The Design of Hybrid Flow Shop Scheduling System with Tabu Search (TS) Method to Minimize Makespan at PT. Plasindo Elok

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Abstract

PT. Plasindo Elok is a manufacturer that has been producing plastic protector and packaging system specifically for oil and gas company. All kinds of product which is produced by PT.Plasindo Elok, have the same sequences and at several production stages, there are a number of parallel machine with its different capacity (hybrid flow shop). The existing production scheduling was based on First Come First Serve (FCFS). The objective of this paper is to design a scheduling system to minimize makespan which could reduce WIP and total production cost. Flow shop heuristic method which is used as a basis to get the optimal makespan are NEH and CDS algorithm. Furthermore, the scheduling sequence of NEH and CDS are used to generate an initial sequence for metaheuristic method, Tabu Search (TS). The result of data processing showed that CDS algorithm represented the minimum makespan compared to NEH algorithm. The proposed methods CDS-TS and NEH-TS, produced the same minimum makespan, 14861,61 minutes with different mean flow time. Both hybrid algorithm (NEH-TS and CDS-TS) could reduce total makespan to 1697,93 minutes or 28,30 hours. The proposed method given to the company was NEH-TS with the production sequence of P10 - P12 - P13 - P8 - P7 - P4 - P5 - P2 - P1 - P11 - P9 - P3 - P14 - P6, NEH-TS was the best algorithm compared to NEH, CDS, and CDS-TS because it produced the least makespan and mean flow time. In addition to facilitate company scheduling calculation, researcher designs a Java based scheduling program.

Keywords

Nawaz, Enscore, and Ham Algorithm (NEH); Campbell Dudek Smith (CDS); Tabu Search Algorithm (TS), Makespan; Software

1. Introduction

Production process in a manufacturing company should be well manage to meet customer's needs in terms of time and amount. Every company strives to have the most effective and efficient scheduling method in order to increase their productivity with a minimum cost and time. Errors and failures in scheduling will disrupt the production's schedule and affect many things such as lack of total amount of production, delays in meeting consumer needs, the amount of work-in-process goods, high production costs (labor, machinery, and electricity), and loss of sale.

Scheduling problem was one of the problems faced by PT. Plasindo Elok. PT.Plasindo Elok applied a manual production scheduling system by an estimator in production subdivision, based on First Come First Serve (FCFS) method. Besides, estimator also needed to determine several jobs that must be prioritized because of customer orders. The estimator previously used their experience and personal considerations in performing production scheduling and also had some difficulties when customers increase their order's number, so that some of the jobs with some different specifications needed to be rescheduled.

PT. Plasindo Elok is classified as semi continuous production type because of large quantity of customer's orders. In producing plastic thread and cup protector, PT. Plasindo Elok applies a production process flow in accordance with hybrid flow shop, which there are several machines such as resin mixer, injection molding, and CNC machine that operate parallelly and production process for all jobs pass through the same sequence The production scheduling method proposed in this study is heuristic method, NEH and CDS as the initial solution. Then, both heuristic method will be conducted as a comparison to find the smallest makespan with Tabu Search as the metaheuristic algorithm. Furthermore, a scheduling program is created to improve the performance of manual scheduling process. The scheduling program application will show the best job sequence and the completion time for all jobs.

2. Literature review

2.1. Scheduling

Scheduling is a decision-making process which is aimed to achieve optimality (Pinedo, 2002). Conway and Forgaty (1967) explained that scheduling is the task of assigning each operation to a specific position or time scale of the specific machine and frequently includes determination of start and completion time. The decision in scheduling that is interpreted as an assignment is in the form of sequencing and timing to start the work, when to determine all of them, first we must find out the sequence of each operations. Scheduling plays an important role in the manufacturing industry because ineffective scheduling will result in a low usage level of existing capacity. Scheduling can't be separated from sequencing because in scheduling there is a sort of job which needs to be done first. Scheduling problems will arise when a set of tasks come together at a certain time (per month, per week, per day), while resources such as machinery and equipment are limited. If it happens, it is necessary to reschedule the sources efficiently.

2.2. Flow shop

In flow shop scheduling, jobs are processed in a set order and each job goes to each machine in a certain time and is only processed once by each type of machine. Each job is processed sequentially, which moves from one machine to the next (liniear precedence diagram) Flow shop characteristic is stated as a direct flow of work. Flow shop scheduling which has the same routing (the same sequence for the usage of machines) is called by flow shop permutation scheduling (Pinedo,2002)

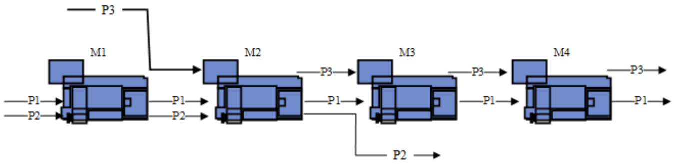


Figure 1 Flow shop

2.3. Hybrid flow shop

Hybrid flow shop is a generalization of the classic flow shop problem where there are several parallel machines in at least one stage of a process (Oguz, Janiak, & Lichtenstein, 2001).

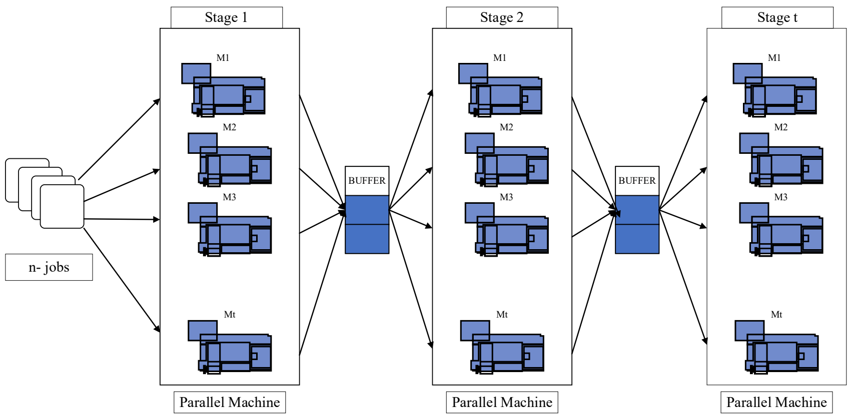


Figure 2 Hybrid flow shop

2.4. Permutation flow shop scheduling problem

A special type of flow shop scheduling problem is a permutation flow shop scheduling problem. The permutation flow shop scheduling problem consists in scheduling n jobs with given processing times on m machines, where the sequence of processing a job on all machine is identical and uni-directional for each job (Rajendran & Ziegler, 2004). The proposed methods to solve flow shop scheduling problems can be classified as an exact algorithm such as a heuristic algorithm like: Hodgson, Branch and Bound, etc. and metaheuristic algorithm: *Simulated Anealling, Genetic*, etc.

2.5. NEH algorithm
NEH algorithm is also referred as an incremental construction algorithm that had been awarded as the best heuristic method in the Permutation Flow Shop Sequencing Problem (FPSP) (Taillard, 1990). NEH initializes job sequences descendingly based on the total processing time of each job. Then a partial sequence calculation is performed, which determines the best sequence of each sequence to be scheduled.

2.6. CDS algorithm
Campbell, Dudek, and Smith algorithm is a scheduling algorithm on series machines which is an approach of the Johnson's rule algorithm. Johnson's rule had been developed by Campbell, Dudek and Smith, which is an algorithm for scheduling several jobs on a number of machines (m machines) that allows to create an alternative scheduling as many as the number of m-1, and choose the best alternative to be implemented.

2.7. Tabu search algorithm
Tabu Search (TS), also called an adaptive memory programming, is a method for solving challenging problems in the field of optimization. The goal is to identify the best decisions or actions in order to maximize some measure of merit (such as maximizing profit, effectiveness, quality, and social or scientific benefit) or to minimize some measure of demerit (cost, inefficiency, waste, and social or scientific loss). The TS technique is rapidly becoming the method of choice for designing solution procedures for hard combinatorial optimization problems. TS method has also been used to create hybrid procedures with other heuristic and algorithmic methods, to provide improved problems solution in scheduling. Tabu Search is begun in the same way as an ordinary local or neighborhood search, proceeding iteratively from one point (solution) to another point until a chosen termination criterion is satisfied. The basic concept of Tabu Search is the effectiveness of process to find the best solution at each stage of tracking (Laguna et al., 1991). In some stages of tracking it can be categorized as a taboo step (forbidden) because it will produce local optimal and also result in repetition search to a previously discovered solution (entrapment). The neighborhood searches are then entered into a list called the tabu list. The search process itself is carried out by determining the initial solution and then moving to the next solutions (neighborhood) and will stop until the stopping conditions are reached.

3. Research Methodology

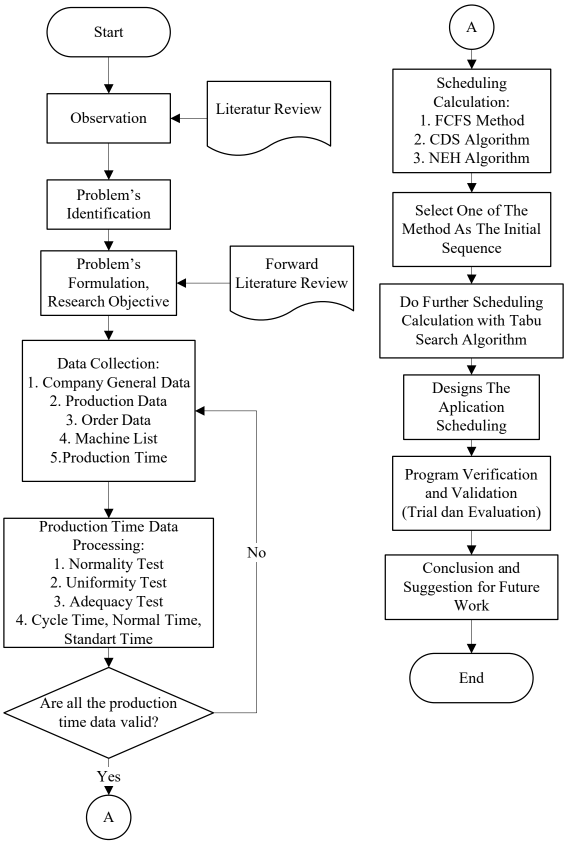


Figure 3 Research Flowchart

As mentioned earlier, this study used NEH and CDS algorithm as the initial solution for the further method, Tabu Search (TS). The first method, NEH algorithm used longest processing time dispatching rule (LPT) and CDS used 6 iterations for finding the best sequence. The scheduling process was done with forward scheduling approach. Furthermore, makespan and mean flow time of both proposed method (NEH-TS and CDS-TS) were compared with the relative error and efficiency index.

4. Result and discussion

4.1. Production data and list of machines

Production data of the company were based on product demand in September 2018 can be found in Table 1. The following is the machines' list along with the capacity of each machine.

Table 1. Product order data for September 2018
(Source: Company Data)

No.	Product Name/Size	Product Mass (kg)	Total PO (unit)
1	PROT 938" TSH 513/523 #39 BOX CEL	1,7	200
2	Plastic 7" TSH MS XT/XC PIN CEL	1,5	700
3	Plastic 7" TSH MS XT/XC BOX CEL	1,25	700
4	COMP. 4-1/2" TSH BLUE CEL, (BOX)	0,45	150
5	PROT 7" TSH 513/523 PIN CEL	1,5	200
6	BLANK 10-3/4" LD CEN, (PIN)	2,15	200
7	PLASTIC PROT. 3-1/2" TSH PH-6 PIN	0,55	420
8	PLASTIC PROT. 3-1/2" TSH PH-6 BOX	0,45	420
9	PLASTIC RING SIZE: 3-1/2" OD	0,1	2500
10	PLASTIC RING SIZE:2-7/8"OD	0,05	14000
11	PLASTIC RING SIZE: 4-1/2" OD	0,15	4000
12	PLASTIC PROT. 5-1/2" TSH BLUE PIN	0,9	250
13	PLASTIC PROT. 5-1/2" TSH BLUE BOX	0,75	250
14	PLASTIC RING SIZE: 9-3/8" OD	0,35	1000

Table 2. Number of machines and machine's capacity
(Source: Company Data)

No.	Machine Name	Qty (Unit)	Capacity	Usage Limitation
1	Material Digital Scale	1		
2	Resin Mixer Machine	2	200 kg	
Injection Molding for Small Size Protector & Bumpering				
3	Lanson LS 200GT-S	1	200 ton	3-1/2"
4	HS 180	1	180 ton	3-1/2"
Injection Molding for Big Size Protector & Bumpering				
5	Niigata NN 350 B	1	350 ton	13-3/8"
6	Fu Chu Shin 400	1	400 ton	13-3/8"
7	MSN 300	1	300 ton	13-3/8"
8	FuChu Shin 260	1	260 ton	10-3/4"
9	Well Tex	1	360 ton	13-3/8"
CNC Threading Machine				
10	Cia Mix CY K 500	1		13-3/8"
11	Daihatsu PNC L 56	1		10-3/4"
12	L-Seiki	1		10-3/4"
13	Mori SL-2	1		7"
14	*Press* and *Lock*	1		
15	*Spray Painting*	1		
16	*QC Labelling*	1		

4.2. Company's time standarizations

Time standarizations were based on the production cycle time which was generated from machines that operate automatically and company's documentation of setup time. Company's time standarization can be found in Table 3.

Table 3. Company's time standarization
(Source: Company Data)

No.	Product Type	Process	Time/Pcs (minute)
1	PROT 938" TSH 513/523 #39 BOX CEL	Setup Injection	74,15
		Setup CNC	58,26
2	Plastic 7" TSH MS XT/XC PIN CEL	Setup Injection	67,41
		Setup CNC	45,38
3	Plastic 7" TSH MS XT/XC BOX CEL	Setup Injection	60,32
		Setup CNC	36,55
4	COMP. 4-1/2" TSH BLUE CEL, (BOX)	Setup Injection	43,57
		Setup CNC	22,29
5	PROT 7" TSH 513/523 PIN CEL	Setup Injection	62,33
		Setup CNC	63,4
6	BLANK 10-3/4" LD CEN, (PIN)	Setup Injection	87,49
7	PLASTIC PROT. 3-1/2" TSH PH-6 PIN	Setup Injection	29,17
		Injection	3,5
		Setup CNC	20,45
8	PLASTIC PROT. 3-1/2" TSH PH-6 BOX	Setup Injection	22,33
		Injection	3
		Setup CNC	18,12
9	PLASTIC RING SIZE: 3-1/2" OD	Setup Injection	28,21
		Injection	2
10	PLASTIC RING SIZE:2-7/8"OD	Setup Injection	24,01
		Injection	1
11	PLASTIC RING SIZE: 4-1/2" OD	Setup Injection	42,59
		Injection	2,5
12	PLASTIC PROT. 5-1/2" TSH BLUE PIN	Setup Injection	44,17
		Setup CNC	25,34
13	PLASTIC PROT. 5-1/2" TSH BLUE BOX	Setup Injection	39,52
		Setup CNC	19,76
14	PLASTIC RING SIZE: 9-3/8" OD	Setup Injection	65,36
		Injection	4

4.3. Time measurement

This research was conducted at PT. Plasindo Elok with direct observation techniques in the production section, using stopwatch. Production time data were collected from 14 jobs in September 2018. Table 4 shows the summary of cycle time measurement.

Table 4. Summary of cycle time measurement

Job	Cyle Time (second)						
	Weighing	Setup Mixing	Injection	Threading	Press&Lock	Spray Painting	Inspection
P1	34,77	200,24	572,43	506,89			4,47
P2	34,77	200,24	475,10	378,97			3,92
P3	34,77	200,24	420,28	351,49			3,42
P4	34,77	200,24	341,21	256,75	17,68	39,87	26,36
P5	34,77	200,24	499,87	470,87			4,67
P6	34,77	200,24	641,19				6,45
P7	34,77	200,24		219,47			4,47
P8	34,77	200,24		200,42			3,48
P9	34,77	200,24					2,29
P10	34,77	200,24					2,16
P11	34,77	200,24					2,84
P12	34,77	200,24	458,15	314,23			4,60
P13	34,77	200,24	371,19	293,16			4,80
P14	34,77	200,24					2,95

4.4. Data testing

The data testing in this study included normality test, uniformity test, and data adequacy test. The normality test used the Kolmogorov Smirnov method with the help of SPSS 20. The data uniformity test were carried out to ensure the observed cycle time/sample data were within the control limits. The level of confidence for these testing were 99.73%, with a value of $Z(\alpha / 2) = 3$. While the adequacy data test used 95% confidence level and 5% accuracy level. Uniformity and adequacy test were calculated based on the assumption that each machine operator works according to the normal distribution pattern. If all observational data had been tested and feasible, then the observation data will continue with data processing.

4.5. Data processing

After all of the data is normal, it has the desired uniformity, and the observation number has met the levels of accuracy and confidence, the next step is to process the data until it is obtained the standard time (Sutalaksana et al, 1979). Normal time is calculated by multiplying the percentage of adjustment with cycle time. The standard time is calculated by multiplying the allowance factor with normal time. The result of the standard time calculation are then added to the setup time of each machine.

Process Time = (Standard Time x Order Quantity) + Setup Time......................................(1)

Table 5 shows the results of processing time calculations.

Table 5. Processing time

Job	Process Time (minute)						
	Weighing	Mixing	Injection	Threading	Press&Lock	Spray Painting	QC&Labelling
P1	3.81	73.76	2382.67	2213.63			20.19
P2	10.68	206.54	7137.77	5685.27			62.04
P3	9.15	177.03	6250.38	5267.65			54.20
P4	0.76	14.75	1094.37	812.90	62.16	135.95	82.79
P5	3.05	59.01	2166.02	2003.81			21.13
P6	4.58	88.52	2796.22				29.26
P7	3.05	59.01	1499.28	2013.15			42.27
P8	2.29	44.26	1282.55	1800.89			32.88
P9	3.05	59.01	5028.35				128.71
P10	7.63	147.53	14024.02				682.44
P11	6.10	118.02	10042.98				255.83
P12	2.29	44.26	2394.99	1672.13			25.93
P13	2.29	44.26	1944.40	1556.42			27.01
P14	3.81	73.76	4065.60				66.54

Table 6. Calculation results of the FCFS method (in minute)

Process	Weighing		Mixing		Injection Small		Injection Big		Threading		Press&Lock		Spray Painting		QC&Labelling	
Job	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
P1	0	3.81	3.81	77.58			77.58	2460.24	2460.24	4673.88					4673.88	4694.07
P2	3.81	14.49	14.49	221.03			221.03	7358.80	7358.80	13044.07					13044.07	13106.11
P3	14.49	23.64	77.58	254.61			254.61	6505.00	6505.00	11772.65					11772.65	11826.85
P4	23.64	24.40	221.03	235.78			235.78	1330.15	1330.15	2143.04	2143.04	2205.20	2205.20	2341.15	2341.15	2423.94
P5	24.40	27.45	235.78	294.79			294.79	2460.81	2460.81	4464.62					4464.62	4485.75
P6	27.45	32.03	254.61	343.13			1330.15	4126.37							4126.37	4155.63
P7	32.03	35.08	294.79	353.80	353.80	1853.09			1853.09	3866.24					3866.24	3908.51
P8	35.08	37.36	343.13	387.39	387.39	1669.94			1669.94	3470.82					3470.82	3503.70
P9	37.36	40.42	353.80	412.81	1669.94	6698.29									6698.29	6826.99
P10	40.42	48.04	387.39	534.91	1853.09	15877.10									15877.10	**16559.54**
P11	48.04	54.14	412.81	530.84			2460.24	12503.23							12503.23	12759.06
P12	54.14	56.43	530.84	575.09			2460.81	4855.80	4855.80	6527.93					6527.93	6553.85
P13	56.43	58.72	534.91	579.17			4126.37	6070.77	6070.77	7627.18					7627.18	7654.19
P14	58.72	62.53	575.09	648.86			4855.80	8921.40							8921.40	8987.94
															Mean FlowTime	**7674.72**

4.6. Current company scheduling

PT. Plasindo Elok used First Come First Serve (FCFS) method in scheduling its production system. The FCFS scheduling sequence produced makespan of 16559.54 minutes and mean flowtime of 7674.72 minutes. Table 6 shows FCFS method calculation.

4.7. CDS scheduling

The calculation of CDS scheduling method was carried out by using 14 job sequences for 7 machines. The number of job sequence/iteration combinations which would be performed was calculated by using the formula k = m - 1. Where m is the number of machine used, because there were 7 stages (7 types of production's machine) so the total iterations that had to be done were up to 6 iterations (k=7-1). The makespan value of each iteration can be found in Table 7 and the best makespan calculation can be found in Table 8.

Table 7. Makespan for each iteration (in minutes)

K	*Makespan*	*Mean Flow Time*
1	17535,60	7400,95
2	14916,81	8791,22
3	14861,61	8807,92
4	16309,49	7794,67
5	14916,81	8597,10
6	16420,65	7347,17

Table 8. CDS method calculation result (k = 3, in minutes)

Process	Weighing		Mixing		Injection (small)		Injection (big)		Threading		Press&Lock		Spray Painting		Inspection	
Job	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
P10	0,00	7,63	7,63	155,15	155,15	14179,17									14179,17	**14861,61**
P4	7,63	8,39	8,39	23,14			23,14	1117,51	1117,51	1930,40	1930,40	1992,57	1992,57	2128,51	2128,51	2211,30
P11	8,39	14,49	23,14	141,16			141,16	10184,15							10184,15	10439,97

Table 8. CDS method calculation result (k = 3, in minutes) (continue)

Process	Weighing		Mixing		Injection (small)		Injection (big)		Threading		Press&Lock		Spray Painting		Inspection	
P9	14,49	17,54	141,16	200,17	200,17	5228,52									5228,52	5357,23
P14	17,54	21,35	155,15	228,92			228,92	4294,52							4294,52	4361,06
P2	21,35	32,03	200,17	406,71			406,71	7544,49	7544,49	13229,75					13229,75	13291,80
P3	32,03	41,18	228,92	405,95			405,95	6656,34	6656,34	11923,99					11923,99	11978,19
P7	41,18	44,23	405,95	464,96	6511,07	8010,36			8311,96	10325,11					10439,97	10482,24
P8	44,23	46,52	406,71	450,97	5228,52	6511,07			6511,07	8311,96					8311,96	8344,84
P6	46,52	51,09	450,97	539,49			3061,91	5858,13							5858,13	5887,39
P13	51,09	53,38	464,96	509,22			1117,51	3061,91	3061,91	4618,32					4618,32	4645,33
P12	53,38	55,67	509,22	553,48			4294,52	6689,51	6689,51	8361,63					8361,63	8387,56
P5	55,67	58,72	539,49	598,50			5858,13	8024,14	8361,63	10365,45					10482,24	10503,37
P1	58,72	62,53	553,48	627,24			6656,34	9039,00	10325,11	12538,74					12538,74	12558,93
															Mean Flow Time	**8807,92**

4.8. NEH scheduling

The first step in the NEH method is to calculate the total amount of processing time for each job, then do Longest Processing Time (LPT) dispatching rules. Guinet, Solomon, Kedia and Dussauchoy (1996) concluded that the LPT rule gives good results for the two-stage makespan problem. The calculations result with the NEH method, showed a sequence of jobs with the smallest makespan of 16014.65 minutes and mean flow time of 7671.57 minutes. The results of makespan calculation with the NEH method can be found in Table 9.

Table 9. Calculation results of the NEH method (in minutes)

Process	Weighing		*Mixing*		*Injection (kecil)*		*Injection (besar)*		*Threading*		*Press&Lock*		*Spray Painting*		*QC & Labelling*	
Job	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
P12	0	2.29	2.29	46.55			46.55	2441.54	2441.54	4113.66					4113.66	4139.59
P10	2.29	9.91	9.91	157.44	157.44	14181.46									14181.46	14863.89
P13	9.91	12.20	46.55	90.80			90.80	2035.20	2035.20	3591.62					3591.62	3618.63
P8	12.20	14.49	90.80	135.06	135.06	1417.61			1417.61	3218.50					3218.50	3251.38
P7	14.49	17.54	135.06	194.07	1417.61	2916.90			3591.62	5604.77					5604.77	5647.04
P9	17.54	20.59	157.44	216.45	2916.90	7945.25									7945.25	8073.96
P5	20.59	23.64	194.07	253.08			253.08	2419.10	2419.10	4422.91					4422.91	4444.04
P14	23.64	27.45	216.45	290.22			290.22	4355.82							4355.82	4422.36
P1	27.45	31.26	253.08	326.85			326.85	2709.52	3218.50	5432.13					5432.13	5452.32
P11	31.26	37.36	290.22	408.24			2419.10	12462.08							12462.08	12717.91
P4	37.36	38.13	326.85	341.60			2035.20	3129.57	4113.66	4926.56	4926.56	4988.72	4988.72	5124.67	5124.67	5207.46
P3	38.13	47.28	341.60	518.64			2441.54	8691.92	8691.92	13959.57					13959.57	14013.78
P2	47.28	57.95	408.24	614.78			3129.57	10267.34	10267.34	15952.61					15952.61	**16014.65**
P6	57.95	62.53	518.64	607.15			2709.52	5505.74							5505.74	5535.00
															Mean FlowTime	**7671.57**

4.9. Scheduling comparison of FCFS, CDS algorithm, and NEH algorithm

The makespan comparison of FCFS, CDS, and NEH can be found in Tabel 10.

Table 10. Makespan value of each iteration

Method	Sequence	Makespan (minute)	Mean FlowTime (minute)
FCFS	1-2-3-4-5-6-7-8-9-10-11-12-13-14	16559.54	7674.72
CDS	10-4-11-9-14-2-3-7-8-6-13-12-5-1	14861.61	8807.92
NEH	12-10-13-8-7-9-5-14-1-11-4-3-2-6	16014.65	7671.57

Based on method comparison table, the CDS algorithm produced the smallest makespan value. Furthermore, the initial method of CDS and NEH were used as the initial solution for metaheuristic algorithm, Tabu Search (TS). The CDS-TS and NEH-TS methods were used as a sequence scheduling comparison to find the best makespan and best mean flowtime value.

4.10. Tabu search scheduling

Tabu Search (TS) scheduling used 3 N-Gen or 3 iterations. The TS algorithm used neighborhood switches for 14 jobs at each iteration. The minimum makespan result from iteration 1 was used as the iteration initialization of stage 2. Then, the minimum makespan result from iteration 2 was used as the iteration initialization of stage 3. If there were several minimum makespan value that was similar, chose the sequence with the minimum mean flowtime. The minimum makespan value of the three iterations for each method was selected as the best scheduling sequence. Table 11 shows the results of the calculation of the CDS-TS and NEH-TS methods.

Table 11. Comparison of CDS-TS and NEH-TS methods

Iteration	CDS-TS		NEH-TS	
	Makespan (minute)	Mean FlowTime (minute)	Makespan (minute)	Mean FlowTime (minute)
Initial Sequence	14861.61	8807.92	16014.65	7671.57
1	14861.61	8013.85	14918.51	7696.51
2	14861.61	7707.17	14863.89	7455.09
3	**14861.61**	**7561.32**	**14861.61**	**7458.47**

The CDS-TS and NEH-TS methods produced the smallest makespan value with the same value that were equal to 14861.61 minutes with different mean flow time and job sequences. In the scheduling of CDS-TS algorithm, the best sequence of jobs is P10 - P4 - P13 - P5 - P14 - P2 - P6 - P7 - P8 - P3 - P11 - P12 - P9 - P1 with mean flow time of 7561.32 minutes. In the scheduling of NEH-TS algorithm, the best sequence of jobs is P10 - P12 - P13 - P8 - P7 - P4 - P5 - P2 - P1 - P11 - P9 - P3 - P14 - P6 with mean flow time of 7458.47 minutes. The results of the neighborhood switch showed that the CDS-TS and NEH-TS method had produced the optimum value (the best makespan) at the third iteration.

4.11. Program design

Java GUI (Graphic User Interface) was a selected application to implement scheduling calculations as a solution for company production scheduling. The Java GUI uses Java programming language with the addition of several components apart from text base/coding such as the addition of symbols, images, templates, and buttons. The Java GUI has a functionality that allows the designed application to run on several different operating system platforms. All required data such as machine types, number of machines, processing time, and routing can be inputted in the templates provided. The data that had been inputted will be recorded as a data base and can be edited if there was an error in data input. The visual design of the scheduling application can be found in Figure 4, 5, and 6.

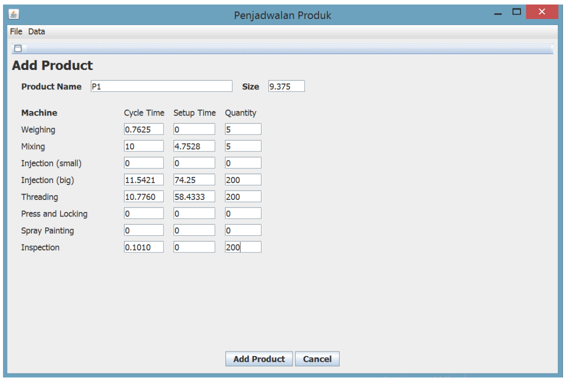
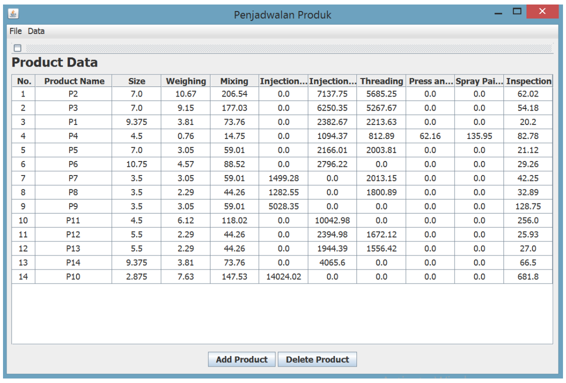
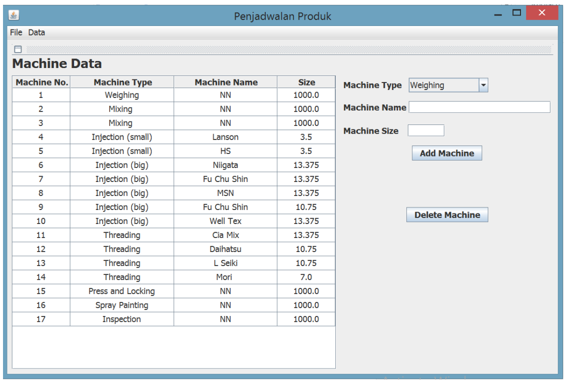


Figure 4. Input view for product and process time of scheduling application



No.	Product Name	Size	Weighing	Mixing	Injection...	Injection...	Threading	Press an...	Spray Pai...	Inspection
1	P2	7.0	10.67	206.54	0.0	7137.75	5685.25	0.0	0.0	62.02
2	P3	7.0	9.15	177.03	0.0	6250.35	5267.67	0.0	0.0	54.18
3	P1	9.375	3.81	73.76	0.0	2382.67	2213.63	0.0	0.0	20.2
4	P4	4.5	0.76	14.75	0.0	1094.37	812.89	62.16	135.95	82.78
5	P5	7.0	3.05	59.01	0.0	2166.01	2003.81	0.0	0.0	21.12
6	P6	10.75	4.57	88.52	0.0	2796.22	0.0	0.0	0.0	29.26
7	P7	3.5	3.05	59.01	1499.28	0.0	2013.15	0.0	0.0	42.25
8	P8	3.5	2.29	44.26	1282.55	0.0	1800.89	0.0	0.0	32.89
9	P9	3.5	3.05	59.01	5028.35	0.0	0.0	0.0	0.0	128.75
10	P11	4.5	6.12	118.02	0.0	10042.98	0.0	0.0	0.0	256.0
11	P12	5.5	2.29	44.26	0.0	2394.98	1672.12	0.0	0.0	25.93
12	P13	5.5	2.29	44.26	0.0	1944.39	1556.42	0.0	0.0	27.0
13	P14	9.375	3.81	73.76	0.0	4065.6	0.0	0.0	0.0	66.5
14	P10	2.875	7.63	147.53	14024.02	0.0	0.0	0.0	0.0	681.8

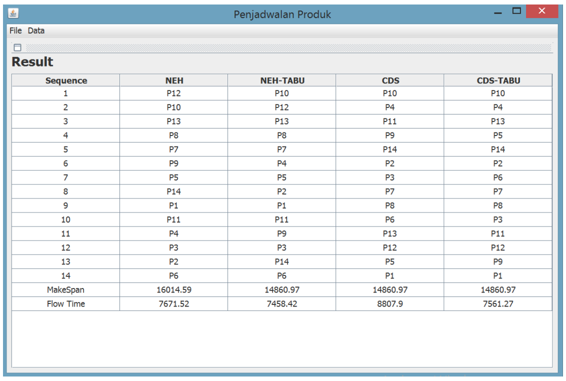
Figure 5. Data base of product and processing time



Machine No.	Machine Type	Machine Name	Size
1	Weighing	NN	1000.0
2	Mixing	NN	1000.0
3	Mixing	NN	1000.0
4	Injection (small)	Lanson	3.5
5	Injection (small)	HS	3.5
6	Injection (big)	Niigata	13.375
7	Injection (big)	Fu Chu Shin	13.375
8	Injection (big)	MSN	13.375
9	Injection (big)	Fu Chu Shin	10.75
10	Injection (big)	Well Tex	13.375
11	Threading	Cia Mix	13.375
12	Threading	Daihatsu	10.75
13	Threading	L Seiki	10.75
14	Threading	Mori	7.0
15	Press and Locking	NN	1000.0
16	Spray Painting	NN	1000.0
17	Inspection	NN	1000.0

Figure 6 Input view for machine

Data that had been input will be processed in a scheduling application. The output are comparisons of the proposed method in the form of production scheduling sequence with minimum objective function, makespan value, and mean flow time. Figure 6 shows the output view of NEH calculation and NEH-TS calculation.



Sequence	NEH	NEH-TABU	CDS	CDS-TABU
1	P12	P10	P10	P10
2	P10	P12	P4	P4
3	P13	P13	P11	P13
4	P8	P8	P9	P5
5	P7	P7	P14	P14
6	P9	P4	P2	P2
7	P5	P5	P3	P6
8	P14	P2	P7	P7
9	P1	P1	P8	P8
10	P11	P11	P6	P3
11	P4	P9	P13	P11
12	P3	P3	P12	P12
13	P2	P14	P5	P9
14	P6	P6	P1	P1
MakeSpan	16014.59	14860.97	14860.97	14860.97
Flow Time	7671.52	7458.42	8807.9	7561.27

Figure 6. Output calculation

5. Program validation

In program validation, the production data in September 2018 was inputted into the program to test whether the program was in accordance with the predetermined algorithm. The job sequences, makespan, and mean flow time results of program's calculations were compared with the results of manual calculation. According to the comparison result, a similar sequence of jobs, makespan, and mean flow time were obtained. The comparison results of makespan and mean flow time calculation can be seen in Table 12.

Table 12. Program validation

Iteration	NEH-TS (minute)				CDS-TS (minute)			
	Makespan		Mean Flow Time		Makespan		Mean Flow Time	
	Manual	Program	Manual	Program	Manual	Program	Manual	Program
0	16014,65	16014,59	7671,57	7671,52	14861,61	14860,97	8807,92	8807,9
1	14918,1	14917,44	7696,51	7696,41	14861,61	14860,97	8013,85	8013,8
2	14863,89	14863,26	7455,09	7455,04	14861,61	14860,97	7707,16	7707,12
3	14861,61	14860,97	7458,47	7458,42	14861,61	14860,97	7561,32	7561,27

6. Conclusion

The initial solution of CDS heuristic algorithm produced smaller makespan value compared to FCFS (First Come First Serve) method and NEH algorithm. The best result of the CDS and NEH algorithm sequences were used as the advanced method initialization stage, Tabu Search (TS). The approach of metaheuristic method was needed to find a near optimal solution with local search. According to the initial methods (NEH and CDS), CDS produced less makespan of 14861,61 minutes than NEH algorithm. But, based on the two extention calculations of the CDS-TS and NEH-TS methods, both of them produced the same minimum makespan of 14861.61 minutes with different job sequences and mean flow time. In scheduling the CDS-TS algorithm, the best job sequence is P10 - P4 - P13 - P5 - P14 - P2 - P6 - P7 - P8 - P3 - P11 - P12 - P9 - P1 with mean flow time of 7561.32 minutes. In scheduling the NEH-TS algorithm, the best job sequence is P10 - P12 - P13 - P8 - P7 - P4 - P5 - P2 - P1 - P11 - P9 - P3 - P14 - P6 with mean flow time of 7458.47 minutes. Both advanced algorithms can reduce makespan values to 1697.93 minutes (efficiency increases by 15%) or 28.3 hours from current company scheduling. The proposed job sequence for companies is in accordance with the NEH-TS algorithm (P10 - P12 - P13 - P8 - P7 - P4 - P5 - P2 - P1 - P11 - P9 - P3 - P14 - P6) because the NEH-TS algorithm produces the smallest mean flow time. The scheduling application is Java based, so it can be shared and used in any kind of OS and it is useful to simplify and quicken the scheduling calculation**.**

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Biographies

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