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Job Scheduling in A Paint Manufacturing Company in Benin City

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Abstract
A job scheduling mathematical model was applied to a paint manufacturing company in Benin City area of Nigeria with a view to develop a framework for the proper scheduling of jobs (orders) in the paint manufacturing company. The problem is addressed by considering customers (n) to be served (where n is large); in what way should customers' order be processed such that the company'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 A1 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 A1 is 4.912. The results show that CDS and A1 heuristics are preferred to the usual method of USO. Accordingly, the CDS heuristic gives the best makespan results, followed by A1 heuristic.

Keywords: Paint Manufacturing, Job Scheduling, Mathematical Model, Makespan, Customers' Order.

1. Introdction

Paint is a substance used for decorating or protecting a surface. It is a liquid mixture, usually consisting of a solid pigment suspended in a liquid, that when applied to a surface dries to form a hard thin decorative or protective coating. It a fluid or semi–fluid material which may be applied to a surface in relative thin layers and which changes to a solid, may or may not be reversible, and may occur by evaporation of solvent or by chemical reaction or by a combination of the two. It usually consists of a binder or a pigment which contributes opacity, color, and hardness, and a solvent or thinner which controls the consistency. In 1500 BC, the Egyptians developed the art of painting using a wide number and variety of colors. They also discovered the present day vanishes using naturally occurring resins as their film forming ingredient (Odior and Oyawale, 2009).

There are numerous types of paints available in the market many of which incorporate special additives to provide decoration or protection for specific applications. The two basic types of paint available are either water-thinned or turpentine-thinned. Water-thinned paints for example are usually used on interior walls and ceilings, primarily because they dry quickly, brushes or rollers clean up easily in water, the paint is less smelly, and doesn't yellow with age. Furthermore, they are available in a range of gloss levels to suit specific room requirements and are resistant to the alkaline present in masonry. Turpentine-thinned paints on the other hand provide a hard durable surface, are easily cleaned, and seal in tanning stains from timber. They also can give a very high gloss.

2 Paint Production Process

There are four major groups of raw materials which are compounded together to form paint and they include; pigments, binder, solvent, and additives.

2.1 Pigments

Pigments are naturally occurring or synthetically produced fine powders which are dispersed or ground into a binding medium to provide the color and covering power as their major function in paints. Most natural pigments are inorganic in nature while others pigments are synthesized.

The organic pigments which make up the wide spectrum of bright colors available to the paint manufacturers are all synthetically produced. Prime pigments are basically concerned with the main function of providing color and opacity and they are either inorganic or organic in chemical structure.

2.2 Binder

The binder is a resin or polymer which is usually organic compound of high molecular weight, and each large molecule can contain many repeating parts in its chemical structure. The binder or resin binds the component pigments together into a cohesive, continuous film and provides the adhesive power for the paint to stick to a substrate. There are natural and synthetic resins, A synthetic resin based on vegetable oils is the alkyd resin. This is a polymer condensed from vegetable oil with a polyacid and a polyalcohol. The oil component provides the gloss, drying ability, flexibility and exterior durability while the other ingredients give the hardness, resistance properties and speed of dry potential.

2.3 Solvent

This is the third major component of paint and has the major purpose of reducing or thinning paints to a suitable handling consistency or "viscosity" for ease of manufacture and application. After the paint has been applied, the solvent evaporates and leaves the dry paint film on the substrate. Solvents used are either organic compounds or water. The major sources of organic solvents are petroleum refining, fermentation of vegetable matter, and chemical synthesis. They are generally divided into two groups, hydrocarbon solvents made up of carbon and hydrogen atoms, and oxygenated solvents which also contain oxygen atoms. Water is another important solvent used in paints. This provides obvious advantages in cost, availability, flammability and toxicity. The widespread use of water in the majority of today's house paints is one of the major reasons for the overwhelming popularity of vinyl and acrylic latex paints.

2.4 Additives

This group of chemicals is comprised of a vast multitude of proprietary and in-house compounds which are employed by paint makers at low levels (usually < 6.5%) in coatings to perform quite specific functions or to counter adverse side-effects of other components. For example, turps-thinned paints contain drying agents which speed up the drying process. They also contain anti-skinnning agents to prevent the paint forming into a tough skin-like covering in the can.

3. 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 (paint) passes through the machines in the same order. Since different quantities are brought for processing and the materials for paint making have the same surface area characteristics, each order requires different amounts of processing time in hours as presented in the scheduling frame work.

***3.1 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

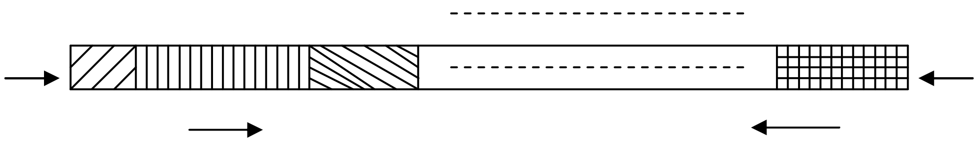
$\bar{F}$ is the mean flow time.

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

3.2 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.



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

$$F(k) = P(1) + P(2) + P(3) + \ldots\ldots\ldots + P(k)$$

$$\therefore\ F(k) = \sum_{i=1}^{k} P(i) \qquad 1$$

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.

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

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

Generally, for n position we have;

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

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

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, l = 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 lth position of processing sequence. Then delete the Ji job from the current list of unscheduled jobs and decrease l 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.

4. Material and Method

The study was conducted on a paint company located in Benin City area of Nigeria which specializes in the production of different grades of paint. An important problem faced in the paint production system is that of determining the time it takes to produce a unit product and meeting the customers' orders on time at a minimum cost without too much delay. The paint production process by the company could be broken down into eight basic activities namely; material drying, weighing of materials, material mixing, dissolving of materials, material filtering, material stirring, inspection and quality control and product packaging. These basic operational activities are presented in Figure 2, while the key to the various unit operations is presented in Table 1.

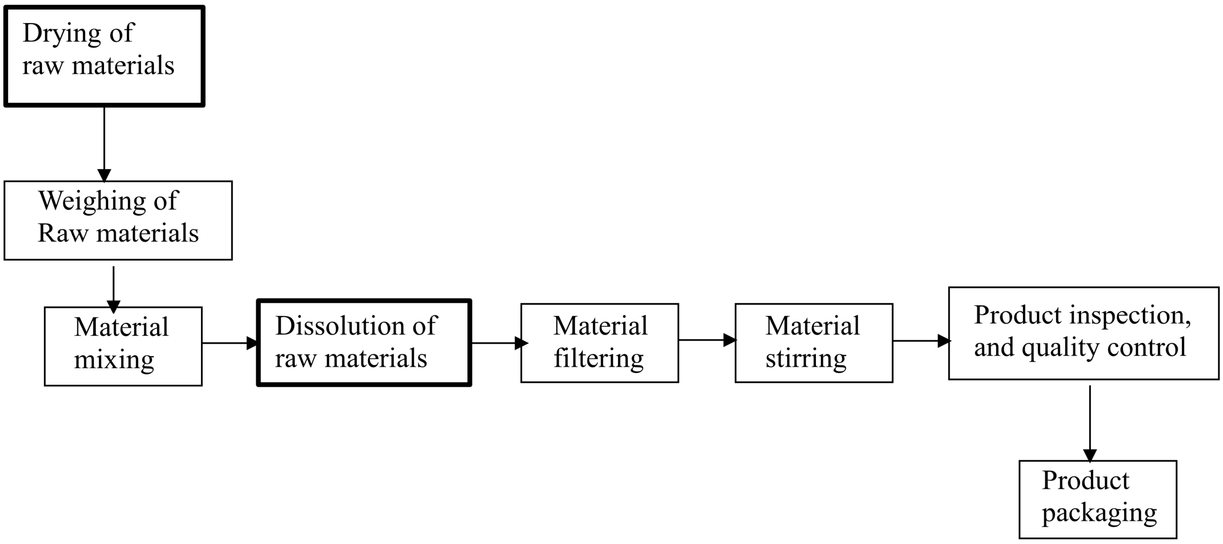


Fig. 2: The Basic Activities in Paint Production Process

Table 1: Key to the various unit operations

Unit operation	Purpose
Drying of raw materials	The raw materials are properly beneficiated and dried
Weighing of raw materials	To weigh the raw materials according to ratios for paint formulation
Material mixing	The raw materials are properly mixed
Dissolving of materials	The mixture of the raw materials are properly dissolved in a solvent
Material filtering	The dissolved materials are properly filtered
Material stirring	The filtered materials are properly stirred.
Inspection and quality control	The produced paint materials are inspected for good quality control
Product packaging	The inspected products are arranged in packages for customers.

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 developed methods (Oluleye et al. 2007) and the traditional method used by the firm.

5 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

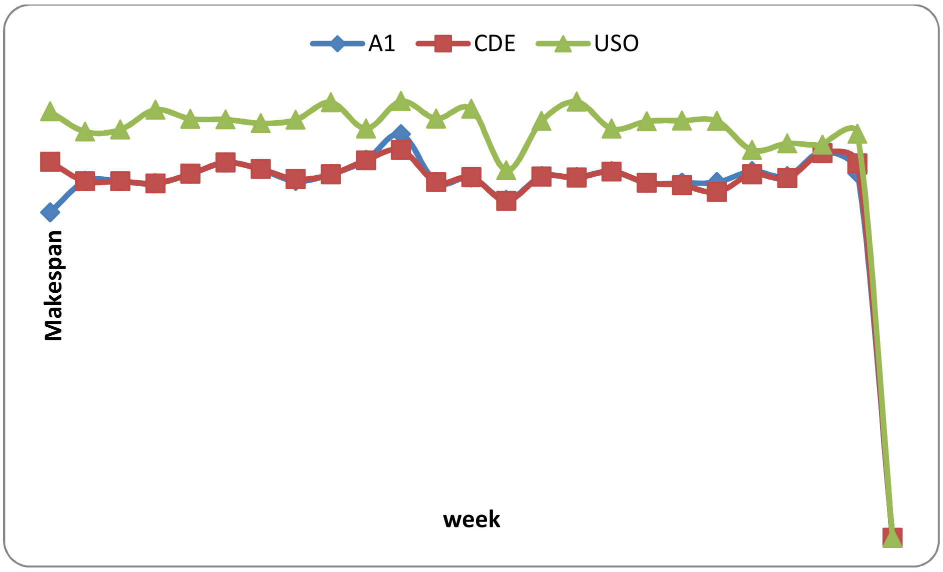


Fig.3 Graph of makesapn from the three methods

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

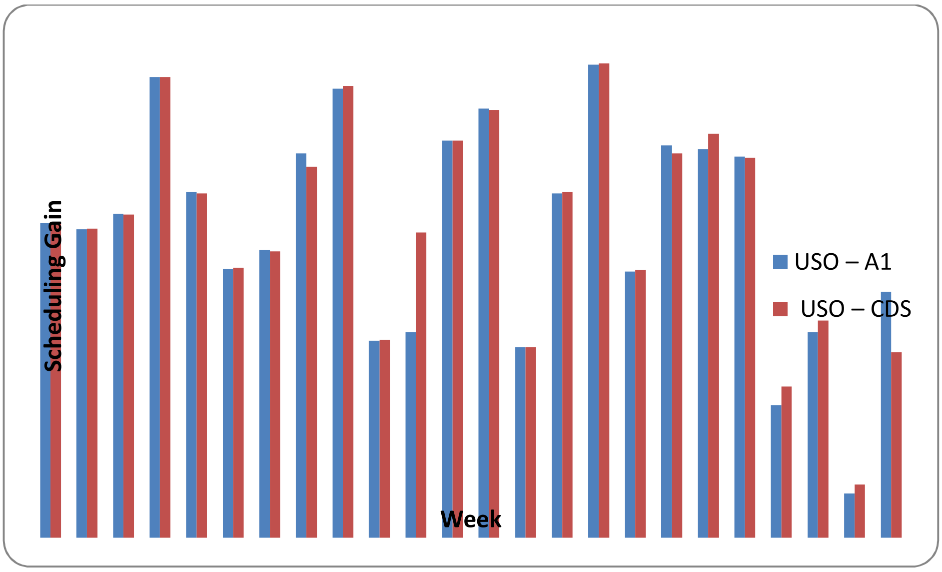


Fig. 4 Graph of scheduling gains for the two methods

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

6 Conclusion

Johnson 2-machine algorithm has been successfully applied to job scheduling in a paint manufacturing company. It has been demonstrated that the conventional approach in scheduling customer orders for oil paint production processing in paint manufacturing company 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 paint manufacturing 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. Therefore, adopting the CDS method will increase the optimum performance of the firm and it was therefore recommended.

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