Job Shop Layout Design Using CRAFT Method

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Abstract:

Smaller production companies, such as job shops, are often incapable of committing significant human or capital resources for the improvement of manufacturing flow times. However, there is considerable demand in these organizations for solutions that offer improvements without the risk involved in expending these resources. This paper presents a study that uses simulation to improve shop floor performance by means of certain operational parameters. In this study, an overview of the plant layout problem is covered for the particular company. The original motivation for redesigning the entire shop floor was the need to realize improvements in material flow and output level. Since the machines were scattered this made it very difficult to study the cost involving the flow of materials through these machines. So for the purpose of analyzing total material handling cost, 10 elements (jobs) were taken which are mainly processed through 5 machines, out of which 7 elements were divided into 2 part families using Sorting – Based Algorithm Method (SBAM) with group technology concept method and similar machines were arranged together to analyze the cost using Computerized Relative Allocation of Facilities Technique (CRAFT). Finally, a new job shop layout was designed, which yield minimum material handling cost.

Keywords: Job shop, Sorting – Based Algorithm (SBA), Computerized Relative Allocation of Facilities Technique (CRAFT).

Introduction:

In the job shop environment, the need to improve manufacturing flow times has always been a critical factor to stay competitive. Simply adding human resources or capital equipment may improve flow times, but these alternatives can add tremendous fixed cost and risk to an organization. Most job shops cannot afford the investment needed to reduce their manufacturing flow time. Therefore, a more economical alternative would be of great value to smaller organizations. In this study, a haphazard arrangements of machines in job shop was clubbed together to form separate machine cells and various layout was designed to investigate improvements in material flow and output level. 10 elements were taken which are processed through five machines (lathe, milling, grinding, slotting, and drilling). Other objectives of the study can be summarized as follows:

- To determine the inherent constraints and the bottlenecks in manufacturing process.
- To increase the percentage of annual production quantity completed on time without extra costs including subcontracting and overtime costs.

- To provide a solid base for supervision and face-to- face communication.

Design of the Study:

To achieve the objectives of the study, the requirements of the following five steps were sequentially satisfied:

1. Part families were formed using Sorting – Based Algorithm Method (SBAM).
2. Similar machines were grouped together to form separate departments.
3. Physical layout of machines (intra-cell) and cells (inter-cell) were developed by means of powerful and well known Computerized Relative Allocation of Facilities Technique (CRAFT) algorithm, which is the basis for many computer-aided layout programs.
4. New manufacturing system was modeled and analyzed to determine the system performance according to predetermined performance measures.
5. Final layout with optimum cost was developed.

Part Family Formation and Layout Design for Group Technology Layout:

According to Nand [1], and Askin and Charles [2], a Group Technology (GT) layout is most appropriate for batch processing because parts are produced in small to medium batches and there is relative stability in the product mix. The GT cell creates a small, cost-effective assembly line within the production operation, but provides much more flexibility than traditional assembly lines. Because each cell is dedicated to producing a group or family of similar parts, switching between similar parts in the family is quick and easy. Only minimal setup time is required, compared with a changeover on an assembly line or with a traditional batch processing or job.

Part - family formation

For the part family formation Direct clustering Method was used:

Step1: For each row of the machine – part incidence matrix, assign a binary weight and calculate a decimal equivalent (a weight).

Step 2: Sort rows of the binary matrix in decreasing order of the corresponding decimal weights.

Step 3: Repeat steps 1 and 2 for each column.

Step 4: Repeating the above steps until the position of each element in each row and column does not change. A weight for each row i and column j is calculated as follows:

$$\text{row}_i = \sum_{k=1}^{n} a_{ik}\, 2^{n-k} \qquad (1)$$

$$\text{column}_j = \sum_{k=1}^{m} a_{kj}\, 2^{m-k} \qquad (2)$$

For instance, table 1 and matrices 1 and 2 show the operation sequence for each part on machines and the first and final iterations for operation sequences.

Table 1: Operations Sequence For each part on Machines

Parts	M. Sequence	Parts	M. Sequence
1	A,B	6	C,D
2	B,A	7	D,E,A
3	A,C,B	8	B,E
4	D,C	9	D,E
5	C,D	10	C,D,E

Matrix 1: First iteration

	1	2	3	4	5	6	7	8	9	10
A	1	2	1	0	0	0	3	0	0	0
B	2	1	3	0	0	0	0	1	0	0
C	0	0	2	2	1	1	0	0	0	1
D	0	0	0	1	2	2	1	0	1	2
E	0	0	0	0	0	0	2	2	2	3

Matrix 2: Final iteration

	1	2	10	4	5	6	9	3	7	8
A	1	2	0	0	0	0	0	1	3	0
B	2	1	0	0	0	0	0	3	0	1
C	0	0	1	2	1	1	0	2	0	0
E	0	0	2	0	0	0	2	0	2	2
D	0	0	3	1	2	2	1	0	1	0

Therefore following Two part family is formed by using Rank Order Clustering method. To deal with the bottleneck parts 3, 7 and 8, one of the following three actions can be taken:

a. It can be machined in one machine cell and transferred to the other machine cell by a material handling carrier.
b. It can be machined in a functional facility.
c. It can be subcontracted.

Parts 3, 7 and 8 were omitted from part family, since there was no movement from one machine to other.

Layout design:

Wilsten and Shayan [3], experiments application of different heuristic approaches to a real facility layout problem at a furniture manufacturing company. The experiment shows that formal layout modeling approaches can be effectively used real problems faced in industry, leading to significant improvements.

Smutkupt, and Wimonkasame [4], used Microsoft Visual Basic to develop a design system based on CRAFT model to add the simulation to a plant layout design. Then, it is used to link the design system to a simulation system in Arena. Finally, the simulation system send back overall results to a report system in Microsoft Visual Basic output form.

Prasad et al [5], designed the manufacturing plant layout by using (CRAFT). JAVA program has been developed to design the optimum plant layout by considering STEP file as input for developing an optimum plant layout.

After the formation of part families it has been seen that different members of part family consists five machining operations as a whole–Lathe (A), Milling (B), Grinding (C), Slotting (D) and Drilling (E). All machines size have the same dimension (28 x 16 ft^2). Figure (1) shows the proposed machine locations in flow shop layout.

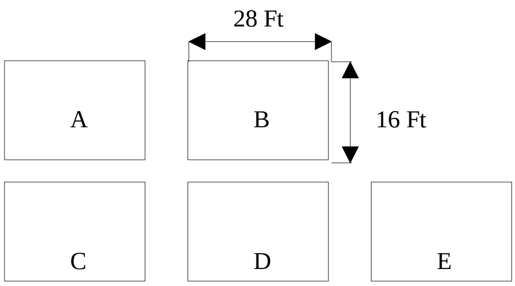

Figure 1: Proposed machine locations in flow shop layout

Optimizing the Job Shop Layout:

For the optimization of plant layout, Computer Relative Allocation of Facility Technique (CRAFT) with aide of computer graphics simulation was used. CRAFT is one of the important computer programs for the quantitative solution of process layout program [6]. The program works in the following manner:

1. Determine department centroids.
2. Calculate rectilinear distance (d_{ij}) between centroids.
3. Calculate transportation cost (c_{ij}) for the layout.
4. Consider department exchanges of either equal area departments or departments sharing a common border.
5. Determine the estimated change in transportation cost of each possible exchange.
6. Select and implement the departmental exchange that offers the greatest reduction in transportation cost.
7. Repeat the procedure for the new layout until no interchange is able to reduce the transportation cost.

Criterion for comparison:

The flow multiplied by the distance and summed over all cells of the chart. We compute the cost for the flow from *i* to *j* as the product of the material handling cost, the flow and the distance between the departments. The cost of the layout is the sum of the flow cost.

$$minZ = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} c_{ij} d_{ij} \qquad (3)$$

Where:

c_{ij} = Material handling cost matrix per unit
f_{ij} = Load matrix
d_{ij} = distance matrix

Computerized Relative Allocation of Facilities Technique (CRAFT):

CRAFT is more popular than the other computer based layout procedures. It is improvement algorithm and starts with an initial layout and proceeds to improve the layout by interchanging the departments pair wise to reduce the total material transportation cost. It does not give the Optimal Layout; but the results are good and near optimal, which can be later corrected to suit the need of the layout planner. Figure (2) demonstrates the Flow Chart of CRAFT.

Features of CRAFT:

It attempts to minimize transportation cost, where **Transportation cost = flow x distance x unit cost**

1. It Requires assumptions that:
   (1) move cost are independent of the equipment utilization.
   (2) move costs are linearly related to the length of the move.

2. Distance matrix used is the rectilinear distance b/w department centroids.

3. CRAFT being a path-oriented method, the final layout is dependent on the initial layout. Therefore, a number of initial layouts should be used as input to the CRAFT.

4. CRAFT allows the use of dummy departments to represent fixed areas in the layout.

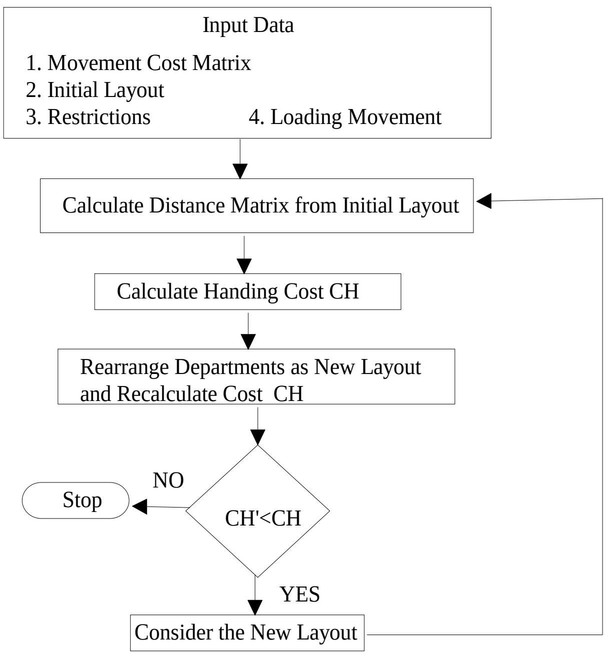

Figure 2: Flow Chart of CRAFT [7]

Input Data

To ascertain these results, estimated data from a job shop was used to aid in developing a Pair – Wise interchange.

Initial layout:

Figure (3) illustrates the initial layout and tables from 2 to 5 show the matrices for load, cost, distance, and total transport cost respectively.

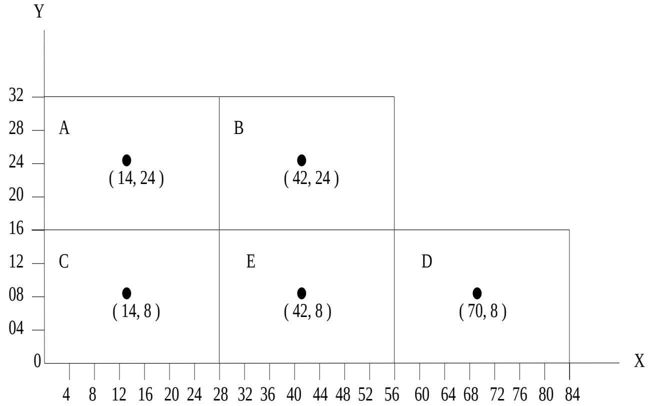

Figure 3: Initial Layout

Table 2: Load Matrix

	A	B	C	E	D
A		1			
B	1				
C				1	2
E					1
D			1	1	

Table 3: Cost Matrix

	A	B	C	E	D
A		1	1	1	1
B	2		1	1	1
C	2	2		1	1
E	2	2	2		1
D	2	2	2	2	

Table 4: Distance Matrix

	A	B	C	E	D
A		28			
B	28				
C				28	56
E					28
D			28	28	

Table 5: Total Transport Cost

	A	B	C	E	D	
A		28				28
B	56					56
C				28	112	140
E					28	28
D			112	56		168
	56	28	112	84	140	420

From table 5, the total transport cost for the initial layout is 420. An interchange between two departments is feasible only if the departments have the same area or they share a common boundary. For the layout shown on above:

- feasible pairs are {A,B}, {A,C}, {B,E}, {C,E}, {E,D}
- and an infeasible pair is {A,E}, { B, E }

After applying the pair – wise interchange, the improved layout is shown in figure (4), and also the improved distance matrix is shown in table 6.

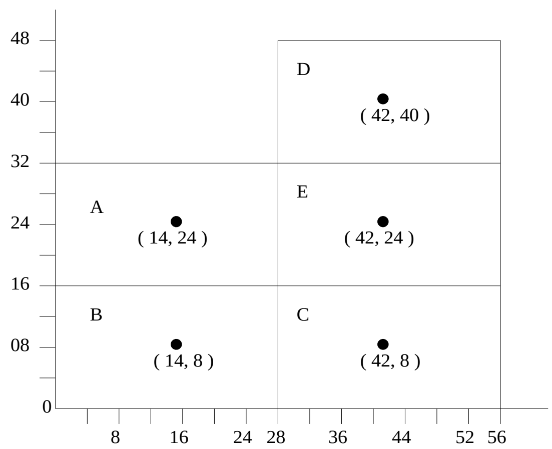

Figure 4: Improved Layout

Table 6: Improved Distance Matrix

	A	B	C	E	D
A		16			
B	16				
C				16	32
E					16
D			16	16	

Table 7 demonstrates the improved total cost. The total travelling distance saving is 180, it means that, the best layout is as shown in figure 4.

Table 7: Improved Total Transport Cost

	A	B	C	E	D	
A		16				16
B	32					32
C				16	64	80
E					16	16
D			32	64		96
	32	16	32	80	80	240

Discussion and Recommendations:

By reconfiguring the machines of job shop by CRAFT method with incorporation of graphics simulation there was a huge reduction in total material handling cost i.e., from 420 Units/Unit period (initial) to 240 Units/ Unit period. The cost was calculated for the single unit of each item. So, this result will be more vital and profitable when the number of units of the items increases.

Conclusion:

This study was aimed at identifying alternative configurations of job shops without investing in additional capital or human resources, and by using layout design technique with incorporation of computer graphics programming. After proposing data of 10 jobs, and five machines a simulation model was developed to approximate the actual shop environment. Based on the results from this initial model, an optimum layout is developed. This final layout that incorporates group technology concept provides an optimum cost. This study shows that total material handling cost can be improved without investing in additional resources. The results are significant for job shops, especially smaller production firms that cannot afford to continually invest in new equipments and hire additional workers. The reconfiguration of floor shop into a group technology environment can reduce total material handling costs, thus improving the profit to the organization. This assist job shops in remaining competitive in the market.

Future continuous work will be, how to make modeling and scheduling for this job shop layout.

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الملخص:

كثيراً ما تكون شركات الإنتاج الصغيرة، مثل مراكز العمل، غير قادرة على توفير موارد بشرية أو رأسمالية كبيرة لتحسين أوقات تدفق التصنيع. ومع ذلك، هناك طلب كبير في هذه المنظمات على الحلول التي تقدم تحسينات دون المخاطر المترتبة على إنفاق هذه الموارد. تقدم هذه الورقة دراسة تستخدم المحاكاة لتحسين أداء ورشة العمل من خلال بعض المعايير التشغيلية.

في هذه الدراسة، يتم تغطية لمحة عامة عن مشكلة تخطيط المصانع لشركات معينة. وكان الدافع الأصلي لإعادة تصميم ورشة العمل بأكملها هو الحاجة إلى تحقيق تحسينات في تدفق المواد ومستوى الإنتاج.

ونظراً لكون الآلات مختلفة الوظائف فأنه من الصعب جداً دراسة التكلفة التي تنطوي على تدفق المواد من خلال هذه الآلات. ولغرض تحليل إجمالي تكلفة مناولة المواد، تم أخذ 10 عناصر (وظائف) تتم معالجتها بشكل رئيسي من خلال 5 آلات، تم تقسيم 7 عناصر منها إلى قسمين من الأسر بمفهوم تكنولوجيا المجموعات باستخدام طريقة الفرز- القائم على طريقة خوارزمية تسمى (SBAM). تم ترتيب الآلات المتماثلة معا لتحليل التكلفة باستخدام طريقة كرافت (CRAFT). وأخيرا، تم تصميم تخطيط ورشة عمل جديدة، والتي تسفر عن الحد الأدنى من تكلفة مناولة المواد.