Comparison of Well-known Scheduling Methodologies: A Case Study

Tadsanee Kaewpaitoon and Jirarat Teeravaraprug

***Abstract*—This paper first explains the well-known scheduling methodologies including FCFS, SPT, EDD, and LPT. Since the scheduling may be done by using the rules of jobs and orders, two types of scheduling methodologies are created namely job-based rule and order-based rule. The methodologies then turn to be double. The eight methodologies are applied in a case study of an electronic manufacturing company in Thailand. It is found that job-based rules always gives better results than order-based rules, and EDD and SPT are the best methodologies.**

***Index Terms*—scheduling, FCFS, SPT, EDD, LPT.**

I. Introduction

Currently, manufacturing industries have attempted to satisfy the three factors of demand, namely, quality, cost, and timing. Scheduling is in charge of the factor of timing [1]. The function of scheduling is then to determine the time needed and to keep the time determined [2]. Scheduling problems exist almost ubiquitously in real-world applications including distribution, transportation, management, construction, engineering, and manufacturing, especially in the industrial engineering world. In many manufacturing system, jobs that are completed early are held as finished goods inventory until their due-dates, and earliness costs are incurred. Contrarily, jobs that are completed after their due dates incur penalty. The objective hence is to meet the due dates of the respective jobs as closely as possible, and consequently minimize the sum of earliness and tardiness of jobs because earliness and tardiness of jobs greatly influence the performance of a schedule with respect to cost. Many scheduling problems on manufacturing industries are quite complex and very difficult to solve. It has been the subject of extensive research and captured the interest of researchers from different research communities such as operation research, artificial intelligence, management science, as well as industrial engineering since the early 1950s [3].

However, in medium or small industries, scheduling problems cannot be solved by using complex mathematics. In such cases, schedulers practically solve the problems mainly by their experiences. The case study is an electronic manufacturing company in Thailand. In the manufacturing process of the company, high percentage of rejected items (about 4 %) is occurred. By the observation, it is found that about half of the rejected items can be reworked. The ones that can be reworked have to be classified by using part number and type of rejection.

There are three main reworked processes: facing process, inspection process, and barrel process. In the facing process, three machines are utilized, where as the inspection process uses two measurement machines. Lastly, the barrel process has only one machine. The process of reworked items would be designed by engineers. Some of them would be reworked by only two processes while the others would be used three processes. Further, each part number would utilize time for reworking differently in each process. Scheduling for reworked items would be done by mainly experience. Therefore, sometimes the reworked items cannot be finished before the order due-date. It results in the late delivery of the customer order and incurs penalty.

This paper tests the well-known scheduling methodologies with the data of the case study. The well-known scheduling methodologies include First Come First Serve (FCFS), Shortest Processing Time (SPT), Earliest Due Date (EDD), and Longest Processing Time (LPT).

Applied the concept of Blocher et al. [4], each well-known methodology above can be divided into two methodologies. FCFS.m is priority to process a job at any given machine goes to that job waiting at the machine having a minimum arrival time of job *j* or order *i* at current machine. FCFS.o is priority to process a job at any given machine goes to that job waiting at the machine having a minimum arrival time of order *I* SPT.m is priority to process a job at any given machine *k* goes to that job waiting at the machine having a minimum processing time of operation *k* of job *j* of order *i*. SPT.o is priority to process a job at any given machine goes to that job waiting at the machine having a minimum processing time of job *j* of order *i*. EDD.m is priority to process a job at any given machine goes to that job waiting at the machine having a minimum due date of order *i* at current machine. EDD.o is priority to process a job at any given machine goes to that job waiting at the machine having a minimum due date of order *i*. LPT.m is priority to process a job at any given machine *k* goes to that job waiting at the machine having a longest processing time of operation *k* of job *j* of order *i*. LPT.o is priority to process a job at any given machine goes to that job waiting at the machine having a longest processing time of job *j* of order *i*. Therefore, this paper applies eight scheduling methodologies to the case study. Five performance measures are used in this paper including average completion time,

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utilization percentage, average tardiness, total late job, and maximum lateness.

II. The Case Study

As stated above, the case study is an electronic manufacturing company in Thailand. Based on the data collection, Table 1 shows the reworked items waiting for processing. 15 jobs with different amount of quantities, reworked processes, cycle times, and due date are included. Based on the eight methodologies above, Tables 2-9 show the results of scheduling. The result of scheduling the first process (Facing process) of FCFS.m and FCFS.o is similar since the priority given to process is based on arrival time and the job ranks by arrival time of the first process and order are the same. However, due to different flow time of each job, the schedules of FCFS.m and FCFS.o for the second process (inspection process) are different and therefore, the schedules for the third process are also different. For SPT.m and SPT.o, the sequences of jobs are different since the first process because SPT.m considers the processing time of each process while SPT.o considers that of all three processes. The orders of jobs then differ and it results in the dissimilar scheduling. The sequences of the first process for EDD.m and EDD.o are identical whereas those of the second and third processes are unlike. Lastly, sequencing by using LPT.m and LPT.o results different scheduling for all processes

III. Discussions

The summation of results is presented in Table 10. Comparing between the same rules with job-based and order-based-rules, it can be seen that job-based rule methodology always gives better average completion time and utilization percentage than the other. Further, with the use of the average completion time and utilization percentage as the measures, SPT is the best one whereas EDD is the second best. LPT is the worst and FCFS is the second worst. When emphasizing tardiness, EDD is the best methodology whereas LPT seems to be the worst one. SPT is the second best and FCFS is the second worst. Therefore, based on the case study, it shows that utilizing SPT or EDD may be a better idea. However, choosing between SPT and EDD methodology may be ambiguous. It depends highly on the company objectives and their costs.

References

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Table 1 Fifteen jobs of the case study

Job No.	Job Title	Quantity	Facing process		Inspection process		Barrel process	
			cycle time	processing	cycle time	processing	cycle time	processing
			(sec)	time (hr)	(sec)	time (hr)	(sec)	time (hr)
1	A5-1MG2	23,638	13	85.36	8	52.53		
2	A5-2RP4	6,826	23	43.61	10	18.96		
3	A0-1PP1	1,612	12	5.37	16	7.16		
4	A0-1PP8	2,408	27	18.06	13	8.70		
5	A0-2GG2	4,602	31	39.63	12	15.34		
6	A2-1MG2	1,000	22	6.11	8	2.22		
7	A2-2F	3,658	11	11.18	17	17.27		
8	A5-1E	8,452	16	37.56	18	42.26	0.50	1.17
9	T5-1E	11,062	16	49.16	17	52.24	0.50	1.54
10	A4-2A	7,180	19	37.90	12	23.93		
11	A9-2CP3	3,456	16	15.40	10	9.60		
12	A3-2PP3	4,600	18	23.00	9	11.50	0.50	0.64
13	A6-2A	6,279	11	19.20	8	13.95	0.50	0.87
14	A4-1G	6,622	24	44.10	13	23.91		
15	A8-2D	6,406	26	46.30	14	24.91		

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Table 2 Scheduling results of FCFS.m methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638	85.36	85.36							52.53	137.89			5.75	6	9	-
2	A5-2RP4	6,826			43.61	43.61			18.96	62.57					2.61	3	4	-
3	A0-1PP1	1,612					5.37	5.37	7.16	12.53					0.52	1	4	-
4	A0-1PP8	2,408					18.06	23.43			8.7	32.13			1.34	2	5	-
5	A0-2GG2	4,602					39.63	63.06	15.34	78.4					3.27	4	6	-
6	A2-1MG2	1,000			6.11	49.72					2.22	51.94			2.16	3	7	-
7	A2-2F	3,658			11.18	60.9					17.27	78.17			3.26	4	6	-
8	A5-1E	8,452			37.56	98.46			42.26	140.72			1.17	141.89	5.91	6	8	-
9	T5-1E	11,062					49.16	112.22			52.24	190.13	1.54	191.67	7.99	8	10	-
10	A4-2A	7,180	37.9	123.26					23.93	174.25					7.26	8	6	2
11	A9-2CP3	3,456			15.4	113.86			9.6	150.32					6.26	7	5	2
12	A3-2PP3	4,600					23	135.22	11.5	199.71			0.64	200.35	8.32	9	8	1
13	A6-2A	6279			19.2	133.06			13.95	188.21			0.87	189.08	7.84	8	6	2
14	A4-1G	6622	44.1	167.36							23.91	214.04			8.92	9	8	1
15	A8-2D	6406			46.3	179.36			24.91	224.62					9.36	10	9	1

Table 3 Scheduling results of FCFS.o methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638	85.36	85.36					52.53	137.89					5.75	6	9	-
2	A5-2RP4	6,826			43.61	43.61					18.96	62.57			2.61	3	4	-
3	A0-1PP1	1,612					5.37	5.37			7.16	69.74			2.91	3	4	-
4	A0-1PP8	2,408					18.06	23.43			8.7	78.43			3.27	4	5	-
5	A0-2GG2	4,602					39.63	63.06			15.34	93.77			3.91	4	6	-
6	A2-1MG2	1,000			6.11	49.72					2.22	95.99			4	4	7	-
7	A2-2F	3,658			11.18	60.9					17.27	113.27			4.72	5	6	-
8	A5-1E	8,452			37.56	98.46					42.26	155.53	1.17	156.7	6.53	7	8	-
9	T5-1E	11,062					49.16	112.23	52.24	190.13			1.54	191.67	7.99	8	10	-
10	A4-2A	7,180	37.89	123.25							23.93	179.46			7.48	8	6	2
11	A9-2CP3	3,456			15.36	113.82					9.6	189.06			7.88	8	5	3
12	A3-2PP3	4,600					23	135.23			11.5	200.56	0.64	201.2	8.38	9	8	1
13	A6-2A	6,279			19.19	133.01			13.95	204.08			0.87	204.95	8.54	9	6	3
14	A4-1G	6,622	44.15	167.4							23.91	224.47			9.35	10	8	2
15	A8-2D	6,406			46.27	179.27			24.91	228.99					9.54	10	9	1

Table 4 Scheduling results of SPT.m methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638					85.36	197.76	52.53	250.29					10.43	11	9	2
2	A5-2RP4	6,826			43.61	105.35			18.96	124.31					5.18	6	4	2
3	A0-1PP1	1,612	5.37	5.37					7.16	12.54					0.52	1	4	-
4	A0-1PP8	2,408			18.06	24.17					8.7	37.15			1.55	2	5	-
5	A0-2GG2	4,602	39.63	83.36							15.34	107.53			4.48	5	6	-
6	A2-1MG2	1,000			6.11	6.11					2.22	8.33			0.35	1	7	-
7	A2-2F	3,658					11.18	11.18			17.27	28.45			1.19	2	6	-
8	A5-1E	8,452			37.56	61.74			42.26	104.00			1.17	105.17	4.38	5	8	-
9	T5-1E	11,062			49.16	154.51					52.24	206.75	1.54	208.28	8.68	9	10	-
10	A4-2A	7,180					37.89	68.26			23.93	92.19			3.84	4	6	-
11	A9-2CP3	3,456	15.36	20.73					9.6	30.33					1.26	2	5	-
12	A3-2PP3	4,600	23	43.73							11.5	55.23	0.64	55.87	2.33	3	8	-
13	A6-2A	6,279					19.19	30.36	13.95	44.32			0.87	45.19	1.88	2	6	-
14	A4-1G	6,622					44.15	112.4			23.91	136.32			5.68	6	8	-
15	A8-2D	6,406	46.27	129.63					24.91	154.54					6.44	7	9	-

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Table 5 Scheduling results of SPT.o methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638					85.36	204.07	52.53	256.59					10.69	11	9	2
2	A5-2RP4	6,826	43.61	83.9							18.96	102.86			4.29	5	4	1
3	A0-1PP1	1,612			5.37	5.37					7.16	12.54			0.52	1	4	-
4	A0-1PP8	2,408			18.06	23.43					8.7	32.13			1.34	2	5	-
5	A0-2GG2	4,602			39.63	63.06					15.34	78.4			3.27	4	6	-
6	A2-1MG2	1,000	6.11	6.11					2.22	8.33					0.35	1	7	-
7	A2-2F	3,658	11.18	17.29					17.27	42.23					1.76	2	6	-
8	A5-1E	8,452	37.56	121.46					42.26	173.38			1.17	174.56	7.27	8	8	-
9	T5-1E	11,062			49.16	156.37					52.24	208.61	1.54	210.15	8.76	9	10	-
10	A4-2A	7,180					37.89	72.44	23.93	96.37					4.02	5	6	-
11	A9-2CP3	3,456					15.36	15.36	9.6	24.96					1.04	2	5	-
12	A3-2PP3	4,600	23	40.29					11.5	53.73			0.64	54.37	2.27	3	8	-
13	A6-2A	6,279					19.19	34.55			13.95	48.5	0.87	49.37	2.06	3	6	-
14	A4-1G	6,622			44.15	107.21			23.91	131.12					5.46	6	8	-
15	A8-2D	6,406					46.27	118.71			24.91	143.62			5.98	6	9	-

Table 6 Scheduling results of EDD.m methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638					85.36	172.16			52.53	224.69			9.36	10	9	1
2	A5-2RP4	6,826	43.61	43.61					18.96	62.57					2.61	3	4	-
3	A0-1PP1	1,612			5.37	5.37			7.16	12.54					0.52	1	4	-
4	A0-1PP8	2,408					18.06	18.06			8.7	26.76			1.11	2	5	-
5	A0-2GG2	4,602					39.63	57.69			15.34	73.03			3.04	4	6	-
6	A2-1MG2	1,000					6.11	63.8			2.22	75.25			3.14	4	7	-
7	A2-2F	3,658			11.18	31.91					17.27	49.18			2.05	3	6	-
8	A5-1E	8,452	37.56	100.36					42.26	142.62			1.17	143.79	5.99	6	8	-
9	T5-1E	11,062			49.16	163.12			52.24	215.35			1.54	216.89	9.04	10	10	-
10	A4-2A	7,180			37.89	69.81					23.93	99.18			4.13	5	6	-
11	A9-2CP3	3,456			15.36	20.73			9.6	30.33					1.26	2	5	-
12	A3-2PP3	4,600					23	86.8	11.5	98.3			0.64	98.94	4.12	5	8	-
13	A6-2A	6,279	19.19	62.8					13.95	76.75			0.87	77.62	3.23	4	6	-
14	A4-1G	6,622			44.15	113.95					23.91	137.86			5.74	6	8	-
15	A8-2D	6,406	46.27	146.63							24.91	171.54			7.15	8	9	-

Table 7 Scheduling results of EDD.o methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638					85.36	172.16			52.53	224.69			9.36	10	9	1
2	A5-2RP4	6,826	43.61	43.61					18.96	62.57					2.61	3	4	-
3	A0-1PP1	1,612			5.37	5.37					7.16	12.54			0.52	1	4	-
4	A0-1PP8	2,408					18.06	18.06			8.7	26.76			1.11	2	5	-
5	A0-2GG2	4,602					39.63	57.69			15.34	73.03			3.04	4	6	-
6	A2-1MG2	1,000					6.11	63.8	2.22	96.02					4	4	7	-
7	A2-2F	3,658			11.18	31.91			17.27	79.85					3.33	4	6	-
8	A5-1E	8,452	37.56	100.36					42.26	142.62			1.17	143.79	5.99	6	8	-
9	T5-1E	11,062			49.16	163.12			52.24	223.78			1.54	225.32	9.39	10	10	-
10	A4-2A	7,180			37.89	69.81					23.93	96.96			4.04	5	6	-
11	A9-2CP3	3,456			15.36	20.73					9.6	36.36			1.51	2	5	-
12	A3-2PP3	4,600					23	86.8			11.5	108.46	0.64	109.1	4.55	5	8	-
13	A6-2A	6,279	19.19	62.8					13.95	93.8			0.87	94.67	3.94	4	6	-
14	A4-1G	6,622			44.15	113.95					23.91	137.86			5.74	6	8	-
15	A8-2D	6,406	46.27	146.63					24.91	171.54					7.15	8	9	-

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Table 8 Scheduling results of LPT.m methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638	85.36	85.36					52.53	137.89					5.75	6	9	-
2	A5-2RP4	6,826			43.61	92.78					18.96	144.28			6.01	7	4	3
3	A0-1PP1	1,612			5.37	159.88					7.16	209.52			8.73	9	4	5
4	A0-1PP8	2,408			18.06	148.4					8.7	202.36			8.43	9	5	4
5	A0-2GG2	4,602	39.63	124.99					15.34	153.23					6.38	7	6	1
6	A2-1MG2	1,000			6.11	154.51			2.22	197.71					8.24	9	7	2
7	A2-2F	3,658	11.18	159.17					17.27	214.98					8.96	9	6	3
8	A5-1E	8,452			37.56	130.34			42.26	195.49			1.17	196.66	8.19	9	8	1
9	T5-1E	11,062			49.16	49.16					52.24	101.4	1.54	102.94	4.29	5	10	-
10	A4-2A	7,180					37.89	128.31			23.93	168.21			7.01	8	6	2
11	A9-2CP3	3,456					15.36	162.85	9.6	224.58					9.36	10	5	5
12	A3-2PP3	4,600	23	147.99							11.5	193.66	0.64	194.3	8.1	9	8	1
13	A6-2A	6,279					19.19	147.49			13.95	182.16	0.87	183.03	7.63	8	6	2
14	A4-1G	6,622					44.15	90.41			23.91	125.31			5.22	6	8	-
15	A8-2D	6,406					46.27	46.27	24.91	71.18					2.97	3	9	-

Table 9 Scheduling results of LPT.o methodology

Job No.	Job Title	Quantity	Facing process						Inspection process				Barrel process		Complete Job	Complete Job (days)	Due date	Over due date
			Machine.1		Machine.2		Machine.3		Machine.1		Machine.2		Machine.1					
			C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hr)	C/T (sec)	Flow time (hrs)				
1	A5-1MG2	23,638	85.36	85.36					52.53	137.89					5.75	6	9	-
2	A5-2RP4	6,826					43.61	127.44	18.96	181.76					7.57	8	4	4
3	A0-1PP1	1,612					5.37	152			7.16	227.45			9.48	10	4	6
4	A0-1PP8	2,408			18.06	162.18			8.7	219.75					9.16	10	5	4
5	A0-2GG2	4,602			39.63	132.94			15.34	197.1					8.21	9	6	3
6	A2-1MG2	1,000					6.11	158.11			2.22	229.67			9.57	10	7	3
7	A2-2F	3,658			11.18	144.12					17.27	220.28			9.18	10	6	4
8	A5-1E	8,452					37.56	37.56			42.26	143.66	1.17	144.84	6.03	7	8	-
9	T5-1E	11,062			49.16	49.16					52.24	101.4	1.54	102.94	4.29	5	10	-
10	A4-2A	7,180	37.89	123.25							23.93	191.51			7.98	8	6	2
11	A9-2CP3	3,456	15.36	161.61					9.6	229.35					9.56	10	5	4
12	A3-2PP3	4,600	23	146.25							11.5	203.01	0.64	203.65	8.49	9	8	1
13	A6-2A	6279					19.19	146.63	13.95	211.06			0.87	211.93	8.83	9	6	3
14	A4-1G	6622			44.15	93.31					23.91	167.57			6.98	7	8	-
15	A8-2D	6406					46.27	83.83	24.91	162.8					6.78	7	9	-

Table 10 Summary of scheduling results

Rules	Total flow time (hrs)	Total late days	Performance measures				
			Average completion time	Utilization percentage	Average tardiness	Total late jobs	Maximum lateness
FCFS.m	1,939.85	9	129.32	0.42	0.60	6	2
FCFS.o	2,228.16	12	148.54	0.36	0.80	6	3
SPT.m	1,396.49	4	93.10	0.58	0.27	2	2
SPT.o	1,417.61	3	94.51	0.57	0.20	2	2
EDD.m	1,500.18	1	100.01	0.54	0.07	1	1
EDD.o	1,591.05	1	106.07	0.51	0.07	1	1
LPT.m	2,526.19	29	168.41	0.32	1.93	11	5
LPT.o	2,828.48	34	188.57	0.29	2.27	10	6

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