The comparison of optimum heuristic and deterministic scheduling rules for job shop scheduling in the manufacture

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Abstract. There are some types of scheduling problems in the production line of manufacturing. One of the most multiple usages of the operational machine for doing some jobs is job shop scheduling. The implementation of the job shop problem in this study uses the input of random order of eight job numbers. The raw materials for the job numbers to do the process and the five type machines are considered. The machines work in different functions to do the jobs for some materials. The materials have processed the work in process (WIP) before they are sent to the warehouse. The proposed of this study is to find the optimal condition of job shop scheduling heuristic and deterministic rules to minimize the makespan, tardiness with the heuristic and some deterministic rules in the Lekin software. The heuristic methods are General SBRoutine and the DASH (shifting bottleneck). The deterministic use Critical Ratio (CR) Rule, First come First Serve Rule (FCFS), Longest Processing Time (LPT), Shortest Processing Time (SPT), Weighted Shortest Processing Time (WSPT) and Machine Sequence (MS). The result shows that the minimum makespan is FCFS method with 47 minutes, the tardiness is 27, and for the machine no3. It produces the effective percentage of The contras deviation performance among the jobs of DASH, and compare to the FCFS is as follow, DASH, LPT, MS, SPT, WSPT are increasing 4.26%; 31.91%; 8.51%; 4.26% and 12.77% respectively.

1. Introduction
The scheduling is the important activity to set up planning for scheduling in the manufacturing process due to produce the various products in a limit time [1]. The products must be delivered to the customer in a scheduling order to fulfill the customer requirement [2]. The more accurate planning scheduling will increase the precision of production activity. Most of the industry always tries to implement the short process and minimize the production cost without any change the quality of the product. The minimum process would increase the productivity of time [3].

The job shop scheduling is the specific model of sharing the machine in the use of the task of jobs where it can be handling in multi difference jobs to optimize the exploitation facilities [4]. The job shop scheduling is more applicable used in the manufacturing with the many lot-sizing orders in the short time to fulfill them. The flow shop scheduling protects the bottle next with the sequence scheduling in one machine [5].

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The process in the production area in manufacture the route activity of the material and the worker always consider the time with the schedule set up. The job keeps in the arrival at the workstation to ready to process to obtain the finish goods. The important thing is how to make sure the raw material is not in a big bottleneck in front of the workstation. Precisely, to keep the process with the small tardiness and makespan. The process of the goods in the flow time has the waiting time for the job to do the sequence in the process.

Let say, \( j \) is the job then \( t_j \) is the processing time, \( f_j \) is ready time, \( d_j \) is the due date, \( C_j \) is the completion time, \( F_j \) is the flow time, \( L_j \) is lateness, and \( T_j \) is tardiness from here we can get the the flow time formula as follow:

\[
F_j = C_j - r_j
\]

The lateness is:

\[
F_j = C_j - r_j
\]

The tardiness is the lateness from the job \( J \) if it fails to meet its due date, or zero, given as:

\[
T_j = \max \{0, C_j - d_j\}
\]

The variable in the job shop scheduling is as follow:

- Makespan as \( C_{\text{max}} \)
- The Maximum Tardiness as \( T_{\text{max}} \)
- The Total Number of late jobs \( \Sigma U_j \)
- The Total Flow Time \( \Sigma C_j \)
- The Total Tardiness \( \Sigma T_j \)
- The Total Weighted Flow Time \( \Sigma W_j C_j \) and Total Weighted Tardiness as \( \Sigma W_j T_j \)

In the Lekin software, there are some methods of job shop scheduling [4], such as heuristic (heuristic General SB Routine) and DASH. The heuristic is the analytical technique used to improve performance through the computational process. The deterministic is the mathematical model where the symptoms can be measured with a high degree of certainty. The deterministic rules in the scheduling are such as CR Rule, First come – First Serve Rule, Longest Processing Time, Shortest Processing Time, and Weighted Shortest Processing Time.

2. The Methods
This study runs with the job shop scheduling in the manufacturing to planning the process of the eight jobs and five machines to produce the products from the machines process. The purpose of this study is to explore the comparative methods from different methods, such as the heuristic and deterministic process. There are some rules for the methods of job shop DASH (shifting bottleneck ), Critical Ratio (CR) Rule, First come – First Serve Rule (FCFS), heuristic General SB Routine, Longest Processing Time (LPT), Shortest Processing Time (SPT), Weighted Shortest Processing Time (WSPT). There are some workstations to implement the process of this study. There are five machines: grinding machine, lathe machine, drilling machine, grinding machine and cutting machine. The machine has some function to do the jobs. The materials were done with the different functions work in the machine's workstation. The eight jobs were done by the machines sequentially to finish the goods. Some jobs are Connection Pipe (CP/J1), Coppell (CPL/J2), Engle iron (EI/J3), Hollow iron (HI/J4), Multi-Plate Rack (MPR/J5), Ring Pipe (RP/J6), Socket (SC/J7), Standard Swing Arm (SSA/J8). There is job shops scheduling method. At the end of the process of this study is to compare the optimal objectives from the routes and time parameters, and then concludes the result.

3. Result and Discussion
This study used the process of manufacturing with five machines and eight jobs to obtain the job shop scheduling to produce some products. The scheduling is used to plan the process of maximum makespan and maximum tardiness time. The job shop scheduling for the Gantt-chart can be seen in Figure 1. Gantt chart is the representation of the bar chart to illustrate the appropriate planning to the schedule where it shows the starting time activity and the finish time activity from each job.
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Table 1. The matrix of routes for the job shop

| Machine   | CP(J1) | CPL(J2) | EI(J3) | HI(J4) | MPR(J5) | RP(J6) | SC(J7) | SSA(J8) | Total |
|-----------|--------|---------|--------|--------|---------|--------|--------|---------|-------|
| 1Welding M| 1      | 3       | 2      | 5      | 3       | 4      | 3      | 2       | 23    |
| 2Lathe M  | 3      | 2       | 2      | 1      | 2       | 3      | 4      | 3       | 20    |
| 3Drilling M| 2  | 4       | 3      | 2      | 1       | 2      | 5      | 4       | 23    |
| 4Grinding M| 3  | 2       | 3      | 3      | 5       | 1      | 4      | 5       | 26    |
| 5Cutting M| 2      | 5       | 5      | 2      | 4       | 3      | 2      | 3       | 26    |
| Total (minute) | 11 | 16      | 15     | 13     | 15      | 13     | 18     | 17      | 118   |

The route of the jobs shows that the sequence of the jobs in a time of process to finished the jobs for each machine. J1 (connection pipe) did the sequence of work with the welding process in 1 hour, then process in the lathe process in 3 minutes, in drilling with 2 minutes, grinding with 3 minutes and at the end do the finishing with cutting in 2 minutes to make it follow the design of the model. The same thing did in the other jobs as well. The total process of the jobs in the workstation machines is 118 minutes.

Table 2. The matrix sequence process for the job shop

| No | Machine | CP(J1) | CPL(J2) | EI(J3) | HI(J4) | MPR(J5) | RP(J6) | SC(J7) | SSA(J8) |
|----|---------|--------|---------|--------|--------|---------|--------|--------|---------|
| 1  | Welding | 4      | 4       | 4      | 1      | 5       | 5      | 5      | 5       |
| 2  | Lathe   | 5      | 5       | 5      | 5      | 4       | 4      | 4      | 2       |
| 3  | Drilling| 3      | 3       | 1      | 3      | 1       | 2      | 2      | 3       |
| 4  | Grinding| 2      | 2       | 2      | 4      | 3       | 3      | 3      | 4       |
| 5  | Cutting | 1      | 1       | 3      | 2      | 2       | 1      | 1      | 1       |

In the job shop scheduling is very common to manage some jobs for some machines in the dynamic interchange between sharing the machines to produce some product. The sequences depend on each production process[6]. The sharing machines are very partially decided in the group of production to
manage the capacity of each machine. This is a local decision. The sharing machine can be seen at the table above.

Table 3. The Process time (Pr.tm) and tardiness (T)

| Time | Job |
|------|-----|
| Process Time (Pr.tm) | CP(J1) | CPL(J2) | EI(J3) | HI(J4) | MPR(J5) | RP(J6) | SC(J7) | SSA(J8) |
| T (Tardiness) | 11 | 16 | 15 | 13 | 15 | 13 | 18 | 17 |
| wT | 15 | 19 | 23 | 27 | 17 | 23 | 25 | 20 |

The Process time (Pr.tm) shows that the total of working time for one job to finished the work. In here the J1 show that the 11 hours to finalize the work. The process of tardiness (T) for each job has the variation while the weighted tardiness (wT) has a different value. The minimum makespan and tardiness are on machine lathe machine and job number 1 (J1).

Figure 2. The trend of process time and tardiness for the job shop

The Process time (Pr.tm) and tardiness (T) shows that the process time increase will make the tardiness increase. It means that the sequence time makes the bottleneck at the machine to process. The longer time to process one item makes the queuing to process so the tardiness should be happening on it.

Table 4. The result of job shop scheduling performance of parameters

| Methods | Time | C_max | T_max | ΣU_j | ΣC_j | ΣT_j | Σw_jC_j | Σw_jT_j |
|---------|------|-------|-------|-------|-------|-------|--------|--------|
| CR      | 1    | 47    | 28    | 8     | 280   | 167   | 1339   | 738    |
| DASH    | 4    | 49    | 27    | 8     | 281   | 168   | 1350   | 749    |
| FCFS    | 1    | 47    | 27    | 8     | 282   | 169   | 1344   | 743    |
| General SB-R | 2 | 47    | 27    | 8     | 282   | 169   | 1356   | 755    |
| LPT     | 1    | 62    | 58    | 8     | 381   | 268   | 1636   | 1035   |
| MS      | 1    | 51    | 29    | 8     | 304   | 191   | 1445   | 844    |
| SPT     | 1    | 49    | 43    | 8     | 278   | 165   | 1236   | 635    |
| WSPT    | 1    | 53    | 47    | 7     | 300   | 188   | 1190   | 595    |

Note: DASH (shifting bottleneck), Critical Ratio (CR) Rule, First come – First Serve Rule (FCFS), heuristic General SB Routine, Longest Processing Time (LPT), Machine Sequence (MS), Shortest Processing Time (SPT), Weighted Shortest Processing Time (WSPT).

There are eight scheduling methods were tried to compare the best result from the planning of the process of making some products. The scheduling methods measured the parameters of Time,
makespan ($C_{max}$), max tardiness ($T_{max}$), number of late jobs ($\Sigma U_j$), total flow time ($\Sigma C_j$), total tardiness ($\Sigma T_j$), total weighted flow time ($\Sigma w_i C_j$), total weighted tardiness ($\Sigma w_i T_j$).

The different operations for the job shop model rules are job shop scheduling, such as DASH shifting bottleneck, Critical Ratio Rule, First come – First Serve Rule, heuristic General SB Routine, Longest Processing Time, Shortest Processing Time, Weighted Shortest Processing Time. The First come – First Serve Rule has the best job shop scheduling system on the parameters of $C_{max}$, $T_{max}$, $\Sigma C_j$, $\Sigma T_j$, $\Sigma w_i C_j$, $\Sigma w_i T_j$.

Figure 3. The route of jobs for each machine in a job shop

The sequence jobs on the workstations are illustrated in figure x where one machine can handle more than one job in the sequence time to make the process time to produce the product effectively.

Figure 4. The performance of the relationship between the objectives

The yellow line shows that the performance of FCFS shows the best due to the points in the triangle corner of $C_{max}$, $T_{max}$, $\Sigma C_j$ have nearest to the center value. It illustrates the figure 4. The $C_{max}$ is 47 and $T_{max}$ is 27 where it is close to the general SB routine scheduling.
4. Conclusion
This paper describes the exploration and analysis of the optimal job shop scheduling for various methods of a certain condition of the job planning. Some methods of the job shops are exploring and compare the performance of the objectives from the process. The heuristic methods are DASH and heuristic General SB Routine and deterministic are CR, FCFS, LPT, SPT, WSPT. The methods are compared the makespan ($C_{max}$), max.tardiness ($T_{max}$), number of late jobs ($\sum U_j$), total flow time ($\sum C_j$), total tardiness ($\sum T_j$), total weighted flow time ($\sum w_j C_j$), total weighted tardiness ($\sum w_j T_j$). The result from the objective show that the FCFS shows outperform than the other methods to minimize the $C_{max}$ and $T_{max}$ and FCFS is a very close result from the Heuristic general SB routine ($C_{max}$) method. The FCFS produce the $C_{max}$ time is 47, $T_{max}$ is 27, $\sum U_j$ is 8, $\sum C_j$ is 280, $\sum T_j$ is 167, $\sum w_j C_j$ is 1344, $\sum w_j T_j$ = 743. The total process of the jobs in the workstation machines is 118 minutes with each jobs time are 11, 16, 15, 13, 15, 18, 17 respectively. The contras deviation performance among the jobs of DASH, and compare to the FCFS is as follow, DASH, LPT, MS, SPT, WSPT are increasing 4.26%; 31.91%; 8.51%; 4.26% and 12.77% respectively. In the real situation, the planning of schedules usually has the gap between scheduling planning and the actual. This situation makes the worker in the factory do the adjustment scheduling in the timespan to create the relevance with the target scheduling on the track due to some factors, such as jobs, machines, order, raw material and the condition of worker’s scheduling. The scheduling must think what, how, when and who to implement the planning. At last, more accurate planning from the scheduling would increase the productivity in the process of a product in the manufacturer.

5. References
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