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บทความวิจัย

Production Planning and Machine Maintenance Schedule of Dragon Green Energy Company, Limited

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Abstract: This research has led to the problem of Dragon Green Energy Co., Ltd., a factory that produces tapioca starch with a production capacity is about 25-50 tons per day. The company has encountered problems in total production planning and scheduling maintenance. The research, therefore, developed a mathematical schedule modeling method to solve problems and the development of integrated applications using scheduling rules, Heuristics Genetics Algorithms (GA), and Local Search (L) becoming Integrated Methods (GA+L). The research found that the total production planning in 2022 was close to the actual production measured from (GAP) which was equal to 2.3 tons, with a margin of error of 0.307 percent. The researchers obtained the value of the company's maintenance scheduling with problems of various sizes, which the program can schedule maintenance using the scheduling rules Heuristic method (GA) and combination method. In scheduling results, the lowest makespan value was measured by the good comparison gap (Gap) together with the comparison of the percentage of time when the machine crashed before and after the research. It was found that the mean value between machine failures (MTBF) increased by 25.332% and the average machine downtime was reduced after the research, accounting for 43.928 percent. This research was therefore by the objectives.

Keywords: Tapioca Starch Production; Total Production Planning; Scheduling Maintenance; Gap

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1. Introduction

Currently, industrial business organizations and industries have high competition to survive in business operations. The organization has adapted in various aspects to be able to compete in the commercial market. Every organization, therefore, focuses on managing the organization's resources to operate in the 4M aspect for improving efficiency [1-3].

In the production process to transform raw materials into finished products must use a machine with high efficiency [4-5]. Due to being a source of carbohydrates and having important properties in food and other related products, Tropica starch manufacturing is one of the important industries [6].

Dragon Green Energy Co., Ltd. has purchased more than 20 million baht per year for tapioca raw materials, both in and outside the area of Uttaradit Province, namely Sukhothai and Phrae Province. There is a 6-month production season from December to May. The production capacity is about 25-50 tons per day, using a large number of machines in every step of production by continuously working more than 1,600 horsepower, using working capital in the business of more than 350 million baht per season. It is raw material cost, labor cost, machine maintenance, fuel utility bills, and other production overheads. From the study of information in the production process of the business, it does not have a clear overall production plan for each month and season. However, the information of past productions has used the expertise and the experience of employees in planning production for each season. In addition, each time production can be produced, tapioca roots must be purchased from farmers through nodes of purchasing yards located in various areas both in and outside Uttaradit Province and transported to the company to produce tapioca starch. Meanwhile, the production is seasonal, and machines used in production must have the least damage. Hence, scheduling maintenance is important to the company both during production and a maintenance period of 6 months, the machine must be serviced to be ready for production during the following season. Accordingly, the problems of Dragon Green Energy Co., Ltd., can be seen in that the production season is only 6 months, but the overview planning both is in the production and machine maintenance, including all waste costs. This research will bring the problem to aggregate planning and maintenance schedules in 2022. It is to find the makespan of the jobs with the least downtime and to compare with pre-research production in 2021, as follows:

1.1 Aggregate Planning

Aggregate production planning is planning that deals with quantities in industrial production processes [7]. This total production plan will consist of a production output plan based on production

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capacity, The production plans consist of raw materials used in production, labor requirement, production cost utilization, [8, 9] determining machinery used, and technology.

1.2 Preventive Maintenance: PM

There is routine maintenance or duration of use by planning to keep the machines used in production under good conditions and with maximum efficiency. It should be planned regularly in advance, including stopping working immediately (Downtime), and reducing the time of the damaged production machinery. This maintenance also slows down the deterioration, wear, and tear of machinery and production pieces of equipment [10, 11]. The goal of preventative maintenance is to reduce emergency repair time and unscheduled repair work and add more tasks and plans. [12, 13]

1.3 Heuristics Algorithms

Algorithmic heuristic methods are about finding answers or considering appropriate values to solve complex problems or NP-Hard level well [14, 15]. The method has been widely used in research and has been developed and improved to be more efficient in finding suitable values continuously, which will reduce the time required to find the correct answer. The methods are the Ant Colony algorithm, Bee Analytical Algorithm, Steel melting simulation algorithm, Local search algorithm, Taboo search algorithm, genetic algorithms, etc. Finding the answer or solution obtained using heuristic algorithms may not be the best solution. But it is a time guideline to find the best answer or solution under good time constraints. [15]

1.4 Scheduling Problems

Scheduling problems are an important and common problem in the manufacturing industry [12, 16]. This is because industrial plants require the most efficient production plan to operate in compliance with regulations, and many limitations in production such as time, machinery, human resources, etc. Therefore, scheduling by selecting a sort order by the task to come into production or maintenance before or after properly [17]. Jobs or products are completed according to customer delivery dates which are indeed something that each establishment expects a lot [13, 18, 19]. Because the process of producing tapioca starch in each season was for 6 months, the most important problem of the business which incurring production costs without output, including labor costs, urgent repair costs energy costs, etc. Machine maintenance is an issue in the research as well.

2. Experimental Procedure

2.1 A Survey of the process problems of the study company

The data about production in the company in 2021 have been studied. The process of tapioca starch is continuous. However, it is a seasonal production for 6 months each year. For the remaining 6 months, machines were shut down for

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maintenance. The data collected from this company has been expressed as follows.

1. The production uses tapioca which is available in Uttaradit province, and outside the area of Uttaradit Province, namely Phrae Province, and Sukhothai Province. The use of tapioca roots is more than 110,000 tons/year.

2. The total production planning for the 2021 season relied on the expertise and experience of staff members. Despite the absence of production cost calculations, comprehensive planning was executed, incorporating data collected from December 2020 to May 2021, with total production costs amounting to 45 million baht.

3. The use of machinery for the production of tapioca starch uses automatic production technology and machines controlled by workers. The pre-research study did not provide a maintenance plan. It uses a method to improve after a crash occurs. While producing and repairing using the expertise of the staff in scheduling, there are 2 types of costs incurred, namely the cost from machine failure during production by replacing spare parts that caused problems during production, and lastly seasonal maintenance work, maintenance costs incurred in 2021 equal to 2,790,000 baht/year.

4. Working capital was spent on the cost of tapioca raw materials, direct labor, electricity, maintenance, water in the production process, fuel oil, chemicals, and fuel 50,750,000 baht in 2021.

2.2 Mathematical Schedule Modeling for the Development of Integrated Production Planning

The aggregate planning in this research had indices, parameters, and Decision Variables as follows:

Indices

i = Index of tapioca-starch-production upstream

j = Index of tapioca-starch-production downstream

Parameters

m = Number of tapioca-starch-production upstream

n = Number of tapioca-starch-production downstream

Rm_{ij}= Raw material costs from i to j

M_{ij} = Maintenance cost of i to j

Cc_{ij} = Chemical cost of i to j

Wc_{ij} = Cost of water production of i to j

Lc_{ij} = Labor cost of i to j

Ec_{ij} = Electricity cost of i to j

Fo_{ij} = Fuel oil cost of i to j

Df_{ij} = Direct fuel cost of i to j

S_i = Source Capacity of the upstream node

D_i = Demand of a downstream node

C_{ij} = Costs of tapioca-starch production from i to j

Decision Variables

X_{ij} = Number of finished goods from i to j

A linear equation of an objective function is shown in Equations 1-5 below:

$$Min \quad \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij} \qquad (1)$$

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Subject to

$$\sum_{j=1}^{n} X_{ij} \le S_i \quad (i = 1,2,3...m) \tag{2}$$

$$\sum_{i=1}^{m} X_{ij} \ge D_i \quad (j = 1,2,3...n) \tag{3}$$

$$C_j = \sum_{i=1}^{m} X_{ij} \left[Rm_{ij} + M_{ij} + Cc_{ij} + Wc_{ij} + Lc_{ij} + Ec_{ij} + Fo_{ij} + Df_{ij} \right] \quad (j = 1,2,3...n) \tag{4}$$

$$X_{ij} \ge 0 \quad (i = 1,2,3...m),\ (j = 1,2,3...n) \tag{5}$$

Equation 1 is an objective function; tapioca-starch production cost of Dragon Green Energy Co., Ltd., which is minimized.

Equation 2 is a conditional equation of total tapioca X_{ij} that is less than or equal to the production capacity of the factory at S_i

Equation 3 is a conditional equation of total tapioca X_{ij} that is more than or equal to the demand of customers or production administrators of the tapioca-starch factory D_i

Equation 4 is an equation of the sum of C_j that is a cost straight to the production costs.

Equation 5 is a conditional equation to answer X_{ij} which is higher than or equal to 0.

The equations to assess Dragon Green Energy Co., Ltd.'s total production planning value gauge efficiency by comparing the production process in 2021 with the pre-research data from 2022's total production planning.

2.3 Development of maintenance planning.

It was found from searching for processes before the research that maintenance information had a high cost. Preventive maintenance can be used to monitor the condition of the condition of machinery and equipment within the factory. It was used to inspect, maintain, or change the equipment at a specified time [14-15] by specifying repair work for each season in conjunction with the scheduling maintenance. It was by dividing maintenance units according to the expertise of employees into workstations. Mean Time Between Failure (MTBF) is measured as shown in Equations 6 and 7 as follows.

The average number of machine damage

$$\eta_{avg} = \frac{\sum_{i=1}^{n} n_i}{N} \tag{6}$$

The mean time between machine failures where n = number of machine breakdowns during production in month i and N = total number of machine breakdowns

$$MTBF = \frac{T}{\eta_{avg}} \tag{7}$$

where T = the time period when machine damage was found.

Mean Time Between Failures (MTBF) of Dragon Green Energy Co., Ltd. with the number of failures encountered during T/total mean time of failure of the Company's machinery, and the relationship between MTTF and MTTR, where MTTF is Mean Time to Failure and MTTR is Mean Time to Repair [15].

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Efficiency measurement from the percentage of time that the machine crashes, Average Machine Down Time (AMD) is shown in Equation 8 as follows.

$$AMD = \frac{\%Machime\ Downtime}{Operation\ Time} x100 \qquad (8)$$

Indices and parameters, decision variables in maintenance scheduling of Dragon Green Energy Co., Ltd., shown in inequality 9 to 18 as follows:

Indices

i = Required maintenance work time from the maintenance plan

j = Machines required for being maintained from the maintenance plan

k and l = represent machines where work is assigned

Parameters

m = Number of maintenance machines

n = Number of tasks

M_i = Working time i

C_i = Completion time

C_{max} = Time to complete all batches

x_{ij} = Assigning workstation j to work i

Y_{ij} = Assigning workstation j to work i will have a value of 1 and 0.

Z_{ijkl} = Binary assignment, such that job i is done by machine k and job j is done by machine l, is equal to 1.

Decision Variables

Minimize C_{max}

Subject to

$$C_{max} \geq C_i \quad where \quad 1 \leq i \leq n \qquad (9)$$

$$C_i - M_i \geq 0 \ where \quad 1 \leq i \leq n \qquad (10)$$

$$\sum_{k=1}^{m} X_{ik} \leq 1 \quad where \ 1 \leq i \leq n \qquad (11)$$

$$Z_{ijkl} \leq X_{ik} \quad where \quad 1 \leq i, j \leq n, 1 \leq k, l \leq m \ (12)$$

$$Z_{ijkl} \leq X_{jl} \quad where \quad 1 \leq i, j \leq n, 1 \leq k, l \leq m \ (13)$$

$$X_{ik} + X_{jl} - 1 \leq Z_{ijkl} \quad where \ 1 \leq i, j \leq n, 1 \leq k, l \leq m \qquad (14)$$

$$C_i - (C_j - M_j) + Y_{ij} MT \geq 0 \quad where \ 1 \leq i, j \leq n \qquad (15)$$

$$C_i - (C_j - M_j) - (1 - Y_{ij}) MT \leq 0 \quad where \ 1 \leq i, j \leq n \qquad (16)$$

$$Y_{ij} + Y_{ji} \geq Z_{ijkl} \quad where \ 1 \leq i, j \leq n, i \neq j, 1 \leq k \leq m \qquad (17)$$

$$Y_{ij} + Y_{ji} \geq Z_{ijkl} \quad where \ 1 \leq i \langle j \leq n, \ 1 \leq l \langle k \leq m \qquad (18)$$

Inequality 9 is the completion time of all assigned maintenance batches C_{max} which is greater than or equal to the time spent on each task C_i.

Inequalities 10 is the start time for C_i - M_i maintenance work which is greater than or equal to 0, indicating that any work cannot be started before time 0.

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Inequality 11 states that only one job will be performed by one maintenance unit.

Inequalities 12 and 13 are the maintenance assignment i assigned to the maintenance unit k and the job j assigned to the maintenance unit l will be either 0 or 1, less than or equal to x_{ij}.

Inequality 14 is used to help determine and value = 0.

Inequality 15, 16 defines the meaning of the values Y_{ij} or explains the relationship between Y_{ij} with C_i, C_j, and M_i. Here both inequalities are considered simultaneously in maintenance work.

Inequalities 17 and 18 are inequalities, so Z_{ijkl} can be either 0 or 1. This means that in this case, task i finishes before task j starts, so both tasks can be performed by maintenance unit k.

2.4 Genetic algorithm heuristic methods

This research employs the Genetic Algorithm method to address maintenance [20-22] scheduling issues and can extend its application to formulate production plans. The outlined method involves the following sequential steps.

2.4.1 Encoding and creating a random initial population from the problem is encoding it in the form of a bit-length string based on the size of the job, Binary Coding. [23]

2.4.2 Old Population is a string that will be selected as a model for creating a new population. The first set of Old Populations is the initial random population of the problem, scheduling maintenance with 2 or more maintenance units.

2.4.3 The operation of the Genetic Algorithm consists of three operations: reproduction, crossover, and mutation as shown in Fig. 1.

In this research, Cycle crossover (CX) and Inversion mutation were chosen because they are used to find the ideal solution in terms of conditional randomness to obtain the appropriate Offspring 1-3 [23, 24].

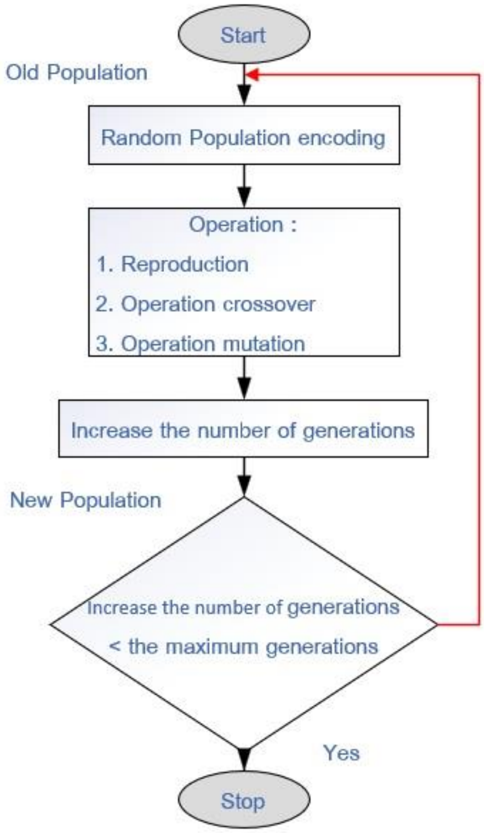

Fig. 1 The steps of the Genetic Algorithm

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1) Reproduction is a process in which each string imitates the value of the target function f(x), which measures its fitness. When the string with higher fitness can be possible to be the high next generation. The method used is to create a roulette wheel.

2) Crossover is a process after the entire population has been processed, and reproduction will be matching members in the mating pool or the whole population at random, and then cross-swap values at random positions or trade parts Cycle crossover was used in this research; CX is shown in Fig. 2.

3) Mutation is a necessary step even with reproduction and crossover. Because the mutation prevents irrecoverable damage; and recovery loss. The research using inversion mutation is shown in Fig. 3.

2.4.4 New Population or Generation, all strings derived from the Genetic Algorithm, which will become the older population for further action, and will repeat until the generation is equal to the design value. The previous population with poor answer values will be eliminated and keep the good chromosomes from the operation process, both crossover and mutation. The next generation as an expanded model is called Generational Enlargement and it will stop when the specified generation is complete [20-24].

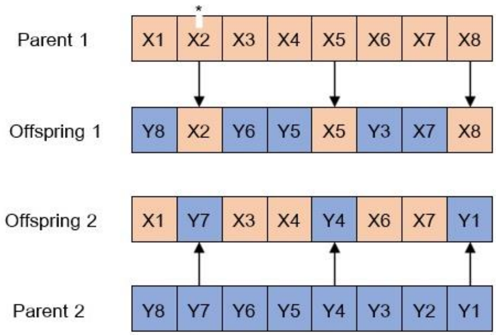

Fig. 2 Cycle crossover (CX)

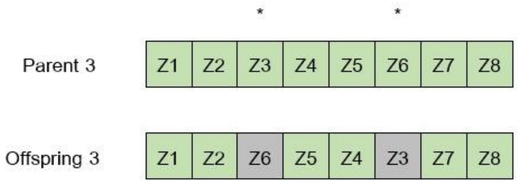

Fig. 3 Inversion mutation

2.5 Local Search Integration Method

The local search integration method is an effective heuristic approach [20, 21, 26, 27] that can be put into the genetic algorithms process in the reproduction section with low probability string commutation. It is from the probable chromosome as measured by the makespan. J. Zheng, et al. [20] and O. Tayfun, & T. Aysegul [21] with their research of the Traveling Salesman Problem: TSP and Vehicle Routing Problems: VRP that used local search methods combined (hybrid) with GA after the Operation process by selecting 1 set of good chromosomes to randomly place in the Allele. It is in the chromosome and then swapped, and it results in a new filtered answer value and a good new local optimum from this process.

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2.6 Development of integrated production planning program and maintenance

The research led to the overall production plan structure, and the maintenance plan; a preventive maintenance (PM), which enables to be divided into 2 main activities in the same program development. This is divided into data acquisition windows by numerical input method and developed a genetic algorithm for scheduling maintenance, which has problems with maintenance work such as problems 6x2, 7x3, 12x3, 15x3, and 20x4, etc. (which 6 is the number of maintenances works of 6 works and 2 are the agencies used in the maintenance of 2 agencies). The researcher has developed a program using the C++ language for development because the finished program cannot process (Run) large problems. The program development has a machine data storage structure, indication of maintenance time, specifying the replacement, interval scheduling maintenance, and analysis of maintenance performance. The numerical figures of both activities are shown in Fig. 4.

It works together with the factorial experimental design 4^2 to test the appropriate parameters of the factors in the work of the genetic algorithm method. It will divide the factor level (Factorial effect) into 2 levels: low (0) and high (1) and have 4 treatment combinations: Population size (50/100), Crossover rate (0.5/1.0), Mutation rate (0.15/0.3), and Max generations (50/100) [23, 24]. There are 16 experiments and 10 rounds of tests with a 20x4 large problem. It was found that the appropriate parameters of the Population size factor were 100, the Crossover rate was 1.0, the Mutation rate was 0.3, and Max generations of 100. The local search method combined with GA will also work based on Max generations of 100.

Fig. 4 shows the program design plan for the production and maintenance of Dragon Green Energy Co., Ltd. when the program development was complete. The software testing was divided into 2 steps: (1) Testing the correctness of the program as follows: A unit test is a functional test of the system in each sub-section to ensure that each part works correctly. An integration test is to bring each unit's data together and test the connection between the units whether it can work properly, and an end-to-end test is to test the system as a whole. By bringing each part of the system to assemble completely and testing the system with users

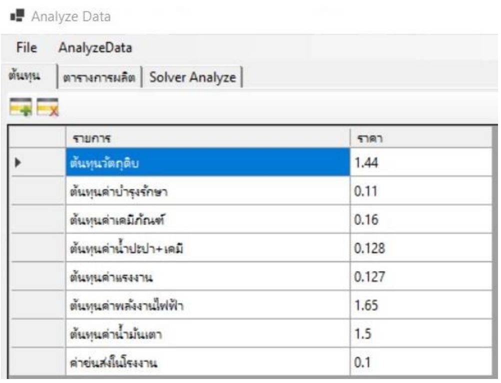

Fig. 4 Program design, production planning, and maintenance of Dragon Green Energy Co., Ltd.

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(2) A Stress test is a test of the efficiency of the system to test whether the system can receive a total amount of production planning information, and enough scheduling data for use. A usability test is a test of the system's usability to improve research and pass on all parts of the developed program.

2.7 Data of total production planning of Dragon Green Energy Co., Ltd.

The data collected from the company consists of purchasing of cassava raw materials, quantity produced per month, labor costs, and cost of maintenance each month. The data collected was started from December 2020 to May 2021 to use the data for post-research comparison, then planned the production by collecting data from December 2021 to May 2022 for a period of 6 months (seasonal cycle 2022). The researcher displayed an example of recording data that occurred in February 2022 for production planning in Table 1.

Table 1 shows that the cost of cassava production was divided into 2 periods per day, namely the production period in time, and part-time production. The cost of production at the time was 4.757 baht per kilogram.

For part-time production, the cost of production was added to the cost of overtime labor. There was an increase in production costs of 0.5 baht per kilogram. The cost of production was 5.257 baht per kilogram. Then the production cost data in February 2022 was used to plan the production by research method. The production plan is shown in Table 2.

Table 2 shows the production planning value including the lowest cost of February 2022 could be seen each week. There were different costs incurred in production on time, and outside of the same time. Costs incurred were not equal, for example, production in week 1 had a cost of 4.790, and production over time had a cost of 5.290. Then the research would be analyzed from Equations 1-5 to determine the decision variable. X_{ij} had a total cost of 492,009 baht and showed the result of finding the answer in Table 3.

Table 1 An example of collecting data on production costs per kilogram in February 2022

Items	Cost Unit (in time) (฿)	Cost Unit (part-time) (฿)
Raw material cost	2.25	2.25
Maintenance cost	0.315	0.315
Chemical cost	0.045	0.045
Water-production cost	0.033	0.033
Labor costs	0.385	0.599
Electricity cost	0.683	0.712
Fuel oil cost	0.953	1.21
Factory freight	0.126	0.126
Total cost/Kilogram	4.790	5.290

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Table 2 The lowest costs of February 2022

	Week1 Cost Unit	Week2 Cost Unit	Week3 Cost Unit	Week4 Cost Unit	Capacity (Tons)
Produced in time 1	4.790	4.778	4.785	4.784	24
Produce part-time 1	5.290	5.278	5.285	5.284	25
Produced in time 2	4.757	4.758	4.763	4.784	25
Produce part-time 2	5.257	5.259	5.263	5.284	25
Demand (Tons)	25	21	28	24	

NOTE: Produced in Time 1 is a production from 8:00 pm-7:00 pm on the 1st and Produce Part-Time 1, which is production from 7:00 pm -05.00 hrs. on the 1st day.

Table 3 An example of production planning including the minimum cost of research method for February 2022

	Week1	Week2	Week3	Week4	Capacity (Tons)
Produced in time 1	0	21	0	3	24
Produce part-time 1	0	0	3	21	24
Produced in time 2	0	0	25	0	25
Produce part-time 2	25	0	0	0	25
Demand (Tons)	25	21	28	24	total cost 492,009 ฿

Table 3 shows the total production value which was planned to be produced in the first to fourth weeks of 25, 21, 28, and 24 tons as needed, respectively. It caused the lowest cost equal to 492,009 baht in February 2022 by multiplying the total production by the cost.

2.8 Schedule maintenance of Dragon Green Energy Co., Ltd.

After the end of the 6-month production season from December 2021 to May 2022, there was a 6-month maintenance period from June 2022 to November 2022, which is part of the maintenance. Production of Dragon Green Energy Co., Ltd. directly, whether they were a replacement of parts, [27] planned maintenance [22], and the replacement of parts according to the service life. There would be labor costs incurred from maintenance both during the production season and during the off-season.

The maintenance plan in this factory had a clear repair plan. The period was timed 5 times and averaged. In the repair, there would be the repair workstation of the staff in the maintenance department. The production department of

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employees who controlled machines and the management who systematically inspected the delivery of work each month as an example, Table 4.

Table 4 shows that there was planned maintenance work utilizing Preventive Maintenance (PM) [10, 11, 19, 22, 27].

Arranging workstations for maintenance and production staff. It was divided into 3 workstations that would result in 7x3 work problems and used to find the makespan value; sequencing maintenance n jobs on m parallel.

The units of the company were with 7 maintenance jobs and 3 maintenance units. The maintenance was parallel which could perform maintenance for all units as the same. The longest-time maintenance scheduling rule method was determined initiatively as shown in Table 5.

Table 4 Week 1 Maintenance Sample for June 2022

Machines	**Cleaning**	**Lubrication**	**Lubricant Changing**	**Belt Inspection**	**Total (minutes)**
1. Shredder	330	10.50	15.85	7.00	363.35
2. Peeler Centrifuge 1	270	9.51	35.54	10.45	325.50
3. Peeler Centrifuge 2	274	9.32	37.44	11.45	332.31
4. Peeler Centrifuge 3	281	10.21	38.53	11.61	341.35
5. Peeler Centrifuge 4	275	10.54	40.22	11.53	337.29
6. Peeler Centrifuge 5	285	10.22	37.55	10.51	343.28
7. Tapioca-root washing machine	342	17.5	40.00	11.21	410.71

Table 5 An example valuation using the longest-first maintenance scheduling rule

Jobs	**Processing Time (minutes)**	**Due Date (days)**
7	410.71	7
1	363.35	6
6	343.28	6
4	341.35	7
5	337.29	7
3	332.31	7
2	325.50	6

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Table 5 shows the application of maintenance time values using the LPT method by scheduling tasks to maintenance units that had maintenance time values. The longest time to do it first was shown as follows.

LPT = (7) 410.71 ≥ (1) 363.35 ≥ (6) 343.28 ≥ (4) 341.35 ≥ (5) 337.29 ≥ (3) 332.31 ≥ (2) 325.50

Then the results of maintenance scheduling using the longest time-first (LPT) maintenance rule were shown in Table 6 as follows.

Table 6 Maintenance scheduling results using the longest time maintenance scheduling rule takes first

Maintenance Unit	Processing Time (Jobs) (minutes)	Total Time (minutes)
1	Machine 7 (410.71) + Machine 3 (332.31)	743.02
2	Machine 1 (363.35) + Machine 5 (337.29)	700.64
3	Machine 6 (343.28) + Machine 4 (341.35) + Machine 2 (325.50)	1,010.13

According to Table 6, it was found that the maintenance of 1, 2, and 3 had a total time of 743.02, 700.64, and 1,010.13 minutes, while the longest makespan was 1,010.13 minutes.

3. Results and Discussion

The research brought the Aggregate Planning Program and the Maintenance Program of Dragon Green Energy Co., Ltd. working in the integrated system to deal with the problem of aggregate planning and scheduling of maintenance as the following:

3.1 Total Production Planning Management

The research addressed the problem of production planning for 2021-2022 which needed to be planned from December 2021 to May 2022. The planning had to fill in capacity data, demand from marketing, and production management costs each month. The research collected data on the production process by obtaining information to plan the total production and compared the results of the actual production operations as shown in Table 7.

The results of total production planning and comparison of the results of actual production operations showed that the amount of total production planning and the actual production volumes were similar.

The volumes were measured from the comparative gap, for example, in January 2022, the total planned production was 645 tons, the actual production was 645 tons, and the comparative gap was 0. The overall comparative gap from December 2021 to May 2022 was 2.3 tons. The implementation

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Table 7 Results of total production planning and comparison of actual production

Date	Production (Million Baht)	Aggregate Planning (Tons)	Actual Production (Tons)	Gap
December 2021	4.57	527	528	1
January 2022	4.55	645	645	0
February 2022	4.56	587	587	0
March 2022	4.43	700	700.3	0.3
April 2022	4.65	445	445.5	0.5
May 2022	4.74	412	412.5	0.5

of the program from December 2021 to May 2022 showed that the mathematical schedule modeling method and the developed program were able to plan the total production. Hence, planning and actual productions were similar. According to the comparison of the report in Table 7, the error was only 0.307 percent.

The comparison of production costs before conducting research showed a production cost in 2021 of 45 million baht, but when planning the total production in 2022, the production cost was 41.5 million baht, with a 4.651 percent decrease in production costs, or an amount equal to 4,651,000 million baht.

3.2 Scheduling of maintenance work of Dragon Green Energy Co., Ltd.

The research was conducted on a maintenance schedule from June 2022 to November 2022 for 6 months in order to solve the planned maintenance problems of Preventive Maintenance (PM) on Dragon Green Energy Company's machinery. Co., Ltd., which found that maintenance management jobs for m maintenance units worked in parallel with more than 2 or more maintenance units. The research compared the lower bound value from any arrangement with the lowest makespan value of the batch. The research used a maintenance scheduling program, which was used to find the common value to find the answer using the Genetic Algorithm (GA) heuristic method, and how it combined Genetic Algorithm with Local Search (GA+L) versus scheduling rules. Research showed below:

3.2.1 Research led to the problem of planned maintenance that had to be maintained to keep the equipment ready for use, and measured from the relationship between MTTF and MTTR, showing the problem of scheduling maintenance of Dragon Green Energy Co., Ltd. as shown in Table 8 as follows:

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Table 8 Result of maintenance schedule of Dragon Green Energy Co., Ltd.

Problem Size	Scheduling Method	Lower Bound	Makespan (Min)	Gap
6 x 2	FIFO	812.100	942.800	130.70
	LPT		818.740	06.64
	GA		815.160	03.06
	GA+L		812.100	00.00
7 x 3	FIFO	995.100	1050.56	490.46
	LPT		1010.13	15.03
	GA		995.10	00.00
	GA+L		995.10	00.00
12x 3	FIFO	1535.810	1567.05	31.24
	LPT		1599.39	63.58
	GA		1542.72	06.91
	GA+L		1535.81	00.00
15x 4	FIFO	1668.78	1894.85	226.07
	LPT		1749.89	81.11
	GA		1668.78	00.00
	GA+L		1668.78	00.00
20x 4	FIFO	2074.81	2251.63	176.82
	LPT		2180.08	105.19
	GA		2074.81	00.00
	GA+L		2074.81	00.00

According to Table 8, the maintenance schedule of Dragon Green Energy Co., Ltd. with problems of various sizes, the program enabled to schedule maintenance and compare the scheduling values of both the scheduling rule method, the heuristic method (GA) with the GA+L. Moreover, they were shown that in the 12x3 problem, the GA+L method found the lowest makespan value with 1535.81 minutes, and the gap of comparison (gap) was 00.00, Problem 15x4, the GA method and GA+L method, found the lowest makespan value equal to 1668.78 minutes, and the comparison gap (Gap) was equal to 00.00 minutes.

3.2.2 Efficiency measurement of Preventive Maintenance (PM) was shown from maintenance data collection. The study measured the efficiency of the Mean Time Between Mechanical Failures (MTBF) by analyzing data from the effects of MTBF from December 2020 to May 2021 after the study from December 2021 to May 2022, in which every period was the production of tapioca starch in 6 months, shown as follows:

1. Comparison of the results of Mean Time Between Machine Failures (MTBF) (Equation 7) found that MTBF before the research in each month were 35.540, 51.210, 64.452, 54.230, and 43. 540 with the average MTBF before the research of 49.794, and MTBF after the research in each month were 82. 550, 81. 410, 87. 450, 82.451, and 84.051 with the average BTBF after the research of 83.582. It was with an increase of MTBF of 25.332% from the comparison.

2. Comparison of mean time to repair from developed program data: The analysis results showed that the mean between crashes before the research was 3.252 and the mean between

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crashes after the research was 1.274, with a decrease in each month after the research, representing 43.703%.

3. Comparison of percentage of machine downtime; Average Machine Downtime (Equation 8): The analysis results are shown in Figure 5.

Fig. 5 shows the average between the machine failures before the research of months 1-5 were 4.61, 4.110, 3.562, 3.640, and 3.280, with an average of 3.840.5. The machine failures after the research of months 1-5 were 1.720, 1.640, 1.461, 1.440, and 1.220, with an average of 1.496. It showed a decrease after the research of 43.934%.

4. Conclusion

This research brought the problems of Dragon Green Energy Co., Ltd., which found problems in total production planning and scheduling maintenance. This research, therefore, created a mathematical scheduling model to solve problems of the company in 2 forms, together with the development of a mixed (hybrid) program using scheduling rules. The heuristic methods of GA and GA+L were used to compare the answers. The research found that total production planning and actual production data collection were close to the planning value. The results of the comparative gap (Gap) were equal to 2.3 tons with 0.307 percent of the comparison of the error, and scheduling maintenance of the company with

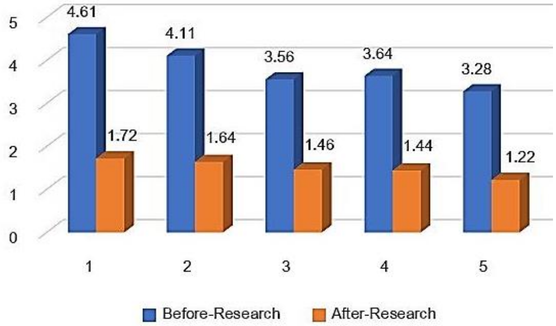

Fig. 5 Comparing the percentage of time Mechanical failure (AMD)

problems of various sizes. The program was able to be scheduled maintainability and compare the scheduling values of both the scheduling rules method and the heuristic methods of (GA) and (GA+L), for example, in a 15x4 problem with the heuristic method GA+L, found the minimum makespan value equal to 1668.78 minutes with a gap value, and the comparison of Gap was equal to 00.00 minutes. Meanwhile, measuring the comparison of the percentage of time revealed that the machine crashes before and after the research, and the mean between the machine crashes decreased after the research, accounting for 43.928%. This research, therefore, meets the objectives of the research.

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