THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

# Modification of an Existing Layout of a Production Line Based on Distance Function

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***Abstract:***
*Plant layout or facility layout planning(FLP) of an industry means planning for the location of all machines, working areas, offices and any other utilities for efficient and smooth production. FLPs aim to locate interrelated units subject to some design criteria and area limitations, with one or multiple objectives. The flow pattern (of goods & service) in the organization/plant determines the layout type and efficient material handling is a main objective of FLP, specially for industries where continuous and mass flow of goods/materials is there in the production line. So taking material handling as main factor to account for, this paper presents a technique of layout improvement based on distance function. The production line of a soft drink refiling company is taken as a case study and effort is made to reduce the length of the conveyors between the facilities, relocate the facilities and thereby reduce the cost associated with material handling (or transportation cost).*
*A modified layout is proposed and it shows a considerable reduction in conveyor length and bottle travelling time which ultimately results in reduction of transportation cost.*

***Keywords***: *Facility layout planning, flow pattern, layout improvement*

## 1. Introduction

Plant layout or facility layout planning (FLP) is about arranging the physical departments or machines within an organization/plant. More specifically, a facility is an entity that facilitates the performance of any job. It may be a machine tool, a work centre, a manufacturing cell, a machine shop, a department, a warehouse, etc. A facility layout is an arrangement of everything needed for production of goods or delivery of services [1]. A well-designed facility layout contributes to overall efficiency of operations and can reduce up to 50% of the total operating costs [2]. Therefore, the research on facility layout of a production line has always been the key research area of industrial engineering domain [3], [4].

According to literature, a FLP features two aspects; it can be solved either quantitatively or qualitatively [5]. The first one is the quantitative approach aiming at minimizing the total material handling cost between departments based on a distance function. The second one is the qualitative approach aiming at maximizing closeness rating scores between departments based on a closeness function [6].

The solution procedures of these approaches are either of construction or improvement type. Construction procedures which are used when layout is developed for the first time need various data like departmental relationship and area, rectilinear distance between them, volume of trips between all pairs of departments etc. Computerized Relationship Layout Planning (CORELAP), Plant Layout Analysis and Evaluation Technique (PLANET) are example of heuristic construction techniques. Improvement procedures require an initial solution in addition to the input needed by the construction techniques. They attempt to reduce the movement cost associated with an initial layout, usually by pair wise interchange of departments, for example CRAFT (Computerized Relative Allocation of Facilities Technique) [7].

The improvement layout technique presented here belongs to the 1st type i.e. quantitative approach. Many research works have been done on improvement for the whole plant by this approach but very few are reported in case of a production line where there is continuous and mass flow of material between sequentially located machines in one line. So such kind of a production line (of a beverage refilling company) is taken as a case study and effort is made to modify the existing layout by reducing the distance of material movement as the efficiency of a layout is typically measured in terms of material handling (transportation) cost [8].

## 2. Research Methodology

As shown in the Fig.1 below, the whole process is comprised of two main modules: information module (IM) and layout module (LM). Under IM, there are two sub-modules- in the 1st one (i.e. $IM_1$) all the information or data regarding the dimensions (length, breath, floor area etc.) of the workshop and all facilities i.e. machines or equipments within it and in the 2nd one ($IM_2$) the sequences of operations, flow of materials between facilities etc are collected.

The facility layout module includes two parts- the initial/current layout and the final layout. With all the information gathered in information module, the initial layout is developed which shows the current positions of the facilities in the production line within the workshop. Then using the distance-based improvement technique which emphasizes on reducing material handling cost based on distance function, a modified final layout is developed.

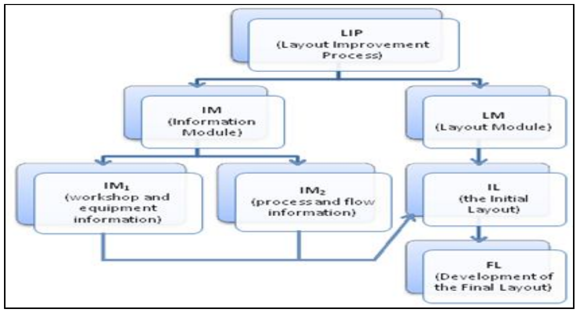


*Figure 1: Components of the layout improvement process*

*2.1. Flow Analysis*

To develop or modify a layout, first we have to know the flow pattern of material in the organization from raw materials to finished product. The plant considered in this paper is a refilling plant of soft-drink. So for the production line, returned empty bottles from market are the raw materials and refilled bottles are the finished product and various operations are done when bottles move from one facility (or machine) to another through the line.

The line layout comprising of eight machines or equipments (or facilities) and the facilities are arranged according to the sequence of operations. The filling capacity of the filler machine is fixed as 260 bottles per minute and bottles are moved between the equipments with the help of conveyor. A schematic diagram of the flow pattern is shown in Fig.2

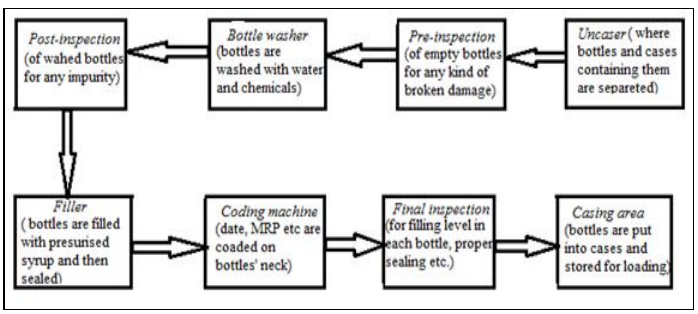


*Figure 2: Flow diagram for the production line*

*2.2. The Initial Layout*

With the collected data regarding the dimensions of the workshop and all equipments within it, the existing layout of the production house of the studied company is developed and is shown in Fig. 3. Taking one corner of the boundary as origin, exact positions of all the facilities with their lengths, breaths and centers are shown. Boundary walls are indicated with red lines and blue arrows indicate the flow path of the bottles through conveyors.

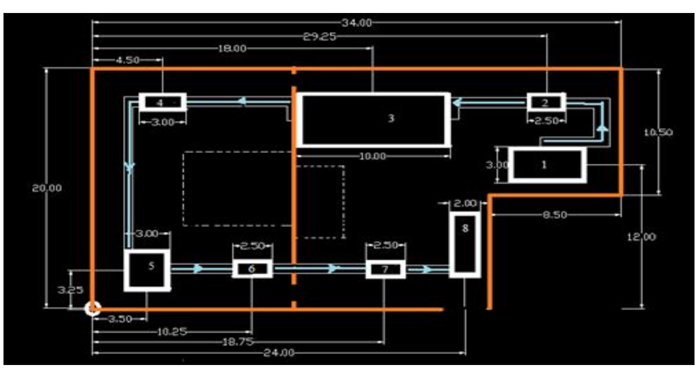

*Figure 3: Existing layout of the production line*

*2.3. Development of the Final Layout*

2.3.1 Mathematical Model

The mathematical model of the layout system considered in this paper only includes layout in one line model while U-type layout models are considered as special cases of one line layout model. The relationship between the two equipments in one line layout is shown in Fig. 3 and the symbol specifications are as follows

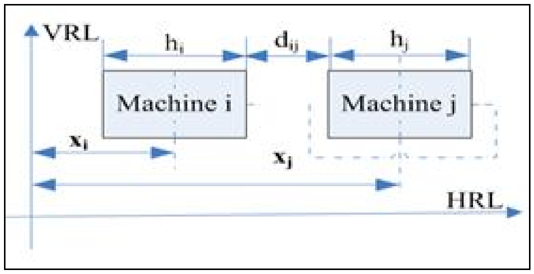


*Figure 4: The variables of the layout in one line model [6]*

Where

- $x_i$ : The distance between the centre of equipment i and the VRL (Vertical Reference Line);
- $x_j$ : The distance between the centre of equipment j and the VRL;
- $h_i$ : The horizontal length of equipment i;
- $h_j$ : The horizontal length of equipment j;
- $d_{ij}$: The minimum distance between equipment i and equipment j in the horizontal direction

Now, mathematically the cost function of transportation in one line can be described as [6] –

$$\min \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} s_{ij} n_{ij} \left| x_i - x_j \right|$$

Constraint condition: $\left| x_i - x_j \right| \geq \frac{1}{2}(h_i + h_j) + d_{ij}$

Where

- m : Equipment numbers;
- $s_{ij}$ : The cost for a unit weight moving unit distance between equipment i and equipment j
- $n_{ij}$: The round trip time of material handling equipment moving between equipment i and equipment j

2.3.2. Assumptions and Considerations

Some assumptions were made to apply the mathematical model for modification of the layout to avoid more complexity and they are as follows

- The machines work continuously in a line without any breakdown for fixed period.
- The value of $S_{ij}$ (i.e. the cost for a unit weight moving unit distance between equipment i and equipment j) for each pair of facility is constant and taken as one.
- Small difference in Y-coordinate is neglected i.e. the facilities are assumed to be situated in two lines, one line with facilities 5,6,7 & 8 and other with facilities 4,3 & 2. (Refer to Fig.3)
- While calculating the dimensions of facilities, spaces for special requirements are also considered. (E.g. one row in the bottle washer contains 24 bottles in the intake portion and bottles are arranged accordingly. So within the length of 10m of the washer as shown in Fig.3, length for this arrangement is included). Conveyors include only the length where bottles actually move from one to another facility.

2.3.3. Limitations

There are some limitations in developing the optimal layout for the production house in this project work. They are as follows

- Three facilities 1, 3 & 5 i.e. the uncaser, bottle washer and the filler machine are fixed i.e. they cannot be moved as they are costly and comparatively large in dimension and so their relocation will be very much expensive.
- Some areas cannot be used (marked by dotted lines in Fig.3) as these are occupied by pipe lines used as passage of syrup and $CO_2$ gas.

2.3.4. Procedure

In case of line layout, understanding how line logic affects line efficiency is relevant. For example, in terms of line efficiency the filler represents the core machine as speed reference of all equipment [9]. As the filler rate is fixed and all other m/c are arranged accordingly, so the material handling time between the facilities in the line is a key factor to consider for smooth production. So, first focus is to find the standard velocity of the conveyor for minimum travelling time and then the correct separation between two facilities for minimization of cost associated with material handling process.

- To determine the required velocity of the conveyor, it is observed that if bottles are arranged in single row, each bottle occupies about 5cm of the conveyor length. As filling rate is fixed as 260 bottles per min for the production unit, so for smooth flow of bottles without back tracking, the maximum velocity of conveyor is taken as 13m/min. (260 ×5=1300cm=13m length is required to accumulate 260 bottles in one min).
- Facilities are then taken pair wise.
- Taking $x_i$ as fixed, $x_j$ is calculated using the constraint condition $|x_i - x_j| \geq ½×(h_i+h_j)+ d_{ij}$
- $d_{ij}$ is calculated as-

if bottles move along the conveyor in only one row, then $d_{ij}$ = 13m
in two rows, then $d_{ij}$ =13/2=6.5m
in four rows, then $d_{ij}$ =13/4=3.25m

2.3.5. The final layout

With the limitations and assumptions mentioned, the final layout is developed using Visual Basic and is shown in Fig.5

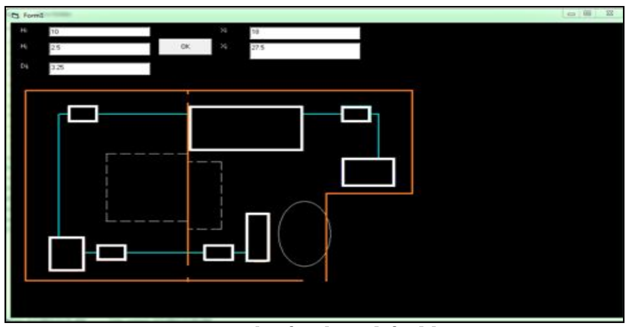

*Figure 5: The final modified layout*

**3. Findings and Discussion**

The position parameters relating to the existing and modified layout of the production line are given in the Tables I and II. The comparison (Table III) clearly shows the advantages or superiority of the final layout over the existing one.

| Facility no. | X- coordinate (previous) | X-coordinate (new) |
|---|---|---|
| 5 | 3.5 | 3.5 |
| 6 | 10.25 | 7.25 |
| 7 | 18.75 | 16.25 |
| 8 | 24 | 19.5 |

*Table 1: previous and new x-coordinates of facilities in line 1 (refer point no. three of limitations)*

| Facility no. | X- coordinate (previous) | X-coordinate (new) |
|---|---|---|
| 4 | 4.5 | 5 |
| 3 | 18 | 18 |
| 2 | 29.25 | 27.5 |

*Table 2: previous and new x-coordinates of facilities in line 2*

| | Existing layout | Final layout |
|---|---|---|
| Conveyor length (m) | 42.7 (by direct measurement) | 34.5 ($\sum d_{ij}$) |
| Bottle travelling time (min.) | 3.36 (by direct measurement) | 2.65 ($34.5m/13ms^{-1}$) |
| Transportation cost function ($\sum s_{ij}n_{ij}|x_i-x_j|$) | 152.04 | 102.1 |

*Table 3: comparison of the two layouts*

It is seen that, with the assumptions and limitations, there is reduction of 8.2 meter in the conveyor length by the proposed distance-based layout improvement technique. There is about 32% reduction in the cost function because of the conveyor length reduction excluding the saving and reduction in energy cost. Some other benefits associated with the reduction are-

- In the current layout, there are eleven motors of capacity 1kw each to run the conveyor. {Four between facility (1)and (3)at an avg. distance of 3 meter, four between (5) and (8) at an avg. distance of 3.25 meter and other between (3) and (5)}. With 4.5 meter conveyor length reduction between facility (5)&(8) and 3.2 meter between (1)&(3), 2 motors can be reduced in these two lines. As a result, there will be reduction in electricity bill (energy cost).
- With filling rate of 260 bottles per min, the maximum production rate is 650cases per hr for the current layout (one case contains 24 bottles). As the travelling time is reduced by 0.71 minute in the proposed layout, so total cycle time or processing time will also reduced by that much and that saved time can be used for more production (Refer Note1*). This will be very much handy in the time of pick demand during summer.
- In the casing or loading area i.e. facility no. (8), 6 to 10 workers perform the task manually and beyond the boundary wall near facility (8), there is the storage area. So lots of man and material movements near facility (8) and during pick hours, sometimes it becomes congested and hazardous. In the proposed layout, facility (8) is located far away (about 5m) from the boundary wall because of which more space is available for the workers for free movement and safety (shown by white circular line in Fig.5). Besides, the storage area can be extended toward the 8th facility by 2-3 meters if required.

**4. Conclusion**

The modified layout proposed here exhibits superiority over the existing layout of the studied production line in terms of reduction in conveyor length and material handling cost. It is also associated with other benefits like reduction in energy cost, increase in production/productivity and more free space for workers. The layout improvement technique presented here is simple and easily adoptable and under some constraints or limitations, it can be used in similar situation involving continuous and mass flow of material. If a simulation model incorporating line time study (i.e. man-machine time, change over time of machines etc.) along with distance function, is developed, it will contribute more towards smooth and efficient production, which will be an important future research direction. The technique can be used to complex layouts with more facilities arranged in line.

[ * Note1: In 1 min. production = 260 bottles
So, in 0.71 min. production= 260× 0.71= 184.6 bottles ~ 184 bottles
or 184/24 = 7.66 cases of more production for the same time input/expended which means increase in productivity]

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