ISyE 4803-REV: Advanced Manufacturing Systems Modeling and Analysis
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Fall 2019

Homework #6

Due Date: ****

Reading Assignment

- The slides posted on the course website on operations scheduling.
- The excerpt from Nahmias on Operations Scheduling posted on the library electronic reserves.
- Your notes from the class lectures.

Problem set:

Solve problems 4, 5, 6, 9 and 10 in the attached pages (these problems are based on the excerpt from Nahmias' book on operations scheduling that is posted on the library electronic reserves).

these numbers are as follows:

Plane	1	2	3	4	5
Landing time	26	11	19	16	23
Number of passengers	180	12	45	75	252

The appropriate objective in this case might be to minimize the *weighted* makespan or the weighted sum of the completion times, where the weights would correspond to the number of passengers in each plane. Notice that the objective function would now be in units of passenger-minutes.

3. An issue that we have not yet addressed is the time that each plane is scheduled to arrive. Assume the following data:

Plane	1	2	3	4	5
Landing time	26	11	19	16	23
Scheduled arrival time	5:30	5:45	5:15	6:00	5:40

Sequencing rules that ignore due dates could give very poor results in terms of meeting the arrival times. Some possible objectives related to due dates include minimizing the average tardiness and minimizing the maximum tardiness.

4. Thus far we have ignored special conditions that favor some planes over others. Suppose that plane number 4 has a critically low fuel level. This would probably result in plane 4 taking precedence. Priority constraints could arise in other ways as well: planes that are scheduled for continuing flights or planes carrying precious or perishable cargo also might be given priority.

The purpose of this section was to demonstrate the difficulties of choosing an objective function for job sequencing problems. The optimal sequence is highly sensitive to the choice of the objective, and the appropriate objective is not always obvious.

Problems for Sections 8.1–8.5

1. Discuss each of the following objectives listed and the relationship each has with job shop performance.
   a. Reduce WIP inventory.
   b. Provide a high level of customer service.
   c. Reduce worker idle time.
   d. Improve factory efficiency.
2. In Problem 1, why are (*a*) and (*c*) conflicting objectives, and why are (*b*) and (*d*) conflicting objectives?
3. Define the following terms:
   a. Flow shop.
   b. Job shop.
   c. Sequential versus parallel processing.
   d. Makespan.
   e. Tardiness.
4. Four trucks, 1, 2, 3, and 4, are waiting on a loading dock at XYZ Company that has only a single service bay. The trucks are labeled in the order that they arrived at the dock. Assume the current time is 1:00 P.M. The times required to unload each truck

and the times that the goods they contain are due in the plant are given in the following table.

Truck	Unloading Time (minutes)	Time Material Is Due
1	20	1:25 P.M.
2	14	1:45 P.M.
3	35	1:50 P.M.
4	10	1:30 P.M.

Determine the schedules that result for each of the rules FCFS, SPT, EDD, and CR. In each case compute the mean flow time, average tardiness, and number of tardy jobs.

5. Five jobs must be scheduled for batch processing on a mainframe computer system. The processing times and the promised times for each of the jobs are listed here.

Job	1	2	3	4	5
Processing time	40 min	2.5 hr	20 min	4 hr	1.5 hr
Promised time	11:00 A.M.	2:00 P.M.	2:00 P.M.	1:00 P.M.	4:00 P.M.

Assume that the current time is 10:00 A.M.

a. If the jobs are scheduled according to SPT, find the tardiness of each job and the mean tardiness of all jobs.

b. Repeat the calculation in part (*a*) for EDD scheduling.

8.6 AN INTRODUCTION TO SEQUENCING THEORY FOR A SINGLE MACHINE

Assume that n jobs are to be processed through one machine. For each job i, define the following quantities:

$$
\begin{aligned}
t_i &= \text{Processing time for job } i,\\
d_i &= \text{Due date for job } i,\\
W_i &= \text{Waiting time for job } i,\\
F_i &= \text{Flow time for job } i,\\
L_i &= \text{Lateness of job } i,\\
T_i &= \text{Tardiness of job } i,\\
E_i &= \text{Earliness of job } i.
\end{aligned}
$$

The processing time and the due date are constants that are attached to the description of each job. The waiting time for a job is the amount of time that the job must wait before its processing can begin. For the cases that we consider, it is also the sum of the processing times for all the preceding jobs. The flow time is simply the waiting time plus the job processing time ($F_i = W_i + t_i$). The flow time of job i and the completion time of job i are the same. We will define the lateness of job i as $L_i = F_i - d_i$, and assume that lateness can be either a positive or a negative quantity. Tardiness is the positive part of lateness ($T_i = \max[L_i, 0]$), and earliness is the negative part of lateness ($E_i = \max[-L_i, 0]$).

Snapshot Application

MILLIONS SAVED WITH SCHEDULING SYSTEM FOR FRACTIONAL AIRCRAFT OPERATORS

Celebrities, corporate executives, and sports professionals are a large part of the group that uses private planes for travel. For many of these people, it doesn't make economic sense to purchase planes. An attractive alternative is fractional ownership, especially for those that have only occasional need of a plane. Fractional ownership of private planes provides owners with the flexibility to fly to over 5,000 destinations (as opposed to about 500 for the commercial airlines). Other advantages include privacy, personalized service, fewer delays, and the ability to conduct business on the plane.

The concept of a fractional aircraft program is similar to that of a time-share condominium, except that the aircraft owners are guaranteed access at any time with as little as four hours notice. The fees are based on the number of flight hours the owner will require: one-eighth share owners are allotted 100 hours of annual flying time, one-quarter share owners 200 hours, and so forth. The entire system is coordinated by fractional management company (FMC). Clearly, the problem of scheduling the planes and crews can become quite complex.

When scheduling planes and crews, the FMC must determine schedules that (1) meet customer requests on time, (2) satisfy maintenance and crew restrictions, and (3) allow for specific aircraft trip assignments and requests. The profitability of the FMC will depend upon how efficiently they perform these tasks. A group of consultants attacked this problem and developed a scheduling system known as ScheduleMiser.[1] The inputs to this system are trip requests, aircraft availability, and aircraft restrictions over a specified planning horizon. Note that even though owners are guaranteed service with only four hours notice, the vast majority of trips are booked at least three days or more in advance. This gives the FMC a reliable profile of demand over a two- to three-day planning horizon. Note that aircraft schedules must be coordinated with crew schedules, as crew work rules cannot be violated.

ScheduleMiser is the underlying engine that drives the larger planning system known as Flight Ops. ScheduleMiser is based on a mixed-integer mathematical formulation of the problem. The objective function consists of five terms delineating the various costs in the system. Several sets of constraints are included to ensure that demands are filled, crews are properly scheduled, and planes are not overbooked. This system was adopted and implemented by Raytheon Travel Air in November of 2000 (now Flight Options) for scheduling their fleet of over 100 aircraft. Raytheon reported a savings of over $4.4 million in the first year of implementation of this system. This is only one example of many mathematical-based scheduling systems that have been implemented in the airline industry.

[1] Martin, C., D. Jones, and P. Keskinocak. "Optimizing On-Demand Aircraft Schedules for Fractional Aircraft Operators," *Interfaces,* 33, no. 5, September–October 2003, pp. 22–35.

Problems for Section 8.6

6. Consider the information given in Problem 4. Determine the sequence that the trucks should be unloaded in order to minimize
   a. Mean flow time.
   b. Maximum lateness.
   c. Number of tardy jobs.

7. On May 1, a lazy MBA student suddenly realizes that he has done nothing on seven different homework assignments and projects that are due in various courses. He estimates the time required to complete each project (in days) and also notes their due dates:

Project	1	2	3	4	5	6	7
Time (days)	4	8	10	4	3	7	14
Due date	4/20	5/17	5/28	5/28	5/12	5/7	5/15

Because projects 1, 3, and 5 are from the same class, he decides to do those in the sequence that they are due. Furthermore, project 7 requires results from projects 2 and 3, so 7 must be done after 2 and 3 are completed. Determine the sequence in which he should do the projects in order to minimize the maximum lateness.

8. Eight jobs are to be processed through a single machine. The processing times and due dates are given here.

Job	1	2	3	4	5	6	7	8
Processing time	2	3	2	1	4	3	2	2
Due date	5	4	13	6	12	10	15	19

Furthermore, assume that the following precedence relationships must be satisfied:

$$2 \rightarrow 6 \rightarrow 3.$$
$$1 \rightarrow 4 \rightarrow 7 \rightarrow 8.$$

Determine the sequence in which these jobs should be done in order to minimize the maximum lateness subject to the precedence restrictions.

9. Jane Reed bakes breads and cakes in her home for parties and other affairs on a contract basis. Jane has only one oven for baking. One particular Monday morning she finds that she has agreed to complete five jobs for that day. Her husband John will make the deliveries, which require about 15 minutes each. Suppose that she begins baking at 8:00 A.M.

Job	Time Required	Promised Time
1	1.2 hr	11:30 A.M
2	40 min	10:00 A.M.
3	2.2 hr	11:00 A.M.
4	30 min	1:00 P.M.
5	3.1 hr	12:00 NOON
6	25 min	2:00 P.M.

Determine the sequence in which she should perform the jobs in order to minimize

a. Mean flow time.
b. Number of tardy jobs.
c. Maximum lateness.

10. Seven jobs are to be processed through a single machine. The processing times and due dates are given here.

Job	1	2	3	4	5	6	7
Processing time	3	6	8	4	2	1	7
Due date	4	8	12	15	11	25	21

Determine the sequence of the jobs in order to minimize

a. Mean flow time.
b. Number of tardy jobs.
c. Maximum lateness.
d. What is the makespan for any sequence?