# ผลกระทบของขนาดพื้นที่จัดเก็บและกฎการจ่ายงานในสายการผลิตแบบตามงานสโตคาสติกพลวัต ด้วยเวลาในการปรับตั้งเครื่องจักรขึ้นกับลำดับงานก่อนหน้าโดยใช้วิธีการจำลองสถานการณ์

# The Impact of the Buffer Size Areas and Dispatching Rules in a Stochastic Dynamic Job Shop with Sequence Dependent Setup Time Using Simulation Approach

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## บทคัดย่อ

บทความนี้กล่าวถึงผลกระทบของขนาดพื้นที่จัดเก็บงานของงานระหว่างทำที่ยังอยู่ในระหว่างกระบวนการผลิตโดยได้ทำการหาผลกระทบของขนาดพื้นที่จัดเก็บกับประสิทธิภาพของกฎการจ่ายงานในรูปแบบการผลิตแบบตามงานสโตคาสติกพลวัต ซึ่งงานวิจัยที่ผ่านมาจะให้ความสำคัญเพียงแค่ขนาดของพื้นที่จัดเก็บแบบไม่จำกัดขนาด ซึ่งคำตอบนั้นไม่สอดคล้องกับอุตสาหกรรมในชีวิตจริง ดังนั้นในบทความนี้ได้ทำการศึกษาขนาดของพื้นที่จัดเก็บงานที่จำกัด เพราะว่าพื้นที่จัดเก็บงานจะช่วยในเรื่องของการลดการเกิดการหยุดชะงักของเครื่องจักร และ ลดความไม่สม่ำเสมอในการผลิตของเครื่องจักรเพื่อเติมเต็มช่องว่างของปัญหาดังกล่าวได้ ดังนั้นในบทความนี้ได้ทำการศึกษากฎการจ่ายงานทั้งหมด 4 แบบ ประกอบด้วย FCFS, LCFS, SPT และ EDD โดยทำการประเมินด้วยตัวชี้วัด makespan, mean flow time, maximum flow time, mean tardiness, maximum tardiness, number of tardy jobs และ machine utilization performance ซึ่งจะถูกนำมาเป็นตัวประเมินประสิทธิภาพของการจัดลำดับงานทั้ง 4 แบบ ด้วยวิธีการจำลองสถานการณ์ (Simulation Approach) โดยการนำข้อมูลจากงานวิจัยก่อนหน้าที่มีปัญหาในการวิจัยในลักษณะเดียวกันมาทำการทดลองหาคำตอบของงานวิจัยชิ้นนี้ ซึ่งคำตอบที่ได้นั้นจะได้จากการ เปลี่ยนกฎการจ่ายงานทั้ง 4 แบบ และเพิ่มขนาดของพื้นที่จัดเก็บงานของงานระหว่างที่ทำจากขนาดปกติ, เพิ่มขึ้น 100%, เพิ่มขึ้น 200% ซึ่งนำไปสู่ผลลัพธ์ที่ดีขึ้น

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**Abstract**

This research studies the buffer sizes area about work in process (WIP) between machines, in order to find the impact of the buffer size area with performance analysis of dispatching rules in a stochastic dynamic job shop manufacturing system (SDJS). In majority of the existing researches, the performance of dispatching rules is focused only unlimited buffer size area but their results do not reflect the realistic scenario. This research aims to investigate the limitation of the buffer size area because it will fix the blocking machine and reduce uncertainty of the machine to fulfill the gap of the problem. Hence, this research aims to investigate FCFS, LCFS, SPT and EDD of dispatching rules in such shop from makespan, mean flow time, maximum flow time, mean tardiness, maximum tardiness, number of tardy jobs and machine utilization performance. These performance measurements of four dispatching rules with buffer size area between machines are reported by using simulation approach. This research also investigates the data from previous studies. Conclusively, the results are shown that the changing dispatching rules and the increased buffer size areas from normal, 100% and 200% can lead to the better results from all performance measurements.

***Keywords:*** *dispatching rules, stochastic dynamic job shop, simulation modeling, makespan, mean flow time, maximum flow time, mean tardiness, maximum tardiness, number of tardy job, machines utilization performance*

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## 1. Introduction

Nowadays, the manufacturing sector develops its processes, and increases the characteristic of just-in-time in the production systems. The just-in-time system takes production advantages to highly integrate manufacturing processes, continuous flow of jobs between workstations, and decreasing storage areas in the shop floor. Particularly, the size of storage areas plays an important role in reducing capital costs and providing flexible planning. However, in ordinary scheduling model, it is always assumed with unlimited buffer size area which is not taken into account in providing a schedule. Therefore, considering the limited buffer capacity between machines with scheduling model will provide a more realistic model.

In reality, limited buffers which have an effect on scheduling problem and their size between machines always occur. It blocks and delays the operations of previous machines or transitional buffers. There are many existing literatures about heuristic and meta-heuristic algorithms. However, there are a few literatures related to the solutions of flow shop scheduling problem with limited buffers (Li and Pan, 2015).

Production scheduling in manufacturing systems, to accomplish an objective, is collaborated with a set of tasks and a set of production resources overtime. Job shop manufacturing system is a set of jobs which are processed by a set of machines and each job specifies the operation order. The job shop scheduling problem is a combination of optimization problem likewise NP-hard and it is the most typical and complicated among assorts production scheduling problems (Xiong et al., 2013). In a dynamic job shop scheduling problem, job is coming constantly over the time in job shop manufacturing system. Furthermore, in stochastic dynamic job shop (SDJS) manufacturing system, at least one parameter of the job (processing time /setup time, release time) is a probabilistic.

In majority of the existing researches, job shop scheduling has always been ignored or only considered with only setup time in the processing time of a job to reduce the complication of solving a job shop scheduling problem. However, their results do not reflect realistic scenarios of manufacturing systems. Setup time is a time used to prepare the resource, for example, setting up the machine for another job or maintaining the machine in operations (Sharma and Jain, 2015). Among most of the situations in the real word practice, a setup operation always happens when shifting from one operation to another operation. Normally, the sequence dependent setup time depends on job on the machine before the previous operations (Allahverdi & Soroush, 2008). It exists in many industries such as chemical processing, plastic manufacturing, paper industry, garment industry, printing industry, and so on. In garment industry, dyeing operation has a limited time for changing the dyeing process from light color shade to deep shade product. On the other hand, there is much more setup time for cleaning the dyeing pipe. In some cases, setup time is equal or greater than operating time. It is evident that sequence dependent setup time in scheduling problems is the most difficult case. In the existing literature, only a few studies have focused on such problems (Abdelmaguid, 2015; Sharma and Jain, 2015).

A dispatching rule is used to select the next job produced from the group of jobs in queue before moving to the machine. Dispatching rules are also kind of sequencing rules or scheduling rules. They are classified into four categories namely processing time based rules, due date based rules, combination rules and rules which are neither processing time based nor due date based. For the manufacturing system, dispatching is one method that is implemented with scheduling of manufacturing while scheduling is a part of production planning. Therefore, to accomplish an effective planning, a proper dispatching rule used in scheduling is required.

Hence, this research aims to investigate the dispatching rules used in the SDJS scheduling problem. The sequence dependent setup time and limited buffer capacity between machines are taken into account by simulation approach.

## 2. Objective

This research aims to investigate the most appropriate dispatching rules in SDJS scheduling problems whereas sequence dependent setup time and limited buffer capacity between machines are considered. Furthermore, the minor objective is to identify the influencing dispatching rules and their significant impacts on the SDJS scheduling problems with sequence dependent setup time and limited buffer capacity between machines.

## 3. Materials and Methodology

The methodology in this paper is primarily carried out into three parts, (1) input/tools, (2) methodology and, (3) output as illustrated in Figure 1. This study begins with the impact of the buffer sizes area and dispatching rules on a stochastic dynamic job shop with sequence-dependent setup time using simulation approach. Finally, this study constructs the simulation model for comparing the impact of buffer sizes area with dispatching rules.

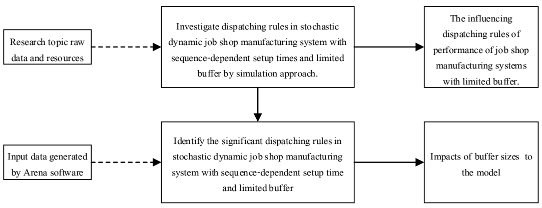


**Figure 1** Steps of proposed methodology

### 3.1 Job shop configuration

In the present study, a job shop manufacturing system with ten machines is selected. The determination of the manufacturing system is determined based on determination of job shop considered by previous studies (Vinod and Sridharan, 2008). It has been indicated that six machines are acceptable to perform the complex structure of a job shop manufacturing system (Wilbrecht and William, 1969; Baker and Dzielinski, 1960). The variations of job shop size do not significantly affect the whole things but have an influence on the relative performance of dispatching rules (Baker and Dzielinski, 1960). With this evidence, most of the researchers study about job shop scheduling problem with less than ten machines (Dominic at el., 2004; Yua and Rama, 2006; Rossi and Dini, 2007). Figure 2 presents the model of job shop configuration which the dispatching rules are changed and the buffer size areas.

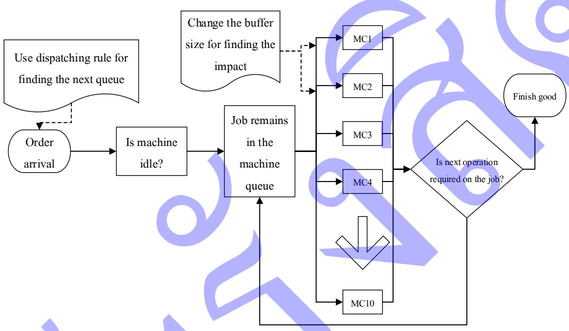


**Figure 2** Job shop configuration

### 3.2 Job data

In this paper, six different job types are used namely job type A, job type B, job type C, job type D, job type E and job type F. All job types have the same arrival probability and require 5, 4, 4, 5, 4 and 5 operations respectively.

**Table 1** Routes of job types

| Job type | Number of operations | Route of the job (machine number) |
|---|---|---|
| A | 5 | 1-6-10-2-4 |
| B | 4 | 8-3-5-10 |
| C | 4 | 7-9-3-1 |
| D | 5 | 5-7-9-2-4 |
| E | 4 | 2-8-1-10 |
| F | 5 | 6-9-1-3-5 |

This study uses secondary data, the data from previous studies. Hence, Table 1 presents that the machines are visited by different job types in their routes. In deterministic scheduling problems, processing time and setup time of the jobs on the machines are fixed. Nevertheless, in the real problems, they are stochastic. Therefore, in the present work, the processing time and setup time are considered in stochastic and assumed to be uniformly distributed in each machine. The processing time and setup time of each machine will be changed to follow the routes of the job. The pattern of processing time on the different machines is selected based on previous studies (Sharma and Jain, 2015). This research inputs the data into the simulation model as the following Figure 2, job shop configuration.

3.3 Dispatching rules

The dispatching rules are one of the earliest approaches to solve job shop scheduling problems. 100 rules, approximately, have been developed and applied in the last decade (Panwalker and Iskander, 1977). The simple priority and dis-patching rules are easily implemented, however, it performs poorly when complexity of scheduling increases (Selsa et al., 2012). The dispatching rules are used to pick a next job which is to be processed on the machine from the input queue of the machine. In this paper, the queue policy, First come first serve (FCFS), Last come first serve (LCFS), Shortest setup time (SPT) and Earliest due date (EDD) are kind of simple priority rules (SPR), which is usually, based on single objective function (Tay & Ho, 2008), used to construct the simulation model.

3.4 Buffer sizes area

The blocking job shop (BJS) problem is an extension of a job shop problem with no buffer constraints. It means that after a job is completed on the current machine, it still remains on that machine until the next machine becomes available. Since there is no buffer constraint condition, a machine cannot start any other operations until a downstream machine receives the semi-finished product which is just processed. This essentially means that the machine is blocked until it releases the product (Zeng et al., 2014). It is evident that buffers can improve line efficiency. Although a cost per unit buffer space is considered, it is often possible to find solutions that provide higher throughput than from the case without buffers. At the same time, a lower design cost is allowed (Tiacci, 2015). Thus, this research aims to intensely investigate the impact of the buffer sizes area with performance analysis of dispatching rules and use three of different buffer sizes (normal size, 100% increase of normal and 200% increase of normal) to check the relationships with the different size and investigate the final result.

3.5 Simulation approach

Simulation approaches seem to be powerful and reasonable for handing with such problems. For some cases of the real-world problems such as nonlinearity, complexity, or stochastic, it cannot be simply addressed by the aid of the mentioned approaches. In this regard, simulation methods might be good alternatives for modeling (Azadeh et al., 2011). Simulation-based scheduling does the experimentation of scheduling rules and the assessment of the effect of different rules on the shop's ability to meet delivery dates and utilized machines (Koh et al., 1996). Hence, this study has applied the simulation approach for investigating the proper solution of the large and complex problem.

3.6 Experimental design for simulation study

This study builds the model of ten machines with buffer sizes area within character of stochastic dynamic job shop problem. In this simulation modeling, a number of experiments on stochastic dynamic job shop scheduling problem have been conducted. The first stage in simulation is to identify steady state period i.e. end of initial transit period. Thirty replications are used for simulation model with 20,000 jobs of each replication.

**4. Results**

4.1 Makespan

Makespan represents completion time of the last job. Its values for different dispatching rules are shown in Figure 3. EDD at buffer size, for 100 percent more than normal size, is the best dispatching rule for this measurement by makespan.

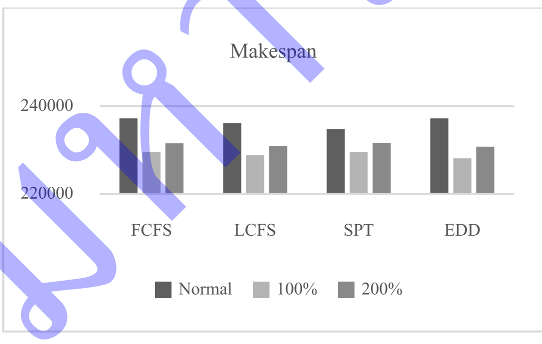


**Figure 3** Makespan

4.2 Mean flow time

The performance of different dispatching rules for mean flow time is shown in Figure 4. It indicates that EDD at buffer size, 200 percent more than normal size, is the best dispatching rule for this measurement by mean flow time.

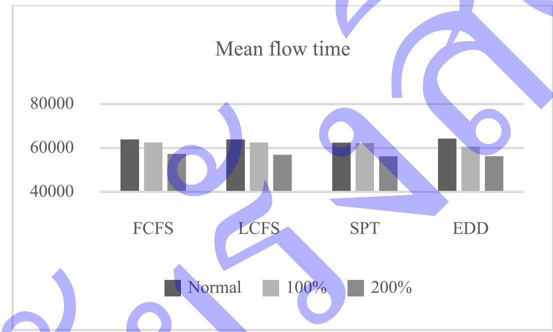


**Figure 4** Mean flow time

4.3 Maximum flow time

Figure 5 shows the performance of assorted dispatching rules for maximum flow time measure. It indicates that the SPT at buffer size, 200 percent more than normal size, provides the best performance.

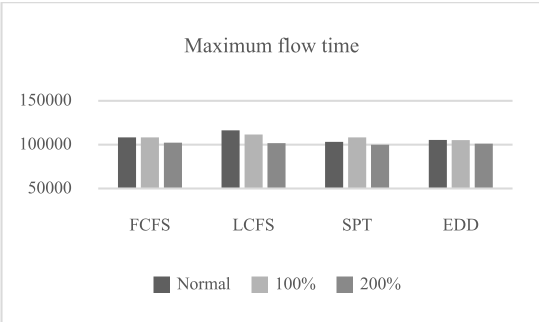


**Figure 5** Maximum flow time

4.4 Mean tardiness

This due date based performance measure is related to the better customer service and contentment. Figure 6 presents the performance of assorted dispatching rules for mean tardiness measure. It illustrates that the SPT at buffer size, 200 percent more than normal size, provides the best performance.

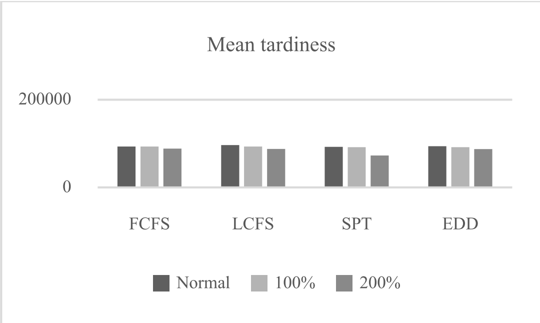


**Figure 6** Mean tardiness

4.5 Maximum tardiness

The performance of different dispatching rules for maximum tardiness is shown in Figure 7. It indicates that SPT at buffer size, 200 percent more than normal size, is the best dispatching rule for this measurement by mean flow time.


**Figure 7** Maximum tardiness

4.6 Number of tardy jobs

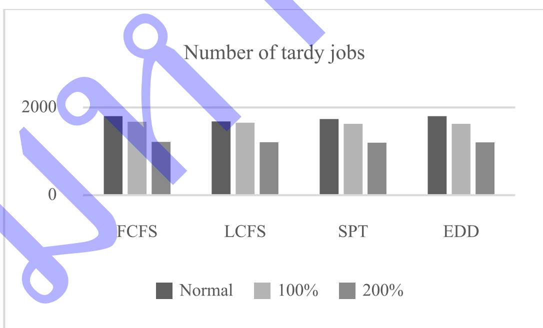


**Figure 8** Number of tardy jobs

Figure 8 presents the performance of assorted dispatching rules for number of tardy jobs measure. It shows that the SPT at buffer size, 200 percent more than normal size, provides the best performance.

4.7 Machines utilization

Figure 9 describes the performance of production line utilization. Buffer size area allows the decreasing of production line utilization. It means that the production line can produce more WIP if the production line has more buffer space.

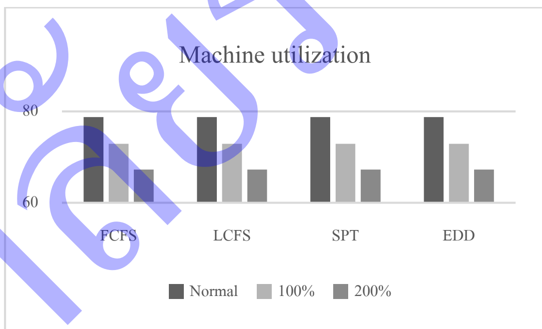


**Figure 9** Machine utilization

**5. Discussion**

The effects of changing the buffer sizes area with three sizes namely normal size, more than normal size 100%, more than normal size 200%, are considered in order to investigate the effect of change in SDJS with four dispatching rules. Figure 3 reveals that there is an increase in makespan value with the buffer size area more than normal 100%, and its result is better than the buffer size area-more than normal 200% since the sequence of the jobs is changed by buffer size area . Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8 represent mean flow time, maximum flow time, mean tardiness, maximum tardiness and number of tardy jobs respectively. These figures indicate that as buffer size areas increase, values of these performance measures increase. This confirm with the real manufacturing environment that waiting of the low buffer size area job is required at the machines blocking until the next station is available. Hence, increasing in values of these performance measures is observed. Figure 9 represents machine utilization performance measure. It indicates that as buffer size areas increase, values of these performance measures increase. This also confirm with the real factor that when the machines finish the production, WIP or product will be kept as buffer and the machines are then allowed to produce the new product. It means when more buffer size areas are added, it allows the increasing of machines efficiency.

**6. Conclusion**

This paper addresses a SDJS scheduling problem while considering sequence dependent setup time. A discrete-event simulation model of the SDJS manufacturing system is developed. The performance of four dispatching rules are assessed. The effect of changing the level of buffer sizes area on manufacturing system performance is also assessed. The simulation results indicate that EDD at buffer size, 100 percent more than normal size, is the best performing dispatching rule for makespan. On the other hand, SPT at buffer size, 200 percent, is the best performing dispatching rule for mean flow time, maximum flow time, mean tardiness, maximum tardiness and number of tardy jobs respectively. The buffer size area affects the performance of the entire system. From simulation analysis, it indicates that as the buffer sizes increase, the utilization of the machines also increases. Finally, this paper can be extended in a number of ways. The future research could be experiment with other dispatching rules and some situations related to job pre-emption and machines breakdown.

**7. Acknowledgement**

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**8. References**

Abdelmaguid, T. F. (2015). A neighborhood search function for flexible job shop scheduling with separable sequence-dependent setup times. *Applied Mathematics and Computation, 260*, 188-203.doi: http://dx.doi.org/10.1016/j.amc.2015.03.059

Allahverdi, A., & Soroush, H. M. (2008). The significance of reducing setup times/setup costs. *European Journal of Operational Research, 187*(3), 978-984. doi: http://dx.doi.org/10.1016/j.ejor.2006.09.010

Azadeh, A., Moghaddam, M., Asadzadeh, S. M., & Negahban, A. (2011). An integrated fuzzy simulation-fuzzy data envelopment analysis algorithm for job-shop layout optimization: The case of injection process with ambiguous data. *European Journal of Operational Research, 214*(3), 768-779. doi: http://dx.doi.org/10.1016/j.ejor.2011.05.015

Baker, C. T., & Dzielinski, B. P. (1960). Simulation of a Simplified Job Shop. *6*(3), 311-323.

Koh, K.-H., de Souza, R., & Ho, N.-C. (1996). Database driven simulation/simulation-based scheduling of a job-shop. *Simulation Practice and Theory, 4*(1), 31-45. doi: http://dx.doi.org/10.1016/0928-4869(95)00022-4

Li, J.-q., & Pan, Q.-k. (2015). Solving the large-scale hybrid flow shop scheduling problem with limited buffers by a hybrid artificial bee colony algorithm. *Information Sciences, 316*, 487-502.doi: http://dx.doi.org/10.1016/j.ins.2014.10.009

Panwalker, S. S., & Iskander, W. (1977). A survey of scheduling rules. *Operations Research*, 45-61.

Selsa, V.,Gheysena, N., & Vanhouckeabc, M. (2012). A comparison of priority rules for the job shop scheduling problem under different flow time- and tardiness-related objective functions. *International Journal of Production Research, 50*(15), 4255-4270.

Sharma, P., & Jain, A. (2015). Performance analysis of dispatching rules in a stochastic dynamic job shop manufacturing system with sequence-dependent setup times: Simulation approach. *CIRP Journal of Manufacturing Science and Technology, 10*, 110-119. doi: http://dx.doi.org/10.1016/j.cirpj.2015.03.003

Tay, J. C., & Ho, N. B. (2008). Evolving dispatching rules using genetic programming for solving multi-objective flexible job-shop problems. *Computers & Industrial Engineering, 54*(3), 453-473. doi: http://dx.doi.org/10.1016/j.cie.2007.08.008

Tiacci, L. (2015). Simultaneous balancing and buffer allocation decisions for the design of mixed-model assembly lines with parallel workstations and stochastic task times. *International Journal of Production Economics, 162*, 201-215. doi: http://dx.doi.org/10.1016/j.ijpe.2015.01.022

V. Vinod, & Sridharan, R. (2008). Dynamic job-shop scheduling with sequence-dependent setup times: simulation modeling and analysis. *The International Journal of Advanced Manufacturing Technology, 36*(3), 355-372.

Wilbrecht, J.K. & Prescott W. B. (1969). The Influence of Setup Time on Job Shop Performance. *Management Science, 16*(4), B-274-B-280.

Yua, X., & Rama, B. (2006). Bio-inspired scheduling for dynamic job shops with flexible routing and sequence-dependent setups. *International Journal of Production Research, 44*(22), 4793-4813.

Zeng, C., Tang, J., & Yan, C. (2014). Scheduling of no buffer job shop cells with blocking constraints and automated guided vehicles. *Applied Soft Computing, 24*, 1033-1046. doi: http://dx.doi.org/10.1016/j.asoc.2014.08.028