AHP Based Productivity Model for a Bottling Plant

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Abstract:
Continuous productivity improvement is essential not only to produce good earnings (profits) but also to stand better in the market. There are so many factors, which are effecting on productivity. Special attention must be given to those factors, which are effecting highly on productivity. An appropriate system is essential to identify those factors, whose contribution to productivity is relatively high. This paper explains such a system where multidimensionality of the related issues has been represented by hierarchical model and subsequently the Analytic Hierarchy Process (AHP) has been applied to identify the contribution to productivity by the different factors of productivity. Case study from a bottling plant of PepsiCo India has been taken to explain the proposed method.

Introduction:
All organizations are required to constantly improve productivity at all levels of their process. This is very much important to improve the level of it services to the customer. Besides, with increased productivity, organizations will be able to optimize resource utilization as well as realize savings in operation costs. Productivity depends upon so many factors based on their role on production. Identification of their contribution to productivity is complicated because it needs a complete qualitative analysis. Analytic Hierarchy Process (AHP) is identified to develop a hierarchy model for factors of productivity based on their contribution to the productivity. A case study from PepsiCo India Holdings Private Limited is taken for testing the hierarchy model.

Concept of Productivity:
Productivity can be defined as the value or quantity of output, which can be produced by one unit of input. Output refers to the product or service produced by an organization. As an example the outputs produced by the National Registration Department is Identity Cards, Birth Certificates, Citizenship Certificates and Certificates for Civil Marriages. Input refers to the resources used to produce the output. These resources include manpower, capital, materials, equipment, plant and other such resources.

In other words, productivity is the concept, which indicates the relationship between the output produced by an organization and the input used. This relationship is shown in the formula below:

Productivity = Output/Input

As an example, when a work team produces, 100 units for output in 20 hours, than the productivity achieved are 5 units of output per hour.

An organization can gauge its productivity levels at various levels, such as the whole organization, division unit or at individual worker level. Productivity levels can be in the form of; cost per unit of output; or man-hours to produce a unit of output.

The concept of productivity is generally associated with the concepts of efficiency, effectiveness and quality. The relationship between productivity and efficiency can be seen from the point of input utilization. An organization is said to be productive when it is able to make optimum or the most efficient use of the allocated resources.
The relationship between productivity and effectiveness can be seen through comparisons between the quality of output actually produced and the quality target by the organization. If the output produced equals the target quality then the organization is said to be effective since it has achieved its target. To achieve this level of effectiveness, the organization is said to be productive. It is in this context that productivity and effectiveness are said to be two inter-linked concepts.

The relationship between productivity and quality can be shown when the output of an organization is linked to its targeted customers. The

aim of an organization is not only to produce the quality of output determined but also to ensure that the output produced conforms to customer requirements. To produce output to the exact quantity targeted an organization need to emphasize productivity, whereas, to ensure that the output conforms to customers' requirements, it needs to stress on quality. Thus, quality and productivity are to complementary concepts and must be given attention by every organization in the production of their goods or service.

Factors of Productivity:

An organization produces many kinds of output to achieve is objectives. To produce this output, it requires basic input such as raw materials, capital, equipment and manpower and these inputs are processed using specific production methods. This process is known as the transformation process. The ability of an organization to improve its productivity is dependent on how efficiently it is able to complete the transformation process. The more efficient the process, the higher will be the productivity since the use of inputs such as labour and capital optimized. The relationship between the concepts of input-transformation-output is shown in figure -1.

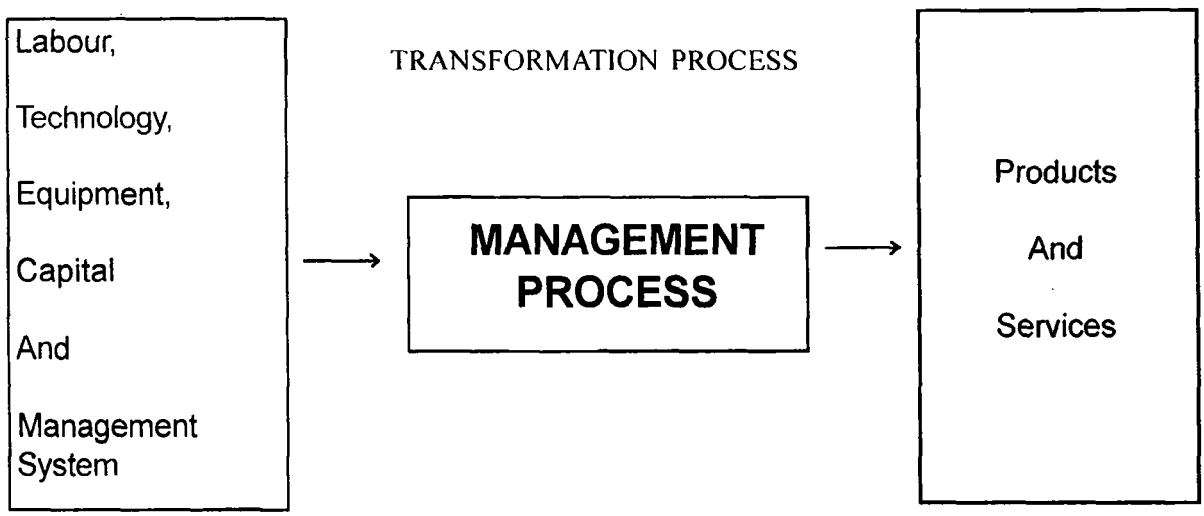


Figure-1: Relationship between Input - Transformation - Outputs

As shown in figure-1, an organization needs to increase management inputs to reinforce the transformation process. Management inputs include systems and work procedures, organization structure and management/office should be able to produce the required output.

To increase productivity, the Management should be measure to strengthen factors, which influence productivity. Eight factors have been identified as critical. These factors are shown in figure-2.

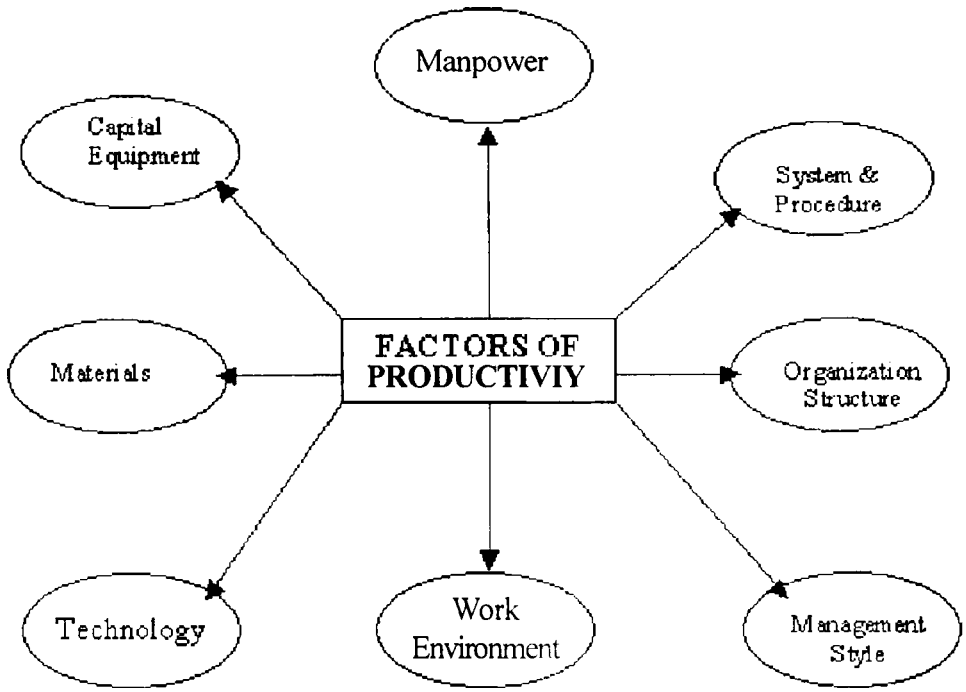


Figure 2: Factors Influencing Productivity

Application of AHP for calculation of weightages of factors of Productivity:

Identification of factors of productivity, which are effecting highly on productivity is rendered complex by the involvement of multi-dimensional factors directly or indirectly influencing the decision situation. In the pursuit of solving this multi-objective decision problem, Analytic Hierarchy Process (AHP) has been identified as the most efficient method due to its unique incorporation of both qualitative as well as quantitative factors and detailing of the problem by a hierarchical mode.

Steps followed in the AHP analysis:

Detailed feasibility reports for all the factors were prepared. The factors were different in terms of operational and management issues. Due to the complex value system of management of this Multinational Company, the prioritizing comprised a set of factors, some of which were conflicting in nature. The study was aimed at prioritizing of factors in such a complex decision making situation, Analytic Hierarchy Process (AHP) technique was applied for solving this prioritizing of factors. AHP technique developed by Saaty (1990) has gained popularity among researchers and practitioners of MADM. It constitutes following steps:

- Representation of the decision problem in the form of a hierarchy as a result of detailed analysis of the problem.
- Evaluation of items of the hierarchy on the basis of a paired-comparison, which represents judgments of decision-making.
- Qualitative assessment of criteria incorporating their contribution to the decision problem.

Representation of the decision problem in the form of a hierarchy:

Analysis of the system initially led to the identification of two areas, which are.

1. Operational Factors.
2. Management Factors.

Eight factors viz. Materials, Man power, Capital equipment, Technology, Work Environment, System and Procedure, Organization structure, Management Style related with these two areas (Operational Factor and Management Factor) were taken into consideration.

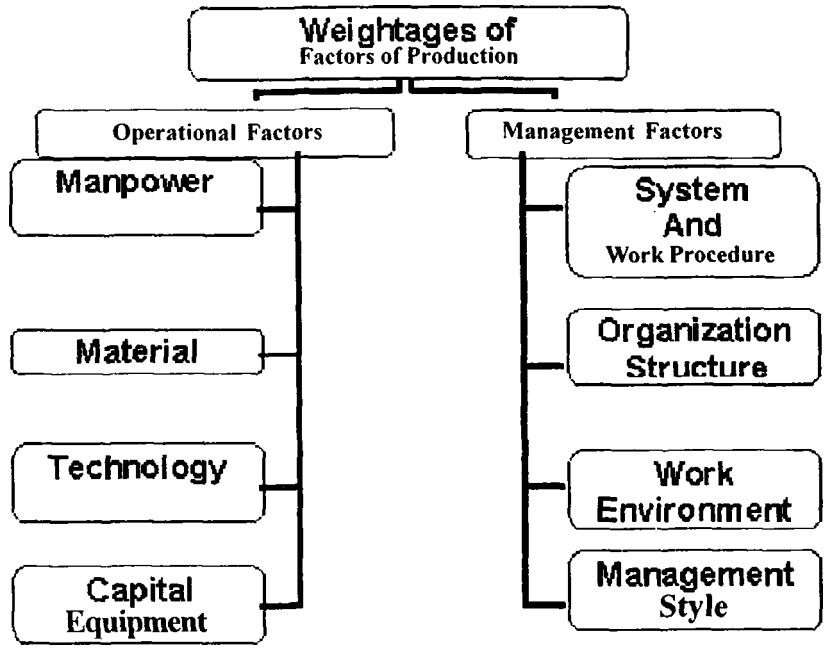


Fig. 3: Hierarchy of the problem

Four factors for example Materials, Manpower, Capital equipment and Technology are coming under the area of Operations Factors. Because effect on productivity by these factors depends action taken during the operations. On the other hand, Work Environment, System and Procedure, Organization structure and Management Style are the factors, which are dependent on Management action. So, these factors of productivity are coming under the area of Management Factors. The hierarchy structure of the problem is illustrated in the figure 3. The problem is divided into three levels. '0' (top) level is the overall goal of "Weightages of Factors of Production". Level-1 and level-2 are the two areas and the eight factors respectively.

Pair wise Comparison Judgments:

The second step is the elicitation of Pair wise comparison Judgments. The scale for making the Judgments is given in the Table 1.

Table 1: Scale of Judgment:

Intensity of Importance on an absolute scale	Definition	Explanation
1	Equal importance	Both activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its viability demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possibility order of affirmation.

The factors in the first level are arranged in the form of a matrix as shown in Table 2 and Judgments are drawn from the decision maker/ expert. When comparing two factors the issues to be analyzed is: "Off the two elements being compared, which is considered more important by the decision maker/expert with respect to the overall goal?" In the same manner the Pair wise comparison matrix is prepared for level-2 as shown in Table 3. The elements to be compared pair wise are the factors with respect to how much important one is than the other with reference to each criterion. In this computation λ_{max} should be exactly equal to matrix size in case of absolute consistent judgment of the decision-maker.

Table 2: Pair wise comparison Matrix for level-1:

	Operational Factors	Management Factors
Operational Factors	1.00	7.00
Management Factors	0.14	1.00

Table 3: Pair wise comparison Matrix for level-2:

(a) For Operational Factors:

	Manpower	Material	Technology	Capital Equipment
Manpower	1.00	0.33	0.14	0.33
Material	3.00	1.00	0.20	1.00
Technology	7.00	7.00	1.00	5.00
Capital Equipment	3.00	3.00	0.20	1.00

(b) For Management Factors:

	System & Work Procedure	Organization structure	Work Environment	Management Style
System & Work Procedure	1.00	0.33	3.00	7.00
Organization Structure	3.00	1.00	5.00	9.00
Work Environment	0.33	0.20	1.00	5.00
Management Style	0.14	0.11	0.20	1.00

Calculation of Local Priorities:

The local priority for the elements in level-1 and 2 are computed as follows: Each column element of matrix is divided by its column total and then the average of the elements in each row is computed which gives the local priority vectors. The local priority vectors for each level is computed and given in the Table-4 and Table-5 for level-1 and level-2 respectively

Table 4: Calculation of Relative Priority for level-1 (λ_{max} = 2):

	Operational Factors	Management Factors	Priority Vector
Operational Factors	0.88	0.88	0.88
Management Factors	0.12	0.13	0.12

Table 5: Calculation of Relative Priority for level-2:

(a) For Operational Factors (($\lambda_{max} = 4$):

	Manpower	Material	Technology	Capital Equipment	PriorityVector
Manpower	0.07	0.03	0.09	0.05	0.06
Material	0.21	0.09	0.13	0.14	0.14
Technology	0.50	0.62	0.65	0.68	0.61
Capital Equipment	0.21	0.26	0.13	0.14	0.19

(b) For Management Factors ($\lambda_{max} = 4$):

	System & Work Procedure	Organization Structure	Work Environment	Management Style	Priority Vector
System & Work Procedure	0.22	0.20	0.33	0.32	0.27
Organization Structure	0.67	0.61	0.54	0.41	0.56
Work Environment	0.07	0.12	0.11	0.23	0.13
Management Style	0.03	0.07	0.02	0.05	0.04

Establishing Weightages for Factors of Productivity:

We lay out the local priorities of the spare parts with respect to each criterion in a table and multiply each column of vector by the priority of the corresponding criterion and add across each row, which results in the desired weight age of each factor as shown in Table 6.

Table 6: Overall Priority Vector:

Factors of Productivity	Operational Factors (0.88)	Management Factors (0.12)	Weightages/Overall Priority Vector
Manpower	0.06	-	0.053
Material	0.14	-	0.123
Technology	0.61	-	0.537
Capital Equipment	0.19	-	0.167
System & Work Procedure	-	0.27	0.032
Organization Structure	-	0.56	0.067
Work Environment	-	0.13	0.016
Management Style	-	0.04	0.005

Prioritization of Factors of Production: Then all the factors are arranged in a descending order as shown as the table-7 given below. It is seen from the table that technology has the maximum overall priority vector (53.70%).

Table-7: Arrangement of Factors according to their contribution on Productivity:

Factors of Productivity	Priorities in terms of Operational Factors	Priorities interms of Management Factors	Weightage/ Overall Priority Vector
Technology	0.61	-	0.537
Capital Equipment	0.19	-	0.167
Material	0.14	-	0.123
Organization Structure	-	0.56	0.067
Manpower	0.06	-	0.053
System & Work Procedure	-	0.27	0.032
Work Environment	-	0.13	0.016
Management Style	-	0.04	0.005

The contribution of operational factors is much more than management factors. It gives an idea that contribution of technology on improvement of productivity is maximum. So, to improve productivity level management should focus highly on this technology factor. On the other hand, management style has then minimum overall priority vector, which conclude that contribution of management style on productivity improvement is minimum.

Financial Impact of Low Productivity:

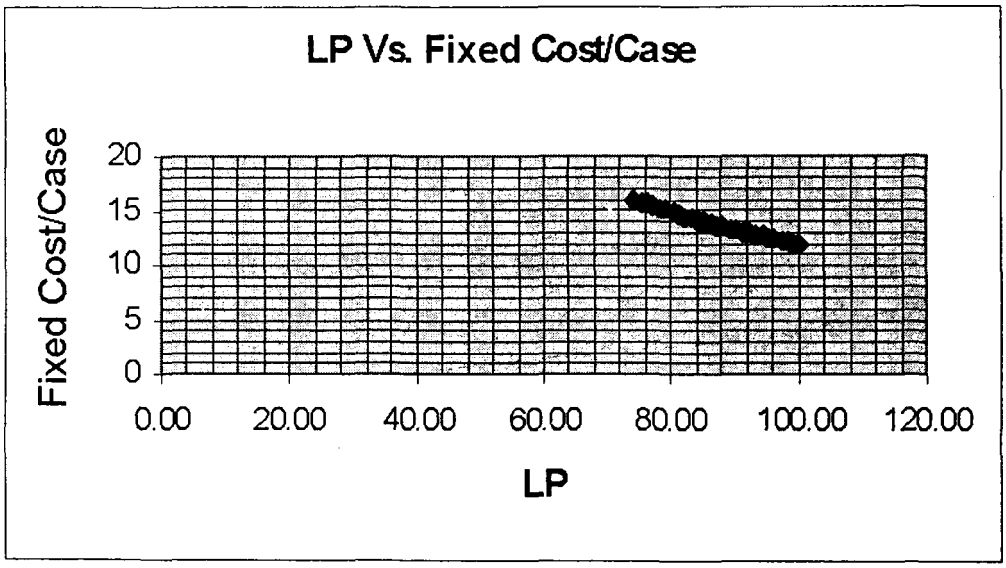
Ultimate aim of the organization is to reduction of cost. Productivity is a key factor behind the reduction of cost. Fixed cost is fixed for the period, and variable cost is also independent of productivity. For a period of production run, if we increase productivity total production or total unit of production will be increased with the same cost, i.e. total cost reduces with the increase of productivity. So, development of relationship between productivity and unit cost of production is essential to see the impact of productivity on cost of production. Relationship between level of productivity and cost per case of production for the month of December, 2004 are as shown in the table 8.

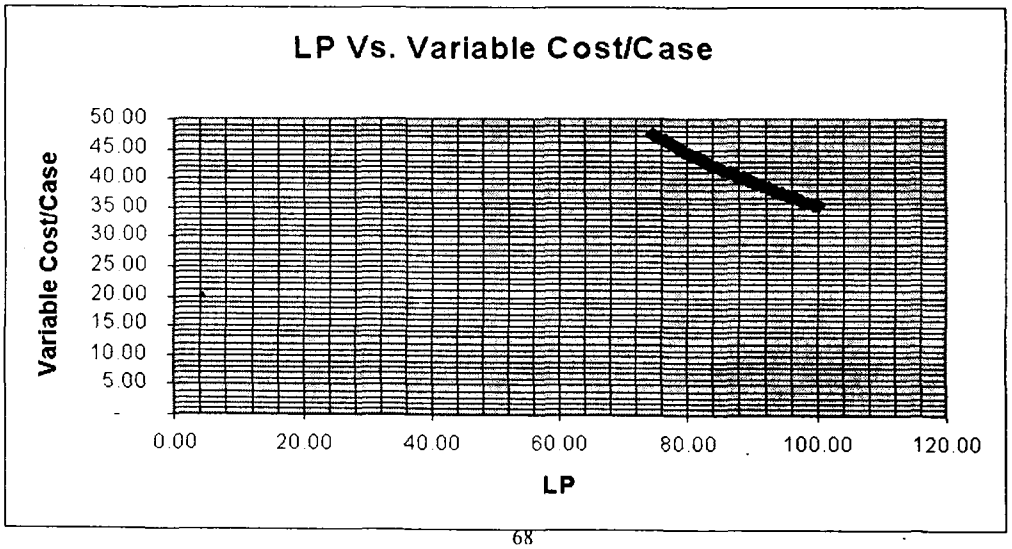
Table 8: Relation between Productivity and Cost/Case:

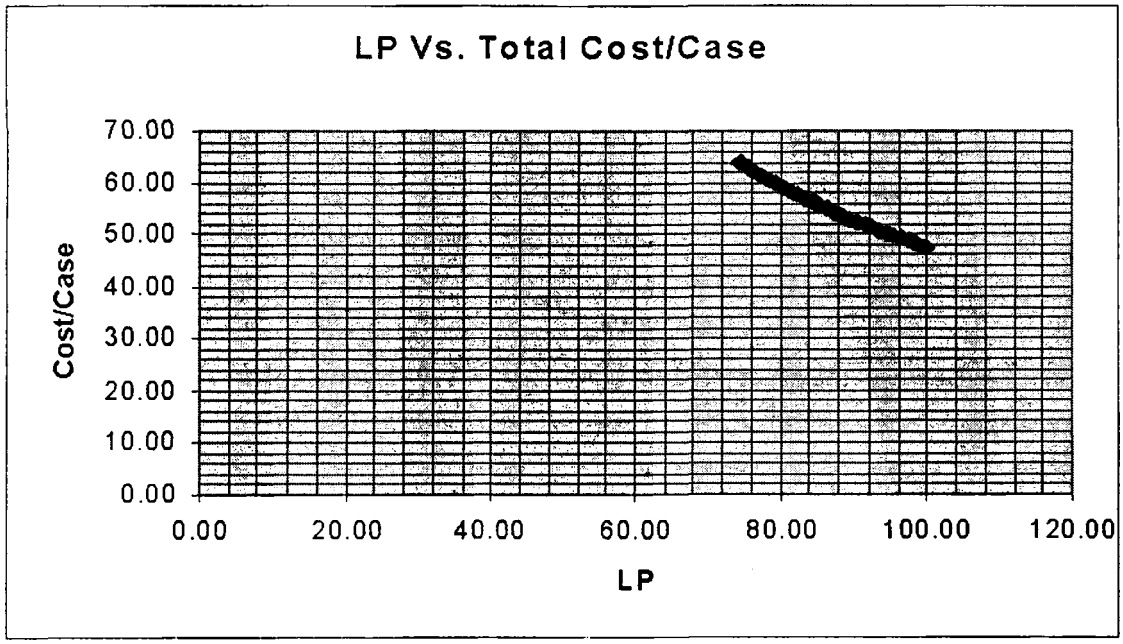
Month	LP	Production with 100% LP	Theoretical Production	FC/Case	VC/Case	TC/Case
12/03	74.50	427954	318826	16.01	47.58	63.59
12/03	75.50	427954	323105	15.80	46.95	62.75
12/03	76.50	427954	327385	15.59	46.34	61.93
12/03	77.50	427954	331664	15.39	45.74	61.13
12/03	78.50	427954	335944	15.20	45.16	60.35
12/03	79.50	427954	340223	15.00	44.59	59.59
12/03	80.50	427954	344503	14.82	44.04	58.85
12/03	81.50	427954	348783	14.64	43.50	58.13
12/03	82.50	427954	353062	14.46	42.97	57.43
12/03	83.50	427954	357342	14.29	42.45	56.74
12/03	84.50	427954	361621	14.12	41.95	56.07
12/03	85.50	427954	365901	13.95	41.46	55.41
12/03	86.50	427954	370180	13.79	40.98	54.77
12/03	87.50	427954	374460	13.63	40.51	54.15
12/03	88.50	427954	378739	13.48	40.06	53.53
12/03	89.50	427954	383019	13.33	39.61	52.94
12/03	90.50	427954	387298	13.18	39.17	52.35
12/03	91.50	427954	391578	13.04	38.74	51.78
12/03	92.50	427954	395857	12.90	38.32	51.22

12/03	93.50	427954	400137	12.76	37.91	50.67
12/03	94.50	427954	404417	12.62	37.51	50.13
12/03	95.50	427954	408696	12.49	37.12	49.61
12/03	96.50	427954	412976	12.36	36.74	49.10
12/03	97.50	427954	417255	12.23	36.36	48.59
12/03	98.50	427954	421535	12.11	35.99	48.10
12/03	99.50	427954	425814	11.99	35.63	47.62
12/03	100.00	427954	427954	11.93	35.45	47.38

Graphical Representation:







Relationship between line productivity (LP) and cost of production (excluding materials cost) for the month of December, 2004 are given in the table 8. On the basis of these data, graphical representation between LP vs. total cost/case, LP vs. fixed cost/case and LP vs. variable cost/case are drawn. If we increase the productivity level by one percentage from 74.50%, the fall in fixed cost per case is Rs. 0.21, whereas the fall in variable cost per case is Rs. 0.63. Operational factors are the key factors behind the variable cost buts managerial factors are the key factors behind the fixed cost. So, it is clear from this analysis that, contribution of operational factors on productivity is more than management factors.

It can be shown that priority vector of operational factors is 0.88, whereas priority vector for management factors is only 0.12, which concludes that contribution of operational factors on productivity are much more than management factors. So hierarchy model can be taken as a decision aid tool to improve the productivity level.

Organization should make the productivity vimprovement effort to an ongoing process. This is because productivity is relative. A productivity level considered high in the past would not be perceived assuch in the present. In view of this, organization should constantly improve their performance. Efforts towards this should be internalized so that it becomes a daily management aspect. An attempt should be made to increase the level of productivity continuously.

Conclusion:

This paper includes a research report on developing a relationship between productivity and cost of production. The unique contribution of this paper lies on development of hierarchy model of factors of productivity with the help of Analytic Hierarchy Process (AHP), which represents an excellent decision aid tool in managing the factors of productivity to improve the level of productivity. Management may take appropriate action on each factor as per the hierarchy model. It is clear from the analysis that the contribution of operation factors on productivity is much more than management factors, which conclude that management should focus more on the operational factors. Besides this, focus should also be given to quality. This is because organizations are not only evaluated on their production capability but also on the capability of the output to meet the needs of members of the public who are their clients.