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# Analytic Hierarchy Process for Site Selection Model for a Ball Bearing Manufacturing Firm

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**ABSTRACT:** This study is based on a site selection model for establish a manufacturing firm by using analytic hierarchy process, the aim of this study focuses on the multi factor evaluationfor selecting the best suited site for a manufacturing firm among 3 suggested sitesas major factors also there are 7 sub-factors (viz. market, land, finance, required labor, transportation, availability of raw material and personal preferences) those surely will influence the growth and goal of a firm.Here AHP has been used as methodological tool for the selection of site. This study is divided in two phases in first to prioritize 7 sub-factors in hierarchical model and in second phase to arrange the best suited site in hierarchical model. This helps to find the appropriate site including the factors those must be considered AHP provided a comprehensive and rational frame work for structuring the decision problem during establishing a site for a manufacturing firm.

**KEY WORDS:**AHP, multi factor evaluation, hierarchical model, methodological tool, manufacturing firm, prioritize.

## I. INTRODUCTION:

In modern business environment, every entrepreneur is faced with the problem of deciding the best site for location of his plant or factory because of its complex nature. The objective of any entrepreneur is to locate the business organization at such a place where it is convenient to run the operations and the total costs are minimized. The plant as well as facility location problem to run the operations efficiently. However, a location selection decision depends on variety of factors so it is considered as a multiple criteria decision-making (MCDM) problem by nature. It is a problem associated with the planning phase of a factory or even a service sector. Based on the goals the projected production needs of the firm strongly influence the actual location search, i.e., entry into new markets, maintenance of market share, product diversification, and new production processes. The sites where an acceptable of sales is essentially guaranteed will be preferred by the firms.

The need of the selection of plant location then generally arises in following condition;

I. When the business is newly started.
II. The existing business unit has outgrown its original facilities and expansion is not possible; hence a new location has to be found.
III. The volume of business or the extent of market necessitates the establishment of branches.
IV. A lease expires and the landlord does not renew the lease.
V. Other social, economic, legal or political factors; for instance, inadequate labor supply, shifting of the market etc.
VI. Introduction of the new product or the services also require the establishment of new location.

**NEED FOR THE RESEARCH PAPER:** The decision on a selecting of a site is most important decision because a poor location is a severe obstacle for any firm and it ruination the owner. Once a mistake is made in locating a firm it becomes very difficult and costly to correct it, especially where big plants are bothered. So, it is very necessary that best care should be taken in the starting stages of the location selection Model. Bad location shows to high cost, onerous transportation, onerous marketing, Dissatisfaction among employees and inadequate quality of product.

**SIGNIFICANCE STUDY:** The study says that the selection of a best site for a firm is depend on the various criteria and sub-criteria. So many Multi Criteria Decision Making (MCDM) methods have been established. Among these methods the Analytic Hierarchy Process (AHP) is well suited for the site selection model. Analytic hierarchy process is used in different areas like as marketing,

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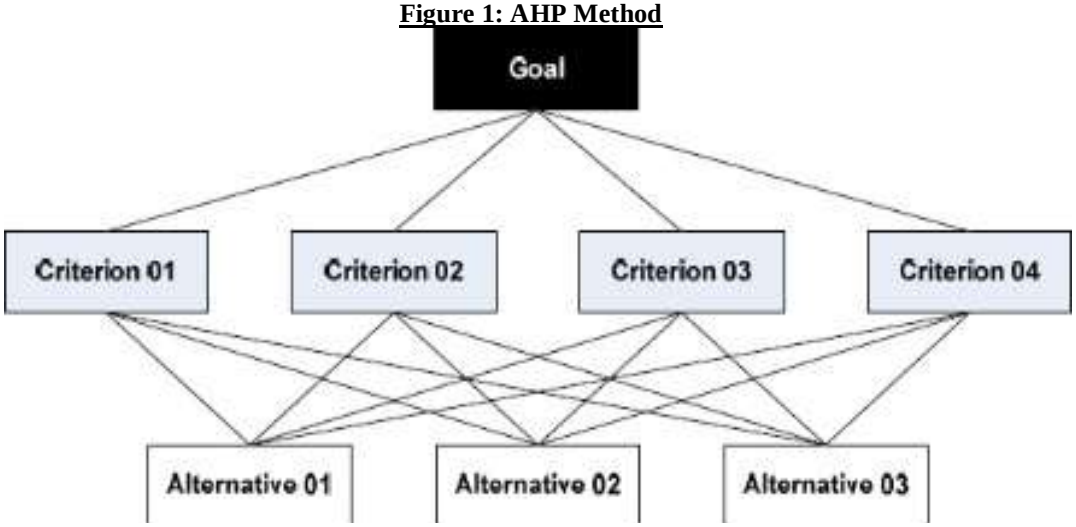
vendor, sports, schools and so on & many studied have also done on the site selection using AHP method.

**ANALYTIC HIERARCHY PROCESS (AHP):** The analytichierarchyprocess (AHP) is a structured technique for organizing and analyzing complex decision, based on mathematics and psychology& developed by Thomas L. Saaty1970s; Saaty partnered with Ernest Forman to develop expert choice software in 1983, and AHP has been extensively studied and refined since then. It represents an accurate approach to quantifying the weights of decision criteria. Individual expert`s experiences are utilized to estimate the relative magnitudes of factors through pair-wise comparisons. Each of the respondents compares the relative importance each pair of items using a specially designed questionnaire.

AHP is an ideal method for ranking alternatives when multiple criteria and sub-criteria are present in the decision-making process. The judgments are expressed in terms of pairwise comparisons of items on a given level of the hierarchy with respect to their impact on the next higher level. The relative importance of one item versus another are expressed by the pairwise comparisons in meeting a goal or a criterion. Each of the pairwise comparisons represent an estimate the ratio of the weights of the two criteria being compared. Because AHP utilizes a ratio scale for human judgments, the alternatives weights reflect the relative importance of the criteria in achieving the goal of the hierarchy.

**Figure 1: AHP Method**




**OBJECTIVES:**

- To study and analyze Literature review of Research Papers to identify the goal.
- Collect opinion from expertise which are related to directly and indirectly to the Site selection of a firm.
- Selection of criteria`s and sub-criteria`s for site selection.
- To obtain the optimal location use conceptual framework model.
- Use EXCEL to ease of calculation of the Model.

## II. LITERATURE REVIEW:

**S. Gothalwal, R. Saha (2015)** Selection of plant location is a multi-person and multi-criteria decision problem. Location selection is a strategic decision that cannot be changed overnight. Even if the location decision is changed at all, a considerable loss is bound to be incurred. In this paper, analytic hierarchy process (AHP) approach is used to arrive at consensus decision. The AHP model is formulated and applied to a real case study to examine its feasibility in selecting the plant location for a manufacturing industry. Different factors were identified affecting the plant location on the five locations suggested by a particular manufacturing industry and then AHP technique was implemented to select the best location out of these five locations. AHP is a powerful and flexible tool for tackling the complex decision problem into a simple concept of hierarchy, which incorporates both financial and non-financial factors influencing the decision alternatives in a systematic way.

**J.Y.L Yap, C. Ching Ho and Choo-Yee Ting (2017)** In the study, the researchers concluded that the selection of a landfill site is a multi-criteria decision making (MCDM) process

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that should consider the political factors as well as the public acceptance apart from only the scientific analysis and data mining. Hence a model was constructed to incorporate all the relevant factors. A hybrid model unite Fuzzy AHP and Fuzzy Weighted Aggregated Sum Product Assessment (WASPAS) has been developed. This model was used when choosing construction site. Depends on the strength of the fuzzy AHP to determine the hybrid model. The weight of the criteria as well as the strength of WASPAS in ranking options places.

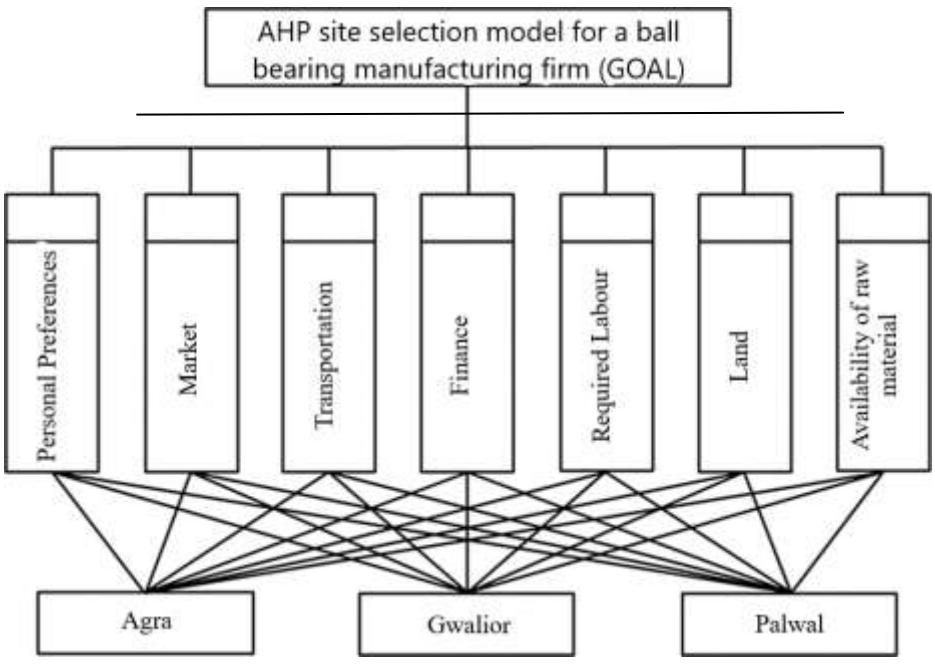
**T. Sahin, S. Ocak, M. Top (2019)** This study examined decision support model for choosing a location to open a new hospital depend on the analytic hierarchy process (AHP). AHP was used as a methodological tool for the site selection. The study was depend on the 6 criteria and 19 sub-criteria. The option were evaluated on a saaty scale from 1to9. The Hierarchical model of analysis, super decisions was carried out using 2.2.6.software program. The most important as well as choosing a suitable locations for the hospital, followed by access, competitors, government, related industry and environmental condition.

**D. Guler& T. Yomralioglu (2020):**The choice of locations of electric vehicle charging stations is one of the most important topics to improve the use of electric vehicle. In this sense, the purpose of this article is to propose an approach that combines Geographic Information System (GIS) techniques and Multi-Criteria Decision Making (MCDM) methods for detecting the suitable location for charging the electric vehicle. In this regard, the Analytic Hierarchy Process (AHP) and the Fuzzy Analytic Hierarchy Process (FAHP) methods are used to compute the weights of norms.

**CRITERIA EVALUATION:** Based on the past literature & expertise opinion, many Researchers have studied the criteria (factor) which are effective for site selection for a ball bearing manufacturing firm. There are seven criteria that for decision making &evaluating the sites available for selection. Seven criteria are
: (I) Availability of raw material (ARM) (II) Market (III) Land (IV) Required labour (RL) (V) Transportation (TRANS) (VI) Finance (VII) Personal preference (PP).

**ALTERNATIVE EVALUATION (LOCATION):**Based on the criteria, many alternative is evaluating for the optimal solution or the best location for a ball bearing manufacturing firm. This study will focus on three alternatives: (I) Agra (Uttar Pradesh) (II) Gwalior (Madhya Pradesh) (III) Palwal (Haryana).

**Figure 2: Hierarchical Structure**



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## III. METHODOLOGY:

- Define the goal or understand problem.
- Pair-wise comparison matrix are execute among the elements at the same level & the upper level by using Saaty`snine-point scale which is shown in Table1.
- The judgment matrices are formulated for all evaluation criteria (ARM, Market, Land, RL, Trans, Finance & PP) as shown in the Table2.

**Table 1: Saaty`s Nine Point Scale**

| Rating | Linguisticattributes |
|---|---|
| 9 | Extremelyimportant |
| 8 | VerystronglytoExtremeimportant |
| 7 | Verystronglyimportant |
| 6 | Stronglytoverystronglyimportant |
| 5 | Stronglyimportant |
| 4 | Moderately tostronglyimportant |
| 3 | Moderatelyimportant |
| 2 | Equaltomoderateimportant |
| 1 | Equalimportant |

**Table 2: Pair-wise Comparison Matrix**

| Factors | ARM | MARKET | LAND | RL | TRANS | FINANCE | PP |
|---|---|---|---|---|---|---|---|
| **ARM** | 1 | 2 | 2 | 3 | 3 | 4 | 5 |
| **MARKET** | 1/2 | 1 | 2 | 3 | 4 | 4 | 6 |
| **LAND** | 1/2 | 1/2 | 1 | 2 | 4 | 5 | 5 |
| **RL** | 1/3 | 1/3 | 1/2 | 1 | 3 | 3 | 5 |
| **TRANS** | 1/3 | 1/4 | 1/4 | 1/3 | 1 | 4 | 6 |
| **FINANCE** | 1/4 | 1/4 | 1/5 | 1/3 | 1/4 | 1 | 3 |
| **PP** | 1/5 | 1/6 | 1/5 | 1/5 | 1/6 | 1/3 | 1 |
| **Sum** | 3.117 | 4.500 | 6.150 | 9.867 | 15.417 | 21.333 | 31.000 |

**Table 3: Normalized Pair-wise Comparison Matrix**

| Factors | ARM | MARKET | LAND | RL | TRANS | FINANCE | PP | Criteria Weight |
|---|---|---|---|---|---|---|---|---|
| **ARM** | 0.3209 | 0.4444 | 0.3252 | 0.3041 | 0.1946 | 0.1875 | 0.1613 | 0.2768 |
| **MARKET** | 0.1604 | 0.2222 | 0.3252 | 0.3041 | 0.2595 | 0.1875 | 0.1935 | 0.2361 |
| **LAND** | 0.1604 | 0.1111 | 0.1626 | 0.2027 | 0.2595 | 0.2344 | 0.1613 | 0.1846 |
| **RL** | 0.1070 | 0.0741 | 0.0813 | 0.1014 | 0.1946 | 0.1406 | 0.1613 | 0.1229 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **TRANS** | 0.1070 | 0.0556 | 0.0407 | 0.0338 | 0.0649 | 0.1875 | 0.1935 | 0.0976 |
| **FINANCE** | 0.0802 | 0.0556 | 0.0325 | 0.0338 | 0.0162 | 0.0469 | 0.0968 | 0.0517 |
| **PP** | 0.0642 | 0.0370 | 0.0325 | 0.0203 | 0.0108 | 0.0156 | 0.0323 | 0.0304 |

- Using existing data in Table2and criteria weights calculation in Table3, the calculation of weighted sum value for the criteria is shown in Table4**.** Estimating the weighted sum value is done by multiplying criteria weights of each criteria to the pair-wise comparison matrix column of the same criteria & determine it for all the criteria.

**Table 5: Criteria Weight Sum Value**

| Factors | Criteria Weight | ARM | Criteria Weight * ARM | Criteria Weight | MARKET | Criteria Weight * Market |
|---|---|---|---|---|---|---|
| **ARM** | 0.2768 | 1.0000 | 0.2768 | 0.2361 | 2.0000 | 0.4721 |
| **MARKET** | 0.2768 | 0.5000 | 0.1384 | 0.2361 | 1.0000 | 0.2361 |
| **LAND** | 0.2768 | 0.5000 | 0.1384 | 0.2361 | 0.5000 | 0.1180 |
| **RL** | 0.2768 | 0.3333 | 0.0923 | 0.2361 | 0.3333 | 0.0787 |
| **TRANS** | 0.2768 | 0.3333 | 0.0923 | 0.2361 | 0.2500 | 0.0590 |
| **FINANCE** | 0.2768 | 0.2500 | 0.0692 | 0.2361 | 0.2500 | 0.0590 |
| **PP** | 0.2768 | 0.2000 | 0.0554 | 0.2361 | 0.1667 | 0.0393 |

| Criteria Weight | LAND | Criteria Weight * Land | Criteria Weight | RL | Criteria Weight * RL | Criteria Weight |
|---|---|---|---|---|---|---|
| 0.1846 | 2.0000 | 0.3691 | 0.1229 | 3.0000 | 0.3687 | 0.0976 |
| 0.1846 | 2.0000 | 0.3691 | 0.1229 | 3.0000 | 0.3687 | 0.0976 |
| 0.1846 | 1.0000 | 0.1846 | 0.1229 | 2.0000 | 0.2458 | 0.0976 |
| 0.1846 | 0.5000 | 0.0923 | 0.1229 | 1.0000 | 0.1229 | 0.0976 |
| 0.1846 | 0.2500 | 0.0461 | 0.1229 | 0.3333 | 0.0410 | 0.0976 |
| 0.1846 | 0.2000 | 0.0369 | 0.1229 | 0.3333 | 0.0410 | 0.0976 |

| TRANS | Criteria Weight * Trans | Criteria Weight | FINANCE | Criteria Weight * Finance | Criteria Weight | PP | Criteria Weight * PP |
|---|---|---|---|---|---|---|---|
| 3.0000 | 0.2927 | 0.0517 | 4.0000 | 0.2068 | 0.0304 | 5.0000 | 0.1519 |
| 4.0000 | 0.3902 | 0.0517 | 4.0000 | 0.2068 | 0.0304 | 6.0000 | 0.1823 |
| 4.0000 | 0.3902 | 0.0517 | 5.0000 | 0.2585 | 0.0304 | 5.0000 | 0.1519 |
| 3.0000 | 0.2927 | 0.0517 | 3.0000 | 0.1551 | 0.0304 | 5.0000 | 0.1519 |
| 1.0000 | 0.0976 | 0.0517 | 4.0000 | 0.2068 | 0.0304 | 6.0000 | 0.1823 |
| 0.2500 | 0.0244 | 0.0517 | 1.0000 | 0.0517 | 0.0304 | 3.0000 | 0.0912 |
| 0.1667 | 0.0163 | 0.0517 | 0.3333 | 0.0172 | 0.0304 | 1.0000 | 0.0304 |

- To get the weighted sum value as shown in Table 5, addition all the row element.

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**Table 5: Weighted Sum Value Matrix**

| Factors | Sum |
|---|---|
| ARM | 2.138151 |
| MARKET | 1.891603 |
| LAND | 1.487443 |
| RL | 0.985829 |
| TRANS | 0.725082 |
| FINANCE | 0.373349 |
| PP | 0.220081 |

- To calculate Consistency index (CI), first divide all the component of the weighted sum value matrices by criteria weight of each criteria as shown in Table6.

**Table 6: Weighted Sum value / Criteria Weight Matrix**

| Factors | Weighted Sum value / Criteria Weight |
|---|---|
| ARM | 7.723169 |
| MARKET | 8.013251 |
| LAND | 8.059101 |
| RL | 8.022435 |
| TRANS | 7.432871 |
| FINANCE | 7.220673 |
| PP | 7.243177 |

- Then compute the average of these value to obtain the Average of Weighted sum value /Criteria weights as shown in Table7.

**Table 7: Average of Weighted Sum value / Criteria Weight**

| Factors | Weighted Sum value / Criteria Weight |
|---|---|
| ARM | 7.714075565 |
| MARKET | 8.000254222 |
| LAND | 8.043663389 |
| RL | 8.009129574 |
| TRANS | 7.425911562 |
| FINANCE | 7.276829268 |
| PP | 7.242131372 |
| Average | 7.673142136 |

- The consistency is check because the pair-wise comparisons are done in a subjective way. The calculation of the consistency Index (CI) are given as below.

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| | | |
|---|---|---|
| **C.I.** | = | **((Average of Weighted Sum value / Criteria Weight) - Number of Factors(n)) ÷ (Number of Factors(n) - 1)** |
| | | Where, Number factors (n) = 7 |
| | = | 0.112190356 |

- Consistency Ratio is the ratio of consistency index (CI) & Random index (RI). The value of random consistency index (RI), for (numbers of criteria n = 7) using Table8**,** R.I = 1.32. So, the consistency ratio Cr is determine as follows:

**Table 8: Random Index for different size of matrix.**

| **Size(n)** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **R.I** | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

| | | |
|---|---|---|
| **Consistency Ratio** | = | **CI ÷ RI** |
| | | Where, R.I = 1.32 |
| | = | 0.084993 |

**Here, Consistency ratio i.e. 0.084993 < 0.10, It is a success.**

- To select the best location from the alternative is the next step of methodology. The pair-wise comparison matrix of every alternative can be formed by using the Saaty`s nine-point scale and then we calculate criteria weights of each alternatives with respect to each criteria (factors) by using the above method. Criteria weights of each element is shown in Table9to Table15**.**

**Table 9: Pair-wise Comparison ARM Matrix**

| **Location** | **Agra** | **Gwalior** | **Palwal** | **Criteria Weight** |
|---|---|---|---|---|
| **Agra** | 1 | 5 | 1/3 | 0.2828 |
| **Gwalior** | 1/5 | 1 | 1/7 | 0.0738 |
| **Palwal** | 3 | 7 | 1 | 0.6433 |
| **Sum** | 4.20 | 13.00 | 1.48 | |

**Table 10: Pair-wise Comparison Market Matrix**

| **Location** | **Agra** | **Gwalior** | **Palwal** | **Criteria Weight** |
|---|---|---|---|---|
| **Agra** | 1 | 4 | 1/3 | 0.2737 |
| **Gwalior** | 1/4 | 1 | 1/6 | 0.0869 |
| **Palwal** | 3 | 6 | 1 | 0.6393 |
| **Sum** | 4.25 | 11.00 | 1.50 | |

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**Table 11: Pair-wise Comparison Land Matrix**

| Location | Agra | Gwalior | Palwal | Criteria Weight |
|---|---|---|---|---|
| **Agra** | 1 | 1/5 | 2 | 0.1676 |
| **Gwalior** | 5 | 1 | 7 | 0.7380 |
| **Palwal** | 1/2 | 1/7 | 1 | 0.0944 |
| **Sum** | 6.50 | 1.34 | 10.00 | |

**Table 12: Pair-wise Comparison RL Matrix**

| Location | Agra | Gwalior | Palwal | Criteria Weight |
|---|---|---|---|---|
| **Agra** | 1 | 1/3 | 4 | 0.2737 |
| **Gwalior** | 3 | 1 | 6 | 0.6393 |
| **Palwal** | 1/4 | 1/6 | 1 | 0.0869 |
| **Sum** | 4.25 | 1.50 | 11.00 | |

**Table 13: Pair-wise Comparison Trans Matrix**

| Location | Agra | Gwalior | Palwal | Criteria Weight |
|---|---|---|---|---|
| **Agra** | 1 | 3 | 1/2 | 0.3202 |
| **Gwalior** | 1/3 | 1 | 1/4 | 0.1226 |
| **Palwal** | 2 | 4 | 1 | 0.5571 |
| **Sum** | 3.33 | 8.00 | 1.75 | |

**Table 14: Pair-wise Comparison Finance Matrix**

| Location | Agra | Gwalior | Palwal | Criteria Weight |
|---|---|---|---|---|
| **Agra** | 1 | 1/2 | 1/3 | 0.1638 |
| **Gwalior** | 2 | 1 | 1/2 | 0.2973 |
| **Palwal** | 3 | 2 | 1 | 0.5390 |
| **Sum** | 6.00 | 3.50 | 1.83 | |

**Table 15 Pair-wise Comparison PP Matrix**

| Location | Agra | Gwalior | Palwal | Criteria Weight |
|---|---|---|---|---|
| **Agra** | 1 | 5 | 3 | 0.6405 |
| **Gwalior** | 1/5 | 1 | 2 | 0.2059 |
| **Palwal** | 1/3 | 1/2 | 1 | 0.1537 |
| **Sum** | 1.53 | 6.50 | 6.00 | |

- The overall criteria weights of each criteria and alternatives is shown in Table 16.

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**Table 16: Overall Criteria**

| Factors | Criteria Weight (Factors) | Criteria Weight (Location) | | |
|---|---|---|---|---|
| | | Agra | Gwalior | Palwal |
| **ARM** | **0.27685** | 0.2828 | 0.0738 | 0.6433 |
| **MARKET** | **0.23606** | 0.2737 | 0.0869 | 0.6393 |
| **LAND** | **0.18457** | 0.1676 | 0.7380 | 0.0944 |
| **RL** | **0.12288** | 0.2737 | 0.6393 | 0.0869 |
| **TRANS** | **0.09755** | 0.3202 | 0.1226 | 0.5571 |
| **FINANCE** | **0.05171** | 0.1638 | 0.2973 | 0.5390 |
| **PP** | **0.03038** | 0.6405 | 0.2059 | 0.1537 |

- The criteria weights of each alternative with respect of criteria is multiplied by the criteria weights of same criteria (Table 3) & does it for all criteria then sum all the multiplication according to the alternative. Finally we get the overall priority of the each alternative as shown below.

Overall Priority of the Agra:
(0.27685*0.2828)+(0.23606*0.2737)+(0.18457*0.1676)+(0.12288*0.2737)+(0.09755*0.3202)+(0.05171*0.1638)+(0.03038*0.6405) = 0.2667
Overall Priority of the Gwalior:
(0.27685*0.0738)+(0.23606*0.0869)+(0.18457*0.77380)+(0.12288*0..6393)+(0.09755*0.1226)+(0.05171*0.2973)+(0.03038*0.2059) = 0.2893
Overall Priority of the Palwal:
(0.27685*0.6433)+(0.23606*0.6393)+(0.18457*0.0944)+(0.12288*0.0869)+(0.09755*0.5571)+(0.05171*0.5390)+(0.03038*0.1537) = 0.4440

## IV. RESULT:

Using the data form tables the criteria and sub-criteria have been taken under consideration, using comprehensible methods, pair wise comparison matrices have developed in order to criteria versus criteria regarding the objective, sub criteria versus sub criteria regarding to concerning criterion. The output of these pairwise comparison matrices was for obtaining a criteria weight for that particular factor with respect to goal and also the criteria weight of the sub-criteria regards to the criterion. Each selection criterion (availability of raw material, market, land, required labor, transportation, finance and personal preference) Palwal is more preferable (overall priority = 44.40%) compared to Gwalior (overall priority = 28.93%) and Agra (overall priority = 26.67%) the result is shown in table 17.

**Table 17: Result**

| Location | PRIORITY |
|---|---|
| **Palwal** | **0.4440** |
| **Gwalior** | **0.2893** |
| **Agra** | **0.2667** |

## V. CONCLUSION:

The purpose of this study to accredit the AHP method when applied for site selection for a ball bearing manufacturing firm factors and subfactors of the model were determined by surveys, interactions with experts and entrepreneurs etc. because having experience in such field. The result of the AHP method shows that Palwal is more preferable alternative/criteria to be considered when selecting a site for a ball bearing manufacturing firm followed by Gwalior and then by Agra. The criteria that plays a big role in selection of site or availability of raw material, market, land, required labor, transportation, finance & personal preferences are as shown in table.

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