Pan American Advanced Institute Program on Process Systems Engineering

BATCH SCHEDULING

EXERCISES

1. A chemical plant producing a pair of final products P1 and P2 is to be scheduled in order to maximize the profit over a time horizon of 24 h. The process involves the production of three intermediates (I1, I2, I3) from feedstocks A and B, which are subsequently transformed into the end products P1 and P2 (see Table 1). Intermediate I3 is synthesized from a (60:40)-mix of intermediates I1 and I2 through Task-3. The quantity of I3 yielded by Task-3 is then applied to the synthesis of the final products P1 and P2 in equal amounts (50:50). Five processing tasks are to be performed in three equipment units (E1, E2, E3), with each one being devoted to a subset of the tasks as shown in Table 2. Capacities of the processing units in Kg are also given in Table 2. Data related to intermediate and final products are included in Table 3.

Task	States Consumed	States Produced
Task-1	Feed-A	I1
Task-2	Feed-B	I2
Task-3	I1, I2 (60% : 40%)	I3
Task-4	I3 (50%)	P1
Task-5	I3 (50%)	P2

Table 1. States consumed and produced by each task

Task	E1	E2	E3
Task-1	3	4	
Task-2	5	5	
Task-3	6	5	
Task-4			3
Task-5			7
Capacity (Kg)	100	200	400

Table 2. Constant task processing times (in h)

State	Initial Inventory (Kg)	Dedicated Tank Capacity (Kg)	Minimum Demand (Kg)	Unit Price ($/Kg)
Feed-A	2000	Unlimited		1
Feed-B	2000	Unlimited		2
I1	--	200	--	-
I2	--	200	--	-
I3	80	500	--	-
P1	50	Unlimited	250	8
P2	50	Unlimited	200	12

Table 3. State Data

a) Find the production schedule that maximizes the profit using:

- a discrete-time scheduling model
- a continuous-time scheduling formulation

b) Let now assume that Task-1 and Task-2 both require heat provided by steam. The coefficient values for the fixed and variable steam consumption terms are:

Task	μ_{ir}	ν_{ir}
Task-1	5	0.20
Task-2	4	0.25

Table 4. Steam consumption coefficients for tasks 1 & 2

Find the new best production schedule maximizing the profit.

2. Let us consider a make-to-stock sequential batch facility involving three processing stages (S1, S2, S3) where a single batch of five different products (P1, P2, P3, P4, P5) all following the same routing (S1$\rightarrow$ S2 $\rightarrow$ S3) are to be produced. In each stage, several identical units are running in parallel (Table 1). Table 2 includes the batch processing time for every product at each stage. Setup times are negligible.

Stage	Set of Equipment Units
S1	E1, E2
S2	E4,E5
S3	E6, E7

Table 1. Set of parallel units in each stage

Product	S1	S2	S3
P1	18	12	9
P2	16	13	11
P3	15	15	12
P4	10	12	15
P5	12	14	10

Table 2. Processing times (in h)

a) Find the production schedule that minimizes the time required to complete all the batches by using:

- the slot-based continuous time model
- the global general precedence continuous formulation

b) Let us consider the following sequence-dependent setup times:

	P1	P2	P3	P4	P5
P1		1.5	1.0	1.2	3.0
P2	1.3		0.9	1.2	1.4
P3	0.8	0.9		0.5	1.0
P4	1.1	2.5	0.7	1.0	1.6
P5	1.0	1.4	0.5	.6	

Table 3. Sequence-dependent setup times

Find the new best production schedule minimizing the makespan.