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Resource Optimization on Flow Shop Scheduling for Industrial Case Using Simulation

Ibrahim Al Kattan, Director, Graduate Program, Engineering Systems Management, American University of Sharjah, ialkattan@aus.edu

Ahmed Al Nunu, Engineering Systems Management, American University of Sharjah, ialkattan@aus.edu

ABSTRACT
The objective of this study is to use the simulation technique to help the decision maker to have all details about resource analysis and make scientific decision. Simulation helps to take right decisions at appropriate time of production by predicting the production bottlenecks, work-in-process (WIP) inventory, resource utilization and feasible schedules. In addition, simulation offers flexibility in the production planning and scheduling and also offers many advantages like visualization of activities through dynamic graphs, plots, tables etc. Additions or modifications of resources could be incorporated and effect the production system which could be clearly observed through animation and graphics before introducing them in the real production system. In this study an industrial problem is addressed by analyzing the capacity of the resources, and the number of transporters and their speed. Necessary changes are made and simulation results are gathered and analyzed. This process is continued till the best results are achieved. Statistical analysis with simulation enhances the production manager to view in depth all scenarios of the operations and resource limitations and optimization.

1. INTRODUCTION
Simulation is the act of mimicking the behavior of real systems, usually using computer software. Simulation is the process of designing and creating a computerized approximate model of a real or proposed system for the purpose of conducting numerical experiments to give us a better understanding of the behavior of that system for a given set of conditions. In other words simulation is program that can be used to numerically evaluate the real life systems by imitating the system's operations or characteristics over certain time [5]. The applications of the simulations in real systems are wide and varied. Simulation could be used to install traffic lights with different sequencing to find the settings to reduce the rush hour traffic, create a facility model with different job priorities to observe the machine utilization and queuing of the jobs and could be used to analyze the performance of a facility by creating variety of the layouts, vehicle layouts and variety of transportation equipment. Numerous simulation software is in the market, some of them are WITNESS, SIMULINK, ITI-SIM, SIMPROCESS, PROMODE AND ARENA.

Scheduling is a decision making process to arrange activities in order to meet certain objectives in order to have resource optimizations and to perform tasks with a given set of criteria and constraints [3]. Resources could be machines, tools, materials, money, and labor. The scheduling problems that occur in the manufacturing industries are very complex in nature and are referred as combinatorial Non-Polynomial (NP) hard problems. Combinatorial NP hard problems are subjected to high complex constraints and only finite numbers of feasible solutions are possible. These problems are very difficult to solve using existing heuristic or conventional methods. In manufacturing industry, job scheduling is very much essential for proper machine utilization, work-in-process (WIP), increases of production rate and for appropriate machine selection. Many scheduling algorithms such as integer programming, dynamic programming, graph theory application, neural network, Tabu search, branch and bound and other heuristic approaches have been attempted to solve general flow shop applications [3]. Most scheduling applications consider only one criterion. However, most of these heuristics approaches generate many alternative scheduling solutions. These alternative solutions could be analyzed in detail with respect to many other performance criteria and resources. Simulation is a powerful tool to investigate these alternative solutions and reach a rational decision of resource optimization depends on the industrial case by case situation.

2. BACKGROUND OF THE INDUSTRIAL CASE
The simulation is conducted on industrial case problem with 10 jobs carried out through 6 different working centers. ARENA simulation software version 7.0 is used to model this problem and observe the results for performance measures like work-in-process, WIP, queue length, inventory space and machine utilization. The model is built based on one of the heuristic method used to obtain several solutions close to optimum. The statistics of the results of the processing times of all 10 parts were collected and also the machine or resource utilization and queue length of all working centers were recorded. The results were analyzed and based on the reading of their utilizations and queue lengths. It was found that some resources are excessively used, which led to slow throughput and also unexpected machine break down. This may drastically reduce the number of parts processed out of the system and increase the average WIP of the system. The points, where these bottlenecks occurred are determined and modifications such as increasing the resource capacity are made to the existing system. Therefore, depending on the nature and the requirements of the company, a production planner may choose the attributes that could improve the company's output and profit. Hence, simulation is the last resort to have a good representation of many alternative schedules considering many performance criteria.

This example is taken from an industrial partner. The production plant produces 45 different components. The first step was to group the 45 components into 4 family parts, led to building 4 manufacturing cells [2]. Further analysis of resource optimization will be conducted in this study by considering only one of the cells which consists of 10 components being manufactured through 6 different work centers. The final data of the case study, such as the processing time and the production volume of each part are given in Table 1. Each part considered as a job order which includes several operations. The processing time and the sequence of each part were recorded. The processing time are normally distributed with the mean and standard deviation for part 1, 2, 3, and 4 on corresponding cell. The processing time for part 5, 6, and 7 on corresponding cell are exponentially distributed with the given mean. The processing time for part 8, 9, and 10 on corresponding cell have triangular distribution with the values of (minimum, most likely, and maximum) as indicated in the table, all the values are given in minutes.

Table 1. Processing time of ten parts and six work centers

Parts	M1	M2	M3	M4	M5	M6	Production Volume
P01	9.5,2		4.1,2.8			9.7,2.4	10 %
P02		10.1,2.1	9.4,3		8.3,1.6	8.1,1.9	14%
P03			11.1,1.7		14.9,2.8	11.9,2	8%
P04	11.9,1.8		8.9,1.6				10%
P05		12	25	19		2	8%
P06			11		9		8%
P07		6	9	10			22%
P08			5,9,22		11,17,23	12.16,21	10%
P09		9,12,21	5,7,17	8,18,22		7,8,21	5%
P10	8,9,17		11,19,25		4,8,16	8,22,36	5%

Table 2. Manufacturing Cell Description

Cell 1	Shaping center	with capability of horizontal and vertical shaper
Cell 2	Turning center	with lathe machine
Cell 3	Drilling center	with 3 drill machines (old and two new with +50% performance)
Cell 4	Sawing center	with contour saw
Cell 5	Milling center	with two machines with special attachment for slab and face milling
Cell 6	Measurement & Inspection	The inspection time are given
Cell 7	Collecting area for shipping	An average of 1 minutes for every handling

3. MANUFACTURING CELL

The flow shop schedule for the manufacturing cell of industrial case problem with 10 jobs carried out through 6 different working centers are shown in Table 2. The layout of the product and material handling is given in Figure 1. The cell consists of six work centers plus the last stage of warehouse for shipping area [5].

4. BUILDING THE SIMULATION MODEL

For modeling this system, it is important to create an entity representing raw material for each part with the corresponding volume. The simulation software define the parts using the *create module* with arriving rate close to exponential rate at 5 minutes as a inflow of the parts. Each cell will be modeled with *an enter, process and leave modules*, except for cell 7 where there is no process. Also we will use a *leave module* for the releasing of the parts to the system and an *enter module* before the *dispose module* which represent the shipping process. For the inter cell transportation a conveyer will be defined in the *conveyer module* and the distances between the cells are introduced in the *segment module*. And for shipping, Fork Lift can be defined in the *transporter module* with the distances in the *distance module*. In this system we have a failure situation for the machines and for the fork

Figure 1. Layout of product flow and material handling

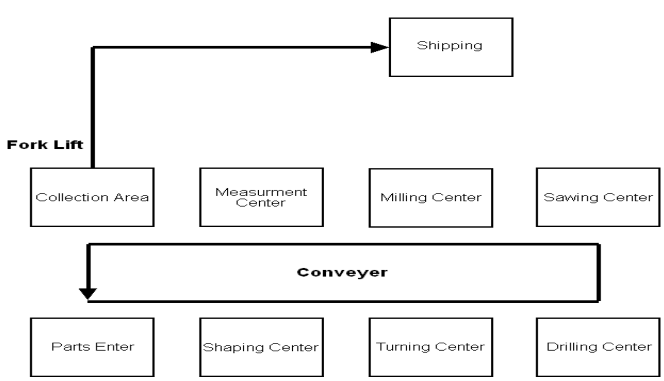

Table 3. Queue Comparison

	First Run - OMC		Second Run - MMC	
Process	Average Number in Queue	Maximum Number in Queue	Average Number in Queue	Maximum Number in Queue
Shaping center	0.5266	5	0.5156	4
Turning center	1.4319	20	1.4060	11
Drilling center	0.3758	8	0.2973	6
Sawing center	2.1543	10	2.6251	14
Milling center	0.4055	5	0.4279	8
Measurement & Inspection	11.6708	36	0.5205	6
Collecting area for shipping	0.2502	6	0.5354	7

lift. It is defined as the failure parameters in the *failure module* and set the *resource module* for each machine.

The simulation runs for 8.5 hours representing a full day of work for 10 samples using the 10 replications of the system. A warm up period of 60 minute will be used to get the system for a steady state. This will help to analyze the queue size of each process, the utilization of each machine, conveyer and the fork lift. Form the above tables we notice that Measurement cell has a high average of queue and Utilization. Also the maximum number of queue for the Turning center is high. To decrease these values we have an option of increasing the number of machine in these cells. This could be implemented by using the Arena optimization tool.

5. TESTING AND ANALYZING THE RESULTS

The optimization tool needs control parameters, objectives and requirements. In this case the number of machines; in the turning; sawing; and measurement cells are considered to be control parameters. The objective is to minimize the number of queue size for the measurement cell. The requirements are to keep the utilization of the measurement machine in a range between 55% - 70%, and to keep the number of queue for the turning, sawing and measurement cells below 10 parts. After running the optimization tool the solution is to add one measurement machine in this cell. The simulation software has been used to compare the output of original manufacturing cell (OMC), and the modified manufacturing cell (MMC). The first run represents the average of ten replications of the OMC, while the second run represents the average of ten replications for MMC.

As a result we manage to minimize the number in queue for the turning center and measurement center, and the utilization of the measurement machine. The output report in Table 3 and Table 4, show the comparison of the first and second run and the utilization for the measurement machine. The average number in queue reduced from 11.6708 to 0.5205 which is a great improvement and the maximum number in queue reduced from 36 to 6. Due to this change the average utilization of the fork lift

Table 4. Utilization Factor Comparison

	First Run	Second Run
Machine name	**Average Utilization**	
Shaping Machine	0.5627	0.5303
Turning Machine	0.5137	0.5429
Drilling Machine old	0.6345	0.5970
Drilling Machine new	0.3968	0.3473
Sawing Machine	0.7140	0.6730
Milling Machine	0.5538	0.5239
Measurement Machine	0.8734	0.6061
Conveyer	0.02683343	0.02611947
Fork lift	0.5294	0.6374

increased from 0.5294 to 0.6374, where the arrival rate to the fork lift increased. However, the increase in the number of machine for the measurement cell reduces the utilization factor. Hence the queue size reduction led to increase the arrival rate for the fork lift leading to higher utilization factor.

6. CONCLUSION

Simulation is used to test this industrial case study with ten jobs conducted on six work centers to analyze the resource optimization. ARENA simulation software version 7.0 is used to model this problem and study the results for different performance measures like WIP, queue length and machine utilization. The model is built based on one of the optimum flow shop sequence obtained from heuristic method and run for 10 replications [2]. The correlation of the processing times of all 10 parts are discussed with respect to the machine capacity, other resource utilization such as WIP and queue length for all 6 work centers. The results are analyzed and modified based on their utilization and queue lengths. Also, the results show that some resources are excessively used and lead to slow throughput. This may drastically reduce the number of parts produced out of the system and increase the average WIP. This causes bottlenecks in the system which could be solved by modifications such as increasing the machine capacity as shown in the modified manufacturing cell. Hence, the average of throughput for all ten parts increased by 21%.

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