Using Geometric Mean Method of Analytical Hierarchy Process for Decision Making in Functional Layout

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Abstract

Layout of any firm must be considered very carefully as the authorities do not want to constantly redesign the layout causing more expenditure. Some of the goals in designing the facility are to ensure a minimum amount of materials handling, to avoid bottlenecks, to minimize machine interference, to ensure high employee morale and safety, and to ensure flexibility. Hence a proper layout should be selected for any manufacturing firm to avoid any problem. In this paper Geometric mean method a mathematical process of Analytical Hierarchy Process (AHP) is used for analysis of functional layout parameters i.e. whether it can be implemented or not under the condition considered.
Keywords: *Analysis, Analytical Hierarchy Process, Conditions, Cellular layout, Geometric mean method, Implementation, Manufacturing firm.*

1. Introduction

Plant layout is an arrangement of physical facilities such as machinery, equipment, furniture etc. with in the factory building [1]. Only the properly laid out plant can ensure the smooth and rapid movement of material, from the raw material stage to the end product stage. Plant layout encompasses new layout as well as improvement in the existing layout. It is an important decision as it represents long-term commitment. An ideal plant layout should provide the optimum relationship among output, floor area and manufacturing process. It should facilitates the production process, minimizes material handling time and cost, allows flexibility of operations, easy production flow, promotes effective utilization of manpower providing them comfort at work. A poor layout will led to various problems; hence a proper layout should be selected for any manufacturing firm to avoid any problem. There are four basic types of layouts for manufacturing facilities; Functional (process), product, fixed position and Hybrid Layouts: cellular manufacturing (CM). Out of all these layouts we are only focusing here on functional layout.

Functional layouts: In a functional layout machines of similar type are arranged together in one department. The initial capital investment and overhead costs are relatively low in such layouts. Breakdown of one machine does not result in complete work stoppage. Even there is greater flexibility of scope for expansion. Hence, functional layout is associated with high machine utilization and shop flexibility working at low/medium and unstable demand with high product variety. These are important reasons why a functional layout is still dominant in manufacturing industry. A general layout of this type can be seen in the Fig 1, were all the machines are grouped according to the process they performed. Process layout is adopted when:

1. Products are not standardized.
2. Quantity produced is small.
3. There are frequent changes in design and style of product.
4. Job shop type of work is done.
5. Machines are very expensive.

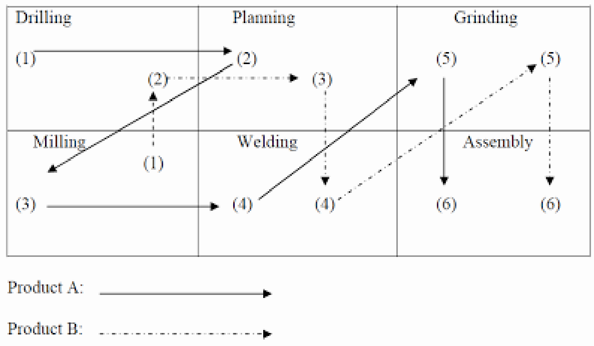

Fig. 1 Functional Layout

The Analytical Hierarchy Process (AHP) was first developed and explained by Saaty in 1980 [3]. In AHP the candidate requirements are compared pair-wise, and to which extent one of the requirements is more important than the other requirement. It allows the problem to be modelled in a hierarchical structure by the decision makers. Decision makers must first understand and determine the goal, criteria and alternatives of the problem before a hierarchic structure can be developed. The AHP then requires the decision makers to carry out simple pair wise comparison judgements (Saaty et al.). The judgements of the decision makers are generally based on the state of mind, situations, learning and the personal experience. There are two ways of generating the comparisons, which are by experience and feeling (Takeda et al [4]). The essence of AHP is to construct a matrix expressing the relative values of a set of attributes .Each of these judgments is assigned a number on a scale. One common scale (adapted from Saaty) is as shown in the Table 1:

Table 1: Saaty Scale

Intensity of importance	Explanation	Definition
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more Important	Experience and judgment slightly favour one over the other.
5	Much more Important	Experience and judgement strongly favour one over the other.
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

The overall summary of implementing the AHP can be classified to three basic principles; i) decomposition of the problem ii) pair wise comparisons and iii) composition of the resulting priorities or synthesis of priorities [5]. Next the three basic principles for AHP are explained further:

A) Decompose of the problem

The problem is decomposed by structuring it in a hierarchical form.

B) Pair wise comparisons

The pair wise comparisons are constructed by comparing pairs of elements in each level of hierarchy with respect to every element in the higher level. These pair wise is used to establish priorities for each set of elements in each level of hierarchy. Comparing the pairs of elements is generated by giving a comparative judgment of preferences for each pair of elements in every level using the Saaty's nine-point scale. This comparison process is carried out to determine which of the element in a pair is more desirable or preferred compared to the others. These comparisons are positioned into a positive reciprocal or pair wise comparison matrix. The derivation of the priorities from pair wise comparisons matrix is the main concept of the AHP .The AHP allows decision makers to derive ratio scale priority or weights from the pair wise comparisons matrices. The priorities or the priority vector for every set in a level is estimated by using the prioritization method (i.e. eigenvector method, additive normalization method, geometric mean method).

C) Composition of the resulting priorities or synthesis of priorities.

This principle is applied to attain the composite priority for the lowest level elements, which are the alternatives based on the overall preferences expressed by the decision makers. Every priority vector (priorities) in the lowest level is weighted by the higher level priorities. The purpose is to attain the composite priority (the overall relative weights of the alternatives) that reflects the overall importance of each alternative. The prioritized ranking of the decision alternatives can be derived from the composite priority.

Ghosh and Wabalickis [5] in their study explore future manufacturing systems considering the criteria workforce, equipment, methods and materials, information processing and throughput time with the help of AHP. Datta [6] evaluate different types of manufacturing systems considering flexibility, quality/reliability, technical feasibility, market position, technology position, investment, throughput, inventory, information, capacity utilisation, employee relations and human factors as the main criteria. Razmi [7] determine the global priority weights for different production planning methods by analyzing the cost, flexibility, market issues and influences. Forman and Gass [8] have discussed applications of AHP for decisions such as choice, prioritisation, resource allocation, benchmarking, quality management, public policy, health care and strategic planning. A recent work on the use of AHP in decision making for flexible manufacturing system by Ozden Bayazit [9] has provided a framework for carrying out this work. In that work pair wise comparison of the considered criteria was performed to evaluate whether implementation of FMS is done or not in a Turkish Tractor Manufacturing company. Likewise, I also try to analyse the functional layout with the help of certain criteria evolved in any type of manufacturing firm by using AHP. The work contains the survey of some manufacturing firm implementing functional layout, understanding the outcomes and than calculating the priority vectors for the criteria being considered to provide a ranking order.

2. Research Methodology

The methodology consists of the survey instrument and all its inclusion and later discussions related to the models using analytic hierarchy process. The first step is determining the basic elements that has to be compared in pair wise matrix form, so that we can conclude at last whether functional layout should be considered by the manufacturing unit under such conditions or not. Factors to be considered while deciding the efficient layout are:

1) Flexibility: It means the ease with which an existing layout can be modified or readjusted in order to satisfy any future expansion or changes.

2) Utilisation of Space: The layout selected should be such that it can use the available space properly in order to move the equipment easily along with their proper placement.

3) Customer satisfaction: There should be less lead time, high delivery speed, good response and also good quality of the product.

4) Capital: There should be use of appropriate amount of capital, neither too low nor too high.

5) Labour constraints: Since this directly affects production, factors like team work, ease of communication, incentives, wages, skill, training, supervision.

6) Product variety: The layout should be such that it should be able to produce a lot of variety in the products with good quality.

7) Material handling: The layout should ensure less material handling i.e. less inter department move, routing should be well defined and also the travel distance is less.

8) Work in process: There should be low work in process in the layout selected.

First of all the matrix should be made for pair wise comparisons with appropriate variables and than the values should be entered on the basis of findings for Functional Layout, as shown in Table 2:

Here the symbols used denotes the following words,

SU: Space Utilization

CS: Customer Satisfaction

LS: Labour Constraints

PV: Product Variety

MH: Material Handling

WIP: Work In Process

Table 2.Result obtained for Functional Layout

Variables	Flexibility	SU	CS	capital	LS	PV	MH	WIP
Flexibility	1	3	2	3	2	4	3	3
SU	1/3	1	1/3	1/2	1/3	1/2	2	3
CS	1/2	3	1	1/2	1/2	1/2	2	3
Capital	1/3	2	2	1	2	1/2	2	3
LS	1/2	3	2	1/2	1	1/3	2	3
PV	1/4	2	2	2	3	1	3	3
MH	1/3	1/2	1/2	1/2	1/2	1/3	1	2
WIP	1/3	1/3	1/3	1/3	1/3	1/3	1/2	1

We convert this matrix into standard matrix to perform the Geometric mean method used in AHP. Hence the standard matrix obtained for Functional Layout is as shown in Table 3

Table 3.Standard matrix for Functional Layout

Variables	Flexibility	SU	CS	capital	LS	PV	MH	WIP
Flexibility	1	3	2	3	2	4	3	3
SU	0.33333	1	0.33333	0.5	0.33333	0.5	2	3
CS	0.5	3	1	0.5	0.5	0.5	2	3
Capital	0.33333	2	2	1	2	0.5	2	3
LS	0.5	3	2	0.5	1	0.33333	2	3
PV	0.25	2	2	2	3	1	3	3
MH	0.33333	0.5	0.5	0.5	0.5	0.33333	1	2
WIP	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.5	1

After obtaining the standard matrix there are three steps that have to be followed in order to obtain the priority vectors according to the GM method. The first step is to multiply every value in each row of the pair wise comparison matrix and power the values by 1⁄n (number of dimension) to obtain the total row. In deriving the priority vector, the total row then is divided by the sum of all the total rows. The priority vector is the normalized vector derived after the process is completed. The procedure for calculation is followed step by step as done below.

Multiply each element in every row and then power of 1/n

Row 1 : $(1 \times 3 \times 2 \times 3 \times 2 \times 4 \times 3 \times 3)^{1/8}$ = 2.4494

Row 2: $(0.33333 \times 1 \times 0.33333 \times 0.5 \times o.33333 \times 0.5 \times 2 \times 3)^{1/8}$ = 0.6867

Row 3: $(0.5 \times 3 \times 1 \times 0.5 \times 0.5 \times 0.5 \times 2 \times 3)^{1/8}$ = 1.0148

Row 4: $(0.33333 \times 2 \times 2 \times 1 \times 2 \times 0.5 \times 2 \times 3)^{1/8}$ = 1.2118

Row 5: $(0.5 \times 3 \times 2 \times 0.5 \times 1 \times 0.33333 \times 2 \times 3)^{1/8}$ = 1.1422

Row 6: $(0.25 \times 2 \times 2 \times 2 \times 3 \times 1 \times 3 \times 3)^{1/8}$ = 1.1464

Row 7: $(0.33333 \times 0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.33333 \times 1 \times 2)^{1/8}$ = 0.5859

Row 8: $(0.33333 \times 0.33333 \times 0.33333 \times 0.33333 \times 0.33333 \times 0.33333 \times 0.5 \times 1)^{1/8}$ = 0.4022

Step 1: Sum all the total rows,

Total sum of the rows = (2.4494+ 0.6867+ 1.0148+ 1.2118+1.1422 + 1.1464+0.5859+ 0.4022) = 8.6394

Step 2: Normalize each total of the row by dividing the total row by the total sum of the rows.

2.4494/8.6394 = 0.2635
0.6867/8.6394 = 0.0754
1.0148/8.6394 = 0.1164
1.2118/8.6394 = 0.1402
1.1422/8.6394 = 0.1322
1.4464/8.6394 = 0.1574
0.5859/8.6394 = 0.0674
0.4022/8.6394 = 0.0465

The priority vector is

$$\begin{pmatrix} 0.2635 \\ 0.0754 \\ 0.1164 \\ 0.1402 \\ 0.1322 \\ 0.1574 \\ 0.0674 \\ 0.0465 \end{pmatrix}$$

Total sum of the priority vector = 1.000

Priority vector

$W = (0.2635, 0.0754, 0.1164, 0.1402, 0.1322, 0.1574, 0.0674, 0.0465)^T$

The total for each priority vector in every method should be equal to 1.We can see the values obtained by us are also correct as the sum results in 1.The matrix is acceptable if the consistency ratio (CR) is below or equal to 0.10 [10]. Nevertheless, the result (ranking of priorities) may be different if the consistency ratio for the pair wise comparison matrix is higher than 0.10, which is not recommended (not accepted) by many of the experts. Therefore the matrix must be adjusted. We will now calculate the CR. It can be obtained by dividing consistency index (CI) by random consistency index (RCI) [11] which is provided in the Table 5:

Table 5.Values of RCI corresponding to n

n	RCI
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.25
7	1.32
8	1.41
9	1.45

"λmax" is obtained to be equal 8.6394 and by using it the value of CI then can be calculated using the formula: $CI = (\lambda max - n)/(n-1)$

Where "n" is the number of the matrix dimension which results in,

$$CI = (8.6394-8)/(8-1) = 0.09134$$

Lastly the CR can be computed by using the formula:

$$CR = CI / RCI$$

This result in:

$$CR = 0.09134/1.41 = 0.0647$$

We can see from the above calculation that the value of CR < 0.10, hence the value obtained by us is correct.

3. Result

At last we can give a ranking order to all the factors considered in our study on the basis of our calculations, as shown in the Table 6:

Table 6: Final result obtained for Functional Layout

Factors considered	Values	Rank
Flexibility	0.2635	1
Space Utilization	0.0754	6
Customer Satisfaction	0.1164	5
Capital	0.1402	3
Labour Constraints	0.1322	4
Product Variety	0.1574	2
Material Handling	0.0674	7
Work In Process	0.0465	8

The result of functional layout can be shown in terms of a graph with all the variables importance in percent form as shown in Fig. 2. It is clear from the graph that the highest percentage is attained in case of flexibility i.e. the most important criteria in case of functional is its flexibility with a percentage of 26.4333 and the least important variable is the work in process i.e. functional layout has a high WIP, with a percentage of about 4.338.Also the values of other variables can be seen through the graph presented.

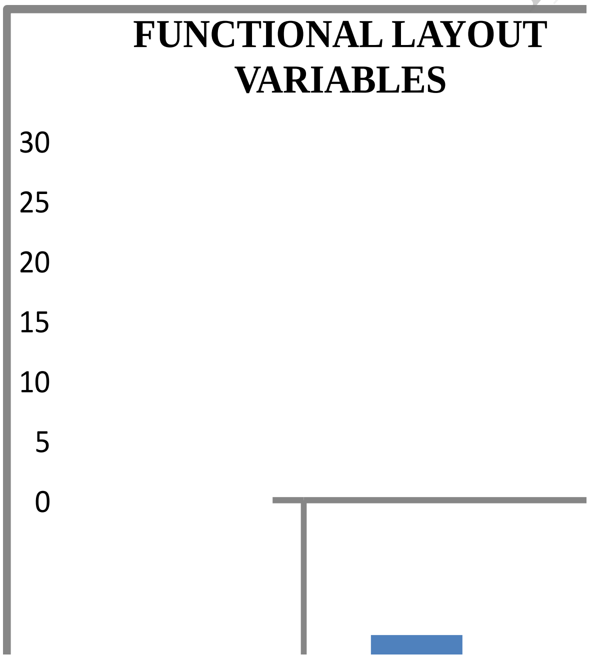

Fig. 2: Variables importance in Functional Layout

4. Conclusions

Any firm wanting to have the factors considered in the order obtained can apply functional layout in their firm for better outcomes. If firms highest priority is flexibility and product variety than it can employ functional layout without thinking too much. However in functional layout work in process and material handling is more because of the stock production in case of functional layout. Also customers are not very much satisfied in this layout because of more delivery time of products.

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