Optimization of Flow Shop Scheduling Problem using Tabu Search Algorithm: A Case Study

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Abstract. This study discusses about scheduling of dining chair processing in a company. Products have been completed according to customer wishes. The problem is classified as flow shop scheduling problem. This paper considers a special case of a six machines of general flow shop scheduling problem which processing time of each job has the longest idle time and waiting time which causes makespan of dinning chair to be high. The goal of this problem is to minimize makespan of product processing. tabu search (TS) algorithm is used to solve this problem. Then performance of tabu search algorithm is compared with Campbell Dudek Smith (CDS) algorithm from literatures. Result shows that tabu search algorithm can improve the makespan in 1968 seconds. This result more effective compare to CDS algorithm that takes longer times 2064 seconds. Tabu search algorithm saving 4.6% makespan with the fastest computing time.

1. Introduction
Flowshop scheduling problem with the minimization makespan criterion has always been a problem that most attracted the attention of researchers. This is a due to the issues that concerns how to produce products with right on time so that it is able to fulfill customer satisfaction [1]. Companies that do not consider schedule production will be reduce customer trust then switch to another competitor firms. Many activities are carried out using the same machine, the completion of work that does not use the right pattern causes problems when the resources work on other tasks, the problem usually triggers a lot of raw materials waiting for the work process which results in too large makespan [2,3].

Many researchers have conducted a study of this scheduling, with the aim of managing flow time, makespan, machine waiting time using the heuristic method using the Campell Dudek Smith (CDS) method which uses the concept of trial and error, solving problems like this usually tends to be fast but the quality of the solution produced low and less optimal [4]. To overcome this limitation, many researchers eventually turned to methods such as the Metaheuristic Algorithms Tabu Search (TS), where this method was inspired by natural events. This method of use is easier because it is applied to computer programming languages so as to provide a better solution than the heuristic method [5-8].

The case in this paper discusses PT XYZ which is a manufacturing company engaged in the manufacture of furniture, the company produces various kinds of component products such as chair dining products and doing a lot of work using the same machine. production at this company has a waste of time which causes the machine schedule to be less efficient, so the total effect of the completion time...
of all work is late from 1 to 5 working days[9]. This flowshop scheduling problem will be solved by searching for algorithms.

2. Research Methodology
In this research conducted, there are several steps that will be shown in figure 1 below:

![Flowchart on research methodology tabu search TS algorithm](image)

*Figure 1. Flowchart on research methodology tabu search TS algorithm*
Based on flowchart, this can explained clearly as details below:

i. Step 1 is the secondary data collection which obtained from previous research using CDS.

ii. Step 2 is the design of TS algorithm. TS algorithm is designed using MATLAB 2013a programming language by determination the initial solution set several parameters in solution search and continued with calculate aspiration criteria.

iii. Step 3 is the numerical example. A numerical example is done manually on the TS algorithm using initial solution from CDS.

iv. Step 4 is the verification of the TS Algorithm. TS algorithm is verified if the solution obtained does not change and the combination of parameters changes. Verification is done to check the results obtained from the TS algorithm meet the parameters and according to the manual calculation.

v. Step 5 is the experiment and computing results: The experimental results are carried out by running the programs for 20 times to get the best solution and calculating the standard deviation to see the performance of the TS algorithm and see the computation time.

vi. Step 6 is the comparison of results of TS and CDS algorithms: Results done to find out how big the levels of reliability of the method inside produce solutions.

3. Numerical Examples and Computational Analysis

3.1 Design of TS algorithm
TS algorithm is an optimization method based on local search where the solution of the problem is using the history solution which is used as a search neighborhood Search to get a solution better in the next search. Besides, TS algorithm also applies restricted area system so that the solution produced not repeated a second time and the solution produced does not produce a solution that is worse than the value for initial solution. The parameters of TS algorithm are shown in table 1.

| Parameter           | Value          |
|---------------------|----------------|
| Tabu List           | 10             |
| Iteration           | 100            |
| Makespan Early      | 2064 Seconds   |
| Early job sequence solutions | g-d-c-l-i-j-a-b-k-h-e-f |

3.2 Numerical Examples
Numerical examples that are performed by using data from previous studies. As for TS design steps are as follows:

i. Input cycle time data used by the job when passing through each machine.

ii. Generate the initial solution in the form of a sequence the initial job obtained uses CDS. The job order is g-d-c-l-i-j-a-b-k-h-e-f.

iii. Determine the cost of early makespan solution is 2064 seconds.

iv. Determine maximum iteration is for 100 times.

v. Tabu list is 10.

Hence, calculating aspiration criteria as shown in table 2.
Table 2. Calculation of the TS Algorithm Manual

| Machine/Work Center | Job sequencing (seconds) |
|---------------------|--------------------------|
|                     | G  | d  | c  | L  | i  | j  | A  | b  | k  | h  | e  | f  |
| Cutting machine     | Start | 0  | 119| 243| 375| 503| 678| 853| 1120| 1271| 1400| 1535| 1662|
|                     | Finish | 119| 243| 375| 503| 678| 853| 1120| 1271| 1400| 1535| 1662| 1797|
| Planer machine      | Start | 119| 243| 375| 503| 678| 869| 1120| 1319| 1456| 1586| 1705| 1816|
|                     | Finish | 227| 354| 491| 629| 869| 1086| 1319| 1456| 1586| 1705| 1816| 1922|
| Planers Machines (Press) | Start | 227| 354| 491| 629| 869| 1086| 1319| 1456| 1586| 1705| 1816| 1922|
|                     | Finish | 227| 354| 491| 629| 869| 1086| 1319| 1456| 1586| 1705| 1816| 1922|
| Spindle Machine     | Start | -  | -  | -  | -  | -  | -  | 1319| 1477| -  | -  | -  | -  |
|                     | Finish | -  | -  | -  | -  | -  | -  | 1319| 1477| -  | -  | -  | -  |
| Grinding Machine    | Start | 227| 354| 491| 629| 1086| 1303| 1632| 1710| 1774| 1859| 1932| 1999|
|                     | Finish | 292| 421| 559| 715| 1180| 1397| 1710| 1774| 1859| 1932| 1999| 2064|
| Drilling Machine    | Start | -  | -  | -  | -  | -  | -  | 1710| 1852| -  | -  | -  | -  |
|                     | Finish | -  | -  | -  | -  | -  | -  | 1710| 1852| -  | -  | -  | -  |

vii. Take an alternative step, move the alternative to do by moving one or two work sequences alternately as many as the specified iteration. But what must be remembered in the TS algorithm is that there is no possibility of repeating the sequence of work that occurs.

viii. Determining the candidate list the solution used, the candidate solution is the result of an alternative step that has a sequence of jobs with the lowest makespan. How it be processed is given in table 3 below.

Table 3. List of Candidate Solutions

| Iteration | Job sequencing | Makespan |
|-----------|----------------|----------|
| 1         | g-d-c-l-i-j-a-b-k-h-e-f | 2064     |
| 2         | d-g-c-l-i-j-a-b-k-h-e-f | 2064     |
| 3         | c-d-g-l-i-j-a-b-k-h-e-f | 2064     |
| 4         | l-c-d-g-i-j-a-b-k-h-e-f | 2064     |
| 5         | i-l-c-d-g-j-a-b-k-h-e-f | 2064     |
| 6         | j-i-l-c-d-g-a-b-k-h-e-f | 2064     |
| 7         | a-j-i-l-c-d-g-b-k-h-e-f | 1977     |
| 8         | g-c-d-l-i-j-a-b-k-h-e-f | 2064     |
| 9         | g-l-c-d-i-j-a-b-k-h-e-f | 2064     |
| 10        | g-i-l-c-d-j-a-b-k-h-e-f | 2064     |
ix. Choose the order of jobs that have the lowest makespan that is the best solution.

### 3.3 Verification of TS algorithm results

The results of TS algorithm solutions obtained from MATLAB will check whether the solution does not violate. The Tabu list and the iteration determined and calculated according to the method manually. Based on table 4, the results obtained from design do not violate the boundaries specified parameters.

| Parameter   | Value     | Unfulfilled Constrain |
|-------------|-----------|-----------------------|
| Tabu list   | 10        | X                     |
| Iteration   | 100       | X                     |
| Early Makespan | 2064 seconds | X                   |

**Table 4. Verification of TS Algorithm**

### 3.3 Results of experiment and computing

Table 5 below is the experimental results from TS stochastic and 20 attempts were made to find out level of TS algorithm data dissemination.

| Experiments | Makespan (seconds) |
|-------------|--------------------|
| 1           | 1970               |
| 2           | 1970               |
| 3           | 1968               |
| 4           | 1968               |
| 5           | 1968               |
| 6           | 1975               |
| 7           | 1970               |
| 8           | 1968               |
| 9           | 1970               |
| 10          | 1968               |
| 11          | 1968               |
| 12          | 1968               |
| 13          | 1970               |
| 14          | 1968               |
| 15          | 1968               |
| 16          | 1968               |
| 17          | 1968               |
| 18          | 1968               |
| 19          | 1968               |
| 20          | 1968               |

| Mean        | 1968.85            |
|-------------|--------------------|
| Standard Deviation | 1.69               |
The standard deviated values are obtained to find out the level of data dissemination as shown in figure 2. The smaller the standard deviation obtained, the results of the experiment are the best.

![Standard Deviation Graph](image)

**Figure 2.** Standard deviation graph

The graph that shows the value of these 20 experiments spread evenly and there was no significant change from the solution what is obtained means that the algorithm has have good performance in producing solution. In each experiments, also presented the best solution chart used to find out in what iterations solutions that have the best value found based on the graph, the job sequence is selected produced to be the best solution as shown in figure 3.

![Best Solution Graph](image)

**Figure 3.** Best solution graph.

The graph shows that the data are in the 16 to 100 constant range and no more changes. That is, at the iteration value of the solution obtained has been convergent. The appearance of the job sequence and makespan of TS algorithm will be presented in figure 4.
The best makespan =

1968

The best sequences =

12 9 1 7 11 5 10 2 3 8 4 6

Figure 4. The best makespan and job sequences.

Next, is the scheduling repair Gantt chart using the TS algorithm So, this can be show in figure 5 as visualize.

Figure 5. Gantt chart scheduling repair using TS algorithm.

Figure 5, on the improved Gantt chart done using TS looks to occur the initial reduction in makespan value 2064 seconds to 1968 seconds.
3.4 Comparison of CDS Result and TS algorithm

| Method | Job Sequence          | Makespan  |
|--------|-----------------------|-----------|
| CDS    | g-d-c-l-i-j-a-b-k-h-e-f | 2064 Seconds |
| TS     | l-i-a-g-k-e-j-b-c-h-d-f | 1968 Seconds |

From table 6, it can be concluded that scheduling completion using TS algorithms is much better than the CDS method. TS algorithm can be shortening the completion time by 4.6%.

4. Conclusion

This paper aims to reduce the makespan of dining chair and compare between the TS method with CDS method. The result of this paper is scheduling using the TS method produces makespan about 1968 seconds, where the makespan value is 96 seconds or 4.6% smaller than compared to results scheduling using the CDS method. Also this shows that the scheduling dining chair use tabu search (TS) algorithm is better than use CDS method.

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