

A Comparison of Job-Shop and Group Technology Using Simulation by ARENA

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Abstract:

Production planning is performed through diverse methods according to the type of the system it is structured upon. One of the most important steps before production planning is to determine which system best fits the firm, and how the facilities should be designed. Both job-shop and group-technology systems have their own pros and cons, each of which is suitable to a specific kind of factory. On the other hand, performance measurement is also important in terms of both productivity and queue factors. A good method to measure the performance is computer simulation by soft wares such as ARENA. This paper utilizes the software for separately simulating both the job-shop and group-technology systems for specific firm, and then compares the results. The results show that the group-technology system is better than the job-shop system in both productivity and queue factors, and it is highly recommended that the system should be changed.

Keywords

Production System Design, Job Shop, Group Technology, Cellular Manufacturing, Computer Simulation.

1. Introduction

Production planning is the best utilization of the resources in order to fulfill the goals in a certain period, called planning horizon [1]. Designing a suitable system to a factory or a workshop not only improves the manufacturing conditions such as quality, leanness, agility, low defects, excellency, etc., but it also develops the business economic conditions. A special production system with a relative facilities layout is appropriate for a certain manufacturing firm. For example, a flow-shop system best fits a firm in which a unique pattern of job sequence is used for all the products types [2]. Meanwhile, mass production is possible due to this system, too. However, if the processes are different and technical, it is better to put the same machines together in order to minimize the number of times the experts should pass through the corridors and gates [2]. The facilities layout, which is called the job-shop, prevents mass production because of high intersections and complicated pathways. Based on group technology and cellular technology, those products parts of the same job sequences are put together in a certain cell as a part family to keep the possibility of mass production besides the factor of diverse processes and semi-manufactured products. Therefore, it seems to be practical to compare the performances of two different types of production systems with their relative facilities layouts [2].

The structural innovation of this study is the notion that two different production systems with their layouts are assumed for a certain imaginary firm and the performances in both systems are compared in details. The performing innovation of the study is using computer simulation for each

system separately. The simulation application was ARENA 13.50.1414. The initial perception of the problem is assuming both systems to be the same, but the following factors show the opposite fact. The factors are (1) the average waiting time in the queue of each machine, (2) the average WIP time of each product, (3) the number of output products in a certain period of time (daily in this study), and finally, (4) the average daily queue length of each machine.

The main idea of the study is based on the fact that it is possible to precisely simulate a manufacturing system by a computer software (here, ARENA) in order to monitor, measure, and record the quantities of the systems. The firm of this study produces and repairs the lower conjuncture of a certain type of water valve in two different diameters. The firm is equipped with two types of lathing machines, three types of milling machines, and a grinding machine. More details shall be discussed later.

The following sections of the paper present the information about the simulation of current (job-shop) and suggested (GT) systems of the firm in a 10-day period. The steps required for converting the system from JS to GT are explained. The comparison of the above factors values finally recognizes the performance-superior system for the firm.

2. Literature Review

Job-shop production system is to arrange the machines with the same process and purpose in a workshop [3]. Group-technology production system is to arrange the machines in a way that the number of transits of the semi-manufactured products and the specialized experts of certain operations is minimized. In order to implement the group technology in a firm, the similar parts of different products are assumed as a part family and the machines related to that part family are located near together in cell [3]. The priority of GT is to maintain both advantages of mass production and diverse processes. Different features of these two systems lead managers to choose one in an appropriate situation. When both systems are possible in a firm, the comparison of performances usually shows the priority of the GT systems. Table 1 illustrates a quick literature review of relevant studies with a focus on the selected factors to compare the performances.

Table 1. Literature review

	Innovation	Factors	Refs
1	Randomly change the process time to determine the manufacturing policy	Production duration average / predictability of production time	[4]
2	Comparing the number of transits	Job satisfaction	[5]
3	Comparing the Job-shop, cellular and a hybrid system with stochastic and deterministic demands	Three queue factors ^I and three process factors ^{II}	[6,7]
4	Converting the job-shop system to GT	WIP / average presence time	[8]
5	Artificial neural networks in simulation by ARENA, SIMAN, and ProModel	Average processing time for each machine / the portion of each product in the firm input	[9]
6	A multi-criteria method in solving the problem of up- and downloading in AVG factories	Lacking time / waiting time / average passed distance	[10]
7	Evolutionary algorithms in simulation to find the approximate time of multi-products distribution in pressing industry	Average and maximum production time / average and maximum delay in input	[11]
8	Comparing job-shop and GT in manufacturing hard discs	Efficiency of grouping / intercellular flow of products / WIP distance	[12]

^IAverage queue length / average waiting time in queue / average presence time

^{II}Average transit time / average passed distance / average WIP time

A review paper discussed on the appropriate groupings in different aspects for techniques and models of planning the integrated production and distribution; the aspects of grouping include complicatedness, solving method, and even the impact on future studies on the area of integrated production and distribution [13].

3. Methodology

This paper compares two systems of production, job-shop and group-technology, in a manufacturing firm of lower conjuncture of a kind of water valve by simulation in ARENA. The queue and performance factors include the average waiting time in a single machine queue, the average queue length for a single machine, the average work in process (WIP) time, the total number of finished products in a 80-hour period (i.e. 10 consecutive working days or 4800 minutes), the total number of products entering the system in the same period, the average time of a single product transit, and the average waiting time of a single product. Comparing the factors values in both systems types, the authors succeeded to make a quantitative criterion for evaluating the efficiency of two production systems and finally choosing the better system for firm.

3.1 The firm description

The firm produces the lower conjunctures of a certain kind of water valve with two different diameters (6 and 8 mm). The customer sometimes returns the product due to the unwanted papilla for further lathing process with more preciseness. Sometimes the customer is dissatisfied because of the small diameter of the product due to wrong measurements, wrong order record, or idea changing. Regardless of the cause, it is only possible for the firm to enlarge the diameter of the valve. From here on, in order to make the explanations easier, the term “valve” would be used instead of “lower conjuncture of a certain kind of water valve”. It is also better to separate four different types of product as follows: Product A – Regular valve with a 6 mm diameter; Product B – Large valve with a 8 mm diameter; Product C – To-be-repaired valve; and Product D – To-be-enlarged valve. The production instruction patterns of all four products are illustrated in Table 2 (The empty cells mean that there is no need of the column process for the row product).

Table 2. Patterns of products processing durations and entering

Pattern of Product	Entrance Time		Lathing Duration		Milling Duration		Grinding Duration	
	Distribution	Parameter	Distribution	Parameter	Distribution	Parameter	Distribution	Parameter
A	Expo	95.91	Expo	15.6125	Expo	60.3125	Fixed	16
B	Expo	108.77	Expo	22.4763	Expo	62.7842	Fixed	20
C	Expo	117.23	Expo	1.5526	-	-	Fixed	35
D	Expo	159.14	-	-	Expo	1.1488	Fixed	44

The firm is equipped with six machines as follows:

1. Grinding machine: G
2. Lathing machines: L_1 – Normal (0.1 mm) and L_2 – Precise (0.001)
3. Milling machines: M_1 – Normal (1 mm); M_2 – Strong (A^{++}); and M_3 – Precise (0.01 mm) but Weak (C)

Jobs/operations sequence of every four product in each of six machines is as follows:

- A: $L_1 - M_1 - G$
- B: $L_1 - M_2 - L_2 - M_2 - G$
- C: $L_2 - G$
- D: $M_3 - G$

No priorities for the products are considered to make the simulation process easier.

3.2 Job-shop production system simulation

In the process-oriented system of production (JS), the firm is divided into three following shops: (1) Lathing Shop (L_1 and L_2); (2) Milling Shop (M_1 , M_2 , and M_3); and (3) Grinding Shop (G) (See Figure 1).

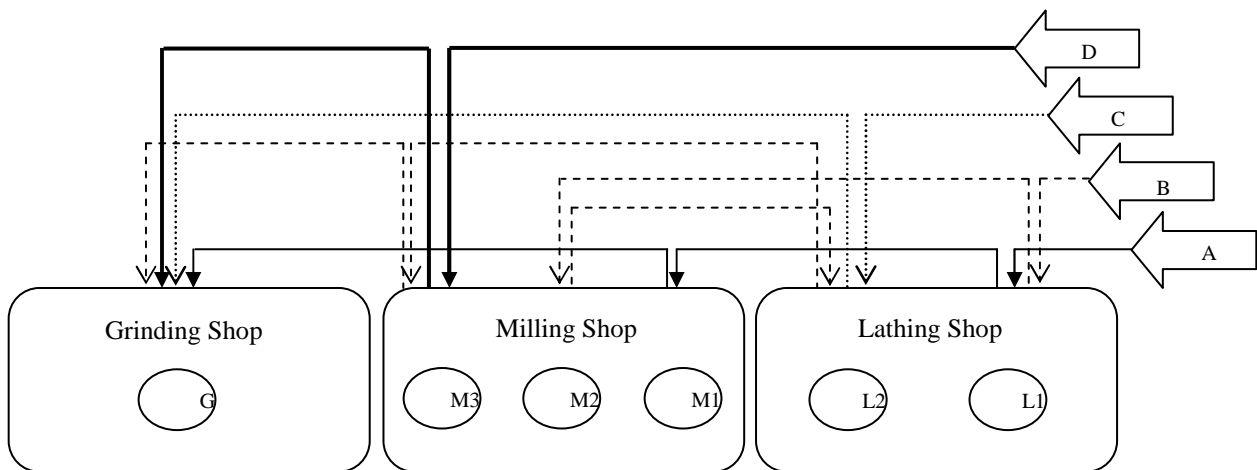


Fig. 1. Job-shop facilities layout

It should be noted that the final preparation operations in this firm include coloring, packaging, and storage, which is ignored in this study due to similarity in both systems. Figure 1 shows the complexity and inefficiency of this system. Transit between two machines within a shop takes less than 1 minute (which is ignored in the study) and transit to a machine in another cell takes 5 minutes approximately.

In fact, the only difference between the two production systems in this study is the transit durations. The final simulation models of both systems are almost the same. The simulation application of ARENA outputs the following results about JS system after being run. The results are generally divided into two categories: machine-based and product-based (shown in Tables 3 and 4, respectively).

Table 3. Machine-based results job-shop system using ARENA

Machine	Mean	L ₁	L ₂	M ₁	M ₂	M ₃	G
Average Waiting Time in Queue	1008.217	994.02	1074.87	902.67	892.92	1086.62	1093.20
Average Queue Length	10.886	18.7123	10.5979	7.0812	5.9661	7.8467	15.1137

Table 4. Product-based results job-shop system using ARENA

Factor (units)	Mean / Sum	Product A	Product B	Product C	Product D
WIP Time (min)	S: 66.603	22.7601	19.9589	12.8524	11.0316
Average Presence Time (min)	M: 2050.703	2039.84	2304.26	1896.65	1962.06
Total Output (in 10 days)	S: 35	12	2	13	8
Total Input (in 10 days)	S: 163	53	40	39	31
Average Transit Time (min)	M: 17.5	20	30	15	5
Average Waiting Time in Queue (min)	S: 1939.188	1930.04	2071.07	1843.82	1911.82

3.3 Group-technology production system simulation

The implementation of Group-technology system requires some initial steps. First, the machine-part matrix is constructed and a method of part family determination (here, binary method [14]) recognizes the part families simply within two stages. In the present study, a temporary elimination of one critical machine (G) and one critical part (B) is required. Two cells are considered for two part families and a separate location out of the cells is assigned to the critical machine (G). A separate production planning is also designed for the critical product (B), which is necessarily a traveling-through-cells production path. Equations (1) and (2) show the results of the part family determination:

$$PF1 = \{A\}, PF2 = \{C, D\} \quad (1)$$

$$MG1 = \{L1, M1\}, MG2 = \{L2, M3\} \quad (2)$$

Figure 2 illustrates the design based on group-technology.

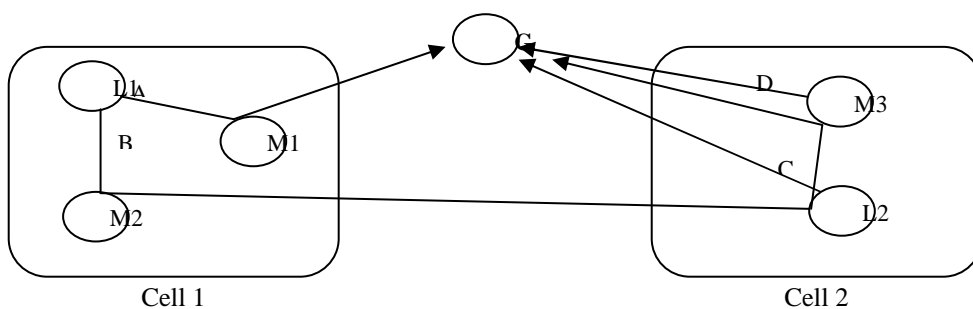


Fig. 2. Group-technology facilities layout

Transit between two machines within a shop takes 1 minute and transit to a machine in another cell takes 10 minutes approximately. Moving from a machine in any cell to machine G takes 4 minutes. The results of running the simulation model of this system are shown in Tables 5 and 6, respectively.

Table 5. Machine-based results group-technology system using ARENA

Machine	Mean	L ₁	L ₂	M ₁	M ₂	M ₃	G
Average Waiting Time in Queue	907.952						
Average Queue Length	9.535						

Table 6. Product-based results group-technology system using ARENA

Factor (units)	Mean / Sum	Product A	Product B	Product C	Product D
WIP Time (min)	S: 58.307				
Average Presence Time (min)	M: 1987.160				
Total Output (in 10 days)	S: 34				
Total Input (in 10 days)	S: 149				
Average Transit Time (min)	M: 8.5				
Average Waiting Time in Queue (min)	S: 365.9329				

The simulation model for both systems in ARENA is shown in Figure 3. A CREATE module for every product and a PROCESS module for every machine is considered. Distribution parameters of product entrance and processes are entered into the modules similarly for both models. Time values of transit for each of the systems are entered separately into their respondent simulation models. As can be seen in Figure 3, some products have to wait in queues before ceasing a machine because it was already being occupied by another product.

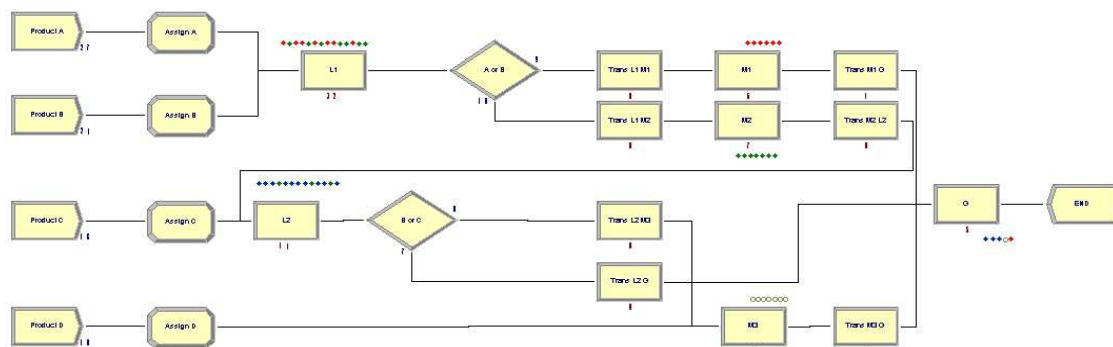


Fig.3. A schematic view of the simulation models in active mode

4. Results and Discussion

As shown in Table 4, job-shop production system could only finish 35 product out of 163 entered ones (finishing ratio = 0.21472 in 10 days). The same results for group-technology system, as seen in Table 6, are 34 finished products out of 149 entered ones (finishing ratio = 0.22819 in 10 days). It shows that GT is a little better than JS in this regard. In the JS system, machines G and L₁ are recognized critical among all, in the average waiting time in queue and the average queue length, respectively. As can be seen in Table 5, machine G is not more critical in the GT system. Only machine L₁ is critical here. Product B has the largest value of presence time in the system, because its production path is longer than that of the others.

The results in Tables 5 and 6 demonstrate that converting the production system improves both queue factors like average waiting time in machines queues and operative factors like the ratio of total output to the total present products (yield), average WIP time, and average presence time (Note that increase in WIP is a good change due to the fixed amount of presence time). Only two

cases of product B (the critical one from the viewpoint of production instruction) are finished in the JS system, while GT succeeded to finish 5 ones in the same period. Product B is not the product with the most processing time in spite of the longest production instruction. The factor is maximum for product A (another sign of satisfaction in GT). Another desirable consequent of converting the system is the decrease of half-manufactured products from 128 to 115 in 10 days (1 % daily).

In general, both queue and operative factors were improved by converting the JS system into GT. It is again noticeable that the only difference between the two systems in this study is the passing time between the machines. It means that it is still possible to increase the system yield much more than now by optimization of part family determination, machine improvement, duplicating the number of critical machines, and so forth. As a whole, the results show the priority of GT in comparison with JS in both categories of factors.

5. Conclusion

Knowing the information about diverse layouts in a firm before the production planning can prevent many problems. Hence, it is vital to study enough before designing and taking decision about production system policy. The study utilizes ARENA application to simulate two different production systems (job-shop and group-technology) for a firm that manufactures the lower conjuncture of a kind of water valve. The application is chosen due to its high efficiency in changing the policy of production needless of changing all the modules. The other privilege of ARENA is being structured and object-oriented.

The results obtained from two simulation models indicate that converting the production system of the firm from job-shop to group-technology (cellular) improves the yield and productivity of the firm. For example, the average number of daily half-manufactured products decreases 0.7 (7 products per 10 days) and the total waiting time in queues decreases 1573.2551 minutes (a significant improvement); thus it is recommended to the managers to convert the system this way in order to improve the firm.

The results also reveal to the managers that which of the systems has better results. Choosing the better policy, they arrange the machines based on the selected layout and attempt to optimize the other factors. Studies of this kind can help the managers to take science-based and statistics-supported decisions. Lack of such studies causes obscurity of the best policy of production in the sight of managers. Decision support systems minimize the probability of loss and help managers guarantee stable benefits in current competitive markets.

Limitations of this study include the non-deterministic nature of the input data, the small scale, tutorial distributions, lack of priority among the products, and so forth. It is recommended to the readers to check other changes such as dividing the shops of the process-oriented system into different shops according to their precision in processing the product. It is also recommended to consider a kind of priority for some products based on some policies, which can be the priority of new customers or satisfying the old ones. Another recommendation is to consider the growth curve of the operators and changing the statistical distributions of processing time. A suggestion could be the hybrid method of MADM (such as lexicography) and part family determination in order to optimize the grouping process. Another possibility for the readers is to consider a more complicated system in order to show the privilege of computer simulation even more. The final suggestion is

elongating the duration of simulation and replicating it many times to obtain normal average results. The authors are trying to combine the method with statistical methods of comparison.

6. References

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