Journal University of Kerbala , Vol. 15 No.1 Scientific . 2017

A Performance of Cellular and Job Shop Manufacturing Systems Using Simulation-A Case Study

تقييم اداء نظامي التصنيع الخلوي والوظيفي باستخدام المحاكاة- دراسه تطبيقيه

Dr. Sanaa Ali Hamza
Al-Furat Al-Awsat Technical University / Kerbalaa Technical Institute- Field: Industrial Engineering-E-mail: sanaalihamza62@gmail.com, Phone: 07802143995

Abstract : –
Cellular manufacturing that is based on group technology philosophy and job shop are two different manufacturing systems that are used widely in many firms and factories. Each of them have some characteristics suitable for some factories based on the production types and the policies of those factories. A performance measurement is very essential for each factory to identify the effectiveness of its manufacturing system. There are many techniques and formulas that are used to identify the performance of the manufacturing systems. One of the well-known techniques that used widely for this purpose is the simulation. The current paper used Arena software for simulating both cellular and job shop manufacturing systems separately in State Company for Mechanical Industries which is located in Iraq. After comparison by using some performance factors, cellular manufacturing showed better performance than job shop in terms of the average transfer time with percent of improvement (60.03)%, average total manufacturing time with percent of improvement (15.97)%,, average work in process time with percent of improvement (10.94)%,, schedule utilization with percent of improvement (7.93)%, and the average number of output products with percent of improvement (18.84)%.
Keywords: Arena software, cellular manufacturing, group technology, job shop manufacturing, simulation

المستخلص
نظام التصنيع الخلوي المعتمد على اسس تكنولوجيا المجاميع ونظام التصنيع الوظيفي هما نظاما تصنيع مختلفان ويستخدمان بشكل واسع في المصانع والشركات. ان كلا من هذين النظامين يمتلك خصائص معينة ويستخدم حسب طبيعة الانتاج المتبعة وحسب سياسة الشركات والمصانع. إن قياس الأداء مهم لكل مصنع لتحديد كفاءة نظامه التصنيعي. وتوجد عدة طرائق لقياس اداء أنظمة التصنيع ؛ وواحدة من الطرائق المعروفة والمستخدمة لهذا الغرض هي طريقة المحاكاة (Simulation). في البحث الحالي تم استخدام (Arena Software) لاجراء عملية المحاكاة لنظامي التصنيع الخلوي والوظيفي بشكل منفصل في الشركة العامة للصناعات الميكانيكية في الاسكندرية. بعد ذلك استخدمت نتائج المحاكاة لاجراء مقارنة بين اداء نظامي التصنيع اعلاه وباستخدام مجموعة من مقاييس الاداء. وقد بينت النتائج ان نظام التصنيع الخلوي اظهر اداء افضل من ناحية متوسط وقت النقل (Average Transfer Time) بنسبة تحسن (60.03%)؛ متوسط الوقت الكلي (Average Total Time) بنسبة تحسن (15.97%)؛ متوسط العمل تحت التنفيذ (Average Work in Process) بنسبة تحسن (10.94%)؛ متوسط عدد المنتجات الخارجة (Average Number of Output Products) بنسبة تحسن (18.84%) وجدولة العمل (Schedule Utilization) بنسبة تحسن (7.93%).
الكلمات المفتاحيه: التصنيع الخلوي؛ تكنولوجيا المجاميع؛ التصنيع الوظيفي؛ المحاكاة؛ برنامج (Arena Software)

1. Introduction

Cellular Manufacturing (CM) is one of the successful applications of the Group Technology (GT) concept. CM divides the manufacturing system into some subsystems that lead to facilitate the management and control of the manufacturing system [1]. Additionally CM leads to get some benefits such as the reduction in the cost of: materials, labor, manufacturing, machines, tools,….etc, and the reduction in the times of: setup, throughput, lead, delivery, waiting, travelling,… etc [2].

Furthermore, it leads to simplify materials flow, improve human relations and decrease work-in-process inventory, enhance the productivity and modify the quality [3]. CM works based on collecting similar parts into groups called families and the related dissimilar machines into groups called cells [4].

However the job shop manufacturing system used for a customized products, low volume and its layout is a process collecting of machines. For example, a group of drill machines are located in one location, lathe machines in another location, shaping machines in another location and so on. Different jobs transfer from one area to another in a different way. Thus, the flow of materials is hard to recognize. This type of layout is suitable for an assemble-to-order or a make-to-order production environment, where the demand fluctuates, the customization is high and the volume of production is low. Since a wide variety of products are produced, workers with various skills and general purpose machines are required in this type of manufacturing system.

In the current paper, the performance of the two manufacturing systems: job shop and cellular manufacturing has been compared. The application of the simulation method is performed based on using Arena software (12.00 CPR 9). The selected performance factors that used for comparison are: average transfer time, average total manufacturing time, average work in process time, schedule utilization and the average number of output products.

The remaining sections of the present paper include the review of the related literature, methodology, company description, job shop and CM systems, simulation models of both systems, the obtained results and finally the conclusions.

2. Literature Review

Cellular manufacturing and job shop systems are two major manufacturing systems in many companies and factories. The structure of CM is based on cells of dissimilar machines and families of similar parts. However, job shop system is based on locating the similar machines in separate workshops. Based on the production type and the policy of the firms, sometimes job shop is suitable to select but another time CM is preferred. When both systems can be used, a comparison refers that CM is more suitable because of its positive impact. The selecting of the appropriate layout design is very essential for each factory before applying the production planning.

Yang and Deane [5] have addressed three important issues affect the cell formation design: set up time, processing time and mix size for part. Altinkilinc [6] has used the simulation method by Arena software to evaluate the layout design of the existing manufacturing system and the new suggested system. The new system based on CM was created by Rank Order Clustering (ROC) and Computerized Relative Allocation of Facilities Technique (CRAFT) for facilities layout. Savory and Williams [7] have integrated the discrete-event simulation model with the Activity-Based Costing (ABC) to offer more precise estimates of manufacturing cost for a U-shape manufacturing cell.

Carvalho et al., [8] have changed the layout design from job shop to cellular production cells in wood-framed pictures and mirrors without losing the flexibility for facing the market demand, increasing the productivity, enhancing the performance and quality. Garbie [9] presented a new methodology for converting the traditional job shop manufacturing system to cellular manufacturing by involving the globalization issues and for justification, the proposed methodology tested by real life case study. Rezaeian and Javadian [10] have applied two methods based on genetic algorithm and multi stage programming to change the job shop system to cellular manufacturing in many stages one after other rather than one stage.

Irizarry et al., [11] have provided a flexible simulation model for cell configuration. They presented different cost functions for comparing and evaluating different alternative manufacturing cells. Their case study involves the design and analysis of different cells. Anbumalar et al., [12], [13] in two papers have applied and evaluated different types of layout design such as: single row, multi rows, U-shape, L-shape and loop layout by using Arena software. The objective of this study is to obtain an optimum layout in order to decrease the movement cost of materials.

Kumar et al., [14] have introduced a sub cell concept and changed the existing layout to CM in an operating sewing floor of garments industry . This CM design led to: increase the flexibility of the production lines, improve the quality and decrease the manufacturing cost. Khaledan and Shirouyehzad [15] presented a comparison between job shop layout and cellular manufacturing layout. They used simulation technique by Arena software in their comparison. Lastly, they prove that cellular manufacturing system showed better performance than job shop system. Metts and Apigian [16] applied low cost solution based on group technology and scheduling rules to job shop companies to reduce the manufacturing flow times, using simulation technique.

3. Methodology

The present paper compares between two manufacturing systems namely : cellular manufacturing and job shop in State Company for Mechanical Industries which manufactures agricultural equipment and located in Iraq. A computer simulation technique using Arena software (12.00 CPR 9) was used for this purpose. Some performance factors were identified in both manufacturing systems such as the: average waiting time, average transfer time, work in process time, average total time, etc. Finally, a comparison based on the obtained performance factors values of the two manufacturing systems has been done to select the suitable one for the selected company.

3.1. Company depiction

The selected company produces different types of agricultural equipment. This company involves two main factories. One of these factories known as production requirement factory was selected for the application of the current study. This factory produces 6 parts on seven machines.

The details about the produced parts, the machines and the sequence of operations is described in the following sections. The old layout of the selected factory is job shop oriented. This type of layout caused many problems to this company such as complex scheduling, low productivity, high manufacturing cost, bad quality, …etc.

So the management policy in the future is to change this layout to CM based on GT principles. Therefore an attempt has been done in the present paper to change the layout from job shop to CM. A computer simulation technique has been followed to compare between the two types of layout (the existing and the new).

Arena software (12.00 CPR 9) was used to apply the simulation method. Lastly, a comparison based on some performance features has been done to identify the effectiveness of both systems, CM and job shop.

3.2. Job shop system

The layout of the selected factory is arranged as job shop and there are six parts of the chosen product under manufacturing (A, B, C, D, E and F). The sequence of operations for each part on the seven required machines (Hopping Ho, Drilling D, Cutting C, Milling M, Heating H, Turning T and Boring B) which are located in seven separated workshops as presented in Table (1). The sequence of operations of the six parts on the seven required machines in the job shop manufacturing system is shown in Fig (1).

3.3. Cellular manufacturing system

In this study, the CM system was created by following some sequence processes starting by using (0-1) matrix which is called machine part matrix. See Table (2). This matrix was built based on the collected data of the particular product of the selected factory. Then, one of the array based techniques called Rank Order Clustering (ROC) [17] was followed to build cells of machines and families of parts for the machine part matrix.

ROC results is shown in Fig (2). The obtained results was arranged in Table (3) to give the number of machine cells and part families. ROC created two cells and two families as presented in Table (3). The results of (ROC) method was arranged in Table (3) to give the number of machine cells and part families.

From Table (3), there are two cells of machines. Cell 1 consists of two machines (D and T) while cell 2 contains 5 machines (B, C, M, H and Ho). On the other hand, from the same Table, there are two families of parts. Parts (A and B) are located in family 1 while parts (D, F, C and E) are located in family 2. The layout of facilities inside these two cells is illustrated in Fig (3).

The red lines refer that parts A and B are exceptional elements which means these parts need some machines from another cell (cell 2) rather than their original cell (cell 1). On the other hand machines B and C are called bottleneck machines which means that these machines operate more than one family of parts, where it is clear that parts A and B are coming from cell 1 to cell 2.

3.4. Simulation models (Arena software)

The simulation models were built for both systems: job shop and cellular manufacturing. The only difference in the two simulation models is the transfer time between machines in each system because of the differences in the layout of machines in each system. The transfer time between machines in each workshop in job shop system is less than 1 minute, so it is ignored in the current study. However, the transfer time between machines in different workshops is 7 minutes, thus it is considered.

On the other hand in CM system, the transfer time between two machines in each cell equal 1 minute while the transfer time to a machine in another cell takes almost 10 minutes. The final simulation models for both manufacturing systems are approximately similar. The output of the Arena model after being run for both systems is illustrated in Tables (4 and 5), where the simulation results are classified based on the products and machines respectively.

The Arena model for both systems includes: (Create module) for each part which is used to enter the entities to the simulation, (Assign module) for each part that is used when the values of some parameters are changed during the simulation, (Process module) for each machine which refers to an activity, usually performed by one or more resources and need some time to complete, (Route module) for each station to record the transfer time between machines, (Station module) for each machine and each station refers to the particular machine that locates in this station and its transfer time was identified in the previous route , (Decide module) to distribute some parts on particular machines and appear as a branch in entity flow and lastly (Dispose module) to obtain the output or refers that the entities are removed from the simulation.

The transfer time values for each system were provided to the simulation model separately. On the other hand, the rest information of the Arena model is same for both systems. The created Arena model for both manufacturing systems is shown in Figures (4 and 5) before and after running. It is clear from Fig (5) the queue of parts on each machine. The simulation model for job shop and cellular manufacturing system was built by Arena software, using (8 replications and 60 minutes running time).

4. Results and discussion

For the results of the simulation models based on the product, it is clear from Table (4) that the average number of finished products of CM system is 82 out of 136 compared with 69 for the job shop manufacturing system out of also 136. So it shows that the number of output for CM is better than the number of output for job shop. The average transfer time in job shop for all parts of (one unit) is 11.66 min compared with 4.66 min for CM, which means that the changing of the existing manufacturing system to CM leads to reduce the average transfer time.

On the other hand, the average the total time with CM is 23.51 min which is better than the same time for the job shop system were the recorded time is 27.98 min. In terms of the average Work in Process (WIP) time, CM recorded 71.28 min compared with 80.04 min for the job shop.

However, for the average waiting time, the results of the job shop system is better than CM results with 81.84 min and 96.97 min respectively . On the other side, regarding the results based on the machine which are shown in Table (5) the average waiting time in queue for the job shop is a little better than CM where the difference between them is almost (19) sec.

Lastly, the scheduled utilization for the CM is 0.68 which is higher and better than 0.63 for the job shop. In conclusion, it is clear from both Tables (4 and 5) that the CM results is better than the job shop results, thus it is highly recommended to change the existing job shop system to cellular manufacturing system. The percent of improvement in the performance factors after changing the manufacturing system from job shop to CM is shown in Table (6).

5. Conclusions

The results that are obtained from the two created simulation models for the previous two selected manufacturing systems refer that, it is very important to convert the existing job shop system to CM because of the positive impact of the CM system. For example increasing the:

1. Average number of finished products with improvement (18.84%)
2. Schedule utilization with improvement (7.93%) and decreasing the:
3. Average transfer time with improvement (60.03%)
4. Average total time with improvement (15.97%)
5. Average work in process time with improvement (10.94%)

Therefore it is very essential to change the job shop system to CM in order to increase the productivity and improve the quality. These types of studies used as an evidence for the mangers to compare between the results of the two manufacturing systems to select the best based on the policy of the company.

6. Recommendations for the future work

For the future work, it is suggested to:

1. Increase the number of replications and the running time of the Arena software.
2. Use manufacturing system more complex than the current one.
3. It is essential to study the manufacturing cost, the material handling cost, ….etc.
4. Use the priority for some products especially the one which need high manufacturing time and leads to delay the delivery times for the customers.
5. Study the influence of including another modules of Arena software such as the scheduling factor to obtain comprehensive view of the manufacturing system.

Table 1 Sequence of operations of the 6 parts on the 7 required machines.

Part	Sequence of operations
A	D-T-B
B	D-T-C
C	H-M-C
D	H-M-B
E	Ho-C
F	Ho-B

Table 2 Machine part matrix (6 parts, 7 machines).

M/P	A	B	C	D	E	F
H	0	0	1	1	0	0
D	1	1	0	0	0	0
C	0	1	1	0	1	0
T	1	1	0	0	0	0
M	0	0	1	1	0	0
B	1	0	0	1	0	1
Ho	0	0	0	0	1	1

Table 3 Cells and families based on ROC results.

M/P	A	B	D	F	C	E
D	1	1				
T	1	1				
B	1		1	1	0	0
C		1	0	0	1	1
M			1	0	1	0
H			1	0	1	0
Ho			0	1	0	1

Table 4 Arena results based on product in job shop and CM systems (60 minutes, 8 replications).

	Job Shop results based on product						CM results based on product					
Part	Average Number in/unit	Average Number out/unit	Average Waiting Time/min	Average Transfer Time/min	Average Total Time/min	Average WIP/min	Average Number in/unit	Average Number out/unit	Average Waiting Time/min	Average Transfer Time/min	Average Total Time/min	Average WIP Time/min
A	32	10	16.43	14	33.47	21.19	32	11	19.10	11	33.12	20.99
B	10	9	10.02	14	27.07	4.71	10	10	10.89	11	24.91	4.15
C	32	15	15.35	14	32.36	20.02	32	19	19.54	2	24.54	16.96
D	32	7	13.78	14	30.74	21.70	32	12	19.39	2	24.41	19.53
E	10	10	8.62	7	17.65	2.94	10	10	8.46	1	11.50	1.91
F	20	18	17.64	7	26.62	9.48	20	20	19.59	1	22.59	7.74
Sum/ Mean	S/136	S/69	S/81.84	M/ 11.66	M/ 27.98	S/80.04	S/136	S/82	S/96.97	M/4.66	M/23.51	S/71.28

Table 5Arena results based on machine in job shop and CM systems (60 minutes, 8 replications).

Machines	Job Shop results based on Machine		CM results based on Machine	
	Average waiting time in queue/min	Schedule Utilization	Average waiting time in queue/min	Schedule Utilization
D	15.72	0.69	15.29	0.69
T	0.75	0.67	0.92	0.70
B	6.72	0.58	7.56	0.71
C	2.44	0.59	2.24	0.65
M	0.68	0.64	0.55	0.74
H	21.18	0.80	21.78	0.80
Ho	11.10	0.50	11.60	0.50
Mean	M/8.37	M/0.63	M/8.56	M/0.68

Table 6 The percent of improvement in the performance factors.

performance factors	**percent of improvement %**
Average Number out	18.84
Average Transfer Time	60.03
Average Total Time	15.97
Average Work in Process (WIP)	10.94
Schedule Utilization	7.93

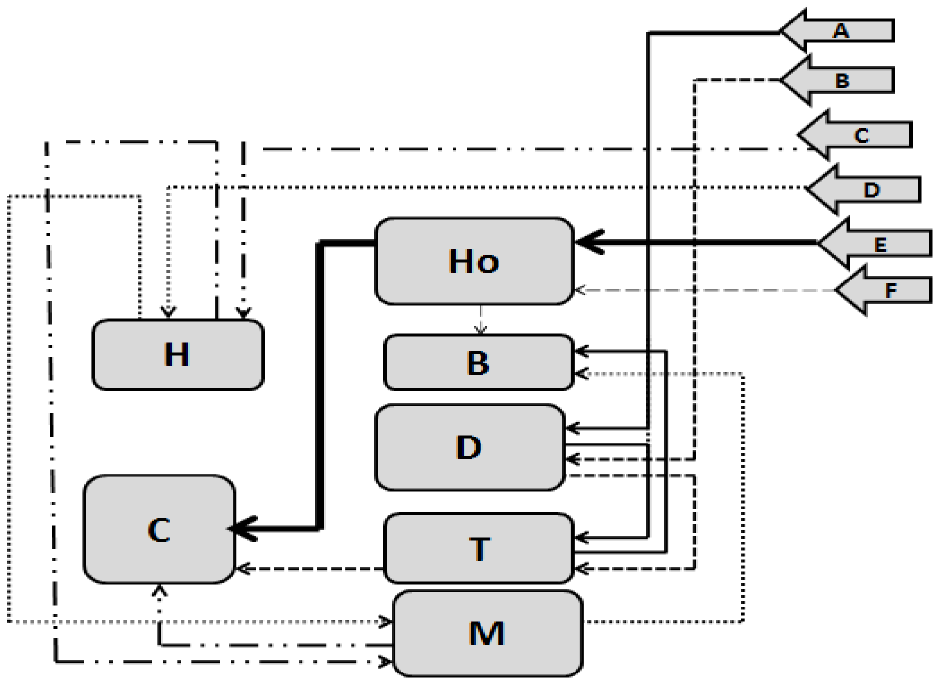

Fig. 1: Sequence of operations in Job shop layout.

```
---- Try No. 1----
  1   1   0   0   0   0  48   2 MachineNo
  1   1   0   0   0   0  48   4
  1   0   1   1   0   0  37   6
  0   1   0   0   1   1  26   3
  0   0   1   0   1   0  12   5
  0   0   1   0   1   0  12   1
  0   0   0   1   0   1   3   7
112 104  22  17  14   9   0   0 power
  1   2   4   6   3   5   0   0   productNo:

---- Try No. 2----
  1   1   0   0   0   0  48   2 MachineNo
  1   1   0   0   0   0  48   4
  1   0   1   1   0   0  44   6
  0   1   0   0   1   1  19   3
  0   0   1   0   1   0  10   5
  0   0   1   0   1   0  10   1
  0   0   0   1   0   1   5   7
112 104  22  17  14   9   0   0 power
  1   2   4   6   3   5   0   0   productNo:

------------------------------------------
Final Result

---- Try No. 3----
  1   1   0   0   0   0  48   2 MachineNo
  1   1   0   0   0   0  48   4
  1   0   1   1   0   0  44   6
  0   1   0   0   1   1  19   3
  0   0   1   0   1   0  10   5
  0   0   1   0   1   0  10   1
  0   0   0   1   0   1   5   7
112 104  22  17  14   9   0   0 power
  1   2   4   6   3   5   0   0   productNo:
```

Fig. 2: The results of ROC method.

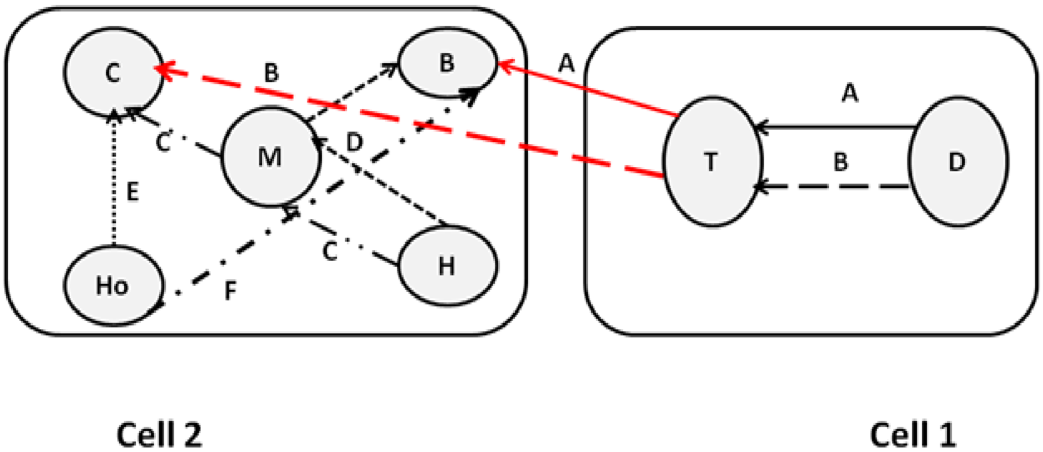

Fig. 3: Cellular manufacturing facilities layout.

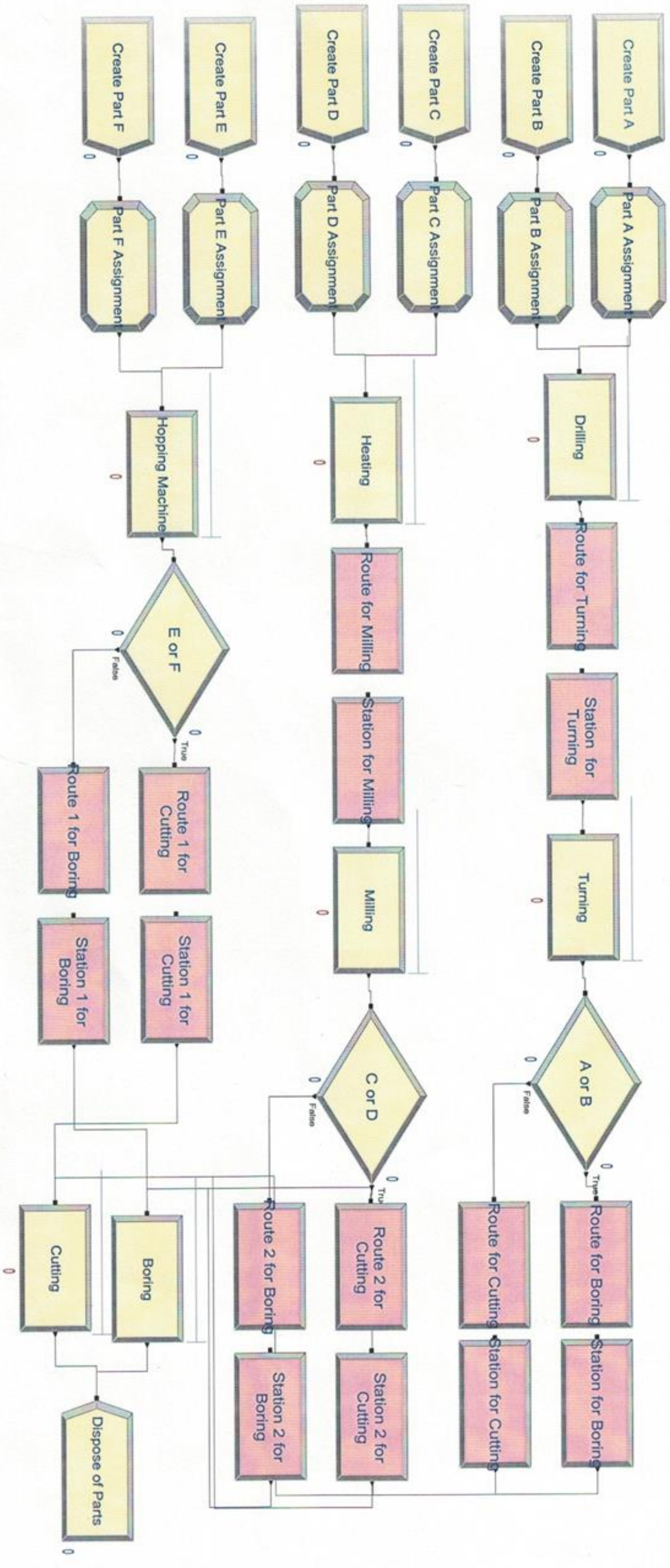

Fig 4: Simulation model for job shop and cellular manufacturing systems **before** running

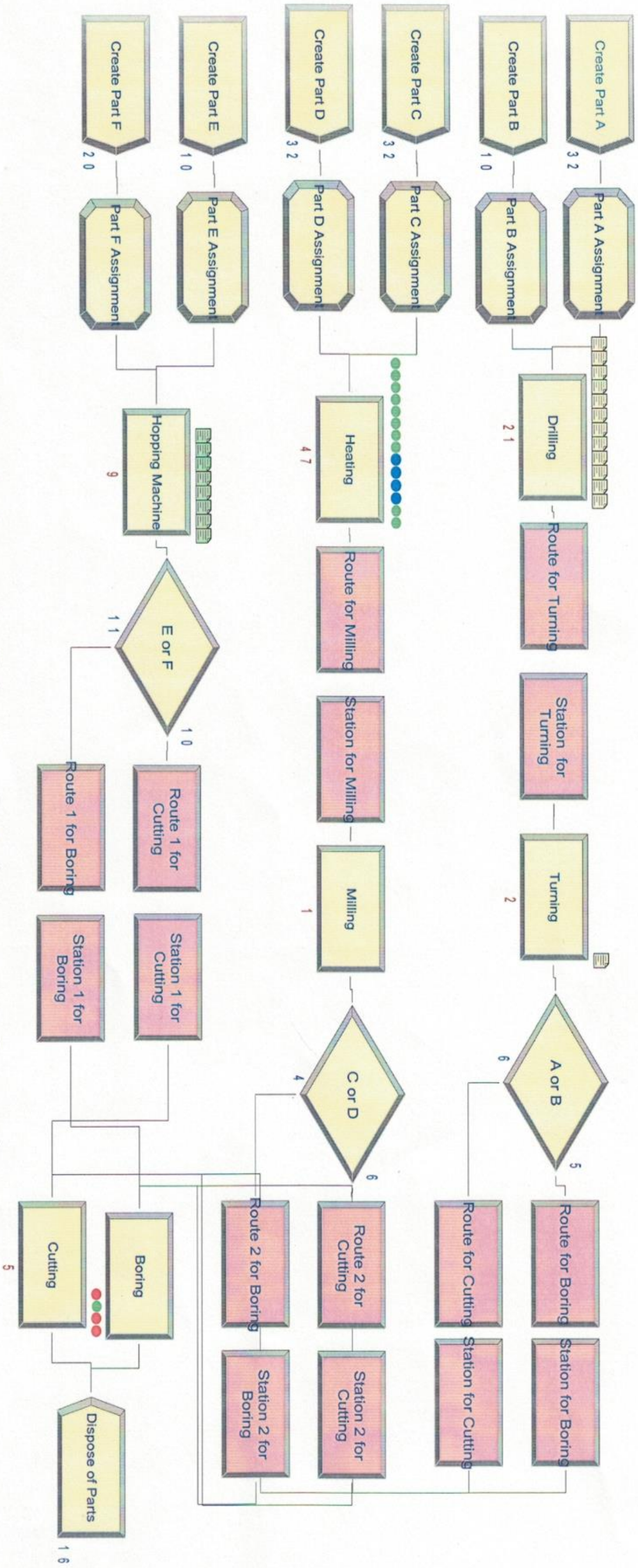

Fig.5: Simulation model for job shop and cellular manufacturing systems after running.

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