JOB SEQUENCING METHODS AND TOTAL ELAPSED TIME MANAGEMENT IN BLOCK PRODUCTION INDUSTRY

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Onikoyi, Idril Adegboyega²

Abstract

The study applied job sequencing algorithm model for total elapsed time management in Osun State. The study examined the significant impact of job sequencing system on total elapse time management and the nexus between job sequencing and on-time delivery. A survey research was employed and data were collected through observation and investigation to pre-production, production and post -production activities of the selected block industry in Odo - Otin Local Government in Osun State. The results revealed that job sequencing model has significant impact on total elapse time management. Also, the finding revealed that saved time will reduce the cycle time, on -time delivery, customer due date of delivery and the total elapse time will be at optimal and this will enhance and boost the buffer stock for unexpected future demand. However, the cost implication of the saved time will enhance the profit of the organisation. Organisations should endeavor to integrate the strategies of job sequencing model into their operations and build a team work toward cost minimization in all their activities.

Keywords: Job sequencing, Johnson rule Algorithm, Production Cost minimization and Total Elapsed time Management.

Introduction

Job sequencing which mean the selection of an order for a series of jobs to be done on a number of service facilities (machines) to reduce the production cost has created need of concern to management scientists. Job sequencing is conceptually perceived by management scientists as the process of production management which involves the assigning jobs to workstations and employees to jobs for specified time periods. Different scheduling methods result in different job sequences, leading to difference waiting time of individual jobs (Nong, Xueping, Tony & Xiaoyn, 2005). Due to the dynamic environment faced by business organisations as an open system, several jobs can be processed at one or more workstation(s). If job sequences or flow of operations are not carefully planned and managed, lapses, time waste, bottlenecks and several jobs may hanged and waiting lines may developed.

In addition, new jobs can enter the process at any time, as a result of the unavoidable dynamic environment. Such complexity puts pressure on both managers of small-scale businesses such as food vendors, welders among others and managers of large scale businesses such as automobile factories, cement factories, saw mills, block industries among others sought for maximum production at minimum cost within a reasonable and profitable time. In spite of the variability of job sequencing among factories, the importance of job sequencing on production cost of block industry cannot be over emphasized because of its necessity and unavoidability. In production, the purpose of job sequencing is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment. Job sequence aims to maximize the efficiency and free flow of the production at a minimum costs and minimum time.

The sole aim of a production manager is the maximum production of quality goods at a minimum cost, which has made worthy of note that the impact of sequencing jobs during operations cannot be ignored. Development and increase in the market for blocks and the number of block industries in Odo Otin Local Government area of Osun State has grown rapidly since the establishment of State. As a result, the managements of most block industry in this area experience the under-use and over-use of resources such as man, machine, and tools like spade.
shovel, and the wastage of materials such as sand, water, cement, boards, among others. This creates unnecessary expenses and increases in the cost of production and consequently, affects the profit margin as a result of the avoidable increase in the cost of production.

Furthermore, a lot of time which is supposed to be utilized for the production of bricks are used in searching for labour, waiting for the late delivery of materials, repair of machines, among others therefore causing waiting lines and bottlenecks which will increase cost and lead to low sales and loss of customers if bricks are not available when demanded. All these problems stagnate the growth of block industries and contribute to late delivery of the product, high cost, poor quality and inability to meet customers’ requirement and there can be no minimization of cost if jobs are not properly sequenced, therefore, there is need to establish the link between effective job sequencing and total elapse time management.

**Objective of the Study**

The objectives are to:

- examine the significant impact of job sequencing system on total elapsed time management.
- explain the relationship between job sequencing and on-time delivery.

**Literature Review**

To improve the production facilities, a set of jobs are executed on the set of machines. For better performance there are large numbers of constraints. Process scheduling theory has been developed to meet all side constraints (Merten & Muller, 1972). Process Schedule is done in such a way that the resulting solution minimizes the given objective function. Many variants of the basic scheduling problem can be formulated by differentiating between machine environments, side constraints and objective functions.

**What is sequencing?**

Sequencing gives the idea of the order in which things happen or come in event. Suppose there are \( n \) jobs \((1,2,3,\ldots,n)\) each of which has to be processed one at a time at \( m \) machine \((A,B,C,\ldots)\). The arrangement of these flows is called job sequencing (Kalavathy, 2000). Sequencing can be defined as the selection of an order for a series of jobs to be done on a number of service facilities (machine). In sequencing, a systematic procedure is adopted in assigning priorities to waiting jobs thereby determining the sequence in which jobs will be processed.

Sequencing problem, thus arises when a few facilities (machines), each render a different kind of services (operations) are to be assigned a number of jobs in such a way that the order of performing operation by the machines on each job remains unaltered, as this order is predefined. For example, if a job requires an operation to be performed first on the machine a, then another operation on machine B, the order of performing operations should remain AB. The purpose of sequencing problems is to complete the job within the minimum possible time, keeping the minimum idle time of the machines (or services). Sequencing problem is by and large as allocation problem.

**Principal assumptions of sequencing**

While solving a sequencing problem, the following assumptions are made:
- One machine can process only one operation at a time.
- Each operation once started must be completed first.
- Preceding operation must be completed before the succeeding one can proceed.
- Processing time is known and fixed and the time taken in transfer of jobs between machines is neglected.
- Machines to be used are of different types.
- Jobs to be processed are known and ready for processing before the period under consideration begins.
Objectives of Job Sequencing

- **Minimizing work in Progress:** Optimal production management aims to minimize work in process. Work in process requires storage space, represents bound capital not available for investment and carries an inherent risk of earlier expiration of shelf life of the products. A queue leading to a production step shows that the step is well buffered for shortage in supplies from preceding steps, but may also indicate insufficient capacity to process the output from these preceding steps.

- **Maintaining minimum average flow time of production:** Task time is calculated on virtually every task in a business environment. It is used in manufacturing, however, most common in production lines that move a product along a line of stations that each performs a set of predefined tasks. The product moves along a line, so bottlenecks (stations that need more time than planned) are easily identified when the product does not move on in time. Correspondingly, stations that don't operate reliably (suffer frequent breakdown, etc.) are easily identified.

- **Maintaining minimize cost of production:** Cost reduction can result in significant product cost saving, manufacturing cost saving, and life cycle cost saving when companies interested in cutting cost implement.

- **Maximizing utilization of production resources:** The available resources i.e machines, men, money and materials will be well utilized and arranged in optimal manner. Sequencing allows job flows in order of pre determined and achieved as speculated.

- **Targeted output achieved as specified:** Supply chain management is involved, When your supplier supply materials needed per time and production is carried out within specification (scheduling) products supplied are more likely to meet customers expectation thereby allowing finished product, inventory without failing to meet their needs for volume and timeliness.

**Classification of Job Sequencing Algorithms/ Models**

Some of the algorithms /models for solving job sequencing problems are explained below;

**TABU Search Algorithm**

Eugeniussz and Czesl (2015) these authors explained TABU search algorithm for the job shop problem. It provided a new approximate algorithm that is based on the big valley phenomenon, and used some elements called path re linking technique as well as new theoretical properties of neighborhoods. The model provided a powerful tool to solve the job shop problem with the makespan criterion. It offered very good accuracy, in comparison to other best known approaches, obtainable in a short running time on a modern PC. The general idea of the algorithm could be applied to other scheduling problems, as an example, the flow shop and hybrid flow shop problem. (Rao, Raju, & Babu, 2013)

**Fuzzy Topsis Method**

Another scholars, Pragati and Manisha (2011) presented Fuzzy TOPSIS model in Job Sequencing Problems on machines of unequal efficiencies. Sequencing problems arise when there are more many jobs to done on series of machines with different time specification. In such problems, they determined an appropriate order or sequence for a series of jobs to be done on a different number of facilities. The processing time on theses machines for the jobs are assumed as imprecise processing time (Rao et al, 2013). Weights were given to each machine according to their efficiency. The gap distance will be defined and calculated, closeness coefficient of each job is ranked in order of their weight to minimize the overall total elapse time.
Payoff System / Model
Joss (2011) proposed a modification to the concept of the potential of Hart and Mas Colell to determine a payoff system for job scheduling problems. The basic understand of this model is the value attached to each job, the job should be assigned to production process or machines base on significant payoff of such job.

Johnson’s Sequencing Rule
Punit and Rakesh (2012) In this study, they proposed an approach to find an optimal path from source to destination by taking advantage of job sequencing technique. They had used n jobs m machine sequencing technique and this was divided into n jobs 2 machine problems. Using Johnson’s sequencing rule, they solved the problem and obtained the (n-1) sub sequences of the route. Using the proposed algorithm, they calculated the optimal sequence, which lead to the shortest path of the network. (Rao et al, 2013). This current study adopts the Johnson’s rule algorithms to reveal the impact of job sequencing to production cost minimization.

Sequencing Model for N-Jobs through Two Machines (Johnson’s rule algorithms)
This type of problem can be described as :
(i) Only two machines A and B, are involved :
(ii) Each job is processed in the order AB, and
(iii)Expected processing times A_1, A_2, A_3…A_n, B_1, B_2, B_3…B_n are known as given below:

<table>
<thead>
<tr>
<th>Job</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>…</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_i</td>
<td>A_1</td>
<td>A_2</td>
<td>A_3</td>
<td>…</td>
<td>A_n</td>
</tr>
<tr>
<td>B_i</td>
<td>B_1</td>
<td>B_2</td>
<td>B_3</td>
<td>…</td>
<td>B_n</td>
</tr>
</tbody>
</table>

Johnson’s Rule
Since the procedure for solving such problems was developed by Johnson and Bellman (1953), this procedure as explained below is known as Johnson’s Rule.

**Step 1.** Select the smallest processing time from A_1, A_2, A_3…A_n and B_1, B_2, B_3…B_n. If there is a tie, select either of the smallest processing time.

**Step 2.** (i) If the smallest processing time is A_r, do the r^{th} job first and place it at the beginning of the sequence.

(ii) If it is B_s, do the s^{th} job last of all and place it at the end of the sequence

(iii) If there is a tie for minimum A_r = B_s, process the r^{th} job first and the s^{th} job in the last

(iv) If there is a tie for the minimum among A_r’s then do any one of them first.

(v) If there is a tie for minimum among B_s’s then do any one of them in the last.

**Step 3.** Repeat step 1 and 2. Continue the process till all the jobs have been assigned a position known as ‘optimal sequence’.

Sequencing of N-Jobs through three Machines
Johnson’s method can be extended to the three machine case if any one of the following conditions is satisfied: Smallest time for a job on machine A is greater than or equal to the largest processing time on machine B or Smallest processing time for a job on machine C is greater than or equal to the largest processing time on machine B. For solving such problems, replace the equivalent problem involving n jobs and two machines. These two (fictitious) machines are donated as X and Y, and corresponding processing time are defined by X_i and Y_i, where

\[ X_i = A_i + B_i \]
\[ Y_i = B_i + C_i \]
Sequencing of N-Jobs through M-Machines
In this type of problem, let expected processing times are represented by a Table of the type shown below:

<table>
<thead>
<tr>
<th>Job</th>
<th>Machine times for n-jobs and m-machines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A₁</td>
</tr>
<tr>
<td>1</td>
<td>A₁₁</td>
</tr>
<tr>
<td>2</td>
<td>A₂₁</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Aₙ₁</td>
</tr>
</tbody>
</table>

Solution to this problem is possible only if any one of the following condition is satisfied. Smallest processing time on machine A₁ is greater than or equal maximum time on machines A₂, A₃,..., Aₘ - 1 or

Smallest processing time on machine Aₘ is greater than or equal to machine time on machine A₂, A₃,..., Aₘ - 1.

Procedure for obtaining optimum sequence involved following steps:
Step 1: Check whether it satisfy the above mentioned condition.
Step 2: If condition is satisfied, proceed further. If not satisfied, method fails.
Step 3: convert the machine problem into an equivalent two machine problem says machine M and N, such that

AᵢM = Aᵢ₁ + Aᵢ₂ + ...... + Aᵢₘ excluding the last machine time
AᵢN = Aᵢ₂ + Aᵢ₃ + ...... + Aᵢₘ excluding the first machine time

Then determine the optimum sequence of m jobs through 2 machines by using the optimum sequence algorithm.

Elapsed Time Management
Elapsed time has to do with the time between starting the first job slated on the machine or a particular facility and the time of completing the last job on the machines. This includes the idle time that occurs on any of the machines during the process. The proper planning, scheduling and controlling of the time is referred to as total elapsed time management. Mathematically; Total Elapsed Time = S₁j₁ M₁ₐ + j₁ M₂ₐ + ............ j₁ Mₙ for Job 1. Also, for Job2 S₂j₂ M₂ₐ + j₂ M₃ₐ + ............ j₂ Mₙ and S₃j₃ M₃ₐ + j₃ M₄ₐ + ............ j₃ Mₙ for Job 3 assumed to be the last job + Idle time on the machines if occurs.

Empirical Review
To improve the production facilities, a set of jobs are executed on the set of machines. For better performance there are large numbers of constraints and objectives must be achieved. Process scheduling is vital and authors have done series of study to meet all side constraints and for maximum gain to be achieved. Process Schedule is done in such a way that the resulting solution minimizes the given objective function.

Comparison of Well-Known Scheduling Methodologies
Tadsanee and Jirarat (2010), in their study Comparison of Well-known Scheduling Methodologies explains the well-known scheduling methodologies including first come first serve, shortest processing time, EDD, and least slack time. Since the scheduling may be done by using the rules of jobs and orders, two types of scheduling methodologies are created namely job-based rule and order-based rule. The methodologies then turn to be double. The eight methodologies are applied in a case study of an electronic manufacturing company in
Thailand. It is found that job-based rules always gives better results than order-based rules, and EDD and shortest processing time are the best methodologies.

Nong, Toni and Xiaoyun Xu (2005) The authors examined job scheduling methods for reducing waiting time variance represents their local level work and considers a single resource on a computer and network system. The paper supports an overall effort to achieve end-to-end Quality of Service (QoS) assurance for individual high priority jobs on an information infrastructure (such as the Internet). They worked on QoS models at the local, regional, and global levels. A local level QoS model aims to provide service stability and dependability on individual resources, leading to standard parts, which enable predictable performance. This simplifies QoS assurance at the regional and global levels. Performance results showed that Verified Spiral gives the best performance for the scheduling methods and problems tested in the study. Balanced Spiral produces comparable results, but at less computational cost.

During their investigation they discovered a consistent pattern in the plot of WTV over mean of all possible sequences for a set of jobs, which can be used to evaluate the sacrifice of mean waiting time while pursuing WTV minimization. This study considered only a single resource and jobs with only information of their processing times. This paper focuses on the VS and BS algorithms. Minimizing Waiting Time Variance (WTV) is a job scheduling problem where schedules on batch of n jobs, for servicing on a single resource, in such a way that the variance of their waiting times is minimized. Minimizing WTV is a well-known scheduling problem, important in providing Quality of Service (QoS) in many industries. Minimizing the variance of job waiting times on computer networks can lead to stable and predictable network performance.

METHODOLOGY
Research Design
The survey research method was used in this study. Observation and investigation was made to production of blocks industry in Okuku, Odo – Otin, Local Government Osun state. This observation affords the research to collect data on steps, time and cost of production of the three types of blocks which are: 6 inches, 9 inches and special block without manipulating any of the variables involved in the study. The study covered all the production activities of the selected block industry in Okuku, Odo – Otin, Osun state.

Sample and Sampling Techniques
Sampling techniques relate to the procedure or method of choosing representatives of study population. Therefore, the researcher adopted simple techniques. Proportionate random sampling technique was used to select the block industry based on the activities and population of the workforce in the selected block industry in Osun state.

Instrumentation
The research instrument for this study adopted is “observation and investigation method” which made the respondents and the activities of the block industry to be well known to the researcher.

Section A – observation The first section focused on information on the number of workers, time used on each process, the process of production and the number of machines in the firm.

Section B – investigation: the second section focused on information on the cost of production. Cost of a bag of cement, sand, water, labour, fuel and other miscellaneous expenses.

Administration of the Instrument
A close observation was made by the members of the research group. The research consulted with the manager of the selected block industry for support and assistance in the
observation and investigation on the subject matter. The managers assisted in justification of the observation made and in sustaining the interest and support by providing adequate information needed. All aspects of the investigation were explained to the respondents and the confidentiality of the information being supplied was guaranteed.

However, through the help of the manager, the researcher was able to ask questions with ease. It took the researcher three weeks to gather the information needed with average of 8 hours per day.

**Fig 1. Block Production process. (Field survey, 2015).**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>QUANTITY PER BAG OF CEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 inches block</td>
<td>50</td>
</tr>
<tr>
<td>9 inches block</td>
<td>40</td>
</tr>
<tr>
<td>Special block</td>
<td>35</td>
</tr>
</tbody>
</table>

*Source: Researcher’s survey, (2015).*

The estimated time used up by the firm per bag of cement on each type of block
Machine

<table>
<thead>
<tr>
<th>MACHINES JOB</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>TOTAL TIME USED UP PER JOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>10</td>
<td>30</td>
<td>45</td>
<td>5</td>
<td>15</td>
<td>115</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>10</td>
<td>35</td>
<td>55</td>
<td>5</td>
<td>12</td>
<td>127</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>50</td>
<td>5</td>
<td>13</td>
<td>108</td>
</tr>
</tbody>
</table>

Job
Job 1 represents 6 inches blocks, Job 2 represents 9 inches blocks and Job 3 represents Special Blocks.

Estimated time used up for Production
Total estimated time used up in the production of 6 inches block per bag of cement is 115 minutes.
Total estimated time used up in the production of 9 inches block per bag of cement is 127 minutes.
Total estimated time used up in the production of special blocks per bag of cement is 108 minutes.
Total estimated time used up in the three types of block per bag of cement each is 350 minutes.

Estimated Cost of Production

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 BAG OF CEMENT COST</td>
<td>₦1800</td>
</tr>
<tr>
<td>A LABOURER COST</td>
<td>₦200</td>
</tr>
<tr>
<td>SAND PER WHEEL BARROW COST</td>
<td>₦200</td>
</tr>
<tr>
<td>FUEL AND OTHER MISCELLANEOUS EXPENSES COST</td>
<td>₦300</td>
</tr>
</tbody>
</table>


Applying the processing of n-jobs through m-machines method

Cost of production for the three jobs with an estimated time of 350 minutes
3 Bags of cement = ₦5400
5 labourers = ₦3000
9 Wheel barrows of sand = ₦1800
Cost of fuel and other miscellaneous expenses = ₦900
Total cost for the three jobs for 350 minutes = ₦11100

STEP 1: Comparism of time
First
Min MA ≥ Max MB√
Min MA ≥ Max MC×
Min MA ≥ Max MD×
Min MA ≥ Max ME√

Last
Min MF ≥ Max MB√
Min MF ≥ Max MC×
Min MF ≥ Max MD×
Min MF ≥ Max ME
STEP 2: Compress
Mα – the last machine satisfied
Mβ – the first machine satisfied

<table>
<thead>
<tr>
<th>MACHINE</th>
<th>JOB</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td></td>
<td>100</td>
<td>115</td>
<td>95</td>
</tr>
<tr>
<td>M2</td>
<td></td>
<td>105</td>
<td>117</td>
<td>98</td>
</tr>
</tbody>
</table>

STEP 3: Sequence
Job 3 has the least time of 95 minutes

<table>
<thead>
<tr>
<th>JOB</th>
<th>3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>MACHINE</th>
<th>JOB</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td></td>
<td>100</td>
<td>115</td>
</tr>
<tr>
<td>M2</td>
<td></td>
<td>105</td>
<td>117</td>
</tr>
</tbody>
</table>

Job 1 has the least time of 100 minutes

| J3 | J1 | J2 |

Therefore the job will be sequenced: JOB 3, JOB 1 and JOB 2

STEP 4:

<table>
<thead>
<tr>
<th>MACHINE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>IDLE TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOB</td>
<td>S</td>
<td>F</td>
<td>S</td>
<td>F</td>
<td>S</td>
<td>F</td>
<td>S</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>70</td>
<td>105</td>
<td>105</td>
</tr>
</tbody>
</table>

S represents start time and F represents finish time
Total elapsed time = 177 minutes (optimal time used for the production)
Idle time for Machine A = 147 minutes
Idle time for Machine B = 137 minutes
Idle time for Machine C = 72 minutes
Idle time for Machine D = 17 minutes
Idle time for Machine E = 12 minutes
Idle time for Machine F = 137 minutes

Time used up by the block industry is 350 minutes
Time used up if proper Job sequencing is applied is 177 minutes
Time saved if proper Job sequencing is applied is 173 minutes

**Conclusion and Recommendations**
From the study conducted, it takes the block industry about 350 minutes to produce fifty 6 inches blocks, forty 9 inches blocks and thirty-five special blocks with one bag of cement allocated to each type of block. It was realized that the application of proper job sequencing takes about 177 minutes for the block industry to produce fifty 6 inches blocks, forty 9 inches blocks and thirty-five special blocks with a bag of cement allocated to each type of blocks.

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whereby machine A will be idle for about 147 minutes, machine B will be idle for 137 minutes, machine C will be idle for 72 minutes, machine D will be idle for about 17 minutes, machine E will be idle for about 12 minutes and machine F will be idle for about 137 minutes. Therefore about 173 minutes is saved and can be utilized in making about forty-nine 6 inches block, thirty-nine 9 inches block and thirty-four special blocks extra.

Therefore, the selection of an order for a series of jobs to be done on a number of service facilities (machine) minimizes production time in block industry. Thus, has a positive impact on total elapse time minimization. The nexus between effective job sequencing and time minimization as revealed from the finding above shown that saving period of idle time and 173 minutes actual time saved will reduce the resources that ought to have been allocated to the period. Also, the time saved will reduce the cycle time or delivery time and customer due date of delivery will be met. From this finding, the total elapse time will be at optimal and this will enhance and boost the buffer stock for unexpected future demand. However, the cost implication of the saved time will enhance the profit of the organisation. The finding supported the conclusion of Rao et al (2013) that sequencing job has the capacity to reduce and manage total elapsed time in production organisation. Organisations should endeavor to integrate the strategies of job sequencing model into their operations and build a team work toward cost minimization in all their activities.

REFERENCES