AMERICAN JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

ISSN: 2153-649X doi:10.5251/ajsir.2010.1.2.139.143

Application of mathematical model to job scheduling in an oil processing firm in Nigeria

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ABSTRACT

The job scheduling mathematical model was applied to small scale oil winning processing in this paper with a view to develop a framework for the proper scheduling of jobs (orders) in oil winning processing firm in Nigeria. The problem is addressed by supposing we have (n) customers to be served (where n is large); in what way should customers' order be processed such that the firm's profit is maximized while the customers are not unnecessarily delayed? The paper addressed the problem by using makespan as a measure of performance while the job orders were sequentially scheduled according to order of priority to achieve optimum results. The mean makespan for the CDS heuristic is 35.99, for AI is 36.08 while for the usual traditional serial order (USO) method is 40.91. The average gain with the application of CDS heuristic is 4.962 and for AI is 4.912. The results show that CDS and A1 heuristics are preferred to the usual method of USO. Accordingly, the CDS heuristic, followed by A1 heuristic, gives the best makespan results.

Keywords: Oil Processing, Job Scheduling, Mathematical modeling, Makespan

INTRODUCTION

Palm oil is a fatty edible vegetable oil, derived from the flesh and the kernel of the fruit of the oil palm tree. The oil palm tree is a tropical, single stemmed tree having feather like leaves that gains a height of around 20 meters. The African oil palm (*Elaeis guineensis* Jacquin) produces two different kinds of oil namely, palm oil and palm kernel oil. Palm oil is extracted from freshly mesocarp of the fruit, which contains 45-55% oil, but varies from light yellow to orange-red in color, and melts at 25^0 C, (Kabagambe *et al*. 2005; Ekwenye and Ijeomah; 2005) The fruits of this tree, that are also the sources of the palm oil grow in bunches, are reddish in color, bigger than plums in size and have a single seeded kernel inside (Ilechie, 1993). According to Olufunke, (2003), the non-cholesterol quality and digestibility of palm oil make it a popular source of energy, and palm oil is used for the manufacture of solid fat products, native soaps, waxes for candles, pomade and fuel for orthodox lamps. Palm oil is also used as crude palm oil, crude palmolien, refined bleached deodorized (RBD) palm oil, RBD palmolien and palm kernel oil (Odior, 2007).

Oladimeji et. al. (2008) formulated a multi-criteria maintenance job scheduling model using a weighted multi-criteria integer linear programming maintenance scheduling framework. Three criteria were used and they include: criteria for the minimization of equipment idle time, manpower idle time and lateness of job with unit parity. Jarvis, (1980) developed a heuristic computerized maintenance system for planning and scheduling and the model includes a scheme that allocates manpower to jobs based on First In First Out (FIFO) queue discipline. A parallel machine scheduling model with job processing times controlled by resource allocation was studied by Chen, (1999). He considered both the continuous type and discrete type of processing times. The objective is to minimize the total cost including the cost measured by a scheduling criterion and the cost of allocated resource. Chen, (1999) described his problem as follows: there are a set of n jobs, N={1, 2, ..., n}, to be processed on m identical parallel machines. Each job j N has a due date dj and a weight wj which are both externally given. Campbell *et al*. (1970) proposed the Campbell-Dudek - Smith (CDS) heuristic which is a generalization of Johnson's two machine algorithm. It generates a set of m-1 artificial two-machine problems from an original m-machine problem while each of the generated problems are solved using Johnson's algorithm. Du, (1993) proposed an AIS approach for solving the permutation flow shop scheduling problem while Liaw, (2008) developed a two-phase heuristic to solve the problem of scheduling two-machine no-wait job shops to minimize the makespan.

Theory: In order to schedule the processing of customers' orders such that maximum profit is obtained, the principles guiding flow shop scheduling are adopted as presented in the mathematical frame work. In this case customers are free to bring their jobs at any time. However, each customer's order (oil palm bunches) passes through the machines in the same order. Since different quantities are brought for processing and the oil palm bunches have the same surface area characteristics, each order requires different amounts of processing time in hours as presented in the scheduling frame work.

Single Machine Sequencing: A single machine sequencing is a flow shop in which the jobs visit the machines in the same sequence. The shop characteristics of a single machine shop is given as:

n / m // F / $\bar{F}$

where n is the number of jobs in the shop

m is the number of machines in the shop

F is the flow shop

$\bar{F}$ is the mean flow time.

n / m is referred to as the hardware and F / $\bar{F}$ is referred to as the software of the system.

Johnson's 2- Machine Algorithm: Johnson's 2 – machine algorithm is a process in which the jobs are scheduled in the machines in such a sequence that gives the minimum makespan. A typical case of Johnson's 2-machine algorithm with n jobs is presented in Figure 1.

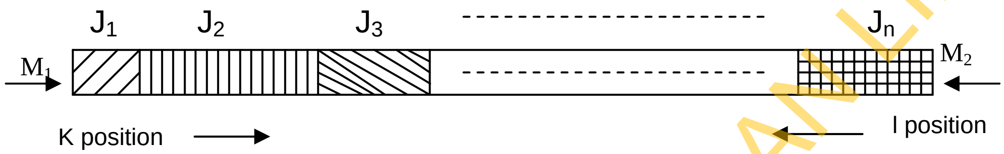

Fig. 1: A typical chart for johnson's 2-machine. algorithm.

The flow time for job J in the kth position is given by

F(k) = P(1) + P(2) + P(3) + ……… + P(k)

$$\therefore F(k) = \sum_{i=1}^{k} P(i) \quad \text{-------------------------------- 1}$$

where P(i) is the processing time for the job in the ith position in the sequence.

This algorithm supposes that we have (n) jobs to be scheduled on two machines i.e. J1, J2, …, Jn,

Then n positions are possible.

$$\text{Total flow time } F_T = \sum_{k=1}^{n} F(k) = \sum_{k=1}^{n}\sum_{i=1}^{k} P(i)$$

$$\text{Mean flow time } \bar{F} = \frac{\sum_{k=1}^{n}\sum_{i=1}^{k} P(i)}{n} \quad \text{-------------------- 2}$$

Generally, for n position we have;

$$\sum_{i=1}^{n} (n-i+1)P(i)$$

$$\frac{\sum_{k=1}^{n}\sum_{i=1}^{k} P(i)}{n} = \frac{\sum_{i=1}^{n} (n-i+1)P(i)}{n} \quad \text{-------------3}$$

The optimizing sequence can be obtained from the following process:

In this case we have (n) jobs to be scheduled on two machines i.e. J1, J2, …, Jn. The optimal solution by Johnson algorithm is obtained as follows:

Step 1: Set k =1, I = n

Step 2: Set the list of unscheduled jobs = {J1, J2, ..., Jn}

Step 3: Find the smallest processing times on first and second machines for the currently unscheduled jobs

Step 4: If the smallest processing time obtained in step 3 for Ji is on the first machine then schedule Ji in kth position of processing sequence. Then delete the Ji job from the list of unscheduled and decrease k by 1.

Step 5: If the smallest processing time obtained in step 3 for Ji is on the second machine then schedule Ji in the Ith position of processing sequence. Then delete the Ji job from the current list of unscheduled jobs and decrease I by 1.

Step 6: Repeat steps 3 to 5 for the remaining unscheduled jobs until all the J jobs are scheduled.

The main objective of this Johnson algorithm of sequentially scheduling the jobs to the two machines from step 1 to step 6 is to achieve the minimum total makespan for optimum job scheduling, which is obtained by summing up the various processing times obtained.

MATERIAL AND METHOD

The study was conducted on an oil palm winning firm with basic operational activities as presented in oil winning process chart in Figure 2, while the key to the various unit operations is presented in Table 1.

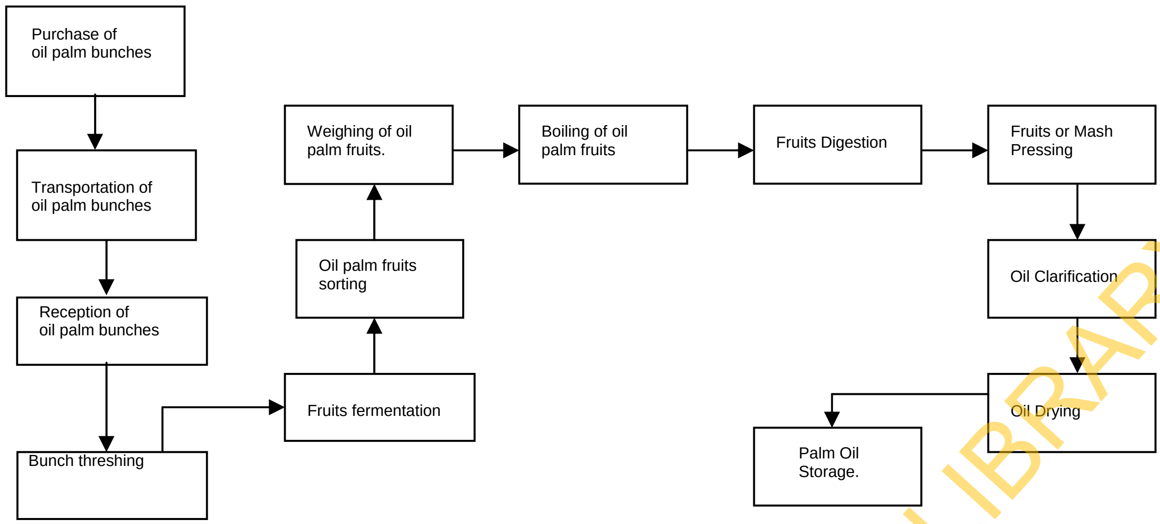

Fig. 2: Summary chart for oil palm processing.

Table 1: Key to the various unit operations.

Unit operation	Purpose
Fruit fermentation	To loosen fruit base from spikelets and to allow ripening processes to abate
Bunch threshing or chopping	To facilitate manual removal of fruit
Fruit sorting	To remove and sort fruit from spikelets
Fruit boiling	To sterilize and stop enzymatic spoilage, coagulate protein and expose microscopic oil cells
Fruit digestion	To rupture oil-bearing cells to allow oil flow during extraction while separating fibre from nuts
Mash pressing	To release fluid palm oil using applied pressure on ruptured cellular contents
Oil purification	To boil mixture of oil and water to remove water-soluble gums and resins in the oil, dry decanted oil by further heating
Fibre-nut separation	To separate de-oiled fibre from palm nuts
Second Pressing	To recover residual oil for use as soap stock
Nut drying	To sterilize and stop enzymatic spoilage, coagulate protein and expose microscopic oil cells

Data were collected for a period of 24 different weeks for 24 jobs (orders). The processing time, which is the amount of time (hours) required to process each customer's order on each machine, is considered close to reality. The scheduling period covers one week which implies that all customers' orders for a week are considered and the scheduling activities are prepared on Monday morning before processing of jobs commences. Normally the processing of customer's orders (jobs) are on a first-come-first-serve basis. Therefore, the first customer to arrive for service is given a serial order 1, the second customer is given serial order 2, while the third is given serial order 3, etc. However, since it was discovered that the firm processes jobs using this serial order, we referred to this method as usual serial order (USO). The method was included in the program so that it can be evaluated alongside the solution methods. The principle here is to monitor the completion time of the last scheduled customer's order. The three methods are adopted and they include: the A1, CDS, and USO, which represent two methods developed by Oluleye and Oyetunji (Oluleye *et al*. 2007) and the traditional method used by the firm.

RESULTS AND DISCUSSION

Table 2 shows the makespan obtained for the three methods (A1, CDS and USO) for the 24-week study period. For all the three methods, the makespan obtained at the fourteenth period were the minimum, showing 33.40 hrs, 33.40 hrs, and 36.42hrs respectively for the A1, CDS and USO methods. Similarly, the makespan obtained for the three methods at the eleventh week were the maximum, showing 40.00hrs, 38.42hrs, and 43.26hrs respectively. It is seen that from the minimum makespan for instance, A1 and CDS methods performed equally, while the traditional approach of USO performed poorly. This implies that if the old approach is continued the jobs for fourteenth week would still stay for an excess of 3.02hrs in the process before being completed which is equivalent to about an extra half a day wasted in a day of 8 working hours.

Table 2: Makespan results for 24 weeks.

Week	Makespan Results		
	A1	**CDE**	**USO**
1	32.25	37.24	42.24
2	35.35	35.34	40.24
3	35.32	35.33	40.45
4	35.12	35.12	42.42
5	36.04	36.06	41.52
6	37.20	37.18	41.46
7	36.52	36.54	41.08
8	35.33	35.54	41.42
9	36.04	36.00	43.16
10	37.42	37.40	40.54
11	40.00	38.42	43.26
12	35.24	35.24	41.54
13	35.70	35.72	42.50
14	33.49	33.40	36.42
15	35.82	35.80	41.28
16	35.72	35.70	43.22
17	36.32	36.30	40.54
18	35.16	35.18	41.27
19	35.18	34.94	41.34
20	35.24	34.26	41.28
21	36.32	36.02	38.42
22	35.82	35.64	39.08
23	38.26	38.12	38.96
24	36.12	37.08	40.02

Table 3 shows the gain in scheduling length when pair-wise comparison of (SO and A1) and (SO and CDS) are made. A critically look through weekly gains reviews that on the average, the (SO – CDS) gains is more than (SO – A1) gains. Table 4 shows the mean values and standard deviations of the makespan. Thus the method with the least mean makespan is CDS, having a mean of 35.99hrs. This is closely followed by A1 with a mean makespan of 36.08 hrs. The worst method remains the traditional with a mean makespan of 40.91hrs. Thus, it is attractive to utilize the CDS method of scheduling jobs on machines for the firm being considered. A further analysis was carried out to find the number of times the various solution methods give the best result as presented in Table 5. It was found that in none of the 24 occurrences did the SO method give the best result. The A1 method shows the best results in 6 occurrences, while for all the 24 occurrences, the CDS method showed the best results in 14 occurrences and this gives credence to the CDS method.

Table 3: Gains in scheduling operation

Week	Scheduling Gains	
	USO – A1	**USO – CDS**
1	4.99	5.00
2	4.89	4.90
3	5.13	5.12
4	7.30	7.30
5	5.48	5.46
6	4.26	4.28
7	4.56	4.54
8	6.09	5.88
9	7.12	7.16
10	3.12	3.14
11	3.26	4.84
12	6.30	6.30
13	6.80	6.78
14	3.02	3.02
15	5.46	5.48
16	7.50	7.52
17	4.22	4.24
18	6.22	6.09
19	6.16	6.40
20	6.04	6.02
21	2.10	2.40
22	3.26	3.44
23	0.70	0.84
24	3.90	2.94

Table 4: Process mean and standard deviation.

Method	Mean Makespan	Standard Deviation
A1	36.07875	1.28714
CDS	35.98958	1.15944
SO	40.91333	1.54473

Table 5: The best solution method.

Methods	Number of Times
A1	6
CDS	14
SO	0
CDS = A1	4

Johnson 2-machine algorithm has been successfully applied to job scheduling in an oil palm winning firm. It has been demonstrated that the conventional approach in scheduling customer orders for oil palm processing in a palm oil winning firm based on the firm usual serial order method in which jobs are scheduled as they arrive for processing fails to satisfy the profit maximization objective of the firm. Three methods were used to analyse the data collected for the palm oil processing firm. The three methods are A1, CDS, and USO, which represent two methods (A1 and CDS) developed and the traditional method (USO) used by the firm. Evidently, CDS performs best, followed by A1, while the worst performance was observed with USO, this is clearly seen in Table 2 and Figure 3. Adopting the CDS method will increase the optimum performance of the firm and it was therefore recommended.

REFERENCES.

Campbell, H G; Dudek, R A; Smith, M L (1970). A heuristic algorithm for n-job, m-machine sequencing problem. J. Management Science. 16: 630-637.

Chen, Z L (1999). Simultaneous job scheduling and resource allocation on parallel machines. Department of Systems Engineering, University of

Pennsylvania, Philadelphia, PA 19104-6315.

Du, J (1993). Minimizing mean flow time in two-machine open shops and flow shops. J. Algorithms. 14: 24–44.

Ekwenye, U N; Ijeomah, C A (2005). Antimicrobial effects of palm kernel oil and palm oil: KMITL Science J. 5: (2) 502-505.

Ilechie, P (1993). Small scale palm oil processing technology in Nigeria (NIFOR), APOpda Seminar on Small and Medium Scale Oil Palm and Coconut Technologies, 6-9th. December, Accra, Gana.

Jarvis, W J (1980). Maintenance planning and scheduling in petrochemical manufacturing environment. National Petroleum Refineries Association, Wash. DC, MC 80: (2) 1-12.

Kabagambe, E K; Baylin, A; Ascherio, A; Campos, H (2005). The type of oil used for cooking is associated with the risk of nonfatal acute myocardial infarction in Costa Rica. The J. Nutrition. 135: (3) 2674-79.

Liaw, C F (2008). An efficient simple metaheuristic for minimizing the makespan in two-machine no-wait job shops. J. Computers and Operations Research. 35: (10) 3276-3283

Odior, A O (2007). Establishment of a small scale oil palm processing plant. International J. Natural and Applied Sciences. 3: (3) 299-305.

Oladimeji, F O 1; Oke, S A; Oluwatoyin, P P (2008). A multi-criteria model for maintenance job scheduling. Maejo International J. Science and Technology. 2: (1) 1-12.

Olufunke, J O (2003). A farmer's appraisal of oil palm development plans in Nigeria, 1989-2001. Nigerian J. Palm and Oil Seeds. 15: (3) 25-38.

Oluleye, A E; Oyetunji, E; Ogunwolu, L; Oke, S A (2007). Job scheduling in a small scale gari processing firm in Nigeria. Pacific J. Science and Technology. 8: (1) 137-143.