Hybrid cellular layout for jobshop manufacturing: A case study

Nadiah Ahmad[1,*], Radin Zaid Radin Umar[1], Puteri Eliani Fikri Abdullah Kamil[1]

[1] Human-Machine Systems Optimization Research Group, Advanced Manufacturing Centre, Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: nadiaha@utem.edu.my

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ABSTRACT – This study applied the concept of hybrid cellular layout to design a new layout for a jobshop. The production flow analysis was performed through the product routings and machine-part matrix. Similarity coefficients were also calculated to analyze the machines interdependencies. Through the creation of layout modules, the proposed layout design is able to reduce the traveling time and distance significantly.

1. INTRODUCTION

For high-mix low-volume production, process layout which organizes machines according to their functions (jobshop), is the common type of layout adopted in industries. Process layout has the advantage of higher machine utilization while giving more flexibility in parts' production. However, process layout can be inefficient as it can lead to longer lead time and higher work in process (WIP). To encourage lean manufacturing, studies have suggested the use of cellular manufacturing that group machines according to part families. While the cellular layout has the advantage of reduced set up time, it limits the shop flexibility in part production [1]. To overcome this limitation, a hybrid cellular layout that combines the characteristic of both functional and cellular layouts were introduced in literature [2-3]. The aim of this study is to apply the concept of hybrid cellular layout to design a new layout for a company that specialized in machining products for various applications. The company wanted to review its current process layout before it moves to a new plant. Due to the company producing high variety of products in low volumes, the implementation of hybrid cellular layout is proposed.

2. METHODOLOGY

The representative sample of parts was selected for analysis using P-Q analysis. For each selected part, the travel time and travel distance within the facility were obtained, as well as the product routing was also recorded. Then, the machine-part matrix was developed to analyze the machines' interdependency. Direct Clustering Algorithm [4] was performed to initially group the machines such that the machines with high interdependencies were grouped together. From the initial machine-part matrix, the similarity coefficients S_{ij} between two machines were calculated according to Equation (1). Thereafter, parts were also grouped based on the similarity coefficients. Overlap in machine requirements were analyzed for potential machine duplicates or machine sharing through hybrid cellular layout.

$$S_{ij} = \frac{\sum_{k=1}^{N} x_{ijk}}{\sum_{k=1}^{N} y_{ik}+z_{jk}+x_{ijk}} \quad (1)$$

where

x_{ijk}= operation on part k performed both on machine i and j.
y_{ik}=operation on part k performed both on machine i.
z_{jk}= operation of part k performed both in machine j.

3. RESULTS AND DISCUSSION

Production data over 6-months period was used to determine the products with the most significant contribution. It was found out that the crank shafts had the highest total production volume with consistent monthly demands. The product information related to crank shafts was obtained to conduct the production flow analysis of the studied facility. The part sample consisted 29 different parts utilizing 13 different machines or workstations. Figure 1 portrays the material flows among machines for existing layout design. It can be seen that the current layout contains many backtracking and machines crossover which led to a lot of transportation waste.

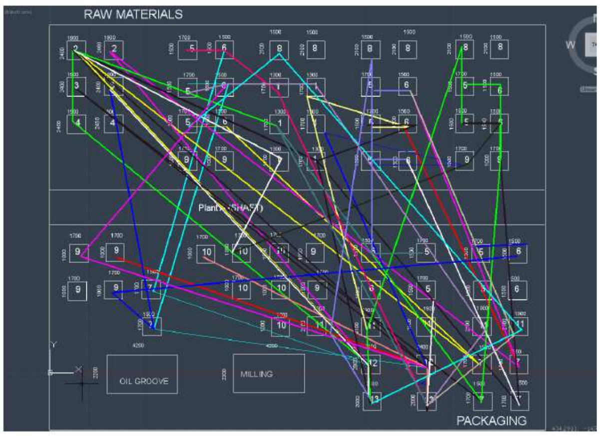

Figure 1 Material flow of existing layout

Figure 2 shows that final machine-part matrix for crank shaft products after performing Direct Clustering Algorithm. From this figure, no apparent independent cells for making specific group of products can be formed. However, several layout modules- smaller sets of machines dedicated for machining groups of parts- can be formed namely cell 1, cell 2 and cell 3. These layout modules can be used to explore hybrid layouts that can streamline the flow of diverse products. Figure 3 portrays the similarity coefficient between pairs of machines.

After further clustering analysis based on the results from the machine-part matrix and similarity coefficients, a new layout design was proposed as shown in Figure 4. Attempt was made to avoid machine duplication as preferred by the company. After considering the availability of the machine quantities and part routings, the machines in cell 2 were separated into several layout modules. These modules contain sets of machines dedicated to processing certain variant of crank shafts. These smaller layout modules were created to avoid too many machines clustered together in order to prevent bottleneck issue from occurring and to simplify further the material flows. This grouping of several different machines into layout modules can decrease the travel distance of parts and have the advantage to ease the machine scheduling as they are dedicated to processing only specific fewer parts.

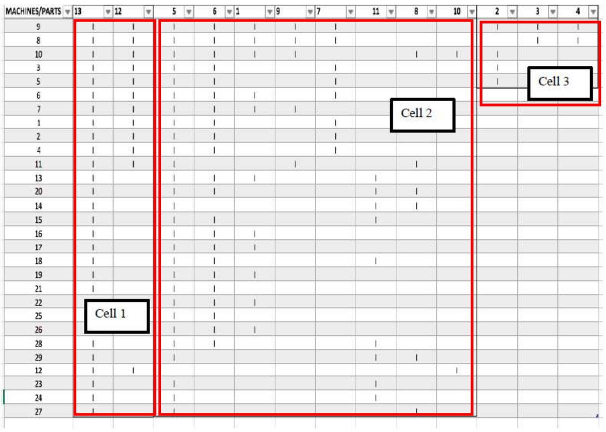

Figure 2 Final Machine-Part Matrix

S^m	1	2	3	4	5	6	7	8	9	10	12	13
1		0.25	0.33	0.33	0.45	0.45	0.18	0.14	0.71	0.29	0.50	0.50
2			0.20	0.20	0.40	0.40	0.38	0.20	0.25	0.17	0.33	0.33
3				1.00	0.20	0.20	0.29	0	0.33	0	0.17	0.17
4					0.20	0.20	0.29	0	0.33	0	0.17	0.17
5						1.00	0.70	0.09	0.45	0.08	0.08	0.08
6							0.70	0.09	0.45	0.08	0.08	0.08
7								0	0.18	0	0.58	0.58
8									0.33	0.67	0.17	0.17
9										0.67	0.5	0.5
10											0.25	0.25
11												1.00
12												

Figure 3 Similarity coefficients between machines

Table 1 shows the comparison in terms of the travelling time, traveling distance and the number of crossover for a sample of parts studied with the highest total machining time. The result shows that the total reduction in traveling time and distance was more than 80% with the proposed layout.

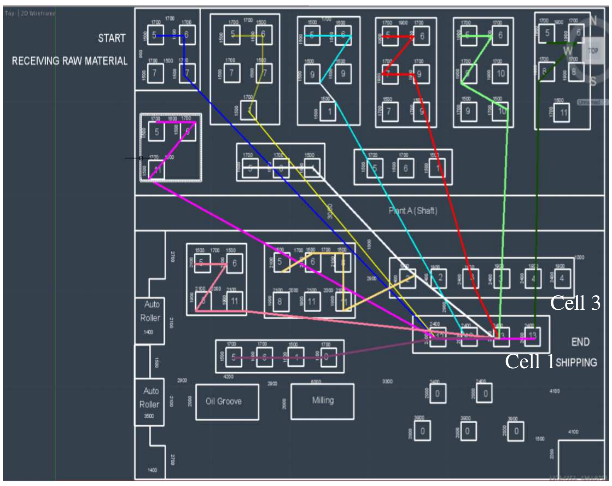

Figure 4 Proposed layout (rectangle shapes around several machines represent layout modules and numeric values inside square shapes represent the machine types)

Table 1 Comparison between existing and proposed layout

Parts	Part 4		Part 9	
Layout	**Existing**	**Proposed**	**Existing**	**Proposed**
Total travelling distance (m)	34	6	70.1	9
Total travelling time (secs)	2040	360	4206	540
No. of crossover	5	1	8	0

4. CONCLUSION

A new layout was proposed for a company that produces machining products. The study proposes the implementation of hybrid cellular layout due to the high-variety nature of the products the company produced. The proposed layout is able to reduce the traveling time and distance significantly and thus reducing the throughput time of the part production through more streamlined production flows.

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REFERENCES

[1] N. Khilwani, Nitesh, B.H. Ulutas, A.A Islier, and K.T. Manoj, *Journal of intelligent manufacturing*, 22, no. 4, pp. 533-544, 2011.

[2] G. Shambu and N.C. Suresh, *European Journal of Operational Research,* vol. 120, no. 2 (2000): pp. 436-458, 2000.

[3] P.Y. Chang, In *Applied Mechanics and Materials*, vol. 465, pp. 672-676. Trans Tech Publications, 2014.

[4] M. Murugan and V. Selladurai, J*ordan Journal of Mechanical & Industrial Engineering*, vol. 5, no. 3, pp. 199-211, 2011.