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Comparison of Harmony Search Algorithm and Scheduling Methods: A Case Study of Installation Lift Company in Thailand

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Abstract — *Priority rules guide the order in which jobs should be processed. The earliest due date method (EDDM), first come, first served method (FCFSM), longest processing time method (LPTM), and shortage processing time method (SPTM) are the most common priority rules for sequencing jobs. Different priority rules give different orders of processing jobs. This research proposed an innovative metaheuristic method called the Harmony search algorithm (HSA) and compared it to traditional priority rules. A set of five criteria were considered to evaluate the best priority method. An installation lift company employed the computational simulation. A set of simulation experiments showed that HSA outperformed the traditional priority rules regarding average completion time and utilization.*

Keywords — *Priority rules, Harmony search algorithm, Average Completion Time.*

I. INTRODUCTION

Current economic growth opens to trade and government policies to reduce import and export taxes to encourage industrial sector entrepreneurs to expand production bases in Thailand. This could cause some entrepreneurs to import raw materials to be processed in Thailand before export to benefit from tax policies such as the Board of Investment (BOI) and the Export Processing Zone (EPZ). Fluctuations in the global economy have caused customer demand to change constantly, forcing businesses in industrial, logistics, and services sectors to improve efficiency and minimize operating costs to increase competition and meet customer needs.

Late product delivery and damage package can pose risks and threats to the company's credibility. These logistics problems could be due to unsystematic production planning, insufficient raw materials procurement, unfunctional instruments or machines, and inefficient personnel. Such situations pressure management to address scheduling problems that generally lead to inefficient performance and establish effective production planning [1].

Many industrial companies are working to develop a production sequencing strategy to achieve higher productivity and minimize cost. For example, a company specializing in lift installation and equipment transportation faces a major problem in failure to deliver the product on time due to inefficient installation planning and excessive overtime labor costs. Therefore, the researcher was interested in studying appropriate job prioritization and applying the results to the case mentioned above to enhance work efficiency and create a positive image for the organization in the future. To identify the ways to better ordering the production program, this research proposed to prioritize jobs to increase installation efficiency by using priority rules, namely EDDM, FCFSM, LPTM, SPTM, and an HSA method, and measured their efficiency based on makespan, average completion time, utilization, the average number of jobs in the System and average job lateness.

II. PRIORITY RULE METHOD

The priority rule for dispatching jobs meant organizing work with the shortest total lead time using the technique of prioritization. These heuristic procedures used rules to find satisfactory outcomes for problems, and methods that made outcomes satisfactory cannot be guaranteed as the best outcome [2]. This method was able to determine outcomes for major problems without requiring much calculation [3]. These heuristic procedures consisted of the following:

1. Earliest Due Date (EDD) – This rule selects work steps with the earliest due date.

2. Least Work Remaining (LWKR) – This rule is selecting work with the least time of work remaining.

3. Most Work Remaining (MWKR) – This rule is selecting work with the most time of work remaining.

4. Most Operation Remaining (MOPNR) – This rule is the work section with the most operations were remaining.

5. Smallest Value Obtained by Multiplying Processing Time with Total Processing Time (SMT) – This method collects work steps with the lowest result from multiplying the work time with the sum of total work time.

6. Shortest Processing Time (SPT) – This method is selecting work steps with the shortest work time.

7. Shortest Total Processing Time (STPT – This technique selects work steps with the shortest total work time.

8. First Come First Served (FCFS) – Select work that came the earliest.

9. Random selection by sampling procedures – This method is depended on the number of steps. Higher numbers of randomly selected samples will have outcomes closer to positive outcomes than lower numbers of samples. [4]-[7]

The criteria of priority rule can be summarized as follow:

1.Average Completion Time.

$$Average\ Completion\ Time\ =\ \frac{(Total\ Flow\ Time)}{(No.\ Of\ \ Jobs)} \quad (1)$$

When Total Flow Time = Processing Time + Idle Time
No. of Jobs = Total job number as shown in equation 1.

2. Utilization

Utilization is a measurement of the ability to utilize production resources. The significance of time lost from idle time can be determined from the following equation 2:

$$\%\ Utilization\ =\ \frac{(Total\ Processing\ Time)}{(Total\ Flow\ Time)} \quad (2)$$

When,

Total Processing Time = Total work time spent in each work

Total Flow Time = Total working time spent plus idle time

3. Average No. of Jobs in the System

The index is the average number of jobs in the System. This indicator measures employee workloads. The high average number of jobs in the System relates to employees with heavy workloads. The index can be determined from the following equation 3:

$$Average\ No.\ Of\ \ Jobs\ in\ System\ =\ \frac{(Total\ Flow\ Time)}{(Total\ Processing\ Time)} \quad (3)$$

4. Average Job Lateness

Average job lateness is the number of late jobs compared to due dates. Average job lateness can be determined from the following equation 4.

$$Average\ Job\ Lateness\ =\ \frac{(Total\ Late\ Days)}{(No.\ Of\ \ Jobs)} \quad (4)$$

When,

Total Late Days are the total number of days with late deliveries from every job.

No. of Jobs means total jobs in that workstation.

III. META-HEURISTIC METHODS

When the problem’s model is more complex, and the problem's size is greater, calculations for some problems' most suitable responses spent a significant amount of time in calculations. Because of the problem mentioned above, the exact method can be seen to no longer be suitable. Therefore, calculations by approximate methods or meta-heuristic methods began to help find answers for the problems mentioned above. Meta-heuristic methods were good methods for finding a good solution in a reasonable time. However, meta-heuristic methods were created to find good solutions for specific problems. When a good answer was found for one problem, meta-heuristic methods may not find a good answer for other problems. Examples of previous well-known meta-heuristic methods were simulated annealing algorithm (SAA) [8], artificial bee colony optimization (ABCO) [9], fly fire algorithm (FFA) [10], and other methods. However, when the developed methods were used to find answers, disadvantages were found in certain areas, such as poor development of answers and unsuitable parameters, causing the most reasonable value for some problems. Therefore, in this study, the researcher was interested in studying the meta-heuristic method of harmony search (HSA), which was a popular method used to solve various problems such as engineering test problems, and trust structure, etc. [11]

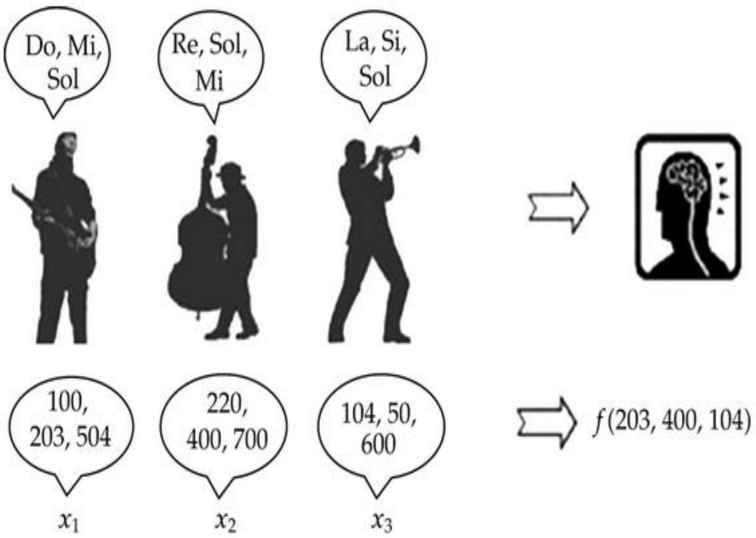

Fig. 1: Concept of Harmony search algorithm [13].

Harmony search algorithm or HSA [12] was first developed by Zong Woo Geem in 2001 by using the principle of a need to copy musicians who want to solve musical instrument harmony problems. Musicians would modify and revise notes to create the best harmony with behaviors expressed in the following 3 models:

1. Musicians would select the best musical notes from memory with accuracy.

2. Musicians would select notes played previously from memory with slight changes in tone.

3. Musicians would play new songs by using random notes.

In general, musicians select one out of three techniques to compose songs. Similarly, HSA consists of three main techniques: Harmony Memory Considering Rate (HMCR), Pitch Adjusting Rate (PAR), and random new solution. The optimization process of the HSA Algorithm consists of four processes as following:

Process 1: Define the objective function, system parameters, and constraint of the problem.

Process 2: Create HM and the initial solution for HM to be recorded.

Process 3: Modified New Harmony by HSA processes.

Process 4: Repeat steps 3 until setting criteria are met [13,14].

The process chart and parameters of HSA are shown in Fig. 2.

IV. CASE STUDY

The case study applied data records from an installation lift company. When installing lifts, the company selling lifts would contact the lift installation company for price quotation and survey shafts when the buyer agrees to buy lifts. Production and import times had a period of 2-3 months, depending on current situations. Lift installation had five important processes consisting of 1) time spent waiting for lifts to arrive from abroad (P1); 2) onsite lift assembly (P2); 3) onsite lift installation; 4) lift testing by the installer (P4), and 5) lift testing by the lift seller's service department (P5). The number of jobs and work time specifications, including delivery schedules, are shown in Table 1 and one year has 52 weeks. The mean installation time of each lift job is shown in TABLE I. TABLE II. demonstrates scheduling sequence of fifteen jobs for each heuristic method.

TABLE I
NO. OF INSTALLATION LIFTS IN 52 WEEKS.

Project	Start date (Week)	Due date (Week)	Working time (Week)
Project 1	21	33	12
Project 2	13	23	10
Project 3	7	19	12
Project 4	36	49	13
Project 5	39	50	11
Project 6	26	43	17
Project 7	11	23	12
Project 8	33	43	10
Project 9	23	40	17
Project 10	6	32	26
Project 11	16	34	18
Project 12	12	29	17
Project 13	17	32	15
Project 14	21	37	16
Project 15	25	42	17

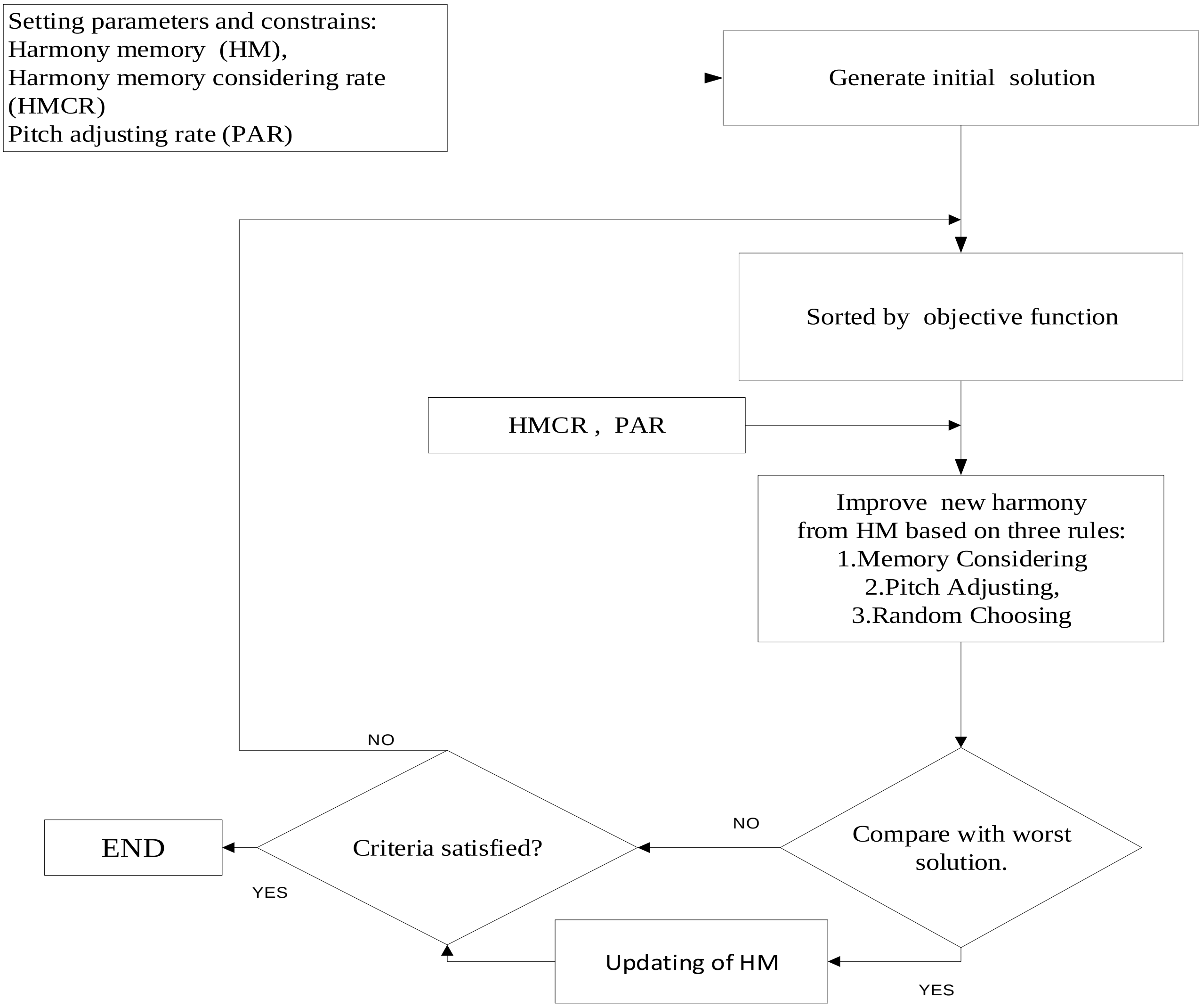

Fig. 2: Process chart of HSA [14].

TABLE II
MEAN INSTALLATION TIME OF EACH JOB.

Project	P1	P2	P3	P4	P5
Project 1	4	2	3	2	1
Project 2	2	1	3	2	1
Project 3	4	2	2	1	2
Project 4	3	1	4	1	1
Project 5	3	2	4	1	2
Project 6	2	2	4	2	1
Project 7	2	2	2	2	1
Project 8	3	1	2	2	1
Project 9	3	2	4	1	2
Project 10	4	1	4	1	1
Project 11	4	1	3	2	2
Project 12	4	2	3	1	1
Project 13	3	2	3	2	1
Project 14	2	1	2	2	2
Project 15	3	1	2	2	2

Fig. 3: Installation lift door and ceiling.

V. RESULTS

In this study, four basic production schedule methods (FCFSM, SPTM, LPTM and EDDM) were compared to a new HSA method by specifying the following parameters referenced from the related studies: HM = 20, HMCR = 0.9, PAR = 0.5, iteration = 5000 and replication = 15. The Visual Basic 2018 program was used with production prioritization results shown in TABLE III and summarized in TABLE VI - V. Concerning each type of indices for minimizing makespan, the FCFS was the worst method while HSA was the best result. Comparison from indices consisting of average completion time, % utilization, the average number of jobs in the System, and average job lateness showed the best index was HSA with an average completion time of 3.53 and a % utilization of 0.60. When calculated in percentages and current prioritization, the average completion time was lower by 7.10 percent while % utilization increased by 7.14%. This was followed by the shortest processing time with an average completion time of 3.6 and a % utilization of 0.59. When calculated in percentages and compared with current prioritization, the average completion time was lower by 3.42 percent while % utilization increased by 5.35%. When compared to various types of job prioritization, prioritization by HSA had the best-simulated results. The Gantt chart of the original method and HSA shows in Fig. 4 and Fig. 5. Comparing to the original methods, HSA reduced the total working time to complete 15 jobs by 2 weeks.

VI. CONCLUSION

From the analysis of data to solve problems only in prioritizing the company's lift installation jobs, the solution using the harmony search method was able to reduce average completion time compared to traditional priority methods. The results demonstrate the effectiveness of meta-heuristic methods applied to solve the problem. To test for greater efficiency, the researchers recommend comparing the efficiency of the harmony search method with innovative methods such as elevator kinematics optimization [15], biogeography-based optimization algorithm [16], and migrating birds' optimization [17] to conduct more studies of the method efficiency. The researchers also suggest applying the harmony search method to test more complex problems such as the traveling salesman problem or aggregate production planning, etc. [18]. Because HSA's parameters impact convergence rate and solution quality, suitable parameter selection should be taken using the experiment method's design.

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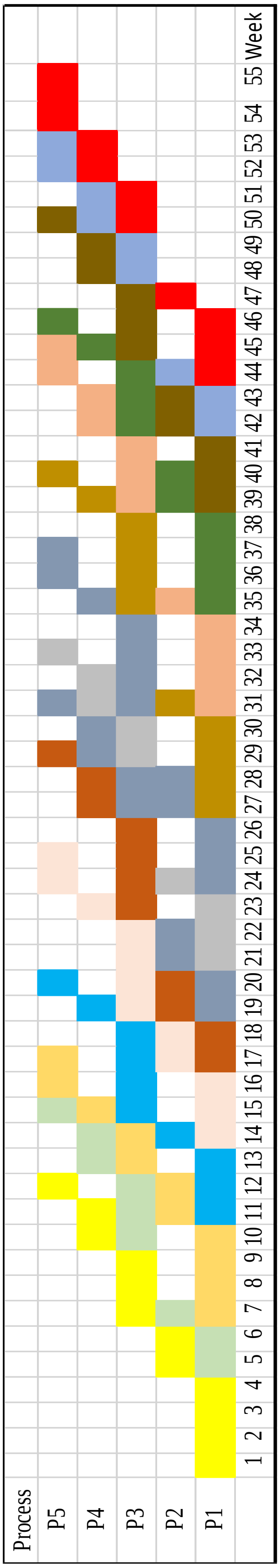

Fig. 4: Gantt Chart of company method (Original)

TABLE III
SEQUENCING AND SCHEDULING OF CASE STUDY (JOB)

FCFS	EDD	LPT	SPT	HSA
10	3	10	2	2
3	7	11	8	6
7	2	12	5	7
12	12	9	3	14
2	10	15	7	4
11	13	6	1	5
13	1	14	4	8
1	11	13	13	9
14	14	4	14	13
9	9	3	12	15
15	15	7	9	1
6	6	1	15	3
8	8	5	6	10
4	4	2	11	11
5	5	8	10	12

TABLE IV
SUMMARY OF SCHEDULING RESULTS.

Rules	Minimize Makespan	Average Completion Time	Utilization	Average Number of Jobs in System	Average Job Lateness
FCFS	57	3.80	0.56	1.43	5.20
EDD	57	3.80	0.56	1.43	1.53
SPT	54	3.60	0.59	1.36	6.67
LPT	55	3.67	0.58	1.38	3.93
HSA	53	3.53	0.60	1.33	5.53

TABLE V
THE RANKING FOR EACH METHOD (5=HIGH,1=LOW)

Rules	Minimize Makespan	Average Completion Time	Utilization	Average Number of Jobs in System	Average Job Lateness
FCFS	2	1	2	1	3
EDD	1	2	1	2	5
SPT	4	4	4	4	1
LPT	3	3	3	3	4
HSA	5	5	5	5	2

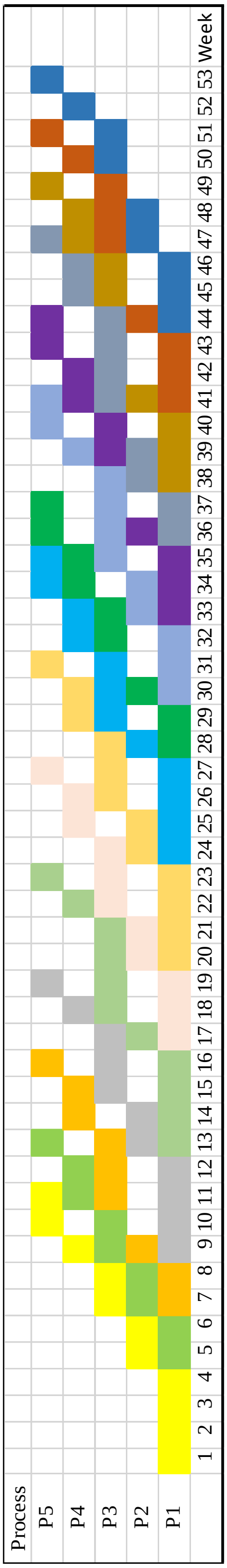

Fig. 5: Gantt Chart of HSA

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