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Simulation Modeling of Scheduling Strategies for a Manufacturing System

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Abstract - **In this paper, the performance of various scheduling strategies has been studied involving multiple parts with some dependent and non-dependent operation sequences. It simulated model is based on the processing sequences of the jobs, processing times and inter arrival times. The different dispatching rules modeled are first come first serve, last come first serve, shortest processing time, longest processing time. The performance of scheduling measures has been studied in terms of the average value added time, waiting time, number in, accumulated time, number waiting and instantaneous utilization of resource and total number seized. A numerical example is illustrated to demonstrate the simulation based approach using ARENA towards modeling of scheduling rules/strategies.**

Keywords - Scheduling, Manufacturing systems, Simulation.

1. INTRODUCTION

A Manufacturing system is considered to be a complex system which is highly dynamic and stochastic in nature. Operational performance of any manufacturing system is dependent on the features of its components as well as the organization of these components within the systems. Most manufacturing systems (e.g. dedicated manufacturing systems, flexible manufacturing system, and reconfigurable manufacturing system) are typically composed of a group of machines in a specific arrangement as per the requirement laid down by the operation precedencies along with automation technologies and a work force [Goyal et al. 2013a, 2013b, 2012a].

Scheduling is considered as one of the vital operational procedure for meeting the due dates and ascertaining proper utilization of the available resources [Phanden et al., 2013, 2012a, 2012b; Sharma et al., 2012]. The production schedule is obtained from the production plan, which is nothing but a complete list of steps to be undertaken for producing certain amount of product in a given specific period. As identified by Dief and ElMaraghy (2007) and Hermann (2007) production scheduling coordinates activities to increase productivity and minimize operating costs. Production scheduling is supposed to fulfill three main objectives. The first involves anticipation of time required so as to avoid late completion. The second goal involves reducing the work in process time. The third objective concerns the utilization of various resources [Phanden et al., 2011a, 2011b].

Firms usually want to fully utilize costly equipment and personnel. Often, there is conflict among the aforesaid objectives. Excess capacity guarantees timely completion of job and reduces work in process time but cause lower work station utilization. Releasing extra jobs to the shop can increase the utilization rate and may improve due-date performance but tends to increase work in process time. The operation sequence is an important aspect of scheduling and it is defined as a sequence of machines on which order the part is to be processed [Goyal et al., 2013c, 2012b, 2012c, 2012d 2011]. Quite a few sequencing strategies (for determining the sequence in which production orders are to be run in the production schedule) have appeared in research works. One of the most commonly applied ways of solving a scheduling problem is by using dispatching rules. Many researchers have tried in the past to measure the performance of dispatching rules in manufacturing systems [Baker, 2014]. The conclusion to be drawn from such studies is that the performance of scheduling rules depends on the configuration and data chosen for the system (loading of the system, processing order etc.) [Priore et al., 2001]. The scheduling rules that are used in manufacturing industries nowadays are namely First Come First Served (FCFS), Last Come First Served (LCFS), Lowest Processing Time (LPT) and Highest Processing Time (HPT). FCFS rule processes incoming jobs in their order of arrival at the work station i.e top pereference is given which arrives earliest in the queue. LCFS rule is just opposite FCFS i.e job arriving latest is given the top priority. In SPT rule the waiting job in the queue which takes least time at the work station is processed earliest. HPT, as the name suggest top priority is given to the job which has highest processing time at that work station. There are many sequencing rules that exists in practice, however the rules mentioned above can easily represent those rules.

2. LITERATURE REVIEW

Generally scheduling is an approach to allocate work to various resources within a system. The sole objective of any scheduling problem is to optimize one or more performance parameters pertaining to design and operation of a manufacturing system. Scheduling principles or rules may be either deterministic or stochastic. In deterministic models all the job data are known whereas stochastic model involves not the data but their distributions. As mentioned by French (1982), analytical modeling for any scheduling problem is very complex in nature. However dispatching rules are techniques that allow using practical aspects of this complexity. Many dispatching rules is present in practice [Panwalker & Iskander, 1988] but none of them can be accepted as the most suitable one, so they should be picked on the basis of operating configurations [Ramasesh, 1990a; Blackstone, et at., 2007; Pierreval and Mebarki, 1997]. Pierreval and Mebarki (1997) proposed a rationale for choosing any dispatching rules based on identification of operating conditions.

There have been many researches on application of simulation in the field of scheduling [Ramasesh, 1990b]. Wu and Wysk, (1988) reported a multi-pass expert control system that uses a predefined discrete event simulation to identify dispatching rules for online control and scheduling in flexible manufacturing system. The set of dispatching rules that are to be evaluated is compiled by an expert system. The expert system formulates the set based on system data, system objective and features of ongoing operation [Wu and Wysk, 1989]. The scheduling strategy is dependent on a dynamic selection of pre-specified rule a new selection is carried out as soon as a new machine becomes available [Pierreval and Mebarki, 1997]. Use of simulation for scheduling purposes is achieving momentum in the present scenario, especially due to the constraints in the heuristics of computational scheduling [Basnet, 2011].

Most organization that simulates their manufacturing system uses professional simulation software. This simulation software has the ability to simulate any manufacturing system irrespective of its complexity. Moreover they can be easily incorporated in the problem. The simulation software that are employed for modeling a manufacturing system are Arena, Extend, GPSS/H, Micro Saint, MODSIM III, SES/workbench, SIMPLE++, SIMSCRIPT II.5, SIMUL8, and SLX [Law and McComas, 1999].

3. DEVELOPMENT OF THE MODEL

A simulation model of a typical manufacturing system is formulated to study scheduling strategies in a manufacturing work place. The proposed model of manufacturing system is shown in Figure 1. This is typical prototype of a manufacturing system with consisting of three work station to process six jobs. A scheduling strategy is used to pick a job to be processed from a set of jobs waiting for service. Although the same situation could have been very difficult to model mathematically, the simulation technique made the hypothetical situation easy to formulate. These strategies may be static or dynamic. There are various scheduling strategies and not one alternative can be selected for a one specific environment. These strategies are then applied in the simulation model of the manufacturing system. However these scheduling have considerable impact on system performance. Hence in recent years, major research and study have addressed these various strategies and their implication on performance. The motive of the proposed simulation is to analyze these strategies in the manufacturing system for the measures like work in process (WIP), utilization, value added time, waiting time etc.,.

In this particular simulation model, a typical design of a manufacturing system was considered having a set of jobs to be processed. Some assumptions were made to achieve an approximated design of a manufacturing system. These assumptions are follows

- The operation sequence for all jobs is rigid.
- A machine operates only one process at a time
- One machine is allocated to one work station.
- There is an continuous operation on the machine, once the processing starts
- The availability of machines is uninterrupted.
- Processing time for different jobs on a work station is different.

The model logic is shown in Figure 1. It should be noted that this particular configurations of jobs and machines have multiple routings. The proposed model consists of three work stations named Work Station 1, 2, and 3 having Machines 1, 2 and 3, which perform processes A, B and C respectively. As mentioned in assumptions each work station is holding a working machine. The system produces six types of jobs each visiting different sequence of work stations, e.g. For Job 1 the sequence is ABC i.e. the job arrives at work station 1 and is followed by 2 and 3. The simulation model was formulated and run on the Arena Simulation tool. Four simulation strategies were employed at the work station. However the simulation tool is capable enough to simulate any work station problem following whichever scheduling strategies. The result reported is for aforementioned manufacturing system configuration. The configuration of the manufacturing system and the routing and processing details are shown in Table 1.

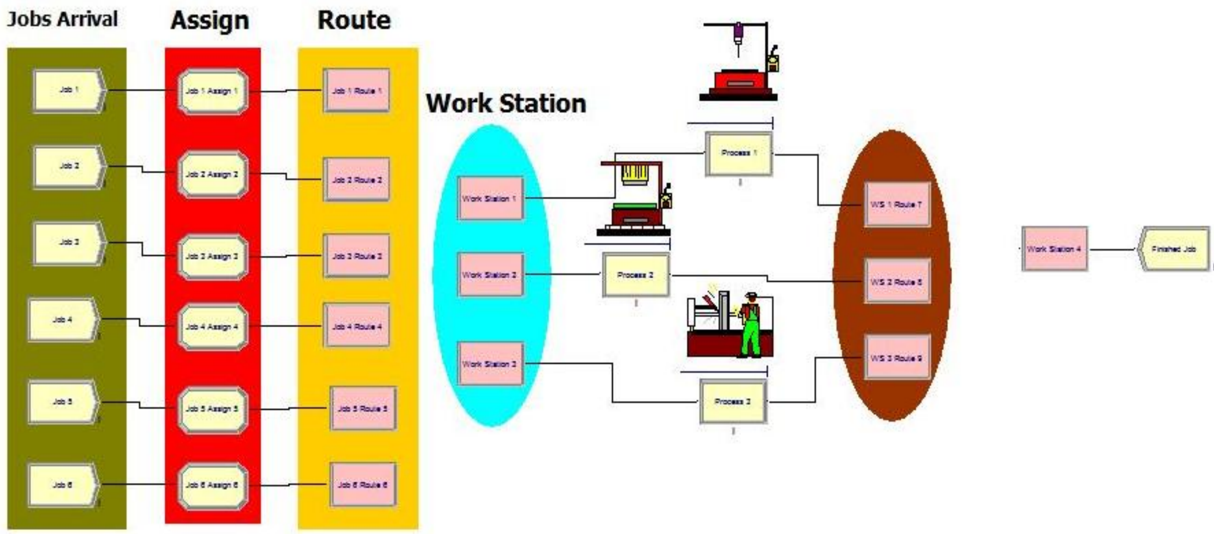

Figure1. Screen shot of simulation model for manufacturing system

Table 1 Jobs process times and process sequences

Jobs	Work Stations			Sequences
	WorkStation 1	Work Station 2	Work Station 3	Processes
Job 1	100	1000	250	ABC
Job 2	1400	400	250	BAC
Job 3	300	1000	1300	CAB
Job 4	500	800	1000	ACB
Job 5	360	100	100	BCA
Job 6	200	150	1500	CBA

4. RESULT AND DISCUSSIONS

For the given configuration and data, the manufacturing system was simulated for different scheduling strategies i.e. first come first served (FCFS), last come first served (LCFS), lowest process time (LPT), highest process time (HPT). The replication length and the number of replications were 1355 hours and 10 respectively. Table 2, Table 3, Table 4 and Table 5 gives the detailed output for all the scheduling strategies employed. Table 2 gives average entity times for all the scheduling strategies, Table 3 gives resource utilization. Table 4 gives work in process details and Table 5 gives the queuing variable details.
The summarized results are as under.

Table 2 Entity time details

Entity Time	FCFS Average (minutes)			LCFS Average (minutes)			LPT Average (minutes)			HPT Average (minutes)		
	Value Added Time	Wait Time	Total Time	Value Added Time	Wait Time	Total Time	Value Added Time	Wait Time	Total Time	Value Added Time	Wait Time	Total Time
Job 1	22.500	1226.11	1248.61	22.5000	915.08	937.58	22.5000	426.94	449.44	22.5000	1242.31	1264.81
Job 2	31.666	1259.95	1294.12	34.1667	317.16	351.32	34.1667	587.99	622.16	34.1667	1165.83	1200.00
Job 3	26.666	665.29	708.63	43.3333	955.22	998.55	43.3333	867.67	911.00	43.3333	781.67	825.00
Job 4	43.333	1019.01	1057.34	38.3333	725.99	764.33	38.3333	432.38	470.71	38.3333	1243.33	1281.67
Job 5	3.333	1045.33	1054.67	9.3333	309.00	318.33	9.3333	114.67	124.00	9.3333	1323.50	1332.83
Job 6	9.166	756.33	787.17	30.8333	391.08	421.91	30.8333	1147.28	1178.11	30.8333	632.17	663.00

4.1WORK STATION UTILIZATION

For the proposed configuration the variation in average work station utilization on application of different scheduling strategies is approximately 59- 66 % for work station 1 whereas it varies from 72-81 % in work station 2 and 97-99% in work station 3. It is observed that the minimal utilization is found at work station and maximum at work station 3 no matter what scheduling strategies are employed. However HPT strategy lowest machine utilization and LCFS strategy is not much of difference. FCFS and LPT are equally good and found to be best among them.

Table 3 Work Station Utilization

Resource Usage	FCFS		LCFS		LPT		HPT	
	Utilization, (%)	Total Number Seized	Utilization, (%)	Total Number Seized	Utilization, (%)	Total Number Seized	Utilization, (%)	Total Number Seized
Machine 1	0.6654	116.00	0.6654	116.00	0.6654	116.00	0.5910	116.00
Machine 2	0.8161	116.00	0.7325	110.00	0.8161	116.00	0.7276	116.00
Machine 3	0.9932	116.00	0.9711	109.00	0.9932	116.00	0.9932	116.00

4.2 WORK IN PROCESS (WIP)

In any manufacturing system higher the work in process lower is the desirability of system. For our proposed model the FCFS, LCFS, HPT rules is observed to be insignificant on the point of work in process (WIP) but the LPT scheduling strategy is showing the best results with lowest WIP count and hence can be safely applied over other three strategies. WIP is varying with the job in consideration shown in Table 3. At some point LCFS is identified as the better option but LPT remains good on overall approach.

Table 4 Work in Process Inventory details

Entity	FCFS Average		LCFS Average		LPT Average		HPT Average	
	Number In	WIP	Number In	WIP	Number In	WIP	Number In	WIP
Job 1	18.0000	16.5867	18.0000	14.9194	18.0000	5.9705	18.0000	16.8020
Job 2	17.0000	16.2362	17.0000	4.4077	17.0000	7.8057	17.0000	15.0554
Job 3	20.0000	10.4594	20.0000	14.7387	20.0000	13.4465	20.0000	12.1771
Job 4	21.0000	16.3868	21.0000	11.8456	21.0000	7.2952	21.0000	20.3506
Job 5	25.0000	19.4588	25.0000	5.8733	25.0000	2.2878	25.0000	24.8691

Job 6	15.0000	8.7140	15.0000	4.6706	15.0000	13.0418	15.0000	7.3395

4.3 WAITING TIME

Again minimum possible waiting time is suitable for any manufacturing process. In these criteria the performance of LPT remains consistent as compared to other strategy. But however LCFS also shows some promising results.

Table 5 Queuing variable details for the proposed model configuration

Queue	FCFS Average (minutes)		LCFS Average (minutes)		LPT Average (minutes)		HPT Average (minutes)	
	Waiting Time Average (minutes)	Number Waiting (Average)	Waiting Time Average (minutes)	Number Waiting (Average)	Waiting Time Average (minutes)	Number Waiting (Average)	Waiting Time Average (minutes)	Number Waiting (Average)
Process A	152.25	13.0338	307.77	26.3480	144.94	12.4077	317.58	23.6932
Process B	108.88	9.3210	71.6667	8.2349	139.69	11.9588	159.23	14.1968
Process C	736.05	63.0123	242.45	19.5036	268.74	23.0062	658.71	56.3918

From the above discussion it is found that the impact of scheduling strategies on performance is observed to be significant. Thus it must be emphasized that the suitable scheduling strategy varies with manufacturing system configuration. Depending upon the configuration data the performance of various strategies varies on attributes such as work station utilization, WIP, waiting time etc.,. However in our proposed model LPT scheduling strategy is found to be best among the four.

5. CONCLUSION

The model developed of a typical manufacturing system and its study on scheduling strategies through arena simulation tool justified the fact that simulation is an important part for performance evaluation in any manufacturing environment. The use of arena simulation quiet helped to achieve the required goal. However the application of various scheduling strategies and its impact on the process efficiency was the main objective. The efficacy of the different strategies varies with system configuration and process data. The simulation can be carried for any number of process parameters and performance measures.

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