Lecture #29

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Status

- Recently, we have discussed:
  - Activities/tasks – processing time
  - Networks to describe the interrelationships among activities, flows, distances, etc.
  - The use of simulation as a tool to describe facility operation
- As we saw with Simulation model, there are many situations in which we will need to serve/process multiple items/entities.
- This means that we need decision rules to determine how to handle these entities – priority rules for entities in the queue.

Common Priority Rules

- Example: job shop with # of parts to be processed
- FCFS – first come, first served
- SPT – shortest processing time
- EDD – earliest due date
- STR – slack time remaining
  - Difference between time remaining before the due date minus the processing time remaining
- LCFS – last come, first served

Perspective on Rules

- FCFS: Run orders in sequence in which they arrive at work center. This "fairness" rule often appropriate for service systems – where service is wanted ASAP.
- SPT: Run orders based on time required to process them (smallest time first). This rule often results in lowest work in process, lowest avg. job completion time, and lowest average lateness. Jobs with long processing times can be extremely late.
- EDD: Run orders with the earliest due date first. This rule works well when processing times are approximately the same.
- STR: Order based on smallest slack time remaining. This rule supports the achievement of due date objectives.

Evaluating a Schedule

- Meeting due dates of customers' orders and/or downstream tasks and assignments.
- Minimizing overall processing time.
- Minimizing work in process.
- Minimizing workers' idle time.

Simplest Scheduling Scenario

- Scheduling n existing orders with One Worker and/or Machine (n/1)
- All items are ready to go – and we do not change our minds part-way through processing – static scheduling situation
- Example: Supervisor of Copy Shop needs to handle five orders.

Copy Shop Example

- **Specific scheduling data on each order:**

Order (in order of arrival)	Processing Time (days)	Due Date (days hence)
A	3	5
B	4	6
C	2	7
D	6	9
E	1	2

  - **All orders require the use of the single color copy machine available. What is the best processing sequence for the 5 orders?**
  - **Want to minimize the mean order cycle time**

FCFS rule

Order	Processing Time	Due Date	Start Time	Completion Time	Lateness	Waiting Time
A	3	5				
B	4	6				
C	2	7				
D	6	9				
E	1	2				
		Average				

FCFS rule schedule

Order	Processing Time	Due Date	Start Time	Completion Time	Lateness	Waiting Time
A	3	5	0	3	0	0
B	4	6	3	7	1	3
C	2	7	7	9	2	7
D	6	9	9	15	6	9
E	1	2	15	16	14	15
		Average		10	4.6	6.8

- **Average order completion time = 10 days**
- **Comparing the due date of each order with its order completion time, we observe that only order A will done be on time. On the average, an order will be late by 4.6 days.**

SPT rule schedule

Order	Processing Time	Due Date	Start Time	Completion Time	Lateness	Waiting Time
E	1	2	0	1	0	0
C	2	7	1	3	0	1
A	3	5	3	6	1	3
B	4	6	6	10	4	6
D	6	9	10	16	7	10
		Average		7.2	2.4	4

- **Average order completion time = 7.2 days**
- **The SPT rule results in lower average order completion time. In addition, orders E and C will be ready before the due date, and order A is late by only one day. On the average, an order will be late by 2.4 days.**

EDD rule schedule

Order	Processing Time	Due Date	Start Time	Completion Time	Lateness	Waiting Time
E	1	2	0	1	0	0
A	3	5	1	4	0	1
B	4	6	4	8	2	4
C	2	7	8	10	3	8
D	6	9	10	16	7	10
		Average		7.8	2.4	4.6

- **Average order completion time = 7.8 days**
- **In this case orders B, C, and D will be late. On the average, an order will be late by 2.4 days.**

LCFS rule schedule

Order	Processing Time	Due Date	Start Time	Completion Time	Lateness	Waiting Time
E	1	2	0	1	0	0
D	6	9	1	7	0	1
C	2	7	7	9	2	7
B	4	6	9	13	7	9
A	3	5	13	16	11	13
		Average		9.2	4	6

- **Avg. order completion time = 9.2 days**
- **Average lateness = 4 days**

STR rule schedule

		A	B	C	D	E
	DD	5	6	7	9	2
	PT	3	4	2	6	1
	STR	2	2	5	3	1
Order	Processing Time	Due Date	Start Time	Completion Time	Lateness	Waiting Time
E	1	2	0	1	0	0
A	3	5	1	4	0	1
B	4	6	4	8	2	4
D	6	9	8	14	5	8
C	2	7	14	16	9	14
		Average		8.6	3.2	5.4

- **Avg. order completion time = 8.6 days**
- **Average lateness = 3.2 days**

Comparison

	Average Completion Time	Average Lateness	Average Waiting Time
FCFS	10	4.6	6.8
SPT	7.2	2.4	4
EDD	7.8	2.4	4.6
LCFS	9.2	4	6
STR	8.6	3.2	5.4

- **The SPT rule yields an optimum solution for the n/1 case average waiting time and average completion time.**
- **The SPT rule ignores the due dates of orders – jobs with longer processing times can often be late.**

Scheduling with Multiple Processors

- n/m case – n jobs handled by m processors – common sequence, no passing
- n/2 case – two orders processed by two machines (workers)
- S. M. Johnson algorithm – minimize overall order completion time, from beginning of first order until completion of last – only optimal for n/2 case

Johnson's rule steps

1. List the completion time for each task for both machines (or workers)
2. Select the order with the shortest completion time
   - If the shortest time is for the first machine, do that order first
   - If the shortest time is for the second machine, do that order last
3. Repeat steps 2 and 3 for each remaining order until the schedule is complete.

Example

- **Four jobs and two workers:**
  - **Step 1: List operation times for each order.**

Job	Completion Time With Worker 1	Completion Time with Woker 2
A	3	2
B	6	8
C	5	6
D	7	4

  - **Steps 2 and 3: Select shortest time and assign. Order A is the shortest with worker 2 – to be performed last (Order A is removed from list).**

Example

- ***Step 4*: Repeat steps 2 and 3 until all orders are scheduled.**
  - **Select the shortest completion time among the remaining orders. Order D is the second-shortest with worker 2, thus is performed second to last.**
  - **Orders A and D are no longer available for scheduling.**
  - **Order C is performed first.**
  - **Now only order B is left.**

❖ **C – B – D – A**

Example

- In summary, the solution sequence is C – B – D – A, and the overall completion time is 25 days, which is a minimum. Also minimized are total idle time and avg. idle time