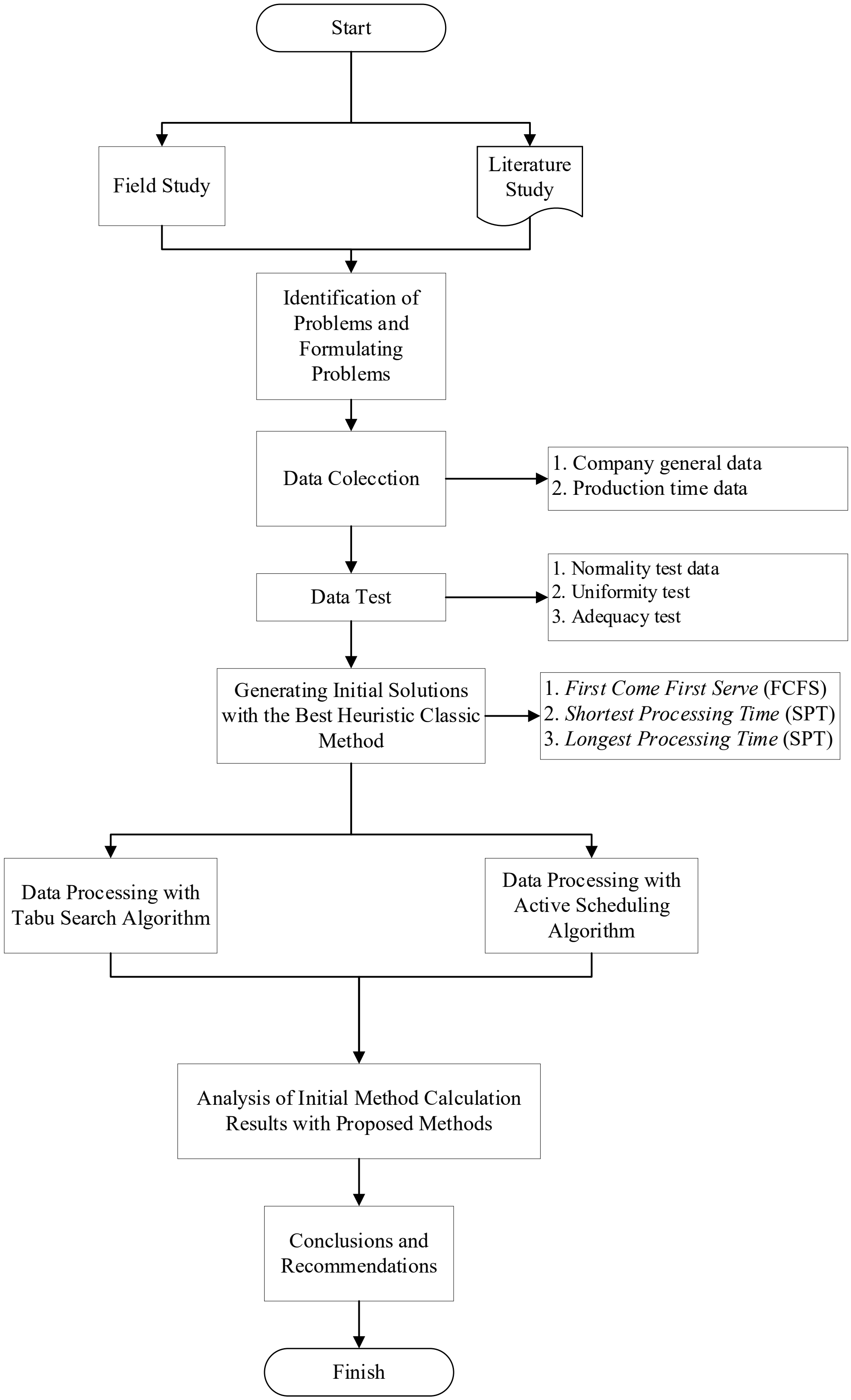


Figure 4 Research Method Flowchart

4 RESULTS AND DISCUSSION

The job shop scheduling requires some data, namely the number of machines used and the production time data for each component. the results of company data observations, are data on the number of machines in table 1 and production time data in table 2.

Table 1 Number of Machine Data

No	Name of Machine	Total	Work
1	Cutting Machine	1	Cutting
2	Laser Machine	1	Cutting
3	Power Press Machine	1	Pounding
4	Press Breake Machine	1	Bending
5	Bench Drill Machine	1	Drilling / Milling
6	Welding Machine	2	Weld
7	Spot Welding Machine	1	Weld spot
8	Punch Machine	1	Embos

Table 2 Standard Production Time Data (Second)

Job	Operation	Machine	Time (Second)	Name
1 (Base)	1	B (Laser Machine)	1146	11B
	2	D (Press Brake Machine)	76	12D
	3	G (Welding Machine)	648	13G
2 (Pole)	1	B (Laser Machine)	141	21B
	2	D (Press Brake Machine)	650	22D
	3	F (Welding Machine)	160	23F
3 (Shelving)	1	A (Cutting Machine)	499	31A
	2	C (Power Press Machine)	180	32C
	3	D (Press Brake Machine)	452	33D
	4	H (Punching Machine)	133	34H
	5	I (Spot Weldig Machine)	238	35I
4 (Support Shelf)	1	A (Cutting Machine)	242	41A
	2	D (Press Brake Machine)	126	42D
	3	E (Bench Drill Machine)	107	43E
5 (Bracket)	1	B (Laser Machine)	114	51B

Scheduling for companies begins with makespan time calculation with classical heuristic methods and continued with tabu search algorithm method. Calculation with classical heuristic method uses 3 methods, namely FCFS (First Come First Serve) method, SPT (Shortest Processing Time First), and LPT (Longest Processing Time First).

From the three classic heuristic methods, the makespan value for the FCFS (First Come First Serve) method is 2760 seconds, with the SPT method (Shortest Processing Time First), the makespan value is 2194 seconds, and the LPT (Longest Processing Time First) method gets the value makespan is 2557 seconds. So that the smallest makespan value is 2194 seconds to be used as the initial solution in scheduling using the tabu search algorithm.

The calculation with an active scheduling algorithm produces a makespan value of 2194 seconds with a sequence of jobs in the machine as shown in table 3 below:

Tabel 3 Sequence of Job Active Scheduling

St[a]	Cj[b]	Tij[c]	Rj[d]	t*	m*	PSt[e]
51B	0	114	114	114	B	51B
41A	0	242	242	242	A	41A
21B	114	141	255	255	B	21B
42D	242	126	368	368	D	42D
43E	368	107	475	475	E	43E
31A	242	499	741	737	A	31A
32C	737	180	917	917	C	32C
22D	368	650	1018	1018	D	22D
23F	1018	160	1178	1178	F	23F
11B	255	1146	1401	1401	B	11B
33D	1018	452	1470	1470	D	33D
12D	1470	76	1546	1546	D	12D
34H	1470	133	1603	1603	H	34H
35I	1603	238	1841	1841	I	34I
13G	1546	648	2194	2194	G	13G

[a] set of operations that can be scheduled at stage t, after PSt is obtained
[b] the fastest operating time $j \in St$ can be started
[c] the time when the job is done on the machine
[d] the fastest operating time $j \in St$ can be completed
[e] partial schedule consisting of scheduled operations

The calculation with tabu search algorithm will be done with the number of iterations of 5 and the number of tabu lists as much as 5, this is done so that the most optimal makespan value of each iteration is not lost, and reduces the same calculation for the data already in the tabu list.

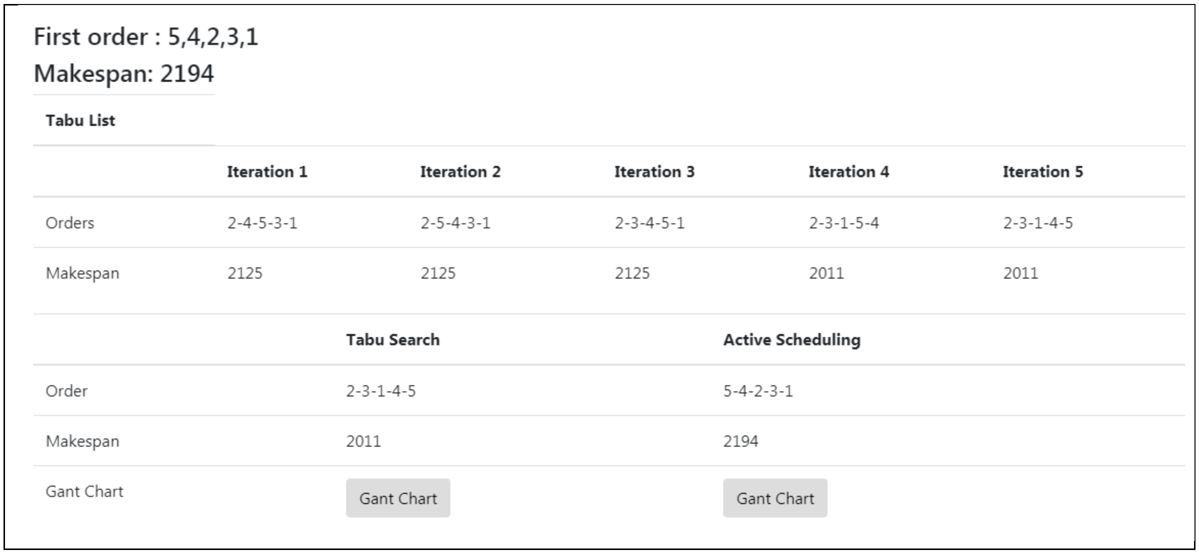
In the calculation with tabu search algorithm, there is a tabu list which can be seen in Table 3.

Table 3 Tabu List

Job Order	2-4-5-3-1	2-5-4-3-1	2-3-4-5-1	2-3-1-5-4	2-3-1-4-5
Makespan	2125	2125	2125	2011	2011
	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5

So the most optimal solution is obtained during the 4th and 5th iterations, with an makespan value of 2011 seconds and the order of each job as:
Iteration 4
Base - Shelving - Tiang - Bracket - Support Shelf
Iteration 5
Base - Shelving - Pole - Shelf Support - Bracket

The results of manual calculations have the same result value with the results using the application program. To run the program application, it is necessary to input the number of jobs, the number of machines, the number of iterations, and the maximum number of operations. After that input process time is needed in each operation and machine, so that a sequence of production processes is formed. Then after entering the input, you will get the results in the application program like Figure 5.



First order : 5,4,2,3,1

Makespan: 2194

Tabu List

	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
Orders	2-4-5-3-1	2-5-4-3-1	2-3-4-5-1	2-3-1-5-4	2-3-1-4-5
Makespan	2125	2125	2125	2011	2011

	Tabu Search	Active Scheduling
Order	2-3-1-4-5	5-4-2-3-1
Makespan	2011	2194
Gant Chart	Gant Chart	Gant Chart

Figure 5 Result From Program

Based on the results of research, the efficiency improvement obtained after rescheduling with the tabu search algorithm method is 27.1% with the following calculations:

Efficiency $=\left|\frac{(2011-2760)}{2760}\right| x\ 100\%$

Efficiency = 27,1 %

The efficiency improvement obtained after rescheduling with the active scheduling algorithm method is 20.5% with the following calculations:

Efficiency $=\left|\frac{(2194-2760)}{2760}\right| x\ 100\%$

Efficiency = 20,5%

So that the tabu search algorithm method produces greater efficiency values than the active scheduling method.

5 CONCLUSION

Initial scheduling conducted by PT. Harmoni Empat Selaras still not optimal, shown by the makespan value which is still higher than the makespan value obtained using the tabu search algorithm method or active scheduling.

From the results of the study it can be said that tabu search is a more optimal scheduling method compared to active scheduling methods and company methods because the tabu search method makes the makespan value of 2011 seconds while the active scheduling method obtained makespan value of 2194 seconds and scheduling from the company amounted to 2760 seconds.

So that the new scheduling with the tabu search method is more efficient 27,1% than the old company scheduling and scheduling with an active scheduling method is more efficient 20,5% compared to the old scheduling used by the company.

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Biography / Biographies

Lina Gozali is a lecturer of Industrial Engineering Department at Universitas Tarumangara since 2006 and be a free-lance lecturer at Universitas Trisakti since 1993. She got Bachelor degree at Trisakti University, Jakarta - Indonesia, then she graduated Master Degree at STIE IBII, Jakarta – Indonesia, and graduated her Ph.D at Universiti Teknologi Malaysia, Kuala Lumpur – Malaysia in year 2018. She taught Production System and Supply Chain Management Subjects and her Ph.D research about Indonesian Business Incubator. She actively writing for almost 40 publication since 2008 in Industrial Engineering research sector such as: Production Scheduling, Plant Lay Out, Maintenance, Line Balancing, Supply Chain Management, Production and Inventory Control. She has been worked at PT. Astra Otoparts , Tbk as International Business Development Department for 4 years, Citibank, N.A as customer service for 1 year , PT. Pandrol as assistant marketing manager for 1 year. PT. Texmaco as merchandiser for 3 years.

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Lilyana Jap is a freelance lecturer of Industrial Engineering Department at Universitas Tarumanagara since 2017, graduated from University of Indonesia, majoring on Environmental Science (industrial scope). She interested with in-depth reasearch of modelling system with systems thinking methodes and system dynamics approachments. Her previous reasearch was using Powersim Studio 10, with utmos analytical about modeling in system dynamics.