The Effect of The Processing Time’s Variance to The Performance of Sequencing Rule

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Abstract. SPT was the most studied rule in sequencing. Most of the research concluded that SPT was the best rule but other research concluded that SPT did not achieve the best performance. Studies shown that performance varies due to a great different environments because there were so many factors affected the performance. One of the factors that lead to differences in the conclusions was varying of processing time. The objective of the paper was to evaluate the effect of processing time’s variance to the performance of sequencing rules. Only processing time variance was being investigated while number of machine was treated as nuisance factor. To achieve this objective, an experiment was designed and the experiment result was analyzed using anova. Performance measure used in the experiment was lateness. Only five sequencing rules were used. The rules were First In First Out (FIFO), EDD, SPT and Slack Time. The experiment found that for a small number of job, the effect of processing time’s variance was not significant to the performance of sequencing rule. For large number of jobs, processing time’s variance had a significant effect on the performance of sequencing rule. For further research, more sequencing rule to be considered while some assumptions is relaxed.

Keywords: Sequencing rule, FCFS, SPT, LPT, EDD, Slack Time, DOE

1. Introduction

The production scheduling problem is one of the main areas in operation management. Generally, the problem can be described to find best way to assign the available resources to the tasks, within the existing constraints that would maximize the desired performance of the system (Nadia Bhuiyan et. al., 2011) Thus, the problem is how to decide the priority of the tasks and create the sequence of the activities in the shop floor. The decision include the selection of the next part to be processed by the machines or the next part to be released into the system.

In many situations, sequencing rule have been used to address scheduling problems due to their simplicity and ease of use. Sequencing rules are rules that prioritize the jobs waiting for processing. Panwalker (1977) states that the most studied sequencing rule is SPT compare to many other sequencing rule. Baker (1965) conclude that SPT is the best rule when the objective is to minimize the mean flow time (Baker&Dzielinski) but Conway (1965) when comparing with 31 rules conclude that SPT dominate the rules despite the fact that it did not achieve the best performance in any experiment. Montazeri and Van Wassenhove (1990) have also studied the effectiveness of the scheduling rules for various system performance measures using a discrete event simulator. They concluded that the SPT priority rule was the second best priority rule for the system under study in terms of average waiting
time. Many studies have shown that performance varies due to great different environments and thus no dispatching or sequencing rule has been found to be optimal for all planning and scheduling problems. The difference in the conclusion occurs because there are many factors that affect the performance of the sequencing rule. One of the factors that lead to differences in the conclusions is varying of processing time which is measured by variance of the processing time. For this reason a research is extended to evaluate the effect of variance’s processing time into the sequencing rules performance. The object to be studied is a dummy system representing a production system to process N job on a single machine with different processing time.

2. Methodology
The effect of variance’s processing time into the sequencing rules performance is studied through an experiment. Design of Experiments (D.O.E.) is used to investigate it’s effect. Design of Experiments is a structured approach in experimentation used to identify the significance of selected variables (factors) on the performance of the system under study. In this approach the required set of experimental runs is created based on the combinations of factors and the levels of these factors. The experiments are performed by measuring the performance measures of the system under study, while changing the values of other factors in the system. The result is to evaluate the impact of these changes.

To evaluate the effect of factor on the performance of the system, it is necessary to define the factors to be studied. The factor to be studied is then classified into controllable factor and uncontrollable factor. The controllable factors is the main design factor. In this research the main design factor is the variance of the processing time. The uncontrollable factor considered in this study are the number of machine and the priority rule. The other factor is not included as controllable factor because the effect of them is already clear. While variance’s processing factor is treated as main factor, the number of job and priority rule used is treated as a nuisance factor because these factors cannot be eliminated. Other factors that can affect the performance is eliminated by setting them at the same condition. Number of job cannot be eliminated because the job is the subject under study. So do the priority rule used in the experiment.

The design of experiment for one main factor with 2 nuisance factor is Latin Square Design. Variance of processing time is set at 5 level. The variance is measured by the range of processing time. There are 5 level of variance of the processing time expressed in range (R). These levels are \( R = 1;5;10;20; \) and 40. R=1 represent a homogenous system. R=5 and 10 represent a low variance and R= 20 and R=40 represent a high variance. As a consequence of a Latin Square Design, the level factor of number of job (N) is also set at 5 namely N= 4; 8; 12; 20 and 28 job. N=4 and N=8 represent a small number of job, N=12 represent a medium number, while N= 20 and N=28 represent a large number of job. The priority rule is selected among many sequencing rule. The priority rule is selected because it is well known algorithm and it has been shown effective used as a reference. All the factor and its level factor are presented in Table 1. The total number of treatment to be carried for the defined factor is presented in Table 1 are 25.

| Level | Main Design Factor | Nuisance Factor |
|-------|-------------------|-----------------|
|       | Processing time   | Number of job   | Priority rule |
| 1     | Range = 1         | 4               | SPT           |
| 2     | Range = 5         | 8               | FIFO          |
| 3     | Range = 10        | 12              | EDD           |
| 4     | Range = 20        | 20              | LPT           |
| 5     | Range = 40        | 28              | SLACK         |
To perform high reliability, each experiment is replicated 10 times. Thus, all the factor-level combinations of the experiment run is replicated 10 times. Hence there will be 250 (25 conditions * 10 experiment replications) experiment treatments is created. In this paper a test on adequacy of data is carried out to prove that the data required is eligible

3. Planning the Experiment

The experiment require processing time, due date, assumption and response variable. Each of them are explained in the follow

3.1 The Processing Time

The main data required to run the experiment is the processing time. The data is a dummy data of N job which is processed in a single production process. The processing time is generated to simulate a single production process of N job with a certain processing time and different variances for a certain due date. The processing time of each job follows a uniform distribution having mean 30. The variance is expressed in term of range. The range is set at 5 different level of range and the number of job is set at 5 level as presented in table 1. So there will be 25 set data of processing time required to run the experiment for each replication. All the dummy data is generated using Microsoft excel software.

3.2 The Due Date Setting

EDD is one of the rule to be studied. To run the EDD rule, it is essential to have a due date for each job. The due date is set at the time the processing time is generated. In this research, the due date is set so that there will be 25% of the job will be delayed. Table 2 perform the arrangement of the due date setting for each set number of job

| Number of Job | Due Date Range |
|---------------|----------------|
| 4             | 90-120         |
| 8             | 180-240        |
| 12            | 270-360        |
| 20            | 450-600        |
| 28            | 630-840        |

3.3 The Assumption

The assumption used in this study is the normative assumption as follow:
- a. The machine can only perform one job at a time and 100% reliable
- b. Preemption and alternate routing are not allowed
- c. Due date are fixed
- d. Set up included in processing time

3.4 The Response Variable Of The Experiment

The objective of the research is to study the effect of processing time’s variance to the sequencing rule performance. ANOVA is used to analyze the experiment result. The performance measure used to analyze the experiment result is lateness.

4. The Experiment Run

The design of the experiment used is Latin Square Design. The effect of processing time’s variance to the performance of sequencing rule under a set of the number of job as a nuisance factor. To randomized the experiment the treatment is set as expressed in Table 3 so that the setup of the experiment design run for 5 level factor mention above, are presented in Table 4
Table 3. The Randomization Of the Experiment Run

| Sequencing rule | Number of job | 4 job | 8 job | 12 job | 20 job | 28 job |
|-----------------|---------------|-------|-------|--------|--------|--------|
| SPT             | R = 1         | R = 5 | R = 10| R = 20 | R = 40 |
| LPT             | R = 5         | R = 1 | R = 40| R = 10 | R = 20 |
| FCFS            | R = 10        | R = 20| R = 1 | R = 40 | R = 5  |
| EDD             | R = 20        | R = 40| R = 5 | R = 1  | R = 10 |
| SLACK           | R = 40        | R = 10| R = 20| R = 5  | R = 1  |

Table 4. The Treatment of The Experiment Run

| Run no | Variance of Processing Time | Number of job | Sequencing rule |
|--------|------------------------------|---------------|-----------------|
| 1      | R=1                          | 4             | SPT             |
| 2      | R=5                          | 8             | SPT             |
| 3      | R=10                         | 12            | SPT             |
| 4      | R=20                         | 20            | SPT             |
| 5      | R=40                         | 28            | SPT             |
| 6      | R=1                          | 4             | LPT             |
| 7      | R=5                          | 8             | LPT             |
| 8      | R=10                         | 12            | LPT             |
| 9      | R=20                         | 20            | LPT             |
| 10     | R=40                         | 28            | LPT             |
| 11     | R=1                          | 4             | FCFS            |
| 12     | R=5                          | 8             | FCFS            |
| 13     | R=10                         | 12            | FCFS            |
| 14     | R=20                         | 20            | FCFS            |
| 15     | R=40                         | 28            | FCFS            |
| 16     | R=1                          | 4             | EDD             |
| 17     | R=5                          | 8             | EDD             |
| 18     | R=10                         | 12            | EDD             |
| 19     | R=20                         | 20            | EDD             |
| 20     | R=40                         | 28            | EDD             |
| 21     | R=1                          | 4             | Slack           |
| 22     | R=5                          | 8             | Slack           |
| 23     | R=10                         | 12            | Slack           |
| 24     | R=20                         | 20            | Slack           |
| 25     | R=40                         | 28            | Slack           |

5. Result

After the data have been generated, there will be 5 sets of the processing time and their due dates for each level of the number of job. The experiment is ready to run as designed in Table 4. The 1st experiment is running for data set of processing time of 4 jobs having Range = 1 using SPT rule. The sequence is then determined and the lateness as the experiment response is computed. Rerun the experiment for the same data set for the rest 9 replication. Continue for the second experiment for the second data set of processing time for 8 jobs having Range = 5. Use SPT to find the sequence and its lateness. Re run for all the replication. Continue to run all the design treatment presented in Table 4. The response variable is then averaged for analysis its variances. The experience result is then analysed using ANOVA. The hypothesis is set as follows:
$H_0: \tau_i = 0$ for all $j=1,2,3,4,$ and $5$

$H_a: \tau_i \neq 0$ at least for one $j$

Table 5 shows the result of ANOVA on average lateness for all number of job (N) used in the experiment including the F-test. Overall experiment result is presented in appendices. The Anova is presented in Table 5.

Table 5. ANOVA For Average Lateness

| Source         | DoF | Sum of square | Mean square | Ftest | Ftable |
|----------------|-----|---------------|-------------|-------|--------|
| Treatment      | 4   | 474122        | 118530.6    | 34.65 | 3.6    |
| Sequencing rule| 4   | 780112.5      | 195028.1    | 57.01 |         |
| Number of job  | 4   | 922358.4      | 230589.6    | 67.41 |         |
| Replication    | 9   | 10100.3       | 1122.3      |       |        |
| Error          | 228 | 779975.1      | 3420.9      |       |        |
| Total          | 249 | 2966668.8     |             |       |        |

The result shows that the effect of processing time’s variance is significant at 99% level of significant. The $F$ value at 3.6 indicate that there was a significant effect of variance of the processing time to the use of sequencing rule. Some fact findings are obtained from this study:

1. Performance of sequencing rule for small number of jobs was not significantly different For a small number of jobs, all sequencing rule almost performed the same result
2. The greater the number of job, the greater its variance. The study showed that, the use of sequencing rule for greater number of jobs perform a different result significantly
3. For a small number of job, the performance of EDD and Slack in term of lateness was not significantly different compare to another rule.

6. Conclusion
The conclusion of the research are explained below.
1. Variance of the processing time had a significant effect to the performance of sequencing rule selected especially for large number of job.
2. The greater the number of job the more significant the effect to the performance of sequencing rule selected
3. For a small number of jobs, all sequencing rule almost performed the same result

Appendices: Experiment Result

| Sequencing rule | Number of Jobs(N) |
|-----------------|-------------------|
|                 | N=4   | N=8   | N=12  | N=20  | N=24  |
| SPT             |       |       |       |       |       |
| Range=1         | 12.0  | 16.2  | 19.1  | 139.8 | 369.1 |
| Range=5         | 8.3   | 41.5  | 74.3  | 50.0  | 353.6 |
| Range=10        | 56.3  | 31.4  | 69.0  | 64.5  | 203.1 |
| Range=20        | 32.8  | 62.1  | 135.9 | 136.5 | 222.0 |
| Range=40        | 1.5   | 31.0  | 61.1  | 123.2 | 333.4 |
| Range=10        | 0.3   | 53.5  | 103.3 | 75.3  | 310.5 |
| Range=20        | 12.3  | 27.0  | 103.3 | 130.5 | 308.7 |
| LPT             |       |       |       |       |       |
| Range=5         | 8.0   | 17.5  | 87.6  | 159.3 | 373.5 |
| Range=1         | 1.3   | 1.4   | 81.7  | 127.1 | 507.4 |
| Range=40        | 50.9  | 17.5  | 102.5 | 61.1  | 328.5 |
| Range=10        | 24.8  | 1.4   | 159.3 | 61.1  | 236.2 |
| Range=20        | 28.8  | 46.4  | 104.0 | 93.7  | 426.8 |
|       | FCFS |       |       |       |       |       |
|-------|------|-------|-------|-------|-------|-------|
|       | Range=10 | Range=20 | Range=1 | Range=40 | Range=5 |       |
|       | 5.3 | 6.7 | 46.1 | 33.4 | 124.6 | 43.3 | 221.6 | 134.3 | 524.2 | 314.7 |
|       | 29.0 | 7.2 | 32.4 | 15.5 | 76.7 | 122.5 | 154.7 | 126.7 | 331.9 | 250.0 |
| EDD  | Range=20 | Range=40 | Range=5 | Range=1 | Range=10 |       |
|       | 7.0 | 3.2 | 3.7 | 8.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 3.9 |
|       | 4.7 | 4.6 | 3.4 | 12.7 | 0.0 | 3.3 | 0.0 | 0.0 | 16.3 | 16.4 |
|       | 4.8 | 4.5 | 8.4 | 6.0 | 4.7 | 0.0 | 0.0 | 0.0 | 13.1 | 17.3 |
|       | 5.4 | 6.5 | 5.6 | 9.8 | 0.0 | 0.0 | 0.0 | 0.0 | 3.2 | 1.0 |
|       | 6.0 | 4.5 | 2.2 | 5.7 | 0.0 | 0.0 | 0.0 | 0.0 | 17.0 | 17.1 |
| SLACK | Range=40 | Range=10 | Range=20 | Range=5 | Range=1 |       |
|       | 3.8 | 10.8 | 0.0 | 0.2 | 3.5 | 9.2 | 8.5 | 4.5 | 0.0 | 0.0 |
|       | 3.4 | 1.2 | 0.0 | 0.8 | 0.5 | 8.2 | 4.8 | 5.1 | 0.0 | 0.0 |
|       | 4.0 | 1.2 | 4.8 | 1.3 | 5.5 | 11.7 | 5.1 | 9.7 | 0.0 | 0.0 |
|       | 13.0 | 4.2 | 6.0 | 4.2 | 4.0 | 1.0 | 4.5 | 4.4 | 0.0 | 0.0 |
|       | 2.0 | 1.2 | 0.0 | 2.3 | 0.8 | 5.2 | 6.4 | 8.4 | 0.0 | 0.0 |

7. References

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