Advance Sustainable Science, Engineering and Technology (ASSET)
Vol. 6, No.3, July 2024, pp. 02403012-01 ~ 02403012-08
ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v6i3.731

Optimization Of Crude Palm Oil Production Machine Scheduling Using The Campbell Dudek Smith (CDS) Method

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Abstract. Palm oil production in Indonesia currently meets 40% of the world's consumption needs. Control and planning of the production process in maximizing performance results that are useful for maximizing profits and minimizing losses can be archived through optimization and scheduling. One method that can be used in scheduling optimization is the Campbell Dudek Smith (CDS) method. By using the CDS algorithm, each treatment to be completed must go throught the work process on each production machine (flowshop) to get the minimum makespan value. This method can be used to sort jobs in the palm oil production process which is carried out at several stations. Where each machine works according to the production process sequence schedule. The results of the optimal job sequence in the palm oil production process using CDS are : J1 – J2 – J3 – J4 – J5 – J6 – J7 – J8 – J9 – J10 – J11 – J12 – J13 with an optimal makespan value of 404 minutes.

Keywords: Campbell Dudek Smith, Makespan, Optimization, Production Machine Scheduling

(Received 2024-06-22, Accepted 2024-07-10, Available Online by 2024-07-13)

1. Introduction

Oil palm plantations are one of the business sectors that are growing rapidly in Indonesia**.** Currently, palm oil production in Indonesia has met 40% of world consumption needs. Based on data from Statistics Indonesia in 2022, palm oil production reached 46.82 million tons, of which 34.84% was produced by smallholder plantations[1]. The results of palm oil processing can be utilized to produce various important products needed by humans in everyday life. Such as cooking oil, butter, paraffin, soap, shampoo, detergent, cosmetics ingredient and vegetable fuel (biodiesel)[2].

Control and planning of the production process in maximizing performance results that are useful for maximizing profits and minimizing losses can be achieved through optimization and scheduling[3]. Optimization and scheduling are ways of controlling and planning the production process. Optimization is defined as an effort to achieve a more efficient and effective result in dealing with a problem[4]. On the other hand, scheduling is the planning process that involves allocating labour and mechanical resources to complete a sequence of activities in accordance with the procedure within a specific amount of time. The palm oil mill uses equipment that operate step-by-step in sequence to turn raw materials from fresh fruit bunches into Crude Palm Oil (CPO). This process involves many processing phases. This production process is commonly referred to as flowshop production[5]. Problems in flowshop scheduling can be solved by grouping tasks at work stations, this is done to get the shortest job sequencing time[6].

The Campbell Dudek Smith (CDS) method will be suitable for problems that have many stages. As is the case in the process of processing fresh fruit bunches into palm oil which is carried out using many stages of the process of using production machinery. This CDS method can be used to get the smallest makespan value with the best and optimal work order in the processing process[7] and [8]. Makespan is the total time required to complete one production job[9]. The processing of crude palm oil occurs at 5 processing stations[10].

2. Methods

This study was carried out in one of PT Perkebunan Nusantara IV palm oil mills by following the procedures in accordance with the made and completed sequence of flows. Applied research is the kind that is utilised to solve problems by offering workable answers that are typically used in daily life. This kind of research involves tracking down sources from books, earlier studies, and journals that are connected to the issues in this investigation. The approach used in this research is a quantitative approach, namely the use of planned variables characterized by symbols in the form of different numbers - different according to the information provided as the character of the symbol. The steps taken to achieve the objectives of this study are:

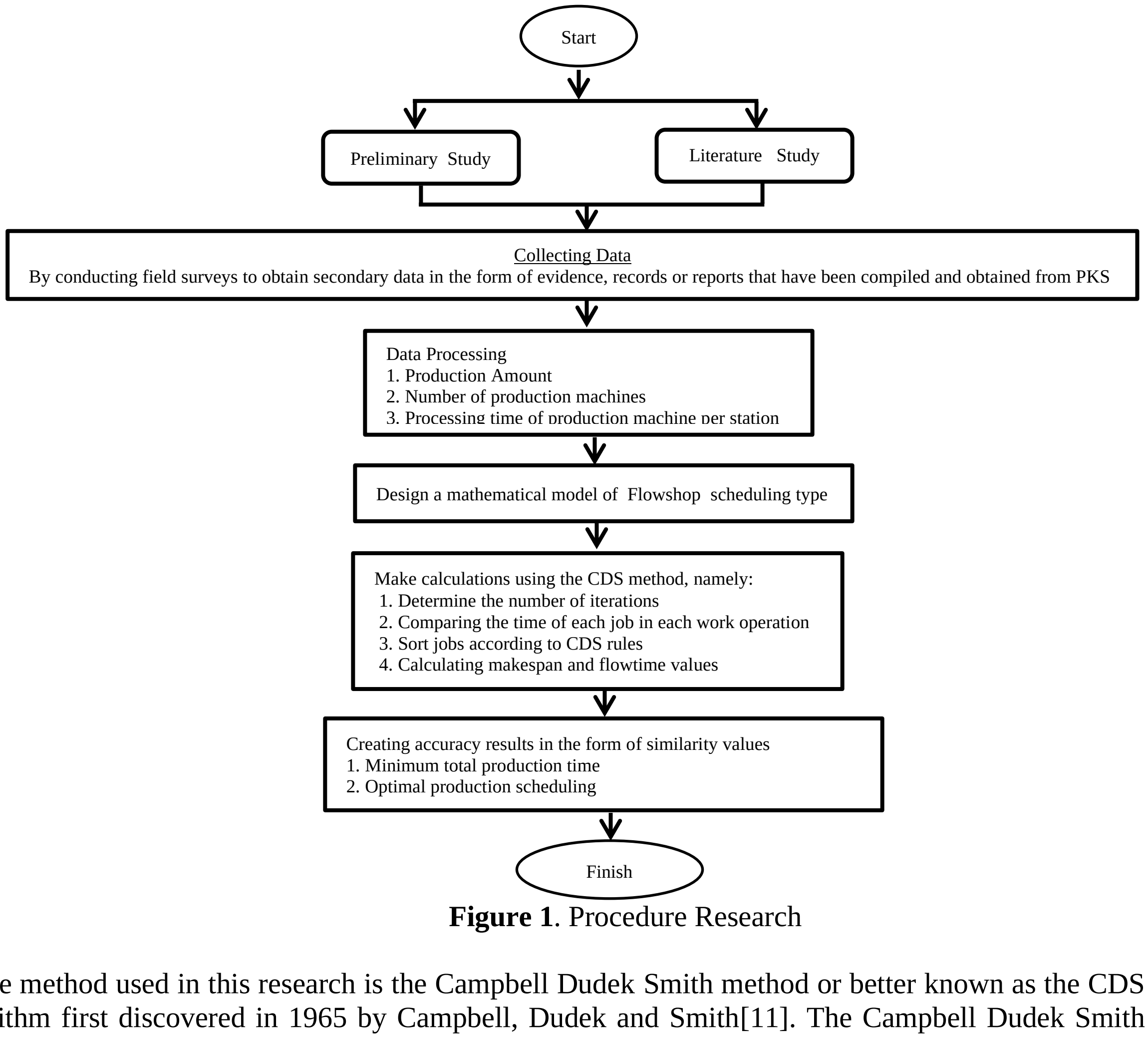

Figure 1. Procedure Research

The method used in this research is the Campbell Dudek Smith method or better known as the CDS algorithm first discovered in 1965 by Campbell, Dudek and Smith[11]. The Campbell Dudek Smith method is the initialization and development of new rules from the Johnso'n algorithm[12]. Johnson's algorithm is a rule used to minimize the makespan value of 2 machines arranged with series rules, which has now become the basis of scheduling theory. This CDS algorithm is a continuous improvement of the Johnso'n algorithm which is used to improve scheduling with multi-stage flowshops[13]. In the

CDS algorithm, each job or task to be completed must pass scheduling on each working machine, this is done to get a ranking of (n) jobs against (m) machines[14]. The CDS algorithm is suitable for multi-stage problems using Johnson's rules and is applied to a new problem obtained from the original value in the order of the first process time, namely[15] :

$$t_{j,1}^{k} = t_{j,1} \text{ dan } t_{j,2}^{k} = t_{j,2} \quad \text{. . . (2.1)}$$

As the processing time of the first machine and the last machine. For the second order, it is formulated with:

$$t_{j,1}^{k} = t_{j,1} + t_{j,2} \quad \text{. . . (2.2)}$$

$$t_{j,2}^{k} = t_{j,m} + t_{j,m-1} \quad \text{. . . (2.3)}$$

As the processing time on the last two machines for the kth sequence:

$$t_{j,1}^{k} = \sum_{i}^{k} = 1^{t_{j,1}} \quad \text{. . . (2.4)}$$

$$t_{j,2}^{k} = \sum_{i}^{m} = m + 1 - k^{t_{j,1}} \quad \text{. . . (2.5)}$$

Description :

i : *job*
j : machine
$t_{j,1}^{k}$: processing time of ith job and first machine
$t_{j,2}^{k}$: processing time of ith job and second machine
m : number of machines used
n : iterations (k =1,2,3,...(m - 1)

The machine with the smallest time from the first machine will be placed at the front of the sequence, while the smallest time from the second machine will be placed at the next or the back of the sequence[16]. From each incoming job must complete the process first on the 'M1 machine and continue on the 'M2 machine until it is completed[17]. This calculation continues with the condition that k = 1, 2, 3, . . ., (m-1), meaning that the calculation price k starts from 1 to m-1[18]. After iteration, the completion time of each iteration will be obtained[19].

By using the (CDS) method, the equation can be solved with the following steps [20]:

- Determine the number of iterations.
- Execute the first schedule, k = 1. Finding the least $t_{j,2}^{k}$ value for each work that is currently in progress will be done at the first and second machine processing times, where $t_{j,1}^{k} = t_{j,1}$ and $t_{j,2}^{k} = t_{j,2}$. This is valid for the upcoming iteration as well.
- Apply Johnson's rule. The job is put at the end of the scheduling sequence if the shortest time is acquired on the second machine, such as ($t_{j,1}$), and the process is started at the beginning if it is obtained on the first machine ($t_{j,2}$). Then, the process is placed at the end of planning.
- Next, take the processes off of the list and reorganise them such that they make up a scheduling order. The processing time of job 1 on machine 1 is total time $t_{1,1}$ and $t_{1,1} + t_{1,2}$ is total time $t_{1,2}$. $t_{1,1} + t_{2,1}$ is the total time $t_{2,1}$. Max { $t_{1,2} + t_{2,1}$ } is the total time $t_{2,2}$ and so forth. The sorting is said to be finished if there are no more tasks. Otherwise, go back to step 1 and repeat the process.

3. Results and Discussion

3.1 Data Collection

In the study of palm oil production machine scheduling optimization has several objectives, namely, maximizing the time of palm oil production machines to get the smallest makespan value, getting the optimal scheduling time to maximize employee performance in increasing palm oil production. Therefore, the data needed to achieve these goals are: a. fresh fruit bunches Production Data for 2023 b. Machine data used at each processing station c. Production time data for each station The production process time obtained from the research site is :

Table 1. Process time data for each station

Station	Part Machine *(m)*	Job (i)	Time (minutes)
Fruit Reception Station	- Weighbridge	J1	18
	- Fruit Sorting	J2	100
	- Loding Ramp	J3	30
	- Transfer Carriage	J4	2
Boiling Station	- Sterilizer	J5	90
Penebah Station	- Hoisting Crane	J6	4
	- Threser	J7	15
Kempa Station	- Digester	J8	25
	- Screw Press	J9	25
Refining Station	- Vibro Sparator	J10	20
	- Oil Purifer	J11	38
	- Single Deck	J12	20
	- Sludge Sparator	J13	17

3.2 Data Processing

From the production process time on each machine there are 13 jobs that must be done sequentially. When determining the iteration of Campbell Dudek Smith (CDS) calculations that need to be considered are [21]:

K(m) = m - 1

K(13) = 13 – 1 = 12

Then, the calculation will be done into 12 scheduling iterations :

Table 2. Scheduling iterations

Iteration	Sequence
1	$t_{i,1}$; t_{m+1-1}
2	$t_{i,1} + t_{i,2}$; $t_{m+1-1} + t_{m+1-2}$
3	$t_{i,1} + t_{i,2} + t_{i,3}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3}$
4	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4}$
5	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5}$
6	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6}$
7	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-7}$
8	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7} + t_{i,8}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-7} + t_{m+1-8}$
9	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7} + t_{i,8} + t_{i,9}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-6} + t_{m+1-7} + t_{m+1-8} + t_{m+1-9}$
10	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7} + t_{i,8} + t_{i,9} + t_{i,10}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-7} + t_{m+1-8} + t_{m+1-9} + t_{m+1-10}$
11	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7} + t_{i,8} + t_{i,9} + t_{i,10} + t_{i,11}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-7} + t_{m+1-8} + t_{m+1-9} + t_{m+1-10} + t_{m+1-11}$
12	$t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7} + t_{i,8} + t_{i,9} + t_{i,10} + t_{i,11} + t_{i,12}$; $t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-7} + t_{m+1-8} + t_{m+1-9} + t_{m+1-10} + t_{m+1-11}$

Scheduling the production process using the CDS method, before the summation iteration becomes :

Table 3. Scheduling iterations

(i) / (M)	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13
M1	18	0	0	0	0	0	0	0	0	0	0	0	0
M2	0	100	0	0	0	0	0	0	0	0	0	0	0
M3	0	0	30	0	0	0	0	0	0	0	0	0	0
M4	0	0	0	2	0	0	0	0	0	0	0	0	0
M5	0	0	0	0	90	0	0	0	0	0	0	0	0
M6	0	0	0	0	0	4	0	0	0	0	0	0	0
M7	0	0	0	0	0	0	15	0	0	0	0	0	0
M8	0	0	0	0	0	0	0	25	0	0	0	0	0
M9	0	0	0	0	0	0	0	0	25	0	0	0	0
M10	0	0	0	0	0	0	0	0	0	20	0	0	0
M11	0	0	0	0	0	0	0	0	0	0	38	0	0
M12	0	0	0	0	0	0	0	0	0	0	0	20	0
M13	0	0	0	0	0	0	0	0	0	0	0	0	17

To apply the CDS method with Johnson's algorithm, the processing time of 3 or more machines can be redesigned into 2 machines, for example for iteration 1 (M-1', M-2') with the rule :

- The activity processing time at iteration 1 is M-1' = $t_{i,1}$
- Activity process time at M-2' = t_{m+1-1}

Iteration 1

M-1' = $t_{i,1}$

M-2' = t_{m+1-1}

Table 4. Scheduling order of iteration 1

Iteration 1	Job												
	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13
M-1'	18	0	0	0	0	0	0	0	0	0	0	0	0
M-2'	0	0	0	0	0	0	0	0	0	0	0	0	17

The calculation time of iteration 1 is $t_{1,1}$= 18 (the length of the process on machine 1) as in table 4. Iteration scheduling using (CDS) becomes :

$t_{1,2}$ = $t_{1,1}$+ 0
= 18 + 0
= 18., dst...

The calculation continues until we get the makespan value as shown in the following table :

Table 5. Calculation of iteration 1

(i) / (M)	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13
M1	18	18	118	148	150	240	244	259	284	309	329	367	387
M2	18	118	118	148	150	240	244	259	284	309	329	367	387
M3	18	118	148	148	150	240	244	259	284	309	329	367	387
M4	18	118	148	150	150	240	244	259	284	309	329	367	387
M5	18	118	148	150	240	240	244	259	284	309	329	367	387
M6	18	118	148	150	240	244	244	259	284	309	329	367	387
M7	18	118	148	150	240	244	259	259	284	309	329	367	387
M8	18	118	148	150	240	244	259	284	284	309	329	367	387
M9	18	118	148	150	240	244	259	284	309	309	329	367	387
M10	18	118	148	150	240	244	259	284	309	329	329	367	387
M11	18	118	148	150	240	244	259	284	309	329	367	367	387
M12	18	118	148	150	240	244	259	284	309	329	367	387	387
M13	18	118	148	150	240	244	259	284	309	329	367	387	404

From the calculation of iteration 1, the following conclusions are obtained in the table below :

Tabel 6. Scheduling order, makespan and flowtime of iteration 1

Scheduling Order	J1-J2-J3-J4-J5-J6-J7-J8-J9-J10-J11-J12-J13
Makespan	404
Flowtime	3.257

Further more, the calculation continues until the 12th iteration, from this calculation the optimal makespan value of the production machine process is 404 with the smallest flowtime value in the 12th iteration. The calculation at the 12th iteration can be seen below:

$$M - 1' = t_{i,1} + t_{i,2} + t_{i,3} + t_{i,4} + t_{i,5} + t_{i,6} + t_{i,7} + t_{i,8} + t_{i,9} + t_{i,10} + t_{i,11} + t_{i,12}$$

$$M - 2' = t_{m+1-1} + t_{m+1-2} + t_{m+1-3} + t_{m+1-4} + t_{m+1-5} + t_{m+1-6} + t_{m+1-7} + t_{m+1-8} + t_{m+1-9} + t_{m+1-10} + t_{m+1-11} + t_{m+1-12}$$

Tabel 7. Scheduling order of iteration 12

Iteration 12	Job J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13
M-1'	18	100	30	2	90	4	15	25	25	20	38	20	0
M-2'	0	100	30	2	90	4	15	25	25	20	38	20	17

Tabel 8. Calculation of iteration 12

(i) / *(M)*	J1	J13	J4	J6	J7	J10	J12	J8	J9	J3	J11	J5	J2
M1	18	18	35	37	41	56	76	96	121	146	176	214	304
M2	18	18	35	37	41	56	76	96	121	146	176	214	304
M3	18	18	35	37	41	56	76	96	121	176	176	214	304
M4	18	18	37	37	41	56	76	96	121	176	176	214	304
M5	18	18	37	37	41	56	76	96	121	176	176	304	404
M6	18	18	37	41	41	56	76	96	121	176	176	304	404
M7	18	18	37	41	56	56	76	96	121	176	176	304	404
M8	18	18	37	41	56	56	76	121	121	176	176	304	404
M9	18	18	37	41	56	56	76	121	146	176	176	304	404
M10	18	18	37	41	56	76	76	121	146	176	176	304	404
M11	18	18	37	41	56	76	76	121	146	176	214	304	404
M12	18	18	37	41	56	76	96	121	146	176	214	304	404
M13	18	35	37	41	56	76	96	121	146	176	214	304	404

Table 9. Scheduling order, makespan and flowtime of iteration 12

Scheduling Order	J1-J13-J4-J6-J7-J10-J12-J8-J9-J3-J11-J5-J2
Makespan	404
Flowtime	1.724

The results of iteration sorting for 13 jobs at 12 iterations

Tabel 10. Summary of iteration results

No.	Iteration	Makespan	Flowtime
1.	Iteration 1	404	3.257
2.	Iteration 2	404	2.690
3.	Iteration 3	404	2.652
4.	Iteration 4	404	2.886
5.	Iteration 5	404	2.472
6.	Iteration 6	404	2.787
7.	Iteration 7	404	2.578
8.	Iteration 8	404	3.112

9.	Iteration 9	404	2.548
10.	Iteration 10	404	2.756
11.	Iteration 11	404	2.577
12.	Iteration 12	404	1.724

It is known from the table above that the makespan value obtained using the Campbell Dudek Smith (CDS) calculation is the optimal 404 minutes in each iteration. With different flowtime values for each iteration. This optimal value can be a reference for employees in the process of working on the production process. So that the work schedule of the first machine to the last machine if sorted using iteration 1 - iteration 12, is obtained as follows:

Table 11. Scheduling Results

Job *(i)*	**Machine *(m)***	**Procses Time (Minutes)**	**Start Time (Minutes)**	**Finish Time (Minutes)**
1.	Weighbridge	18	0	18
2.	Fruit Sorting	100	18	118
3.	Loading Ramp	30	118	148
4.	Transfer Carriage	2	148	150
5.	Sterilizer	90	150	240
6.	Hoisting Crane	4	240	244
7.	Theresr	15	244	259
8.	Digester	25	259	284
9.	Secrew Press	25	284	309
10.	Vibro Sparator	20	309	329
11.	Oil Purifer	38	329	367
12.	Single Deck	20	367	387
13.	Sludge Sparator	17	387	404

4. Conclusions:

In this study, scheduling with the Campbell Dudek Smith approach entails 13 jobs that are divided into 12 iterations. The makespan duration was optimised to 404 minutes using the Campbell Dudek Smith technique, which was employed in this study to minimise the makespan value for palm oil production. Optimal scheduling using the Campbell Dudek Smith method was obtained in iteration 12 with the smallest flowtime, namely 1,724, but because the production process at the palm oil factory runs using a pure flowshop type, the scheduling of each job must run sequentially and pass through every working machine without exception. So the optimal scheduling is obtained in iteration 1, namely with the scheduling sequence: J1 – J2 – J3 – J4 – J5 – J6 – J7 – J8 – J9 – J10 – J11 – J12 – J13 . This scheduling is in accordance with the scheduling rules currently applied to palm oil mills. However, to maintain to stability of the production machine, a machine maintenance scheduling routine is required. This needs to be done to prevent big problem to the palm oil production machine. So, that later the production process can archive maximum production results in accordance with the Company's Work Plan and Budget. For further research, it is hoped that it will focus more on calculating makespan each station on the palm oil production machine.

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