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Facility Layout Improvement for Enhancing Productivity: an Application of Systematic Plant Layout

Abstract:

One of the major prerequisites for effective operations of a manufacturing plant depends on the sufficiency of a good facility layout. A well-planned facility layout enables better utilization of resources and thereby better production control. The purpose of this research was to analyse the effectiveness of the layout improvement through systematic plant layout planning (SLP) method. Factors like relationship diagram/affinity chart, material flow, space requirements etc. were studied to propose a modified layout according to the SLP method.

The study found that the improved plant layout not only optimised the material flow and space requirements but in addition it enormously reduced the material handling cost of the plant thereby bringing better operational efficiency.

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Introduction

With increased competition and demand, companies need to raise their efficiency in production in order to keep up with the competition and eventually sustain in the market. At the same time, being competitive requires the production process to be capable of manufacturing more of the products but at a lower cost thereby increasing the efficiency. There are many ways to unravel the problems concerning productivity, for example through quality control (QC), implementation of total quality management (TQM), time standardization, appropriate plant layout etc. productivity could be enhanced.

Plant layout perfection is considered as one of the fine tools to attain high levels of efficiency. Plant layout design has become a fundamental factor of today's industrial plants which can influence parts of work efficiency. It helps in suitably planning and allocating resources like employees, supplies, machines, and other engineering supports and amenities to develop the most effective plant layout.

Plant layout refers to the arrangement of physical facilities such as machinery, equipment, furniture etc. within the factory building. An efficient layout will allow the quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of material to the shipment of the finished product. Plant layout supremely involves the distribution of space and arrangement of equipment in such a manner that overall operating costs are minimized.

Effective facility planning can reduce significantly the operational costs of a company. Proper analysis of facility layout design could result in the improvement of the performance of the production line. This can be realized by minimizing material handling costs; reducing idle time; maximizing the utilization of labour, equipment and space.

A good placement of facilities contributes to the overall efficiency of operations and can reduce until 50% of the total operating expenses [1].

Another study found that working with no standard time nor facilitating tool will result in confusion among the staff and they end up spending too much time on work [14]. The way to solve these problems was to improve the steps in working and the area where they worked through observation and fieldwork as well as proposing tools to facilitate the work to set balance and find the standardized time.

Continuous assessment of product demand, flow between departments, and evaluation of the layout to determine the time at which a redesign should be performed is necessary for maintaining a good facility layout for multiple periods [4]. The redesign of an existing layout is expensive but can be justified when there is a sufficient reduction in material handling cost.

The purpose of this paper was to find out an improved layout design using a systematic layout planning method so as to improve productivity but at a reduced investment. This case study was conducted in a frozen meat factory located in Ernakulam in Kerala; and the original layout of the plant, material flow, placement of the different units, distances between the units were all studied. The efficacy of the new proposed layout was also decided by computing the material handling cost.

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Review of Literature

There has been quite a number of research done on facility layout and its advantages. However, there are only a few literatures available on facility layout using systematic layout planning method. In this session, pertinent pieces of literature are presented.

The design of a facility is a strategic issue that is having a significant impact on the manufacturing units[6]. It is essential to reallocate the plants' equipment in a way that they do not alter the manufacturing process but reduces the distance between different workstations which in turn reduces the material handling cost.

A study on the production process for a cable box to form metal found that improper plant layout has a serious implication on the duration of the production process[19]. The researcher found that the job cannot be completed within the standard time.

Vollmann suggested guidelines to assist in the analysis of the layout problem [16]; however, each layout problem has its own characteristics. The optimal design of the physical layout problem should be solved in the early stages of the system design[8]. Modern factories should have this planning requirement catered for in their physical design.

Muther suggested systematic layout planning (SLP) as an improvement method. In this method, a proximity matrix which signifies nearness of each facility is graphically represented. Flowcharts can also be developed showing quantitative relationships[10].

Though systematic layout planning (SLP) is widely used in the manufacturing industry for facility layout planning, there are instances where it has been used in retail stores [5] and the design of fabrication units [18]. It was found that by using analytical tools, SLP can be stretched to include store layout planning [5].

Layout generation and evaluation are often challenging and time-consuming due to its inherent multiple objective natures and its data collection process [2]. Past and emerging research has been aimed at developing a solution methodology to meet these needs [20]. However, algorithmic approaches have focused mainly on minimizing flow distance in order to minimize material handling costs. On the other hand, procedural approaches have relied heavily on experts' experience. Ongoing engine reconditioning process layout of the automobile industry are studied and a new layout is developed based on the systematic layout planning pattern theory to reduce engine reconditioning cost and increase productivity. The number of equipment and travelling area of material in engine reconditioning have been analysed. The detailed study of the plant layout such as operation process chart, activity relationship chart and the relationship between equipment and area has been investigated. The new plant layout has been designed and compared with existing plant layout. The new plant layout shows that the distance and overall cost of material flow from stores to dispatch area are significantly decreased. The implementation of the proposed model will help in the overall improvement of the production performance of the engine reconditioning unit of the corporation [3].

At this point, it will be relevant to indicate that in the mid- 1970s a discussion was raised in the

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literature concerning the facility layout problem [13]. In this paper, the researcher discussed the comparison between layout solutions generated by computer algorithms and ones based on human visual methods. The results of the research showed that visual methods gave a better performance than the computer software available at that time. Kajondecha in his research aims to improve the plant layout of pulley's factory to eliminate obstructions in material flow and thus obtain maximum productivity [7]. The present plant layout and the operation process of each section (i.e. sand mould, core warehouse, core making, disassembly surface finishing, furnace, and inspection sections) have been investigated. The problem in term of the material flow of each operation section was identified. The result showed that disassembly surface finishing and inspection sections should be allocated to make good material flow. The suitable of new plant layout can decrease the distance of material flow, which raises production.

Another study the plant layout of manufacturing industry was studied to make optimum space utilization, eliminate obstructions in material flow and thus obtain maximum productivity[15]. The result showed that raw material section, cutting section and fabrication shops should be allocated to make the good material flow. The suitable of new plant layout can decrease the distance of material flow and transportation cost which raises production cost [17].

Methodology

This paper used systematic layout planning (SLP) [10] as the tool to solve a layout design problem in the frozen meat factory. The work focuses on improving the facility design of the production floor. Though the meat processing firm follows a process layout, it has been following the old layout for years which has resulted in high material handling effort and increased material handling cost. The problems were studied and systematic layout planning was proposed to modify the plant layout. Descriptive research was used for the study. The study included 17 departments of the company including the supervisor room. The process involved in performing systematic layout planning is relatively uncomplicated and it is a proven tool in providing layout design guidelines in practice[11], [9]. The systematic layout planning method is a step-by-step procedure of plant design from input data and activities to an evaluation of plant layout. Its major advantage is that it clearly documents the logic of the layout and easily allows input from all levels of staff [4].

The SLP has 3 main stages comprising 8 steps in total.

Stage1 is the input data collection.
- Step 1: Collection of data on P (product) and Q (quantity).
- Step 2: Finding out the space requirements.
- Step 3: Preparing the from- to - chart
- Step 4: Process sequence
- Step 5: Analysing flows of material
- Stage2 is the procedure process, which is represented by:
- Step 6: Relationship diagram with closeness rating.
- Stage3 is output stage which includes:
- Step 7: Developing layout.
- Step 8: Evaluation of the proposed layout.

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Data Source

The data needed for the study were collected from the workers and supervisors of the production department. The entire blocks in production floor were analysed and the process sequences for three products namely, sausage, cutlet and canned products were considered for research.

The data necessary for the study:

- Product variety (P): This element is the key factor which affects the composition and relationship of all the facilities, equipment categories and material handling way.
- Quantity (Q): This element affects the layout scale, equipment amount, handling workload and construction area.
- The existing plant layout.
- The distance between various blocks in the present layout.

Tools Used for Analysis

Two main tools were used for the analysis of plant layout under systematic layout planning. Each tool tries to find out the intensity of the relationship between various blocks in terms of quantity of flow and the closeness required.

- From - to - chart: The 'from to chart' is a routing planning chart, it consists of a matrix. The blocks in the production floor are written down the left-hand side of the form and across the top. The quantity of flow between various blocks is written down.
- Relationship graph: The activity relationship diagram is also called the affinity analysis diagram and it shows the relationship of every department, office, or service area with every other department and area.

Case Study

Procedure for Analysing Plant Layout

In this particular study done in a meat processing unit, 17 blocks including the supervisor's room and office were considered. The plant layout is designed taking into consideration the process sequence of the products like sausage, cutlet and canned products.

The detailed step by step process of data collection is given below

Stage 1: Before revamping the layout using SLP model, it's necessary to study the existing plant layout and its drawbacks. Stage one of systematic layout planning consists of five steps wherein all the input data regarding the products under study like the quantity, material flow, intensity of flow etc. were examined. This process will enable the researcher to pinpoint on the shortcomings of the layout and come up with details that have to be corrected. The process followed in collecting the data is given in sequence.

Step 1: The first step was to identify the products in production. For the purpose of research, the products considered were sausage, cutlet and canned products in beef, chicken and pork meat varieties. The quantity of material flow was ascertained to be 20,000 Kg.

Step 2: The space requirements for all the 17 blocks including the office and supervisor's room were assessed and the space requirements are given below.

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No	Blocks	Area(l*b)	Area(m^2)
1	Slaughter hall	4.55*11.45	52.0975
2	Chilling1	2.8*1.2	3.36
3	Chilling2	7.55*1.2	9.06
4	Process hall	4.1*6.125	25.1125
5	Cutting area	7.55*12.25	92.4875
6	Curing	4.1*6.125	25.1125
7	Cold storage 1	2.8*5.53	15.484
8	Cold storage 2	8.01*5.53	44.2953
9	Canning	6.5*7.6	49.4
10	Cooking room	10.2*3.9	39.78
11	Chicken slaughtering	6.5*11.17	72.605
12	Chicken cutting	6.5*7.6	49.4
13	Processing area	6.5*7.6	49.4
14	Cold storage 3	6.5*7.6	49.4
15	Cold storage 4	6.24*6.26	39.0624
16	Supervisor room	5.4*3.3	17.82
17	Office	3.3*3.3	10.89
		Total Area	644.7667 m^2

Table 1. Space Requirements of Various Blocks, Source: Data Analysis

Step 3: In this step, the quantity of flow between the 15 production blocks was assessed and the data was depicted below using from- to chart. The chart aids to find out the intensity of material flow between the production blocks.

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	1	2	3	4	5	6	7	8	9	10	12	13	14	15	Total
1	■	4500	4500												9000
2		■		1200											1200
3			■	1200											1200
4				■	2400										2400
5					■	300	2200	400		300					3200
6						■			200						200
7					400		■								400
8								■							
9									■					200	200
10					200					■					200
11											600				600
12											■	600			600
13												■	600		600
14					200								■		200
15														■	
Total		4500	4500	2400	3200	300	2200	400	200	300	600	600	600	200	20000

(Refer Table 1 to know the name of the blocks corresponding to the number. For example number 1 corresponds to slaughter hall)

Table 2. From-to-Chart (all in kg), Source: Data Analysis

It can be seen that a total of 20,000 Kg of material is flowing in this plant. The total flow is given at the bottommost and rightmost cells in the chart which helps in finding out the blocks with large material flow. The blocks 16 and 17 which is the supervisor's room and office room respectively is not shown in the chart since no material flow is happening in these blocks. The chart reveals that the block five (cutting area)has got the highest intensity of material flow hence block five is given top priority since it handles a large quantity of material flow. The second largest flow happens from block 7 (cold storage 1) to the cutting area, therefore, it may be economical to place these two blocks (5 and 7) together.

This chart also helps in finding out the material handling effort in the plant by analysing the quantity of flow. The number of moves can be calculated from the chart which acts as the basis of comparison.

Step 4: The next step is to ascertain the process sequence of the products under study namely sausage, cutlet and canned products in the three meat varieties.

Sausage:

Pork	1-2-4-5-7-5-8
Beef	1-3-4-5-7-5-8
Chicken	11-12-13-14-5-7-5-8

The last four blocks of the sausage making are the same irrespective of the meat variety. Block 8 (cold

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storage 2) is the area where final sausage packets are stored.

Cutlet:

Pork   1-2-4-5-10-5

Beef   1-3-4-5-10-5

Chicken   11-12-13-14-5-10-5

In cutlet too the last three blocks of the cutlet making are the same irrespective of the meat variety. From the cutting area, cutlet packets are taken to the outlets for sale.

Canned products:

Pork   1-2-4-5-6-9-15

Beef   1-3-4-5-6-9-15

Chicken   11-12-13-14-5-6-9-15

In the case of canned products, the last four sequences are the same for all three variants. The block 15 (cold storage 4) is the area where final canned product packets are stored.

Step 5: In this step, the distance between the blocks and the number of movements between the blocks were analysed from the from-to-chart. The total distance of the product is the real distance between the blocks and the number of movements. From the table below it could be seen that the total distance between the blocks were 6002.55 metres.

Process	Distance(m)	No of moves	Total Distance(m)
1-2	14.9	30	447
1-3	12.1	30	363
2-4	4.1	30	123
3-4	2	30	60

Process	Distance(m)	No of moves	Total Distance(m)
4-5	1	120	120
5-6	19.8	15	297
5-7	23.34	110	2567.4
5-8	22.4	20	446.8
5-10	3.6	15	54
6-9	14.625	10	146.25
7-5	11.09	20	221.8
9-15	45.76	10	457.6
10-5	11.67	10	116.7
11-12	2.35	30	70.5
12-13	2	30	60
13-14	2	30	60
14-5	39.15	10	391.5
		Total	6002.55 m

Table 3. Distances and Number of Movements, Source: Data Analysis

With the completion of the five steps, all the necessary information for performing SLP was obtained. The next stage is to ascertain the relationship or the closeness between the 17 units. However, before performing this exercise, it is essential to study the existing layout and its shortcomings.

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Present Plant Layout

The layout below depicts the present layout of the meat processing unit which is under study.
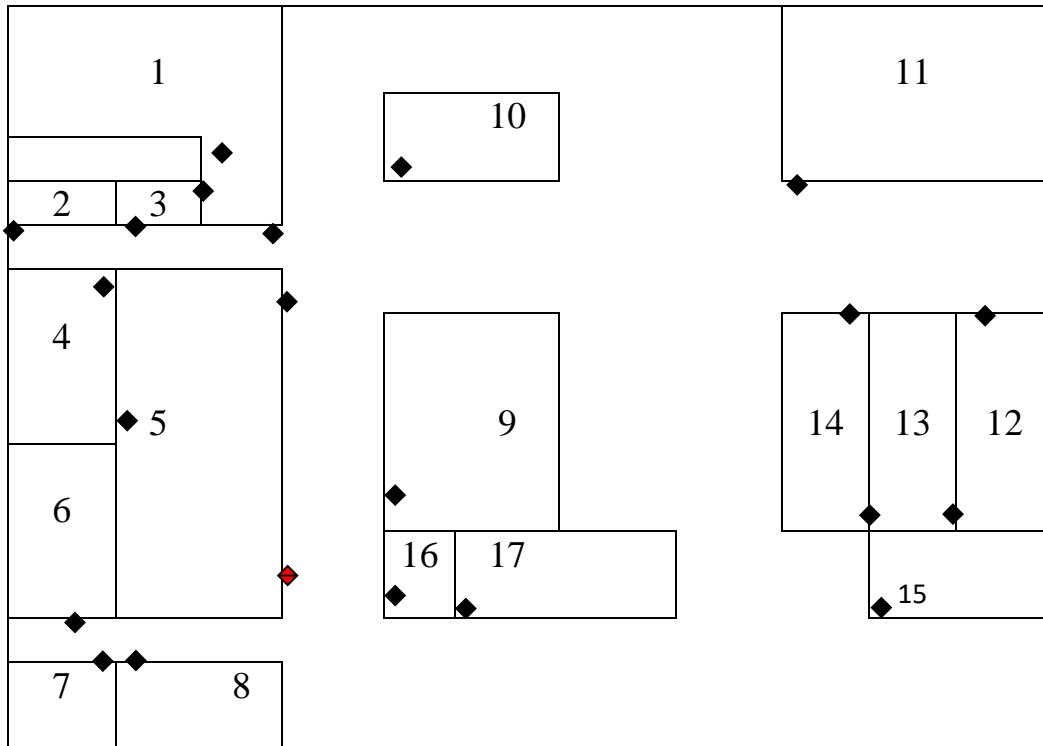

Figure 1. Present Plant Layout

1 Slaughter hall

2 Chilling Unit 1

3 Chilling Unit 2

4 Process hall

5 Cutting area

6 Curing

7 Cold storage 1

8 Cold storage 2

9 Canning

10 Cooking room

11 Chicken slaughtering

12 Chicken cutting

13 Processing area

14 Cold storage 3

15 Cold storage 4

16 Supervisor room

17 Office

◆   Exit point

◆   Entry point

Analysis of Material Handling Effort of the Existing Plant Layout

Very manufacturing firm will have material transportation. Material handling cost account for 10 to 30 % of the total operational cost, depending on the layout design and the material being transported (IISE). Material handling efforts could be reduced by systematic layout planning [12].

- The distance travelled by trolley in one day = 6002.55m
- There are 2 shifts per day
  - The distance travelled per shift = 6002.55/2 = 3001.275m
  - Wages of workers = Indian Rupee 1200 i.e. $17.10
  - No of workers = 25
  - Average material handling cost/meter = (number of worker*salary of one worker per day)/average distance travel per day = (25* 17.10/30)/3001.275=$ 0.004747
  - Total material handling cost/day = 0.004747 *6002.55 = $28.5

Designing the improved plant layout

Before designing the improved plant layout, the limitations of the current plant layout from the above analysis are stated below.
- High material handling the cost
- Improper design of the entry and exit points
- Increased material handling effort
- Wastage of time

In order to improve the plant efficiency, material handling effort has to be reduced. The distance table and the from-to-chart helps to formulate a relationship diagram in which the importance of affinity of various blocks is shown. The affinity rates are given by:
- A - direct flow/greater quantity
- E - depending upon the previous activity
- I - equal/same facilities requirement
- O - convenience
- U - no significance

Stage 2: Procedure process

Step 6: Relationship diagram with closeness rating: The intensity of the relationship between the blocks is represented in this diagram. The from-to-chart results are taken into account for constructing a relationship chart.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Score
1		A	A	E	U	U	U	U	U	U	U	U	U	U	U	O	U	28
2			I	A	E	U	U	U	U	U	U	U	U	U	U	U	U	24
3				A	E	U	U	U	U	U	U	U	U	U	U	U	U	21
4					A	E	E	U	U	U	U	U	U	U	U	U	U	23
5						A	A	A	E	A	U	U	U	A	U	O	U	36
6							U	U	A	U	U	U	U	U	E	U	U	19
7								I	U	U	U	U	U	U	U	U	U	12
8									U	U	U	U	U	U	U	U	O	10
9										U	U	U	U	U	A	U	U	12
10											U	U	U	E	U	U	U	10
11												A	E	U	U	O	U	14
12													A	E	U	U	U	12
13														A	U	U	U	8
14															U	U	U	3
15																U	O	3
16																	O	2
17																		

Figure 2. Relationship chart with closeness rating

Grade

- **A** - Absolute necessary
- **E** -Essential
- **I** -Important
- **O** -Ordinary closeness
- **U** -Unimportant

Score

- **A** - 5
- **E** - 4
- **I** - 3
- **O** - 2
- **U** -1

For example: Consider block 1 and 2. They must be placed adjacent to one another so it is given the grade A and score 5. The total score for block 1 will be 28 after evaluating its relation with all the other blocks and the score for block 2 is 24.

Findings

The main areas of concern based on the relationship graph and from-to-chart are a long distance from cold storage to the cutting area, the long distance between curing and canning and the unscientific design for entry and exit points. The improved plant layout is given below.
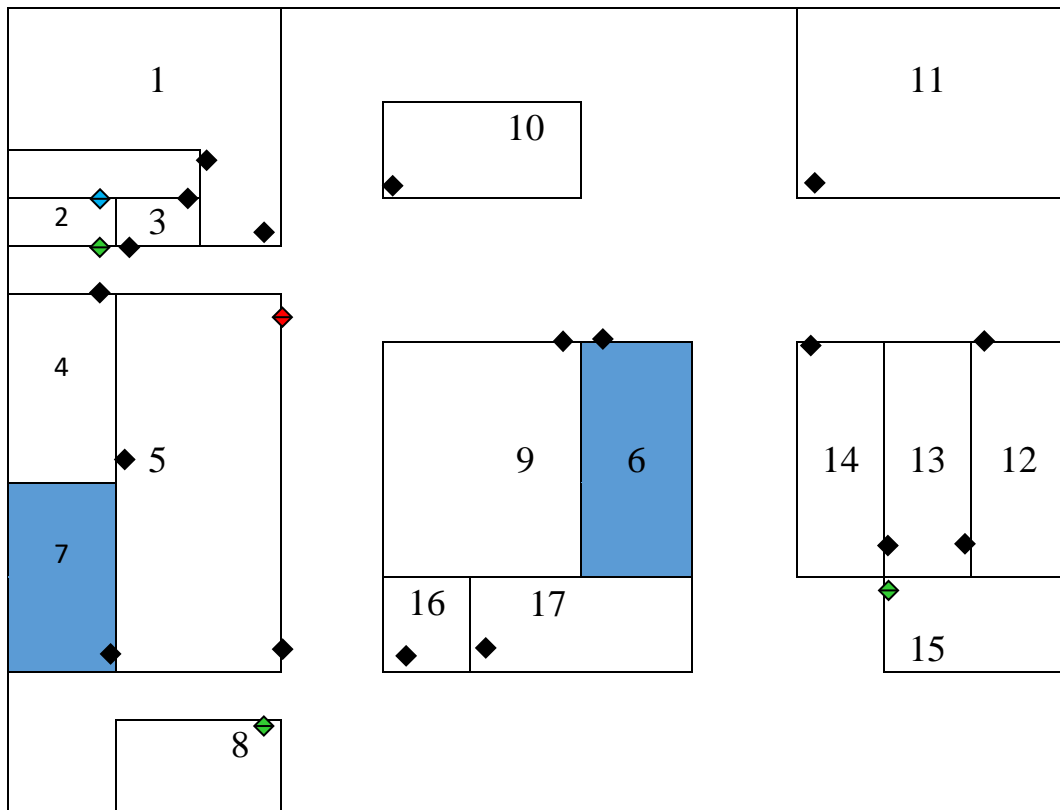
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Figure 3. Improved plant layout

| ◆ | Exit point | ◆ | Shifted entry point |
| ◆ | Entry point | ◆ | New entry point |

Modifications:

- The position of cold storage 1 is moved adjacent to the cutting area. The curing block is moved near to the canning.
- The entry point of chilling 1 is shifted towards the right and is given a new entry point for the flow from slaughtering hall.
- The entry point of cold storage 2, cold storage 4 is shifted and entry and exit points of cutting area are interchanged.

New distance between blocks

Process	Distance(m)	No of moves	Total Distance(m)
1-2	8.55	30	256.5
1-3	8	30	240
2-4	3.75	30	112.5
3-4	2	30	60

4-5	1	120	120
5-6	19.75	15	296.25
5-7	1	110	110
5-8	3	20	60
5-10	16.85	15	252.75
6-9	1	10	10
7-5	1	20	20
9-15	26.6	10	266
10-5	4.6	10	46
11-12	2.35	30	70.5
12-13	2	30	60
13-14	2	30	60
14-5	28.9	10	289
		Total	2329.5

Table 4. New analysis of material flow, Source: Data Analysis

Analysis of material handling effort of the improved plant layout

- Total material handling cost/day

= (Average material handling cost/meter) * total distance

= $ 0.004747*2329.5 = $11.058

Effectiveness of SLP

The effectiveness of Systematic layout planning can be understood by comparing the material handling effort and cost of the present plant layout and proposed plant layout. The plant layout using SLP reduced the distance between the blocks which are shown in the table. The total distance for the process sequence with respect to the present and proposed plant layout is represented as TD1 and TD2 respectively.

Process sequence	TD1(m)	TD2(m)
1-2	447	256.5
1-3	363	240
2-4	123	112.5
3-4	60	60
4-5	120	120
5-6	297	296.25
5-7	2567.4	110
5-8	446.8	60
5-10	54	252.75
6-9	146.25	10
7-5	221.8	20
9-15	457.6	266
10-5	116.7	46
11-12	70.5	70.5
12-13	60	60
13-14	60	60
14-5	391.5	289
Total	6002.55 m	2329.5 m

Table 5. Comparison of distance, Source: Data Analysis

The distance has been reduced from 6002.55 m to 2329.5 m by the improved plant layout designed using systematic layout planning. The material handling cost comparison is given in the table below.

	Present plant layout	Proposed plant layout
Total distance	6002.55 m	2329.5 m
Average material handling cost/meter	$ 0.004747	$ 0.004747
Total material handling the cost	$28.5	$11.058

Table 6. Comparison of Material Handling cost, Source: Data Analysis

By simple modifications, the material handling cost has been reduced from $28.5 to $ 11.058 which is a huge difference (refer table 6). The modified plant layout has little changes with respect to the present layout in the plant. The material handling effort of 6002.55m is reduced to just 2329.5m which in-turn will improve the plant efficiency as the workers need not travel long distances for material handling.

Conclusion

The research has established the effectiveness of systematic layout planning in enhancing the productivity of the plant through this modified facility layout planning. A case study was achieved in a frozen meat processing unit, a small scale industry. It was seen that by unassuming modifications the material handling cost has been drastically reduced. As the chosen plant is small in size, the modified plant layout has little changes with respect to the present layout in the plant. However, the material handling effort has reduced from 6002.55m to just 2329.5m which in-turn will improve the plant efficiency as the workers need not travel long distances for material handling. This reduction in material handling could contribute to equivalent time and effort savings which would have been put into productive use. Thus the project resulted in a better layout with the minimum material handling cost and effort.

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