Assembly Systems Project

Planning Production for Multi-Product Assembly Systems with Bottleneck Resources

Introduction

A jet engine manufacturing firm produces a range of engine models for both commercial and military customers. While the end products are vastly different, their supply chains and manufacturing lines share key resources. Limited capacity in forging, a manufacturing step required for parts going into every single final product, are resulting in delays throughout the product line, disgruntled customers, and internal disputes among product managers fighting to prioritize their supplies. Adding forging capacity in the short to medium terms is not possible. Not only is the equipment extremely expensive, it will take over a year to build and install. As a result, the firm is looking for a short-term solution that makes the best of the capacity available.

A system-wide perspective is thus needed to schedule the various production steps throughout the supply chain and streamline the process for on-time product delivery so as to minimize the costs and rippling effects of the part supply shortages.

Product Information

Each end product is complex, composed of thousands of parts. The product structure is described by its bill of materials (BOM), which is typically represented as a product tree diagram that shows the components making up each subassembly at each level of the assembly process, along with the number of units needed; see Figure 1. To explore the joint scheduling of production of various products, managers have provided a simplified BOM containing the critical components for their two most profitable products, which we will refer to as end items 1 and 2.

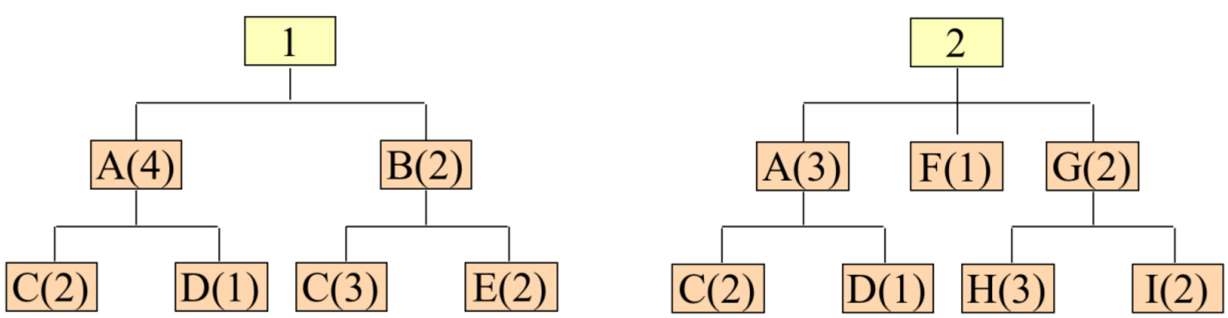

Figure 1: Product tree diagram for the two leading products

In addition, they have provided the weekly holding costs (H) and delay penalties (P) for each part to guide the scheduling of production towards minimizing these costs.

	Part										
Cost	1	2	A	B	C	D	E	F	G	H	I
H	100	200	15	15	4	2	2	50	20	5	2
P	1000	2000	150	150	40	20	20	500	200	50	20

Figure 2: Holding and delay penalty costs per week.

Committed Orders

Management is most concerned about their ability to deliver their outstanding orders for these two products over the next 10 weeks. Delays carry a steep penalty per week of delay, as described above, and can severely damage their hard-earned trust from their most valuable customers. Committed orders over the next 10 weeks are collected in the table below:

	Week									
End Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	5	5	5	8	8	8	8	8	5	5
2	5	5	5	8	8	8	8	8	5	5

Figure 3: End item demand for each week in the horizon.

In addition, there are orders of 20 units of part C to be delivered on week 3, 8 units of part D on week 5, and 2 parts F on week 7.

Process Capacity

The forging process has been proven to be the bottleneck for the firm's entire supply chain. All the lower level parts {C, D, E, H, I} undergo this process, which is performed by a single production line running 24 hours a day, 7 days a week. The production times R and required change-over (setup) times S for each of these parts are as follows:

	Part				
Time (mins)	C	D	E	H	I
R	30	30	30	30	60
S	120	120	120	120	120

Figure 4: Processing (R) and setup (S) times for the bottleneck process.

MIE 578 Supply Chain Logistics

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Assignment

The goal is to develop a practical tool that the firm can use to streamline the production at each level of the supply chain with that of the bottleneck resource in order to optimize profits. The following steps are suggested to systematically address all aspects of the problem.

1. Write an AMPL data file that captures the given information on the BOM and on demand. **[10 points]**

2. Write and run an AMPL model to calculate all of the parts that will need to be produced and when to satisfy those demands assuming zero lead times and no capacity constraints. **[15 points]**

3. Assume now a lead time of one week for each step. Change your model to consider this. Will your data file need to change as well? **[15 points]**

4. Change your model to incorporate the processing times and capacity constraints. Find the lowest cost production schedule given the holding costs (H) and penalties (P) for each part. **[10 points]**

5. Change your model to incorporate the setup times and solve again. **[20 points]**
   a) Solve first assuming both X (production) and z (setup) are non-negative continuous variables.
   b) Solve requiring z to be binary variables.
   c) Solve requiring in addition the production X to be integer. Compare the production schedule, cost and solution time of the three solutions and explain the differences.

   Hint: *You can calculate the CPU time taken by the AMPL solution process by adding the command* *display* _total_solve_time;

6. In exploring longer term solutions, management would like to understand the value associated with increasing capacity by a factor of 2 or 3? What would you recommend? **[30 points]**

Note: You are not required to use AMPL. You can use Python/Gurobi or any other language and solver of your choice.