Application of Analytical Hierarchy Process for Domestic Refrigerator Selection

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Abstract – Selection of most suitable product, process, strategy, or service option under several alternatives having varying degree of choices or, preferences with a number of sub-criteria is often a tedious, time consuming and sometimes even a confusing task. In this present investigation, a multi-criteria decision making (MCDM) system tool, namely Analytic Hierarchy Process (AHP), is adopted to ascertain the best possible selection of a domestic refrigerator from a number of alternatives having varying degree of sub-criteria covering all technical, economic, capacity requirement and personal choices aspects. The results obtained are also validated by consistency checking.

Index Terms – AHP, multi criteria decision making, domestic refrigerator selection, consistency.

1. INTRODUCTION

The Analytic Hierarchy Process (AHP), developed by Thomas Saaty (1970), is a widely used multi-criteria-decision-making tool for dealing with complex decision making process and help the decision maker to set the priorities and to select the best possible alternative among a number of alternatives or criteria with a couple of sub-criteria having varying degree of preferences and combination of choices. Apart from the objective and subjective aspects of a decision, AHP also checks consistency of the decision maker's evaluations and thus reduce the uncalled for bias in the decision making process. The AHP methodology can be successfully employed for selection of optimal decision in different complex decision making situations in practically all fields, be it personal, production process, business, marketing, research & applications, domestic or service sector etc. Apart from AHP, other multi-decision-criteria techniques like MAXMIN, MAXMAX, TOPSIS, SMART, SAW, ELECTRA [1-5] is also used. Adoption of a particular method depends on problem being address like choosing, ranking or, sorting etc. However, AHP is one of the most important multi-criteria-decision-making tools.

This present paper constructs an AHP methodology using the example of choosing best domestic refrigerator for a typical middle class family range of India with the help of market survey considering the relative preferences of the customers for different selective criteria and their sub-criteria. Also the consistency of the decision is checked which reinforces the validity and reduce the biasness in decision making process.

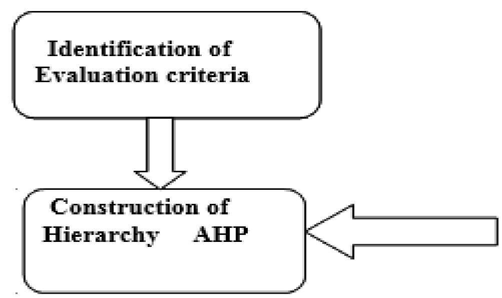

Fig-1: Steps of evaluation procedure [6]

The step-wise procedure of AHP is presented as follows:

- Step 1(structuring the problem): Identify the problem and structure the evaluation criteria alternatives.
- Step 2(evaluating the alternatives): Collect the reviews by rating according to own reference and Construct the pair wise comparison matrix.
- Step 3(prioritize or finalize the most weightage one): Construct the hierarchy and calculate the weights and the priorities of the alternatives.
- Step 4 (constancy checking): Check the consistency ratio, for acceptance which should be less than or equal to be 0.1.

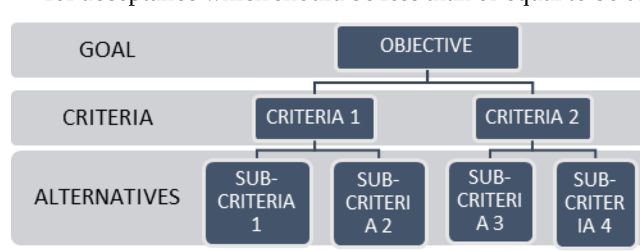

Fig-2: AHP hierarchy of goals, objectives and alternatives.

2. THEORETICAL ANALYSIS

The AHP method is used to solve a complex decision making problem having several attributes by modeling unstructured problem under study into hierarchical forms of elements. The essential components of a hierarchical system are the main goal, criteria that affect the overall goal, sub-criteria that influence the main-criteria and finally the alternatives available to the problem. To obtain the degree of relative importance of elements at each level a pair wise comparison matrix is developed by following T.L.Saaty's [6] 1-9 preference scale as shown in table 1.

Saaty's pair wise comparison scale	*Compare factor of I & j*
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values when compromise is needed

Table-1: Preference scale

Then the eigenvector and the maximum Eigen value (λ_{max}) are derived from pair wise comparison matrices. The significance of the Eigen value is to assess the strength of the consistency ratio CR of the comparative matrix in order to validate whether the pair wise comparison matrix provides a completely consistent evaluation. The final step is to derive the consistency index and consistency ratio. Further detail procedure of AHP is not given here as is available in standard literature like [5,6]

2.1. Application of AHP in selection of best domestic refrigerator:

Domestic refrigerator selection is a confusing and time consuming process that requires extensive reviews of market survey for possible selection. Comprehensive reviews provide information about refrigeration configurations, their capacity selection, cooling technology selection, star rating etc. Yet, the selection task stays vulnerable with the lack of some intellect in the process. In this paper, a rational approach is presented to help find the best refrigerator considering multiple criteria factors.

The following five numbers of criteria are considered:

- Capacity or size of refrigerator
- Star rating
- Door type
- Cooling technology
- Color

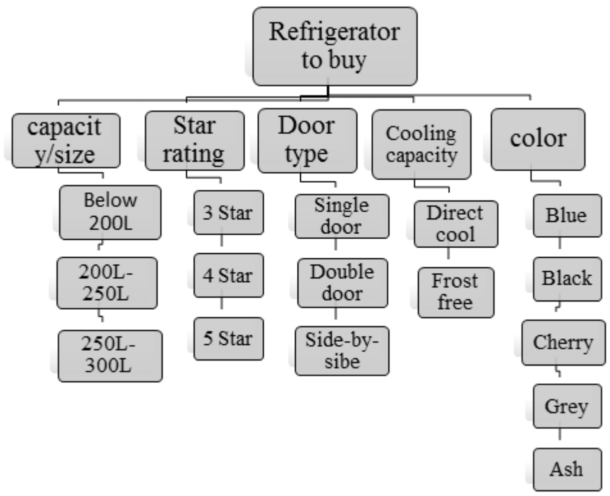

Fig 3: AHP domestic refrigerator selection hierarchy

2.2. Reviews of some customer or buyers:

The ratings on criteria and sub-criteria for domestic refrigeration selection are evaluated from the users and prospective middle class buyers of refrigerators, comprising of 1 to 4 family members, through physical market survey. Based on this AHP method is employed for best possible selection.

Order of preference of the criteria's and sub-criteria according to the groups of people are given below in table 3, 4,5,6,7.

Table-2: 1st group –

Criteria preference (by order)	**sub-criteria preference (by order)**
Size	200L-250L
Star rating	5 Star
Door	Single
Cooling Technology	Frost free
Color	Cherry

Table-3: 2nd group –

Criteria preference (by order)	**sub-criteria preference (by order)**
Star rating	5 Star
Size/capacity	250L-300L
Door type	Double
Color	Cherry
Cooling technology	Frost free

Table-4: 3rd group-

Criteria preference (by order)	**sub-criteria preference (by order)**
Size/capacity	250L-300L
Star rating	5 Star
Cooling technology	Frost free
Color	Blue
Door type	Double

Table-5: 4th group-

Criteria preference (by order)	sub-criteria preference (by order)
Size/capacity	200L-250L
Star rating	3 Star
Cooling technology	Direct cool
Door	Ash
Color	Single

Table-6: 5th group-

Criteria preference (by order)	sub-criteria preference (by order)
Size/capacity	200L-250L
Star rating	4 Star
Cooling technology	Direct cool
Color	Grey
Door type	Single

3. CALCULATIONS AND RESULTS

3.1. The comparison matrices and their respective calculations are described below-

Table-7: Pair-wise comparison matrix between main criteria

Comparisons	Size/capacity	Star rating	Door type	Cooling technology	color
Size/capacity	1	3	7	5	9
Star rating	1/3	1	5	3	7
Door type	1/7	1/5	1	1/3	3
Cooling technology	1/5	1/3	3	1	5
Color	1/9	1/7	1/3	1/5	1
Total	1.787302	4.67619	16.33333	9.533333	25

The calculations for these items are explained next for illustration purposes. Synthesizing the pair-wise comparison matrix is performed by dividing each element of the matrix by its column total. For example, the value 0.559503 in Table 8 is obtained by dividing 1 (from Table 7) by 1.787302, the sum of the column item in Table 8(1+1/3+1/7+1/5+1/9=1.787302).

The priority vector in Table 8 can be obtained by finding the row averages. For example, the priority of Size with respect to the main criterion in Table 9 is calculated by dividing the sum of the rows *(*0.559503+0.641548+0.428571+0.524476+0.36) by the number of criteria (columns), i.e., 5.Now, estimating the consistency ratio is as follows:

Dividing all the elements of the weighted sum matrices by their respective priority vector element, we obtain:

Table-8: weightage calculation

Comparison	Size/capacity	Star rating	Door type	Cooling technology	Color	Row average	Weight %
Size	**0.55950**	**0.64154**	**0.42857**	**0.52447**	**0.36**	**0.50281**	**50.28195**
Star rating	**0.1865**	**0.2138**	**0.3061**	**0.3147**	**0.2800**	**0.26023**	**26.02316**
Door capacity	**0.0799**	**0.0428**	**0.0612**	**0.0350**	**0.1200**	**0.06777**	**6.77776**
Cooling technology	**0.11190**	**0.07128**	**0.18367**	**0.10490**	**0.20000**	**0.13435**	**13.43504**
Color	**0.0622**	**0.0305**	**0.0204**	**0.0210**	**0.0400**	**0.034821**	**3.482081**
Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**100.0**

Table-9: Consistency calculation

Size	**5.455432**
Star rating	**1.413523**
Door type	**5**
Cooling technology	**5.2035**
Color	**5**
Total	**22.19477**

The consistency obtained in table 9 is done by multiplying the matrix row with the respective row average and dividing the result by the respective row average value. For example, in table 7 the first row represents size/capacity and in table 8 row averages are calculated. Hence the result is calculated by matrix multiplication that is [(1*0.502819) + (3 *0.260232) + (7* 0.067778) + (5* 0.13435) + (9 * 0.034821)] = 2.74309931. The result obtained is divided by the first row average that is 2.74309931/0.50282=5.45543. Similarly, all the other consistency is calculated.

The average of these values is computed to obtain λmax

λmax =(5.455432+1.413523+5+5.2035+5)/5

=4.43895

Now, the consistency index, CI, is determined as follows:

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

$= (4.43895-5)/ (5-1)$

$= -0.14026$

Selecting appropriate value of random consistency ratio, RI, for a matrix size of five using Table 2, RI is found as 1.12.Then the consistency ratio, CR, is calculated as follows:

$CR= CI/RI = -0.14026/1.12$

$= -0.12523$

As the value of CR is less than 0.1, the judgments are acceptable.

Table-10: Consistency check

Average consistency	4.438954
CI	-0.14026
RI	1.12
Consistency	-0.12523
Consistent	YES

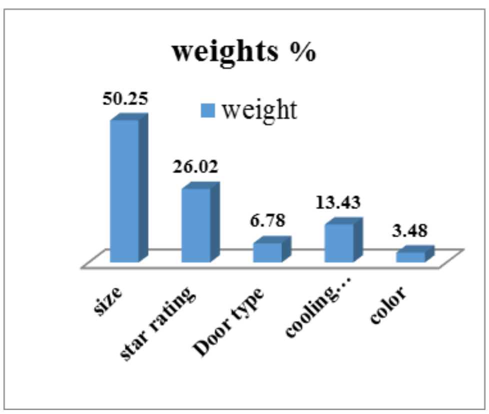

Fig 4: Graph showing the weightages of the criterion

Table-11: Pair-wise comparisons matrix between main sub-criteria on criteria (size/capacity)

Comparison	below 200L	200L-250L	250-300L
below 200L	1	1/5	1/7
200L-250L	5	1	1/3
250-300L	7	3	1
Total	13	4.2	1.47619

Similarly, others table can be calculated following the procedure shown above.

λ_{max}=4.438954 , CI=-0.14026 , RI=1.12,CR=0.12523<0.1= OK

Table-12: Consistency check

Average consistency	4.438954
CI	-0.14026
RI	1.12
Consistency	-0.12523
Consistent	YES

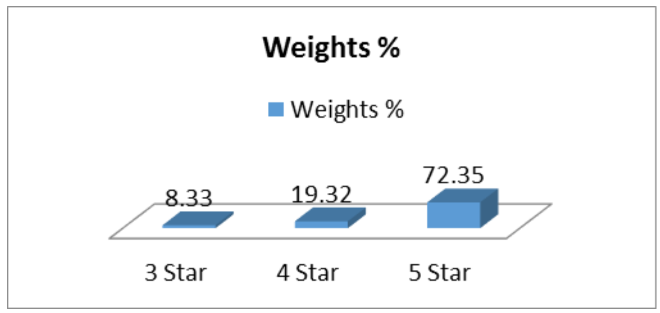

Fig 5: Graph showing the weightages of the criterion

Table-13: Pair-wise comparisons matrix between main sub-criteria on criteria (Star rating)

Comparison	3 STAR	4 STAR	5 STAR
3 STAR	1	1/3	1/7
4 STAR	3	1	1/5
5 STAR	7	5	1
Total	11	6.3333	1.3429

Table-14: Consistency check

no of comparison	3
average consistency	3.065819
CI	0.032909
RI	0.58
Consistency	0.05674
Consistent	YES

λ_{max}=3.065819, CI=0.032909, RI=0.58 , CR=0.05674<0.1= OK

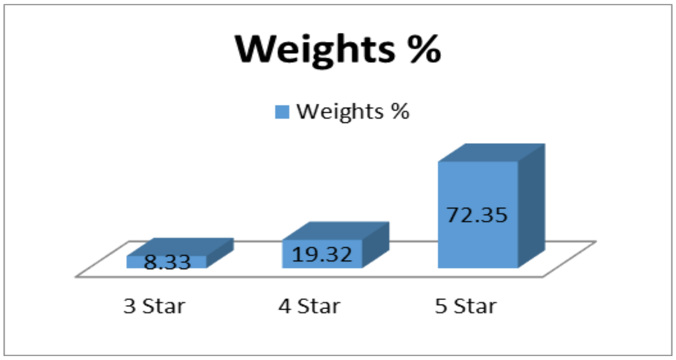

Fig 6: Graph showing the weightages of the criterion

Table-15: Pair-wise comparisons matrix between main sub-criteria on criteria (Door type) –

Comparison	double	Single	side-by-side
double	1	5	7
single	1/5	1	3
side-by-side	1/7	1/3	1
Total	1.342857	6.333333	11

Table-16: Consistency check

no of comparison	3
average consistency	3.065819
CI	0.032909
RI	0.58
Consistency	0.05674
Consistent	YES

λ_{max}=3.065819, CI=-0.032909, RI=0.58 , CR=-0.05674<0.1= OK

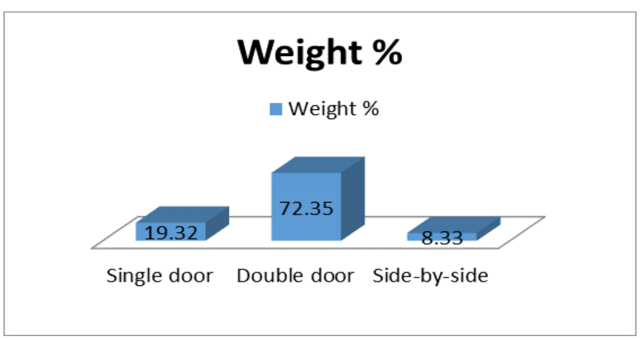

Fig 7: Graph showing the weightages of the criterion

Table-17:Pair-wise comparisons matrix between main sub-criteria on criteria (Cooling technology) –

comparison	direct cool	frost free
direct cool	1	1/7
frost free	7	1
Total	8	1.142857

Table-18: Consistency check

no of comparison	2
Average consistency	2
CI	0
RI	0
Consistency	0
Consistent	YES

λ_{max}=2, CI=2 , RI=2 , CR=0<0.1= OK

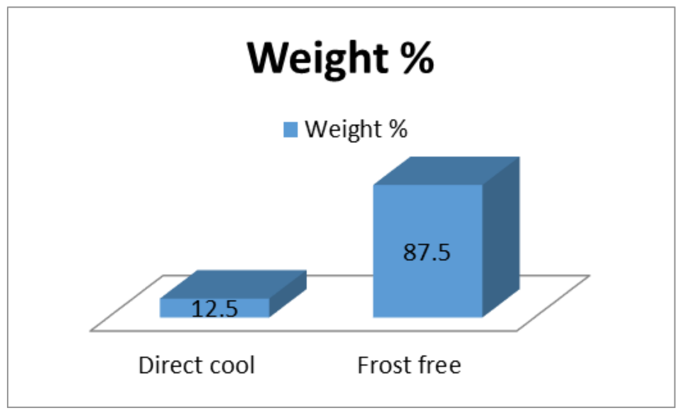

Fig 8: Graph showing the weightages of the criterion

Table-19: Pair-wise comparisons matrix between main sub-criteria on criteria (Color)

Comparison	blue	black	Cherry	grey	Ash
blue	1	4	1	3	1
black	1/4	1	1/5	1/3	¼
cherry	1	5	1	3	3
grey	1/3	3	1/3	1	1/3
ash	1	4	1/3	3	1
Total	3.583333	17	2.866667	10.33333	5.583333

Table-20: Consistency check

no of comparison	5
Average consistency	5.19267
CI	0.04817
RI	1.12
Consistency	0.04301
Consistent	Yes

λ_{max}=5.19267, CI=0.04817, RI=1.12 , CR=0.04301<0.1= OK

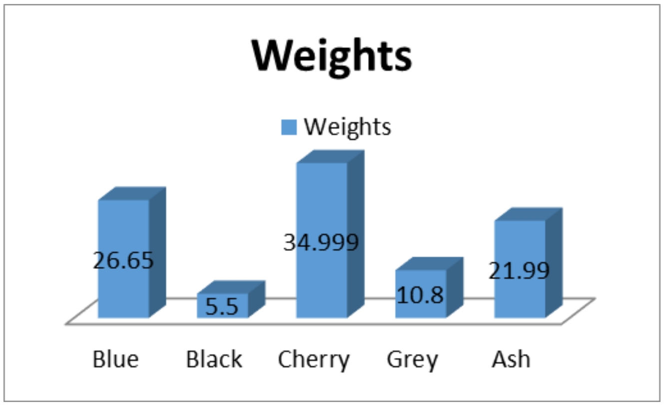

Fig 9: Graph showing the weightages of the criterion

Final weightage of criteria and sub-criteria after using normalized matrix, equations

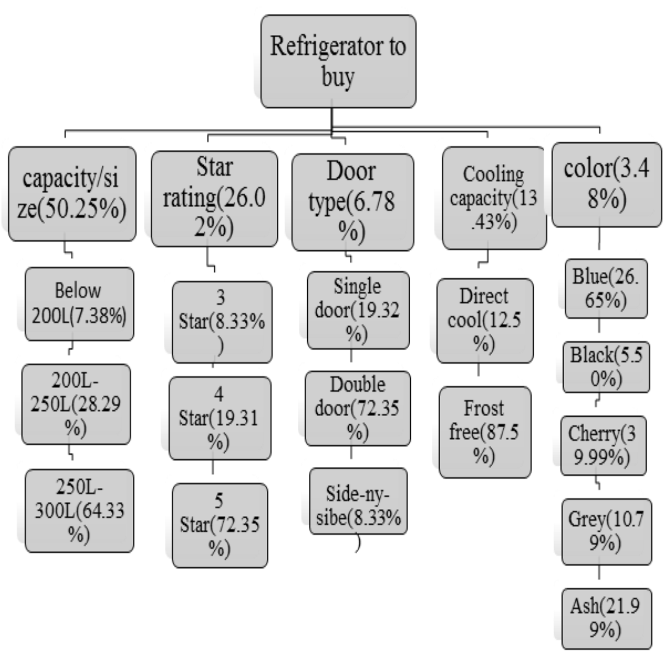

Fig 10: Chart showing the weightage % of the criterion

Table-21: Model analysis

Model	Size/capacity (M)	Star rating (N)	Door type (O)	Cooling technology (P)	Color (Q)	Overall priority (M+N+O+P+Q)
A	**200L-250L (28.29%)**	**4 Star (19.31%)**	**Single door (19.31%)**	**Direct cool (12.5%)**	**Cherry (39.99%)**	**119.4%**
B	**250L-300L (64.33%)**	**3 Star (8.33%)**	**Double door (72.35%)**	**Frost free (87.5%)**	**Blue (26.65%)**	**259.16%**
C	**250L-300L (64.33%)**	**5 Star (72.35%)**	**Side-by-side (8.33%)**	**Frost free (87.5%)**	**Grey (10.79%)**	**243.30%**
D	**Below 200L (7.38%)**	**5 Star (72.35%)**	**Single door (19.31%)**	**Direct cool (12.5%)**	**Ash (21.98%)**	**133.52%**
E	**200L-250L (28.29%)**	**3 Star (8.33%)**	**Double door (72.35%)**	**Direct cool (12.5%)**	**Black (26.65%)**	**148.12%**

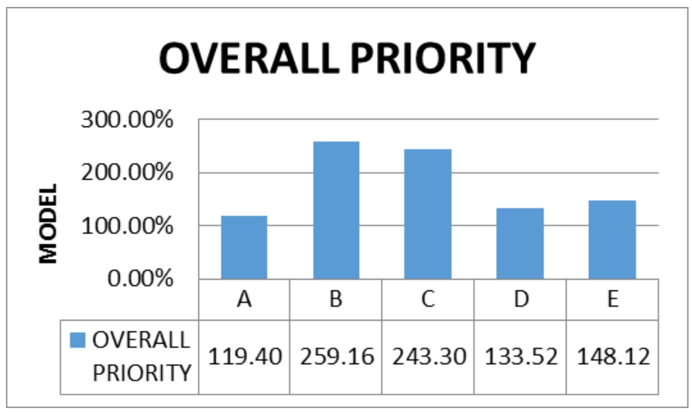

Fig-11: Graph showing overall weightage priority and their ranking

The domestic refrigerator model is now ranked according to their overall priorities of criteria and sub-criteria, as follows: B, C, E, D, and A, indicating that B is the best qualified model for selection.

4. CONCLUSION

AHP technique has been adopted for selection of best possible refrigerator for a middle class family. Preferences of customers for five most useful refrigerator selection criteria and sub-criteria and their relative weightages are evaluated from market survey. The detail AHP analysis is presented and consistencies are also checked. Finally the best possible refrigerator model is selected and priorities of other alternatives are ranked. The same procedure may be extended to consider more other criteria and sub-criteria for best possible selection.

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