IE424 Homework II –Part I & II – Fall 2023
Due date: Part I-Dec. 17, 2023- 23:59 hrs
Due date: Part II-Jan. 3, 2024- 23:59 hrs
You may work in Teams of TWO
Submit your report to ODTUClass

Part I:

ÇETİ produces various types of chocolate products (items), like bars, tablets, and wafers (gofret), in their plant located in Newtown. At the end of each month the master production plan for each week of next three months is prepared for each product (item) considering the demand forecasts for items and capacity of the plant. Then at the beginning of each week a detailed production schedule is prepared for that week and executed.

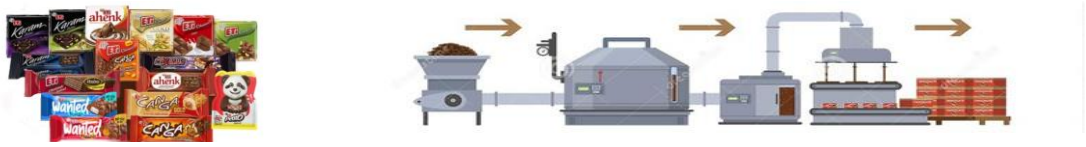


Fig. 1. Products and production lines

The products are produced on three different continuous lines which involves the preparation of the chocolate mix, molding and packaging operations (Fig 1.). Basically there exist four different family types of products where a major setup of the line is required when production switches from one family to the other, Table 1. Then for each item a minor setup is required. The line production capacities differ with respect amount of production per hour with respect to the items.

Suppose at the beginning of a specific week batches of 15 items are required to be produced in the next two days(1) (i.e. Monday and Tuesday) and the following data is provided in Table 2. An item that can not be completed by Tuesday (end of) will be considered tardy however they should be completed next day. Each item has a weight which identifies the importance of the order relative to the others. The orders for these items can not be split nor preempted. Line 1 is the most efficient line (fastest) and Lines 2 and 3 are 5% and 10% slower than Line 1 respectively. The capacity of Line 1 with respect to the items are given in Table 2. All the lines work for the 6 shifts of these two days and a shift is 8 hours long. You may assume 100% efficiency of the lines and labor during a shift and the week starts with no items (jobs) on lines therefore major setup will not be incurred for the first item to be processed on the machines.

To produce these items also labor force is required to operate (including setups) the machines on the lines and handling between machines. Labor requirements for the items are provided in Table 2 and they do not differ with respect to different lines.

(a) Develop suitable mathematical model(s) for each of the following objectives (performance measures)*.
   i. Minimize Makespan
   ii. Minimize Total Flowtime
   iii. Minimize Total Weighted Flowtime
   iv. Minimize Total Tardiness

v. Minimize Total Weighted Tardiness
vi. Minimize Total Number of Tardy Jobs
vii. Minimize Total Weighted Number of Tardy Jobs

Be sure that the models are **linear integer and **efficient** in terms of solution times.*

(b) Using the models you developed in part (a) find the corresponding optimal schedules for each objective. Also record the other performance measures respectively for each objective. Provide a summary table as you have done in Homework 1.

(c) For each objective of part (b) provide the total labor requirements for each of the shifts so that the Human Resources unit can plan workforce requirements for the shifts.

(d) Comment on your results and suggest a production schedule for these two days.

Table 1. Major Setup times between types in hours (symmetrical)

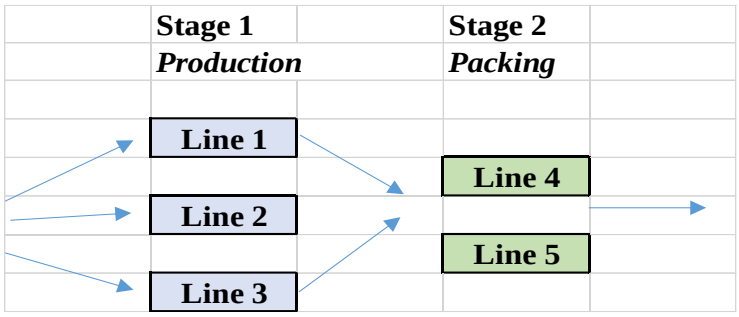
Type i/j	2	3	4
1	2	4	6
2	-	2	4
3	-	-	2

Table 2. Relevant data for 15 items

Item	Type	Weight	Capacity for line 1 (kg/hr)	Demand (kg)	Minor Setup time (hrs)	Number of Labor required
1	1	6	900	4600	0.60	8
2	1	9	900	10700	1.40	12
3	1	4	900	12700	1.60	10
4	1	9	900	6300	1.00	9
5	1	10	900	2200	1.80	6
6	2	4	700	7400	1.80	14
7	2	9	700	12000	1.60	5
8	2	2	700	5700	0.40	9
9	2	1	700	10800	1.40	15
10	3	6	1200	5800	0.20	7
11	3	4	1200	14400	0.80	13
12	3	9	1200	5900	1.80	11
13	3	6	1200	7100	1.40	7
14	4	1	1100	7200	2.00	15
15	4	4	1100	3200	0.60	15

(1) *In actual application, ÇETİ has to prepare schedules for around 100 different items , 10 lines over a week of 18 shifts.*

Part II:
Consider the following additions to Part I. Some items produced in Stage 1 (on lines 1-3) are also required to be packed in Stage 2 on one of the two Packing Lines (may identify as Lines 4 and 5) depicted as follows:



Type 1,2,and 3 items require packing whereas type 4 items will be delivered without packing. Again the batches of items can not be split nor preempted on any of the stages. For Packing Lines the major and minor setup durations are half of Stage 1. Lines 4 and 5 are 5% and 10% slower than Line 1 respectively. The Packing Lines 4 and 5 require 12 and 15 workers for any of the items respectively. It is possible to start the setup for an item on Packing Lines after that item is started to be produced on Stage 1, i.e. when the setup (major and minor) of the item is completed on Stage 1, however –obviously- setup on a packing line is not possible if that line is busy with packing another item.

With the additional packing operations the management still considers the items to be **tardy** if not completed within the first **six** shifts.

For this part consider the following to be delivered:

(a) Develop suitable mathematical model(s) for each of the following objectives (performance measures)*.

i. Minimize Makespan
ii. Minimize Total Flowtime
iii. Minimize Total Weighted Flowtime
iv. Minimize Total Tardiness
v. Minimize Total Weighted Tardiness
vi. Minimize Total Number of Tardy Jobs
vii. Minimize Total Weighted Number of Tardy Jobs

Be sure that the models are **linear integer and **efficient** in terms of solution times.*

(b) Using the models you developed in part (a) find the corresponding optimal schedules for each objective. Also record the other performance measures respectively for each objective. Provide a summary table as you have done in Homework 1. Also give a Gantt chart for the solution of the Makespan objective.

(c) For Makespan objective of part (b) provide the total labor requirements for each of the shifts so that the Human Resources unit can plan workforce

requirements for the shifts. **However for this part, the labor requirement of a line on a shift is determined as the maximum of the labor requirements of the items processed on that line and shift.** For example, if items 1 and 2 are both produced on Line 1 during a shift then the labor requirement for that line on that shift will be Max{8,12}=12 workers.

(d) Compare your results with the ones you obtained in Part I, i.e. single stage model. Comment on your results and suggest a production schedule.

(e) What may be some policies and/or suggestions you may have to implement in order to improve the performance of the system?