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An investigation of order review / Release policies and dispatching rules for assembly job shops with multi objective criteria

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Abstract

This work deals with the significant aspects of a simulation based experimental study of two shop floor control polices: order review/ release (ORR) and dispatching rules for scheduling an assembly job shop in which multi-objective criteria is considered. A simulation of model of an assembly job shop which consists of one assembly work station with two machines and seven machining work stations with two machines in each work station is developed. Six dispatching rules and four ORR mechanisms identified from the literature are incorporated in the simulation model. Grey relational analysis is used for ranking the dispatching rule-ORR combinations. The performance measures considered in this study are mean flow time, mean tardiness and machine utilization. Simulation experiments have been conducted in an environment with products consisting of single level assembly structure, two level assembly structure and three level assembly job structures. The results indicate that Job Due Date rule with Interval Release policy performs better in comparison with the other dispatching rule- ORR combinations investigated in this study.

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Keywords: Assembly Job Shop; Simulation; Scheduling; Multi-Objective; GRA.

1. INTRODUCTION

Scheduling of jobs or services have significant role in many manufacturing and service industries. Scheduling problems are classified into many; among that one important type is job shop scheduling problem. In job shop configuration, different machines are available in a machine shop. A job may need some or all these

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machines in a specific sequence according their requirement. The general Job Shop Scheduling (JSS) problem is a strong NP-hard problem (Rinnoy et. al 1979) and very difficult to solve computationally. In the literature, it is found that most of the studies focused only on conventional job shop system which processes string type jobs only. However, Scheduling assembly job shop which have serial, assembly operations and multi-level jobs is relatively less investigated (Pereira, 2011).

According to Wong (2009), assembly job shop scheduling problems (AJSSP) are classified two types, first type allowing machining to root components only and second type allowing machining to not only root components but also assembly components. A number of solution techniques to handle the AJSSP have been developed over the years. The solution techniques include dispatching rules, constructive heuristics and meta-heuristics. Hence, almost all the studies on AJSSP focusing only on single objective optimization. No significant research has been reported in the area of scheduling of an assembly job shop with multi-objective criteria.

While using dispatching rules alone, jobs continuously arrive to the shop floor without any review. This situation can cause increase of work-in- process inventory, increase of congestion, decrease of flexibility and increase of lead time. For overcoming this drawback, Order review/release (ORR) policy is another shop floor control method used in the present study along with dispatching rule. By controlling the flow of production orders, namely, timing of arrival and number of units of the job to the shop floor, ORR improves the system performance. Based on the usage of machine load information, ORR policies are classified into two types: 1) Policies that do not consider load information. 2) Policies that consider load information. Both the types of ORR policies are used in the present study.

Grey Relational Analysis (GRA) is one of the techniques used to solve multi-attribute decision making problems (Fung 2003, Kuo et al. 2008). The first step of GRA analysis involves translating each performance measure in a comparable manner. This solution is called comparability sequence. This comparability sequence is used for defining a reference sequence. The next step is to determine grey relational coefficient. Finally, a grey relational grade between the reference sequence and every comparability sequence is calculated based on the grey relational coefficients. The comparability sequence which has the highest grey relational grade between the reference sequence and itself is the best choice and the alternative associated with this comparability sequence is the best alternative.

This work proposes a model for multi-objective scheduling of an assembly job shop using a combination of priority dispatching rules and ORR mechanisms. The assembly job shop consists of one assembly work station with two machines and seven machining work stations with two machines in each work station. A simulation of model of the shop is developed using the simulation software, Arena (version 14.0). Six dispatching rules for scheduling jobs and four ORR mechanisms for shop control identified from the literature are incorporated in the simulation model. Grey Relational Analysis is used for ranking the dispatching rule-ORR combinations. The performance of the shop is evaluated using the measures such as mean tardiness, mean flow time and machine utilization. The remaining sections of the paper are organized in the following manner:

Section 2 describes the details of the configuration of the assembly job shop production system considered in the present study. Section 3 provides the results and analysis. Conclusions are presented in section 4.

2. ASSEMBLY JOB SHOP SYSTEM CONFIGURATION

The assembly job shop system configuration considered in the present simulation study is similar to that considered by Natarajan et al. (2007). The system configuration includes shop floor settings, due dates of different products, assembly level of structure of different products, simulation settings and performance measures selected for the study.

2.1 Assumptions made

The assumptions made in this study are listed hereunder:

- Each machine can perform only one operation at a time.
- Preemption of jobs is not allowed.
- Precedence relationship between operations should be followed.
- In a given level of assembly, a job visits a machine only once.
- There are no alternative routes for jobs.
- Due date and job structure of each product are known in advance.
- Flow time includes processing time and waiting time only; setup, transport and loading times are assumed to be negligible.
- Machines are continuously available, i.e., there are no breakdowns.

2.2 Assembly Job-Shop Simulation Model

The simulated shop floor consists of two divisions, a machining shop and an assembly shop. The machining shop consists of seven work centers with two machines in each work center. The assembly shop consists of two machines. Assembly starts only after all machining operations of an item are completed. Job arrivals at the system follow Poisson distribution. Each machining work center for processing has the same probability of being chosen since routing is generating randomly.

The processing times and the assembly operation times follow uniform distribution in the range 1-20 and 5-20 respectively. The number of operations for each item or subassembly follows uniform distribution in the range 2-7. Simulation runs are conducted at 90% system utilization level. By varying the mean job arrival rate, different utilization levels can be obtained. In the present study, Poisson process with a mean job arrival rate of 3.10 units per hour that produces a system utilization rate of 90% is used. The due-date of an arriving job i is determined by Adam et al (1993) using its critical path length (li), the allowance factor (c) and job arrival time (ti), i.e., $d_i = t_i + c \times l_i$. The allowance factor considered in all problems is 1.5.

Three types of product structure are used in this study:

- Single level assembly structure with one level of assembly
- Two level assembly structure with two levels of assembly
- Three level assembly structure with three levels of assembly

2.3 Simulation Settings

The simulation settings are fixed as follows:

- Run length: 1000 job completions
- Number of replications: 20
- Warm up period: the first 250 jobs (jobs numbering from 251 to 1250 are considered for computation of performance)

The simulation model has been developed using Arena simulation software (version 14.0) on a PC with Intel® Core(TM) i3–2350 CPU @ 2.30GHZ and 4 GB RAM.

2.4 Dispatching Rules

The following dispatching rules are considered in this study:

- FCFS (First Come First Serviced)
- FASFS (First Arrival into System First Serviced)
- SPT (Shortest Processing Time)
- JDD (Job Due Date): Products with the earliest due date will be processed first.
- ECT (Earliest Completion Time): Products with the earliest completion time will be processed first
- LF-ECT (Latest Finish time-Earliest Completion Time): The item/subassembly having minimum value of LFij is chosen for loading among the waiting items/subassemblies at the machine.

2.5 Order Review/Release policies

The following ORR mechanisms reported in the literature have been used in the experiments.

- Immediate Release (IMM)
- Interval Release (IR)
- Backward Infinite Loading (BIL)
- Maximum load (MXL)

3. RESULTS AND DISCUSSION

The performance of the six dispatching rule-four ORR techniques under comparison is evaluated with respect to three performance measures. Mean flow time is defined as the average time; a job spends in the system. Mean tardiness is the average tardiness of all jobs completed, where tardiness of a product is the difference between completion time and due date of that product. Machine utilization denotes the overall utilization of the machines in the system.

Table 1 gives the results for mean flow time, mean tardiness and machine utilization obtained from the simulation study.

Table 1 Performance of dispatching rule-ORR combination

Sl. No.	Dispatching rule-ORR combination	Mean Flow time	Mean Tardiness	Machine Utilization (%)
1	ECT-IMM	309.19	115.47	83.75
2	FASFS-IMM	309.86	115.48	83.74
3	FIFO-IMM	537.22	201.76	81.70
4	JDD-IMM	308.92	115.36	83.75
5	LF ECT-IMM	309.81	115.51	83.74
6	SPT-IMM	353.37	150.16	80.86
7	ECT-IR	265.81	103.86	82.56
8	FASFS-IR	274.45	89.17	82.54

9	FIFO-IR	611.26	197.28	81.67
10	JDD-IR	268.15	86.48	82.57
11	LF ECT-IR	265.99	103.77	82.55
12	SPT-IR	360.76	102.96	80.71
13	ECT-BIL	295.30	111.04	83.53
14	FASFS-BIL	295.96	110.84	83.53
15	FIFO-BIL	536.24	200.94	81.71
16	JDD-BIL	294.87	110.63	83.53
17	LF ECT-BIL	294.85	110.73	83.53
18	SPT-BIL	354.58	151.16	80.81
19	ECT-MXL	298.04	107.37	81.99
20	FASFS-MXL	298.60	107.27	81.99
21	FIFO-MXL	496.09	185.580	80.88
22	JDD-MXL	297.53	107.37	82.00
23	LF ECT-MXL	298.09	107.37	81.98
24	SPT-MXL	341.89	147.85	80.81

The above results are presented in graphical format in Figure 1, 2 and 3.

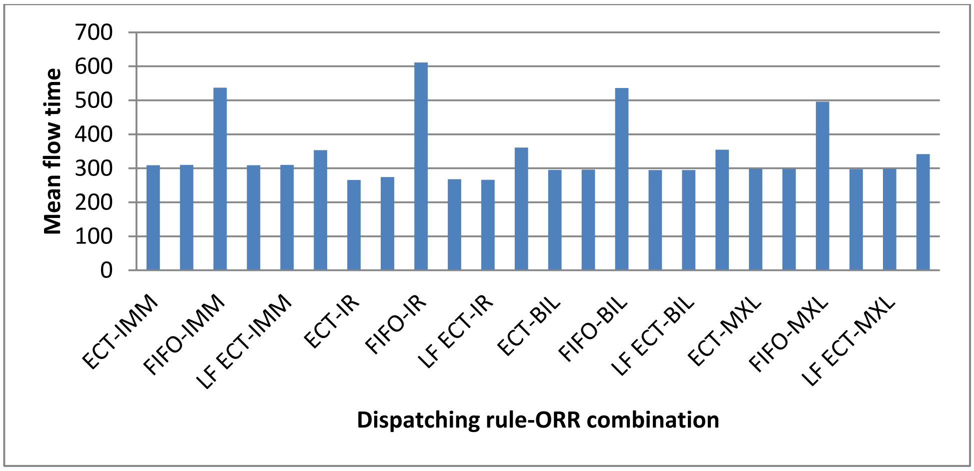

Figure 1: Mean flow time for dispatching rule-ORR combination

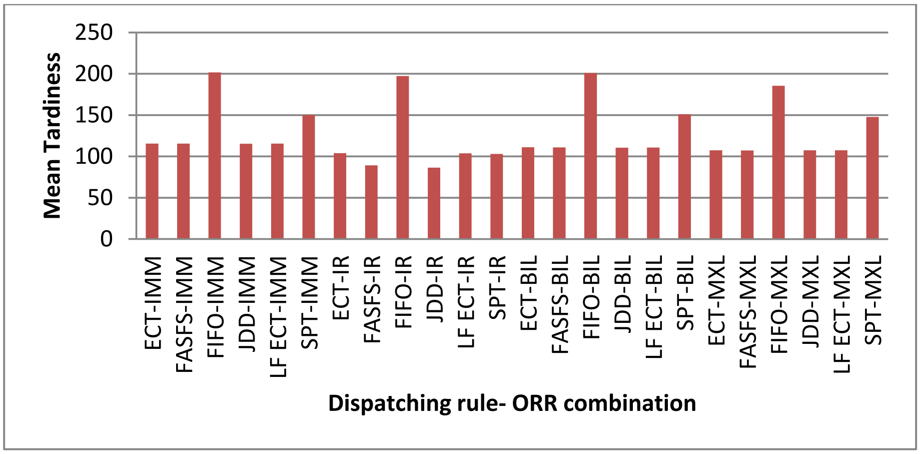

Figure 2: Mean tardiness for dispatching rule-ORR combination

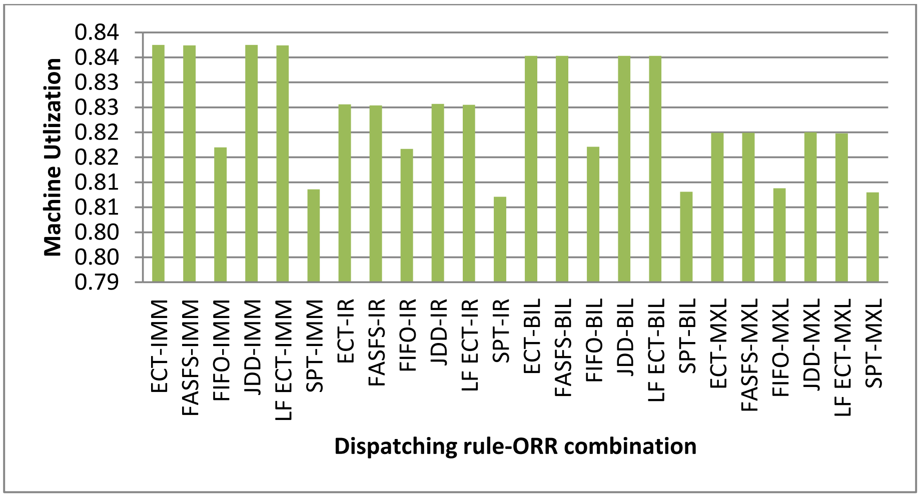

Figure 3- Machine utilization for dispatching rule-ORR combination

When the performance measures are considered as single objectives, FIFO with ORR techniques gives worst result in terms of mean flow time and mean tardiness, but for the machine utilization measure, all dispatching rules have almost similar performance.

To determine best performing rule-ORR combination in terms of the three objectives taken together, Grey Relational Analysis (GRA) is used.

3.1 Results obtained using Grey Relational Analysis

The steps involved in GRA analysis are as follows:

- Grey relation generation
- Grey relational coefficient calculation

Grey relational grade calculation

The weights of the three performance attributes considered in this study are set to be equal all. i.e., 1/3. Table 2 shows the ranking of dispatching rule-ORR combinations based on GRA. Ranks are obtained using grey relational grade. The combination that has the maximum value of the grey relational grade is ranked as the best. From the results shown in Table 2, it is evident that JDD-IRR combination emerges as the best dispatching rule-ORR mechanism in the present study.

Table 2 Ranking obtained using GRA

Dispatching rule-ORR combination	Rank
JDD-IR	1
FASFS-IR	2
JDD-IMM	3
FASFS-IMM	4
LF ECT-IMM	5
JDD-BIL	6
LF ECT-BIL	7
ECT-BIL	8
FASFS-BIL	9
ECT-IR	10
LF ECT-IR	11
JDD-MXL	12
ECT-IMM	13
ECT-MXL	14
FASFS-MXL	15
LF ECT-MXL	16
SPT-IR	17
SPT-MXL	18
SPT-IMM	19
SPT-BIL	20
FIFO-MXL	21
FIFO-BIL	22
FIFO-IMM	23
FIFO-IR	24

5. CONCLUSION

In this research, six existing dispatching rules and four order review/release techniques have been experimented in scheduling an assembly job shop with respect to multi-objective criteria. Mean flow, mean tardiness and machine utilization are used as the performance measures. The Job due date rule with interval release policy is found to be the best performing combination among dispatching rule-ORR mechanisms investigated in this simulation study. Selection of the best alternative while considering multiple performance attributes is very important in manufacturing environments. This research demonstrates the application of gray relational analysis for solving the multi objective decision making problem. In this study, all the performance measures are assigned equal weight; however, weights can be varied depending upon the requirements of a given situation. In the simulation experiments, three levels of product structures are considered. Further experimentation can be carried out with more levels of product structure.

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