.

WS	Cycle time	Batch size	Setup time	Processing time
1	2.229	151	30	0.25
2	3.008	151	20	0.2
3	2.232	151	45	0.15

WS	Cycle time	Batch size	Setup time	Processing time
1	2.22	149	30	0.25
2	2.99	149	20	0.2
3	2.221	149	45	0.15

WS	Cycle time	Batch size	Setup time	Processing time
1	3.227	501	30	0.25
2	4.168	501	20	0.2
3	4.169	501	45	0.15

So consolidating all the above cases,
When batch size is less than 150 units, WST-3 is the bottleneck.
When batch size is greater than 150 units, WST-1 is the bottleneck.

Batch size	0	------------>------------>	150	------------>------------>	Infinity
Bottle-neck	WST-3			WST-1	

[c] Explain how the process designer might use the takt time to identify the best batch size for each WS.

Takt time: Cycle time with which the system has to operate to meet the demand, we then allocate batch size.

Takt time: (Setup time + processing time * batch size) / Batch size

Takt time: Available working time/customer demand = (60 / 10) = 6 mins/unit

By doing trial & error and approximation,
the Batch size for the demand of 10 units where Cycle Time < TAKT time is calculated.

Recommended Batch Size = Flow Rate x Setup Time / 1- (Flow Rate x Time per unit)

We know that Takt Time = (1/Throughput) = (1/Flow Rate)

So, Recommended Batch Size = (1/Takt Time)*Setup Time / (1-(1/Takt Time*Time per unit))

Below we are calculating batch size for which the cycle time < Takt time

WS	Cycle time	Batch size	Setup time	Processing time
1	5.25	6	30	0.25
2	5.2	4	20	0.2
3	5.775	8	45	0.15