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# OPTIMIZATION OF PLANT LAYOUT FOR A STATE ROAD TRANSPORT CORPORATION

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## ABSTRACT

Facility layout design is a strategic issue and has a significant and lasting impact on the efficiency of a manufacturing system. An ideal facility layout provides the optimum relationship among output, floor area and manufacturing process. Traditionally, the facility layout problem is solved using many methods like heuristics, Mathematical programming, Knowledge based approaches etc. This paper presents a case study for optimizing the layout with minimum cost in an automobile manufacturing company. Since it is an automobile assembly plant, the company has both process as well as product layouts. The first visit to the company revealed a variety of problems due to its improper layout. For optimizing the present layout of the plant Graph theory and assembly line balancing principle is used. This work studies the impacts of implementing the modified layout based on Graph theory in a transport corporation, in terms of cost and production line efficiency. The cost analysis shows a savings of about 15% per bus in manufacturing by this method. The proposed layout does not require so much of restructuring. By investing an amount of around 25 Lakhs, restructuring can be done also, the profit can be attained within a short payback period of two months. The implementation of proposed model will help in the overall improvement of production performance of the bus body building unit of corporation.

**Keywords**: Facility layout, Graph Theory, Material handling costs, Assembly line balancing

## 1. INTRODUCTION

The paper titled “Optimization of plant layout for a State Road Transport Corporation” is aimed at identifying some of the major problems regarding the present layout of the bus body building unit of a public sector transport corporation under the government of Kerala, and to develop an efficient layout design, so as to improve the production performance of the firm.

Facility planning is very important in manufacturing process due to their effect in achieving an efficient product flow. It is estimated that between 20% -50% of the total costs in manufacturing is related to material handling. This cost can be reduced until 30% through an effective facility planning. Proper analysis of facility layout design could improve the performance of production line such as decrease bottleneck rate, minimize material handling cost, reduces idle time, raise the efficiency and utilization of labour, equipment and space.

The study addresses these problems by designing a product layout with the principles of line balancing for enhanced productivity and higher product outputs at the scheduled time or at a shorter cycle time. The study will be of benefit to production managers in the automobile assembly plant as well as research and development scholars in the automobile industries.

## 2. BASIC OPERATION OF MANUFACTURING

In KSRTC-central works, Bus Body Building unit deals with the construction and assembly of various parts for the construction of bus. They are doing bodybuilding works for different classes of buses like City ordinary, Fast passengers, Super fast, Super deluxe etc. Presently, around 516 employees are working under this unit. With the present manpower, they can manufacture a maximum of 40 buses per month.The prime component in construction of a bus is chassis, which KSRTC presently purchases from leading vehicle manufacturers like TATA and ASHOK LEYLAND. The chassis is brought to this unit and the body is built through a series of stages.

The basic stages coming under the construction of a bus is shown below:

- Mounting of cross bearers and structures
- Flooring of Platform and Construction of Front cowl
- Paneling Works
- Fitting of Seat frames Painting
- Painting
- Fitting of Vertical post, Grab rail and Window rail
- Finishing Works
- Fully Built Bus

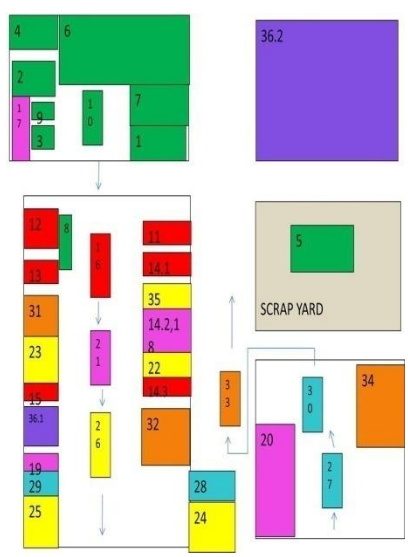
## 3.EXISTING LAYOUT OF THE COMPANY

The present layout of the bus body building unit of the company is shown in the fig1.In the existing layout, the work centres are not located in the true order of product flow. In the fig, the blocks in the centre portions of the plant represents the workstations, the others represents the workcentres. The data regarding the present layout of the bus body building unit is shown in the table1.

TABLE 1. PRESENT LAYOUT DATA

| | |
|---|---|
| No. of Work stations | 7 |
| No. of Work centres | 29 |
| No. of Employees | 516 |
| No. of buses manufacturing per month | 40 |
| Total area of the Plant | 5700 m2 |
| Labour cost | ₹s.103193 |
| Total cost of construction per bus (excluding chassis cost) | ₹s.522612 |
| Total flow time per bus | 92 hrs |
| No. of job required per bus | 325 (2600 hrs) |

FIGURE 1. PRESENT LAYOUT



## 4. PROBLEM DESCRIPTION

In Bus Body Building unit, the work centres are not located in the order of product flow. Hence prolonged movements and several cross movements are existing in the present layout. Also, so many time consuming activities are existing in the present layout due to the lack of proper equipments .The other issues coming under the present layout are work delays, human safety issues, pollution etc.

In order to achieve a smooth material flow and to make the working environment more flexible , the existing plant layout is need to be modified .Hence we can use plant more effectively . There by, the cost of production per bus can be reduced also; the productivity of this unit can be raised.

## 5. ANALYSIS OF EXISTING LAYOUT

In this section the existing layout is studied in detail to facilitate improvement. As a part of the work the first step to be done is collection of department details.
The precedence diagram is drawn along with this to gain a basic understanding on the material flow and also to identify the major activities and its successors as well as itspredecessors. The precedence diagram that has been used is given in the fig 2.

TABLE 2 AREA OF DEPARTMENTS

| No. | Department Name | Area (m2) | No. | Department Name | Area (m2) |
|---|---|---|---|---|---|
| 1 | C-channel cutting centre | 39.2 | 19 | Shutter leaf work | 19.2 |
| 2 | Cross bearer work centre | 38.4 | 20 | Shutter setting | 134.4 |
| 3 | Square pipe cutting centre | 16 | 21 | Workstation 3 | 24 |
| 4 | Pipe bending centre | 57.6 | 22 | Courier box door | 19.6 |
| 5 | Phosphating plant | 192 | 23 | Door work centre | 115.2 |
| 6 | Structure work centre | 405.6 | 24 | Luggage work | 192 |
| 7 | Footboard work centre | 78.4 | 25 | Seat frame work | 153.6 |
| 8 | Angle iron cutting centre | 8 | 26 | Workstation 4 | 24 |
| 9 | Angle iron drilling centre | 16 | 27 | Workstation 5 | 24 |
| 10 | Workstation 1 | 24 | 28 | Sleeve fitting | 96 |
| 11 | Sheet bending & cutting | 58.8 | 29 | Vertical post | 19.2 |
| 12 | Glass frame work centre | 115.5 | 30 | Work station 6 | 24 |
| 13 | Flat iron cutting centre | 57.6 | 31 | Coach builder | 96 |
| 14 | Front cowl work centre | 117.6 | 32 | Upholstery work | 117.6 |
| 15 | Safety bracket work centre | 19.2 | 33 | Work station 7 | 24 |
| 16 | Workstation 2 | 24 | 34 | Electrical section | 59 |
| 17 | Top sheet bending | 9.6 | 35 | Corner glass | 20 |
| 18 | Outside top work centre | 98 | 36 | Store | 1600 |

As a part of the analysis, distance matrix and flow matrix is to be prepared. The distance matrix has been developed using the rectilinear distance between the departments having material flow. The rows and columns in the matrices indicate the departments and are given numbers from 1-36 in the table. The flow matrix is developed by calculating the number of trips travelled for per product for the departments having material flow.

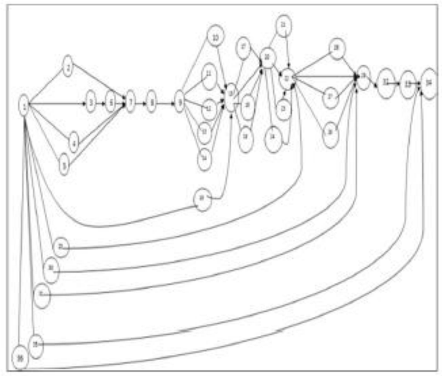


FIGURE 2 PRECEDENCE DIAGRAM

**Determining material handling cost**

For analysis, the unit cost of material flow is required. Since this is not available with the company, it is calculated indirectly as below

Total manufacturing cost per bus is Rs.5,22,612 as given by company and assume material handling cost is 20-25% of the total production cost per bus. For analysis taking 20% material handling cost, then material handling cost is Rs.1,04,522 per bus. The unit material handling cost, Cij can be calculated as given below

$$Cij = MHC/ D \qquad (1)$$

where D is the total distance travelled by the material. Here the calculated unit material handling cost, $c_{ij}$ is 19. The total Material handling cost, MHC incurred in a manufacturing process can be estimated by using the following formula;

$$MHC = \Sigma\Sigma\, c_{ij}\, d_{ij}\, f_{ij}$$

for all i,j=1,2,….n (2)

where $C_{ij}$ is the unit material handling cost, $d_{ij}$ ,$f_{ij}$ are the distance and flows between the departments, whose values can be collected from the distance and flow matrices. Hence the total material handling cost in the present layout is Rs.2, 64,844.

## 6. LITERATURE REVIEW

In this section researches regarding various approaches for solving the facility layout problem are discussed. Alternate layouts can be generated using lean layout concepts such as ‘group technology’ and ‘systematic layout planning’, which facilitate relocating the equipment according to product processing [4]. The main Production Line Balancing Problems such as queuing, idling time etc can be minimized by Multi-Objectives Model (MOM) and Genetic Algorithm (GA). The outcome of the Mixed Models (MM) assists to reduce the queuing and the idling time through harmonizing the tasks in each workstation. In addition to balance the distribution of the new workers in order to get the optimal solutions, as well as improving the ability of PL with the high production rate[2].

For improvement in process layout, Graph theory can be used with the framework of systematic layout planning methodology. The cost analysis shows a saving of about 62.4% per year in material handling cost by this method [1].The most well known heuristic methods in optimizing layout design are Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA). Tabu Search (TS) is a mathematical optimization method, belonging to the class of local search techniques. A genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Simulated annealing (SA) is a generic probabilistic metaheuristic for the global optimization problem of applied mathematics, namely locating a good approximation to the global minimum of a given function in a large search space [7].

Genetic algorithm has wide number of alternatives through which different types of layout can be designed at minimum time without any hazards. This idea can be applied in any type of layout in manufacturing organization or any corporate sector or any pharmaceutical company and so on [8]. Alternate layouts can be generated using lean layout concepts such as 'group technology' and 'systematic layout planning', which facilitate relocating the equipment according to product processing [6].The application of assembly line balancing heuristics to designing a product layout for automobile assembly to provide a platform for high utilization of labour and equipment, which is necessary for scheduled completion of motor manufacturing processes in product development project [5].

The key innovative practices in facility layout planning includes few of the modern Facility Layout Planning designs viz. CRAFT(Computerized Relative Allocation of Facilities Technique),SLP(systematic layout planning),QAP(Quadratic Assignment Problem), and Basic models like Assembly line balancing, Mixed model line balancing, Group technology layouts, Material handling cost method, Flexible manufacturing system(FMS) too. The desired results is towards the finding out way of facility locations designs offering better productivity and enhanced overall organizational efficiency in all-around[3].

## 7. MODIFIED LAYOUT DESIGN BY GRAPH THEORY AND ASSEMBLY LINE BALANCING HEURISTIC

As shown from the previous calculation, material handling costs of the present layout is not a satisfactory one. This needs to be improved by making changes in the existing layout. As seen in the literature review there is a variety of tools and techniques for the purpose. But due to its simplicity graph theory for improvements in the existing layout is used.

### Application of Graph theory

A typical graph theoretic heuristic for the layout problem consists of the following steps;
Step 1: Construction of Activity Relationship Chart from Precedence diagram
Step 2: Construction of Activity Relationship diagram from Activity Relationship Chart Step 3: Development of Block Layout from Activity Relationship diagram
Step 4: Development of Modified Plant Layout from Block Layout

### Construction of REL chart

Activity Relationship chart or REL chart gives the information about closeness between the departments. In REL chart, all pairs of relationships are evaluated and closeness rating (A, E, I, O, U) is assigned to each pair.

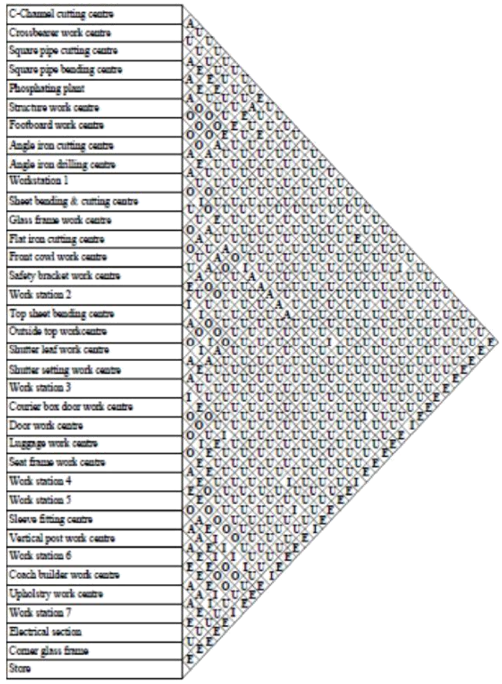



FIGURE 3. REL CHART

**Construction of Activity Relationship diagram**

In the Activity relationship diagram, vertices denote facilities and edges denote the existence of flows. The relationship diagram is obtained by placing A (Absolutely important) activities closer and U (Unimportant) activities farther. The relationship diagram so obtained is represented in Fig and the numbers in the circles indicate the number that is assigned to each department in the REL chart.

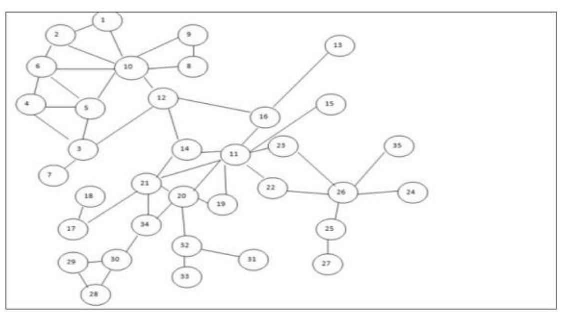


FIGURE.4 RELATIONSHIP DIAGRAM

**Construction of Block Layout**

Then the relationship diagram is converted to the block layout in the next stage. The block layout shows the departments and its area requirements in blocks. The block layout is given in the fig. In Block layout, the edge in activity relationship graph becomes the boundary between departments.

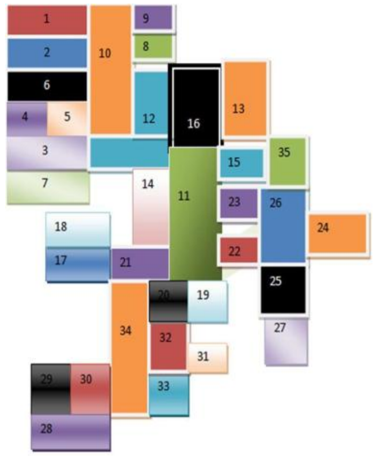


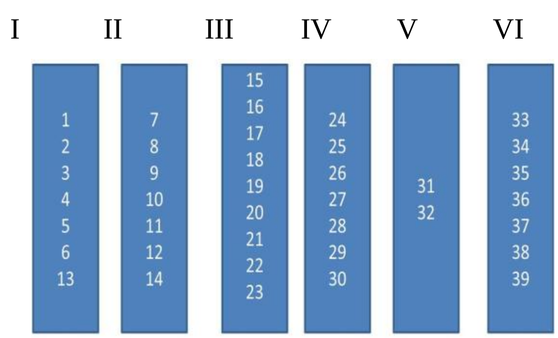

FIGURE 5. BLOCK LAYOUT

**Application of Assembly line balancing**

By integrating the principles of line balancing with the block layout, a better modified layout can be obtained. The procedures proposed by Kilbridge and Wester numbers are assigned to each operation describing how many predecessors it has. Operations with the lowest predecessors are assigned first to the workstations. The procedure consists of the following steps.

1. Construct the precedence graph
2. List in column I, all work elements that need not follow others.
3. List in column II, all work elements that must follow those in column I continue the other columns in the same way. The elements within a column can be assigned to workstations in any order provided all the elements of previous column have been assigned
4. Select a feasible cycle time.
5. Assign work elements to the station such that the sum of station time does not exceed the cycle time.

In the task assignment, the selected feasible time is 20.Work element 1 is selected first because it has the least number of predecessors. Therefore, we assign element 1 to station 1.Element 7 cannot be added to station 1,otherwise the station time will exceed the cycle time; therefore, we assign element 7 to station 2 and continue with the above process.




**Modified layout design**

The modified plant layout is modelled in AutoCAD software, which is shown in the figure. One of the major highlight of the modified layout design is that the locations of workcentres are in the true order of product flow. Also, crossover and longer movements are less in the modified layout design when compared with the present layout. Hence the distance travelled by the material can be reduced to a greater extent in the modified layout. By implementing the proposed design, we can also improve the production performance parameters like flow time, line efficiency etc.

In order to implement the modified layout design, so much of restructuring is not required. One of the major step to be taken as a part of the layout modification is that rearranging the location of workcentres as per the modified layout design. Also, the new locations of store and phosphating process plant as per the modified layout design will help to access the raw materials very easily. No extra space is required to implement the modified layout design.

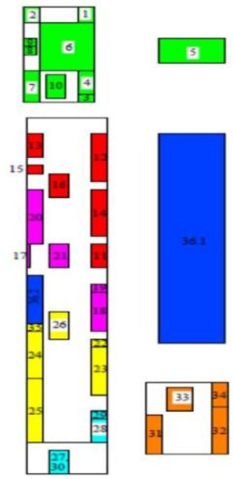


FIGURE 6. MODIFIED LAYOUT

## 8. ANALYSIS OF PLANT LAYOUTS

The present layout and modified layout can be analyzed in terms of following parameters.

- Distance
- Production time(Flow time)
- Material handling cost
- Labour cost
- Production rate
- Production line efficiency

**Distance**

In the present layout, the total distance travelled by the material is 5377.45 m. While in the case of modified layout, the total distance travelled by the material is 3309.3 m(by using distance matrices). The distances travelled by the material came down by 38%, which can be seen clearly at the distance matrix of modified layout.

**Production time (Flow time)**

In present layout, production time required for assembling a bus is 92 hrs. Since time taken for transportation is also a function of total task time, the reduction in total distance will also reduce the total production time. Total time taken for transportation is 10.5% of total production time (by calculation).In present layout, the total time taken for transportation is 9.6 hrs while in the case of modified layout, the total time taken for transportation is 6.02 hrs (by calculation) . Hence, the time saved is 3.64 hrs (4 % of total production time).In modified layout, total production time per bus is 88.3 hrs.

**Labour cost**

Since production hours are directly related to labour hours, reduction in total production time will reduce the total labour hours. In the present layout, for the production time 92 hrs, the required labour hours is 2600 hrs (std.labour hrs). The labour cost incurred for 2600 labour hrs is Rs.1, 03,193.While in the case of modified layout, for the production time 88.3 hrs, the required labour hours is 2488 hrs (by calculation).The labour cost incurred for 2488 labour hrs is Rs. 98,757 (by calculation).Hence, the total labour cost saved in the modified layout design is 5%.

**Material handling cost**

Total material handling cost in the present layout is Rs.2, 64,844**.** Total material handling cost in the modified layout is Rs.1, 93,158**.** Material handling cost saved is 27.1 %

**Production rate**

In the present layout, the cost of construction for manufacturing one bus is Rs.522612. While in the case of modified layout, the cost of construction for manufacturing one bus is Rs.4, 45,766. Hence, total cost that can be saved per month for manufacturing 40 buses is Rs. 30, 73,840. With these costs, the production rate can be increased from 40 to 46.

**Production line efficiency**

The production line efficiency, E of an assembling process can be estimated by using the following formula;

$$E = T/(C \times N) \quad (3)$$

where T is the Total time or Flow time, C is the Cycle time and N is the no. of workstations. In the present layout, T is 92hrs, C is 26 and N is 7. Hence, the production line efficiency, E of the present layout is 50.5 %.While in the case of modified layout, T is 92hrs, C is 20 and N is 6. Hence, the production line efficiency, E of the modified layout is 76.7 %.

**Economic Feasibility Analysis**

A feasibility analysis is done to check the practicability of proposed layout. In the proposed layout, the total material handling cost that can be saved per bus is Rs.71, 686.The total production time that can be saved per bus is 3.7 hrs .The total labour cost that can be saved per bus is Rs.4296.Hence, the total cost of production that can be saved per bus is 76, 846.Thus, the total cost that can be saved per month (for 40 buses) is Rs. 30, 73,840.Total cost to be invested for restructuring the plant is Rs.24,21,000 (around 25 Lakhs).Hence, the required payback period is 2 months.

## 9. COMPARISON OF PLANT LAYOUTS

The results obtained were analyzed and compared in terms of several parameters which are shown in the table4.The existing layout and modified layout were compared in terms of parameters such as distance, material handling costs, flow time, labour cost and production rate

TABLE 3. COMPARISON OF PLANT LAYOUT

| Parameters | Existing layout | Modified layout |
|---|---|---|
| Distance | 5377.5 m | 3309.3 m |
| Material handling cost | 264844 Rs | 193158 Rs |
| Production time(Flow time) | 92 hrs | 88.3 hrs |
| Labour cost | 103193 Rs | 98897 Rs |
| Production rate | 40 | 46 |

## 10.CONCLUSION

The proposed model based on Graph theory is found to be effective in solving the above mentioned problems. The production rate increased by 17%, the production time per bus came down by 5% and the cost of construction came down by 15% .By optimizing the layout design, the total manufacturing cost that can be saved per bus is Rs.76, 846. By investing an amount of around 25Lakhs restructuring can be done with a short payback period of two months. It is expected that the implementation of proposed model will help in the overall improvement of production performance of the bus body building unit of KSRTC.

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