Job Shop Layout Improvement with Simulation Technique: A Case of Metal Sheet Production

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Abstract. This paper investigates the improvement of job shop layout with simulation technique. A case study of Siam GN metal sheet, the manufacturer of customized metal sheet products was used. The objective is to increase production efficiency and reduce materials handling distance and time. Data regarding product and machine type were collected. CORELAP (Computerized Relationship Layout Planning) and Group technology based on ROC (rank order clustering) algorithm were applied to design the improved layouts. ARENA software was used to simulate the new layout from both techniques. The simulation show that CORELAP layout reduce production time by 17.12% while group technology layout reduces materials handling time by 11.41%. CORELAP layout therefore, was chosen for implementation. Simulation techniques allows user to experiment with different scenario hence selecting the most appropriate one without interfering with the actual process.

1. Introduction

Job shop is a small manufacturing process that produce customized products in small batches to serve numbers of customer in the same time. Typical layout used in job shop is the ‘process layout’ in which similar activities or machines are located together in the same department. The advantage of this type of layout including high flexibility, difficult to disrupt and easily supervised (1). In this kind of layout, products move through departments with different paths according to their production route. However, some departments might have high movement frequency; these departments should be located close to each other in order to minimize material handling.

Typically, layout problems are related to the location of machines and departments in a factory. Most of these problems are NP hard (2) To find the layout that minimize material handling with optimization algorithm is very difficult due to the nature of the problem in job shop that involve large number of product, which follows different path through the factory. Various methods have been used to design layout that minimize material handling distance. This research utilizes simulation approach, which the simulation of actual production process was developed as computer model. This model was used to test different layouts in order to find the layout with minimum material handling distance. Simulation model helps the test various layout scenario without interfering with the actual process.

To demonstrate the use of simulation techniques, a case study of a manufacturer of metal sheet production at Siam GN metal sheet was used. The company is located in Lamphun province in the northern part of Thailand. The company has 4 main product groups as shown in Figure 1; namely metal roof sheet, roof flashing, galvanized beam and sheet metal fence panel.
2. Literature review
The research applied CORELAP and Group technology to design new layout, the related concept regarding both techniques are briefly describe in this section.

2.1. CORELAP
This algorithm was introduced in 1967 by Rock C. Lee and Moore (3). CORELAP algorithm is based on total closeness rating (TCR). It develops layouts by location rectangular-shaped departments. The TCR rating is the sum weighted rating between the new department and its neighbor in the layout (4). TCR for each department can be calculated using the following equation

\[ TCR_i = \sum_{j=1}^{m} r_{ij} \]  

where, \( m \) = number of departments

2.2. Group technology
Group Technology is a method that identifies the similar attribute of product design and manufacturing process in order to identify machine groups and part families to create manufacturing cell with minimum moves into other cells (5). The research employ rank order clustering (ROC) method which as following algorithm (6)

Step 1: Create \( n \times m \) matrix \( b_{ij} \) (binary number for part and machine), where \( n \) in parts and \( m \) is machines

Step 2: For each row of \( i \), compute \( \sum_{j=1}^{m} b_{ij} \cdot 2^{m-j} \)

Step 3: Rearrange the rows in descending order based on the computed numbers

Step 4: For each row of \( j \), compute \( \sum_{i=1}^{n} b_{ij} \cdot 2^{n-j} \)

Step 5: Rearrange the columns in descending order based on the computer numbers

Step 6: Repeat step 1 until there no change is observed in step 3 and 5

Step 7: Stop

3. Research methodology
The research methodology started with data collection, and then two layouts were designed based on CORELAP and ROC. Finally, both layouts were compared using simulation method. The detail methodology is described as follows.

3.1. Data collection
In this stage product related data including type, size, shape and demand volume were collected. Next, multi product process chart was used to summarize routing of each product. From to chart was used to collect both distance and frequency of materials handling between machines. Distance was calculated using rectilinear formula. For instance the distance between machines that has coordinate of \((x_i, y_i)\) and \((x_j, y_j)\) can be calculated from \( |x_i - x_j| + |y_i - y_j| \)
3.2. CORELAP layout design
Composite movement frequency between machines were calculated from data in from-to chart. The frequency obtained is coded in to A, E, I, O, U and X where A represent highest relationship and X is undesirable relationship. TCR is calculated by substitute A = 10000, E = 1000, I = 100, O = 10, U = 0 and X = -10000. Machines are then assigned according to CORELAP algorithm.

3.3. ROC layout design
Part-machine matrix was construct where column represent the 14 different products and row represent the 23 machines in the shop. If the production of the specific product require that specific machine, the value in that correspond cell become 1, otherwise 0. Then layout was developed according to ROC algorithm described in section 2.2.

3.4. Simulation
Arena software was used to develop the simulation model of the factory. The first model is the current layout, which represents the baseline of the analysis. This model was verified by comparing number of finished product obtained from the model with number of input. The criteria of acceptance is that the different should be less than 5 lots. The model was also validated by comparing average time of actual process with average time of model process and the different should be less than 5%. After the model pass the verified and verification processes, the model of CORELAP layout and ROC layout was developed and the results from the 3 models were compared.

4. Results and Discussion
4.1. Basic information regarding the case study company layout
The majority of product manufactured in the case study company is metal roof sheet (74%), roof flashing (15%), sheet metal fence panel (8%) and then galvanized beam (3%). Each product category can be divided in to sub-category. For example, metal roof sheet has 5 different shapes and sheet metal fences has 2 different sizes. There are total of 15 sub-categories.

![Figure 2. Products of Siam GN metal sheet.](image)

Multi product process chart is shown in Table 1 with the total of 23 machines and 15 products sub-category. As can be seen each product follows different path through out factory.

4.2. New layout design
The two new layout design are shown in Figure 3. CORELAP block diagram shown in Figure 3a) was developed by firstly place machine 5 in the matrix, then machine 3 and 17 which have close relation ship with machine 5 was located close to machine 5. The process repeat until the final block design was
obtained. The block diagram was expanded to fit actual space by taking into account of the space requirement of each machine.

Table 1. Multi product process chart.

|    | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | Decolier 1 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 2  | Decolier 2 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3  | Decolier 3 |   | 1   |     |     |     |     |     |     |     |     |     |     |     |     |
| 4  | Decolier 4 |   | 1   | 1   |     |     |     |     |     |     |     |     |     |     |     |
| 5  | Roof forming 750 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 6  | Roof forming 760 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 7  | Roof forming (Spain) |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 8  | Roof forming |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 9  | C beam forming |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 10 | Roll forming with PE 750 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 11 | Roll forming with PE |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 12 | Crimping machine 750 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 13 | Crimping machine 760 |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 14 | Barre rolling |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 15 | Ridge rolling |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 16 | Louvres rolling |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 17 | Cutting machine |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 18 | Small fence forming |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 19 | Large fence forming |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 20 | Folding machine |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 21 | Folding machine |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 22 | Crimping machine |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 23 | Foam injection |   |     |     |     |     |     |     |     |     |     |     |     |     |     |

ROC layout design are shown in Figure 3b). This layout was developed by firstly applying ROC algorithm to group products into 2 groups. Then the machine used to manufacture those products were group accordingly and two separate cells was designed in the new layout.

Figure 3. New layout design.

4.3. Simulation models

Arena software was used to simulate actual production process. 5 models were developed for roof type 750, roof type 760, roof flashing and fence, roof spain type and C-beam. An example of a model of roof flashing and fence is given in Figure 4. The simulation started with create module. In this step, entity name and quantity were specified. Then the entity type was assigned with assign module. Next, process module was used to simulate production process with production time and distribution identified from input analyzer. Decide module was used next to decide which entity enter which machine.
Table 2 compare current layout with the two new layout. In terms of material handling distance, CORELAP layout reduce 13.66% of distance in comparison with current layout while ROC layout only reduce distance by 4.37%. Similarly, total production time was reduced more with CORELAP layout at 17.12%. Therefore, CORELAP layout is superior in both criteria and was chosen for actual implementation.

| Models          | Material handling distance | % decrease in distance | Total production time (min) | % decrease in time |
|-----------------|---------------------------|------------------------|-----------------------------|-------------------|
| Current layout  | 355.70                    | n/a                    | 2110.97                     | n/a               |
| CORELAP layout  | 307.11                    | 13.66%                 | 1749.64                     | 17.12%            |
| ROC layout      | 340.14                    | 4.37%                  | 1870.058                    | 11.41%            |

5. Conclusion

This paper presents the application of simulation model in order to select the best layout which minimize materials handling distance and total production time. The research start with collecting data regarding product, production routing and materials handling frequency. Two layout was designed based on CORELAP and ROC algorithm. Arena simulation was used to simulate current layout and the two improved layout. CORELAP layout was found to be superior to ROC layout in both material handling distance and total production time.

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