

Analysis Of Functional Layout Using Analytical Hierarchy Process (AHP)

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Abstract

The efficiency of production depend on how well the various machines, production facilities and employees amenities are located in a plant. Layout means planning for the location of all machines, utilities, employee workstations, customer service areas, material storage areas, aisles, rest rooms, lunchrooms, drinking fountains, internal walls, offices, and computer rooms, and for the flow patterns of materials and people around, into, and within buildings. A poor layout will led to various problems like increase work in process, overload the material handling and also contribute to inefficient set up, longer queues and many more. Hence a proper layout should be selected for any manufacturing firm to avoid any problem. In this paper Analysis of Functional layout i.e. the conditions under which it can be implemented is studied by using Analytical Hierarchy Process (AHP).

Index term: Analysis, Analytical Hierarchy Process, Conditions, Functional layout, Implementation, Manufacturing firm.

1. Introduction

Layout of any firm must be considered very carefully because 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. There are five 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 are designed to accommodate variety in product designs and small batches .This layout use general purpose machines that can be changed over rapidly to new operations for different product designs. These machines are usually arranged according to type of process being performed. The

equipment in a process layout is of general purpose. Workers are skilled at operating the equipment in their department. The advantage of functional layout is flexibility. They are inefficient because jobs or customers do not flow through in an orderly fashion; backtracking is common. Plus the workers may experience much "idle time" if they are waiting for more work to arrive from a different department. Material storage space in a process layout must be large to accommodate the large amount of in-process inventory. Functional layouts in manufacturing firms require flexible material handling equipment (such as forklifts) that can follow multiple paths, move in any direction, and carry large loads of in-process goods. All areas of the facility must have timely access to the material handling equipment. Functional layouts in service firms require large aisles for customers to move back and forth and ample display space to accommodate different customer preferences.

Analytical Hierarchy Process: The Analytical Hierarchy Process (AHP) was first developed and explained by Saaty in 1980. Regnell et al claim that even though this is a promising technique, the technique itself is not adapted to distributed prioritization with multiple stakeholders; hence it has to be modified in one way or another. 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., 1994). 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 (Saaty, 2003; Takeda et al1987). Saaty states that the intensity of importance should be according to 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.

AHP Methodology: The methodology consists of the survey instrument and all its inclusion and later discussions related to the models using analytic hierarchy process. It evaluates various elements by comparing them to one another two at a time (pair wise comparison). Comparisons are made using a scale of 'absolute judgements' that represents how much more one element dominates another with respect to a given reference point. AHP is very flexible and can be adapted to different needs and contexts. Criteria (or attributes) can be decided in advance or through a participatory process (increase transparency and dialogue). Criteria can be tangible and intangible can have sub criteria and be as many as necessary. The process can involve as many participants as required.

The numbers of alternatives to evaluate can also vary.

AHP Step 1: Define

- Define the 'problem', the need and purpose of the decision (goal).
- List the alternatives to evaluate (options)
- Set up the criteria and sub-criteria (attributes).
- Define the stakeholders and groups to involve in the process.

AHP Step 2: Structure

- Structure the Decision Hierarchy.
- Set up the hierarchy using the elements defined in Step 1.
- Goal on the top level, criteria in the intermediate level, set of options in the lowest level.

AHP Step 3: Pairwise Comparison

- Compare elements to one another, two at a time, with respect to their impact/ importance on an element above them in the hierarchy.
- Use numerical values to conduct the pairwise comparisons, constructing a set of pairwise comparison matrices.

AHP Step 4: Calculate relative priorities

- Values in step 3 are processed to obtain numerical priorities or weights given to the elements.
- Mathematically, AHP derives priorities using the values of the principal right eigenvectors of the comparison matrices.
- Priorities are absolute numbers between zero and one, without units or dimension.

AHP Step 5: Aggregate priorities

- Aggregate relative priorities to produce overall priorities (final evaluation metrics) which sum to 1.000.

Compare the final results: In ranks (normalizing the priorities)

2. RESEARCH METHODOLOGY

The work starts by determining first the basic elements that has to be compared in pairwise matrix form, so that we can conclude at last which layout should be considered by the manufacturing unit.

Factors to be considered while deciding the efficient layout are:

Flexibility: The layout should be such that it can be readjusted or modified according to future expansion or changes.

Utilization of Space: There should be a proper & optimal usage of space to ensure that all the equipment is properly placed & the handling of materials is done is done best in such a space.

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

Labour constraints: Since this directly affects production, factors like team work, ease of communication, incentives, wages, skill, training, supervision along with attractiveness of a facility, ventilation, lighting, restrooms & cafeterias have to be provided for maximum employee participation.

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

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.

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

Since we have decided the major variables to use in this research work, we will now construct a matrix where the pair wise comparison of the variables can be done using the Additive Normalization Method of AHP.

First of all the matrix should be made for pair wise comparisons with appropriate variables and then 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

	Flex ibili ty	SU	CS	ca pit al	LS	PV	M H	W I P
Flexi bility	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
Capit al	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

After creating the matrix we will convert this matrix into standard matrix so that the calculation needed by the Additive Normalization Method used in AHP can be performed easily. Hence the standard matrix obtained for Functional Layout is as shown in Table 3:

Table 3. Standard matrix for Functional Layout

	Flex ibili ty	SU	CS	ca pit al	LS	PV	M H	W I P
Flex ibili ty	1	3	2	3	2	4	3	3
SU	0.33 333	1	0.3 33 33	0.5	0.3 33 33	0.5	2	3
CS	0.5	3	1	0.5	0.5	0.5	2	3
Capit al	0.33 333	2	2	1	2	0.5	2	3
LS	0.5	3	2	0.5	1	0.3 33 33	2	3
PV	0.25	2	2	2	3	1	3	3
MH	0.33 333	0.5	0.5	0.5	0.5	0.3 33 33	1	2
WIP	0.33 333	0.3 333 3	0.3 33 33	0.3 33 33	0.3 33 33	0.3 33 33	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 Additive Normalization Method, so that a rank can be provided to all the variables considered according to the Functional Layout. The steps involved are as follows:

Step 1: Sum each column values separately

Column 1: $1+0.33333+0.5+0.33333+0.5+0.25+0.33333+0.33333 = 3.58332$

Column 2: $3+1+3+2+3+2+0.5+0.33333 = 14.83333$

Column 3: $2+0.33333+1+2+2+2+0.5+0.33333 = 10.16666$

Column 4: $3+0.5+0.5+1+0.5+2+0.5+0.33333 = 8.33333$

Column 5: $2+0.33333+0.5+2+1+3+0.5+0.33333 = 9.66666$

Column 6: $4+0.5+0.5+0.5+0.33333+1+0.33333+0.33333 = 7.49999$

Column 7: $3+2+2+2+2+3+1+0.5 = 15.5$

Column 8: $3+3+3+3+3+3+2+1 = 21$

Step 2: Now divide each element of the column With the sum of that column

We will get the following values after performing step 2 as shown in the Table 4:

Table 4. Values obtained after Step 2

	Flex ibili ty	SU	CS	cap ital	LS	PV	M H	W IP
Fl ex ib ili ty	0.27 907	0.2 02 24	0.1 96 72	0.3 600 0	0. 20 68 9	0.5 333 3	0. 19 35 4	0. 14 28 5
S U	0.09 302	0.0 67 41	0.0 32 78	0.0 60	0. 03 44 8	0.0 666 6	0. 12 90 3	0. 14 28 5
C S	0.13 953	0.2 02 24	0.0 98 36	0.0 60	0. 05 17 2	0.0 666 6	0. 12 90 3	0. 14 28 5
C ap it al	0.09 302	0.1 34 83	0.1 96 72	0.1 20	0. 20 68 9	0.0 666 6	0. 12 90 3	0. 14 28 5
L S	0.13 953	0.2 02 24	0.1 96 72	0.0 60	0. 10 34 4	0.0 444 4	0. 12 90 3	0. 14 28 5
P V	0.06 976	0.1 34 83	0.1 96 72	0.2 40	0. 31 03 4	0.1 333 3	0. 19 35 4	0. 14 28 5
M H	0.09 302	0.0 33 70	0.0 49 18	0.0 60	0. 05 17 2	0.0 444 4	0. 06 45 1	0. 09 52 3
W IP	0.09 302	0.0 22 47	0.0 32 78	0.0 399 9	0. 03 44 8	0.0 444 4	0. 03 22 5	0. 04 76 1

Step 3: Now compute the average of all elements in each row of the Table 4 to get the priority vector

$$W1=(0.27907+0.20224+0.19672+0.36000+0.20689+0.53333+0.19354+0.14285)/8 = 0.26433$$

$$W2=(0.09302+0.06741+0.03278+0.060+0.03448+0.06666+0.12903+0.14285)/8 = 0.08045$$

$$W3=(0.13953+0.20224+0.09836+0.060+0.05172+0.06666+0.12903+0.14285)/8 = 0.11129$$

$$W4=(0.09302+0.13484+0.19672+0.120+0.20689+0.06666+0.12903+0.14285)/8 = 0.13625$$

$$W5=(0.13953+0.20224+0.19672+0.060+0.10344+0.04444+0.12903+0.14285)/8 = 0.12591$$

$$W6=(0.06976+0.13483+0.19672+0.240+0.31034+0.13333+0.19354+0.14285)/8 = 0.17767$$

$$W7=(0.0930+0.03370+0.04918+0.060+0.05172+0.04444+0.066451+0.09523)/8 = 0.06171$$

$$W8=(0.09302+0.02247+0.03278+0.03999+0.03448+0.04444+0.03225+0.04761)/8 = 0.04338$$

The priority vector is

$$\begin{pmatrix} 0.26433 \\ 0.08045 \\ 0.11129 \\ 0.13625 \\ 0.12591 \\ 0.17767 \\ 0.06171 \\ 0.04338 \end{pmatrix}$$

Total sum of the priority vector = 1.000

Priority vector

$$W = (0.26433, 0.08045, 0.11129, 0.13625, 0.12591, 0.17767, 0.06171, 0.04338)^T$$

According to Golany and Kress (1993), 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 of all the priority vector results in 1.

The matrix is acceptable if the consistency ratio (CR) is below or equal to 0.10 (Kardi et al., 1999; Liu et al., 1999; Anderson et al., 2003; Bodin, 2003). 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 (Liu et al., 1999; Anderson et al., 2003; Bodin, 2003). Therefore the matrix must be adjusted. From the

study, it shows that consistency ratio is an important step in determining the priority vector. Hence we will now calculate the consistency ratio (CR). It can be obtained by dividing consistency index (CI) by random consistency index (RCI) which is provided below 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

λ_{max} is obtained to be equal 8.690858 and by using it the value of CI then can be calculated using the formula (Kumar and Ganesh, 1996b; Kardi et al., 1999; Liu et al., 1999; Anderson et al., 2003):

$$CI = (\lambda_{max} - n) / (n - 1)$$

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

$$CI = (8.690858 - 8) / (8 - 1) = 0.098694$$

Lastly the CR can be computed by using the formula (Kumar and Ganesh, 1996b; Kardi et al., 1999; Liu et al., 1999; Anderson et al., 2003):

$$CR = CI / RCI$$

This result in

$$CR = 0.0988694 / 1.41 = 0.06999$$

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

3. CONCLUSION

Any firm wanting to have the above factors in the order obtained can apply functional layout in their firm for better outcomes. For ex. If a firms highest priority is flexibility and product variety than it can employ functional layout.

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	0.26433	1
Space Utilization	0.08045	6
Customer Satisfaction	0.11129	5
Capital	0.13625	3
Labour Constraints	0.12591	4
Product Variety	0.17767	2
Material Handling	0.06171	7
Work In Process	0.04338	8

4. FUTURE WORKS

More work can be done by using different layouts, we can either study the different factors involved in other layouts and also can compare two layouts using Analytical Hierarchy Process.

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