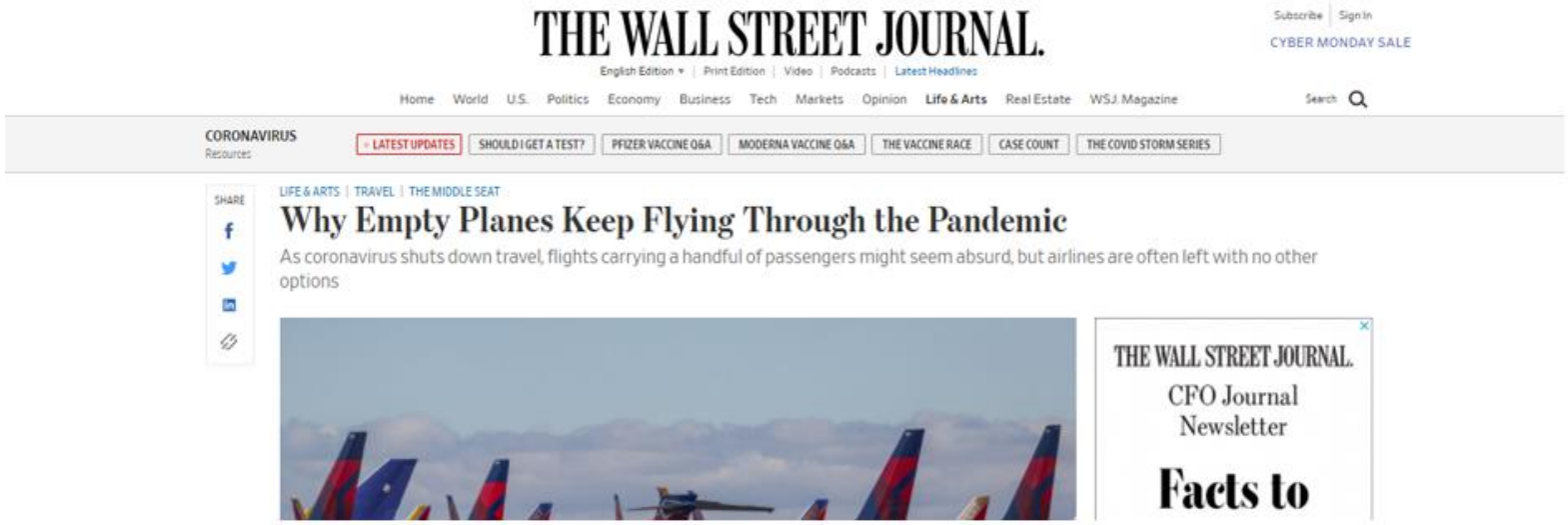
Operations Scheduling



Why our skies are full of empty planes ?

75% of Airlines grounded their capacity

90% of the Air-Traffic Disappeared

99% of the flights have been less than 20% of passengers

Operational reasons:

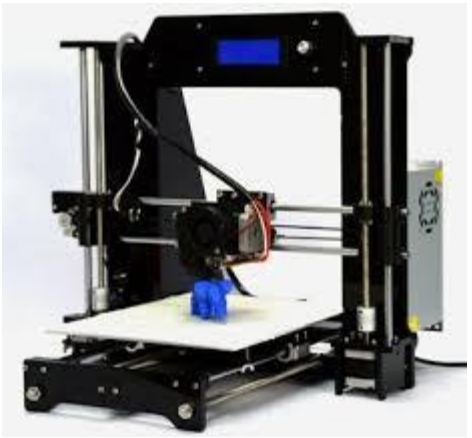
1. Fight Connection Schedule
2. Crew Schedule
3. Maintenance Schedule
4. Parking Schedule

Classification of Scheduling Systems in Manufacturing and Service Industry

1. Single Machine Scheduling
2. Flow Shop Scheduling
3. Job Shop Scheduling

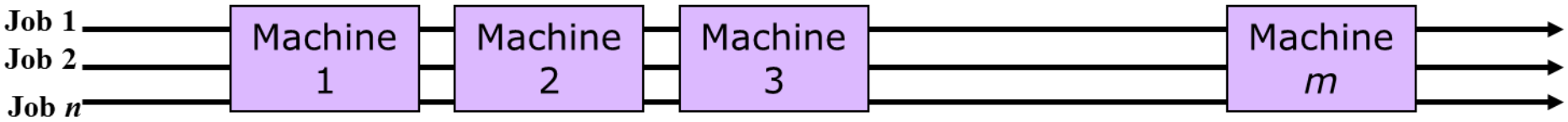
Single Machine Scheduling: Assigning a group of *n* jobs (tasks) to a single machine or resource

For Example: Xerox Machine and 3D Printers



Customer Jobs	Processing Time in min	Due Time in min
1	20	25
2	15	20
3	55	70
4	29	35
5	10	10

Flow Shop Scheduling – *n* jobs and *m* machines



Flow Shop Scheduling:

The order in which the machines are required to process a job is called process sequence of that job.

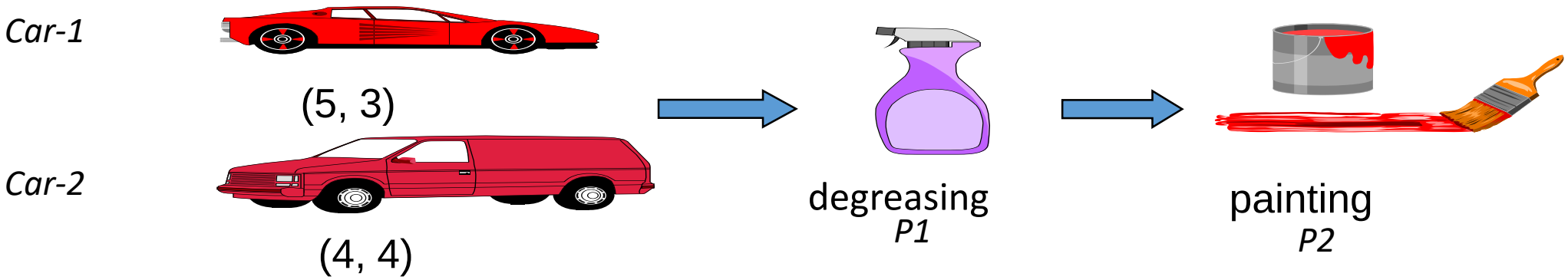
The process sequence of all the jobs are the same.

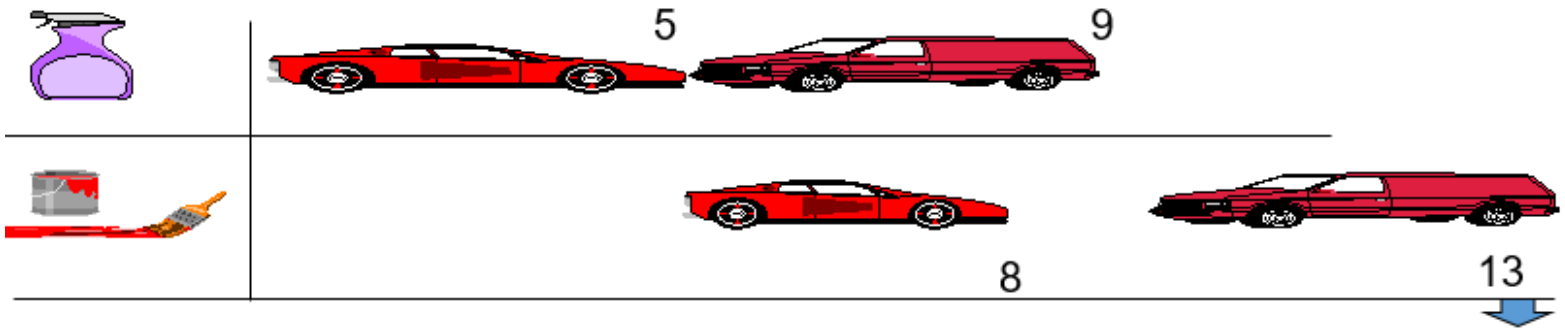
But the processing times of various jobs on a machine may differ.

Example: A car painting factory

Two jobs are waiting – Car 1 and Car 2

	Machines and Processing Time in hr.	
Jobs	Degreasing	Painting
Car 1	5	3
Car 2	4	4



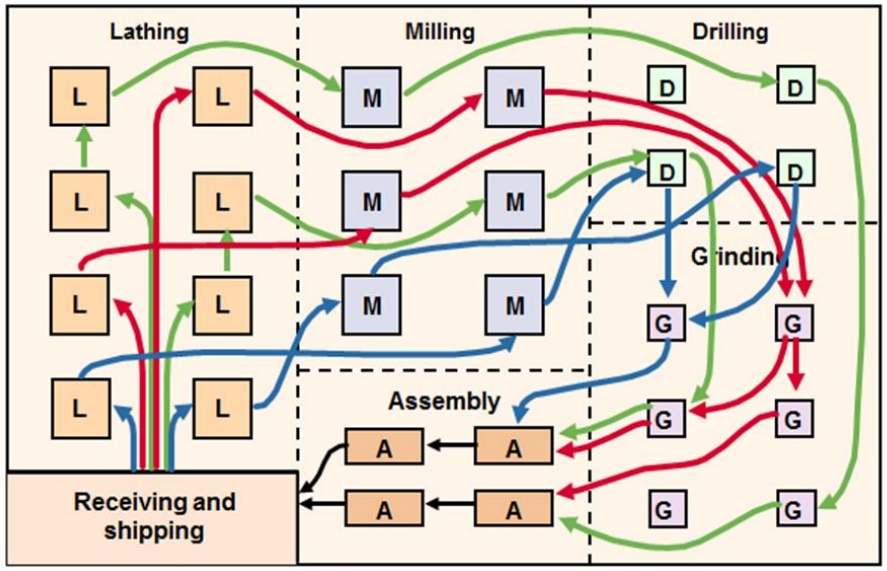


The final completion time=13

Flow Shop – *n* jobs and *m* machines
Process Sequence will be same
Processing Time will differ

Job Shop Scheduling: *n* jobs and *m* machines | Process Sequence will be differ | Processing Time will also differ

In Job Shop, the machines are arranged in functional groups (i.e., a lathe department, a milling department, a heat-treating oven, assembly stations, and so on).



S. No	Components	Process sequence	Processing Time in hr.
1		2-3-5	3
2		1-4	2.2
3		2-3	1
4		1-4	3
5		1-5	2.7
6		1-3-4	3.2
7		3-5	4

S. No	Machines
1	Lathe 
2	Milling 
3	Drilling 
4	Grinding 
5	Threading 

Other Examples: Hospitals and Departments Stores (Super Markets)

Single Machine Scheduling Problem

Key Terms to understand in scheduling problem

1. Processing Time (t_j) – It is the time required to process job j. The processing time, t_j will normally include both actual processing time and set-up time.
2. Due Date (d_j) – It is the time at which the job j is to be completed
3. Completion Time (C_j) – It is the time at which the job j is to be completed
4. Ready Time (r_j) – It is the time at which job j is available for processing.

   The ready time is the different between the arrival time of that job and the time at which that job is taken for processing.

Performance Measures

Lateness – the difference between the completion time of a job and its due date. For example, if a job is due on day 10 and it is completed on day 12, then it is late 12 − 10 = 2 days.

Lateness can also be negative. For example, if the job is due on day 10, but it is completed on day 7, then it is –3 days "late," which means it is three days early. It might seem odd to have a negative lateness, which means the job is early, but this is a relatively common definition of lateness.

Tardiness - if a job is completed after its due date, then the tardiness of a job is the difference between its completion time and its due date. If the job is completed before its due date, then tardiness is 0. In some sense, the tardiness measure makes more sense than lateness because a job never has negative tardiness.

Make Span - Completion time of the last job processed

Methods to solve the single machine scheduling problem

Priority Rule Method	Algorithm
Priority Rule used in Scheduling for sequencing the jobs 1. Shortest Processing Time (SPT) 2. Longest Process Time (LPT) 3. Earliest Due Date (EDD) 4. First-Come-First-Served (FCFS)	Hodgson's Algorithm

Priority Rules for Job Sequencing

- Shortest Processing Time (SPT) – Sequencing the jobs in increasing order of processing time.
- Longest Process Time (LPT) – Sequencing the jobs in decreasing order of processing time.
- Earliest Due Date (EDD) - Sequencing the jobs in increasing order of due date.
- First-Come-First-Served (FCFS) – This rule schedules the jobs simply in the order of job arrivals. (No priority based on processing time and due date)

Example Problem

Consider the following data on jobs waiting to be processed on a single machine. They are listed here in order of their arrival at the machine:

Jobs	1	2	3	4	5	6	7
Processing time	2	6	8	4	14	12	10
Due Date	6	30	19	12	24	18	12

Develop a schedule for these jobs based on following sequence rules: SPT, LPT, EDD and FCFS. The calculate the Makespan, Maximum Tardiness, Number of Late Jobs, Total Flow Time and Total Tardiness

Shortest Processing Time (SPT) – Sequencing the jobs in increasing order of processing time.

SPT Sequence: 1,4,2,3,7,6,5

Jobs	1	2	3	4	5	6	7
Processing time	2	6	8	4	14	12	10
Due Date	6	30	19	12	24	18	12

Job	1	4	2	3	7	6	5
Processing Time	2	4	6	8	10	12	14
Completion Time	2	6	12	20	30	42	56
Due Date	6	12	30	19	12	18	24
Lateness/Tardiness	-4	-6	-18	1	18	24	32

Makespan	56
Max Tardiness	32
Number of Late Jobs	4
Total Flow Time /Sum of Completion Time	168
Total Tardiness	75

Longest Process Time (LPT) – Sequencing the jobs in decreasing order of processing time.

LPT Sequence: 5,6,7,3,2,4,1

Jobs	1	2	3	4	5	6	7
Processing time	2	6	8	4	14	12	10
Due Date	6	30	19	12	24	18	12

Job	5	6	7	3	2	4	1
Proce Time	14	12	10	8	6	4	2
Completion Time	14	26	36	44	50	54	56
Due Date	24	18	12	19	30	12	6
Lateness/Tardiness	-10	8	24	25	20	42	50

Makespan	56
Max Tardiness	50
Number of Late Jobs	6
Total Flow Time /Sum of Completion Time	280
Total Tardiness	169

SPT Makespan	56
Max Tardiness	32
Number of Late Jobs	4
Total Flow Time /Sum of Completion Time	168
Total Tardiness	75

Earliest Due Date (EDD) - Sequencing the jobs in increasing order of due date.

EDD Sequence: 1,4,7,6,3,5,2

Jobs	1	2	3	4	5	6	7
Processing time	2	6	8	4	14	12	10
Due Date	6	30	19	12	24	18	12

Job	1	4	7	6	3	5	2
Proce Time	2	4	10	12	8	14	6
Completion Time	2	6	16	28	36	50	56
Due Date	6	12	12	18	19	24	30
Lateness/Tardiness	-4	-6	4	10	17	26	26

Makespan	56
Max Tardiness	26
Number of Late Jobs	5
Total Flow Time /Sum of Completion Time	194
Total Tardiness	83

First-Come-First-Served (FCFS) – This rule schedules the jobs simply in the order of job arrivals. (No priority based on processing time and due date)

FCFS Sequence: 1,2,3,4,5,6,7

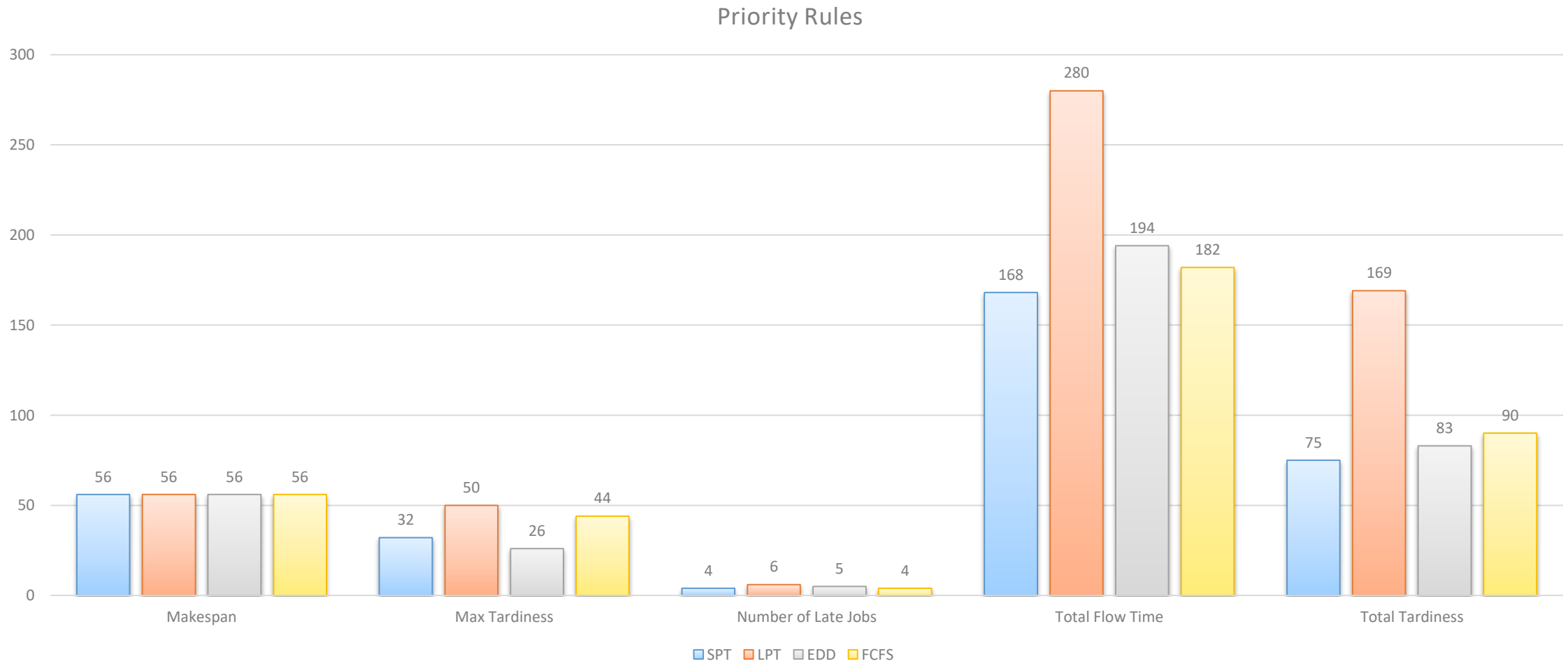
Jobs	1	2	3	4	5	6	7
Processing time	2	6	8	4	14	12	10
Due Date	6	30	19	12	24	18	12

Job	1	2	3	4	5	6	7
Proce Time	2	6	8	4	14	12	10
Completion Time	2	8	16	20	34	46	56
Due Date	6	30	19	12	24	18	12
Lateness/Tardiness	-4	-22	-3	8	10	28	44

Makespan	56
Max Tardiness	44
Number of Late Jobs	4
Total Flow Time /Sum of Completion Time	182
Total Tardiness	90

Comparison

	Makespan	Max Tardiness	Number of Late Jobs	Total Flow Time	Total Tardiness
SPT	56	32	4	168	75
LPT	56	50	6	280	169
EDD	56	26	5	194	83
FCFS	56	44	4	182	90



Hodgson Algorithm

Hodgson Algorithm

SPT Sequence: 1,4,3,2,7,6,5

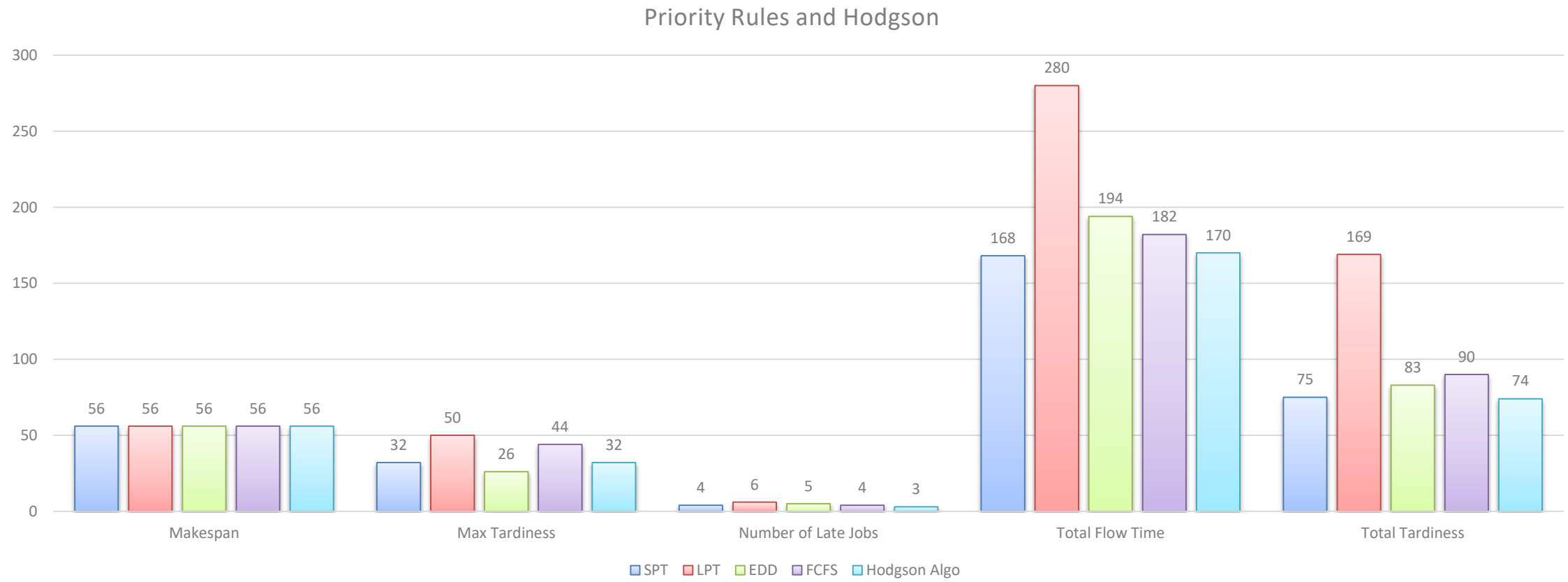
Jobs	1	2	3	4	5	6	7
Processing time	2	6	8	4	14	12	10
Due Date	6	30	19	12	24	18	12

Job	1	4	3	2	7	6	5
Processing Time	2	4	8	6	10	12	14
Completion Time	2	6	14	20	30	42	56
Due Date	6	12	19	30	12	18	24
Lateness/Tardiness	-4	-6	-5	-10	18	24	32
Tardy(1) & No Tardy (0)	0	0	0	0	1	1	1

Makespan	56
Max Tardiness	32
Number of Late Jobs	3
Total Flow Time /Sum of Completion Time	170
Total Tardiness	74

Comparison

	Makespan	Max Tardiness	Number of Late Jobs	Total Flow Time	Total Tardiness
SPT	56	32	4	168	75
LPT	56	50	6	280	169
EDD	56	26	5	194	83
FCFS	56	44	4	182	90
Hodgson Algo	56	32	3	170	74



- Thank You