Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 26 (2015) 247 – 251

www.elsevier.com/locate/procedia

12th Global Conference on Sustainable Manufacturing

Production Layout Optimization for Small and Medium Scale Food Industry

Yosra Ojaghi[a], Alireza Khademi[a], Noordin Mohd Yusof[a,*], Nafiseh Ghorbani Renani[a], Syed Ahmad Helmi bin Syed Hassan[a]

[a]*Dept. of Materials, Manufacturing & Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia (UTM), 81310 Johor Bahru, Malaysia*

* Corresponding author. Tel.: +6075557048 ; fax: +6075566159. *E-mail address:* noordin@fkm.utm.my

Abstract

According to the number of competitors in the global marketplace, it is important for companies to reduce their costs and expenses in order to be a sustainable competitor. As a case study, a company producing meatball and soup paste located at Bayan Lepas, Penang was selected with a view of finding a sustainable layout that minimizes travel distance, material handling and losses. A few steps were taken to achieve this aim. Firstly, several layouts were generated using two types of construction techniques, viz. Systematic Layout Planning (SLP) and Graph Based Theory (GBT). In the next step, the Efficiency Rate (ER) of each layout was calculated. The layout with the highest ER was then selected and optimized by using Pairwise Exchange Method (PEM). The result showed that the ER of the selected layout improved from 90.43% to 94.78% after optimizing. Based on this study, it was found that even the best selected layout could be improved, and it is necessary to conduct facility and layout planning before any factory set up to ensure sustainable process and reduce losses.

Peer-review under responsibility of Assembly Technology and Factory Management/Technische Universität Berlin.

Keywords: Sustainable Layout; Facilities Layout Planning; Systematic Layout Planning (SLP); Graph Based Theory (GBT); Pairwise Exchange Method (PEM); Efficiency Rate (ER)

1. Introduction

As the number of competitors in the global marketplace is increasing very fast, surviving in this environment is not easy. Sustainable manufacturers have to produce high quality products at the lowest possible price. Many factors affect the finished-goods prices. The first step to decrease the price is to find the costs and losses in the factory. One of the main factors influencing costs is poor facility design that means a poor production layout in the factory. Muther [1] believed that spending a little time on layout planning before installation reduces losses significantly. Obtaining a good layout at the time of installation instead of poor layout will save a lot of capital investment and production lost. Poor layout requires subsequent rearranging which is time-consuming and costly. Different methods and algorithms are developed by facility planners for obtaining a proper layout. The techniques that are going to be used in this study are explained in the following section. These manufacturers also need to produce a variety of products and increase their capacity in order to compete in the market place.

This study focuses on developing a new production layout for a meat processing company in view of the need to increase the production capacity.

2. Literature review

Spending a little time to plan the arrangement before installation can prevent unnecessary losses [1]. Planning the layout at the outset before building the plant or office is the best way to reduce the costs remarkably. Producing products or delivering services at high quality, with less cost and in short time using the fewest resources is the objective of properly managing a facility [2]. It is important that the facilities must be managed properly in order to attain the objective.

There are many procedures and algorithms that can assist facility planners to construct the new layout or improve the

Peer-review under responsibility of Assembly Technology and Factory Management/Technische Universität Berlin.
doi:10.1016/j.procir.2014.07.050

current layout [3]. Tompkins et al. [4] discussed that several approaches and algorithms have been developed to aid facility planners who are divided into two distinct categories, including construction and improvement. Construction methods help planners to develop a sustainable layout from the beginning, but improvement ones generate a number of alternatives for the existing layout [4].

Several facility planning techniques could be used to develop a new layout or improve the current layout such as Systematic Layout Planning (SLP), Pairwise Exchange Method (PEM), Graph Based Theory (GBT), Dimensionless Block Diagram (DBD), Total Closeness Rating (TCR), etc. In this study, three facility planning methods have been used to design the sustainable layouts which are SLP, GBT, and PEM.

2.1. Systematic Layout Planning (SLP)

SLP is a procedure developed by Muther [1]. It involves eleven steps and is able to find a number of solutions for the layout. Chien [5] categorized the eleven steps of SLP into four parts that are data input, procedure's process, output results and evaluation process. He also modified SLP to use this procedure for different shapes and hexagons. By using this modified SLP, departments can be divided into sub departments. Additionally, SLP is a powerful approach and at the same time is easy to use [6]. Ermin et al. [7] developed the overall factory layout in spite of limitation in size, position and unit relationship. Improving the plant layout using SLP method will decrease the material flow considerably [8].

2.2. Graph Based Theory (GBT)

Foulds et al. [9] stated that solving the layout problem can be separated into two phases: adjacency phase and design phase. Separating problem into two problems shows that GBT is a powerful tool that enables facility planners to design the layout. In modern manufacturing design, the layout for machines is very important because of its costs [10]. GBT is useful for constructing a new layout. This algorithm is adjacency-based and the distances between departments are not considered. In this method, Relationship chart (REL chart) is required to choose the sequence of department. Additionally in this approach, the adjacency of the departments is shown by using graph [2].

2.3. Pairwise Exchange Method (PEM)

PEM is suitable for improving or redesigning the current plant layout. This method can be used for both equal and unequal departments. Adjacency-based and distance-based problems can be solved by this specific method [4].

3. Methodology

According to the problem statement mentioned in the introduction section, the first step for this study is to determine the required number of machines based on the new capacity. Based on the operation process chart for meatball and soup paste, thirteen departments should be considered.

How to calculate the area of each department is very important. The size and the number of machines; and the adequate area required around them should be determined. Sufficient space for aisles' width is to be provided in any factory. For main aisle, 12 to 20 ft. in width is required [11,12]. The aisle for human needs to be 2.5 ft. in width while 12 ft. is required for two lift truck to pass each other in the aisle [11,12]. In this paper, 6 ft. space around machines with long height was considered. Finally, the required area for each department was calculated and presented in Table 1.

In developing a layout, several alternatives are needed in order to select the best layout and then optimize it. To generate several alternatives, different facility planning techniques were used. Two construction methods, SLP and GBT, were chosen to generate a number of alternatives for this specific case.

For both methods, REL chart is required to show the importance of adjacency between each pair of departments. REL chart related to this case study is shown in Fig. 1.

3.1. Systematic Layout Planning (SLP)

In SLP technique, REL chart was used to develop the relationship diagram and the space relationship diagram. For this study, both are shown in Fig. 2 and Fig. 3, respectively. By using SLP procedure, four different alternatives were generated for this case study.

Table 1. List of departments and required space

No.	Department	Size (meter)
1	Receiving Department	4 × 12
2	Raw Material Storage	4×5 (Changeable)
3	Crushing Department	5.8 × 6
4	Peeling Department	6 × 3.5
5	Chopping-Mixing Department	3.5 × 2.7
6	Chopping Department	2 × 2.5
7	Forming-Cooking Department	5.6 × 12.5
8	Cooking-Mixing Department	2.5 × 3
9	Blasting Department	5 ×13.5
10	Packaging Department	2.4 × 6.8
11	Filling Department	2 × 2.5
12	Food Court	3 × 5
13	Finished Goods Department	2.5 × 4
14	Washroom & Toilet	4.58 × 4.88

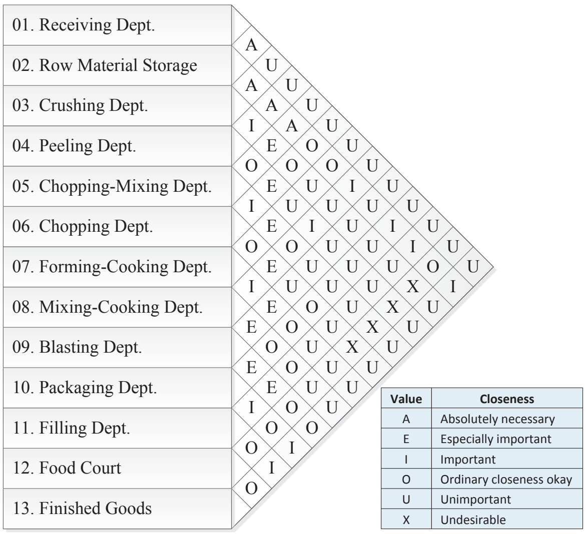

Fig.1. REL chart

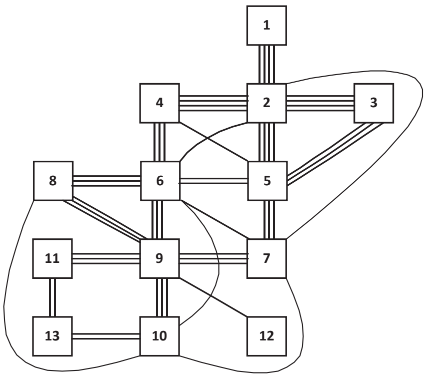

Fig. 2. Relationship diagram

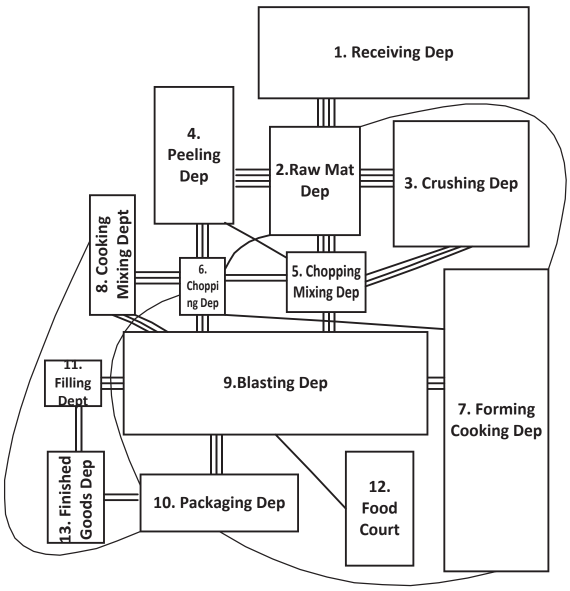

Fig. 3. Space relationship diagram

3.2. Graph Based Theory (GBT)

The REL chart for SLP was also used in the GBT method. This is because the importance of adjacency was the same. Regarding the Total Closeness Rating (TCR), the REL chart was translated to the numbers based on Table 2. Fig. 4 illustrates the REL chart translated to the numbers.

Table 2. Sign translated to numbers based on TCR

Sign	A	E	I	O	U	X
Number	6	5	4	3	2	1

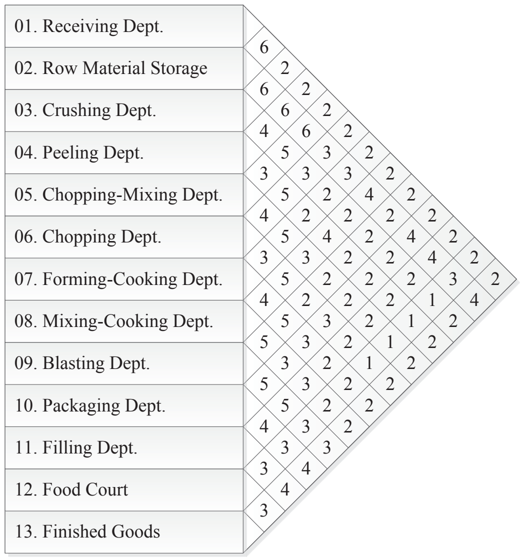

Fig.4. REL chart translated to numbers

GBT technique uses the REL chart (Fig. 4) to find the most important adjacency between departments and to determine the priority of selecting departments in the algorithm. The final graph obtained using GBT is shown in Fig. 5. In the next step, cross arcs were drawn to connect center of triangles. The final graph including cross arcs is shown in Fig. 6.

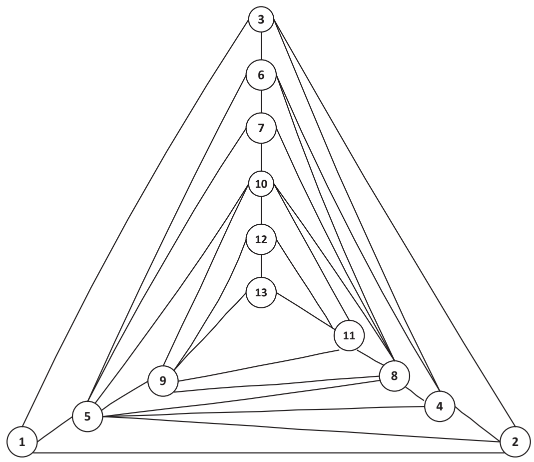

Fig. 5. Final graph obtained using GBT

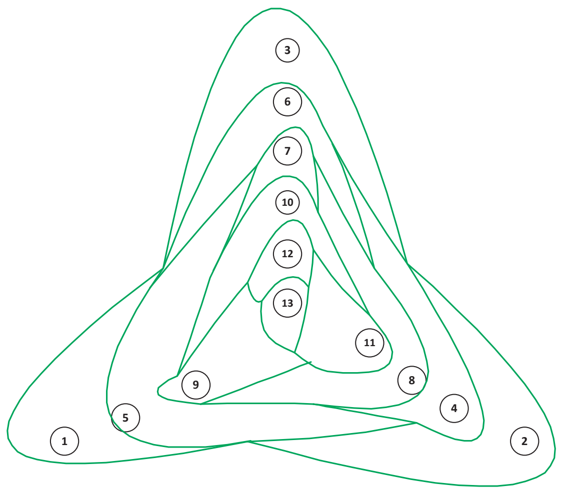

Fig. 6. Final graph including cross arcs

In this final graph, each node was considered as a department. Therefore this graph shows the adjacency of departments in the layout. The final step was to generate and set the layout according to this graph. Finally, two different layouts were generated by GBT.

4. Results

In total, the use of SLP and GBT has resulted in six different layouts involving thirteen departments. Choosing the best layout was the most important part of this study. There are several methods that can be used to find the best layout among alternatives. Efficiency Rate (ER) method was selected to calculate the level of efficiency for the different layouts generated. ER is the sum of relationship score for all departments in the layout divided by sum of the expected relationship for all departments. The formula to calculate the ER is as follows:

$$R = \frac{\sum department\ adjacency\ score}{\sum relationship\ score}$$

The layout with highest ER was selected as the best alternative. As can be seen from Table 3, alternative three 'SLP-3' with 90.43% ER is the layout with the highest score. Fig. 7 shows the selected alternative 'SLP-3' including meatball (Red line) and soup paste (Blue line) flow of materials.

Table 3. Calculated ER for each alternative

No.	Alternative	Calculation	ER
1	SLP -1	187 / 230	81.30 %
2	SLP-2	192 / 230	83.47 %
3	**SLP-3**	**208 / 230**	**90.43 %**
4	SLP-4	174 / 230	75.67 %
5	GBT-1	158 / 230	68.69 %
6	GBT-2	188 / 230	81.74 %

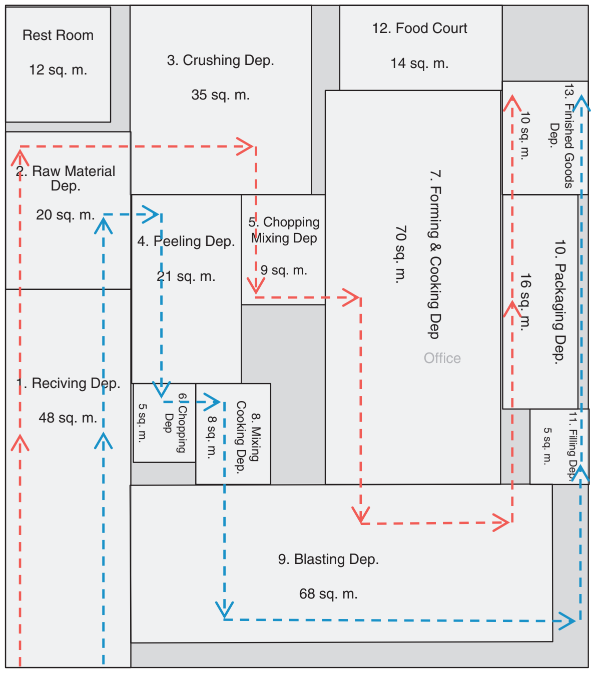

Fig. 7. SLP-3 including flow of materials

Having selected the best alternative layout which has the highest ER in the previous step, the next is to improve the layout. PEM algorithm was utilized to improve layout 'SLP-3'. In this case, the use of this algorithm requires a long time as it involves thirteen departments. Therefore, programming was a good solution as it was able to reduce the lengthy calculations and raise the accuracy. In this study, MATLAB software was used to program PEM. Input data was one row array that was according to the spiral order of departments in the current layout 'SLP-3'. Output of MATLAB software showed that the order of departments should be '1, 2, 3, 5, 4, 6, 8, 9, 7, 15, 10, and 12'.

The layout in Fig. 8 illustrates the arrangement of the departments in this plant layout according to the order that was suggested by the MATLAB software. To show the improvement of this layout, ER was calculated again for this layout. The results are shown in Table 4.

Table 4. Final comparison

No.	Alternative	Calculation	Score
1	SLP -1	187 / 230	81.30 %
2	SLP-2	192 / 230	83.47 %
3	**SLP-3**	**208 / 230**	**90.43 %**
4	SLP-4	174 / 230	75.67 %
5	GBT-1	158 / 230	68.69 %
6	GBT-2	188 /230	81.74 %
*****	**Improved SLP-3**	**218 / 230**	**94.78 %**

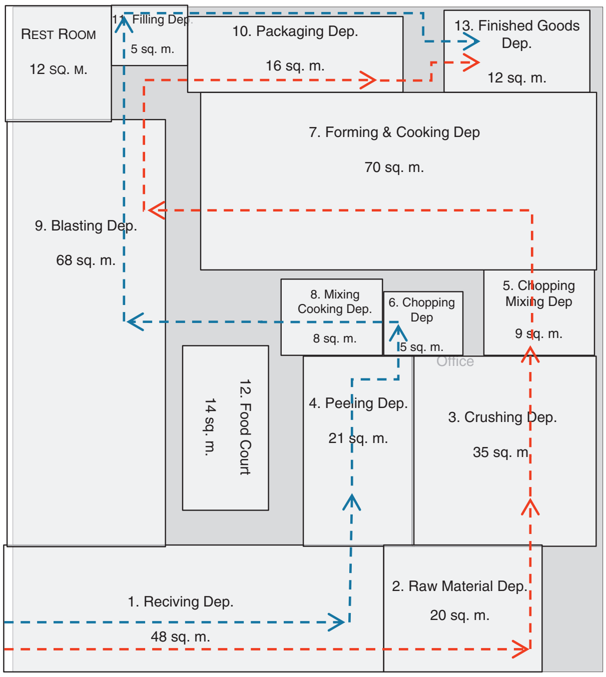

Fig. 8. Improved layout using PEM including flow of materials

5. Conclusion

The goal of this study is to develop a new production layout for a meat processing company in view of the need to increase the production capacity using facility planning and design techniques. The first step is to generate several layouts to raise the probability of finding the sustainable layout with higher efficiency, and the second step is to select the best layout and improve it.

SLP and GBT are two types of construction techniques for facility planning, which are widely used in previous studies during the past decades. Six alternative layouts were generated in this study using SLP and GBT. The layout with the highest ER was selected as a sustainable layout among other alternatives. Relationship score was based on the flow of materials and the importance of adjacency between departments. The best alternative was improved by using PEM, which is an improvement technique. To avoid lengthy calculations and to increase the precision of the algorithm, MATLAB software was opted. The input of this program was the order of departments in the spiral way. The output was the improved layout which is the improved order of departments in the spiral way. Calculating the ER for improved layout shows that the score of the best layout increased from 90.43% to 94.78% after optimization. Based on this study, it is found that even the best selected layout could be improved. Therefore, the result indicates that it is necessary to conduct facility and layout planning before any factory set up to ensure sustainable process and reduce losses.

Acknowledgements

Financial support from the Ministry of Higher Education (MOHE) and Universiti Teknologi Malaysia (UTM) through vote Q.J130000.2524.06H09 is acknowledged with gratitude.

References

[1] Muther R. Systematci Layout Planning. Cohners Publishing Company, 1973.
[2] Heragu SS. Facilities Design. CRC Press Taylor & Francis Group, 2008.
[3] Djassemi M. Improving Factory Layout under a Mixed Floor and Overhead Material Handling Condition. Journal of Manufacturing Technology Management 2007; 18(3):281-291.
[4] Tompkins W, Bozer & Tanchoco. Facilities Planning. John Wiley & Sons, Inc., 2010.
[5] Chien TK. An Empirical Study of Facility Layout Using a Modified SLP Procedure. Journal of Manufacturing Technology Management 2004;15(6):455-465.
[6] Hassan MMD. Toward Guiding the Selection of a Layout Procedure. Journal of Manufacturing Technology Management 2007;18(3):292-303.
[7] Ermin Z, Kelou C, Yanrong Z. Overall Layout Design of Iron and Steel Plants Based on SLP Theory. IFIP International Federation for Information Processing 2010;345:139-147.
[8] Wiyaratn W, Watanapa A, Kajondecha P. Improvement Plant Layout Based on Systematic Layout Planning. IACSIT International Journal of Engineering and Technology 2013;5.
[9] Foulds LR, Gibbons PB, Giffin JW. Facilities Layout Adjacency Determination: An Experimental Comparison of Three Graph Theoretic Heuristics. Operations Research 1985:1091-1106.
[10] Leung J. A New Graph-Theoretic Heuristic for Facility Layout. Management Science 1992;38:4.
[11] Entezari A. Facilities Planning. Tehran: Jahan Jame Jam, (Farsi Text Book) 2005.
[12] Tompkins JA, White JA, Bozer YA, Tanchoco JMA. Facilities Planning. Fourth Edition. John Wiley & Sons, Inc. 2005.